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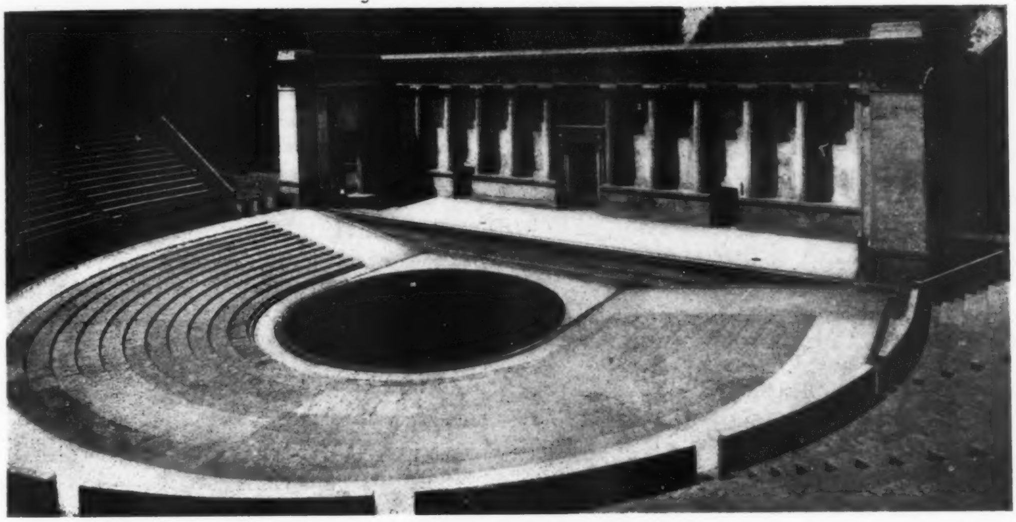

FIG 2. GREEK THEATRE AT THE UNIVERSITY OF CALIFORNIA.
MR. JOHN GALEN HOWARD, *ARCHITECT*
(SEE PAGE 276)

# THEATRE ACOUSTICS

*By* WALLACE C. SABINE, HARVARD UNIVERSITY

VITRUVIUS, De Architectura, Liber V. Cap. VIII. (*De locis consonantibus ad theatra eligendis*). "All this being arranged, we must see with even greater care that a position has been taken where the voice falls softly and is not so reflected as to produce a confused effect on the ear. There are some positions offering natural obstructions to the projection of the voice, as for instance the dissonant, which in Greek are termed κατηχοῦντες; the circumsonant, which with them are named περιηχοῦντες; and again the resonant, which are termed ἀντηχοῦντες. The consonant positions are called by them συνηχοῦντες."

"The dissonant are those places in which the sound first uttered is carried up, strikes against solid bodies above, and, reflected, checks as it falls the rise of the succeeding sound."

This paper, which follows a number of papers printed in THE AMERICAN ARCHITECT and elsewhere during the past fifteen years on the general problem of architectural acoustics, is the beginning of a series of articles dealing with the application of the principles and the data thus produced to a number of classified problems.

The preceding papers were published in the Proceedings of the American Institute of Architects, 1898, the Dictionary of Architecture, THE AMERICAN ARCHITECT, 1900, the *Engineering Record*, 1900 and 1910, the Proceedings of the American Academy of Arts and Sciences, 1906, and in the *Harvard Architectural Quarterly*, 1912. These references are given because of frequent inquiries for reprints the supply of which is exhasted. Material for three other general papers dealing with "Coefficients of Absorption," "Loudness," "Interference and Resonance" has already been gathered, and should shortly appear.

Other articles to follow this will deal separately with the modern opera house, music halls for choral and orchestral concerts, private music rooms, large municipal auditoriums, and, perhaps the most difficult and varied of all, the church auditorium.

"The circumsonant are those in which the voice spreading in all directions is reflected into the middle, where it dissolves, confusing the case endings, and dies away in sounds of indistinct meaning."

"The resonant are those in which the voice comes in contact with some solid substance and is reflected, producing an echo and making the case terminations double."

"The consonant are those in which the voice is supported and strengthened, and reaches the ear in words which are clear and distinct."

This is an admirable analysis of the problem of theatre acoustics. But to adapt it to modern nomenclature, we must substitute for the word dissonance, interference; for the word circumsonance, reverberation; for the word resonance, echo. For consonance, we have unfortunately no single term, but the conception is one which is fundamental.

It is possible that in the above translation and in the following interpretation I have read into the text of Vitruvius a definiteness of conception and an accord with modern science which his language only fortuitously permits. If so, it is erring on the better side, and is but a reasonable latitude to take under the circumstances. The only passage whose interpretation is open to serious question is that relating to dissonant places. If Vitruvius knew that the superposition of two sounds could produce silence, and the expression "*opprimit insequentis vocis elationem*" permits of such interpretation, it must stand as an observation isolated by many centuries from the modern knowledge of the now familiar phenomenon of interference.

### Interference

Interference is a phenomenon common to all types of wave motion. The best introduction to its discussion is by reference to water waves and in particular to an interesting example of tidal interference on the Tongking Peninsula. The tide of the Pacific Ocean enters the Chinese Sea through two channels, one to the north of the Philippine Islands, between Luzon and Formosa, and the other through the Sulu Archipelago between Mindanao and Borneo. The northern channel is short and deep; and the tide enters with very little retardation. The other channel, although broad, is shallow, tortuous, and broken by many small islands; and the tide in passing through is much retarded. The two tides thus entering the Chinese Sea produce an effect which varies from point to point. At one port on the Tongking Peninsula, these tides are so retarded relatively to each other as to be six hours apart. It is high tide by one when it is low tide by the other. It also so happens that at this point the two tides are equal. Being equal and exactly opposite in phase, they neutralize each other.

Because tidal waves are long in comparison with the bodies of water in which they are propagated, their interference phenomena are obscure except to careful analysis. When, however, the waves are smaller than the space in which they are being propagated, the interference system becomes more marked, more complicated, and more interesting. Under such circumstances, there may be regions of perfect quiet near regions of violent disturbance.

Subjecting the parallel to a more exact statement, whenever two water waves come together the resulting disturbance at any instant is equal to the algebraic sum of the disturbances which each would produce separately. If their crests coincide, the joint effect is equal to the sum of their separate effect. If crest and trough coincide, their joint effect is the difference between them. If their relative retardation is intermediate, a wave results which is intermediate between their sum and their difference and whose time of maximum does not occur simultaneously with the maximum of either of the components.

The phenomenon is one which may be produced accurately on any scale and with any type of wave motion. Thus sound consists of waves of alternate condensation and rarifaction in the air. If two trains of sound waves cross each other so that at a given point condensation in the two trains arrive simultaneously, the rarifactions will also arrive simultaneously, and the total disturbance is a train of waves of condensation and rarifaction equal to the sum of the two components. If one train is retarded so that its condensations coincide with the other's rarifactions, the disturbance produced is the difference between that which would be produced by the trains of waves separately. Just as a tidal wave, a storm wave, or a ripple may be made to separate and recross by some obstacle round which it diffracts or from which it is reflected, and recombining produce regions of violent and regions of minimum disturbances, so sound waves may be diffracted or reflected, and recombining after travelling different paths, produce regions of great loudness and regions of almost complete silence. In general, in an auditorium the phenomenon of interference is produced not by the crossing of two trains of waves only, but by the crossing of many, reflected from the various walls, from the ceiling, from the floor, from any obstacle whatever in the room, while still other trains of waves are produced by the diffraction of the sound around columns and pilasters.

A source of sound on whose steadiness one can rely is all that is necessary in order to make the phenomenon of interference obvious. A low note on a pure toned stop of a church organ will serve the purpose admirably. The observer can satisfy himself that the note is sounding steadily by remaining in a fixed position. As soon, however, as he begins to move from this position by walking up and down the aisle he will observe a great change in loudness. Indeed, he may find a position for one ear which, if he closes the other, will give almost absolute silence, and this not far from positions whe e the sound is loud to the extent of being disagreeable. The observer in walking about the church will find that the phenomenon is complicated. It is, however, by no means random in its character, but definite, permanent, and accurate in its recurrence, note for note. The phenomenon while difficult is by no means impossible of experimental investigation or of theoretical solution. Indeed this has been done with great care in connection with the study of another problem—that of the Central Criminal Court Room in London known as Old Bailey. The full primary explanation of the methods and results of this general investigation would be inappropriately long in an article dealing with the acoustics of theatres; for while interference is a factor in every auditorium, it is on the whole not the most seriously disturbing factor in theatre design.

The subject of interference would not have been given even so extended a discussion as this in a paper dealing with theatres were it not that recently there has been proposed in Germany a form of stage setting known as the Kuppel-horizont for sky and horizon effects, to accompany the Fortuny system of stage lighting, in which interference may be a not inconsiderable factor unless guarded against. The Fortuny system, which in the opinion of some competent judges is an effective form of stage lighting, consists primarily in the use of indirect illumination, softened and colored by reflection from screens of silk. As an adjunct to the system, and in an endeavor to secure a considerable depth to the stage without either great height or an excessive use of sky and wing flies, a cupola is recommended to go with the Fortuny lighting as shown in the accompanying figures taken from the publications of the *Berliner Allegemeine Electricitäts Gesellschaft*. In Figures 3 and 4, the cupola is shown in section and in plan. Lights A and B illuminate the interior of the cupola; C and E light the area of the stage on which the principal action occurs. Cloud effects, either stationary or moving, are projected on the surface of the cupola by a stereopticon. The great advantage claimed for this form of stage setting is the more natural arrangement of stage properties which it makes possible, and the elimination of numerous flies. On the other hand there is some criticism that this lighting results in an unnatural silhouetting.

So detailed an explanation of the diagrams and the purpose of the several parts is necessitated by the fact that it is as yet an unfamiliar device in this country. It has been introduced recently in a number of theatres in Germany, although I believe not elsewhere, unless possibly in one theatre in England. It has been called to my attention by Professor Baker as a possible equipment of the theatre which is proposed

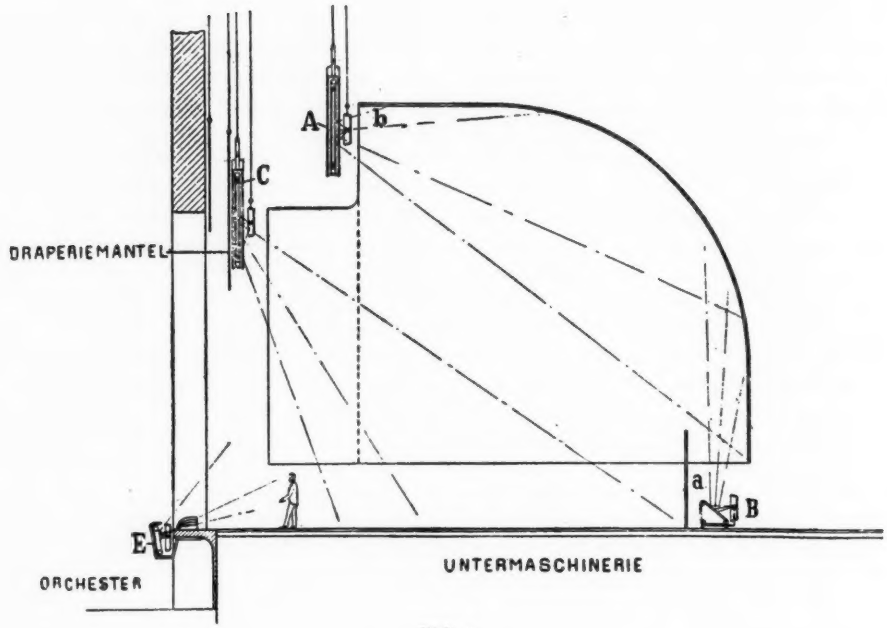


FIG. 3

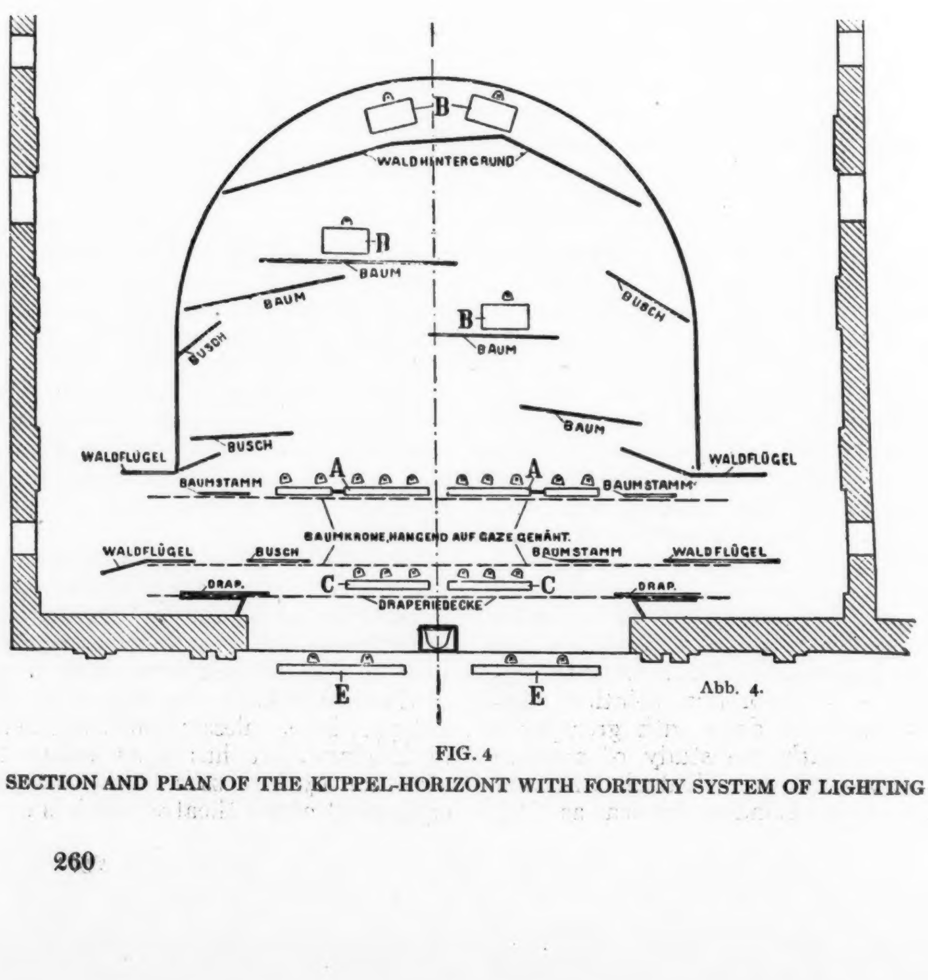


FIG. 4

SECTION AND PLAN OF THE KUPPEL-HORIZONT WITH FORTUNY SYSTEM OF LIGHTING for the dramatic department of Harvard University, and it is reasonable to regard it as a probable factor in theatre design in other countries than Germany.

In Figure 5 is plotted the interference system established in this space, on a standing head level of five feet from the floor of the stage, by a sustained note tenor C in pitch. The intensity of the sound is indicated by contour lines very much as land elevation is indicated on the maps of the Geodetic Survey. In this plot, account has been taken of the sound reflected from the cupola and from the floor. No account has been taken of the reflection from the walls of the main auditorium since this would be a factor only for sounds prolonged beyond the length of any single element in articulate speech. Even in the case of a very prolonged sound the modification of the interference system of the stage and cupola by the rest of the auditorium would be very slight.

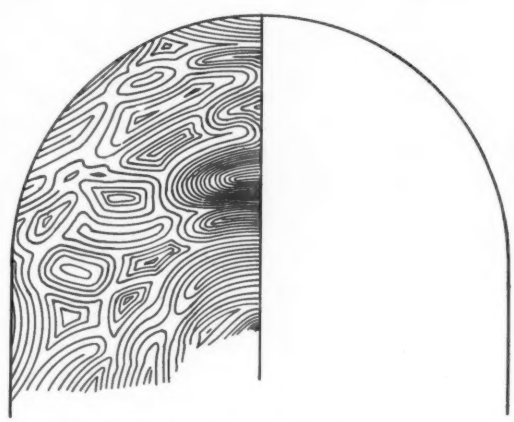

FIG. 5. INTERFERENCE SYSTEM FOR TENOR C IN THE KUPPEL-HORIZONT, HAVING A THIRTY-SIX FOOT PROSCENIUM OPENING. THE INTENSITY OF SOUND IS REPRESENTED BY CONTOUR LINES, THE MAXIMUM VARIATION BEING FORTY-SEVEN FOLD.

The interference system on the stage in question being determined wholly by the floor and cupola, it may be computed, and in the preparation of the chart was computed, by the so-called method of images. The sound reflected from the floor comes as from a virtual image as far beneath the floor as the mouth of the speaker is above it. Each of these produce real images by reflection from the interior of the cupola. Bearing in mind that these real images show the phenomenon of diffraction and some astigmatism, and taking into account the phase of the sound as determined by reflection and by distance, the calculation is laborious but not difficult. It involves but the most familiar processes of geometrical optics.

The disturbing effect of this interference system is not so great when the speaker is well in front of the center of curvature of the cupola, and of course it is almost always more or less broken by the stage properties, as indicated in Figures 3 and 4. Nevertheless, it is well to bear in mind that the quarter sphere form, as indicated in the diagrams, is neither necessary from the standpoint of illumination nor desirable from the standpoint of acoustics. Acoustically a flatter back with sharper curvature above and at the sides is preferable.

It should be repeated that the interference system is established only when the tones are sustained, in this case over one-tenth of a second, and is more of an annoyance to the actor on the stage than to the audience. With shorter tones it becomes an echo, and in this form is quite as annoying to the audience as to the actor. It should be added that the interference changes with change of pitch, but preserves extreme maxima and minima for a central position in a spherical or partly spherical surface. Finally in music, since sustained tones occur more than in speech, the interference is more disturbing. The effect of such spherical stage recesses on music is shown by those otherwise unusually excellent auditoriums, Orchestra Hall in Chicago, and the Concert Hall at Willow Grove Park near Philadelphia.

### Reverberation

"Circumsonant places" were rare and almost wholly negligible difficulties in Greek and Roman theatres. However, they were common in the temples, and were even more pronounced in some of the older Roman palaces. It must have been in the experience of such conditions, wholly foreign to the theatre of which he was writing, that Vitruvius made this portion of his analysis of the acoustical problem. Given the fundamental form of the Greek theatre it required no special consideration and little or no skill to avoid such difficulties. However, this is not true of the modern theatre, in which excessive reverberation is more often the defect than any other factor.

If a sound be produced briefly in a wholly empty, wholly closed room, having perfectly rigid walls, it will be reflected at each incidence with undiminished intensity, and, travelling to and fro across the room, will continue audible almost indefinitely. Of course no theatre, ancient or modern, satisfies these conditions and the sound loses at each reflection, diminishing in intensity, until in the course of time it crosses what the experimental psychologist calls the "threshold of audibility." In the Greek theatres the duration of audibility of the residual sound after the cessation of a source of ordinary loudness was never more than a few tenths of a second; in a modern theatre it may be several seconds. The rapidity with which the sound dies away depends on the size of the theatre, on its shape, on the materials used for its walls, ceiling, and furnishings, and on the size and distribution of the audience. The size and shape of the theatre determines the distance travelled by the sound between reflections, while the materials determine the loss at each reflection. No actual wall can be perfectly rigid. Wood sheathing, plaster on wood lath, plaster on wire lath, plaster applied directly to the solid wall, yield under the vibrating pressure of sound and dissipate its energy. Even a wall of solid marble yields slightly, transmitting the energy to external space or absorbing it by its own internal viscosity.

Absorption by the walls and other objects in the process of reflection, including in this transmission through all openings into outer space as equivalent to total absorption, boundary condition in other words, are practically alone to be credited with the dissolution of the residual sound. But Vitruvius' statement that the sound "is reflected into the middle, where it dissolves" challenges completeness and at least the mention of another factor, which, because of its almost infinitesimal importance, would otherwise be passed without comment.

Assuming, what is of course impossible, a closed room of absolutely rigid and perfectly reflecting walls, a sound once started would not continue forever, for where the air is condensed by the passing of the wave of sound, it is heated, and where it is rarified, it is cooled. Between these unequally heated regions and between them and the walls, there is a continual radiation of heat, with a resulting dissipation of available energy. In the course of time, but only in the course of a very long time, the sound would even thus cease to be of audible intensity. This form of dissipation might well be called in the language of Vitruvius "*solvens in medio*;" but, instead of being an important factor, it is an entirely negligible factor in any actual auditorium.

Practically the rapidity with which the sound is absorbed is dependent solely on the nature of the reflecting surfaces and the length of the path which the sound must traverse between reflections, the latter depending on the shape and size of the auditorium. It was shown in a series of papers published in THE AMERICAN ARCHITECT in 1900, and in another paper published in the Proceedings of the American Academy of Arts and Sciences in 1906, that given the plans of an auditorium and the material of which it is composed, it is possible to calculate with a very high degree of accuracy the rate of decay of a sound in the room and the duration of its audibility. In the first of the above papers there was given the complete theory of the subject, together with tables of experimentally determined coefficients of absorption of sound for practically all the materials that enter into auditorium construction, for sounds having a pitch one octave above middle *c* (vibration frequency 512). In the second of the above papers there were given the coefficients of absorption of building materials for the whole range of the musical scale.

In the careful design of a room for musical purposes, the problem obviously must include the whole range of the musical scale, at least seven octaves. It is not so obvious that the study must cover so great a range when the primary use is to

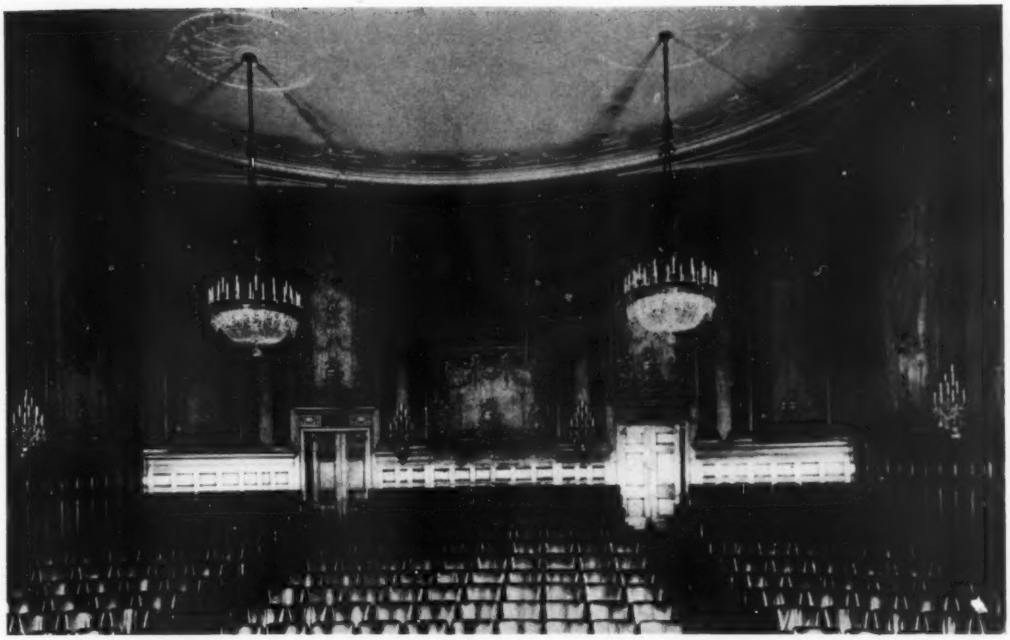

FIG. 6. THE LITTLE THEATRE, NEW YORK
MESSRS. INGALLS AND HOFFMAN, *ARCHITECTS*

be with the spoken voice. The nearest study to architectural acoustics is the highly developed science of telephony, and in this it is apparently sufficient for much of the work to adapt the theory and design to the single frequency of 800, approximately *a* in the second octave above middle *c*. But for some problems the investigation must be extended over a considerable range of pitch. Similarly experience in the architectural problem shows that with some of the materials entering into building construction there occurs a sharp resonance within a not great range of pitch. It is therefore necessary to determine the reverberation even for the speaking voice, not for a single pitch but for a considerable range and the quality of a theatre with respect to reverberation will be represented by a curve in which the reverberation is plotted against the pitch.

Without undertaking to give again a complete discussion of the theory of reverberation, and referring the reader to the earlier (1900) numbers of THE AMERICAN ARCHITECT, it will suffice to give a single illustration. For this I have selected Mr. Winthrop Ames' "Little Theatre" in New York, designed by Messrs. Ingalls and Hoffman, because the purpose and use of this auditorium was defined from the beginning with unusual precision. The purpose was the production of plays which could be adequately rendered only by the most delicate shades of expression, which would be lost in considerable measure if the conditions were such as to necessitate exaggeration of feature or of voice. The definition of its use was that it should seat just less than 300, and that all the seats were to be as nearly as possible of equal excellence, with the important assurance that every seat would be occupied at every performance.

The final plans and elevations of the Little Theatre are shown in Figures 7 and 8. The initial pencil sketch was of an auditorium differing in many architectural details, acoustical considerations sharing in, but by no means alone dictating, the steps leading to the final solution of the problem. The first calculations, based on the general lines of the initial sketch, and assuming probable materials and plausible details of construction (plaster on tile

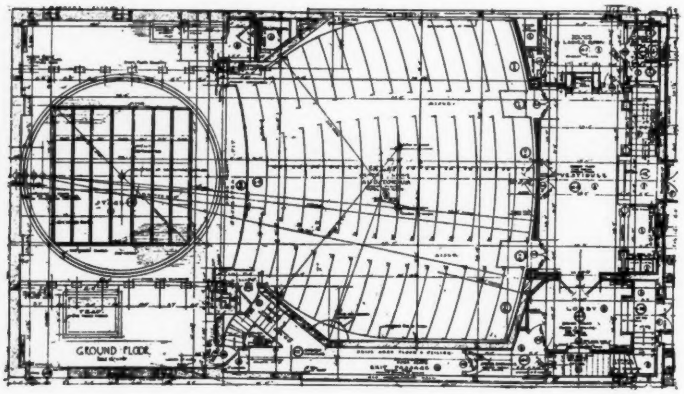


FIG 7

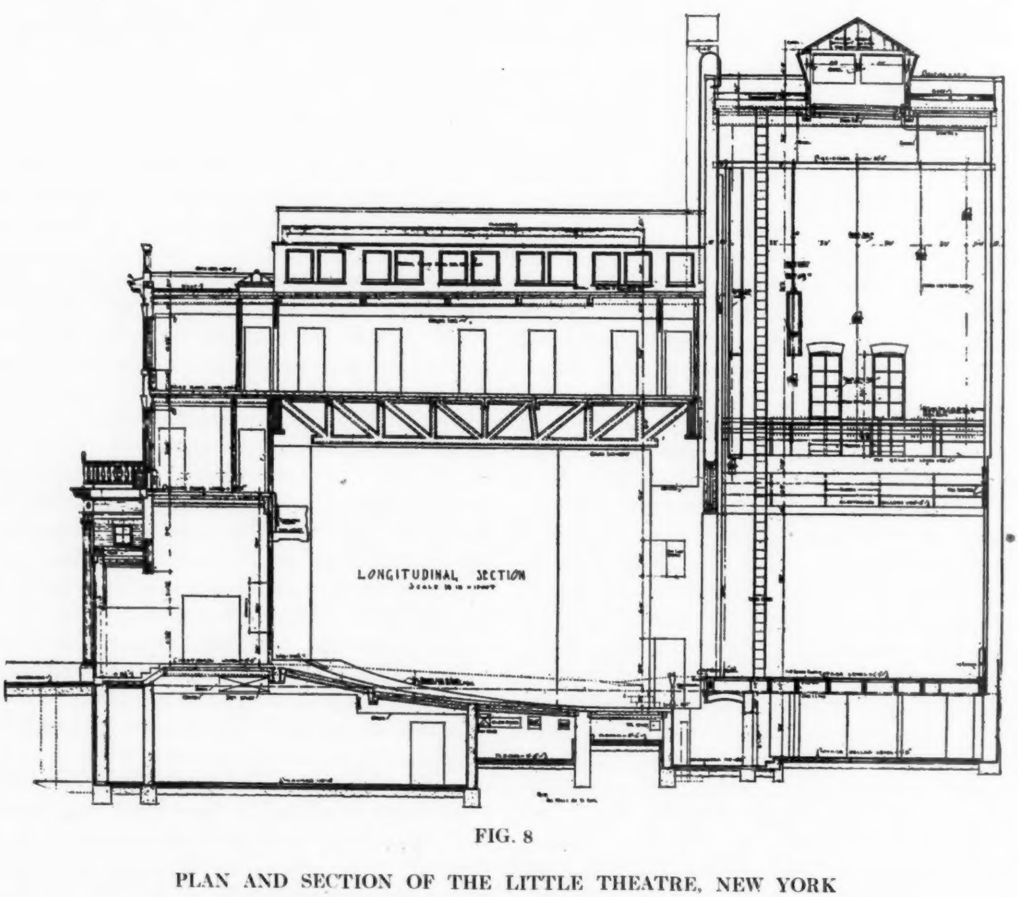


FIG. 8

PLAN AND SECTION OF THE LITTLE THEATRE, NEW YORK

MESSRS. HOFFMAN AND INGALLS, *ARCHITECTS* walls, plaster on wire lath ceiling, solid plaster cornices and moulding), gave a reverberation as shown in Curve 1 in Figure 9. This would not have been in excess of that in many theatres whose acoustical qualities are not especially questioned. But the unusual requirements of the plays to be presented in this theatre, and the tendency of the public to criticize whatever is unconventional in design, led both Mr. Ames and the architects to insist on exceptional quality. The floor was therefore lowered at the front, the ceiling was lowered, and the walls near the stage brought in and reduced in curvature, with, of course, corresponding changes in the architectural treatment. The rear wall, following the line of the rear seats, remained unchanged in curvature. The side walls near the stage were curved. The net effect of these changes was to give an auditorium twenty-eight feet high in front, twenty-three feet high at the rear, forty-eight feet long and forty-nine feet broad, with a stage opening eighteen by thirty-one, and having a reverberation as shown by Curve 2. In order to reduce still further the reverberation, as well as to break acoustically the curvature of the side and rear walls, "acoustic felt" was applied in panels. There were three panels, six feet by thirteen feet, on each of the side walls, and seven panels, two four feet five inches by thirteen feet, two five feet by ten feet, two two feet by four feet,

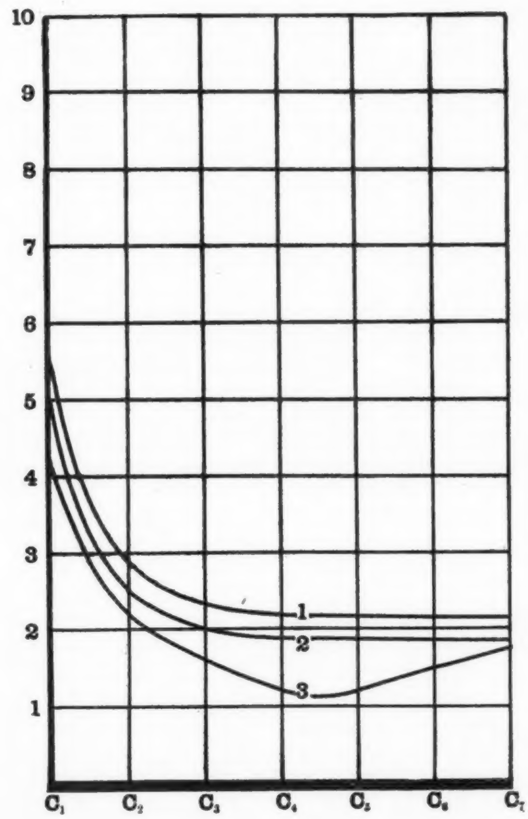


FIG. 9. REVERBERATION IN SECONDS OF THE LITTLE THEATRE, FOR NOTES OF DIFFERENT PITCH, $C_3$ BEING MIDDLE C, CURVE 1 FOR THE FIRST DESIGN, CURVE 2 FOR THE SECOND, AND CURVE 3 FOR THE THIRD AND AS BUILT.

and one eight feet by seven feet, on the rear wall. The resulting reverberation is shown by Curve 3 in the diagram. Throughout, consideration was had for the actual path of the sound in its successive reflections, but the discussion of this phase of the general problem comes in the next section and will be illustrated by other theatres.

It should be said, parenthetically but none the less emphatically, that throughout this paper by theatre is meant an auditorium for the spoken drama.

## Echo

When a source of sound is maintained constant for a sufficiently long time, a few seconds will ordinarily suffice, the sound becomes steady at every point in the room. The distribution of the intensity of sound under these conditions, is called the interference system, for that particular note, of the room or space in question. If the source of sound is suddenly stopped, it requires some time for the sound in the room to be absorbed. This prolongation of sound after the source has ceased is called reverberation. If the source of sound, instead of being maintained, is short and sharp, it travels as a discreet wave or group of waves about the room, reflected from wall to wall, producing echoes. In the Greek theatre there was ordinarily but one echo, "doubling the case ending," while in the modern theatre there are many, generally arriving at a less interval of time after the direct

FIG. 10. THE NEW THEATRE, NEW YORK
MESSRS. CARRERE AND HASTINGS, *ARCHITECTS*

sound and therefore less distinguishable, but stronger and therefore more disturbing.

This phase of the acoustical problem will be illustrated by two examples, the New Theatre, the most important structure of the kind in New York, and the plans of the theatre now building for the Scollay Square Realty Company in Boston.

Notwithstanding the fact that there was at one time criticism of the acoustical quality of the New Theatre, the memory of which still lingers and still colors the casual comment, it was not worse in proportion to its size than several other theatres in the city. It is therefore not taken as an example because it showed acoustical defects in remarkable degree, but rather because there is much that can be learned from the conditions under which it was built, because such defects as existed have been corrected in large measure, and above all in the hope of aiding in some small way in the restoration of a magnificent building to a dignified use for which it is in so many ways eminently suited. The generous purpose of its founders, the high ideals of its manager in regard to the plays to be produced, and the perfection otherwise of the building directed an exaggerated and morbid attention to this feature. Aside from the close scrutiny which always centers on a semi-public undertaking, the architects, Messrs. Carrere and Hastings, suffered from that which probably every architect can appreciate from some similar experience of his own, an impossible program. They were called on to make a large "little theatre," as a particular type of institution is called in England; and, through a division of purpose on the part of the founders and advisers, for the Director of the Metropolitan Opera was a powerful factor, they were called on to make a building adapted to both the opera and the drama. There were also financial difficulties, although very different from those usually encountered, a plethora of riches. This necessi-

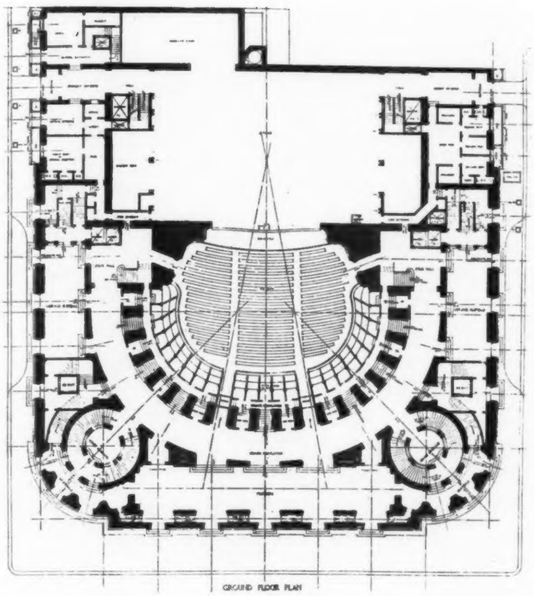


FIG. 11

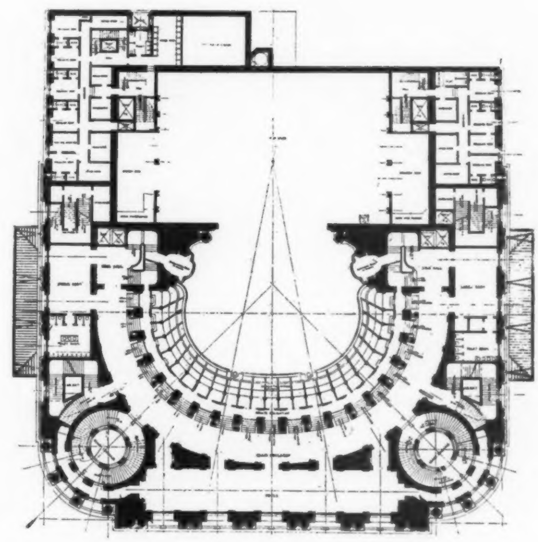

FIG. 12

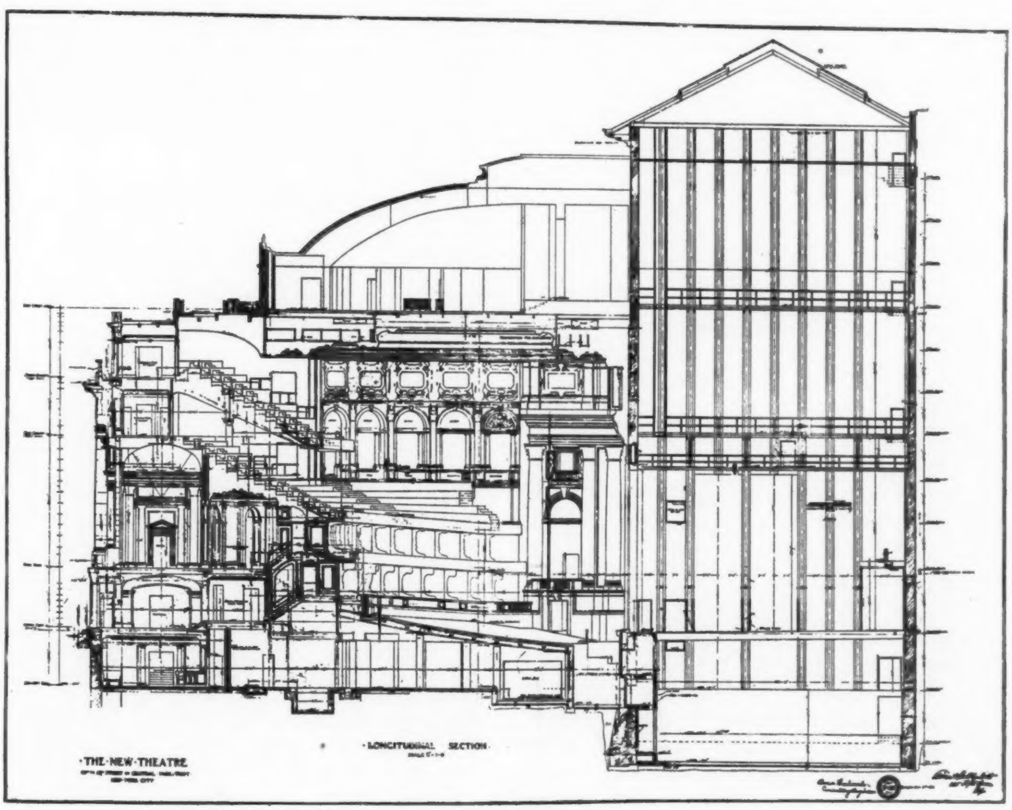


FIG. 13

**PLANS AND SECTION OF THE NEW THEATRE, NEW YORK**

MESSRS. CARRERE AND HASTINGS, *ARCHITECTS* tated the provision of two rows of boxes, forty-eight originally, equally commodious, and none so near the stage as to thereby suffer in comparison with the others. Finally there was a change of program when the building was almost complete. The upper row of boxes was abandoned and the shallow balcony thus created was devoted to foyer chairs which were reserved for the annual subscribers. As will be shown later these seats were acoustically the poorest in the house.

Encircling boxes are a familiar arrangement, but most of the precedents, especially those in good repute, are opera houses and not theatres, the opera and the drama being different in their acoustical requirements. In the New Theatre this arrangement exerted a three-fold pressure on the design. It raised the balcony and gallery twelve feet. It increased both the breadth and the depth of the house. And, together with the requirement that these boxes should not extend near the stage, it led to side walls whose most natural architectural treatment was such as to create sources of not inconsiderable echo.

The immediate problem is the discussion of the reflections from the ceiling, from the side walls near the stage, from the screen and parapet in front of the first row of boxes and from the wall at the rear of these boxes. To illustrate this I have taken photographs of the actual sound and its echoes passing through a model of the theatre by a modification of what may be called the Toeppler-Boys-Foley method of photographing air disturbances. The details of the adaptation of the method to the present investigation will be explained in another paper. It is sufficient here to say that the method consists essentially of taking off the sides of the model, and, as the sound is passing through it, illuminating it instantaneously by the light from a very fine and somewhat distant electric spark. After passing through the model the light falls on a photographic plate placed at a little distance on the other side. The light is refracted by the sound waves, which thus act practically as their own lens in producing the photograph.

FIG. 14. PHOTOGRAPH OF A SOUND WAVE, *W W*, ENTERING A MODEL OF THE NEW THEATRE, AND OF THE ECHOES $a_1$, PRODUCED BY THE ORCHESTRA SCREEN, $a_2$ FROM THE MAIN FLOOR, $a_3$, FROM THE FLOOR OF THE ORCHESTRA PIT, $a_4$, THE REFLECTION FROM THE ORCHESTRA SCREEN OF THE WAVE $a_3$, $a_5$ THE WAVE ORIGINATING AT THE EDGE OF THE STAGE.

In the accompanying illustrations reduced from the photographs the enframing silhouettes are shadows cast by the model, and all within are direct photographs of the actual sound wave and its echoes. For example, Figure 14 shows in silhouette the principal longitudinal section of the main auditorium of the New Theatre. *WW* is a photograph of a sound wave which has entered the main auditorium from a point on the stage at an ordinary distance back of the proscenium arch; $a_1$, is the reflection from the solid rail in front of the orchestra pit, and $a_2$, the reflection from the floor of the sound which has passed over the top of the rail; $a_3$ is the reflection from the floor of the pit, and $a_4$ the reflection of this reflected wave from the rail; while $a_5$ originated at the edge of the stage. None of these reflections are important factors in determining

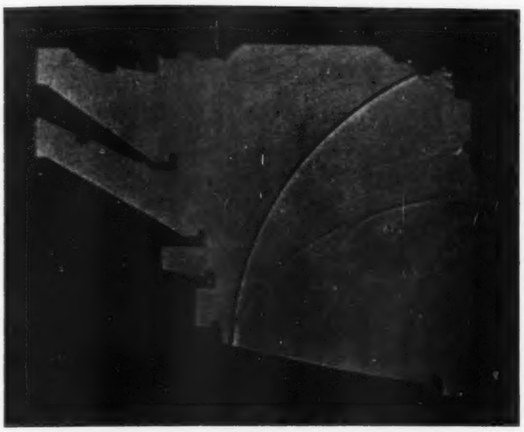

FIG. 15

FIG. 18

FIG. 16

FIG. 19

FIG. 17

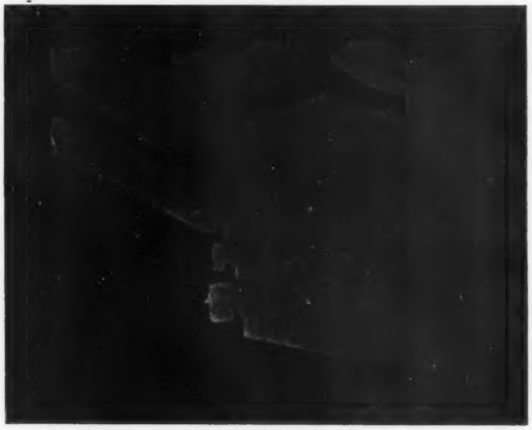

FIG. 20

TWO SERIES OF PHOTOGRAPHS OF THE SOUND AND ITS REFLECTIONS IN THE NEW THEATRE—15 TO 17 BEFORE, 18 TO 20 AFTER THE INSTALLATION OF THE CANOPY IN THE CEILING. THE EFFECT OF THE CANOPY IN PROTECTING THE BALCONY, FOYER CHAIRS, BOXES, AND THE ORCHESTRA CHAIRS BACK OF ROW L IS SHOWN BY COMPARING FIGURES 19 AND 20 WITH FIGURES 16 AND 17.

the acoustical quality of the theatre, but the photograph affords excellent opportunity for showing the manner in which reflections are formed, and to introduce the series of more significant photographs on the preceeding page.

Figures 15, 16 and 17 show the advance of the sound through the auditorium at .07, .10 and .14 second intervals after its departure from the source. In Figure 15, the waves which originated at the orchestra pit can be readily distinguished, as well as the nascent waves where the primary sound is striking the ceiling cornice immediately over the proscenium arch. The proscenium arch itself was very well designed, for the sound passed parallel to its surface. Otherwise reflections from the proscenium arch would also have shown in the photograph. These would have been directed toward the audience and might have been very perceptible factors in determining the ultimate acoustical quality.

FIG. 21. PHOTOGRAPH OF THE DIRECT SOUND, *W W*, AND OF THE ECHOES FROM THE VARIOUS SURFACES; $a_{2,3}$, A WAVE, OR ECHO, DUE TO THE COMBINATION OF TWO WAVES WHICH ORIGINATED AT THE ORCHESTRA PIT; $c_1$ FROM THE OVAL PANEL IN THE CEILING; $c_2$ AND $c_3$, FROM THE CEILING MOULDINGS AND CORNICE OVER THE PROSCENIUM ARCH; $c_4$, A GROUP FROM THE MOULDING SURROUNDING THE PANEL; $c_5$, FROM THE PROSCENIUM ARCH; $b_1$, $b_2$, $b_6$ FROM THE SCREENS IN FRONT, AND THE WALLS IN THE REAR OF THE BOXES, BALCONY AND GALLERY.

The system of reflected waves in the succeeding photograph in the series is so complicated that it is difficult to identify the several reflections by verbal description. The photograph is therefore reproduced in Figure 21, lettered and with accompanying legends. It is interesting to observe that all the reflected waves which originated at the orchestra pit have disappeared with the exception of waves $a_2$ and $a_3$. These have combined to form practically a single wave. Even this combined wave is almost negligible.

The acoustically important reflections in the vertical section are the waves $c_1$, $c_2$ and $c_3$. The waves $b_1$ and $b_2$ from the screen in front of the boxes and from the back of the boxes are also of great importance, but the peculiarities of these waves are better shown by photographs taken vertically through a horizontal section.

The waves $c_1$, $c_2$, $c_3$ and $b_1$ and $b_2$ show in a striking manner the fallacy of the not uncommon representation of the propagation of sound by straight lines. For example, the wave $c_1$ is a reflection from the oval panel in the ceiling. The curvature of this panel is such that the ray construction would give practically parallel rays after reflection. Were the geometrical representation by rays an adequate one the reflected wave would thus be a flat disc equal in area to the oblique projection of the panel. As a matter of fact, however, the wave spreads far into the geometrical shadow, as is shown by the curved portion reaching well out toward the proscenium arch. Again, waves $c_2$ and $c_3$ are reflections from a cornice whose irregularities are not so oriented as to suggest by the simple geometrical representation of rays the formation of such waves as are here clearly shown. But each small cornice moulding originates an almost hemispherical wave, and the mouldings are in two groups, the position of each being such that the spherical waves conspire to form these two master waves. The inadequacy of the discussion

FIG. 22

FIG. 25

FIG. 23

FIG. 26

FIG. 24

FIG. 27

PHOTOGRAPHS SHOWING THE REFLECTIONS, IN A VERTICAL PLANE, FROM THE SIDES OF THE PROSCENIUM ARCH, THE PLANE WALL BELOW THE ACTORS' BOX, AND THE RAIL OR SCREEN IN FRONT OF THE BOXES. THE PHOTOGRAPH TAKEN IN NUMERICAL SEQUENCE SHOW THE PROGRESS OF A SINGLE SOUND WAVE AND ITS REFLECTIONS.

of the subject of architectural acoustics by the construction of straight lines is still further shown by the waves reflected from the screens in front of the boxes, of the balcony, and of the gallery. These reflecting surfaces are narrow, but give, as is clearly seen in the photograph, highly divergent waves. This spreading of the wave beyond the geometrical projection is more pronounced the smaller the opening or the reflecting obstacle and the greater the length of the wave. The phenomenon is called diffraction and is of course one of the well known phenomena of physics. It is more pronounced in the long waves of sound than in the short waves of light, and on the small areas of an auditorium than in the large dimensions of out of door space. It cannot be ignored, as it has been heretofore ignored in all discussion of this phase of the problem of architectural acoustics, with impunity. The method of rays, although a fairly correct approximation with large areas, is misleading under most conditions. For example, in the present case it would have predicted almost perfect acoustics in the boxes and on the main floor.

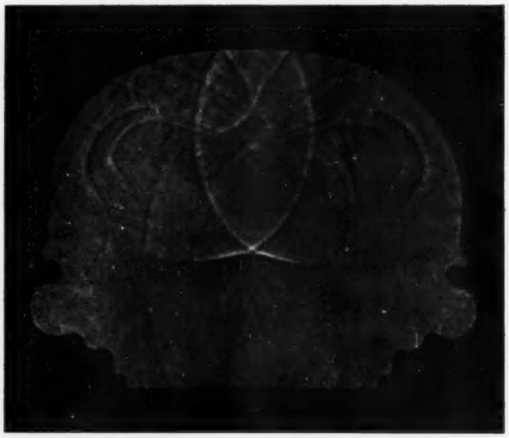

FIG. 28. A PHOTOGRAPH, ONE OF MANY TAKEN, SHOWING IN VERTICAL SECTION ONE STAGE OF THE REFLECTION $b_2$, FIG. 21. THESE REFLECTIONS WERE ELIMINATED BY THE ARCHITECTS IN THE SUMMER FOLLOWING THE OPENING OF THE THEATRE, BUT HAVE BEEN IN PART RESTORED BY SUBSEQUENT CHANGES.

The third photograph in the series shows the condition in the room when the main sound wave has reached the last seat in the top gallery. The wave $c_1$ has advanced and is reaching the front row of seats in the gallery, producing the effect of an echo. A little later it will enter the balcony, producing there an echo greater in intensity, more delayed, and affecting more than half the seats in the balcony, for it will curve under the gallery, in the manner just explained, and disturb seats which geometrically would be protected. Still later it will enter the foyer seats and the boxes. But the main disturbance in these seats and the boxes, as is well shown by the photograph, arises from the wave $c_2$, and in the orchestra seats on the floor from the wave $c_3$.

In the summer following the opening of the theatre, a canopy, oval in plan and slightly larger than the ceiling oval, was hung from the ceiling surrounding a central chandelier. The effect of this in preventing these disturbing reflections is shown by a comparison, pair by pair, of the two series of photographs, Figures 15 to 17 and Figures 18 to 20. It is safe to say that there are few, possibly no modern theatres, or opera houses, equal in size and seating capacity, which are so free from this particular type of disturbance as the New Theatre at the present time.

In the study of the New Theatre photographs were taken through several horizontal sections. It will be sufficient for the purposes of the present paper to illustrate the effect of curved surfaces in producing converging waves by a few photographs showing the propagation of sound through a single section in a plane passing through the parapet in front of the boxes. The reflected waves shown in Figure 22 originating from the edge of the proscenium arch and from the base of the column can be followed throughout all the succeeding photographs. In Figure 23 are shown waves originating from the plain wall beneath the actor's box and the beginning of some small waves from the curved parapet. It is easily possible, as it is also interesting and instructive, to follow these waves through the succeeding photographs. In Figure 25 the sound has been reflected from the rear of the parapet; while in Figure 26 it has advanced further down the main floor of the auditorium, narrowing as it

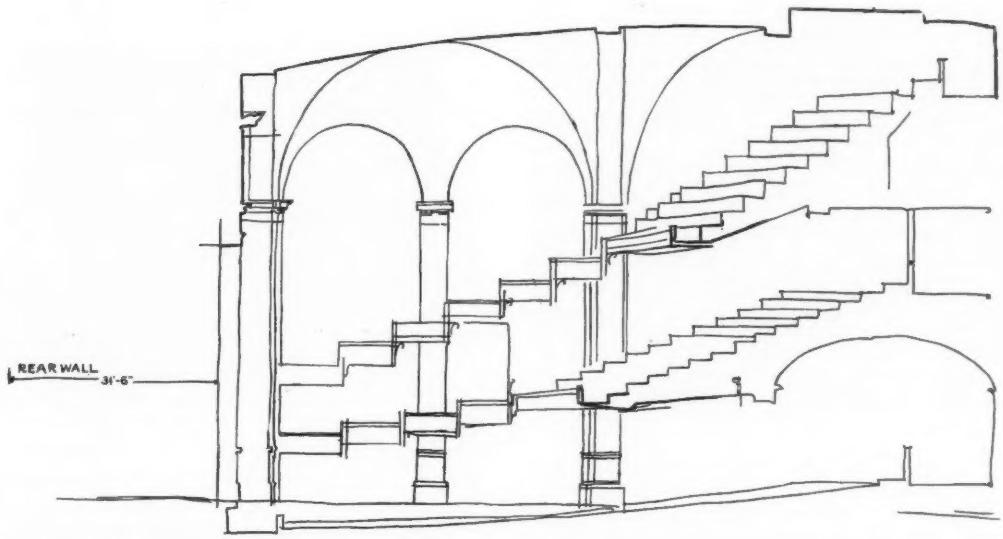


FIG. 29. SECTION IN PENCIL SKETCH OF SCOLLAY SQUARE THEATRE, IN BOSTON
MR. C. H. BLACKALL, *ARCHITECT*

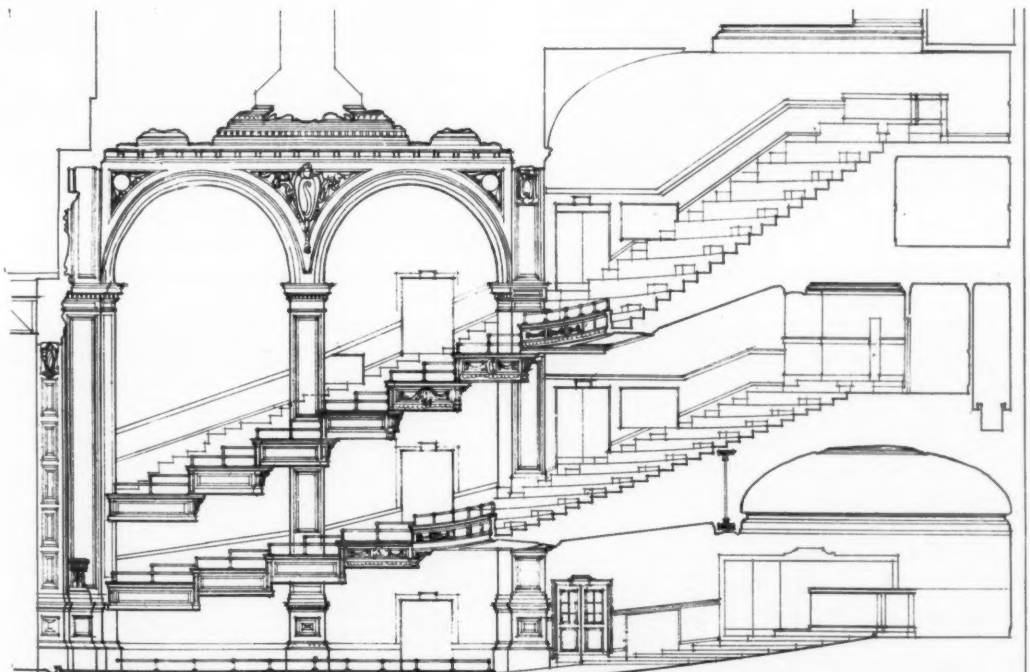

FIG. 30. FINISHED SECTION OF SCOLLAY SQUARE THEATRE BOSTON
MR. C. H. BLACKALL, *ARCHITECT*

proceeds and gaining in intensity. The waves reflected from the parapet outside of the aisles are here shown approaching each other behind the wave which has been reflected from the parapet between the aisles. Waves are also shown in Figure 26 emerging from the passages between the boxes. Indeed, it is possible to trace the waves arising from a second reflection from the proscenium arch of the sound which, first reflected from the corresponding surfaces on the other side, has crossed directly in front of the stage. With a little care, it is possible also to identify these waves in the last photograph.

Although many were taken, it will suffice to show a single photograph, Figure 28, of the reflections in the plane passing through the back of the boxes. These disturbing reflections were almost entirely eliminated in the revision of the theatre by the removal of the boxes from the first to the second row and by utilizing the space vacated together with the anterooms as a single balcony filled with seats.

An excellent illustration of the use of such photographs in planning, before construction and while all the forms are still fluid, is to be found in one of the theatres now being built in Boston by Mr. C. H. Blackall, who has had an exceptionally large and successful experience in theatre design. The initial pencil sketch, Figure 29, gave in the model test the waves shown in the progressive series of photographs, Figures 31 to 33. The ceiling of interpenetrating cylinders was then changed to the form shown in finished section in Figure 30, with the results strikingly indicated in the parallel series of photographs, Figures 34 to 36. It is of course easy to identify all the reflections in each of these photographs—the reflections from the ceiling and the balcony front in the first; from the ceiling and from both the balcony and gallery front in the second; and in the third photograph of the series, the reflections of the ceiling reflection from the balcony and gallery fronts and from the floor. But the essential point to be observed in comparing the two series pair by pair, is the almost total absence in the second series of the ceiling echo and the relatively clear condition ba k of the advancing sound wave.

### Consonance

Consonance is the process whereby, due to suitably placed reflecting walls, "the voice is supported and strengthened." It is the one acoustical virtue that is positive. It is also the characteristic virtue of the modern theatre, and that through which this complicated auditorium surmounts the attendant evils of interference, reverberation and echo. Yet such is our modern analysis of the problem that we do not even have for it a name. On the other hand, it is the virtue which the Greek theatre has in least degree. It is therefore all the more interesting that it should have been included in the analysis of Vitruvius, and should have received a name so accurately descriptive. Indeed, one can hardly make explanation of the phenomenon better than through the very type of theatre in which its lack is the one admitted defect.

The Greek theatre enjoys a not wholly well founded reputation for extremely good acoustics. In most respects it is deserved; but the careful classical scholar, however gratified he may be by this praise of a notable Greek invention, regards himself as barred by contemporaneous evidence from accepting for the theatre unqualified praise. Every traveller has heard of the remarkable quality of these theatres, and makes a trial wherever opportunity permits, be it at beautiful Taormina, in the steep sloped theatre at Pompeii, the great theatre at Ephesus, or the "little theatre" on the top of Tusculum—always with gratifying results and the satisfaction of having confirmed a well known fact. Perhaps it is useless to try to traverse such a test. But there is not a theatre in Italy or Greece which is not in so ruined a condition today that it in no way whatever resembles acoustically its original form. If its acoustics are perfect today, they certainly were not originally. Complete "scaena" and enclosing walls distinctly altered the acoustical conditions. The traveller has in general tested what is little more than a depression in the ground, or a hollow in a quiet country hillside. As a matter of fact, the theatre in its original form was better than in its ruined state. Still, with all its excellencies it was not wholly good. Its acoustical

FIG. 31

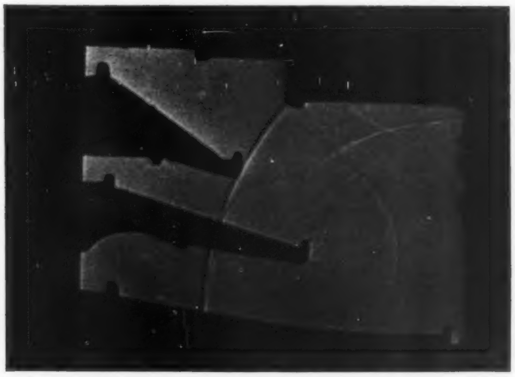

FIG. 34

FIG. 32

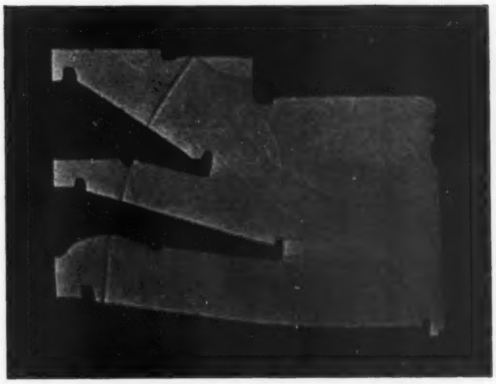

FIG. 35

FIG. 33

FIG. 36

TWO SERIES OF PHOTOGRAPHS SHOWING, FIGURES 31 TO 33, THE REFLECTIONS WHICH WOULD HAVE RESULTED FROM THE EXECUTION OF THE FIRST PENCIL SKETCH OF THE SCOLLAY SQUARE THEATER (FIGURE 29), AND, FIGURES 34 TO 36, FROM THE EXECUTION OF THE SECOND SKETCH BY MR. BLACKALL (SHOWN IN FINISHED SECTION IN FIGURE 30).

qualities were not wholly acceptable to its contemporaries, and would be less acceptable in a modern theatre, and for modern drama.

The difficulty with such casual evidence is that it is gathered under wholly abnormal conditions. Not only are the ruins but scant reminders of the original structure, but the absence of a large audience vitiates the test, as it would vitiate a test of any modern theatre. But while in a modern auditorium the presence of an audience almost always, though not invariably, improves the acoustics, in the classical theatre the presence of an audience, in so far as it has any effect, is disadvantageous. The effect of an audience is always twofold—it diminishes the reverberation, and it diminishes the loudness or intensity of the voice. In general, the one effect is advantageous, the other disadvantageous. But in the Greek theatre, occupied or unoccupied, ruined or in its original form, there was very little reverberation. In fact, this was its merit. On the other hand, the very fact that there was little reverberation is significant that there was very slight architectural reënforcement of the voice. One might well be unconvinced by such *a priori* considerations were there not excellent evidence that these theatres were not wholly acceptable acoustically even in their day, and for drama written for and more or less adapted to them. Excellent evidence that there was insufficient consonance is to be found in the megaphone mouthpieces used at times in both the tragic and the comic masks, and in the proposal by Vitruvius to use resonant vases to strengthen the voice.

The doubt is not as to whether a speaker, turned directly toward the audience and speaking in a sustained voice, could make himself heard in remote parts of a crowded Greek theatre. It is almost certain that he could do so, even in the very large and more nearly level theatres, such as the one at Ephesus. Better evidence of this than can be found in the casual test of a lonely ruin is the annual performance by the staff of the Comédie Française in the theatre at Orange. But even this, the best preserved of either Greek or Roman theatres, is but a ruin, and its temporary adaptation for the annual performance is more modern than classical. A much better test is in the exercises regularly held in the Greek Theatre of the University of California, designed by Mr. John Galen Howard, of which President Wheeler speaks in most approving terms. The drama, especially modern drama, differs from sustained speech and formal address in its range of utterance, in modulation, and above all in the requirement that at times it reach the audience with great dynamic quality but without strain in enunciation. Mere distinctness is not sufficient. It was through a realization of this that the megaphone mouthpiece was invented—awkward in use and necessarily destructive of many of the finer shades of enunciation. That it was only occasionally used proves that it was not a wholly satisfactory device, but does not detract its evidence of weakness in the acoustics of the theatre.

The megaphone mouthpiece bears to the acoustics of the Greek theatre the same evidence, only in a reciprocal form, that the mask itself bears to the theatre's illumination. It was not possible to see in bright daylight, particularly in the bright sunlight of the Mediterranean atmosphere, with anything like the accuracy and detail possible in a darkened theatre with illuminated stage. The pupil of the eye was contracted, and the sensitiveness of the retina exhausted by the brilliancy of the general glare. Add to this that the distance from the stage was very much greater in the Greek than in the modern theatre, audience for audience, and one can realize the reason for the utter impossibility of facial expression in Greek dramatization except by artificial exaggeration. The heaviness and inflexibility of these devices, and therefore their significance as proof of some inherent difficulty in dramatic presentation, is emphasized by the delicacy of line and fine appreciation of the human form shown in other contemporaneous art.

Not less significant in regard to the acoustics of the Greek theatre are the directions given by Vitruvius for the reënforcement of the voice by the use of resonant vases:

"Accordingly bronze vessels should be made, proportional in size to the size of the theatre, and so fashioned that when sounded they produce with one another the notes of the fourth, the fifth, and so on to the double octave. These vessels should be placed in accordance with musical laws in niches between the seats of the theatre in such position that they nowhere touch the wall, but have a clear space on all sides and above them. They should be set upside down and supported on the side facing the stage by wedges not less than half a foot high. . . . With this arrangement, the voice, spreading from the stage as a center and striking against the cavities of the different vessels, will be increased in volume and will wake an harmonious note in unison with itself."

There is good reason for believing that this device was but very rarely tried. This, and the fact that it could not possibly have accomplished the purpose as outlined by Vitruvius, is not germane. The important point is that its mere proposal is evidence that the contemporaries of the Greek theatres were not wholly satisfied, and that the defect was in lack of consonance.

It would be inappropriately elaborate and beyond the possible length of this paper to give in detail the method of calculating the loudness of sound in different parts of an auditorium. That subject is reserved for another paper in preparation in which will be given not merely the method of calculation but the necessary tables for its simplification. It is, however, possible and proper to give a general statement of the principles and processes involved.

In this discussion I shall leave out as already adequately discussed the phenomenon of interference, or rather shall dismiss the subject with a statement that when two sounds of the same pitch are superposed in exact agreement of phase, the intensity of the sound is the square of the sum of the square roots of their separate intensities; when they are in opposite phases, it is the square of the difference of the square roots of their intensities; but when several sounds of the same pitch arrive at any point in the room with a random difference of phase their probable intensity is the simple numerical sum of their separate intensities. It is on the assumption of a random difference of phase and an average probable loudness that I shall here consider the question. This has the advantage of being the simpler and also a first approximation in an auditorium designed for articulate speech.

When sound spreads from a spherically symmetrical source it diminishes as the square of the distance. When the sound is being propagated, still in space unrestricted by walls or ceiling, but over the heads of a closely seated audience, the law of the diminution of the sound is more rapid than the law of the inverse square. This more rapid diminution of the sound is due to the absorption of the sound by the audience. It is a function of the elevation of the speaker and the angle of inclination of the floor—in other words, the angle between the sight lines. The diminution of the intensity of the sound due to distance is less the greater this angle.

If the auditorium be enclosed by not too remote walls, the voice coming directly from the speaker is reënforced by the reflection from the retaining walls. However, it is obvious that the sounds reflected from the walls and ceilings have traversed greater paths than the sound of the voice which has come directly. If this difference of path length is great, the sounds will not arrive simultaneously. If, however, the path differences are not great, the reflected sounds will arrive in time to reënforce the voice which has come directly, each syllable by itself, or, indeed, in time for the self support of the sub-syllabic components. It is to this mutual strengthening of concurrent sounds within each element of articulate speech that Vitruvius has given the name "consonance."

Thus in the computation of the intensity of the voice which has come directly from the speaker across the auditorium it is necessary to take into consideration not merely the diminution of intensity according to the law of the inverse square of the distance and the diminution of the intensity due to the absorption by the clothing of the audience, but also, as a compensating factor for the latter, the diffraction of the sound from above which is ever supplying the loss due to absorption, while in computing the intensity of the sound reflected from any wall or other surface one must take into consideration all this, and also the coefficient of reflection

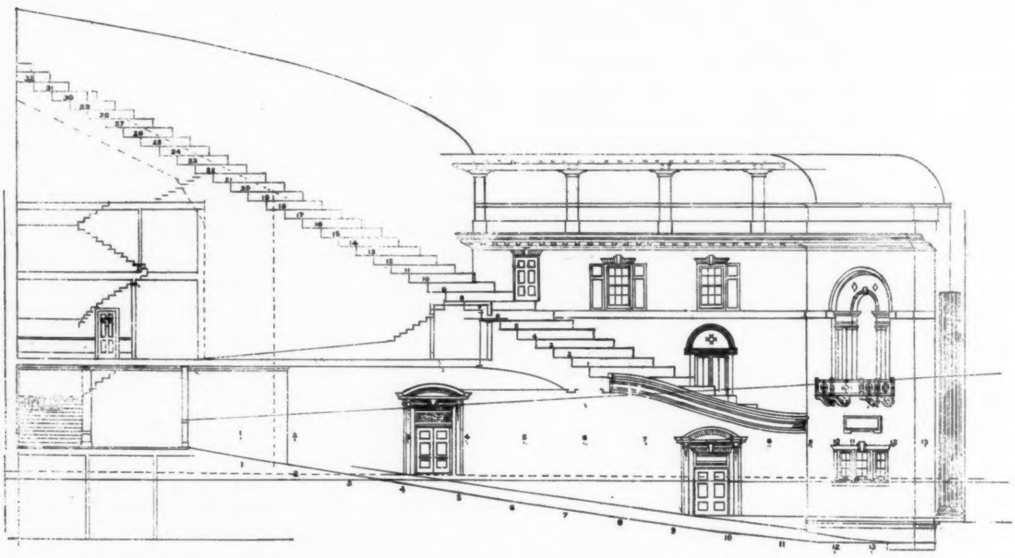

FIG. 37. THE HARRIS THEATRE, MINNEAPOLIS, FIRST DESIGN.
MESSRS. CHAPMAN & MAGNEY, *ARCHITECTS*

of the wall and the diffraction due to the restricted area of the reflecting element.

Abstract principles are sometimes tedious to follow even when not difficult. In Figure 38 is shown a photograph taken in an investigation for the architects, Messrs. Chapman and Magney, of the Harris Theatre, to be erected in Minneapolis, which affords an excellent example of both favorable and unfavorable conditions in respect to consonance. The initial sketch for this theatre offered no problems either of interference or reverberation, and of echo only in the horizontal section. The only very considerable question presented by the plans was in respect to consonance and there in regard only to the more remote parts of the floor and of the balcony. The particular photograph here reproduced records the condition of the sound in the room at such an instant as to bring out this aspect of the problem in marked degree.

FIG. 38. SHOWING THE CONSONANCE IN THE BALCONY OF THE HARRIS THEATRE. THIS RELATES ONLY TO CONSONANCE IN THE VERTICAL SECTION.

The forward third of the balcony in this theatre affords an excellent example of consonance, for the reflection from the ceiling arrives so nearly simultaneously with the sound which has come directly from the stage as to "strengthen and support" it and yet "leave the words clear and distinct." The interval between the two, the direct and the reflected voice, varies from .01 seconds to .03 seconds. Back of the first third, however, the consonance from the ceiling gradually diminishes and is practically imperceptible beyond the middle of the gallery. Back of that point the direct voice diminishes rapidly since it is passing in a confined space over the highly absorbent clothing of the audience. The loss of intensity at the rear of the gallery is increased by the carrying of the horizontal portion of the ceiling so far rearward. While the effect of this is to throttle the rear of the gallery it obviously strengthens the voice in the forward third. Although there is thus some compensation, on the whole the forward part of the gallery does not need this service so much as the rear seats. The photograph shows this process clearly: the main sound wave can be seen advancing after having passed the angle in the ceiling. The wave reflected from the ceiling can be seen just striking the gallery seats. It is evident that at the instant at which the photograph was taken the sound wave was receiving the last of this support by the sound reflected from the ceiling.

The photograph also shows how the sound after passing the ceiling angle spreads into the space above, thus losing for the moment thirty per cent. of its intensity, a loss, however, to be regained in considerable part later.

On the main floor the reflection from the ceiling strengthens the direct voice only for the long syllabic components. Nevertheless, in comparison with other theatres the forward part of the floor of this theatre will be excellent. There will be just a trace of echo immediately under the front of the balcony, but this will be imperceptible beyond the first four rows of seats under the balcony. It is obvious from the photograph that there is no consonance in the rear of the main floor of the auditorium under the balcony.

A not unnatural, certainly a not uncommon, inquiry is for some statement of the best height, the best breadth, and the best depth for a theatre, for a list of commended and a list of prohibited forms and dimensions. A little consideration, however, will show that this is neither a possible nor the most desirable result of such an investigation.

For a simple rectangular auditorium of determined horizontal dimensions there is a best height. When, however, the horizontal dimensions are changed the desirable height changes, although by no means proportionally. When the floor is inclined, when the walls are curved, when there are galleries and connecting corridors, when the material of construction is varied in character, the problem becomes somewhat more intricate, the value of each element being dependent on the others. Moreover it is futile to attempt to formulate a standard form even of a single type of auditorium. How greatly the design must vary is well illustrated in the four theatres which have been taken as examples—the Little Theatre with all the seats on the main floor, the Harris Theatre, very long, very broad, and with but a single gallery, the Scollay Theatre with two galleries, and the New Theatre with two rows of boxes and two galleries. The fundamental conditions of the problem, not the entirely free choice of the architect, determined the general solution in each case. Acoustical quality is never the sole consideration; at best it is but a factor, introduced sometimes early, sometimes late, into the design.

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# NEW YORK THEATRES FORTY ODD YEARS AGO

*By* ROBERT GRAU

IN 1870 there were less than ten theatres in New York City, but these were practically all of one class where the scale of prices ranged from twenty-five cents to $1.50. The leading theatre at this period was located at the corner of Fourteenth Street and Sixth Avenue and was called the *Théatre Francais.* The theatre stands today very little changed, save that it is devoted to moving pictures.

The only theatres above Fourteenth Street were the Brougham Theatre on West Twenty-fourth Street, adjoining the Fifth Avenue Hotel, and Wood's Museum where Daly's Theatre now stands. It will be news to many to know that Daly's Theatre, save for decorations and minor alterations, is practically the same as the famous old playhouse where two generations ago two performances were given daily by a superb stock company, while in the lobbies various freaks were wont to hold sway to the amazement of the theatre-goers of that day. In the stock company were such players as Louis Aldrich, Thomas W. Keene, McKee Rankin and Henry Lee.

Wallack's was at Thirteenth Street and Broadway, while around the corner, practically the same house, too, as it stands today, was the Union Square Theatre, where "Bob" Butler presented variety shows that would put to shame the best seen on Broadway today, save for spectacular features. The Union Square was the leading variety theatre up to the time when Sheridan Shook and A. M. Palmer installed in the house the famous stock company which included among others, Clara Morris, Rose Eytinge, Kate Claxton, Sarah Jewett, Jeffreys Lewis, Charles R. Thorne, John Parselle, McKee Rankin and F. F. Mackay. Wallack's became the Star Theatre, when Lester Wallack moved with his model company to the house that still bears his name at Thirtieth Street and Broadway.

Fourteenth Street was quite as prominent four decades ago as it is today, for besides the *Théatre Francais,* where Ristori appeared and where French opera bouffe was first revealed, there was the Academy of Music, the same house in every way as it is today, and here grand opera passed through enough vicissitudes to merit a special article, but its glories are not likely to be lessened in the memory of "old-timers" by the fact that this grand old structure, too, became a moving picture theatre for a time.

Steinway Hall, whose exterior still stands as it did in the '70's, was the one concert auditorium, and a grand place of the kind it was! Here were heard the great Rubinstein, the ponderous Wieniawski and the two Pattis, Adelina and Carlotta.

I recall the advent of Adelina when she came hither under her own management, because no impresario would pay her $4,000 a night. The diva made the error of charging $10 a seat and faced a beggarly array of empty seats at her opening concert, though she was then in her prime, in fact, only on this visit was she heard at her best. The tournée was threatened with disaster, but an intrepid American showman, Henry E. Abbey, who had made a fortune with Sarah Bernhardt on her first tour here, arranged terms with Patti, reduced the seat scale of prices by one-half, paid the diva $4,000 a night and made another fortune for himself.

Steinway Hall was also the scene of the triumphs of the younger sister of Patti's. Carlotta, who had a voice scarcely less marvelous than her more celebrated sister. She was handicapped, however, by her lameness, which necessitated her confining her appearances to the concert platform, though she did appear once in grand opera, in Mozart's "The Magic Flute." The memory of this event at the Academy of Music will last forever for all of those who were privileged to be entertained by the exquisite art of the diva will always refer to the occasion in a discussion of similar events.

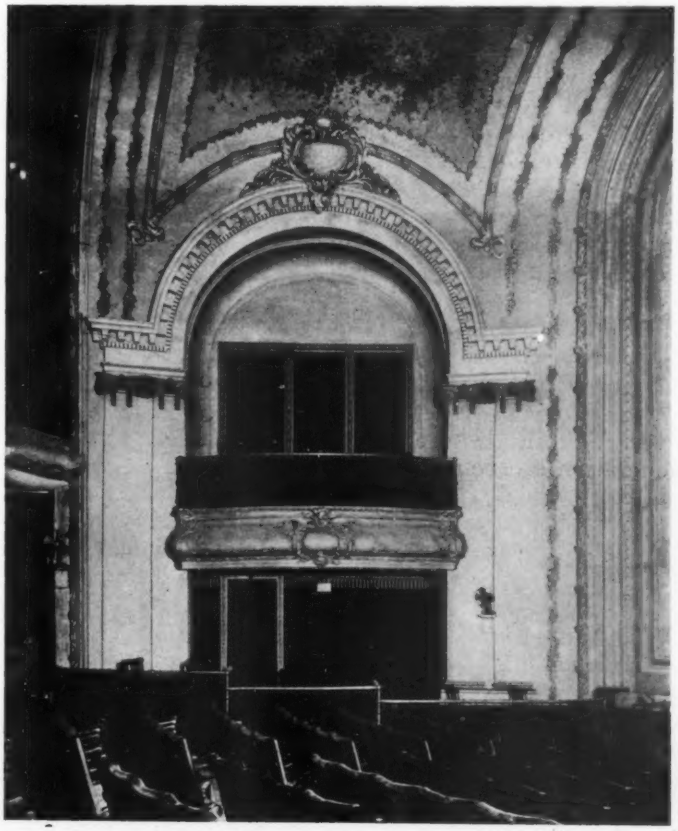
Among others who dignified Steinway Hall were Christine Nilsson, who came in the early '70's and created a furore, and with her were heard Teresa Careno and Emile Sauret, both of whom are still potent attractions, with no indication that four decades of activity suggest the end of their extraordinary careers.

Charles Dickens came to Steinway Hall in readings, so did Charlotte Cushman, while Mrs. Scott Siddons was the distinguishing feature of two consecutive seasons in the same concert room.

Around the corner from Steinway Hall, where the "Deutsches Theater" now stands, was Irving Hall, where famous balls were given. It was here that the late King Edward, then the Prince of Wales, was given a grand welcome in a ball and reception which was at the time the most colossal event of the year, or of many years for that matter. Irving Hall was famous for its "pop" concerts, given under the direction of Lafayette Harrison, an old-time impresario, who once remarked that the ultimate destination of his kind was either the county jail or the mad house, and it would seem that he was indeed a prophet, though in recent years a few of his successors have died, leaving enough for their funeral expenses, their lives being sacrificed prematurely in the effort to avoid the fate of their predecessors.

New Yorkers of today may observe a vacant site just below Astor Place, on the east side of Broadway, and a truly historic location it is! For years this property has lain dormant, and only in the last few years have the owners, the Astor Estate, seen fit to tear down the old building, which had stood there vacant for more than a decade. Its last use was for fistic events and before that it was known as "Ye London Streete," but for forty years this site was occupied by theatres of every sort. It was originally a church and became famous as the New York Theatre, where the renowned Worrell Sisters had their home, and here they were wont to appear in such burlesques as "Ixion," "The Forty Thieves," and "The Field of the Cloth of Gold." This theatre had perhaps the most checkered career of any in New York's history—at some time or other every manager had his try at it, until it came to be called "The Morgue."

At 720 Broadway was Lina Edwin's Theatre, a bijou house, which afterwards housed the famous Kelly and Leon Minstrels. A little further down was the Olympic Theatre, where George L. Fox made his memorable 500-night-run as "Humpty-

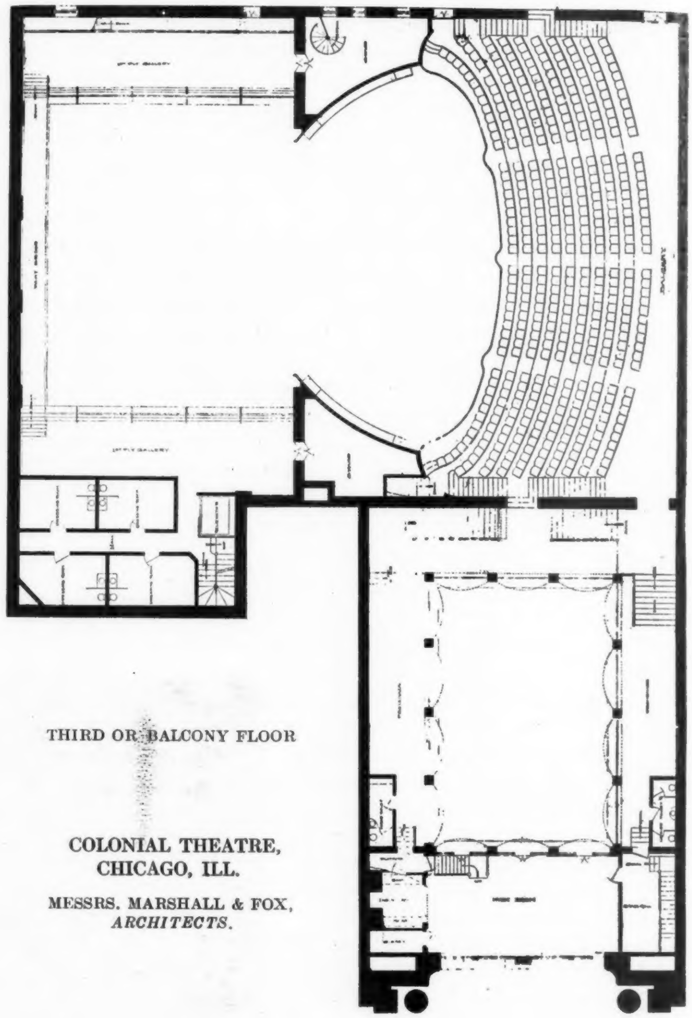


COLONIAL THEATRE, CHICAGO ILL.
MESSRS. MARSHALL & FOX, *ARCHITECTS.*

Dumpty." Poor Fox!—when he died, pantomime went with him to the grave. He was truly a great actor who took a serious view of his art. His aspiration to a tragedian's career tended to shorten his day and he could not reconcile himself to the fact that only as a clown was he acceptable to the public.

The old Metropolitan Theatre was at 585 Broadway. Here the famous San Francisco Minstrels had their permanent abode, until they moved up to Twenty-eighth Street and Broadway. They were succeeded at "585" by Tony Pastor who for years innumerable presented "polite variety there.

Across the street was Niblo's Garden, a theatre with more historic worth attached to it than any that can be recalled. Niblo's will always be best known for the great spectacles which Jarrett and Palmer presented there, the first of which "The Black Crook," ran for two years and was often revived afterwards. It was in this production that the peerless Morlachi and the dainty Bonfanti set old New York literally crazy with their remarkable toe dancing.



THIRD OR BALCONY FLOOR

COLONIAL THEATRE, CHICAGO, ILL.

MESSRS. MARSHALL & FOX, *ARCHITECTS.*

Bonfanti still lives and is now presiding over a studio where dancers of another generation are benefiting from her consummate art and knowledge. Bonfanti in the height of her career was married to a young banker of the Hoffmann family, but he did not long survive the wedding. Morlachi was married to the world-renowned scout, W. H. Omnohundro (Texas Jack), and the two lived happily together for many years.

Niblo's was the scene of the many great achievements of the Kiralfy family. There were three brothers and three sisters, and they were the first to introduce their peculiar type of Hungarian dances. Of the brothers the eldest was Imre, who afterwards became a great managerial figure and is now a millionaire magnet in London, where he provides the great pageantry for the Earls Court exhibitions. Arnold, the youngest, and considered the best dancer of the three, died in 1908 in destitute circumstances.

The Kiralfy Sisters had short public careers, all having married and retired many years ago. One married Al. Parkes, a well known newspaper man, who was dramatic editor of the New York *Mercury*, a periodical which cut a wide swath in New York forty years ago. Another sister married Edmund Gerson, an impresario. Madame Gerson is now in a sanitarium at Stam-

*(Continued an page 284)*

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Page A. Robinson, *Western Manager*

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## "THEATRE ACOUSTICS"

IT is a rare privilege to be able to present an exhaustive article from an authoritative pen on a subject as important, yet so little understood as theatre acoustics. In this issue, Professor Sabine discusses the subject, not merely from the standpoint of the scholar—an attitude which men of affairs are so inclined to deprecate—but also from the experience of one whose practical knowledge has been sought when practical results were needed.

Our increasing scientific understanding of acoustics, due largely to the researches of Professor Sabine, is but one phase of the ever-increasing complexity in architectural practice. As the searchlight of investigation is directed upon each of the elements and properties of building construction, the more fully we realize that no one man can be a specialist in every one of them. Rather, the architect is coming more and more to be a director of other men's services in producing the design which he had conceived as a whole. The director, however—as well as the small practitioner who "does his own work"—should have an accurate general knowledge of the methods employed by experts and it is to this end that we present Professor Sabine's article.

## THE FUNCTION OF A BUILDING CODE

IN nearly every American city the building code is a subject of ever-recurring discussion with a view to its possible revision and improvement. The fact that this phantom is never permanently appeased is due in part to the generally prevailing methods of framing legislation whereby laws that should embody scientific knowledge of technical matters are oftener than not devised by more or less educated politicians with many suggestions from interested commercial bodies.

It is but natural and proper that a merchant should protect his legitimate interests before the law, but there is sometimes an unfortunate tendency to take advantage of code revision in order to gain, or attempt to gain, a monopoly or special privilege and thus exclude possible competition. What is the public's concern regarding the building code? Obviously it cares nothing for the rivalry of commercial interests, *per se*, but demands that the material and construction of buildings may be such as insure both safety and economy.

The criterion of building-safety is not a matter of specific methods and materials, but rather a compliance with the requirements of adequate physical tests. Economy is generally assured by the possibility of competition, but this condition cannot be realized if the products of any given commercial interest are favored to the exclusion of all others. When, through lack of technical knowledge or the importunities of self-seekers the lawmakers specify exclusive methods and materials, it is but fair to assume that their object is the assurance of public safety, regardless of that economy to the owner, which results from the possibility of selection from among a number of suitable products. The results of this method of law-making are obviously illogical and detrimental to the public welfare.

The building law should be elastic. Just as in the past we have altered our methods of construction in the interests of greater safety, so in the future other and better ways may suggest themselves under any circumstances. It is unfair to the inventor and detrimental to the advance of the building art to forbid the use of any new method or material, provided it is able to withstand a reasonable physical test.

We predict that in the future the law will devote itself to requiring results rather than to specifying methods and materials. It is for the law to fix standards of safety and at the same time to permit competition—a dual condition which can be most intelligently obtained through the recommendations of scientific and practical men rather than through the legislation of a non-technical body. The law should give to builders and those planning their structures the widest latitude consistent with safety; it is the prerogative of the architect to specify the definite materials and methods of construction best adapted to the requirement of each individual building.

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## NEW YORK THEATRES FORTY ODD YEARS AGO

(*Continued from page* 282)

ford, Conn., where she was obliged to take up her residence several years ago.

Whenever I happen to hie myself to the lower part of the now Greater City, I have always been impressed with the changes which time has rung, and nowhere has this seemed so significant as on the block between Spring and Broome Streets on Broadway, with its vast array of mercantile buildings and warehouses. There is nothing about this local today to remind one of the glories of the old *Théatre Comique*, where Harrigan and Hart reigned supreme, and where the famous "Mulligan Guards" came into being. Here was indeed a typical spot, and it is enough to make one who has gazed upon the spectacle of other days shudder to find himself in the gloom and desertion which prevails here after dark—where—and it does not seem so long ago—once was the most brilliantly lighted and the gayest spot to be found in the big city—a veritable "Rialto"—as I recall it!

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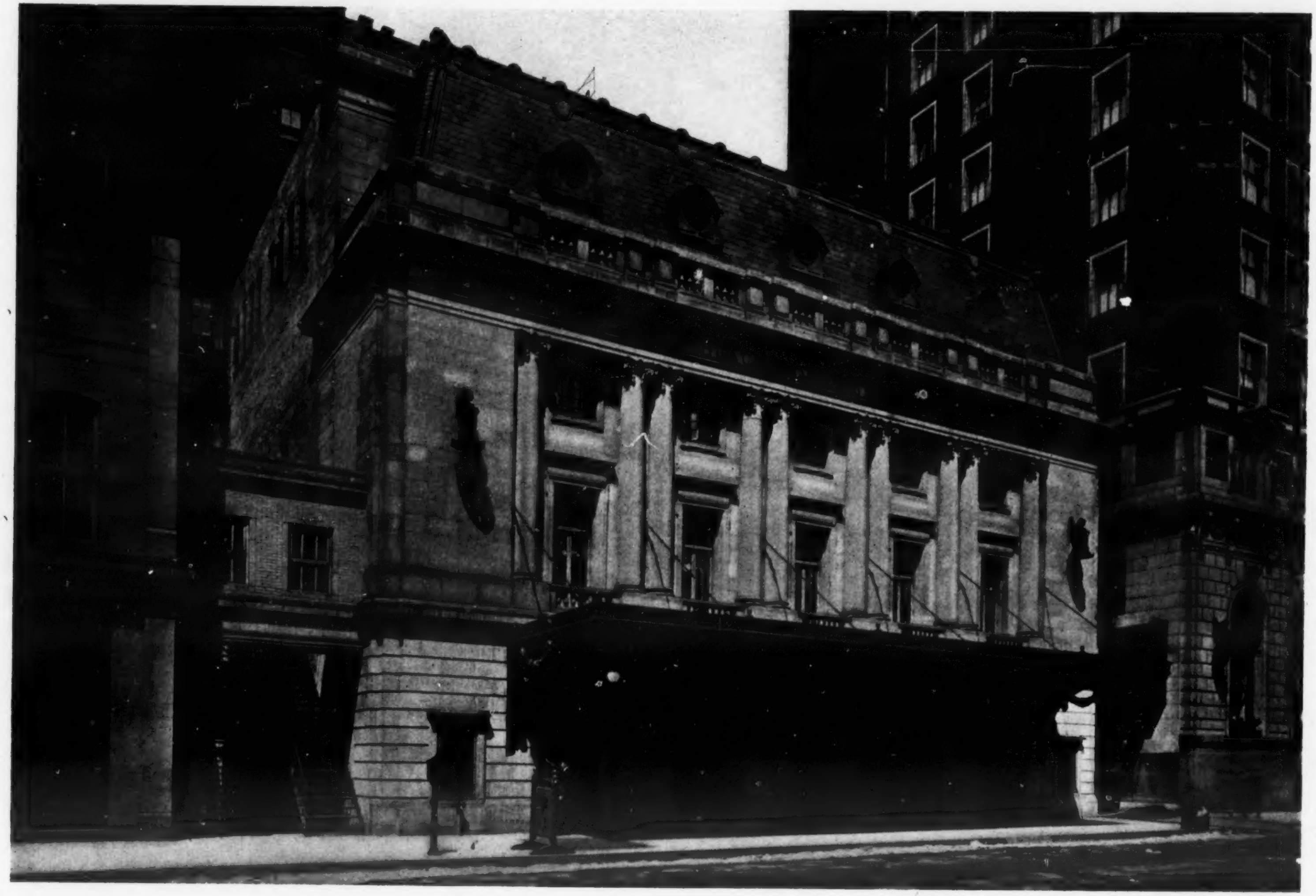
## GREEK REFINEMENTS ACCEPTED BY SALOMON REINACH

IN a review of Professor W. H. Goodyear's recent book on "Greek Refinements," Salomon Reinach, who is known as one of the most able art historians and archæologists in Europe, gives expression to the following which has been translated from the French:

"Intentional departures from true vertical and horizontal lines were first established in 1837, as the result of a minute study of the Parthenon. Some archæologists and critics denied that these variations were intended, others endeavored to justify them by optical explanations. In reality the purpose was quite a different one. The question at stake for ancient architects was to avoid monotony and coldness which are inherent in geometric perfection. To this end they sometimes made their lines in convex curves and sometimes made them concave. If optical corrections have been purposed we should always find the lines convex. It is the great distinction of Mr. Goodyear to have established the existence of these 'refinements' in a number of ancient and mediæval buildings; no one before him had suspected that the mediæval builders had followed the principles of the Greek artists. It is quite true that he has been treated as a visionary. The attempt has been made to explain everything (as the Germans say wegerklären) by the magical word 'settlement'; but today it is clear that Mr. Goodyear has won his case. When we think about it these 'refinements' are not more surprising than the methods of good sculptors in giving a slight asymmetry to their figures: those who have modelled rigorously symmetrical heads, like Canova, have been cold and tiresome artists.

"The present book, as its title indicates, is especially concerned with the Greek monuments. Mr. Goodyear shows absolute loyalty in realizing that his explanations have been foreshadowed by Hoffer and Bontmy, as the facts which he emphasizes, were first established in 1837-38 by Hoffer, Penrose and Pennethorne; but his own accomplishment is such that he is able to add to it without fear by recognizing that of his predecessors."



BLACKSTONE THEATRE, CHICAGO, ILL.

MESSRS. MARSHALL & FOX, *ARCHITECTS*

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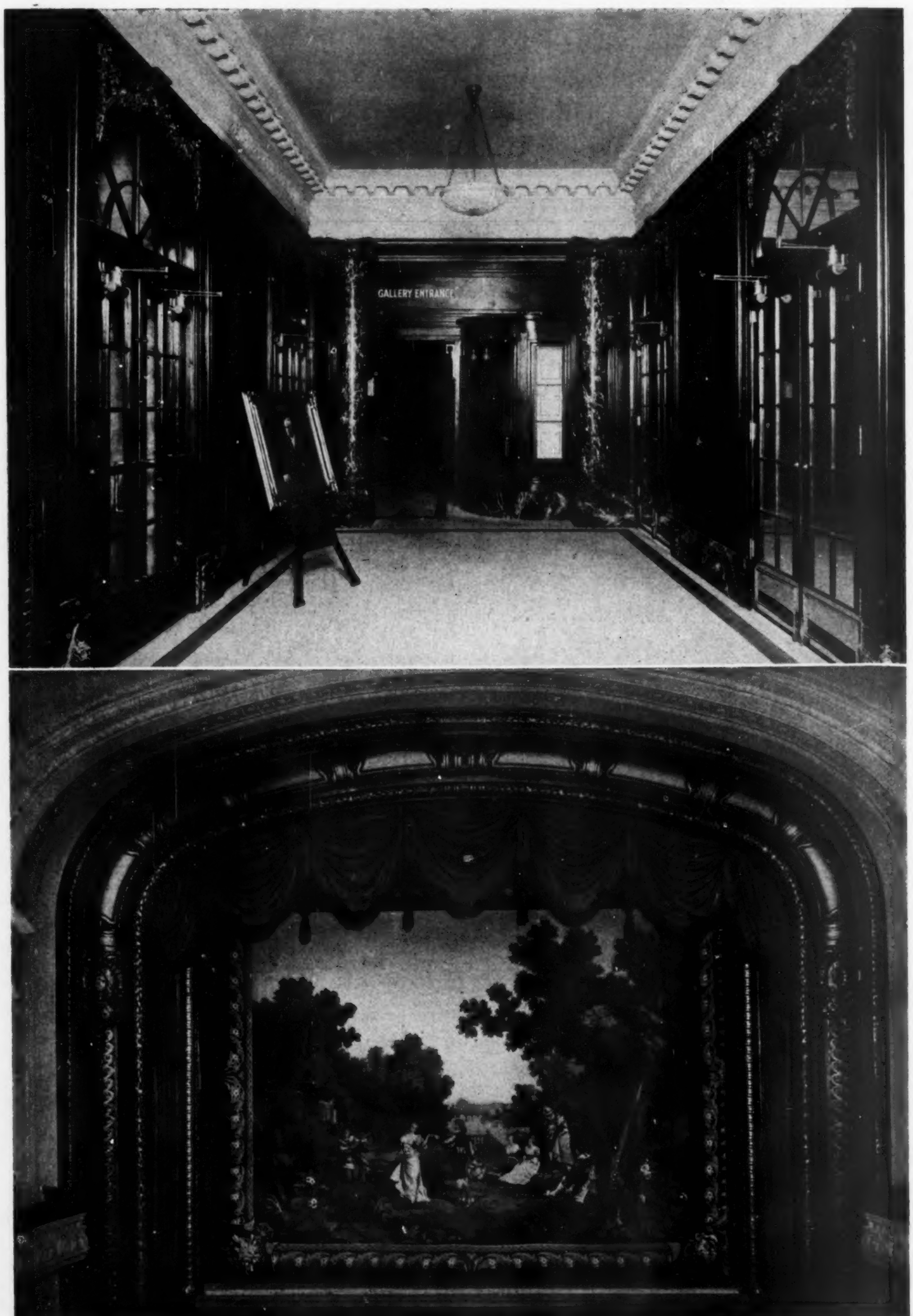
MAIN, OR ORCHESTRA FLOOR

VIEW FROM STAGE

BLACKSTONE THEATRE, CHICAGO, ILL.

MESSRS. MARSHALL & FOX, *ARCHITECTS*




ENTRANCE LOBBY AND DROP CURTAIN

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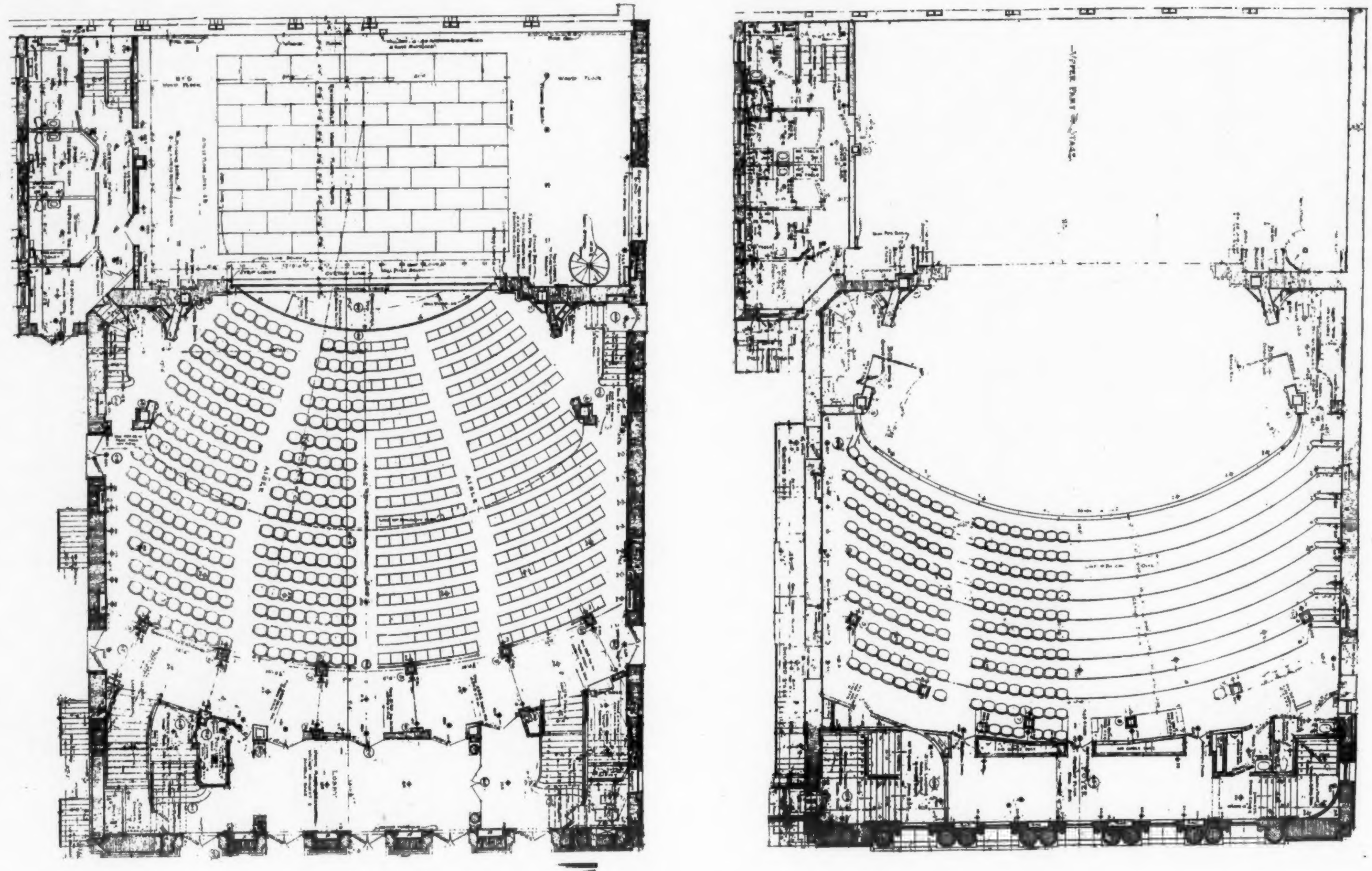


MAIN FLOOR AND BALCONY PLANS

BLACKSTONE THEATRE, CHICAGO, ILL.

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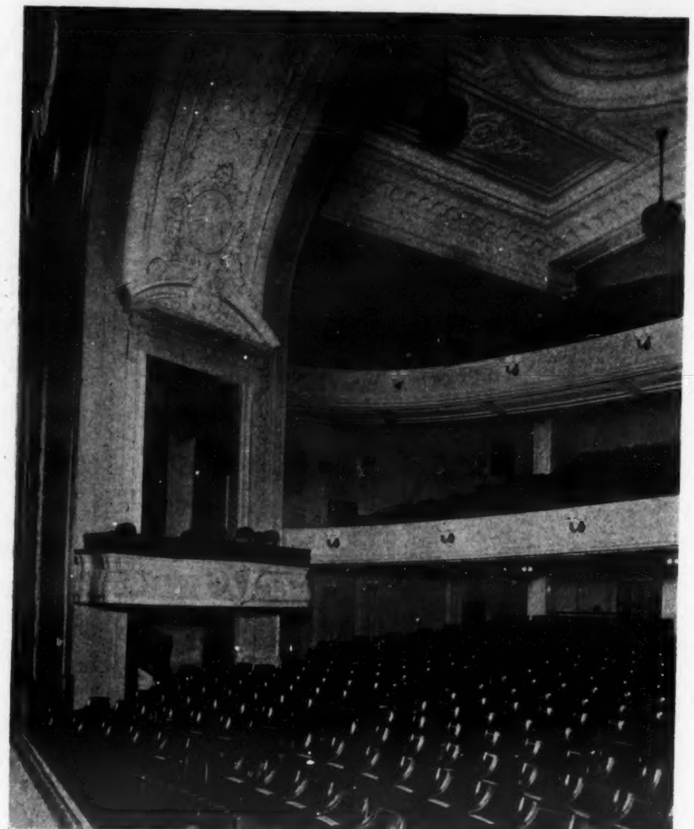

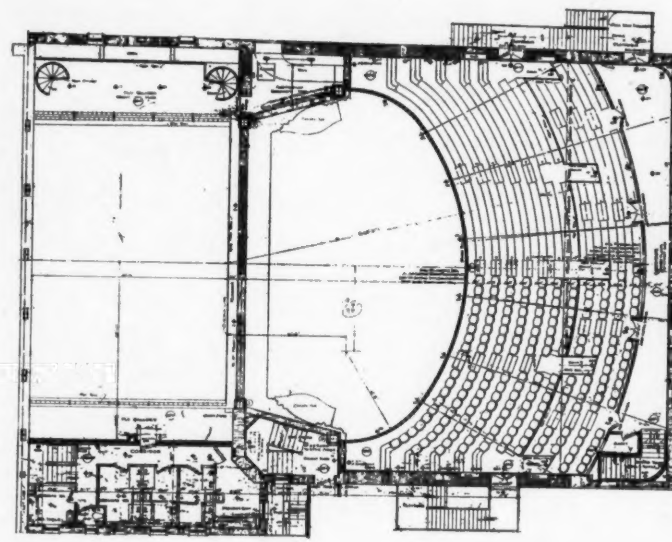

GALLERY PLAN

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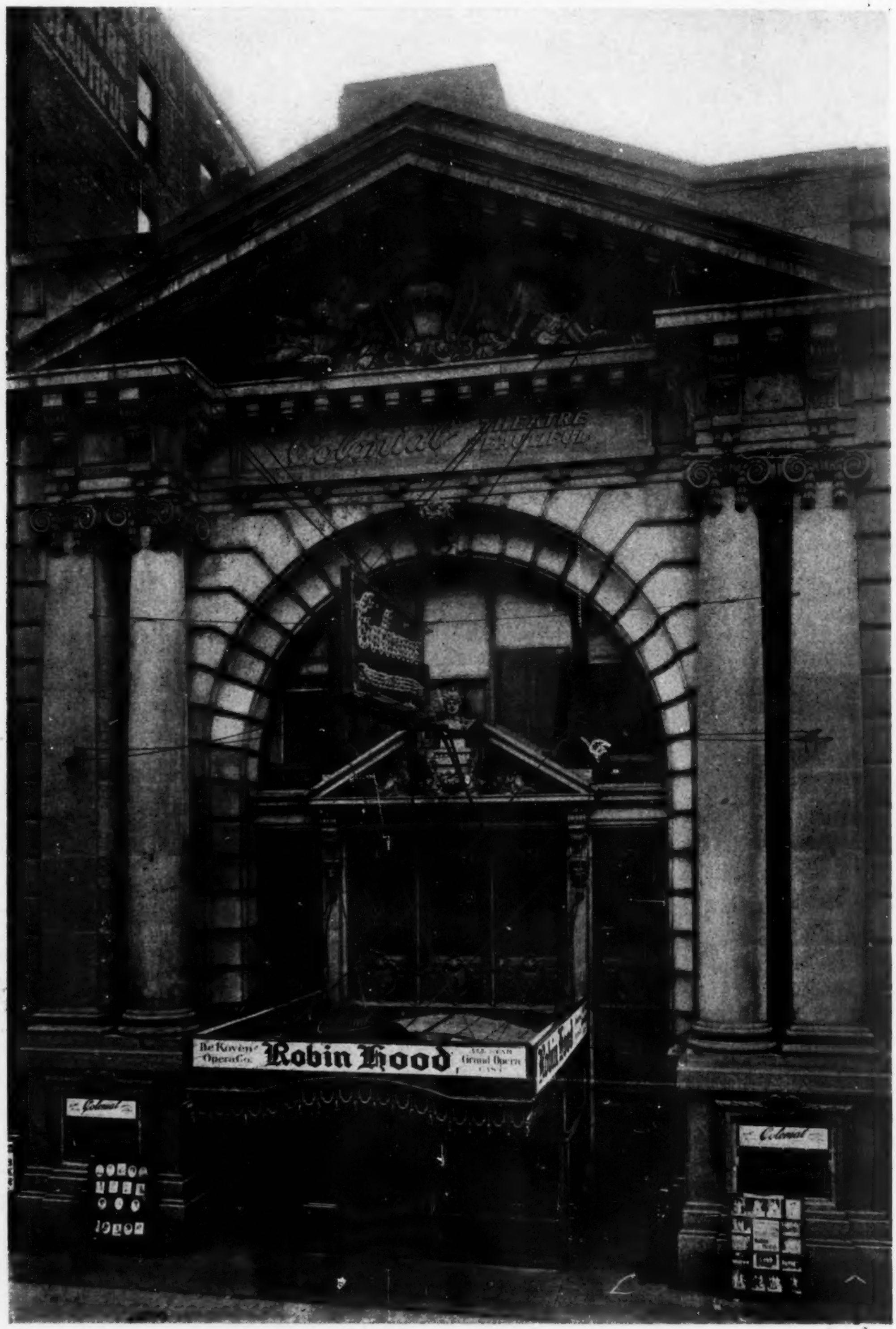


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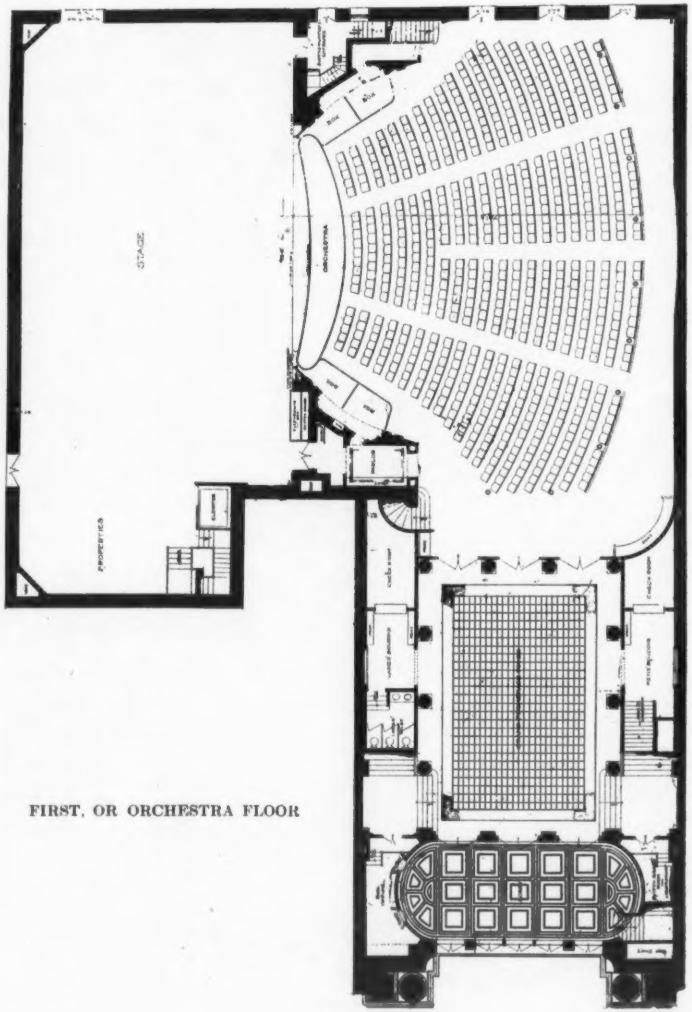
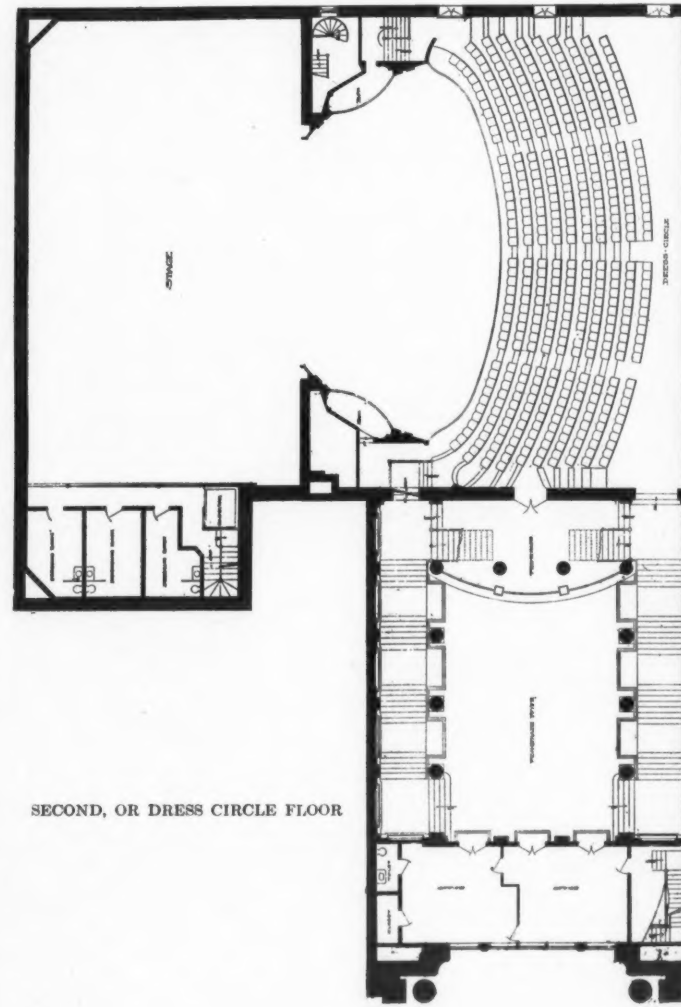


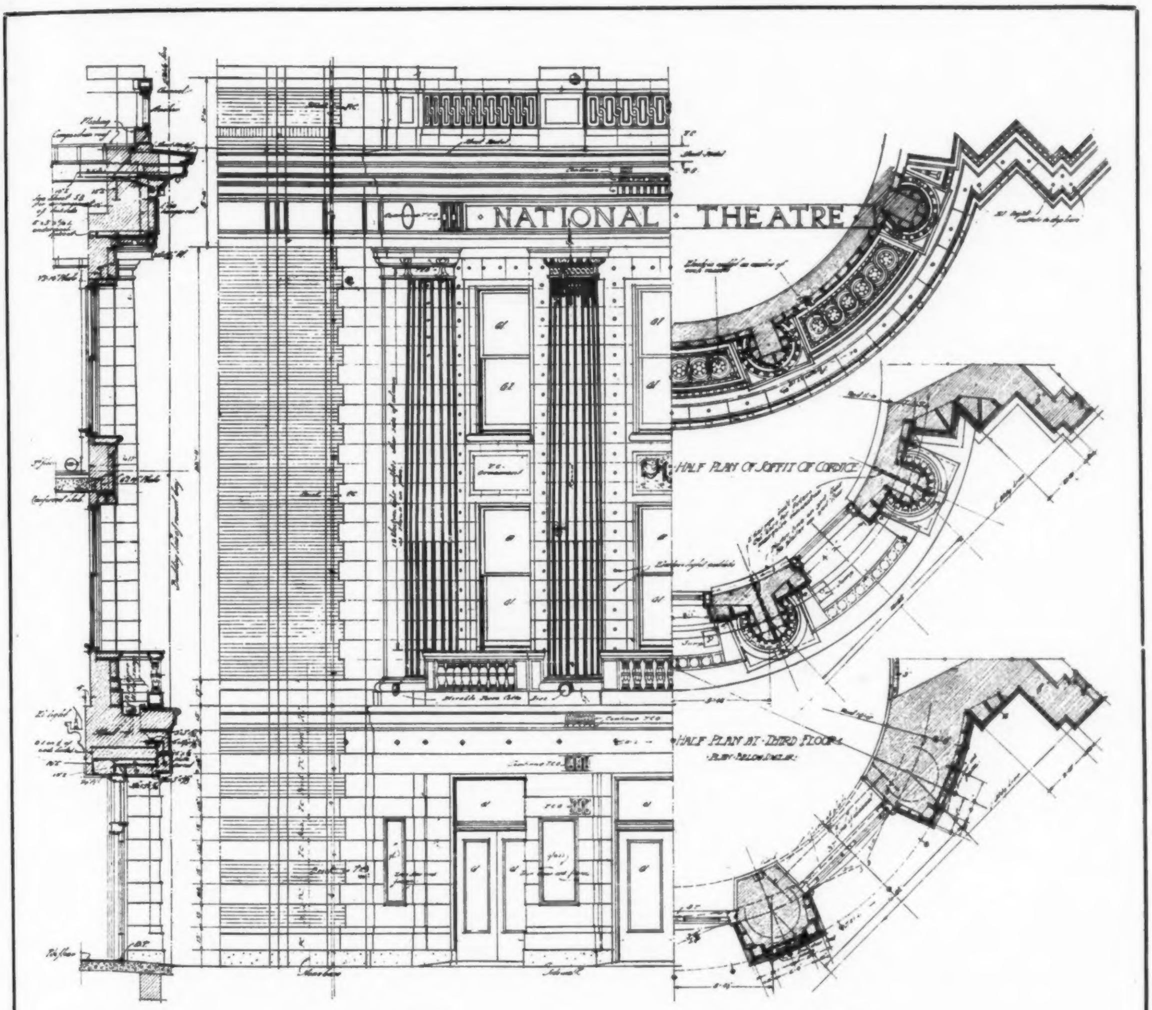

FIRST, OR ORCHESTRA FLOOR




SECOND, OR DRESS CIRCLE FLOOR

COLONIAL THEATRE, CHICAGO, ILL.

MESSRS. MARSHALL & FOX, *ARCHITECTS*

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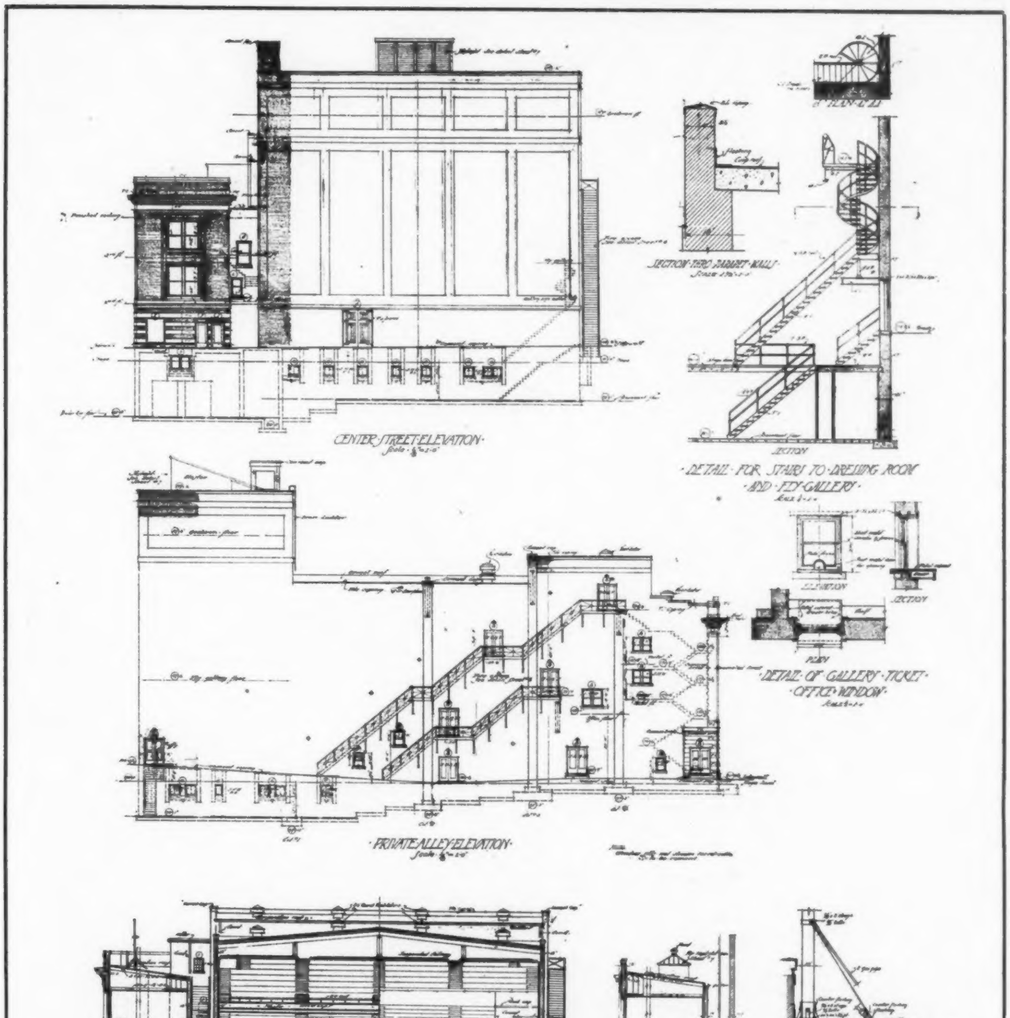


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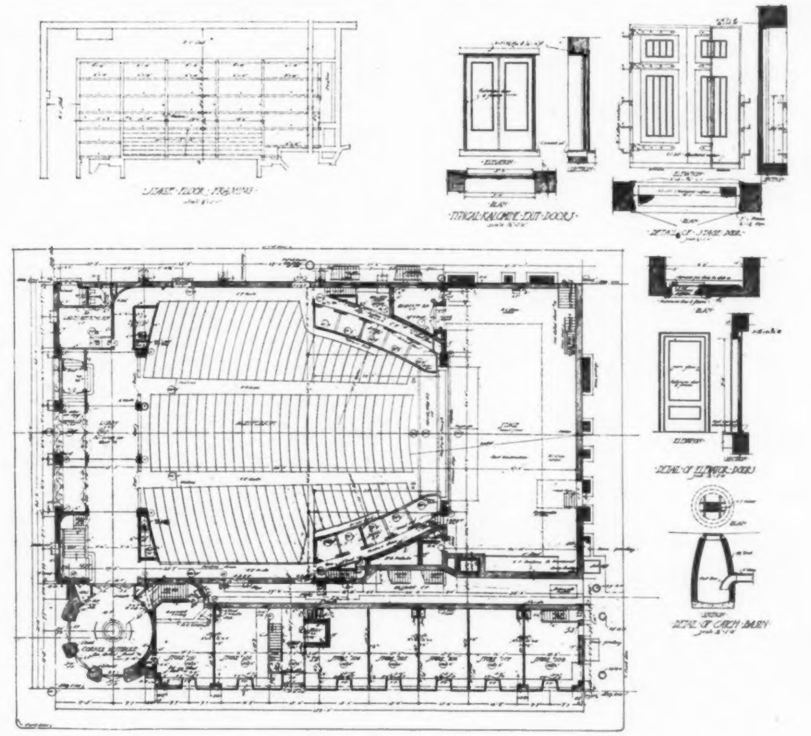
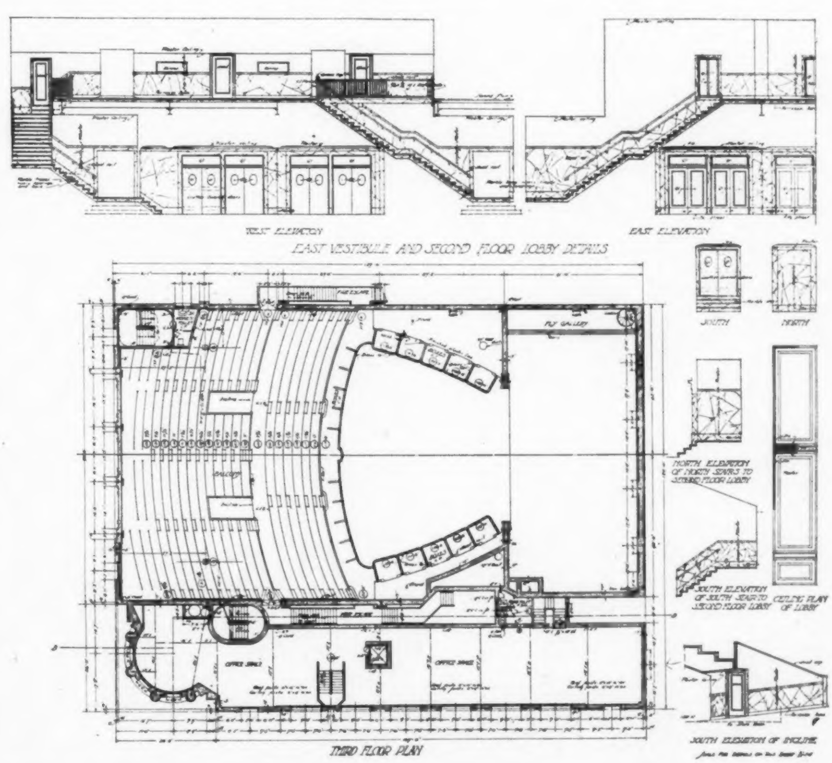



FIRST FLOOR PLAN

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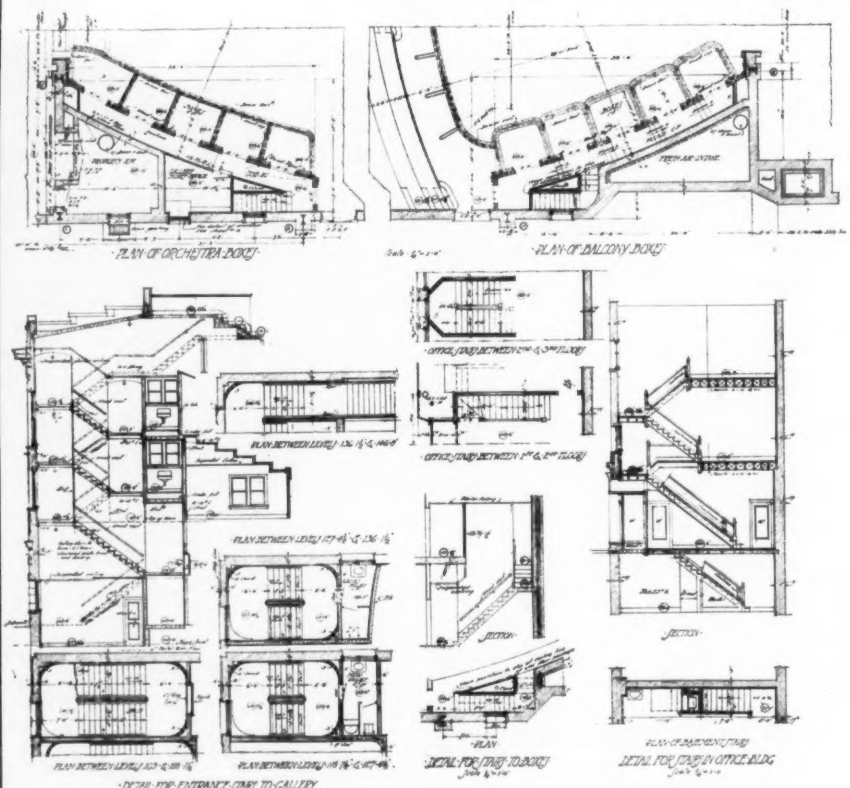


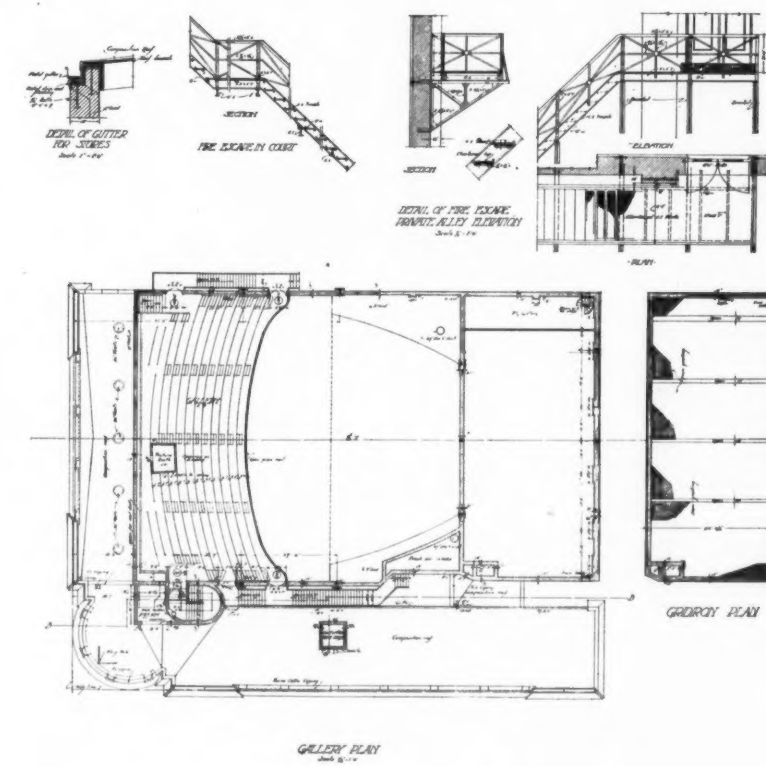


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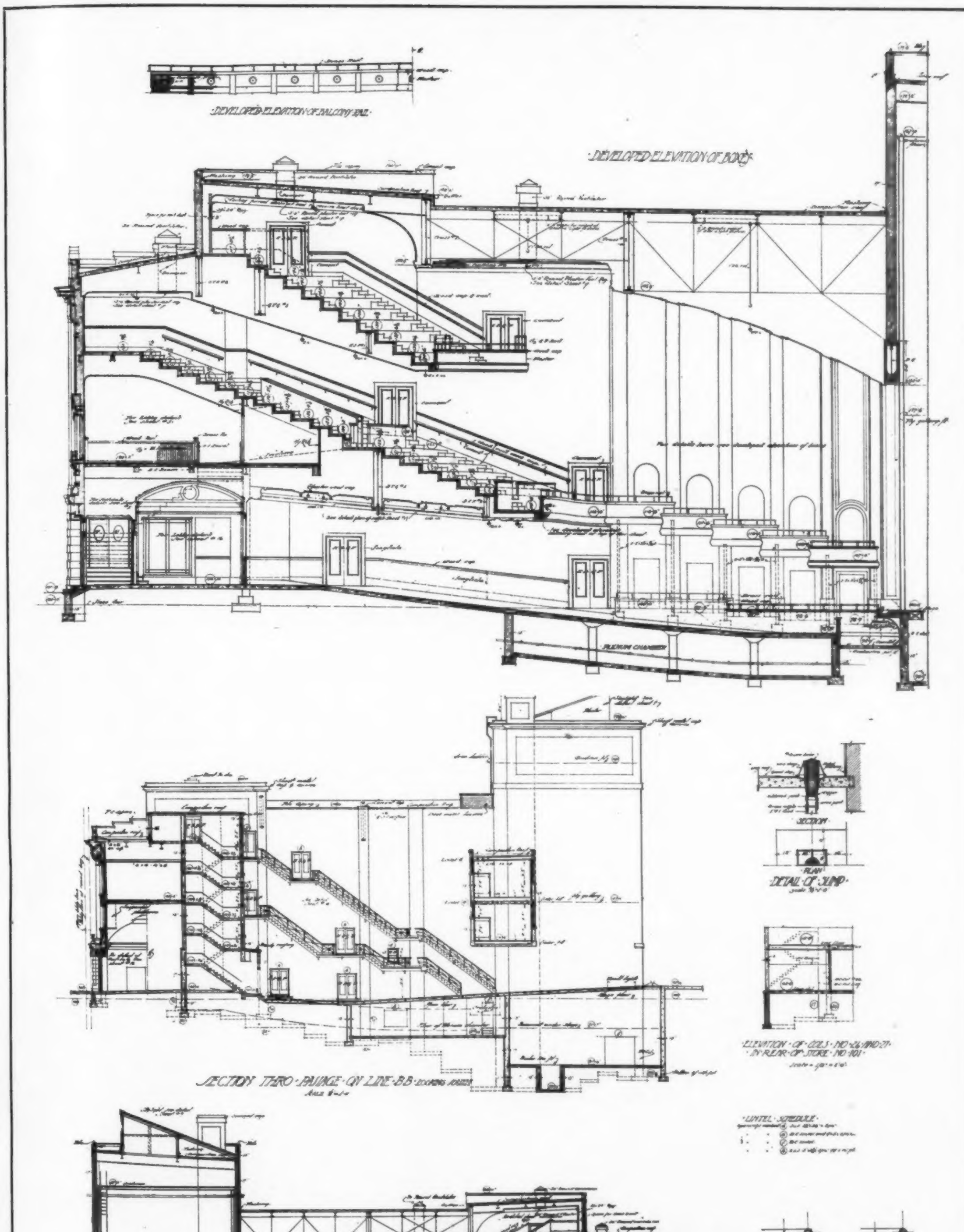


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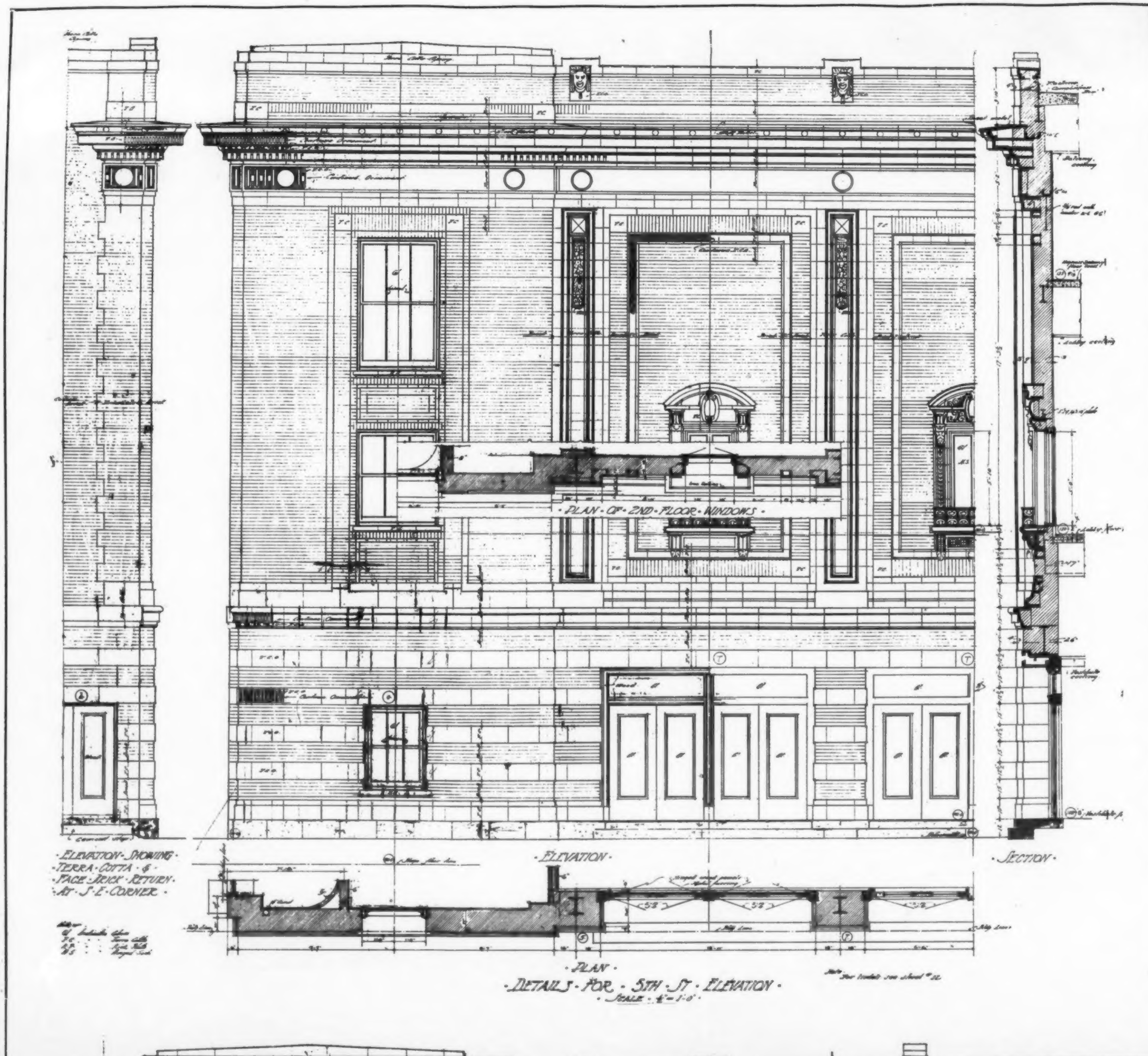
·ELEVATION·SHOWING·
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·FACE·BRICK·RETURN·
·AT·S·E·CORNER·
·PLAN·OF·2ND·FLOOR·WINDOWS·
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·SECTION·
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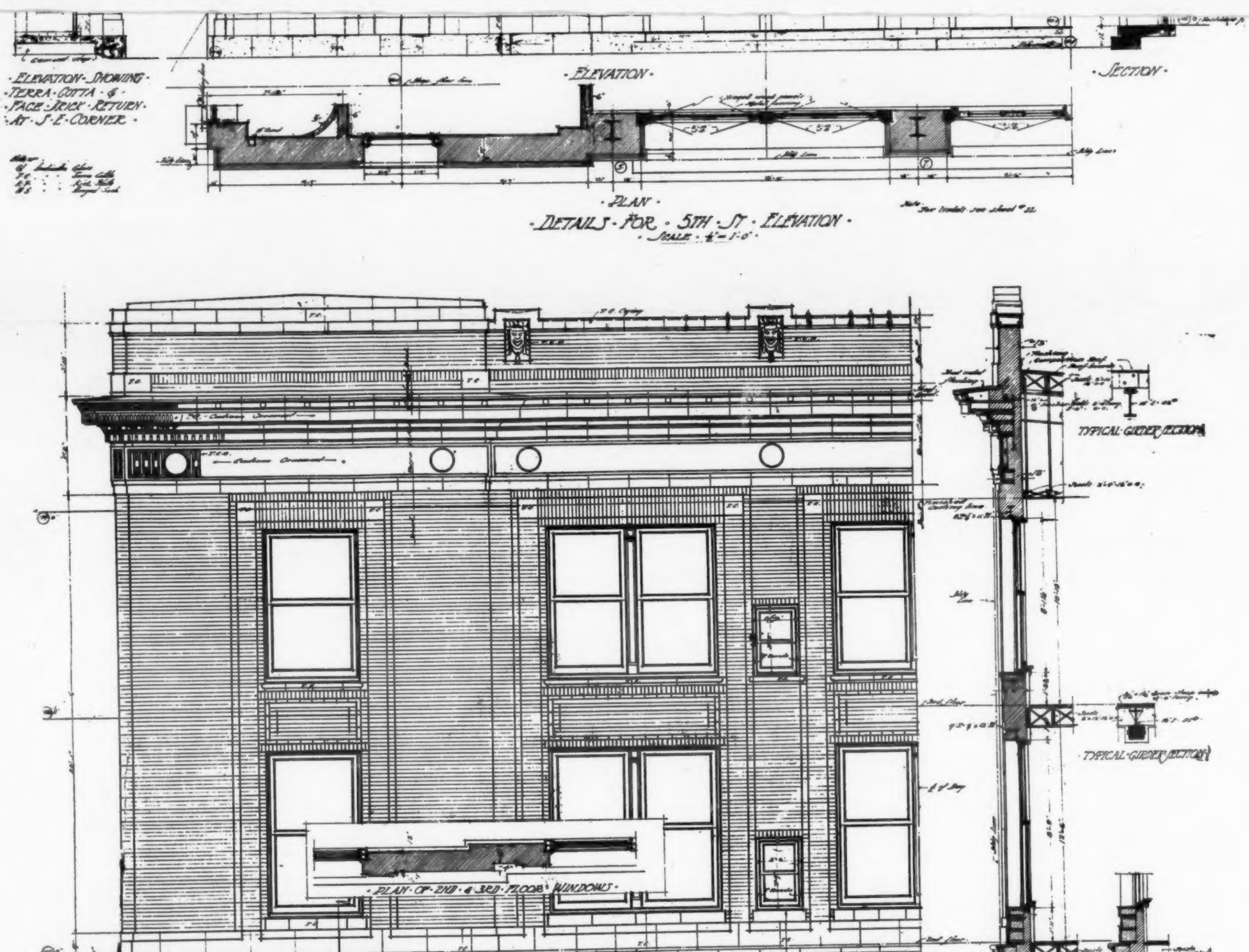
·DETAILS·FOR·5TH·ST·ELEVATION·
·SCALE·¾"=1'-0"·

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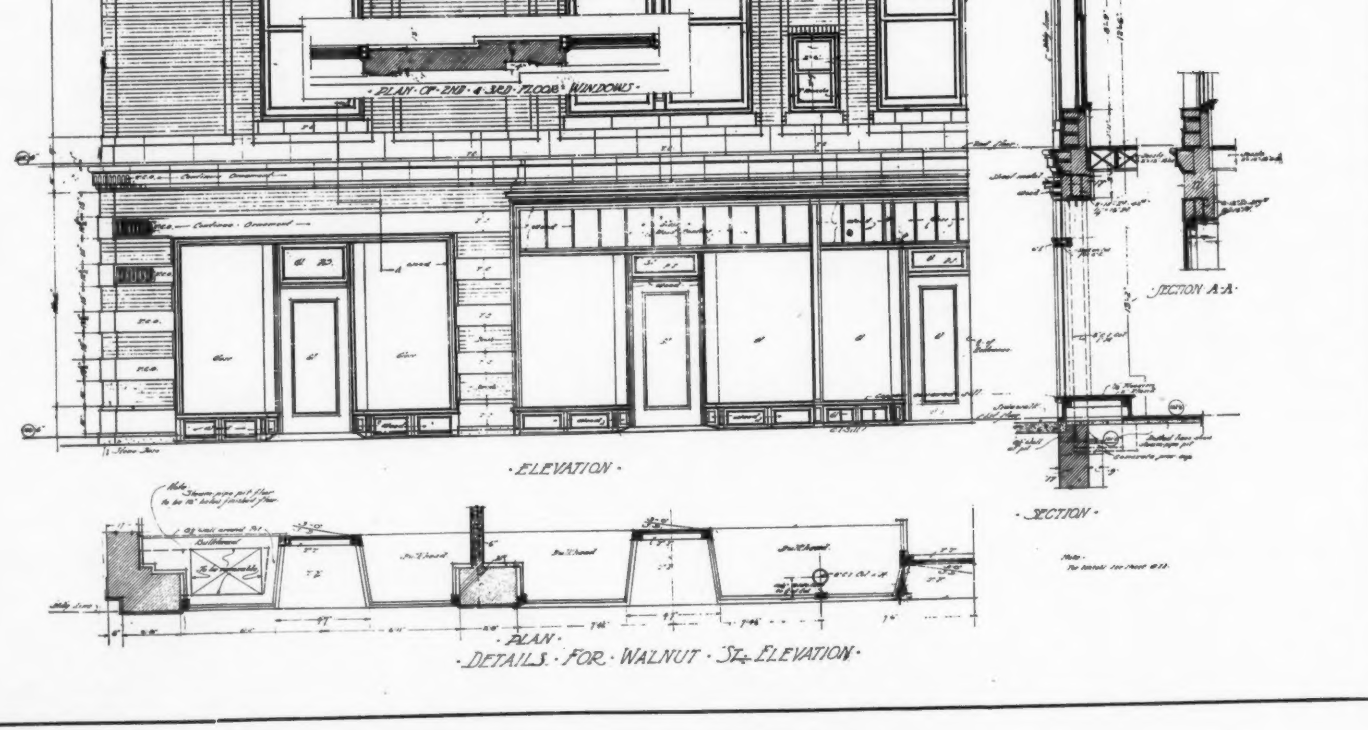


**NATIONAL THEATRE, LOUISVILLE, KY.**

MR. ALBERT KAHN, *ARCHITECT;* MR. ERNEST WILBY, *ASSOCIATE*

# Current News and Comment

## MINNEAPOLIS TO TRY ZONE SYSTEM

Minneapolis is the first city in the United States to try the system of "districting," which is not uncommon in Europe, particularly in Germany. A law enacted by the legislature of Minnesota at its last session permits cities with a population in excess of 50,000 to establish exclusive districts.

When petitioned by fifty per cent. of the property owners in a neighborhood a city council may, by a two-thirds vote, designate such neighborhood, either as a residential or as an industrial district. The city council of Minneapolis February 28th passed its first resolution under this act, and has now designated several districts, which, however, comprise only a small part of the city.

## MEMBERSHIP TRANSFER SYSTEM

In our issue of July 9th, 1913, was published a letter from the San Francisco Architectural Club to the Architectural Club of America, asking for their co-operation in the organization of a Membership Transfer System.

In answer to this letter the following clubs have responded favorably:

Cincinnati Architectural Club, Detroit Architectural Club, Cleveland Architectural Club, Boston Architectural Club, Chicago Architectural Club, St. Louis Architectural Club, Washington Architectural Club.

The San Francisco Architectural Club have made the following amendment to their Constitution and are forwarding same to the aforesaid clubs for similar action:

"Former members of Clubs registered in the Architectural Club Transfer System, upon presenting their applications, accompanied by their first quarterly (or as required by various club laws) dues and a certificate from the Secretary of said Club, stating their initiation fee and that applicant is in good standing, may be admitted to this Club without payment of the initiation fee; provided, that should the initiation fee of said Club be less than that of this Club, he shall pay the difference."

A list of the clubs registered in the System will be published in this magazine from time to time, including any other matters of interest.

The Membership Transfer Committee will be pleased to hear from any Clubs desiring to affiliate with the System.

Address all communications to Membership Transfer Committee, care of San Francisco Architectural Club, 126 Post Street, San Francisco, Cal.

## SURETIES ON BUILDING CONTRACTS

Editor, The American Architect,

Sir: I have read with great interest Mr. Simpson's article, in one of your recent issues, on the liability of sureties on building contracts. I am satisfied that these articles by Mr. Simpson will have the effect of opening the eyes of owners and architects to the advisability of investigating before investing in the so-called guarantee contained, in accordance with popular belief, in a surety company's bond.

A frank and open discussion of the legal position which surety companies generally assume will undoubtedly have beneficial results in one respect at least, and that is, in making owners realize the fact (which has been known to many for some time) that a surety company bond is a matter of certain expense, but not always of certain protection.

As an attorney I have been familiar for some time with the pitfalls of the surety bond and have, of course, known how many are the defenses that the companies can, when so minded, set up to even the just claims of owners, and to what extent the courts have been obliged, by reason of the hard and fast technicalities of law, to unwillingly aid the companies.

Mr. Simpson is unquestionably right when he states that the tendency of the courts to construe contracts of the surety companies most strongly against them and not against the insured, is increasing each year.

It is most puzzling to understand why people whose necessities compel them to secure surety company bonds have been willing to continue accepting them indiscriminately in spite of the fact that there is a strong tendency on the part of some surety companies when called upon to furnish the protection to which an owner believes himself entitled, to look not to see how they can carry out the putative obligations of their bonds, but first and foremost how any financial loss to themselves can be avoided. As conditions are at present, there seems to be only one simple and invariably effective way for an owner to protect himself against the contractor, and that is by withholding enough money from successive payments earned, to complete the contract at any time, if the contractor fails to carry out his obligation or becomes incapacitated to an extent that renders him incapable of doing so.

I am prepared to admit that cases have come under my own observation where the surety company has been willing to assume all obligations of the contractor, on the contractor's default, but in each one of these, if I mistake not, the amount due from the owner, or the security exacted from the contractor when bond was written, was so large that the surety company stood no possible risk or chance of loss by carrying out the work and thereby fulfilling its own contract. However, I do not wish to be considered unjust or even biased in my attitude, and if my experience in this regard is exceptional, I shall be only too glad to hear of authenticated cases in which the above course has not been followed, and will be the first to give credit where it is due. My experience in cases where a loss threatens, is that the surety company regularly denies liability; such denial is general and given without explanation. When suit is brought the owner is confronted with the numerous defenses, which are suggested and pointed out in Mr. Simpson's article, in actual cases. The company usually hires an attorney on an annual retainer, and presumably has found it less expensive where there is possibility of material loss to simply deny liability and take a chance in a lawsuit.

Now what is the remedy? It seems to be in publicity. Owners and architects should take some affirmative action to compel a change in the form of surety company bonds. They should make it their business to make known individual cases where the surety companies deny liability and hide behind the technicalities of their policies. A publication such as yours should be freely resorted to by architects and owners in airing their grievances. They should make it plain that if no remedy is offered by the surety companies a different system will be adopted in making contracts by which larger percentages will be withheld from the contractor until completion of his work, in return for which the contractor will receive the whole or part of the premium that would have been paid to the surety company under the old system.

I am sure that you are in thorough sympathy with any movement which looks to making it easier and more inviting for an owner to build and to receive protection against loss through the contractor, particularly if he pays for it.

Yours very truly, C. A. RIEGELMAN.

## BALL OF THE S.B.A.A.

The Society of Beaux-Arts Architects, New York City, will give a Ball of the Fine Arts at the Hotel Astor on Friday, February 20, 1914. The costumes worn will be Venetian of the XV century period.

## PERSONAL

In a competition for the new Y. W. C. A. building at Washington, D. C., Messrs. Donn and Deming, of that city, were the successful competitors.

Wasmansdorff & Eastman, architects, Lewistown, Mont., announce the opening of an office at Great Falls, Mont., and desire manufacturers' catalogues and samples.

Arthur T. Remick, Architect, 103 Park Avenue, New York, desires to announce that after December 15th he became associated with Henry Wilhelm Wilkinson, Architect. The new address is 15 West 38th Street, New York City.

The partnership heretofore existing between S. R. Badgley and W. H. Nicklas, under the title of Badgley & Nicklas, Architects, Cleveland, Ohio, has been dissolved by mutual consent. Current work of the firm will be completed under mutual arrangement between the former partners.

Mr. Badgley will continue in the practice of Architecture at 6408 Euclid Avenue, and Mr. Nicklas at 1900 Euclid Avenue, Cleveland, Ohio.

Mr. Nicklas will be pleased to receive manufacturers' samples and catalogs.

## OBITUARY

We have recently been informed of the death of Mr. Alfred Zücher, formerly a practicing architect of Buenos Aires, Argentina.

# INDUSTRIAL INFORMATION

*IN this section will be found information concerning late catalogues issued by manufacturers of building materials, fixtures or equipment. Also under this head will be printed, from time to time, certain data relative to new devices or methods of construction considered to be of interest to architects. Architects are invited to make use of* THE AMERICAN ARCHITECT'S *Catalogue Files and Information Department whenever they can do so to advantage. Any assistance we can render or information we can furnish in this connection will be freely given.*

### CHAIRS FOR OFFICE AND PUBLIC BUILDINGS

Attractively prepared pamphlets have been received describing the products of the Milwaukee Chair Co., whose general sales office is in Chicago, and Eastern office at 425 West 28th Street, New York City. For more than forty years, it is stated, the company has specialized in producing seating equipment of superior quality and great variety of design for office and kindred commercial uses. Chairs bearing the trademark of the company are sold only through authorized dealers who can supply all designs ranging from the inexpensive all-wood to the more costly full upholstered leather chairs. The company is prepared to execute special orders according to architects' drawings and specifications. Prompt service is promised on all orders of this character for banks, court houses, hotels, clubs, libraries and government buildings.

The literature of the company is mailed to architects upon request.

### WIRE GLASS

Fire protectionists of national standing are quoted as estimating that twenty-five per cent. of the fire loss in America is due to lack of adequate window protection. Those who are interested in reducing the $250,000,000 fire loss which this country suffers annually, and who have to pay their pro rata proportion in advance in surance rates due to lack of proper con struction for the prevention of fire, will doubtless be interested in the pamphlet entitled "Exemplars," issued for free distribution by the Mississippi Wire Glass Company, with main offices at 220 Fifth Avenue, New York City.

The text contains chapters on "Historical Points on Wire Glass," "Information on Glazing," and extracts from a paper read before the Insurance Society of New York, entitled "Efficiency of Wire Glass Windows."

Photographs of many prominent buildings throughout the country from New York to San Francisco, in which the products of this company have been used, are well reproduced. In addition, are many halftones picturing the many forms of polished, rough and figured wire glass, with directions for their proper specification.

The company recommends the use of wire glass not only for window openings, but for elevator fronts and openings in corridor walls and partition walls between offices. Detail drawings are given which show the proper methods of installing such partitions.

### TRADEMARKED ROOFING SLATE

Indication of the increased tendency toward trademarking manufactured building material is seen in the products of the Bangor Slate Association, Bangor, Pa.

This company has recently adopted the practice of marking each piece of No. 1 Genuine Bangor Slate in order to protect their customers against substitution of other materials. The use of this slate is said to insure a perfect, long wearing and non-fading roof. A folder giving the names of the various brands will be mailed to architects upon request.

### THE PARKER DOWNFLOW BOILER

The Parker Downflow Boiler is designed in accord with the scientific principles which should be followed in evaporating water into steam, according to a booklet published for free distribution by the Parker Boiler Company, Philadelphia, Pa.

It is stated that the combination of boiler and economizer in one setting, with the downward course of the water and steam in tubes, increases the efficiency of the heating surface by bringing the coolest water next to the coolest gases. Dry steam, under all conditions, is said to be assured by the formation of the drum which has separate chambers for water and steam, with anti-priming valve between.

Another advantage claimed is the strong

non-reversible flow through continuous elements, as distinguished from the uncertain circulation in separate tubes. The utmost safety and ease of cleaning are further features claimed by the manufacturers.

### GRADING RULES OF WESTERN LUMBER MILLS

As a large part of the product of Western lumber mills is sold at a considerable distance from the point of manufacture, it is important that both buyer and seller shall be fully informed as to the meaning of grades and terms in use by the trade. To this end, a booklet has been prepared by the West Coast Lumber Manufacturers' Association, Tacoma, Wash., which gives their standard qualification, grading and dressing rules for Douglas fir, spruce, cedar and Western hemlock products. Many dimensioned cross sections of dressed flooring, ceiling, siding and roofing are illustrated and will doubtless prove of interest and value to architects in specifying the products of Western lumber mills.

### DRAWING MATERIALS AND SUPPLIES

Perfect tools do not insure perfect workmanship, but no one has any legitimate excuse for handicapping meritorious efforts with imperfect equipment.

As an aid to the selection of all drafting room materials needed by the architect and engineer, the A. S. Aloe Company, St. Louis, Mo., have issued a linen bound catalogue of 382 pages. Conscious of the standing which more than fifty years of reputed success and progress have given this firm, they claim to esteem it their foremost duty to maintain a reputation for absolute reliability of goods, as well as for good will, in their dealings with customers.

Among the exhaustive list of equipment illustrated and described, may be mentioned —drawing papers and tracing cloth of all varieties, blue-printing equipment, engineers' transits, architects' levels, compasses, tapes, drawing instruments, inks, water colors, drafting tables, and filing cabinets.

Prospective customers are invited to apply for this valuable reference work.

### DECORATING SUGGESTIONS

The Sherwin-Williams Co., 601 Canal Road, Cleveland, Ohio, are publishers of attractive literature of considerable suggestive value to architects. Among their booklets mailable to members of the profession on request, may be mentioned *The Spectrum*, published as a monthly house organ, which contains articles on decorating suggestions and other matters of general interest.

Their portfolio of suggestions for painting and decorating contains chapters entitled "What Coloring Shall I Use?", "Caring For the Home Exterior," "Decorating the Home Interior," and "Getting the Job Done Right,"—titles which are sufficiently suggestive of the character of the text.

The portfolio of plans for home decoration contains several colored plates giving suggestions for color schemes in domestic work both exterior and interior. Descriptive text accompanies the plates.

### MECHANICAL REFRIGERATION

The United Refrigerator and Ice Machine Co., Kenosha, Wis., are specialists in the manufacture of refrigerators and coolers for all purposes. They claim that their equipment embodies all the improvements of mechanical refrigeration, together with many special features. The fact that they manufacture and supply complete outfits from the ammonia compressor to the architectural treatment of the cooler is claimed to be a great advantage over the buying of equipment in several different places, as it avoids delays, shifting of responsibility and frequent needless expense. United ice machines are said to be adapted especially for use in cold storage plants, creameries, hotels, public institutions, ice cream factories, greenhouses, meat markets, groceries, apartment houses, et cetera.

One reason for the special efficiency claimed by this company is the method of insulating their refrigerators. The insulating material used is known under the trade name of "Fibercel," which is said to be far superior to insulation that has a tendency to sag or disintegrate.

Literature describing the wide range of this company's manufacture will be mailed to architects upon request.