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# Testing of Energy Efficient Fisonic Devices at the Woolworth Building in New York City

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**Abstract:** The Fisonic Devices (FD)s are supersonic, condensing heat pumps with a patented internal geometry that causes steam and water to mix and accelerate, converting a minute fraction of fluid's thermal energy to physical trust (pump head) with the outlet pressure higher than the pressure of the working medium at the inlet of the FD. The FD replaces the tube and shell heat exchanger and heats the water by direct contact with steam. The use of the FD allows reducing the terminal temperature difference between steam and water, the required steam consumption, and the amount of cold potable water required to quench the condensate. The operation of the Fisonic system results in reduction of building steam, cold water and sewer costs. The purpose of the described project was to manufacture, install, test, and demonstrate the performance and energy efficiency of the FD's for the space heating system of the major City of New York steam consumer - Woolworth building. The test of FD's resulted in reduction of the annual steam supply in comparison with the existing system by 20%, elimination of cold quench water consumption, and reduction of steam, water, and sewer costs.

**Keywords:** Fisonic Pump, Fisonic Device, Heat Exchanger, Steam Saver

## 1. Introduction

Most of buildings in U.S. supplied with steam convert the district heating or boiler generated steam into hot water in tube and shell heat exchangers. The hot water is then used for space heating and domestic hot water service. At some customers steam is also supplied to absorption or steam driven chillers for cooling purposes. The condensate in many buildings (particularly old district steam systems like Con Edison in New York City) is not returned to the steam generation source and discharged to the sewer system. In order to reduce the condensate temperature to about 150F (the sewer system requirement) the condensate is quenched with cold potable water.

The building owner in addition to the steam cost also pays additional cost for quenching water and sewer discharge fees. The discharge of the condensate/water mixture consumes a substantial capacity of the City sewer system and the sewer treatment facilities. This situation results in high steam, water and sewer charges to the customers and high make-up water cost for steam generating plants.

In order to improve the end-use energy efficiency and the environment Hudson Fisonic Corporation (HFC) and Joseph Technology Corporation (JTC) under the NYSERDA sponsorship performed demonstration testing of emerging technology of Fisonic Devices (FD) [1-12]. The FD's are supersonic, condensing nozzles with a patented internal geometry which causes steam and water to mix and accelerate, converting a minute fraction of fluid's thermal energy to physical trust (pump head) with the outlet pressure higher than the pressure of the working medium at the inlet of the FD (Figure 1). The FD replaces the tube and shell heat exchanger and heats the recirculated building water by direct contact with steam. The use of the FD allows reducing the terminal temperature difference between steam and water, the required steam consumption and the amount of cold potable water required to quench the condensate. The operation of the Fisonic system results in reduction of building steam, cold water and sewer costs.

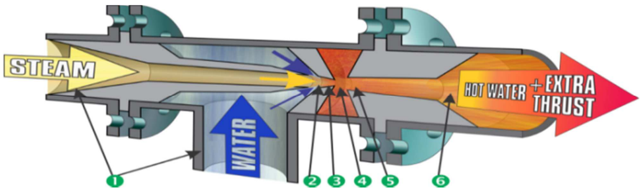


***Figure 1.*** *Diagram of Fisonic Device.*

1. Water and steam enter the Fisonic device separately. 2. The streams merge into a highly compressible 2-phase mixture. 3. Narrowing inlet compresses and accelerates 2-phase mixture to Mach 1 condition. 4. At Mach 1, steam condenses in the 2-phase mixture, yielding hot water and Nano bubbles. Acceleration at Mach 1 condition causes the Nano bubbles to collapse similar to cavitation). 5. Cavitation process results in conversion of the system thermal energy to kinetic thrust. 6. Hot water exits the device at a higher pressure than the initial steam and water inlet pressures.

## 2. Demonstration Tests of FD for Space Heating System

The Woolworth Building designed by architect Cass Gilbert and completed in 1913, is an early US skyscraper. The building is supplied with Con Edison district steam. The 10 inch steam line enters the building basement at 170 to 180 psig. Pressure reducing valves reduce the entrance pressure to 60 psig, and afterward from 60 to 3-10 psig, typically the pressure is 3 psig. A 3 inch steam line supplies steam to tube and shell steam to hot water heat exchangers from which hot water is supplied to different sections of the building. The analysis of the space heating system of the building and discussions with the building management indicated that the testing of the Fisonic Devices can be performed in two separate space heating branches: 5 story building section and unit heater section. Each loop requires individual metering and monitoring of existing system and system with installed Fisonic system.

The main objective of the project was to evaluate energy and water savings for space heating at the Woolworth building resulting from replacement of existing tube and shell heat exchangers by the Fisonic Devices (FD"s). This objective was achieved by comparing the monitored energy and water use during the heating period with the energy and water use with the FD's consumed during a similar period.

Figure 2 presents the diagram of the existing space heating system of the 5 story building.

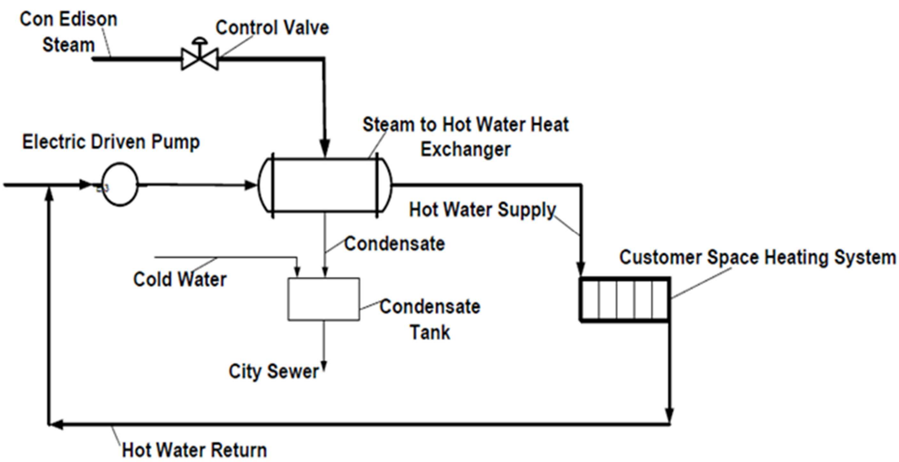


***Figure 2.*** *Existing Steam Space Heating System.*

Figure 3 presents the diagram of the Fisonic system with a plate and frame heat exchanger which prevents any direct contact of steam from the Fisonic Device heating loop with the existing space heating system. The introduction of a highly efficient plate and frame heat exchanger with terminal temperature difference of 1-2F provides the opportunity to prefabricate the total module with the Fisonic device and simply connect the package to the existing system.

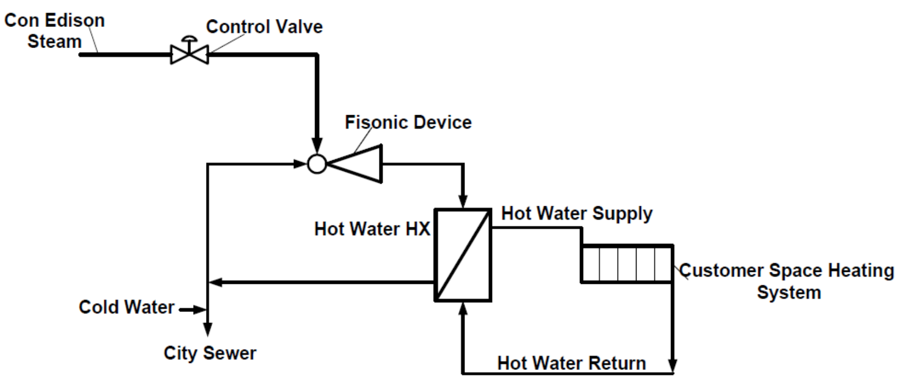


***Figure 3.*** *Diagram of Fisonic System Installation for Space Heating.*

In order to demonstrate the energy savings associated with the Fisonic devices the following steps were necessary:

(1) Select instrumentation and equipment for measuring flowrates, temperatures and pressures of steam, hot and cold water use at selected space heating systems in the building in order to capture the existing (baseline) system data and the system with Fisonic devices data.
(2) Install instrumentation and additional monitoring equipment, collect and analyze the baseline data.
(3) Install the Fisonic devices at selected space heating systems.
(4) Install instrumentation and additional monitoring equipment, collect and analyze the system with Fisonic devices data.
(5) Compare the baseline and Fisonic devices operational data normalized to the same 30 years outdoor temperatures.

All the necessary equipment and instrumentation have been sized and the specifications for purchasing and installation of equipment and metering devices developed. The specification was issued for bids to qualified HVAC contractors. The necessary equipment and instrumentation was purchased and installed at the 5 Story building.

Figure 4 presents a diagram of the 5 story building space heating system with installed instrumentation. The installation includes the existing closed tube and shell water heat exchanger HX2 which currently provides heating to the 5 Story building. The existing pumps P3 and P4 on the right provide circulation of hot water throughout the 5 Story building. The diagram also shows the Fisonic device and plate and frame heat exchanger.

Figures 5 and 6 present the pictures of the test installation. First the testing of the existing system with tube-and-shell heat exchanger was performed. The logger recorded all parameters with an interval of 5 minutes. The daily 288 readings for each parameter were compiled and averaged data for each day were obtained. Based on recorded data of steam consumption at different outdoor temperatures was used to develop a relationship logarithm The regression equation for the test data is found using the INTERCEPT and SLOPE correlation coefficient $R^2$ value for 0.9 for the equation is found using the CORREL function. The $R^2 = 0.89879732$ is calculated by squaring the correlation coefficient. The actual relationship equation between the steam load and outdoor temperature was developed. Using the developed equation and the normalized for the past 30 years average outdoor temperatures the total annual space heating steam consumption for the Existing 5 Story Building Section was estimated.

The identical multi-month testing was performed for the existing system equipped with the Fisonic Device. The comparison of test results has demonstrated that the steam savings for the Fisonic System in comparison with the existing system are 19.1%. The condensate discharge temperature after the FD was not higher than 150F and therefore no quench water was required. This eliminated the associated water and sewer charges for the building owner.

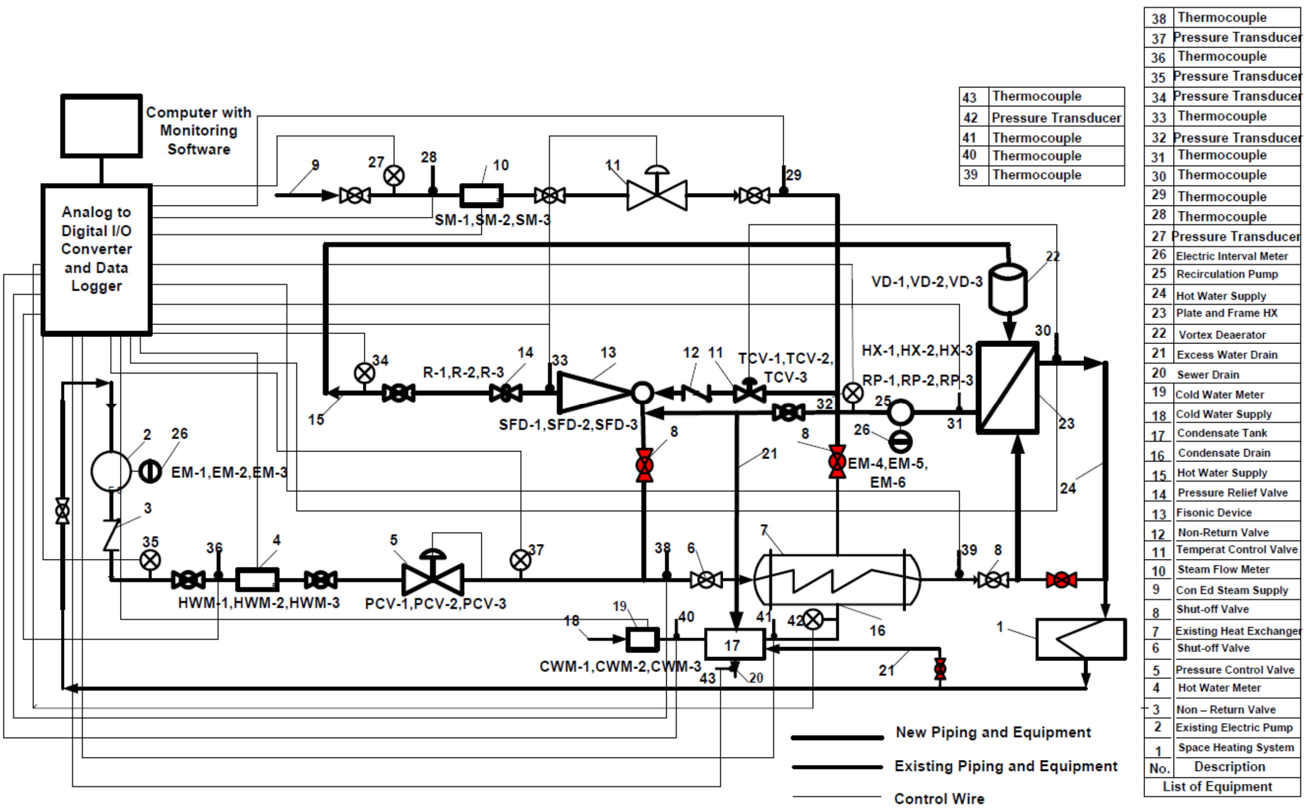


***Figure 4.*** *Monitoring Diagram of the Space Heating System Equipped with Fisonic Device.*

# 3. Testing of the Unit Heater

Most of the modern space heating systems in typical buildings have multiple Unit Heaters for conditioning the air. Therefore testing a Unit Heater equipped with a Fisonic device in a commercial building was very important. The Woolworth owner provided for test one of the large building Unit Heater. The project team has performed substantial refurbishing work on the selected heater before testing (cleaned the existing steam coil, cleaned and installed a new hot water coil, equipped the fun with a variable speed motor, installed the Fisonic Device, and also connected and insulated all piping and installed all necessary instrumentation for testing separately the steam and a hot water coil.

The equipment and instrumentation pictures at the Unit Heater system are presented in Figures 7 and 8. Figure 7 displays the principal diagram of the Unit Heater Installation. The existing Unit Heater in the winter heats cold air to a temperature of 80F. The Unit Heater consists of a steam coil supplied with low pressure steam. The steam coil is displayed on the right side of the Figure 8. When the steam condenses the condensate is drained in a newly installed condensate tank and afterwards discharged to the sewer. Before the condensate is drained to the sewer it is mixed with cold potable water.

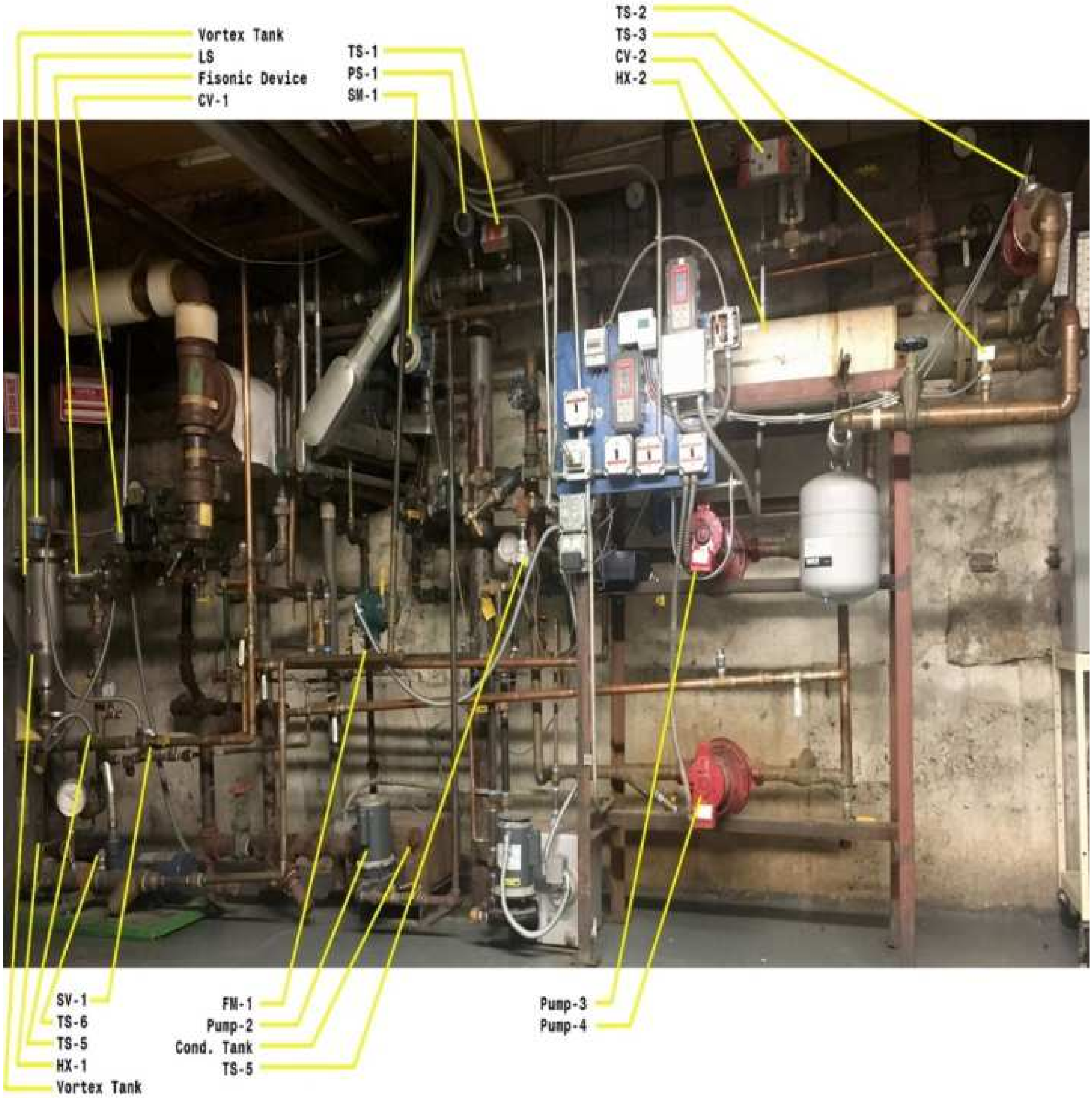


***Figure 5.*** *Overall View of Test Installation.*

***Figure 6.*** *Fisonic Device, Vortex Tank, Plate and Frame Heat Exchanger and Water Pump.*

The steam heats the water in the Fisonic Device and the excess water flow equal to the condensed steam flow is collected in the condensate tank and afterwards drained to the sewer. The operation of the steam and hot water coils are alternated. After the steam coil is tested it is disconnected and the hot water coil put in operation.

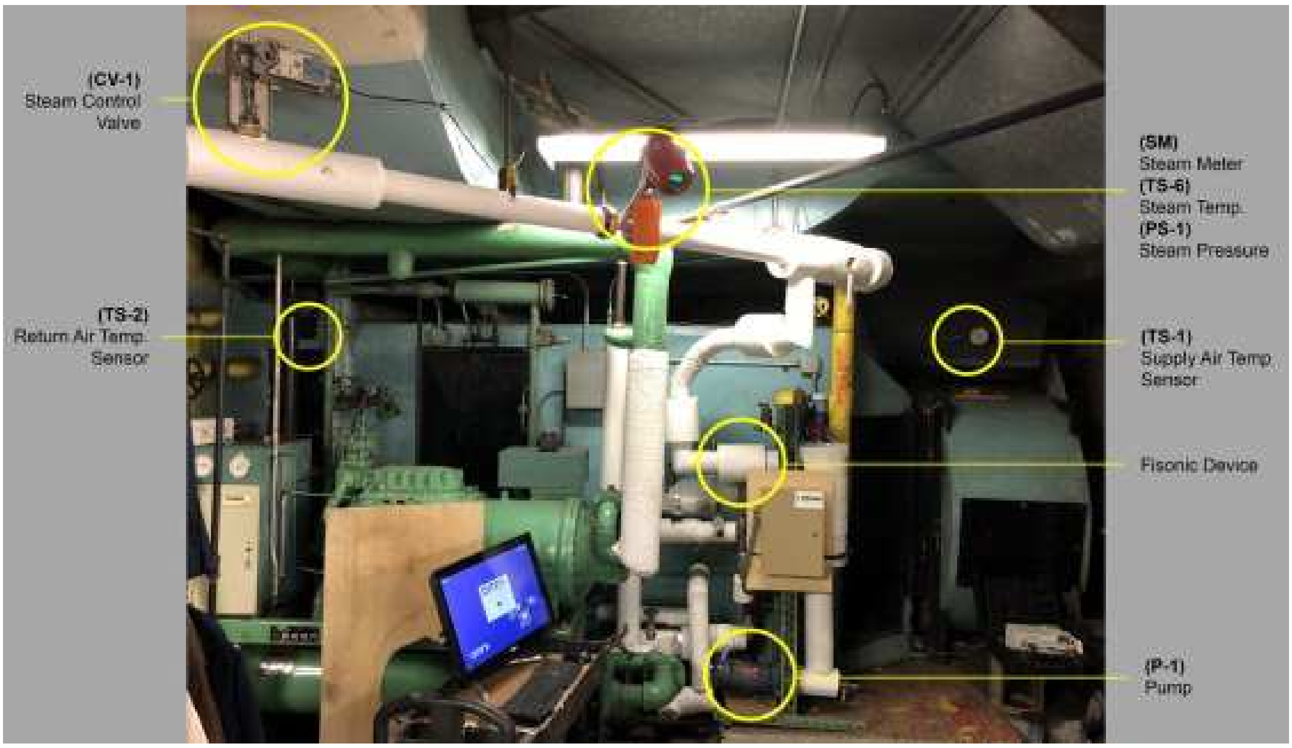


***Figure 7.*** *Overall View of the Unit Heater Test Installation.*

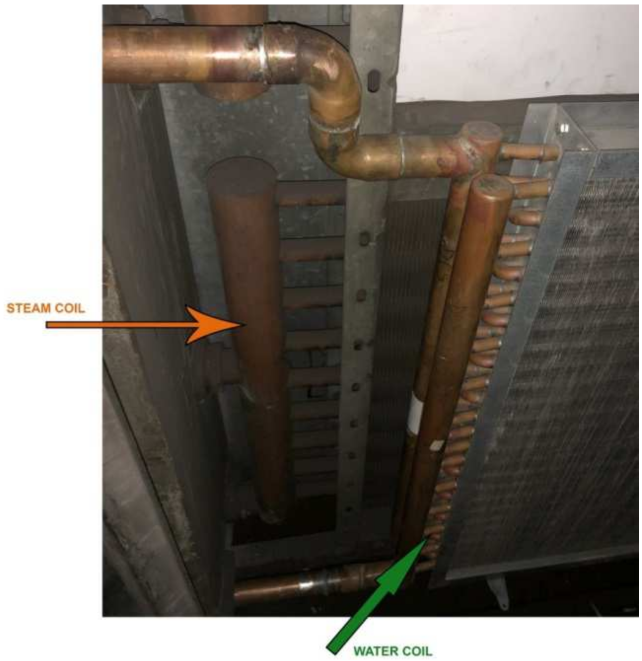


***Figure 8.*** *Steam and Hot Water Coils of the Unit Heater.*

## 4. Unit Heater Steam Coil Test Results

The unit heater air outlet temperature was set for 80F. The inlet air temperature in the unit heater has changed in accordance with outdoor temperature.. The logger recorded all parameters with an interval of 5 minutes. The daily 288 readings for each parameter were compiled and averaged data for each day were obtained. It is important to note that the temperature of the condensate leaving the steam coil ranged between 190-210F. A dependence logarithm of steam heat load on the outdoor temperature was developed. Using this logarithm and the normalized for the past 30 years monthly average outdoor temperatures the total annual space heating steam consumption for the steam Unit Heater was estimated.

In order to perform the comparison of the existing system with the Fisonic system an identical hot water coil was installed inside the Unit Heater. The coil is equipped with a Fisonic Device set up. The coil is supplied with steam from the same piping header. The steam heats the water in the Fisonic Device and the excess water flow equal to the condensed steam flow is collected in the condensate tank, metered and afterwards drained to the sewer. The temperature of the condensate ranged between 85 and 119.7F and therefore no cold water addition is required.

Using the same methodology the total annual space heating steam consumption for the Fisonic system was estimated. The test results demonstrated that the steam savings for the Fisonic System in comparison with the existing system is 21.96%.

## 5. Conclusion

The current project resulted in the following conclusions:

(1) The test of FD's for space heating system at the Woolworth building resulted in reduction of annual Con Edison steam supply in comparison with the existing system by 20%, elimination of cold quench water consumption, and reduction of steam, water and sewer costs.

(2) The life-cycle comparison estimates for a new building considering installation of a typical tube-and shell heat exchanger versus Fisonic System indicated a payback of 1.2 years and for an existing building retrofit with Fisonic Devices 3.3 years.

(3) The utilization of FD shall result in the following major benefits: reduction in steam, potable water and sewer cost to existing and new businesses in New York City and NYS, reduction of pollutants release in New York City particularly GHG, and job creation. The best application of Fisonic Devices is the replacement of the existing tube-and shell heat exchangers and feed water heaters in power plants [13].

The domestic hot water system with the FD was independently tested City at the 455 Broadway Building by City Laboratory of New York City and demonstrated savings of 21% [14]. HFC also obtained the Global Underwriters Laboratories Certification [15].

## Acknowledgements

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