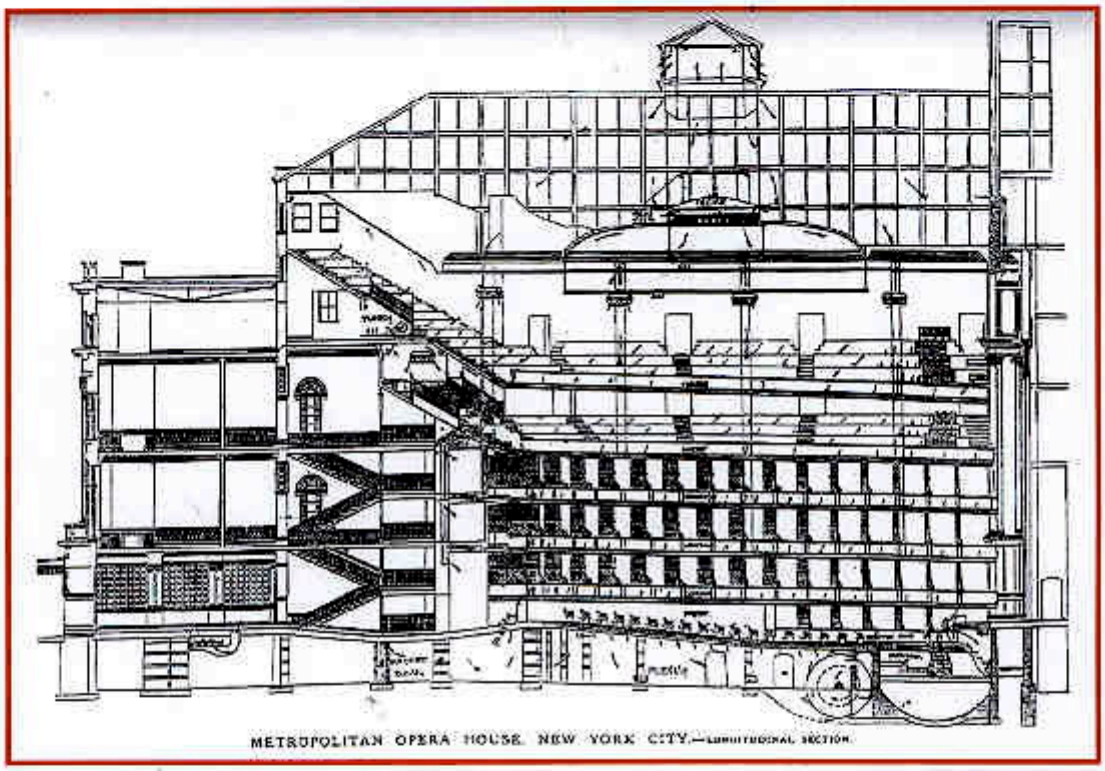
Nineteenth Century Theatres

Old Metropolitan Opera House, New York

Date Built/Opened: 1883
Seating Capacity: originally 3045, increased to 3849 in 1892
Architect: Josiah Cleaveland Cady
HVAC Engineer: Frederic Tudor Jr [*The Comfort Makers*, entry 210]
HVAC System: Plenum (pressurised) fresh air ventilation system with heated water pan humidifier, 12.5 ft diameter fan supplying about 70,000 ft^3/min
Status: Building destroyed by fire in 1892 and rebuilt. New Opera House built at Lincoln Centre in 1966
References: *Ventilation and Heating*, John S Billings, The Engineering Record, London, 1896
The Golden Horseshoe, Martin Secker & Warburg, London, 1965

Nineteenth Century Theatres

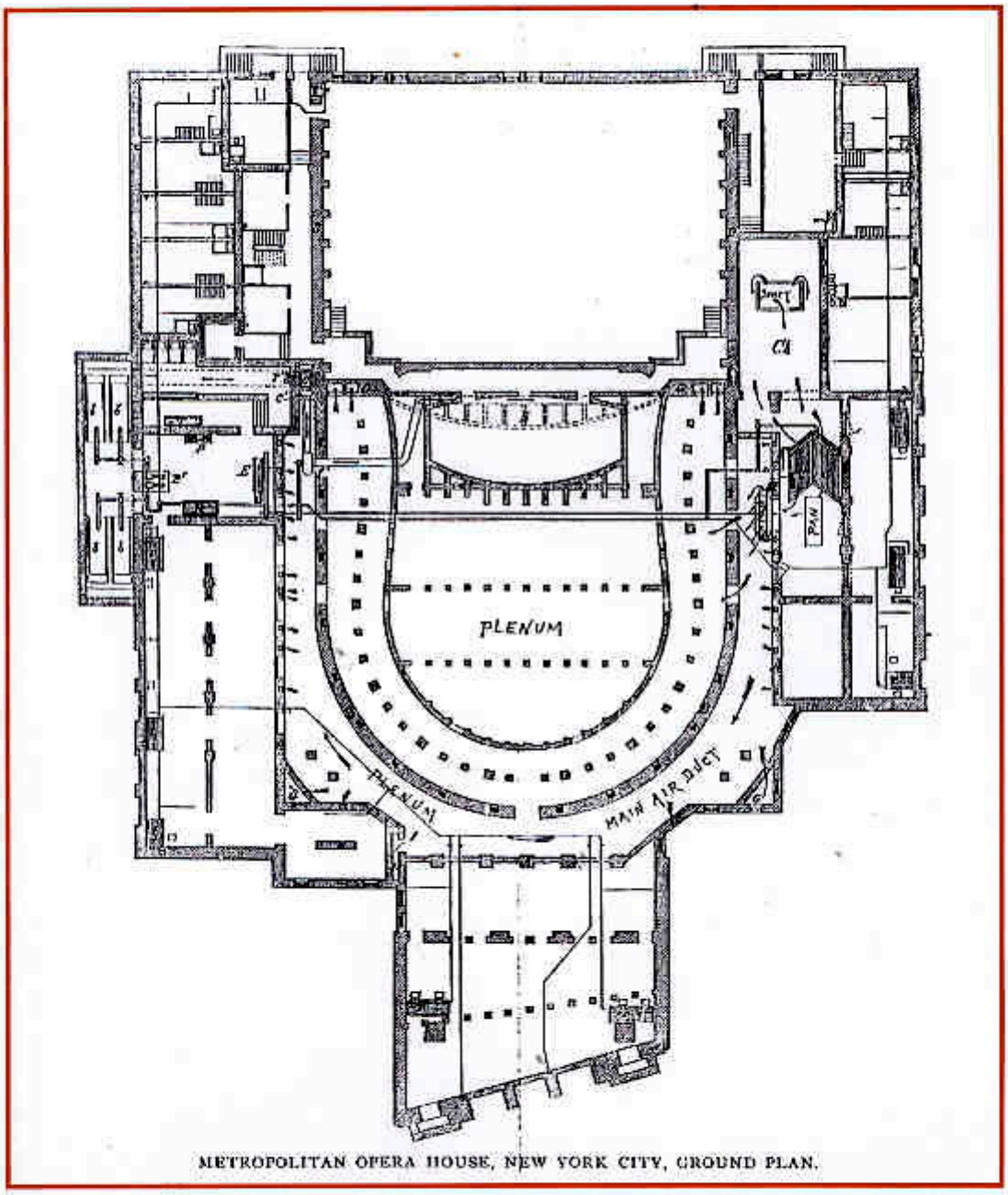
Old Metropolitan Opera House, New York



METROPOLITAN OPERA HOUSE, NEW YORK CITY.—LONGITUDINAL SECTION.

Nineteenth Century Theatres

Old Metropolitan Opera House, New York



METROPOLITAN OPERA HOUSE, NEW YORK CITY, GROUND PLAN.

Old Metropolitan Opera House, New York

and comfort.

The Metropolitan Opera House, in New York City, recently burned, was another large building of this class in which excellent results were secured, so far as heating and ventilation are concerned. The apparatus in this case was devised by Mr. Frederic Tudor, and is described in *The Sanitary Engineer* of December 6 and 13, 1883.

The principle involved was "plenum ventilation," the object being to have a pressure within the building slightly in excess of that of the air without the walls, so as to insure an outward current through crevices of doors or windows or through accidental openings. To this end the shaft (at the right of the stage on the ground plan) 7'x10'6" (73.5 square feet), was provided in connection with the fan, *f*. Air was taken in at a height of 75 feet from the ground, and 60 feet below the top of the boiler chimney, and as remote therefrom as possible. The air drawn down through the shaft entered a settling chamber, 48x20 feet, with a height of 10 feet, and thence it was drawn through the heating coils *C C*, or passed around through the swinging doors, as shown, to the fan. From the fan the general course of the air is through the main air duct, between the walls *A* and *B* in the basement in the direction of the arrows, but all the basement within the walls *A A* is subject to the same pressure. From the basement room immediately under the auditorium floor the air was admitted through many 4x4-inch openings made through the brick arches into the space between the arches and the floor. From this space the air for the occupants of the parquet chairs passed through the risers of the floor steps on which the chairs

Nineteenth Century Theatres

Old Metropolitan Opera House, New York

were set. In these risers were openings continuous at their face, but of peculiar construction, and covered with No. 16 galvanized iron perforated with $\frac{1}{10}$-inch holes.

The air which supplied the boxes was carried from the main air

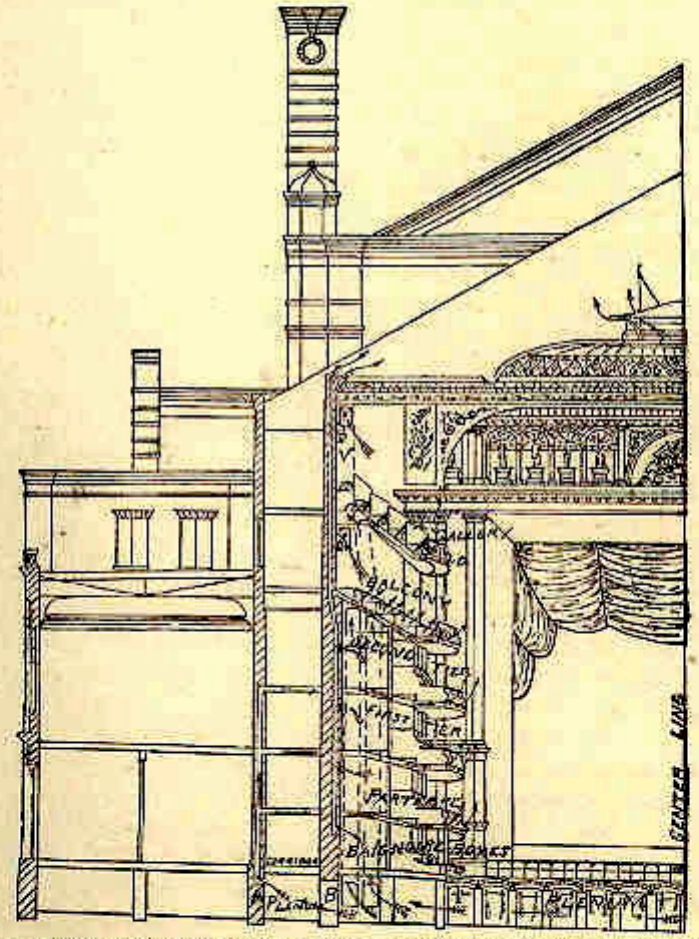


FIG. 130.—METROPOLITAN OPERA HOUSE, NEW YORK CITY.—TRANSVERSE SECTION.

duct in the flues in the wall *A* to the spaces between the floors and ceilings, as shown on transverse section, and discharged at the edges of the tiers at *a a*. Its course was then upward and backward, to the flues in the wall *B*, which had an exhausting power derived from the

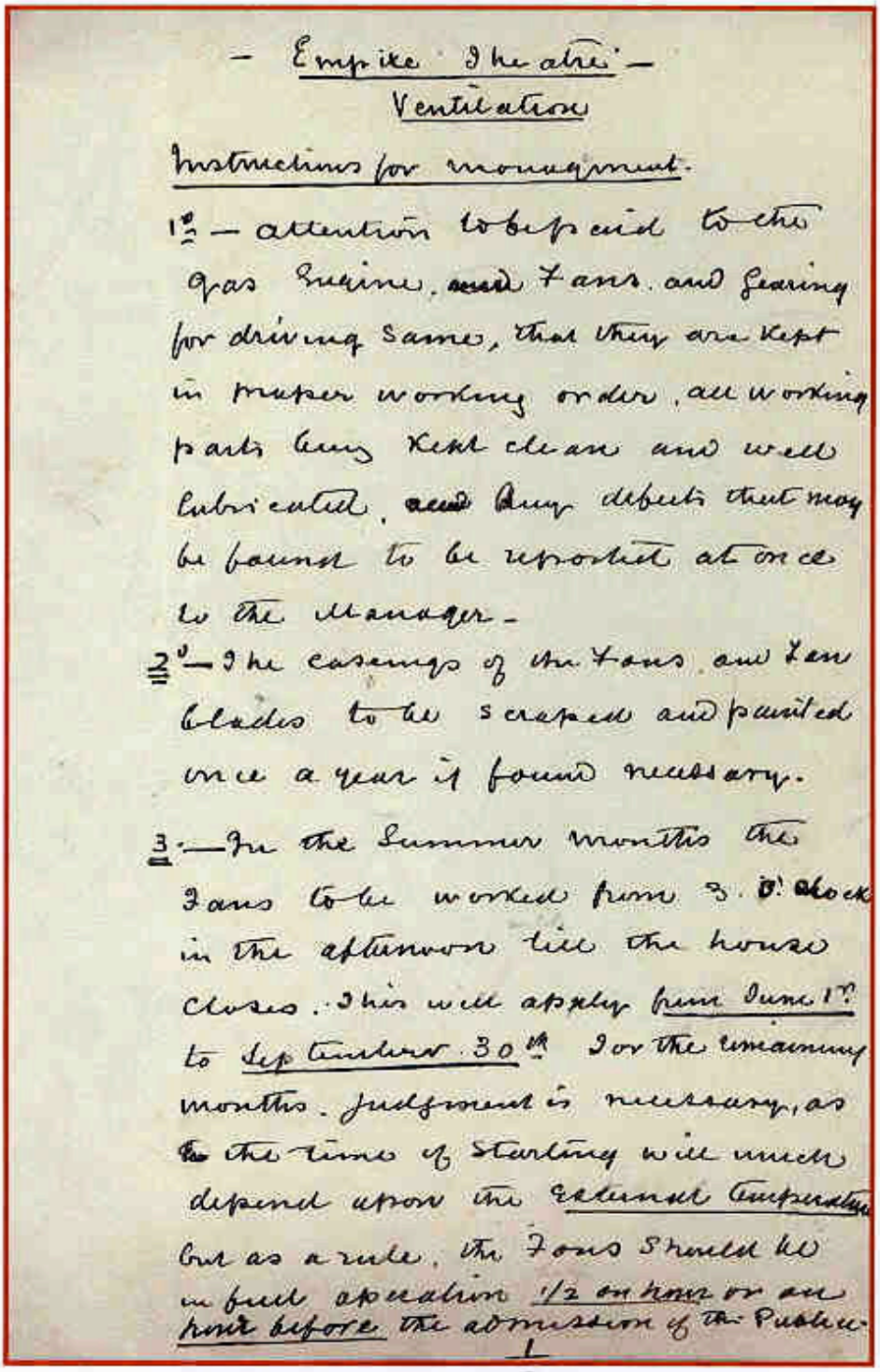
Nineteenth Century Theatres

The Empire Theatre, Leicester Square, London

Date Built/Opened: 1884
Seating Capacity: Unknown
Architect: Thomas Verity
HVAC Engineer: Wilson Weatherley Phipson [*The Comfort Makers*, entry 203]
HVAC System: Mechanical ventilation, fans driven by gas engine and using the gas lighting to assist warming up
Status: Unsuccessful as a theatre, became a music hall in 1886. Replaced by Empire cinema in 1927
References: *Wilson Weatherley Phipson: Victorian Engineer Extraordinary,* Brian Roberts, electronic book on Heritage Group website

Nineteenth Century Theatres

The Empire Theatre, Leicester Square, London



– Empire Theatre –

Ventilation

Instructions for management.

1st – attention to be paid to the gas engine, and Fans, and gearing for driving same, that they are kept in proper working order, all working parts being kept clean and well lubricated, and any defects that may be found to be reported at once to the Manager –

2nd – The casings of the Fans and Fan blades to be scraped and painted once a year if found necessary.

3rd – In the Summer months the Fans to be worked from 3. O'clock in the afternoon till the house closes. This will apply from June 1st to September 30th For the remaining months, judgment is necessary, as the time of starting will much depend upon the External Temperature but as a rule, the Fans should be in full operation 1/2 an hour or an hour before the admission of the Public.

1

Letter 12 March 1890

Nineteenth Century Theatres

The Empire Theatre, Leicester Square, London

4 — The gas burners to be cleaned and overhauled twice a year, once after the summer working, and before commencing same. i.e. in May, and November.—

5 — The principal points to attend to in the management of the Ventilation arrangements, is that the atmosphere of the House is fresh before the admission of the Public. and for this purpose the attendants should as early as possible visit the building and have all available openings for admitting fresh air in operation, so as to produce a complete ~~no~~ natural circulation of fresh air over the House —

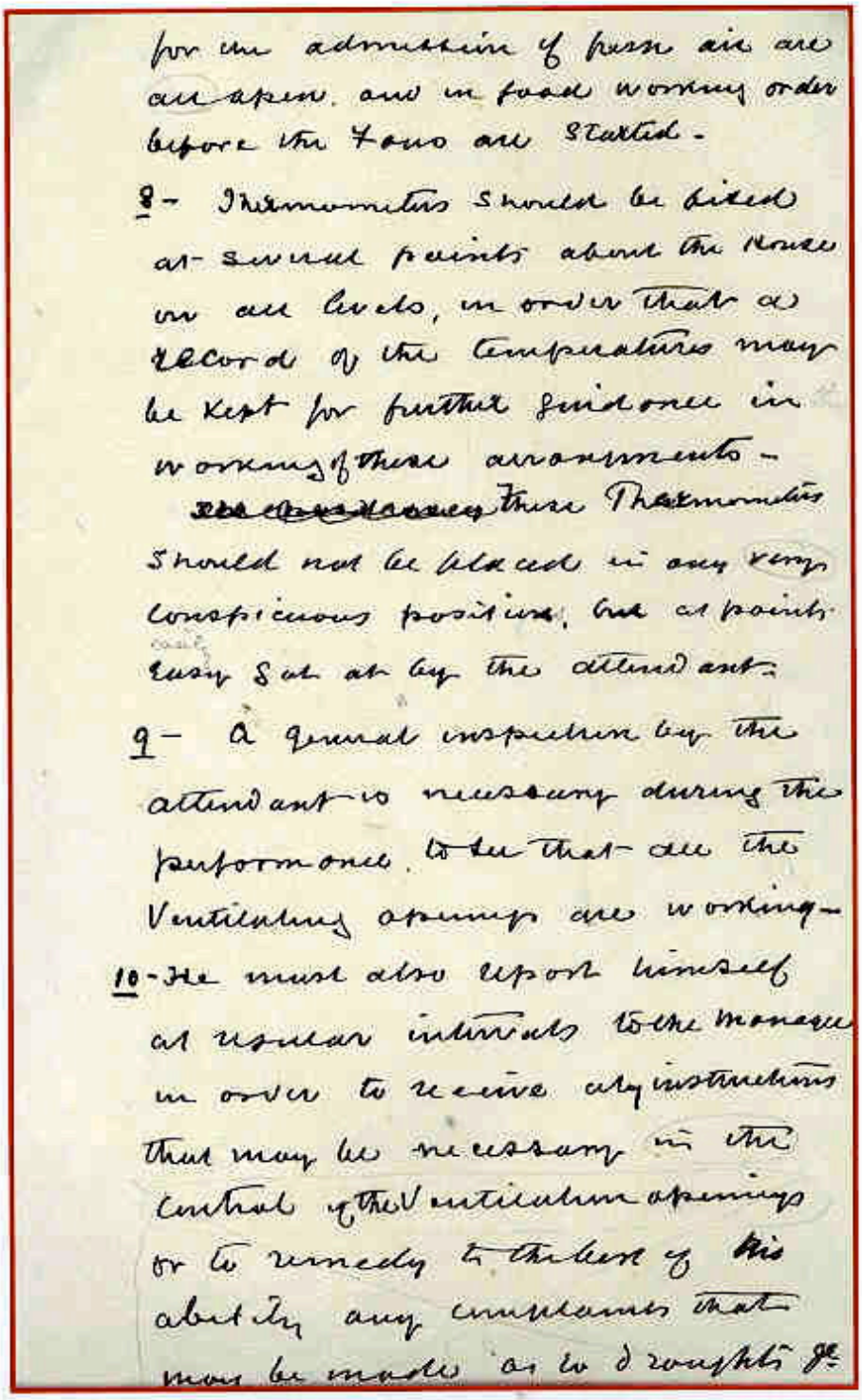
6 — It would also be advisable in order that this circulation of the air be kept up as long as possible that the drop curtain be not lowered before 7. o'clock —

7 — The attendants should also see daily that all the Ventilating shafts and openings over the doors

Letter 12 March 1890

Nineteenth Century Theatres

The Empire Theatre, Leicester Square, London



for the admission of persons are all open, and in good working order before the doors are opened.

8- Thermometers should be fixed at several points about the House on all levels, in order that a record of the temperatures may be kept for further guidance in working of these arrangements. ~~xxx xxxxxxxx~~ These Thermometers should not be placed in any very conspicuous position, but at points easily seen at by the attendants.

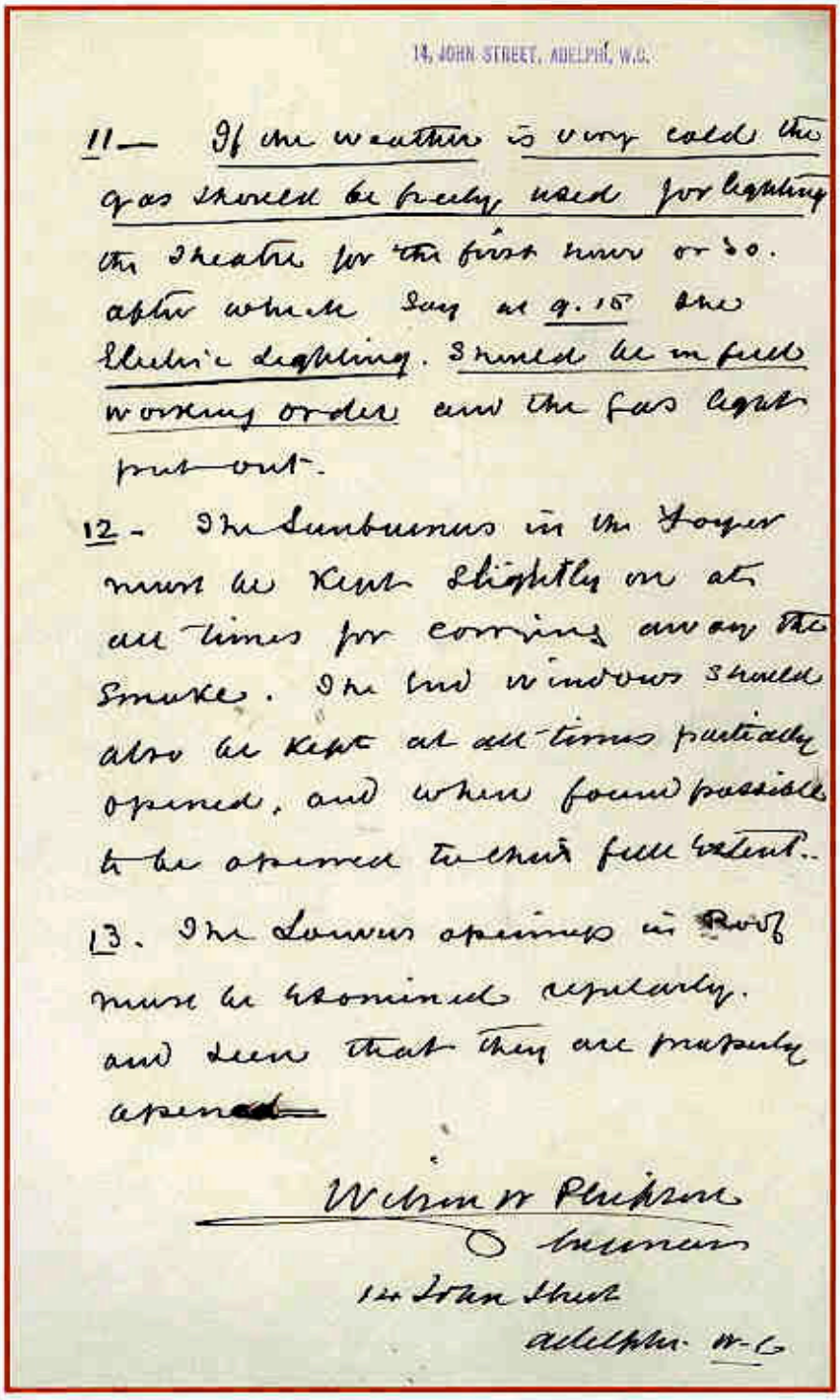
9- A general inspection by the attendant is necessary during the performance, to see that all the Ventilating openings are working.

10- He must also report himself at regular intervals to the Manager in order to receive any instructions that may be necessary in the control of the Ventilating openings or to remedy to the best of his ability any complaints that may be made as to draughts &c.

Letter 12 March 1890

Nineteenth Century Theatres

The Empire Theatre, Leicester Square, London



14, JOHN STREET, ADELPHI, W.C.

11— If the weather is very cold the gas should be freely used for lighting the Theatre for the first hour or so. after which say at 9.15 the Electric lighting. should be in full working order and the gas light put out.

12 - The Sunburners in the Foyer must be kept slightly on at all times for carrying away the smoke. The end windows should also be kept at all times partially opened, and when found possible to be opened to their full extent.

13. The Louvers openings in Roof must be examined regularly. and seen that they are properly opened

Wilson W Phipson
Business
14 John Street
Adelphi W.C.

Letter 12 March 1890

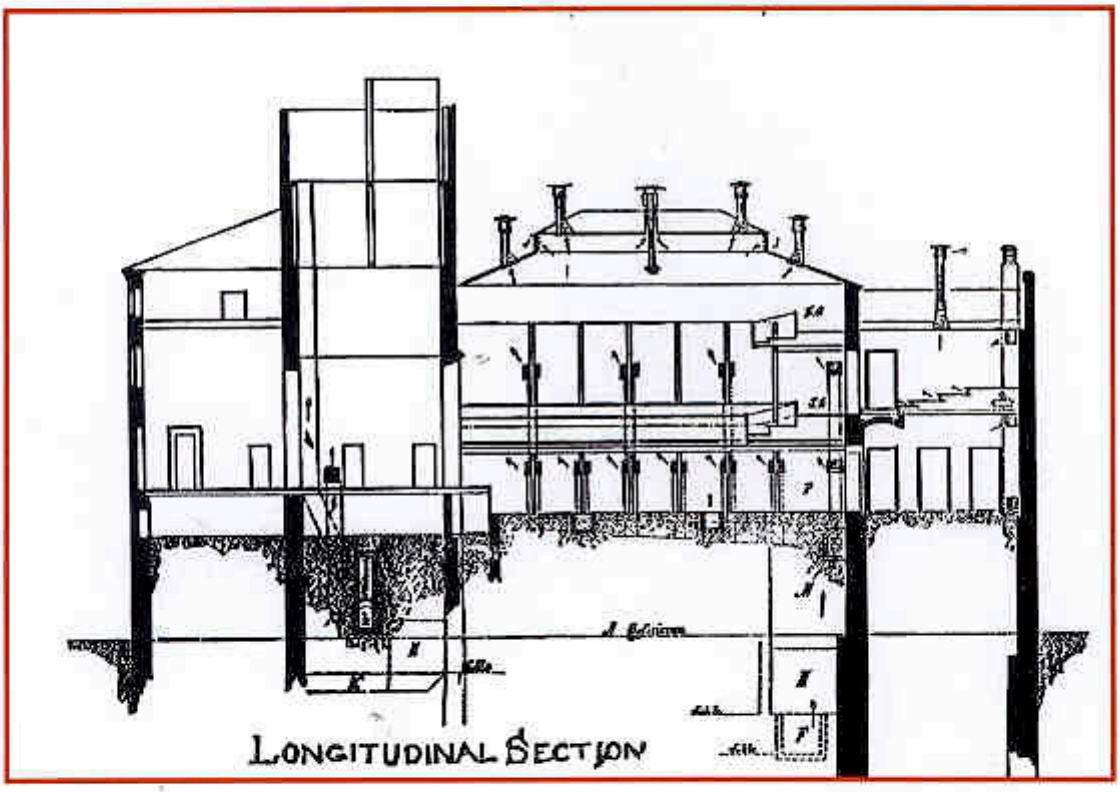
Nineteenth Century Theatres

Vienna Orpheum

Date Built/Opened: before 1886
Seating Capacity: Unknown
Architect: Unknown
HVAC Engineer: Unknown
HVAC Systems: Supply air ventilation upwards from basement with extract through roof chimneys
Status: Unknown
References: The Engineering Record, 1886

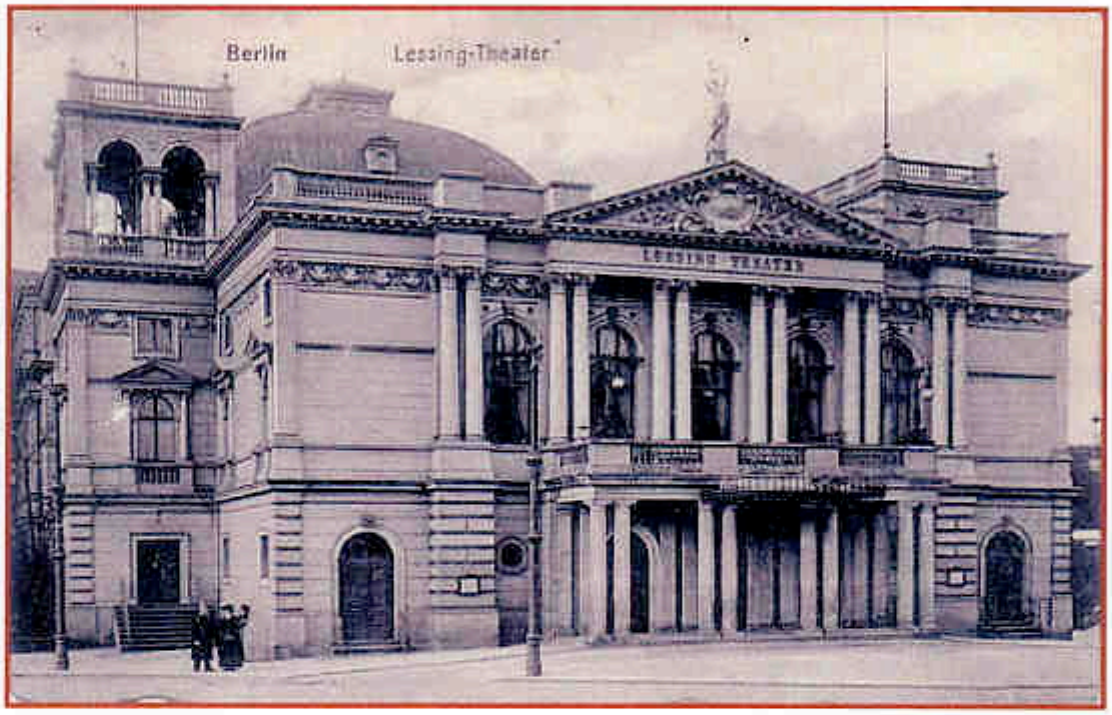
Nineteenth Century Theatres

Vienna Orpheum



Nineteenth Century Theatres

The Lessing Theatre, Berlin



Date Built/Opened: 1888
Seating Capacity: 1100
Architect: Julius Hennicke & Hermann Philipp von der Hude
HVAC Engineer: Unknown
HVAC System: Fresh air ventilation system supplied beneath the seats at the rate of 1410 ft^3/person and at a velocity of 1.3 ft/sec
Status: Destroyed by bombing in 1945
References: *Ventilation and Heating*, John S Billings, The Engineering Record, London, 1896

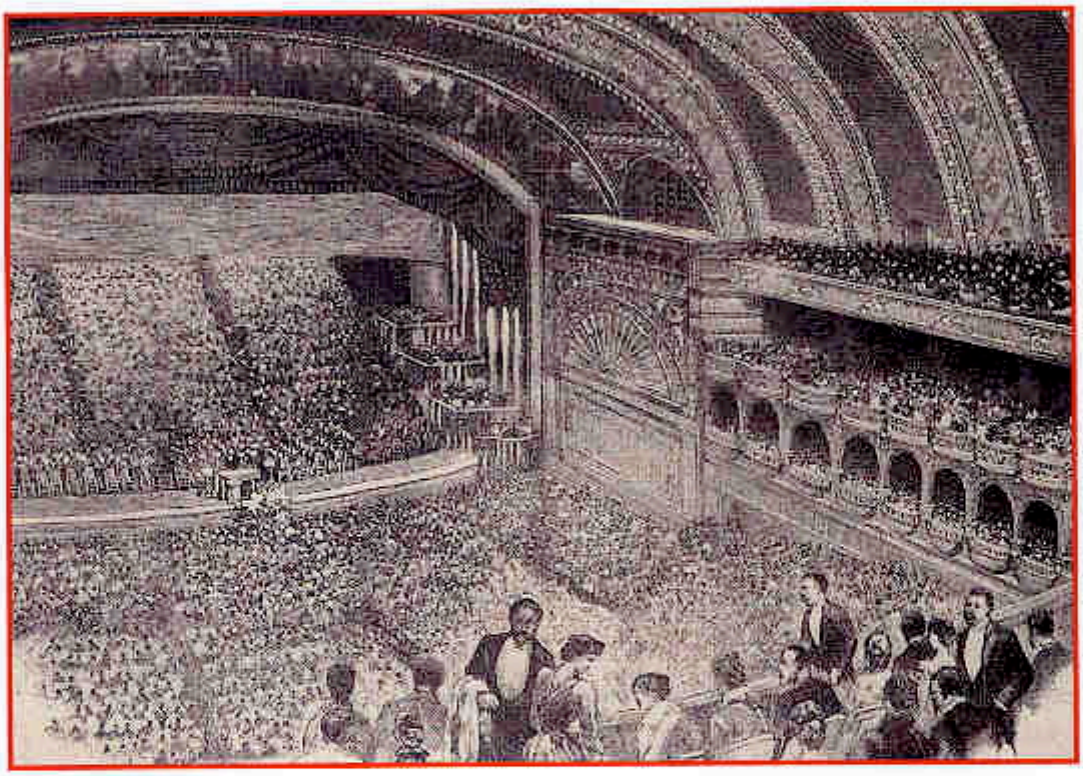
Nineteenth Century Theatres

Auditorium Building Theatre, Chicago

Date Built/Opened: 1886-90
Seating Capacity: About 5000 persons but some 6000 with temporary seating
Architect: Dankmar Adler & Louis Henri Sullivan [*The Comfort Makers*, entries 198 & 199]
HVAC Engineer: Unknown
HVAC System: Ventilation system with water spray cooling or humidification and unusual ornamental plaster hemispherical air diffusers. Fantastic decorative ceiling lighting arrangement into which the plaster diffusers are integrated, with a total of 5000 house lights. There was a steam distribution system across the front of the stage to create a dramatic "smoke effect" if required and an extensive hydraulic system for enlarging the proscenium opening, elevating or depressing various sections of the stage floor and lifting machinery. Notable for its amazing acoustics and excellent sightlines designed by Adler on the "isocoustic curve" principle.
Status: Remodelled with upgraded services and re-opened 1967
References: *Eighty Year Old Theatre Reopens*, Heating, Piping & Air Conditioning, November 1967
The Chicago School of Architecture, Carl W Condit, The University of Chicago Press, 1964

Nineteenth Century Theatres

Auditorium Building Theatre, Chicago

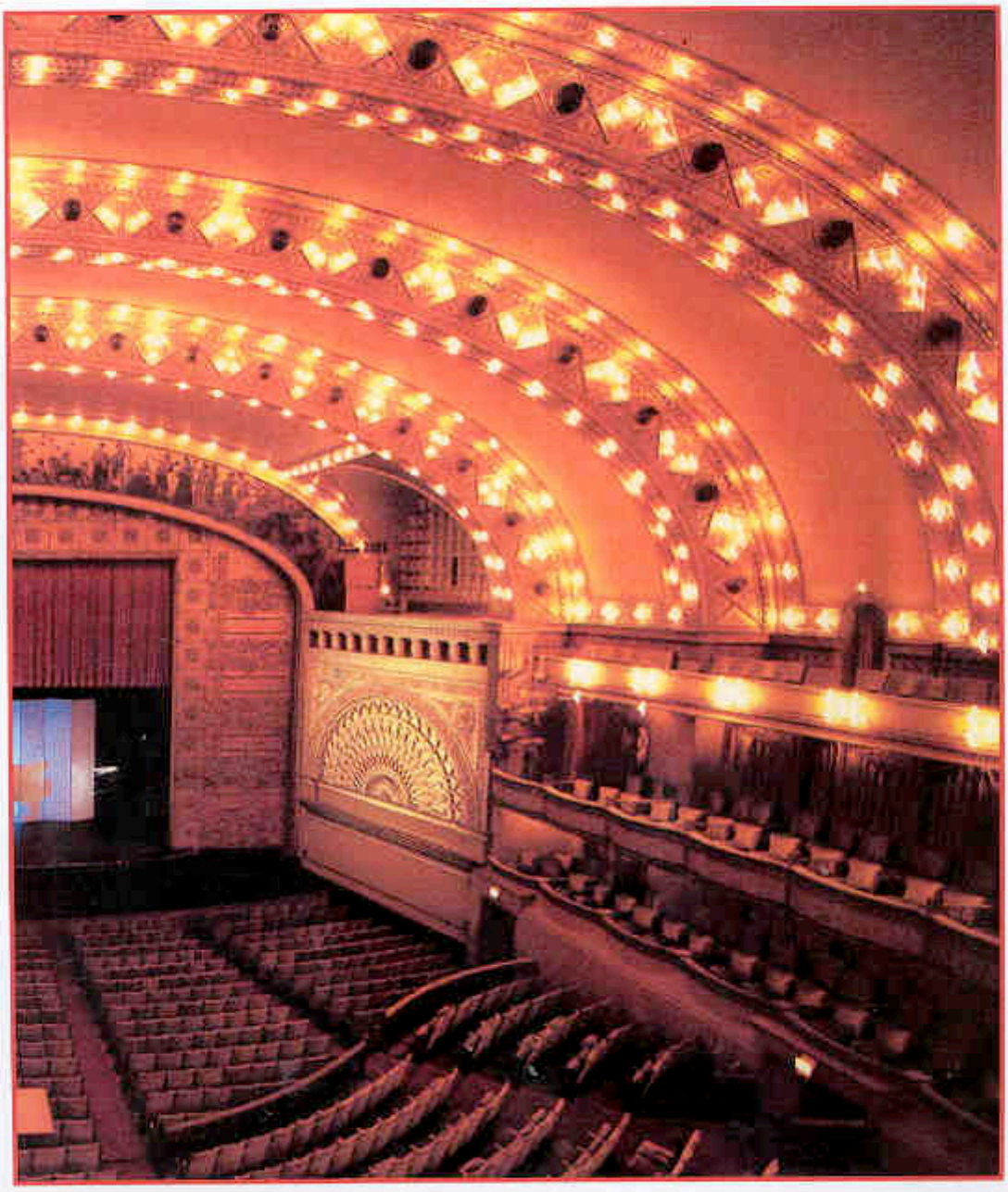


Opening night 9 December 1889

Plaster supply air diffuser

Nineteenth Century Theatres

Auditorium Building Theatre, Chicago

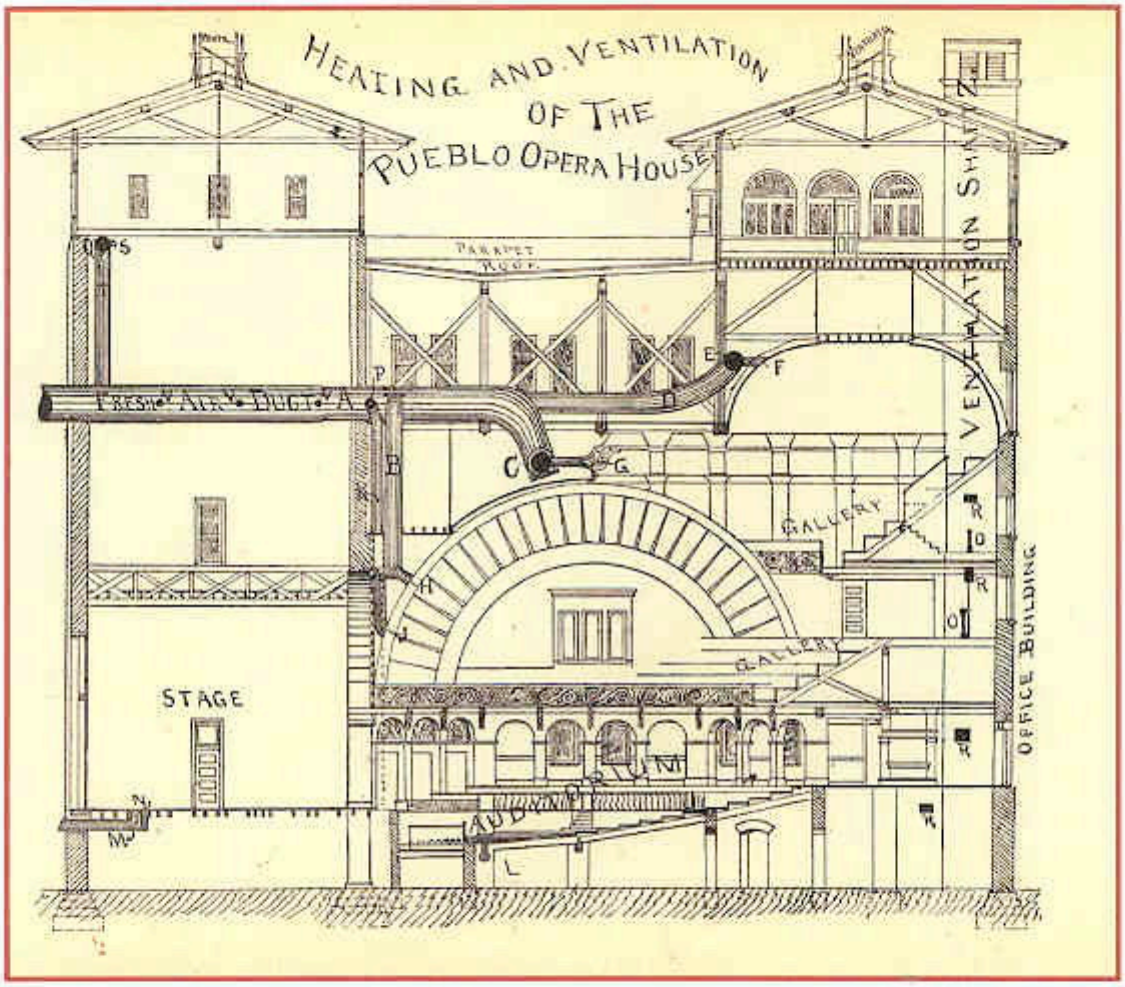


Nineteenth Century Theatres

The Grand Opera House, Pueblo, Colorado

Date Built/Opened: 1890
Seating Capacity: unknown
Architect: Dankmar Adler & Louis Sullivan of Chicago Sullivan [*The Comfort Makers*, entries 198 & 199]
HVAC Engineer: L H Prentice Company, Chicago
HVAC System: Fresh air ventilation system with arrangement for mixing tempered (preheated) air and hot air in varying proportions.
Status: Building destroyed by fire in 1921
References: *Ventilation and Heating*, John S Billings, The Engineering Record, London, 1896

The Grand Opera House, Pueblo, Colorado



The heating and ventilation of the Pueblo Opera House, at Pueblo, Col., are described and illustrated in *The Engineering Record* of May 23 and May 30, 1891, from which the following summary is taken:

Figure 144 is a ground floor plan of the building.

Figure 145 is a plan of the second floor, the third and fourth floors being substantially the same.

Figure 146 is a section of the stage and auditorium.

The main fresh-air duct *A*, from the propelling fan, is 54 inches in diameter, and is made of galvanized iron. Its branches carry air to the registers *F G H*. *O O* are direct radiators, and *R R* are openings into the foul-air shaft *Z*.

Nineteenth Century Theatres

The Grand Opera House, Pueblo, Colorado

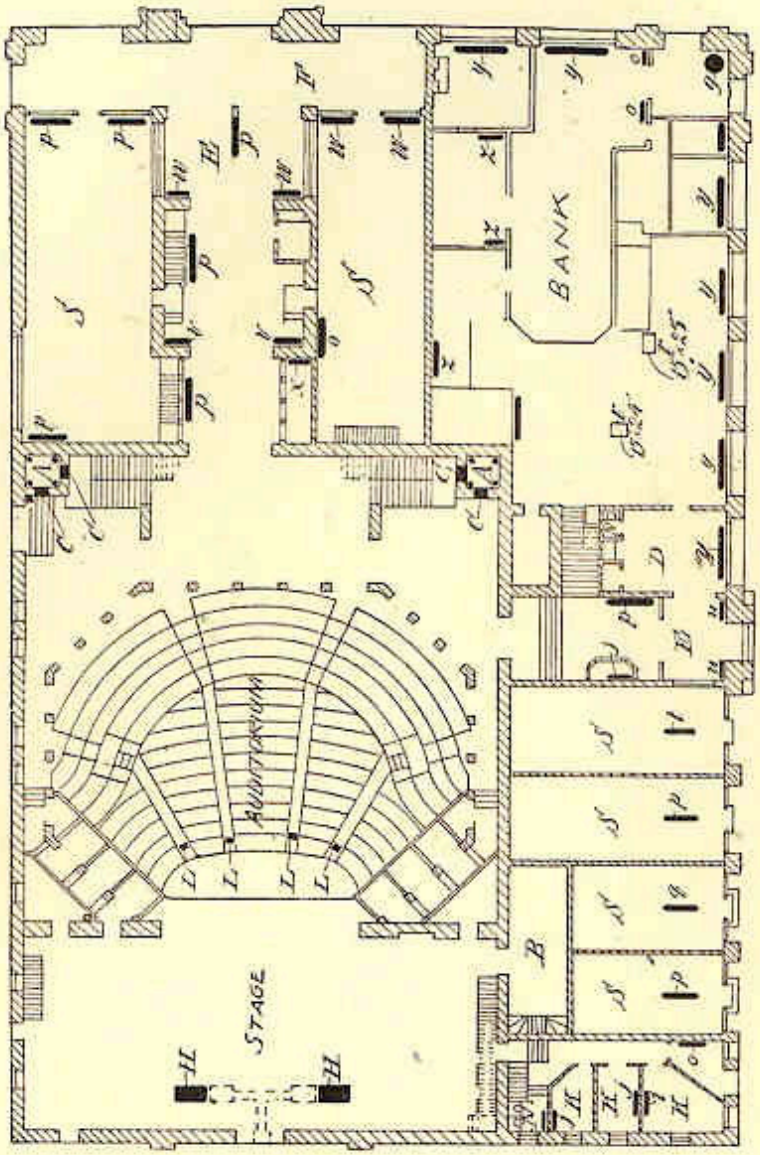


FIG. 144.

B.—Property room.
D.—Office.
E.—Vestibule.
F.—Lobby.
K.—Dressing room.
N.—Toilet room.

S.—Stores.
A.—Ventilating shaft.
H H.—Registers, 3x4 feet.
L L.—Registers from hot-air flues.
C C.—Openings into foul-air flues.
g h i, etc.—Direct radiators.

Nineteenth Century Theatres

The Grand Opera House, Pueblo, Colorado

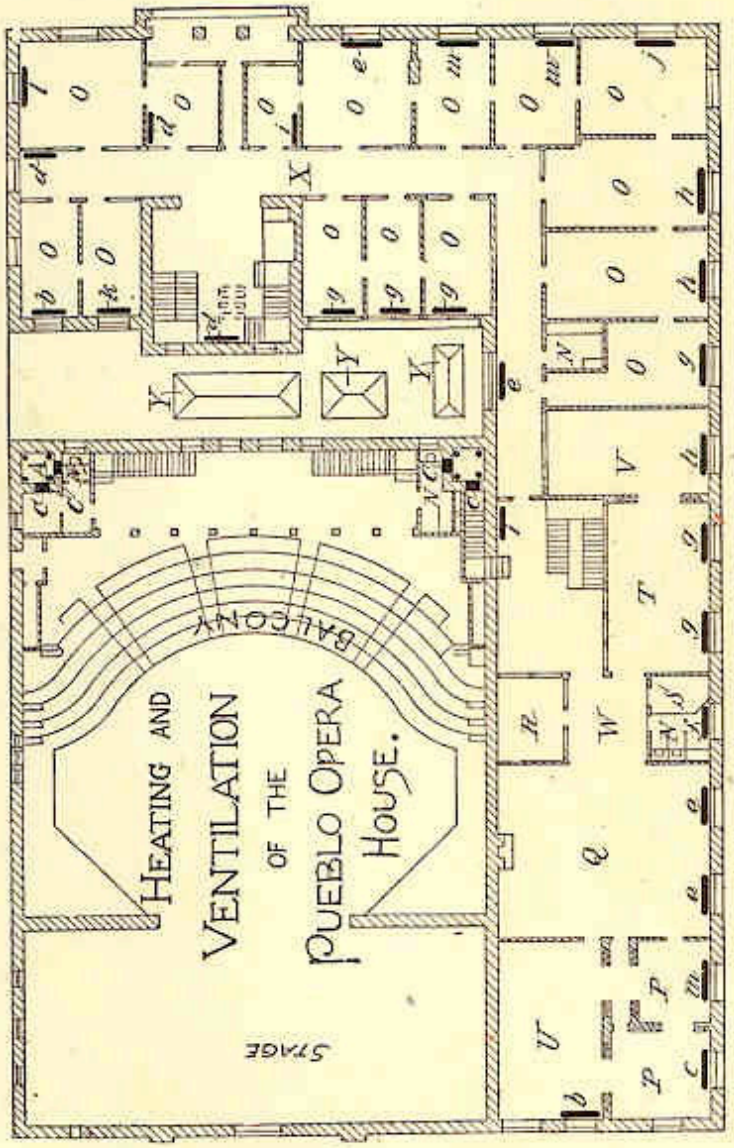


FIG. 145.

O.—Offices.
P P U.—Card rooms.
Q.—Billiard room.
Y.—Skylights from first-floor roof.
The small letters indicate direct radiators.

The Grand Opera House, Pueblo, Colorado

Figure 147 is a diagram plan of the air ducts.

Figure 148 is a plan of the fan chamber *Y* and coil room *X* in the second story of the boiler house. Figure 149 is an elevation at *Z Z*, Fig. 148. *B* is a 7-foot Sturtevant fan driven by the engine *E*, and discharging blast through the 54-inch conduit *A*.

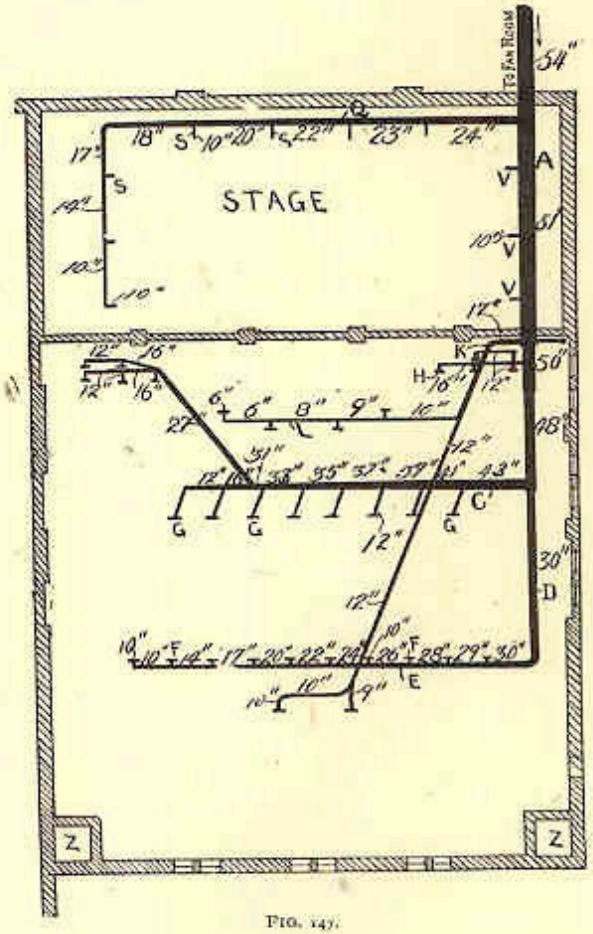


FIG. 147.

At *C* are the 12 heater coils, each eight pipes high, eight pipes wide, and 7 feet 6 inches long, supported on a pipe frame *L*. *W W*, etc., are counterweights balancing valve door *N*, which is operated by cord *H* from the engine room. Door *N* does not quite cover the whole opening in the partition *P*. When fully raised, as here shown, a lower

The Grand Opera House, Pueblo, Colorado

space *O* is left, through which the fan draws air, which has entered at *M*, and passing through the coils *C* has been slightly tempered and is delivered, comparatively cool, in duct *A*. If the door *N* is dropped to the floor the inlet is closed at *O*, and another one is opened at *Q*, from which the hottest air in chamber *X* is admitted to *Y*. Interme

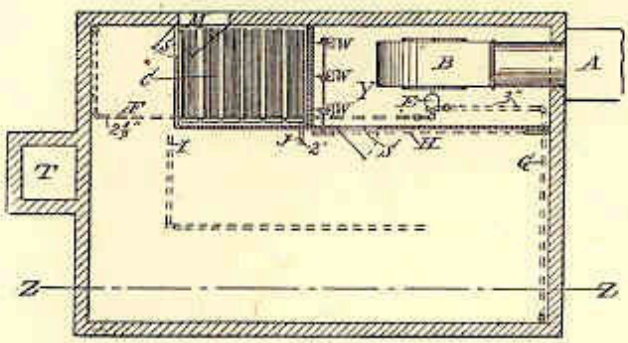


FIG. 148.

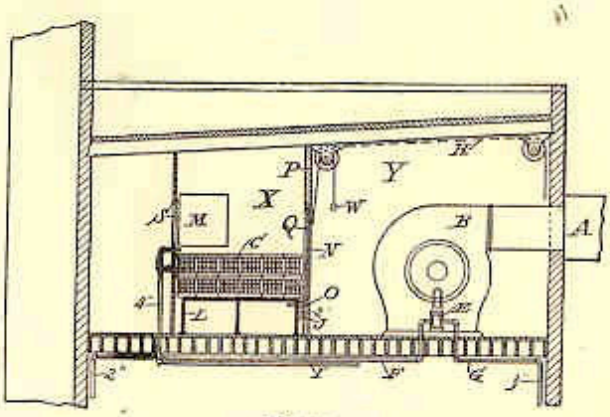


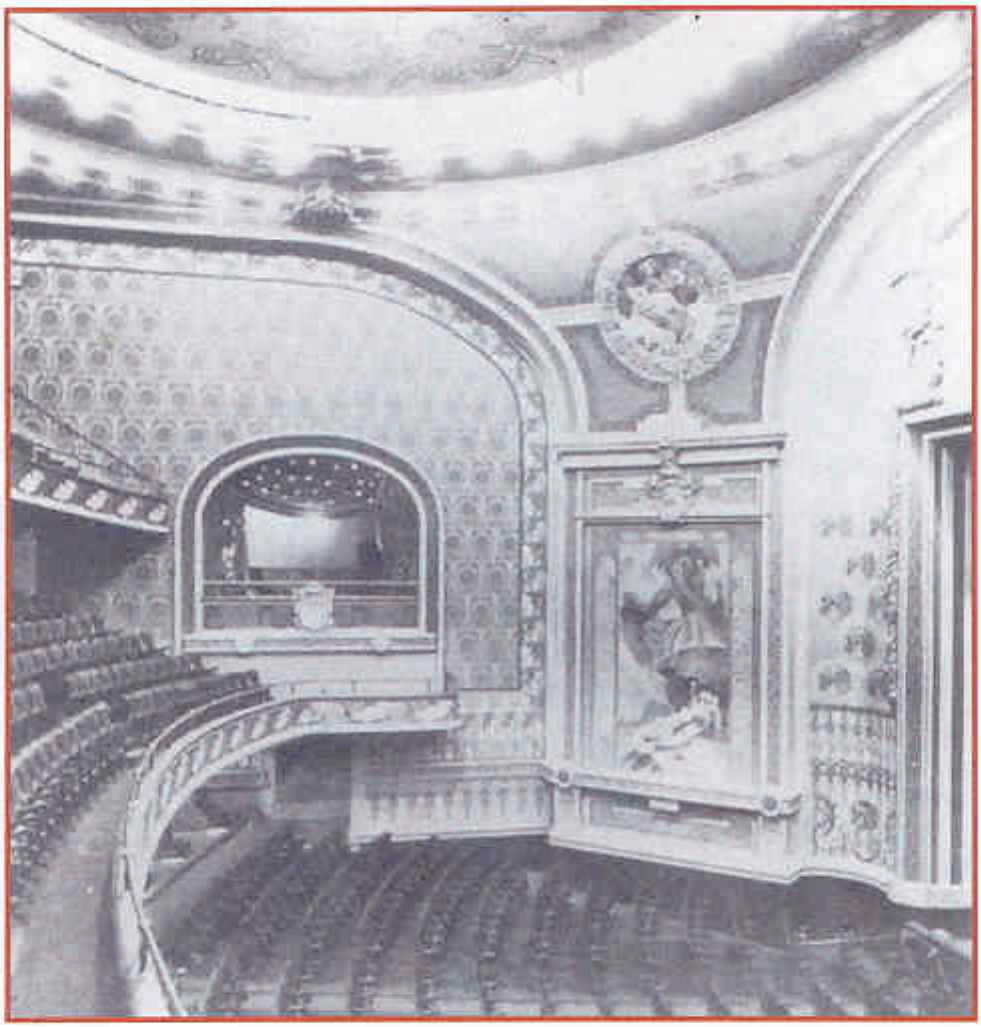
FIG. 149.

diate positions of door *N* enable the introduction of hot and tempered air in any desired proportions. *S S* are entrance doors to the chambers; *T* is the smoke-stack; *F* and *G* are steam and exhaust pipes to engine *E*; *I* is a steam pipe to radiator coils.

The heating and ventilating system was designed and installed by the L. H. Prentice Company, of Chicago, Ill. Adler & Sullivan, of Chicago, were the architects.

Nineteenth Century Theatres

Lenox Lyceum, New York
[later New German Theatre]



Date Built/Opened: c.1890 (?),
remodelled as New German Theatre 1908 (pictured)
Seating Capacity: Lyceum 2300 with 800 person dining room
Architect: New German, Herts & Tallant with Alphonse Mucha
HVAC Engineer: Unknown
HVAC Systems: Mechanical supply and extract ventilation 60,000 ft3/min with mains water cooling coil in fresh air
Status: Remodelled 1908.
References: *Ventilation and Heating*, John S Billings, The Engineering Record, London, 1896

Nineteenth Century Theatres

Lenox Lyceum, New York

Figure 134 is a plan of the basement of the Lenox Lyceum in New York City, which is described as follows in *The Engineering Record* of February 1, 1890:

The main portion of the building is circular in form, and is almost wholly taken up by the auditorium, which is 75 feet high and 135 feet in diameter, with a total seating capacity for 2,300 persons. The dining-room in the basement will seat 800 persons. Around this room

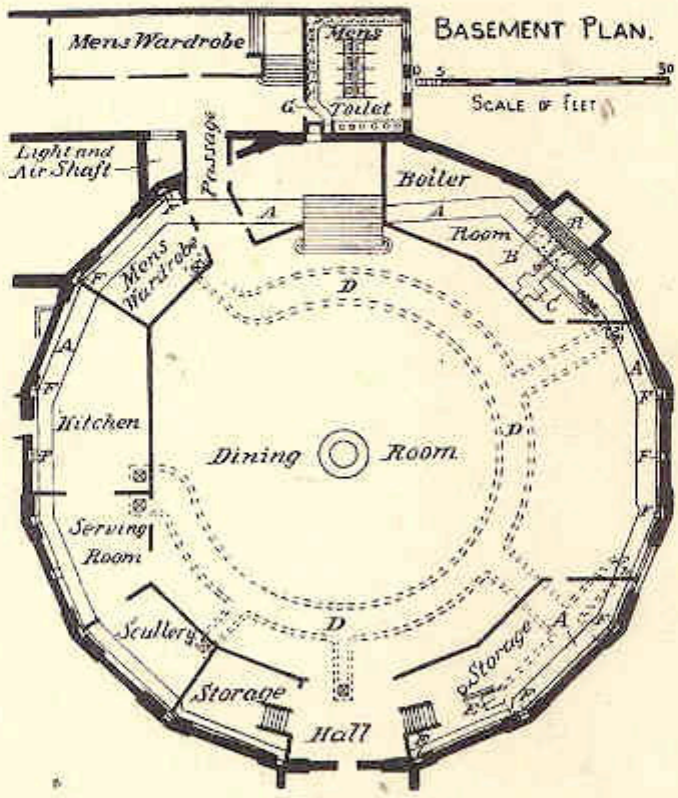


Fig. 134.

are arranged the overhead fresh warm air ducts *A A*, branching out right and left from an 8x4-foot Sturtevant blower *B*. Fresh air is taken in through a flue in the south wall, having a sectional area of 20 square feet, and is passed over a large steam radiator of special design, being finally delivered into the galvanized-iron distributing duct

Nineteenth Century Theatres

Lenox Lyceum, New York

The entire contents of the auditorium and dining-room amount to 900,000 cubic feet, and the blower is designed to effect a complete change of air every 15 minutes. Branch pipes run from the main hot-air duct, and are conpected to a series of gratings placed near the floor of the auditorium. These are covered with perforated zinc plates through which the flow of fresh warm air is brought down to a velocity so low that there is no possibility of draught. Hot-air flues *F* also rise to the gallery floor.

The hot-air supply for the dining-room is taken from the same blower through the duct *C* issuing near the ceiling, but the air is heated to a much higher temperature than that entering the auditorium, and is delivered in proportionately smaller volume. The higher temperature is secured by interposing in the duct *C* a separate radiator as shown. This air supply is entirely discontinued when a proper temperature has once been secured in the room.

Regulation of the temperature is effected automatically by Johnson electric heat regulators, which control the steam supply to the radiators in the fresh-air flue according to the temperature of the auditorium and of the air entering it. One of the regulators also controls the large 10-foot ventilator in the roof of the auditorium, by which a uniform volume of fresh air is delivered, and a practically fixed temperature is maintained in the auditorium.

A thermostat, or electrical thermometer, is placed in the auditorium, another in the main air duct near the fan, each capable of making electrical connection with the electro-pneumatic valve, which shuts off the steam supply to the radiators when the auditorium becomes warm. The delivery of fresh air is maintained, although at a reduced temperature, and to prevent the air from falling below 72 degrees, no matter what temperature the air in the room may be, the thermostat in the main duct, at 72 degrees, permits just enough steam to enter the coils to raise the air to 75 degrees, when the steam is again turned off.

But should the temperature of the auditorium fall below 70 degrees, or the degree at which the thermostat is set, the auditorium thermostat would turn on steam regardless of the thermostat in duct, and so continue to control the steam supply until the temperature in the auditorium rises to the degree required.

Still another thermostat in the auditorium is set 4 degrees higher than the thermostat which controls the coils. When the atmosphere in auditorium is heated to the degree at which this thermostat is set the large 10-foot ventilator is opened, permitting the heated air to escape.

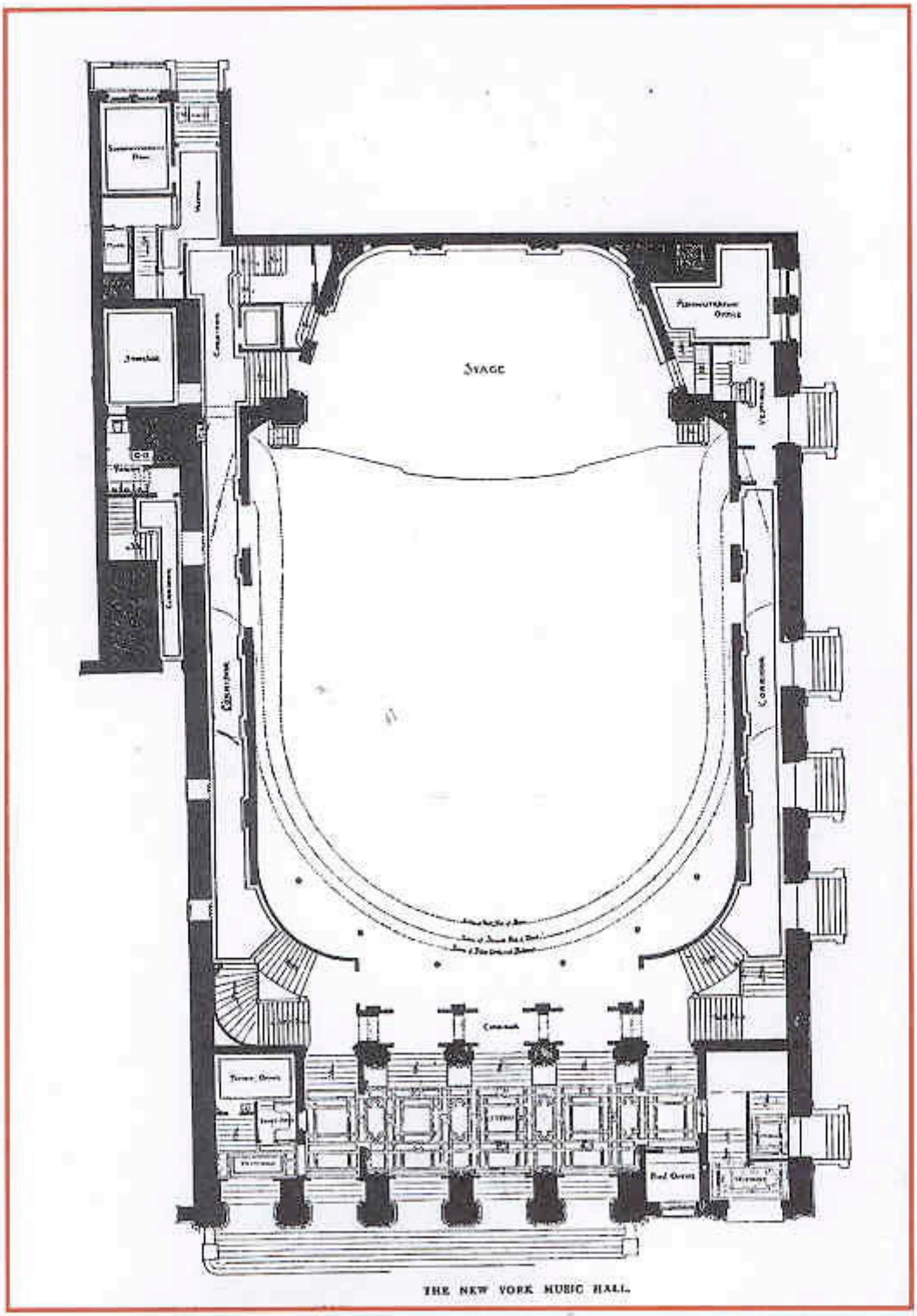
The volume of fresh air entering the building is capable of variation by increasing or diminishing the number of revolutions of the blower. Ordinarily the speed of the latter is 100 turns per minute, at which the capacity of the blower is about 40,000 cubic feet of air per minute.

For the purpose of ventilation a large brick duct *D D*, was built below the dining-room floor, encircling the room. Branches from this lead to register boxes in the floor at various points, and also in the kitchen, and the foul air is drawn into the duct and discharged into the open air by a 4x6-foot Sturtevant exhauster *E*, driven by a 10 horse-power vertical engine. This exhauster has a capacity of 15,000 cubic feet of air per minute. The movement of the air will always be from the main auditorium to the dining-room, thence to the kitchen, and finally into the exhaust duct. Odors from the kitchen or dining-room are thus prevented from rising to the main auditorium. Above the urinals in the toilet-room an exhaust duct *G*, of 3-square foot section is arranged, having small openings downward, as shown by dotted lines, and discharging into a flue leading to the roof. The ventilation there is effected by natural draught, which is sufficiently strong to create a flow of air into the toilet-room from the adjoining spaces on opening the door.

The apparatus is designed also to cool the building in warm weather. For this purpose a tank is arranged underneath the engine-room to hold cold water, which is forced through the radiator in the fresh-air flue by a small circulating pump.

Nineteenth Century Theatres

New York Music Hall [later Carnegie Hall]



THE NEW YORK MUSIC HALL.

The Engineering Record, 1891

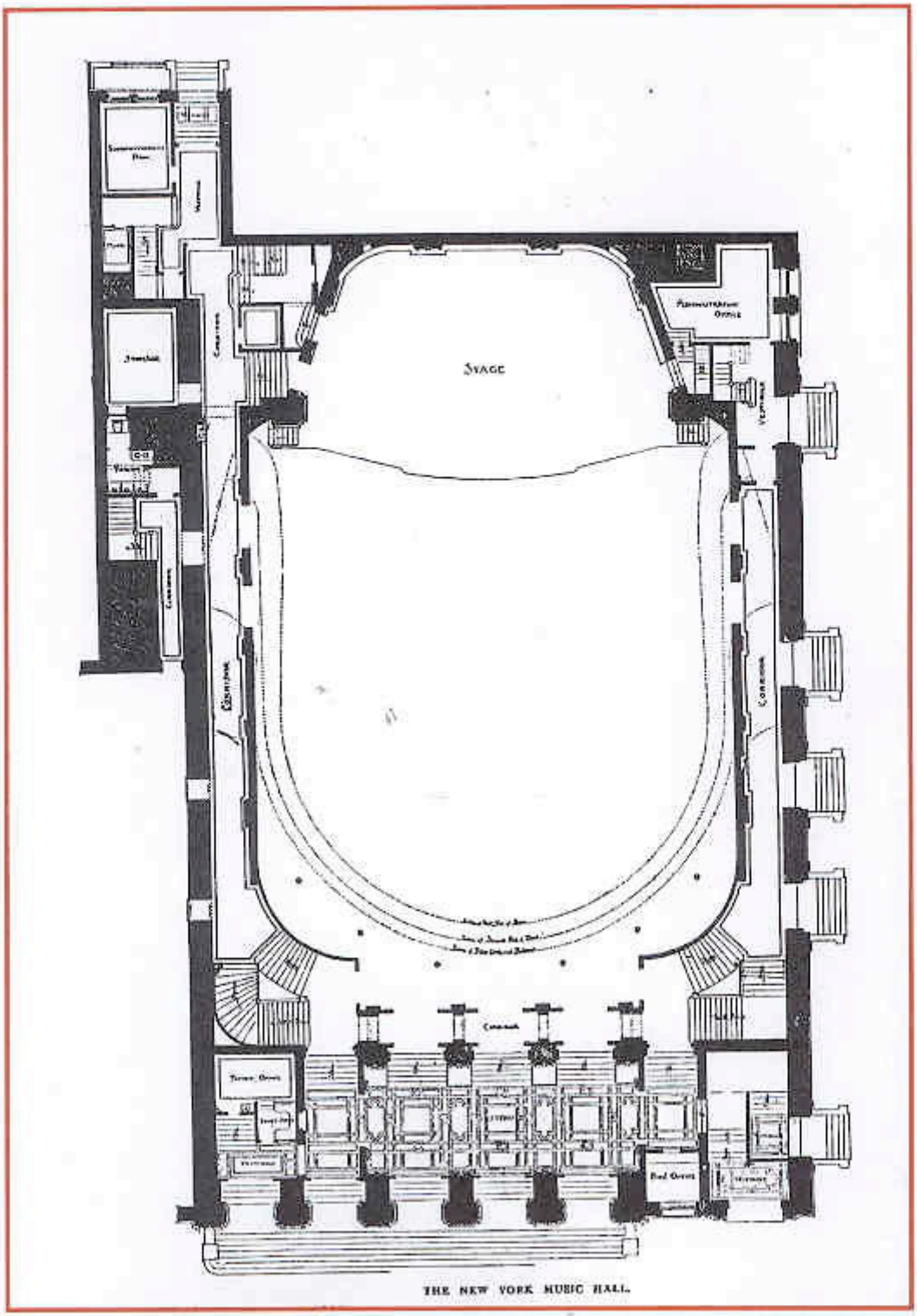
Nineteenth Century Theatres

New York Music Hall [later Carnegie Hall]

Date Built/Opened: 1891
Seating Capacity: Main Hall 3000, Recital Hall 1200
Architect: William Burnett Tuthill with Richard Morris Hunt & Dankmar Adler
HVAC Engineer: Alfred R Wolff [*The Comfort Makers*, entry 211]
HVAC System: Mechanical ventilation and ice block cooling system with air supply to the main auditorium through a perforated ceiling.
Status: Towers added 1894 and 1896. Comprehensively renovated in 1986
References: *Ventilation and Heating*, John S Billings, The Engineering Record, London, 1896

Nineteenth Century Theatres

New York Music Hall [later Carnegie Hall]

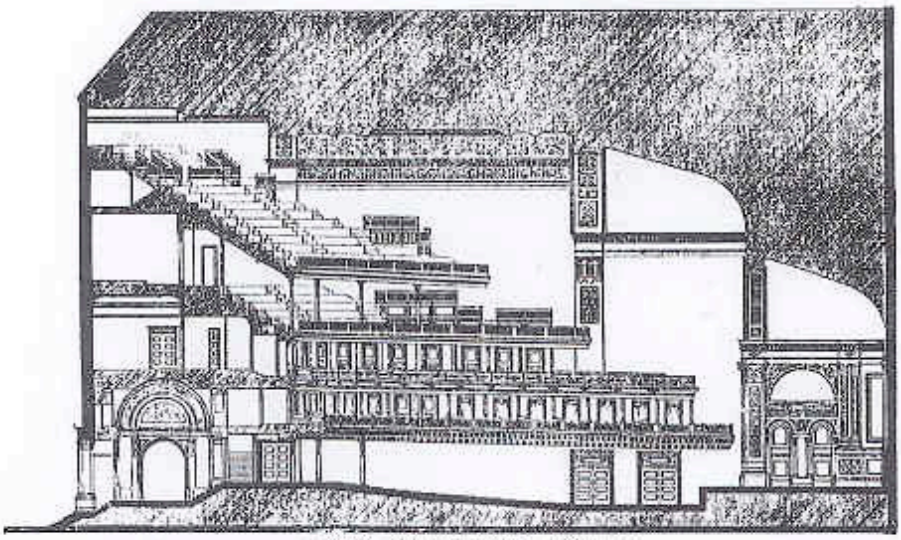


THE NEW YORK MUSIC HALL.

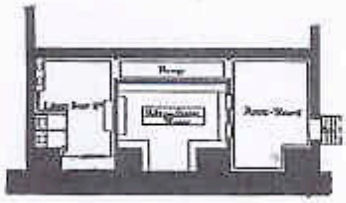
The Engineering Record, 1891

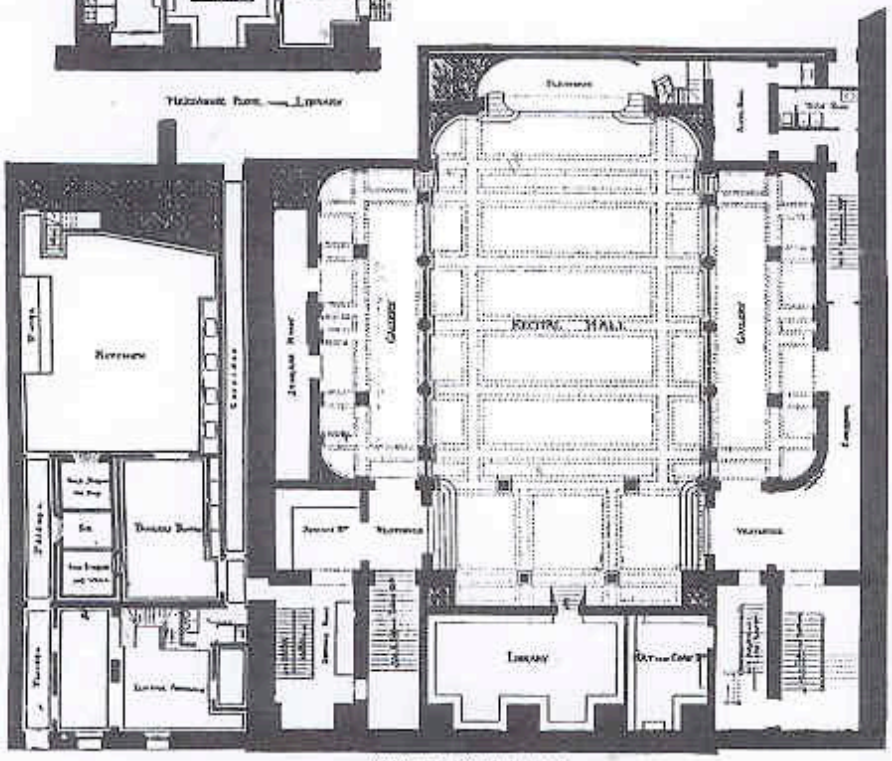
Nineteenth Century Theatres

New York Music Hall [later Carnegie Hall]



GENERAL SECTION THROUGH MUSIC HALL.

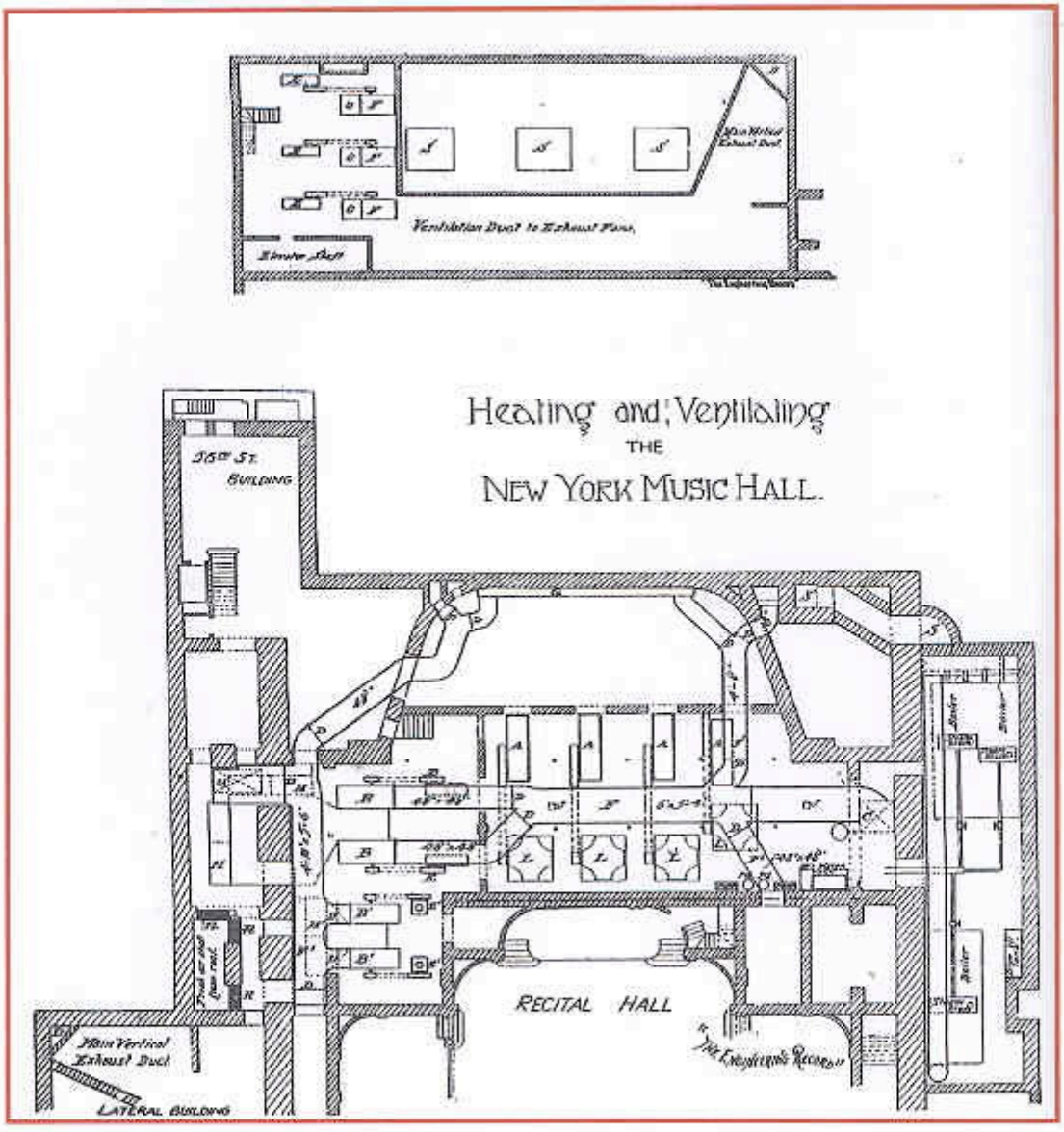




PLAN OF RECITAL HALL.

Nineteenth Century Theatres

New York Music Hall [later Carnegie Hall]



The Engineering Record, 1891

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With this amphitheater may be compared the New York Music Hall founded by Andrew Carnegie, a full description of which, with plans, is given in *The Engineering Record* of July 4, 1891, and February 6, 1892. The main concert hall has a seating capacity of 3,000, the recital hall beneath this seats 1,200. The fresh warmed air enters the music hall through numerous perforations in or near the ceiling,

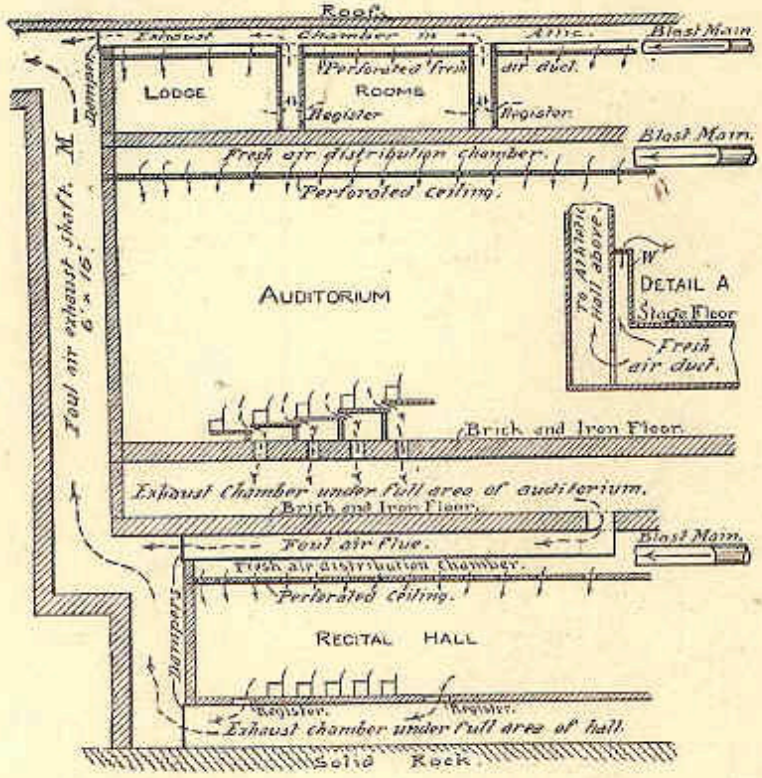

FIG. 129.

being forced in by two 7-foot Sturtevant blowers which draw it through heaters of 1¼-inch pipe containing 6,600 square feet of heating surface.

Figure 129 is a general vertical section of the main building, not to scale or accurate position, but intended as a diagram to show the distribution of fresh air and the withdrawal of foul air in the principal

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rooms. Detail A shows the method of supplying extra heat and air to the stage through perforations in the horizontal top of the 6-foot wainscoting *W*, around the walls.

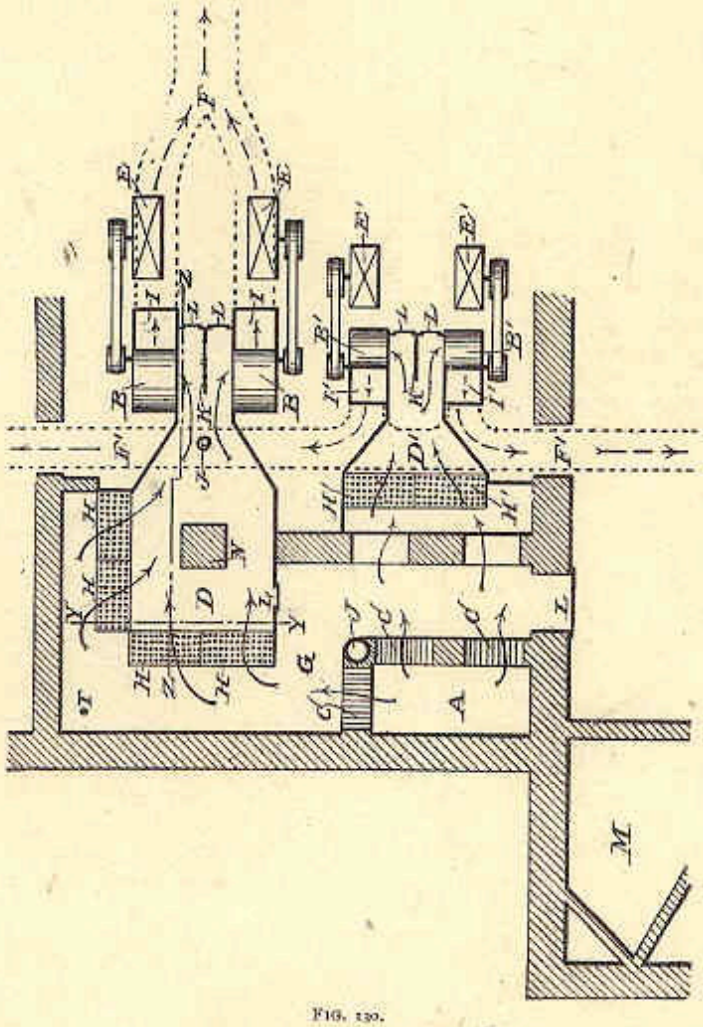

FIG. 130.

Figure 130 shows the heating, cooling and blowing plant. *A* is the fresh-air shaft from the roof, 6x12 feet, supplying the distributing

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chamber *G*. In warm weather ice may be placed in the racks *C C* to cool the air. The blowers *B B* draw the air into the chambers *D D* through the steam radiators *H H*. *E E* are the engines driving the blowers, and *F* is the main air duct having a cross-section of 30 square feet.

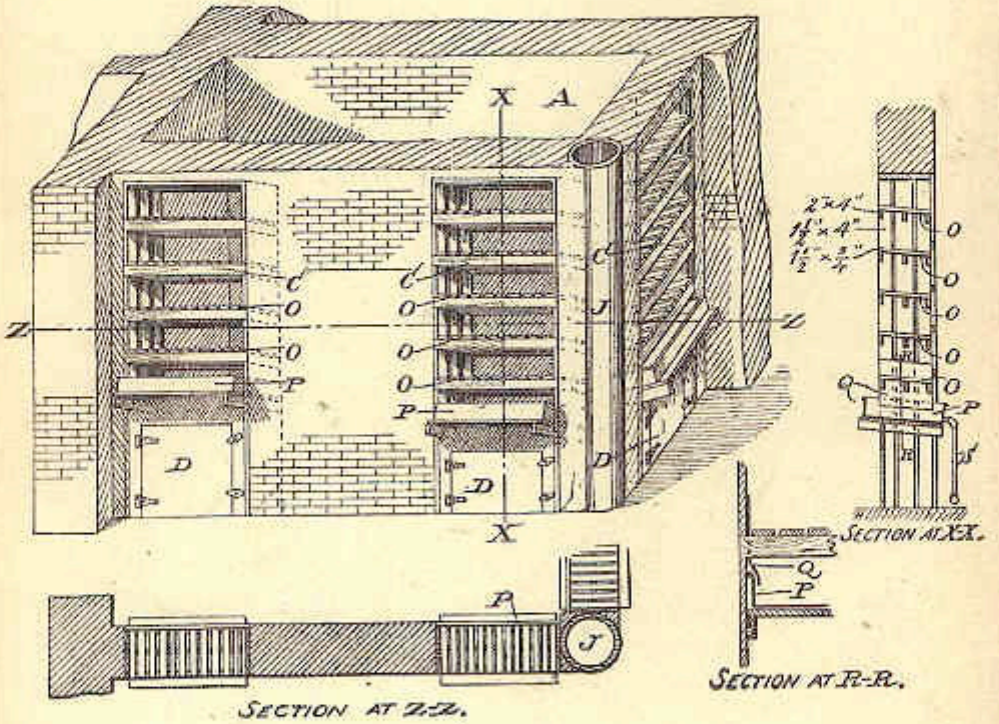

FIG. 131.

Figure 131 shows the bottom of the fresh-air shaft *A*, with its outlets. *O O* are the ice-racks; *P P*, iron drip-pans. *S S* are waste-pipes; *D D*, doors.

Figure 132 is a perspective view from *T*, Fig. 130, of the chamber *D*, two sides of which are composed of radiators *H H*. *U* is the steam supply and *V* the drip pipe.

Figure 133 is a section at *s s* Fig. 130 showing the inlet to the blower and the check valve *F*, which opens with the blast but closes against

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back pressure. The air is drawn out from the hall by a separate fan system, being taken from or near the floor levels, and carried in a shaft to the roof where the exhaust fans are located. It will be seen that this

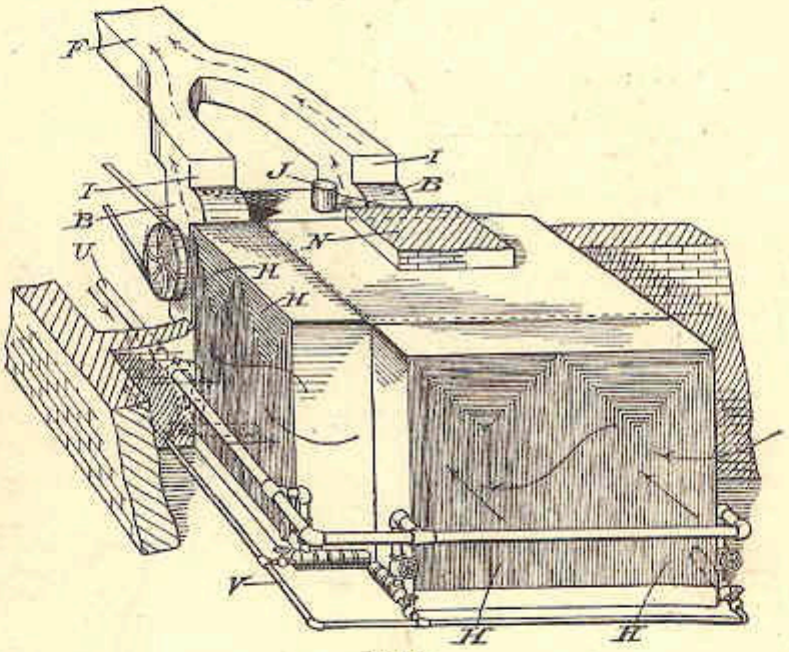

FIG. 132.

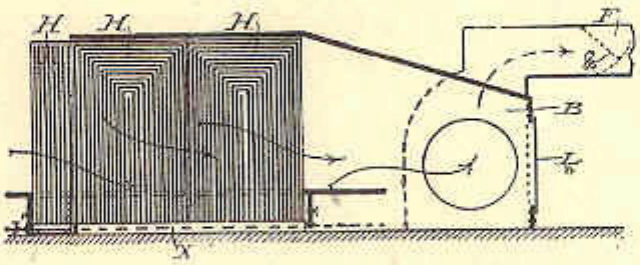

FIG. 133.

is a system of downward ventilation, the efficiency of which can only be maintained by a considerable expenditure for power.

Nineteenth Century Theatres

The Royal English Opera House, London
[later The Palace Theatre of Varieties]

Date Built/Opened: 1891
Seating Capacity: Unknown
Architect: T E Collcut & G H Holloway (master builder)
HVAC Engineer: Unknown
M & E Systems: Mechanical supply and extract ventilation with ice block cooling. Own electricity generating plant serving about 2000 lamps, then said to be the largest theatrical installation in the world (the Auditorium Theatre, Chicago had 5000 lamps)
Status: Renamed in 1892
References: *Victorian & Edwardian Theatres*, Victor Glasstone, Thames & Hudson, 1975