REPORT OF THE BOARD OF EXPERTS

ON THE

Central Station Heating and Power Supply System

OF THE

NATIONAL HEATING COMPANY.

ROSSITER W. RAYMOND, PH.D.
C. C. MARTIN, C. E.
PROF. GEO. W. PLYMPTON.
THEO. N. VAIL,
President.

WILLIAM LUDLOW,
Gen. Manager.

A. V. ABBOT,
Chief Engineer.

D. ELWELL,
Sect'y. and Treas.

NATIONAL HEATING COMPANY,
OPERATING THE
PRALL SYSTEM
OF
CENTRAL STATION HEATING
AND POWER SUPPLY.

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The plant and the report.

At this time we note the dissension among men, not considering the experimental and practical bases while we are discussing public heat distribution employed, and the constant uncertainty in every action and attention, and the percentage of successful results, those do not for evil and a
BROOKLYN, March 26, 1888.

THEODORE N. VAIL, ESQ., President National Heating Co.,
44 Broadway, New York.

Dear Sir: The undersigned having examined, at your request, the Prall system of heat distribution as exemplified in the plant and operations of the Boston Heating Co., at Boston, Mass., respectfully present the following preliminary report. A further report, now in preparation, will deal with some questions, more intelligible and interesting to engineers than to the general public, which are not considered here, and will give more fully the experimental and theoretical data upon which the present report is based.

At this time we shall state briefly, and with as little technical discussion as possible, the general advantages of public heat distribution, and the principal methods hitherto employed, and the opinion at which we have arrived concerning the Prall system, as shown in practical operation at Boston; its practicability, its safety, and the relation of its mains to the streets of cities and to other pipes and subways therein.

GENERAL ADVANTAGES OF PUBLIC HEAT DISTRIBUTION.

The present system, or lack of system, involves many evils and dangers, among which we may name:

1. The constant peril of conflagration, arising from the existence in every city of thousands of fires often carelessly kindled and attended, or burning in worn and defective stoves and furnaces, or with defective flues. The large percentage of conflagrations from this source—nearly all, indeed, that do not arise from incendiarism—is proof of this peril; and a striking confirmation is found in the
increase of conflagrations which attends very cold weather, showing how disastrously the defects of the domestic apparatus are revealed under any extraordinary demand. The annual money loss to the community from this source is immense.

2. The growing danger from steam boilers of all sizes, distributed in buildings and under sidewalks, and employed in running elevators, dynamos, printing presses, and other machinery. That destructive accidents from this source have hitherto been few, is a gratifying circumstance, which must not be permitted to obscure the fact that the danger is constantly increasing with the number of such boilers, and with the growing age of those now in use.

3. The great waste of fuel by incomplete combustion and excessive radiation of heat, due to the small scale of operation, which is unfavorable in every respect to high economy. This waste is augmented greatly when fires are periodically put out and kindled.

4. The enormous expenditure of labor and the well nigh intolerable nuisance to the community, involved in the delivery of coal to individual buildings and the removal from them of ashes. This evil is greatest in cities where, as in Brooklyn, such operations must be performed in front of the house. It is well known that they constitute the greatest of all obstacles to the maintenance of clean streets; and it is only necessary to observe the effect of a single snowstorm, impeding for a day or two the regular operations of the city ash carts, to realize the enormous mass of worthless material which has been laboriously carried to every house in order that it may be laboriously removed. Under this head we may mention also, in passing, the nuisance of ashes in the house, enhancing the labors of sweeping and dusting, and the deterioration of carpets and furniture.

5. The sanitary evils resulting from the consumption in combustion of the oxygen of the air in buildings, the
escape of the gases of combustion into rooms, and the constant discharge of such gases, together with smoke, into the atmosphere overhead. The increasing use of bituminous coal, even in the so called "anthracite cities," adds importance to the last named evil, which is the most tangible to the senses, and may become a serious injury to business as well as health. The London fog is declared by high authority to be precipitated smoke; and the atmosphere of Pittsburg, before its deliverance by natural gas, furnished an American example scarcely less striking. But even when smoke is relatively absent, vitiation of the air by the domestic combustion of fuel is admitted to be one of the chief elements of the inferior sanitary condition of cities.

6. The inconvenience, to the individual consumer of heat, of the labor and care involved in its generation to meet the fluctuating requirements of circumstances, and the waste of capital employed in the installation and maintenance, in every house, of a heat generating, as well as a heat distributing, plant.

Other collateral disadvantages might be adduced; but this list presents an aggregate so large as to justify the conclusion that the objections urged against any remedy must be weighty indeed to counterbalance such strong arguments in its favor. Certainly if such a remedy be mechanically practicable, with, to say the least, equal safety to the public, and no greater cost to the consumer, it should be heartily encouraged.

METHODS OF HEAT DISTRIBUTION.

It will be observed that many of the evils of the present system, mentioned above, arise from the distribution of impure solid fuel to individual consumers. A step in advance is the circulation, from a central manufacturing station, of gaseous fuel, in the same manner as illuminating gas is now circulated. Such a system is now in use at Pittsburg and other places, where natural gas is available for the purpose. With all its advantages, it is open to the objection that it
does not remove the sanitary evils due to combustion on the premises of the consumer, and it presents, in addition, peculiar dangers due to the poisonous character of the gas, its inflammability, and the facility with which it forms, in relatively small proportions mixed with air, an explosive mixture.

Moreover, the leakage of gas from the mains impregnates the soil, and the usual fuel gas ("water gas") is believed to have a peculiarly destructive effect upon certain substances widely used in the insulation of electric conductors underground. In Brooklyn the destructive corrosion even of lead pipes inclosing and protecting such conductors, is believed to have been produced by illuminating gas manufactured by "carburett" water gas. These objections exist already in the case of our illuminating gas system. They are simply outweighed by the advantages of that system. But they constitute some of the strongest arguments for its replacement by some other means of lighting; and the proposition to add to the quantity of gas now circulated in the streets for that purpose the much greater quantity required for heat and power, would require, particularly as to the sanitary effect upon the soil, most serious consideration.

Other practical methods have for their object the distribution of the heat itself, instead of the fuel. Obviously, if this can be done without ruinous waste in transit, it must be the best. To accomplish it, the heat must be first communicated to a gaseous or liquid medium, the temperature of which is thereby raised, and which, being delivered to the consumer at a high temperature, gives out, as it cools, the heat he requires. As such media, air, steam and water have been employed; and of these air is obviously impracticable for long distances, by reason of its low specific heat and specific gravity. A cubic foot of water at 400° F., for instance, weighs about 1260 times as much as a cubic foot of air at the same temperature, while a pound of water, in losing one degree of temperature, will give out nearly four times as much heat as a pound of air. The ratio of the efficiency by volume of water to that of air, as a medium
for the distribution of heat, is nearly 5,000 to 1. This discrepancy may, indeed, be considerably reduced by the greater speed which can be imparted to the current of air; but it will still remain true that air is for long distances too bulky a vehicle, with far too little carrying power.

As compared with steam at 400° F., a cubic foot of water weighs, in round numbers, 100 times as much. But the steam, in cooling down to say 200° (or below the point of condensation for atmospheric pressure) will give out per unit of weight 5.8 times as much heat as the water; and, moreover, at the temperature named, under similar conditions of pressure and dimensions of main, the steam will flow about 10 times as fast as the water, and thus, in a unit of time will deliver \( \frac{5.8 \times 1}{100} \) = 0.58 as much heat. For the conditions named, therefore, the relative efficiency of water and steam is 100 to 58. It is not proposed to enter here into a discussion of the varying conditions which may affect this comparison, or the mechanical considerations which may enter the problem in practice. It is sufficient to say at present that the high specific heat of water (nearly the highest known) coupled with its specific gravity, make it theoretically the best vehicle for the purpose now under consideration.

THE BOSTON HEATING COMPANY’S SYSTEM.

The principle of the Prall system, as exemplified by the Boston Heating Co., is the constant circulation of water at high temperature and pressure (say 400° F. and 250 lbs. per square inch) from the boilers at the station, through the supply mains, and back into the boilers. This circulation is maintained by pumps. From this constant current, keeping the supply main always full, water is tapped at as many points as may be necessary to supply consumers of heat. Except for cooking, which requires about 350°, and for heating air, the temperature and pressure of the supply main are far greater than are needed for either heat or power. The water is delivered in relatively small quantity, through tubes \( \frac{1}{4} \) inch (for ordinary cases, up to
perhaps one inch as a maximum) in diameter. Its further treatment depends upon the use to which it is put by the consumer. It may be employed to heat air, instead of the ordinary hot-air furnace, in which case it will be introduced directly into a radiating coil, through which the cold air is to be passed. Or it may be similarly used, in a suitable apparatus, to perform all the operations of cooking, not requiring a higher temperature than 350°—which comprises boiling, baking, and probably everything except broiling, in which case there is perhaps required not so much a higher temperature throughout the substance as a peculiar rapid surface-action of flame. At present, however, the general application of the hot-water supply is in the form of steam, for heating through radiators and for engine power. In such cases, the water is allowed to expand, in a vessel called a converter, into steam of the required pressure, in which condition it is distributed, as it would be from the steam space of an ordinary boiler, through the building.

The condensed steam from a house system, including the "drip" of the steam pipes and converter, and the condensed "exhaust" of the engines, is conveyed to another main, in which it returns to the station, separate from the hot water supply main, to be again fed into the boilers, where the heat it has lost is restored to it.

In theory, therefore, the water serves exclusively as a vehicle for conveying heat. It is wholly returned to the boilers after every circuit—a part coming back unused, in the hot water circulating main, and the remainder, considerably cooler, in the return main. The work of the boilers is to supply the heat necessary to run the pumps and other machinery at the station, to make up the losses by radiation and conduction throughout the system, and to replace what has been abstracted by consumers.

PRACTICABILITY OF THE SYSTEM.

From the standpoint of the consumer, this question assumes the form: Can the above theory be put into
practice so as to give an always available supply of heat, as capable of regulation as a domestic supply would be, and at a reasonable price?

From the standpoint of the producer, the question is: Can this be done at a commercial profit, for a price not exceeding the cost to the consumer of the present system, and without reconstructing the present interior distributing systems of buildings?

For it is in most cases not likely that the producer could build up a profitable business on new buildings alone, or induce consumers generally to adopt the new system at the cost of expensive installation and maintenance.

We are convinced that both these questions may be answered in the affirmative. Our investigations among consumers in Boston have satisfied us that, to a distance of nearly two miles from the boiler station, dry steam is delivered at any desired pressure. The circulation in the buildings of the highly heated water itself, either for heating air or for cooking, we were not able to see, since the company has as yet no customers thus employing it. But we see no reason to doubt that this application would be equally successful.

This high degree of mechanical efficiency is due to the remarkable thoroughness and skill with which the plant of the company has been planned and constructed, the excellent workmanship of every part, and the constant and vigilant inspection which is maintained. For these essential elements of success, credit is chiefly due to Mr. Arthur V. Abbot, the Chief Engineer of the National Heating Company, who designed the work and superintended personally the details of its execution, and of whose ability and fidelity we take pleasure in making this public acknowledgment. That neither safety, efficiency, nor economy can be secured in an undertaking of this kind without the greatest skill and care in its execution, has been strikingly illustrated in New York, where one steam distributing company has been completely ruined for lack of them, while another, under competent engineering and business management, has achieved a substantial success.
As to the economy and profit of the system, regarded from the standpoint of the producer, we shall speak more fully in our detailed report. A few general observations, however, may be appropriate here.

As already noted, the boilers have to furnish heat, \((a)\) to run pumps, etc., at the station; \((b)\) to make up losses by radiation, etc., throughout the system; and \((c)\) to replace the heat abstracted by consumers. This presupposes that there is no leakage of water in the system—a perfection which is so closely approximated by the admirable joints and fittings employed by the company that, judging from the experience of the weeks of its operation, about 200 gallons of water per annum will cover its total waste. This is a great advantage, not only in the saving of water bills, and in independence of the municipal water supply, but also in the freedom from boiler incrustation, such as attends the heating of constantly new supplies of water.

Of the items of boiler work above named, it is evident that economy and profit are proportional to the excess of \(c\) over the sum of \(a\) and \(b\); for \(c\) represents the goods sold, while \(a\) is the cost, and \(b\) the waste, in transportation. Now \(a\), the heat expended at the station, consists of the power for one steam engine (driving a dynamo, etc.), which may be set down as a constant, and the power consumed in pumping. The pumps maintaining the circulation have to overcome only the friction of the current, which is proportional to the length of the main (the diameter being uniform) and to the square of the velocity of the current, and wholly independent of the temperature and pressure of the water. The work of the pumps forcing the cooler return water into the boilers is proportional to the amount of that water. But the work of the hot water pumps is not so simply calculated. What they do is to maintain a certain average speed of circulation through the supply main, so that the loss of heat in transit shall not cool the current too much.

This loss constitutes a portion of loss \(b\), already attended to, the other portions being the losses in the station itself and in the cool water return main. The loss of heat units...
in the hot water circulation is constant for a given temperature and size of main per unit of time and per linear foot of main. But the difference in temperature between the outgoing and the returning hot water, which represents this loss, varies inversely with the speed of the current. Since the work of the hot water pumps varies directly as the square of the velocity, it is evident that economy requires the minimum speed of circulation, consistent with other conditions. But in order to secure to the consumer nearest to the return end of the main a sufficiently high temperature of water supply, the loss in temperature during transit must not be too great. The minimum speed for a given length of line to secure this result having been determined while the circuit is closed to consumers, the minimum of pumping work is thus fixed. But this work does not, as the volume of circulation is increased to supply consumers, increase in proportion to the square of the initial velocities, for the reason that the abstraction of the water by consumers progressively decreases the velocity of the current, so that the average velocity is not nearly proportional to the amount passing through the pumps.

With regard to the loss of heat by radiation from the system it may be said that it has been reduced to a minimum by a very thorough jacketing of all heated parts with asbestos. The loss in the station house has not been exactly measured. The loss in the four inch hot water main at Boston has been determined by a test with the consumers' shut-off, and found to be, for 375° initial temperature of the water, and a speed of the circulating current of 1.5 feet per second, about 4° F. of temperature, or say one unit of heat for each foot of main per minute.

Since the pumping power of the station is equal to the maintenance of a current of 15 feet per second, with consumers shut off, it is evident that with sufficient boiler power the amount of heat delivered to consumers can be enormously increased, with a progressive increase in profit. The station is at present delivering, as nearly as can be ascertained, about 600 Centennial Horse Power to con-
sumers, at a total expenditure and loss of, perhaps, 200 horse power.

Besides the economy involved in the return of the partially cooled water (at a temperature of about 180° F) to be reheated in the boilers—an advantage which is possessed by no other system with which we are acquainted—there is an additional gain by the use of this water as it is received, to condense the exhaust steam from the machinery of the station. The practicability of this has been questioned; but it is undoubtedly now successfully done at Boston, and is perfectly feasible so long as the return water, though so high in temperature, is received in sufficient volume for the purpose.

THE SAFETY OF THE SYSTEM.

Many persons have entertained apprehensions concerning the pressure (250 lbs. per square inch) carried in the boilers and mains of this system. As to the boilers, we do not hesitate to say that, in our judgment, the concentration of the business of generating steam at a station where this is exclusively attended to, and in boilers of the best modern types, expressly made for the purpose, thoroughly tested beforehand, operated by a trained force of skilled workmen, and constantly under vigilant inspection, and fed, moreover, with a continual return of the same clean water, is incomparably safer, even at 250 to 300 lbs. pressure, than the present system of scattered boilers.

As to the mains, connections, joints and valves, we are able to say, after examination, that they seem to us amply strong, tight and durable, and that the daily inspection of every part of the line maintained by the company insures it against the development of unnoticed defects. The pipes and joints are all tested to many times the maximum strain which they will ever have to bear in practice.

Moreover, the bursting of a hot water pipe would not involve an explosion, any more than the opening of a cock upon such a pipe involves it. Through a large fissure there might be a considerable outburst of scalding water,
and a man directly before it might be injured. But the conditions attending a boiler explosion are absent. There is no fire below, giving continually fresh heat; no depth or large mass of superheated water; and the cooling effect of the rapid expansion of the emerging water strongly diminishes the tendency to a propagation of the disturbance. In fact, Mr. Abbot has encountered, during his experiments, this very contingency of the bursting of an imperfectly welded pipe, filled with water at somewhere about 375°, and without serious injury beyond a disagreeable drenching.

The large margin of strength in all the pipes, boilers and machinery of the company is a further guaranty of safety.

RELATION OF THE SYSTEM TO THE STREETS.

This point was considered specially important, since two of the undersigned are members of the Board of Commissioners of Electrical Subways for the City of Brooklyn, and determined to oppose the introduction of anything into the streets of this city which would imperil the durability or efficiency of the electrical subways or impair the operation of the conductors laid therein. It was, therefore, with the explicit reservation of their freedom to condemn the Prall system on this ground, however great might be its merits in other respects, that they undertook the present examination.

The conduit of the Boston Heating Company presents, however, so complete a protection as to dispel all fears on this head. The asbestos non-conducting jacket on the mains reduces the temperature from near 400° inside the pipes to not more than 110° on the outside, and around this is an air space of two inches; then a brick arch; then another air space; then another brick arch; and then the earth. Moreover, the conduit is placed from four to six feet below the surface, whenever this is practicable, it being for the interest of the company to avoid all changes in the heat losses due to weather. Except in rare cases, where for some special reason the conduit has come very near the surface, no effect in the drying of moisture or
the melting of snow can be distinguished. We passed through the slightly snow covered streets of Boston without being able to detect by such evidence the route of the hot water main. Where the main occupied the shadier side of a street, the snow was disappearing first on the other side, as if there were no difference of conditions underground. All this was to be expected, after the proof of the small loss of heat furnished by the relative temperature of the two ends of the supply main. It requires 140 heat units to melt a pound of snow which is just beginning to melt; and the total loss from this main is only one heat unit per foot per minute. Considering only the radiation from the upper half of the pipe, and allowing for a distance of four feet between it and the surface, we may calculate that if the whole of this heat were transmitted in straight lines to the surface, through a medium which stopped none of it, and were totally consumed in the melting of snow, there would be about enough of it to melt one pound in fifty-four hours. To gain further assurance on this point, we consulted the Mayor of Boston, who had vigorously opposed the introduction of this system into the city, vetoing the franchise, etc., also the City Engineer, and the representatives of the Bell Telephone, the Edison Electric Light, etc. The Mayor confessed frankly that he had been agreeably disappointed in the results of the new system; that neither any of the city departments nor any other parties had expressed complaint, and that the only objection he still entertained was the general objection to all enterprises which required the digging up of the streets, because it was practically impossible to relay the pavements (especially of certain kinds) in as good permanent condition as before the disturbance. The other officials consulted gave the same verdict. The electrical companies had noticed no effect whatever upon their underground lines from the neighborhood of the Heating Company's conduit. The electrician of the Telephone Co. assured us that at one point its conduit actually crossed through that of the Heating Co., and rested in actual con-
We placed a number of small electric light bulbs, connected in parallel, so as to make the heat generated by the bulbs sufficient to melt the asbestos but not to touch it. We are therefore convinced that a conduit constructed like that of the Boston Heating Co. can carry in its main water heated to 400° or 450°, and very likely much hotter, without interfering in any way with gas or water pipes or electrical subways in its neighborhood.

In conclusion, we would express our judgment, formed upon a careful study of all available data, that the Prall system of distributing heat, if embodied in a plant as substantial, well arranged and amply provided with the appliances of economy and safety as that which we have had the pleasure of examining in Boston, is perfectly practicable and highly advantageous; and that we believe it can be carried on to the mutual profit of the producers and the consumer of the heat, and with great benefit to the community.

R. W. Raymond.
C. C. Martin.
Geo. W. Plympton.