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perature, the heating apparatus is approximately of the same size as that required if low pressure steam were the heating medium.

THE PRESENT STATUS AND FUTURE OF HOT WATER DISTRIBUTION

By A. Margolis, Dipl. Ing., V. D. I.

The hygienic and economical advantages of hot water heating have led to its general adoption in Germany. In the other European countries hot water heating is also generally preferred. Before the war the Prussian authorities had made comparative investigations which proved that the fuel consumption with hot water heating is less by 20 to 25 per cent than with steam heating. It stands to reason that during the last decades new buildings, other than dwelling houses and hospitals, such as government offices and factory buildings have, in increasing proportions, become equipped with hot water heating. Similarly, as a matter of course, hot water distribution was universally adopted for hospitals, institutions and grouped industries and the like. In Germany this movement has been particularly influenced by the fact that hospitals generally are built in decentralized system. Establishments with twenty or more two- or three-storied houses are quite common.

The heating installation, as a rule, is laid out for an air temperature difference of 36° F., with 194° F. water temperature in the flow pipe. At the beginning of the heating season the temperature in the flow pipe is kept low, say at 122° F., later it is gradually increased to 158° F. or 176° F., but rarely up to 194° F.

A special advantage of the hot water heating is the utilization of steam of very low pressure.

The dearth of fuel in Germany after the war induced many industrial undertakings to improve their heating systems by utilizing the exhaust steam for hot water distribution. Notably the firm of Rud. Otto Meyer, which the author has the honor to represent, has equipped most of the steel works of the Ruhr District with hot water distribution plants utilizing the exhaust steam from rolling mill and blowing engines, steam hammers and the like. The fact that many works require heat not only for heating shops and buildings but for manufacturing process as well led to the system of superheating hot water with converters for hot water or steam heat as wanted. Many industrial plants nowadays are working with superheated water of 376° F.

In order to prevent steam being liberated, water above 212° F. must be kept under pressure. A diagram of such a plant for superheated water according to the patents of Rud. Otto Meyer is shown in Fig. 1. The temperature of the water coming from the boiler in the flow pipe is reduced to below its boiling point by admixture of water from the return pipe. The pump is arranged in the flow pipe so that the whole system is kept under additional pressure, preventing all danger from the formation of steam and shocks in the pipe system.

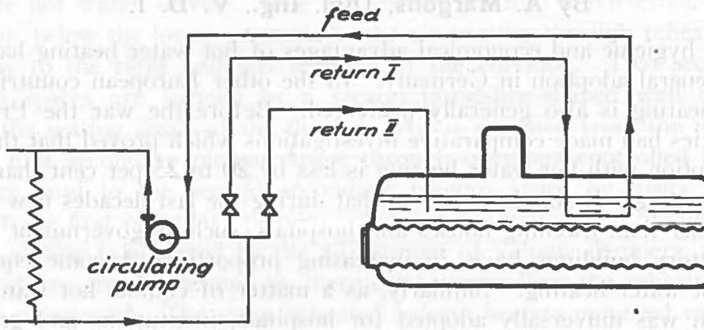

FIG. 1—Plant for Superheated Water

This arrangement has the great advantage that the superheated water is kept in circulation and that there is no need for steam traps with their return pipes and all their drawbacks and inconvenience. Considering that a great hospital equipped with the ordinary hot water heating system in addition to its hot water distribution requires an additional steam line with drains and a return, and two added pipe lines for the supply of hot service water, the adoption of superheated water distribution is very tempting.

Closer investigation, however, of this system soon shows its several drawbacks as well. Every building requires it own separate transformer service for hot water heating, the supply of steam, and domestic hot water. In case of forced circulation each building must have it own pumps in addition. With these additional transformer and pumping plants, with their measuring and control apparatus, the simplicity of the superheated hot water system is considerably impaired and the cost of its installation increased. There are also difficulties in running such plants. The flow pipe temperature regulation may be adapted in a certain degree to the requirements of the season. This regulation, however, becomes limited when steam is to be generated at the same time, a difficulty that may be overcome by the provision of a second flow pipe. One of these then will serve the heating system, the other one, being kept in service during the year, serves for the generation of steam and hot water supply.

However, the satisfactory results obtained with hot water distribution have had but little influence upon the design of district heating plants. When, upon the termination of the war, the author proposed the installation of the district heating plant at Hamburg, it had first been the idea to build it as a hot water distribution system. From the beginning, he had pleaded for the necessity of combining district heating with the public electric light and power supply. Such combination results in a saving of investment and capital cost for the boiler plant, a reduction of the fuel bill of the combined heat and power plant, and a considerable saving in operating personnel. Since the working pressure of the existing boilers was very low—only 163 lbs. gauge—it was desirable to keep the back pressure as low as possible, which could best be obtained with a hot water supply system. Closer investigation, however, showed that a large number of the buildings were heated by steam and this made compulsory the choice of a low pressure steam supply.

Of course, the steam heating plants could have been supplied from a superheated water system as well, but by doing this the generation of electric energy would have become very small or quite impossible, resulting in a serious loss of economy. Circumstances in other cities were similar, and for this reason, most district heating systems in Germany as well as several abroad, as in Paris, have been built on the Hamburg System with steam distribution of low pressure from 14 to 42 lbs. Only some plants supplying steam to textile works have been built for higher pressures, as at Forst, Germany, of 85 lbs., and at Brünn, Czechoslovakia, 128 lbs.

The supply of steam has the great advantage that both steam and hot water heating plants can be supplied, and that the measuring of the heat consumed can be effected by means of cheap and reliable condensation meters. In contradistinction to general American practice, the condensate is returned and used in feeding the boilers. When using the closed return pipe system of the Hamburg type, ordinary steel tubes have proved quite satisfactory. The loss of condensate as a rule amounts to only a few per cent so that the costs for the make-up of feed water are insignificant.

Under the prevailing conditions the number of hot water distribution plants as yet has remained small, and we shall now proceed to describe some of the typical installations as erected at Berlin-Steglitz, Dresden, Leningrad and Hamburg.

The township Steglitz, a Berlin suburb, has erected a district heating plant designed to serve about 3,000 dwellings in 1927–28. The hot water distribution system is laid out for a capacity of approximately 160 million B.T.U. per hour, and today has a duty of about three-fourths of this figure. The district supplied, with very few exceptions, has hot water heating, a few older blocks only had and still have retained their old stoves and are supplied with hot service water only.

The heat distribution is effected by means of three pipe lines, one feeder for heating with a water temperature according to the season of from 122 to 194° F., a second feeder with water of from 176 to 194° F. for the hot service water supply and one return pipe. The boiler pressure is 185 lbs. gauge, the steam temperature being 662° F. There are two steam turbine-generators of 3,000 k.w. each, working during the heating period with an average exhaust pressure of 7.1 lbs. abs. The loss of power in consequence is comparatively small. The heating is being sold on the flat rate system.

The Municipality of Dresden too, in 1927–28, erected a district heating plant with hot water distribution in the inner city. Both government and office buildings, but no dwelling houses, are supplied. By the end of 1934 the heat demand amounted to about 105 million B.T.U. per hour. Out of this, 40 million B.T.U. per hour were for steam heating. The distribution is effected by means of three pipe lines, two feeders of 10″ internal diameter, and one return pipe of 14″ internal diameter.

The boiler pressure is 525 lbs. gauge, and the pressure at the throttle of the turbine 483 lbs. gauge. The water is heated up to 257° F. by steam of 25 lbs. pressure extracted from the turbine and then by extracted steam of from 142 to 213 lbs. gauge brought up to 284° F. One of the feeders serves for the hot water, the other for the steam heating plants, but in the case of emergency both services can be performed by one of the lines.

The whole pipe line system is kept under a pressure of 85.1 lbs. Each service in the buildings, such as hot water heating, steam generation and domestic water heating, must have a separate transformer.

The measurement of the heat supplied is effected by Wagner meters.

In recent years, in several buildings, the heating of the water in the hot water heating plants has been effected by the injection of superheated water. The expansion tank is connected to the return pipe of the respective building and the surplus water is returned into the common return pipe by means of a separate pump actuated from the level of the water in the expansion tank. This procedure is said to have come up to expectation, but the reliability of the service, however, is impaired by it.

A peculiar type of hot water distribution has been installed at Leningrad (USSR). The territory of the district is plain, but the height of the buildings varies. The water head of the expansion tanks varies between 49 and 121 feet, and an increase of pressure in the single heating systems of the buildings had to be avoided. The feed line water, which in the station has been heated by exhaust steam to from 212 to 239° F., is cooled down in the building (point 0 in Fig. 2) by the admixture of return water, to the desired temperature. The expansion tanks in the buildings remain and the overflow having passed the loop S falls in the common return pipe leading the water by gravity into an open collecting tank in the station. From this the pumps then pump it through the counter-flow heaters into the flow pipes. The pumps, therefore, must produce sufficient pressure to overcome the pipe friction in the feeder and the static head of the highest expansion tank, in this case 121 feet. The circulation of the heating water

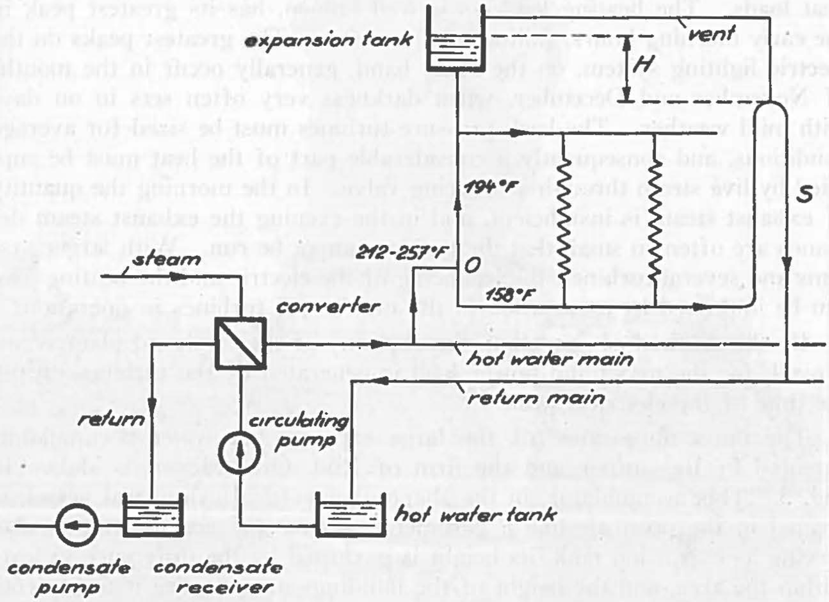

Fig. 2

in the building is secured by the difference of level in the expansion tank and the top of the siphon in the overflow pipe (distance H in Fig. 2). This plant at the beginning of 1934 was delivering 48 million B.T.U. per hour, but very large extensions are being prepared.

The system employed at the district heating plant at Utrecht (Holland), known there under the name of Van De Voude-System, is similar to the above, but is now being rebuilt.

The hot water distribution at Hamburg is built after the standard closed system for an air temperature difference of 45° F., but provision is made to increase this difference up to 72° F. The hot water is getting its heat at the old station "Poststrasse," now lying idle, through exhaust steam at 14 lbs. gauge pressure, and from the stations "Carolinenstrasse" and "Bille" situated at a distance of 1.37 miles and 2.68 miles, respectively. The heat is measured by the Samson meter with great accuracy.

The most remarkable feature of the Hamburg plant is not so much the distribution system, but the heat storage connected with it. Apart from the general advantages of heat storage, such as equalizing the fluctuations of the load, reducing the size of boiler heating surface, raising the boiler efficiency, etc., its paramount advantage in connection with district heating plants lies in its possibility of balancing the fluctuations in the power and heat loads. The heating load, as is well known, has its greatest peak in the early morning hours, falling off thereafter. The greatest peaks on the electric lighting system, on the other hand, generally occur in the months of November and December, when darkness very often sets in on days with mild weather. The back pressure turbines must be sized for average conditions, and consequently a considerable part of the heat must be supplied by live steam through a reducing valve. In the morning the quantity of exhaust steam is insufficient, and in the evening the exhaust steam demands are often so small that the turbine cannot be run. With larger systems and several turbines, the balancing of the electric and the heating load can be improved by a variation in the number of turbines in operation.

By this method of operation, the economy of the combined plant is improved, for the maximum power load is generated by the turbines during the time of the electrical peak.

The outer appearance of the large capacity hot water accumulator, patented by the author and the firm of Rud. Otto Meyer, is shown in Fig. 3. This accumulator, in the shape of a vertical cylindrical vessel, is erected in the open air like a gasometer. Since the accumulator is also serving as expansion tank, its height is governed by the difference in level within the area, and the height of the buildings may require it to be from 65 to 130 feet high, or even more. This accumulator has the advantage of requiring the least material and space, and it can be sized for any volume of hot water desired. The large capacity hot water accumulator of the Hamburg District Heating Works contains about 700,000 gallons of water, with a storage capacity of 400 million B.T.U. Such hot water storage, of course, is possible only when the heat, or at least an essential part thereof, is distributed in the shape of hot water. The size of the hot water load connected to it at Hamburg is 72 million B.T.U. out of a total of 520 million B.T.U.

In spite of this low proportion of hot water service, the effect of the hot water storage on the total heating load has been most beneficial. The accumulator practically replaces the total boiler plant at "Poststrasse" station, and reduces the morning steam peak by 60,000 lbs. per hour.

The diagram of connections of the accumulator is shown in Figs. 4 and 5. The water, after being heated in the "Poststrasse" station, is forced by a pumping plant there, to the consumers and to the storage tank erected

FIG. 3—Large Capacity Hot Water Accumulator

at the end of the first pipe line system. From the accumulator a second section of consumers is supplied with heat by the aid of another pumping station beside it. By the heat storage, not only the load factor of the boilers and turbines is improved, but also that of the steam mains and of a

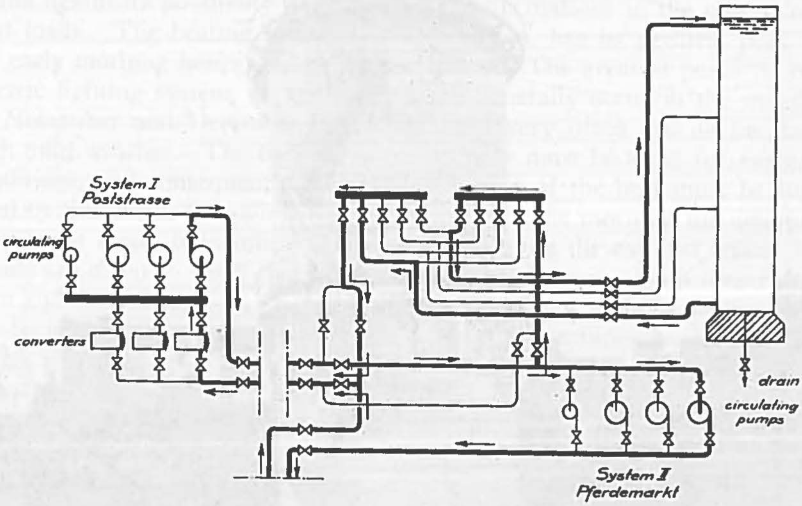

FIG. 4—Accumulator Connections

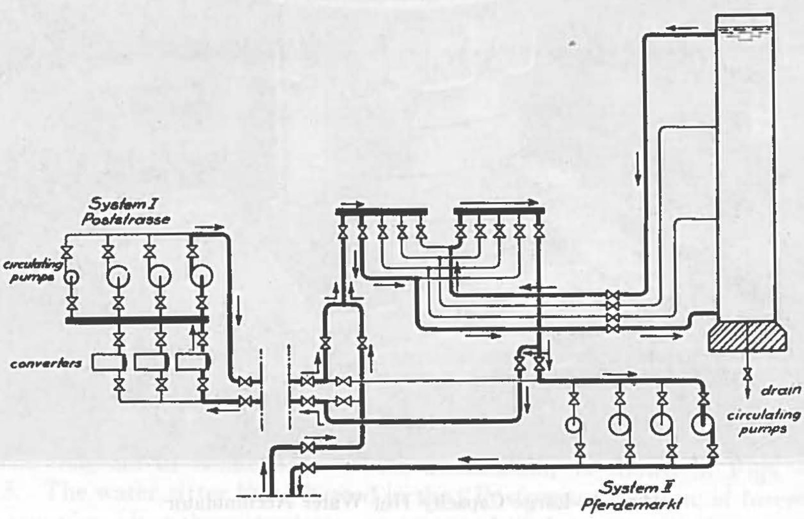

FIG. 5—Accumulator Connections

portion of the hot water pipes. The heat stored in the afternoon, evening or at night is delivered to the consumers in the morning and forenoon of the following day.

The thermal losses are quite small. The drop of temperature in 24 hours with the accumulator shut off amounts to but ½ to 3/5° F. When the accumulator with a temperature of 203° F. is taken out of service at the end of May, the heating supply can be started up at the end of September from the accumulator alone, still having a temperature of about 122° F., without firing the boilers. After a little while, of course, the boilers must be put in service.

In attempting, in the face of the aforenamed four typical examples of heat distribution by means of water heated to below or above 212° F., to foretell the future development of district heating plants, both the technical and the economical aspects have to be considered. The Leningrad system is out since it offers no advantage. If the buildings within the area are of different heights and if an increase of pressure in their heating plants is to be avoided, then it is better to heat the water indirectly, as is done at Dresden, or, as will be shown, step-wise in two or more stages.

In choosing superheated water for the distribution system, the question at once arises as to the temperature to which the superheating shall be carried. The higher the temperature, the lower become the costs of the distribution piping system. An increase in temperature, however, rapidly decreases the power generation. No general rules can be given, the conditions must be determined by calculation in every case.

Regarding the safety of superheated water distribution, no fear need be entertained. Since the days of the failure of the Boston distribution system in 1888–89, which had been using water of 380° F., the engineering progress in the heating line has been so great that similar mistakes can be avoided. Nevertheless, a distribution system with superheated water, by its nature, involves greater dangers than one with normal hot water or steam. It must also be mentioned that all repairs or the connection of any additional consumer become much more difficult. Such work cannot be carried out during a single night, since the letting off of the superheated water is no easy matter. This is the reason why at Dresden the distribution has been equipped with three pipe lines in order to enable the lines to be taken out of service one after the other without an interruption of the supply. This provision increases the difficulties of the installation, and quite considerably increases its cost.

In view of the great influence of the capital cost on the economical aspect of district heating, it is important to keep the investment as low as is compatible with safety. An increase in capital investment in the distribution system is admissible only when an increase of the power supply can be obtained thereby.

The introduction of combined heat and power supply and its furthest possible improvement is of great importance for the further progress of district heating. From this point of view the level of temperature for the heating would have to be kept as low as possible. But already with a normal hot water system working with a maximum flow pipe temperature of 194° F., the heating of the water can be effected with an average vacuum of 15". By raising the throttle pressure of the steam to 1,700 lbs., and its temperature to 896° F., the steam consumption in lbs. per k.w.h. will be the same as if it were operating at a much greater vacuum, when supplied with steam at 355 lbs. and 716° F. The greater heat value of the high pressure steam is of little importance.

It is possible, therefore, to make available for useful purpose, heat that would otherwise be lost in condenser water, and obtain double duty from power generating boiler investment.

The hot water distribution for the solution of the heat storage problem is of great importance. The large capacity hot water accumulator is the cheapest accumulator for heat storage in existence. Its cost amounts to only about ⅓ of that of the boiler heating surface saved by it. The improvement of the load factor of boilers and exhaust turbines amounts to almost 50%, and the operating economy is considerably improved. As already mentioned, there is practically no limit to the size of the large capacity accumulators.

For the district heating system with a heat demand of 1,720 million B.T.U. per hour planned for a dwelling house area in the western parts of Berlin, Messrs. Rud. Otto Meyer, acting as Consulting Engineers to the Berlin Power Supply Co. (Bewag), have tentatively proposed four large capacity hot water accumulators, each of 2,120,000 gals. capacity, and about 1,280 million B.T.U. per hr. heat storage capacity.

It may be urged against this heat storage system, that hot water distribution is but rarely possible. This may readily be conceded as long as the total town heat supply is considered as a whole. In each town, however, there are areas that offer themselves to this method of heat supply. Even an investigation of existing steam service lines will often show such areas. The insertion of a large capacity hot water storage then will show an additional advantage in improving the load factor of the steam mains. Judging from the success of the hot water heating plant of the 60 Wall Tower Building as reported in the proceedings of the National District Heating Association of 1934, it may be expected that hot water heating systems will also be adopted for skyscrapers in U. S. A. It is possible, for such buildings, to limit the individual distribution systems to quite small areas or even to install a hot water accumulator for one single large building only. The accumulator can be charged in the evening or over night so that the steam mains are relieved of this load during the hours of biggest demand. A diagram showing the connections of such an accumulator for two zones is shown in Fig. 6. At the converter stations for the individual hot water distribution systems, the steam pressure above that required for heating may be used for the generation of electric energy. This brings us to the conclusions regarding the future developments of district heating.

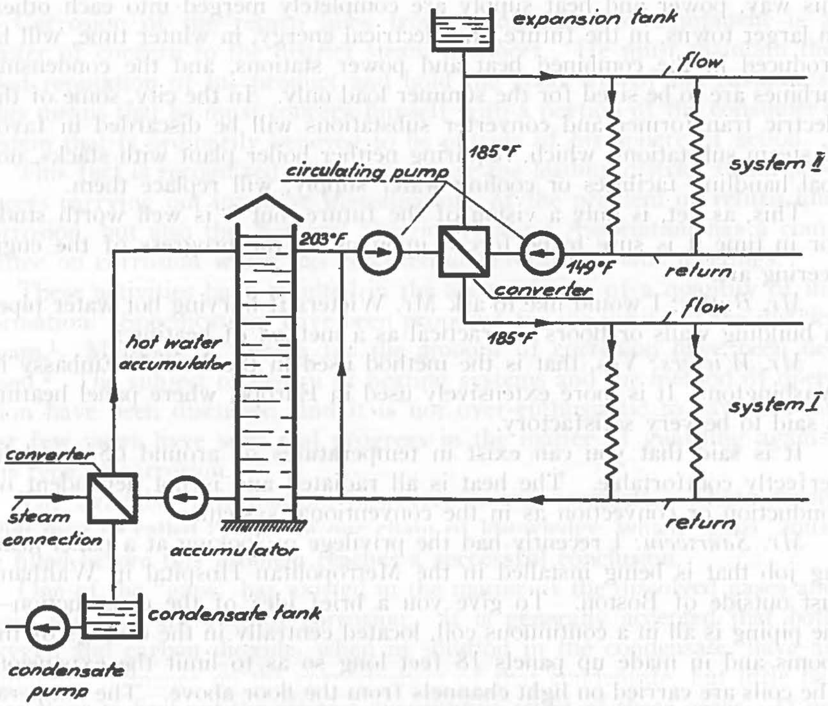

FIG. 6—Two-zone Accumulator Connections

In view of the many steam heating plants, the primary heat distribution will be effected by steam. To an extent, however, the steam piping will be designed for the supply of the various hot water distribution sections. The substations for the heating of the water to be provided at the center of these sections are to be arranged to serve as electrical substations as well. Large capacity hot water accumulators will serve for the equalization of the varying loads in the power and heating services. The main power station will be equipped with a high pressure plant, say of 1,420 lbs., and exhaust back pressure turbines driving generators and delivering the steam for heat distribution at a pressure of say 113.6 lbs.

This steam is distributed in the steam supply pipe system and used for heat conversion and power generation in the substations as well. In this way, power and heat supply are completely merged into each other. In larger towns, in the future, the electrical energy, in winter time, will be produced in the combined heat and power stations, and the condensing turbines are to be sized for the summer load only. In the city, some of the electric transformer and converter substations will be discarded in favor of steam substations, which, requiring neither boiler plant with stacks, nor coal handling facilities or cooling water supply, will replace them.

This, as yet, is only a vision of the future, but it is well worth study for in time it is sure to be forced upon us by the progress of the engineering art.

Mr. Butler: I would like to ask Mr. Wieters if burying hot water pipes in building walls or floors is practical as a method of heating?

Mr. Wieters: Yes, that is the method used in the British Embassy in Washington. It is more extensively used in Europe, where panel heating is said to be very satisfactory.

It is said that you can exist in temperatures of around 65°, and be perfectly comfortable. The heat is all radiated and is not dependent on conduction or convection as in the conventional system.

Mr. Saurwein: I recently had the privilege of looking at a panel heating job that is being installed in the Metropolitan Hospital in Waltham, just outside of Boston. To give you a brief idea of the construction—the piping is all in a continuous coil, located centrally in the ceilings of the rooms and in made up panels 18 feet long so as to limit the expansion. The coils are carried on light channels from the floor above. The temperature of the water, as circulated, is never above 130 or 135° F., and there is about a 15° temperature drop between the incoming and outgoing line.

Metal lath is wired to the under side of the pipes, and the plaster is pressed through the metal lath and up against the sides of the pipe, so that practically the entire pipe in encased in plaster. The plaster below the metal lath is about ½ to ¾ inch thick. The plaster at the under side of the pipe is about ½ inch thick and the piping is covered on the top side with 2 inches of cork. Test reports show that the temperature in the room does not vary more than 2° from the ceiling to the floor, which seems almost unbelievable. To me it is quite an interesting development and I am anxious to try it at the next opportunity.

Each of the coil banks is under thermostatic control, so that the temperature of the room may be regulated very closely. The Johnson Compressed Air Control is used in this building.