Air Conditioning American Movie Theatres 1917-1932

Technical Papers 1

Development of Carbon Dioxide Refrigerating Machines 1916

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Air Conditioning American Movie Theatres
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Practical Air Conditioning 1936

The Dawn of Air Conditioned Theatres

Congratulating Ice and Refrigeration on the service it has rendered the arts of ice-making and refrigeration and the deserved success of the publication, I confidently predict, as I also wish, its continued success.

Ice and refrigeration are great industries and Ice and Refrigeration is their Bible.

Carbon dioxide as a refrigerant has met with relatively small favor in this country as compared to ammonia. In Europe CO_2 machines are more largely employed. However, in this country carbon dioxide machines have been built and used during the entire 25-year period since Ice and Refrigeration was founded and are still being built by a few manufacturers. The following brief account of CO_2 machines by Fred Wittenmeier, manager of Kroeschell Bros. Ice Machine Co., the largest builders of CO_2 ice machines in this country, will therefore be of interest:

Development of Carbon Dioxide Refrigerating Machines.

By F. Wittenmeier, Chicago.

THE development of the CO_2 refrigerating machine and apparatus has all come about in the past twenty or twenty-five years. My experience with the CO_2 machine started in the spring of 1897 when I was engaged by Grommes & Ullrich to install and start in operation a CO_2 refrigerating machine which they had imported from Germany and which was built by Scharrer & Gross of Nurnberg. This machine was used for cooling the wine cellar located in the Marquette building, Chicago. The machine had a capacity of two tons refrigeration and was rather small for the work intended.

On July 30th, 1897, the Kroeschell Bros. Ice Machine Co. was organized. The company started to build small CO_2 compressors using the patents of Julius Sedlacek. The first machines built were the "Northpole" vertical type from one to three tons capacity and horizontal machines of ten to twelve tons refrigerating capacity. The construction of the vertical Northpole type of compressors was discontinued in 1900.

Previous to 1897 there were several attempts made to introduce the CO_2 machine, which came to my notice. Wilhelm Griesser, engineer and architect, installed a machine at a brewery in Chicago, which, however, did not prove successful. Emil C. Bumiller also had something to do with this venture and a second plant which Mr. Bumiller tried to install in Montana proved a failure. I have not the exact date but the plant installed in Montana was about 1890.

Twenty years ago bronze castings were principally used for construction of valves for CO_2 machines, but this has since been abandoned and steel forgings are used for the high pressure valves and fittings.

For the small CO_2 compression machine cylinders are made for a displacement of from 1200 to 1400 cubic inches per ton refrigeration but considerably less displacement is required for the larger compressors.

Fifteen or twenty years ago carbon dioxide could be bought in 50-pound drums at eight cents per pound, but now it can be purchased in cylinders of the same capacity at four to five cents per pound. The cost of construction of machinery and apparatus, however, was much cheaper twenty years ago than it is today, owing to lower cost of material and labor at the earlier period.

In the early days submerged condensers were used exclusively for small plants and atmospheric for large ones. But today double-pipe condensers are used almost exclusively. The first double-pipe CO_2 condensers were designed by the Kroeschell company in 1902 and we believe these were the first double-pipe CO_2 condensers used anywhere.

Where sea water is to be used in the condensers, the water tubes of the double-pipe condenser are either copper or lead lined. Where the submerged condenser is used the coils are made of copper which has high heat conductivity and is not affected by sea water. The CO_2 does not attack any metal.

In the earlier period mainly small machines were built, although 50-ton compressors were installed in 1900, which are still in successful operation. As the demand grew, larger machines were designed and they are now being built up to 200 tons refrigerating capacity in twenty-four hours. During the past five years a line of vertical marine type compressors of from one to twenty tons refrigerating capacity has been designed, both steam and electric driven and this type of machine has been accepted by the United States Navy and has been installed in a number of battleships, among others the *New York*, *Pennsylvania* and *Arizona*. We are now working on a contract for the U. S. S. Battleship *New Mexico* and we consider the marine work one of the best fields for CO_2 machines.

We also find hotel work and apparatus for restaurants, hospitals, club buildings and office buildings a good field and we note with pleasure that in many cases the CO_2 machine is now specified exclusively. Another good field for the CO_2 machine is air cooling for dining rooms, office buildings and manufacturing plants. My first experience in this line dates back to 1905 where I designed the direct expansion air cooler in connection with the ventilating system and air washer now extensively used for ventilating rooms and buildings.

I also note with pleasure that a number of refrigerating machine manufacturers who formerly built ammonia machines and apparatus exclusively are now also building CO_2 refrigerating machines, but I believe that this company is the pioneer in CO_2 refrigeration, and that we are the first concern in this country that made a specialty of this line of business and that has developed a successful machine and apparatus.

As an account of earlier experiments to introduce CO_2 machines, the following history of his experience twenty-five years ago, by Heywood Cochran, now connected with the Carbondale Machine Co., Carbondale, Pa., will be of interest:

Cooling of Theatres and Public Buildings

Fred Wittenmeier
Refrigerating Engineering
October, 1922

REFRIGERATING ENGINEERING

VOL. 9 OCTOBER, 1922 NO. 4

Cooling of Theatres and Public Buildings*

FRED WITTENMEIER, Chicago. Ill.

THE cooling of theatres and buildings, with a view of making their occupants more comfortable, has attracted much attention in late years and has developed into a considerable industry in which mechanical refrigeration is used to advantage.

The engineering work so far accomplished in this field has demonstrated that when banquet halls and restaurants are properly cooled in this manner they will obtain a reputation for being a comfortable place to go and will hold their patronage the entire year.

The same is true of theatres and motion picture houses, many of which have been and are being now equipped with cooling apparatus, mostly houses having from 2,000 to 4,000 seats. Considering the fact that such houses operate 6 to 9 hours each day and the seats are sold from three or four times a day, it makes a tremendous difference in the receipts if the house is filled 80% on the average or only 40% or less.

Large banks have also found it advisable to install air-cooling systems, thereby keeping their rooms more comfortable for their employees, for being comfortable they will work steadily, having their minds on the job, and, consequently, get out more work in a given time.

The same benefits can be derived in cooling offices and work shops and some work in this line has been done.

It must be our aim to spread correct information among engineers and architects, so that they may know what can be done and how the ventilating system should be designed to permit mechanical refrigeration, and this will open a large field for the refrigerating engineer.

Such cooling plants are of large capacities and the question of low operating expenses, as well as first cost, is of vital importance. The development of the CO_2 system of refrigeration, with which the author has been closely identified, has helped considerably to make the installation of air-cooling apparatus possible and profitable.

The author's experience in this work dates back to 1905. In 1907 he designed and installed an air-cooling apparatus of 140 tons refrigerating capacity for the Pompeian room and banquet hall in the Congress Hotel in Chicago, Ill.

When this matter came up he conceived the idea of using the CO_2 direct expansion system for cooling the air, in connection with the ventilating system, by placing the cooling coils in the air washer spray chamber. This system has proved most economical in operation. It requires the least amount of space, does away with the expense of pumping large quantities of brine and is absolutely safe, as a leak in a pipe or joint would not contaminate the air so that it could be noticed by the occupants of the rooms cooled, and repairs can be made when convenient to the engineer or attendants.

The success of this installation was instrumental in many others being installed soon thereafter and the CO_2 system has been adopted for such work most generally, as has also the practice of installing the direct expansion coils directly into the air washer of the ventilating system.

The ventilating system should be designed to effect about eight changes of air per hour. A 2,000 seat house requires a fan capacity of about 50,000 cu. ft. per min. This would correspond to a house having about 275,000 cu. ft. of space. Good results are obtained by providing 2½ tons of refrigerating capacity, 24 hours rating, per 1,000 cu. ft. of fan capacity per min. In southern cities it is advisable to increase the refrigerating capacity by 25%. About 50% of the air is recirculated. In other words, where the fan capacity is 50,000 cu. ft. per min., 25,000 cu. ft. of fresh air is taken in and 25,000 cu. ft. is taken from the exhaust ducts and delivered by a return duct to the air washer to be recooled, purified and recirculated. This has proved good practice, as the air leaving the auditorium at a temperature of below 80° F. requires less cooling than that taken from outdoors when the temperature is 90° or above.

The water circulating pump for the air washer should have at least 50% greater capacity than that ordinarily provided for the ventilating system, to give sufficient spray water for the direct expansion coils.

A water distributing pipe is provided on each section of cooling coils and the water dropping from pipe to pipe is collected in the pan below and recirculated.

Spray heads are placed before and after the cooling coils and are fed by the same pump. The air is cooled by the water in the spray chamber and the water is cooled by the direct expansion coils at the same time.

The coil surface required with this arrangement is 35 lineal feet of 1¼ in. pipe per ton of refrigeration. The advantage is quite material, if one considers the fact that about three times this amount of pipe would be required if the coils are submerged in a tank.

The temperature of the circulating water in the spray chamber and collecting tank is maintained at about 58° F. The pressure in the CO_2 coils is about 30 atmospheres, which corresponds to an evaporating temperature of 22° F. The comparatively high temperature of the air and water, combined with the high velocity of the water running over the cooling coils, prevents the formation of ice on the coils. The spray chamber is designed to give a velocity of not exceeding 500 ft. per min. to the air.

The refrigerating capacity of the CO_2 compressor, standard rating, for cooling brine to 15° F., is based on a temperature of 0° F. Under air-cooling conditions, on account of the high suction pressure maintained, the capacity is about 45% greater than the ordinary rating; therefore, a compressor of 100 tons refrigerating capacity

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* Read at Ninth Western Meeting of THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS, Detroit, Mich., May 24, 25 and 26, 1922.

is doing 145 tons of work under conditions as stated above.

The air leaving the cooling chamber has a relative humidity of near 100%. Passing through the eliminators, the temperature starts to rise and rises still more as it passes through the air ducts. This amounts to about 8° F., on the average, and effects a corresponding drop in the relative humidity before the air enters the auditorium, thereby placing it in a condition to absorb heat and moisture while passing through the room.

Where more exacting conditions are required, it is necessary to provide additional refrigerating capacity, cool the air to a lower temperature of say 50° F. and reheat so as to obtain the desired temperature and humidity. This, however, is not considered necessary for public buildings and theatres and is generally not called for.

In some cases the author has found it practicable to obtain a re-heating effect by installing a heat exchange, so that the incoming warm air would meet the outgoing cold air. The air ducts were so arranged that a galvanized iron partition would separate the two ducts in such a way as to present the largest possible area between the incoming and the outgoing air. This heat exchanger can be installed at a very small additional expense and has proved most effective and economical.

With this arrangement, the Main Restaurant of the Congress Hotel (the French Room) was kept at a temperature of 72° F. and a relative humidity of 70% automatically by thermostatic control, using the steam vento coils to reheat the air when necessary to obtain the desired humidity and temperature.

For theatres, the most commonly used method of introducing air is through so-called "mushrooms" located in the floor in rows between the seats of the entire auditorium. The air enters the room at a low velocity and rises upwards towards outlets located at the highest point of the balcony, where fans deliver it to the exhaust chimneys. With this arrangement, air entering the auditorium does not agitate the entire space from the floor to the ceiling, but instead, follows the incline of the floor away from the stage towards the exhaust fans.

In banquet halls or dining rooms, the system is generally so arranged that the air enters through registers or grills in one wall, about six or seven feet from the floor and travels across the hall towards outlets provided in the opposite wall. When such halls are very wide or irregular in shape, ducts, either inlet or exhaust, may be built around the columns. In some cases, part of the air has been allowed to go into the hotel lobby with good success. In other cases, it was allowed to travel through the kitchen adjoining the dining room and then to the exhaust fan provided for ventilating the kitchen and kitchen ranges.

To illustrate the amount of water condensed and removed from the air cooled while passing through the spray chamber, the following figures, from tables prepared by Prof. C. F. Marvin for the United States Department of Agriculture in 1910 are quoted:

Air at 96° F., 50% rel. humidity contains	8.813 gr. moisture	
" " 60° " saturation "	5.745 " "	
Moisture removed	3.068 "	per cu. ft.

For 50,000 cu. ft. of air circulated per min., allowing 7,000 grains of moisture per pound, there will be 21.9 pounds of water per minute removed from the air by condensation. This amounts to 1,314.84 pounds or 158 gallons per hour. This is an extreme case, as air at 96° F. is generally at a lower relative humidity. Air at 96° F. and 40% relative humidity contains 7.050 grains and the amount of water removed under the same conditions would be 1.305 grains per cu. ft. or about 67 gallons per hour.

To find the refrigerating capacity required for a plant to cool a 2,000 seat theatre, the following calculations have been found reliable:

TABLE I—AIR-COOLING PLANT TO MAINTAIN A TEMPERATURE OF 78° F. IN THEATRE; OUTSIDE TEMPERATURE 96° F. AND 51% R.H.; SEATING CAPACITY, 2,000; FAN CAPACITY, 50,000 CU. FT. PER MINUTE; RECIRCULATE 50% OF AIR.

FRESH AIR

25,000 cu. ft. of air per min., cooled from 96° F., 51% relative humidity, to 60° F., 100% humidity = 27° drop.

1 cu. ft. of air at 96° F., 51% R.H., contains .... .001295 lb. moisture
1 cu. ft. of air at 69° F., 100% R.H., contains .... .001119 " "
Moisture precipitated per cu. ft. .000176 " "

.000176 × 25,000 × 60 = 264 lb. of water per hr. precipitated.

$$\frac{264 \times 1{,}060 \times 264 \times 27}{12{,}000} = 23.91$$ tons of refrigeration required to cool and precipitate moisture.

$$\frac{25{,}000 \times .001119 \times 27 \times 60}{12{,}000} = 3.77$$ tons of refrigeration required to cool moisture not precipitated.

$$\frac{25{,}000 \times 60 \times 24 \times .0181 \times 27^\circ}{208{,}000} = 61.08$$ tons of refrigeration required to cool the air.

RECIRCULATED AIR

Heat emitted by each occupant = 300 B.t.u. per hour

$$\frac{2{,}000 \times 300}{12{,}000} = 50$$ tons of refrigeration
Lights (estimated) = 5 " " "
Leakage through walls, etc. = 10 " " "
Total .... 65 " " "

$$\frac{65 \times 12{,}000 \times 55}{50{,}000 \times 60} = 14.3^\circ \text{ F. rise in temperature.}$$

$$\frac{50{,}000 \times 60 \times 14.3}{55 \times 12{,}000} = 65 \text{ tons. } \tfrac{1}{2} = 32.5 \text{ tons.}$$ The other half is included in the calculations for fresh air introduced.

SUMMARY

Fresh air. 23.91+3.77+61.08=88.76 tons of refrigeration
Recirculated air .... 32.50 " " "
Total ....121.26 " " "

.0181 = (specific wt. of air times specific heat) × 1° = .0181 B.t.u. required to raise 1 cu. ft. of air 1° F.

Therefore, 1 B.t.u. will raise 55 cu. ft. air 1° F.

TEST ON AIR COOLING APPARATUS AT THE BLACKSTONE HOTEL

Attention is called to the fact that two different calculations are made for arriving at the tonnage, due to the condensation of moisture. One figure is taken from Kent and the other from the Smithsonian Institute tables.

At the same time, it was shown by indicator cards taken from the engine operating the CO_2 compressor that the power required for delivering one ton of refrigeration under conditions as shown in the following calculations did not exceed 1 horsepower per ton of refrigeration.

Air circulated, cooler No. 2 = 14,000 cu. ft. per min.
" " " " 3 = 16,000 " " " "
" " " " 4 = 18,050 " " " "

Total .... 48,050 " " " "

Temperature drop 16° F.
Refrigeration necessary to cool 48,050 cu. ft. of air per min. through 16° F. = 48,050 × 16 × 60 × 24 × 0.0747 × 0.237 ÷ 284,000 = 69 tons.
Moisture per cu. ft. in air at 78.31° F. and 71½% R.H. = ... 0.001074 lbs.
Moisture per cu. ft. in air at 61.85° F. and 100% R.H. = ... 0.000881 "

Moisture condensed by cooling the air = ... 0.000193 "
The above data taken from Kent, Page 484.
Amount of air cooled per min. = 48,050 cu. ft.
48,050 × 60 × 0.000193 = 556.42 lbs. of water per hour precipitated.
Refrigeration necessary to precipitate moisture = (556.42 × 1,060 + 556.42 × 16) ÷ 12,000= .... 49.9 tons
Refrigeration required to cool air.......... 69. "
Add 3% for losses sustained in air coolers... 3.57 "
Total .... 122.47 "

The latent heat per lb. which must be disposed of to effect condensation = 1,060 B.t.u.
The range of temperature through which the moisture is cooled = 16° F.
Air cooling capacity according to Smithsonian Institute Tables.
Difference condensed by cooling the air = 0.0001557 lbs.
Air cooled per min. = 48,050 cu. ft.
Water precipitated per hr. = 48,050 × 60 × 0.0001557 = 449 lbs.
Refrigeration necessary to effect precipitation of moisture = (449 × 1,060 + 449 × 16) ÷ 12,000 = ... 40.3 tons
Refrigeration necessary to cool air......... 69. "
Add 3% for losses sustained in air coolers... 3.28 "

Total .... 112.58 "

The air capacity above mentioned was used for cooling the hotel dining room, barber shop and banquet hall. The displacement was based on eight changes of air per hour, with no recirculation of air.

The test made at the Blackstone Hotel came well within the contract requirements and the power required as shown by indicator cards taken at the steam engine at the same time show the power required was less than 1 h.p. per ton of refrigeration.

With a motor-driven compressor the author recommends the use of 1 h.p. per ton of refrigeration, 40° rating for units of over 70 tons capacity. For smaller units about 1¼ h.p. should be figured for the motor per ton of refrigeration.

He finds that in most cases the space available for the refrigerating and cooling apparatus is in the same building below or adjoining the auditorium or banquet hall. It is, therefore, necessary to have the apparatus running as quietly as possible, and on account of the large number of people assembled it is advisable to use a refrigerating medium which combines safety with economy in operation. Economy is very essential and the man who has to pay the power bills is very much interested in the operating cost. However, the safety of the apparatus is of much greater importance and should be given first consideration.

It is believed that the information given above will be of interest to all refrigerating engineers and that it will be of assistance to engineers who have such problems before them. If any one person should desire additional information on any point brought up it will be a pleasure to answer any and all questions.

TABLE II—AIR TEMPERATURE OBSERVATIONS IN CONNECTION WITH SYSTEM INSTALLED IN RIVIERA THEATRE, CHICAGO, ILL.*

Location of readings	Dry Bulb °F.	Wet Bulb °F.	Rel. Humidity %	Dry air out of mushroom
On street in shade	94.5	73	35	...
On street in shade	94	73	36	...
Row U. west side	76	68.5	65.5	69
Row C. west side	74	67	70	68.5
Row T. east side	76	69	70	68.5
Row A. east side	74.5	67.5	70	68
Balcony east side	76.5	69.5	70.5	72
Balcony west side	77.5	69	65.5	74
				Temperature in water pan
Air leaving cooling spray chamber	64	63.5	97.5	58° F.
Fan intake	67	64	84	...

Seating capacity 2,000, 80% filled.

Dry and wet bulb readings have been taken about four feet above floor.

Consecutive readings tabulated for auditorium and balcony have been taken in the adjoining mushrooms or distance apart above the floor corresponding to the spacing of the mushrooms.

Readings in the halls have been taken about ten feet apart.

Compressor running at 74 r.p.m. (maximum speed 100 r.p.m.).

Only 74% of capacity used.

Table III shows cost of electric current for operating air-cooling plant in the Riviera and Central Park Theatres, Chicago, Ill., during the summer months of 1920, refrigeration being used for all months but May:—

TABLE III

	RIVIERA THEATRE	CENTRAL PARK THEATRE
Month	Seating Capacity 2,000	Seating Capacity 2,000
May	$587.00	$433.00
June	784.00	667.00
July	742.00	624.00
August	759.00	751.00
September	776.00	596.00

DISCUSSION

E. S. H. Baars—It is my understanding that heating engineers consider 70% relative humidity bad practice; 50% or 60% being desirable.

Mr. Wittenmeier—No, 60% is very good, also 65%. Heating engineers are not on the same side of the fence with us. They are bothered with dry air, especially with steam heat, and are trying to get a higher relative humidity. They say 50% is all right. It is all right, with steam heat; 40% is too low. That is why we put pans

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*Observations have been made with sling Psychrometers. Dry bulb readings have been checked with two calibrated mercury thermometers. Observations made July 4, 1919, between the hours of 3:40 and 5:05 p.m.

of water on our radiators, so as to get a higher relative humidity. We, in cooling, introducing cool air into the rooms which leaves the cooler at 100% relative humidity, have to re-heat that air before it gets to the audience and we do that by leading it through long air ducts uncovered, or by installing heat exchangers. If a relative humidity of 60% is desired, coolers suitable for the purpose are installed and the air is cooled down to 50° or lower and then reheated to 60°, 65° or 70° and exactly the conditions desired are secured. It is simply a matter of capacity and re-heating.

E. S. H. Baars—It is not so much a method of specifying, it is more what is comfortable for the people. There is quite a difference between 60% and 70% relative humidity. I would like to hear from ventilating engineers who have had experience in that line.

Mr. Wittenmeier—All I can say on this matter is, that 72° to 75°F. with 70% humidity feels comfortable. Some people demand this and some people demand that, and it is up to us to give them advice, tell them how good results can be obtained, what we consider good practice, what has proved good practice and what has been done. Then, if they specify, say, 55, 60 or 70% humidity, we tell them how it can be done. Relative humidity of 50% is all right, 60 is all right, 70 is pretty good. On a hot day when the outside humidity is 75% and the temperature is 96°, I find that to sit in a room at a temperature of 75° is very comfortable.

In the French Room of the Congress Hotel where they have specified 70° some people complained; within a week they were working with 73° and 74° F. They found that the diners did not want it 70°; they wanted 74° and, if it is very hot, if it is 90° outside or above, it is good practice to keep that room at about 76°. Too much of a change is not desirable. If the temperature difference between the outside and inside air is 15°, it is comfortable.

Secretary Ross—I would think, Mr. Wittenmeier, that 20° would be too much of a variation.

Mr. Wittenmeier—It is not for me, but for some people I believe it is. I have heard people complain about it, so we try to keep about 12° or 15° difference between the temperature outside and that inside the dining rooms.

Secretary Ross—Wouldn't 12° be better than 20°?

Mr. Wittenmeier—I know people who thought 20° all right. I made one test where we took temperature readings in a theatre all afternoon and maintained it at 76° when it was 96° outside. The owners of the house thought it was fine; they insisted on having it. They think that is about right for moving picture houses, and we have to be guided a good deal by what people want; we can give them practically anything in temperature as well as humidity.

G. A. Horne—It seems to me, Mr. Chairman, that we have been depending altogether too much in the question of public health when considering the effect of atmospheric conditions on temperature. We have those figures published by the Weather Bureau everywhere. We also have relative humidity, but it is a well known fact that the comfort and sensitiveness of the body depends on the wet bulb temperature. It is not dry bulb temperature but wet bulb temperature which chiefly affects bodily comfort.

In conditioning air in hot weather it would seem to be desirable to establish standard temperatures and humidities best suited for health and comfort with given outdoor conditions. I do not know what such temperatures and relative humidities should be. In my own office, where the effect of refrigeration gave a temperature of 70° F. with a high relative humidity when the outside temperature was 90°, it was uncomfortably cool and, I would say, detrimental to health. In other words it would seem advisable not to have too great a contrast between the outside and inside conditions.

We are advised by physicians and heating engineers that 68° F. is the correct temperature. There should be a correct wet-bulb temperature specified corresponding to 68° dry-bulb temperature. While I believe that 68° with the correct relative humidity is about right under winter conditions, this temperature is too low in hot summer weather, no matter what relative humidity is obtained, as the contrast is too great.

G. T. Voorhees—I cooled my office in Boston for several years, a good many years ago, and came to the conclusion that the proper temperature and humidity is such that you never think of it. At about 75° and 75% relative humidity, the question of temperature never enters your head, as you are neither hot or cold. None of us ever caught cold, and we would go up town during a very hot day and walk on the sunny side of the street, feeling perfectly comfortable.

G. A. Horne—Just one other thing I would like to say that has a bearing on this: If 68° is correct in winter time with low humidity, it would certainly seem that 68° or 70° in summer would be too low for the reason that you have, as a rule, heavy clothes on in winter whereas you are lightly dressed in summer.

Mr. Wittenmeier—I want to point out that these are the tests made at the Riviera Theatre. The wet bulb readings during the entire afternoon varied between 69½° and 68½° in different parts of the house. The wet-bulb readings were 70° and 68½°.

G. A. Horne—Dry-bulb, was that?

Mr. Wittenmeier—That was wet-bulb, dry-bulb 74°, 70°, 78°.

G. A. Horne—You think that would be all right?

Mr. Wittenmeier—That was considered good conditions. I had my family in there that afternoon. I wanted to get their opinion. They didn't know what was going on, what was being done, but they told me what they thought about it. They said it was comfortable.

I want to read to you a specification calling for a cooling outfit for a bank building. I just want to read this so you will get an idea of what is demanded.

Here is one case in a Southern city. We had a specification which says that the capacity of the refrigerating plant for air cooling shall be based on outside conditions of 105° F. with 45% relative humidity. There is to be maintained in the rooms of each story—there are several stories—a temperature of 79° F. and 88% relative humidity. You can see at once that they knew what they were up against. They wanted to keep down the capacity and still give them comfortable conditions. If they had said here that they wanted 70% humidity, it would have added about 50% to the capacity of the cooling plant.

As it is, this very plant—I installed it and made a test on it later—runs up to 250 tons capacity, so that is what they call for, 79° F. when the outside temperature is 105° with 88% relative humidity or 82° with 80% relative humidity.

My advice has been to keep a temperature of about 15° below the outside temperature, and with a relative humidity that will enable you to sit down in a dining room or theatre without perspiring so that you won't feel uncomfortable but will rest. You will have your mind on things that you see without being bothered with a handkerchief.

We get this result by maintaining a temperature of 76° or 78° with 75% relative humidity, and I assure you that you will feel comfortable in such a house. You

(*Continued on page* 132)

Cooling of Theatres and Public Buildings

(*Continued from page* 118)

can try it out in Chicago; there are many houses where they have such conditions.

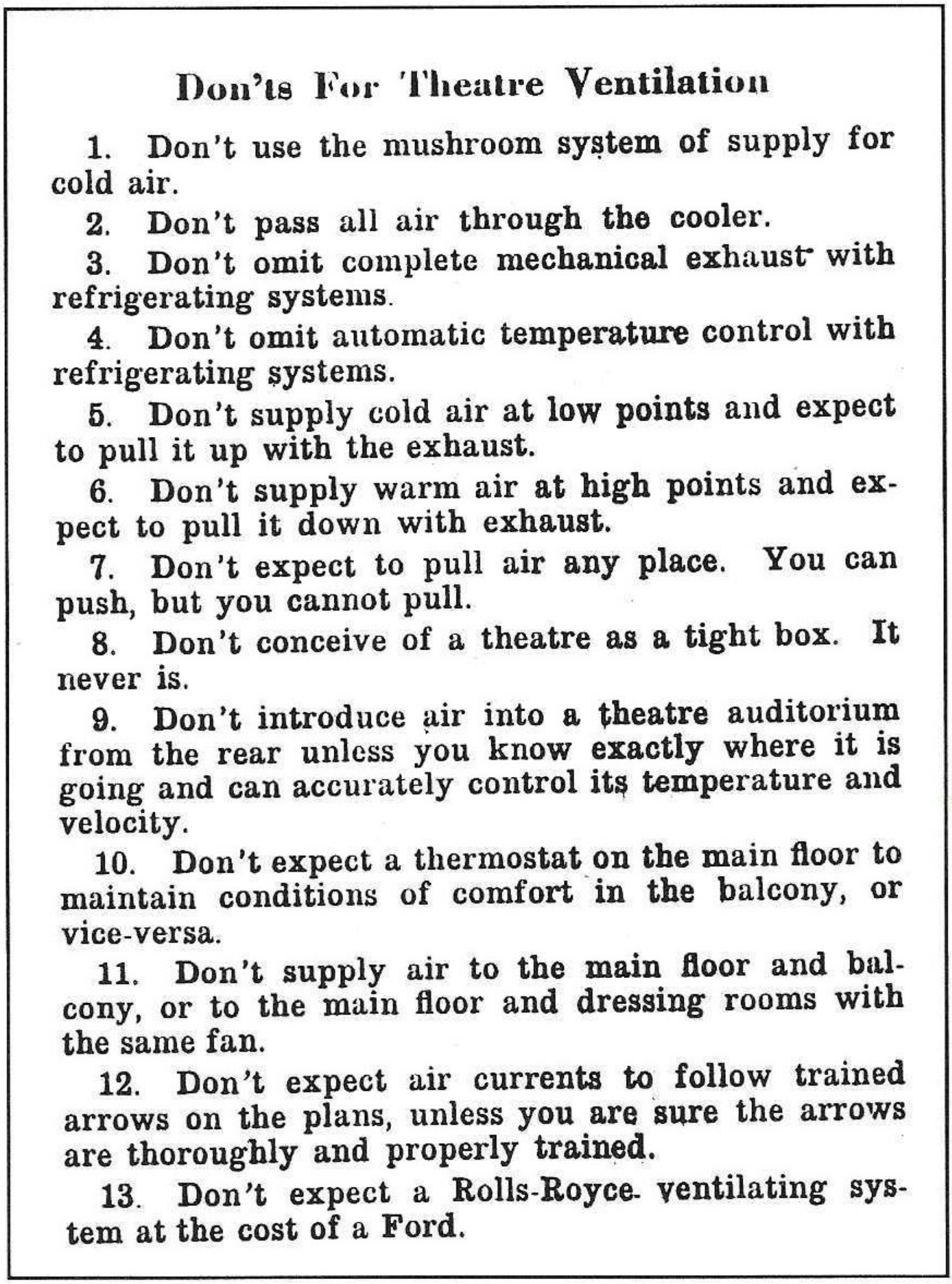
There are large temperature variations from one day to another. We have in Chicago at times a temperature change of 30° inside of five or six hours. If you follow the Chicago *Tribune*, which prints every morning the relative humidity and temperature report of the day before, you will sometimes find in the morning a relative humidity of 35%, while the same afternoon will show 80%.

By having a cooling plant with such variable conditions, outside, we are able to get uniform conditions within a few degrees temperature difference and with very little change in relative humidity.

We can vary the relative humidity and temperatures, while outside we have to take it as it comes, even a temperature drop of 40° in one day, as I have known.

Don'ts for Theatre Ventilation

E. Vernon Hill's Rules for Effective Theatre Design
1925



Don'ts For Theatre Ventilation

1. Don't use the mushroom system of supply for cold air.

2. Don't pass all air through the cooler.

3. Don't omit complete mechanical exhaust with refrigerating systems.

4. Don't omit automatic temperature control with refrigerating systems.

5. Don't supply cold air at low points and expect to pull it up with the exhaust.

6. Don't supply warm air at high points and expect to pull it down with exhaust.

7. Don't expect to pull air any place. You can push, but you cannot pull.

8. Don't conceive of a theatre as a tight box. It never is.

9. Don't introduce air into a theatre auditorium from the rear unless you know exactly where it is going and can accurately control its temperature and velocity.

10. Don't expect a thermostat on the main floor to maintain conditions of comfort in the balcony, or vice-versa.

11. Don't supply air to the main floor and balcony, or to the main floor and dressing rooms with the same fan.

12. Don't expect air currents to follow trained arrows on the plans, unless you are sure the arrows are thoroughly and properly trained.

13. Don't expect a Rolls-Royce ventilating system at the cost of a Ford.

Figure 11-46 *E. Vernon Hill's rules for effective theater design in 1925 sought to avoid the problems that prevailed in many theaters: "Until recently . . . it was the practice to install one or two noisy exhaust fans and spot a few unvented gas radiators about. When the combination of garlic, Fleur de l'Orient, halitosis, etc., became unbearable, the organ and the big propeller fans would be started. Some of these old propeller fans are quite the equal of the organ in noise-generating characteristics, but they move the air out, and down the aisles comes a flood of cool air, striking the patron on the back of his perspiring neck and legs. Naturally, we are behind in our hospital building program." (Buck, E.S. 1928. Theater air conditioning in the Southwest.* The Heating and Ventilating Magazine, *February, p. 74) (from* The Heating and Ventilating Magazine, *March 1925, p. 45.)*

Air Conditioning in the Theatre

Lewis Leeds
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REFRIGERATING ENGINEERING

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Air Conditioning in the Theatre

L. L. LEWIS, Newark, N. J.

THE AUTHOR of this paper sets forth the general, financial, or economic considerations under the subject specified. Each item is considered with respect to cost, and the question of what to do about cooling or ventilation appears as it would face the theatre manager. The fundamentals of this kind of management are given as a basis. For purposes of comparison, these costs are balanced against the simple plan of ordinary ventilation, and the relation established is boiled down to very tangible figures.

WITH FIRST thought upon this subject the writer found that there seemed to be two very definite and divergent lines of treatment. The first was that the engineering element could be presented to the refrigerating engineer. The second was that the refrigerating engineer could be left to do some of his own thinking about his own business, but that a few moments could be given to the consideration of the beneficial effect of applications upon the purchaser. This idea has led to the decision to deal primarily with the economical features of the application of air conditioning to the theatre, and to attempt to show at the present time some of the reasons why we shall soon be saying, "Well, I wonder why all this wasn't done long ago."

It would seem advisable, before starting the economical survey, to spend a few moments in a very general analysis of air conditioning in the theatre. The theatre to be considered is the so-called movie house, having 1500 or more seats, and presenting motion pictures and vaudeville in various proportions. Some theatres of this kind will open at 10 or 10:30 in the morning, usually with an abbreviated show, consisting only of pictures. The majority will open at 12 or 1 o'clock. The customary schedule is to run the pictures four, five or six times, with the vaudeville acts presented three or four times, and so placed between runs of the pictures that a person entering the house at any time may see the complete entertainment, without having to see any of it twice. Many of these theatres have a sliding scale of prices, charging the highest rates for the evening performances.

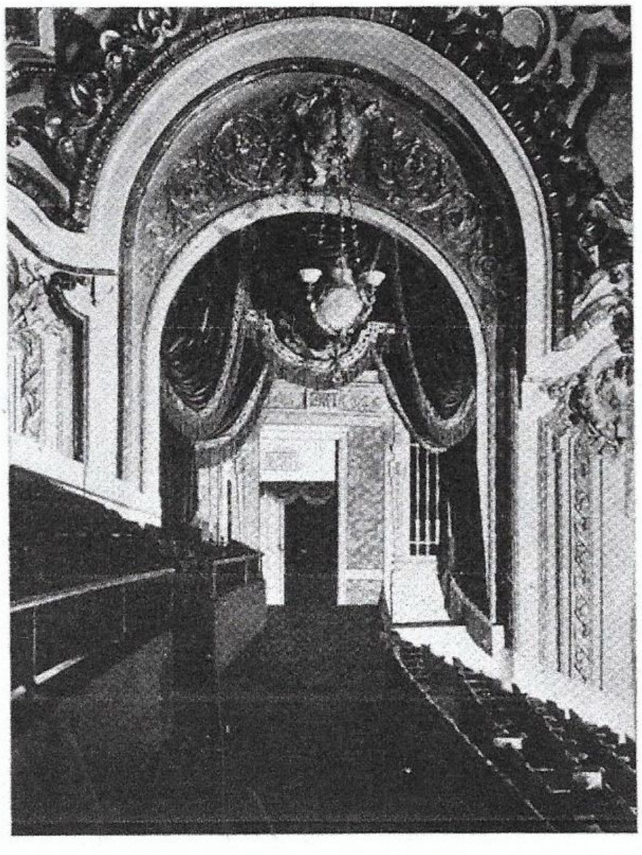


FIG. 1. INTERIOR OF THEATRE SHOWING COMPLEX DESIGN OF CEILING.

There are three vitally essential elements in the application of air conditioning to the theatre. These are:

1—The maintenance of a definite, controllable air circulation.

2—The maintenance of a suitable relative humidity.

3—The maintenance of suitable temperatures.

To these might be added the fourth element of cleansing the air of the greatest possible amount of dirt which it carries. This last is important, because a complete disregard of it may hasten the not inexpensive procedure of having the theatre "dark" for a number of weeks, with the loss of as much as $15,000 or $20,000 per week in box-office receipts, and the very considerable expense of redecoration.

With respect to the three vital essentials, let it be emphasized that the establishing of definitely controlled circulation is placed first upon the list, not only for emphasis, but also because it is the one element of air conditioning which has caused more failures than any of the others. The engineer who has to choose between drafts and stagnation does not occupy an enviable position. He not only has all of the types from red-heads to bald-heads to deal with, but also occasionally has the somewhat reluctant co-operation of the artist.

No practical system has yet been designed to remove 100% of the dirt and dust carried by the air, and, therefore, the outlets through which the air is delivered to the theatre should be so designed and located as to reduce to a minimum the ugly streaking, which is a too well-known characteristic of ventilating systems.

If the theatre consisted of four square walls and a flat ceiling, this problem would not be a difficult one, because then the conditions would be essentially the same for every theatre.

The pictures presented here (Figs. 1 and 5) illustrate two extremes encountered by the engineer in establishing his equipment in the theatre. Fig. 2 illustrates diagramatically the essentials of the air conditioning process applied to the theatre.

In most of the early attempts, the engineer has chosen as nearly perfect stagnation as it was practical to obtain. The result has been that while the dry and wet bulb thermometers showed that the audience should be comfortable, as a matter of fact, they were not, and until the advent of the American Society of Heating and Ventilating Engineers' Effective Temperature Chart, none too much was understood of the reason therefor.

The standards of the old system called for the delivery of air at outlet velocities not to exceed 250 or 300 ft. per minute. Since then, it has become a more or less common practice to use velocities as high as 1,000 ft. per minute, and six theatres are now operating with an entirely new system, in which the air is introduced into the theatre at velocities ranging up to 4,000 ft. per minute. In the present day installation, the engineer has sought to obtain a definite, uniform circulation, which constantly brushes away the film of air in immediate contact with the bodies of the audience.

No one likes to be subjected to a high humidity, and, therefore, the humidity must be carried low. The system must be designed for maintaining a relative humidity as low as practical with a completely filled theatre. The difficulty of doing this will be slight, as compared with the difficulty of maintaining the relative humidity at a sufficiently low point when only a few people occupy the theatre.

In the reference to the element of temperatures, the plural is used, because not the same, but varying temperatures must be maintained in different parts of the theatre, in order to produce equal degrees of comfort. While air circulation, humidity and temperature have been considered separate, it must be understood that for the same degree of comfort, higher temperatures are permissible with higher rates of circulation, and also higher temperatures with lower relative humidities. There may be a great difference in comfort between two theatres, in which psychrometric readings show identical conditions of temperature and humidity.

Another reason for attaching less importance to the engineering features of air conditioning in theatres, is that the refrigerating load in a theatre varies widely and rapidly. It is quite different from the load in a manufacturing plant, the ideal of which is to get into production at the blast of the morning whistle, and continue at full production until quitting time.

This does not mean that the theatre manager, or owner, would not like to have "standing room only" as the hourly report. The fact remains that during a large part of the time when the theatre is open, it is showing to from 5 to 10% of its capacity. The theatre which opens at noon does not fill quickly, and may consider itself fortunate if by 1:30 it has sold tickets for one-third of its seating capacity. But shortly after 1:30, the afternoon crowd begins to arrive and by 2:30, on a successful day, the theatre should be well-filled, probably to from 80 to 90% of its seating capacity. It will be fairly well filled from 2:30 on until about 4:30, when the afternoon show will "break".

Fig. 2 serves to show a typical attendance curve for a cinema theatre.

By five o'clock not more than one-third of the seats will be occupied, and by six o'clock, 90 to 95% will be empty. They will run the pictures with scarcely a hand-full of people in the theatre until about seven o'clock, when the evening crowd will begin to arrive, and by 7:30 or eight, the theatre should be well crowded. The highest peak will be reached between 8:30 and nine, in which the total number of people occupying the theatre may reach 133% of the seating capacity. Then the evening show will "break" around nine o'clock, with possibly 80 to 90% of the seats filled from nine o'clock until ten, after which the crowd rapidly dwindles until the theatre closes.

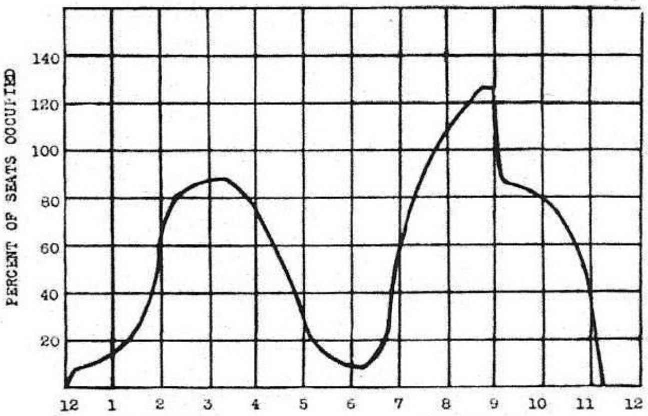


FIG. 2. CHARACTERISTIC CURVE OF THEATRE ATTENDANCE

Inasmuch as the people account for the greatest part of the heat to be absorbed, the heat storage, or fly-wheel effect of the theatre and air conditioning equipment must be taken into consideration in determining the size of the air conditioning equipment. The equipment should not be designed to absorb heat at the maximum rate at which it is given off, because the peaks are of slight duration, and a much smaller equipment will give satisfactory results. The relation between the peak load and the capacity of a satisfactory equipment is a matter largely of experience.

The purpose of this is to compare the annual cost of operation of two theatres, one equipped with air conditioning apparatus, in the present-day conception of that term, and the other equipped with ventilating equipment designed in accordance with the present-day practice for that type of system.

The air conditioning apparatus will consist of the usual fan, duct work, heater, dehumidifier or spray cooler, refrigerating equipment, and automatic control, arranged for both the return and recirculation of air from the theatre. The ventilating equipment will consist of a fan, duct work, heater, air washer, and either hand or automatic arrangement for the return of air from the theatre. In each case, the operating cost would be estimated for a unit of 1,000 seats, excluding any treatment of the theatre lobby, or public, or service rooms.

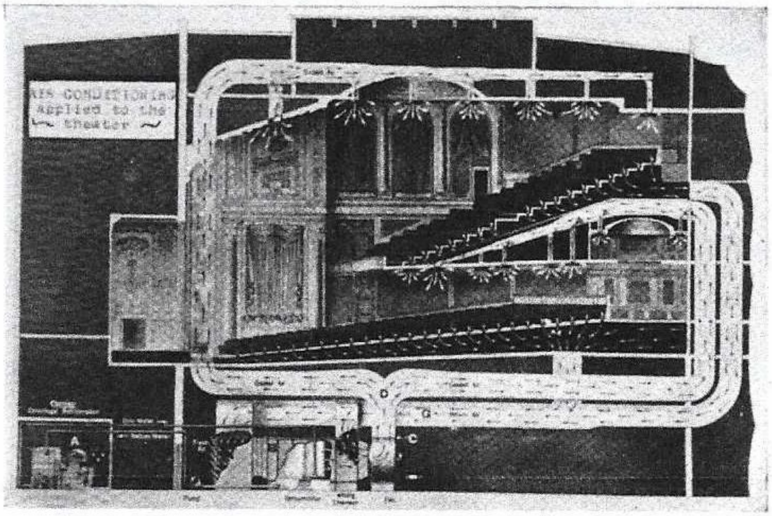


FIG. 3. SECTIONAL VIEW OF THE THEATRE SHOWING AIR CONDITIONING EQUIPMENT AND AIR CIRCULATION

AIR CONDITIONING EQUIPMENT

DEPRECIATION

The cost of the air conditioning equipment, including foundations and building construction work, the service connections for electric current, water supply, sewage, and steam, will average about $32,000.

This must not be taken to mean that every installation can be made at a figure even near this unit price. The location of the apparatus, the shape and design of the building, the proximity of sources of water, electrical and steam supply, may vary this item as much as 25%, either up or down.

It is considered that fifteen years would be a fair life for this equipment. With proper attention and proper maintenance, equipment of this nature should easily be kept in service for that length of time. The useful life of the theatre for a show of a certain character, however, is limited to a considerably shorter period by the whims of those who furnish the box-office receipts.

There are many old theatres that continue to show to capacity houses, but it seems that in considering the item of depreciation, it would be risky to charge off an equipment of this nature in a period exceeding ten years. The annual depreciation, therefore, will be taken as 10% of $32,000, which is $3,200.

INTEREST

The theatre man's money should be worth 6%, and this interest should be charged against the air conditioning system, as it would, if invested in any other manner. The depreciation, however, is regularly reducing the investment, so that the average annual charge for interest will be 6% of ½ of the total investment, or $960.

POWER IN SUMMER

In the cost of power to operate the system, several items make their appearance. First in interest will come the refrigeration, which in this case should not require more than 63 h. p. The average amount of power which is consumed will vary over a fairly wide range, and is governed by a number of variables, the principal ones of which are the temperature of the condenser water, the wet bulb temperature of the outside air and the number of people in the theatre.

It is true that the purpose of making an installation is to keep the house crowded to capacity, but it must be remembered that a house which can afford a cooling system must operate continuously from early afternoon until close to midnight. A certain amount of time is required for the audience to assemble,—the audience must be expected to take some time off for dinner, and toward the close of the show, the audience will gradually thin out.

When both the air conditioning apparatus and the refrigerating machine are fully equipped with automatic regulation, which is capable of taking advantage of every opportunity to save power, or when the plant is operated by a man more anxious to be continually on his feet making adjustments than in his chair thinking, the actual power consumption can be very greatly reduced. The judgment in this case is that the average consumption will not exceed ½ of the maximum, so that the average amount of power consumed by the refrigerating machine will be 32 h. p.

The amount of power required for driving the fan forms a fairly considerable part of the power cost. The fan must be kept in continuous operation, to maintain air circulation. Any saving obtained by slowing the fan down is of questionable value, because lower temperatures and lower humidities must be carried, to give equal comfort conditions, with the lesser circulation. The average amount of power required for the fan is 10 h. p. The amount of power required for the spray pump, which brings the refrigerated water in contact with the air, thus washing and cooling it, forms a fairly considerable part of the total.

The conditions surrounding this are almost identical with those affecting the operation of the fan, and 9 h. p. is considered a fair power consumption for the spray pump.

The average amount of power used by the refrigerating machine, fan and spray pump is, therefore, the summation of 32, 10 and 9, which equals 51 h. p.

On the basis of 0.9 of a K. W. per h. p., the current consumption is 46 K. W. A rate of 2.5c per K. W. seems to be a fair average of the rate paid by a large number of theatres, although some of them are fortunate in obtaining power at as low a price as 0.9c, while there are several paying as high as 4.5c. At 2.5 per K.W.H. the average hourly cost of power is $1.15. In all but the southern parts of the United States, it will be found necessary to run the refrigerating machine during approximately one-third of the month of May, all of June, all of July, all of August, and about two-thirds of September. The summation of this is very nearly one-third of a year.

The operation of the plant, (considering the possibilities of an occasional shut-down in favorable weather), is 10 hours per day for 120 days, for the average theatre. The total time of operation is, therefore, approximately 1200 hours, and the cost of power for that one-third of the year known as the summer season is $1,380.

WATER IN SUMMER

The amount of condenser water will average 1.5 gal. per ton, so that a maximum of 95 gallons per minute will be required, when it is available at 75° F. In the item of power, credit was taken for the favorable variations in the temperature of this water, for during many of the hours of operation, the temperature will be considerably below 75°. The quantity of water will vary with the tonnage, which we have previously taken as averaging one-half of the maximum.

Our average water consumption, is, therefore 47.5 g. p. m. or 378 cu. ft. per hr. The cost of this water will vary from 40c per M. cu. ft., in a few very fortunately located cities, to $2.50 per M.

The theatre will not be in a position to get as low a rate as might an industrial plant, which would have a continuous demand, so that if $1.25 is considered a fair average, the cost of water is, therefore 47c per hour. In a season of 1200 hours, this would amount to $570.

POWER IN WINTER

The foregoing has covered the power and the water, for the summer period. There will be a corresponding winter period of four months, in which the characteristics of the heating load will be almost identical with those of the refrigerating load.

The amount of power required by the fan will be 10 h. p., as in summer operation. It is quite essential to operate the spray pump, in order that the cost of redecoration may be postponed, and in order to maintain a suitable relative humidity. Proper piping connections will permit operation with less power, so that this item may be reduced from 9 h. p. to approximately 6, and the total winter power consumption becomes 16 h. p. This amounts to 14.4 K. W. and the hourly cost of power, 36c. There will be approximately 1200 hours of winter operation, while the theatre is open.

This is all that need be considered, because there are few theatres which are not protected by adjoining or surrounding commercial buildings, so that it is unnecessary to operate the Air Conditioning equipment, except to start it somewhat ahead of the opening of the box office, to bring the theatre up to temperature, and to maintain it at proper temperature during the performance.

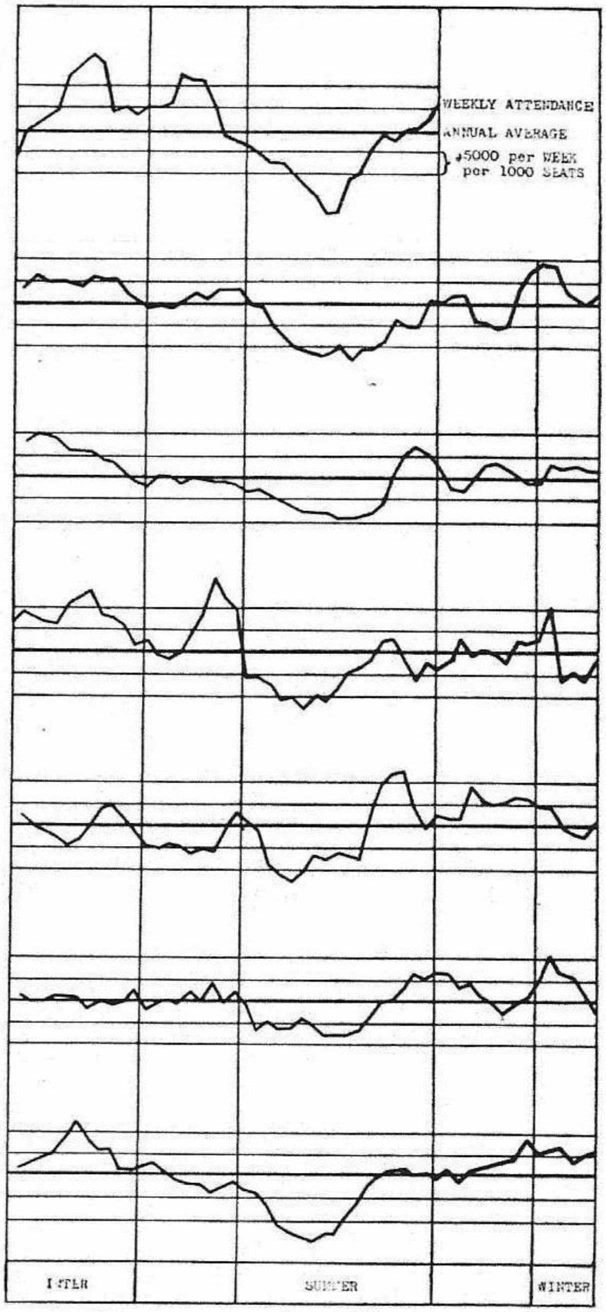


FIG. 4. CURVES SHOWING THE ATTENDANCE IN THEATRES WHICH ARE NOT COOLED

Twelve hundred hours at 36c an hour, therefore, represents the cost of power during the winter season, the total being $430.

STEAM IN WINTER

This air conditioning system should be equipped with automatic regulation, which proportions the ventilation to the heat load in the theatre. Since the people contribute the greater part of the heat, the amount of air supplied for ventilation is, therefore, automatically proportioned to the number of people in the audience.

A sufficient amount of air is returned from the theatre to prevent that being taken in for ventilation from freezing. Thus, the customary tempering heater is dispensed with, and the steam requirements of the equipment cut approximately in two. Circulation is maintained with the minimum amount of outside air, by the admission of recirculated air at a point between the outlet of the spray chamber and the inlet of the fan.

The heating period will consist of about one hour per day for preheating, and not more than six of the remaining ten hours of theatre operation. During the other four hours of theatre operation cooling will be required even in mid-winter.

The preheating will be done with very little steam, because no ventilation will be taken during that period. Steam will be required at the rate of 324 lb. per hr., which at 75c per M., for a period of 700 hrs., gives the cost of steam for heating. It must be borne in mind that this excludes the services of the fireman, the firing being done by the engineer employed to look after the equipment. It also excludes the cost of heating all the other parts of the theatre, such as the stage, dressing room, and other auxiliary rooms which would have to be heated, regardless of whether or not the theatre was air-conditioned. The amount of this is $175.

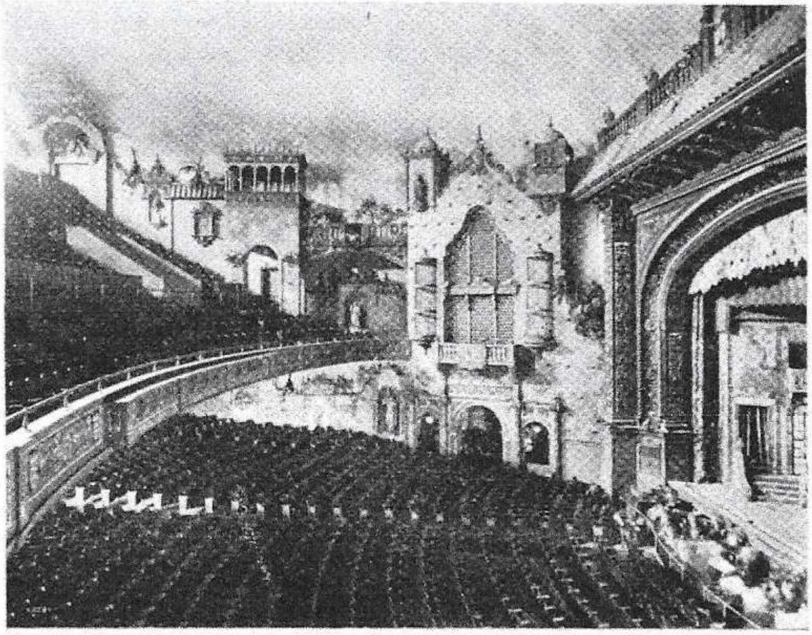


FIG. 5. INTERIOR OF ATMOSPHERIC THEATRE SHOWING PLAIN CEILING IN WHICH NO OUTLETS CAN BE PLACED

INTERMEDIATE SEASON POWER

The four remaining months of the year make up the intermediate season, in which the outside temperature is such that the air, when treated by a spray of recirculated water, is sufficiently cool to maintain comfortable conditions in the theatre without refrigeration. The power required by the fan and the spray pump will be the same as that required for winter operation, which has previously been shown to amount to $430.

INTERMEDIATE SEASON STEAM

The amount of steam required is very slight, but it is absolutely essential to the maintenance of proper conditions. If this steam can be purchased from a distributor, the cost will be low, but if it must be generated, the proportionate cost increases on account of the manner in which the boilers must be fired.

The demand is much less than the demand during the winter months, but inasmuch as the boilers must stand by, with banked fires for a number of hours, the cost per 1000 pounds must necessarily increase. It seems reasonable, therefore, to take this amount as being half of the winter heating, so that it will be $90.

MISCELLANEOUS

The items to complete the list of costs would be maintenance, oil, refrigerant, and sundry supplies, which should not exceed $1,000.

The services of two engineers, who will be required to serve in two shifts, will amount to an average of $5,000.

TABLE I

The total cost of operation, for 1000 seats, according to the preceding figures is as follows:

Depreciation	$ 3,200.00
Interest	960.00
Power in summer season	1,380.00
Water in summer season	570.00
Power in winter season	430.00
Steam in winter season	175.00
Power in intermediate season	430.00
Steam in intermediate season	90.00
Miscellaneous supplies	1,000.00
Attendance	5,000.00
Total	$13,235.00

This must hastily be admitted to be a fairly considerable sum of money. No claim is made that its size can be reduced by dividing it, but, nevertheless, the sole purpose for its expenditure is the provision of more comfortable conditions for the patrons of the theatre, which in most of the large cities will operate 365 days out of the year. The cost of operation per 1000 seats is, therefore, $36.30 per day, or 3.66c per seat, per day.

A reasonable expectation is that each seat in a high-class theatre will be sold two and a half times, average, for each day, so that the price for providing comfort throughout the entire year becomes something like 1.5c per patron.

VENTILATING EQUIPMENT

But this is not a net increase, for while it has not been long since an architect marveled at an appropriation of $2500, for the ventilating equipment of a 3300-seat theatre, a good ventilating equipment is considered a necessary part of the equipment of every high-class theatre.

DEPRECIATION

The cost of such an equipment, including the foundations and building construction work, service connections for electrical current, water supply, sewage and steam, will average about $12,000. per 1000 seats.

The depreciation on this ventilating equipment, on the same basis as the air conditioning equipment, will amount annually to $1,200.

INTEREST

The interest on the investment, on the same basis, will amount to an annual charge of $360.00.

POWER

Less power will be required to operate the ventilating equipment. The fan will require 10 h. p. as it would for the air conditioning equipment, but good washing and a reasonable amount of evaporative cooling can be obtained with a smaller volume of spray water and a lower spray pressure, so that 5 h. p. may be considered as a fair figure for the spray pump and the total power consumption reduced to 15 h. p., which is slightly less than the average annual power consumption for the air conditioning equipment.

A somewhat higher power rate might be charged against this equipment, because of the lesser power requirements of the system. Inasmuch as this is not a big item, the same rate will be taken and the annual cost of power for operating the fan and spray pump for 3600 hours, becomes $1,215.

WINTER STEAM

The question of winter steam is not an easy one to answer. When filled with people any theatre will completely heat itself, during the coldest of winter weather. The theatre manager discovered this long ago, and a very large number of them have resorted to the practice of bringing the theatre up to temperature and then shutting down the ventilating equipment. This has cut down the coal bills, but at the same time, has stopped air circulation, and, of course, ventilation. The result is a warm, stuffy and malodorous theatre.

The only feasible way of considering this item, therefore, seems to be that of considering the cost of not running, in its effect on patronage, to be equal to the cost of supplying steam. While it is beyond question that the same results in circulation and ventilation will require much more steam with this system, it does not seem fair to charge it with more than the other. On the same basis as for the air conditioning system, the cost of steam in such a theatre will be $175.

INTERMEDIATE STEAM

During the intermediate season, conditions will be practically the same as those for the winter season, and the cost of steam will be $90.

MISCELLANEOUS

The cost of maintenance annually is much lower and is taken as $300.

Two men will be required to operate the equipment, but neither of them need be quite such high-class men as are required for the air conditioning system. The annual cost of attendance is, therefore, taken as $4,000.

The total annual cost of operation per 1000 seats is, therefore, as shown in Table II.

When spread over 365 days, the daily charge becomes $20, the cost per seat per day, 2c, and the cost per expected patron 0.8c.

Thus, the difference between the cost of the present way of doing things, and the cost of providing ideal conditions of comfort, is 0.7c per expected patron.

Looking at this from another angle, we find that the difference between the cost of operating the air conditioning system, and the cost of operating the ventilating system, per 1000 seats, per year, is $5,895.

TABLE II

Depreciation	$1,200.00
Interest	360.00
Power	1,215.00
Steam for winter season	175.00
Steam for intermediate season	90.00
Miscellaneous supplies	300.00
Attendance	4,000.00
Total	$7,340.00

The difference per day, per 1000 seats, is $16.15, or the cost of 46 tickets, at an average price of 35c. When running four complete shows per day, there is an opportunity of selling 4000 tickets, and an expectancy of selling an average of 2500.

An increase of slightly less than 2% in the patronage would, therefore, pay the cost of producing ideal comfort.

DISCUSSION ON—Mr. S. C. Bloom, the first to discuss the paper, thanked the author for rationalizing the subject of the economies of air conditioning for this application. He expressed the belief that

(Continued on page 88)

This paper was presented before the Society at the Fourteenth Western Meeting, on May 23, 1927. L. L. LEWIS received his engineering training at the University of Kentucky, graduating in 1907. He remained at that institution for one year as an instructor. Since 1909 he has been associated with the Carrier Company holding positions from draftsman and estimator to his present connection as Secretary and Chief Engineer.

Air Conditioning in the Theatre

(Continued from page 60)

theatre managers have continued to install air conditioning in their houses, not because of the comfort obtained, but because of the financial benefit derived therefrom. He also thought that the plan will eventually spread to office buildings as well, because of the increase in efficiency of employees which it is recognized will result.

President Carrier remarked to the effect that the main problem in the theatre is one of cooling rather than of heating, as the only heat needed is that used for heating the air for ventilation.

A statement made by Mr. Harry Harrison, to the effect that tests made in City College of New York, some ten years ago, showed that ventilation did not affect the efficiency of employees, was refuted by Mr. Bloom. The latter cited as an example, a large office building which, by neglecting some needed repairs, was caught in a spell of hot weather, bringing forth a storm of protest from the office manager because of the loss in office efficiency. President Carrier added that the tests which had been referred to, led to the conclusion that temperature was the most important thing, stating that the report specified that both temperature and humidity were vital points in efficiency.

Mr. L. Howard Jenks then cited the incident of the Black Hole of Calcutta, in which a great many British soldiers were crowded into one small room, with the result that all but one died. At the time, it was said they would all have lived if only the moisture could have been excluded; the amount of CO_2 would have had no effect on them. This view was supported by President Carrier, who mentioned experiments made by the American Society of Heating and Ventilating Engineers on humidity, at the Bureau of Mines in Pittsburgh. These tests proved that where conditions are such as would be produced by a large number of people in an unventilated space, where temperature and moisture would rise, that life cannot exist for more than a few hours.

Mr. Stephen Bennis stated that especially in New York City, competing theatres are putting in air conditioning apparatus for profit, and expressed the belief that the movement will spread to business houses for business reasons. He also suggested that the heating system be reversed into a cooling system, and be taken into the schools and farms eventually.

The last remark was taken up by Mr. Lewis, who said that the trouble with many cooling systems is that they are only heating systems reversed. One criticism which he said might be made of his paper was that it did not group all of the costs of operation of the refrigerating machine against the box office receipts for the summer months, when that part of the equipment was in operation. Mr. Lewis stressed that this paper did not deal with a plant designed as a heating system with refrigeration attached to it. This plant is designed as a cooling system. It operates as a cooling system, even on the coldest winter days, because when the theatre is filled with people the heat which they supply is greater than the heat loss by radiation through the walls and roof of the building. He recommended that this sort of a system be operated 365 days out of the year, and the cost of its operation be distributed over that same period.

Mr. H. G. Venemann asserted that he once had been asked by letter if it would be possible to cool a church on Sunday during the summer months. He had replied that it would be possible but impracticable, as the amount of money invested for the short period would be prohibitive. According to Mr. J. C. Goosmann, churches are now being cooled by air conditioning apparatus successfully. Mr. Jenks told of a theatre which depended on a psychological effect for its cooling system. A cake of ice was put under each register with a light turned on it. Apparently everybody felt that it did some good.

Heating, Ventilating And Cooling

American Theatres of Today
1927

Heating, Ventilating and Cooling

The proper control of air conditions in a theatre is not a matter of simple or ordinary design. It is a problem that should be intrusted only to competent engineers experienced in this type of work. Air conditioning in a theatre introduces a multiplicity of problems particularly to provide for seasonal changes. For example, while the animal or body heat from the audience and the heat from numerous electric light bulbs may be an asset in cold weather, they produce a highly objectionable condition in warm weather. A stage with too little radiation results in the front portion of the orchestra being under heated and induces noticeably strong air currents through the auditorium. The general procedure has been to have the auditorium moderately warm when the audience entered and then to gradually balance the bodily heat from the audience and heat from the lights by reducing the heat supplied from the boilers. The motion picture theatre, however, with an almost constantly changing audience, introduced new problems for solution. The proper heating of the auditorium has always proved an annoying problem. The size and shape of the room, the large opening to the stage and the large number of people seated close together, present a heating problem that requires the most careful consideration. The heating of dressing rooms, retiring rooms, toilet rooms and similar areas present no unusual heating problem. The lobby, however, where doors are continually opened and closed, requires entirely different and separate attention. To prevent cold air from being blown into the auditorium, the air in the lobby must be very quickly heated.

In contrast to the provision of a comfortably warm temperature in cold weather,

FOYER, STADIUM THEATRE, WOONSOCKET, R. I.

Frank B. Perry, Formerly Perry & Whipple, Architect.

there is the matter of providing a comfortably cool temperature in warm weather. A proper change of air or ventilation is further essential to the comfort of the patrons. This service of comfort, largely governed by the condition of the air in the auditorium, is dependent upon air movement, humidity and temperature.

A gravity two-pipe system or a vacuum return line system has been found to be the most satisfactory type of heating. Boiler locations are often practically fixed by the city theatre code. The New York City code prohibits placing the boilers under the auditorium or under the stage. This frequently requires placing the boilers under the sidewalk. Boston prohibits the installation of boilers under sidewalks or public thoroughfares and Chicago permits them to be installed as desired. The demands upon the boilers are heavy and ample capacity should be provided. The type of boiler selected depends very largely upon the size of the theatre. The heating mains should be so divided that the sections of the building having different heating demands are served independently.

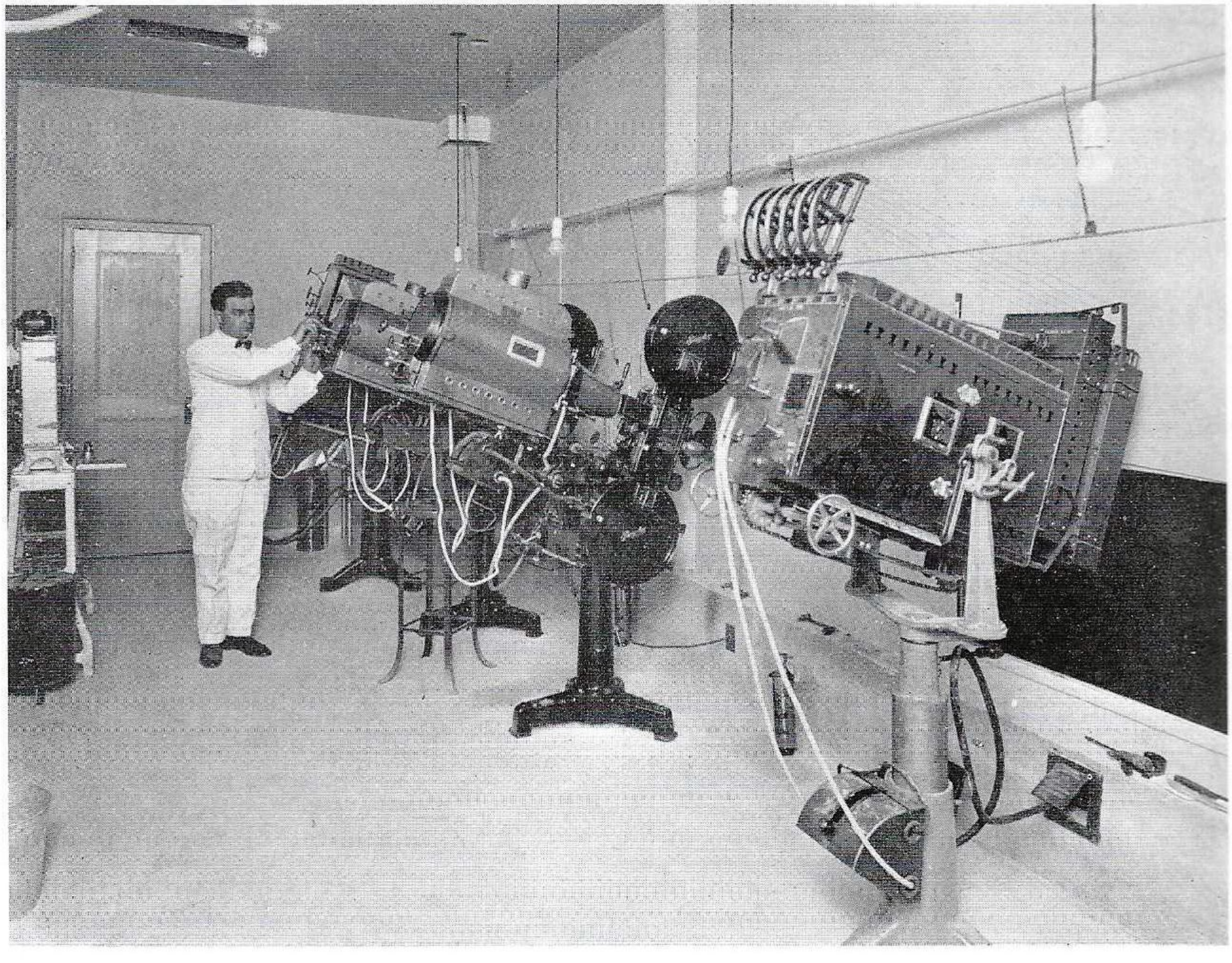
As before stated, the stage must have a sufficient quantity of radiation. Wall radiators are usually placed at different levels on the back wall of the stage from a point near the floor to a point about two-thirds the height of the stage loft and pipe coils in the stage vent, and over the top of the proscenium. Direct radiation, placed in recesses near entrance and exit doors of the auditorium to warm the air at these points, is sufficient in this portion of the building. Banks of direct radiation in recesses near the lobby doors will usually be found the best solution of the lobby heating problem. A fresh air supply, separate or connected with the auditorium air supply, is sometimes used in the lobby to assure a circulation of air over these radiators.

Auditorium heating has been well described as a de-heating problem rather than one of heating, for it is practically entirely a matter of ventilation. One of two systems is commonly used. In one type, air is introduced at the floor line and taken out at the ceiling. The other system operates on the opposite principle, that is, the air is brought in through the ceiling and removed at the floor. The downward system has many logical arguments in its favor and is claimed to result in a greater uniformity of temperature. The amount of air that should be supplied the auditorium per person is a debatable question. It is well established, however, that the supply should not be less than 15 nor need be more than 30 cubic feet per minute per person. A difficulty encountered in designing the ventilating system is to secure uniform temperature in all parts of the auditorium. Where the system is not properly designed, the temperature will be found to vary from a low point in the front of the orchestra near the stage to a high point in the rear of the balcony. The fundamentals of proper ventilation in theatres are the proper distribution of a correct quantity of fresh air delivered at comfortable velocity, correct humidity and correct temperature.

Cooling systems are being extensively used in conjunction with theatre ventilation. Where these are used and the system is correctly designed and installed, the air conditions may be maintained uniformly comfortable at all seasons of the year. A modern and efficient air conditioning system consists of a refrigeration machine connected with a dehumidifier, motor driven fan, air supply ducts and return air ducts. Fresh air mixed with the return air from the auditorium is drawn, by means of a centrifugal fan, through the dehumidifier where it is cooled, cleansed and dehumidified. From this it is delivered to the ceiling of the auditorium and balcony soffit by ducts, and returned through air ducts connected with openings in the floors of the auditorium and balcony under the seats. The same system may be used summer and winter, except that in winter the refrigeration machine is not used.

Air conditioning has three distinct functions,—air movement, temperature control and control of relative humidity. The combination of these three functions presents a complicated problem and complete air conditioning cannot be secured unless all three are controlled. If such a system is to function properly, it must be automatically controlled.

The service of comfort is one of very great importance to the theatre owner for, if they can avoid it, people will not patronize theatres that are other than comfortable. This is true in spite of the possibility of better film and entertainment presentations. As a result it is false economy to attempt to secure results with inadequate equipment. Every theatre is an individual problem and the heating, ventilating and cooling equipment must be solved as such. No more definite rules can be given for their design than in the case of the design and plan of the theatre as a whole.



PROJECTION ROOM, CAPITOL THEATRE, PORT CHESTER, N. Y.

THOMAS W. LAMB, ARCHITECT.

Air Conditioning American Movie Theatres
1917-1932

Building Theatre Patronage (Ventilation)

John F Barry & Epes W Sargent
1927

BUILDING THEATRE PATRONAGE

MANAGEMENT AND MERCHANDISING

By

JOHN F. BARRY

AND

EPES W. SARGENT

FIRST PRINTING
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CHALMERS PUBLISHING COMPANY
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CHAPTER XXXIII

VENTILATION

IF all the important factors which influence theatre attendance are to be considered, ventilation cannot be overlooked. There was a time when warm weather seriously interfered with theatre attendance everywhere. To-day, in some great modern theatres where air conditioning equipment is installed, warm weather really helps to build theatre patronage. Such theatres are actually "summer resorts" where relief is sought from the heat.

On the hottest, most uncomfortable days such theatres provide an air condition which in purity, air movement, temperature and humidity equals what is found at pine-clad mountain-top resorts. This is not poetry; it is fact. People appreciate the fact. Equipment has made theatre attendance during the summer months equal to that of winter months, in some cases people actually coming into the theatre to get "cooled off."

But relatively few theatres are so equipped. The others have a real problem. If ideal conditions are not possible because equipment is inadequate, at least some approximation to the ideal condition is possible. It is ridiculous to think that the problem is solved by hanging a sign in the lobby reading "20 degrees cooler inside." Such signs dripping with painted icicles do not convince the suffering public. By avoiding such theatres they make it evident that the manager is misstating the fact, and as usual misstatement reacts unfavorably in the long run.

In these days of severe competition, when distinctive institutional factors determine theatre attendance, proper ventilation can be used by the alert manager to attract patronage which otherwise might be lost. Even with meagre equipment much can be done to improve conditions. Besides, a skillful use of color can create the impression that conditions are better than they actually are. Then, attractive advertising by spot-lighting the air conditions of a particular theatre will draw patronage from a competitor who neglects this important factor.

Damages.

Patron comfort is the main objective in regulating ventilation; but, irrespective of patrons, the matter is important. Defective ventilation shortens the life of theatre decorations and theatre furniture. The damage caused to drapes by dirty air is evident. Besides, if proper humidity is not maintained, overheated air causes furniture to crack, because the dry air draws out its moisture. Paintings also can be ruined if dried out by air with a low percentage of moisture which strips the paint from the canvas. Cracked ceilings, soiled drapes, warped chairs, damaged organ consoles are but a few of the many expensive effects due to improper ventilation.

Patron Comfort.

But patron comfort is the chief consideration. Certain air conditions make satisfactory entertainment impossible. Headaches, irritableness, nausea, dizziness, "that tired feeling" can be caused by two hours spent in a badly ventilated theatre. People within an enclosure absorb oxygen and breathe out carbon dioxide. Unless new oxygen is supplied, that invigorated feeling and that relaxation which entertainment should give are impossible. Besides the evident discomfort, there is serious likelihood of illness; a low percentage of moisture in the air makes one susceptible to diseases of the nose and throat because the natural moisture of the tender membranes is dried out. Drafts, too, can cause colds.

Four Factors.

Proper ventilation involves four factors: clean air, circulation, the proper temperature, and proper humidity.

The factor of cleanliness involves the elimination of odors, dust and dirt. Circulation involves the avoidance of draft, the expulsion of dead air, and a uniform supply of pure air at the rate of about 25 cubic feet of air per minute per person within the enclosure.

Humidity.

The quality of the air is most important. This is not a matter merely of degree of warmth or cold. It includes also the proper degree of humidity. Humidity is moisture carried by the air. The amount of moisture the air can carry depends on the temperature. Warm air will carry more moisture than cold air. Warm, dry air takes moisture very rapidly from the surface of the human body. If a room at 40 degrees is heated to 75 degrees without the addition of more moisture, the humidity decreases as the temperature increases. Humidity has a direct bearing on comfort, both in summer and in winter. For example, with the temperature at about 70 degrees we feel very warm. Yet in the winter within our homes, with the temperature at 70 degrees, we may feel chilly. The difference in feeling is due to humidity. In the summer months with a heavy percentage of humidity in the air, perspiration or body moisture does not evaporate quickly, and because our bodies cannot throw off their heat quickly because of the blanket of moisture, we feet the heat and the oppressive weakening mugginess. In any heated enclosure during winter the dry air takes moisture off quickly and causes the chilly feeling because there is no blanket of moisture to keep in the heat.

The motion picture theatre, regardless of extremes in weather outside the theatre, has a serious problem in the very fact that many people within an enclosure radiate heat and moisture. Besides, the theatre lights also radiate heat. Moreover, the sudden change in the number of people present causes rapid change in temperature and humidity. It is a simple matter to keep the theatre properly heated. But patron comfort does not depend alone on degree of heat. Looking at a thermometer to determine patron comfort is ridiculous. It is like measuring the square feet of an area by considering only the width or only the height. Comfort depends on a proper percentage of moisture at a given temperature. Both temperature and humidity must be considered.

The humidity condition of an enclosure is calculated by reading a hygrometer. This is a double thermometer with one bulb exposed to the air to register the temperature; the other thermometer has its bulb covered with a wick immersed in water. This water is absorbed by the air. The evaporation causes loss of heat. Therefore the wet bulb thermometer will always register lower than the dry bulb. The difference in reading will depend on the rate of evaporation which is caused by the humidity condition of the surrounding air. The evaporation if the air is drier is faster than it would be if moisture in the air were heavy.

Relative Humidity.

The wet bulb reading, as such, does not indicate humidity. The difference in reading between the dry and wet bulb must be referred to in the Relative Humidity Table, which indicates what the humidity is at a definite temperature according to the difference in reading between the wet and the dry bulb thermometer. (Note Relative Humidity Table in appendix.)

These readings must be accurate. A difference of only 2 degrees in the wet bulb reading would make an error of 8 degrees in calcuating relative humidity at some temperatures.

Ideal Conditions.

Patron comfort depends, therefore, on the relation between the temperature and humidity. Research has proved that maximum comfort is possible during the summer months with a dry bulb temperature of between 73 and 76, and a relative humidity of between 40 and 45; and in the winter months with a dry bulb temperature between 70 and 73, with a relative humidity between 40 and 55.

A hygrometer can be purchased at small cost from any weather instrument company. One will suffice for theatre use because the air condition of the auditorium is practically uniform for temperature and humidity.

It is one thing to know what the ideal is, and how it can be calculated; it is another thing to maintain ideal air conditions within the theatre. There are few theatres equipped with self-regulated systems maintaining ideal conditions. The managers at other theatres can do nothing better than secure from the manufacturer of the equipment installed, instructions on how it can be used to best advantage. During the winter months proper humidity conditions are the main problem. If air cannot be passed through water spray, wet towels in the hot-air ducts, or even behind radiators, will add some moisture.

During the summer months, if air cannot be artificially cooled, the least that can be done is to circulate more air, because air in motion seems cooler than it actually is. Proper maintenance of fans, vents, mushrooms, filters, coils, and air chambers will help to get better results.

Never close the theatre after the last performance until fresh air is brought in from every possible source. Closing the theatre immediately after the performance without this attempt at ventilation means that odors will remain in the theatre over-night, and it becomes just that much harder to air the theatre properly in the morning before patrons enter the theatre.

Colors.

Much can be done by the use of seasonal colors during the summer months to make the theatre seem cooler than it actually is. Green, blue-green and blue-violet in theatre lighting and theatre decoration are suggested. Light seat covers and light drapes, ferns and greens, buzzer fans with streamers, lattice exit doors, cool uniforms for the theatre staff, ice water or even lemonade served to the patrons, are a few of the things that help to summer comfort.

Advertising.

During the summer months, the theatre advertiser should not overlook the fact that patronage is attracted by convincing copy that the theatre offers an escape from the heat. A useful practice in this connection is a report of theatre temperature as compared with street temperature during certain hours of the day. It is evident that in the lobby attempts should be made to suggest the coolness within. Consequently, warm colors will be avoided. Neatness and cleanliness will be insisted upon. A new coat of white paint for the marquee will be a good investment. Awnings and buzzer fans will also help to attract.

Conclusion.

It cannot be doubted that motion picture entertainment is as much a necessity in the summer months as at any other time. This has been proved by attendance at theatres where proper air condition exists. But like any other influence which determines theatre attendance, this must be advertised. If proper ventilation were found at every theatre, it would not be so strong a selling point. Because it is not, the alert manager has in it a very potent factor for building theatre patronage.

Air Conditioning American Movie Theatres
1917-1932

Heating and Ventilating a Theatre

Edward A Kingsley
American Theatres of Today
1930

AMERICAN THEATRES OF TODAY

CHAPTER VII

HEATING AND VENTILATING A THEATRE

By EDWIN A. KINGSLEY, *Consulting Mechanical Engineer*

SOME one once said that there are five requisites to the design and construction of a successful theatre: safety, good acoustics, good vision, comfortable seats, and pleasant surroundings. I would add one more: good air. In fact, it might be better to substitute the word "comfort" instead of "comfortable seats" and list the other requisites as they are. For comfort includes the seats, the space between the seats, the size of the lobby and foyer and the matter of heating and ventilating as well. For a theatre patron cannot be comfortable, no matter how comfortable the chairs may be to sit in, if the theatre is not properly heated and ventilated.

Naturally these days when architects and engineers work in such close cooperation, the theatre architect almost invariably entrusts the heating and ventilating of a theatre to an engineer who specializes in this field. He therefore puts up to another the problem of the installation of apparatus, by which fresh air is brought into the building and distributed and foul air is taken out. But I think it is advisable for the architect to familiarize himself with the fundamental principles which guide the heating and ventilating engineer in his work so that the necessary appliances may be installed with the least effort and to the greatest economy for the owner. So I will write only in generalities rather than going into the subject in too great detail. Besides, each problem has its own solution and what might be desirable in one theatre would not apply at all to another.

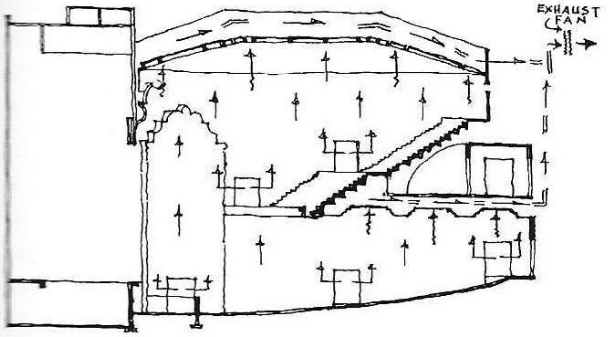


Figure 1
The exhaust system

Generally speaking, then, we might say that there are four systems by which a theatre may be heated and ventilated. They are (1) the exhaust system; (2) the supply system,—down-feed; (3) the up-feed system; and (4) the air-washed cooling system. The first or exhaust system is the simplest, the cheapest and the least effective. It is used in small, cheap houses. Fresh air is supplied only by means of open doors, windows, and so forth. There is no supply fan or fresh air intake other than these. The air is exhausted by means of ducts which lead to an exhaust fan. Grilles in the soffit of the balcony and in the ceiling of the auditorium lead to these ducts and so the foul air is taken out of the theatre and the doors and so forth, open again to let in more fresh air. The supply system is almost the reverse of the exhaust system. Fresh air is brought in through an intake and a supply fan; it then passes through a heater which gives it the desired temperature, and is distributed downward throughout the theatre by means of ducts in the ceiling and in the balcony soffit. The foul air is then forced out through the doors and other openings. It may be said here that about 50 to 75 per cent of the air can be used in recirculation, the amount being governed by thermostatic controlled dampers. In some cases, too, the air

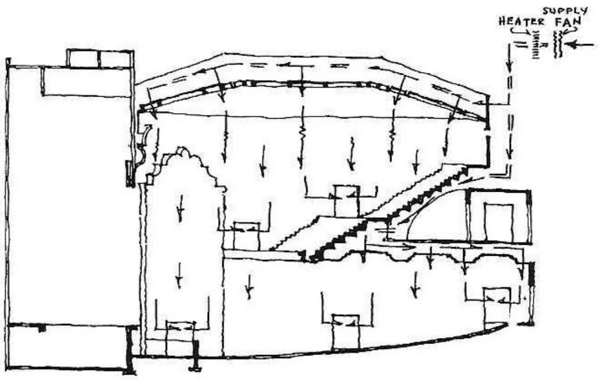
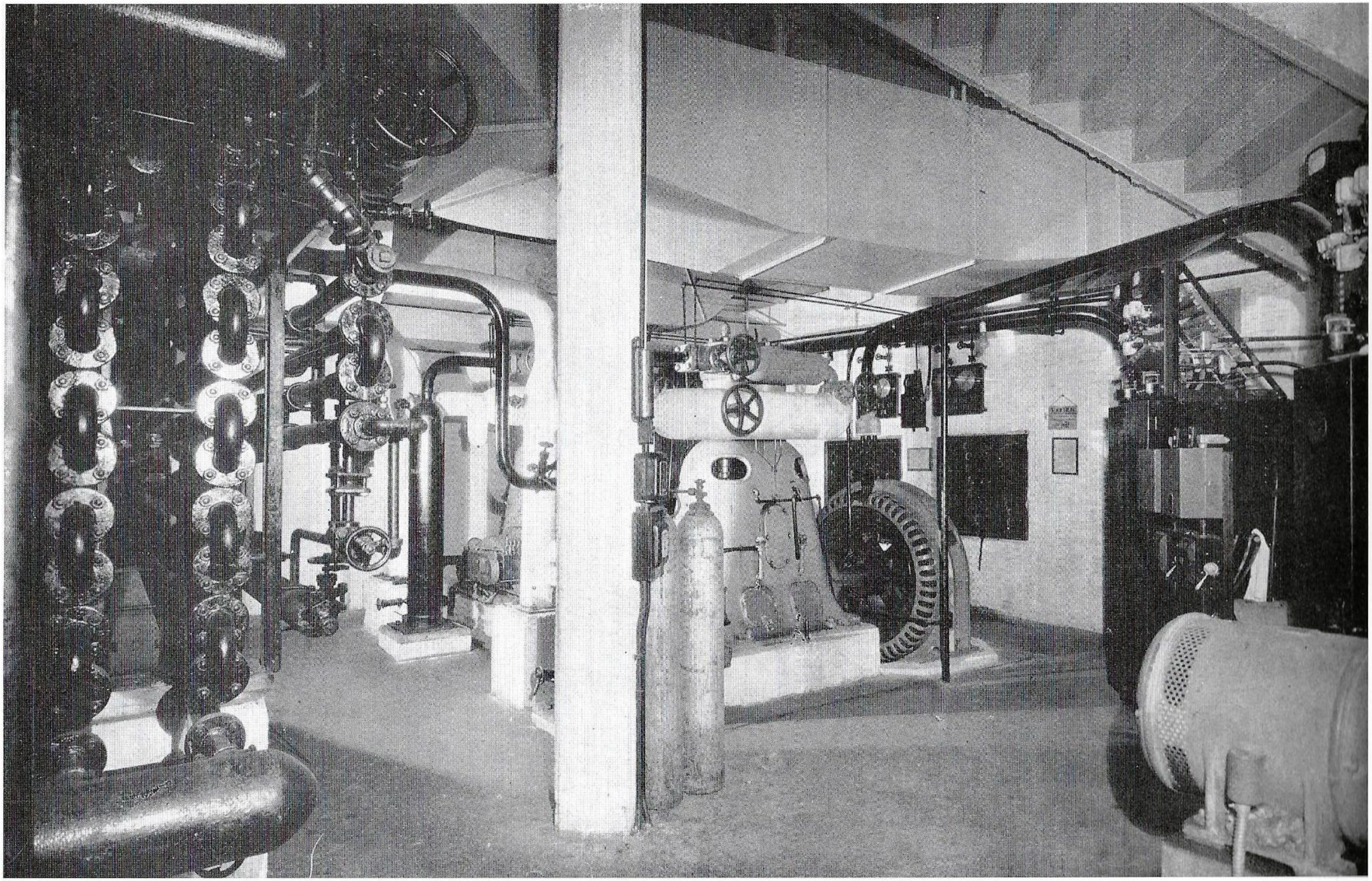


Figure 2
The supply system—down-feed



Refrigeration plant, Kings Theatre, Brooklyn, New York
C. W. & Geo. L. Rapp, architects

is partly purified by filters before it passes through the heaters.

The up-feed system is more complicated. A supply fan located near the fresh air intake duct brings the air through the filters, passes it through the heaters and it is distributed by ducts to floor mushrooms or aisle hoods in the orchestra and mushrooms, aisle hoods or step grilles in the balcony. The foul air is let out through grilles in the auditorium ceiling and balcony soffit and carried by means of exhaust ducts to the exhaust fan and then outside. In this system also 50 to 75 per cent of the air can be used in recirculation.

The air-washed cooling system is generally a down-feed system. Between the supply fan and the heaters is an air washer. Ducts lead to grilles in the auditorium ceiling and in the balcony soffit and thus the air is distributed downward throughout the house. The foul air leaves by means of floor mushrooms or aisle hoods in the orchestra and step grilles or mushrooms in the balcony, and is taken to the exhaust fan by means of ducts. About 50 to 75 per cent of the air is recirculated by means of a by-pass damper placed in the exhaust fan, thermostatically controlled. Where it is desired to install an air conditioning system, a refrigeration plant is added to this air-cooling system. This plant is usually located in the basement of the building and it supplies cold water to the air washer so that fresh air is cooled to the desired temperature as it is led to the ducts by which it is distributed throughout the house. Where air cooling or air conditioning plants are installed it is necessary to also install wet and dry blub control.

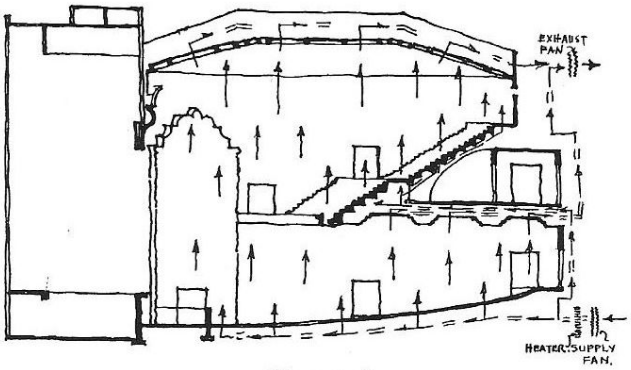


Figure 3

The up-feed system

In every case, supply and exhaust fans may be located wherever is most convenient. It is sometimes thought that fans must always be in the top of a building. This is not always desirable or convenient. It is interesting, perhaps, to note that all basement rooms are heated and ventilated separately. The dressing rooms, too, are controlled by another system. In some cases this is a supply and exhaust system and in others an exhaust system only. A separate exhaust-only system is also installed for the toilets. It is also necessary that projection booths have a separate exhaust system of ventilation.

The size, amount and location of supply and exhaust grilles, mushrooms, aisle hoods and step grilles is determined by the amount of air in cubic feet supplied to each person in the house per minute (C. F. M.). In cheap houses this generally runs from 20 to 30 C. F. M., 20 being the minimum. In medium priced houses the rate is apt to be increased to 25 to 30 C. F. M., while in the better class houses 30 C. F. M. is generally found to prove more satisfactory.

In all cases where fans are installed it is essential that the fans have proper sound deadening foundations and that all ducts and grilles are properly sized so as to prevent noise from entering the theatre, as well as to prevent annoying drafts. In first class houses the spaces used for ventilating apparatus are soundproofed.

Where refrigeration is used it is also essential that spaces assigned to the refrigerating apparatus be entirely enclosed with soundproofing material. Where cooling and air conditioning systems are used it is sometimes necessary to install a cooling tower, but this greatly increases the cost and the only justification for the use of cooling towers is in those cases where the city or municipality will not otherwise allow the use of water. The cooling tower is generally located on the roof of the theatre.

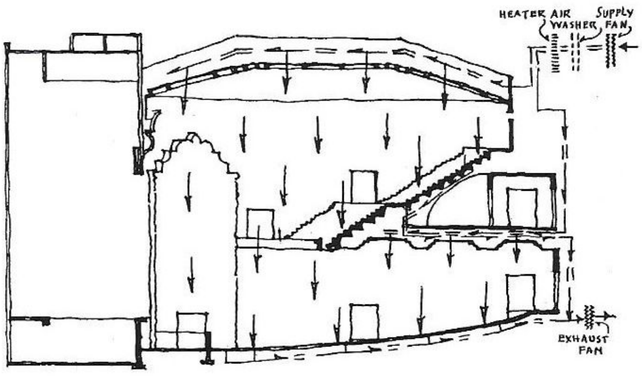


Figure 4

The air-washing cooling system

Air Conditioning American Movie Theatres
1917-1932

Carbon Dioxide For Theatre Cooling: An Exposition of How System Works

A N Chandler
Motion Picture News
4th October, 1930

Carbon Dioxide for Theatre Cooling; An Exposition of How System Works

Official of Carbon Dioxide Division of Frick Company of Waynesboro, Pa., Describes the System and Lets Reader Draw Own Conclusions

By A. N. CHANDLER

COMFORTABLE indoor conditions are not provided by temperature alone. Humidity and air movement have much influence, and each application is a problem in itself. The theatre, department store and office building differ from each other in the character of work done, kind of occupants, and number per unit of floor area.

In the theatre the audience is still for a period ranging from two to three hours. Of course, people are coming and going at all times but their number is relatively small in proportion to the total number which is seated. People who are sitting still present an entirely different problem from those in a department store where they are moving about. Those in a theatre should feel no draughts or cold air currents. Occupants of office buildings require special consideration. Here there are relatively few in number in each office. They must get a supply of conditioned air of proper temperature and humidity to suit their needs. Each office presents a different problem.

In laying out nearly all air conditioning work, space for the equipment is at a premium. Often it has to be fitted in anywhere regardless of whether it is the ideal place or not. Often it is an afterthought or has to be applied to an existing building, in which case it presents a very difficult problem. Not only is space for the refrigerating apparatus frequently hard to find but to make room for installation of the air ducts is another problem.

Carbon Dioxide Compressors

There are several kinds of refrigerating apparatus which can be applied to air conditioning work. Some of them provide a greater refrigeration tonnage than others per area of floor space occupied. Figure 1 shows an installation of two carbon dioxide compressors placed in a theater near New York City. These require a floor space of 300 sq. ft. and head room of 9 ft.-6 in. Each is the totally enclosed type and has no vertical shaft stuffing box. The stuffing box is of the horizontal rotating type. The compressor is equipped with an oil pump which keeps the bearing under oil pressure of from 400 to 500 pounds at all times. The stuffing box is kept cool by means of a gland in which gas from the suction line is allowed to expand.

Figure 2 shows a cross section of a typical enclosed type carbon dioxide compressor. The thrust bearing takes the crank shaft thrust and equalizes the pressure between the crank case and the atmosphere. It operates at all times under oil pressure.

Each compressor is built with a starting by-pass and safety valve. This valve is of the spring type which blows at 1,500 pounds pressure and repeats when the pressure is relieved from 200 to 300 pounds.

In order to eliminate noise the carbon dioxide compressor and motor are often placed on foundations of cork. In other cases, the foundation is built in a pit which has been lined with cork.

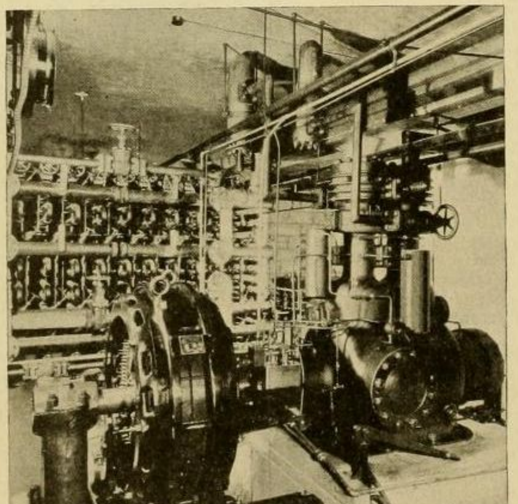


FIGURE 1

One of the two large carbon dioxide compressors which furnish refrigeration for air conditioning the Newark theatre, Newark, N. J. Double-pipe condensors may be seen in the background

Carbon Dioxide Condensers

One type of CO_2 condenser consists of an eight-inch double extra heavy pipe with seven 1½-in. pipes welded into the tube head. The water heads are of cast iron and divide the shell into several water passes. Figure 3 shows a view of such a condenser. These can be arranged any number of pipes high depending on head room available. They can be placed on 18-in. horizontal centers. Each shell can be arranged to take from 20 to 40 gallons of water per minute, depending upon the range of temperatures desired or work to be done. The water leaving the condenser is within a few degress of the carbon dioxide liquid temperature off the condenser.

As an example, an installation requiring 350 tons refrigeration and using shell and tube condensers could be arranged in a floor space 7 feet wide by 22 feet long. Furthermore, this space allows room for carbon dioxide and water headers. On this installation, the head room required would be 11 feet 6 inches.

Another system is a typical carbon dioxide double pipe welded condenser. It is made up of 1¼ inch water pipes throughout. The four top sections are made up of 2½ inch extra heavy pipe and the remaining eight pipes of 2 inch extra heavy pipe. The 2½ inch and the 2 inch pipes are welded to the 1¼ inch pipes at each end. The reason for the larger top section is to absorb the pulsation of the carbon dioxide gas from the compressor which causes a cushioning effect. The water is so arranged that the coolest water comes into contact with the coolest gas, making the temperature of the carbon dioxide liquid off the condenser near the initial water temperature. Figure 1 shows several stands of double pipe welded condensers.

It is the general practice to supply each carbon dioxide installation with an oil separator and scale trap. These are inserted in the pipe lines between the compressor and condenser and in the suction line from evaporator. These vessels are either of welded construction or of cast steel, according to the standard of the manufacturer. The oil separator is always provided with an oil drain valve and with baffles which are perforated for catching and holding oil. The construction of the scale trap embodies a screen for catching any of the scale or dirt coming from the evaporating side.

This trap must be made so that this screen can be cleaned thoroughly at intervals.

Carbon Dioxide Receiver

The next important feature in the refrigeration cycle is the carbon dioxide receiver. This is used to collect and store the liquid which has been condensed in the condenser. The ordinary practice is to provide the receiver with valves for the inlet, drain, and outlet connections. Each receiver should also be provided with a gage glass equipped with automatic shut-off valves in case of breakage of gage glass. A safety valve should also be furnished in case all the valves should close and the liquid grow warm, causing an increase in pressure. The size of the liquid receiver varies, of course, with the size of the installation but it is good practice to have it sufficiently large to hold the major portion of the charge in the system.

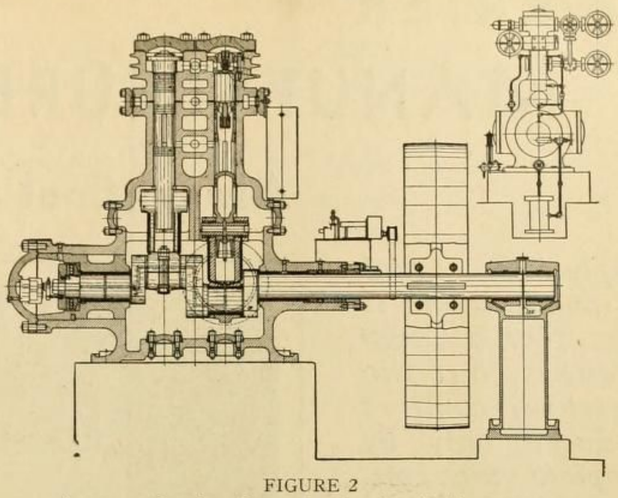


FIGURE 2

A cross-section view of an enclosed carbon dioxide compressor

Pipe Connections

Another system is a typical carbon dioxide cycle. The pipe connections between parts are most important. General practice today seems to be to make a complete welded job of all the connections, making provision by means of bends for expansion. In carbon dioxide work, all pipe connections should be bent, wherever possible, with a long bend. This gives the gas more of a chance to flow smoothly, and eliminates the chance of vibration in the pipe lines. It must be remembered that in the discharge lines the gas attains a velocity of from 800 to 1,200 feet per minute at a pressure of from 1,000 to 1,400 pounds. Should this gas meet a right-angled bend, it would cause a severe shock which would pass to the hangers and be transmitted to the building.

In all large carbon dioxide pipe work, it is customary to anchor the lines to the floor and to provide cork pads so the shock will not be passed to the building. Elimination of all vibration is a very important factor on air conditioning work.

Water Cooling Apparatus

Air conditioning may require that air be dehumidified by passing it through the cool water sprays and filtering during summer months and used as a humidifier in winter months, at which time the air is preheated and humidified by the water and there tempered before delivery. Many air conditioning jobs are a combination of air conditioning and warm air heating systems. That is, in summer the air is cooled and dehumidified by passing through cooled water sprays and filtered; in winter it is preheated, humidified by water sprays, filtered and tempered.

Water used for spraying and dehumidifying the air may be cooled by several means, such as Baudelot cooler type coils, tank with submerged coils, or with special type coils and agitators.

The Baudelot cooler type construction entails a number of coils, standing vertical, over which water is distributed by means of sprinkler pipes or troughs. The coils are ordinarily galvanized and may have several pipes submerged in a tank. The water is then taken and pumped through nozzles in the dehumidifier. The Baudelot cooler type water cooler involves considerable space and requires an insulated room, which is rather expensive. It does, however, get a greater heat transfer than the plain tank submerged coils.

The tank and coil method of water cooling pertains to submerged coils in a tank. The tank is arranged with baffles to give the water velocity and thereby promote the heat transfer between the water and carbon dioxide gas in the pipes. The water is pumped from the tank to the dehumidifier. The discharge is taken from the tank from one end and returned to the other end.

The third method of water cooling referred to is by means of using special types of coils in a closed tank. This arrangement is adaptable to flooding with carbon dioxide liquid. High heat transfer is often secured with this method by means of special agitators developed for this purpose. By this method, the plant is not dependent on the water pumps for its agitation, and any particular dehumidifier can be operated independently of the other. The cooling units can be arranged so that the amount of water cooled can be varied. Cooling the water independent of the dehumidifier unit

(Continued on page 100)

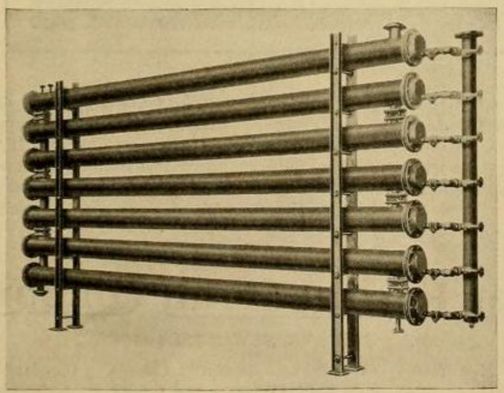


FIGURE 3

A multi-pass shell-and-tube CO_2 condensor, showing stand of seven 8 inch shells. The valves are not illustrated

Better Acoustics Boost Box-Office

(*Continued from page 86*)

tors there is another that has an appreciable place in show psychology, illusion. The sound must appear to come from the picture and yet the listener must be allowed to feel that he is in the same room with the speaker. With present day recording the areas around and immediately in back of the horns should be sound reflecting, which allows the "room tone" of the recording to become associated with the "room tone" in front of the theatre so that the listener unconsciously feels that he is in the same room with the speaker.

With so many factors bearing upon the net result, each presenting its reduction factor however small, it behooves the exhibitor who wishes to preserve and increase his success, to see that all reduction factors within his control are kept to the absolute minimum.

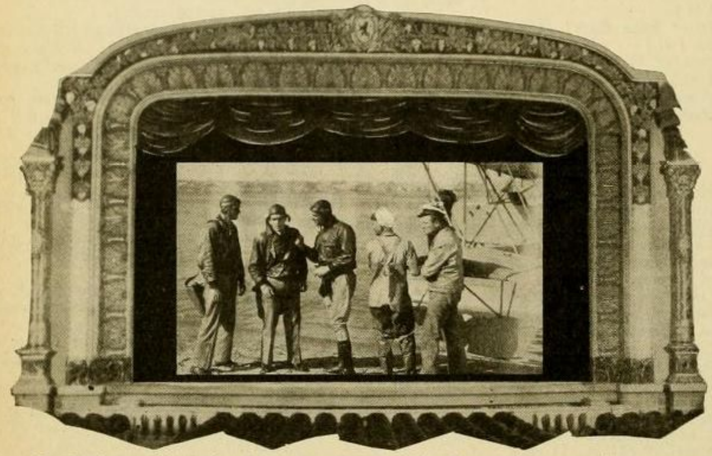
The best possible equipment obtainable, properly operated in a theatre that is acoustically correct and free from extraneous noise, is the only possible answer to "easy listening" and increasing receipts.

New Advertising Contract

Dallas—New contract for use of advertising films in member theatres has been signed by Allied Theatre Owners of Texas with the Alexander Film Co. of Colorado Springs.

Gets Wurlitzer Ad Post

Cincinnati—R. A. Schirmer is new advertising director of the Rudolph Wurlitzer Co. He succeeds Philip B. Reister. Schirmer formerly was Reister's assistant.



Intimate Theatre In Geddes Group

(*Continued from page 67*)

of the front entrance foyer, box offices, manager's office, producer's offices. At the rear of the building are the green room, director's office, stage manager's office, stage door entrance, waiting room, and freight elevator entrance.

GENERAL NOTES ON BUILDING: Surrounding the dome that spans both stage and auditorium are two concentric light galleries with locations for lamps at many angles. All lamp positions are invisible to the audience as seated during the performance. Inside the railing in front of the first row of seats is a circular row of lamps for throwing light upward (as footlights do on a proscenium stage). All lights are controlled from a single switchboard. The overall diameter of the auditorium, including the promenade, is 132 feet, and of the circular stage 30 feet. The longitudinal axis of the theatre is 300 feet. From the stage floor to the peak of the dome above is 65 feet. The basement is 25 feet below the ground level.

Carbon Dioxide Theatre Cooling

(*Continued from page 73*)

tends to give the plant flexibility and is adaptable to automatic humidity control.

Still another arrangement for cooling water is that of installing direct expansion carbon dioxide coils directly in the spray chamber of the dehumidifier. The carbon dioxide is expanded in the coils and the water is sprayed over them and thus cooled. The ail is blown through the water and thus cooled and dehumidified at the same time. This arrangement results in a saving of floor space for the water cooling unit; the dehumidifier must be increased in size to accommodate the coils.

The method of distributing this cooled and dehumidified air depends on the type of building involved.

Television and Wide Film Topics at S. M. P. E. Meet

Demonstration of two-way television by the Bell telephone laboratories will be one of the features of the fall meeting of the Society of Motion Picture Engineers, to be held at the Pennsylvania Hotel, New York, October 20-23.

"Wide film standards will receive its fair share of discussion at the meeting," according to President J. I. Crabtree, in correcting a statement made by the press that wide film would be "tabooed" at the meeting.

Recent Progress in Air Conditioning

Willis H Carrier
Refrigerating Engineer
March, 1931

RECENT PROGRESS IN AIR CONDITIONING

New Developments in Field of Refrigeration As Outlined at Midwest Power Conference by Willis H. Carrier, President of the Carrier Corporation

AT the refrigeration session of the Midwest Power Engineering Conference in Chicago February 10, air conditioning problems were covered in comprehensive fashion by Willis H. Carrier, technical leader of the Carrier Corporation, past president of the A. S. R. E., and president of the A. S. H. V. E. An abstract of his material follows.

In his earliest beginnings man had only a few needs of the simplest most basic character, namely food and protection from the elements. At first he merely took what nature provided, but as time went on through his ability to discover, think and invent he progressively improved his supply of food through husbandry. He learned to provide against future need through systems of storage, culminating in cold storage by artificial refrigeration. For a long time its only use was for the preservation of food; not until today, relatively speaking, has man begun to use refrigeration to advance his personal comfort in controlling his atmospheric environment.

As in the case of many other arts, the development of the art of air conditioning came about through the demand of industry for climatic conditions which would render its processes of manufacture independent of atmospheric conditions. Many materials in their process of manufacture are more sensitive to the changes in humidity conditions than man. There are now more than one hundred different applications of air conditioning to manufacturing processes, many of them requiring refrigeration for removing moisture and heat from the air in summer as well as raising the temperature and humidity in winter.

Refrigeration employed in air conditioning for industrial processes usually pays for itself in a relatively short period of time. It also gives a valuable power load. It is estimated that in industrial air conditioning in the United States alone more than 40.000 tons of refrigeration are employed requiring a peak load demand of more than 50,000 h. p.

However, it is in the application of refrigeration to air conditioning for human comfort that by far the greatest field lies. In fact it is estimated that more than 75,000 tons of refrigeration are at present used in the United States for this purpose, requiring a maximum demand of probably over 90,000 h. p., and this is only the beginning, and with motors for driving auxiliaries in air conditioning systems, such as fans and pumps, the power requirement is probably in the neighborhood of 135,000 h. p.

One of the most interesting researches, which has received world wide recognition, has to do with heat losses from the human body under various atmospheric conditions. It has determined the total heat lost by the body under varying atmospheric conditions and the component loss separately. The relations of temperature, moisture and air motion to the sensation of comfort have been discovered and tabulated. A measure of these relations termed effective temperature has been found expressed. For example, they find that a temperature of 65° F. with still and saturated air is equally comfortable to a temperature of 76° F. in air almost free from water vapor. Both conditions are said to have the same effective temperature and, for convenience, that of the saturated air, in this instance 65° F., is used as the temperature of reference and called the *effective temperature.*

It has been found that the average human being, at rest, has a heat output of approximately 400 Btu. per hour, the approximate equivalent of a 120-watt electric light, and this remains remarkably constant through all normal ranges of temperature and moisture variation and changes of clothing.

Since the heat given off by the human body is substantially constant except under extreme conditions, it is evident that the balance of the heat not taken care of by radiation and conduction through the clothing must be taken care of by evaporation through perspiration, and this is exactly what has been found to occur by these researches at the laboratory. Therefore, the evaporation from the human body, assuming constant metabolism, depends entirely on radiation and convection, and this in turn is affected by the temperature of the surroundings and the clothing. At a temperature of 70° a normal man at rest, normally clothed, will transmit about 76% of his bodily heat as sensible heat by radiation and convection, while the balance of approximately 24% will be dissipated through evaporation of perspiration and from the lungs. This proportion is apparently in no way affected by the relative humidity of the surrounding air. Similarly, at 86° temperature about 38% will be sensible heat, while 62% will be removed by perspiration, and at about 100° dry bulb temperature all the heat in the human body must necessarily be removed by perspiration.

For every individual normally clothed there is a certain effective temperature at which he experiences the greatest comfort. This effective temperature for greatest comfort, termed the *optimum effective temperature,* depends, of course, upon the clothing, and it also varies with different individuals with the same clothing, and also differs between summer and winter. It has been found by researches at Harvard that an optimum comfort line giving a maximum comfort to 97% of the individuals tested was 66° for winter and 71° for summer (See Fig. 1).

MECHANICAL REQUIREMENTS

The cooling of industrial plants is generally for the benefit of the product, and here the requirement is primarily for the reduction and control of relative humidity with the control of temperature as a secondary, although often important consideration.

In certain processes in rayon manufacture, for example, reasonably low relative humidities must be maintained, but unless the air is dehumidified by refrigeration it would have to be heated up to such an extent that the working conditions would be unbearable in hot humid weather; therefore refrigeration is used to permit the control of humidity without excessive rise in temperature.

In the manufacture of cigars and cigarettes the same condition obtains, except that the product itself is also affected by high hot temperatures causing a softening of the tobacco similar to the effect of increased humidity, so there is a definite limitation on temperature as well as an exact relative humidity control to be provided.

Where air conditioning, however, is applied to human comfort we are interested primarily with the effect of the atmospheric conditions upon the people. This necessitates a method of air distribution which avoids sudden changes in temperature and noticeable drafts, a problem not met with in industrial applications. Another problem in air conditioning for comfort is the greater quantity of air to be distributed per square foot of floor space in thickly occupied auditoriums. And perhaps the greatest difficulty in this respect is the practical necessity of concealing all duct work and making the outlets and methods of distribution conform with the architectural scheme of the building and with the details of its decoration.

Two principal types of distribution have been found satisfactory for theaters and other auditoriums. One is the panel system in which the air is blown directly downward on a panel displaced slightly below the general ceiling level. In large office buildings and banking rooms this deflector panel is sometimes incorporated with the lighting fixtures.

The other type used principally in theaters is known as the ejector system. In this the air is blown through a series of nozzles placed on the ceiling in the rear of the auditorium and directed towards the stage. The success of this system depends upon the fact that cold air blown horizontally into the room near the ceiling carries with it three to four times as much warm air by induction effect. This induction effect is what produces the return circulation. The cold air is thoroughly diffused and passes backwards in a slight uniformly distributed current over the entire lower half of the auditorium.

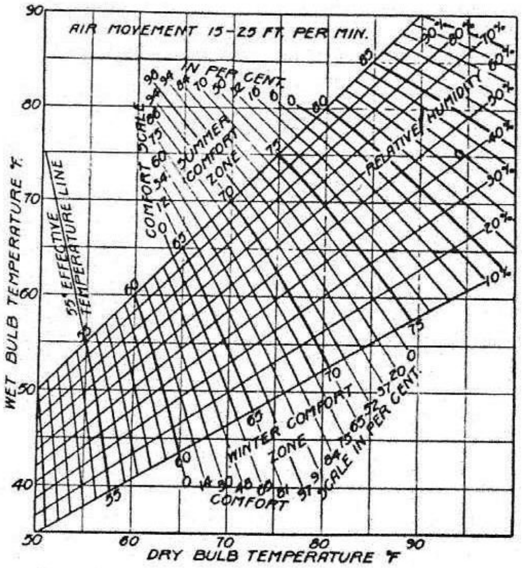


FIG. 1. COMFORT CHART ISSUED BY THE HARVARD SCHOOL OF PUBLIC HEALTH

Upward circulation with distribution at the floor line has been found an utter failure. This method of distribution for ventilation in years past was the favorite one with the ventilating engineer, and indeed it had become a standardized method of ventilation procedure, when cold air was introduced at 10° to 15° below the room temperature.

The Senate Chamber and House of Representatives were formerly ventilated by the upward system, and for years such ventilation was condemned by every one concerned. Two years ago the old system was condemned as obsolete and a downward system installed in both chambers, giving perfect conditions in the summer and improvement in the ventilation during the winter as well. This installation was probably one of the most difficult technically, because of the following requirements:

(1) Practically absolute quietness of operation.

(2) Perfect temperature distribution at all parts and at all levels regardless of the nature of the occupancy and regardless of the effect on the glass roofs and ceilings.

(3) Entire absence of noticeable air movements or drafts.

(4) A temperature control adjustable to outside weather conditions.

(5) A relative humidity control which would give agreeable dryness of the air in summer and overcome the naturally excessive dryness of the air in winter.

(6) The air had to be introduced in such a way that the source would not be noticed by the casual observer, nor in any way mar the architectural effects of the ceilings.

The purpose of an air conditioning installation should be to produce in the auditorium air that is reasonably dry, but with not too low a dry bulb temperature. The relative humidity in fact should be between 45% and 55% with temperatures as high as 78° or 80° in hottest weather, a condition under which a person will not feel a shock entering from the outside and yet the perspiration will be gradually removed from the body and from the clothing.

Air conditioning of the smaller space in office buildings presents a somewhat different problem. Practically an individual control of each office is required in cooling just as required in heating. In addition to this, rearrangement of offices may interfere seriously with any stereotyped system of distribution. In practically all offices, however, the space underneath the window is always available for air distribution as well as for heating.

FIELDS OF APPLICATION

The possible fields for the application of air conditioning are many and varied. There are only a few more than 300 air conditioned theaters in the country, less than 10% of the total. There are barely half a dozen office buildings equipped with air conditioning equipment, and only a dozen or so department stores out of the 500 odd large stores in the different cities. Banks are beginning to install air conditioning systems, finding the improved atmosphere inviting to customers and stimulating to employees. It is only a question of time until conditioned air will be expected and demanded by the public in restaurants and hotel dining rooms. Of the 100,000 restaurants in this country, at least 10% are large enough to make profitable use of this new improvement.

Small stores, shops, laboratories and factories are the fields open for the installation of the unit air conditioners developed in the last few years. There is not a single hospital with an air-conditioned ward; although here atmospheric comfort is even more essential than in ordinary surroundings. Cooled conditioned air was introduced on railway diners for the first time in the summer of 1930; the B. & O. lines and the Santa Fe each equipped a diner which proved to be a great success (R. E. 21, 2, Feb., 1931). The greatest market of all will of course be the home; systems are now available, particularly for air conditioning in the winter, and before long equipment will be on the market which will make it possible to cool or dehumidify all or a portion of the home during the summer. The process will consist of passing the air through a spray of refrigerated water or over cold surfaces through which cold liquid is circulated. There are strong indications that gas will be the energy medium for the production of this cooling.

ENGINEERING REQUIREMENTS

In air conditioning and cooling in summer the enginering requirements are much more exacting than for heating in winter.

In heating buildings there are only two principal items to be considered: (1) heat transmission through windows and walls of various construction due to difference between the inside and outside temperature and to some extent wind velocities, (2) infiltration due to window leakage, etc. which is effected both by temperature difference and wind velocity.

In summer cooling and air conditioning, however, in addition to allowing for the two factors already mentioned as required in heating, we must allow for sunlight on walls and windows and roof. The sunlight effect alone may make a variation of two to one in refrigeration requirements between a southern or western exposure and a northern exposure. In office buildings especially, the effect of sunlight may add as much as 1/3 to the total requirements. This can readily be seen when it is appreciated that the heating effect of sunlight may be more than 4 Btu. per sq. ft. per min. in this latitude.

A whole modern ventilation system in an office building costs about as much as a heating system, while the necessary refrigeration for complete air conditioning in addition to ventilation and heating, will increase these installation costs by about 50%. In other words, in a complete air conditioning plant we may charge about 1/3 to heating, 1/3 to ventilation and 1/3 to refrigeration.

SUMMER AND WINTER LOADS FOR VENTILATION & AIR CONDITIONING

Type of Building	Initial Cost Per Sq. Ft.	Annual Overall Cost Per Sq. Ft.	Unit Costs (Based on annual overall costs)	Annual Power Costs (Rate in parenthesis)
Department Store 160,000 sq. ft. 6,250 people	$1.80	.32	32c/yr./sq. ft. of Sales Area	$15,923 (3c/K.W. hr.)
Office Building 325,000 sq. ft. 2,540 people	1.25	.19	1c/man hour	$13,896 (1.2c/K.W. hr.)
Plant Office Building 42,560 sq. ft. 300 people	2.00	.31	3c/man hour	$ 2,694 (3c/K.W. hr.)
Restaurant and Cafeteria 12,644 sq. ft. 760 people	3.60*	1.16*	1c/meal	$ 4,748* (3c/K.W. hr.)
Hotel (Guest Rooms) 120,000 sq. ft. 600 people	1.50	.50†	20c/room/day	$13,600 (3c/K.W. hr.)

*Higher initial and operating costs are due to a larger required capacity to provide for unusual heat load, more frequent air change, and larger number of people.

†Higher operating cost due to longer period of daily operation.

Note that both initial and annual costs are based on heating, ventilating and conditioning. In most cases, heating and ventilating are normal expenses which must be paid anyway. The actual added cost of adding air conditioning, which also provides for heating

Air Conditioning American Movie Theatres
1917-1932

Practical
Air Conditioning

Harold L Alt
1936

PRACTICAL AIR CONDITIONING

A Treatise for the
Designer, the Contractor
and the Practical Man

By
HAROLD L.ynn ALT

DOMESTIC ENGINEERING COMPANY
1900 PRAIRIE AVENUE
CHICAGO

CHAPTER XIII

HOW TO AIR CONDITION A THEATER

MANY a good air conditioning installation has been made ineffective by poor distribution of the entering air resulting in cold drafts and complaints from the occupants. The location and velocities of the exhaust grilles seem to exert little, if any, effect on the distribution but the location and velocities of the supply grilles and inlets exert every influence on the equality of the air temperature, the elimination of drafts and the producing of an air conditioning system which will give the highest satisfaction. Therefore, it is necessary to give special thought in air conditioning systems to the method to be pursued in inserting the supply air into the room and this is especially true when cooling is contemplated.

As a general rule it may be said that the more the incoming air flow is broken up and mixed with the room air before the cooled air falls to the floor, the better are likely to be the results secured. To accomplish this it generally is necessary in large rooms to have a considerable number of outlets distributed around the ceiling so that comparatively small quantities of cooled air enter at each outlet. Moreover, such outlets should be located as high as possible to give a better opportunity for the cooled air to mix with the warmer room air before coming into contact with the occupants. In other words, the effort is to cool the air of the room rather than to cool the occupants of the room, the occupants desiring simply a tempered atmosphere and not drafts of cool air.

The terms upward ventilation and downward ventilation have been used for years to differentiate between air systems in which the general air flow is from the floor toward the ceiling and where the flow is in the reverse direction from the ceiling toward the floor. The terms will be used in this discussion in the usual and accepted meaning. In cooling with air conditioning it has been found a necessity to use the downward ventilation method owing to the difficulty experienced with upward ventilation which causes cold feet and the fact that, with upward ventilation, the cooled air has practically no opportunity to mix with the room air before it strikes the occupants.

This has been so thoroughly proved that, for the purposes here, all central air conditioning systems will be assumed to be of the downward ventilation type and no other method will be considered. This brings the consideration of air distribution down to the simpler basis of where, at the ceiling, shall the air be entered and where, at the floor, shall it be drawn off.

The design of the ceiling will have a great deal of influence on the type, size and kind of ceiling inlet employed but in general it can be stated that ceiling inlets may be grouped into

a. Grilles
b. Coves and Cornice Slots
c. Plaques
d. Special Fixtures.

Under the heading of *grilles* there is the ordinary cast iron or pressed steel grille, the ornamental bronze grille and, sometimes, the ornamental plaster grille. When used in the ceiling and with cooled air, such grilles should be of relatively small capacity and the use of such grilles for volumes of over 3,000 c.f.m. is very questionable. Unless they are unusually high above the floor—such as occurs in the main ceiling of a theater over the orchestra—they usually will be found to require some type of deflector to prevent the cooled air dropping down directly onto the heads of the occupants below.

Cove and cornice slots are effective for air distribution especially when the slots can be arranged to deliver the air in the approximate areas desired. It will be found that the ornamental design of the ceiling will control this slot location to a considerable extent. When slots are used, the space back of the slot usually is boxed in with sheet metal, or plaster partition, and volume dampers are placed in the air branches leading into this boxing so as to control the air going to different portions of the slot. Fig. 54 shows a typical detail of a slot in the ceiling such as was employed in one of the theaters in which air conditioning has been installed. The slot exit velocity generally is made not over 250 to 300 f.p.m.

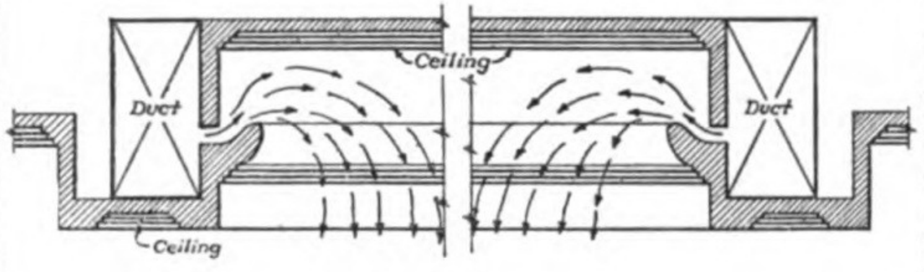


Fig. 54—Typical detail of a slot in the ceiling for introducing air

Plaques are often a pleasing method of masking the air inlets in the ceiling and may be made in almost any style so long as the perimeter, or measure around the edge of the plaque, when multiplied by the open height at the perimeter, gives sufficient area to pass the desired amount of air at a velocity of about 300 to 400 f.p.m. Slightly higher velocities are desirable with plaques than should be used with grilles owing to the advantages gained by sending the air out radially from the plaque in a slightly greater circle thus securing better mixture with the room air before the cooled air begins to drop. Fig. 56 shows a typical detail of one style of plaque.

Special fixtures may be made of almost any design, may be round, square or oval and may or may not be combined with lighting. They operate in the same manner as the plaques but usually do not have a free opening around the perimeter in which space some sort of bar grating frequently is employed, so that the diameter of the fixture must be made about one-third larger than a plaque—assuming that the bars take up about one-third of the free perimeter area—or else the depth below the ceiling must be increased in order to obtain an equivalent outlet area. Fig. 55 and Fig. 57 illustrate designs for such fixtures.

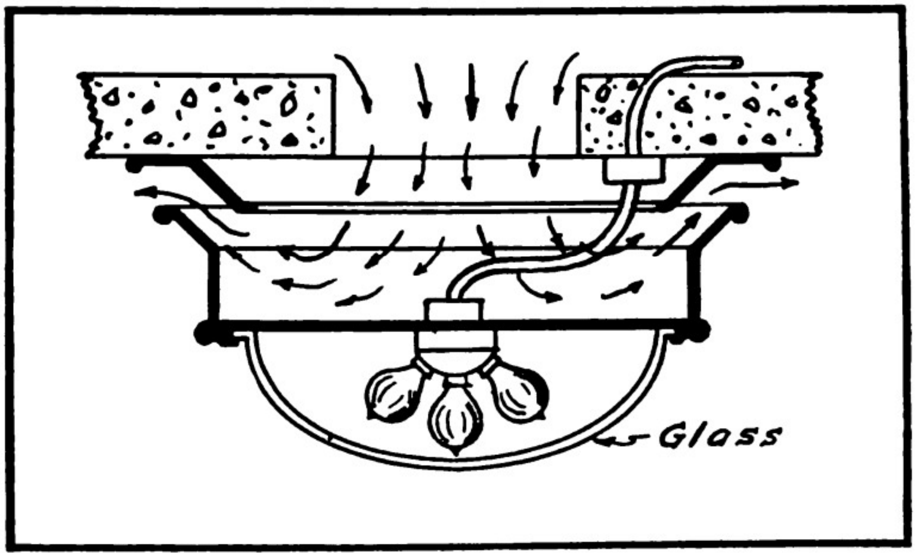


Fig. 55—Another type of special fixture designed for air distribution

Large Air Quantities in Theatres

In theater work there are very large quantities of air to be introduced through the ceiling and, while the ceiling height over the orchestra is sufficient to secure fine mixing with the room air before the cooled air reaches the floor, over the balcony and under the balcony are two places which require careful treatment. In both these places the ceiling is likely to be very close to the floor especially in the rear of the balcony and great care must be exercised to prevent cold drafts in these locations.

The first thing to be done is to determine the total air required to remove the heat generated and transmitted and then, as a check, to divide this by the number of seats and standees; generally the air per person will run between 20 and 30 c.f.m. Then the air is proportioned over the ceiling so that the portion of the main ceiling over the orchestra will supply the air necessary for the people in the orchestra in front of the front line of the balcony; the portion of the main ceiling over the balcony is then supplied with sufficient air for the balcony and the ceiling under the balcony is supplied with sufficient air for the portion of the orchestra under the balcony plus the standees.

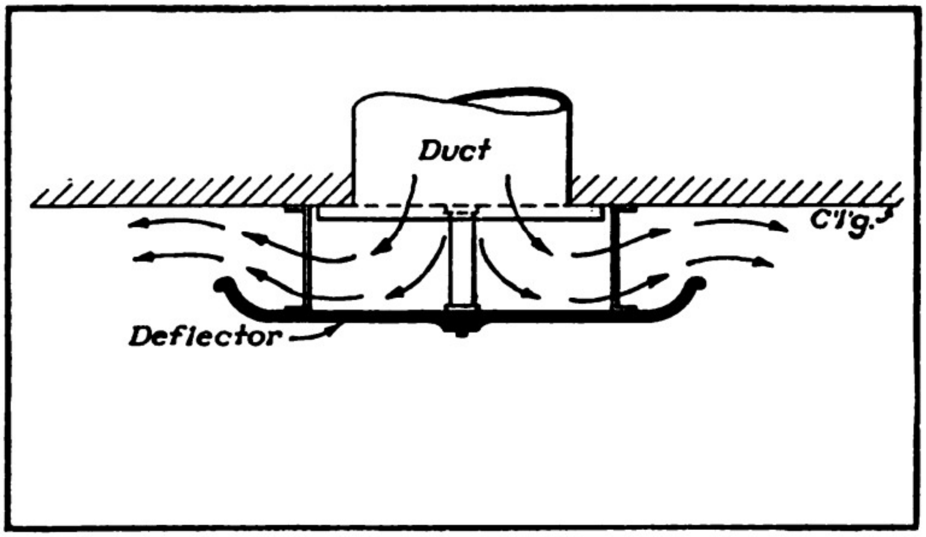


Fig. 56—Typical design of plaque for air introduction

The ceiling inlets are placed toward the proscenium arch, in preference to away from this arch, so that the air, in moving toward the rear of the theater where most of the exhausts frequently are located, will flow against the faces of the audience rather than against the back of the neck. In fact nothing makes more trouble than a cool air flow against the back, while the same air flow against the face, produces no discomfort whatever.

The exhaust outlets for the balcony are frequently placed in the step risers, or mushrooms are used under the seats. A little exhaust is taken out of the orchestra pit and mushrooms are used in the front portion of the orchestra with exhaust grilles along the standing rail in the rear of the orchestra. Other exhaust grilles may be placed along the side walls on the aisles at the floor and under the boxes where opportunity offers. Only about 75 per cent of the air need be provided for in the exhaust outlets and these may be run as high as 300 to 400 f.p.m., without causing noticeable drafts.

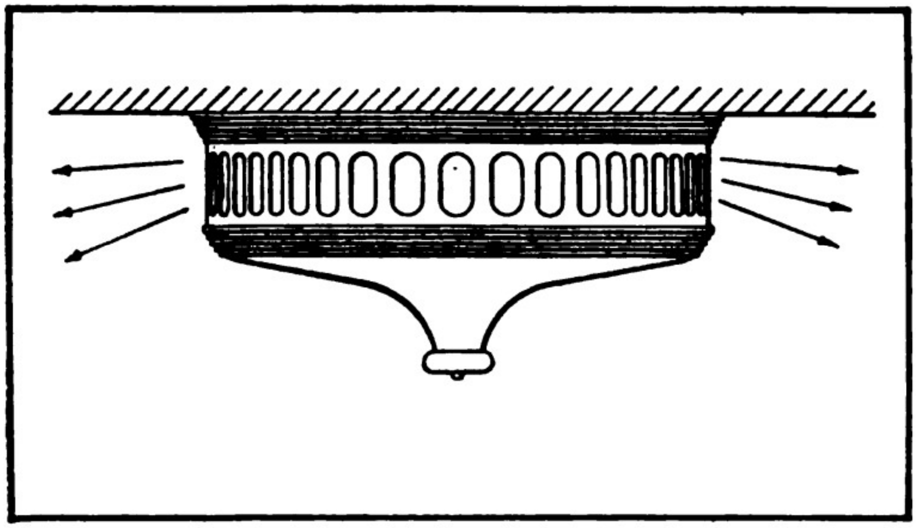


Fig. 57—One type of special fixture designed for distribution of air to a conditioned room

It has proved to be an absolute necessity to use plaques or special inlet fixtures under the balcony with these spaced fairly close together and with low velocities. Over the balcony some advantage can be gained by placing the inlets out toward the front of the balcony and allowing the air to sweep back toward the balcony step riser grilles or mushrooms.

Problem

In the theater shown in Fig. 58 it is desired to install a regular theater air conditioning system suitable for year-round operation and with a total number of occupants of 3,000, the lighting amounting to 100,000 watts and the roof wall and floor transmission, for 15 degrees below the outside temperature, to 65,000 Btu. per hr.

Solution

In the above problem there is no sun effect to be considered and it will be assumed that the inside conditions, when the outside is at the maximum of 95 deg. Fahr. and 50 per cent relative humidity, will be about 80 deg. Fahr. and 50 per cent relative humidity. The lighting of 100,000 watts will be taken at about ¼ of the total connected load which is assumed as about the largest portion of the lighting that will be in use at any one time for an extended period. The heat to be removed, then, will be seen to be generated by three separate sources: the transmission through the walls and roof, the electric heat, and the body heat of the occupants. Setting these down first in order to determine

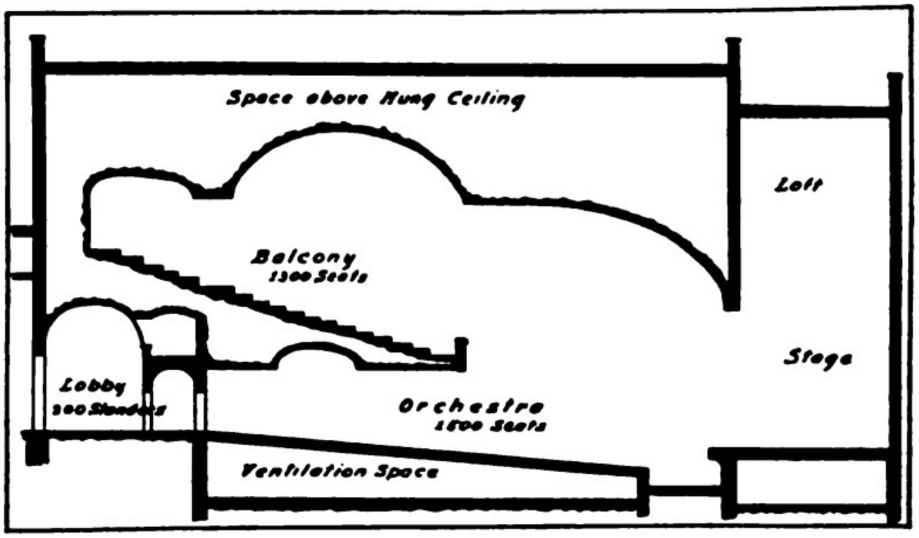


Fig. 58—Cross section of theater which it is desired to air condition

the amount of air necessary gives the following:

Walls and Roof .... 65,000 Btu.
Electricity
100,000 watts × 3.4.... 85,000

4

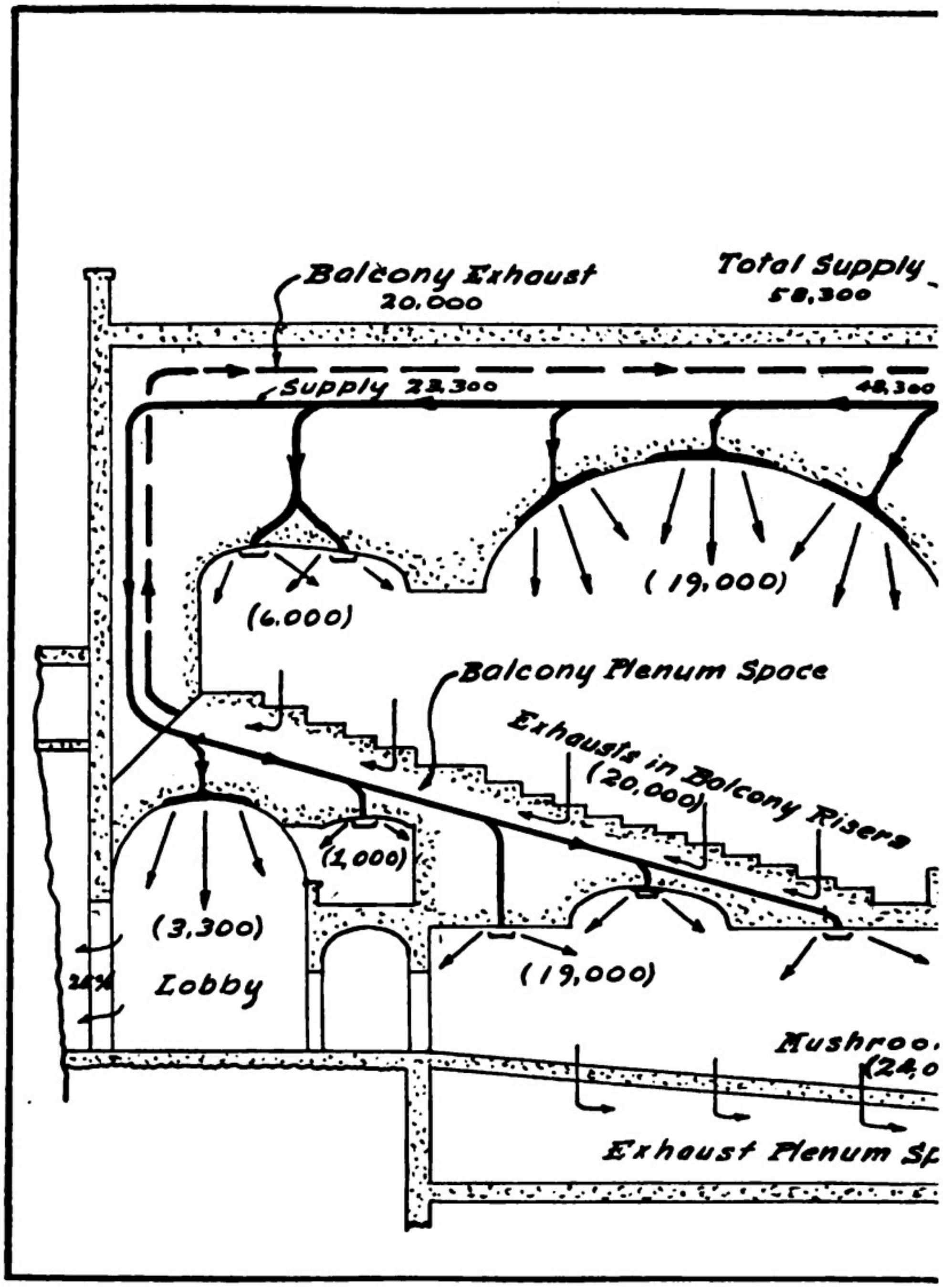
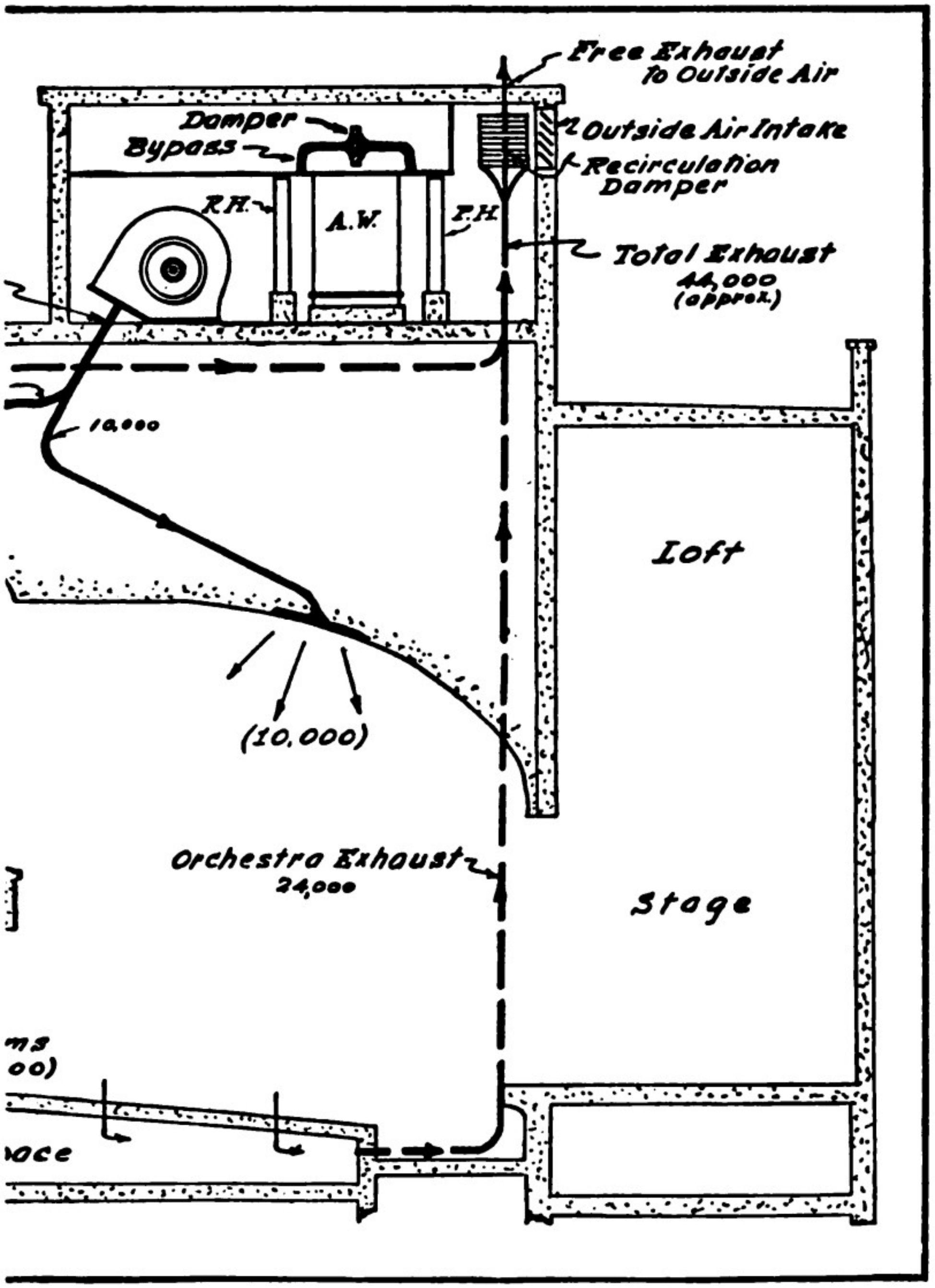


Fig. 59—Layout of air conditioning system for a theater which

Body—sensible
215 Btu. × 3,000......645,000

Total heat to be removed......795,000 Btu. per hr.
Adding 10 per cent for safety.. 79,500



shows how distribution of air is arranged in this problem

Total heat on which air quantity is based ....874,000 Btu.

If the air is entered 15 degrees below the room temperature (because of having a high ceiling) the quantity of air required to remove one Btu. in warming up to the room temperature is approximately 4 cu. ft. Therefore the total quantity of air required will be

874,500 Btu. × 4 or 3,498,000 cu. ft. per hr.,

or

3,498,000 / 60 or 58,300 c.f.m.

This is a ratio of

58,300 / 3,000 or 19 plus c.f.m. per occupant.

and 58,300/13.34 is about 4,371 lb. per hr., say 4,370.

It will be assumed that the customary 75 per cent recirculation will be employed and in this case the cooling of the outside air will amount to

25% × 4,370 lb., reduced to the washer temperature and the dehumidifying of the return air will consist of removing the moisture added by the occupants which is equal to the following per pound of air circulated:

$$\frac{175 \text{ Btu.} \times 3{,}000 \times 7{,}000}{60 \times 1{,}000 \text{ Btu.} \times 4{,}370 \text{ lb.}} \text{ or 14 grs. approx.}$$

It has been shown on page 140 that with 75 per cent recirculation and 14 grains per pound added to the air in the room, the washer temperature with bypassing must be about 46 deg. Fahr. and that the percentage of the total air passing through the washer will be around 44 per cent. Of this 44 per cent passing through the washer 25 per cent is outside air and the balance of 19 per cent (44% — 25%) is recirculated air.

Cooling the air then amounts to

Outside air

$$\frac{25\% \times 4.370 \text{ lb.}, \times (95 \text{ deg. Fahr.} - 46 \text{ deg. Fahr.}) \times 0.24}{200 \text{ Btu.}}$$

or 64.2 tons

Recirculation air

$$\frac{19\% \times 4.370 \text{ lb.}, \times (80 \text{ deg. Fahr.} - 46 \text{ deg. Fahr.}) \times 0.24}{200 \text{ Btu.}}$$

or 33.8 tons

Total refrigeration load for cooling.... 98.0 tons

Dehumidifying the air then amounts to

Outside air

$$\frac{25\% \times 4.370 \text{ lb.} \times (128 \text{ g.} - 46 \text{ g.}) \times 1{,}000 \text{ Btu.}}{7{,}000 \text{ g.} \times 200 \text{ Btu.}}$$

or 63.5 tons

Recirculation air

$$\frac{19\% \times 4.370 \text{ lb.}, \times (78 \text{ g.} - 46 \text{ g.}) \times 1{,}000 \text{ Btu.}}{7{,}000 \text{ g.} \times 200 \text{ Btu.}}$$

or 18.9 tons

Total for dehumidifying air.......... 82.4 tons

TOTAL REFRIGERATION FOR ALL PURPOSES .... 180.4 tons

Refrigeration per 1,000 occupants

180.4 tons / 3,000 × 1,000 or 60 tons (plus).

The usual ratio of tonnage per 1,000 occupants usually varies between 60 and 70 tons in theater work.

As far as incorporating the system in the building is concerned, downward ventilation will be used and the supply ducts run above the hung ceilings over the main auditorium and under the balcony. In order to reduce the cost, a plenum space for exhaust air will be used under the main floor and in the space under the balcony. Into this space exhaust air will be admitted through mushrooms located so that the exhaust will be removed at the locations thought most desirable. In the main ceiling grilles will be used with a velocity of about 300 f.p.m., and placed throughout the ceiling area in as well distributed a manner as the construction of the ceiling will permit. In low spaces plaques will be used and, in moderately high spaces, circular fixtures.

Apparatus Assumed Placed in Penthouse

In this particular instance the apparatus will be assumed to be placed in a penthouse on the roof although it may be placed in the hung ceiling space just on the room side of the stage wall, if care is used to prevent noise reaching the audience, or it may be located in the basement if sufficient space of suitable height can be found. In the case of a penthouse the space usually can be arranged to suit the equipment and the height is practically unlimited.

The illustration marked Fig. 59 shows the duct system as designed, with the air quantities arranged in proportion to the number of occupants within the range of each outlet. The exhaust from the main floor is carried up to the roof in the rear of the boxes and the exhaust from the gallery is carried up the rear of the auditorium and across in the hung ceiling so as to unite with the exhaust from the main floor. The combined exhaust is then run up past the penthouse with an opening into the outside air intake for the supply fan so that any proportion of the exhaust up to 75 per cent can be recirculated; a free exhaust is carried past the penthouse and discharges to atmosphere through a control damper. Fresh air enters the penthouse through the louvred damper shown and any amount of fresh air can be used from a minimum of 25 per cent up to a maximum of 100 per cent. The 25 per cent of cooled air, not recirculated, finds its way out through the doors and cools the entrance which is a good advertisement on a hot day, when this cooled air blows out on the street and tells the passerby that the theater has a comfortable temperature.

Air Conditioning American Movie Theatres
1917-1932

Scientifically Cooled-
The Dawn of Air
Condition(ed) Theatres

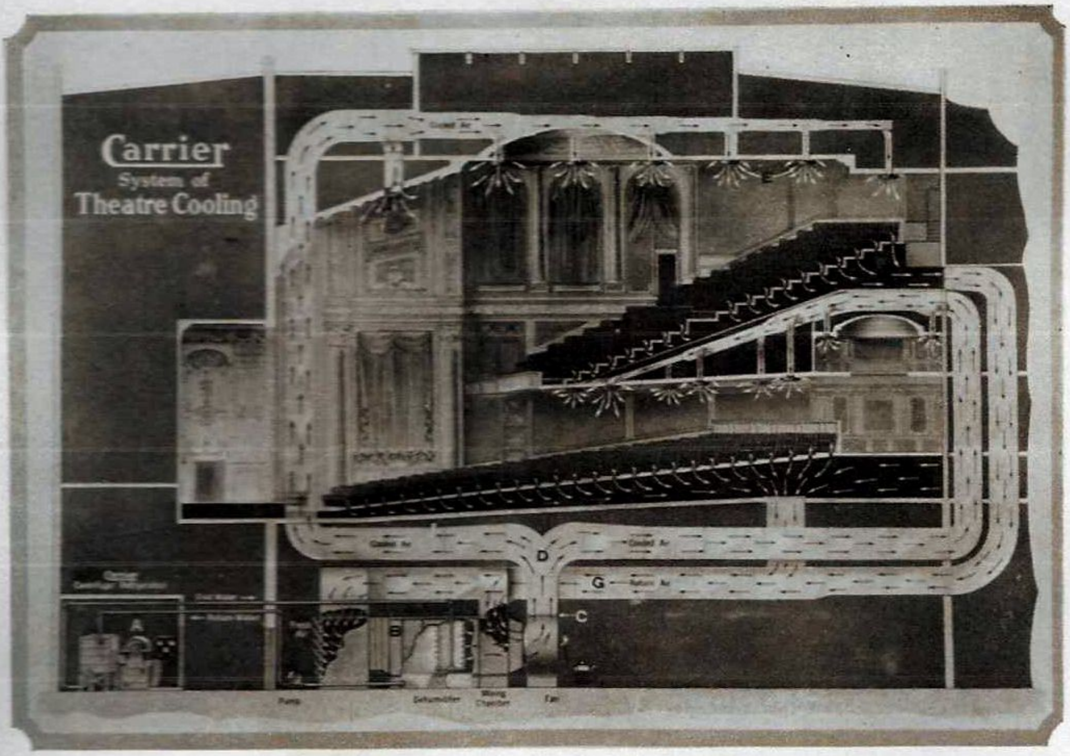
Theatre Historical Society of America

Theatre Historical Society of America

The Official Tumblr of the American Theatre Architecture Archive

Scientifically Cooled! - The Dawn of Air-Condition Theatres

Imagine it is the dog days of summer you are overheated and would like a place to relax and get out of the sun. You see a show is about to start at the local theatre, you buy a ticket, and take your seat. Now imagine that it is still hot in that theatre. I have a hard time with this one because I can say with a fair degree of certainty that all of my movie/theatre experiences have been in air conditioned theatres with the worst case scenario being that the air conditioning wasn't working all that well but it was still on. In the early days of movie going this wasn't always the case.



A. The Carrier Centrifugal Refrigeration unit which cools the water for the spray chamber.

B The spray chamber on dehumidifier where the air is dehumidified, cooled and cleansed.

C. The centrifugal fan which draws the air through the spray chamber and passes it through metal ducts to the theatre.

D. The large metal ducts through which conditioned air is passed to the ceilings of the theatre.

E The downward diffusion outlets through which the air is diffused over the audience, reaching the Breathing Zone first with complete absence of draughts.

F The chambers beneath the balcony and orchestra seats into which the air is drawn from the theatre.

G The large metal ducts through which the used air passes back to the spray chamber to be rewashed, cooled, dehumidified and mixed with fresh air.

Above is a diagram of a Carrier system of air-conditioning developed after early systems. The Rivoli theatre in New York, NY was one of the first major theatres Carrier worked on.

Some theatres left their doors opened and others closed up shop for the very hot months. Early methods to cool theatres saw owners storing ice underground in the cool months and then when temperatures rose they fanned cool air across the blocks of ice in the theatre. These methods had mixed results.

In 1917 Barney Balaban of the Balaban & Katz chain took ideas he learned while working as a chief clerk in a cold storage plant and applied them to the Central Park theatre in Chicago that the chain was building. They used “an electric, motor-driven refrigerating compressor and cooling coils, with air ducts to convey the ‘cooled’ air to the theatre auditorium” (”Annual Pioneer Award” 7). Due to some initial skepticism this idea had to be heavily marketed but once word spread it was a great success. Soon this was a major technology and draw that theatres could not do without.

> "Delightfully COOL Inside"

In a time when most working class families could not afford individual air conditioners for their homes and apartments, movie theatres often advertised their cooling systems in large attention-grabbing signs.

(credit: American Theatre Architecture Archive, Theatre Historical Society of America)