HUBBARD

The Steam Heating and Ventilating Equipment for a Modern Office Building

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THE STEAM HEATING AND VENTILATING EQUIPMENT FOR A MODERN OFFICE BUILDING

BY

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

George Wallace Hubbard

ENTITLED

"The Steam Heating and Ventilating Equipment for a Modern Office Building"

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF

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THE STEAM HEATING AND VENTILATING EQUIPMENT
FOR A MODERN OFFICE BUILDING

In this day of large fireproof buildings, those to be used for office purposes are in a distinct class of their own. Architecturally and structurally the office building is different from all others. Covering as it does in some cases, an entire city block, and towering two hundred, three hundred or more feet in the air, it is designed throughout so as to give the maximum amount of office space. But this space, in order to be of value, must be light, therefore the offices must not be so deep that the light from the windows cannot penetrate all parts of the room. Hence the building must have large windows, and many of them, and in large structures it is customary to build a light court in the center, so that the inside offices may be as light and as valuable as those on the street fronts. So it is that we have the modern office building, - a structure like an immense inverted box, made of steel and tile, or other fireproof material, with its large, light and comfortable offices. But this building, simple as it may appear when described, has many problems in store for the heating and ventilating engineer.
He it is who must go over the plans of the building and determine how much it is to be heated, the arrangement of radiators and coils, the system of piping best adapted to the conditions, how much space is to be mechanically ventilated, and by what means, - in short to determine the system of heating and ventilating that will give the most practical results with the least expenditure of money, as regards both the initial cost and the maintenance.

There are but two general systems of steam heating, one in which the steam enters the piping system at low gauge pressure, - say three pounds - and returns as water of condensation without pressure; the other in which the steam enters the piping system at low gauge pressure and returns as water of condensation under a vacuum of, say five inches. With either of these systems the mains may be placed in the basement or sub-basement and feed up to the radiators in the various stories through a series of distributing risers, or the mains may be placed in the attic and feed down to the radiators through the distributing risers which must then be joined into a return main in the base-
ment or sub-basement. In a similar manner, with either of these systems, the radiators and coils may be connected to supply risers only, or to both supply and return risers.

Under favorable conditions a gravity system will operate as satisfactorily as a vacuum, and it is often used in smaller buildings. However, with this system the pipes must be larger than are required for a vacuum system, and there is not the positive circulation throughout that can be obtained by the use of a vacuum, so that it is seldom used in large office buildings.

As to whether the mains are to be run in the basement or sub-basement, or in the attic, no fixed rule can be given and the use to which the basements and attic are to be put will often have much to do with determining this point. It is obvious that if the Safety Deposit Department of a high grade bank, or a first class restaurant, is to be located in the basement that large steam mains within this space would be highly objectionable; on the other hand, if the attic is finished similar to the other stories, and it is the inten-
tion to make it of equal value for renting purposes, large mains at this point should be avoided as much as possible. Usually, however, the space in the attic is of less value than the space in the basement, so that the mains are placed at the top of the system. In this case the steam and water of condensation in the risers are traveling in the same direction - downward. In this case, also, the distributing risers are smallest in the first and second stories where it is often desirable to conceal them and where for architectural reasons the columns in which they are concealed must be kept as small as possible.

If, on the other hand, the mains are placed in the basement, the steam traveling upward is moving in a direction opposite to the water of condensation; this, it is contended by some, is a disadvantage, but if the mains and risers are properly proportioned for this condition there is no reason why it should not be as satisfactory as where both are traveling in the same direction. An argument sometimes advanced in favor of placing the mains in the basement is that they will receive better attention from the engineer; this ought
not to be true, but it is undoubtedly a fact to some extent.

As to whether the radiators are to be connected to a one pipe or a two pipe system, there is more opportunity for a divergence of opinions. With a single pipe system the pipe sizes are larger than with a two pipe system and the branches to radiators must be kept short, and installed with a good pitch in order to obtain proper circulation. If the Paul system of piping (consisting of steam supply pipe and corresponding air pipes connected to the various radiators, with a pump to exhaust the air) is used, the best results can be obtained by installing a steam supply and an air riser for each vertical row of radiators, which usually requires almost double the number of risers that would be used for a two pipe system, where one riser is used to supply the steam and a separate riser is used to return the water of condensation. The steam supply risers in the Paul system are larger than the ones in the two pipe system, but the air risers are smaller than the corresponding return risers, so that the risers taken in pairs, ought to cost approximately the same to install. However the number of
risers is so much greater in the Paul system that the complete installation must run considerably higher in cost.

The amount and kind of radiation to be installed depends upon the location of the building, its exposure and the nature of its occupancy. As a general proposition a sufficient amount of radiation must be installed to maintain a temperature in the various rooms at approximately seventy degrees Fahrenheit, during all ordinary weather. It is not necessary, however, to install enough radiation to maintain this temperature when the outside temperature is at the lowest point recorded by the government weather bureau, and a point about ten degrees above this will ordinarily be sufficient for all practical purposes. A continued cold period at a lower temperature is extremely unlikely and even if it does come, the temperature of the room can drop a few degrees below the normal without causing serious discomfort. Under the circumstances, therefore, to install a greater amount of radiation would not only be expensive but unnecessary and impractical.

It is usually conceded in this climate that there must be additional radiation on the north and west
sides of the building in order to compensate for the cold winds coming from these directions, and in high buildings, it is sometimes claimed still further radiation must be installed in the upper stories, on account of the extreme exposure. However, the weather strip used at the present time has done much to reduce the loss of heat through leakage around the windows of the rooms, and it is no longer necessary to provide the additional radiation on either the north and west sides in the upper stories, if the windows are sufficiently protected in this manner.

Sometimes, on account of the risk from fire, the windows are made with wire glass and metal sash. This is very much colder than the ordinary window with clear glass and wood sash, and cannot be made to fit in place so well; on this account more radiation must be provided at these points, usually amounting to thirty-three to fifty per cent more than the amount required for the ordinary condition.

In some cases the nature of the occupancy of the building is such that a temperature higher or lower than seventy degrees must be maintained, and under these conditions the amount of radiation must be
increased or decreased as required.

There are so many different rules for proportioning radiating surface, and the results obtained from their use are so divergent that it is difficult to know which one to use. The writer has used what is known as Baldwin's rule for the past ten years, and has found that it gives very satisfactory results in this class of work when the size of the rooms is not too great, and there are no unusual openings for circulation of air into or out of the rooms. This rule is "Glass plus one-ninth the exposed wall surface (or glass equivalent) multiplied by a factor depending upon the temperature outside, the temperature to be maintained in the room, and the temperature of the steam."

This factor is temperature in the room minus the temperature outside divided by the temperature of the steam minus the temperature in the room. In the climate of Chicago, heating is generally based on a minimum temperature of ten degrees below zero, under which condition the factor becomes $70 - (-10) + \frac{212 - 70}{-10} = 70$ or approximately $56$. It is claimed by some that the contents of the rooms as well as the exposed surfaces should be taken into account in figuring the amount of radiation to be installed, but this varies so
greatly that there seems to be no logical way of computing this amount. If one room which it is desired to heat is only twenty feet deep with exposure on one side, and the room adjoining is fifty feet deep, with the same exposure, any rule which takes into account the contents of the rooms, must show a much greater amount of radiation necessary in the latter room than in the former. But this is not true for with the same amount of exposed surface in the two rooms there can be no appreciable difference in the amount of loss by leakage. Cooling can come only from the exposed surfaces, so that any rule which provides for the amount of radiation necessary to compensate for this will give satisfactory results for offices such as are ordinarily found in our large office buildings. This will not, however, be sufficient for stores in the first story with doors from the street, or for very large rooms with numerous openings for inlet or exit of air. Under these conditions the writer has found it more satisfactory to install the amount of radiation called for by Carpenter's rule, which is \( .776 \) glass plus \( .23 \) exposed wall plus \( .02 \) contents multiplied by the difference in temperature to be maintained in the room, and that outside divided by
250. The multiplication above gives the total number of heat units lost per hour by radiation and conduction, and when divided by 250 as noted, gives the radiating surface required, in square feet. (The factor .23 is approximate only and varies with the kind of wall used, and its thickness.)

The best place to locate radiators is below the windows as it is at these points that the heating surfaces are most effective, the columns of heated air rising from the radiators, meeting the columns of cold air falling along the glass surfaces, mixing with them, and being dissipated in the rooms. But the radiators should be of such height that they will not extend above the sill of the window. Coils in skylights are most effective when placed near the glass, keeping the surface warm, and preventing cold air from falling to the floor.

In determining the size of radiators it should be kept in mind that the arrangement of offices is changed every year or two as old tenants move out and new come in, or as old tenants find that new requirements make re-arrangement of offices necessary or desirable. For this reason the size of the radiators
should be such as will give the most flexible arrangement possible, which will not increase the cost of installation to an unwarranted degree. By careful study a system can be designed which will require but little change as the offices are remodeled, - it will, of course, cost somewhat more at the time of installation, but will prove a saving in the end. The writer has found that the most flexible arrangement is to place two radiators in each span - if there are but two windows in this space, the radiators should be of equal size, but if there are three, one radiator should contain one-third the total amount of radiation required in the space, and the other two-thirds; by combining the radiators of the various spans in pairs, installing first two large radiators and then two small ones, followed by two large and two small ones, continued around the full length of the outside walls of the building the minimum number of radiators practicable is installed. With two radiators of equal size in a span they need never be disturbed as partitions between offices are changed; with two radiators of one-third and two-thirds the total required it may become
necessary to reverse the arrangement at times, the smaller radiator taking the place of the larger, and vice versa, but this is an easy operation, requiring only that the radiators be disconnected, moved and reconnected. If it becomes necessary to put three radiators in a span as sometimes happens, the larger of the two radiators can be rebuilt to suit the new conditions, the smaller one remaining untouched.

Radiators are now made of either cast iron or steel, and can be obtained in heights varying from thirteen to forty five inches. The cast iron is more often used, and usually in plain pattern, as this, having a smooth surface, is more easily kept clean. They are cast in sections, put together with slip or screw nipples and are so built that the sections can be taken apart at any time this becomes necessary. This gives cast iron radiators a tremendous advantage over steel, for the latter, after being built a definite size at the factory cannot be changed, if not of proper size, but must be replaced by a new radiator or radiators. On the other hand steel radiators are very much lighter - weighting only about two and one half pounds per square foot of radiation compared with seven and one half in cast iron radiation -
and are shorter for the same amount of radiating surface. These two points are of both advantage and disadvantage to this type of radiation. Being lighter they are not so stable as the cast iron, and are more easily moved out of position after being set, but they are more easy to handle; being shorter; they will allow more space for office furniture, and this is often of advantage. For a long time the manufacturers of steel radiators had difficulty in making the joints tight and getting all parts thoroughly galvanized, failure to do which resulted in pitting of the radiators and consequent leaks. This difficulty has been largely done away with, and steel radiators have now been installed in some of the largest buildings, where they are apparently giving satisfaction.

Coils for skylights, or for other places requiring this class of radiation can be made of any size pipe desired. The writer prefers one and one-quarter inch pipe when it can be used, but the size must be determined in each case by the local conditions, - the amount of heating surface required, space available for receiving
this radiation, etc.

The method of controlling the steam supply to the radiating units means much to the owner, and to the renting agent of a large office building. If hand valves are placed on the supplies to the radiators it is an open question whether the tenants will control the amount of heat in the rooms by opening and closing the valves, or by opening and closing the windows, leaving the valves open for the greater part of the time. It is obvious that if the control valves be left open all of the time, much of the heat given off by the radiators will be wasted; this is of little concern to the tenants, so long as enough heat is provided to keep all the rooms comfortable, but it is of great importance to the one who is buying the coal and furnishing the heat. In order to remove this source of loss several systems of automatic control have been introduced, all of which, however, operate in practically the same manner, - a diaphragm valve is placed on the supply to each radiator, and these valves controlled individually, or in groups of two, three or four as desired, by thermostats, which open or close
the valves by compressed air as the temperature in the rooms falls one degree below or rises one degree above a predetermined point. The thermostats should be placed in the same rooms as the radiators they control, and at points which will be least affected by air currents and unusual changes of temperatures, - usually in about the centers of the rooms, or in partitions well away from the outside walls. A third method of radiator control is by graduated valves placed on the supplies, with steam ports of such sizes that the steam supplied to each radiator will be sufficient to heat the whole radiator, or only a portion, as desired. This arrangement is somewhat more economical in the use of steam than with the ordinary valves, but it is questionable whether any real saving is effected. However, there is no doubt about the value of the automatic system of supply, which can be used to advantage in any large office building, though even here it can be omitted from the first story store rooms, where the outside doors are constantly being opened and closed, and in entrances, vestibules, stairs, corridors, attic, pent houses, and other public places directly under the control of the
employees of the building, and where the radiation must be kept on or off continuously. In a small building the initial cost of the system and the interest on the money invested might be greater than the saving effected by automatic control, and in this case it becomes not a question of economy, but of convenience to the tenants as to whether automatic or hand valve control is to be installed.

With the use of a two pipe vacuum system some form of return valve is necessary. Until recently the type known as the float valve has been used almost exclusively, but it does not close tight, allowing some steam to pass through, necessitating the use of condensing water in order to maintain a vacuum in the system and this fact taken together with noise in operation and high cost of maintenance has led to the adoption in most of the new high grade buildings of a type of thermostatic valves. This is positive in action, operates noiselessly and without the use of condensing water, and up to the present time seems to justify the claim that it does not require as much attention as the float valve, or so great a cost of maintenance.
While there are many things in connection with the heating system that must be given careful consideration by the mechanical engineer, they are few compared to those presented by the ventilating system. All portions of the building must be provided with fresh air, and those portions which are not provided with windows and doors supplying the air naturally must be provided with some other system which will supply the necessary amount by mechanical means; this is usually effected by a fan system with distributing ducts. In some cases fresh air from outside is forced into the spaces to be ventilated, and foul air allowed to find its outlet through elevator shafts, doors, stairs, and other openings; in other cases this is reversed, fresh air being allowed to enter through such openings and foul air being exhausted by a fan system and discharged out of doors; in still other cases, a double system of ducts is installed, so that fresh air is supplied and foul air exhausted mechanically. The last arrangement is the one advocated by the writer, with the fresh air inlets and exhaust outlets well distributed. It is only in this way that the supply to all parts of the rooms can be definitely controlled; with any other it
is impossible to prevent the air from short circuiting from one opening to another, producing strong currents at these points and leaving dead pockets between. It is often extremely difficult to devise an arrangement of ducts which will provide an even distribution without interfering with the architectural design, or other work which must be installed, and usually the engineer must be satisfied to install a system which is a fair approximation of the one which he would like to use for the rooms under consideration. However, it is usually true that the general outline of his design can be maintained.

The amounts of air supplied or exhausted must of course depend entirely upon the use to which the rooms are to be put, - in the opinion of the writer ten complete changes of air should be provided in the mechanical or heating plant; six in ordinary storage spaces; six to eight in safety deposit or similar spaces; ten in toilet rooms and janitor's closets; twenty to thirty in kitchens, and such a number for rooms used for other purposes as will provide an ample supply of fresh air, - this varies greatly, depending upon the size of the rooms, nature of occupancy, etc., but usually runs between six and three. Much can be said as to where the air should
be introduced into or taken out of the rooms. The writer has found that in general the best results can be obtained in the mechanical or heating plant by supplying fresh air at points about eight feet above the floor, deflected downward at an angle of approximately forty-five degrees, and exhausting foul air from points as near the ceiling as possible, thus providing a fresh supply at all times to the men working on the floor and taking the air away from the hottest place. Rooms used for storage purposes, and in general all rooms in the basements, (except the mechanical or heating plant) can be supplied with fresh air at the ceiling: in this case it is preferable to exhaust the foul air through grilles in or near the floor. One disadvantage of this is that the exhaust grilles are apt to be covered with boxes or other articles, effectually closing the outlets and nullifying that portion of the ventilating system. But it is impossible to make any system foolproof, and the tenant must see to it that the openings are kept free. One arrangement adopted by the writer, and which is giving satisfactory results, is to place fresh air ducts in the corridors, with branches about fifteen feet apart entering the rooms on both sides supplying the air at the ceiling, and the exhaust ducts
either in the ground or behind a false wall at the opposite side of the rooms, with outlets about fifteen feet apart exhausting the air through grilles in or near the floor. With such an arrangement, the fresh air ducts can be concealed by the installation of drop ceilings in the corridors, so that only the fresh air inlets and exhaust outlets are exposed to view, leaving the interior of the room free for treatment in any way the owner or tenant may desire. Sometimes the nature of the occupancy of a room may be such as to make it desirable to reverse the operation, the fresh air being introduced near the floor and the foul air being exhausted in or near the ceiling. But it is hard to design a system of this type which will give satisfactory results, on account of the very slow velocity at which the air must enter the room in order not to produce drafts. A velocity of one hundred feet per minute under these circumstances is high while there can be no objection to a velocity of two hundred and fifty, or even three hundred feet, when the air is introduced at the ceiling.

Fresh air blown through the radiators in the entrance vestibules will not only increase the efficiency of the radiators, but will provide a supply of
fresh air to the corridors of the first story.

Toilet rooms and janitor's closets should not be supplied with fresh air mechanically, but there should be an ample exhaust system, the fresh air being derived from the adjoining rooms or corridors, through grilles in the doors. The outlets in the toilet rooms should be preferably near the floor, and in the janitor's closets near the ceiling.

If a system of ventilation is to be installed for a story above the basement, it is the opinion of the writer that the fresh air should be introduced into the rooms through openings under radiators placed under the outside walls, and allowed to filter up through the radiators, mixing with the cold air falling in front of the windows, tempering it, and dissipating it in the rooms. In this case the foul air should be removed through grilles in the ceiling.

The fresh air intake fan system ought to be in the cleanest place it is practicable to reach; ordinarily the best results will be obtained if the air is taken from the second or third story level, - if taken from a point lower than this the supply will contain much
of the dust and dirt of the street level, while if taken from a point near the roof it will contain soot and dirt from the chimneys in the vicinity. Another argument in favor of locating the intake as low as possible, but high enough to keep comparatively free from the street dirt, is the loss of space in carrying it up through the building: loss in rental in this way is still further augmented by the increased cost of operation due to the additional friction in a long intake.

The air after passing through the intake must be purified either by passing through filters or air washers. The former will provide all the purification required by the air supply to the mechanical or heating plant, and to the entrance vestibules of the first story, and inasmuch as it is less expensive to install and maintain than the latter it is used for this class of work to a great extent. In its simplest form it consists of a series of cheese cloth screens or bags through which the air is made to filter, the total area being such that the velocity of the air passing through will not exceed fifty feet per minute.

For a better class of work air washers are
used. This apparatus consists of a series of spray heads or nozzles through which the water is pumped under pressure and a series of baffle plates on which the air after passing through the spray chamber and picking up moisture impinges, losing the moisture picked up in passing through the spray and practically all of the suspended matter originally contained in the air. With either of these methods the air entering the fans is much cleaner than when it enters the intake, but the best results can always be obtained by having as clean air as possible to start with.

It is, of course, necessary to heat the air supplied to the rooms, and this is especially true in case air washers are used, in order to provide against the freezing of the water. The type of heating coil usually used for this purpose consists of a series of pipe coils set in a cast iron base; in a number of instances, however, a cast iron type of fan heater has been used to advantage. This is more flexible than the pipe coil heater, inasmuch as it is more compact, and is susceptible of greater variation in arrangement. In calculating the capacities of heating coils the writer uses the following formula: The heating surface in
square feet is equal to the quantity of air supplied per hour, multiplied by the number of degrees raised, multiplied by .02, divided by 1000 and the whole divided by 1.5. In this formula .02 is the approximate number of heat units necessary to raise the temperature of the air one degree, 1000 is the approximate number of heat units given off by the condensation of one pound of steam and 1.5 is the condensation per square foot of heating surface. The coils should have such a free area for the passage of air that its velocity will not exceed twelve or thirteen hundred feet per minute; the more this can be decreased the better it will be, for the cost of operation of the fan increases enormously as the velocity of the air through the coils increases. In general the air supplied to the mechanical or heating plant should be heated about fifty degrees; to sub-basement space, eighty degrees; to basement space, ninety degrees, and to entrances one hundred and forty degrees. It is customary in making such an installation to divide the coils for each fresh air fan into two groups, one placed on the suction side of the fan, and known as the tempering coils, and the other on the discharge, called the reheat- ing coils. There is a by-pass installed in connection
with each set of coils, provided with dampers so arranged that any desired proportion of the air will pass through the coils, while the balance passes through the by-passes. A single damper under the tempering coils is usually sufficient for all purposes, but a pair of dampers, placed one in the hot air connection and the other in the tempered air connection to each duct leaving the fan, will give the most satisfactory arrangement for the by-pass under the reheating coils. The steam supply to the heating coils can be controlled by valves similar to hand valves on radiators, or by a system of temperature regulation; if, however, an air washer is to be used, the first section of the tempering coils should be controlled by a hand valve, so that the heat cannot be shut off entirely from the coils, without the knowledge of the engineer in charge, as a precaution against the freezing of the water in the air washer. As a usual thing, the writer arranges the work in such a manner that both coils and dampers are thermostatically controlled, (except the first section of the tempering coils) this giving the most satisfactory results.

The fans used for supplying fresh air and exhausting foul air are usually of either the centrifugal
or multivane type. Both operate positively, and the results accomplished are the same. The multivane fan, however, is more compact than the centrifugal, occupying less space for the same capacity, and is considerably more economical in the use of power; these points, of course, are naturally in its favor, but its higher initial cost sometimes operates against it. It has been the usual practice in ventilating work to make the fans motor driven, sometimes through a belt or chain drive, sometimes through a direct connection. But, a leather belt slips and a chain drive is noisy, so that a direct connected type of fan is coming into use more and more. In general it may be said that for all classes of service the multivane fan, with direct connected motor, is the most economical and satisfactory in operation, its lower cost of maintenance offsetting its higher first cost.

Fresh air fans should be located as near the points supplied as possible in order to avoid long lines of ducts, which are more or less unsightly, and which must, on account of the friction of the air passing through, require greater motor capacity as well as larger and more expensive fans. On the other hand the fresh air intakes to the fans should be kept free, and as these are much
larger than the discharge ducts, any preference that can be given in the location of the fans should be in favor of short intakes. A fair velocity of air in the intakes is one thousand feet per minute, while in the discharge ducts this can be increased to two thousand or even more without difficulty. Then, too, the width of the discharge ducts can usually be made much greater than that of the intakes, and the writer has found that a depth of sixteen inches in the ducts where they leave the fans will usually give the best results in both construction and operation; the total width of the discharge may be anything necessary to give the depth stated, but the width of a single duct should not be more than four times its depth.

Exhaust fans should be placed so that the discharges will be kept as short as possible, hence they are often placed at the top of the building, and are arranged to discharge above the roof, where the foul air will produce the least annoyance.

If steam mains and risers are left uncovered they will serve as heating surface, and the amount of surface in radiators and coils can be reduced by this amount, but inasmuch as there is no control of this heat
when steam is turned on the building, it is very much better to cover the pipes and use larger radiators. Magnesia covering is sometimes used for this purpose, and is the most effective covering that can be obtained, but is too expensive to justify its use to any great extent in a heating system. Instead, moulded asbestos covering is often used on the supply mains and air cell or wool felt covering on the supply risers. Air cell covering, however, is apt to be unsatisfactory, for unless it is thoroughly dried before it is put in place it will shrink when steam is turned on, leaving an open space at the ceiling, which is unsightly, and cannot be remedied except by putting on an additional short piece of covering which makes a bad joint. This can be concealed by putting on an additional strip of canvas full height of the story, but is expensive and should be unnecessary. The wool felt covering is not open to this objection, but when installed makes a neat appearance. No covering need be installed on return risers or mains, unless they are concealed, in which case they should be covered the same as supply risers.

Fresh air intakes should be covered to pre-
vent condensation, and fresh air ducts passing through portions of the mechanical or heating plant, or other highly heated portions of the building should be covered to prevent absorbing a portion of this heat and carrying it to portions of the building where it would be objectionable. This can be done by covering the intakes and ducts with air cell sheets, wired in place and covered with canvas; sheets on the intakes should be one-half inch thick and on ducts, at least double that.

While the foregoing covers the principal points to be kept in mind in designing a heating and ventilating system for an office building, some arrangement must be made for returning the water of condensation to the boilers.

In a gravity system of heating, if the boiler pressure carried is not too high, this can be done by gravity; otherwise boiler feed pumps will be required drawing from a tank installed to receive the condensation as it leaves the heating system.

In a vacuum system of heating, it is necessary to introduce vacuum pumps to take out the air, if a single pipe system, or the air and water together if a two pipe system. In the former case the water of condensation is
returned to the boilers in the same manner as in a gravity installation; in the latter the vacuum pumps can discharge into a standpipe of sufficient height to overcome the steam pressure in the boilers, provided with a vent pipe to remove the air, and an overflow pipe to return the water to the boilers by gravity; into a tank placed at the same height and arranged with the same connections, or into a receiving tank at the same level as the pumps, with a vent pipe for air, and suction to the boiler feed pumps. Obviously the first is the least expensive, but it is also the least satisfactory, for the surface of the water from which the air is released must necessarily be kept small. If an elevated tank is used, space must be provided for it in an upper story of the building, and the pumps must be arranged to pump against this head, - whether or not these points will prove objectionable depends upon the conditions of the actual installation involved. There may also be some difficulty in providing for automatic fresh water supply to this tank. If a tank at the level of the pumps is used, the vacuum pumps can be arranged to pump against very low head, and the boiler feed pumps depended upon to return the water to the boilers. In this case there can be no difficulty
in making proper connection for fresh water supply to the tank, and the whole apparatus being under the eye of the engineer will probably receive more attention and give better results than either of the other methods. In addition the horse power required to return the water to the boilers will be less, which is a distinct advantage, especially if the pumps are designed to be motor driven and the electric current is purchased from an outside company.

If feed water heaters are installed in the building the condensation from the heating system can be returned directly to the heaters without the use of a receiving tank, and fed into the boilers by the regular boiler feed pumps.

The best way to illustrate is by means of an actual installation, - let us therefore take the new office building of one of the largest banks in Chicago.

It occupies an entire block, approximately 322 feet in length and 165 feet in width, with three stories below the street and twenty stories and attic above, and with an interior light court approximately 154 feet in length and 54 feet in width. Being built for a bank for its own use, the whole design must depend
to a very great extent on the treatment of the main banking room. After much study it was decided that the entire second story should be devoted to this purpose, with a grand stair case from the entrance hall at each end of the building. The elevators, - twenty four in number, - are placed in groups of six near the corners, two groups arranged to serve the lower stories and two the upper. Stairs, smoke stack and the other utilities that must go into the building are placed adjacent to the elevators. This gives an unobstructed space for banking purposes the full width of the building and almost two hundred feet long, with additional space between the bank of elevators extending to the street at each end; at the sides and ends this is forty feet high, while in the center, beneath an immense arched skylight, it reaches seventy feet. Lighted by windows on all sides, and by the skylight above, this room becomes almost ideal for its purpose. At the rear and sides of the elevator banks are committee rooms, officers' quarters, etc., and these, being on the street fronts are as well located as any offices in the building.

In the first story there is a wide corridor connecting the two entrances, and on either side are two trust companies, operated in connection with the bank and
occupying all of the story except the corners, which are laid out for stores.

The safety deposit department is located at one end of the basement, extending across the full width of the building and one hundred and twenty five feet long. Adjacent to this and likewise extending across the width of the building is additional space used by the Bank for its vaults and special utilities, occupying almost as much space as the safety deposit department.

Starting with the above as fixed points the stories above the main banking room to the twentieth, are arranged for offices, there being a large suite in each corner, and sixty three smaller offices in each story. Janitors' closets and toilet rooms for men are located in all stories, except the twelfth where a large toilet room for women, with rest room and hospital in connection takes the place of the men's toilet. The attic and pent houses contain the main steam and plumbing pipes, exhaust fans, ducts, house tanks for the water supply and elevator machinery. The portion of the basement not used by the bank is used by the building for storage purposes and for lockers and toilet rooms for its employees, while a portion of the sub-basement, and the sub-sub-basement are for the mechanical plant.
It may be of interest to note in passing that the plant which is arranged to furnish all power and light required for the building, and to heat it by exhaust steam in winter, consists of four boilers of five hundred horse power each, and four generating units of three hundred and fifty kilowatts each and two of two hundred kilowatts each. These are placed in the sub-sub-basement, and extend through the sub-sub-basement and sub-basement stories, the boiler room with its boilers, boiler feed pumps, feed water heaters, air compressors, vacuum pumps, tanks and coal bunkers, occupying an area of almost 10,000 square feet, and the engine room with its engines, generators and switchboards an area of 4,300 square feet. The water supply and ejector plants occupy the balance of the sub-sub-basement, about 1,700 square feet, this being all the space excavated to this depth. The remainder of the plant is located in the sub-basement, the refrigerating plant occupying 1,600 square feet, and the ventilating plant 7,200 square feet.

Exhaust steam for heating is carried from the engines to a low pressure header in the sub-sub-basement, from which all supplies for the heating system are taken. But in cold weather there will be times when the engines cannot supply enough steam for heating the entire building and when it will be necessary to supplement this steam with
steam directly from the boilers; this is done through a high pressure connection from the boiler header to the low pressure header, provided with a pressure reducing valve.

In this building a two-pipe vacuum system of heating was designed, vacuum, because the length of piping was so great that a gravity system would have an extremely sluggish circulation, and also to keep the sizes of piping as small as possible, two pipe, in order to reduce the number of pipes to a minimum with the lowest cost of installation. The mains for the stories above the first are run in the attic, a single riser placed in the pipe shaft supplying steam to the distributing mains at this point; this permitted the use of small pipes around the street walls in the banking room in the second story where they were to be concealed, and the elimination entirely of the pipes around the court walls - these are joined together in a pipe gallery in the fourth story, and carried to the sub-basement at one point. It often happens that heat is wanted in the first story of a building before it is wanted in the upper stories and to provide for this condition an independent system is laid out to supply the heat necessary
for this story, the mains being run at the sub-basement ceiling and branches carried up through the basement to the radiators in the first story; the same system supplies steam for the radiators in the interior of the main banking room and for the coils in the main skylight. Placing the safety deposit department of the bank in the basement was sufficient reason for locating the steam supply and return mains for the underneath system, and the return mains for the overhead system at the sub-basement ceiling. A third main taken from the low pressure header supplies the fan coils of the ventilating system.

The supply riser for the overhead system carrying as it does eighty five per cent of the total radiation of ninety nine thousand square feet in the building is eighteen inches in diameter. It is set on a pipe standard at the bottom and is allowed to expand its full height; in the attic it divides to supply the risers, which are located at the columns on the street and court walls. The expansion of a pipe extending this height is approximately four inches; there is no objection to this in the main riser which is located in a pipe shaft where it is readily accessible, and which is installed with bends at the top to take care of the expansion, but it
will not do in the distributing risers, as this amount of expansion would trap the radiators, and might even break the connections. To avoid this the risers, both supply and return - are fastened in the second, seventh, thirteenth and nineteenth floors, and arranged to permit of expansion in both directions from these points; spaces are framed in the fourth, tenth and sixteenth floors where loops are installed in the risers. In this way the maximum amount of expansion in any riser at a radiator connection is about one half inch which can easily be taken care of by providing radiators with high legs. Sleeves are to be placed around all risers where they pass through the floors; these not only provide protection for the risers, but the floor plates at the top cover the openings in the finished floors, and the openings at the bottom are so made as to receive the covering on the risers.

The radiators throughout are of the cast iron type, with the sections put together with screwed nipples. Around the street fronts of the building where there are two windows in each span, there are two radiators of equal size; around the court where there are three windows in each span there are two radiators, one of which is one-third of the total radiation required, and the other two-
thirds. In general these radiators are twenty-six inches high, which is the maximum height that can be installed without exposing the tops above the sills of the windows. The skylight coils are made of wrought pipe, and those under the arched skylight are bent to follow the line of the glass.

The radiators and coils in the vestibules, attic and pent houses are provided with hand valves, all other radiators and coils are provided with diaphragm valves with thermostats in the rooms, giving an arrangement which will be as efficient and as economical in the use of steam, as can be devised. The return valves on the radiators and coils are of the thermostatic type, and the vacuum system is arranged so that the water of condensation is returned to the feed water heaters.

The question of the best method for heating and ventilating the main banking room was a most vital one. To place radiators around the outside walls to provide heat, depending upon the occupants to open or close the windows as necessary to provide ventilation did not seem practical, and no scheme of mechanical ventilation could be devised that did not take much space that was needed for other purposes. So it was that a
direct-indirect system was adopted, the fresh air being taken from the top of the windows of the first story, and being admitted to the banking room through openings in the floor under the radiators. In order to make this system as flexible as possible these openings are arranged with dampers and deflectors so that the air is made to enter the room through the radiators or above them, as desired, thus entering either warmed, or at outside temperature; these dampers are provided with thermostatic control. In addition to the automatic dampers, provision is made for opening or closing the openings by hand when necessary. This allows a supply of fresh air at all times around the walls and the staircases provide the same in the center of the room. Foul air is exhausted at the base of the skylight by two large fans in the attic. The entire system as laid out is designed to provide adequate heating and ventilation without producing unpleasant drafts and without the cost of maintenance that would be entailed by the use of a complete mechanical ventilation system.

In this building all parts of the sub-sub-basement, sub-basement, and basement are provided with complete systems of ventilation, the air being mechanically
supplied and exhausted. In addition the entrance vestibules in the first story are provided with a fresh air system and the trust departments, janitors' closets and toilet rooms are provided with exhaust systems.

Owing to the nature of the building it was impossible to take the fresh air from a point above the second floor, or to locate all the intakes at one point. In a way this may be considered a disadvantage, for the fan units are scattered, and they probably will not receive quite as much attention as they would if they were in one room, but on the other hand it is of advantage, for the arrangement adopted permits the installation of the ducts with fewer crossings, and with a consequent increase in story height over that which would obtain if all the fans were together. As it is, fan intakes of approximately the same area are located at the ceiling of the first story, having a width of two spans, and a depth of two feet; these intakes are carried to the sub-basement and arranged to supply the various fresh air fans, there being independent fans to supply the boiler room, engine room, sub-basement and building portion of basement, safety deposit department of the bank, bank vaults and the entrances at either end of the building.
The fans supplying fresh air to the sub-basement and various portions of the basement are provided with air washers, and those supplying the boiler and engine rooms and the entrances, with filters only, and each fan is provided with the number of heating coils necessary to properly heat the air for the space to which it is to be supplied, this being fifty degrees for the boiler and engine rooms; ninety for the sub-basement and basement, and one hundred and forty for the entrances; all are provided with temperature control on both coils and by-pass dampers. The fans are of the multivane type direct connected to motors, giving the maximum efficiency and occupying the least amount of space. The ducts leading from the fans are of galvanized iron, and are run at the ceiling in such a manner as to give the best distribution of air to the space supplied; in the boiler and engine rooms this supply enters at points near the ceiling; in the entrances the air is blown through radiators, making them more efficient and at the same time reheating the air which mixes with and tempers the cold air coming in through the doors. In order that the ducts supplying air to the safety deposit department may be concealed they are placed behind a false wall; in the bank space in the
basement the same result is accomplished by running them in furred ceilings.

The exhaust fans are of the same type as the fresh air fans and are placed in the attic and pent houses, there being independent fans for the mechanical plant, sub-basement and building portion of basement, bank portion of basement, safety deposit department, trust company's space in the first story and janitors' closets and toilet rooms. The air from the mechanical plant is exhausted at the ceiling where it is the warmest and from all other portions of the sub-basement, basement and first story at points in or near the floor, the ducts being run so far as possible in a manner similar to the fresh air ducts. For the sub-basement, however, the ducts are run in the ground and are protected against deterioration by a layer of concrete six inches thick placed around them. Much difficulty has been experienced in keeping the floors of rooms over boiler and engine rooms from becoming heated from below; in this installation a vitrified asbestos ceiling is placed over these rooms with a clear air space of eight inches above it; openings are provided into this space for the admission of cooler air from the surrounding rooms and a connection made to the exhaust fan for the mechanical plant, the whole being
arranged so that there will always be a current of cool air between the ceiling of the mechanical plant and the floor above.

All heating mains are covered with moulded asbestos covering, except the distributing supply risers and concealed return risers, which are covered with wool felt covering, lined with asbestos; in addition all pipes which are in any way exposed to cold are covered with a frost proof covering. The fresh air intakes and all portions of the fresh air ducts exposed in the boiler and engine rooms are covered with air cell covering, one-half inch thick on the intakes and one inch thick in the plant.

The writer believes that this system of both heating and ventilating is the most complete and modern that can be devised for this building. But, the problems in office building construction are not the same today that they were one year or five years ago, nor the same as they will be one year or five years hence. The present type of return valve, the multivane fan, temperature control, and even the sky-scraper itself as now constructed are all recent developments, and the problems of the heating and ventilating engineer will be greater in the future than they have been in the past. Questions of controlling
the humidity and cooling the air supply, systems of which are being developed in hotels and restaurants, are already being asked in respect to office buildings, and these as well as many others will arise for solution.