Proceedings of the Institute of Radio Engineers
Volume 19, Number 1 *January, 1931*

THE DESIGN AND CONSTRUCTION OF BROADCAST STUDIOS*

By
O. B. Hanson and R. M. Morris
(National Broadcasting Company, New York City)

Summary—*The science of sound, for years one of the most neglected of subjects related to physics, has during the past decade been the subject of much interesting research. A certain amount of impetus has been added to this work by the phenomenal growth of radio broadcasting owing to the necessity of providing studios suitable from an acoustic standpoint.*

This paper indicates certain facts relative to the science of acoustics and sound control and shows how they are applied in the construction of present day studios for radio broadcasting. Examples are given as well as methods of overcoming difficulties in practical application of principles.

In the past decade of radio broadcasting, tremendous strides have been made in development of equipment, methods of operation, and program technique chiefly due to the stimulus created by its rapid general acceptance by the public. We have constantly been faced with the problem of providing sufficient facilities, especially from a studio standpoint, to meet the increasing program traffic requirements of network broadcasting.

Ten years ago our ideas on broadcast studios were very meager compared to our knowledge and information of the present day. In 1923 what was believed to be quite an adequate studio layout for years to come consisted of two studios, one 22×35 ft. and one 16×20 ft. with a main control room common to both. Little, if any, time was spent on rehearsals in those days with the result that the two studios were sufficient to keep a continuous program on the air.

With the coming of sponsored broadcasting and the necessity for careful rehearsing and well worded announcements, much more time was devoted to rehearsals. As a comparison it might be interesting to note that on important programs it is now necessary to have anywhere from five to fifteen hours of rehearsal for one hour of program on the air. This fact accounts very largely for the increase in the number of studios required for one program channel today.

For the operation of two networks, which would obviously involve an elaborate plant, at least four studios would be required for program service alone and a number of others of varying size to handle rehearsals and auditions.

* Decimal classification: R612.1×534. Original manuscript received by the Institute, September 27, 1930. Presented before Fifth Annual Convention of the Institute, August 18, 1930, Toronto, Ont., Canada.

Since nearly all rehearsals and auditions require practically the same studio conditions and apparatus necessary for program service, there is no particular point in providing studios for rehearsal purposes only. All studios should be made part of a common system for the creation of broadcast programs. The variation in number of performers and type of performances necessitate considerable variation in the size

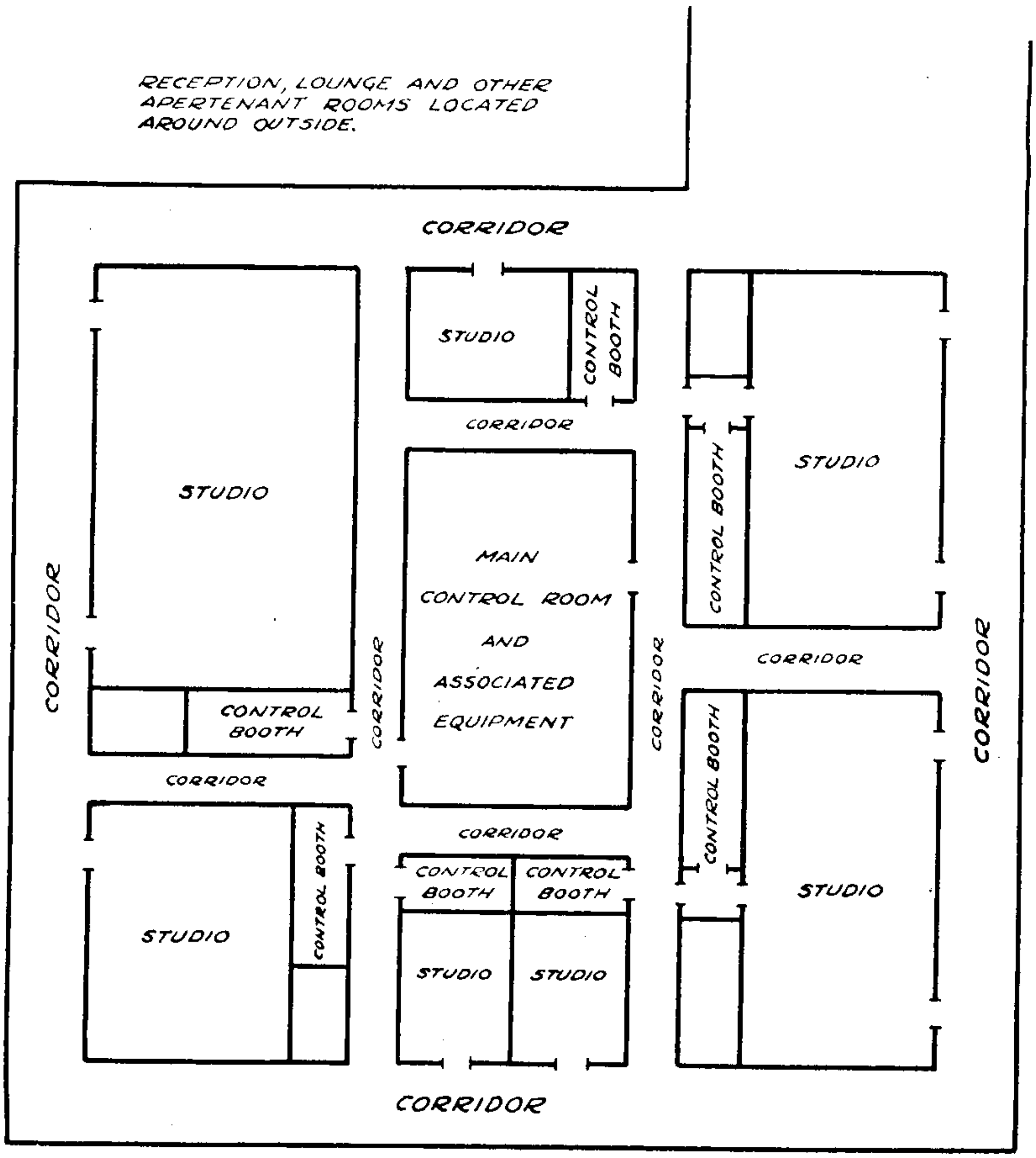

Fig. 1—Ideal studio plan.

of the studios. It is usually desirable that the same studio be used for broadcasting as for the rehearsal, in order that the carefully determined position of the instruments and microphone in the studio may be retained for the broadcast.

The problem of handling the increased number of musicians and performers becomes serious when it is possible that two or more programs may be conducted simultaneously, with several rehearsals also in progress in other studios. Such a condition might necessitate the presence of a total of three hundred or more musicians and other artists. It is necessary, therefore, to give serious thought to the placing of studios in order that they may be economically and efficiently operated not only from the technical standpoint, but also from that of reducing to a minimum the confusion which might exist among the musicians and visiting artists.

What is considered to be the ideal layout for a group of studios has been worked up from what may be referred to as a central control system. This consists primarily of a central main control room surrounded immediately by individual control rooms directly adjacent to their respective studios. The studios are approached on the opposite side by corridors through which the artists and performers may enter the studios. This makes for efficiency in the technical operation of the system and makes the studios readily accessible from a common point, for the production staff. An illustration of this fundamental plan is shown in Fig. 1.

It is obvious that with such a layout great pains must be taken in insulating the individual studio units against the transmission of sound, in order that each studio unit may function satisfactorily without acoustical interference from adjacent studios. Obviously any failure of the sound insulation system would render these groups useless. It is not only imperative that sound originating within the studio be kept within the desired bounds, but also that noises originating perhaps outside the building be prevented from entering the studios. Such rigid requirements call for elaborate methods of sound control and indicate that studios should preferably be constructed without windows or openings to the exterior. If it is necessary to provide such openings in studio walls special consideration will have to be given to making them incapable of sound transmission to any appreciable degree.

A brief outline of requirements covering the design of a group of broadcast studios is given herewith:

(1) Location

The studio group should be located in that part of a metropolitan area which is most accessible to artists. This is, of course, adjacent to the theater and concert hall centers. In the case of New York City, this section would be bounded on the north by 59th Street, on the south by 42nd Street, on the east by Madison Avenue, and on the west by 8th Avenue. It is also desirable for a studio group to be located on a street well known to the general public.

(2) Type of building

It is desirable to locate in a building which is under construction, or on which construction has not yet begun, so that the steel work may be readily modified to provide the area (clear of columns or supports) necessary for large studios. Although a studio group could be built on the lower floors of the skyscraper type of building, this is not economical as the cost of steel spans to support the tall buildings would be prohibitive. If it is necessary to occupy a finished building, a location in the upper floor of the loft type of structure such as used for department stores and light manufacturing is probably most satisfactory.

(3) Sound insulation

Means must be provided to prevent the transmission of sound from one studio to another or from the outside into any studio. Studios should be built as a box within a box, the inner box mechanically insulated against vibration from the outer, and the outer, of course, supported on the steel structure. To be highly effective complete soundproofing necessitates that the studio floor, walls, doors and glass partitions be to all intents and purposes hermetically sealed.

(4) Air conditioning and ventilation

A ventilating system of the ordinary type is not sufficient for broadcast studios. Large groups of musicians rapidly increase the temperature and humidity necessitating that the air be replaced frequently with cooled and dehumidified air. To accomplish this, a system of air conditioning is necessary. A more detailed description of this system is given later on in this paper.

(5) Acoustic treatment

Perhaps one of the most important considerations as far as the production of the program itself is concerned is the acoustic condition within the studio. It is necessary to provide within the studio sufficient sound absorbing material to reduce the reverberation time to the desired optimum value. Variation in the amount of sound absorption should be provided for, to compensate for variations in the size of the musical groups. The acoustic material used should of course have a frequency-absorption characteristic satisfactory over the entire musical range.

(6) Lighting

The individual music stand lighting system used in concert work is not adapted to broadcast studios as the location and size of the groups performing are too varied. Lighting cables layed on the floor are also somewhat of a nuisance. The lighting, therefore, must be from overhead and of sufficient strength to enable the musicians to read manuscript with ease. It has been found necessary to provide approximately 20 foot candles. Facilities must also be provided for supplying power to the portable flood lights used for taking photographs.

(7) Decoration of studios

Although this problem does not immediately concern the engineer except wherein it may affect the acoustic condition, considerable stress should be placed on the importance of the proper architecture and decoration of the studios. This has a psychological effect upon the mood of the artists which influences their performance. In some of the later designs of the NBC studios, the decoration has been rather elaborate.

(8) Technical operating requirements

In the design of the main control room equipment and the equipment which is associated with the individual studio control rooms, it must be borne in mind that all studio equipment should be electrically interlocked in order to provide the necessary flexibility. Any studio should be capable of instantaneous connection with the outgoing circuits at the will of the master transmission supervisor. In operating a centralized studio group, it is assumed that a control operator will be stationed in the studio control booth of each studio in use to control volume and monitor the outgoing programs, and that a supervisor will be located in the main control room to superintend general technical operation. It is not intended in this article to describe the technical apparatus used in connection with broadcasting but rather to describe in detail the design of studios and to discuss factors influencing this work.

The adaption of the ideal plan shown in Fig. 1 to an actual building should be of interest as an illustration. Of course definite rules can hardly be set down to govern application of principles. It is a matter of careful study and thought, in each individual case. Fig. 2 shows how the central control plan was adapted to the building occupied by the NBC at 711 Fifth Avenue, New York City. An even better idea can be obtained by reference to the cutaway view of the studio layout shown in Fig. 3. It is desirable of course to keep the studios on one floor if possible, but such is hardly economical at such locations as Fifth Avenue, due to limited floor area.

A description of the newly completed Chicago Studios of the NBC will further illustrate the foregoing principles.

Fig. 4 shows how the ideal layout was adapted to the building conditions found in the Merchandise Mart building. It will be noted first of all that the studios vary in size but are of similar shape. It has been found that the studio dimensions have an influence on the acoustic conditions and from experience an empirical formula for determining this is worked out as follows:

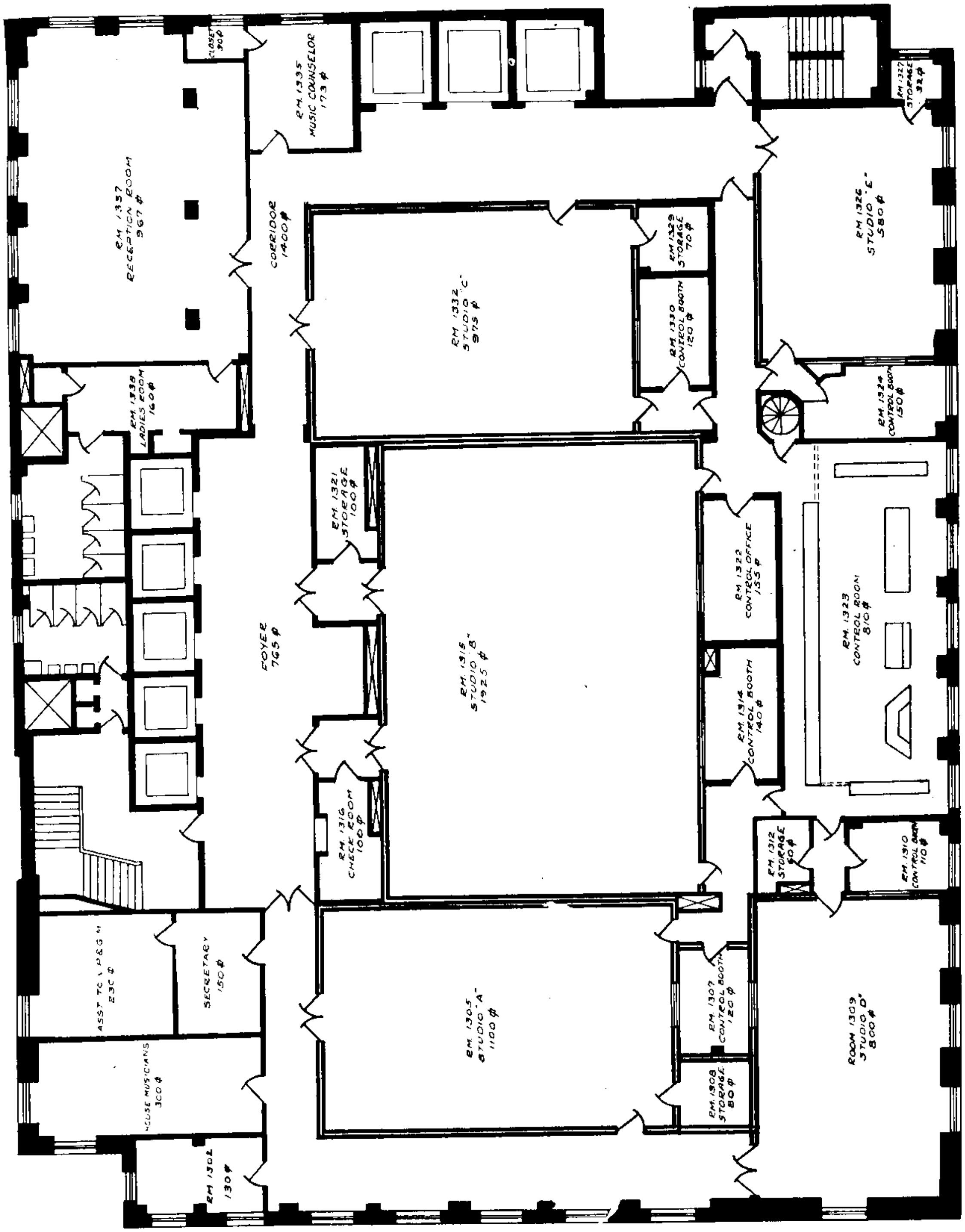

Fig. 2—Plan of 13th floor, 711 Fifth Avenue, showing arrangement of studios.

It has been found from experience that the dimensions of a studio to be most satisfactory from an acoustical as well as an esthetic consideration, should be approximately in the ratio 2–3–5 for the height, width, and length, respectively.

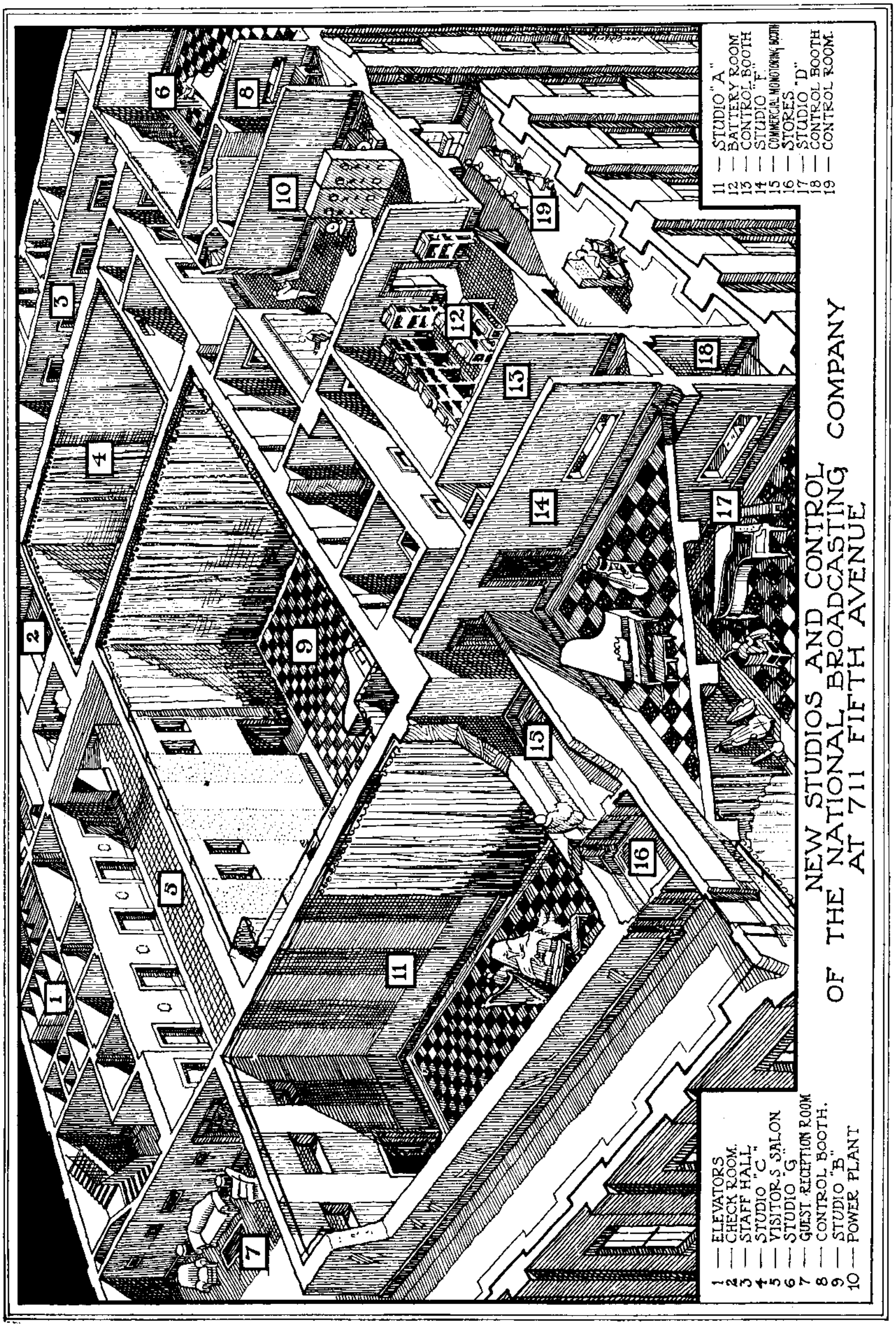
NEW STUDIOS AND CONTROL
OF THE NATIONAL BROADCASTING COMPANY
AT 711 FIFTH AVENUE
1 — ELEVATORS
2 — CHECK ROOM.
3 — STAFF HALL
4 — STUDIO "C"
5 — VISITOR'S SALON
6 — STUDIO "G"
7 — GUEST RECEPTION ROOM
8 — CONTROL BOOTH.
9 — STUDIO "B"
10 — POWER PLANT
11 — STUDIO "A"
12 — BATTERY ROOM
13 — CONTROL BOOTH
14 — STUDIO "F"
15 — COMMERCIAL MONITORING BOOTH
16 — STORES
17 — STUDIO "D"
18 — CONTROL BOOTH
19 — CONTROL ROOM.

Fig. 3.

Using this ratio the approximate dimensions of a studio in terms of its height are,

$$\text{width} = \frac{3}{2}h \tag{1}$$

$$\text{length} = \frac{5}{2}h \tag{2}$$

On first consideration it would seem that the capacity of a studio would be proportional to floor area. It has been found, however, that

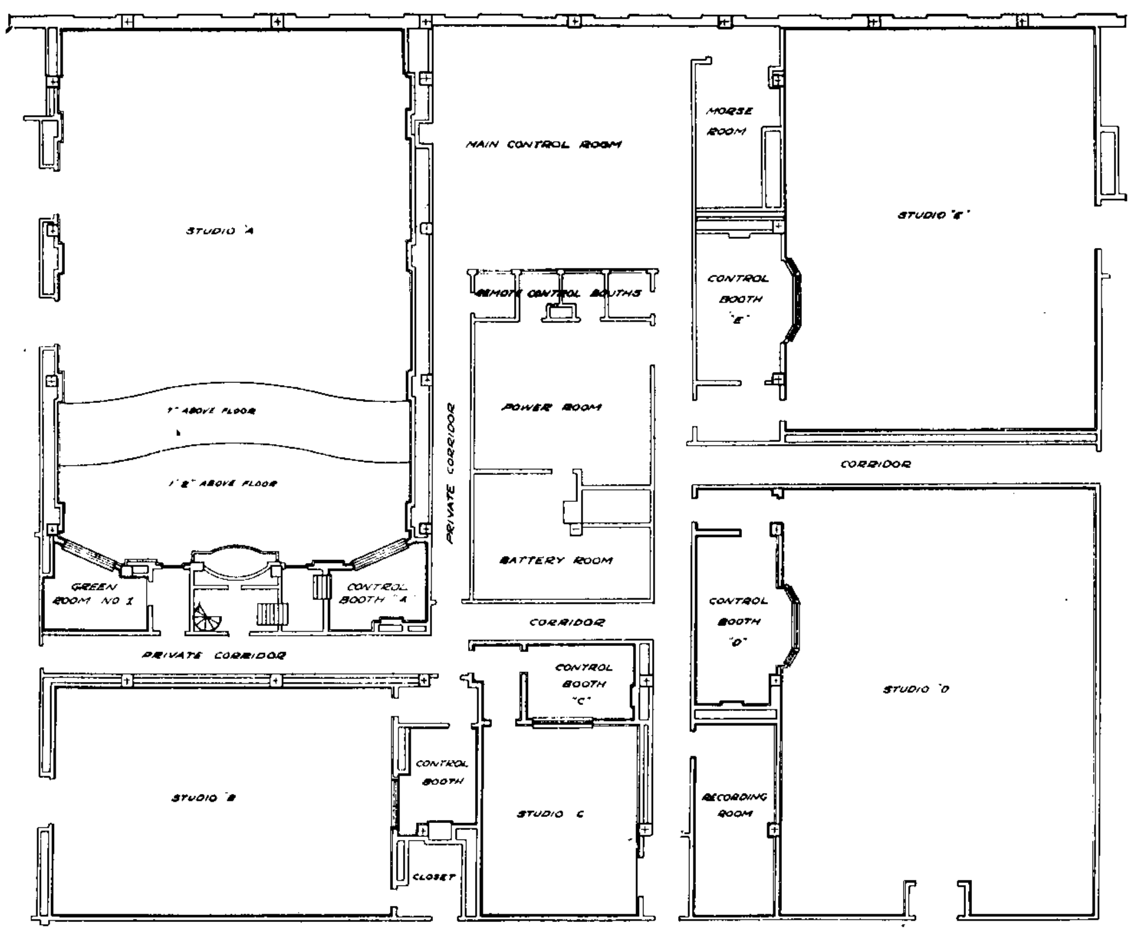

Fig. 4—Studio and control room layout—Chicago.

it is more nearly proportional to volume for two reasons. First, the ventilating requirements are directly proportional to the normal studio capacity and second, the floor area required per artist in the case of large groups is less than required in smaller groups due usually to the greater percentage of vocalists and artists playing the smaller instruments.

It is possible, therefore, to say that

$$V \propto N \tag{3}$$

or

$$V = KN \tag{4}$$

where V = Volume of studio in cubic feet
N = Number of artists constituting normal capacity.

From experience it has been found that

$$K = 750$$

therefore

$$V = 750N = \frac{15}{4}h^3 \tag{5}$$

$$h = 5.87\sqrt[3]{N} \tag{6}$$

In order that the minimum studio size shall have a ceiling height of not less than 8 feet

$$h = 8$$
$$\sqrt[3]{N} = 1.37$$
$$N = 2.55 \tag{7}$$

Expression in final form, therefore, is

$$h = 5.87\sqrt[3]{N - 2.5} \tag{8}$$

This relation is shown in graphical form in Fig. 5 which also gives the values of width and length. It should of course be remembered that these values are approximate and should be considered only as a guide. Construction limitations will probably be the deciding factor in the actual dimensions finally decided upon.

Table I gives in tabular form the dimensions of the Chicago group of studios to illustrate typical compromises which must usually be made. Dimensions of Studios C and F are notable for their deviation from the proper ratio, while Studios A and B fall rather close to the prescribed value.

TABLE I

STUDIO DIMENSIONS
CHICAGO INSTALLATION

Studio	Length	Width	Height
A	72′–0″	47′–0″	26′–6″
B	45′–6″	31′–2″	21′–6″
C	26′–0″	21′–0″	10′–0″
D	57′–2″	42′–0″	21′–6″
E	54′–1″	42′–0″	21′–6″
F	26′–0″	21′–0″	10′–0″

The building in which or upon which the Chicago Studios have been erected is of immense proportions, being considered the largest building in the world. The roof over the eighteenth floor has an area of approximately 200,000 square feet, so that there was ample space to erect a studio group without serious complication of the steel problem. With practically no restrictions on outside dimensions these studios were placed as desired, in the shapes desired, grouped around the central control room, and the exterior wall erected about the whole. It will be

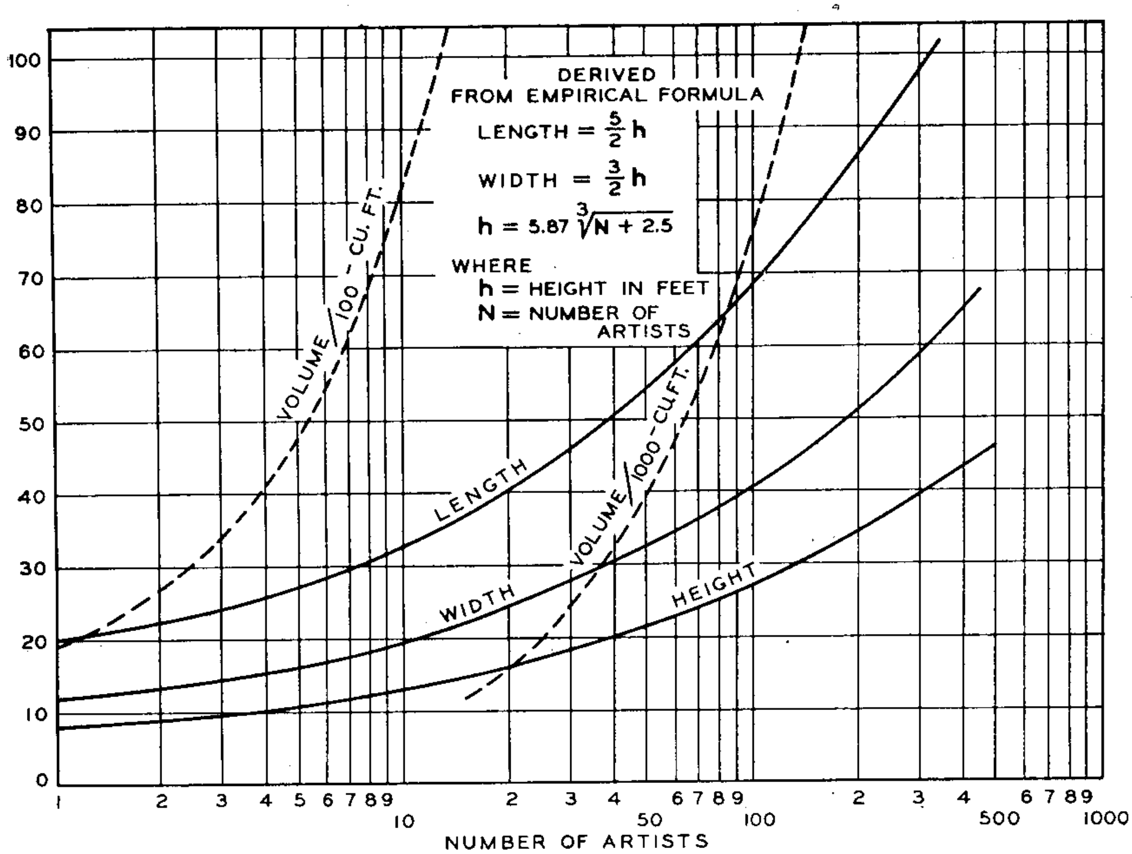

Fig. 5—Relation of studio capacity to studio dimensions and volume in standard broadcast practice.

noted by reference to the plan, Fig. 4, that each studio unit includes its individual control room, double entrance vestibules and an observation gallery, all of which are insulated against sound transmission from the other studio units. In addition to the floating floors, walls, and ceilings which were provided, corridors are placed between the studio units to assist further in sound insulation. No studio wall is immediately adjacent to that of another.

All studios are readily accessible from the central control point. Provisions for artists' entrance are on the side of the studio away from the control room, so that there is no cross traffic between performers and production and technical staff. In addition to the studios, ample space was provided for storage batteries, power supply, ventilating

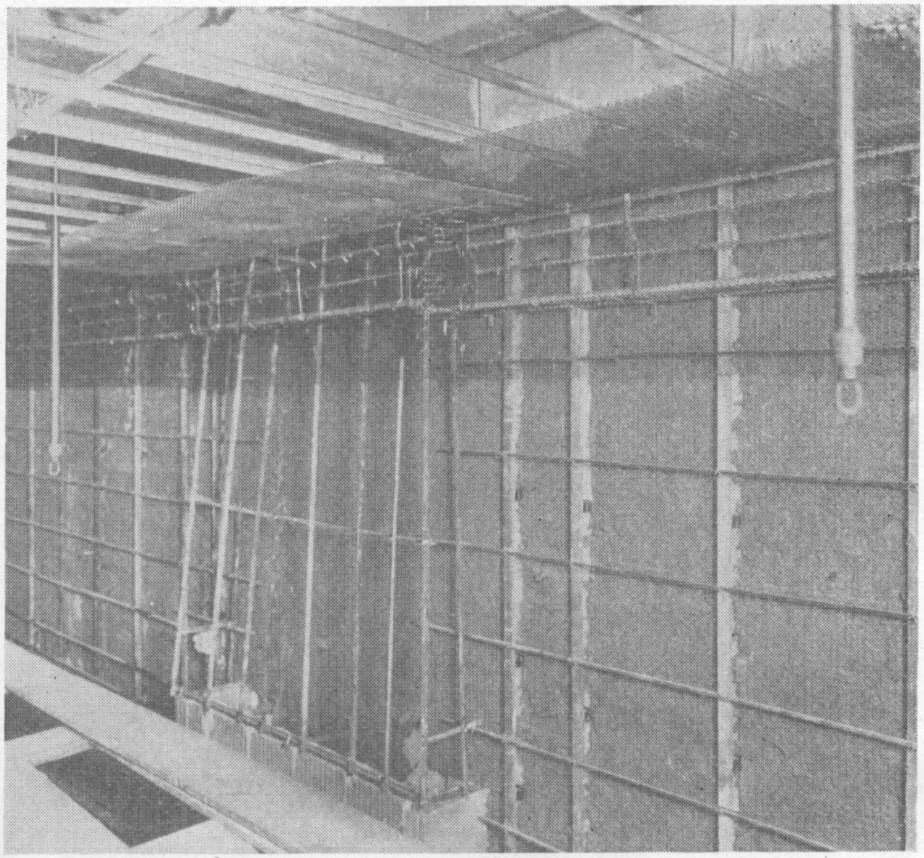

Fig. 6—View of soundproofing showing wall and ceiling.

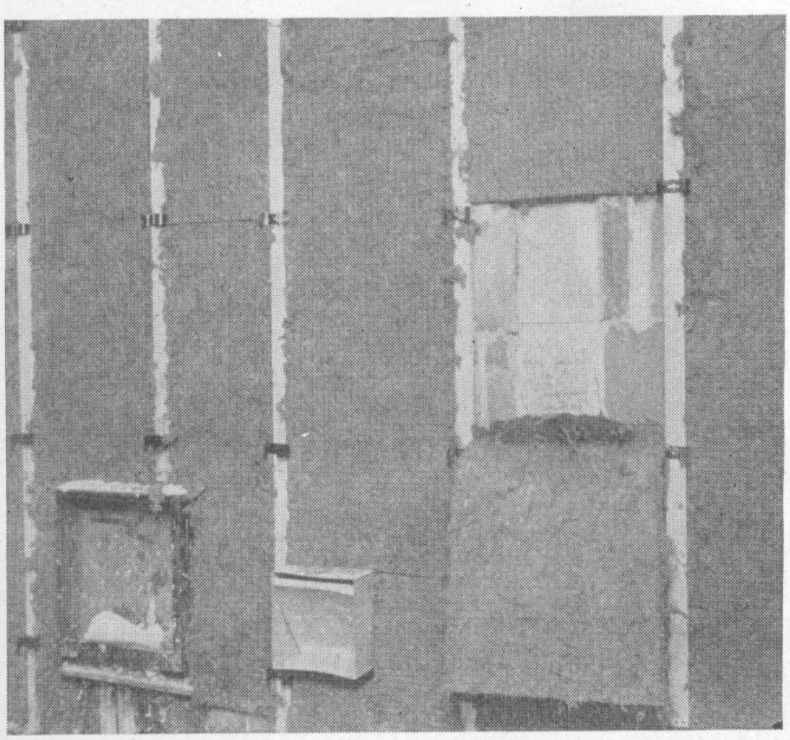

Fig. 7—View of soundproofing on wall (close-up).

equipment, speech input equipment, and line terminal and switching equipment for the routing of network programs originating in other cities through the Chicago control room.

Acoustically treated monitoring booths in the control room are

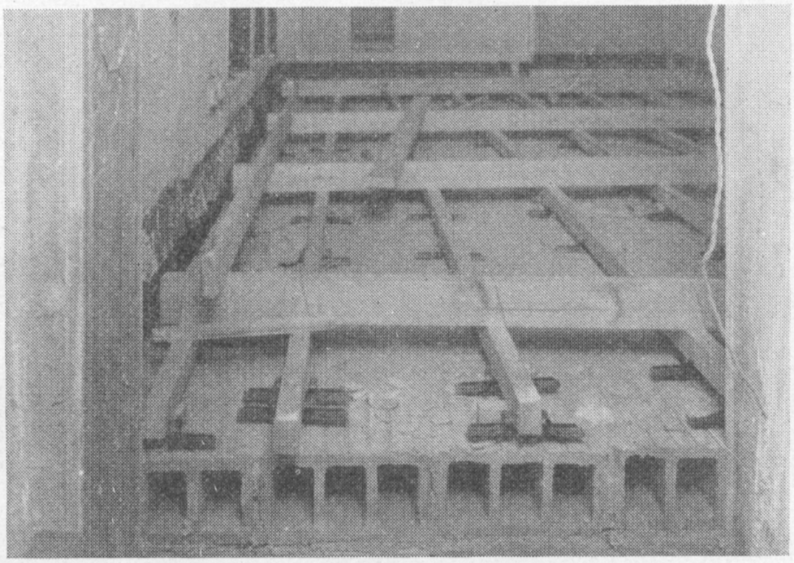

Fig. 8—View of floor without fill.

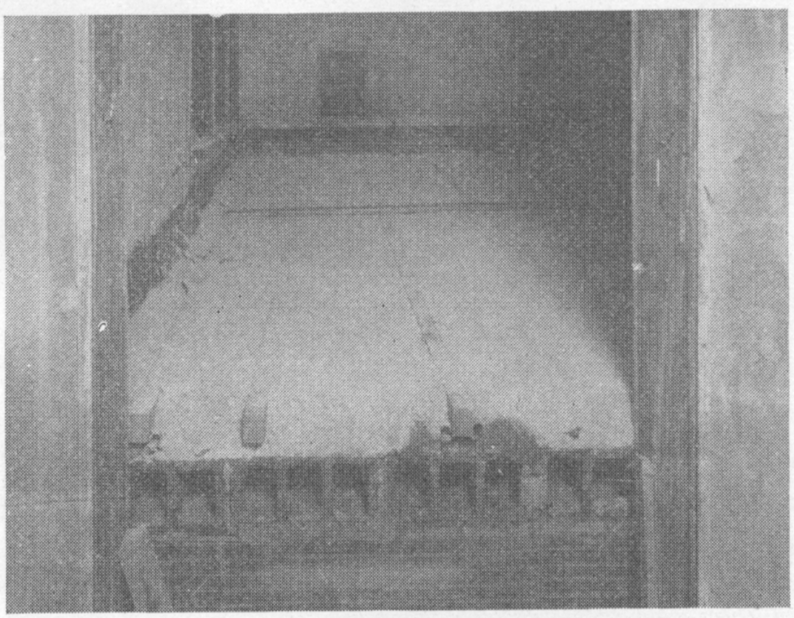

Fig. 9—View of floor with fill.

provided for the proper monitoring of through programs and for checking the transmission of network stations.

Following is a more detailed description of the system used in the Chicago plant of soundproofing studios and their individual control rooms, and the construction of transparent partitions and soundproof walls. The main walls of the studios are erected of a single layer of fourinch terra cotta tile. On the studio side of these walls are placed steel spring clips on 18-inch centers and on these clips in turn is placed metal lath. (See Figs. 6 and 7.) The same treatment is applied to the ceiling. To prevent the possibility of reverberation in the space be-

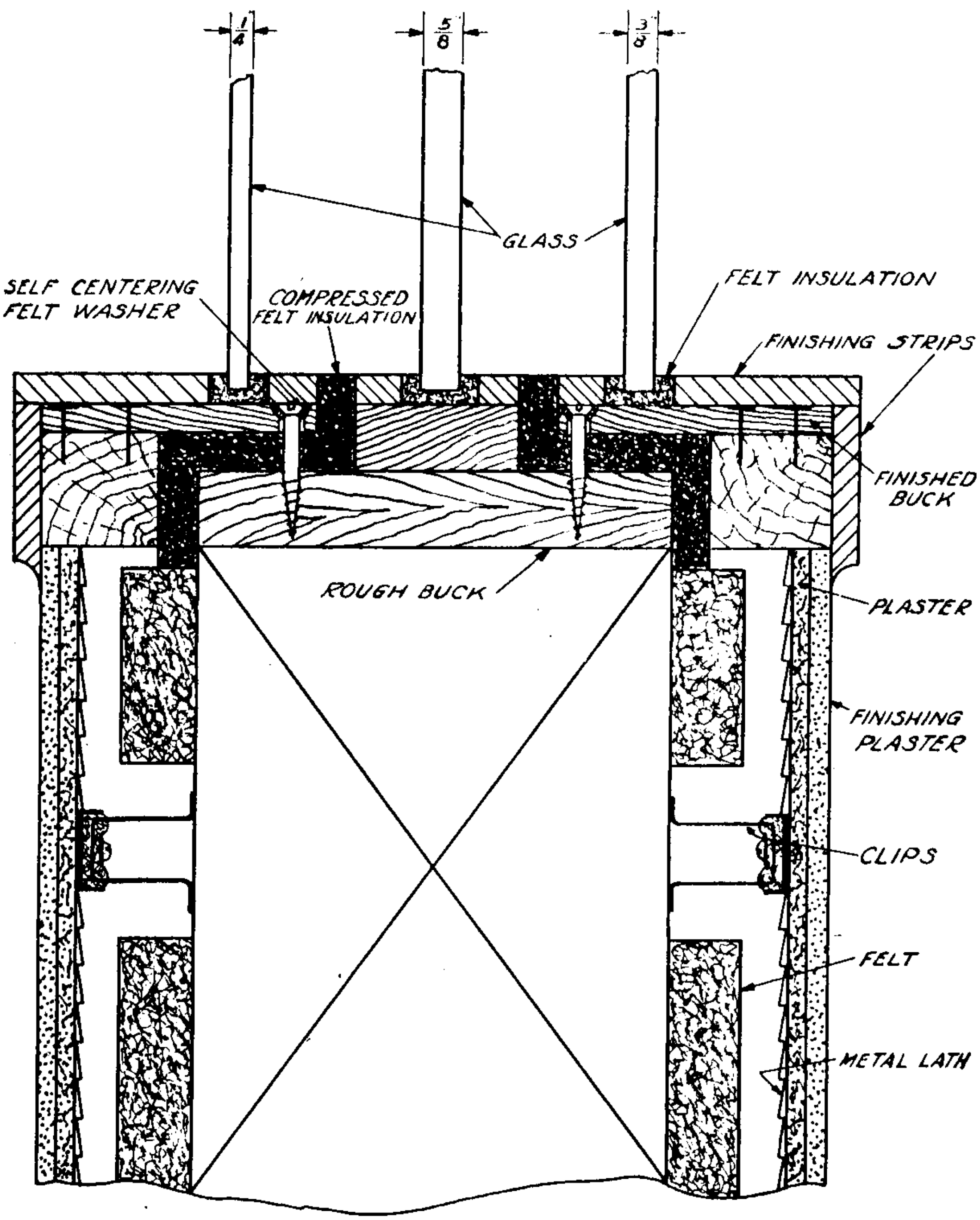

Fig. 10—Soundproof window construction.

tween the outer wall and the main terra cotta walls, hair felt or similar sound absorbing material is placed on the main wall in the spaces between the spring clips and the walls. This also applies to the area back of the hung ceiling. The ordinary layer of rough plaster is then applied to the metal lath and on top of this the acoustic treatment or hard plaster, as may be specified.

A similar system of soundproofing is placed upon the floor except that the springs in this case support wooden sleepers. Before laying the wooden floor, the space between the concrete slab and the top of the wooden sleepers is filled with some light sound absorbing material, such as mineral wool or thermo-fill, to prevent resonance in the floating floor. (See Figs. 8 and 9.)

This construction provides walls, floors and ceilings which are floating on spring clips. The attenuation to sound originating in the studio through such a partition when completed is approximately sixty decibels, even at frequencies as low as sixty-four cycles. The attenuation of course is much greater at the higher frequencies. This same soundproofing treatment is applied to the walls of the adjacent control booths so that the sound insulation is doubly effective between the studio and its control booth, which aids in eliminating interaction between the loud-speaker operating in the control booth, and the microphone and permits monitoring without acoustic interference from the studio.

The necessity for a transparent partition between each studio and its control room presents somewhat of a problem to obtain attenuation comparable with the walls themselves. Three pieces of glass of varying thicknesses, namely, 1/2 in., 3/8 in., and 1/4 in. are used in this partition, each piece mounted on a separate buck, the bucks in turn being mounted, one on the terra cotta partition and the other two on their respective floating partitions. Figs. 10 and 11 show this construction in more detail. Three different thicknesses of glass are used to stagger the natural period of the panels, which helps considerably in increasing the attenuation. The system of soundproofing described may be compared in its action to an electrical filter.

The installation of such an elaborate method of soundproofing may seem overcautious, but the success or failure of the studios when put in operation are dependent upon this factor. Even from the economic point of view, however, this is less expensive than the erection of double terra cotta or brick walls and more effective due to separation of the floor from the main structure.

A number of tests were conducted on various makes of doors suitable for studio use and a door was built, to the NBC's specifications, of comparatively light construction which has an attenuation of approximately forty decibels. The entrance to all studios is through vestibules with a soundproof door at each end. This gives in effect a sound lock analogous to an air lock to a pressure chamber so that access to studios in operation is possible. The vestibules are treated acoustically to have high sound absorption. The attenuation through such doors and vestibule is even in excess of that of the studio partitions. It is possible to erect doors of such weight and dimensions that only one door is necessary, but such is not practical. In placing the doors, great care must be exercised to see that proper contact is made against

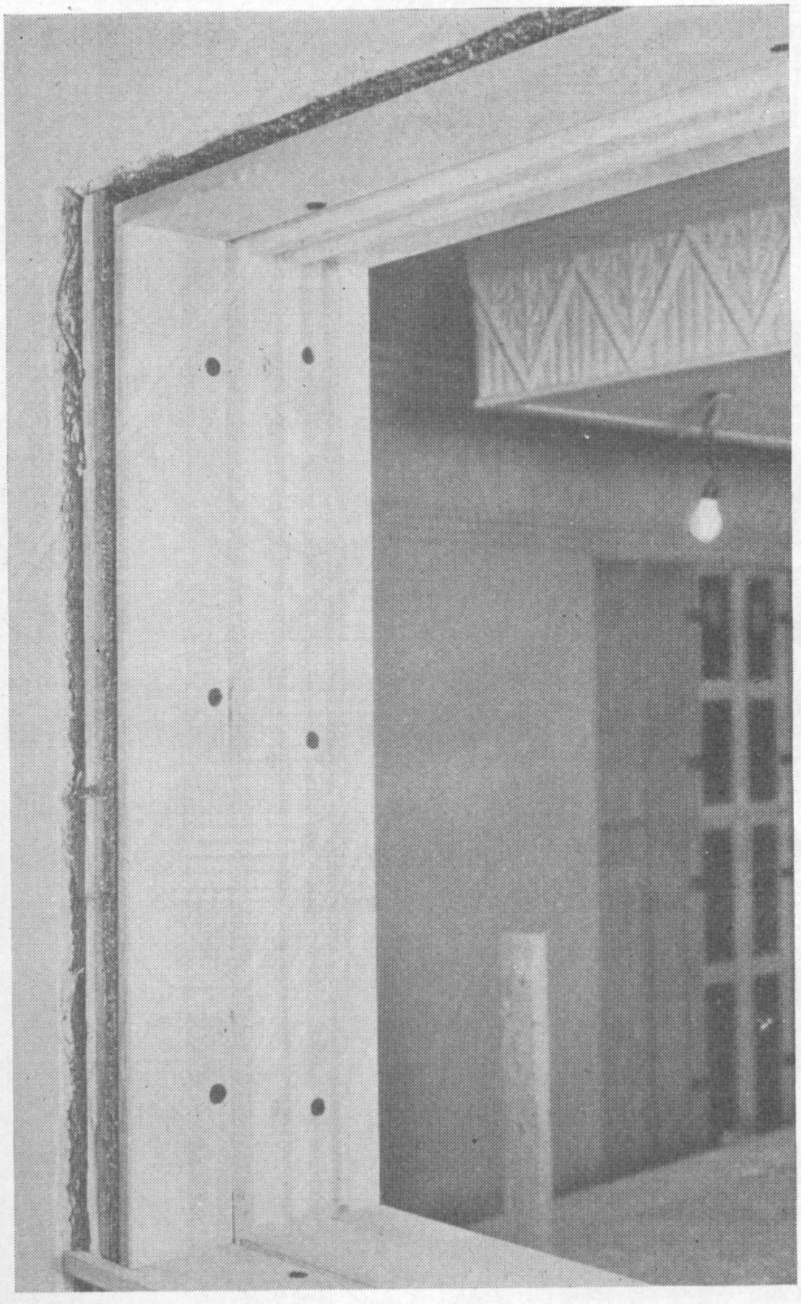

Fig. 11—View of soundproof window frame.

the jambs, two of which are provided. The door when closed is practically air-tight, even at the floor.

The system of ventilation in the Chicago studios is that manufactured by the Carrier Engineering Corporation. A detailed description of this ventilation system is not necessary, as its operation is well

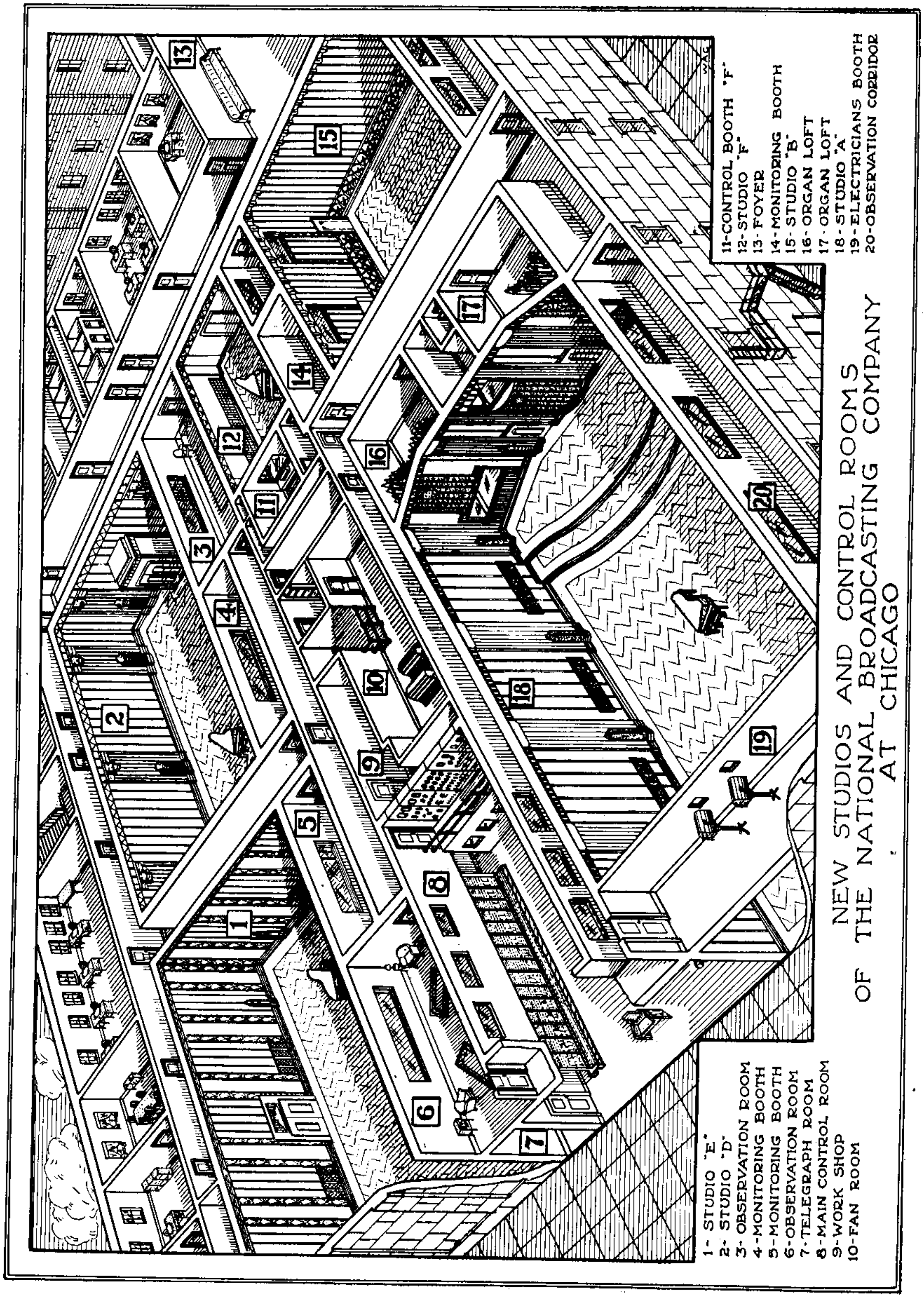
1- STUDIO "E"
2- STUDIO "D"
3-OBSERVATION ROOM
4-MONITORING BOOTH
5-MONITORING BOOTH
6-OBSERVATION ROOM
7-TELEGRAPH ROOM
8-MAIN CONTROL ROOM
9-WORK SHOP
10-FAN ROOM
11-CONTROL BOOTH "F"
12-STUDIO "F"
13-FOYER
14-MONITORING BOOTH
15-STUDIO "B"
16-ORGAN LOFT
17-ORGAN LOFT
18-STUDIO "A"
19-ELECTRICIANS BOOTH
20-OBSERVATION CORRIDOR
NEW STUDIOS AND CONTROL ROOMS
OF THE NATIONAL BROADCASTING COMPANY
AT CHICAGO

FIG. 12.

known to engineers. It might be well, however, to mention the peculiarities of the system which adapt it to broadcast studios. The most important factors are the prevention of transmission of sound through the metal work of the ducts themselves and through the air columns within the ducts. The former is taken care of by wrapping the outside of the ducts with a sound absorbing material to damp the vibrations of the metal walls. A system of sound absorbing baffles are used within the ducts to prevent transmission through the air column. These are of course installed in both the supply and exhaust ducts and are placed where they will be most effective in preventing the transmission of sound in either direction. This makes a cross section of the duct appear honeycombed, except that the partitions are square instead of hexagonal. These muffler sections are approximately fifteen feet in length. The acoustic material used is a form of Mexican moss wrapped in a membrane to prevent it from being scattered throughout the duct. Other forms of acoustical treatment, of course, could be used. Actual baffles built of sound absorbing boards erected similar to an automobile muffler were used in the New York studios of the NBC but these, although equally effective, occupy more space and cause more resistance to air flow than the method used in the Chicago studios. Emphasis must be placed on the necessity of independent studio ducts back to the main fan and the provision of individual steam and air flow control. Individual temperature control is necessary as certain studios may be vacant while others may be in use to capacity, thus calling for a different incoming air condition for each studio.

It has been found from experience that it is rather difficult, in the matter of acoustic treatment, to obtain the desired and expected results solely on the basis of frequency-absorption characteristics as supplied by the manufacturers.

The essential reason for this is that such characteristics were determined under conditions differing from those under which the material is applied in the studio. This difference is particularly noticeable in the type of wall construction herein described. At the present time almost all existing determinations of frequency absorption characteristics of commercial acoustic treatments have been taken by the Sabine reverberation method using a chamber of solid masonry where transmission through the walls is negligible. In the case of studio walls the transmission through the floating partition to the acoustic treatment behind is far from negligible at frequencies below 250 cycles. There is also a certain amount of absorption at low frequencies in this partition, independent of acoustic treatment, due to actual motion under sound pressure. It is therefore desirable, since all present acoustic treatments are somewhat deficient in low-frequency absorption, to apply an acoustic treatment which will reduce as little as possible the inherent effective absorption of the soundproof partition. From this standpoint an acoustic treatment therefore should have a low density and be non-rigid.

Tests conducted in experimental studios have shown increases in reverberation time at 64 cycles, of approximately 100 per cent due to application of an acoustic treatment not having these qualities. The actual figures in this case were 0.95 seconds before application and 1.9 seconds afterwards. Under identical conditions the application of a light, flexible, acoustic treatment caused a reduction in reverberation time from 1.0 second to 0.85 second.

The optimum reverberation time for broadcast studios is generally believed to be somewhat less than the standards set by Watson and Sabine for auditoriums mainly because of the fact that the acoustics of two rooms enter into the final result. A satisfactory value of reverberation time for studios of 2,000 to 3,000 cubic feet is approximately 0.7 seconds; for studios of 100,000 cubic feet, approximately 1.1 seconds.

It should be emphasized, however, that the type of music being rendered plays by far the greater part in the value of reverberation time giving most satisfactory results. Fast moving, stacatto selections require much less reverberation than is permissible, and in fact desirable, in the case of slow moving largo passages.

In general, two-thirds of the wall area is treated with acoustic treatment previously selected and found satisfactory for the purpose, the remaining third being treated with hard plaster of irregular surface. In the Chicago Studios the wall areas are broken up by pilasters of hard plaster, the pilasters in turn being V'd to break up the reflected wave front. The ceilings are also broken up with coffers of varied size.

It has been the purpose of this paper to outline briefly the problems encountered in the design and construction of studios suitable for radio broadcasting and to set forth practical solutions to the problems. This paper was prepared from experience in answering questions of others faced with this problem in the past, as well as from first-hand experience in the design of the studio groups mentioned. It is hoped that it may serve to some degree as a guide to those encountering this problem in the future.