THE PRALL SYSTEM

OF

Heating Cities

AND

Supplying Power by Hot Water.

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In this age of progress, to which modern invention has contributed so much to the health and comfort of living, it is surprising to find that only at this late day is public interest awakened to the necessity of some substitution for the unhealthy and troublesome hot-air furnace.

It is true that the more modern and expensive establishments, such as hotels, public buildings, and a few of the more costly private houses, have been provided with steam-heating apparatus, but while it may justify the expenditure for separate steam generators, and maintenance thereof, in such places, it would not be within the means of the masses to do so, hence many attempts have lately been made to make steam wholesale as it were, and retail it to customers both for heating, and power purposes, through pipes, extending over a large area, and at considerable distances from the generators or boilers.

Confined to comparatively small areas the system has proved profitable, as shown by the Manhattan Real Estate Association, who for many years past have supplied the district lying between Thomas and Worth streets on Broadway, New York, with both heat and power, from a battery of boilers. The system has met with equal success in other cities for many years, notwithstanding the immense loss from radiation and condensation. But it has been proven there is a limit to conveying heat and power through so light and condensable a medium as steam for any long distance underground with any degree of economy.

A knowledge of these facts led the inventor to conduct an exhaustive series of experiments, which convinced him, and the large number of experienced and practical engineers who witnessed them, that the only medium which could be profitably and economically employed for the purpose of conveying large quantities of heat and power long distances underground, was water under a high temperature, thereby availing himself of the immensely greater density of water and greater capacity for absorbing heat under pressure.

Now, what is the Prall Hot Water System in its practical adaptation?

It consists in conveying the heat and power directly from the heat generator, through underground pipes, by the medium of highly heated water under confined pressure, and delivering it from the mains, through service-pipes and meters to consumers, and after that converting it into steam. Converting the hot water into steam is accomplished by simply reducing the pressure by means of a valve, and providing a steam converting tank, from which tank steam may be drawn for any purpose. A return pipe is provided which conveys all the water of condensation not used for domestic or other purposes back to the heat generator, thereby saving all the units of heat not available for heating purposes.

Why is this so greatly superior to a steam system?

(1.) Because it does not cost one-half as much for pipes to convey the same amount of heat and power.

(2.) Because it does not lose one-half as much heat by radiation and condensation in conveying the same amount of heat and power, on account of the greatly reduced size of the pipes.

(3.) Because it saves a large percentage of the fuel, by returning all the unused condense water to the heat generator.

(4.) Because the exact amount of heat and power used by each consumer can be accurately determined by measurement, which cannot be done in a steam system. All of which reasons can be undeniably substantiated, as will be presently shown.

In doing so it becomes necessary to furnish the intelligent investigator with a full, clear and concise synopsis of the system, together with such data and calculations as will enable him to comprehend and appreciate its vast superiority.

In the operation of the system, as has already been implied, a large generating apparatus is located conveniently to the district to be supplied. The pipes conveying the hot water therefrom and returning the condensed water thereto, are laid in the same trench, and so connected as to allow of a forced circulation. These pipes being covered with a non-conducting composition so as to prevent as much as possible the radiation of heat therefrom. A force pump or trap is employed to return all water of condensation not used to the heat generator.

The following simple calculations, based upon well established laws, will clearly show the advantages of hot water as a medium of conveying heat and power:

A cubic foot of water heated to a temperature of 376° F., equivalent to a pressure of about 160 pounds above the atmosphere, will give off 14,125 available units of heat when the pressure is relieved and temperature is reduced to 150° F., which is about the temperature to which it can be used economically for heating purposes. The result of reducing the pressure is to cause the conversion of a certain amount of water into steam. The quantity of steam thus generated will be about 275 cubic feet volume, containing 37 units of heat each = 10,175 units. 14,125 — 10,175 = 3,950 units, which are utilized for heating by indirect radiation. Now taking a cubic foot of steam at the same temperature (376° F.), which has a pressure the same as the water, it has only 355 available units of heat. Thus it will be seen that a cubic foot of water contains about 40 times as many available units of heat as a cubic foot of steam, and will produce a proportionately greater volume of steam, when the pressure is relieved. There would still remain in the water of condensation the units of heat between 150° and that usually contained in the water taken from any source, in ordinary weather, which would be about 50°, leaving a balance of 100° in each pound of water, there being 62.5 pounds per cubic foot = 6,250 units, which in the Prall System is utilized by being returned to the heat generator, whereas if discharged as condense water would be a total loss.

The return pipe, used for conveying the condense water back to the heat generator, it will thus be seen is the source of immense saving in fuel, while it adds but a comparatively small amount to the total cost of the plant to return it, as it will be laid in the same trench in which the supply pipe is laid, with no additional cost for digging or repaving, but simply the cost of the pipe is to be added. The radiation from it, containing as it does water at so low a temperature, would be scarcely worth taking into account, and it would prevent in some measure the radiation from the supply pipe adjacent to it. No building which is heated by steam economically, wastes the condense water, as every one knows. If it is so important on a small scale, it becomes much more so on a large one. Of course much of the condense water will be used in private residences for domestic purposes, and in some cases even more than the whole amount would be required; but for public places and large buildings used for offices, and for steam-power purposes, very little, if any, warm water is needed, and in such cases it would be a total loss of a large proportion of the entire heat. Certain it is that no more profitable expenditure could be made than by laying a condense water return pipe.

It will be seen by the calculation that only about four and one-half times the quantity of condense water is formed by this system in conveying the same number of available units of heat as when the water is all evaporated into steam, occupying forty times its space, and necessarily requiring much larger pipes for its conveyance, and involving much greater cost and loss of heat from radiation. And to a steam system also must be added the loss of all the water of condensation formed in the mains, which would add about one-third more to the amount when steam is sent through long underground pipes.

As has been shown a cubic foot of water contains 14,125 available units of heat, which can be utilized in heating; the cost of returning the condense water thereof becomes insignificantly small in comparison with the great saving of heat gained. For example: A cubic foot of water converted into steam, at a pressure due to 376° F., absorbs 848 units of latent heat per pound, which equals 848 × 62.5 = 53,000 units of latent heat per cubic foot evaporated, and when added to the sensible heat, which is 10,250 units per cubic foot = 63,250 total units of heat. But its volume, by evaporating into steam, has been increased 178 times that of the water before evaporation and having the same temperature and pressure. Hence the units of heat required to put a cubic foot of water into the generator, against a pressure equal to that of the steam evaporated from the water, would be $\frac{1}{178}$ part of the entire units of heat contained in the 178 cubic feet of steam evaporated at 376°, which would be 355 units, to which must be added 20 per cent. for pumping friction = 426 units. This small number of heat units would return a cubic foot of condense water, from which in the hot-water system 14,125 available heat units were derived.

And as the pressure within the heat generator forces the water through the pipes and connected radiators to the condense water pump, the same as when steam direct is conveyed for heating purposes in buildings, it is evident that no additional force is required, except to overcome the pressure due to the temperature of the water when it was discharged from the generator, plus the friction in putting it back, and as not over one-half of the water discharged would be returned (the remainder being used for domestic purposes), a very low pressure of steam could be used in the radiators, which pressure would suffice to force the condense water through the trap and return pipe to the pump, in a manner as simple as ordinary waste water is conveyed from houses. The temperature of the water so returned would be proportionate to the amount of radiating surface exposed in the indirect radiator, through which it was caused to pass before reaching the discharge trap, irrespective of the temperature or pressure of the steam used in the connected pipes and radiators, which pressure would be determined by the amount of reduction produced by the regulating valve, connecting them with the main supply pipes, and, as will be presently shown, not over one pound pressure would be required to return the estimated one-half of the whole amount of hot water used in heating a distance of a mile through a six-inch pipe. It will thus be seen that a very low pressure of steam in the buildings may be used.

Now a cubic foot of water heated to 376°, as before stated, yields 14,125 available units of heat, and this multiplied by 178, which would represent the space occupied by the steam evaporated from a cubic foot of water at that pressure and temperature, equals 2,584,250 units of heat, while in a steam system the same volume yields only 67,125 available units of heat, and to put 178 cubic feet of water back into the generator it would require 75,828 units, which equals about 3 per cent. of the whole available heat units. In a steam system the loss in condense water alone is, as has been shown, over 12 per cent. of the entire available heat units, even when discharged at 150°, which is the same temperature at which we have estimated the return water for the hot-water system, which shows for it 9 per cent. saving in condense water alone, independent of the difference in loss by radiation, which would be fully double as great as in the hot-water system.

Having shown clearly and beyond dispute that there is a great gain in returning the condense water to the generator, and that it is practical to accurately measure the amount of heat contained in the supply water at any given temperature, we will now consider the size of pipe required for conveying it, and for an example we will take a district of one mile in length from the generator:

It is estimated that the space to be heated is 80 feet deep on each side of the street and 30 feet high, which would be 4,800 cubic feet for every lineal foot of street. One cubic foot of steam contains 37 available units of heat at its lowest available pressure for heating purposes. It is estimated that one cubic foot of steam will heat one cubic foot of space for 16 hours. The 37 units of heat contained therein being sufficient to heat 50 cubic feet of air from 30° to 70°, thus renewing and heating one cubic foot fifty times in 16 hours. Hence, 20 squares of 200 feet front each, being one mile, including the street crossings, and which would therefore have 19,200,000 cubic feet of space to be heated, would require 19,200,000 cubic feet of steam for 16 hours per day, being 1,200,000 cubic feet of steam per hour, or 710,400,000 units of heat per day, or 44,400,000 per hour, being 111,000 units of heat per house per hour, reckoning 20 to the block, both sides of street. Now one cubic foot of water contains 14,125 available units of heat, therefore 44,400,000 divided by 14,125 will equal the cubic feet of water required per hour, which is 3,143, or for a day of 16 hours 50,288 cubic feet.

Now we find that a 6-inch pipe, one mile long, with a head equal to 20 pounds pressure, estimating the delivery as being uniformly distributed along the line of pipe, from the beginning to the end, will deliver about 3,570 cubic feet per hour, or 57,620 cubic feet per day of 16 hours; now the available units of heat in a cubic foot of water being 14,125, 3,570 cubic feet will give off 50,420,250 units of heat for one hour's delivery, and for a day of 16 hours, the units of heat delivered would be 806,724,000, or about 13 per cent. more than the whole amount estimated. Presuming that not over one-half the condense water would be used for domestic purposes, which would be 1,785 cubic feet per hour, the remaining half could be returned through the same size pipe (6-inch) with less than 6 pounds pressure, for we find that 6 pounds pressure on the return main will deliver 1,820 cubic feet per hour.

The cost of laying one mile of 6-inch pipe, including supply and return pipes, for digging, covering pipes, and repaving, both pipes being laid in the same trench, would be $3.37 per foot = $17,793 per mile, independent of the small branch connecting pipes. The cost of laying 4-inch supply and return pipes would be about one-half of this amount. The cost of heating a mile in a populous city with the average buildings 80 feet deep, 30 feet high, and 20 feet wide, and situated on both sides of the street, which would make 400 houses to the mile, 20 per block, including the street crossings. Each house contains 48,000 cubic feet, but it is estimated that one-fourth of this space, or 12,000 cubic feet only is required to be heated constantly for 16 hours per day for the average consumer, which would equal 400 houses × 12,000 cubic feet = 4,800,000 cubic feet of steam per day of 16 hours, being 11,100,000 units heat per hour, or 177,600,000 units of heat per day.

Hence the amount of water required for the purpose would be delivered through a 6-inch pipe, with a pressure or head of only 2 pounds, and one-half of the condense water (supposing the remainder to be used for domestic purposes) could be returned to the heat generator with a pressure less than one pound, and a 4-inch pipe, with a pressure of 20 pounds, would be quite sufficient for the purpose, since a 4-inch pipe will deliver 1,200 cubic feet of water = 16,950,000 units of heat per hour, or 271,200,000 units per day of 16 hours equals, at 37 units per cubic feet, 7,329,730 cubic feet of steam, and as only 4,800,000 are required, we have over 50 per cent. excess.

Now a house is estimated to require 444,000 units to heat it for a day of 16 hours, and as one pound of coal imparts in practice at least 9,000 units to the water, 444,000 ÷ 9,000 = about 50 pounds of coal per day for each house which, at $3.50 per ton = 9 cents per day, or for a year of 200 days, $18. The amount of water required hourly per house would be less than 2 cubic feet.

Cost of plant for one mile of street, including 400 houses, laid with six-inch mains:

Building lot, heat-generators, and setting	$6,250
Cost of mains laid	17,793
Capital invested	$24,043

Cost of operation:

2,000 tons of coal, at $3.50 per ton	$7,000
Attendance	600
Clerks and office expenses	2,000
Repairs	1,000
Annual expenses	$10,600

Net income:

400 houses, at $100	$40,000
Deduct expenses	10,600
Surplus	$29,400

This shows a return of considerably over 100 per cent. on investment. The surplus in one square mile, with 16,000 buildings, would be $1,176,000 per annum.

Having thus demonstrated beyond dispute (for the quantity of water which can be delivered through a pipe is not involved in any uncertainty), that 271,200,000 units of heat can be conveyed by the medium of the water discharged from a four-inch pipe in a day of 16 hours, with a pressure of only 20 pounds, we will now estimate what can be done with steam. In consequence of the great diminution in volume, caused by the rapid condensation in such long pipes, exactitude in calculation is impossible. After carefully examining the works of such eminent engineers as Box, Rankine, and others, we find that it would require at least a 14-inch pipe to deliver the same units of heat, with no greater loss in pressure, and we believe that the practical results, well known to engineers familiar with the conveyance of steam long distances, will corroborate their calculations.

It is estimated that steam, at a pressure due to a temperature of 376° (which is the pressure we have calculated for water), has a density of 4.66 times that of air at 62°, and as the velocity in gases is in proportion to the pressure and density, and the friction in proportion to the velocity, we find by the rule for calculating air and water that the volume of steam delivered at the density given will be about 6⅔ times that of water under the same conditions, but it requires that it should be 40 times that of the water in order to yield as many units of available heat, without taking into account the large amount lost by extra radiation and condensation, which would require fully ⅓ more. Hence it will be seen that by hot water fully 8 times as much available heat may be delivered, and thus requiring 8 times as large a pipe for steam as for water.

Practice proves this substantially, for we find that in no case where anything approaching such an amount of steam as would be required to heat a mile of buildings located on both sides of the street, has it been even estimated to use pipes of smaller capacity, and it is doubted very much whether that capacity will be half sufficient for the purpose, as good engineers have informed us that 75 per cent. of the total amount of the steam generated was lost by condensation in a much less distance, and when the pipes were covered in a most careful manner. But allowing that a mile of buildings could be heated though a 14-inch, or even a 12-inch pipe, by steam, it will not be difficult to estimate the difference in the cost for pipes, and the loss from radiation. We find that a 12-inch pipe costs, net, $4.50 per foot, while a 4-inch pipe is only 50 cents, but in this system two pipes are required, which would be as $1 to $4.50 per lineal foot. The expense of covering, etc., would be proportionately great. This first great difference in cost between the water and a steam system is not the most important matter to consider, but the perpetual loss from the large surface exposed to constant radiation is, for the surface exposed in a 12-inch pipe = 452 square inches per foot, for a 4-inch pipe = 151 square inches per foot, or less than one-third; and even if a 6-inch pipe were employed the surface per foot = 226 inches, or less than one-half, and the price of a 6-inch pipe is only $1 per foot.

We think we have said sufficient to call the attention of those interested, to a careful investigation for themselves, feeling convinced they will find the water system has vastly more in it than at first appears without examination.

For power purposes this system would have an equal advantage over a steam system, but as all large consumers have the same facilities for making steam that any general supply system would afford, it is hardly probable that they could afford to pay the loss by radiation consequent to a long delivery, and an additional profit on the outlay to a furnisher; but for small purposes, such as elevators, etc., it will no doubt be largely employed.

The experiments referred to at the commencement of this pamphlet we will now briefly describe:

In conducting the first experiment, 1,000 feet of 1½-inch supply pipe was laid underground and covered with ¾-inch of hair felting, and wrapped with tar-paper; the pipe had 20 rectangular bends in it. A return pipe was also laid for the return-water of condensation; this was covered in the same manner as the supply pipe. A small upright water heater (about 3 H. P.), was located, and the supply and return pipe was connected with it. The water was heated to from 60 to 110 pounds pressure, and was forced from the generator by a pressure due to the temperature of the water, through the supply pipe, and at the terminal end, 1,000 feet from the heat generator, it was drawn off through a ½-inch pipe, and conducted through a water meter, which was found to accurately measure the water passed through it; from the meter it was conducted to a pressure regulating valve, constructed to give any pressure it was desired to establish; from the valve it was conducted to a steam converting tank, to which steam-pipes were connected, extending for several hundred feet to several large direct steam radiators. The water from the converting tank was conducted to an indirect radiator, with about 400 feet of 1-inch pipe, placed in a cabinet, provided with openings, extending into the open air and into the building. It was found that the difference in temperature of the water at the heat generator, and at the end of the 1,000 feet of pipe, was only about 1½°. The water from the indirect radiator was discharged through a trap, after being reduced to about 150°, and was forced back to the pump located at the generator by the pressure of the steam within the converter, which was from 2 to 10 pounds. The water was returned to the generator through the return pipes. The temperature in the supply pipe at the converter was somewhat surprising, but can be accounted for by the great density of the water and its capacity for receiving and retaining heat. It was found that after remaining stagnant in the pipes for 53 hours, in the coldest weather of the winter, that it still retained a temperature of 100°. Its temperature being about 332° on stopping circulation.

In the second experiment the apparatus employed was similar to the first, except that the supply pipe was 2,130 feet in length, and was a 2½-inch pipe, the generator also being much larger than the one in the first experiment and the steam converter being also larger. The object of this experiment was to develop steam for power purposes as well as for heating. The results proved quite as satisfactory. A steam-engine, driving a machine-shop, was driven at full speed, the loss by reduction in temperature being only 5°. The pressure in the water-heater was about 100 pounds, and the 2,130 feet of supply pipe had 22 rectangular bends in it.

It has been clearly demonstrated that at a high temperature of the water a very much better result can be obtained, and that with water heated to about 376°, or about 160 lbs. gauge pressure, steam power may be developed at almost any distance within a city limit from one heat generator with very little loss from radiation. For such purposes the steam converter should be constructed with a large evaporating surface, which is obtained by causing the water to discharge from the regulating valve, and pass over thin sheet-iron plates within the converting tank, the object being to reduce the temperature thereof to the lowest point practicable for the pressure employed, the remaining degrees of heat left in the water being returned to the generator, when not required for heating purposes, together with the condensed water from the engine, the same as the ordinary condensation from radiation is returned.

In putting down a plant for many streets the supply pipes may all be connected at the intersections of the streets or not, the difference would not be great in the practical result, as the pipes in each line of streets running in cross directions would connect with the main supply pipe at right angle sides of the plant. Thus it will be seen that the flow of water will be from each right angle main supply pipe directly through the pipe in the plant connected with it, and the return water would flow from all directions of the plant to the point of lowest pressure, from which point the main return pipe would extend to the generator. Both the supply and return pipe should be placed in a water-tight box, after being carefully covered with felting. The connections should be made with both supply and return pipes from each building, on laying them, which connection should be controlled by a cock from without the building, in a manner similar to that adopted in ordinary gas or water supply pipes.

In this system the expense of the meter for determining the number of cubic feet of hot water each consumer uses will be about $5, and about the same for the steam converter when required for heating purposes in ordinary dwelling houses. The pressure regulating valve for reducing the pressure from the main to that required in the house would be about $7 additional for such purposes, all of which are patented under this system and would be furnished at reasonable rates, as also steam and hot water cooking apparatus.

As in this system a nearly uniform temperature can be maintained, the charge to the consumer would be made per cubic foot, which would contain a given number of units of heat and capable of making a proportional amount of steam.

The generators or water heaters should be put up in batteries, so that the service may be increased at any time to suit the demand.

This system is thoroughly covered by Letters Patent, both in America and abroad, and the claims which we append will show how broadly the invention is secured. The claims are as follows :

"In an apparatus for heating buildings, the heating tank, the hot water street main connected therewith, the circulating pump, and the heat radiator and a meter, substantially as shown and described.

"In an apparatus for heating buildings, a hot water tank, a hot water street main, a circulating pump, a differential or pressure reducing valve, and a heat radiator of a building, as set forth.

"In an apparatus for heating buildings, one or more hot water reservoirs, and one or more hot water pipes connected therewith, having branch pipes connected with a pressure reducing valve, and with an evaporating chamber, and with a heat radiator, and with a meter, substantially as shown and described.

"In an apparatus for heating buildings, the hot water generating tank, and a street main connected thereto at a point below the water line, branch pipes connecting said main pipe with a circulating chamber arranged in connection with a steam generating chamber, as specified, in such a manner as to transmit the heat from the circulating water chamber to the evaporating chamber, substantially as set forth.

"In an apparatus for heating buildings, the heating tanks and the pipe or pipes for conveying the hot water, connected therewith, branch pipes for conveying hot water to a radiator, an exhaust opening to convey the water from the radiator, and a meter for measuring the water passed through the radiator, constructed and operating substantially as shown and described.

"In an apparatus for heating buildings, the heating tanks and the pipes connected thereto, as specified, in such a manner as to convey the water therefrom ; a force-pump, or its equivalent, for circulating water therein, and a radiator connected thereto, in combination with an air-heating chamber, provided with inlet and outlet openings, for receiving and delivering the air, and with a meter, substantially as set forth.

"In an apparatus for heating buildings, the heating tanks and the hot water street mains connected thereto, provided with expansion and contraction joints and with a covering of non-conducting material, the branch pipe for conveying the hot water to a building, a pressure-regulating valve for reducing the pressure, an evaporating tank for converting the water into steam, and a heat radiator of a building, provided with a condense water-receiver and with a registering pump for removing the water, constructed and operating substantially as shown and described.

"In an apparatus for heating buildings, the heating tank, the hot water street main pipe connected therewith, a circulating pump for forcing the water through the pipe, and branch pipes and meters for connecting the main street pipe with a circulating heater, arranged to transmit heat to a steam generating tank or hot water tank, substantially as described, said tank being constructed to be supplied with a liquid, and provided with return pipes for conveying the condensation to the generating tank for reheating, substantially as shown and described.

"In an apparatus for heating buildings, a water evaporating chamber, adjacent to a chamber adapted to circulate water of a higher temperature, the radiator arranged to receive steam from the evaporating chamber, and the whole provided with cocks and valves, substantially as shown and described.

"The within described method of conveying, by means of a pump or its equivalent, hot water through underground street mains, provided with branch pipes and with meters for the purpose of delivering and measuring said hot water used for heating purposes in buildings, having radiators, with connected cocks and valves, for controlling the heat in the same, substantially as set forth."

From the foregoing it will be evident to any practical mind that this system for supplying heat and power over an extended area, and delivering it to numerous consumers, when accurate measurement becomes necessary, will be vastly superior to a steam system, and it has been shown beyond dispute that much larger dividends for the investment can be made, and with much more satisfactory results to both the supplier and consumer.

We have demonstrated that with about one-half of the money invested in the plant, and saving over half the loss by radiation, and a large additional gain by utilizing the condense water, that a dividend of 25 per cent. from this source alone could be paid, which in a steam system would be a total loss.

For further information apply to

W. E. PRALL,
71 Broadway, N. Y.
(Room 108.)