Development and Testing of Fisonic Devices at the Woolworth Building in New York City

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Development and Testing of Fisonic Devices at the Woolworth Building in New York City

Final Report

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Abstract

Most of the buildings in New York State (including New York City with the world's largest Con Edison district steam system) currently convert district or boiler generated steam into hot water in tube-and-shell heat exchangers. The hot water is then distributed by electrically driven pumps throughout the building for space heating and domestic hot water service. The steam is also supplied to absorption or steam driven chillers for cooling purposes. The condensate in the Con Edison and many other steam systems is discharged to the sewer system, rather than returning to the steam source. In order to reduce the condensate temperature from 212°F to about 150°F (the sewer system requirement) the condensate is quenched with cold potable water. The described system results in increased costs for building steam, cold water, and sewer.

The purpose of the current project was to manufacture, install, test, and demonstrate the performance and energy efficiency of the Fisonic Device (FD) for the space heating system at the Woolworth Building, a Con Edison steam customer. FDs are supersonic, condensing nozzles with a patented internal geometry that causes steam and water to mix and accelerate. As the mixture continues through the FD, the velocity decreases, allowing its outlet pressure to increase to a level higher than the steam at the inlet of the FD.

The current project resulted in the following conclusions: (1) the test of FDs for space heating 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 and (2) the life-cycle comparison estimates for a new building considering a typical tube-and-shell heat exchanger versus Fisonic system would provide a payback of 1.2 years and for an existing building retrofit with Fisonic devices in 3.3 years.

The utilization of FD results in the following benefits: reduced (1) steam, potable water, and sewer cost to existing and new businesses in New York City and State, (2) pollutant release in New York City, particularly greenhouse gases (GHG), potable water consumption, and sewer discharge rate, and (3) reducing energy costs will make it easier for existing facilities to remain in business and expand. Moreover, the increase in business profitability that results from lower energy costs will stimulate business investment and employment growth, and (3) increased employment for the New York-based manufacturer of Fisonic devices.

Potential benefits for FDs in the State of New York were energy savings: \$12.0 million; Water and Sewer discharge savings: \$0.65 million; Environmental Pollution Reductions: NOx – 3,036 lbs/yr, Particulates – 1,215 lbs/yr, VOC –445 lbs/yr and CO_2 – 16,166 metric ton/yr.

Keywords

Fisonic device; transonic flow; steam; condensate; working stream; injected stream; surface heat exchanger; direct contact heat exchanger; space heating; domestic hot water; water circulating pump; steam saving device; water saving device

Acknowledgements

The project was sponsored by the New York State Energy Research and Development Authority (NYSERDA) and Hudson Fisonic Corporation, Inc. (HFC).The project was performed by Hudson Fisonic Corporation, Inc (HFC) and Joseph Technology Corporation, Inc (JTC) in close cooperation with the Woolworth Building Management (Vice President Mr. Roy Suskin). The Fisonic devices for the project were manufactured by the Division, LLC Company of New York.

The contributions made by above participants and Mr. Dimitri Chernyy from Hudson Fisonic Corporation are very much appreciated.

The extensive contribution, suggestions, and guidance of NYSERDA Project Manager Mr. Robert Carver were particularly helpful.

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S.1 Background

Most of the buildings in New York State (including New York City with the world's largest Con Edison district steam system) currently convert district or boiler generated steam into hot water in tube-and-shell heat exchangers. The hot water is then distributed by electrically driven pumps throughout the building for space heating and domestic hot water service. The steam is also supplied to absorption or steam driven chillers for cooling purposes. The condensate in the Con Edison and many other steam systems is discharged to the sewer system, rather than returning to the steam source. In order to reduce the condensate temperature from 212°F to about 150°F (the sewer system requirement) the condensate is quenched with cold potable water. The described system results in increasing the costs of building steam, cold water, and sewer.

In order to improve the environment and create end-use energy efficiency for steam systems, the Hudson Fisonic Corporation (HFC)—in close cooperation with Con Edison and under the NYSERDA sponsorship—evaluated (NYSERDA project number 10511) the feasibility of an emerging technology, the Fisonic device (FD), in 2008–2009.

FDs are supersonic, condensing nozzles with a patented internal geometry that causes steam and water to mix and accelerate. As the mixture continues through the FD the velocity decreases, allowing its outlet pressure to increase to a level higher than the steam at the inlet of the FD. 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 reduces the terminal temperature difference between steam and water, that is, the required steam consumption and the amount of cold potable water required to quench the condensate. The operation of the Fisonic system results in cost reductions associated with building steam, cold water, and sewer.

During 2012–2013, HFC and JTC in close cooperation with Con Edison and under the NYSERDA sponsorship performed extensive testing of the Fisonic device at a constructed test facility, designed in particular for the FD and located at Con Edison Headquarters (NYSERDA project number 203346.).

The purpose of the current project was to manufacture, install, test, and demonstrate the performance and energy efficiency of the FD for the space heating system at the Woolworth building, Con Edison steam customer. During the demonstration process, HFC also started the commercialization of the FDs by marketing and installing devices at other NYC buildings with Con Ed steam systems. HFC also engaged the manufacturer, Division LLC Corporation, located in Long Island City, in the device fabrication process.

S.2 Test Results and Potential Savings

The current project resulted in the following conclusions:

- The test of FDs for space heating 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.
- The life-cycle comparison estimates for a new building considering a typical tube-and-shell heat exchanger versus Fisonic system would provide a payback of 1.2 years and for an existing building retrofit with Fisonic devices 3.3 years.

The utilization of FD results in the following benefits:

- Reduce steam, potable water, and sewer cost to existing and new businesses in New York City and State.
- Reduce pollutants release in New York City particularly greenhouse gases (GHG), potable water consumption, and sewer discharge rate.
- Reducing energy costs will make it easier for existing facilities to remain in business and expand. Moreover, the increase in business profitability that results from lower energy costs will stimulate business investment and employment growth.
- Increase employment for the New York-based manufacturer of Fisonic devices.

Potential benefits for FDs in the State of New York were estimated as follows:

- The International District Energy Association (IDEA) has recorded the total capacity of district steam systems in NYS as 25,806,551 lb/hr (Ref.1). This amount also included the capacity of Con Edison steam system of 11,676,551 lb/hr (Ref.2, page 19). So, the district steam capacity of NYS systems without Con Edison is: (25,806,551 – 11,676,551) = 14,806,551 lb/hr.
- The annual capacity utilization hours of the Con Edison steam system are 1911 (Ref.2, page 19). Using this number we obtain the annual district steam consumption in NYS as: (14,806,551*1911) = 28.3 billion lb/hr. Assuming that 5% of these buildings can be equipped with Fisonic devices the potential benefits for the NYS are estimated as follows: Energy Savings: $12.0 million; Water and Sewer discharge savings: $0.65 million; Environmental Pollution Reductions: NOx – 3,036 lbs/yr, Particulates – 1,215 lbs/yr, VOC –445 lbs/yr and CO_2 – 16,166 metric ton/yr.

S.3 Commercialization of Fisonic Devices in New York State

The customer value proposition is that the Fisonic devices can provide substantial steam, water, and sewer cost savings ae well as reduce carbon footprints in existing and new space heating and domestic hot water systems. The best application of Fisonic devices involves the use of steam (active fluid) and water (passive fluid).

In addition to the savings associated with steam, water, and sewer costs, benefits of FDs over standard tube-and-shell heat exchangers also include the following:

- Instantaneous startup for water heating, which eliminates water storage tanks.
- Easy to install with much smaller space requirements.
- No moving parts.

Existing heating systems are typically oversized and not easily controlled. The system is equipped with sophisticated controllers and variable frequency drive (VFD) pumps that optimize the heating system control. For a large space heating system, multiple FDs are grouped together in a parallel arrangement on a skid. This approach has several benefits including the following:

- Allows one size device to work over a large range of flow conditions.
- Optimizes the operation of the Fisonic system and increases annual efficiency.
- Permits isolation and replacement of individual devices without a complete shutdown of the skid.

S.4 Potential Sales

In order to estimate order of magnitude potential sales of Fisonic devices, Hudson Fisonic Corporation provided a preliminary cost estimate of $70,000 for major proprietary Fisonic Components (Fisonic nozzle, control system, and profit) of one Fisonic device. The final installation cost of the Fisonic system will depend on the physical characteristics and heat demand of the building dictated by the engineering assessment. Large buildings will require the installation of multiple Fisonic devises for disparate purposes and sections of the building (space heating, domestic hot water, pool, restaurant, etc.) and optimum control. This is reflected in the following estimates.

1. Domestic hot water and space heating use for commercial users:
   - The value proposition to the building owner: replacement of surface type heat exchangers with direct contact FDs results in reduction of energy consumption of about 20% and substantial water and sewer savings. U.S. Energy Information Administration's (EIA) Commercial Buildings Energy Consumption Survey (CBECS) reported that in 2012 (Ref.3) there were approximately 48,000 buildings receiving 253 trillion British thermal

units (TBtu) for their main space heating source from district heating systems (Ref.3, Table C.1 Total Energy Consumption by Major Fuels). Assuming the proportion of buildings receiving district steam heating in the CBECS sample is the same as the proportion of district steam heating systems for the IDEA data base (Ref.4, e.g., 98%), 46,000 commercial buildings were supplied by district steam heating. If 5% of these are suitable for Fisonic devices, the number of buildings would be 2,300. If 1% of these buildings used Fisonic devices, the number of buildings would be 23. The potential revenue from sales of Fisonic devices can be estimated as $280,000 (HFC sale price for four Fisonic device for a single building) * 23 buildings=$6.4 million.

2. Heating of Feed Water in Thermal Power Plants:
    - This major market group includes power plants engaged in the generation of electricity. In the U.S. there are over 2700 operable electric generating plants (50 MW and above). Each plant is a potential site for six Fisonic devices. Assuming 3% of these power plants are equipped with Fisonic devices, the potential revenue can be estimated as $420,000 (HFC sale price of six Fisonic devices for a single plant) * 81 plants=$34 million.

S.5 Market Summary

The above order-of-magnitude estimates demonstrate that the market potential for Fisonic devices in the U.S. is about $40 million with total of 578 Fisonic devices.

S.6 Commercialization Business Models

A number of different business models could be used to implement the Fisonic technology. The three models evaluated for this project were direct equipment sales, performance-based contracts, and licensing agreements.

S.6.1 Manufacturer and Supplier of Fisonic Systems by a Network of Sale Representatives

To set up the manufacturing facilities in New York State, HFC anticipates obtaining financial support from the NYC and NYS economic development agencies, the New York City Energy Efficiency Corporation and the NY Green Bank. This will allow to support initially a crew of six to 10 people. In the second and third manufacturing year the number of employees will be increased to 15. The first year HFC can manufacture and deliver about 20 Fisonic systems. Depending on the size of the NYC and NYS support, the production and sale of Fisonic systems could increase to 40 units in the second year.

S.6.2 Performance-Based Contracting

The ability to offer a performance-based contract depends on having (1) an organization capable of supporting this business strategy and (2) the financial resources to underwrite the capital cost of the equipment and installation during the early (nonrevenue) stages. To properly sustain a business based on performance contracting requires full control of the product (Fisonic components and algorithms), which means the ability to design, fabricate, assemble, install, and maintain the FD at the customer facility.

S.6.3 Licensing

HFC is planning to license Fisonic technology to companies (like GE) currently serving special sectors of potential market (such as power plants). The most valuable asset owned by the HFC will be the agreement for the exclusive use of the Fisonic patents and product for these applications. In this case, the licensee will market, manufacture, and service the Fisonic devices.

S.7 Up-to-Date Activities

S.7.1 Demonstration of FD Performance

During the last four years with the substantial support of NYSERDA, the HFC demonstrated the operational advantages of FDs in commercial installations in the Woolworth building. During the same period HFC at its own expense installed and conducted demonstration testing of FDs in NYC at 455 Broadway, 475 Broadway, and 39 Broadway. The domestic hot water system at the 455 Broadway building was independently tested by City Laboratory and demonstrated savings of 21 % (Ref.5).

HFC also obtained the Global Underwriters Laboratories Certification (Ref.6) and secured a number of U.S. and International Patents for the Fisonic technology (Ref.7-11).

During the development and demonstration of FDs, HFC secured close cooperation of a manufacturer (Division LLC) that has the capability to manufacture the devices. During the development and demonstration activities HFC optimized the design of the FDs and concluded that the devices should be a closed-loop device separated from the customer space heating and domestic hot water systems by a plate and frame heat exchanger. This will avoid the direct introduction of steam into the existing customer piping system and heating elements as well as circumvent potential steam chemistry related liability issues.

HFC also concluded that the FD system offered to potential customers should be a skid mounted installation including the FD, plate, and frame heat exchanger, along with non-condensable gases removing device, control devices, and VFD pumps. The skid mounted system will have only four piping connections (supply and return water, steam supply, and condensate drain) to the existing system which tube-and-shell heat exchanger will be bypassed.

S.7.2 Marketing

During the development and demonstration process HFC conducted an extensive marketing and promotion campaign which included the following activities:

- Numerous presentations of Fisonic technology to various technical conferences and shows.
- Extensive discussions with numerous potential users of FDs (Con Edison, General Services Administration Veteran Administration of NYC, universities, district heating companies).
- Extensive discussions with various manufacturers of heat exchange equipment (Spirax/Sargo, TACO, General Electric, TRANE, Schneider Electric, Johnson Control, Thermolift, Green Technology Accelerator Center, Alstom, Con Edison and ABB).
- Extensive discussions with a number of Investment Companies (Queensland Investment Company of Australia, Gramercy Development, General Electric, Alstom).
- A website of Fisonic technology has been developed (www.fisonicsolutions.com).

HFC proposed exclusive licensing agreements to the above listed companies. HFC also offered the energy saving performance contracting instruments (ESPC) to a number of universities and commercial customers.

S.8 Path to Commercialization

The short-term HFC marketing activities include the following:

- Retrofitting with Fisonic devices in the 51 buildings connected to the City of New York's Con Edison Steam System. After successful demonstration of savings from Fisonic devices in the 455 Broadway building (Ref. 5), NYC has expressed desire to proceed with wide implementation of FDs at other City buildings. HFC is presently involved in discussions with City officials on this topic.
- HFC is close to obtaining permission from NYC Veteran Administration for installation of Fisonic systems in their facilities. After a successful demonstration testing of FDs, the system will be replicated in VA facilities in the State.
- HFC has proposed to the United States Department of Energy (DOE) to evaluate and include the Fisonic technology in the DOE Best Steam Practices Program.

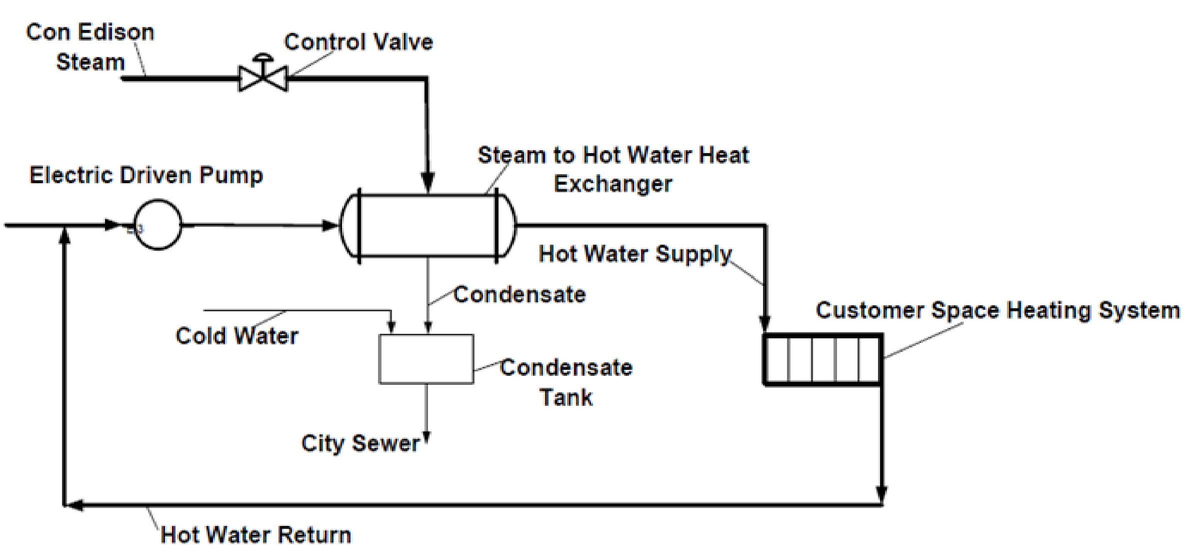
1 Introduction

1.1 Background

Many U.S. cities have extensive underground steam distribution systems. Cities like New York, Philadelphia, Boston, Indianapolis, Detroit and others have major piping networks throughout their downtown areas which deliver steam to commercial and residential customers. Consolidated Edison Company of New York (Con Edison) currently serves with district steam about 1600 large customers in Manhattan and owns three major steam generating plants: 59th station, 74st station, and East River combined cycle plant. The total annual steam sales amount to 22 billion lbs (revenues about $700 million).

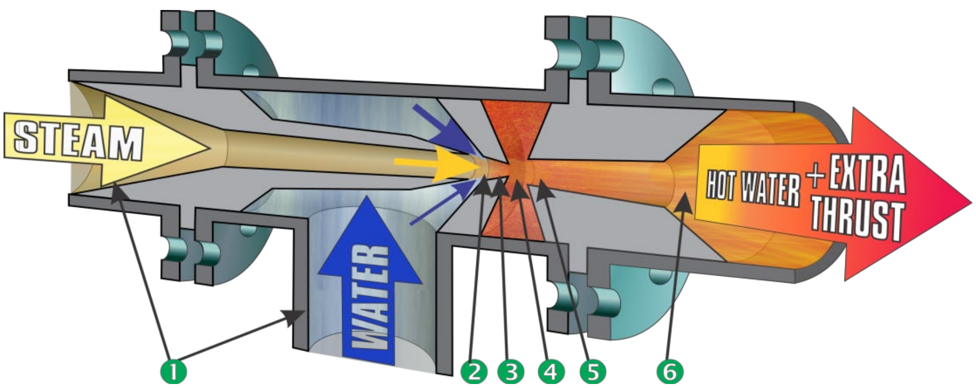
The steam pressure delivered to the customers ranges between 150 and 180 pounds per square inch gauge (psig). The customers use the steam for space heating, domestic hot water, and cooling (through steam driven and absorption chillers). Figure 1 presents the principal diagram of Con Edison steam use for space heating. At the customer facilities the Con Edison steam is condensed in a tube-and-shell heat exchanger and the steam condensate is discharged into the City sewer system. The discharge of the condensate consumes a substantial capacity of the City sewer system and the sewer treatment facilities. In order to reduce the temperature of the discharged stream the condensate is quenched with cold potable water, thus further aggravating the sewer system problems. This situation results in high charges to customers for steam, water, and sewer and high make-up water cost for Con Edison steam generating plants.

Figure 1. Existing Space Heating System



The purpose of the current project was to demonstrate the performance of the FDs for the space heating system of a major Con Edison steam customer, the Woolworth building. The Fisonic device (Figure 2) is a supersonic, condensing nozzle with a patented internal geometry that causes steam and water to mix and accelerate, converting a minute fraction of the fluid's thermal energy to physical kinetic thrust with the outlet pressure higher than the pressure of the working medium at the inlets of the FD. 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 reduces the terminal temperature difference between steam and water, the required steam consumption, and the amount of cold potable water and sewer discharge.

Figure 2. Diagram of Fisonic Device



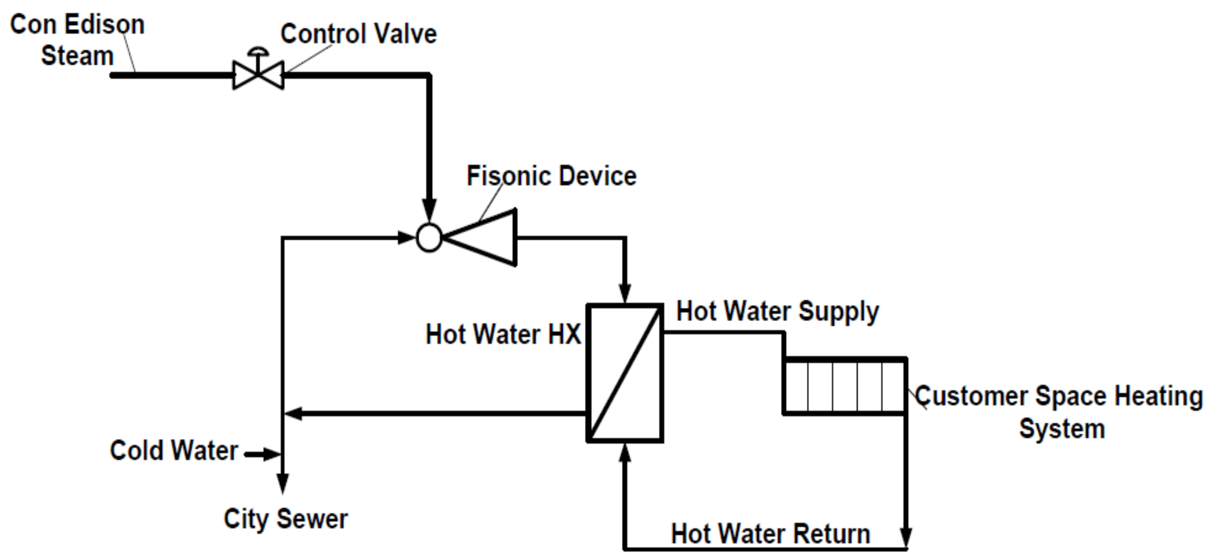
1. Water and steam enter the Fisonic device separately.
2. The streams merge into a highly compressible two-phase mixture.
3. A narrowing inlet compresses and accelerates two-phase mixture to Mach 1 condition.
4. At Mach 1, steam condenses in the two-phase mixture, yielding hot water and nano bubbles.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

The diagram of the Fisonic system installed at the steam customer is presented in Figure 3.

In 2008–2009 Hudson Fisonic Corporation (HFC) and Joseph Technology Corporation (JTC) in close cooperation with Con Edison and under the NYSERDA sponsorship evaluated the feasibility of the emerging Fisonic device technology (NYSERDA project number 10511). During 2012–2013 HFC and JTC in close cooperation with Con Edison and under the NYSERDA sponsorship performed extensive testing of the Fisonic device at a test facility constructed specifically for the device and located at Con Edison Headquarters (NYSERDA project number 203346).

In order to start wide implementation of Fisonic devices in the industry a commercial demonstration of the features and potential energy savings was required. The purpose of the current project was to develop, design, manufacture, install, and monitor the operation of Fisonic devices for space heating at commercial conditions in the Woolworth building. The project had to determine the steam and potable water savings from the technology in real operating conditions as well as start the commercialization process.

Figure 3. Diagram of Fisonic System Installation for Space Heating



2 Description of Woolworth Building Space Heating System

2.1 Brief History of the Woolworth Office Building

The Woolworth Building, designed by architect Cass Gilbert and completed in 1913, is an early U.S. skyscraper. More than a century after the start of its construction, it remains, at 792 ft, one of the one-hundred tallest buildings in the U.S., as well as one of the twenty tallest buildings in New York City. The building opened on April 24, 1913. President Woodrow Wilson turned the lights on by way of a button in Washington, D.C. that evening.

The Woolworth Building is covered in Skyros veined marble, has a vaulted ceiling, mosaics, a stained-glass ceiling light and bronze fittings. Over the balconies of the mezzanine are the murals *Labor* and *Commerce.* Corbel sculptures include Gilbert with a model of the building. The building's facade was restored between 1977 and 1981, during which much of the terra-cotta was replaced with concrete and Gothic ornament was removed. The building has 56 floors, now operational are 27 floors; from 28th to 56th floor there is currently a remodeling project. Under the direction of renowned architect Thierry W. Despont, the top building floors are being converted into condominium residences. Today, the building houses, among other tenants, TTA Inc., Control Group Inc., and the New York University School of Continuing and Professional Studies' Center for Global Affairs.

2.2 Space Heating System

The building is supplied with Con Edison district steam. The 10-inch steam line enters the building basement at 170 to 180 psig. The Con Edison building steam meter is installed in the basement. Pressure reducing valves reduce the entrance pressure to 60 psig, and then later from 60 to 3–10 psig, typically the pressure is 3 psig.

The building has a closed-loop hot water system for space heating. Space heating of the building is provided by four steam to water heat exchangers installed in the basement. The condensate is collected in three high-, medium-, and low-pressure tanks and after quenching with cold potable water, it is released to the sewer system. There is one heat exchanger installed on the 10th floor. The heat exchanger supplies water/glycol mixture to the outdoor air fan coils in order to prevent freezing.

The 12-inch hot-water supply manifold is connected to three 10-inch vertical risers which reach the 27th floor. From the risers, the hot water is distributed to two wings of the building. The three 10-inch return lines are connected to the 12-inch return manifold. The water is pumped by three 75 HP (850 gpm) and two 60 HP (600gpm) pumps. Building perimeter has hot-water radiation heat.

The heating system includes 10 floors of baseboard hot-water radiation from two heat exchangers supplied with 3 psig steam, 11 floors are equipped with forced air from electric window units (each 1 ton, 400 cfm). Temperature ranges from 90–135°F. Space heating water circulating pumps include 3 x 75 HP (850 gpm, 355 ft head), 2 x 60 HP pumps (600 gpm and 280 feet). Typically, in operation are two pumps (1 x 75 HP + 1 x 60 HP) pumping hot water through four heat exchangers.

A 3-inch steam line supplies steam to one tube-and-shell steam to hot water heat exchanger from which hot water is supplied to a separate five-story office section of the building. Two pumps circulate the water throughout this section.

Two Lesley indirect domestic hot water heaters are installed for the pool. However, the pool is not currently in operation. Two expansion tanks have been installed on the 27th floor.

The building is also equipped with three EVO 2000 gas fired boilers installed in the basement. Each boiler capacity is 2 million British thermal units.

2.3 Domestic Hot Water System

The building is equipped with three Lesley domestic hot-water steam to hot-water heaters and pumps installed in the basement. The total capacity of the domestic hot water (DHW) is 100 gpm. Three additional Lesley domestic hot-water steam to hot-water heaters and pumps are installed at the 9th floor.

2.4 Air Conditioning System

The building is equipped with a central air system; each floor on 10 floors have an 80-ton cooling unit with electric and cooling coils and each floor on 11 floors have an 80-ton unit with switchover hot water/cooling coils. The capacity of the existing chillers are 2 x 400 ton and 2 x 300 ton with vane control.

Chilled water supply temperature is typically 43°F with a supply and return temperature differences of 3°F to 4°F. The terminal units have 2- and 3-way control systems.

For emergency situations the building has a steam driven pump for fire protection. However, the pump does not run often.

2.5 Energy Consumption

The building monthly steam consumption and cost for 12 months is presented in Tables 1 and 2 and Figure 2. Water and sewer consumption and cost are provided in Table 3.

Table 1. Building Monthly Steam Consumption

Month	1,000 lbs	Cost, $	HDD
Jan	1,824	74,201	977
Feb	1,147	51,655	514
Mar	1,153	51,888	514
Apr	681	18,558	256
May	370	13,527	34
Jun	379	14,085	-
Jul	353	12,724	-
Aug	294	11,886	-
Sep	337	13,426	85
Oct	464	19,156	259
Nov	1,763	78,600	961
Dec	1,988	95,615	1,110
Total	10,753	455,322	4,710

Figure 4. Building Monthly Steam Consumption

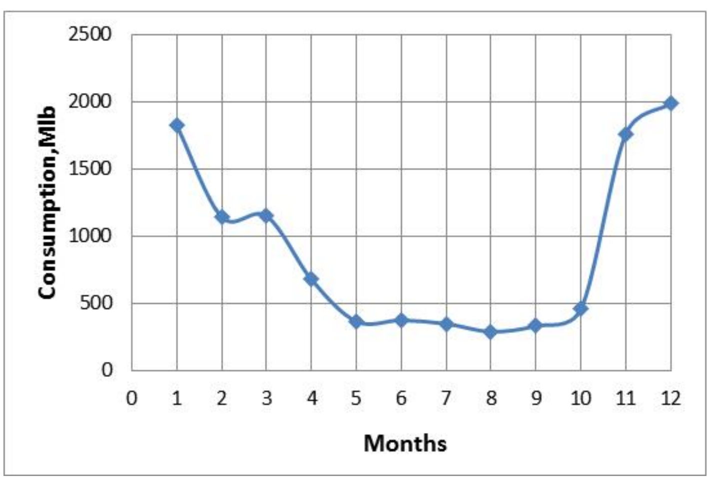


Table 2. Space Heating and Domestic Hot Water Steam Consumption

Month	Total Steam, 1,000 lbs	DHW Load, 1,000 lbs	Space Heating, 1,000 lbs
Jan	1,824	366	1,458
Feb	1,147	366	781
Mar	1,153	366	787
Apr	681	366	315
May	370	370	-
Jun	379	379	-
Jul	353	353	-
Aug	294	294	-
Sep	337	337	-
Oct	464	366	98
Nov	1,763	366	1,397
Dec	1,988	366	1,622
Total	10,753	4,295	6,458

Table 3. Water and Sewer Consumption and Cost

Meter #	Period	Number of Days	Usage, cu.ft	Water Cost, $	Sewer Cost, $	Total Cost, $
1	2/1/2018 to 5/2/2018	90	73,200	2,855	4,539	7,394
2	2/2/2018 to 5/2/2018	90	13,900	1,332	2,117	3,449
1	5/2/2018 to 8/1/2018	91	71,500	6,850	10,891	17,741
2	5/2/2018 to 8/1/2018	91	7,800	747	1,188	1,935
1	8/1/2018 to 11/2/2018	91	8,200	786	1,249	2,035
2	8/1/2018 to 11/2/2018	91	9,400	901	1,432	2,223
1	11/2/2018 to 2/1/2019	91	132,100	12,655	20,122	32,777
2	11/2/2018 to 2/1/2019	91	16,500	1,581	2,513	4,094
	Total		332,600	17,705	44,051	71,757

3 Development of Fisonic Systems and Instrumentation for Testing

The analysis of the space heating system at the Woolworth building and discussions with the building management indicated that the testing of the Fisonic devices can be performed in two separate space heating branches: the five-story building section and unit heater section. Each loop requires individual metering and monitoring of existing system and system with installed Fisonic system.

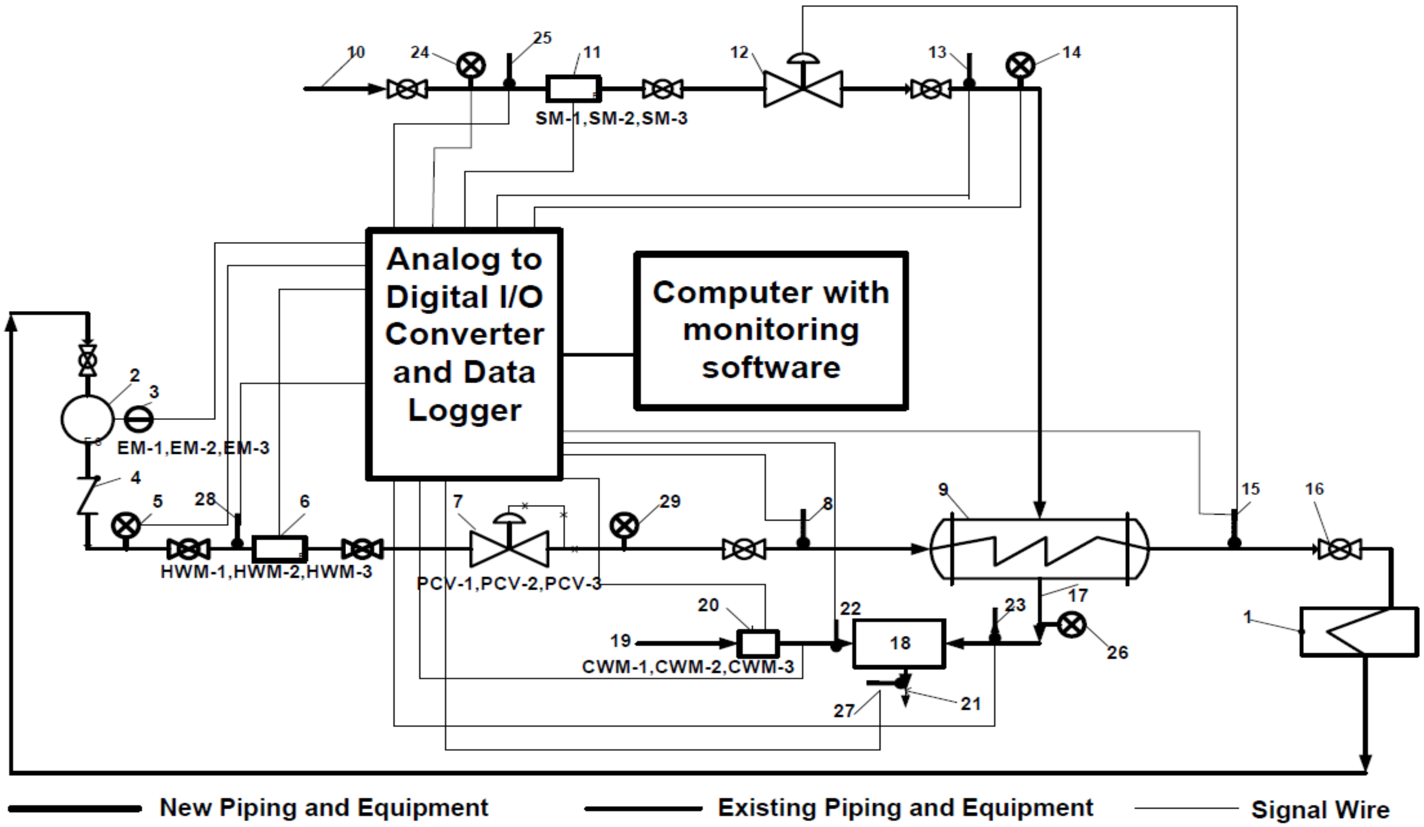
The main objective of the project was to evaluate energy and water savings for space heating at the Woolworth building as a result of replacing the existing tube-and-shell heat exchangers with the Fisonic devices. This objective was achieved by comparing the monitored energy and water use during the heating period with the energy and water use with the FDs consumed during a similar period.

The Con Edison district steam enters the Woolworth building and branches off to each selected section, heating the hot water in existing heat exchangers. The heated water is circulated throughout the selected loops by existing electric pumps. After passing through the heat exchangers the steam condensate is directed to a condensate tank, from which the mixture is diluting with cold potable water and discharged into the city sewer. For testing, each loop had to be equipped with detailed metering, instrumentation, and monitoring equipment. In order to determine the consumption of steam and water (hot and cold) for the existing systems, the testing equipment must have appropriate metering and instrumentation.

Figure 5 presents the installed metering equipment for obtaining the steam and water consumption information for the existing system. The major equipment includes steam and water consumption meters and sensors for water temperatures and pressures.

Figure 6 presents 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 1–2°F provides the opportunity to prefabricate the total module with the Fisonic device and simply connect the package to the existing system.

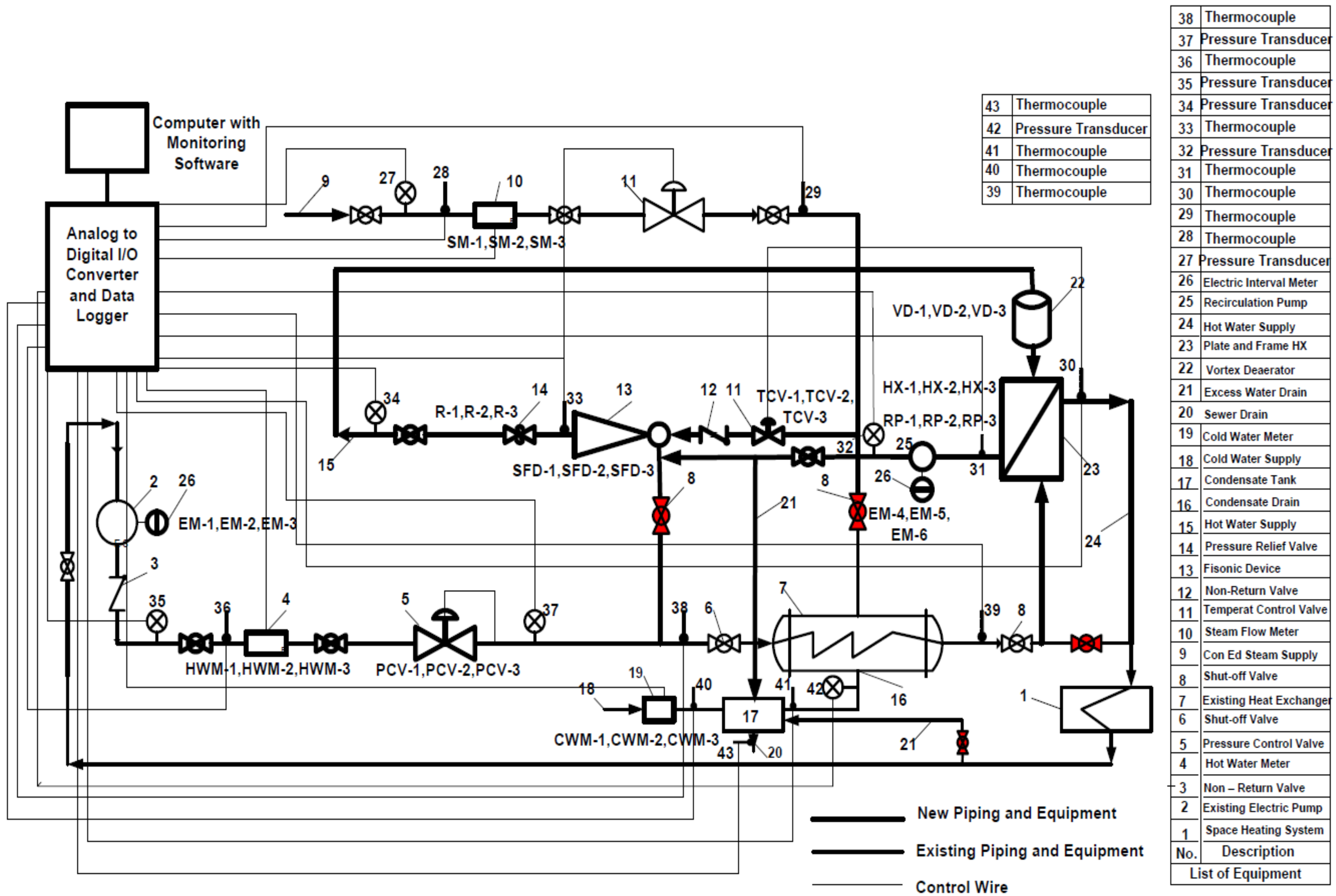
Figure 5. Monitoring Diagram for Current Energy Use of the Existing System



No.	Description
29	Pressure Transducer
28	Thermocouple
27	Thermocouple
26	Pressure Transducer
25	Thermocouple
24	Pressure Transducer
23	Thermocouple
22	Thermocouple
21	Sewer Drain
20	Cold Water Meter
19	Cold Water Supply
18	Condensate Tank
17	Condensate Drain
16	Shut-off Valve
15	Thermocouple
14	Pressure Transducer
13	Termocouple
12	Temperat Control Valve
11	Steam Flow Meter
10	Steam Supply
9	Heat Exchanger
8	Thermocouple
7	Pressure Control Valve
6	Hot Water Meter
5	Pressure Transducer
4	Non – Return Valve
3	Electric Interval Meter
2	Existing Electric Pump
1	Space Heating System

List of Equipment

Figure 6. Monitoring Diagram of the Space Heating System Separated from the Fisonic Device by a Heat Exchanger



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

- 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 device data.
- Install instrumentation and additional monitoring equipment, collect, and analyze the baseline data.
- Install the Fisonic devices at selected space heating systems.
- Install instrumentation and additional monitoring equipment, collect, and analyze the system with Fisonic devices data.
- Compare the baseline and Fisonic devices operational data normalized to the same 30-year outdoor temperatures.

3.1 Data Acquisition Equipment

Data acquisition equipment consisted of the following:

- Flow of steam and hot- and cold-water consumption meters.
- Pressure and temperature transducers
- Data Logger system
- Scanning and data recording
- Data collection methods

3.2 Flow Consumption Meters

3.2.1 Temperature Measurements

Temperature data was taken using type J thermocouples. The thermocouples were calibrated by the equipment supplier before delivery to site. The Allen Bradley Data Logger incorporated a built-in reference junction thermistor with an accuracy of +/- 0.3°F which is used to compensate for the cold junction offset associated with thermocouple temperature measurement.

3.2.2 Pressure Measurements

Pressure data was taken using Hall Effect Pressure Transducers. The transducers were calibrated by the equipment supplier before delivery to site. The Allen Bradley Data Logger incorporated a built-in reference junction thermistor allowing self-calibration of the transducers.

3.3 Data Logger System

The heart of the data acquisition systems were the loggers that provided signal conditioning and digitizing of analog inputs. All the sites involved with this project were using the Allen Bradley Logger system. This device provides eight differential inputs (16 single-ended), two pulse counters, three switched excitation voltage outputs, and eight digital input/output channels for frequency measurement, digital control, and triggering.

3.3.1 Scan Rate and Data Recording

The data logger's scan rate is a result of how many individual measurements and analog-to-digital conversions are made during each scan. The logger integrates each voltage signal for a full 25 milliseconds, and, since there are 10 channels (the tenth is the logger battery voltage), the fastest expected scan rate is one scan every 250 milliseconds (4 Hertz) per second. The actual scan rate is somewhat slower than this, but the system should easily complete a scan of the inputs once every second. For memory conservation purposes, the system was set up to continually average the data over time and then to write a record to the system memory every five minutes.

3.3.2 Data Collection Methods

The data was collected from the test sites by directly downloading to the loggers. The data was accessible by modem. All monitoring equipment was calibrated on-site prior to project initiation and was also verified for accuracy whenever data was retrieved from the test sites. The major parameter—steam consumption—was measured directly and verified by measurement of the British thermal unit (Btu) supplied to the space heating water.

Table 4 summarizes all instrumentation used to perform the tests in two selected heating loops. Detail information is presented in appendices 1 and 2 at the end of this report.

Table 4. List of Instrumentation and Equipment for Woolworth Fisonic Device Testing

#	Designation	Quantity	MFG	Type	Model #	Expected Value	Range/ Rating	Accuracy	Function
	Steam and Condensate								
24	PG	3	Honeywell	Absolute Pressure Trand	PX2AS2XX100PA CHX	50 psig	0-100 psi	1%	Steam Supply Pressure for 5 story, air handler and 27 story
25	TG	3	Omega	Type J Thermocouple Probe	tc-j-npt-g-72	300F	32-1200 deg F	0.75%	Steam Supply Temperature for 5 story, air handler and 27 story
11	SM-1	1	Sierra	Vortex Steam Meter	240i-VTP-1-F4-F2-DD	15-250 lb/hr	60-250F and 150 psig	<1%	Steam Flow Meter for 5 story and air handler
11	SM-2	1	Sierra	Vortex Steam Meter	240i-VTP-1-F4-F2-DD	15-250 lb/hr	60-250F and 150 psig	<1%	Steam Flow Meter for 27 story section
13	TG	3	Omega	Type J Thermocouple Probe	tc-j-npt-g-72	300F	32-1200 deg F	0.75%	Steam Supply Temperature for 5 story, air handler and 27 story
14	PG	3	Honeywell	Absolute Pressure Trand	PX2AS2XX100PA CHX	50 psig	0-100 psi	1%	Steam Supply Pressure for 5 story, air handler and 27 story
26	PG	3	Honeywell	Absolute Pressure Trand	PX2AS2XX100PA CHX	50 psig	0-100 psi	1%	Steam Supply Pressure for 5 story, air handler and 27 story
23	TG	3	Omega	Type J Thermocouple Probe	tc-j-npt-g-72	300F	32-1200 deg F	0.75%	Condensate Temperature for 5 story, air handler and 27 story
18	Condensate Tank	2	B&G	Cylinder		250F	50 psig		Condensate Tank for 5 story and air handler
18	Condensate Tank	1	B&G	Cylinder		250F	50 psig		Condensate Tank for 27 story section
20	CWM-1, CWM-2	2	Omega	Turbine with Pulse Output	FBT-4607 3/4"	50-700 lb/hr	30-120F	<1%	Cold Water Flow Meter for 5 story and air handler
20	CWM-3	1	Omega	Turbine with Pulse Output	FBT-4607 3/4"	500-2.500 lb/hr	30-120F	<1%	Cold Water Flow Meter for 27 story
20	FM Processor	2	AMCO		T210 Electronic				Converts FM20 to 4-20 mA signal
20	FM Processor	1	AMCO		T210 Electronic				Converts FM20 to 4-20 mA signal
22	TG	3	Omega	Type J Thermocouple Probe	tc-j-npt-g-72	300F	32-1200 deg F	0.75%	Cold Water Temperature for 5 story, air handler and 27 story

Table 4 continued

#	Designation	Quantity	MFG	Type	Model #	Expected Value	Range/ Rating	Accuracy	Function
27	TG	3	Omega	Type J Thermocouple Probe	tc-j-npt-g-72	300F	32-1200 deg F	0.75%	Condensate Dtain Temperature for 5 story, air handler and 27 story
30	PG	3	Honeywell	Absolute Pressure Trand		50 psig	0-100 psi	1%	Steam Supply Pressure for 5 story, air handler and 27 story
11	Check Valve	2	RWV	Swing Check	236	3"	50-125 psig		Check Valve for 5 story and air handler
11	Check Valve	1	RWV	Swing Check	435	5"	50-125 psig		Check Valve for 27 story
26	SV-1, SV-2	2	Sharpe	Gate Flanged	35116 Series 1PRG4	3"	200 psig 450F		Steam Supply Shutoff Valve for 5 story and air handler
26	SV-3	1	Milwaukee	Globe	2981-M	5"	200 psig 450F		Steam Supply Shutoff Valve for 27 story
11	TCV-1,TCV-2	2	Johnson Cont	Steam Control	WG2000 Series 3"	50-700 lb/hr	100-250F		Temperature Control Valve for 5 story and air handler
11	TCV-3	1	Johnson Cont	Steam Control	WG2000 Series 5"	500-2000 lb/hr	100-250F		Temperature Control Valve for 27 story section
5	PG	3	Honeywell	Absolute Pressure Trand	PX2AS2XX100PA CHX	50 psig	0-100 psi	1%	Hot Water Pressure for 5 story, air handler and 27 story
28	TG	3	Omega	Type J Thermocouple Probe	tc-j-npt-g-72	300F	32-1200 deg F	1%	Hot Water Temperature for 5 story,air handler and 27 story
6	HWM-1, HWM-2	2	Khrone	Electromagnetic Flow Meter	Waterflux 3000	50,000 to 500,000 Btu/h	60 to 300F at 150 psig	<1%	Hot Water BTU meter for 5 story and air handler
6	HWM-3	1	Khrone	Electromagnetic Flow Meter	Waterflux 3000	200,000 to 2,000,000 Btu/h	60 to 300F at 150 psig	<1%	Hot Water BTU meter for 27 story
6	FM Processor	3	Khrone		IFC100				Converts FM6 to 4-20 mA signal
29	PG	3	Honeywell	Absolute Pressure Trand	PX2AS2XX100PA CHX	50 psig	0-100 psi	1%	Hot Water Pressure for 5 story, air handler and 27 story
8	TG	3	Omega	Type J Thermocouple Probe	tc-j-npt-g-72	300F	32-1200 deg F	0.75%	Hot Water Temperature for 5 story,air handler and 27 story
15	TG	3	Omega	Type J Thermocouple Probe	tc-j-npt-g-72	300F	32-1200 deg F	0.75%	Hot Water Temperature for 5 story,air handler and 27 story
30	TG	3	Omega	Type J Thermocouple Probe	tc-j-npt-g-72	300F	32-1200 deg F	0.75%	Hot Water Temperature for 5 story,air handler and 27 story

Table 4 continued

#	Designation	Quantity	MFG	Type	Model #	Expected Value	Range/ Rating	Accuracy	Function
	Hot Water FD Loop								
12	DFD-1,DFD-2	2	Division LLC	Hudson Fisonic Corporation	UL Approved	Steam 700 lb/hr	Water 50 gpm		Direct Fisonic Device for 5 story and air handler unit
12	DFD-3	1	Division LLC	Hudson Fisonic Corporation	UL Approved	Steam 2,500 lb/hr	Water 50 gpm		Direct Fisonic Device for 27 story section
31	TG	3	Omega	Type J Thermocouple Probe	tc-j-npt-g-72	300F	32-1200 deg F	0.75%	Hot Water Temperature for 5 story,air handler and 27 story
13	R-1,R-2-Pressure Relief Valve	2	Leser	ANCI Class 300	447 - DN 25	150 psig	100-300 psig		Safety relief valve for 5 story and air handler
13	R-3-Pressure Relief Valve	1	Leser	ANCI Class 300	447 - DN 25	150 psig	100-300 psig		Safety relief valve for 27 story section
32	PG	3	Omega	Type J Thermocouple Probe	tc-j-npt-g-72	300F	32-1200 deg F	0.75%	Hot Water Discharge Temperature
16	E-1, E-2	2	B&G	PT Diaphragm	ASME	Volume 100 gal	125 psig		Expansion Tank for 5 story and air handler
16	E-3	1	B&G	PT Diaphragm	ASME	Volume 300 gal	125 psig		Expansion Tank for 27 story
15	AS-1, AS-2	2	B&G	Vertical Tank	EASB	250F/150 psig	Water 50 gpm		Air Eliminator for 5 story and air handler
15	AS-3	1	B&G	Vertical Tank	EASB	250F/150 psig	Water 200gpm		Air Eliminator for 27 story
17	RP-1, RP-2	2	B&G	Series 80	Capacity 50 gpm/110 ft	1750 rpm	2 HP		Recirculation Pump for 5 story and air handler
17	RP-3	1	B&G	Series 80	Capacity 200 gpm/130 ft	1750 rpm	10 HP		Recirculation Pump for 27 story
18	EM-4. EM-5	2	Electro Ind.	Commercial Power Meter	Shark 200s	3,000 to 15,000 kWhr	400mA signal	0.20%	Electric Consumption and Load Meter for 5 story and air handler
18	EM-6	1	Electro Ind.	Commercial Power Meter	Shark 200s	10,000 to 50,000 kWhr	400mA signal	0.20%	Electric Consumption and Load Meter for 27 story
22	VD-1, VD-2	2	Division LLC	Hudson Fisonic Corporation	Air Removal	300F	50 gpm		Vortex Deaerator for 5 story and air handler

Table 4 continued

#	Designation	Quantity	MFG	Type	Model #	Expected Value	Range/ Rating	Accuracy	Function
22	VD-3	1	Division LLC	Hudson Fisonic Corporation	Air Removal	300F	200 gpm		Vortex Deaerator for 27 story
23	HX-1, HX-2	2	Taco	Plate and Frame	Brazed TB80x70	1575 MBH	ASME approved		Fisonic Device for 5 story and air handler unit
23	HX-3	1	Taco	Plate and Frame	Brazed B65 Mx100	6,000 MBH	ASME approved		Fisonic Device for 5 story and air handler unit
31	TG	3	Omega	Type J Thermocouple Probe	tc-j-npt-g-72	300F	32-1200 deg F	0.75%	
25	RP-1, RP-2	2	B&G	Series 80	Capacity 50 gpm/110 ft	1750 rpm	2 HP		Recirculation Pump for 5 story and air handler
25	RP-3	1	B&G	Series 80	Capacity 200 gpm/130 ft	1750 rpm	10 HP		Recirculation Pump for 27 story
26	EM-4, EM-5	2	Electro Ind.	Commercial Power Meter	Shark 200s	3,000 to 15,000 kWhr	400mA signal	0.20%	Electric Interval Meter
26	EM-6	1	Electro Ind.	Commercial Power Meter	Shark 200s	10,000 to 50,000 kWhr	400mA signal	0.20%	Electric Interval Meter
32	PG	3	Honeywell	Absolute Pressure Trand	PX2AS2XX100PA CHX	50 psig	0-100 psi	1%	Hot Water Discharge Pressure
13	SFD-1, SFD-2	2	Division LLC	Hudson Fisonic Corporation	UL Approved	Steam 750 lb/hr	Water 50 gpm		Separated Fisonic Device for 5 story and air handler unit
13	SFD-3	1	Division LLC	Hudson Fisonic Corporation	UL Approved	Steam 2,650 lb/hr	Water 50 gpm		Separated Fisonic Device for 27 story
8	SV-4, SV-5	2	Sharpe	Gate Flanged	35116 Series 1PRG4	3"	50-125 psig		Shuoff Valve for 5 story and air handler
8	SV-5	2	Milwaukee	Globe	2981-M	5"	50-125 psig		Shutoff Valve for 27 story

Table 4 continued

#	Designation	Quantity	MFG	Type	Model #	Expected Value	Range/ Rating	Accuracy	Function
	Monitoring Equipment								
	MC	1	Apple	MacBook	Pro				Computer to collect and process data
	Control Panel (PLC, TCC, etc.)	2	Advanced Control	HoneyWell Components					Logging and Control Panel
	Analisys Software	1	GE	Rockwell RX Logic 5000	Cimplicity				Software analytical
	Winterm Thermal Heat Transfer	1							
	Mathcad	1							Analytic software

4 Equipment Specifications and Bids for Purchasing and Installation of Equipment and Instrumentation

All the necessary equipment and instrumentation was sized and the specifications for purchasing and installing equipment and metering devices developed. The construction specification, including the detailed equipment and instrumentation parameters, is presented in appendix 1 and 2.

The specification was issued for bids to qualified HVAC contractors. The obtained bids were offered by three well-qualified companies with extensive HVAC experience in commercial buildings in New York City (appendix 3). The cost offered by the bidders was relatively close and the average cost was $526,902. Taking into account the familiarity with Fisonic devices, it was recommended to proceed with D.P. Facilities Company with a bid proposal of $516,490. Selection of this bid did not increase the NYSERDA budget cost share in the HFC contract with NYSERDA.

The summary project cost breakdown of the bid is presented in Table 5.

Table 5. Project Construction Cost Breakdown

Cost Component	Cost, $
Total Equipment and Instrumentation Purchase Cost	181,184
Monitoring Equipment Purchase Cost	38,340
Subtotal Purchase Cost	219,524
Total Equipment and Instrumentation Installation	164,085
Monitoring Equipment Installation	7,715
Piping and Supports Installation	125,166
Subtotal Installation Cost	296,966
Total Project Cost	**516,490**

On February 9, 2016, NYSERDA granted HFC permission to proceed with the construction phase of the project.

5 Description and Testing of the Fisonic Device at the Five-Story Building Section

5.1 System Description

Figure 7 presents a diagram of the five-story building, space heating system with installed instrumentation. The installation includes the existing closed tube-and-shell water heat exchanger HX2 that currently provides heating to the five-story building, in which the existing pumps, P3 and P4 on the right, function to circulate hot water. The diagram also shows the Fisonic device along with a plate and frame heat exchanger.

Figure 7. Diagram of the Existing Five-Story Building Equipment and Instrumentation

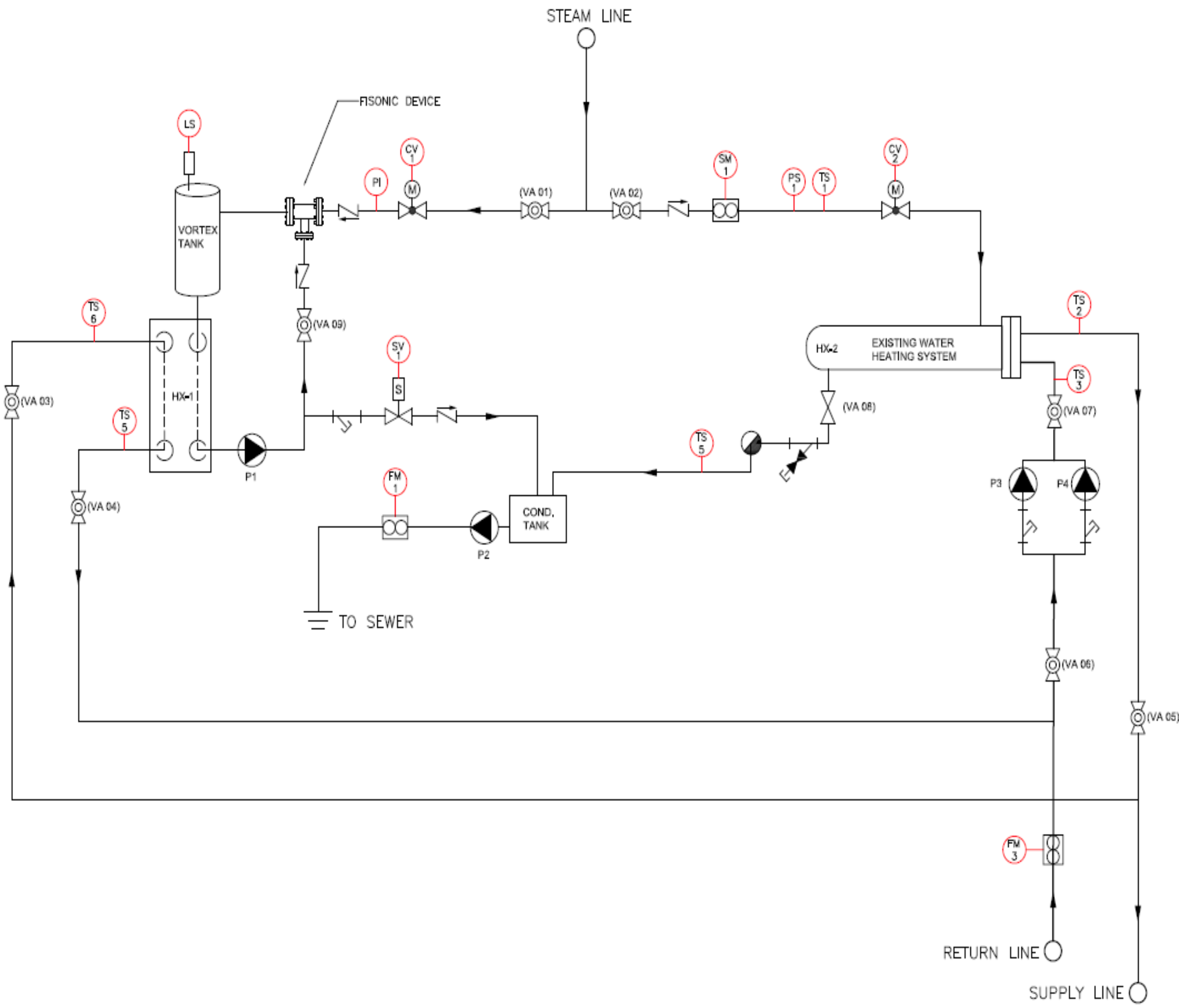


Figure 8 displays the overall view of the installation with detail labels of all equipment.

Figure 8. Overall Picture of Five-Story Installation

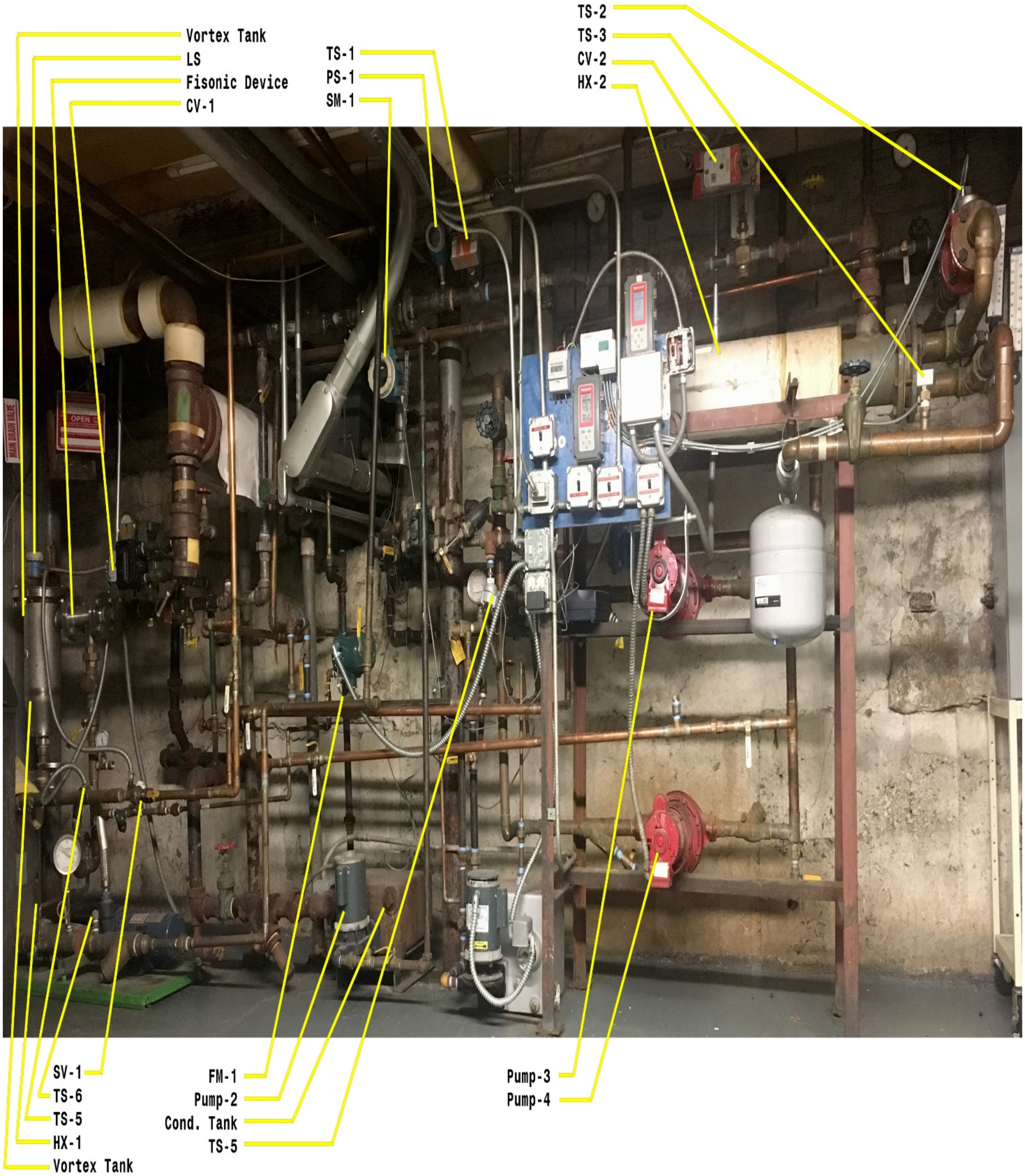


Figure 9 displays the tube-and-shell heat exchanger, control panel, and expansion tank.

Figure 9. Tube-and-Shell Heat Exchanger, Control Panel, and the Expansion Tank

Figure 10 displays the existing space heating heat exchanger, hot water flow meter, and supply/return water temperature sensors.

Figure 10. Hot Water Flow Meter and Temperature Sensors

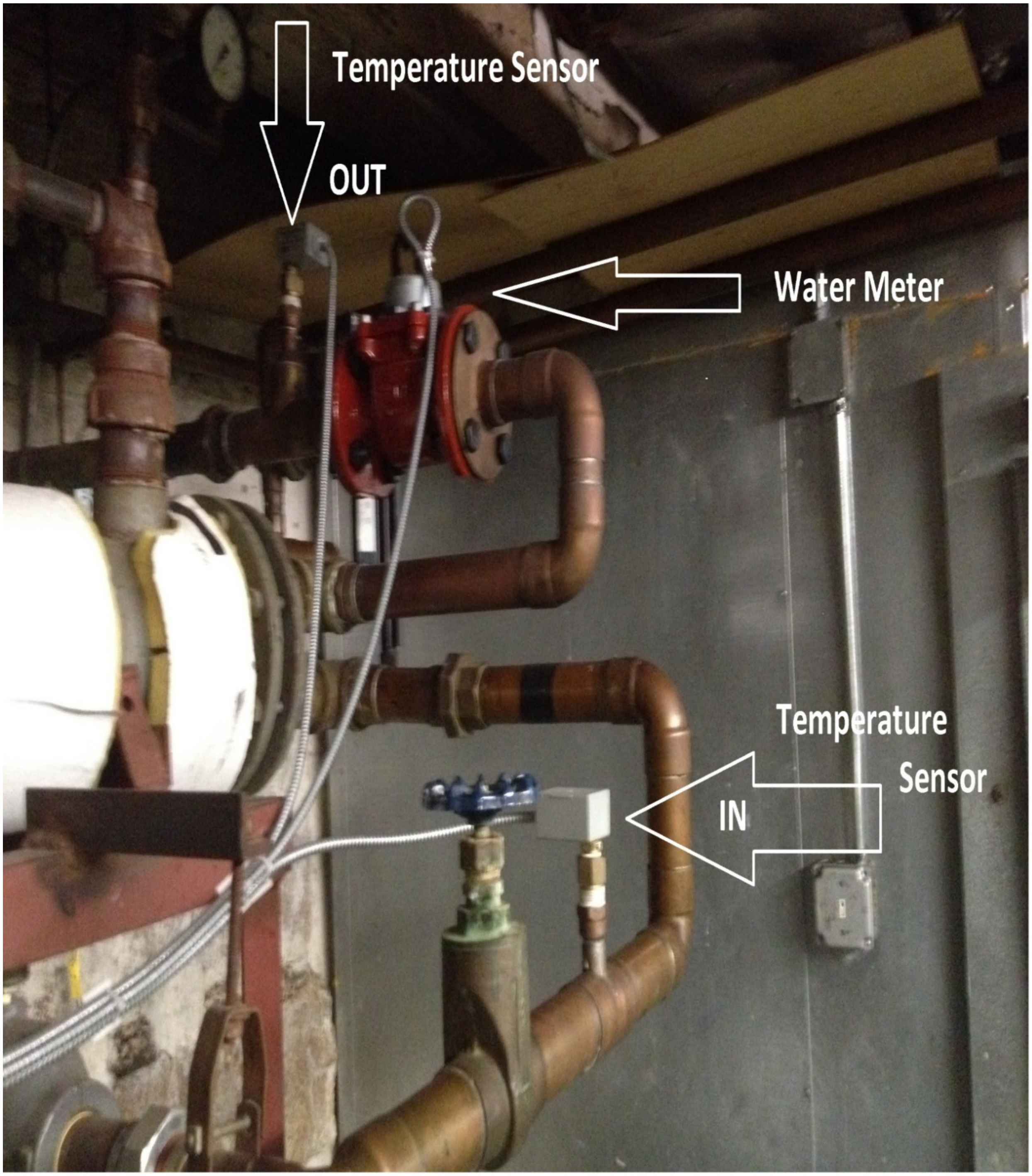


Figure 11 displays head of tube-and-shell space heat exchanger, hot water flow meter, expansion tank, and thermometer and pressure gages.

Figure 11. Head of Tube-and-Shell Space Heat Exchanger, Hot Water Flow Meter, Expansion Tank, and Thermometer and Pressure Gages

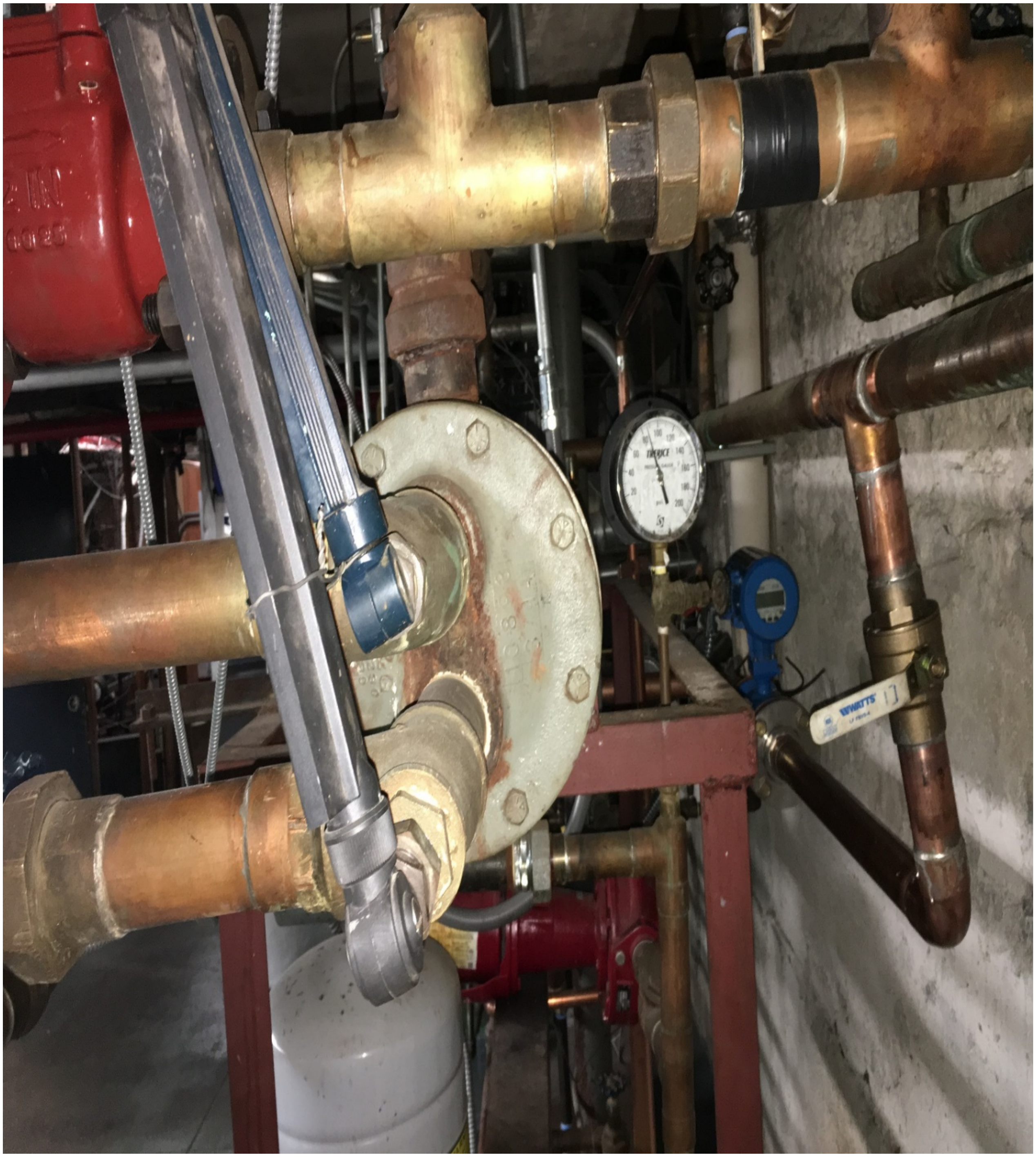


Figure 12 displays the components of the Fisonic system: Fisonic device, vortex tank, plate and frame heat exchanger, and water circulating pump.

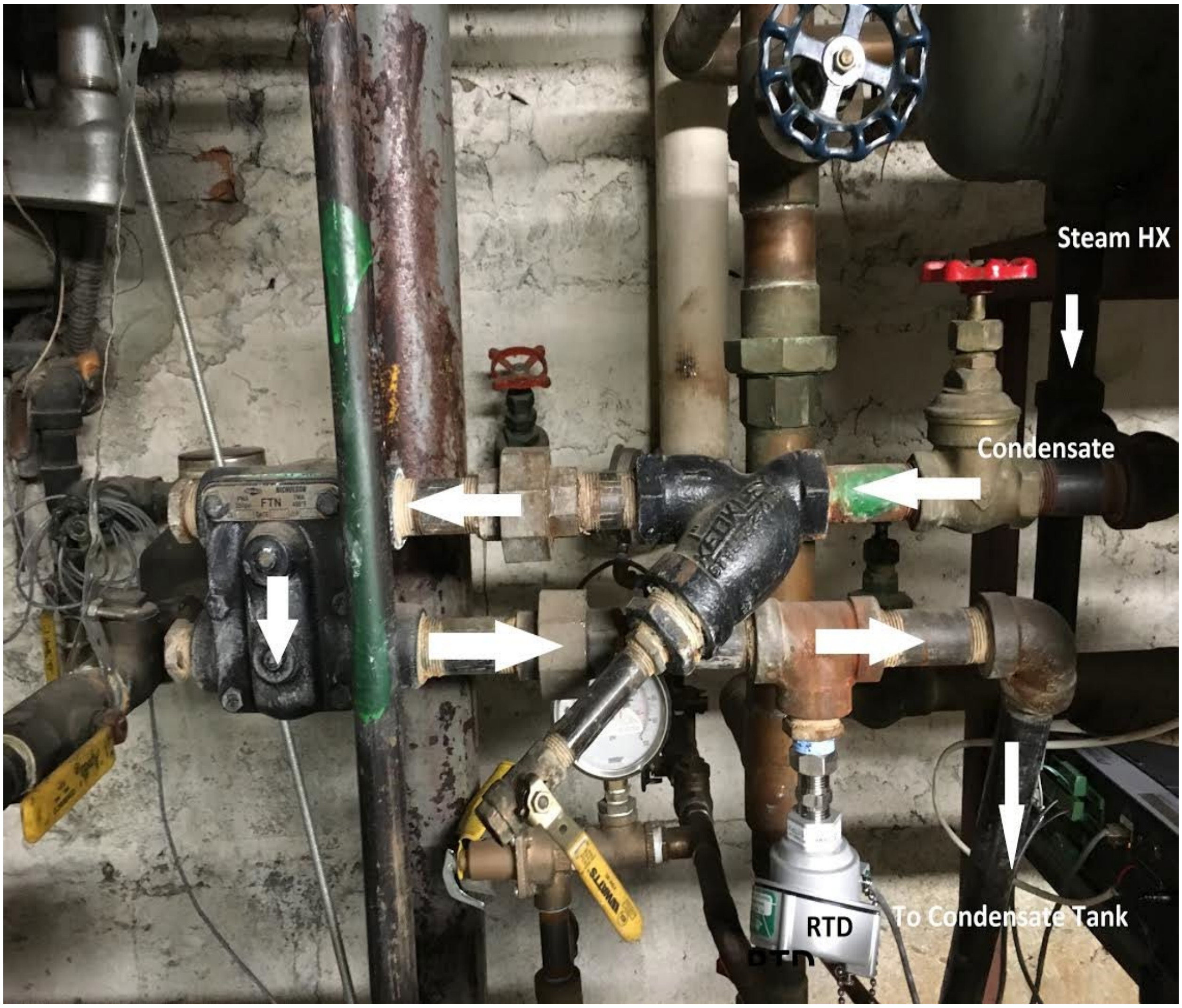
Figure 12. Fisonic Device, Vortex Tank, Plate and Frame Heat Exchanger, and Water Circulating Pump

Figure 13 displays the condensate tank, condensate pump, and the condensate flow meter.

Figure 13. Condensate Tank, Condensate Pump, and the Condensate Flow Meter

Figure 14 shows the condensate drain from the tube-and-shell heat exchanger into the condensate tank.

Figure 14. Condensate Drain from the Tube-and-Shell Heat Exchanger into the Condensate Tank



Condensate flow meter is shown in Figure 15.

Figure 15. Condensate Flow Meter

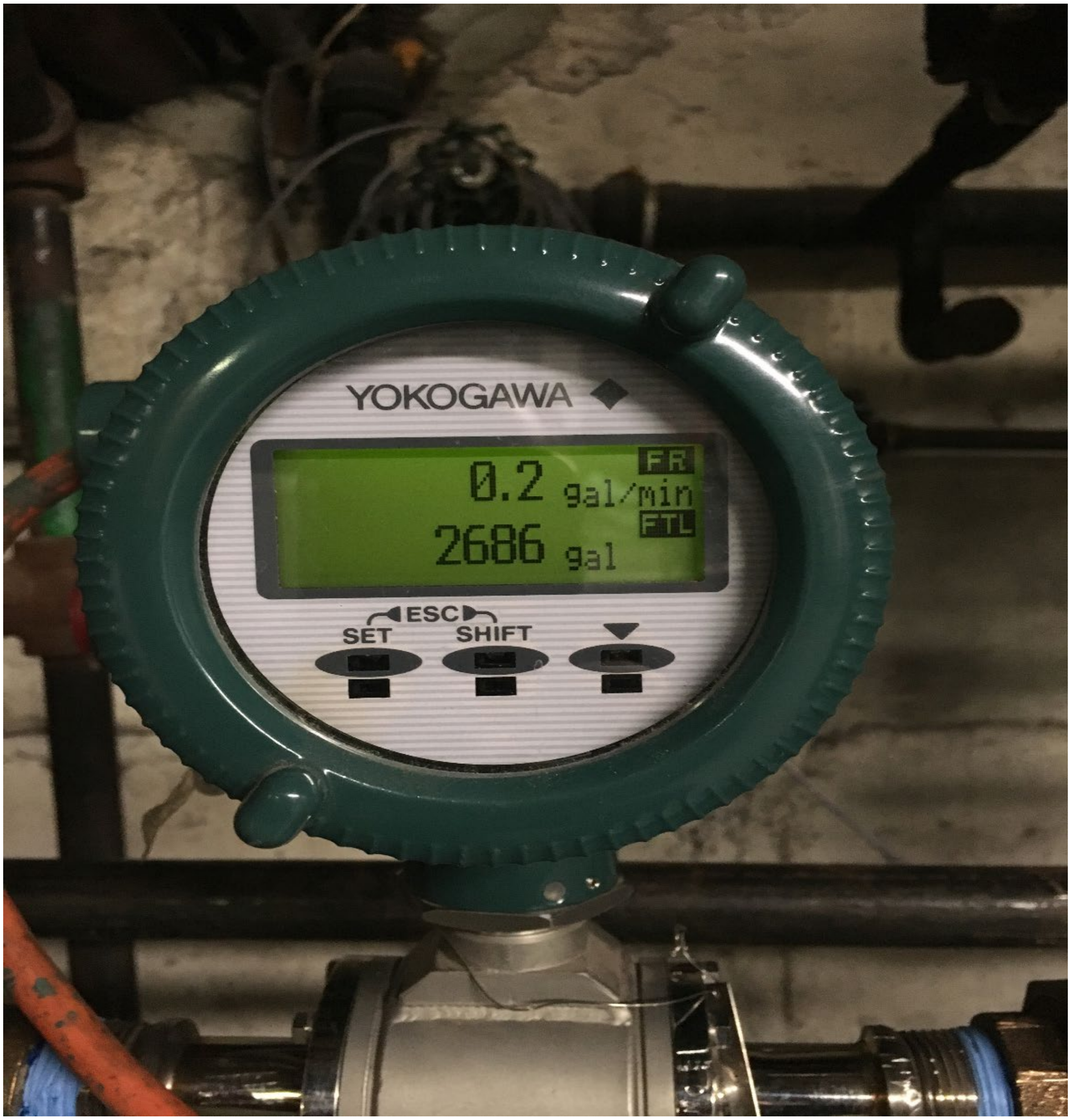


Figure 16 displays another view of the condensate tank, condensate pump, and part of the control panel.

Figure 16. Condensate Tank, Condensate Pump, and Control Panel

Figure 17 displays the ElectricMeter (EKTMetering), ESTEC BTU Meter, and Honeywell Temperature Display.

Figure 17. Electric Meter (EKT Metering), ESTEC BTU Meter, and Honeywell Tempertature Display

Figure 18 displays the new steam meter and certification document.

Figure 18. Steam Meter

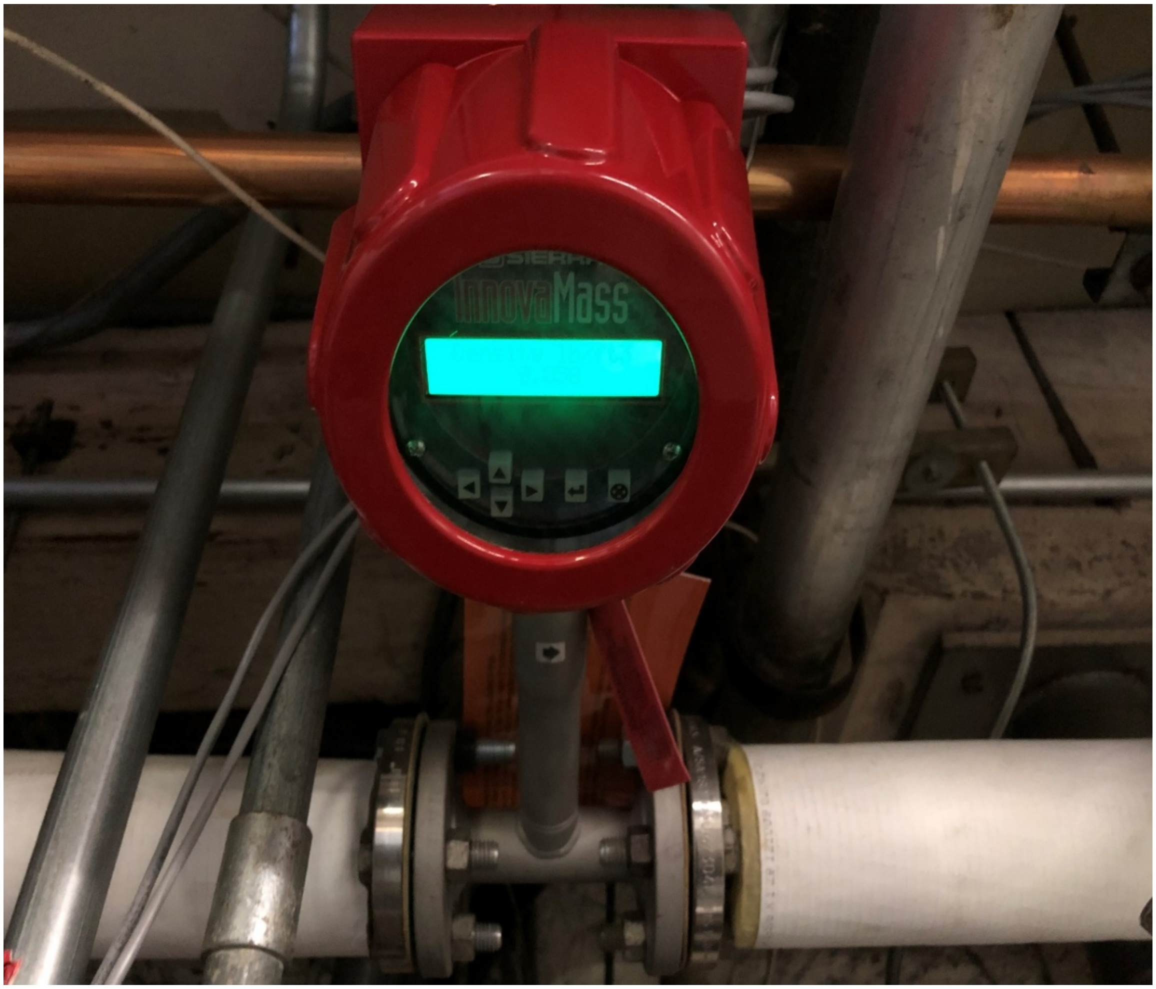


Figure 19. Steam Meter Installation

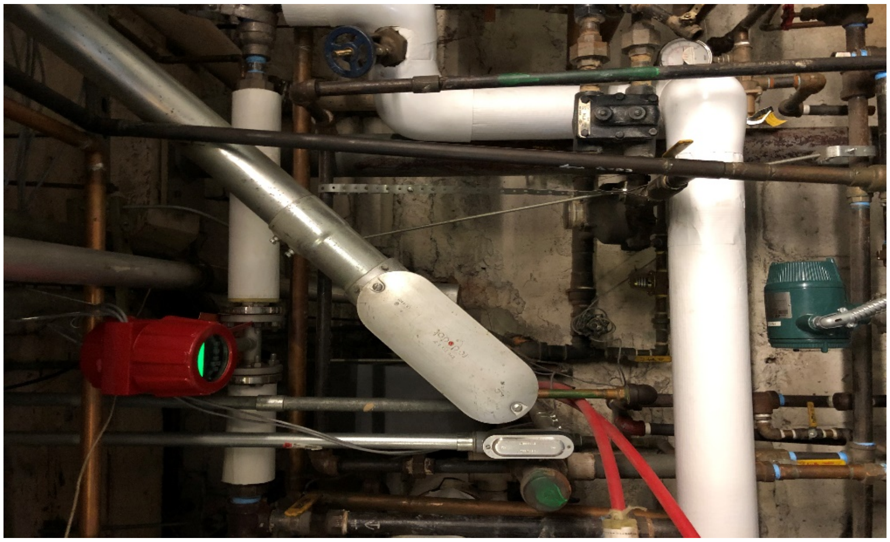


Figure 20. Steam Meter Calibration Certificate

SIERRA®

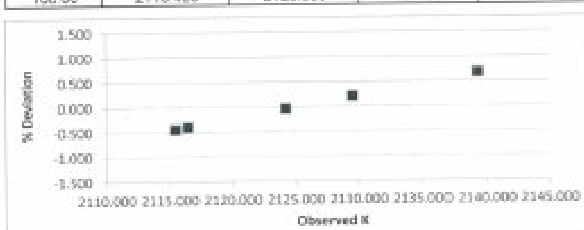
5 Harris Court, Building L / Monterey, CA 93940
800.866.0200 / 831.373.0200
fx 831.373.4402
www.sierrainstruments.com

CERTIFICATE OF CALIBRATION

Certificate File # 18120510534212139

Applicant/Customer	Name	HFC FISONIC		
	Sales Order	188378		
	Purchase Order	1232		
Instrument	Model	240i-VTP-1-F4-E2-DD-P2-V6-ST-MP2		
	Serial number	12139		
	Tag #:	N/A		
	Input Power	24 Volts DC		
	Customer Line Size	1" F/B 150#		
	Customer Flow Full Scale	388.00	lb/hr	
	Customer Operating Temperature	250.035	F	
	Customer Operating Pressure	15.00	Psig	
	Maximum Transducer Pressure	100.00	Psia	
	Accuracy Specification ±	1.00	% Reading	
Calibration Lab	Cal. Method / Asset / Cal Due Date	Water Loop	1641 / MFG-649 Rev. A	March 16, 2019
	DMM / Asset / Cal Due Date		1704	November 30, 2019
Calibration Data	Date of Calibration	December 5, 2018		
	Calibration Due Date	December 6, 2019		
	Calibration Line Size	1" F/B 150#		
	Calibration Temperature	70.26	F	
	Calibration Pressure	14.75	Psia	
	Reference Temperature	70.13	F	
	Reference Pressure	14.71	Psia	
	Maximum Temperature	392.00	F	
	Maximum Pressure	100.00	Psia	
	SCR Number	N/A		
	Other	N/A		
Performance Data	Base K	2125		

Sample Point %	Observed K	Predicted K	Deviation %	Status
20.00	2124.226	2125.000	-0.036	Passed
40.00	2115.480	2125.000	-0.448	Passed
60.00	2129.531	2125.000	0.213	Passed
80.00	2139.350	2125.000	0.675	Passed
100.00	2116.426	2125.000	-0.403	Passed



Traceability The instrument specified above was calibrated with measurement standards traceable to the national measurements standard of NIST. All calibration procedures were done in accordance to guidelines set for by our Quality Management system in compliance with ISO 9001:2008.

Calibration technician [signature] **Q.C.Technician** [signature]

Figure 20 continued

Sierra InnovaMass 240i/241i ValidCal Certificate

5 Harris Court, Building L • Monterey, California • (800) 866-0200 • (831) 373-0200 • Fax (831) 373-4402 • www.sierrainstruments.com

Meter Information:

Serial Number:	12139
Tag:	N/A
Manufacturer Date:	12/4/2018
Up Time:	N/A
Firmware Version:	v1.1.118
Firmware Date:	Apr 17 2018
Firmware Time:	14:15:22
Calibration Date:	12/5/2018
Calibration Due Date:	12/5/2019
PCA Revision	Raptor II v1.0

Meter Configuration:

Dial-A-Fluid

Fluids	Units	Full Scale
Steam_TP_Comp	Lbs/hr	388.00

Dial-A-Pipe

Type	Pipe I.D.
ss-rough	0.957000 In

Meter Validation:

Hardware Validation

Flow Sensor	Passed
Temperature Sensor	Passed
Temperature Overrange	Passed
Pressure Sensor	Passed
Pressure Overrange	Passed
SD Card	Passed
UART	Passed
MCU Voltage	Passed
Main Board Buttons	Passed
Digital Communications	Passed
Signal Noise	Passed

4-20mA Analog Output Validation

	4 mA	Output	DAC	20 mA	Output	DAC
Flow (Lbs/hr)	4.004	0.0	720	19.999	388.000	3602
Temperature (F)	4.003	32.000000	722	20.005	392.000000	3609
Pressure (Psig)	4.004	-14.695951	721	20.005	85.304047	3604

Alarm Relay Passed

Totalizer Relay Passed

Figure 21 displays the data recording logger.

Figure 21. Logger

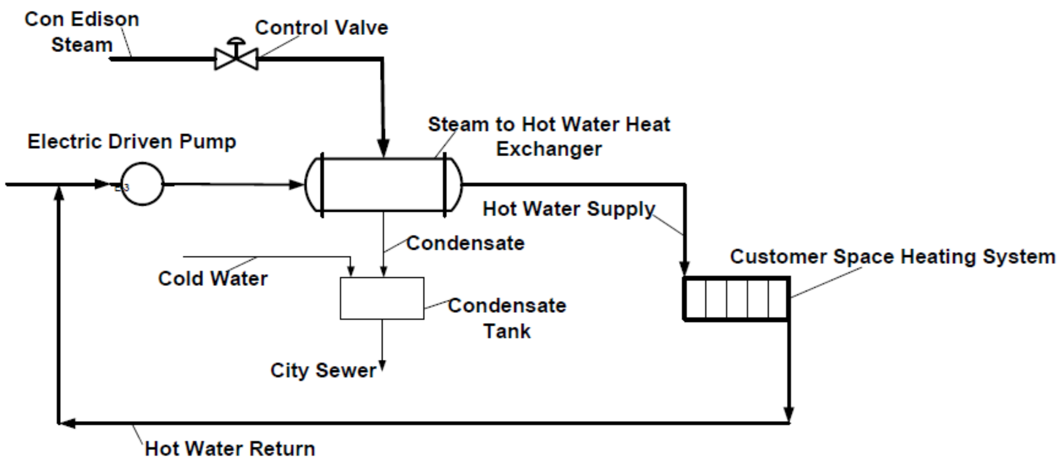
Figure 21. continued

5.2 Testing of the Existing System with Tube-and-Shell Heat Exchanger

Originally during the testing, the steam consumption was recorded by measuring the flow of condensate. The NYSERDA Project Manager recommended to install direct metering of steam consumption supplied to the existing and Fisonic systems. In 2018 HFC purchased from Sierra Manufacturer the new calibrated steam meter (Figures 18–20).

At the beginning of the 2018–2019 heating season the team started testing the existing heating system at the five-story building section (Figure 22).

Figure 22. Diagram of Existing Five-Story Section of the Building



The logger recorded all parameters with an interval of 5 minutes. The daily 288 readings for each parameter were compiled and averaged, and the team produced data for each day. The recorded data is presented in Table 7 and displayed in Figure 23 The regression equation for the test data is found using the INTERCEPT and SLOPE function in Excel. The correlation coefficient R^2 value 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 is found to be:

Equation 1. Daily Steam Load= 4949.553938 - Average Monthly Outdoor Temp.*76.8959135

Using equation 1 and normalized (monthly average for the past 30 years) outdoor temperatures, the total annual space heating steam consumption for the existing five-story building section was estimated. The results are presented in Table 7.

Table 6. Test Results of Existing Heating System with Tube-and-Shell Heat Exchanger

Date	Aver.Daily Outdoor Temp. F	Aver.Daily Water Supply Temp. F	Aver.Daily Water Return Temp. F	Daily Steam Load,Lb/Day
11/10/2018	43.8	124.5	120.9	1362
11/11/2018	41.3	138.4	133.2	1932
11/12/2018	43.5	128.3	124.2	1556
11/15/2018	33.7	152.7	146.7	2246
11/16/2018	40.2	138.4	133.7	1763
11/21/2018	40.0	138.5	133.4	1873
11/22/2018	24.3	156.2	149.6	2468
11/23/2018	25.4	156.2	149.5	2506
11/24/2018	40.4	137.2	132.6	1688
11/25/2018	50.5	110.8	108.5	833
11/26/2018	51.0	107.3	105.1	789
11/27/2018	42.4	131.1	126.7	1629
11/28/2018	40.2	139.3	134.1	1918
11/29/2018	42.8	130.3	126.2	1525
11/30/2018	41.0	135.5	130.8	1726
12/1/2018	42.5	129.6	125.7	1431
12/2/2018	50.3	112.0	109.7	852
12/3/2018	55.1	105.9	104.0	682
12/5/2018	36.0	147.7	142.0	2135
12/6/2018	35.3	152.2	146.0	2477
12/7/2018	36.2	149.8	143.6	2275
12/8/2018	31.9	156.1	149.4	2476
12/9/2018	33.5	155.4	148.9	2439
12/10/2018	35.2	151.4	145.1	2355
12/11/2018	36.8	149.2	143.2	2217
12/12/2018	38.5	142.0	136.8	1906
12/13/2018	38.8	140.8	135.3	2025
12/14/2018	49.9	106.5	104.4	710
12/15/2018	50.7	106.6	104.5	755
12/16/2018	41.1	132.0	127.8	1625
12/17/2018	42.8	130.3	126.0	1644
12/18/2018	34.7	153.1	146.9	2309
12/19/2018	36.1	145.4	139.9	2239
12/20/2018	44.1	133.8	129.3	1738
12/22/2018	46.8	132.6	128.4	1622
12/23/2018	41.1	136.0	131.0	2066
12/24/2018	39.6	139.1	133.5	2286
12/25/2018	37.6	147.4	140.7	2489
12/26/2018	39.3	143.0	137.1	2394
12/27/2018	41.9	135.5	130.5	1973
12/30/2018	40.5	142.2	137.5	1842
12/31/2018	43.5	140.3	135.7	1818
1/2/2019	39.9	140.8	136.0	1955
1/3/2019	42.8	138.5	133.9	1860

Figure 23. Dependence of Daily Steam Load on Outdoor Temperature for the Existing Five-Story Building

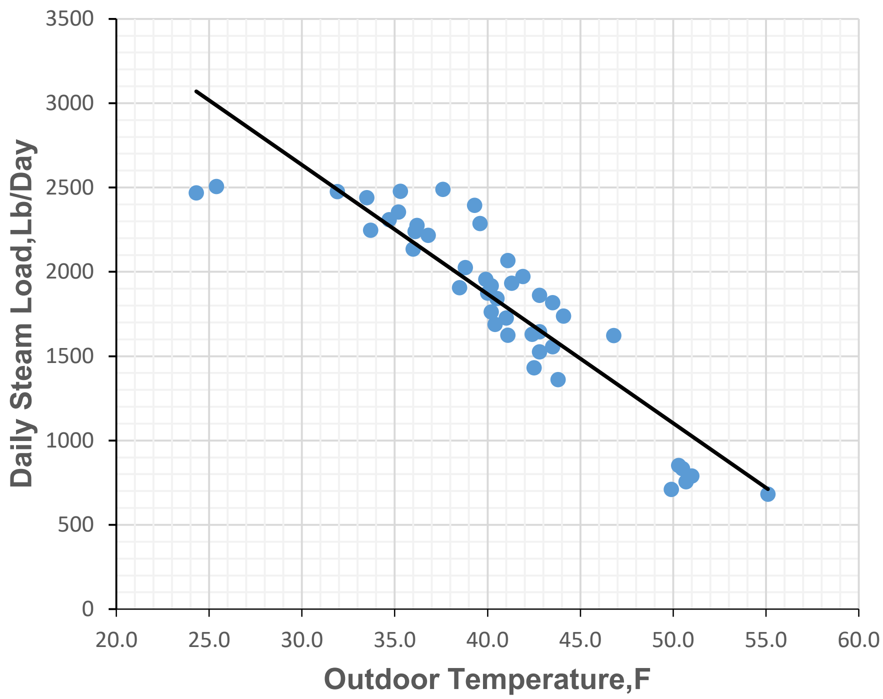


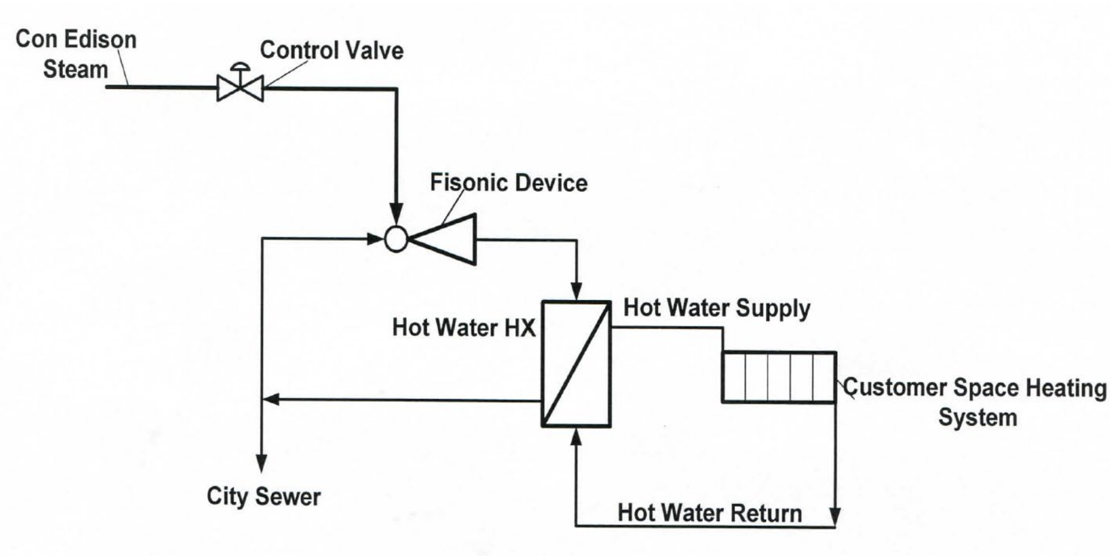
Table 7. Normalized Annual Steam Load of the Existing Five-Story Building

Month	Average Monthly Outdoor Temp.	Daily Steam Load,Lb/Day	Days/Month	Normalized Monthly Steam Load,Lb/Month
January	32.2	2,474	31	76,679
February	33.4	2,381	28	66,674
March	41.1	1,789	31	55,463
April	52.1	943	30	28,298
May	62.3	159	31	4,927
October	58.7	436	31	13,509
November	47.4	1,305	30	39,141
December	35.5	2,220	31	68,812
	Annual Steam Load, Lb/Year			353,503

5.3 Testing of Existing System Equipped with Fisonic Device

The existing five-story building section was equipped with a closed-loop Fisonic system (Figure24). The closed-loop Fisonic device is separated from the existing space heating system by a plate and frame heat exchanger.

Figure 24. Diagram of Closed-Loop Fisonic System



On January 9, 2019 the contractor started testing the Fisonic system using the new calibrated steam meter. The testing was finished on February 18. The logger recorded all parameters with an interval of 5 minutes. The daily 288 readings for each parameter were compiled and averaged, and the team produced data for each day. The recorded data is presented in Table 5-3 and displayed in Figure 5-20. The regression equation for the test data is found using the INTERCEPT and SLOPE function in Excel. The correlation coefficient value for the equation is found using the CORREL function. The $R^2 =$ **0.0.9451744** is calculated by squaring the correlation coefficient. The actual relationship equation is found to be:

Equation 2. Daily Steam Load= 3854.968014 - Average Monthly Outdoor Temp.*58.910375

Using equation 2 and normalized (monthly average for the past 30 years) outdoor temperatures, the total annual space heating steam consumption with the Fisonic Heating System of the five-story building section was estimated. The results are presented in Table 8.

Table 8. Test Results of the Heating System with Fisonic Device

Date	Aver.Daily Outdoor Temp. F	Aver.Daily Water Supply Temp. F	Aver.Daily Water Return Temp. F	Daily Steam Load, Lb/Day
1/9/2019	41.5	127.9	120.3	1378.0
1/10/2019	33.8	149.1	137.4	2048.0
1/11/2019	27.3	152.0	139.5	2241.0
1/12/2019	30.2	148.9	137.2	2125.0
1/13/2019	33.2	147.8	136.6	2012.0
1/14/2019	30.3	148.9	137.0	2136.0
1/15/2019	31.9	144.8	133.6	2098.0
1/16/2019	35.1	144.4	133.3	1884.0
1/17/2019	31.1	150.5	138.2	2136.0
1/18/2019	36.0	143.1	132.5	1832.0
1/19/2019	37.7	139.6	130.2	1642.0
1/20/2019	32.1	142.3	132.3	1724.0
1/21/2019	14.0	151.7	137.0	2597.0
1/22/2019	23.2	151.6	136.6	2198.0
1/23/2019	39.2	133.3	124.0	1611.0
1/24/2019	50.1	109.9	105.5	860.0
1/25/2019	35.6	144.5	133.5	1908.0
1/26/2019	31.0	149.6	137.7	2127.0
1/27/2019	43.1	123.7	117.0	1162.0
1/28/2019	30.7	150.1	138.0	2156.0
1/29/2019	36.2	140.9	130.7	1789.0
1/30/2019	23.0	151.4	136.9	2604.0
1/31/2019	14.3	158.9	143.1	3062.0
2/1/2019	18.2	156.9	142.5	2731.0
2/2/2019	26.6	151.7	138.7	2301.0
2/3/2019	41.5	128.0	119.9	1343.0
2/4/2019	48.6	110.8	106.0	828.0
2/5/2019	54.5	103.0	99.9	619.0
2/6/2019	43.2	124.0	116.7	1197.0
2/7/2019	43.2	123.6	116.7	1175.0
2/8/2019	43.9	122.4	115.5	1173.0
2/9/2019	29.5	152.0	139.8	2113.0
2/10/2019	31.1	150.2	138.7	2054.0
2/11/2019	35.8	143.5	133.0	1830.0
2/12/2019	33.4	148.6	136.9	2069.0
2/13/2019	37.1	141.0	130.8	1763.0
2/14/2019	39.9	132.8	124.0	1499.0
2/15/2019	52.0	107.0	103.0	725.0
2/16/2019	39.8	133.3	124.8	1476.0
2/17/2019	33.6	147.0	136.1	1926.0
2/18/2019	35.8	143.2	133.0	1760.0

Figure 25. Dependence of Daily Steam Load on Outdoor Temperature

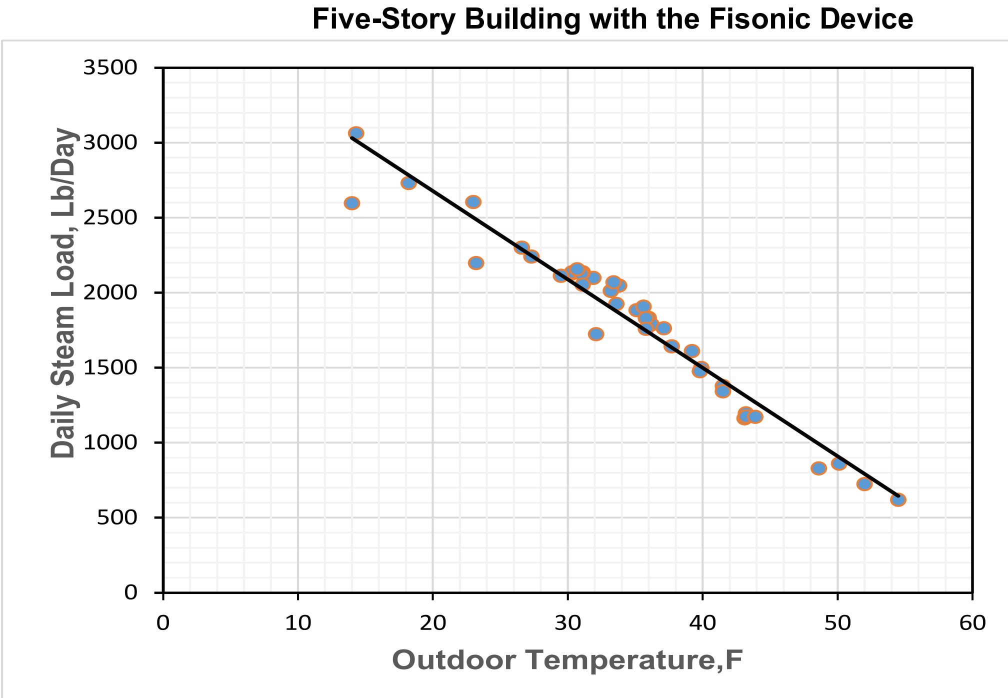


Table 9. Normalized Annual Steam Load of the Five-Story Building with the Fisonic Device

Month	Average Monthly Outdoor Temp. °F	Daily Steam Load, Lb/Day	Days/Month	Normalized Monthly Steam Load, Lb/Month
January	32.2	1,958	31	60,700
February	33.4	1,887	28	52,846
March	41.1	1,434	31	44,446
April	52.1	786	30	23,572
May	62.3	185	31	5,730
October	58.7	397	31	12,305
November	47.4	1,063	30	31,878
December	35.5	1,764	31	54,673
	Annual Steam Load, Lb/Year			**286,151**

The steam savings for the Fisonic system in comparison with the existing system are the following:

Equation 3. **1-(286,151) / (353,503) = 19.1%**

-Where the annual steam load of the existing heating system of the five-story building is 353,503 Lb/Year.

6 Description and Testing of the Fisonic Device at the Unit Heater

6.1 System Description

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 testing for one of the building's unit heaters. The project team has performed substantial refurbishing work on the selected heater before collecting the baseline data (cleaned the existing steam coil, cleaned and installed a new hot water coil, equipped the fan with a variable speed motor, installed the Fisonic device, as well as connected and insulated all piping and installed all necessary instrumentation (with newly purchased calibrated steam meter) for testing separately the steam and a hot water coil.

The equipment and instrumentation pictures at the unit heater system are presented in Figures 26 to 32. Figure 26 displays the principal diagram of the unit heater installation. The existing unit heater in the winter heats cold air to a temperature of 80°F. 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 26. 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. The flow of the cold water and all necessary temperatures and pressures are metered and recorded by a logger. The steam consumption by the steam coil is recorded in relation to the outdoor air temperature.

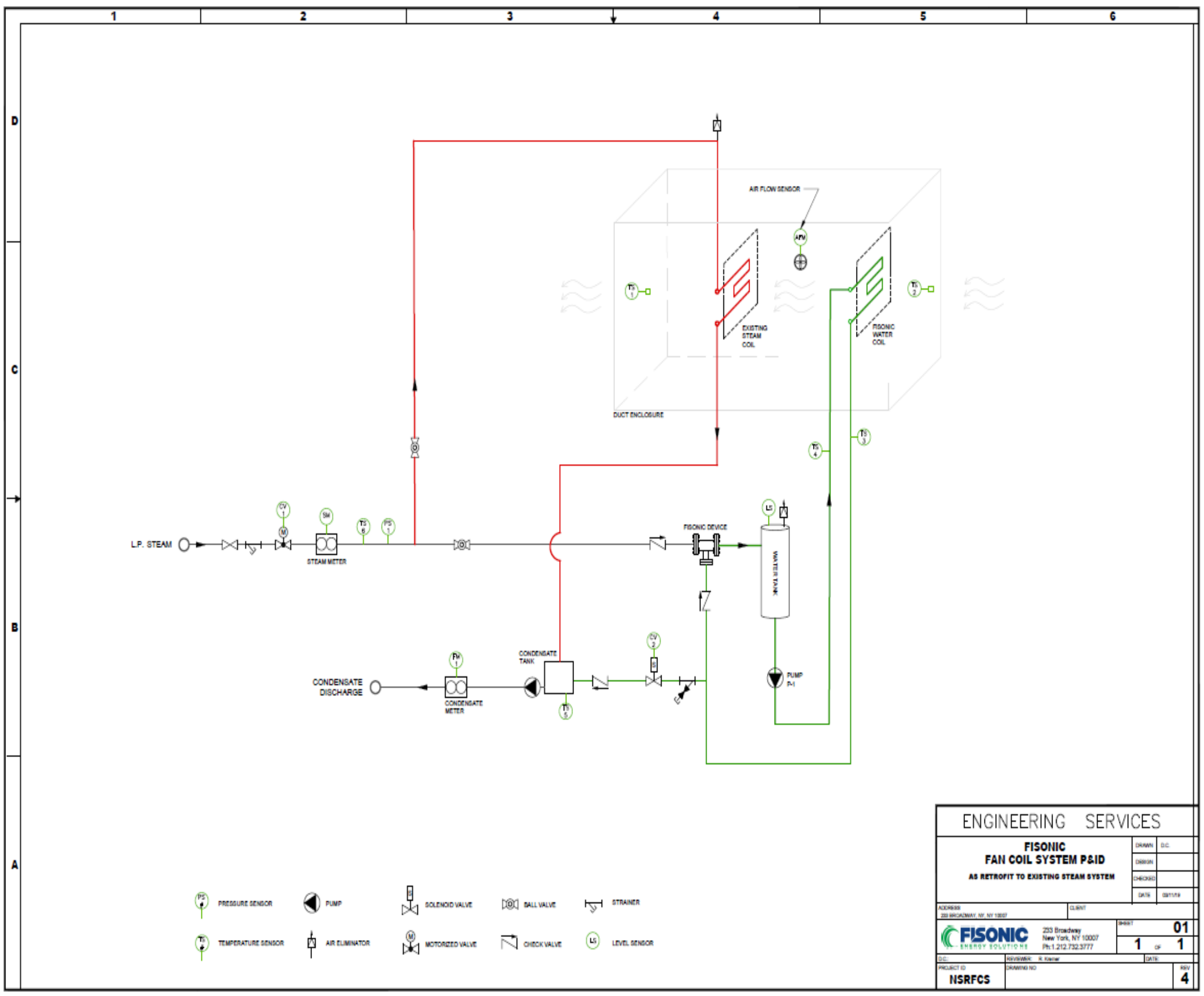
In order to perform the comparison of the existing system with the Fisonic system an identical hot water coil was installed inside the unit heater (the hot water coil is shown on the left of the system diagram, Figure 26). The coil is equipped with a Fisonic device set up. The coil is supplied with steam 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 and later 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. The steam consumption for the hot water coil is metered in relation to the outdoor air temperature.

Figure 27 displays the steam supply to the existing steam coil (yellow colored pipe insulation) and the new Fisonic device installation (white colored pipe insulation). Figure 28 displays the Fisonic device system installation including the hot water coil. Figure 32 displays the existing steam coil and steam supply piping.

The refurbished unit heater was commissioned and put into operation. Tests were performed first with the steam coil in operation and afterwards on the hot water coil equipped with the Fisonic device.

Figure 26. Diagram of the New Unit Heater Test Facility



The overall view of the test installation is presented in Figures 27 and 28.

Figure 27. Overall View of the Test Installation

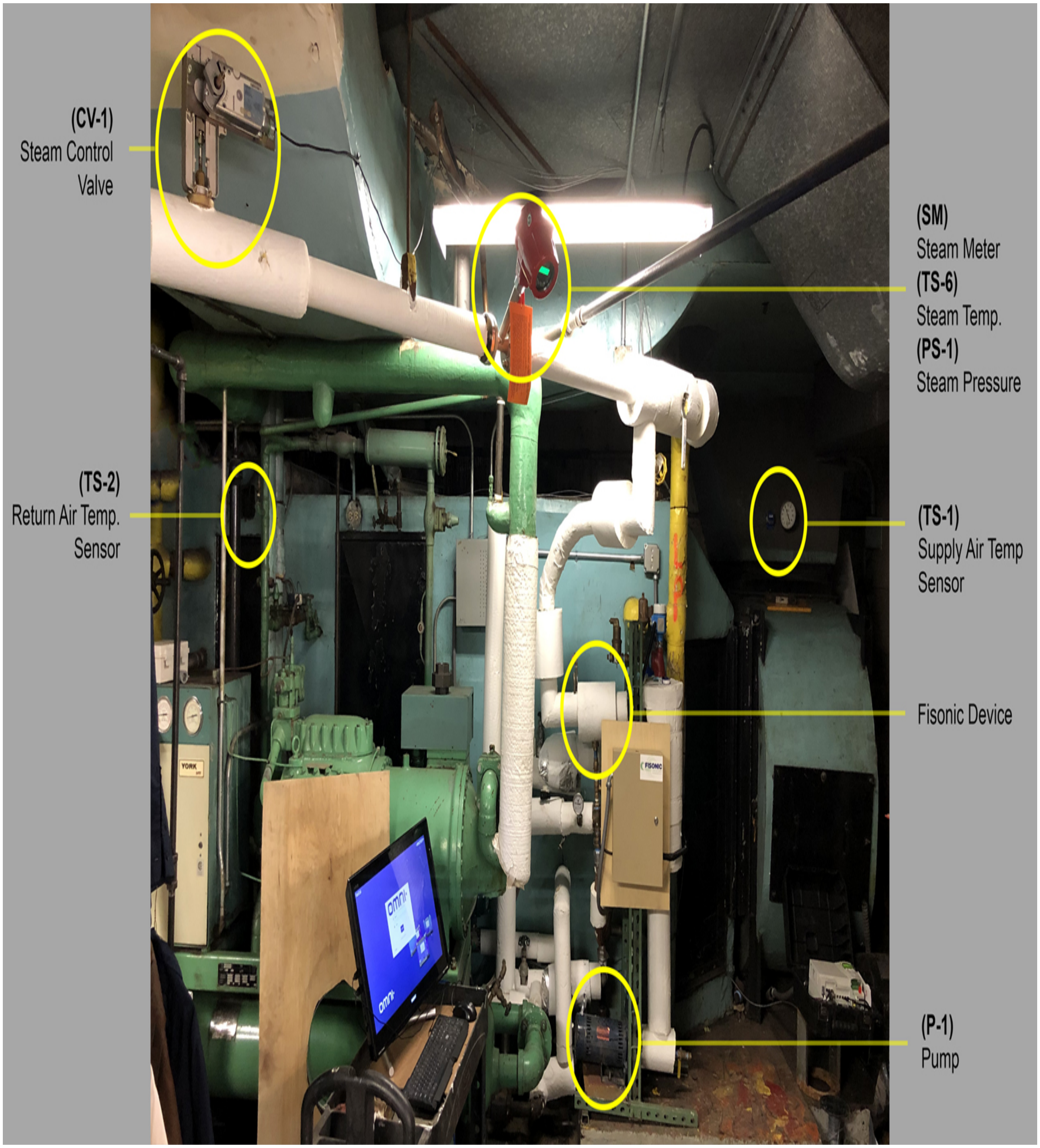


Figure 28. Overall View of the Test Installation

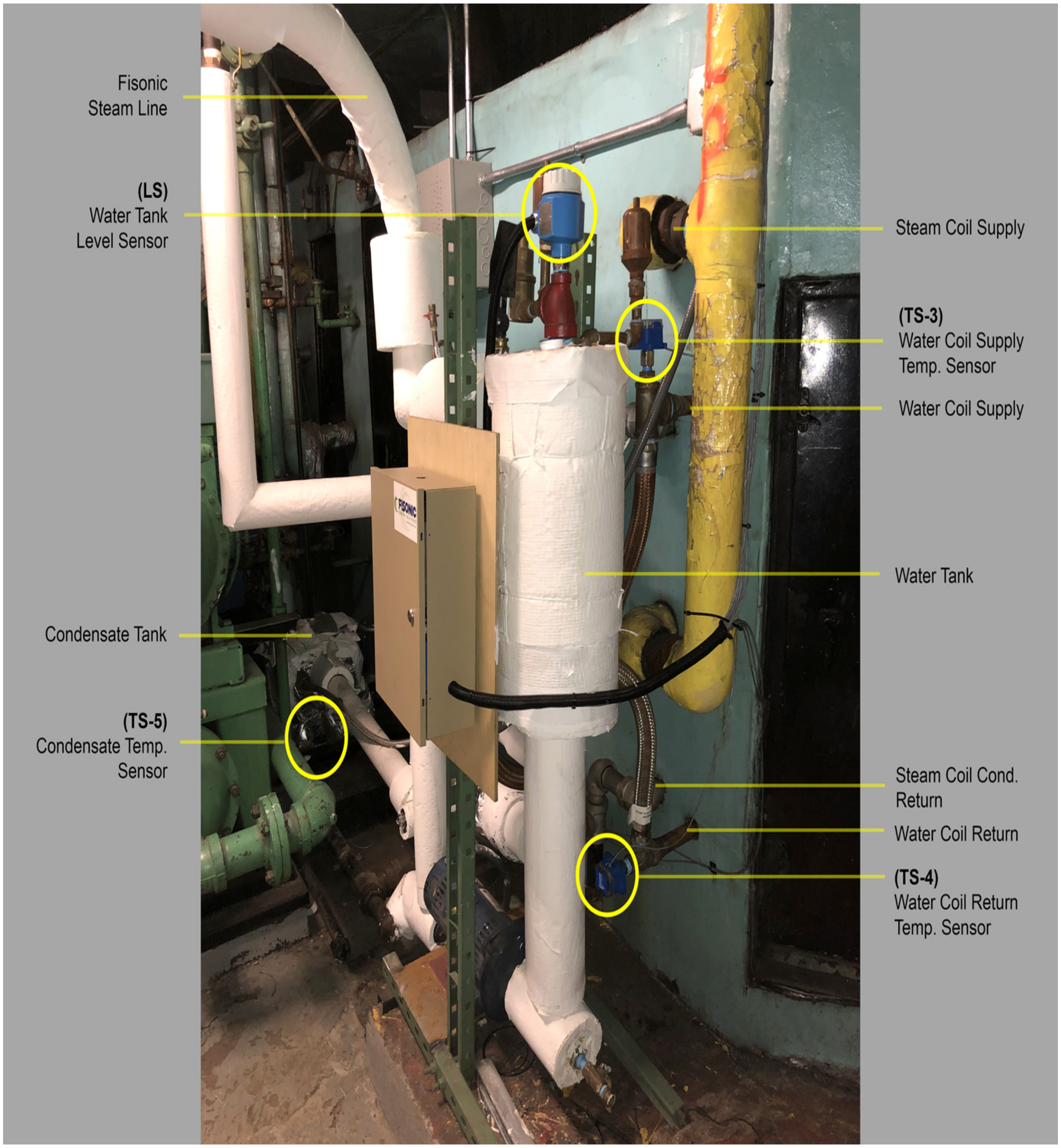
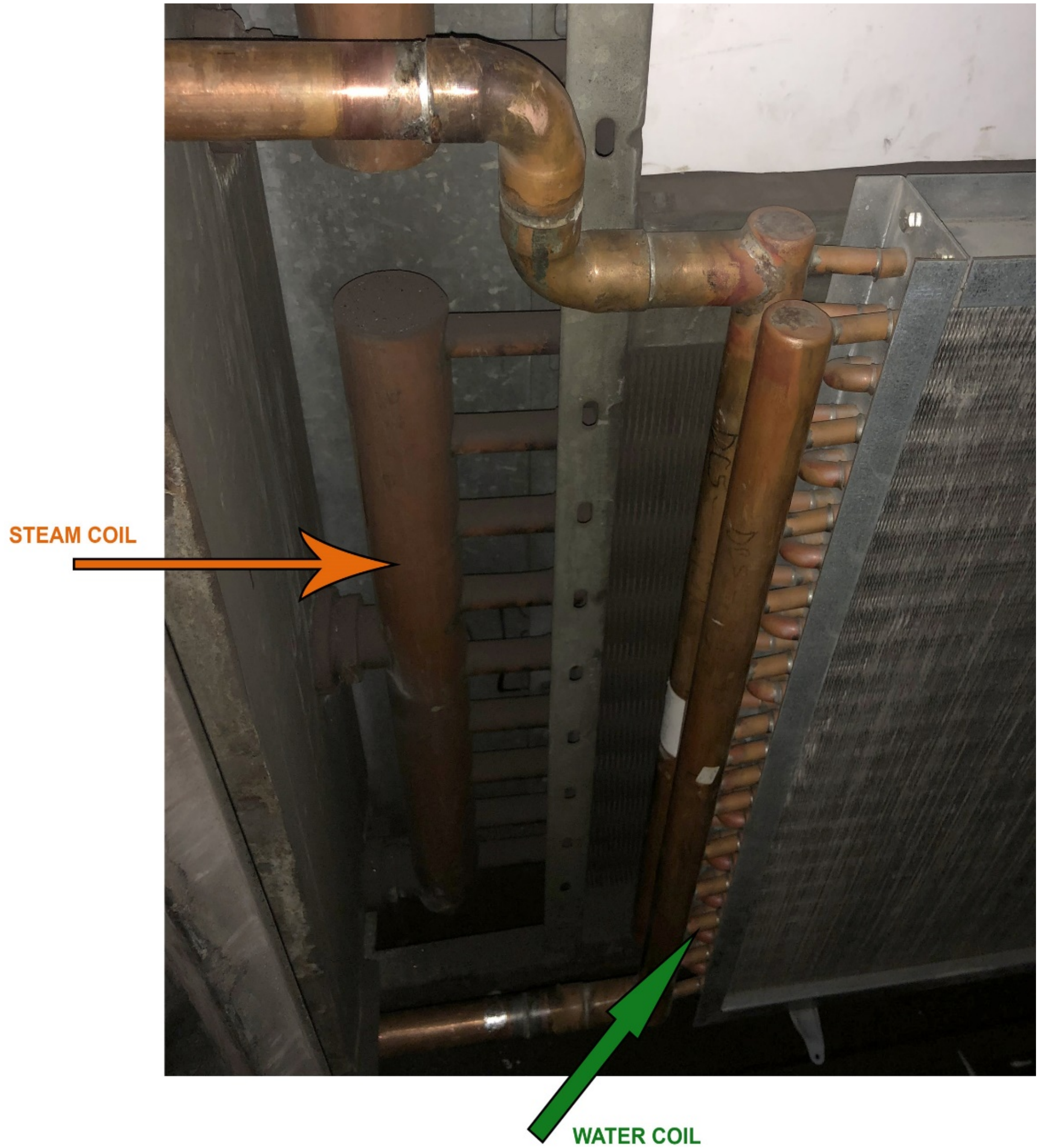


Figure 29. Pictures of Steam and Water Coils



The coil size is 28" by 60".The air flow was measured by an anemometer in 9 points of the coil cross-section (Figure 30).

Figure 30. Anemometer for Measuring Cross Section Air Flow

6.2 Unit Heater Steam Coil Test Results

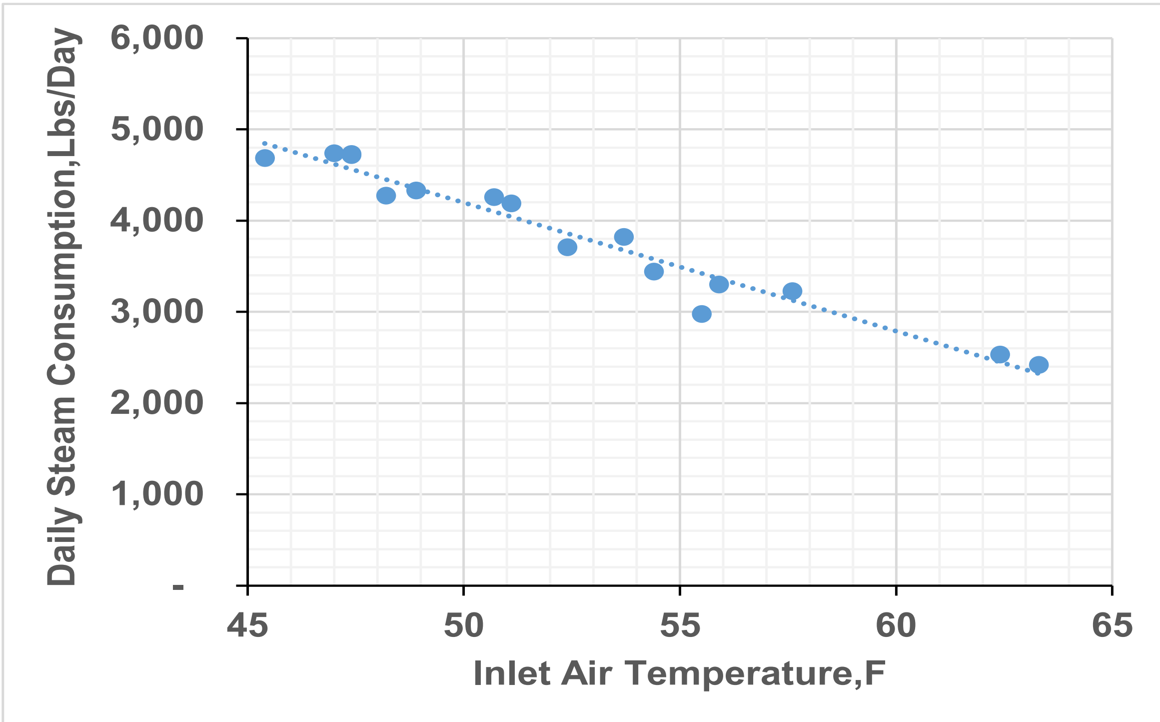
The unit heater air outlet temperature was set for 80°F. The inlet air temperature in the unit heater has changed in accordance with outdoor temperature. The testing started on March 1, 2019. The logger recorded all parameters with an interval of 5 minutes. The daily 288 readings for each parameter were compiled and averaged, and the team produced data for each day. It is important to note that the temperature of the condensate leaving the steam coil ranged between 190–210°F .

The recorded air inlet temperatures and the daily steam load data are presented in Table 10 and displayed in Figure 31.

Table 10. Results of Steam Coil at Unit Heater without Fisonic Device

Date	Aver. Daily Outdoor Temp.F	Steam Cond. Exit Temp. F	Daily Steam Load,Lb/Day
3/1/2019	48.2	209.8	4,272
3/2/2019	54.4	183.2	3,443
3/3/2019	45.4	182.3	4,687
3/4/2019	52.4	193.9	3,708
3/6/2019	48.9	207.4	4,332
3/7/2019	47.0	199.8	4,739
3/8/2019	47.4	189.4	4,729
3/9/2019	50.7	173.5	4,259
3/10/2019	47.4	187.9	4,718
3/11/2019	55.9	163.3	3,302
3/12/2019	55.5	208.9	2,979
3/13/2019	51.1	209.5	4,190
3/14/2019	53.7	209.5	3,823
3/15/2019	63.3	207.2	2,421
3/16/2019	62.4	206.7	2,531
3/17/2019	57.6	206.7	3,226

Figure 31. Dependence of Unit Heater Steam Load on Inlet Air Temperature



The regression equation for the test data is found using the INTERCEPT and SLOPE function in Excel. The correlation coefficient R^2 value for the equation is found using the CORREL function. The $R^2 = 0.9496$ is calculated by squaring the correlation coefficient. The actual relationship equation is found to be:

Equation 4. Daily Steam Load= 11,251.06 - Average Outdoor Air Temp.*141.042

Using equation 7 and normalized (monthly average for the past 30 years) outdoor temperatures, the total annual space heating steam consumption for the steam unit heater was estimated. The results are presented in Table 11.

Table 11. Normalized Monthly Steam Load for the Steam Unit Heater

Month	Aver. Monthly Outdoor Temp., °F	Daily Steam Load, Lb/Day	Days/Month	Normalized Monthly Steam load, Lb/Month
January	32.2	6,709	31	207,994
February	33.4	6,540	28	183,127
March	41.1	5,454	31	169,081
April	52.1	3,903	30	117,082
May	62.3	2,464	31	76,387
October	58.7	2,972	31	92,128
November	47.4	4,566	30	136,969
December	35.5	6,244	31	193,566
	Annual Steam Load, Lb/Year			1,176,334

6.3 Test Results of Unit Heater Hot Water Coil Equipped with Fisonic Device

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 setup. 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 later drained to the sewer. The temperature of the condensate ranged between 85°F and 119.7°F, and therefore no cold water addition is required.

The recorded air inlet temperatures and the daily steam load data are presented in Table 12 and displayed in Figure 32.

The regression equation for the test data is found using the INTERCEPT and SLOPE function in Excel. The correlation coefficient R^2 value for the equation is found using the CORREL function. The $R^2 = 0.949559$ is calculated by squaring the correlation coefficient. The actual relationship equation is found to be:

Equation 5. Daily Steam Load= 9,255.745 - Average Outdoor Air Temp.*120.53

Using equation 8 and normalized (monthly average for the past 30 years) outdoor temperatures, the total annual space heating steam consumption for the steam unit heater with the Fisonic device was estimated. The results are presented in Table 12.

Table 12. Test Results of Hot Water Coil at Unit Heater with Fisonic Device

Date	Aver. Daily Outdoor Temp.F	Steam Cond. Exit Temp. F	Daily Steam Load,Lb/Day
3/20/2019	53.6	108.1	2,832
3/21/2019	52.0	111.4	2,980
3/22/2019	54.9	112.8	2,590
3/23/2019	58.1	114.5	2,358
3/24/2019	60.1	115.2	2,059
3/25/2019	62.2	114.4	1,895
3/26/2019	56.7	115.0	2,423
3/27/2019	49.0	111.4	3,242
3/28/2019	53.4	114.3	3,212
3/29/2019	61.7	115.2	1,887
3/30/2019	62.0	114.7	1,863
3/31/2019	62.1	107.4	1,768
4/1/2019	58.2	106.7	1,796
4/2/2019	51.0	116.2	3,142
4/3/2019	62.9	113.7	1,774
4/4/2019	64.5	111.5	1,616
4/5/2019	51.0	115.8	3,146
4/6/2019	60.9	105.2	1,865
4/7/2019	63.8	103.4	1,571
4/8/2019	67.0	101.3	1,130
4/9/2019	57.2	117.0	1,969
4/10/2019	66.0	99.9	1,235
4/11/2019	57.3	119.7	2,192
4/12/2019	61.4	108.0	2,141
4/13/2019	71.5	85.0	582
4/14/2019	70.2	87.4	821
4/15/2019	68.2	91.5	930

Figure 32. Dependence of Unit Heater with FD Steam Load on Inlet Air Temperature

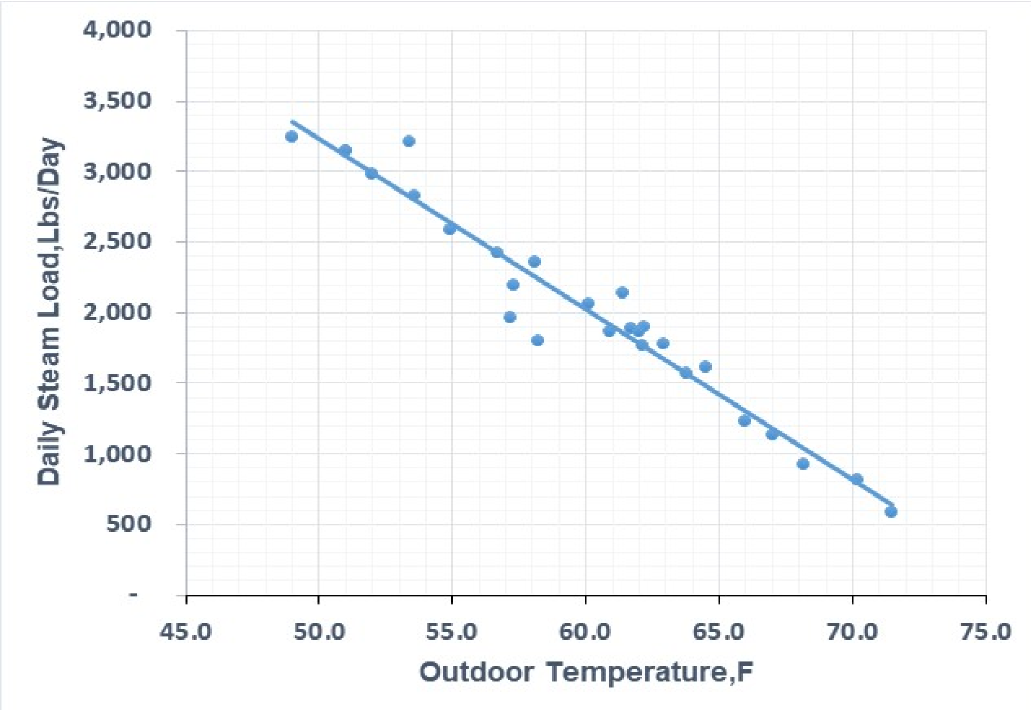


Table 13. Normalized Monthly Steam Load for the Steam Unit Heater with Fisonic Device

Month	Aver. Monthly Outdoor Temp., °F	Daily Steam Load, Lb/Day	Days/Month	Normalized Monthly Steam load, Lb/Month
January	32.2	5,375	31	166,615
February	33.4	5,260	28	146,441
March	41.1	4,302	31	133,361
April	52.1	2,976	30	89,284
May	62.3	1,747	31	54,148
October	58.7	2,181	31	67,600
November	47.4	3,543	30	106,279
December	35.5	4,977	31	154,258
	Annual Steam Load, Lb/Year			**918,013**

The steam savings for the Fisonic system in comparison with the existing steam system are the following:

1 - (918,013) / (1,176,334) = 21.96%. This result correlates well with the test results of 21% steam savings obtained by the NYC DCAS (Ref.3)

7 Economic Analysis, Benefits, and Impacts

Until April 2011 only one percent of all buildings in New York City produced 86 percent of the total soot pollution— more than all the cars and trucks in New York City combined. These buildings produced the pollution through the burning of the dirtiest grades of heating fuel available, known as residual oil, or No. 6 and No. 4 heating oil. In April of 2011, the City required the building owners to switch from No. 6 and No. 4 oil to cleaner fuel. Eight thousand NYC buildings were financially impacted by the motivation to act quickly to increase efficiencies and reduce energy unit costs. Currently, building owners and managers are not permitted to use No. 6 or No. 4 oil for new boiler or burner installations; instead they must use one of the cleanest fuels, such as low-sulfur No. 2 oil, district steam, natural gas, or biodiesel. By 2030 all buildings must convert to one of the cleanest fuels.

Energy conservation is a priority in the NYC plan to reduce the City's carbon footprint. The implementation of Fisonic devices offers substantial potential for energy savings in heating systems and pollution reduction in all major sectors of the NYC energy infrastructure. The long-term comparative tests of Fisonic devices at the Woolworth Building clearly demonstrated that the FDs provide energy savings of about 20% for a Con Edison steam customer and substantial water savings in comparison with the existing space heating systems. The impact of Fisonic technology on energy system economics is much larger than savings derived from traditional technologies used to improve energy efficiency.

Fisonic system retrofits provide the quickest, cleanest, most economical and non-intrusive way to upgrade energy system efficiencies in existing structures—avoiding expensive, disruptive processes that require tearing down and rebuilding. The systems lower production costs combined with high, positive impact of the retrofits generate substantial customer savings in energy and maintenance costs.

These advantages are of prime importance in view of the recent NYC council resolution of April 18, 2019 requiring every building over 25,000 sq. ft. to reduce carbon emissions by 40 percent by 2030 and 80 percent by 2050 as part of Governor Andrew M. Cuomo's Green New Deal. The ability to implement quotas for CO_2 emissions further accelerates and increases profitability. Fisonic technology is essentially a simple, versatile, compact heat exchange device that eliminates the need for inefficient conventional heat exchangers.

The economic benefits from Fisonic technology in comparison with the existing system for the Woolworth building are presented in Table 14.

In accordance with NYC water board, the current water cost is $3.90 per 100 cubic feet (748 gallons). The sewer rate is set at 159% of the water charges. The combined cost of water and sewer is $10.10 per 100 cubic feet (total $2.3/1,000 lb). The following actual current unit costs were used in the life-cycle analysis: average steam unit cost: $42.3/1,000 lb; combined water and sewer cost: $10.10 per 100 cu.ft; maintenance cost for the existing and the FD systems 3% of capital cost.

Table 14. Annual Steam and Water Parameters and Costs

Parameters	Units	Conv. Syst	FD System
Peak Space Heating Steam Load	lb/hr	5,200	4,160
Annual Steam Consumption	1,000 lbs	10,753	8,602
Annual Condensate Flow	1,000 lbs	10,753	8,602
Annual Steam Cost	$	455,322	364,258
Annual Condensate Flow	Gal	1,287,784	1,030,228
Annual Condensate Flow	100 cu.ft	1,154	923
Annual Quench Water Flow	100 cu.ft	1,292	-
Annual Condensate and Quench Water Flow	100 cu.ft	2,446	923
Annual Cost fo Quench Water and Sewer	$	24,706	9,326

The life-cycle comparison estimates are presented for two options: a new building considering installation of a typical tube-and-shell heat exchanger versus a Fisonic system (Table 15), and an existing building retrofit with Fisonic devices (Table 16). As one can see from the life-cycle analysis, the levelized payback ranges between 1.2 and 3.3 years. The levelized payback (LPB) estimates—similar to levelized cost of energy (LCOE), also referred to as the levelized cost of electricity or the levelized energy cost (LEC—are measurements used in the power industry to compare alternative methods of energy production.

The potential benefits the of FDs for the Con Edison steam customers are estimated as follows:

- **Energy Savings:** assuming the implementation of FDs by 30% of the Con Edison customers (540 buildings with current steam consumption of about 6.6 billion lbs per year), the potential reduction in steam consumption will result in annual cost savings to the customers of about 6.6 million * 20%*$42.3 =$55.8 million.

- **Water and Sewer Savings**: Using the above assumptions, the annual savings associated with cold water consumption and sewer discharge are estimated at 6.6 million*20%*$2.3/1,000 lbs=$3 million.
- **Job Creation**: Using 16 job years per $1 million of energy savings (Ref. 12), it is estimated that project implementation will result in creation of 893 job years.
- **Environmental Benefits:** Using the following emission reduction factors in lbs/yr/1,000 lbs (Ref.13): NO_x –10.74 x 10^{-3}; Particulates – 4.3 x 10^{-3}; VOC – 1.5 x 10^{-3}; CO_2 -114.4; the environmental benefits are estimated as the following pollution reductions in lbs/year: NO_x – 14,000; Particulates – 6,000; VOC – 2,000; and CO_2 –76,000 metric ton.

The potential benefits of use of FDs in the State of New York were estimated as follows:

- The International District Energy Association (Ref. 1) provided the total capacity of district steam systems in NYS as 25,806,551 lb/hr. This amount also included the capacity of Con Edison steam system of 11,676,551 lb/hr (Ref.2, page 19). So, the district steam capacity of NYS systems without Con Edison is: (25,806,551 – 11,676,551) = 14,806,551 lb/hr.
- The annual capacity utilization hours of the Con Edison steam system is 1911 hours (Ref.2, page 19).Using this number we obtain the annual district steam consumption in NYS as: (14,806,551*1911) = 28.3 billion lbs/hr. Assuming that 5% of these buildings can be equipped with Fisonic devices the potential benefits for the NYS are estimated as follows: **Energy Savings**: $12.0 million; **Water and Sewer** discharge savings: $0.65 million**;** **Environmental Pollution Reductions:** NOx – 3,036 lbs/yr, Particulates – 1,215 lbs/yr, VOC –445 lbs/yr and CO_2 – 16,166 metric ton/yr.

Table 15. Life-Cycle Analysis for a New Building

Year	System with Fisonic Device				System with Shell and Tube HX				Total Benefits, $
	Capital, $	Steam, $	Water and Sewer,$	O&M, $	Capital, $	Steam , $	Water and Sewer,$	O&M, $	
1	560,000				410,000				(150,000)
2		364,258	9,326	11,200		455,322	24,706	7,200	102,444
3		371,543	9,513	11,424	-	464,428	25,200	7,344	104,493
4		378,974	9,988	11,652		473,717	25,704	7,491	106,297
5		386,554	10,488	11,886		483,191	26,218	7,641	108,423
6		394,285	11,012	12,123		492,855	26,743	7,794	109,972
7		402,170	11,563	12,366		502,712	27,277	7,949	112,171
8		410,214	12,141	12,613		512,767	27,823	8,108	113,731
9		418,418	12,748	12,865		523,022	28,379	8,271	116,005
10		426,786	13,385	13,123		533,482	28,947	8,436	117,571
11		435,322	14,054	13,385		544,152	29,526	8,605	119,923
12		444,028	14,757	13,653		555,035	30,116	8,777	121,490
13		452,909	15,495	13,926		566,136	30,719	8,952	123,920
14		461,967	16,270	14,204		577,458	31,333	9,131	125,482
15		471,207	17,083	14,488		589,008	31,960	9,314	127,991
16		480,631	17,937	14,778		600,788	32,599	9,500	129,541
17		490,243	18,834	15,074		612,803	33,251	9,690	132,132
18		500,048	19,776	15,375		625,060	33,916	9,884	133,660
19		510,049	20,765	15,683		637,561	34,594	10,082	136,334
20		520,250	21,803	15,996		650,312	35,286	10,283	137,832
21		530,655	22,893	16,316		663,318	35,992	10,489	140,589
22		541,268	24,038	16,643		676,585	36,712	10,699	142,047
23		552,094	25,240	16,975		690,116	37,446	10,913	144,888
24		563,135	26,502	17,315		703,919	38,195	11,131	146,293
25		574,398	27,827	17,661		717,997	38,959	11,354	149,218
Total	560,000	11,081,407	403,434	340,725	410,000	13,851,743	751,603	219,037	2,996,817
NPV	560,000	7,604,084	265,946	233,806	410,000	9,505,095	515,751	150,304	1,920,890
					Levelized Payback				1.2 years
					IRR				70%

Discount Rate is 3%, Escalation Cost is 2%. The levelized payback (LPB) is the net present payback period over the lifetime of a Fisonic device. LPB is equal to the life of the project (25 years) divided by the ratio of sum of life benefits (2,996,817) to the initial investment (150,000).

Table 16. Life-Cycle Analysis for Existing Building

Year	New System with Fisonic Device				Existing System with Shell and Tube HX				Total Benefits, $
	Capital, $	Steam, $	Water and Sewer,$	O&M, $	Capital, $	Steam , $	Water and Sewer,$	O&M, $	
1	410,000				-				(410,000)
2		364,258	9,326	8,200		455,322	24,706	7,200	105,444
3		371,543	9,513	8,364		464,428	25,200	7,344	107,553
4		378,974	9,988	8,531		473,717	25,704	7,491	109,419
5		386,554	10,488	8,702		483,191	26,218	7,641	111,607
6		394,285	11,012	8,876		492,855	26,743	7,794	113,219
7		402,170	11,563	9,053		502,712	27,277	7,949	115,483
8		410,214	12,141	9,235		512,767	27,823	8,108	117,109
9		418,418	12,748	9,419		523,022	28,379	8,271	119,451
10		426,786	13,385	9,608		533,482	28,947	8,436	121,086
11		435,322	14,054	9,800		544,152	29,526	8,605	123,508
12		444,028	14,757	9,996		555,035	30,116	8,777	125,147
13		452,909	15,495	10,196		566,136	30,719	8,952	127,650
14		461,967	16,270	10,400		577,458	31,333	9,131	129,286
15		471,207	17,083	10,608		589,008	31,960	9,314	131,872
16		480,631	17,937	10,820		600,788	32,599	9,500	133,499
17		490,243	18,834	11,036		612,803	33,251	9,690	136,169
18		500,048	19,776	11,257		625,060	33,916	9,884	137,779
19		510,049	20,765	11,482		637,561	34,594	10,082	140,534
20		520,250	21,803	11,712		650,312	35,286	10,283	142,117
21		530,655	22,893	11,946		663,318	35,992	10,489	144,959
22		541,268	24,038	12,185		676,585	36,712	10,699	146,505
23		552,094	25,240	12,428		690,116	37,446	10,913	149,435
24		563,135	26,502	12,677		703,919	38,195	11,131	150,931
25		574,398	27,827	12,931		717,997	38,959	11,354	153,949
Total	410,000	11,081,407	403,434	249,459	-	13,851,743	751,603	219,037	3,088,083
NPV	410,000	7,604,084	265,946	171,179		9,505,095	515,751	150,304	1,723,516
					Levelized Payback				3.3 years
					IRR				27%

8 Commercialization of Fisonic Devices in New York State

Customer value propositions for the Fisonic device include its ability to provide substantial cost savings for steam, water, and sewer as well as to reduce the carbon footprint in existing and new space heating and domestic hot water systems. Although the device is designed to handle a number of different fluids and gases, its best applications involve the use of steam (active fluid) and water (passive fluid). In addition to steam, water, and sewer cost reductions, benefits of the FD over standard tube-and-shell heat exchangers also include the following:

- Instantaneous startup for water heating, eliminating water storage tanks.
- Easy to install with much smaller space requirements.
- No moving parts.

The existing heating systems in the buildings are typically oversized and difficult to control. The Fisonic system is equipped with sophisticated controllers and VFD pumps, allowing a much-improved optimized heating control system. For a large space heating system, multiple FDs are grouped together in a parallel arrangement on a skid. This approach has several benefits including the following:

- Allows a one-size device to work over a large range of flow conditions.
- Optimizes the operation of the Fisonic system and increases annual efficiency.
- Permits isolation and replacement of individual devices without a complete shutdown of the skid.

8.1 Potential Market Applications of Fisonic Devices

The following are applications best suited for FDs:

- Heating water for space heating and domestic use for commercial and multifamily residential users.
- Heating of feed water in thermal power plants.

The following are key decision drivers for markets:

- Operating/Energy Cost: This is a driver in the decision-making process; however, energy costs are one of several operating expenses.
- Maintenance Cost: A consideration, but of secondary order. Facilities also value systems that can allowed continued operation if a piece of equipment needs routine service or a repair.

- Initial Capital Cost: Sensitive to the cost of new equipment, but willing to spend if recovery is within acceptable payback period.
- Regulatory Requirements: Very important in light of the current NYC environmental requirements.
- Reliability: Extremely important. If the system goes down, there is no alternate source of heating available. Operators are, therefore, very sensitive to the needs of the customers who depend on the reliable energy delivery. This makes equipment reliability a major driver in the decision process.
- Superior Performance and Environmental Impact: System operators are concerned about these factors and view them as an important issue when making decisions.

8.1.1 Potential Sales

In order to estimate order of magnitude potential sales of Fisonic devices, Hudson Fisonic Corporation (HFC) provided a preliminary cost estimate of $70,000 for major proprietary Fisonic Components (Fisonic nozzle, control system and profit) of one Fisonic device. The final installation cost of the Fisonic system will depend on the physical characteristics and heat demand of the building dictated by the engineering assessment. Large buildings will require installation of multiple Fisonic devises for separate sections of the building (space heating, domestic hot water, pool, restaurant, etc.) and optimum control. This is reflected in the following estimates.

8.1.1.1 Domestic hot water and space heating use for commercial users:

The value proposition to the building owner: replacement of surface type heat exchangers with direct contact FDs results in reduction of energy consumption of about 20% and substantial savings of cost of water and sewer.

EIA's Commercial Buildings Energy Consumption Survey (CBECS) reported that in 2012 (Ref.3) there were approximately 48,000 buildings receiving 253 TBtus for their main space heating source from a district heating system (Ref.3, Table C.1 Total Energy Consumption by Major Fuels). Assuming the proportion of buildings receiving district steam heating in the CBECS sample is the same as the proportion of district steam heating systems for the IDESA data base (Ref.4) (e.g., 98%), 46,000 commercial buildings received district steam heating. If 5% of these are suitable for Fisonic devices, the number of buildings would be 2,300. If 1% of these adopted Fisonic devices, the number of buildings would be 23. The potential revenue from sales of Fisonic devices can be estimated as $280,000 (HFC sale price of four Fisonic device for a single building) * 23 buildings=$6.4 million.

8.1.1.2 Heating of Feed Water in Thermal Power Plants:

This major market group includes power plants engaged in the generation of electricity. Heat rate of a steam turbine-based power plant is the common measure of system efficiency. It is defined as a ratio of the useful energy output (electricity) by the plant to the energy (fuel) input to the power plant boiler. A typical steam turbine- based power plant has a heat rate of about 9,000 Btu/kWhr (Ref. 14).

A typical power plant has six closed type feed water heaters and one direct contact feed water heater (deaerator). If the closed feed water heaters are replaced with direct contact heaters, the extracted steam terminal loss at the closed feed water heaters is recovered and power plant efficiency increased (and heat rate of the plant is decreased). Replacing the direct contact heaters with direct contact Fisonic devices offers an opportunity to reduce the heat rate by about 100 Btu/kWhr and improve power plant efficiency by 100/9000=1% (Ref.15).The condensate of the extracted steam is mixed with feed water and no water saving takes place.

In the U.S. there are over 2700 operable electric generating plants (50 MW and above). Each plant is a potential site for six Fisonic devices. Assuming that 3% of the power plants will be equipped with Fisonic devices, the potential revenue can be estimated as $420,000 (HFC sale price of six Fisonic devices for a single plant) * 81 plants=$34 million.

8.1.2 Market Summary

The above order-of-magnitude estimates demonstrate that the market potential for Fisonic Devices in the U.S. is about $40 million with a total of 578 Fisonic devices.

8.2 Business Models

There are a number of different business models that can be used to implement the Fisonic technology. The major requirement is the need for a stable business entity to conduct the daily operations of the Fisonic technology including marketing, design, fabricate, installation, and servicing Fisonic device equipment skids. Hardware for Fisonic technology must be manufactured and assembled by an established fabricator under an exclusive contracting basis. The product can then be offered to industry either through direct equipment sales, performance-based contracts, or licensing agreements.

8.2.1 Manufacturer and Supplier of Fisonic Systems by a Network of Sale Representatives

Establishing a new business requires an upfront investment before the first sales can be made. Those investments include the employment of engineering and administrative staff, securing of manufacturing capability, production cost, and rolling out marketing/sales activities. For the last four years HFC at its own cost has been marketing and suppling the Fisonic devices and managing installation crews (HFC has extensive experience of over 20 years in performing construction services of HVAC systems in Manhattan).

Once established with sales over 20 units annually, the HFC can go about setting up a business to exploit the Fisonic technology. HFC can set up manufacturing facilities by themselves. In this case HFC will manufacture the Fisonic nozzles and have control on the proprietary technology. The total Fisonic package will be provided by an integrator such as Alstom.

To set up the manufacturing facilities in New York States, HFC anticipates obtaining financial support from the NYC and NYS economic development agencies, the New York City Energy Efficiency Corporation and the NY Green Bank. This will allow HFC to support an initial crew of six to 10 people. In the second and third manufacturing year, the number of employees will be increased to 15. The first year HFC can manufacture and deliver about 20 Fisonic systems. Depending on the size of the NYC and NYS support, the production and sale of Fisonic systems could increase to 40 units in the second year.

The company can be organized into different departments including the following:

- Engineering services
- Fisonic device package sales
- Field services (installation and maintenance)
- Business support services

8.2.2 Performance-Based Contracting

One of the attractive options widely used in the energy services business is the performance-based contract. Performance-based contracting essentially passes most of the risk of the FDs performance to the HFC, who only profits if the device works as advertised. The customer shares the resulting savings from the Fisonic technology with the HFC. This approach eliminates the customer upfront capital costs associated with the purchase of new equipment. The HFC will recover its upfront costs in a reasonable time frame based on the savings accrued by the application of the technology. Thereafter, the HFC will enjoy a long-term stream of profits from the continued use of the Fisonic technology by a satisfied customer. The customer avoids any financial risk while recognizing the benefits of lower operating costs from using the Fisonic technology. The pay back occurs when the Fisonic system delivers promised benefits which are then shared by the customer.

The ability to offer a performance-based contract depends on two conditions: (1) owning an organization capable of supporting this business strategy with (2) the financial resources to underwrite the capital cost of the equipment and installation during the early (nonrevenue) stages. To properly support a business based on performance-based contracting requires full control of the product (Fisonic components and algorithms), which means the ability to design, fabricate, assemble, install, and maintain the FD at the customer facility.

Upon the expiration of the performance contract period, the customer has the option to renew the performance contract or to continue utilizing the Fisonic equipment under his own management for an annual rental fee.

8.2.3 Licensing

HFC is planning to license Fisonic technology to companies (such as GE) currently serving special sectors of potential market (such as power plants).The most valuable asset owned by the HFC will be the agreement for the exclusive use of the Fisonic patents and products for these applications. In this case the licensee will market, manufacture, and service the Fisonic devices.

8.3 Up-to-Date Activities

8.3.1 Demonstration of Fisonic Performance

During the last four (4) years with the substantial support of NYSERDA the HFC demonstrated the operational advantages of FDs in Woolworth building commercial installations. During the same period HFC at its own expense installed and conducted demonstration testing of FDs at the City 455 Broadway, 475 Broadway, and 39 Broadway Buildings of the NYC.

The domestic hot water system at the City 455 Broadway Building was independently tested by City Laboratory and demonstrated savings of 21 % (Ref.5).

HFC also obtained the Global Underwriters Laboratories Certification (Ref.6) and secured a number of U.S. and International Patents for the Fisonic technology (Ref.7-11).

During the development and demonstrations of FDs, HFC secured close cooperation of a manufacturer (Division LLC) which has the capability to manufacture the FDs. During the development and demonstration activities HFC optimized the design and concluded that the FD should be a closed-loop device separated from the customer space heating and domestic hot water systems by a plate and frame heat exchanger. This will avoid direct introduction of steam into the existing customer piping system and heating elements and potential steam chemistry related liability issues. The pumping advantages of the Fisonic systems will be recognized in district heating and industrial applications. HFC also concluded that the FD system offered should be a skid mounted installation including the FD, plate and frame heat exchanger, non-condensable gases removing device, control devices, and VFD pumps. The skid mounted system will have only four piping connections (supply and return water and steam supply and condensate drain) to the existing system in which tube-and-shell heat exchanger bypasses.

8.3.2 Marketing

During the development and demonstration process HFC conducted an extensive marketing and promotion campaign which included the following activities:

- Numerous presentations of Fisonic technology to various technical conferences and shows.
- Extensive discussions with numerous potential users of FDs (Con Edison, GSA, Veteran Administration of NYC, Universities, District Heating Companies).
- Extensive discussions with various manufacturers of heat exchange equipment (Spirax/Sargo, TACO, General Electric, TRANE, Schneider Electric, Johnson Control, Thermolift, Green Technology Accelerator Center, Alstom, Con Edison and ABB.
- Extensive discussions with a number of Investment Companies (Queensland Investment Company of Australia, Gramercy Development, General Electric, Alstom).
- Worldwide web site marketing and demonstration projects has been developed, presenting results of demonstration testing (www.fisonicsolutions.com).
- HFC proposed exclusive licensing agreements to the above listed companies. HFC also offered the energy saving performance contracting instruments (ESPC) to a number of universities and commercial customers.

- During the marketing activities it was determined that the major obstacle to implementation of FDs is lack of space heating tests of FD at commercial installation and comparison of savings with existing systems. Therefore, the results of the current project are a major step to commercialization. The other obstacle is attaining a reliable record comparing the customer's steam consumption with and without FDs. This obstacle is aggravated by the complexity of steam system operations in existing large buildings. To avoid the obstacle, the project team resolved the issue by testing the existing system before and after the installation of Fisonic system.

For future customers, multiple Fisonic systems equipped with metering systems should be installed throughout the building. Total metered annual steam consumption of the system with Fisonic devices will be compared with the steam sales to the building by the Con Edison or other district steam supplier. Another important factor for cost comparison is the demand charge for hourly steam use recently introduced by Con Edison. The multiple Fisonic systems equipped with sophisticated controls and VFDs allow optimizing the demand charges and reducing the cost of purchasing steam for the building owner.

There are two marketing concerns with implementation of the commercialization of FDs:

- Proposed FD implementation is based on a marketing approach that targets the replacement of existing equipment.
- Every existing potential customer is already meeting their heating needs with conventional equipment. To justify the installation of the Fisonic system the potential savings should provide a short payback period. The economic analysis presented above demonstrates the high-economic effectiveness of the FDs.

HFC's extensive experience with FD implementation in Russia and China (installation of close to 5400 Fisonic units) has demonstrated that the most applicable and profitable application of FDs is the district heating industry of cities and large industrial customers. For example, the large space heating system of the Kirov Ship Manufacturing facility in St. Petersburg is equipped with 48 Fisonic devices. Therefore, HFC is actively marketing the FDs to the U.S. district heating systems.

8.4 Path to Commercialization

8.4.1 Challenges and Risks

When marketing the Fisonic device to potential customers, it is important to kept in mind that most potential customers have their heating needs met with tube-and-shell heat exchangers. Anyone interested in selling the devices must therefore demonstrate to the potential customer the reasonable payback period of the Fisonic system and the carbon foot-print reduction.

In order to promote the potential sales of the Fisonic devices for the applications outlined above, numerous demonstration projects should be conducted (particularly for electric power generation and industrial applications).

The preliminary selling price of $70,000 for the Fisonic components was established, and the experience with customers demonstrated the price is reasonable. However, it should be noted that the total Fisonic system installation cost depends on existing heating systems and piping arrangements.

The ability to establish and maintain a viable business with the Fisonic device depends on the ability to protect the value of that asset. Therefore, exclusive rights for the Fisonic technology are an essential prerequisite to business development. Patent research must continue to establish the level of protection from imitation that the current patents offer.

Efforts to license the Fisonic technology for specific application (such as GE and Alstom power plants) should continue. Worldwide rights are preferred, but at a minimum, North American rights are essential.

A detailed market analysis of the above applications for Fisonic devices must be conducted. This includes collection of detail information about steam supply systems in the NYS and interviews with industry advocates and industry focus groups. Currently HFC is negotiating installation of various Fisonic systems with 15 Manhattan buildings.

It is of prime importance to perform the following activities:

- Exploit the Con Edison connection: Encourage Con Edison to purchase several units for installation and demonstration testing. Establish credibility with other utility industry customers.
- Exploit demonstration projects: Using performance data from current demonstration projects case studies can be developed to showcase the benefits from the Fisonic device. Demonstration projects should continue to be offered to selected potential customers.

In order to establish product recognition in the marketplace the following high-level marketing activities will be performed:

- Exhibitions at numerous industry trade shows.
- Extensive advertisement in trade magazines.
- Targeted mailings to key people at the decision-making level.
- Extensive briefings on the customer sites and at technical conferences.

From a cost perspective, it is better to engineer one design and replicate it multiple times than to custom design each equipment skid that is ordered. Replicated designs allow economies of scale in the manufacturing process as volume price breaks can be achieved for such cost items as isolation valves, internal nozzle material and fabrication, and pipe housing material and fabrication. The simplification also applies to the level of effort required for the engineering and sales staff taking the order, processing the design, and completing the assembly. The top applications involve steam heating of water. Except for the equipment arrangement on the skid, components and assembly can be standardized resulting in efficiencies not achievable with the one-of-a kind unit.

The Fisonic system is protected by several HFC obtained and pending patents, alleviating the technology risk. There is practically no manufacturing risk because the materials, machinery, and skilled labor for production are readily available. The business model risk will be reduced by developing the manufacturing option with the NYS and NYC economic development agencies support. The marketing risk is minimized by the new regulation requiring environmental improvement of building systems and reduction of energy consumption. The execution risk will be alleviated by the initial NYS and NYC Veteran Administration support (currently in negotiation).

It should be noted that HFC has a disable veteran certification providing company bidding advantages.

8.4.2 Marketing Activities

The short-term HFC marketing activities include the following:

- Retrofitting with Fisonic devices. The City of New York owned 51 buildings connected to the Con Edison Steam System. After successful demonstration of Fisonic device savings in the 455 Broadway Building (Ref. 5), NYC has the desire to proceed with wide implementation of FDs. HFC is presently involved in discussions with NYC on this topic.
- HFC is close to obtaining permission from NYC Veteran Administration for installation of Fisonic systems in their facilities. After demonstration testing of FDs the system can be replicated in VA facilities in NYS.
- HFC is involved in discussions with the General Service Administration (GSA) in Washington, DC about installation of FDs at their facilities.
- HFC has proposed to the United States Department of Energy (DOE) to evaluate and include the Fisonic technology in the DOE Best Steam Practices Program.

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Appendix A: Construction Specification for Installation of Fisonic Equipment and Instrumentation

A.1 Definitions and Major Requirements

A.1.1 Introduction

The purpose of the project is to purchase and install Fisonic devices at the Woolworth Building in New York City, along with associated equipment and metering devices for monitoring the building's space heating system as well as determining steam, electric, and potable water savings from this technology. The Fisonic device (FD) is a supersonic, condensing heat pumps with a patented internal geometry that causes steam and water to mix and accelerate, converting a minute fraction of the fluid's thermal energy to physical kinetic thrust (pump head) with the outlet pressure higher than the pressure of the working medium at the inlets of the FD.

The analysis of the space heating system of the Woolworth building demonstrated that the existing system includes two separate hot water loops: (1) the five-story loop and (2) the unit heater loop. Each loop requires separate monitoring of existing system and installation with a separate Fisonic device. The principal design diagrams of the existing and the Fisonic systems are presented in Figures 5 and 6.

Figure 5 exhibits the necessary metering and monitoring equipment to obtain the energy and water consumption information for the existing system. The major monitoring instrumentation includes steam and cold water consumption meters, an electric meter to monitor the electric consumption, and thermocouples and pressure transducers, a data logger and a computer with appropriate software for remote monitoring of test data.

Figure 6 presents the metering and monitoring equipment to obtain the energy and water information for the same system operating with the Fisonic device.

After entering the building, the Con Edison district steam branches off to each selected section and heats hot water in existing heat exchangers. The heated water is circulated throughout the selected loops by the constant speed electric pumps in the original system. The steam condensate after the heat exchangers is directed to a condensate tank, where the mixture is diluted with cold potable water and discharged into the city sewer. In order to determine the consumption of steam, hot and cold water, and electricity for the existing systems, the loops need to be equipped with appropriate metering and instrumentation.

Figure 6 presents the system with Fisonic devices in which the FD heating loop is separated from the existing space heating system by a plate and frame heat exchanger that allows the heat to indirectly transferred to the space heating water. The introduction of a highly efficient plate and frame heat exchanger with terminal temperature difference of 1–2°F provides the opportunity to prefabricate the total module with the Fisonic device and simply connect the package to the existing system with two pipes. Therefore, it is proposed by the HFC to test Fisonic systems at the five (5) story section and the Unit Heater of the Woolworth building.

The steam line is equipped with gate valve and a steam flow meter. The flow meter and other equipment specifications are presented in Tables A-1 to A-15. The steam line is equipped with a steam trap line for drainage of the condensate during facility start-up. Following the temperature control valve, a non-return check valve is installed. The check valve will prevent any water back flow from the Fisonic device into the steam line. After the check valve steam will enter inter the Fisonic device.

The systems will be equipped with extensive instrumentation which allow to accurately measure, record and log all the pressures, temperatures and flows of steam, cold and hot water, and electricity during the operation of the systems. The detailed description of all equipment and instrumentation is tabulated in Table 4.

A.1.2 Definitions

- Owner is defined as the Woolworth Company of New York.
- Hudson Fisonic Corporation (HFC) is responsible for purchasing the major equipment, construction management and performance of the tests.

- Contractor is defined as the installer of the Fisonic device (FD) and associated metering and monitoring equipment at the three selected hot water loops at the Woolworth building as specified by the HFC. The scope of work, terms and conditions are strictly as mutually agreed to by the contractor and HFC.

A.1.2.1 Scope of Work

The installation contractor is responsible to the HFC for satisfactorily installing the equipment and instrumentation in the Woolworth building. HFC will supervise the work. The contractor and HFC will comply with the Woolworth environmental health and safety requirements specified in the Host Agreement executed by the Woolworth Management and HFC.

The scope of the work is not limited to the work outlined herein, but includes all other items of the work, labor, and material as may be necessary to accomplish the intent of this specification. The scope of work will include all labor necessary for installing all equipment, control work, electrical work and services such as the following:

1. Valve off and chain the valve on the existing steam supply. Install all necessary components of the test facility in accordance with the Figures 5 and 6 and the specification.
2. Install all necessary piping, valves, traps, and fittings to make a complete and operational system. On the piping, welded or screwed connections are permitted. If using screwed fittings, use schedule 80 piping.
3. Electrical work. All electrical work will be done with EMT with oil resistant wiring. Separate 15-amp circuit breaker with breaker lock for Btu meter terminated in a 4-inch square “1900” box with cover located near Btu meter.
4. The contractor is responsible for successful hydrostatic test of all installed piping and equipment.

A.1.2.2 Drawings

Figures 5 and 6 indicate the approximate location of all equipment and piping, and will be considered as approximately correct, but it is understood that they are subject to such modifications that are found necessary and desirable at the time of installation so as to meet any job conditions. Any and all such changes will be made by the contractor without extra charge to the HFC**.**

A.1.2.3 Coordination and Supervision

The contractor will provide adequate and competent supervision at all times when work is being performed as well as cooperate with all other trades to avoid interferences and delays.

A.1.2.4 Local Conditions

The contractor should be prepared to do the following:

- Visit the site and become familiar with conditions affecting the work. No additional payment will be made on claims that arise from not being aware of existing conditions.
- Exercise extra care when working in areas where steam supply services may exist. Any costs for repair of damage to such services become the responsibility of the contractor causing damage.
- Provided necessary alterations and connections to existing utilities. When it is necessary to temporarily interrupt a service, arrange with the owner in advance to determine the least disruptive time. Performed work during normal working hours and in conformity with approved work progress schedule.
- Provide temporary services of any nature required to keep the building mechanical services functioning. Remove temporary services when permanent facilities are completed.

A.1.2.5 Protection

The contractor should adhere to the following protective measures:

- When setting up a pipe shop and cutting and threading machines, protect area against staining and abrasion. The cost of correcting any such condition will be charged against the contractor.
- Protect finished floors from chips and cutting oil by use of chip receiving pan and oil proof cover.
- Protect equipment and finished surfaces from welding and cutting spatters with baffles and splatter blankets.
- Protect finished surfaces from paint droppings and insulation adhesive, etc.

A.1.2.6 Product Handling

HFC will purchase and deliver all specified equipment to job site.

- Provide all scaffolding, tackle, hoists, and rigging necessary for placing mechanical materials and equipment in their proper place. Scaffolding and hoisting equipment must comply with applicable federal, State, and local regulations. Remove temporary work when no longer required.

- Arrange for packaging of the equipment that must be hoisted to prevent damage or distortion caused by the hoisting operation.
- Protect equipment from dirt and moisture.

A.1.2.7 Damage and Emergency Repairs

The contractor is responsible for the following repairs:

- Assume responsibility for any damage caused by leaks in the piping system installed or reworked under this contract. Repair the damage without extra cost to HFC.
- HFC reserves the right to make emergency repairs as required to keep equipment in operation, without voiding the contractor's guarantee or relieving responsibility during warranty period.
- Restore grounds, insulation, piping, building, etc. to original condition whenever the work causes damage.

A.1.2.8 Guarantee and Warranties

The contractor warrants that equipment and all work is installed in accordance with good plumbing practice, that equipment meets requirements specified as well as guarantees that work is completed in a reasonable time and corrective measures on components not operating as specified.

A.1.2.9 Equipment Supports

The contractor will provide all supports, shelving, brackets, inserts, and anchor bolts for all equipment and items supplied and installed.

A.1.2.10 Cutting and Patching

The contractor is responsible for cutting, patching, and fitting work that may be required to make its several points come together properly. The contractor must lay out the work to avoid unnecessary cutting and patching. Cutting and patching of all holes in walls, partitions, floors, building chases, or other openings that may be required, will be done at the contractor’s expense.

A.1.2.11 Material and Workmanship—General Requirements

The contractor will carefully examine and check the provided documents before accepting the contract, starting work, or purchasing any materials—and will call attention to any changes or additions that are necessary to fulfill guarantees called for. By not drawing attention to these additions or changes, it will be assumed that the contractor is in agreement with the contract and will be bound thereby.

A.1.2.12 Codes and Permits

- The contractor will comply with all rules, regulation of New York State, county, and New York City authorities having jurisdiction over the premises.
- Secure and pay for all permits and certificates of inspection required.

A.1.2.13 Standards

The contractor will comply with the applicable provisions of the latest edition of the following industry standards:

- American Society of Testing Material
- American Welding Society Code
- ASME Boiler and Pressure Vessel Code
- ASME Power Piping Code B31.1
- National Electrical Code
- National Fire Protection Association Standards
- NY State Building and Fire Protection Code

A.1.2.14 Products

Quality of Material

- All materials furnished will be new, of the best quality, grade, and current models for which replacement parts are available. The workmanship will be in all respects of the highest quality.

A.1.2.15 Piping Material and Fittings

- Pipe as hereinafter scheduled will conform to the following ASTM designations:
  - Steel Schedule 40: ASTM A-53 Grade A/B
    Note: Seamless Steel Schedule 80 is required for threaded connections for district heating piping.
  - Copper Tube: ASTM B-88
- Fittings as hereinafter scheduled will conform to the following ASTM designations:
  - Cast Iron: A-126
  - Malleable Iron: A-197
  - Steel Welding: A-234
  - Silver Solder: B-88

- The following manufacturers are acceptable for furnishing materials listed under each group:
  - Steel Pipe: National Tube Co. or equal
  - Copper Tube: Chase Brass & Copper Co. or equal
  - Fittings of Cast Iron: Malleable Iron or Brass: Crane Co. or equal
  - Fittings of Welded Steel: Tube-Turn or equal
  - Pipe and Fittings Schedule as shown in Table below.

Table A-1. Pipe and Fittings Schedule

SERVICE	PIPE	JOINT	FITTINGS	RATING psi/F
Steam and Hot Water	40/80 Black	Welded, Flanged	St Steel 300/3000lb	150/300
Secondary Hot Water	40 Black or "L" Copper	Welded, Flanged Screwed, Soldered	L.-125lb; M.I. 125lb; Copper	150/250 150/250
C Cold and Hot Potable Water	"L" Copper	Sol Soldered, Screwed Flanged	Wrought	125/225

- Strainers will be "Y" type of the same size and material as the pipe line in which they are installed. Strainer will be furnished with Monel screens with mesh of 1/16" to protect the flow meters. A strainer will be provided at all equipment that utilizes a precision seat.
- Unions will be as manufactured by E. M. Dart Co. or approved equal:
  - Non-Ferrous: 2 inch and smaller, all bronze body
  - Ferrous: Material compatible with the service pressure and temperature rating.
  - Dielectric unions will be used on all steel to copper joints "EPOS" or equal.

A.1.2.16 Steam and Hot Water Piping

- Piping to be standard weight steel, black, schedule 40 welded, conforming to ASTM Standards A-53 Grade A/B, as manufactured by National Tube Company or approved equal. If threaded valves and fittings are used for district heating, schedule 80 piping will be used for the threaded portion of the piping system.

A.1.2.16 Hot and Cold Potable Water Piping

- Piping will be seamless copper, Type "L," as manufactured by Chase Copper and Brass Co. or equal.
- Fittings will be wrought copper, flanged, sweat or screwed pattern using 95-5 solder. NO OTHER solder will be used.
- Ball valves, sweat ends for water service as shown on the drawings, will be Watts or approved equal.

A.1.2.17 Pressure and Thermometers Gauges

- Pressure gauges will be installed where shown on the drawings.
    - Pressure gauges will be 4.5-inch dial, drawn steel case and ring, white face, black figures.
- Thermometer: 9-inch red mercury with die cast aluminum case and unbreakable lens, separable sockets, white face with black figures. Ranges will be as required so normal operation is at about the middle of the face and adjustable angle if necessary.
    - Thermometers will be located on the equipment and rotated so that they can be read by a man standing on the floor with normal room illumination.
    - Thermometer will be manufactured by Trerice or equal and be industrial series grade.
    - A 30^{o}F to 300^{o}F range thermometer will be used to measure the steam and water temperature. All other thermometers will have the standard range of 30^{o}F to 300^{o}F unless otherwise specified.

A.1.2.18 Water Specialties

- Cold water make-up will have a full range adjustment pressure reducing valve, iron body, built-in-strainer, and anti-siphon check valve, with ASME label as manufactured by Bell & Gossett Company, Taco, Watts or approved equal.
- At every high point, provide a manual air vent valve for system air relief.
- Provide a combination full-flow balance and shut-off valve "Circuit Setter Plus" by Bell & Gossett Co., or approved equal where shown on the drawings.
- Provide a tangential type air separator Bell & Gossett Rolairtrol or approved equal. The air separator is to be constructed for 125 psi working pressure and constructed in accordance to the ASME Code stamped with "U" symbol and supplied with Form U-1 Certifying National Board Compliance. Each unit, when installed and operated in accordance with manufacturer's instructions, should be furnished with a performance guarantee.
- Relief valve(s) will be designed in accordance to ASME code. Each valve will be piped separately no closer than 6 inches to the floor. Relief valve will be sized to relieve 100% of the heating capacity.

A.1.2.19 Heat Exchangers

- Brazed plate type heat exchangers will utilize 316 stainless steel. The maximum working pressure will be 150 psi with a test pressure of 225 psi. Each side of the plate heat exchanger will be tested separately at the respective hydrostatic test pressure.

The brazed plate heat exchanger will be manufactured by Mueller, Tranter, Bell & Gossett or approved equal.

A.1.2.20 Insulation

Insulation jackets, adhesives, and finish throughout will conform to the requirements of NFPA 255 and UL 723 for a maximum flame spread of 25 and ASTM E-84.

Insulation will be as manufactured by Armstrong Cork, CertainTeed-St. Gobian, Owens-Corning, Pittsburgh Plate Glass or approved equal.

Adhesives and finishes will be as manufactured by Armstrong Cork, Benjamin Foster, Insul-Coustic, 3-M Company, Zeston or approved equal or aluminum lagging. Minimum thickness of insulation will be 1.5 inches thick for pipe size 2 inches and less and will be 2 inches for pipe sizes over 2 inches.

A.1.2.21 Backflow Preventers

Backflow preventers will be of the reduced pressure principle type conforming to the applicable requirements of AWWA C506. Backflow preventer will be of bronze material, 125 psi and manufactured by Watts or approved equal.

A.1.3 Installation

A.1.3.1 Pipe Installation by Contractor

- The location of piping, as indicated in Figures 5 and 6 unless otherwise noted, is diagrammatic only, and the exact location will be the responsibility of the contractor for the correctness of field dimensions and will check all grades, lines, measurements and other data in anyway affecting the work. Make offsets as may become necessary to meet the actual field conditions. The contractor will not be entitled to any extra compensation for any additional work or expense arising from his failure to do so.
- The contractor will use every precaution in the installation of all classes of piping to prevent dirt, chips, or other foreign material from entering the interior of piping. All pipes will be cleaned and blown out to the satisfaction of the HFC before closing of any line. The ends of piping and openings in the apparatus of fittings will be capped or plugged during the construction of the system to keep out dirt or foreign matter. The caps and plugs are to remain until permanent and final installation is made.

- Pipe sleeves, inserts, hangers, and supports as well as equipment supports will be furnished and set by the contractor, along with responsibility for their proper and permanent location. Pipe will not be permitted to pass through footings. The contractor is responsible for the cost of any cutting and patching to be required for pipes where the above were not installed or where improperly located. Suitable hangers and supports will be furnished for all horizontal and vertical piping.
- All steel pipes, throughout the job, will be reamed smooth and all burrs removed before being installed. Pipe or tubing will not be split, bent, flattened nor otherwise injured, either before or during the installation. Full lengths of pipe will be used wherever possible.
- Reducing fittings will be utilized in making reductions in size of pipe. Bushings will not be allowed.
- Unions or flanges will be installed at all equipment and at other such places as may be necessary to disconnect piping or at each piece of equipment or accessory which may have to be disconnected to make repairs.
- All piping connections to risers or equipment will be from the top of mains. Particular care will be used to assure proper air venting.
- Piping subject to expansion will be flexible and installed to safely absorb all defection stresses. All piping will be erected to insure a perfect and noiseless circulation throughout the system.

A.1.3.2 Hangers, Anchors, and Supports

- Equipment and accessories will be set level plumb and in proper alignment with walls and floors.
- All piping and equipment will be supported in a substantial and safe manner rigidly strong to prevent vibration from any cause and anchored sufficiently to prevent undue strain on branch lines connection fixtures or equipment. Pipe will be supported to maintain grade and pitch. Hangers, etc. will permit the piping to expand and move as necessary.
- All hangers will be installed to maintain required grading and pitching of lines and so as to prevent vibration while allowing for proper expansion and movement of piping and will be secured in approved inserts wherever possible and practicable. Field drilling where required will be done by the contractor.
- Piping will be supported at all changes of direction, base of risers and on all branch lines regardless of lengths.
- Where two or more lines run parallel, approved type trapeze hangers may be used.
- Approved bolts and inserts will be used for connecting hanger supports, fixtures, or equipment to masonry. Wooden plugs will not be used. Provide necessary templates and bolts. Set bolts in sleeves of proper length and size.

- The use of perforated strap iron will not be permitted. Piping on side walls will be supported from approved "J" type bracket. No piping will be hung from piping or equipment of other trades. Hangers will be wrought iron, malleable iron, copper or steel as manufactured by Grinnell or approved equal. Roller type hangers will be used on all insulated lines and all piping 3 inches and larger. Clevis type hangers will be used on all 2.5 inches and smaller pipe size.

A.1.3.3 Insulation Installation

- General: The work covered by this specification will consist of furnishing all labor, equipment, material and accessories and performing all work necessary for the installation of all insulation for all piping.
- Insulation will be applied to clean, dry surfaces. Piping will be tested before insulation is applied or joints will be left uncovered until tests have been performed. All lumps of plaster, cement, and paint will be removed before insulation.
- All insulation will be installed in complete accordance with the manufacturer's instructions and recommendations.
- All sections of insulation will be tightly butted together. Laps will be applied according to manufacturer's published recommendations to maintain a tight seal on the lap, a field coat of vapor barrier adhesive will be applied. In areas where insulation is run exposed, laps will face the wall or ceiling to enhance appearance; in concealed areas they will face downward to facilitate inspection.
- The piping may be insulated before testing, leaving all fittings and joints uninsulated until after hydrostatic tests are completed.

A.1.3.4 Electrical Installation

The contractor will furnish and install all power and control wiring from power source to all components for a complete installation including circuit breakers and enclosures if necessary. All electrical work will match existing wiring (i.e., conduit, electrical metallic tubing, romex) and be in accordance with the National Electrical Code.

Contractor will provide a separate circuit with a 15-amp circuit breaker with a breaker lock for the flow meters.

A.1.3.5 Hydrostatic Tests

The hydrostatic test will be conducted by the contractor in accordance with all applicable codes and witnessed by HFC.

A.1.3.6 Pipe Welding Requirements

The contractor will use 300/3000 pound rated welded fittings. Socket welded fittings up to and including 2-inch pipe will be fully seated, then backed off approximately 1/16 inch between end of pipe and bottom of fitting. Seal welding of pipe threads or bolt threads is prohibited.

Contractor will conform to American Society of Mechanical Engineers (ASME) or American Welding Society (AWS) welder performance qualifications before the start of welding. This qualification may be substituted in place of the Engineers' standard as stated in paragraph 3.08. Proof of welder performance qualifications will be on record with the Engineer prior to the start of any welding.

Appendix B: Equipment Specifications

Table B-1: STEAM METERS

Identification	SM-1, SM-2
Function	Steam Flow Metering
Manufacturer	E&H or compatible
Flow Range	100 to 700 lb/hr
Type	VORTEX
Turndown Ratio	40/1
Temperature range	60 to 600F
Pressure Rating	250 psig
Accuracy	<1%
Display via	4…20 mA signal
Body	SS Casting
Connection	Flanged

Table B-2: HOT WATER BTU METERS

Identification	HWM-1, HWM-2
Function	BTU Metering
Manufacturer	ISTEC or compatible
Capacity Range	50,000 to 500,000 BTU/hr
Type	Turbine with Pulse Output
Turndown Ratio	40/1
Temperature Range	60 to 300F
Pressure Rating	150 psig
Accuracy	<1%
Display Via	4…20 mA signal
Body	SS Casting
Connection	Flanged
Temperature Sensors	Platinum RTDs
Power Supply	10-Year Lithium Battery

Table B-3: COLD WATER METERS

Identification	CWM-1, CWM-2
Function	Cold Water Flow Metering
Manufacturer	AMCO or compatible
Capacity Range	50 to 700 lb/hr
Type	Turbine with Pulse Output
Turndown Ratio	40/1
Temperature Range	30 to 120F
Pressure Rating	50 psig
Accuracy	<1%
Display Via	4…20 mA signal
Body	Brass
Connection	Threaded
Temperature Sensors	Platinum RTDs
Power Supply	10-Year Lithium Battery

Table B-4: ELECTRIC METERS for EXISTING ELECTRIC PUMPS

Identification	EM-1, EM-2
Function	Electric Consumption and Load
Manufacturer	GE kV2c or compatible
Capacity Range	3000 to 60,000 kWhr
Type	Commercial ANSI Meters
Communication Interface	RS232/485
Display via	400mA signal
Accuracy	0.20%
Data Storage	Yes
Programming	Versatile with Softswitches

Table B-5: FISONIC DEVICES

Identification	FD-1, FD-2
Function	Heating Water
Manufacturer	DIVISION LLC
Steam Capacity	700 lb/hr
Water Capacity	50 gpm
Type	UL approved

Table B-6: RECIRCULATING PUMPS

Identification	RP-1,RP-2
Quantity	2
Manufacturer	B&G or EQUAL
Rated Speed,rpm	1750
Rated Capacity,gpm	50
Total Dinamic Head,ft	110
Motor Horcepower,HP	2

Table B-7: ELECTRIC METERS for RECIRCULATING PUMPS

Identification	EM-4,EM-5
Function	Electric Consumption and Load
Manufacturer	GE kV2c or compatible
Capacity Range	3,000 to15,000 kWhr
Type	Commercial ANSI Meters
Communication Interface	RS232/485
Display via	400mA signal
Accuracy	0.002
Data Storage	Yes
Programming	Versatile with Softswitches

Table B-8: AIR ELIMINATORS

Identification	AS-1 and AS-2
Quantity	2
Manufacturer	B&G or EQUAL
Rated Capacity	50gpm
Design Pressure	125 psig
ASME Code	Stamped
Compression Tank Outlet	1.5 " NPT

Table B-9: EXPANSION TANKS

Identification	E-1 and E-2
Quantity	2
Manufacturer	B&G or EQUAL
Volume	100 gal
Design Pressure	125 psig
ASME Code	Stamped

Table B-10: SEPARATORS

Identification	AS-1 and AS-2
Quantity	2
Manufacturer	B&G or EQUAL
Rated Capacity	50gpm
Design Pressure	125 psig
ASME Code	Stamped
Compression Tank Outlet	1.5 " NPT

Table B-11: PLATE AND FRAME HEAT EXCHANGERS

Identification	HX-1 and HX-2	
Quantity	2	
Manufacturer	Alfa-Laval or Equal	
Type	Brazed, ASME Stamped	
Heat Transfer,MBH	500	
Temperatures	Supply from FD	Return from FD
Inlet Temperature,F	220	180
Outlet Temperature,F	150	120
Pressure Drop,psig	2	5

Table B-12: VORTEX DEAERATORS

Identification	VD-1, VD-2
Function	Water Deaeration
Manufacturer	Division LLC or compatible
Capacity	50gpm
Type	Vortex
Temperature Range	60 to 300F
Pressure Rating	125psig
ASME Code	Stamped
Piping Connection	1.5"NPT

Table B-13: PRESSURE RELIEF VALVES

Identification	R-1 and R-2
Quantity	2
Manufacturer	WATTS or Equal
Rated Capacity	500 MBH
ASME Code	Stamped
Set Pressure/Temperature	150/210 psig/F
Inlet/Outlet Pipe Size	2/2 inch

Table B-14: TEMPERATURE CONTROL VALVES

Identification	TCV-1 and TCV-2
Quantity	2
Manufacturer	JC or Equal
Design Flow	50-700 lb/hr
Max. Pressure Drop	4 psig
Min.Turn Down	30/1
Max. Pressure Rating	125 psig
Min. Cv	27gpm
Min. Close Off Pressure	50 psig

Table B-15: PRESSURE CONTROL VALVES

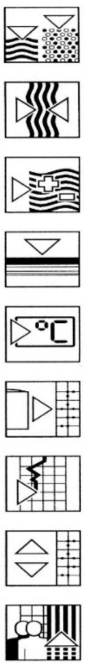
Identification	PCV-1,PCV-2
Manufacturer	JC or compatible
Type	Electric
Design Flow	50gpm
Maximum Pressure Drop	4 psig
Pressure Rating	125 psig
Minimum Turn Down	30/1
Min. Close Off Pressure	100 psig

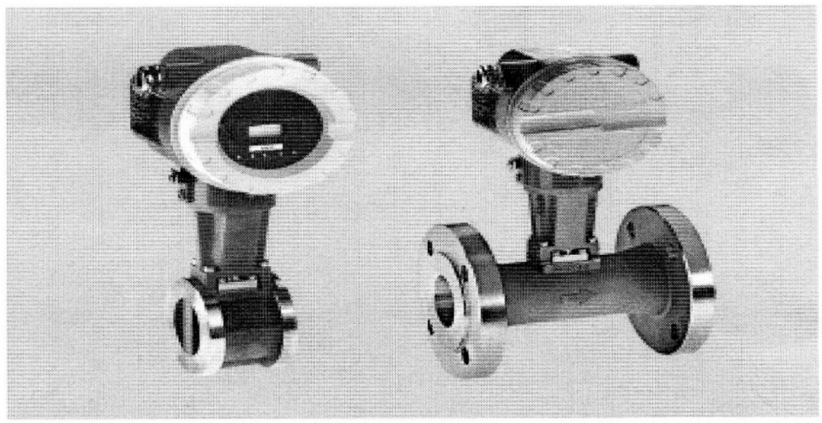
B.1. STEAM METERS

Technical
Information
TI 040D/06/en
No. 50084974

Vortex Flow Measuring System *prowirl 77*

Reliable Flow Measurement of Gases, Steam and Liquids





Safe
- Verified electromagnetic compatibility according to IEC and NAMUR
- Every instrument hydrostatically pressure tested
- Sensor and electronics self-diagnostics with alarm function
- Proven capacitive sensor: high resistance to thermal shock, water hammer and vibration
- Sensor, meter body and bluff body made of stainless steel, NACE MR 0175 conform

Accurate
- Low measuring uncertainty: <1% o.r. (gas, steam) <0.75% o.r. (liquids)
- Wide turndown of up to 40:1
- Every flowmeter wet calibrated

Flexible
- One standard, compact flowmeter for all fluids and a complete process temperature range of –200...+400 °C
- Available in pressure ratings up to PN 160/Cl. 600
- Flanged and high pressure version with standard ISO face-to-face lengths (DN 15...150)
- Wafer version with standard 65 mm face-to-face length

Universal
- HART communication for remote reading and configuration
- Fieldbus communication via PROFIBUS-PA interface
- Operating under E+H Windows software "Commuwin II", can be fully configured off-line
- Output signal simulation

Endress+Hauser
The Power of Know How

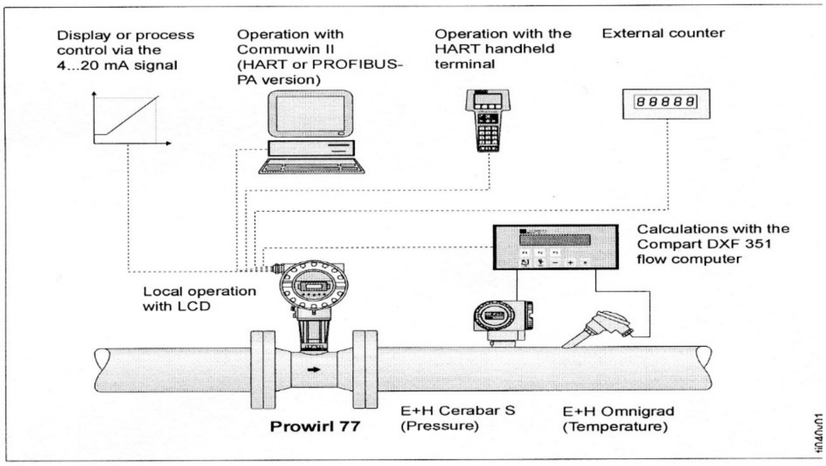
Measuring System

Applications

The Prowirl 77 vortex flowmeter is suitable for measuring the volumetric flow of steam, gases and liquids from –200...+400 °C and up to a pressure rating of PN 160/ANSI Cl. 600.

Prowirl 77 is commonly used for utility measurements as well as in process applications in various branches as Chemicals, Petrochemicals, Power and District Heating.

Prowirl 77 measures the volumetric flow at operating conditions. The E+H Compart DXF 351 flow computer calculates the flow in mass, energy or corrected volume units from signals of Prowirl 77 and additional pressure and temperature transmitters. If the process pressure and temperature at the measur ing point are constant and accurately known, Prowirl 77 can also be pro- grammed to display the flow rate in these units.



Prowirl 77 can be used as an individual meas- urement instrument or as part of a process control system.

Transmitter

All Prowirl 77 transmitters have the following features:

- Self-monitoring electronics and sensor
- IP 67 / NEMA 4X ingress protection
- Built-in electromagnetic interference immunity (EMC)

Versions

The Prowirl 77 transmitter is available in the following versions:

- PFM (unscaled two-wire current pulse)
- 4...20 mA/HART
- PROFIBUS-PA

All versions can be supplied either for safe area use, or for hazardous areas as intrinsically safe ("Ex i") or explosion proof ("Ex d") versions (For PROFIBUS-PA, Ex i or safe area only).

PFM

This is the most basic version, with a two-wire PFM pulse output for connection to the E+H Compart DXF 351 flow computer. All settings required can be made by using DIP switches on the transmitter.

4...20 mA / HART

This version has a 4...20 mA current output signal (with optional HART digital communication). The transmitter is avail- able with either LCD and keys for local operation or as a blind version. Instruments with display and operating keys can also be set to output either scaleable voltage pulses (Open Collec- tor) or unscaled current pulses (PFM). After a loss of power supply the totalizer remains at the value last shown.

HART communication enables the instru ment to be remotely configured and measured values to be displayed. Complete off-line configuration can also be carried out using the Windows- supported E+H Commuwin II software.

PROFIBUS-PA

With a PROFIBUS-PA version, a connec- tion to fieldbus systems according to the IEC 1158-2 international standard at 31.25 kbit/s is possible.

Meter Body Construction

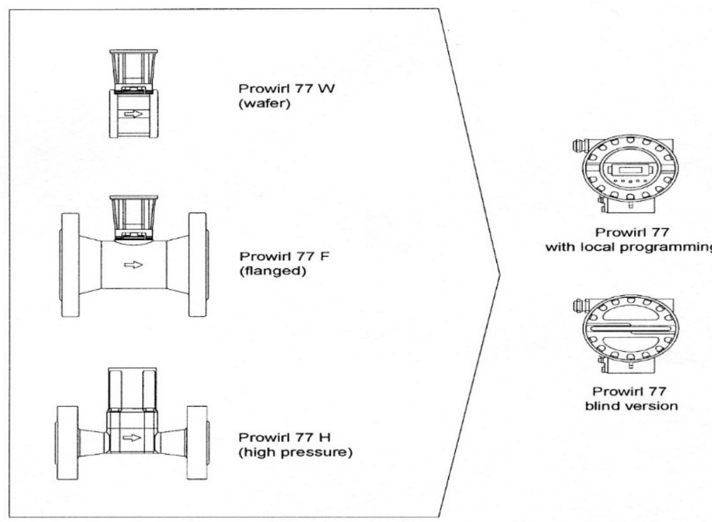
All Prowirl 77 meters have the following features:
- High resistance to water hammer in steam lines due to the steady fixing of the cast bluff body.
- Quality stainless steel casting, according to NACE MR 0175, all wetted parts traceable to 3.1B
- Hydrostatically pressure tested
- TÜV preliminary testing (nominal diameters DN 15...150)

Prowirl 77 W
(Wafer, DN 15...150)
This space-saving wafer body is wide and mounted easily with th of a mounting set (see page 7). enables easy and accurate cent the meter body in the pipeline.

Prowirl 77 F
(Flange, DN 15...300, bigger nor diameters on request)
This design offers standard ISO face lengths (DN 15...150).

Prowirl 77 H
(High pressure, DN 15...150)
This sensor is designed for the u at high process pressures up to PN 160/Cl. 600 and features star ISO face-to-face lengths as well.

Measuring system Prowirl 77

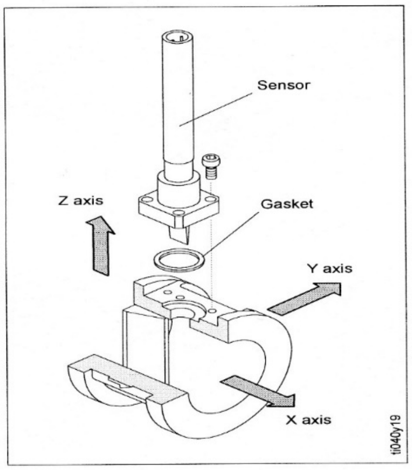


Calibration

All Prowirl 77 flowmeters are subject to wet calibration before leaving the factory.
For use as a quality-relevant measurement point (ISO 9000), Prowirl 77 is available with calibration procedures traceable to EN 45001 and corresponding internationally recognised certificates according to regulations of EA (European Organisation for the Accreditation of Laboratories).

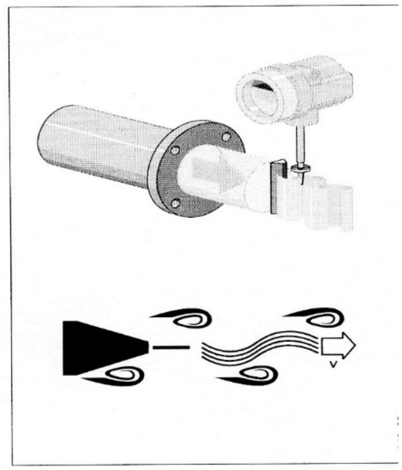
Function

Capacitive Sensor
The sensor of a vortex flowmeter has a decisive effect on the efficiency, ruggedness and reliability of the entire measuring system.
The proven E+H patented capacitive measurement technique (in more than 50'000 installations world-wide) is designed into the Prowirl 77.
The sensor is mechanically balanced so that pipeline vibrations are directly eliminated and do not have to be filtered out electronically. Prowirl 77 is in every axis insensitive to vibrations up to at least 1 g in the full frequency region to 500 Hz.
These specifications also apply to the most sensitive Y axis (see Fig. below), the axis in which the sensor detects vortex shedding.



The high sensitivity of the sensor guarantees measuring ranges that start at low values even with low fluid densities, enabling a wide turndown.
The design and position of the capacitive sensor behind the bluff body ensures that it is especially resistant to water hammer and temperature shock in steam lines.

Measuring Principle
The operating principle is based on the Karman vortex street. When fluid flows past a bluff body, vortices are formed alternately on both sides of the body and are then shed by the flow. Pressure changes are created by the vortices which are detected by the sensor and converted into electrical signals. Within permissible operating limits (see "Technical Data", page 23) the vortices are shed at very regular intervals so that the frequency of shedding is proportional to the flow rate.



The K-factor is used as a constant of proportionality:

$$\text{K-factor} = \frac{\text{pulses}}{\text{volume unit [dm}^3\text{]}}$$

The K-factor is a function of the geometry of the flowmeter and within application limits is independent of flow velocity and of the fluid properties viscosity and density. It is thus also independent of the type of fluid to be measured, whether it is steam, gas or liquid.
The primary measuring signal is already digital (frequency signal) and linearly proportional to the flow rate. The K-factor is determined in the factory by a wet calibration after the production process and is not subject to long-term or zero point drift. The flowmeter contains no moving parts and requires no maintenance.

Planning and Installation

Vortex flowmeters require a fully developed flow profile as a prerequisite for accu flow measurement. The following instructions must therefore be observed when installing Prowirl 77 in the pipeline.

Meter body inner diameters
The process piping internal diameter of a given nominal size varies depending c the class of pipe (DIN, ANSI Sch40, Sch80, JIS etc.). When ordering, part of the order code specifies the type of piping into which the meter will be installed, anc this same piping type is used at the factory for the wet calibration. Both Prowirl 7 (wafer) and Prowirl 77 F (flanged) can be used in DIN, ANSI Sch40 and JIS Sch piping. Sch80 piping is available for the flanged (Prowirl 77 F) and high pressure (Prowirl 77 H) version.

Inlet and Outlet Sections
Where possible, the vortex flowmeter should be mounted upstream of any flow disturbances such as elbows, reducers or control valves. The longest section of straight pipe should be between the disturbance and the flowmeter. The diagrams on the right show the minimum section of straight pipe required downstream from the disturbance as a multiple of the pipe diameter (DN). Where two or more disturbances are located upstream of the flowmeter, the longest recommended upstream pipe section is to be observed.

The section of straight pipe downstream from the flowmeter should be of sufficient length so that the vortices can develop properly.

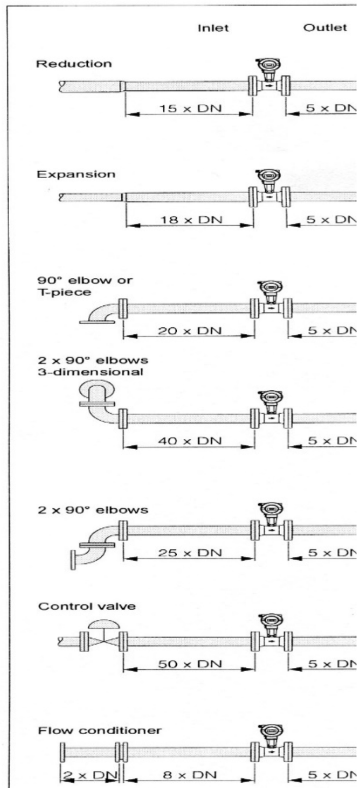
Flow Conditioner
If it is not possible to observe the inlet sections specified above, a specially developed perforated plate flow conditioner can be installed as shown on the right. The flow conditioner is held between two piping flanges and centred with the flange bolts.
As a rule, it also reduces the inlet section required downstream from the flow disturbances to 10 x DN, maintaining full measuring accuracy.

Examples when using the Flow Conditioner

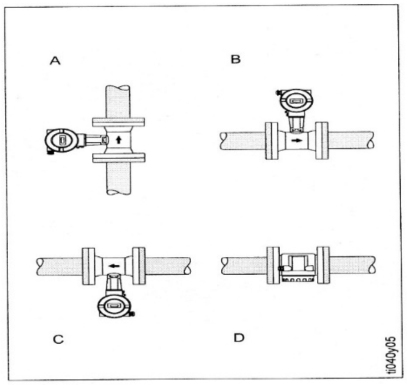
Δp [mbar] = 0.0085 · ρ [kg/m^3] · v^2 [m/s]

- Example with steam:
  p = 10 bar abs.
  t = 240 °C ⇒ ρ = 4.39 kg/m^3
  v = 40 m/s
  Δp = 0.0085 · 4.39 kg/m^3 · (40 m/s)^2
  = 59.7 mbar

- Example with H_2O condensate (80 °C)
  ρ = 965 kg/m^3
  v = 2.5 m/s
  Δp = 0.0085 · 965 kg/m^3 · (2.5 m/s)^2
  = 51.3 mbar



Planning and Installation

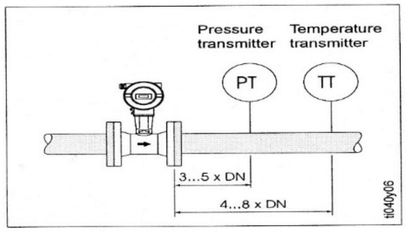


Orientation as a function of fluid temperature

Orientation
The Prowirl 77 can generally be mounted in any position in the piping. An arrow showing the direction of flow is marked on the meter body.

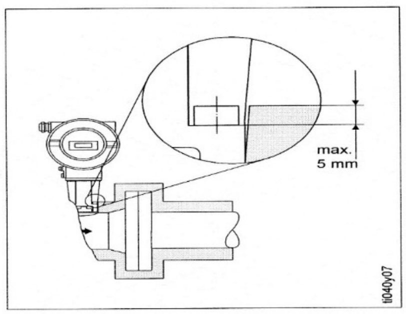
Liquids should flow upwards in vertical pipelines (Position A), in order to ensure that the pipeline is always full.

For horizontal pipelines, positions B, C and D are possible. With hot piping (e.g. steam), position C or D must be selected in order to respect the maximum permissible ambient temperature for the electronics. (For ambient temperatures, see page 24).



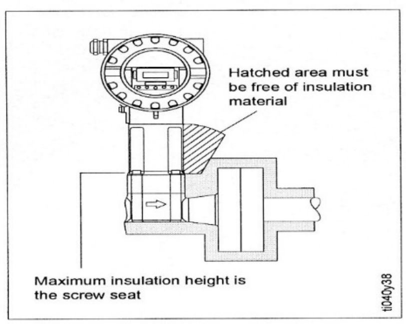
Mounting the pressure and temperature sensors

Pressure and Temperature Measuring Sensors
Pressure and temperature measuring instruments are to be installed downstream from Prowirl 77 so that they do not affect the proper formation of vortices.



Piping insulation wafer/flanged version

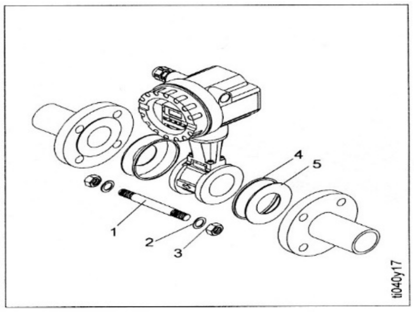
Piping Insulation Wafer/Flanged version
Pipeline insulation is often necessary to prevent energy loss in hot processes. When insulating Prowirl 77, ensure sufficient pipe stand surface area is exposed. The exposed area serves as a radiator and protects the electronics from overheating.



Piping insulation high pressure version

Piping Insulation High Pressure Version
The pipe stand must be free from insulation in order to guarantee temperature radiation and therefore to keep the electronics from overheating.

Mounting Set

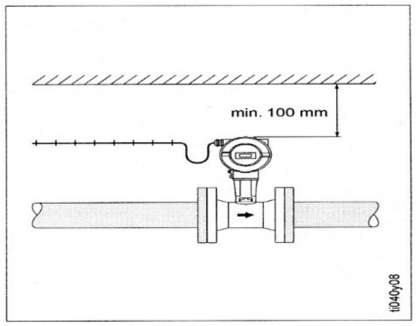


Mounting set for wafer version

Wafer-style flowmeters can be accurately centred using a mou set which consists of:

1 Bolts
2 Washers
3 Nuts
4 Centering rings
5 Gaskets

Minimum Spacing



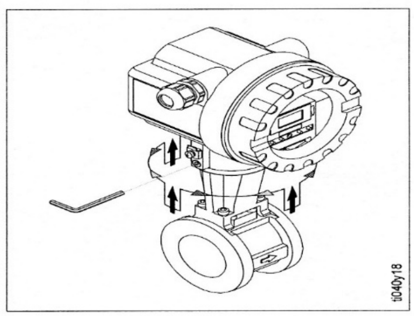
Minimum spacing

When servicing or connecting tl "Flowjack" flow simulator, it is fir sary to unplug the electronics h from the pipe stand. When insta the piping, observe the followin lengths and minimum spacing:

Minimum space:
100 mm in all directions

Cable length required:
L + 150 mm

Electronics Housing



Rotating the electronics housing

The electronics housing can be on the pipe stand in 90° steps s the local display can easily be r

The display unit itself can be tu 180° so that it can be read ever the sensor electronics are mour below (Position C, see page 6).

B.2 BTU and HOT WATER METERS

iSTEC
Flow Measurement & Control

Model 5202
Remote Type BTU Calculating Unit

Measures the total energy used or transferred in a liquid system. BTUs are calculated by multiplying the system temperature difference by the flow. An ideal choice for simple, compact, and cost-efficiency.

FEATURES

- Automatic Heat/Cool Changeover
- Battery or 24V Powered
- Pulse Output for Energy Value
- Additional Meter Inputs
- Liquid Crystal Display
- Chip Card Technology
- Data Storage

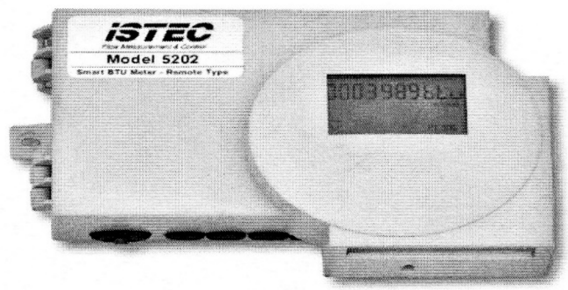
APPLICATIONS

- Combination Heat/Cool Systems
- Heating Only Systems
- Cooling Only Systems
- Solar Systems
- Geothermal Systems
- Efficiency Measuring Verification
- Heat Reclaimers

SYSTEM OVERVIEW

ISTEC BTU Meters measure energy usage by multiplying flow and temperature difference, e.g., BTUs = Flow x ΔT.

As the water (or other liquid) passes through the system piping, the flow meter's turbine rotates and sends impulses to the electronic calculating unit. The sensors of the electronic calculating unit measure the supply and return water temperature. Flow and ΔT are used to calculate BTUs which are displayed on a non-resettable LCD.



HOW TO SELECT A 5000 SERIES BTU METERING SYSTEM

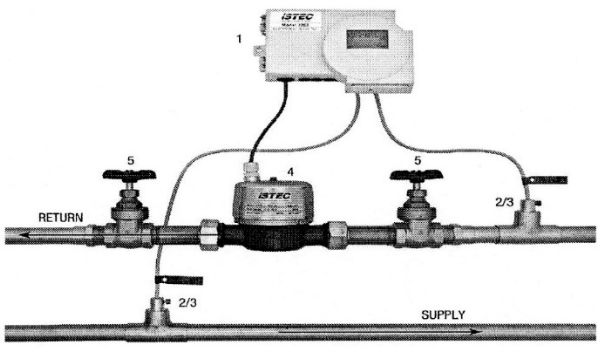
1) Calculating Unit Model 5202 with 6-Year Battery & Open Collector Pulse
2) Power Supply (Choose One):
   10-Year Lithium Battery (P/N 5016)
   24V AC Power Adapter w/Dry Contact Pulse* (P/N 5011)
3) Sensor Set (Choose One):
   Pipe Sizes to 1" (P/N 5601)
   Pipe Sizes 1-1/4" to 3" (P/N 5602)
   Pipe Sizes 4" + (P/N 5603)
4) Immersion Well Set (Choose One):
   P/N 5701 use with P/N 5601
   P/N 5702 use with P/N 5602
   P/N 5703 use with P/N 5603
5) Options & Accessories:
   Chip Card Reader (P/N 5301)
   M-Bus Module** (P/N 5012)
6) Flow Meter with Pulse: **IMPORTANT** – Verify maximum system temperature and pressure as well as flow rate and pipe size before selecting flow meter. Flow Meter must be equipped with pulse output for connection to BTU Meter. See <u>1700 Series Engineering Manual</u> or <u>1800 Series Engineering Manual</u> for details.

** Transformer Required*
*** M-Bus Hub Required*

ISTEC
Flow Measurement & Control

Model 5202
Remote Type BTU Calculating Unit

COMPONENT DESCRIPTION

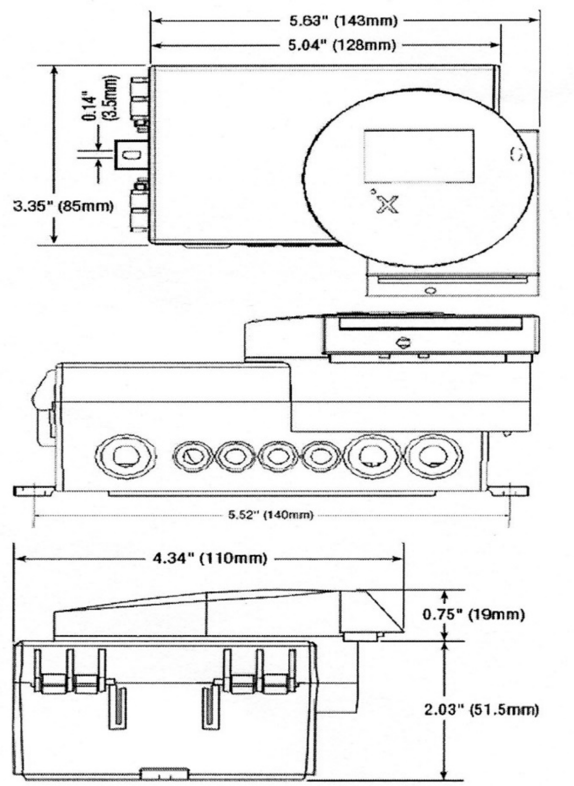


All ISTEC BTU Meter Systems consists of the following components:

1) **Electronic Calculating Unit** (Model 5202) – Solid-state circuitry for accurate and reliable operation with automatic compensation for water density. Non-resettable LCD indicates flow, temperatures and BTU's.
2) **Temperature Sensors** – Platinum RTDs for fast response and high accuracy. Sensors are available in lengths of 1-1/2", 3-1/2" and 5-3/4".
3) **Sensor Wells** – Wells are available in three sizes: 1-1/2", 4" and 6".
4) **Flow Meter** – Industrial grade multi-wing turbine type with pulse output. Sizes up to 1-1/2" have union connections, 2" and larger have ANSI standard 150# flanges.
5) **Stop Valves** – The flow meter should always be installed with a stop valve on each side for easier servicing.

TECHNICAL SPECIFICATIONS

- Temperature Range: 23°F to 356°F (5°C to 180°C)
- ΔT Range: 0.225°F to 333°F (0.125°K to 185°K)
- Ambient Conditions: 14°F to 158°F (-10°C to 70°C)
- LCD: 7-Digit
- Sensors: Platinum RTD
- Power Supply: Battery or 24V AC
- Output: Open Collector or Dry Contact
- Dimensions: L – 5.04" (128mm)
  L1 – 5.63" (143mm)
  H – 3.35" (85.1mm)
  D – 0.14" (3.5mm)



ISTEC
Flow Measurement & Control

Model 5202
Remote Type BTU Calculating Unit

BTU METERING SYSTEM SPECIFICATION:
MODEL 5202 AS MANUFACTURED BY ISTEC CORPORATION

The contractor shall furnish and install as shown on the plans an electronic BTU Metering System. The system shall be designed and programmed exclusively for energy (BTU) metering. It shall be factory assembled, calibrated and tested, incorporating the following features:

ELECTRONIC CALCULATING UNIT

The Electronic Calculating Unit, Model 5202, shall be of solid state microprocessor based construction incorporating Chip Card Technology.

It shall be capable of measuring heating and/or cooling energy (BTU's). The changeover from heating to cooling energy measurement shall be performed automatically. The unit shall contain a non-resettable Liquid Crystal Display (LCD) to continually indicate the total accumulated heating BTU's. The unit shall allow the user to access the following information on the LCD: supply temperature, return temperature, temperature difference, total flow, momentary energy consumption, momentary flow rate, maximum energy consumption and maximum flow rate. In addition, the LCD shall provide status and error indication, including segment test, days-of operation as well as type of error. The Electronic Calculating Unit shall automatically compensate for fluid density. It shall contain a terminal strip for connection to the temperature sensors and flow meter.

CHIP CARD SYSTEM

The Electronic Calculating Unit shall incorporate Chip Card Technology to provide error-free transfer of data to a Chip Card. The Chip Card shall be capable of storing information from approximately 80 units. A Chip Card Reader and software shall be available to transfer the data from the Chip Card into a computer for trend logging and billing purposes.

POWER SOURCE

The Electronic Calculating Unit shall be powered by an integral 6-year battery. An optional 10-year battery or 24V, 60Hz Power Adapter is available.

SENSORS

Temperature sensors shall be the Platinum RTD type to provide high accuracy, stability and long term reliability. The sensor probe shall be available in lengths of; 1-1/2", 3-1/2" and 5-3/4" to accommodate different pipe sizes. They shall be designed to fit tightly into immersion wells that are inserted into the water flow.

SENSOR WELLS

Sensor Wells shall be 1-1/2" long x 3/8" NPT for pipe sizes up to 1", 4" long x 1/2" NPT for pipe sizes 1-1/4" to 3" and 6" long x 1/2" NPT for pipe sizes 4" and above. A locking screw is incorporated to secure the sensor.

OUTPUT

The Electronic Calculating Unit shall provide an open collector or dry contact pulse output proportional to the heating energy count.

FLOW METER

(See 1700 Series Engineering Manual or 1800 Series Engineering Manual for details.)

A separate Flow Meter shall be utilized so various temperatures, pressures and flow rates can be accommodated. It shall be the multi-wing turbine type, Istec Model _________. It shall have a line size of ______ inch(s) (________mm). The body shall be constructed of brass/cast iron. The unit shall have a hermetically sealed mechanical counter, which shall be non-resettable. It shall be constructed so that the flow insert assembly and counter can be replaced without removing the meter body. The Flow Meter shall have an accuracy of + 1.5% at_______ gpm (________ lph). It shall have a continuous flow rating of________ gpm (________ m 3ph). The peak flow, which the meter cannot be subjected to for more than one hour per day, shall be______ gpm (_________ m 3ph). The Flow Meter shall provide a "pulse" type output of 1 contact closure for every 1/10/100 gallon(s) of flow (metric counters provide 1 pulse for every 1/10/100 liter(s) of flow).

ELECTRIC METER

A billing interval meter measures and records electrical use each hour. Data collected by the meter is used to verify load reduction and calculate appropriate payment for participation in demand response programs.

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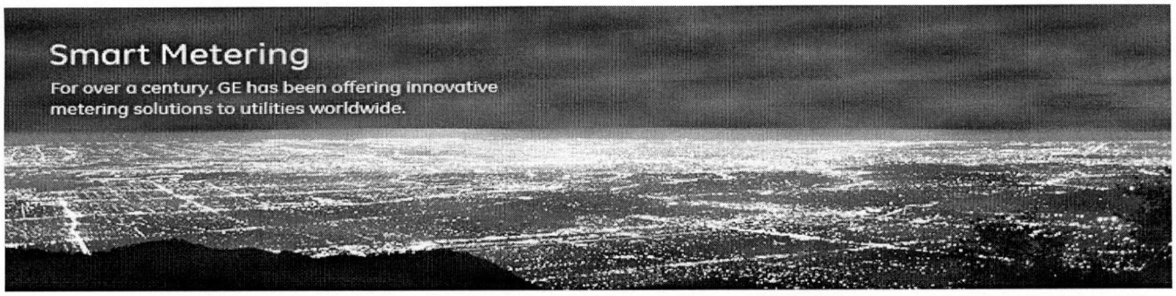
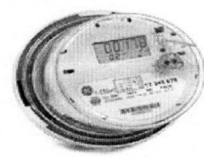


Product Lookup

Smart Metering

- Overview
- ANSI Meters
- IEC Meters
- Software & Tools
- Grid IQ AMI P2MP
- Smart Metering Operations Suite

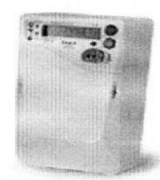
ANSI® Smart Meters



With our I-210™ family of residential, single phase meters and our kV2c™ family of C&I polyphase meters, GE provides a product suite that provides complete smart metering solutions.

→ VIEW ANSI METERS

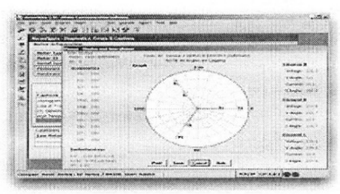
IEC® Smart Meters



The SGM1100™ and SGM3000™ families of IEC Smart Meters represent the expansion of the GE solid-state electronic meter technology into a product line that is compliant to IEC standards. GE offers high quality residential single phase and polyphase smart meter configuration. Both meter families share commonalities based on GE's basic quality principles such as robustness, reliability durability and security, but they differ in the number of additional advanced metering features.

→ VIEW IEC METERS

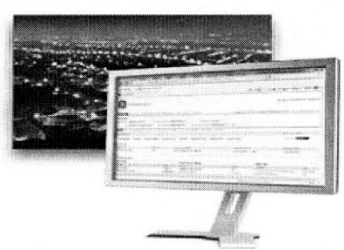
MeterMate™ Software



The task of generating a program for electronic meters can be a complicated one. GE's MeterMate™ program creation software is easy to use and makes the job of creating and maintaining programs for electronic meters simple.

→ VIEW METERMATE SOFTWARE

Grid IQ AMI P2MP



GE's Grid IQ Advanced Metering Infrastructure (AMI) Point-to-Multipoint (P2MP) Solution provides grid connectivity for smart metering, distribution monitoring and sensing applications through a wireless network built from the ground up. Grid IQ AMI P2MP delivers a portfolio of sensing solutions across multiple grid applications with world class geographic coverage.

This solution features SMOS (Smart Metering Operations Suite), a set of software tools to manage and operate your smart meter estate.

Appendix C: Description of Fisonic Systems and Instrumentation Bids

The specification including the Figures 3-1 and 3-2 were distributed to a number of HVAC and instrumentation contractors. As the result of the communication with different contractors three bids were received. The detail bids are presented below. The bidders are briefly described below.

D.P. Facilities (DPF) located at Long Island City, NY, started in 1983 as a design / build firm specializing in "Turnkey" engineering design / construction and maintenance of large scale enterprise mission critical enterprise data centers. In 2000, DPF expanded to joint ventures in real estate development and ownership of data center telecom hotel buildings. Mr. Mark Gerard the president of the company, has over 30 years of experience in all elements of design, development and operations. Mr. Gerard is well familiar with Fisonic devices. DPF provides mechanical, electrical, fire suppression, structural and security services. DPF can produce design drawings, specifications, bid documents and project budgets. DPF's project team includes a full complement of engineers and construction personnel that specialize in constructing various type of facilities. The DPF bid is provided in below. The bid provides a detailed breakdown of all equipment, instrumentation and installation costs. The total bid is $ 516,490.

Mosto Technologies Inc. (MTI) was incorporated in 1997 and has continually served numerous New York facilities. Mr. Steve Mosto, the company president, has been in the New York commercial building market for the past 25 years working with Class A commercial buildings, saving them millions of dollars in energy annually. He founded Mosto Technologies in 1997 and pioneered new technology steam system solutions to reduce Con Ed steam usage through detailed audits, complex metering, and real-time consumption and loss monitoring. By working with Con Ed Steam, consulting engineers, buildings owners/operators and mechanical contractors, he has created a niche expertise that is unique and in demand. Mosto Technologies now provides full energy service support by tracking all utilities in real time, chiller plant optimization as well as full HVAC system efficiency services. Mosto Technologies also partnered with MACH Energy, the leader in real-time energy monitoring and Donnelly Mechanical, a leading mechanical and energy service contractor in NYC. The Mosto bid is provided in below. The bid provides a detailed breakdown of all equipment, instrumentation and installation costs. The total bid is $ 537,552.

The O&M Electric Company located in Manhattan, NY and is in business for over 20 years. The company performs mechanical and electric work in commercial and industrial buildings in New York City area. The O&M Company bid is provided in Attachment. The bid provides a detailed breakdown of all equipment, instrumentation and installation costs. The total bid is $ 523,810.

C.1 Bid Proposals

NYC DOB GENERAL CONTRACTOR LICENSE # **007986**

D. P. FACILITIES INCORPORATED
CONSULTING DESIGNERS / BUILDERS

31-00 47TH AVENUE LONG ISLAND CITY, NY 11101
212-645-4300

December 2, 2015

Mr. Robert Kremer
President
Hudson Fisonic Corporation
44-02 23rd Street
Long Island City, NY 11101

Dear Mr. Kremer

We are pleased to submit our proposal for installation of the testing and monitoring system for the Fisonic Devices at the Woolworth building. Our proposal is prepared in accordance with your specification and attached Figures 1, 2, and 3.As you have requested the proposal includes a detailed breakdown of equipment and installation costs (See Attachments 1-5).

ATTACHMENT 1: System Setup 1 (Fig.1) Monitoring the current energy and water use	
• Instrumentation cost	$38,351
• Instrumentation Installation	$26,840
ATTACHMENT 2: System Setup 2 (Fig.2) Space Heating System with Direct Connection of Fisonic Device	
• Instrumentation cost	$42,559
• Instrumentation Installation	$35,350
ATTACHMENT 3: System Setup 3 (Fig.3) Space Heating System with Separated Fisonic Device	
• Instrumentation cost	$69,925
• Instrumentation Installation	$75,410
ATTACHMENT 4: Main Piping, Supports and Insulation	$104,200
ATTACHMENT 5: Monitoring Equipment	
• Hardware	$31,740
• Software	$6,600
Subtotal	**$429,975**
General Conditions 7.5%	**$32,248**
Subtotal	**$462,223**
Insurance 2.75%	**$12,711**
Subtotal	**$474,934**
NYC Sales tax 8.875 %	**$41,556**
Total	**$516,490**

Please let us know if you have any questions.

Sincerely

Mark Gerard
President

Mosto Technologies, Inc.
244 Madison Avenue #190
New York, NY 10016
212-239-1422 (f) 212-239-4008

Mr. Robert Kremer
President
Hudson Fisonic Corporation
44-02 23rd Street
Long Island City, NY 11101

Dear Robert,
Mosto Technologies Inc. is submitting the proposal for installation of Fisonic systems at the Woolworth building. Mosto proposal is guided by the designs and specification in Figures 1, 2, and 3. As designed in your plans and instructions at the site visit the design proposals for the dual Fisonic systems, have separate installation costs and designs, which are specific for each system's instrumentation and the total cost of piping, supports and insulation.

Piping Works Pipe Supports and Hangers	$	76,000 24,000 12,000
System Setup 1 Installation Cost System Setup 1 Equipment Price	$	36,000 43,825
System Setup 1 Installation Cost System Setup 1 Equipment Price	$	39,500 43,280
System Setup 1 Installation Cost System Setup 1 Equipment Price	$	81,200 79,533
Control and Monitoring Equipment	$	32,550
Subtotal General Conditions 2.5% Subtotal NYC Sales tax 8.875 %	$	467,888 11,697 479,585 42,563 522,148
Total, $		537,552

NYSERDA, a public benefit corporation, offers objective information and analysis, innovative programs, technical expertise, and support to help New Yorkers increase energy efficiency, save money, use renewable energy, and reduce reliance on fossil fuels. NYSERDA professionals work to protect the environment and create clean-energy jobs. NYSERDA has been developing partnerships to advance innovative energy solutions in New York State since 1975.

To learn more about NYSERDA's programs and funding opportunities, visit nyserda.ny.gov or follow us on Twitter, Facebook, YouTube, or Instagram.

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