MACHINERY'S REFERENCE SERIES

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No. 66

A Dollar's Worth of Condensed Information

Heating and Ventilating Shops and Offices

By CHARLES L. HUBBARD

Price 25 Cents

CONTENTS

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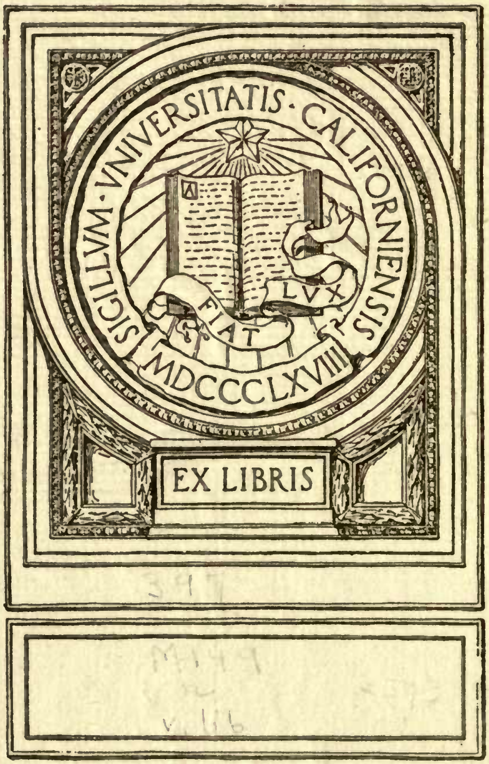
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HEATING AND VENTILATING SHOPS AND OFFICES

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49-55 Lafayette Street, New York City

CHAPTER I

SHOP HEATING BY DIRECT RADIATION*

While it is probably true that a large proportion of the shops and foundries erected at the present time are equipped with hot-blast heating, there are still many cases where for various reasons the older form of heating by direct radiation seems preferable to the owners, and to these a few practical points in regard to the proper methods of installing and operating a system of this kind may be of considerable value. For example, a shop may be heated by a system of direct radiation, which originally gave satisfaction, but which, owing to numerous changes and extensions, fails to operate properly. The owner may feel that it is necessary to install an entirely new system of heating, when perhaps a few changes or additions may make the old one as good as

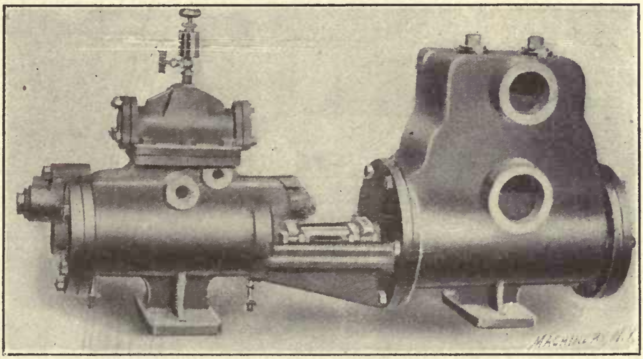


Fig. 1. Special Vacuum Pump for Obtaining Necessary Suction in an Overloaded System

new. Again, an addition to the plant may be in progress and it is desired to extend the present system of direct heating rather than install a hot-blast apparatus in a single building. The object of this chapter is to give some of the faults of direct heating as commonly found in shops and factories, together with suggestions for overcoming them entirely or in part. Rules to be observed in laying out and installing new work will also be given, as well as a review of correct methods of extending present systems to include new buildings or additions to old ones. Some of the points to be considered in connecting a heating system with a power plant will also be touched upon.

Faults of Direct Heating Systems

Among the most common causes of trouble in existing plants which have been changed and enlarged from time to time are small

* MACHINERY, July, 1910.

pipes, insufficient grading, and air binding. The system may have worked satisfactorily in the beginning, when doing only the work for which it was designed, but numerous additions have so overloaded the supply mains and branches that the pressure is considerably reduced in the more remote parts of the system. In addition to this, the returns are flooded by the increased amount of condensation, and the result is poor circulation of steam, cold pipes, and water-hammer.

Matters are made worse by the fact that there are usually no basements in which to carry sealed or wet returns; hence it is necessary to rely on drainage through dry returns, which are much more

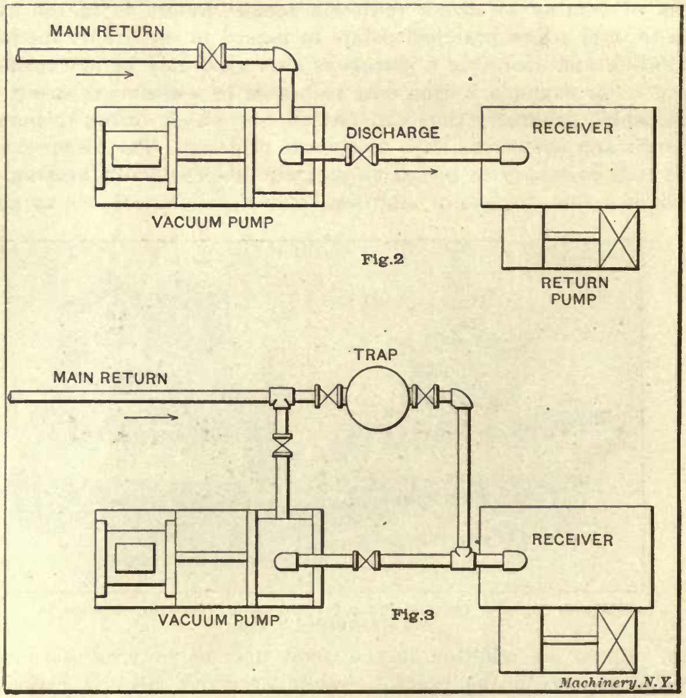


Fig. 2. Method of Connecting Vacuum Pump, used continually, to the Return. Fig. 3. Method of Connecting Vacuum Pump, when used only at Intervals, to the Return

likely to give trouble than when the mains are sealed. Both supply pipes and overhead returns in extended systems are likely in time to sag and form pockets for the accumulation of condensation. This results in the holding back of air in certain parts of the piping and coils, and causes poor circulation and water-hammer.

About the only way to deal with a situation of this kind is to first re-grade the piping wherever it is found necessary to give the required pitch in the right direction, and then attach some form of suction to the end of the main return. If the system of piping is quite extensive and in bad condition, it may be best to place the matter in the hands of some engineering concern making a specialty of vacuum systems for the return of condensation. There are many cases, however, where the necessary results can be secured by home-made methods, or by means within the reach of any good steam fitter.

The necessary suction is best obtained by attaching a special vacuum pump to the main return. Pumps for this particular purpose can be obtained from the best manufacturers, and one of well-known make is shown in Fig. 1. The condensation from heating systems of this kind is usually trapped into a vented receiver, from which it is automatically pumped back to the boilers. In attaching a vacuum pump to the return, the connections may be made as shown in Fig. 2, when it is intended to use the pump all the time, or as shown in Fig. 3, when it is desired to retain the trap and use the pump simply for clearing the system of air in the morning when first warming up, or at intervals during the day when the circulation becomes sluggish. There are many cases where the system will work satisfactorily after the pipes and coils are once cleared of air, and steam circulation established. Operating

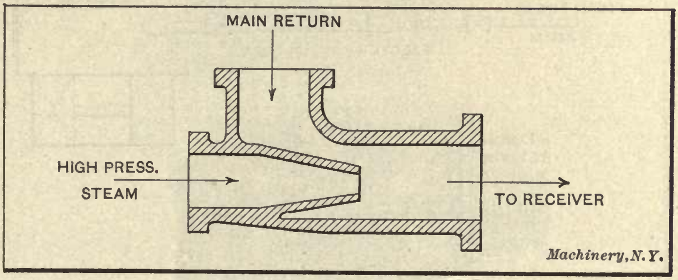


Fig. 4. Steam Ejector used for Clearing the Pipes and Starting up the Circulation

the vacuum pump for a short time in the morning is often all that is necessary.

Sometimes an ordinary steam ejector connected into the return is all that is necessary to clear the pipes and start up the circulation. Such a device is shown in Fig. 4, and the method of connecting it into the return main, in Fig. 5. Sometimes defective circulation may be confined to one particular building or section of the heating plant. In this case all that is necessary may be to connect an ejector into this particular branch, and exhaust the air and water once or twice a day as may be required. If this branch connects with the main return at some distance from the receiving tank, the exhaust may be blown outboard, as it will be operated only for a short time and the waste will be small. Connections for the arrangement above described are shown in Fig. 6. Whenever ejectors are used in this way it is necessary to have steam at a higher pressure for operating them.

The principal feature in the patented vacuum systems is the automatic valve placed at the return end of the coil or radiator which opens only to allow the passage of air and water, and closes in the presence of steam. If the ordinary radiator valve is used and left wide open, there will be short-circuiting through the nearer coils and radiators, while very little, if any, vacuum will be formed in the returns and coils more remote from the pump.

When the plant is not too large, very good results may be obtained by throttling the return valves, leaving an opening just sufficient to care for the condensation under the slight vacuum formed in the returns. When this is done, the radiators and coils should be inspected at frequent intervals to make sure that the throttled valves do not become clogged. If this occurs, they should be opened wide and the steam and water allowed to blow through for a short time, which will usually

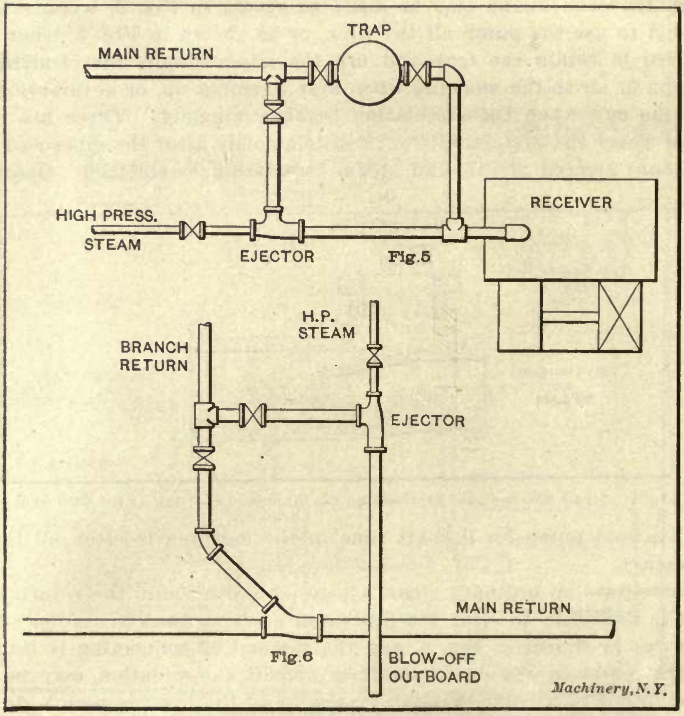


Fig. 5. Method of Connecting the Ejector with the Return Main. Fig. 6. Ejector Connected with a Branch having Defective Circulation

serve to clear them. Sometimes it is not necessary to throttle the valve on each coil and radiator, but they can be grouped together and a throttle valve placed in the branch return from each group. Special thermostatic traps or valves are now on the market which can be used on the return end of the radiators and coils in connection with a vacuum pump if so desired, such a trap being shown in Fig. 7. These open automatically to allow the passage of air and water from the coil.

Throttling and automatic return valves must only be used when the vacuum pump is to be operated continuously, as otherwise the coils would not drain properly when returning by gravity without a vacuum.

There are several types of patented vacuum systems in use, some operating by exhausting the air from the radiators through special air-valves, while the condensation flows to the receiving tank by gravity in the usual manner. In others the vacuum is attached to the return main in a manner similar to the method already described, no air valves being used. The latter arrangement is preferable for the class of buildings under consideration, as it overcomes the effect of improper grading of the return pipes to a considerable extent, and also makes it

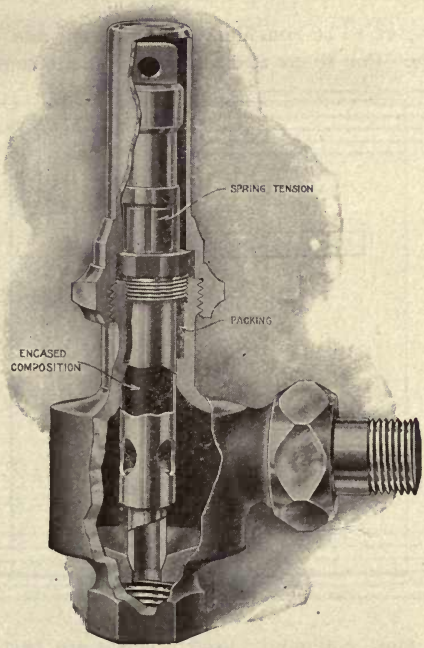


Fig. 7. Thermostatic Valve used on the Return End of Radiators

possible to work with less distance between the heating coils and the return mains.

Design of a New System

Let us next take up some of the points to be considered in the design of a new system. We will assume that it is to operate by gravity without the use of a vacuum pump, it being a simple matter to add this accessory should the plant outgrow the gravity method for the return of condensation. The first step in the design of a new system is to compute the amount of heating surface. For ordinary conditions, with low-pressure steam, there should be about one square foot of heating surface for each 10 square feet of wall surface, and the same amount for each 4 square feet of glass surface. If the building is in an especially exposed location or not particularly well built, use the constants 8 and 3 in place of 10 and 4. For one-story buildings and upper floors having an exposed roof surface without attic space beneath it, count the roof the same as wall. The square feet of heating surface can be reduced to linear feet of pipe by the following:

TABLE I

Square feet of surface multiplied by		Linear feet of
3	=	1- inch pipe
2.3	=	1¼-inch pipe
2	=	1½-inch pipe

The next point to be considered is the form and location of the radiating surface. For shops and similar rooms, circulation coils of 1¼-

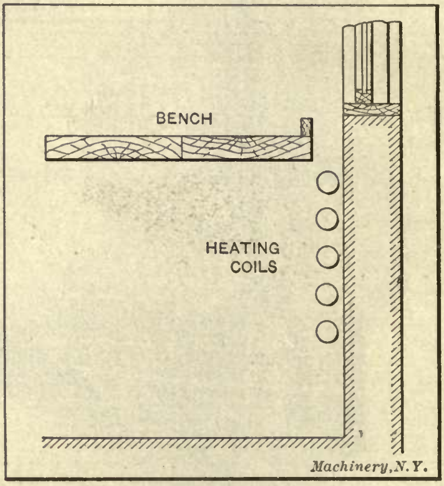
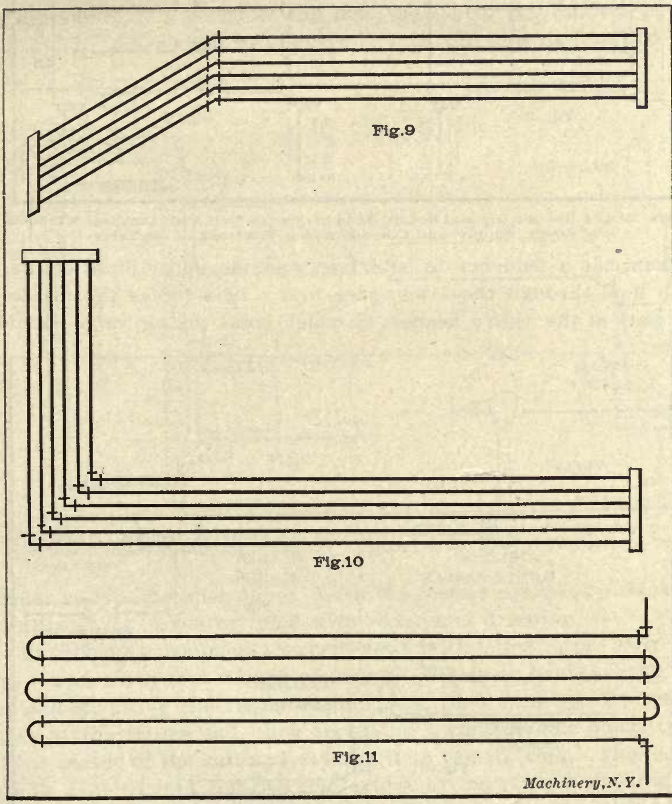


Fig. 8. A Good Method of Placing the Heating Coils

inch pipe are most commonly used. These are best placed along the walls beneath the windows, but if for any reason this cannot be done, they may be suspended on the side at a height of 8 or 9 feet above the floor. This height, again, is governed to some extent by the position of shafting, cranes, etc., and must be located to suit the actual conditions in each particular case. An ideal way to place the coils, from a heating standpoint, is shown in Fig. 8. By setting the bench out about 3 inches from the wall, the warm air from the coil rises in front of the windows where it is most needed.

If there is no basement in which to carry the return pipes, there is sometimes difficulty in using this arrangement, for if they are carried above the floor it is likely to bring them too close to the bottom of the coils. If the supply pipes are of good size so as to keep up the pressure, the return may run within 18 inches of the lowest pipe of the coil; but for ordinary conditions 24 inches is better. If the vacuum system is used, the return may be carried much closer to the coil. Sometimes sufficient space may be obtained by carrying the return in a trench. In other cases there may be enough room to carry the returns beneath the floor; but in case this is done, they should be thoroughly protected against freezing.

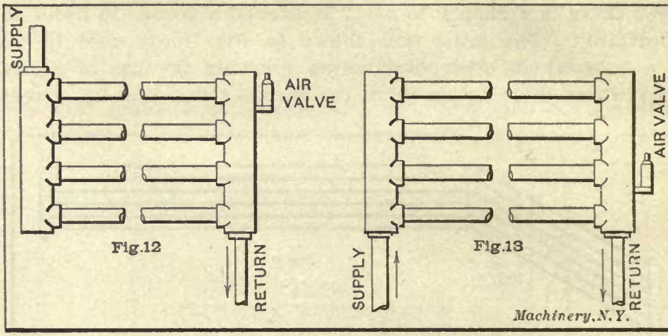
Common forms of heating coils are shown in Figs. 9, 10, and 11. The coil in Fig. 9, called a branch coil, is shown in perspective and is used wherever there is a chance to carry it around a corner in order to secure flexibility. The miter coil shown in Fig. 10 is used in places where a doorway or other obstruction prevents the use of a branch coil, and where there is space on the wall for carrying up a vertical



Figs. 9, 10 and 11. Branch Coil, Miter Coil, and Return Bend or Trombone Coil

portion to care for expansion. Overhead coils are usually of the miter form, laid on the side and supported by means of pipe-rolls and hangers. The wall coils are supported on hook-plates made especially for the purpose. Fig. 11 shows a "return bend" or "trombone" coil, which is used where there is no opportunity for breaking the coil around a corner or carrying it up the wall as in Fig. 10.

In making the steam and return connections to coils, care should be taken to arrange them in such a way as to obtain the necessary air venting and drainage. Figs. 12 and 13 show the supply and return ends of a branch coil with different methods of steam supply and the corresponding position of the air valve. Fig. 12 shows the more common way of supplying steam to the top of the header. In this case



Figs. 12 and 13. Supply and Return Ends of Branch Coil with Different Methods of Steam Supply, and Corresponding Positions of Air Valve

the steam has a tendency to be driven past the upper pipes of the coil and to flow through the lower ones first. This forces the air to the upper part of the return header, at which point the air valve should be

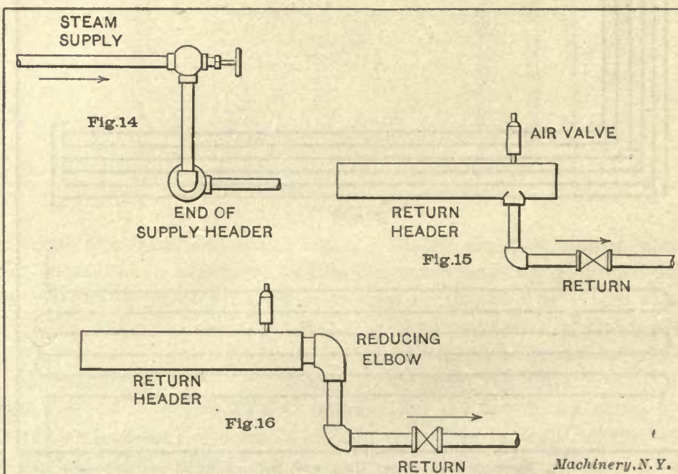


Fig. 14. Method of Making Connection with an Overhead Coil. Fig. 15. Method of Connecting Return Main to Coils. Fig. 16. Using an End Connection between Return Header and Return Main

located as indicated in the illustration. Sometimes, on the upper floors, it is more convenient to connect the supply into the bottom of the header as in Fig. 13. In this case the conditions are reversed and the air valve should be placed near the bottom of the return header instead of at the top.

Fig. 14 shows the method of making the connections with an overhead coil. When possible, it is best to use what is known as a "side-outlet" branch-T for the return header, as this, when in position, makes it possible to connect the return pipe into the bottom of the header, thus securing better drainage. The return mains and branches should always be carried at a lower level than the coils, as shown in Fig. 15. Sometimes it is not possible to obtain the side-outlet headers when wanted. In this case an end connection may be used, provided a reducing elbow is employed, taking in the full size of the opening at the end of the header as shown in Fig. 16. The opening in the return header should never be bushed when used in this way. In placing the air valve, it is better to tap into the top of the header, as shown in Fig. 12, rather than to connect it into the plug in the end of the

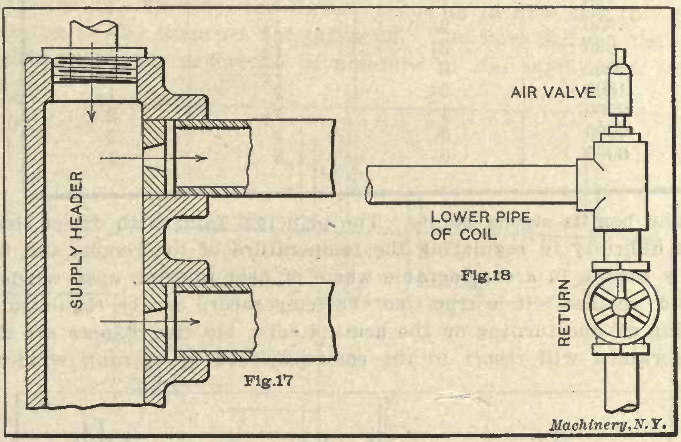


Fig. 17. Method of Equalizing the Flow of Steam from the Header to the Different Pipes in the Coil. Fig. 18. Method of Attaching Air Valve to Trombone Coil

header as is sometimes done. With the former connection there is less liability of its becoming filled with water and dripping.

One difficulty commonly experienced with circulation coils is that the steam, when first turned on, is quite likely to flow through certain pipes first, filling the return header, and then entering the remaining pipes at the return end, thus pocketing a considerable quantity of air in the center of the coil and causing it to remain cold. This condition can be avoided to a considerable extent by inserting a bushing with a small opening, about ¼ inch in diameter, in each pipe opening at the supply end as shown in Fig. 17. This equalizes the flow of steam to the different pipes and causes the whole coil to fill evenly from the supply end. Fig. 18 shows a good way of attaching the air valve and making the return connection for a trombone coil. In this case the steam flows through each pipe of the coil in series, so there is no danger of air pocketing unless steam enters the return end from some other coil.

The sizes of supply and return pipes may be taken from Table II, which may be used for lengths of run up to 200 or 250 feet; for greater lengths the pipes should be increased a size or more according to conditions.

Thus far only steam heating has been considered. When there is plenty of exhaust from the engines so that the matter of steam economy does not have to be considered, this method of heating is very satisfactory and has its strong points. The principal fault with direct steam is the difficulty in regulating the temperature of the rooms, and this usually results in a considerable waste of heat through open windows in mild weather. It is true that the temperature can be regulated by shutting off and turning on the heating coils, but the chances are that the workmen will resort to the easier method of opening windows.

TABLE II

Square Feet of Radiation	Size of Steam Pipe	Size of Dry Return	Size of Sealed Return
60	1	3/4	3/4
100	1 1/4	1	3/4
130	1 1/2	1	1
350	2	1 1/4	1
650	2 1/2	1 1/4	1
1000	3	1 1/2	1 1/4
1600	3 1/2	2	1 1/2
2200	4	2 1/2	2
4000	5	3	2
6000	6	3	2 1/2

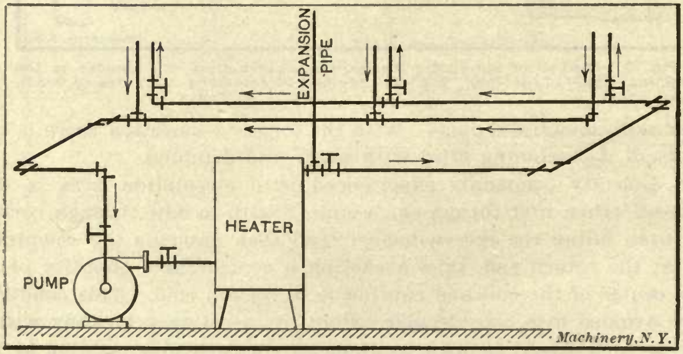


Fig. 19. Two-pipe System for Forced-circulation Hot-water Heating

This has its advantage in providing a certain amount of fresh air, but ventilation by means of open windows in cold weather is not always desirable. If a vacuum system is used, a considerable range in temperature can be obtained by using a vacuum reducing valve which allows steam pressures below the atmosphere to be carried in the heating system.

When considerable live steam is necessary for heating, and it is desired to economize in its use, very satisfactory results may be obtained by the use of hot water under forced circulation. In this way the entire heating system is under the control of the engineer who can vary the temperature of the water to suit the requirements at all times. Under these conditions of warming very little heat will be lost through open windows. The piping need be no more complicated nor the heating surface more extended than in the case of low-pressure steam heating. By placing the expansion tank at a sufficiently high elevation, and using a small amount of live steam, the temperature of the water may be made to equal that of low-pressure steam in the coldest weather.

The mains for forced circulation are usually carried in one of two ways. In the two-pipe system shown in Fig. 19 the supply and return are carried side by side, the former reducing in size and the latter increasing as the branches are taken off. The flow through the coils is produced by the difference in pressure in the supply and return

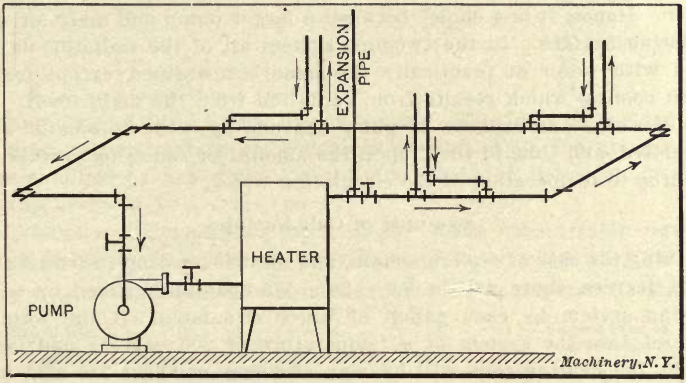


Fig. 20 Single Pipe or Circuit System for Forced-circulation Hot-water Heating

mains. As this is greatest nearest the pump, it is necessary to place throttle valves in the branches to equalize the flow to the different parts of the system.

The single pipe or circuit system is shown in Fig. 20. In this case a single main is carried entirely around the building, the ends being connected with the suction and discharge of the pump, as shown.

The supply risers are taken from the top of the main and the returns connected into the side, a short distance along the line. Circulation through the risers and coils is due partly to gravity (the hotter water rising from the top of the main to the coil and the cooler return-water falling through the return pipe) and partly to the drop in pressure in the main between the points at which the supply and return pipes are connected. When there is a basement in which the circuit main may be carried, this system of piping is the simpler, but the two-pipe system has the advantage of a decided drop in pressure between the supply and return mains, so there is much greater flexibility in running the pipes, which makes it much better adapted to the conditions found in shop heating. Both supply and return mains may, for example, be carried at the ceiling, or both at the floor, or one at the ceiling and the other at the floor. A good arrangement for a two-story building is to carry both mains at the ceiling of the first story, and connect with the first floor coils by drops and with the second floor by risers. In a one-story building both mains are usually carried overhead, as they are less in the way of machinery and other equipment.

In the circuit system it is customary to count on a drop in pressure of about 20 degrees between the pump suction and discharge, and in the two-pipe system to allow a drop of about 40 degrees. In the circuit system the return water from the radiators flows back into the main, so the supply to the radiators along the line becomes cooler and cooler as the distance from the pump increases. For this reason, a larger volume of water must be circulated at a less drop in temperature, or the size of the heating coils and radiators must be increased along the line to make up for an excessive drop in temperature of the circulating water. Hence, it is a choice between a larger pump and main, or more radiating surface. In the two-pipe system all of the radiation is supplied with water at practically the same temperature, except for the slight cooling which results from radiation from the main itself. The size of mains and capacity of pump depends upon the volume of water circulated, and this, in turn, upon the amount of radiating surface and the drop in temperature of the circulating water.

Example of Calculations

Taking the case of a circuit main, and allowing a drop in temperature of 20 degrees, there will be $8.3 \times 20 = 166$ heat units given up to the heating system by each gallon of water circulated. If the water is pumped into the system at a temperature of 200 degrees and cooled to 180, the heating coils will have an efficiency of about 220 heat units per square foot of surface per hour. Hence there should be $220 \div 166 = 1.33$ gallon of water circulated per hour for each square foot of radiation, or $\frac{1.33 \times 100}{60} = 2.2$ gallons per minute for each 100 square feet of radiation. Assuming approximate velocities of flow of 3.4 feet per second for pipes 3 inches in diameter and under, 5.0 feet for 4-inch pipes, 5.7 feet for 5- and 6-inch pipes, and 8.0 feet for 7- and 8-inch pipes, we have in Table III the pipe sizes for various amounts of radiating surface. These sizes are suitable for mains up to 1500 feet in length, or even 2000 feet in special cases, if necessary.

The mains in the two-pipe system may be made somewhat smaller, owing to the greater drop in temperature allowed. On the other hand, the radiation will be slightly less efficient, owing to the lower average temperature of the water. Proceeding as before, and allowing a drop in temperature from 200 to 160 degrees, we have $8.3 \times 40 = 332$ heat units given up by each gallon of water circulated. Assuming in this case an efficiency of 210 heat units for the radiation, we have $210 \div 332 = 0.63$ gallon of water required per hour for each square foot of radiation, or $\frac{0.63 \times 100}{60} = 1.05$ gallon per minute for each 100 square feet of radiation. Using the same velocities as before, we have in Table IV the sizes of pipe mains for the two-pipe system. These sizes are also

TABLE III

Size of Circuit Main, Inches	Square Feet of Direct Radiation Supplied
3	3,400
4	9,000
5	16,000
6	22,000
7	43,000
8	56,000

TABLE IV

Size of Mains for Two-pipe System, Inches	Square Feet of Direct Radiation Supplied
3	7,000
4	18,000
5	32,000
6	44,000

for circuits up to 1500 to 2000 feet in length. Should it be decided to use a drop in temperature of 30 degrees instead of 40, the amount of surface supplied by any given size of pipe would be the mean of the quantities given in Tables III and IV.

The branches and risers to the coils are made considerably larger than the mains, in proportion to the volume of water which they carry.

TABLE V. SIZES OF RISERS AND COIL CONNECTIONS FOR THE SINGLE-MAIN OR CIRCUIT SYSTEM

Size of Pipe, Inches	Square Feet of Radiation
¾	20
1	40
1¼	70
1½	120
2	250
2½	300

TABLE VI. SIZES OF RISERS AND COIL CONNECTIONS FOR THE TWO-PIPE SYSTEM

Size of Pipe, Inches	Square Feet of Radiation
¾	40
1	80
1¼	150
1½	250
2	500
2½	600

The pipe sizes in Tables V and VI may be used for the circuit and two-pipe systems, respectively.

Pumps

Pumps of the centrifugal type are best adapted to this class of work on account of their simplicity and the low-pressure heads required.

For the sizes of pipe given in Tables III and IV the required pressure head for overcoming the friction in the mains will not exceed 40 feet for straight lengths of pipe up to 1500 feet. Each long-turn L and T adds 4 and 9 feet, respectively, to the length of the main. Centrifugal pumps may be driven by direct-connected steam engines, turbines, electric motors, or may be belted to a convenient line of shafting. Fig. 21 shows a belt driven pump of this type.

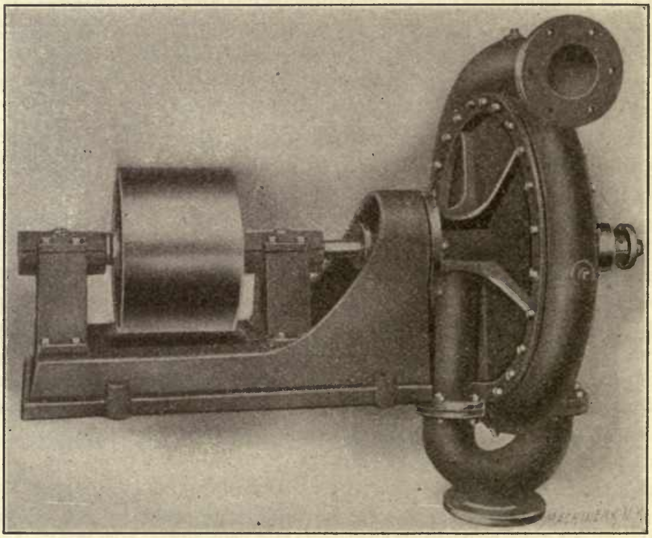


Fig. 21. Belt-driven Centrifugal Pump for Heating Service

The horsepower required for driving a centrifugal pump is given by the equation:

$$\text{H.P.} = \frac{H \times V \times 8.3}{33{,}000 \times E}$$

in which H = friction head in feet,

V = gallons of water moved per minute,

E = efficiency of pump, which may be taken as 0.50 for average conditions.

In heating work the pumps are commonly run under a head of 20 to 50 feet. Table VII gives the capacity and power required for driving medium lift pumps at medium speeds.

Table VII is for the type of pump which would probably be used if belt-driven. If a direct-connected steam engine driven pump were employed, a larger impeller at a lower speed would be used, and for a motor or turbine-driven pump a small impeller at a high speed is required.

Heater

The water is usually heated in a closed feed-water heater with the connections reversed, that is, with the steam on the inside of the tubes and the water on the outside. Any good form of heater can be used for this purpose by providing it with steam connections of sufficient size. In the ordinary form of heater, the feed water flows through the tubes, and the connections are therefore small, making it necessary

TABLE VII

Size of Delivery, Inches	Rated Capacity in Gallons Per Minute	Revolutions per Minute for Different Pressure Heads				H. P. for each Foot Pressure Head
		20-foot Head	30-foot Head	40-foot Head	50-foot Head	
2	100	780	945	1090	1210	0.063
3	240	710	850	970	1080	0.136
4	430	640	765	870	960	0.217
5	730	530	635	720	800	0.309
6	1050	480	570	650	715	0.446
7	1440	405	485	550	605	0.606
8	1880	355	420	480	530	0.791

to substitute special nozzles of large size when used in the manner described. When computing the required amount of heating surface in the tubes of a heater, it is customary to assume an efficiency of about

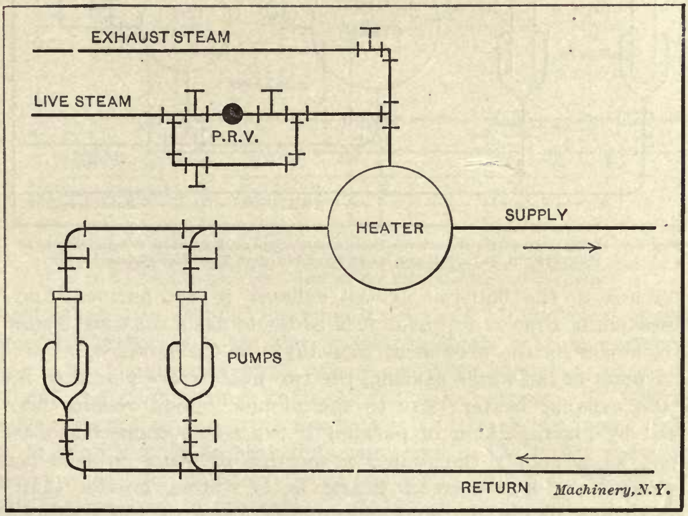


Fig. 22. Diagram of Connections between Pump and Heater when Live and Exhaust Steam are used in the same Heater

200 heat units per square foot of surface per hour per degree difference in temperature between the water and steam.

Taking the case of a two-pipe system where the water is delivered at 200 degrees and returned at 160, the average temperature of the water passing through the heater will be, approximately, 180 degrees. If exhaust steam is supplied to the heater at atmospheric pressure, there will be a difference of $212 - 180 = 32$ degrees between the steam and water, thus giving an efficiency of $200 \times 32 = 6400$ heat units per square foot of heating surface. Hence $6400 \div 210 = 30$ square feet of direct heating surface that may be supplied from each square foot of tube surface in the heater. Commercial heaters are commonly built on a basis of 1/3 of a square foot of tube surface per horsepower, from which it is seen that

$$\frac{6400}{3 \times 210} = 10$$ square feet of radiating surface supplied by each horsepower of the heater, or, in other words, one commercial horsepower of heater is required for each 10 square feet of direct radiation.

When there is not sufficient exhaust steam for heating requirements, live steam may be admitted to the heater through a pressure-reducing valve, provided the exhaust is purified of oil so the condensation may

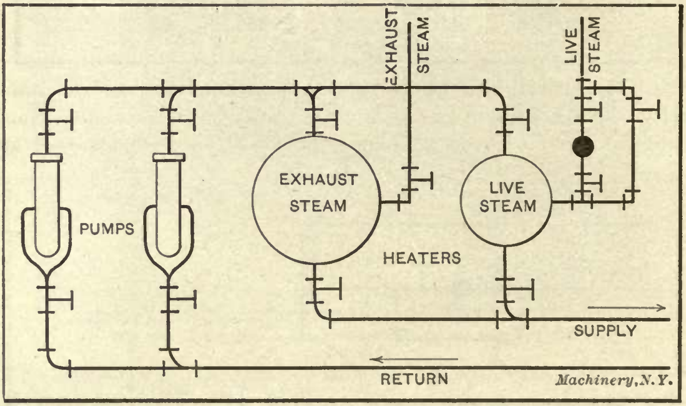


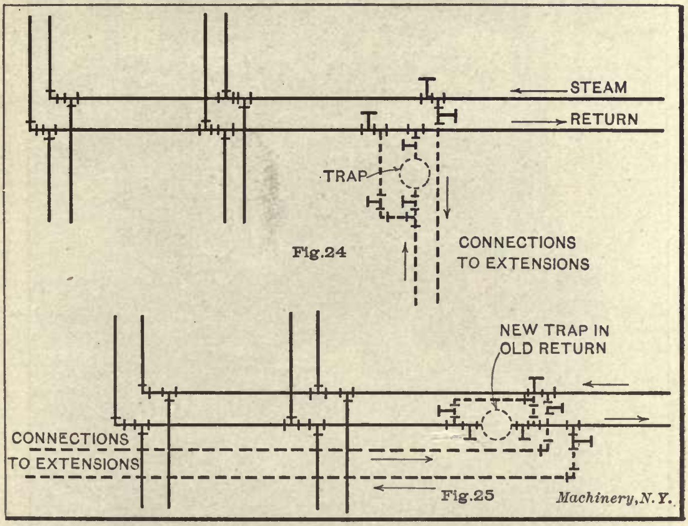
Fig. 23. Diagram of Connections between Pump and Heater when Separate Heaters, in Parallel, are used for Live and Exhaust Steam

be returned to the boilers. If the exhaust is not purified, and the condensation is allowed to waste, it is better to use a separate heater for the live steam on the ground of economy. In the Evans-Almirall patented system of hot-water heating, the two heaters are placed in series, with the exhaust heater next to the pumps. Good results may be obtained by placing them in parallel if the water connections are so throttled as to supply the proper proportion of water to each heater. The efficiency of a live steam heater is, of course, greater than one using exhaust, owing to the higher temperature of the steam. The efficiency for any given pressure can be easily determined by the methods already given.

The general methods of making the connections between the pumps and heaters are shown by the diagrams in Figs. 22 and 23. In the first case the live steam is used in the same heater with the exhaust, and in the second, separate heaters are used, connected in parallel. It is best to provide two pumps, each capable of doing the entire work, for if the pump gives out, there is no way of warming the building until it is repaired. In making the connections, the arrangement should be such that any part of the apparatus can be cut out without interfering with the operation of the remainder. All fittings about the pumps and heaters should be of the long-turn pattern, and sweep bends of wrought-iron pipe should be used in the mains for making right-angled turns, when possible.

Extensions to Existing Plants

In making extensions to a plant already in use, the first step is to determine if there is sufficient boiler power in reserve to provide steam for the additional heating surface. If the present boilers are loaded



Figs. 24 and 25. Methods of Making Connections for Additions located near the Boiler-room, and at the Extreme End of the Line

up to their full capacity, new boilers should be installed, allowing one horsepower for each 10 square feet of direct heating surface. Next see if the supply and return mains are large enough to carry the additional radiation, using Table II for this purpose. If not, separate mains should be run from the boilers and receiving tank. Sometimes it is necessary to go back only part way to the boiler room to find a point where the mains are large enough to do the entire work without too great a drop in pressure.

If the addition is of considerable magnitude—a new building, for example—it is usually best to place an independent trap on the return, especially if it is nearer the boilers than the rest of the system. Where several buildings or wings are drained through a single return main it is often of advantage to place a trap in the return from each building and vent the receiving tank to the atmosphere. When the addition is at the extreme end of the line and the main is not of sufficient size to care for the extra load, it is usually much cheaper to run a separate supply and return, parallel to the old lines, than to enlarge them, owing to the work of disconnecting and connecting the various branch pipes along the line. Figs. 24 and 25 show methods of making connections for additions located near the boiler-room and also at the extreme end

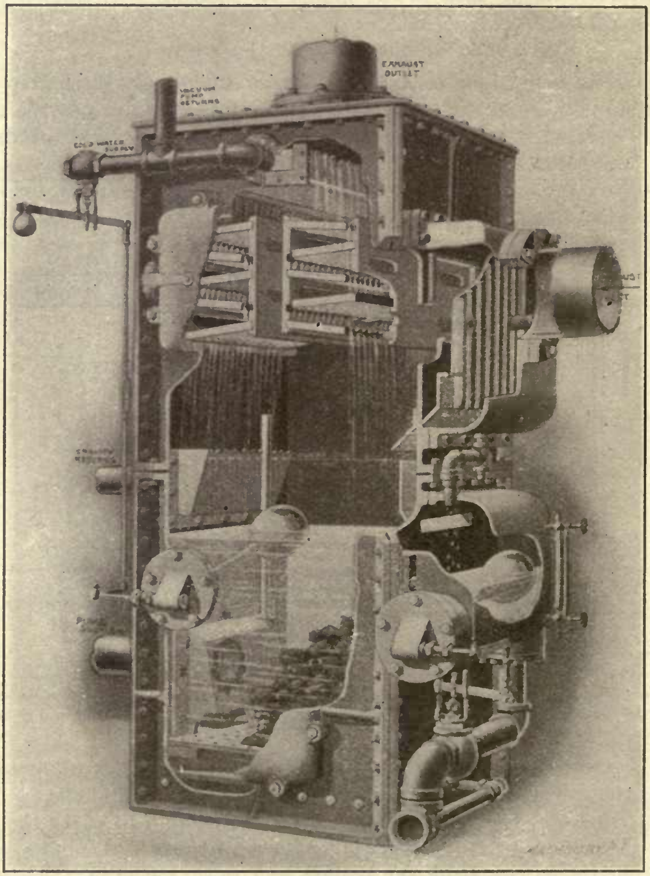


Fig. 26. Open Heater Combining Oil Separator, Feed-water Heater, Purifier, Return Tank and Filter

of the line. The full lines represent the old system of piping and the dotted lines the new.

Connecting Heating System to Power Plant

In connecting a heating system with a power plant, it is nearly always advisable to plan for using as much of the exhaust steam as may be necessary for heating the feed water, as this effects a constant saving in summer as well as in winter. With non-condensing engines

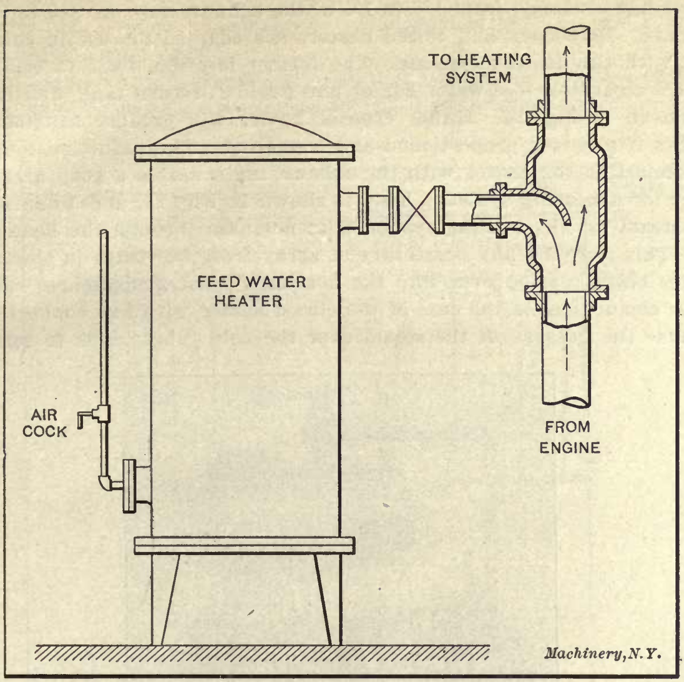


Fig. 27. Induction Method of Connecting the Heater with the Exhaust Main

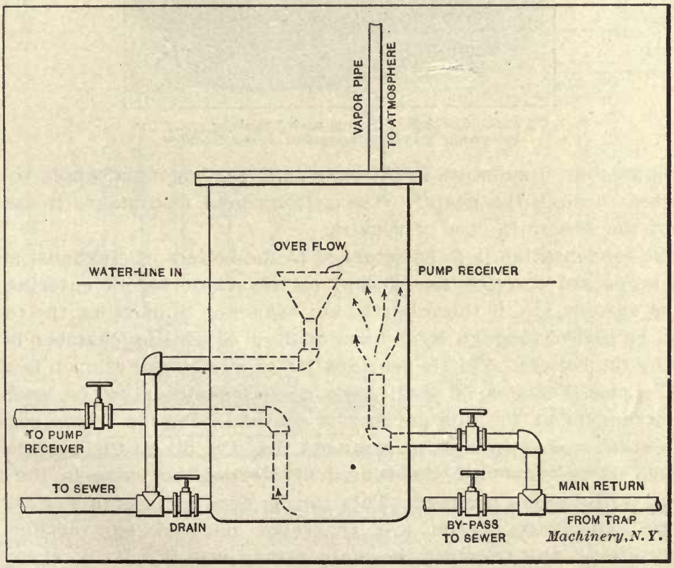


Fig. 28. Arrangement for passing the Return through a Settling Chamber

of average economy, from 1/6 to 1/5 of the exhaust may be used for this purpose. Both open and closed heaters are adapted for use in connection with the heating systems. The former is often made to combine the oil separator, feed-water heater and purifier, return tank, and filter, as shown in Fig. 26. Either type of heater will produce satisfactory results if properly proportioned and connected. The induction method of connecting the heater with the exhaust main makes a good arrangement for a heating system. This is shown in Fig. 27, and when used, the steam for the heating system does not pass through the heater at all. This prevents any possibility of spray from the trays in the open heater being carried over into the heating system, and secures rather dryer steam than in the case of the closed heater with two connections, because the passage of the steam over the cold tubes tends to form a

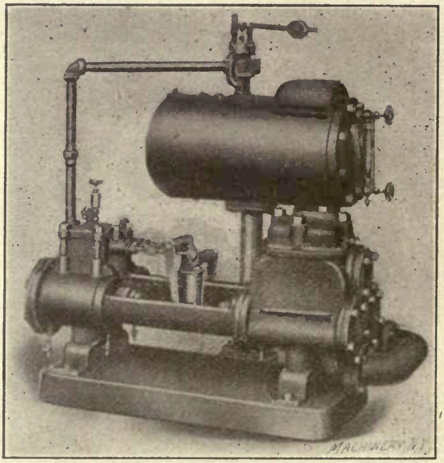


Fig. 29. Combined Pump and Receiver used for returning the Condensation to the Boilers

certain amount of moisture in the surplus steam when the whole volume is passed through the heater. The arrangement also makes it easy to cut out the heater in case of repairs.

If the condensation is to be returned to the boilers, the exhaust steam must be passed through an efficient oil separator before entering the heating system, and if there is still any tendency to priming, the return should be passed through some form of filter or settling chamber before entering the boilers. This is provided for in most types of open heaters, but if a closed heater is used, some special device must be used. A good arrangement for this purpose is shown in Fig. 28. This consists of a cast-iron settling tank so arranged that the oil on the surface can be made to overflow into the funnel by closing the valve in the pipe leading to the pump receiver. This can be done at intervals as the oil collects. The best results are generally obtained by venting the receiving tank and trapping the main return into it. If the system is fairly compact, a simple trap may be used, placing it near the tank, but if two or more buildings are included, it is best to place a trap in the return from each.

In small plants a combined pump and receiver of the type shown in Fig. 29 is commonly used for returning the condensation to the boilers,

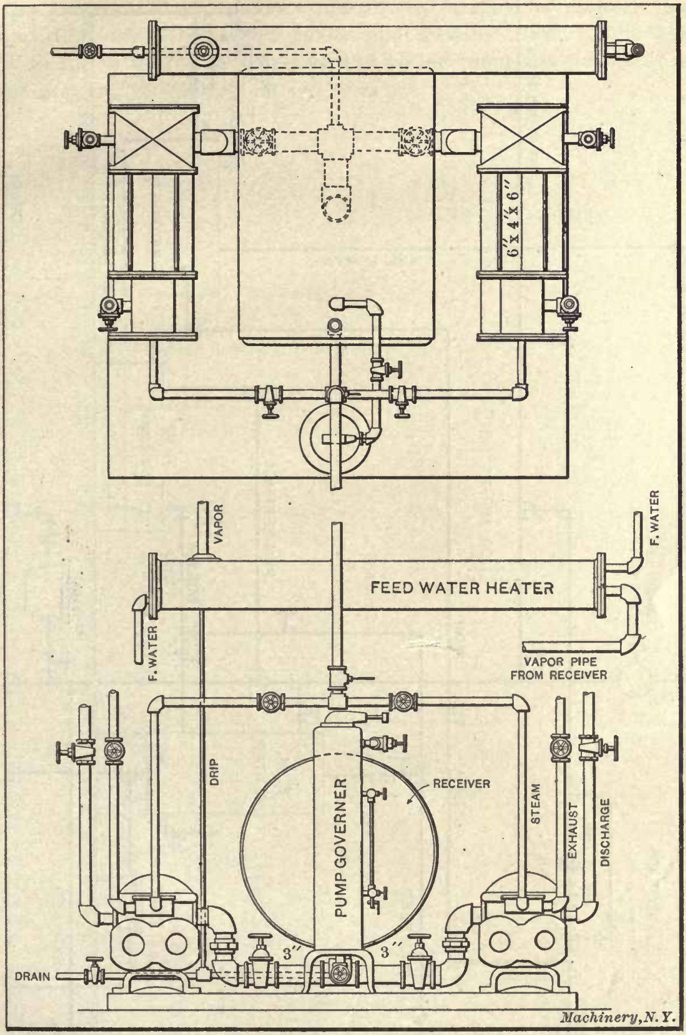


Fig. 30. Arrangement of Duplex Pump and Receiver for Large Plant

but in the case of large and important heating systems it is best to use two pumps, each of sufficient capacity to do the whole work. When two pumps are used, they should be run alternately to keep them in good condition. Fig. 30 shows a good arrangement for duplicate pumps

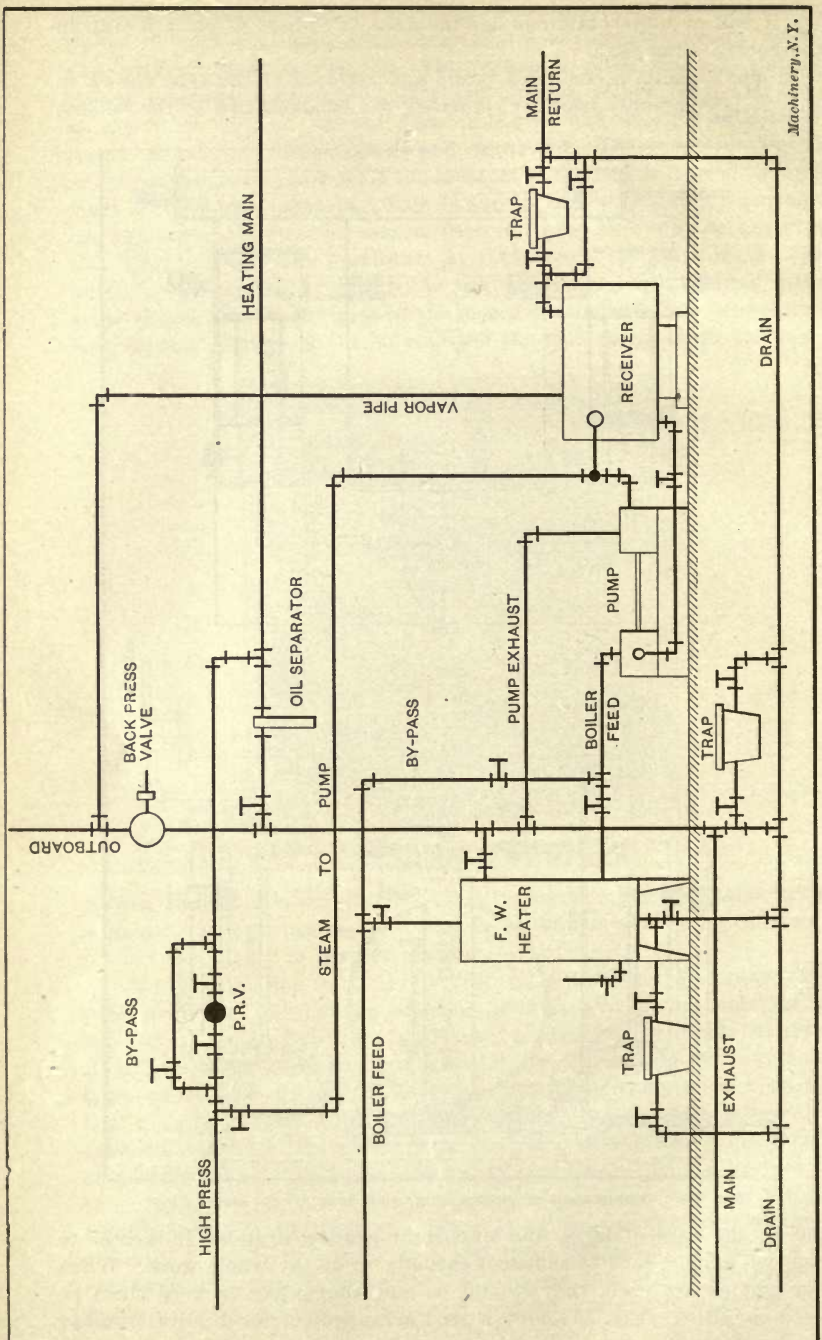


Fig. 31. General Method of Making Pipe Connections for Combined Power and Heating Plant

and receiver. The pumps are operated automatically by means of a governor or regulator located in front of the tank, as shown. This admits steam to the pumps by means of a float valve when the water in the tank rises above a given point.

The diagram, Fig. 31, shows the general method of making the pipe connections for a combined power and heating plant. This diagram will be found useful in planning the boiler room equipment of a new plant and in remodeling an old one.

CHAPTER II

HEATING AND VENTILATING OFFICES IN SHOPS AND FACTORIES*

The previous chapter has been confined to the heating installation in the machine and erecting rooms, without any special mention of the conditions to be met with in the proper ventilation of the offices and drafting-rooms. As a matter of fact, the requirements are more exacting here than in the shop proper, where the cubic space is usually large compared with the number of occupants, and where, under average conditions, the workmen are more actively engaged than those employed in office work. If clear and alert minds are required anywhere about a manufacturing establishment, it is in the offices and drafting-rooms, and such a condition can be brought about only by providing the rooms with an abundance of pure, fresh air, at the proper temperature and without drafts.

Rooms of this kind are usually heated by direct radiation, or, if the shops are equipped with a hot-blast system, the air pipes are extended to the offices. In case of direct radiation, there is no means of providing ventilation except through open windows; the drafts produced in this way are a common cause of colds and a general lowering of the efficiency of the office force. Again, the requirements of the shop and the office are not the same, and a hot-blast system which gives satisfactory results in the former may be far from suitable for office ventilation. When the air is rotated within the building it is hardly suitable for the offices, on account of odors which it may contain, and also because its purity is hardly up to the standard required for this purpose. Again, if the entire air supply for the hot-blast apparatus is taken from out-of-doors, and is therefore of the required purity, the temperature requirements may not be the same for the office as for the shop, and the chances are that the former will become overheated unless the registers or dampers are partly closed, which, of course, results in a corresponding reduction in the air supply.

It is the object of this chapter to point out several different ways, more or less efficient, according to their cost, by means of which the ventilation of the offices may be improved. Let us first take the case of an office heated by direct radiation, and where the finish of the room is such that the matter of appearance is not of great importance. The arrangements shown in Figs. 32 to 36 can be made without great expense by the shop carpenter, with a little assistance from a galvanized iron worker. The idea in each of these cases is to bring fresh air in through the window by raising the lower sash slightly, and to pass the air over and between the sections of the radiator before delivering it into the room. Arrangements of this kind cannot be depended upon to always deliver a fixed quantity of air like a fan, because the amount

* MACHINERY, February, 1910.

will vary somewhat with the strength and direction of the wind and also with the outside temperature, but fair results may be obtained in this way at a very reasonable cost.

The objection is sometimes raised that the radiator being proportioned for direct work only, cannot be depended upon to warm outside air for ventilation also. In a considerable number of cases coming to the attention of the writer, no trouble has ever been experienced from this source. Direct radiators are commonly proportioned for zero weather and therefore, much of the time, are larger than is necessary, and also, as the air passes over them at a higher velocity and lower temperature, their efficiency is much increased. In extreme weather the amount of fresh air can be reduced temporarily, or the window can be closed entirely and the air rotated over the radiator by openings provided for that purpose.

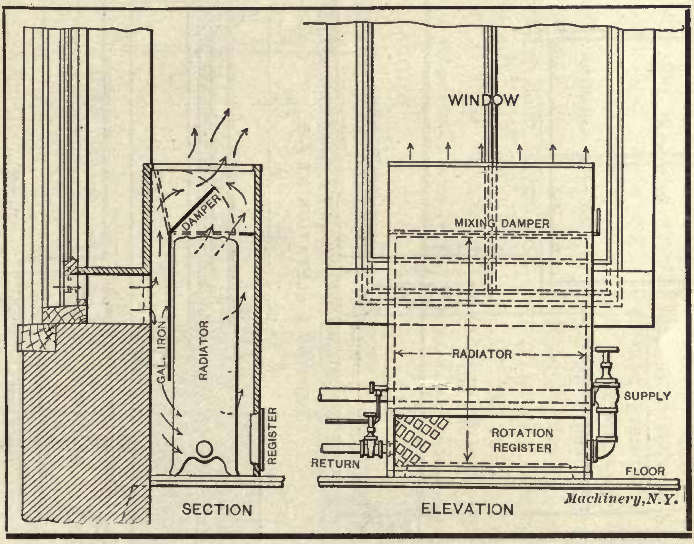


Fig. 32. Arrangement when Radiator is placed directly in front of Window

Fig. 32 shows the method of enclosing a radiator which stands directly in front of a window and projects above the sill. The casing is made of 7/8-inch sheathing with galvanized iron damper and inner casings as shown. When the mixing damper is thrown to its extreme upper position, as shown by dotted lines, all of the entering air passes downward back of the radiator, and then upward between the sections, where it becomes heated and is discharged into the room through the open top of the casing. When it is desired to reduce the temperature of the room, the mixing damper can be thrown to the right, thus admitting a mixture of hot and cold air without reducing to any great extent the volume of air supplied. By closing down the damper on top of the radiator, practically all heat will be shut off. A register placed in the front of the casing, near the bottom, serves to take air from the room when it is desired to use the radiator for heating only, as at night time.

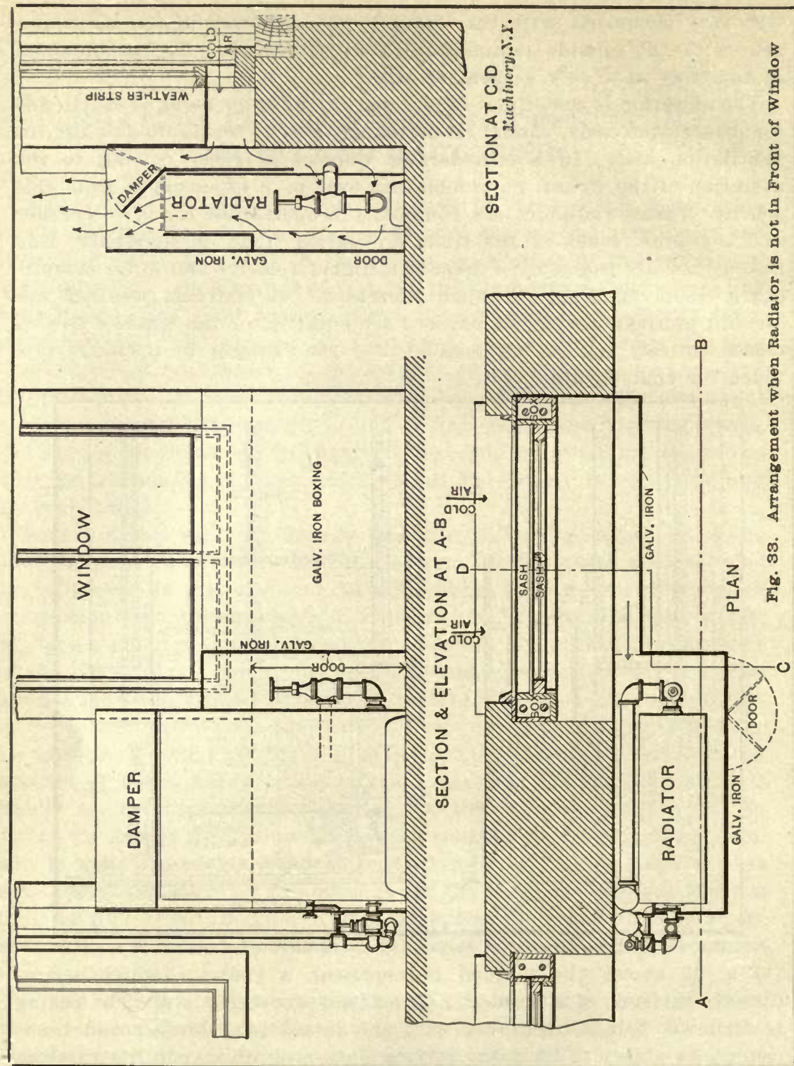


Fig. 33. Arrangement when Radiator is not in Front of Window

Fig. 33 shows a plan, elevation and section of the casing and damper when the radiator stands at the side of a window instead of in front, as in Fig. 32. In this instance the whole casing is made of galvanized iron, although wood may be used if desired. The general principle is the same here as in Fig. 32, the only difference being its adaptation to another position of the radiator. The register for the rotation of air in this case is replaced by a door in the front of the casing, which may be opened at night, or when ventilation is not required.

In Fig. 34 the radiator occupies a position across the end of the room at right angles to the window, Fig. 35 showing the plan view. Here the

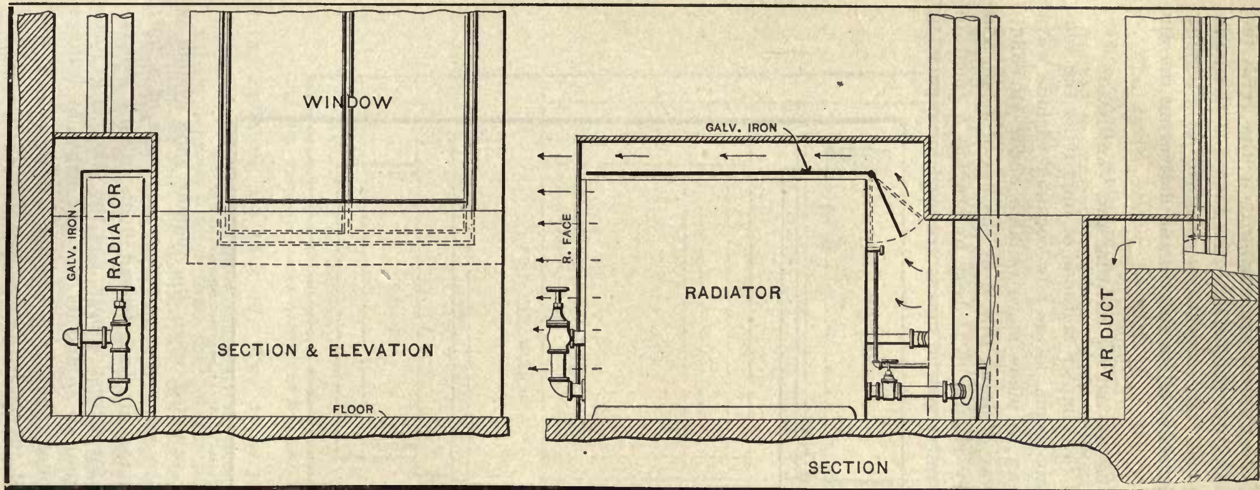


Fig. 34. Arrangement used when the Radiator is placed along a Wall at Right Angles to the Window. See Fig. 35 for Plan View

arrangement of casing and damper is somewhat different from those already described. In this case the air is delivered into the room through a register face or grille at the end of the boxing, instead of at the top, as before. This arrangement is only adapted to pipe radiators or a deep sectional radiator of very open pattern, as the air passes through it lengthwise instead of upward between the sections. The mixing damper here extends across the end of the radiator and deflects the entering air either through the radiator or over it, according to the temperature desired. The radiator is enclosed in a galvanized iron casing, open at each end, while the passages for the cold air are of wooden sheathing, as shown. Air is admitted for rotation through a door or register in the wooden boxing.

Sometimes, in buildings of mill construction with heavy brick walls, the radiators are set in recesses in front of the windows. A very satisfactory way of encasing them and admitting fresh air is shown in Fig. 36. With this arrangement no extra space is required, as the front of the casing is in line with the inner face of the wall and does not project into the room. A thorough mixture of the warm and cold air currents is obtained by carrying up a shield above the mixing damper, as shown, and delivering the air near the sash.

Using Fans for Impelling the Air for Heating and Ventilation

Having taken up some of the simpler methods of improving the ventilation in offices and drafting-rooms, let us now consider various ways in which the air supply may be made more reliable under all conditions. The only practical way of doing this is by the use of a fan, and to get the most satisfactory results it is best to provide a separate apparatus for these rooms, unless special means are used for regulating

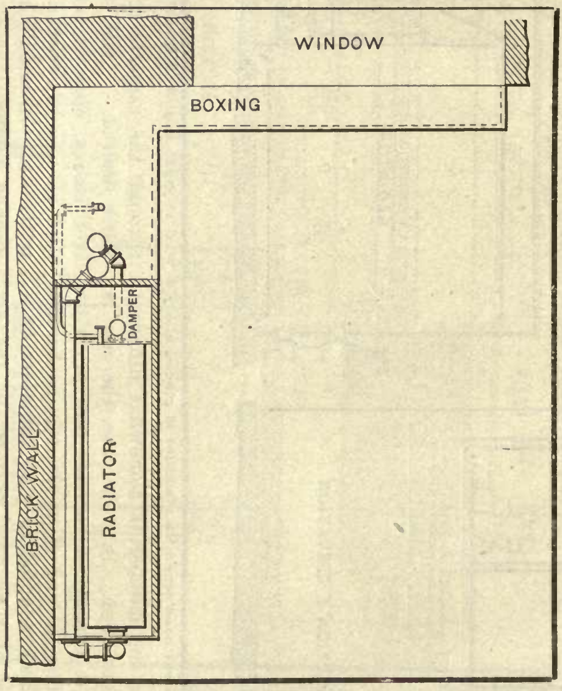


Fig. 35. Plan View of Arrangement Shown in Fig. 34

the temperature of the air supplied when the regular shop system is made use of. There are two ways of ventilating by means of a fan; one is to exhaust the vitiated air and depend upon inward leakage around doors and windows for a fresh supply, and the other is to force in fresh air and allow the foul air to find its way out either by leakage or through specially provided flues or transoms. Both supply and vent fans are made use of in special cases, but this is not usually necessary under ordinary conditions. The method of supplying fresh air under pressure is more satisfactory for general ventilation, as it gives an opportunity of warming it and also permits of better distribution. When the exhaust system is used the fresh air at outside temperature leaks in, and in so doing is very liable to produce uncomfortable drafts near the doors and windows.

The device shown in Fig. 37 is the simplest form of fan supply. This, in a sense, is a makeshift, but for single rooms where it is desired to improve the ventilation without very much expense, it may be made to give very good results when properly installed and operated. This is adapted to rooms with sufficient direct radiation to warm them comfortably in zero weather. Such rooms, as already stated, will be overheated a greater part of the time, unless part of

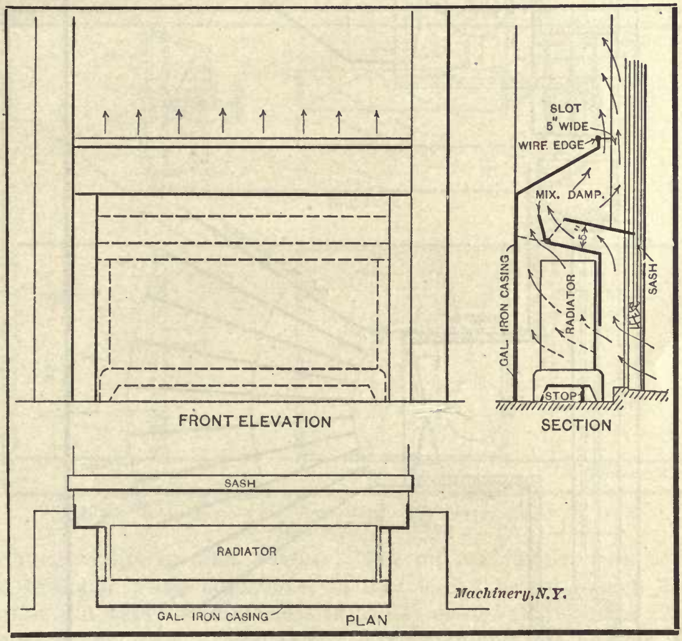


Fig. 36. Radiator placed in front of Window, in a Niche in Thick Brick Wall

the radiators are shut off. The upper part of rooms heated in this way contains a considerable body of pure air at a temperature ten to fifteen degrees higher than that of the air near the floor; hence, if a certain amount of outside air can be mixed with this to bring the temperature down to 68 or 70 degrees, it will gradually fall to the breathing level, and thus, by proportioning the outside air supply to the surplus heat given off by the radiators, a very marked improvement in the purity of the air may be obtained.

The apparatus consists of an ordinary desk fan placed in a wooden boxing so arranged as to draw outside air from the top of a window, the upper sash being dropped slightly, and to discharge it in a thin fan-like sheet near the ceiling. The object of this is to thoroughly mix it with the warm air of the room before it has a chance to fall in the form of a cold draft. Narrow registers, with cords for opening and closing from the floor, are placed in each side of the boxing around the fan, as shown. When the cold air supply is too great, and drafts are felt, the sash may be partially closed and the side registers opened slightly, as may be required. In this way the cold air is reduced and part of the supply is drawn from the room and recirculated. This, of course, reduces the ventilation, but the volume of fresh air

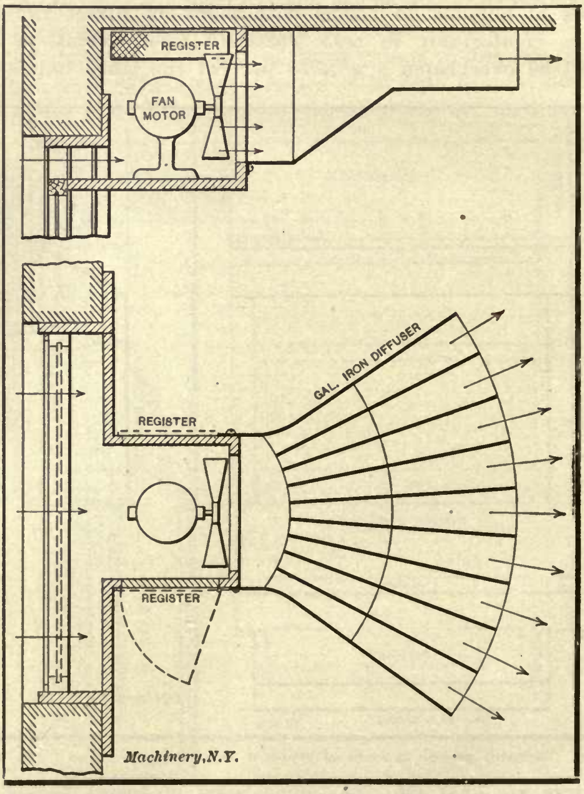


Fig. 37. Simple Arrangement for Desk Fan Ventilation

must be sacrificed rather than to allow the presence of cool drafts. A 12-inch desk fan run on the medium speed will answer very well for a room containing from 6 to 8 people. The diffuser opening may be about 4 inches in depth by 4 feet in length, the object being to secure a thorough mixing of the air.

A better arrangement, though more expensive, is shown in Fig. 38. This is adapted to the ventilation of several rooms by extending the distributing duct from the fans by means of suitable branches. The apparatus is hung from the ceiling at some convenient point in the shop, as shown in Fig. 39, and takes its air from the upper part of a near-by window. The air is warmed by means of a special heater made up of pin radiators, and divided into three or four separately-valved sections for regulating the quantity of heat as required at different seasons of the year. Close regulation for varying the temperature of the air during different parts of the day is secured by the use of a mixing damper which "by-passes" a part of the air through a separate passage under the heater, where it mixes with the hot air just before it enters the fan.

An important point in an arrangement of this kind is to keep the cold air by-pass entirely separate, as shown in the section in Fig. 38, so that the air will not be warmed to any extent while being drawn past the heater. Otherwise it will be difficult to secure a sufficiently

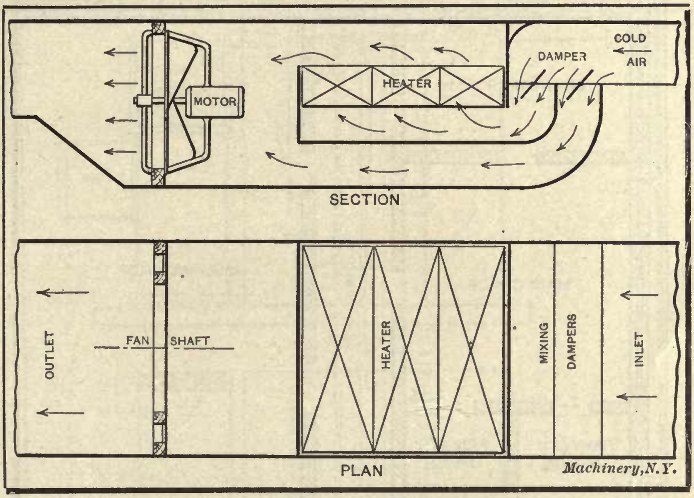


Fig. 38. Arrangement for Ventilating with Heated Air, or for both Heating and Ventilation

low temperature in mild weather. The mixing damper may be operated by hand, being adjustable, so that it can be set in any desired position. A better arrangement is to use one of the systems of automatic control, with a "graduated" mixing damper, as by this means the apparatus requires no particular attention after the thermostat is once set.

This type of apparatus is more especially adapted to cases where the rooms are heated by direct radiation, and the air supplied at a temperature of 68 or 70 degrees, for ventilation only. The heater can be made of sufficient size to both ventilate and warm the rooms if desired, although if the space to be warmed is of considerable extent, it is more common to use the outfit shown in Fig. 40, simply because it is more compact. If the heater in Fig. 38 is used for ventilation only, a "hot-air" thermostat should be placed in the duct and set to maintain an air temperature of 68 or 70 degrees. If the heater is proportioned to warm the rooms as well, a "room" thermostat should be used instead, this being placed upon an inner wall of the room.

In case the air is to be delivered at a fixed temperature for ventilation only, a dial thermometer should be placed in the side of the air duct at some convenient point beyond the fan. This is necessary for setting and adjusting the thermostat if automatic control is used, and for operating the hand mixing damper in other cases. When the apparatus is used for heating also, all adjustments of thermostat and damper are done by means of an ordinary wall thermometer, which indicates the temperature of the room. The fan shown in this case is of the disk type, driven by a direct-connected motor. If more con-

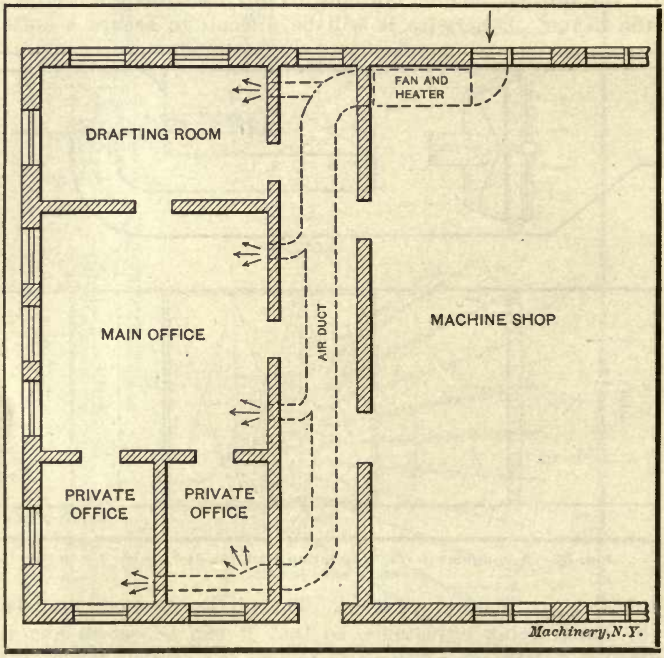


Fig. 39. Plan of Offices with Apparatus shown in Detail in Fig. 38 installed

venient, a belted high-speed motor may be used, or the fan may be driven from a convenient countershaft. High-speed motors are not usually objectionable about a shop, as quietness of operation is not of great importance in locations of this kind.

The computations for determining the size of fan and heater are simple. The air supply should be based on 2,400 to 3,000 cubic feet per occupant per hour, which allows a small margin for overcrowding at times without inconvenience. The square feet of surface in the heater for ventilation may be computed by the equation

$$S = \frac{O \times C \times 1.3}{1,500} \qquad (1)$$

in which

S = square feet of radiating surface,

O = number of occupants,

C = cubic feet of air per hour per occupant = 2,400 to 3,000.

When the heater is used for warming the rooms in addition to ventilation, the following may be used:

$$S = \frac{(O \times C \times 1.3) + T}{1,000} \qquad (2)$$

in which S, O, and C are the same as in (1), and T = the total heat loss from the rooms in heat units per hour. The value of T in average

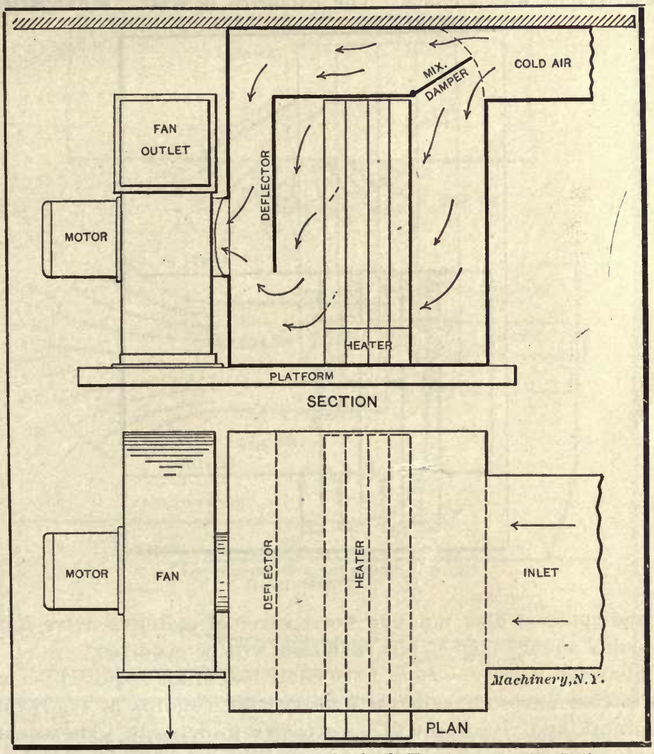


Fig. 40. A Compact Apparatus for both Heating and Ventilation

cases may be found by multiplying the glass surface by 90, the net wall surface by 20, adding the results, and multiplying by the following factors, according to exposure:

TABLE VIII

Exposure	Factor	Exposure	Factor
North	1.32	Northwest	1.26
East	1.12	Southwest	1.10
South	1.0	Northeast	1.22
West	1.20	Southeast	1.06

The size and speed for the average disk fan and the horsepower of motor is given below.

TABLE IX

Diam. of Fan, Inches	Revolutions per Minute	Cubic Feet of Air per Minute	Horsepower of Motor
18	530	1,000	0.08
21	450	1,400	0.09
24	400	1,800	0.12
30	320	2,900	0.18
36	270	4,200	0.25

Example: The offices and drafting-room in a shop contain an average of 36 people; there are 300 square feet of window surface and 600 square feet of wall surface. The exposure is west. What will be the size and speed of disk fan, and horsepower of motor to drive it? Also, how many square feet of pin radiation will be required?

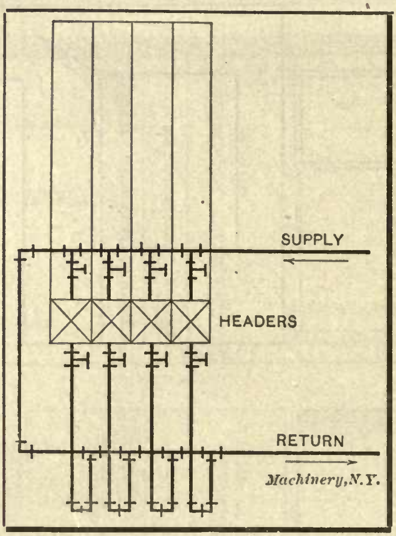


Fig. 41. Piping for a Heater of the Hot-blast Type

We have 36 × 3,000 ÷ 60 = 1,800 cubic feet of air required per minute, which, from Table IX, calls for a 24-inch fan running at 400 revolutions per minute and requires 0.12 horsepower to drive it. The square feet of surface in the heater is found by substituting the known quantities in equation (2); the first step is to find the value of *T*.

Glass 300 × 90 = 27,000
Wall 600 × 20 = 12,000

39,000 × 1.20 = 46,800.

Substituting in the equation, we have

$$S = \frac{(36 \times 3{,}000 \times 1.3) + 46{,}800}{1{,}000} = 187$$

Fig. 40 shows an outfit which may be used in the same way as the one just described, when it is desired to have the apparatus as compact as possible. In this case a blower of the steel plate type is used instead of a disk fan, and a pipe heater of the regular hot-blast type takes the place of the pin radiators. This apparatus may be supported upon a platform or upon I-beams suspended from the ceiling or roof of the shop. The same idea regarding air-ways and mixing damper as in the arrangement shown in Fig. 38, is carried out here. The deflector in front of the heater prevents the air from being drawn directly across the hot pipes when the mixing damper is set for all, or

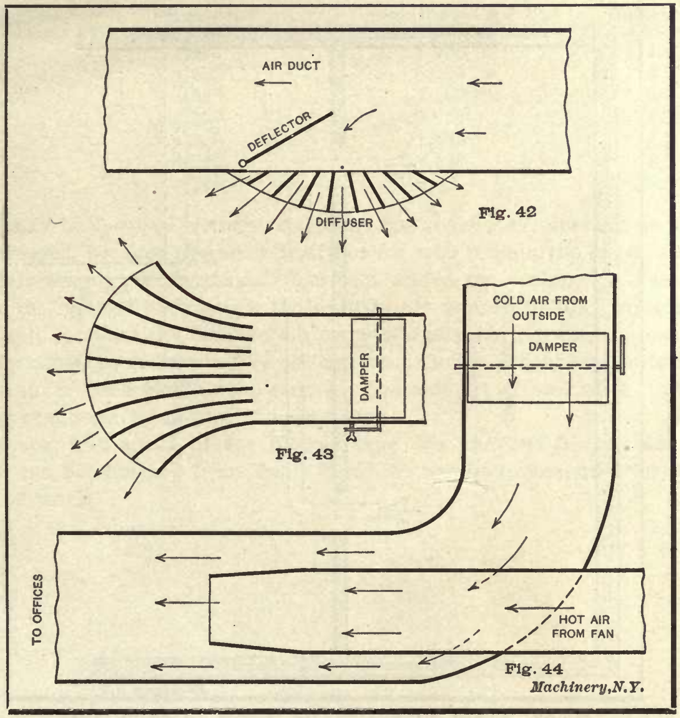


Fig. 42. Outlet for Hot Air from Side of Duct. Fig. 43. Diffuser Outlet and Adjusting Damper for End of Branch Duct. Fig. 44. Injector Arrangement for Mixing Hot and Cold Air

nearly all, cool air. The mixing damper shown is for hand manipulation. In case the automatic arrangement is employed, the double damper shown in Fig. 38 should be used.

Pipe heaters for ventilation only should be 6 or 8 pipes deep, and the square feet of heating surface may be computed by equation (1) by substituting 1,800 for 1,500 in the denominator of the second member. When used for heating as well as ventilating, the heater should be from 12 to 14 pipes deep, and the surface computed by equation (2), substituting 1,200 for 1,000 in the denominator. In all of the computations for heaters it has been assumed that steam at a pressure of about 5 pounds would be used.

The piping for a heater of the hot-blast type is shown in Fig. 41. The special point brought out here is the method of making the return connections from the different sections with the main return. Each separate return in this case is sealed against the others by a siphon loop to prevent the condensation from backing from one into the other, which is apt to occur if this precaution is not taken to prevent it. As the coldest air strikes the outer sections, condensation is more rapid and the pressure is slightly less than in the inner ones; hence the

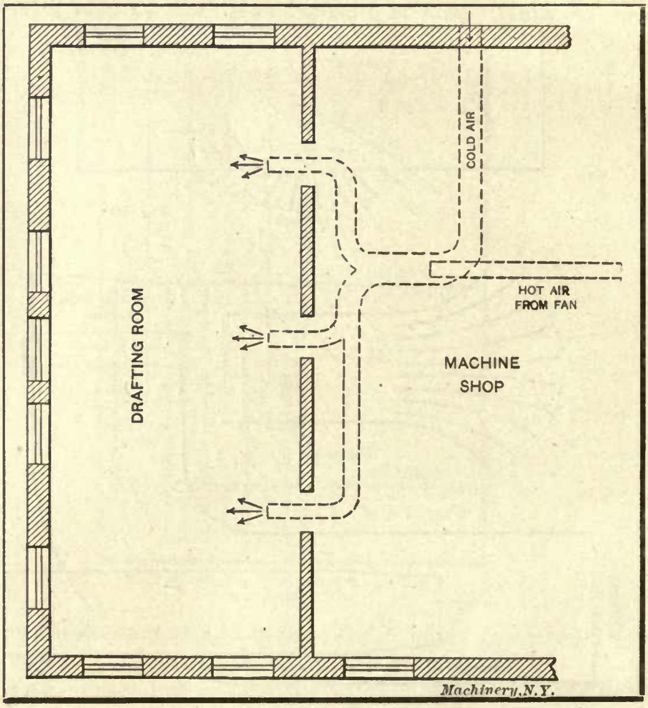


Fig. 45. Method of Connecting the Outside Air Supply to the Injector shown in Detail in Fig. 44

necessity of sealing the returns. As the pressure in the return main is always slightly higher than in the heater, owing to the drip connection with the supply main, it is necessary to make the legs connecting with the heater longer than the others, as the highest column of water is always in this side of the loop.

Of equal importance with the fan and heater is the method of distributing and discharging the air to get the best results without perceptible drafts. Fig. 42 shows an outlet for delivering air from the side of a duct where diffuser blades are used for spreading the air as it enters the room. An adjustable deflector is provided to catch the desired amount of air it is desired to deliver at each outlet. Fig. 43 shows a diffuser outlet and adjusting damper for use when the air is discharged at the end of a branch instead of from the side of a duct, as in Fig. 42.

When the main shop is heated by a hot-blast system taking all, or a considerable portion of its air from out-of-doors, an "injector" arrangement like that shown in Fig. 44 may be used for mixing a certain amount of cold outside air with the hot air from the fan, when the temperature of the rooms becomes too high. In this way the temperature may be lowered without reducing the air supply; instead, it will be increased, because the amount of hot air will remain the same while a certain amount of outside air has been added for cooling it. Fig. 45 shows the way of connecting the outside air supply to the "injector." It is well to make this connection some distance back from the outlets to the rooms, in order to give an opportunity for a thorough mixture of the air before reaching the rooms. The amount of cool air required can be regulated by means of a damper.

TABLE X

Diam. of Fan-wheel, Inches	Revolutions per Minute	Cubic Feet of Air per Minute	Horsepower of Motor
30	540	3,600	1.6
36	450	5,000	2.0
42	380	7,000	3.0
48	330	8,600	3.7
54	300	11,000	4.5
60	270	13,500	5.5
72	240	16,500	6.8

The size and speed of the blower type fan and the horsepower of motor, can be obtained from Table X, which has been computed for this class of work.

CONTENTS OF DATA SHEET BOOKS

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