# CAir Conditioning American Movie Theatres
# 1917-1932

# Technical Papers 3

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# The Ventilation of Large Auditoriums

*Roy S M Wilde*
*Trans. ASHVE, 1920*

### No. 571

# THE VENTILATION OF LARGE AUDITORIUMS

By Ray S. M. Wilde, Detroit, Mich.

Member

THE discussion of this subject will be confined principally to the modern type theatre and treated from the standpoint of the practical application rather than as a purely scientific analysis of the theories of air movements in large rooms. In the final analysis of the proper type of ventilation system, I have tried to catch the general public view, for it must be borne in mind that the success of any undertaking must be measured by the opinion of the public mind.

When man roamed at will enjoying all things beautiful, he breathed the pure ozonated air of the new earth unmindful of the problems of sanitation. But, with millions of poor humans trying to be healthy and happy in the artifical confines of the large cities, all this is changed. Man's early desire for education and pleasure developed in him the desire to meet other members of the race in social discourse, these first meetings doubtlessly being held in the open air, where the only universally successful type of ventilating system was adequate to meet every need. Later there was the amphitheatre with its surrounding walls, and banked seats, open to the sky; here also the problem of ventilation had not presented itself. After a few centuries, there was the predecessor of the modern theatre, the old opera houses of Europe in which some attempts were made to provide ventilation; as a rule, however, the natural movement of the air was thought sufficient, as in all buildings of this character there is considerable movement of air, due to varying temperatures of air currents, caused by high ceilings and balconies.

It has been my fortune to design in the neighborhood of 100 systems of various types in varied classes of theatre buildings and it seems to me that we are just beginning to know the proper type of system to install to give the nearest to perfect satisfaction. There are three potent factors that enter into the design of a ventilating system for a moving picture house, other than the scientific calculations, and they are: *cost; operation and maintenance;* and the *architect.*

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Paper presented originally before Michigan Chapter; also at the Semi-Annual Meeting of the American Society of Heating and Ventilating Engineers, St. Louis, Mo., May, 1920.

The first factor of cost interests the owner; usually his chief concern is to know the number of seats he can cram into a certain space, and the size of the money bag at the end of the week. After "sitting in" in many arguments with the owner and the architect, and feeling that they are convinced that a good ventilating system would be an asset, we find that our "Waterloo" comes when they ask "What do your consider the best system of ventilation?" adding, that Mr. Smith has the mushroom, washed air type and likes it, Mr. Jones has the side wall inlets, supply fan without air washer and likes it, someone else has a couple of disc wheels in the attic and says it's the only system, and so on. Here the engineer must use tact and diplomacy, for in making a man invest several thousand dollars in a ventilating system, one must be sure he is going to be satisfied with it when it is in operation.

Operation and maintenance enter into the cost and concern the owner to the fullest extent. The plant must be simple and fool proof, as the helpers usually found around a theatre for this work are not sufficiently trained. Many an excellent system has been given a knockout by some poor fellow bungling a complicated system, because he couldn't help it.

The architect is our best friend and yet our worst enemy, for he designs beautiful interiors and yet does not seem to realize that space is necessary for heating and ventilating apparatus. Many of us have pondered and worried for days, trying to squeeze two fans and an air washer into space where one would fit tightly. Then too, the architect does not like radiators, nor the grilles we must have to let air in and out, and countless other details, too numerous to mention.

We have installed almost every combination of system that could be devised and most of them have worked out successfully. I shall now describe in a general way several of these systems, first the apparatus and then the different schemes of air entrance and exit.

The one way mechanical type of ventilating system is one having a supply fan with tempering stacks, discharging air into the auditorium, at the side walls about 7 ft. above the floor, heated air in winter, and air as received from the outside in the summer time; foul air is exhausted through ventilators in the roof. The two way type has an exhaust fan in addition to the supply fan as described for the one way type. The three way type has a main supply unit, main exhaust unit, and an auxiliary supply unit which is installed in the attic, usually consisting of one or more large, slow speed disc wheels, drawing air in directly from outside and discharging it into the auditorium at the ceiling. When the purse strings are flexible enough, air washers are installed as well as temperature and humidity controlling apparatus.

The question of air distribution is one that has been given considerable attention, but there still seems to be a great divergence of opinion as to the proper methods or locations for air entrance and exit. In order to bring the matter up for discussion let us consider several types that I have experimented with. The first is what is known as the "mushroom" type, which is primarily an up-feed system; a large plenum chamber or duct is usually placed under the main auditorium floor, and mushroom ventilators placed under each seat; in the balcony, the space underneath is used as a plenum chamber and mushroom outlets are placed under as many seats as possible. Fresh air is forced into the auditorium through these outlets and is supposed to rise to the ceiling where it is removed by an exhaust fan in the attic. A small amount of air is usually exhausted at the floor near the orchestra pit to overcome draughts from the stage.

The theory advanced for this system is that heated air rises, and therefore, with an even distribution of upward moving air, this is a perfect system. This type of system is very popular in some parts of the country, but I suggest that it is not sound in theory. While it is true that heated air rises, what happens to it when it meets a colder, heavier body of air coming the other way?

There are two objections to this system that are enough to condemn it from the viewpoint of the public; one is the chilling effect on the spine of this stream of air coming up around one's feet; the other is the fact that one is breathing air that has come up from the floor, by his feet and over his clothing or that of somebody else—nothing to be alarmed at, but not a pleasant thought.

The next system we might call a combination side wall and mushroom system. In this type, the air supply for the main floor is blown in from side walls about 7 ft. above the floor, the balcony being supplied by mushroom outlets under the seats from a plenum chamber under the balcony. This system is a combination up-feed and down-feed. An exhaust fan is used, taking 75 per cent of the air up and 25 per cent down at the floor.

This scheme works well for the main floor, but it is impossible to keep the temperature down in the balcony. I have in mind a certain job where this scheme was used, in which a temperature of 72 deg. was maintained on the main floor with 70 deg. outside, but there was a temperature of 87 to 90 deg. in the balcony. The owner complained bitterly about this and we were given a free rein with the equipment on hand to improve the results. I had the opinion that we needed more air action over the balcony, so we installed two disc fan wheels in the attic, drawing in outside air, and discharging it into the auditorium over the balcony through the ceiling. The results were marvelous, for we were able to reduce this temperature difference to 5 deg. and everybody was satisfied. This was really the beginning of the so-called three way type of ventilating system which we have used quite extensively.

At this point let me suggest that some movement should be started very soon to establish uniform laws in all states, governing the ventilation requirements for various types of buildings, based of course on the answer of our Bureau of Research to the vital question:

What is Proper Ventilation? Almost every state, city or hamlet has a ventilation code all its own, setting forth a minimum requirement that means very little, and often creating hardships by inserting some peculiar requirement without proper study of the entire problem. To my mind, this code writing is an engineer's job, and we should not sit by and let laymen and lawyers make codes, governing engineering work.

The modern theatre presents several phases of the ventilation problem that are not easy to solve, but I believe we are nearing the solution today. Two types of theatres prevail today, one known as the legitimate house, which shows the large productions, and the other, the large movie house as we know it.

In the legitimate type, not more than two performances are shown in a day; during each performance, the auditorium is occupied for about 2½ hours, and it is entirely possible to maintain a good standard of ventilation for this short period with comparatively small apparatus, provided some thought is given to the proper condition of the air within the house before the audience enters. If a standard of 60 deg. fahr. with about 40 per cent relative humidity is set up in the auditorium as the audience enters, and this is maintained at the apparatus during the performance, splendid results are possible.

The large movie house, which is usually about 75 per cent full for 10 or 12 hours each day, presents a problem that is more difficult to solve. We have tried several modifications of the three way type and have found the following arrangement to give very good distribution and even temperatures: A main supply unit to supply air to auditorium main floor from the side walls at a rate of 20 cu. ft. per minute per occupant, and a main exhaust fan of equal capacity, exhausting 50 per cent of the air from the floor line and 50 per cent from the ceiling at rear of balcony. We provide an auxiliary supply unit of sufficient size so the combined capacity of supply units will change the air in the auditorium every three or four minutes, the auxiliary supply unit being in the attic and discharging air over the balcony, running full capacity for summer and about one-half capacity for winter service when required. This system is one of the best thus far developed and will give very good cooling effects by the absorption method during the summer months.

There is still another system which I shall mention in order to get it under discussion, and that is the down-feed system, where the fresh air (cooled or heated) is supplied through the main ceiling and the foul air exhausted at the floor line. Carefully designed, it is my opinion that this is the best method of air distribution for a large auditorium.

We might mention the cooling system using refrigeration. Those that have been installed are quite successful, but the average installation requires an initial investment of about $30,000 in addition to the regular ventilating equipment and about $75 per day for operation cost. It costs $3,000 per degree of cooling effect, a 10 deg.

difference being guaranteed. If our theatres were built like cold-storage houses, this could be done more cheaply, but the building cost would then be considerably more than the cost of the refrigeration apparatus. There is also a question in my mind as to the effect of the lower temperature on the general health of the public with this type of system.

## DISCUSSION

H. M. HART: I am not going to back down entirely on favoring floor introduction of ventilation, as I am not quite ready for that. There are objections to floor introduction; but if properly controlled, I cannot help but feel that better distribution is obtained with introduction through floor ventilators. My observation has been that going into auditoriums that are ventilated with that system, properly operated and controlled, the sensation is generally pleasant, and the air is fresh and free from odors. With the other systems drafts are encountered and the distribution is not obtained, resulting in air pockets. I have seen some cases of the floor introduction where results were unpleasant; but it is merely the fault of the operator of the plant, and not of the system at all. For that reason it has been condemned, and I don't think it is fair to condemn a system because some operator does not do his duty. There is one auditorium in Chicago where the air for the auditorium, which has two balconies, is introduced entirely through floor gratings on the main floor. Careful records of temperatures have been kept all over auditorium and balconies for four or five years, four readings being taken during each performance. During the cold weather the temperature never rises above 72, at any point, and in order to obtain that result, the temperature of air that is introduced through these ventilators under the seats, sometimes goes down as low as 60 deg. It has been my observation that one cannot introduce air under the seats or at a lower temperature than 66 deg. without having it objectionable and not over a velocity of 100 ft a min.

THE PRESIDENT: My experience has been that the mushroom system of introduction is satisfactory where there is a good temperature control.

H. M. HART: I am not strong for automatic control of the auditorium with the floor introduction system. I think if the operator is wide awake, he can get better results with a hand control. For with the automatic control there are sudden changes of temperature and a sudden change of temperature is objectionable; while with hand control, the man with a little experience, observing weather conditions, can tell at what temperature he should introduce the air to get the right results, thereby doing away with the sudden fluctuation. The reverse is true with the overhead system. The sudden change of temperature in introducing fresh air above the head, if it does not strike in the back of one's neck, is a pleasant sensation, especially when it gets very warm or cool in the auditorium. I am not in favor of trying to maintain absolutely uniform conditions of temperature. It may sound as though I were contradicting myself, but in speaking of the two systems, there are two things to consider, one is the floor introduction system and the other the overhead introduction system. In the overhead introduction system, the changes of temperature are not objectionable and not so noticeable. The fact that it strikes one in the face is rather a pleasant sensation.

A MEMBER: Some years ago, I made some tests on theatre ventilation before the mushroom ventilator was designed, and the air was introduced at the floor at an exceptionally low velocity. The velocity was so low that it was practically impossible to measure it. I could feel it by wetting my hand, and the air was distributed about the room by using the basement of the theatre to get funnel chambers, and it came through the legs of the chairs, through 3½ in. holes, and through the wood work in the floor. It was then distributed through lattice work. In running these tests, I had the air analyzed very carefully by chemical analysis. The building was used for two performances a day, evening and afternoon, every day in the week. The ventilation obtained there, was practically as pure as outdoor air. We were getting perfect ventilation with a diffusion over the entire theatre so gradual that no one noticed any air flow. I experimented with the audience by changing the temperature to 55 deg., and the audience began to cough and get restless as though they were cold. They didn't know what was going on; but the average temperature for the breathing line was about 70 deg. which checks very well. I checked my temperature at the time and it seemed to do very well with the amount of heat that was expected to be given off from the body sitting quiet, and from the experiment I made, there, I am strongly in favor of properly designed ventilation, widely distributed and diffused.

**Air Conditioning American Movie Theatres**
**1917-1932**

# Heating, Ventilating and Cooling Plant of the Tivoli Theatre

*Power Plant Engineering,*
*Vol. XXVI, No.5, 1st March, 1922*

# POWER PLANT ENGINEERING

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VOL. XXVI CHICAGO, MARCH 1, 1922 No. 5

# Heating, Ventilating and Cooling Plant of the Tivoli Theatre

### REFRIGERATION STORAGE CAPACITY ENABLES COMPRESSOR TO HANDLE 100 PER CENT EXCESS PEAK

THE TIVOLI THEATRE, opened to the moving picture-loving public during the last year, is now a byword with every fan, not only in Chicago but in the outlying districts. Its architecture is beautiful and distinctive. The main foyer, for instance, is typical of the architecture employed throughout the building. It is of the Louis XV period and is modeled after the style of the Chapelle at Versailles. To convey some idea of its size, it is 70 ft. or six stories high, 75 ft. wide and 125 ft. long and is capable of accommodating with comfort 1500 people. The theatre proper has a seating capacity of approximately 4000. It was built for Balaban & Katz, of Chicago, at a cost of $2,000,000. The architectural work was done by C. W. and Geo. L. Rapp, also of Chicago.

Passing by the beauty of the place, we go to the inside works, that part which serves to make the theatre comfortable for the patrons—to keep it warm in winter and cool in summer, to maintain an adequate supply of correctly conditioned fresh air at all times. This indispensable service is forthcoming continuously, but it is

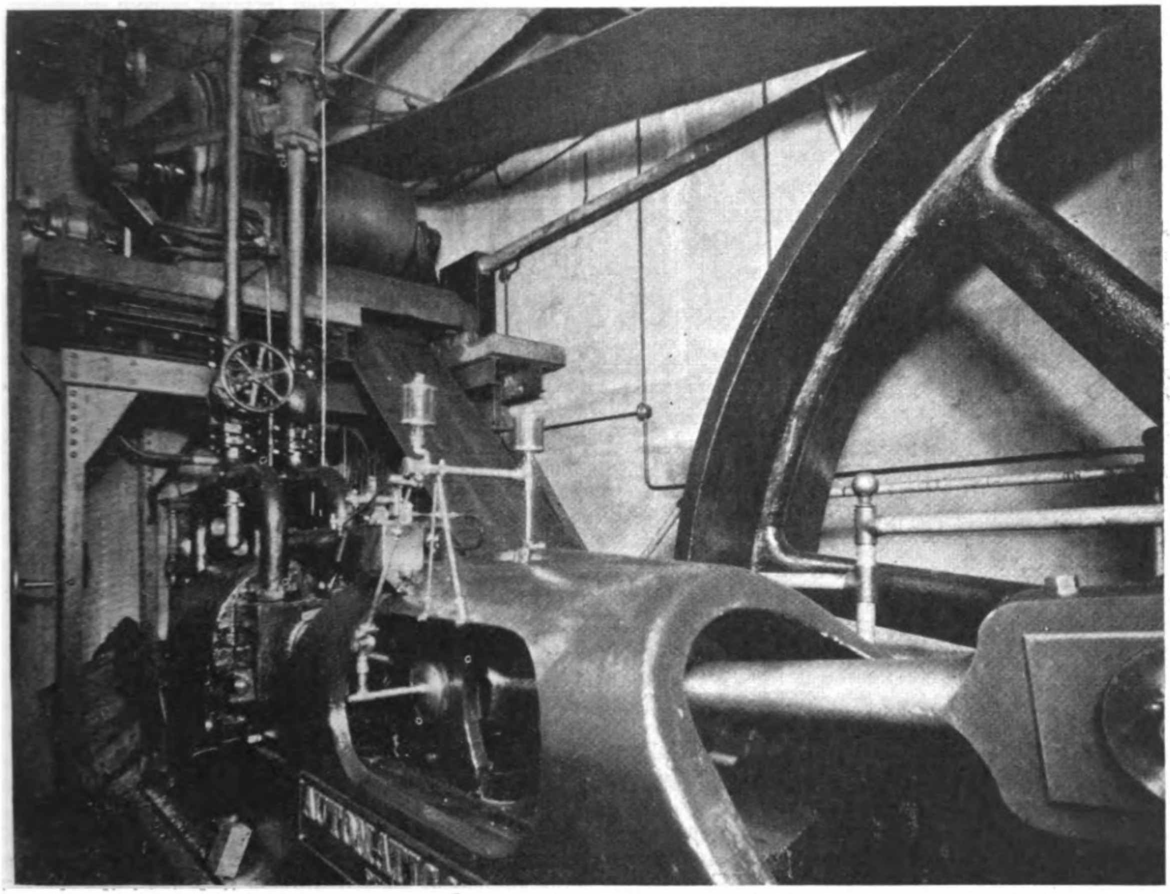

FIG. 1. CRANK END VIEW OF $CO_2$ COMPRESSOR AND ITS DRIVE

a service which is not in itself manifest and is likely to be taken for granted. These commodities, for such they are, warmth and fresh air, are supplied by the heating and ventilating plant.

The Tivoli theatre has no power plant in the accepted sense, that is, there are no prime movers; all electrical energy for motors and lighting is purchased from outside. The plant consists entirely of apparatus for heating, cooling and ventilating the building, which, excepting for the refrigerating system used for cooling the spray water for washing and cooling the air, was installed by Mehring & Hanson, refrigerating engineers, according to designs by M. C. Hartman, consulting engineer. All of this apparatus is located in a basement beneath the foyer. The main floor of the theatre is built directly on the ground so that this is the only basement in the building.

To contribute further to the well being and comfort of the patrons, there is provided a spray nozzle in the main air duct for the purpose of injecting a fine spray of perfume into the air. Perfume is mixed with compressed air by means of a special mixing valve, the compressor supplying the air. This device, which is made by the Thompson Neeb Mfg. Co., is controlled by clockwork to spray a given quantity of perfume once every hour.

Fresh air is taken in through a large duct along the north wall of the building from a 12 by 12-ft. opening at the north end of the east wall at a point 30 ft. above the alley level. At the inner end of this duct the cold air is passed through a bank of Vento coils where it is preheated to about 50 deg., more or less depending on the temperature and humidity required in the building. It is then passed through an area of fine water spray also having a temperature of about 50 deg., where the dust is removed and where it becomes saturated at the existing temperature. Then, after passing through a series of baffles where any entrained moisture is removed, the air is drawn through three sets of Vento reheating coils by three blowers and is forced to three main divisions of the building, the main floor, the balcony and the main lobby or foyer.

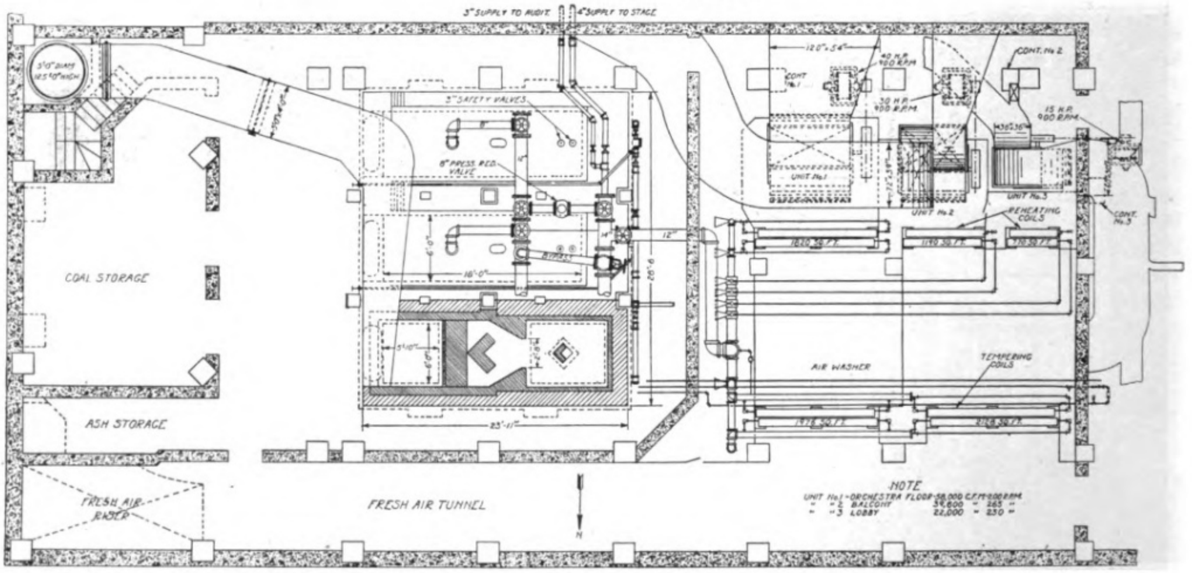

FIG. 2. PLAN OF BOILER AND FAN ROOMS

The preheating or tempering coils have an equivalent direct radiation surface of 4112 sq. ft. arranged in four units two stacks deep and two stacks high. The reheating coils are arranged in three separate groups in three ducts, and are individually controlled to give the desired temperature in main section of the house. The orchestra floor coils are arranged two deep and two high and have a total surface of 1820 sq. ft. The balcony coils contain 1190 sq. ft. and the lobby 770 sq. ft., a total of 3780 sq. ft.

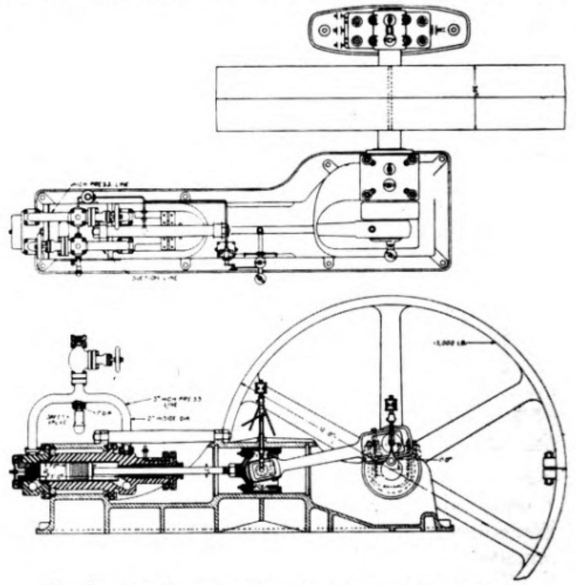

FIG. 3. PLAN AND ELEVATION OF CARBON DIOXIDE COMPRESSOR

An automatic bypass damper is provided below each bank of coils so that when but little reheating is required the air may be passed through these openings and thus materially reduce the resistance of the system.

The fans or blowers are all of the Sirocco type made by the American Blower Co. Unit No. 1, the orchestra floor fan, is of the double inlet type and has a rated capacity of 58,000 cu. ft. per min. at a pressure of 1¼ in. water. It runs at 200 r.p.m. and is belt driven from an induction motor having a capacity of 40 hp. at 900 r.p.m. At rated load it uses 100 amp. per phase. The balcony fan, also of the double inlet type, has capacity for 39,000 cu. ft. per min. at 1½ in. pressure. It is belt driven at 265 r.p.m. by a 30-hp. motor running at 900 r.p.m. This motor takes 74 amp. per terminal at rated load. The lobby fan is of the single inlet type and delivers 22,000 cu. ft. per min. at 1¼ in. It runs at 230 r.p.m. and is belt driven by a 15-hp. motor running at 900 r.p.m.

The ducts leading from the fans are of such size as to give velocities not to exceed 1000 ft. per min. which has been found a safe maximum allowable where quietness of operation is desirable or essential as in this installation. To eliminate as far as possible the noise incident to the operation of the blower from being carried to the house, a canvas neck is inserted in the duct at the outlet of the fan. The layout of this apparatus is shown in Fig. 2.

The temperature of the air discharged from the balcony and main floor fans is kept virtually the same at about 70 deg. while that from the lobby fan is somewhat less. To maintain an even temperature of air delivered to the main floor, supplementary heaters are provided at the entrance of each fresh air supply tunnel, under the floor, from which separate ducts lead to mushroom vents. These conditions are for winter. During the summer months, the lobby is kept several degrees warmer than the rest of the house, which is maintained at a higher temperature than in winter—about 74 or 75 deg.

The temperature in the theatre is controlled from multiple thermostats which are located in the duct behind the reheaters.

In the manager's office a switchboard is arranged so that by operating push buttons located on this board, the duct thermostats may be set for any desired temperature between 62 deg. and 72 deg. and if so desired can cut off the thermostatic control entirely, allowing the full heating effect of the coils to be used for rapid heating of the theatre. The lobby fan is controlled by a multiple thermostat in conjunction with a pilot thermostat which, when the temperature in the lobby reaches a predetermined point, allows the duct thermostat to operate and furnish air at 68 to 70 deg., as desired, for ventilation, and if the temperature drops below the desired point in the lobby the pilot thermostat cuts off the duct thermostat and allows the full heating effect of the coils to be utilized.

The system has, in connection with the fans, dampers which operate to allow fresh or recirculated air to be used with the ventilating system. These switches are of the two-point type which allow the dampers to be held closed, half open, or full open. This allows the use of all fresh air or part fresh air and part return air or all return air. The dampers are furnished by the Johnson Service Co., and are operated by pneumatic switches on the same switchboard as the thermostat adjusting devices. Compressed air is furnished to the temperature control system by means of electrically driven air compressor units, which are automatic in their operation.

Used air is exhausted partially by natural convection through ventilators on the roof and partially by means of an exhaust fan located on the upper balcony level, which is capable of handling 50,000 cu. ft. per min. It is driven at 153 r.p.m. by a 25-hp. induction motor running at 600 r.p.m. This fan discharges through a vertical shaft through two sets of automatic louvered dampers either up to the atmosphere or down to the fresh air intake duct, there to be mixed with the fresh air and recirculated. These dampers are regulated from the engineer's office to allow any proportion of recirculated air to be used. Ducts leading to this fan are so proportioned that 30,000 cu. ft. per min. are taken from the balcony and 20,000 from the main floor. Adjacent to this main exhaust is a 3-hp. exhauster which removes 4600 cu. ft. per min. from the toilets. Another 3-hp. fan located back stage handles 2500 cu. ft. per min. from the stage and wings.

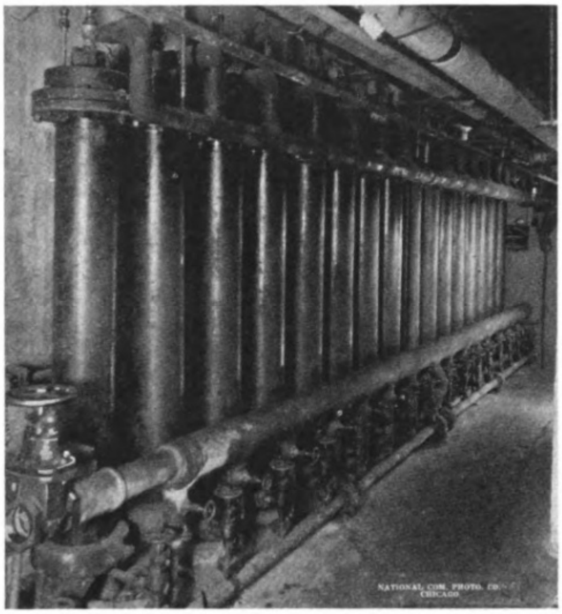

FIG. 4. BATTERY OF SIXTEEN 10-T. CONDENSER UNITS

In addition to the 4112 sq. ft. of tempering and the 3780 sq. ft. of reheating coils, there is distributed throughout the house, principally along the walls, 6200 sq. ft. of heating surface primarily to take care of the wall losses. The total heating surface of 14,092 sq. ft. is supplied with steam at 4 or 5 lb. pressure, depending on the amount of heat required, through a reducing valve from a battery of three 150-hp. boilers, also shown in Fig. 2.

These boilers are located in the east section of the basement under the balcony. They are of the horizontal return tubular type, 72 in. diameter and 18 ft. long containing seventy-four 4-in. tubes. This gives a tube surface of 1395 sq. ft. and an effective shell area of 170 sq. ft. totaling 1565 sq. ft. which, at a 10 sq. ft. builders' rating, gives a little over 150 hp. Steam is generated at 10 lb. pressure, is taken off through 8-in.

leads and after being reduced is collected in a 14-in. header from which a 12-in. supply to the Vento coils and other sundry direct radiation mains are taken. There are two 3-in. safety valves on each, set to blow at 12 lb. pressure.

The furnace setting is what is known as the Chicago Standard No. 8 setting. The grate, designed for hand firing, is 6 ft. wide and 5 ft. 10 in. deep, giving an area of 35 sq. ft. It is 2 ft. 2 in. off the boiler room floor and 3 ft. below the boiler shell. The bridge wall at the end of the grate extends to within 18 in. of the shell. Back of this the combustion space is divided in half by a pier which extends to within 1 or 2 in. of the shell. On each side there is left a space 14 in. wide for the passage of the gases of combustion. Immediately behind this pier the side walls converge to mix the two streams. The minimum width of the gas passage here is 2 ft. 8 in. As the height at this point is 5 ft. 1 in., the area is 13.5 sq. ft. or only 39 per cent of the grate area. From this throat the furnace gases expand into a secondary combustion chamber, where combustion is completed. From here the gases return through the flues to the breeching which has a maximum area, at the base of the stack, of 20 sq. ft. The stack is 125 ft. high and has an area at the top of 19.6 sq. ft.

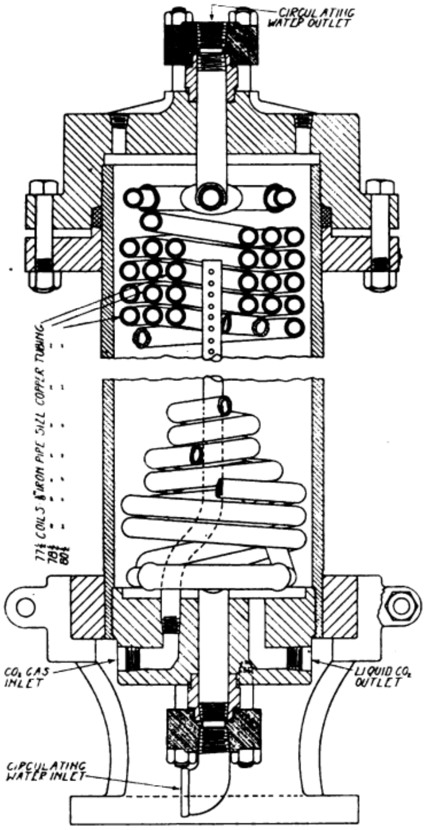

FIG. 5. SECTION OF CONDENSER UNIT

The Pocahontas coal used is stored in a bin across the firing aisle from the boiler fronts. It is delivered in trucks and dumped directly into the bins through manholes in a driveway on the alley level. Ash is stored in a small bin alongside the coal storage. Periodically, it is lifted to the surface in buckets by means of an electric hoist, loaded onto trucks and carted away.

At the present time, even with the outside temperature not far above zero, it has been found necessary to use only one of the boilers. During the months of December and January the average coal consumption was 2.37 T. per day, which corresponds to an average rating of about 130 hp.

Condensate from the heating system is returned under vacuum to a receiving tank in the compressor room and from there pumped back into the boiler. Vacuum is maintained by a 35 amp. 5-hp. vacuum pump of the rotary type running at 155 r.p.m.

### REFRIGERATING UNIT

THE REFRIGERATING system employed to effect the cooling of the spray water used for cleaning and saturating the ventilating air is of the $CO_2$ type. The compressor, a view of which is shown in Fig. 1 and a plan and elevation in Fig. 3, was built by the Automatic Carbonic Machine Co. It is of the horizontal double-acting type and has a rated capacity at 84 r.p.m. of 150 T. This unit is driven by a 27-in. open belt from a General Electric 150-hp. slip ring induction motor which is mounted on a platform about 10 ft. from the floor, near the head end of the compressor. The motor operates on three-phase, 220-v., 60-cycle current, just as the other motors in the plant, and requires about 400 amp. per terminal.

The compressor has a bore of 7¼ in. and a stroke of 24 in. At this speed, the compressor handles 96 cu. ft. of gas per min., or 405 lb. at 25 atmospheres pressure.

On account of the high pressures encountered and the great variation in the resisting torque, the machine is equipped with a heavy 12-ft. flywheel having a face 30 in. wide, and weighing 15,000 lb. to impose a more even resisting moment on the motor.

The safety valve in the discharge line is of a design not ordinarily met with in other classes of work where lower pressures are encountered. Besides a regular spring loaded pop valve there is in series with it and on the atmospheric side a thin phosphor-bronze diaphragm about 0.010 in. thick and about ⅝ in. in diameter which ruptures when the compressor pressure reaches a certain pre-determined maximum and allows the $CO_2$ to escape to atmosphere. The pop valve is simply used for the purpose of preventing excessive loss of the refrigerating medium. It is of course necessary to replace the diaphragm after every rupture. The object of the double valve is to prevent constant loss of gas at operating pressures due to leakage past the pop valve.

Ordinarily a source of much annoyance in the operation of a $CO_2$ compressor is the leakage past the piston and stuffing-box. To eliminate this loss to as great an extent as possible, the piston is made exceptionally long, 12 in. in this case, and is provided with six leak-proof piston rings. The piston rod is packed with 15 in. of special packing. Pressure adjustment on the packing to suit the temperature of the rod is obtained by screwing in or out the gland. The gland is turned by means of worm gearing, the worm being turned by means of a crank.

In making a choice of the refrigerating plant for this installation, the ammonia system was discarded and the engineers on the job handed down a decision in favor of carbon dioxide as the refrigerating medium to be used for a number of reasons. The principal one was that the space available was rather inadequate and a machine had to be chosen which would give the required capacity with a minimum amount of floor space. The space required for the condenser for $CO_2$ gas is much less than that for ammonia because copper tubing can be used in the first case which may have a much smaller surface on account of the greater heat conducting quality.

In a public building of any kind, the escape of ammonia gas is highly undesirable and dangerous to life if present in any appreciable quantities. On the other hand, slight leakage of carbon dioxide is unnoticeable on account of its lack of odor and is not dangerous unless present in relatively large quantities. It was for these reasons then that a $CO_2$ system was employed.

The compressed gas at a pressure of from 70 to 76 atmosphere or 1030 to 1120 lb. abs. is piped over the storage tank to a battery of condensers also supplied by the Automatic Carbonic Machine Co. along the west wall of the building and just south of the storage tank, as shown in Fig. 4. There are 16 individual condensers in this battery, each having a capacity of 10 T., a section of which is shown in Fig. 5. The condenser is of the vertical shell and tube type which requires a small amount of floor space of 3 by 24 ft. or 72 sq. ft. as compared with about 320 sq. ft. required for a double pipe condenser. Including all fittings, etc., a condenser unit of this type can be installed in about 35 per cent of the volume required for a double pipe type.

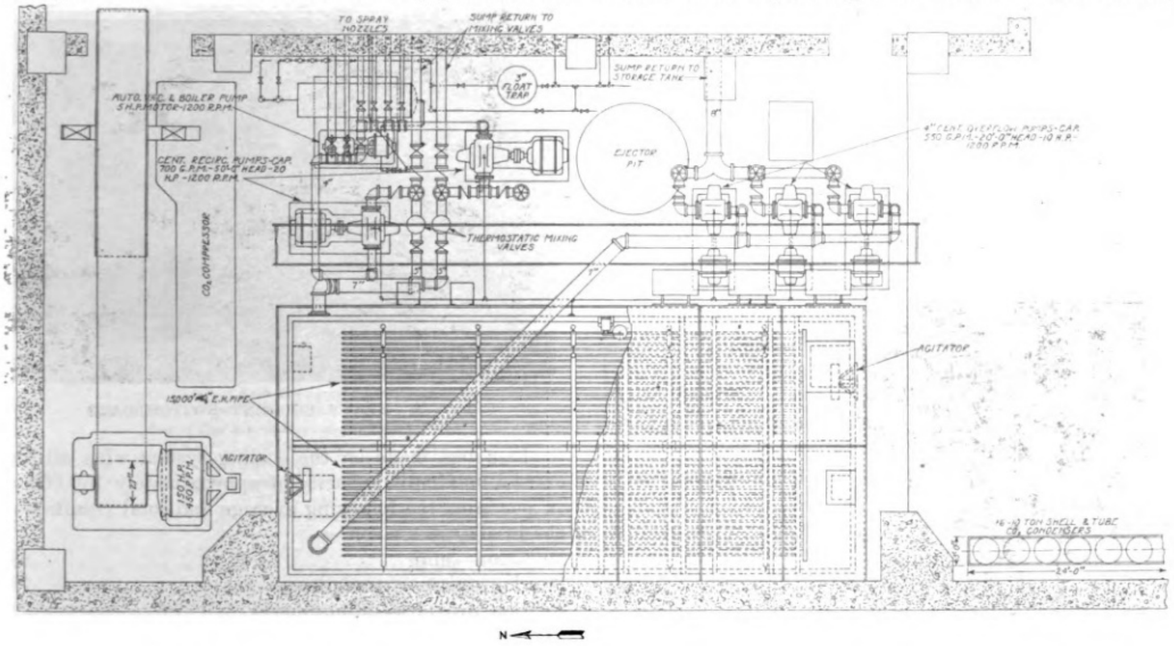

FIG. 6. PLAN OF PUMP AND COMPRESSOR ROOM SHOWING STORAGE TANK AND CONDENSER

The condenser consists of a 9-in. extra heavy steel pipe ½ in. thick which forms the shell, on which are fitted two cast-steel manifold heads. The lower head has connections for gas inlet, liquid outlet and circulating water inlet. The top head is provided with a circulating water outlet connection. Three copper coils arranged in parallel conduct the cooling water through the shell from bottom to top. $CO_2$ gas enters at the bottom at the center of the head and ascends through a riser to near the top of the shell. Here the gas escapes to the shell where it comes in contact with the cold coils and is condensed. The condensate collects at the bottom and is piped to a main liquid header at the top of the storage tank. From here it is admitted through four ¾-in. so-called pressure relation valves, or expansion valves, to the expansion coils in the tank. After evaporation, the gas is drawn off at a pressure of from 20 to 26 atmospheres through a collecting header and enters the compressor.

The storage tank is 12 ft. 8 in. wide by 28 ft. long by 12 ft. high and has a volume of 4250 cu. ft. In it is disposed 15,000 ft. of 1¼-in. extra heavy expansion piping which, with the return bends, occupies a space of about 250 cu. ft., leaving a net volume of 4000 cu. ft., which, when filled to the top will accommodate 250,000 lb. of water.

During the hot afternoons of the summer months, the load on the cooling system is increased tremendously and frequently the system is called upon to meet a peak of 250 T. refrigerating capacity. There are conditions which arise at times which require as much as 300 T. These are peak conditions and have to be met for only an hour or two a day. If a compressor were installed to take care of this maximum demand, it would mean that most of the time, the compressor would be working at much less than its rated capacity with a consequent loss of efficiency. Owing to the fact that the theatre is open from 2 p.m. to 12, or 10 hr., a full capacity machine would be idle the rest of the time or 14 hr. a day, which of course means heavy stand-by charges. In order, then, to increase the capacity factor and the efficiency of the machine and to decrease the cost of current incident to the high maximum demand of a full capacity compressor, a refrigerating machine of only 150 T. rating was installed, in conjunction with a storage system.

With this storage arrangement, a much smaller compressor is practical and although the initial investment is virtually the same, when the added cost of the tank is considered, the compressor can operate for a much longer period. For normal summer operation, the compressor is started up at about 7 a.m. and from that time until the load comes on is building up a reserve. Thus the compressor runs 17 instead of 10 hr. a day and the capacity factor is increased from about 42 per cent, which would be realized with a 250-T. compressor and no storage, to about 71 per cent with a 150-T. machine and storage capacity.

By starting at 7 a.m. and storing cooling capacity in the tank until 2 p.m., 12,600,000 B.t.u. cooling capacity is stored. During this time, the water will be cooled from an average maximum temperature of 55 deg. to 32 deg. and after that about 47,000 lb. of ice will be made. When the demand comes on at 2 o'clock, about ½ in. of ice will have formed on the expansion coils. This ice maintains the water temperature at 32 deg. until about 7:00 or 7:30 p.m., after which the compressor carries the load practically unaided. The water temperature gradually rises, however, until at midnight it has reached its maximum of about 55 deg.

Cold water flows from the bottom of the storage tank through a 7-in. line to the suction of either one or both of two Pennsylvania centrifugal pumps shown in the plan of the pump room, Fig. 6, having a capacity of 700 g.p.m. each under a head of 50 ft. Each is direct connected to a 20-hp. induction motor having a normal speed of 1200 r.p.m.

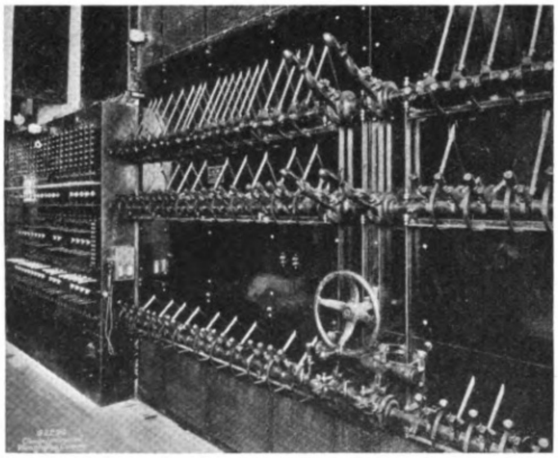

FIG. 7. LIGHT DIMMER COTROL

The temperature of the water to the spray nozzles is controlled by two thermostatically operated mixing valves located in the suction valve line. These valves mix return water from the spray chamber sump with that from the storage tank in correct proportion to give the desired spray temperature.

Surplus water in the sump is pumped back to the storage tank by any one or all of three centrifugal pumps with capacity for 550 g.p.m. each. These pumps work against a 20-ft. head and are directly connected to 10-hp. motors which run at 1200 r.p.m. When 100 per cent cold water is used for the spray the return pumps handle the same amount of water as the supply pumps. As the maximum capacity of the latter is 1400 g.p.m. and of the former 1650, there is never danger of flooding the spray sump.

The return pump motors are automatically controlled by float switches in the sump tank. When the level in this tank reaches 18 in., a float switch closes the circuit on one of these pumps and starts it. If the water continues to rise, the second pump is thrown in at 26 in. At a level of 28 in., the third is cut in and as the return is then in excess of any possible input, the level falls.

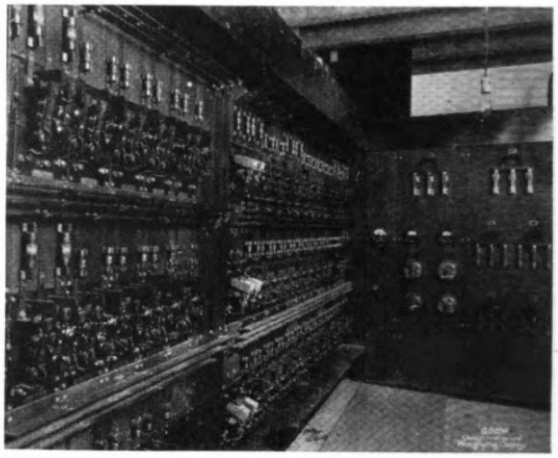

FIG. 8. HEAVY CURRENT SWITCHBOARD

In a test made on the cooling system with all fans on at a maximum capacity of approximately 150,000 cu. ft. per min., the following average and total results were observed:

| | |
|---|---|
| Duration—min. | 88 |
| Head pressure—atmospheres | 75 |
| Suction pressure—atmospheres | 32 |
| Temperature condensing water in—deg. F | 70.5 |
| Temperature condensing water out—deg. F | 85.5 |
| Temperature difference—deg. F | 15 |
| Quantity circulating water cu. ft. per min | 39 |
| Temperature water to storage tank—deg. F | 57 |
| Temperature water from storage tank—deg. F | 43 |
| Temperature difference—deg. F | 14 |
| Water circulated—lb. per min | 2710 |
| Average kilowatt input to motor | 165 |
| Temperature air in—deg. F | 72 |
| Temperature air out—deg. F | 64 |
| Temperature difference—deg. F | 8 |

When the difference between the temperatures entering and leaving the tank became constant at 12½ deg., the machine showed capacity of 170 T.

### ELECTRICAL EQUIPMENT

To one who has witnessed the lighting effects produced in this theatre as an integral part of the program, the impression is beautiful beyond comparison. The

# Influence of Moving Picture Theatres

*American Builder*
*June 1924*

# Influence of Moving Picture Theatres

## The Public Now Demands Fine Architecture, Luxurious Fittings and Decorations in All Places of Amusement

THE theatre has had an interesting evolution. Just as the actors reflect human life and "hold the mirror up to nature," so the buildings which house the theatre reflect the advancement of the human race.

The warlike character of the ancient Romans and their lust for conquest is clearly reflected in their amphitheatres. Here we find dens for wild beasts brought from foreign lands and facilities for combat and slaughter. Class distinction, too, is revealed by the arrangement of boxes and seats and there are many other indications of customs and character. The ancient Greeks, in their early theatres, showed by the arrangements for chorus and declamation their philosophical bent and their love for poetry.

The theatre is said to have originated in China, but little is known regarding its arrangement and use. The first recorded stone theatre in Rome was built by Pompey, 55 B. C. The first Greek theatres were located in surroundings which formed a natural amphitheatre—usually at the base of a hill. At the outset, it is probable there were only the natural seats provided by nature. Later, the seats were of wood and, still later, of hewn stone. Many of these stone seats are still to be seen at the site of the early Theatre of Dionysius, at Athens.

The Tivoli Theater, in the Woodlawn District, Chicago, Is Typical of the Extensive Plants Not at All Unusual of Moving Picture Theaters. No class of buildings command more architectural skill or engineering ingenuity. Rapp & Rapp, architects.

Thespis was the first to introduce professional actors, who declaimed the plays of Aeschylus, Sophocles and Euripides. Their theatre was not enclosed by walls or roof. The Roman amphitheatres were enclosed by walls only.

Even the early English theatres of Shakespeare's time had no roofs except over the stage. They were operated only during warm weather seasons. Spectators stood or brought stools, principally for use during intermissions. A large public stoup of ale stood at the entrance, where all might quench their thirst free of charge.

Shakespeare, himself, was manager of the Globe Theatre. At first, being an innovation, the theatre was frowned upon by the more conservative. It was not considered proper for a young woman of good repute to be seen there. This resulted in velvet masks being worn by those women who did attend.

The box was an early development of the English theatre. The rabble stood in the pit but spectators of the upper class were accommodated in boxes or even on the stage. As time went on and the patronage of the aristocracy increased, additional boxes were installed in double tiers. This led to a complete wall of boxes surrounding the pit and adjoining the proscenium arch at both sides. Class distinctions were probably responsible for the installation of galleries when seats were installed in the pit, prices advanced and a better class of patrons occupied the "orchestra seats." There was then a somewhat reduced demand for boxes and the partitions were torn out, which left the balcony—a shallow affair at the back of the house.

When the partitions were removed from the boxes, it left the structural columns exposed. As balconies were enlarged, additional supporting columns were needed, which obstructed the view from many seats on the lower floor. This has been a serious defect in American theaters, only remedied within recent years.

Today very few theaters are being constructed with more than one balcony and this is partly due to the influence of moving pictures. The popularity of moving pictures has enlarged the field and the possibili-

Luxury Has Found No greater Development Than in the Moving Picture Theater. Above, a corridor of the Tivoli, Chicago.

The Proscenium Arch is a Field for Luxuriant Color, Heightened at Will by the Skillful Use of great Batteries of Multicolored Lights, Which Vary the Lighting Colors, Tones and Intensity at the Will of the Operator.

The Foyer of the Tivoli (Below) Rises to a Vaulted Ceiling of Cathedral-like Height and Reveals a Wealth of Architectural Ornamentation.

ties for profit and brought about keen competition. This competition has led directly to many improvements, to make these theatres more attractive. The gallery, with its long, toilsome climb, has passed into history.

The angle of vision to the screen is an important factor in present-day design of theatre buildings. There must be at least 35 feet between the curtain line and the balcony rail, so that the "stepping," or pitch, will not be too great. The picture booth is usually placed on the mezzanine or balcony and the optical rule is that the angle of the light rays must not exceed 25 per cent. If this is exceeded, distortion results. Also, the front of the balcony must not obscure a view of the entire screen from the back.

Early theatre construction in this country often had brick or masonry walls but the flooring, "stepping," bridging and furring were of wood. For this reason, the galleries were firetraps. It was found that 75 per cent of all lives lost in theatre fires could be traced to gallery and balcony patrons. The effort to eliminate this danger has been an important factor in causing designers of theatre buildings to omit all but the first balcony. As now designed, the danger of trampling on stairways in case of panic is small indeed.

When steel construtiou was first introduced, it had a profound effect on theatre design. Not only did it reduce the fire risk—it greatly increased the loads which could be carried and made longer spans possible. This led to the substitution of one large balcony for a number of balconies and gallery, without cutting down the seating capacity. There remained, however, the obstruction of the columns. Engineering skill has now completely solved this problem and theatre patrons do not have to peer around posts in modern auditoriums.

The method of supporting balconies without obstructing columns is frequently by means of the "K" truss—very similar in shape to a letter "K." This truss is a cantilever supported on columns close enough to the side walls and rear walls to avoid any obstruction of view. The "K" truss has a bearing in the side walls and also in the wall at the back of balcony. It has the advantage of requiring less head room than a plate girder and, consequently, allows a greater seating capacity in the balcony. Second balconies are sometimes hung from roof trusses.

Fires and panics have taken a heavy toll from the lives of theatre patrons, which has led to strict municipal supervision and regulation of theatre design. This applies particularly to the number, location and size of stairways and exits and to the fire resisting qualities of the building material and finish. It requires the marking and lighting of exits, regulates the number and size of aisles, the grouping of seats, the "stepping" of floors and many other details.

The width of corridors is fixed by the Chicago building ordinance at a minimum of 4 feet and of stairways at 20 inches for every 100 persons in the room served by the stairway. Thus, where the seating capacity of a balcony is 800, the stairways would have to be 13 feet 4 inches wide. All stairways must have handrailings on both sides, and, when over 7 feet wide, must have double intermediate hand rails. Stairways can only extend 13 feet 6 inches between landings. Treads must not be narrower than 10 inches nor have a rise greater than 8 inches.

A solid brick wall is required between the auditorium and the stage, with a steel curtain in the proscenium arch. There are many other stringent provisions in this ordinance relating to the construction and equipment of theatres. It is so thorough in its public safety provisions that it has been adopted as a model by a large number of cities in the United States.

Practically every theatre erected today is equipped for the showing of motion pictures. In fact, the "movies" have been responsible for a theatrical building boom. A number of years ago there was a tendency to cheap, small structures. Today remarkably fine structures are being erected for this purpose. Many are scientifically designed, beautifully adorned and classic in their architecture. Lobbies frequently have graceful columns, artistic sculpture, mosaic floors and tile ornament, while foyers, lounges, corridors and smoking rooms are often adorned with murals by accomplished artists. Stairways, passageways and aisles have resilient, silent treads. The plaster decoration, painting, color and lighting effects of these auditoriums are usually of great beauty and harmony. They are frequently equipped with large, expensive pipe organs, in addition to orchestras. Heating and ventilation are often ideal, providing 30 cubic feet of fresh air per person per minute. In winter and summer, the air is kept at 70 degrees.

The modern theatre is more perfectly ventilated, heated and cooled than most other structures. In winter, fresh air is drawn from outside through steam tempering coils, which warms it. From here it goes to air-washers located in the basement, which remove dust or other impurities.

These air-washers are of galvanized, non-rusting metal and, in them, the air is passed through a fine water spray. This spray, from a number of specially designed nozzles, fills the spray chamber and falls into a sump below. From there, the water is passed over scrub plates, strained, goes to a circulating pump and is again forced through the nozzles in the spray chamber.

The entrained water is now removed from the air by means of eliminator plates and the air passed over steam heating coils and a steam ejector, to heat and humidify it. It is then forced by a fan into a plenum, or air chamber. From here, ducts take the warm, fresh air to the auditorium, where it is usually admitted through openings under the seats and the vitiated air drawn out by exhaust fans located in the ceiling. The inlets for the warmed air in the winter and the cooled air in the summer is usually through mushroom openings raised above the floor far enough to prevent dust or refuse from falling into them when the fans are not at work.

In the summer, refrigerating coils take the place of the tempering and heating coils. By this means, delightfully fresh and cool air is delivered to the auditorium during warm weather.

The heating and ventilating problem in the average theatre can be better appreciated when it is remembered that between 5,000,000 and 6,000,000 cubic feet of air is passed through the heating and ventilating system of a large theatre in one hour.

It is impossible, in an article of this length, to describe or even mention all the beautiful new theatres which have been erected in the United States during the last few years. One of the most recent examples of fine theatre construction is the B. F. Keith Palace Theatre, of Cleveland, designed by Rapp and Rapp, architects, of Chicago.

This theatre is located in a 21-story office building of steel frame construction, with concrete floor slabs and with foundations resting on concrete piles. The building stands on a lot which measures 135 feet by 300 feet and the area of all floors totals 200,000 square feet. It is imposing in appearance and of modern design and equipment throughout.

The theatre, itself, is one of the most beautiful in the United States and seats 3,600 people. Its main lobby, staircases and mezzanine constitute an art gallery of rare beauty in architectural design, decoration and paintings by original masters. The main lobby is 18 feet wide by 75 feet long. The walls of the lobby

*(Continued to page 336.)*

## Air Conditioning American Movie Theatres
## 1917-1932

# Keeping Cool
# Rivoli New York
# Metropolitan LA

*Los Angeles Time*
*6th September, 1988*

Carrier Corp.

When New York's Rivoli Theatre installed an air-conditioning system in 1925, it revolutionized the movie industry.

# Keeping Cool Was Once a Hot New Idea

By ALICE STEINBACH, *The Baltimore Sun*

Let us begin with the alarm going off and the radio going on.

The 7 a.m. temperature: 86 with a predicted high reaching into three digits.

So another scorcher of a day dawns and you get up, drink some iced orange juice, jack up the air conditioning, take a cold shower, mousse your hair, dress in loose clothes and—what the heck, this isn't so bad once you get the hang of it—prepare to take on whatever the weatherman throws at you.

Then you open the front door.

It's only 8 a.m., but already heat waves are shimmering off the blacktop on your driveway. A solitary jogger, looking like an automated cadaver in nylon tank top and shorts, runs by. Your unwatered garden droops in the thick, humid air, and your long-haired cat looks like a good candidate for storage at the refrigerated fur vaults.

There's an eerie, deserted feeling out on the streets. That's when you notice the pulsating sound: Hmmmmmmmmmmmmm.

Undulating through the still, hot air, the voice of the air conditioner is heard in our land.

□

Air conditioning. Imagine how different life would be today if in 1902 an inventive young Cornell graduate—25-year-old Willis Carrier—hadn't devised a way to lower simultaneously the temperature of—and the humidity in—air by pumping it over refrigerated coils. He patented his invention under the name "Apparatus for Treating Air."

In the late 1800s, there had been some attempts to reduce air temperature by blowing fans over ice or cooled liquid, but the real breakthrough in the perfection of what we now call air conditioning (a term coined in 1906 by engineer Stuart Cramer) came about because of Willis Carrier's insight that it was necessary not only to cool the air but also to remove the moisture.

The first installation of his new idea was in 1902 at a Brooklyn printing plant. Soon the Carrier Corp. was air-conditioning factories and plants across the country. In

**Please see COOL, Page 4**

Los Angeles TIMES Sept. 6, 1988 Pt-V Page 1

GRAUMAN'S METROPOLITAN RENAMED PARAMOUNT IN 1929

# COOL: Air Conditioning

**Continued from Page 1**

1906, Carrier air-conditioned the first paper mill, in New York; in 1907, the first pharmaceutical plant, in Detroit; in 1908, the first celluloid film plant, in New Jersey; in 1909, the first tobacco warehouse, in Kentucky; in 1910, the first candy plant, in Milwaukee; and in 1911, the first bakery, in Buffalo.

Then, in 1912, Willis Carrier was engaged by the Emerson Drug Co. in Baltimore to install air conditioning in the building where the company produced one of its best-selling products: Bromo-Seltzer. The moisture in the air, it seemed, was a problem that affected the effervescing qualities in Bromo-Seltzer. Many other drug companies across the country followed the company's example.

### Hudson's Pioneered

It was not until the 1920s that the idea of using air conditioning to benefit people—as opposed to bettering industrial production—took hold. It made its debut in "comfort-cooled" movie theaters.

Nationally, the first movie house to install air conditioning was Grauman's Metropolitan Theater in Los Angeles in 1922. But the idea really took off when New York's remodeled Rivoli Theatre opened on Memorial Day, 1925, fully air-conditioned. During the next five years, more than 300 theaters around the country were air-conditioned.

The first department store to be air-conditioned was J.L. Hudson's in Detroit, in 1924. It rejuvenated summer sales, and retailers around the country began to think about trying the invention.

The 1930s ushered in the use of air conditioning in hospitals. Again, Willis Carrier had been the first to air-condition a hospital ward; in 1914 he air-conditioned the premature babies' nursery at Allegheny General Hospital in Pittsburgh.

### Homes Sales Leaped

But the real breakthrough in the years preceding World War II was in the use of air conditioning to cool employees working in office buildings. "Until then the idea that people should be cool while they worked was considered somewhat fanciful," commented American Heritage magazine in a 1984 article on air conditioning.

The forward march of air conditioning was brought to an abrupt halt with the advent of World War II. It resumed after the war with residential cooling as its main target. The success of air-conditioned hotel rooms had given consumers a taste of what it was like to sleep in cool air.

But home air conditioning did not really take off until the early 1950s. Before then, the air-conditioning units were too expensive and too bulky and, most important, they required installation by a contractor. Then, with the development in the early '50s of a simple, box-type unit that could be plugged into an electrical outlet by the homeowner, sales leaped. In 1953, dealers sold more than a million home units as compared to 74,000 in 1948.

By 1962, air conditioning had been installed in 6.5 million homes in the United States. Now two-thirds of all new homes built in the United States come equipped with air conditioning. Another 29% or so have some sort of room air conditioning.

And private cars? In 1986, four out of five cars came factory-equipped with air conditioning.

□

Air conditioning. For better or for worse, it changed the way we live. It opened up industry in the South and contributed dramatically to the growth of the Sun Belt. Nationwide, it improved production rates in factories and offices. It takes the misery out of the dog days of summer for those who can afford it and improves the comfort of the elderly, the sick and the hospitalized.

But there are those who feel we've lost something, too, in this climate-controlled world. A strong sense of place, perhaps. Now, they say, you can't tell the difference between summer in Atlanta and summer in Boston. And a point might be made that the air conditioning of America has separated us even more from the heartbeat of nature—from those reliable, predictable changes of season that really mark our lives in a way that naming a precise month and day and year do not.

Can you remember? It was after supper on a summer evening and all the fathers and the mothers sat outside with the children. The air was still and hot and the only sound was that of the screen door slapping shut. And then someone turned on the sprinkler and the grass grew damp and cool, and your mother let you lie face down in it. And then it grew dark and the stars came out but it was still too hot to go in. So you fell asleep on the grass, dizzy from the beauty of it all.

---

## Class on Hypertension

A free class for persons with high blood pressure will be offered by Kaiser Permanente Medical Center, 4867 Sunset Blvd., from 7 to 10 p.m. Sept. 15. Topics will include medications, diet and relaxation techniques.

Information: (213) 667-4472.

# Rockefeller Centre
# The Challenge of
# Keeping Cool

Menu
Search
CALMAC
We make comfort cooling for a greener, smarter future.

# Rockefeller Center

## Read about the challenge of keeping one of New York City's most iconic properties cool.

### Project Facts

- Home to NBC, Radio City Music Hall and the world-famous ice skating rink and Christmas tree
- 14,500 tons of steam and electric driven chillers
- Ice making chiller sized to provide 8,600 ton-hours of thermal energy storage
- 1025 kW of thermal energy storage
- Download the case study (/stuff/contentmgr/files/0/385c3a02481e43418cff6961c65bc3df/files/rockefeller_center_case_study_hpac_engineering.pdf)
- Watch the video (/rockefeller-center) .

Rockefeller Center is one of the most recognized commercial properties in the world.

### OVERVIEW: THE CHALLENGE OF KEEPING COOL ONE OF NEW YORK CITY'S MOST ICONIC PROPERTIES

Rockefeller Center is one of the most recognized commercial properties in the world. Defining midtown Manhattan, Rockefeller Center encompasses the six square blocks between Fifth Avenue and the Avenue of the Americas from 48th to 51st Streets. The landmark property consists of approximately 8 million rentable square feet in ten buildings with unique, internationally recognized architectural features. Rockefeller Center is not only a place of business but also a premier destination for world-class shops and restaurants. It is home to NBC, Radio City Music Hall and the world-famous ice skating rink and Christmas tree. The complex was built during the Art Deco period of the early 1930s and is currently co-owned and operated by Tishman Speyer.

Since 1996, Tishman Speyer has been dedicated to preserve and restore this New York landmark, increase tenant comfort, and make sustainable improvements to preserve the assets of the iconic building.

## CHALLENGE: THERMAL ENERGY STORAGE BOOSTS ENERGY EFFICIENCY AT ROCKEFELLER CENTER

To supplement the existing air conditioning by pumping chilled water around the entire Rockefeller Center complex, Joseph Szabo, currently managing director at Tishman Speyer, wanted to investigate technologies that could be incorporated into the complex's existing chilled water infrastructure. Mr. Szabo approached the Trane, a leading global provider of indoor comfort systems and services and a brand of Ingersoll Rand, to investigate the feasibility of applying Trane high efficiency electric chillers and CALMAC energy storage technology to Rockefeller Center.

The buildings of Rockefeller Center are served by a central chilled water plant containing 14,500 tons of steam and electric driven chillers. The water is distributed around the entire building campus through a primary water loop which travels around the perimeter of the site. There are six primary pumps located in the main plant, four having 6,000 GPM capacity at 125hp and two having 2,000 GPM capacity at 50hp. Each individual building has pumps which then draw off of the primary loop and send the main plants chilled water to heat exchangers located within each building. There are seventeen of these primary chilled water riser pumps which range in size from 1000 GPM at 40hp up to 3500 GPM at 200hp. The secondary side of the heat exchangers have pumps which serve the air handlers and fan coils which serve the tenant spaces, and individual building pumps draw chilled water to heat exchanges located within each building.

One of the biggest challenges has traditionally been the critical tenant requirement of supplying chilled water at the required temperature and flow to satisfy tenant comfort and lease requirements in all buildings of the Center at all times of the year. While the supply and pumping capacity has always met requirements, Tishman Speyer sought a way to deliver the water more efficiently.

## SOLUTION: STORING ENERGY IS THE ANSWER

After learning of some of the successes of applying thermal storage to buildings throughout New York City, Mr. Szabo approached Fred Limpert at Trane and Mark MacCracken of CALMAC to conduct an analysis of the complex and identify the feasibility of applying Trane high efficiency electric chillers and CALMAC ice storage technology to Rockefeller Center. Tishman Speyer wanted an analysis to see how it could improve efficiency and lower overall energy costs.

“The thermal energy storage installation has simplified plant operations and we no longer have to make those tough, on-the-spot decisions as to when and if to turn on chillers in the main plant. Turning on chillers of this size can result in large electrical demand cost penalties, especially in New York City which has a high electrical demand utility rate structure,” said Joseph Szabo, currently managing director at Tishman Speyer
Trane and CALMAC spent the subsequent weeks investigating the financial and efficiency benefits of applying thermal storage technology specifically to Rockefeller Center.

Instead of meeting summer peak demand with a single electric chiller, the solution was to install an ice making chiller sized to provide 8,600 ton-hours of energy storage. When it's time to cool, especially during peak demand periods, cooling from the ice storage tanks is used instead of the electric chiller, keeping electricity demand as low as possible.

An additional benefit of having the energy storage available is greater operational flexibility. The stored cooling can be used as it is needed from a couple of hours to several hours to optimize plant efficiency while keeping demand and cooling costs low.

Due to the expansive footprint of the Rockefeller Center site, there were a number of locations that were considered for a thermal energy storage plant. It was eventually determined that the optimal location was in areas on the other side of the property from the main plant. Having the energy storage plant located away from the main plant has shifted the burden of pumping chilled water from the main plant to the outer buildings. As the ice burn is injected to the Center's primary chilled water loop, the variable frequency drives on the main plant's primary chilled water pumps are able to be ramped down as the chilled water required by the outside buildings is satisfied by the chilled water being provided by the ice plant.

The operators are now able to have the primary chilled water pumps running at lower amperage levels than the system had previously allowed. In the summer, with the ice burning during peak demand periods (usually 12 noon to 6 p.m.), the plant only has to run one of the three chillers. (Typical burn times are 8 hours in summer and 15 hours in the winter.) In the winter, when cooling loads are low, they can just burn the ice and only run the ice making chiller at night. No chillers need to run during the day.

"The ice plant has provided a level of operational flexibility that has allowed my engineering staff to make intelligent decisions at any point in time that ensures we are able to balance tenant comfort with plant operational efficiency," said Mr. Szabo. "The thermal energy storage installation has simplified plant operations and we no longer have to make those tough, on-the-spot decisions as to when and if to turn on chillers in the main plant. Turning on chillers of this size can result in large electrical demand cost penalties, especially in New York City which has a high electrical demand utility rate structure."

## RESULTS: ICE= FROZEN ASSETS

As Tishman Speyer began incorporating the energy storage plant into their overall heating, ventilation and air-conditioning (HVAC) strategy at Rockefeller Center, they began to see a positive ripple effect on all aspects of the plant's operation. While there was an immediate benefit in allowing the operators to shift on-peak cooling loads to off-peak, there was an added benefit of allowing the operating staff to use the rate of ice melt, or "burn," to meet the current needs of the buildings.

"Not only does the Ice Storage refrigeration plant provide 'banked' cooling capacity for peak demand periods during the day, it also increases your operational flexibilities to the assets during spring and fall seasons, when you can side stream the ice reserve with smaller refrigeration machines to reduce your overall demand in shoulder months," said Joseph Szabo, currently managing director at Tishman Speyer.
Prior to the energy storage plant, on peak cooling days, the building engineers would run one 4,000 ton steam turbine chiller, one 4,000 ton electric chiller, and one 2,500 ton electric chiller. Incorporating the ice burn into the operation of the main plant allowed Tishman to eliminate putting the 2,500 ton electric chiller on line. The operators also take advantage of the fact that the ice burn rate can be adjusted from four hours to 10 hours as needed based on plant conditions.

"Not only does the Ice Storage refrigeration plant provide 'banked' cooling capacity for peak demand periods during the day, it also increases your operational flexibilities to

the assets during spring and fall seasons, when you can side stream the ice reserve with smaller refrigeration machines to reduce your overall demand in shoulder months," Szabo said.

The installation of a thermal energy storage system has significantly improved the energy efficiency of Rockefeller Center and dramatically lowered overall energy costs.

## SUMMARY: ICE CAN WORK FOR YOU

Energy storage systems are uniquely designed to meet a building's efficiency and energy cost needs. Many types of applications, small or big, from schools and hospitals to commercial office buildings and retail establishments use ice storage. Each system is designed to work with each specific building, taking into account the number of chillers and tanks, how often the tanks and chillers are online, if operators are needed, financial analysis and building size and use, etc.

While Rockefeller Center uses the ice chiller only at night to make ice, then utilizes a partial storage strategy during the day, other installations may use the same chiller that makes ice to provide cooling in conjunction with the ice tanks during the day. Each installation is different, but they all work to reduce cooling costs and peak electric demand.