Demonstration of Performance and Energy Efficiency of Fisonic Devices at the Con Edison Test Facility

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Demonstration of Performance and Energy Efficiency of Fisonic Devices at the Con Edison Test Facility

Final Report

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Abstract

The report presents the results of testing of two types of Fisonic Devices (Fisonic Pumping Device, FPD, and Fisonic Heat Generating Device, FHGD) at Con Edison test facility located at Con Edison Headquarters at 4 Irving Place, New York.

The Fisonic Devices (FDs) are supersonic, condensing heat pumps with a patented internal geometry which causes steam and water to mix and accelerate, converting a minute fraction of fluid's thermal energy to physical trust (pump head) with the outlet pressure higher than the pressure of the working medium at the inlet of the FD. The FD heats the recirculated building water by direct contact with steam and transports the water through-out the building-thus eliminating the tube and shell heat exchanger and the electrically driven pump. The use of the FD allows reducing the terminal temperature difference between steam and water, the required steam consumption, the amount of cold potable water and temperature and flow rate of liquid discharged to the sewer.

The tests demonstrated that: (1) The FPD reliably operates as a direct contact heat exchanger;(2) The FPD has the capability to create discharge pressure higher than the pressure of the working (steam) and injected (cold water) streams, thus operating as a pump; (3) The discharge pressure is increasing with the higher water temperature rise in the FPD; (4) The FPD reliably operates as an indirect contact heater in a domestic hot water (DHW) system resulting in reduction of steam consumption by 14.7% in comparison with the conventional DHW system.

Testing of the Fisonic Heat Generating Device (FHGD) observed small temperature rises from 0.3 F to 1.1 F in a bench-scale piping system.

During the testing of the FD at Con Edison the project team started the commercialization of the FDs by engaging the manufacturer - Division LLC Corporation, located in Long Island City, New York, in fabricating and preparing the necessary facilities and equipment for serial production of FDs. The project team also identified and conducted discussions with a number of Con Edison customers in New York City who has an interest in testing the FD system in their buildings.

Keywords

Acknowledgements

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Acronyms and Abbreviations

°F	degrees Fahrenheit
Btu	British thermal units
Con Edison	Consolidated Edison Company of New York
DHW	domestic hot water
FD	Fisonic device
FPD	Fisonic pumping device
FHGD	Fisonic heat generating device
Gpm	gallons per minute
HFC	Hudson Fisonic Corporation
lbs	pounds
Mlbs	1,000 pounds
m/s	meters per second
MWh	megawatt-hours
NYS	New York State
psia	absolute pressure in pounds per square inch
psig	gauge pressure in pounds per square inch
u	injection coefficient
VOCs	volatile organic compounds

Summary

S.1 Background

Consolidated Edison Company of New York (Con Edison) currently serves electricity, gas, and district steam to about 1,800 large customers in Manhattan and owns three major steam generating plants: 59th station, 74st station, and the new East River combined cycle plant. The total annual electric sales amount to 55 million megawatt-hours (MWh; revenues about $7.5 billion), gas sales to 117 million dekatherms (revenues about $1.6 billion) and district steam sales to 28 million Mlbs (Mlbs = 1,000lbs; revenues about $700 million).

The steam pressure delivered to the customers ranges between 150 and 400 pounds per square inch gauge (psig). The customers use the steam for space heating as well as domestic hot water and cooling (through steam driven and absorption chillers). Many buildings convert the district 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. After steam condenses in heat exchangers, the condensate is discharged to the city sewer system. The discharge of the condensate (maximum discharge flow rate reaches about 10 million pounds per hour during the peaking loads) consumes a substantial capacity of the sewer system and the sewer treatment facilities. To reduce the temperature of the discharged condensate to 150 °F (city requirement), it is mixed with cold potable water, thus further aggravating the sewer system problems. The described system requires expensive heat exchangers (with associated maintenance cost), electrically driven pumps for hot water transport (with associated maintenance and electric cost) and substantial amounts of cold potable water. This situation results in high energy, water and sewer charges to the customers and high make-up water cost for Con Edison steam generating plants.

To improve the end-use energy efficiency for Con Edison customers, Hudson Fisonic Corporation (HFC) and Joseph Technology Corporation (JTC) in close cooperation with Con Edison and under the NYSERDA sponsorship tested and demonstrated the operation of an emerging technology known as the Fisonic Device (FD). Professor Vladimir V. Fisenko developed FDs. These supersonic, condensing devices have a patented internal geometry, which causes steam and water to mix and accelerate, converting a minute fraction of fluid's thermal energy to physical thrust (pump head) with the outlet pressure higher than the pressure of the working medium at the inlet of the FD. The FD heats the recirculated building water by direct contact with steam and transports the water throughout the building, thus eliminating the tube and shell heat exchanger, and the electrically driven pump. Using the FD reduces the terminal temperature difference between steam and water; the required steam consumption; the amount of cold potable water; and temperature and flow rate of liquid discharged to the sewer.

S.2 Purpose of the Project

The purpose of the current project was to install, test, and demonstrate the performance of two types of FDs (Fisonic Pumping Device [FPDs] and Fisonic Heat Generating Device [FHGDs]) at Con Edison test facility, which is located at Con Edison Headquarters (4 Irving Place, New York, NY 10003). The following tasks were performed:

- Design of test installation for the Fisonic devices.
- Preparation of equipment specifications.
- Development of detail testing program and test protocol.
- Selection and design of instrumentation for testing.
- Total installation cost estimate.
- Procurement of equipment and instrumentation.
- Obtaining construction permits.
- Installation of demonstration equipment and instrumentation.
- Construction supervision.
- Testing of two Fisonic devices.
- Analysis of test results.
- Economic analysis.
- Evaluation of benefits and impacts.
- Development of a commercialization plan.
- Preparation of draft and final reports.

S.3 Test Results

The optimum performance of the Fisonic Pumping Device (FPD; stable discharge pressure) depends on the following parameters: cold water temperature increase in the FPD, injection coefficient (u – ratio of the injected cold water mass flow to the steam flow), pressure of the working steam, temperature of the cold water, and back pressure after the FPD.

The tests resulted in the following conclusions:

- The FPD reliably operates as a direct contact heat exchanger.
- The FPD has the capability to create discharge pressure higher than the pressure of the working (steam) and injected (cold water) streams, thus operating as a pump. The tests confirmed that the discharge pressure from the FPD can be higher than the pressure of the working (steam) and injected (cold water) streams when the working steam entering the FPD is under vacuum.
- The FPD reliably operates like a pump and overcomes the resistance of the system in which it operates. This data is in good agreement with test results obtained at the Nuclear Center in Lyon, France.
- The discharge pressure is increasing with the higher water temperature rise in the FPD.
- The injection coefficient is reduced with higher temperature rise in the FPD.
- The FPD reliably operates as an indirect contact heater in a domestic hot water (DHW) system resulting in reduction of steam consumption by 14.7% in comparison with the conventional DHW system.
- The tests results of the FPD are in good agreement with values estimated by the equations presented in this report and prove that these equations could be used for the preliminary design of FPDs .

Testing of the Fisonic Heat Generating Device (FHGD) observed small temperature rises from 0.3 °F to 1.1 °F in a bench-scale piping system. One approach to obtain more conclusive results could be to retest a FHGD in a large commercial building, where the heating system can provide substantial retention time for the water processed in the FHGD and to allow harvesting of all the heat from the small bubbles generated in the FHGD when they collapse. Such tests will be performed during the commercialization of the FDs at district steam customers.

S.4 Benefits of Fisonic Devices

The benefits of FPDs are:

- Reduce the energy cost to existing and new businesses in New York City and New York State (NYS). Estimates demonstrate that use of FPDs for Con Edison customers will reduce their annual electric consumption by about 80% and the steam consumption by about 16% when compared with the existing system (see Section 9 of this report).
- Improve the efficiency of the Con Edison district steam system. Estimates demonstrate that the make-up water flow rate and the total water flow rate to be discharged to the sewer for the FPD system can be reduced by about 50%.
- Facilitate the long-term business growth in the Con Edison service territory and NYS and enhance economic development.
- The reduction of energy cost 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.
- Improve the environmental conditions in New York City.
- Start manufacturing FPDs in New York State and increase employment for the New York-based manufacturer of FPDs.

The potential benefits of using FPDs for the Con Edison customers are estimated as follows:

- **Energy Savings:** Assuming the implementation of FPDs by 30 percent of the Con Edison customers (540 buildings with current steam consumption of about 8.4 million Mlbs per year), the potential reduction in steam consumption will result in annual cost savings to the customers of about $32 million**.** The potential annual savings of the customers in electric consumption are estimated at $6.7 million.
- **Water and Sewer Savings**: For the above assumptions the annual savings associated with cold water consumption and sewer discharge are estimated at $4 million.
- **Job Creation**: Using 32 job years per $1 million of energy savings (EPRI, "Guidelines for Assessing the Feasibility of District Energy Projects," www.epri.com) it is estimated that project implementation will result in creation of 1025 job years.
- **Environmental Benefits:** Using the following emission reduction factors in lbs/yr/Mlb
- NO_x :10.74×10^{-3}; Particulates: 4.3×10^{-3}; volatile organic compounds (VOCs): 1.5×10^{-3}; CO_2: 60
- The environmental benefits are estimated as the following pollution reductions in lbs/year, except CO_2:
- NO_x :15,000; Particulates: 5,900; VOC: 2,100; and CO_2: 37,600 tons/year.

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

The annual primary energy consumption in NYS for buildings and industry is about 1,316 Trillion British thermal units (TBtu) (NYSERDA 2012). Assuming that 5 percent of this energy is supplied by steam with conventional heat exchangers and electrically driven pumps, the current steam consumption can be estimated as 66 million Mlbs/year. Applying the above described methodology for estimating the energy savings with the use of FDs, the potential benefits for New York State are estimated as follows:

- Energy Savings: $386 million,
- Water and Sewer discharge savings: $31 million,
- Environmental Pollution Reductions:
  - NO_x : 116,000 lbs/yr, Particulates : 45,600 lbs/yr, VOC: 16,200 lbs/yr and CO_2 : 290,600 ton/yr.

S.5 Commercialization Plan

During the testing of both FDs at Con Edison testing facility, the project team started to commercialize the FDs by engaging the manufacturer, Division LLC Corporation, located in Long Island City, New York, in fabricating and preparing the necessary facilities and equipment for serial production of FDs. The project team also identified and conducted discussions with numerous Con Edison customers in New York City who has an interest in testing the FD systems in their buildings.

To facilitate wide implementation of FDs the following activities are planned:

- HFC will start manufacturing both kinds of FDs in New York State.
- HFC will start a number of commercial demonstration projects by installing and testing FDs at the Con Edison customers.
- Taking into account the substantial potential energy savings and reduction of condensate and potable water discharge in the city sewer system, HFC will market FDs to the Con Edison customers, city and state administration, consulting engineers, and HVAC equipment vendors. All entities must be comfortable with the concept of using FDs, and all must be convinced of the cost effectiveness and benefits that it will provide.
- Many existing customers are in the process of replacing or upgrading an existing HVAC system, so local engineers and HVAC contractors are in an ideal position to market FDs by providing technical guidance. The city and state administration can also play an important role in marketing, especially when it comes to renovations of existing buildings and new construction, by passing an ordinance that would require every building in the district steam service area consider use of FDs as a prerequisite for obtaining a construction permit.
- HFC is planning to conduct regular seminars aimed at providing to potential customers, consulting engineers, and HVAC equipment vendors complete information concerning the benefits of FDs and recommending retrofit procedures and equipment.
- The results of the demonstration projects will be widely disseminated to the steam customers in the New York City and NYS by publications in technical magazines and presentation to two organizations, namely the Building Owners and Management Association (BOMA) and the Manufacturing Association and Industrial Development Agencies.

1   Introduction

Most of the buildings in New York State that receive district steam (including Manhattan buildings receiving steam from Con Edison) convert it into hot water in tube and shell heat exchangers. The hot water is then distributed by electrically driven pumps through-out the building for space heating and domestic hot water (DHW) service. The steam is also supplied to absorption or steam driven chillers for generation of chilled water. After steam utilization the condensate is discharged to the city sewer system. To reduce the condensate temperature from 215-220 °F to about 150 °F (the city sewer requirement) the condensate is mixed with cold potable water. The described system requires expensive heat exchangers (with associated maintenance cost), electrically driven pumps for hot water transport (with associated maintenance and electric cost) and substantial amounts of cold potable water.

FDs are supersonic, condensing devices with a patented internal geometry which causes steam and water to mix and accelerate, which converts a minute fraction of fluid's thermal energy to physical thrust (pump head) with the outlet pressure higher than the pressure of the working medium at the inlet of the FD. FDs replace both the tube and shell heat exchanger and the electrically driven pump. The FD heats the recirculated building water by direct contact with steam and transports the water through-out the building-thus eliminating the tube and shell heat exchanger and the electrically driven pump. Using FDs allows reducing the terminal temperature difference between steam and water, the required steam consumption, the amount of cold potable water usage and reduction of temperature and flow of liquid rejected to the sewer.

The purpose of the current project was to install, test, and demonstrate the performance and energy efficiency of two types of FDs at Con Edison test facility installed at Con Edison Headquarters at 4 Irving Place, New York, NY 10003. The project was sponsored by New York State Energy Research and Development Authority (NYSERDA), Con Edison, and Hudson Fisonic Corporation (HFC; involved in the development of the FDs).

The report presents the results of performing the following tasks:

- Design of testing installations for both Fisonic pumping devices (FPDs) and Fisonic heat generating devices (FHGDs).
- Preparation of equipment specifications.
- Development of detail testing program and test protocol.
- Selection and design of instrumentation for testing.
- Total installation cost estimate.
- Procurement of equipment and instrumentation.
- Obtaining construction permits.
- Installation of demonstration equipment and instrumentation.
- Construction supervision.
- Testing of two FPDs and FHGDs.
- Analysis of test results.
- Installing and testing a commercial DHW unit equipped with a FD.

- Economic analysis.
- Evaluation of benefits and impacts.
- Commercialization plan.
- Preparation of draft and final reports.

During the demonstration process, the project team also started the commercialization of the FDs by engaging the manufacturer, Division LLC Corporation, located in Long Island City, New York, in fabricating and preparing the necessary facilities and equipment for production of FDs.

1.1   Benefits of Fisonic Devices

The benefits of FPDs are:

- Reduce the energy cost to existing and new businesses in New York City and NYS. Estimates demonstrate that use of FDs for Con Edison customers will reduce their annual electric consumption by 80% and the steam consumption by 16.4 percent (see Section 9 of this report) when compared with the existing system.
- Improve the efficiency of the Con Edison district steam system. Estimates demonstrate that the make-up water flow rate and the total water flow rate to be discharged to the sewer for the FPD system can be reduced by about 50%.
- Facilitate the long-term business growth in the Con Edison service territory and NYS and enhance economic development.
- The reduction of energy cost 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.
- Improve the environmental conditions in New York City.
- Start manufacturing the FDs in the New York State and increase employment for the New York-based manufacturer of FDs.

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

- **Energy Savings:** Assuming the implementation of FDs by 30 percent of the Con Edison customers (540 buildings with current steam consumption of about 8.4 million Mlbs per year), the potential reduction in steam consumption will result in annual cost savings to the customers of about $32 million**.** The potential annual savings of the customers in electric consumption are estimated at $6.7 million.
- **Water and Sewer Savings**: For the above assumptions the annual savings associated with cold water consumption and sewer discharge is estimated at $4 million.
- **Job Creation**: Using 32 job years per $1 million of energy savings (EPRI, "Guidelines for Assessing the Feasibility of District Energy Projects," www.epri.com), it is estimated that project implementation will result in creation of 1,025 job years.
- **Environmental Benefits:** Using the following emission reduction factors in lbs/yr/Mlb (NO_x :10.74×10^{-3}; Particulates: 4.3×10^{-3}; volatile organic compounds (VOCs): 1.5×10^{-3}; CO_2: 60), the estimated pollution reductions in lbs/year, except CO_2, are:

  - NO_x :15,000; Particulates: 5,900; VOC: 2,100; and CO_2: 37,600 tons/year.

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

The annual primary energy consumption in NYS for buildings and industry is about 1,316 Tbtu (NYSERDA 2012).Assuming that 5% of this energy is supplied by steam with conventional heat exchangers and electric driven pumps, the current steam consumption can be estimated as 66 million Mlbs/year.Applying the above described methodology for estimating the energy savings with the use of FDs, the potential benefits for the NYS are estimated as follows:

- Energy Savings: $386 million.
- Water and Sewer discharge savings: $31 million.
- Environmental Pollution Reductions:
  - NO_x : 116,000 lbs/yr, Particulates : 45,600 lbs/yr, VOC: 16,200 lbs/yr and CO_2: 290,600 ton/yr.

2 Theoretical Basis of Fisonic Devices

2.1 Fisonic Pumping Device (FPD)

FPDs are pumps with patented optimized internal geometry. The injected water is typically supplied through a narrow circumferential channel surrounding the working nozzle. In this design, the injected water enters the mixing chamber with high velocity in parallel with the velocity of steam (Figure 1).The mixing chamber typically has a conical shape. The FPDs operate with high expansion and small compression ratios.

Figure 1. Diagram of Fisonic Pumping Device
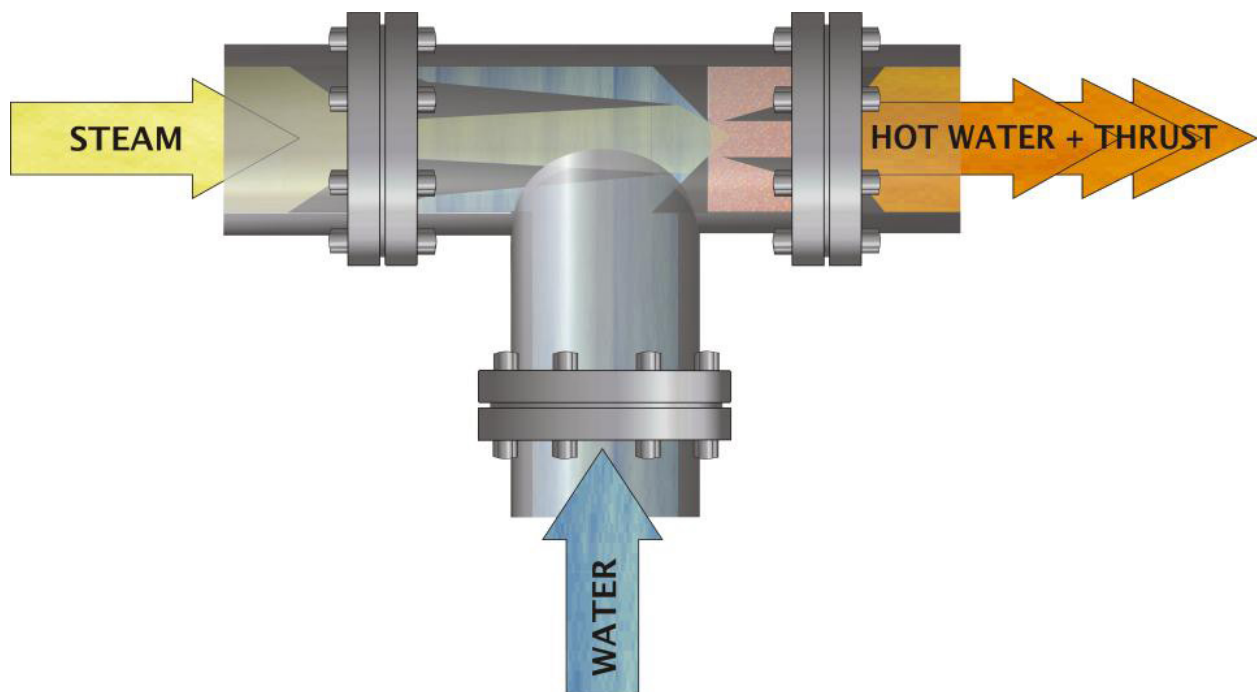
The discharge pressure in the FPDs is typically higher than the pressure of the working (steam) and injected (water) streams (Figure 2). The optimized internal geometry of the FD causes the working (steam) and the injected (water) streams to mix and accelerate, creating transonic conditions and converting the minute fractions of the streams thermal energy to physical thrust (pump head) with the discharge pressure higher than the pressure of the mixing streams. The main reason behind this phenomenon is the high compressibility of homogeneous two-phase flows (Fisenko 1978,1979, 1980, 1981a, 1981b,1987, 1999). The sonic speed in such systems is much lower than the sonic speed in liquids and gases. As shown in Figure 3, the minimum sonic velocity occurs when the volumetric ratio of the streams is 0.5.

Figure 2. Pressure Distribution in the Fisonic Device

P_s – Initial steam pressure

P_w – Initial water pressure

P_d – Discharge pressure of hot water
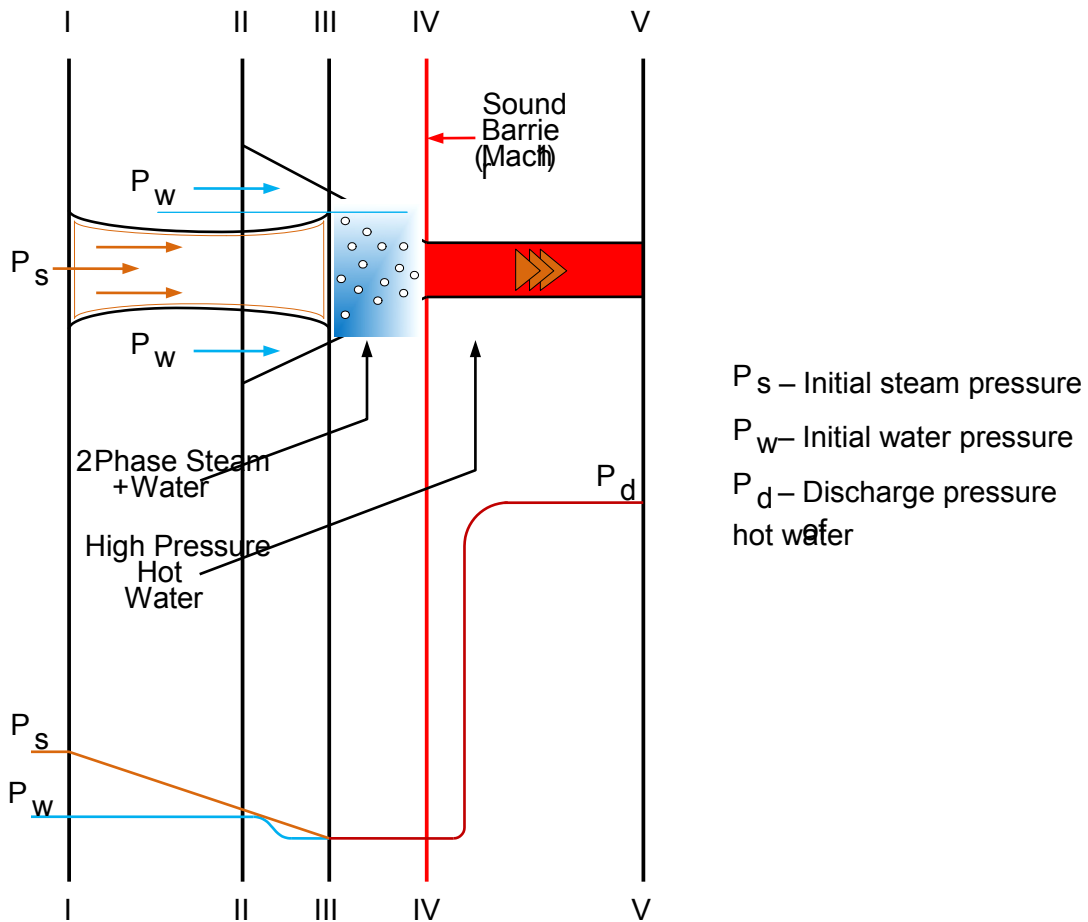
Figure 3 shows that when there is no liquid, the ratio β equals one, and if there is no gas, the ratio β equals zero. When there is 50% liquid and 50% gas (two phase flow), the ratio β is equal 0.5 and the sonic velocity is less than 65 feet per second (ft/s). Generally, the ratio of the mixture is much lower than in gases and liquids alone.

Equation 1 defines sonic speed as:

$$S^2 = \frac{kP}{\rho} \qquad\qquad (1)$$

where:

- k = isentropic exponent of the two-phase mixture, equal to the ratio of specific heats (ratio of the heat capacity at constant pressure to heat capacity at constant volume).
- P = pressure.
- ρ = density of the medium.
- S= sonic velocity (meters per second [m/s]).

Figure 3. The Dependance of Sonic Speed from Volumetric Ratio of Streams

β = ratio of volumetric gas to liquid plus gas composition ($\beta = \frac{V_g}{V_g + V_{ld}}$).
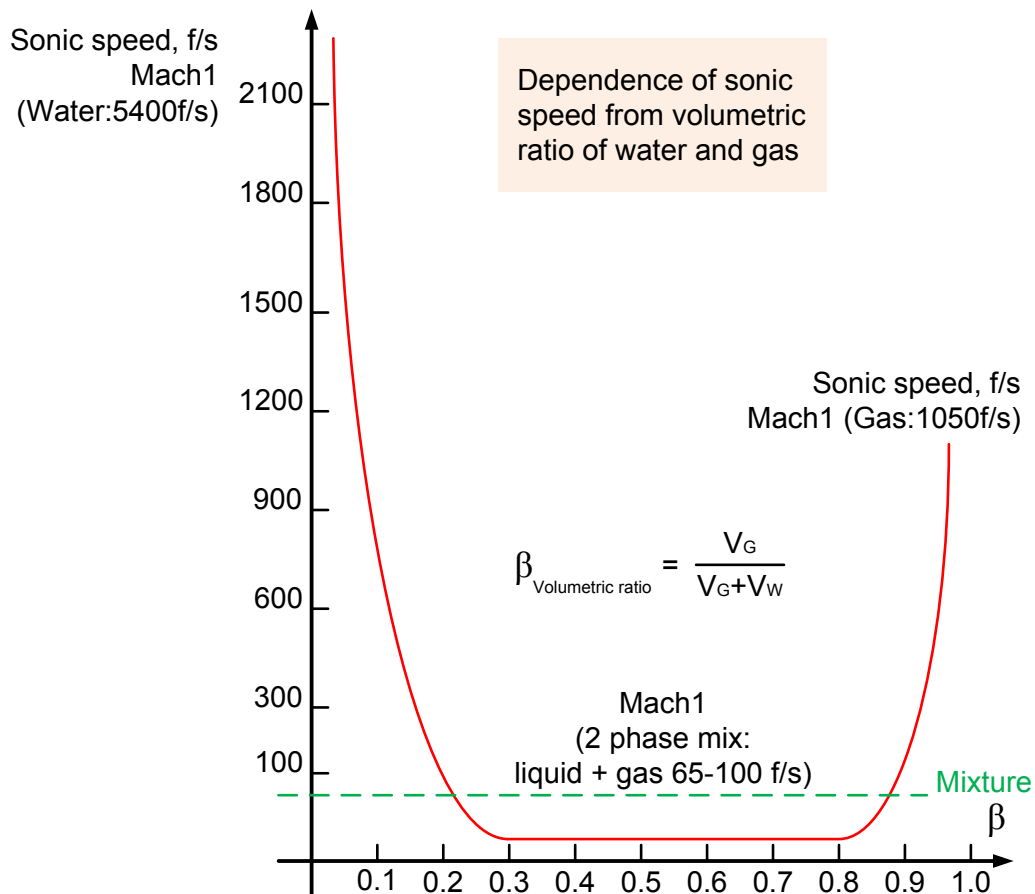
For determining the isentropic exponent (k), Professor Fisenko developed Equation 2:

$$\frac{k_g(k+1)-2k}{k_g-1} = k\,\beta\left[1+\left(\frac{1}{\beta}-1\right)^2\right] - 2\left(\frac{1}{\beta}-1\right)\left(\frac{1}{\varepsilon}-1\right) \tag{2}$$

where:

- k_g = isentropic exponent of gas in the mixture; ε = critical ratio of gas to liquid pressures.
- β = ratio of volumetric gas to liquid plus gas composition ($\beta = \dfrac{V_g}{V_g+V_{ld}}$).

Equation 3 describes the dependence of the discharge pressure after the FPD (jump pressure, P_2) from the pressure before the jump inside of the FPD (P_{bj}):

$$P_2 = k\,P_{bj}\,M^2 \tag{3}$$

where:

- M = Mach Number (the ratio of the flow's speed to the local sonic speed, M = W/S).

Equation 2 shows that the isentropic exponent (k) of a homogeneous two-phase flow is determined by the isentropic exponent of gas in the mixture (k_g) and the ratio of volumetric gas to liquid plus gas composition(β) and does not depend on the liquid characteristics.

For the pressure jump condition, the sound velocity is related to stream velocities by the following relationship:

$$S^2 = W_1 \bullet W_2 \tag{4}$$

where:

- W_1 = stream velocity before the jump.
- W_2 = stream velocity after the jump.

For the homogeneous two-phase flow where the $\rho_g \ll \rho_{ld}$, the $M^2 = \dfrac{1}{1-\beta}$.

Equation 5 describes the work balance of the FD (Sokolov and Zinger 1989):

$$\frac{k}{k-1} P_w V_w \left[\left(\frac{P_w}{P_i} \right)^{\frac{k-1}{k}} - 1 \right] = (P_d - P_i) V_w (u + 1) \tag{5}$$

where:

- $k = \dfrac{C_p}{C_v}$; 1.3 for superheated steam; or 1.13 for dry saturated steam.

- C_p = specific heat at constant pressure.

- C_v = specific heat at constant volume.

- w, i, d subscripts denote the parameters of the working, injected, and discharge streams, respectively.
- P = pressure.
- V = specific volume.
- μ = injection coefficient equal to the ratio of injected and working flow rates.

Table 1 presents some values of discharge pressure (P_d) estimated in accordance with the Equation 5 for different injecting coefficients at the following conditions: the working superheated steam pressure (P_w =145psi, T=395 °F, V=3.36 cubic feet/lb) and the injected water pressure (P_i =14.5 psi, T= 50 °F and V=0.16 cubic feet/lb).

Table 1. Dependence of Discharge Pressure on the Injection Coefficient

μ	20	50	100
P_d (psi)	4,400	1,820	926

In the FPDs, transonic flow of homogeneous two-phase stream is achieved by the reduction of the sonic velocity at Mach Numbers equal or higher than one ($M \geq 1$) at low stream velocities.

As the result of exchange of motion impulses between the working steam and injected water streams, the sonic velocity in the mixing chamber is reduced. The stream at the entrance to the mixing chamber (throat) has a velocity equal or larger than the local sonic velocity. As the result of the stream deceleration, the temperature and pressure at the exit of the mixing chamber increase. The pressure becomes higher than the saturation pressure at the saturation temperature of the mixture. Inside the specific design geometry of the FPD, the discharge pressure can increase by few times higher than the pressure of the working steam. The liquid phase in the mixing chamber is actually a foam type structure with a very highly turbulized surface area, which is why the dimensions of the FD are very small

when compared with conventional surface type heat exchangers. In the diffuser, the steam pressure is further increased.

Substantial differences in this process take place with small differences in injection coefficients. The reduction of injection coefficient, (from a reduction in the injected water flow rate while steam flow rate remains constant), leads to the increase of the water temperature to the saturation temperature corresponding to the pressure in the mixing chamber and, because of the shortage of water for condensation of all steam, the performance of the FPD breaks down. This mode determines the minimum injection coefficient. In this mode, the operational and geometry factors influence the characteristics of the FPD.

With an increase of the injection coefficient (from an increase in injected water flow rate while the steam flow rate is constant), the water temperature in the mixing chamber is reduced. At the same time, the water pressure is reduced because of velocity increase in the mixing chamber. The increase of the flow rate of injected water leads to the reduction of the pressure at the entrance into mixing chamber up to the saturated pressure corresponding to the temperature of the heated water. Reduction of the backpressure doesn't cause the increase of the water flow rate because further pressure drop in the mixing chamber is impossible. This pressure drop determines the flow rate of the injected water and cannot be increased. Further reduction of backpressure at this conditions leads to flashing (cavitation) of the water at the mixing chamber. The cavitation of water in the mixing chamber determines the maximum (limiting) injection coefficient. It should be noted that this operational condition is the working mode of the FPD. This explains the important feature of the FPD – the independence of the discharge flow from the back pressure at the cavitation mode.

The specific characteristics of the FPD are closely related to the geometry of the mixing chamber. Equation 6 describes the discharge pressure after the mixture exits the cylindrical shape mixing chamber of the FPD:

$$P_d = P_w \left[T_{w1} \frac{f_{w1}}{f_3} + \frac{K_1}{\varphi_3} k_w T_{wc} \lambda_{w1} \frac{f_{wc}}{f_3} - \left(1 - 0.5\varphi_3{}^2\right) k_w \left(\frac{2}{k_w+1}\right)^{k_w+1/k_w-1} \frac{V_d}{V_w} \left(\frac{f_{wc}}{f_3}\right)^2 (1+u)^2 \right] + \left(1 - \frac{f_{wc}}{f_3}\right) P_i \ \dots\dots \ (6)$$

where:

- $T_{w1} = P_i/P_w$.
- f_{w1} = cross section of the working nozzle exhaust.
- f_3 = cross section of the mixing chamber exhaust.
- K_1 = working stream velocity coefficient.
- φ_3 = diffuser stream velocity coefficient.
- $T_{wc} = P_c/P_w$ = ratio of pressure in the critical section of the working nozzle to the working pressure.
- λ_{w1} = ratio of the velocity of working stream at adiabatic flow to the critical velocity.
- f_{wc} = cross section of critical section of the working nozzle.

Equation 7 determines the relationship between the pressure at the entrance in the mixing chamber (P_2) and the injection coefficient (u):

$$\frac{P_2}{P_w} = \frac{P_i}{P_w} - \frac{k_w}{2} \left(\frac{2}{k_w+1}\right)^{k_w+1/k_w-1} \left(\frac{f_{p*}}{f_2}\right)^2 \frac{v_i}{v_w} (1+u)^2 \tag{7}$$

where:

- f_{p*} = critical cross section of the working nozzle.

Figure 4 presents the dependence of the discharge pressure on the injection coefficient at different cross section ratios. The increase of cross section ratio leads to the increase of injection coefficient and reduction of the discharge pressure. In the FD, the minimum and maximum injection coefficients are limited by the water boiling conditions in the mixing chamber. Under these conditions, the pressure in the mixing chamber will became lower than the saturation pressure (cavitation) at the water temperature in the mixing chamber. Both these pressures at the given parameters of working steam, injected water, and FD dimensions depend on the injection coefficient.

At the higher temperature of the injected water, the condensation rate of working steam is less intensive than at the colder temperature. At these conditions, the condensation process may not be completed at the entrance chamber and part of the mixing chamber may be occupied with noncondensed working steam. As a result, the cross section area for injected water flow will be partially reduced and the maximum injection coefficient will also be reduced.

Figure 4 shows that for the given conditions and the maximum injection coefficient of 57 (see curve 3), the discharge pressure after the FPD is 23.2 psi and the pressure increase over the injected water is 11.6 psi. At the minimum injection coefficient of 8 (curve 3), the discharge pressure after the FPD is 36.3 psi and the pressure increase of the injected water is 24.7 psi. At the smaller cross section ratio, the working range of injection coefficients is reduced substantially. The discharge pressure at these conditions is increasing. At the maximum injection coefficient of 26 (see curve 2), the discharge pressure is 52.2 psi (a pressure increase of 40.6 psi above the injected water at 11.6 psi). At the minimum injection coefficient of 8 (curve 2), the discharge pressure is 63.8 psi with pressure increase by 52.2 psi. Further reduction of the cross section ratio results in reduction of difference between minimum and maximum injection coefficients until, at some point, they became equal. At the further reduction of the cross section ratio, the FPD cannot be operated.

The limiting injection coefficient can be estimated from Equation 8:

$$u = \sqrt{\frac{2}{k}\left(\frac{k+1}{2}\right)^{\frac{k+1}{k-1}}} \; x \; \frac{f_3}{f_{wc}} \sqrt{\frac{P_i - P_s}{P_w}} \sqrt{\frac{v_w}{v_i}} \; - 1 \qquad (8)$$

where:

- P_s = the saturation pressure in the mixing chamber.

Figure 4. Estimated Performance of FPD

Steam Working Pressure is 87 psi. Injection Pressure is 11.6 psi.

Performance Curves 1, 2, 3, and 4 of the FPD have Different Cross section Ratios of

1; 1.8; 4; and 10, respectively. mn Curve represents Maximum Injection Coefficients.
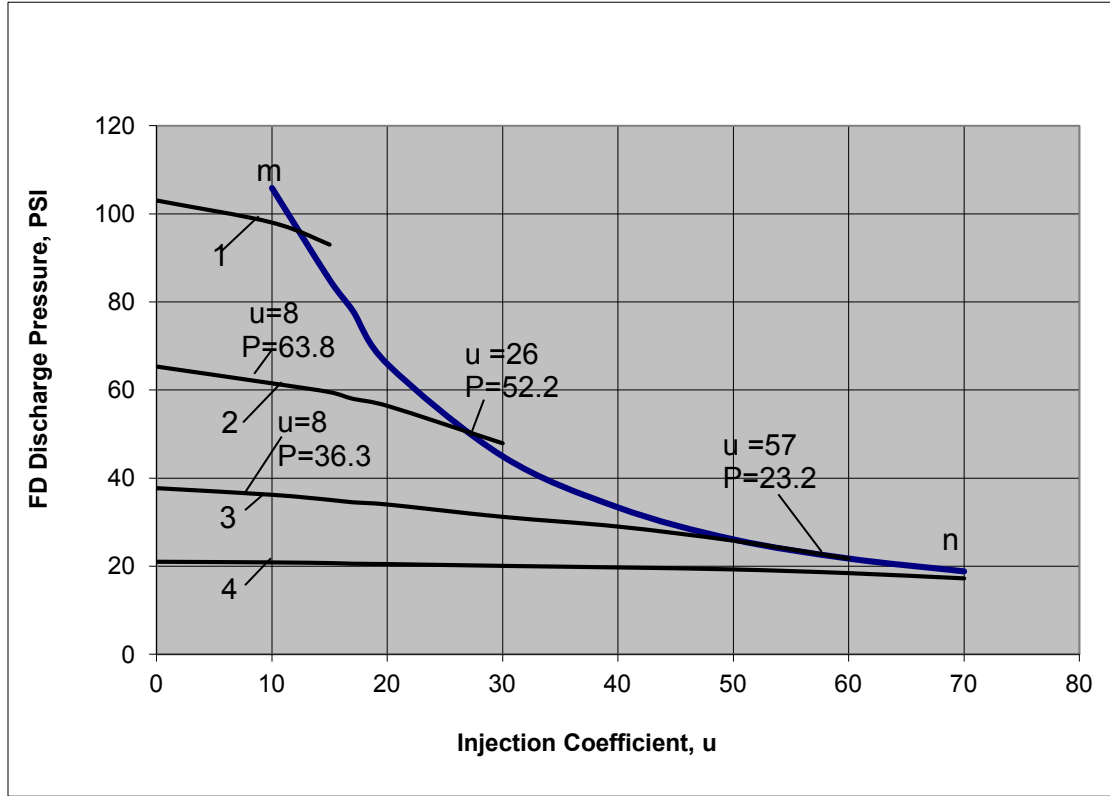
The maximum injection coefficient is estimated from Equation 9:

$$u = \frac{C\sqrt{P_i - P_s}}{(P_d - P_i) + (2 - \varphi_3^2)(P_i - P_s)} - 1 \tag{9}$$

where C is defined by Equation 10, and υ_w and υ_i = specific volume of working and injected streams, respectively:

$$C = \frac{2K_1}{\varphi_3}\sqrt{\frac{k_w}{k_w + 1}}\sqrt{\frac{\upsilon_w P_w \lambda_{w1}}{\upsilon_i}} \tag{10}$$

2.2 Fisonic Heat Generating Device (FHGD)

Recent analysis and testing of FDs performed by Professor Fisenko resulted in a conclusion that conversion of the internal energy of overheated liquid into work can be achieved both with the presence of a "cold" heat-transfer agent and without it. Furthermore, under specific pressure values at the entrance into the FD and specific internal geometric parameters, the "cold" liquid itself becomes the two-phase medium before the pressure jump. From this phenomenon, Professor Fisenko made a controversial conclusion that under the specified conditions, the heat transfer from a less-heated stream to a more-heated stream becomes possible (Fisenko 1999, 2000, 2012; Fisenko and Sychikov 1977).

The experiments, carried out by Professor Fisenko, have demonstrated that by changing the internal geometry of the FPD it was possible to increase the temperature of water in the device by several degrees. In this case, the heat output of the flow after FPD exceeded the power supplied by the electric motor. The task, however, is of having enough time to remove the generated heat before the flow molecular bonds will be restored in the pump, and the temperature of flow is reduced. It should be noted that the power input in the FPD does not have to be an electric motor pump.

Professor's Fisenko's opinion is that all FDs--independent of their application to the larger or smaller degree--realize the effect of obtaining additional heat from the water. At the present time, different methods to generate heat in the FD from the water are in the stage of field experiments (methods published by Dr. Potapov in Russia). The description of two types of Fisonic heat generating devices (FHGD) provided below is based on a recent U.S. patent issued to Professor Fisenko (Fisenko 2012). Figure 5 presents a schematic view of a flow section of a FHGD using liquid (hot water) as a working medium. Figure 6 presents a schematic using steam as a working medium.

Figure 5. Schematic Diagram of FHGD Using Water as a Working Medium
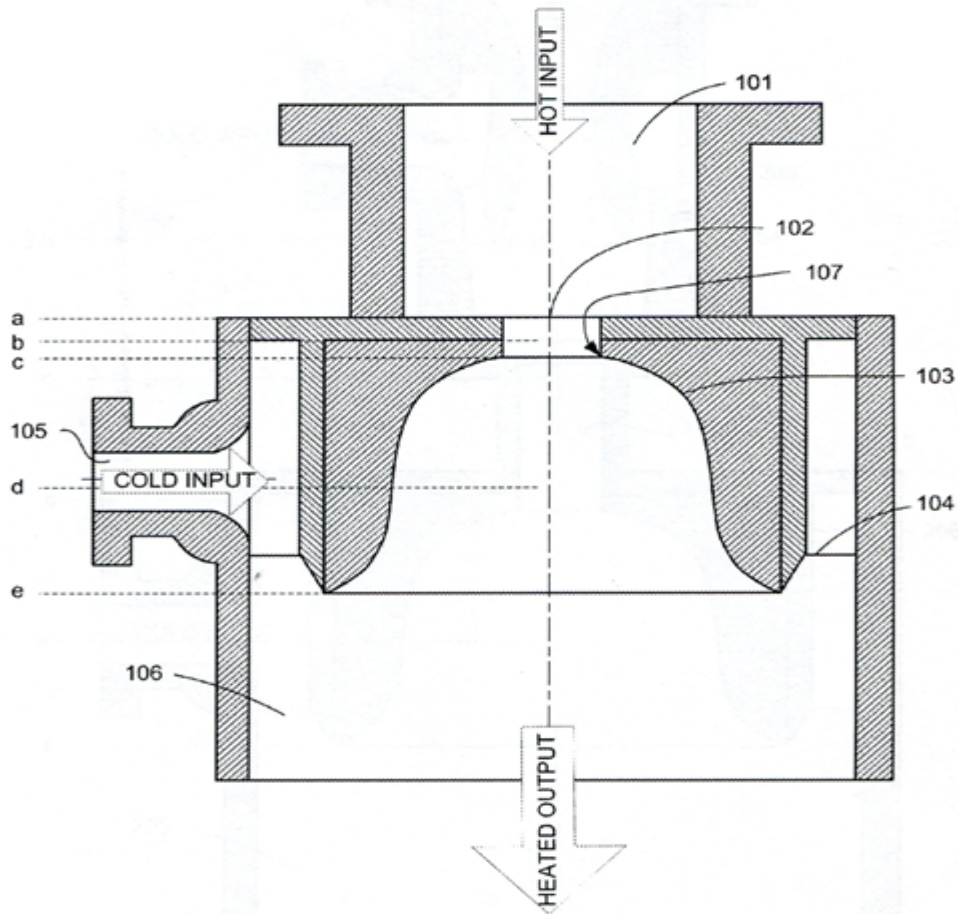
Hot water is fed under pressure into the nozzle 101, and then flows into accelerating diffuser 103 through the vapor generating nozzle 102. In section (a) of nozzle 102, the flow separates from the sharp edge, narrows, and pressure in it decreases, causing boiling of the flow continuing in the narrow section (b). The volumetric ratio of gas to liquid phases becomes equal to one third, the flow becomes supersonic and a sudden change of a pressure takes place in the outlet 107 from the nozzle 102 in the section(c). In the entrance to the accelerating nozzle 103 the flow is primarily liquid with microscopic vapor bubbles, which, being the vapor generating centers, facilitate rapid initiation of liquid boiling while pressure in two-phase flow decreases. The nozzle 103 has a diffusing profile with variable divergence. Here, the mixture's density decreases and velocity increases. In section (d), the flow becomes critical

and it further expands with supersonic velocity. In section (e), the velocity reaches its maximum and the pressure reaches its minimum. Cold water is fed to the annular mixing nozzle 104 through the branch pipe 105. Here the cold water also boils due to the low pressure in the section (e) and mixes with the two-phase flow coming from the accelerating nozzle.

At the exit of nozzle 104, the flows are mixed in such ratios and with such parameters that after immediate exchange of movements the two-phase mixture is fed to the outlet pipe 106 at a supersonic velocity. The transition to the outlet 106 causes a sudden change (increase) of pressure in the pipe 106. During the sudden change of pressure, the dual-phase flow transforms sharply into a homogenous isotropic single-phase liquid subsonic flow characterized by a volumetric gas to liquid ratio of less than one-third. Here, the sharp change of the state of phase flow is accompanied simultaneously by heating of the flow during the sudden change of pressure. The flow of homogenous liquid is filled with microscopic vapor bubbles formed at this stage. This flow is supplied to a consumer as a heated liquid, providing an efficient and rapid thermal transfer from the input heating medium. The process is similar to cavitation and the FHGD has to be manufactured from materials which can sustain the erosion effect.

A FHGD can also use vapor (steam) as a working medium. The vapor (steam) is supplied under pressure into the inlet 101 of the FHGD. Consequently, the cold water is heated by a transfer of a larger amount of heat from the vapor, as well as the process of the formation of the dual-phase flow is intensified. Here, as previously described, two phase conversions are taking place in the flow, i.e., the conversion of the flow of the mixture by the sudden change of pressure and the conversion of the flow to the supercritical conditions. An essential difference exists in that device: the conversion of the flow of the working stream carried out in first device does not require a special acceleration for boiling, and also allows the process of heating the cold stream to be accelerated. The bubbles formed in the liquid after a sudden change of a pressure serve as the centers of vapor generation during the liquid boiling in the accelerating nozzle.

Figure 6 is a schematic view of a flow section for a multi-stage FHGD using vapor as a working medium. The device operates as follows: the vapor is supplied under pressure into the convergent-divergent nozzle 202 section (a). The outflow from the nozzle 202 enters into the mixing chamber 204, while a first cold stream for heating is also fed into the mixing chamber 204 from the receiving chamber 201 through the nozzle 203. During mixing of the streams between sections (b and c) in the mixing chamber 204 downstream of the nozzles 202 and 203, a vapor-liquid mixture is formed. The vapor-liquid flow is accelerated to a supersonic speed by the converging entrance to the cylindrical part 205 of the mixing chamber. The vapor-liquid flow may have a volumetric gas/liquid ratio of about one-third around the entrance to the cylindrical portion 205.

After entering the cylindrical part 205 of the chamber, the vapor-liquid flow decelerates and undergoes a sudden increase in pressure. The cylindrical part 205 may be designed as in Figure 6 to cause the deceleration and pressure increase. With the sudden increase of pressure, the two-phase vapor-liquid flow is changed into a homogenous

isotropic single-phase subsonic liquid flow with entrained microscopic bubbles having a volumetric gas/liquid ratio of less than one third. In addition, heating of this flow occurs during the sudden change of pressure in the cylindrical part 205 of the mixing chamber as a result of the reduction of the vapor phase. The flow is therefore discharged into the downstream nozzle 206 at a subsonic speed and elevated temperature.

Figure 6. Schematic Diagram of FHGD Using Vapor as a Working Medium
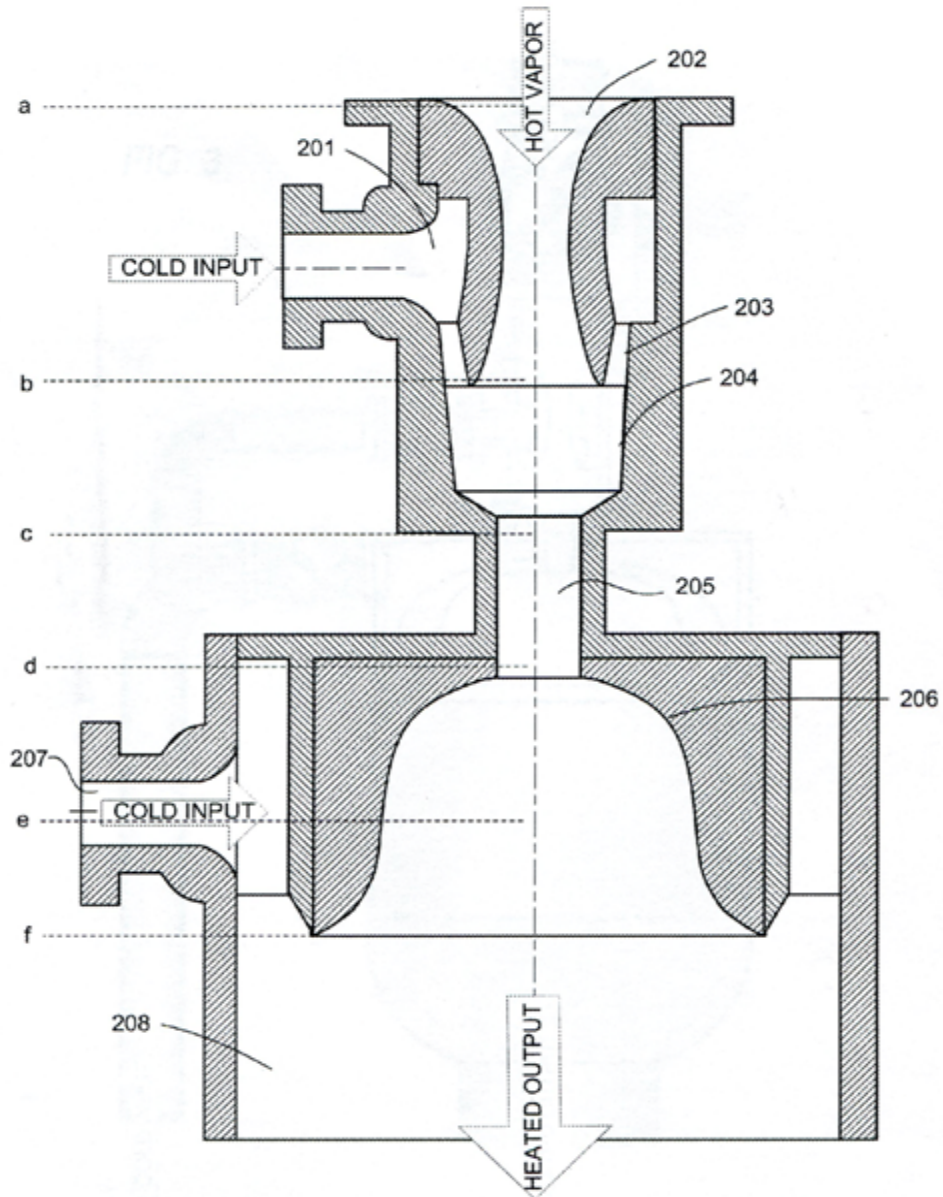
The liquid flow is then accelerated to a velocity at which the liquid flow will boil in the accelerating vapor-liquid nozzle 206. The nozzle 206 may have a diffusing profile with variable divergence, as shown. The process flow again achieves the conditions of a non-homogenous dual-phase flow with a volumetric liquid/gas ratio of more than one third and a Mach number of 1 inside the accelerating nozzle section (e) portion of the profiled divergent nozzle 206. Then, the liquid flow is accelerated to a maximum velocity with a Mach number substantially greater than one in the outlet from the accelerating nozzle 206.

3 Description of the Fisonic Pumping Device (FPD) Test Facility

The demonstration test facility was designed and constructed on the 20th floor of Con Edison headquarters at 4 Irving Place, New York, NY 10003. Figure 7 presents the schematic diagram of the installed FPD.

Figure 7. Schematic Diagram of the Tested Fisonic Pumping Device
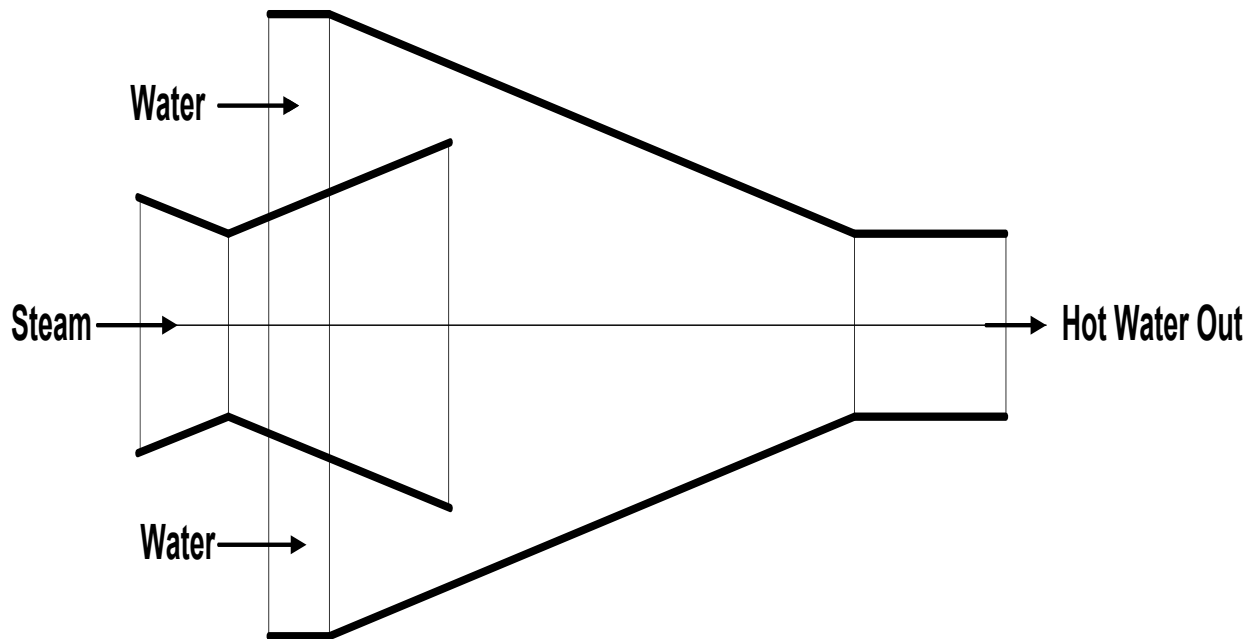
Con Edison limited the steam pressure entering the FPD to 15 psig. To meet this requirement, the FPD was designed with steam supply nozzle of 9.45 millimeter (mm; 0.372 inch) and hot water discharge nozzle of 6.25 mm (0.246 inch). Figure 7 shows that the cold water is injected through a narrow annular gap surrounding the working nozzle so that water is flowing into the mixing chamber at a high speed, directed parallel to the velocity of the working steam coming from the central axis of the FPD nozzle. The mixing chamber has a conical shape, and the discharge nozzle has a cylindrical shape.

The FPD test facility installation is presented in Figure 8. The test facility was connected to Con Edison existing steam, cold water and drain lines. During the tests, Con Edison supplied saturated steam and cold potable water to the facility.

The steam supply for the test facility is branched off with a 2-inch line from the Con Edison building heating system at 50 psi pressure. The steam line is equipped with gate valve and a 1-inch steam flow meter FM1 (Figure 8). The flow meter and other equipment specifications are presented in Appendix A. Con Edison requested that the test facility utilize steam with a maximum pressure of 15 psig. Therefore, a pressure regulator/emergency shutoff device PRV1 is installed after the gate valve 2. During start up, the condensate, which may accumulate in the steam line, is drained. The steam line is also equipped with an additional pressure regulator and the hot water temperature control valve TRV. The steam line is equipped with a steam trap line for drainage of the condensate during facility start-up. Following the TRV valve, a non-return check valve is installed. The check valve prevents any water back flow from the FPD into the steam line. After the check valve, steam enters the FPD.

Cold potable water from the existing Con Edison line was supplied to the FPD. The cold water flow was metered by the flow meter FM2, passes through the back flow preventer, a check valve and entered the FPD.

In the FPD, the cold water is mixed with steam, heated, and accelerated to a higher pressure than the mixing streams. The water flow rate discharged from the FPD is measured by the flow meter FM3 (Figure 8). After the flow meter the hot water is discharged into the condensate tank, from which it is drained to the collection tank located in the basement.

The test facility is equipped with extensive instrumentation which allows accurately measuring, record and logging all the pressures, temperatures and flows of steam and cold and hot water during the performance of the tests. Figure 8 shows the instrumentation, and pictures of the test facility are presented in Figures 9 to 14. Detailed descriptions of all equipment and instrumentation are in Appendix A.

Figure 8. Installation of Fisonic Pumping Device Test Facility
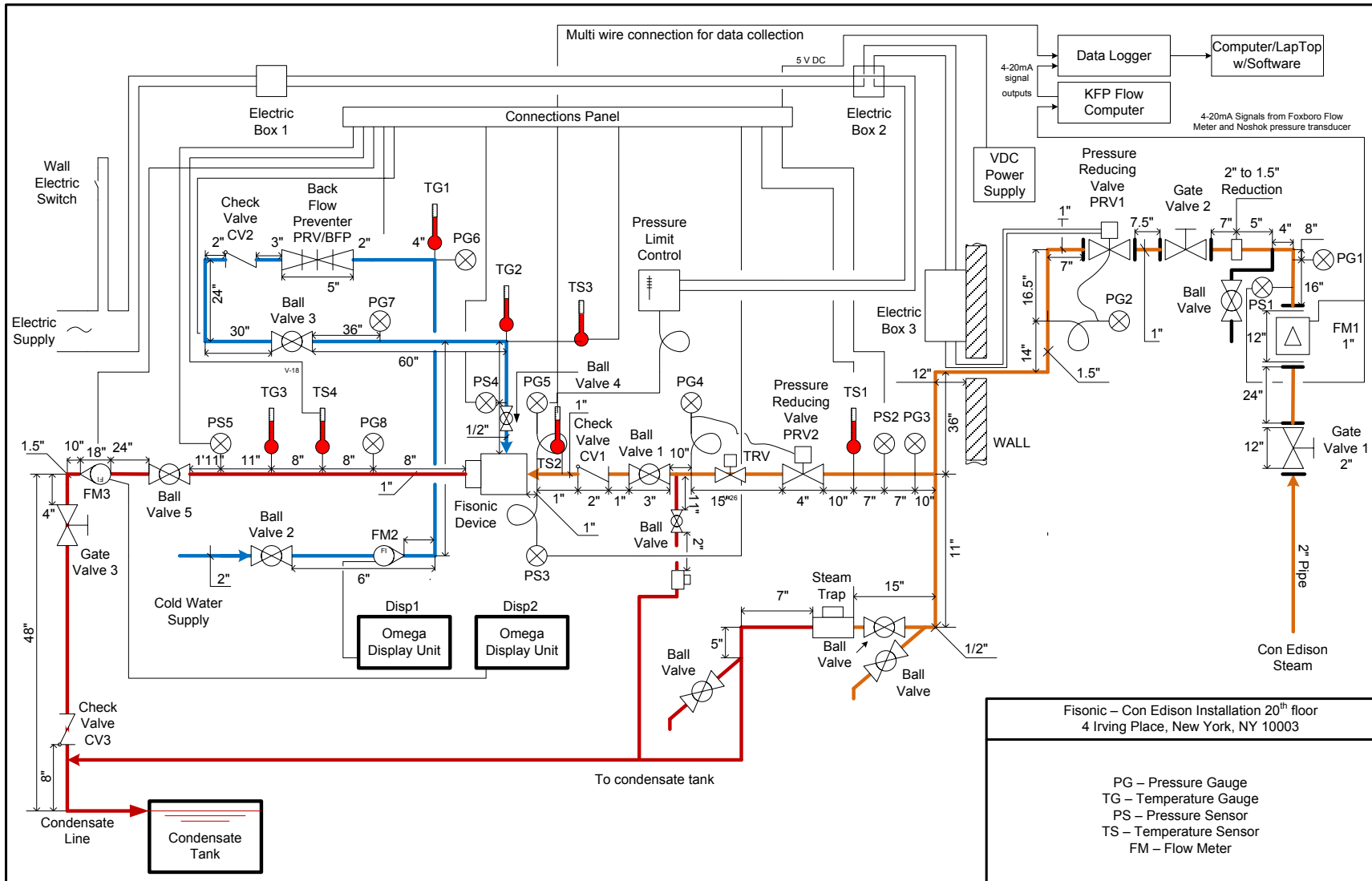
Figure 9. The Fisonic Pumping Device
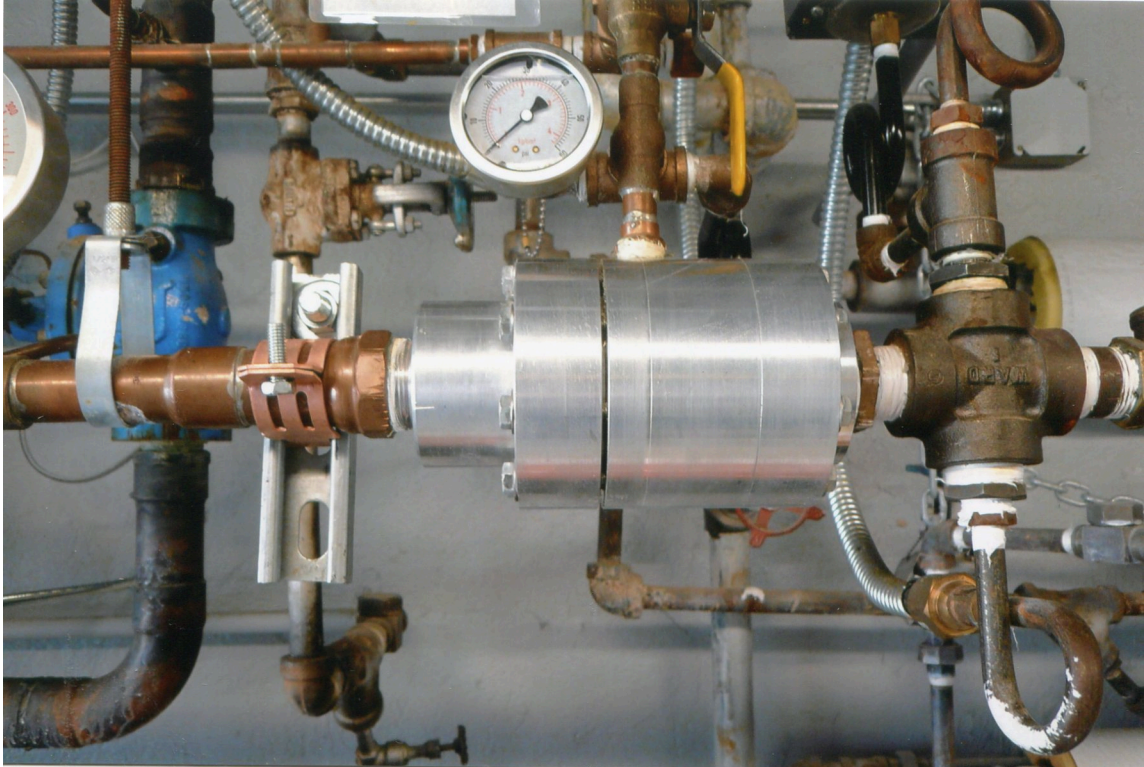
Figure 10. Overall View of FPD Test Facility

Figure 11. Con Edison Steam Supply to Test Facility

Figure 12. Steam Pressure Reducing Valve

Figure 13. FD Discharge Temperature Steam Control Valve
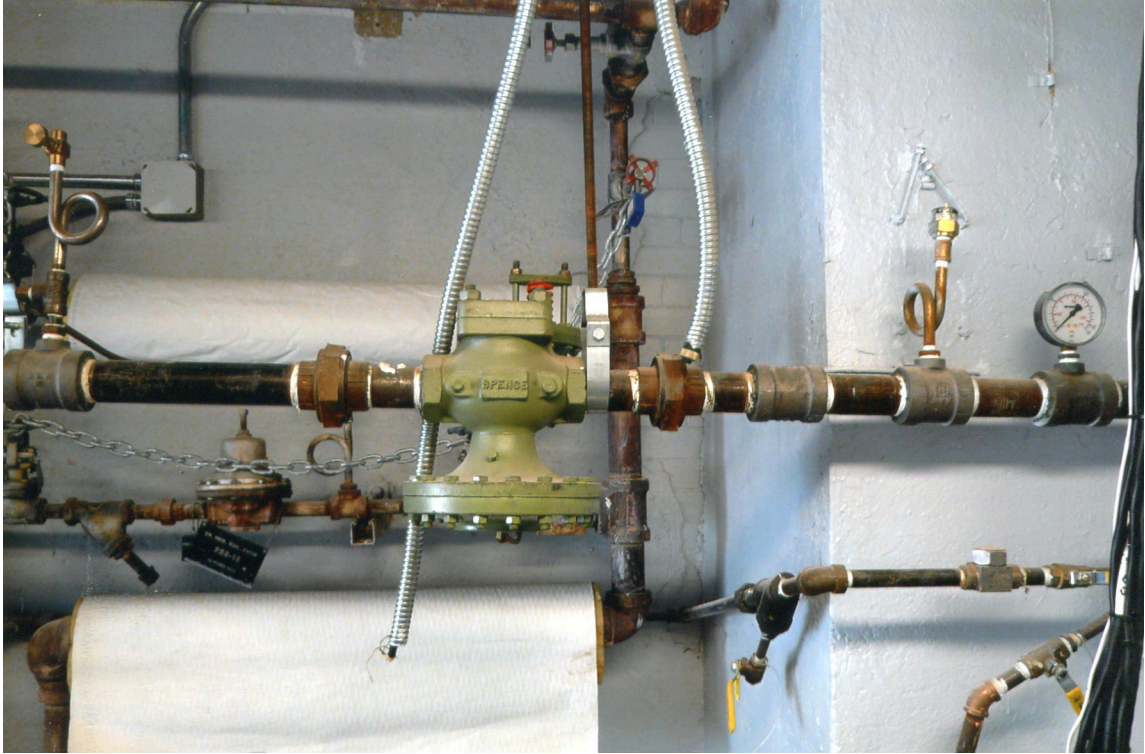
Figure 14. Cold and Hot Water Flow Meters

4   Description of Test Protocol

4.1   ANSI/ASME Performance Test Code

Con Edison requested that the FD test facility comply with applicable test procedures documented in the ASME Performance Test Code 24-1976 (Ejectors). The relevant requirements of this code are presented in this section.

4.1.1   Definition of Ejector Parameters

The ejector stability is defined as the relation of motive fluid pressure or the discharge pressure to breakdown and recovery of the pumping action.

Absolute pressure is the pressure measured from absolute zero; i.e., from an absolute vacuum. It equals the algebraic sum of the atmospheric pressure and the gauge pressure.

Total pressure is the pressure measured at the stagnation point when a moving stream is brought to rest and its kinetic energy is converted by an isentropic compression from the flow condition to the stagnation pressure. It is the pressure usually measured by an impact tube.

Velocity pressure is the total pressure minus the static pressure in a stream. It is generally measured by the differential reading of a Pitot tube.

Suction pressure is the static pressure prevailing at the suction inlet of the ejector expressed in absolute units.

Discharge pressure is the static pressure prevailing at the discharge of the ejector expressed in absolute units.

Motive-fluid pressure is the static pressure prevailing at the nozzle inlet expressed in absolute units.

Total temperature is the temperature which would be measured at the stagnation point if a stream were brought to rest and its kinetic energy converted by an isentropic compression from the flow condition to the stagnation temperature.

Suction temperature is the temperature of the fluid at the suction inlet of the ejector.

Motive-fluid temperature is the temperature of the motive fluid at the nozzle inlet.

Stability is used in this code to describe a characteristic of the ejector pumping action. If the discharge pressure is too high, or if the motive-fluid pressure is too low, the flow stream at the suction may momentarily reverse and the ejector is said to be unstable. Stable operation is identified as that condition at which the suction pressure is not decreased by either a further decrease in the discharge pressure or a further increase in the motive-fluid pressure. The term does not necessarily apply to single stage ejectors designed for very low compression ratios nor to multistage ejectors working at suction pressures above their normal range.

Breaking pressure is that pressure of either the motive fluid or the discharge which causes the ejector to become unstable.

Recovery pressure (pick-up pressure) is that pressure of either the motive fluid or the discharge at which the ejector recovers to a condition of stable operation.

Capacity is the weight-rate of flow of the fluid compressed and discharged by the ejector.

Motive-fluid consumption, for steam or other fluids, is the weight-rate of flow passing through the motive nozzle at specified conditions of temperature and pressure.

4.1.2 Test Conditions

The significant factors to be considered in planning a test or for appraising the results are:

- Suction pressure.
- Suction temperature.
- Discharge pressure.
- Suction-fluid composition.
- Suction-fluid rate (capacity).
- Pressure limits for operating stability.
- Quantity of motive fluid.
- Pressure and temperature of motive fluid.
- Quality of motive fluid.

4.1.3 Instruments

The initial calibration of the instrument involved should be available prior to the test. Recalibration should be made after the test for those instruments of primary importance, which are liable to variations or change as a result of test use. Any change of the instrument calibrations that will result in more than ±2 percent in any calculated quantity may be cause for rejection of the test.

The test set-up should provide suitable means for the establishment of uniform velocities at the ejector suction inlet.

The instruments and measuring apparatus that may be required for a code test are:

- Barometers.
- Thermometers and/or thermocouples.
- Bourdon-type pressure gauges and U-tube manometers.
- Absolute vacuum gages and differential pressure gauges.
- Fluid meters and measuring tanks.

Atmospheric pressure should be measured with a mercury barometer of Fortin type. The instrument should be fitted with a vernier suitable for precise reading and have attached a thermometer for indicating the instrument temperature. It should be located close to the test setup and supported on a structure free from mechanical vibration. Where the use of mercury is prohibited, an acceptable substitute may be used.

The barometer should be read at uniform intervals throughout the test period, the temperature of the instrument should also be recorded.

Suction and the discharge pressures should be measured with the appropriate primary standard gauge.

The instruments should be sensitive, accurate, and readable within 1.0 percent of the operating temperature. The operating range should be suitable for the temperature to be measured.

The temperature measuring device should be installed in the flowing stream of the fluid being measured and so located that no significant quantity of heat should be transferred to it by radiation or conduction other than that of the medium being measured.

For steam, the temperature should be computed from the pressure and temperature existing ahead of the measuring flow nozzle using tabulated properties or a Mollier chart at constant enthalpy. If the heat generating device is using hot water as the primary fluid, the enthalpy will be estimated based on the measured temperature and pressure of the fluid.

The motive-fluid pressure shall be measured as close to the ejector nozzle as possible, care being taken to avoid line pressure drop and velocity effects from valves or elbows. Gauges used should be with guaranteed maximum error of 1.0 percent of their full-scale reading.

Final capacity measurements may be made only after the stable operating values of motive and discharge pressure have being determined. The test should be made only within the range of stable operation.

The preliminary operation should continue until all adjustments of motive-fluid pressure, superheat, discharge pressure, and cooling water have been made. After temperatures have reached steady-state conditions, all traces of wet steam are removed, the capacity should be varied throughout the full determined range, and the stability of the ejector system observed.

The FD limits for stable operation, in terms of motive-fluid pressure and discharge pressure, should be determined before the final measurements of capacity are taken.

The minimum motive pressure shall be determined as follows: with the capacity and discharge pressure held constant, the motive pressure shall be lowered slowly until the ejector is "broken" (characterized by a sharp rise or fluctuations in the suction pressure).

The maximum discharge pressure shall be determined by procedures similar to those for the minimum pressure.

4.2   Test Protocol

The installation presented in Figure 8 is equipped with an extensive system of metering and recording devices that comply with the above outlined code requirements. Water valves (WV), pressure gauges (PG), temperature gauges (TG) and flow meter (FM) references in the following tasks can be found in Figure 8.

4.2.1 Prior to Test

4.2.1.1 Task 1. Hydrostatic Test of the Total Installation

The maximum steam and water supply pressures shall not exceed 50 psig during the performance test. To test the structural integrity of the testing apparatus, it is proposed that a hydrostatic test of the installation be performed to a maximum of 100 psig. Valves WV1 and WV6 should be closed and water should be introduced from WV2. This pressure should be held for 10 minutes with no visual leakage and drop in test pressure. The emergency relief valve will be set for 110 psig.

4.2.1.2 Task 2. Functional Test of all Equipment

Functional test of all control and shut-off valves should be performed in order to confirm their working conditions and then returned to performance test position.

4.2.1.3 Task 3. Calibration of the Instrumentation

All instrumentation should be calibrated by the manufacturers and confirmed to be in working condition.

4.2.1.4 Task 4. Check Steam Traps

Check steam traps to ensure that they are functioning properly and that they are drained.

4.2.1.5 Task 5. Check Steam Pressure

Measure the available steam pressure with PG1 (see Figure 8 for location of PG1) and determine that steam pressure is adequate for test purposes. The steam pressure provided by Con Edison should be not higher than 15 psig.

4.2.1.6 Task 6. Check Water Temperature

Check if water temperature is adequate for test purposes. The temperature of cold water provided by Con Edison should not be higher than 80 °F.

4.2.2 Performing Tests

Note that in all tests, cold water flow should be first introduced in the FD. After water flow is established, the steam should be slowly introduced to the FD.

4.2.2.1 Task 7. Water Flow Test

Gradually open valve WV2 and record water pressure from PG6 onto the data sheet. Next, gradually open valves WV5 and WV6. After three minutes, start recording pressure PG6; temperature TG6; water flow with flow meter FM2; and PG5, TG5, TG8, and PG8.

Determine the available cold water flow, inlet pressure, and temperature. Conduct cold water flow tests in the available range of flow rates and measure the FD water pressure drop without introducing steam. Based on these tests establish the water flow range for performance tests.

4.2.2.2 Task 8. Performance Tests

Make sure that the valves WV2, WV5 and WV6 are open and the cold water is flowing at the minimum selected flow rate. Gradually open the steam valve WV1 and the trap blow down line. Keep the blow down line open for 15 minutes in order to drain all condensate. Measure and record on the data sheet all flows (FM2, FM1, FM3), temperatures (TG5, TG4, and TG8) and pressures (PG5, PG4, and PG8). Change the water flow by using the PRV2 and discharge temperature TG8 by using the TRV in the available range of water flow rates. Record all listed flows, temperatures, and pressures on the data sheet. Table 2 lists all planned tests.

4.2.2.3 Task 9. Performance Test for Heating Domestic Hot Water

In addition to the test installation presented in Figure 8, a separate water loop with a heat exchanger should be installed and tested in order to demonstrate the capability of FD heat DHW with a heat exchanger.

4.2.3 Post Test

4.2.3.1 Task 10. Analysis of Field Test Results

- Tasks to analyze the field test results are:
  - Develop a relationship of the cold water temperature increase (TG8 – TG5) in the FD from the inlet steam pressure PG4 in the available range of water flow and pressure.
  - Develop performance curves of the FD - relationship of the FD discharge pressure PG8 from the cold water temperature increase (TG8 – TG5) in the FD for different cold water flow rates FM2 and pressures PG5.
  - Develop a relationship of the discharge temperature from the FD TG8 from inlet steam pressure PG4.
  - Validate all streams' flows, temperatures and enthalpy parameters by accurate heat balance computerized calculations.

Table 2. Tabulation of Planned Tests

Test #	Cold Water Flow, gpm	FD Inlet Cold Water Temperature,F	FD Outlet Water Temperature,F	Estimated Steam Flow, lb/hr
1	1.5	60	70	6
2	1.5	60	70	6
3	1.5	60	70	6
4	3.0	60	70	13
5	3.0	60	70	13
6	3.0	60	70	13
7	4.0	60	70	17
8	4.0	60	70	17
9	4.0	60	70	17
10	1.5	60	80	13
11	1.5	60	80	13
12	1.5	60	80	13
13	3.0	60	80	26
14	3.0	60	80	26
15	3.0	60	80	26
16	4.0	60	80	17
17	4.0	60	80	17
18	4.0	60	80	17
19	1.5	60	90	19
20	1.5	60	90	19
21	1.5	60	90	19
22	3.0	60	90	39
23	3.0	60	90	39
24	3.0	60	90	39
25	4.0	60	90	52
26	4.0	60	90	52
27	4.0	60	90	52
28	1.5	60	120	39
29	1.5	60	120	39
30	1.5	60	120	39
31	3.0	60	120	78
32	3.0	60	120	78
33	3.0	60	120	78
34	4.0	60	120	103
35	4.0	60	120	103
36	4.0	60	120	103

Table 2. Tabulation of Planned Tests (Continued)

Test #	Cold Water Flow, gpm	FD Inlet Cold Water Temperature,F	FD Outlet Water Temperature,F	Estimated Steam Flow, lb/hr
37	1.5	60	130	45
38	1.5	60	130	45
39	1.5	60	130	45
40	3.0	60	130	91
41	3.0	60	130	91
42	3.0	60	130	91
43	4.0	60	130	121
44	4.0	60	130	121
45	4.0	60	130	121
46	1.5	60	150	58
47	1.5	60	150	58
48	1.5	60	150	58
49	3.0	60	150	116
50	3.0	60	150	116
51	3.0	60	150	116
52	4.0	60	150	155
53	4.0	60	150	155
54	4.0	60	150	155
55	1.5	60	170	71
56	1.5	60	170	71
57	1.5	60	170	71
58	3.0	60	170	142
59	3.0	60	170	142
60	3.0	60	170	142
61	4.0	60	170	190
62	4.0	60	170	190
63	4.0	60	170	190
64	1.5	60	190	84
65	1.5	60	190	84
66	1.5	60	190	84
67	3.0	60	190	168
68	3.0	60	190	168
69	3.0	60	190	168
70	4.0	60	190	224
71	4.0	60	190	224
72	4.0	60	190	224

5 Results of Fisonic Pumping Device (FPD) Testing

The major purpose of the tests was to demonstrate that the FPD has the capability to operate as a direct contact heat exchanger and a pump creating discharge pressure higher than the pressure of the working (steam) and injected (cold water) streams. Five groups of tests were conducted: one without steam and four with steam.

The optimum performance of the FPD (stable discharge pressure P_d) depends on the following parameters: cold water temperature increase in the FPD, injection coefficient (u – ratio of the injected cold water mass flow to the steam flow), pressure of the working steam (Pw), temperature of the cold water, and back pressure after the FPD.

At the beginning a number of dry tests (without steam supply) were conducted. The obtained hydraulic characteristic of the FPD without steam supply is presented in Figure 15. Figure 15 shows that the dependence of the pressure drop in the FPD system from water flow is similar to a conventional water system curve.

Figure 15. Dependence of Pressure Drop From Cold Water Flow Rate Without Steam Supply
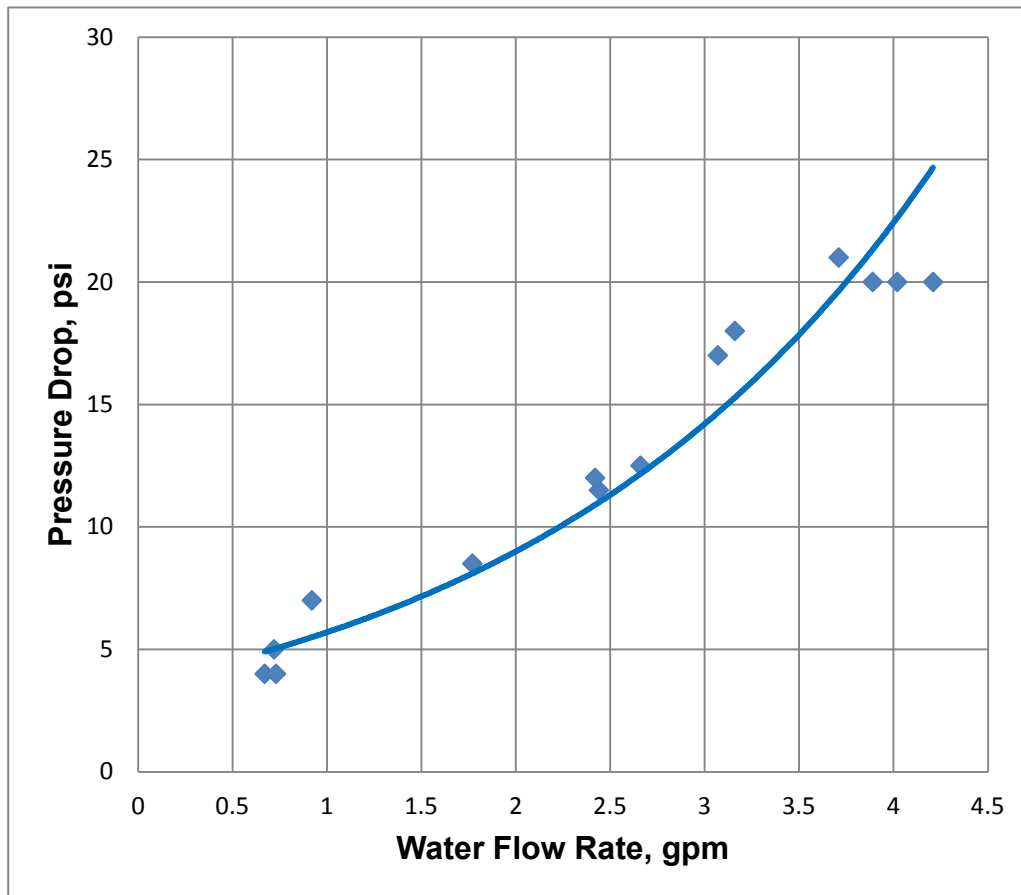
Figure 15 shows that the available range of available cold water flow rates was between 1 and 4.5 gallons per minute (gpm). The FPD tests were performed in this cold water flow range.

The first group of tests was performed with cold water flows ranging between 4.69 and 4.93 gpm. The cold water temperature during those tests was relatively stable, ranging between 72 °F and 76.3 °F. The pressure of the cold water before the FPD ranged between 18.1 psig and 23.4 psig. The pressure of the working steam in front of the FPD ranged between 13.7 psia (vacuum) and 11.8 psig. The discharge pressure from the FPD ranged between 7.7 psig to 46.9 psig. The temperature of the water discharged from the FPD ranged between 108.3 °F and 201.6 °F. Table 3 shows that the described tests clearly demonstrated the capability of the FPD to create discharge pressure higher than the pressure of the working (steam) and injected (cold water) streams. As a matter of fact, tests demonstrated that the discharge pressure is higher than the pressure of the working (steam) and injected (cold water) streams when the working steam entering the FPD is under vacuum. Similar results were obtained independently by the U.S. Underwriters Laboratories global safety science company (Table 3 and Appendix D).

The tests demonstrated that the discharge pressure is increasing with the higher water temperature rise in the FPD (Figure 16), and the injection coefficient is reduced with higher temperature rise in the FPD (Figure 17).

Table 3. Tabulation of Tests with Higher Discharged Pressure in FPD

Tests Location	Test Number	Cold Water Supply to FD			Steam Supply to FD			Hot Water Exit from FD			Equivalent BHP
		Pressure psig	Temperature, F	Flow, gpm	Pressure, psig	Temperature, F	Flow, lb/hr	Pressure, psig	Temperature, F	Flow, gpm	
Con Edison Tests	22	-2	73	2.1	2.3	238	143	1	176	2.43	0.0014
	23	-3.6	73	2.2	-1.8	238	112	10.7	158	2.4	0.0188
	72	11.7	73	4	8.8	237	195	31.6	165.2	4.44	0.0552
	73	11.7	73	4	9.2	238	195	31.7	167	4.45	0.0550
	74	11.3	73	4	5.6	229	161	31.5	154.9	4.35	0.0586
	59	11.8	73	3.85	9.3	238	195	31.6	165	4.32	0.0529
	60	11.9	73	3.86	9.2	238	194	31.8	165	4.43	0.0551
	61	12.1	73	3.89	9.2	238	195	31.9	171.3	4.32	0.0537
	62	12	73	3.89	9	238	194	31.9	170.6	4.29	0.0536
	51	19.8	72	4.40	6.4	237	173	41.8	148	4.75	0.0795
	31	21.4	72	4.95	5.8	236	173	26	138	5.3	0.0383
	32	21.3	72	4.83	6	238	172	44.9	138	5.17	0.0941
	33	21.3	72	4.81	7.5	238	185	45.2	140	5.18	0.0931
UL Tests		2			7			36			
		-12			7.5			0.4			
		-9			6			32			

Figure 16. Dependence of Discharged Pressure versus Water Temperature Rise in FPD

Cold Water Flow Range: 4.69 and 4.93 gpm.

Figure 17. Dependence of Injection Coefficient on Temperature Rise in FPD for the First Group of Tests
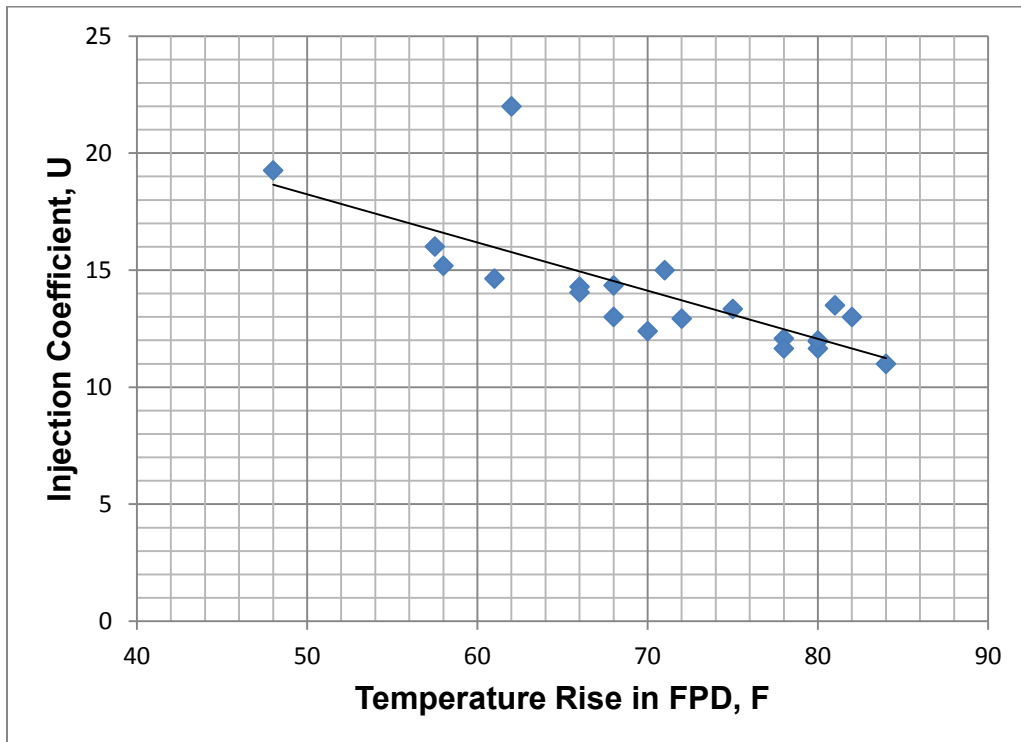
Figure 18 compares the dependence of injection coefficients estimated by Equations 8-10 on the working steam pressure (Curves 1-4).Our test points are placed on the estimated Curve 1. The injection coefficients obtained during the above described tests were for water injection pressure of about 12 psi and cold water temperature of 68 °F. The comparison of test points with Curve 1 shows a relativley good agreement between estimated values and actual test results. This comparison and shape of the estimated Curves 1-4 indicate that the equations presented in Section 2 of this report can be used for the preliminary design of all FPD devices.

The second group of tests was performed with cold water flows ranging between 3.17 and 4.40 gpm. The cold water temperature during those tests was relatively stable ranging between 72° F and 76.4 °F. The pressure of the cold water before the FPD ranged between 3.7 psig and 20.7 psig. The pressure of the working steam in front of the FPD ranged between 1.1 psig and 9.2 psig. The discharge pressure from the FPD ranged between 0.2 psig to 40.3 psig. The temperature of the water discharged from the FPD ranged between 140 °F and 183 °F. The tests confirmed the capability of the FPD to create discharge pressure higher than the pressure of the working (steam) and injected (cold water) streams (Table 3). The tests indicated that the increase in temperature rise in the FPD results in the reduction in the injection coefficient (Figure 19).

Figure 18. Dependence of Discharge Pressure on Injection Coefficient in FPD in First Group of Tests

Steam pressure in front of FD: Series 1: 14.5 psig; Series 2: 29 psig; Series 3: 58 psig; Series 4: 87 psig.
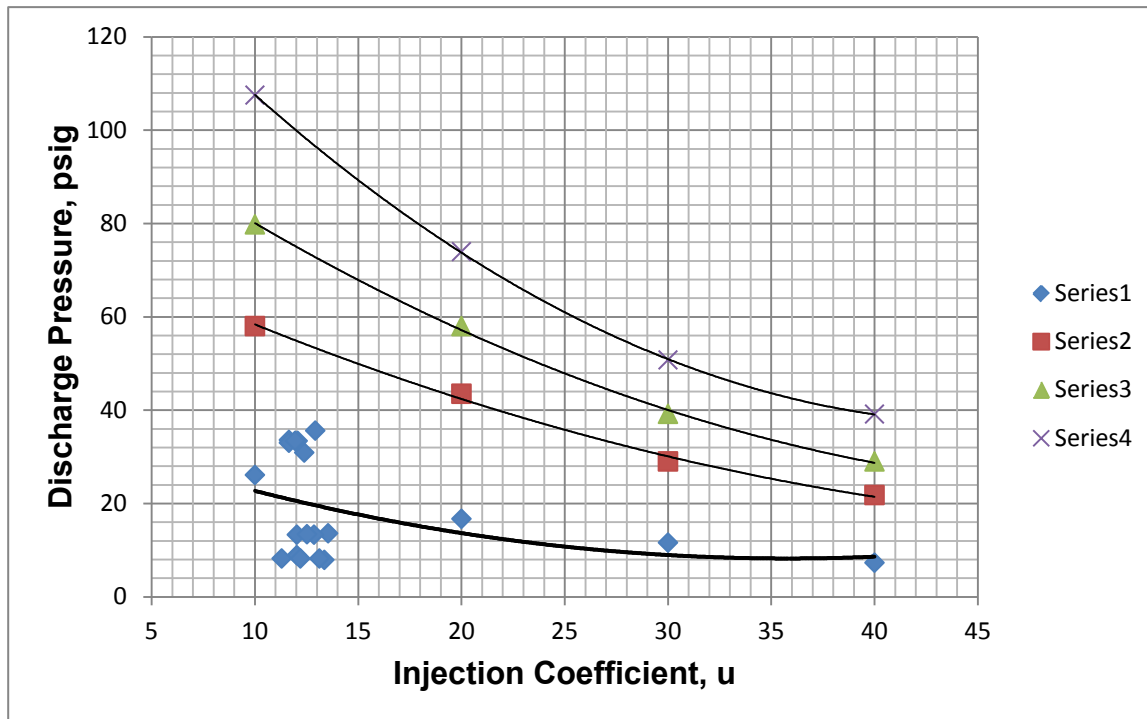
Figure 19. Dependence of Injection Coefficient on Temperature Rise in FPD for the Second Group of Tests
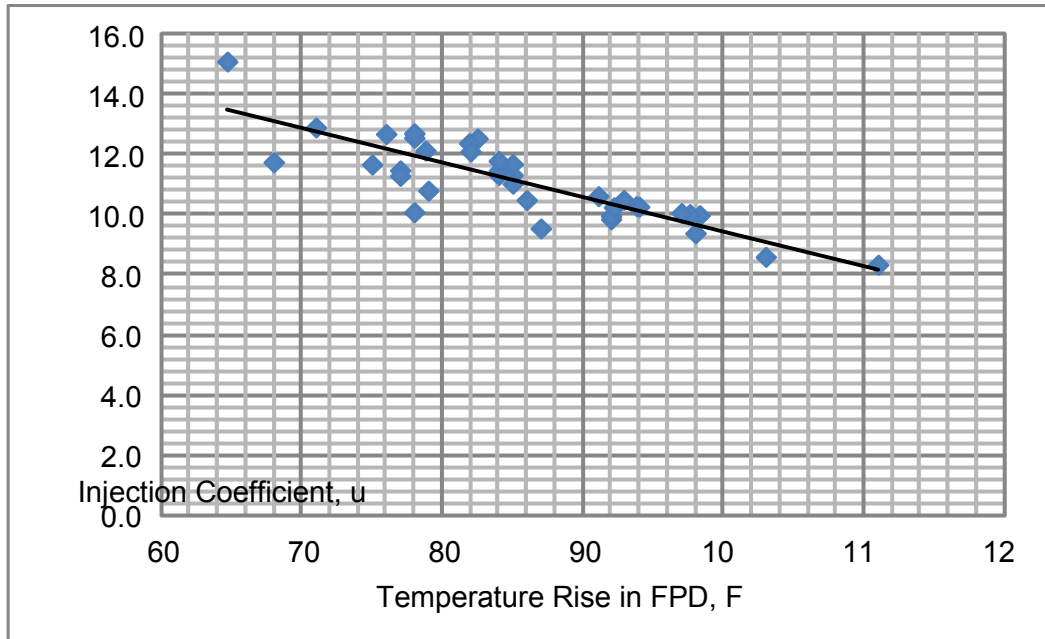
The second group of tests demonstrated the impact of back pressure on the operation of the FPD. When the valve on the water discharge line was completely open, the discharged pressure after the FPD decreased to 0.2 – 1.0 psig. When the valve on the water discharge line was partially closed, the discharged pressure after the FPD increased to 17.7 – 40.3 psig, depending on the closure rate of the valve (or the back pressure). This result indicates that the FPD operates like a pump and overcomes the resistance of the system in which it operates. Figure 20 shows the impact of the back pressure with four different discharge pressure curves. The results of Con Edison actual tests are presented in Table 3 and are in good agreement with test results (Deberne et al. 1999) obtained in the Nuclear Center in Lyon, France (Figure 21).

The third group of tests was performed with cold water flows ranging between 2.1 and 3.3 gpm. The cold water temperature during those tests was between 72 °F and 81.2 °F. The pressure of the cold water before the FD ranged between -0.5 psig and 25.6 psig. The pressure of the working steam in front of the FD ranged between -0.1 psig and 13.9 psig. The discharge pressure from the FPD ranged between 13.9 psia (vacuum) to 36.8 psig. The temperature of the water discharged from the FPD ranged between 76 °F and 180.8 °F. Of specific interest are the series of tests performed with negative (vacuum) pressure of injected water of 10.7 psia (vacuum) and working steam pressure ranging between 14.6 and 11.9 psia (vacuum). Under these conditions the discharged pressure from the FPD was ranged between 10.5 to 17.4 psig. The described tests once again confirmed the capability of the FPD to create

discharge pressure higher than the pressure of the working (steam) and injected (cold water) streams (Table 3), even when the injected cold water and the working steam entering the FPD are under vacuum. The equivalent pumping power in brake horse power obtained in the tests is presented in Table 3. For the third series of tests there is a similar relationship between the increase in temperature rise in the FPD and the reduction in the injection coefficient (Figure 22).

Figure 20. Effect of Back Pressure on Discharge Pressure Increase
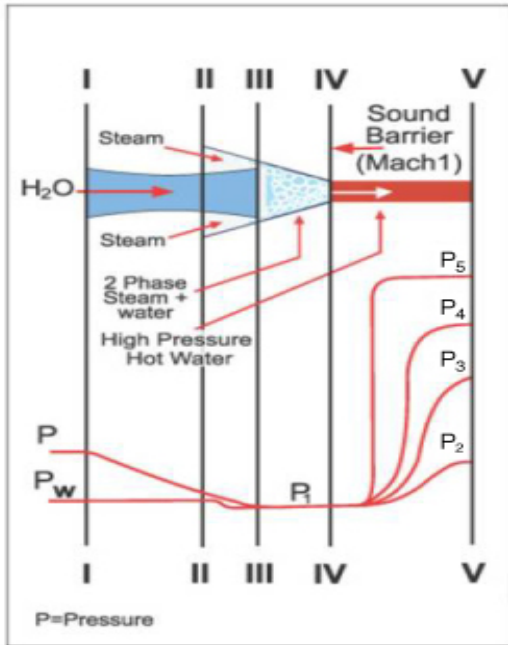
Figure 21. Pressure Profiles for Several Back Pressures (Inlet Steam Pressure 90 psig, Inlet Water Temperature 73 °F) (Deberne et al 1999)
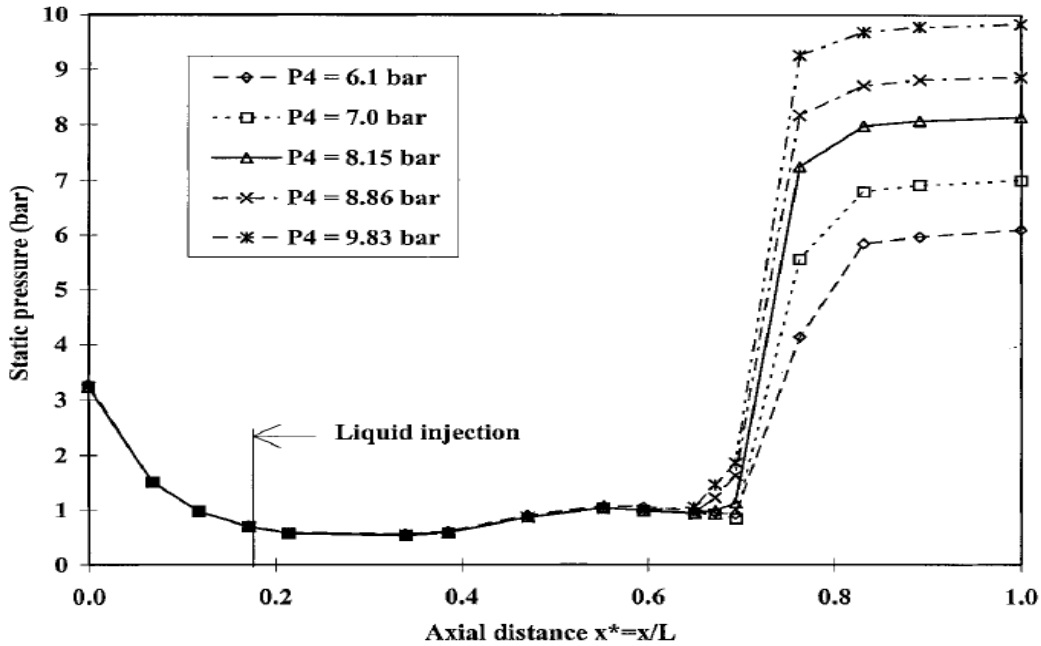
Figure 22. Dependence of Injection Coefficient on Temperature Rise in FPD for the Third Group of Tests
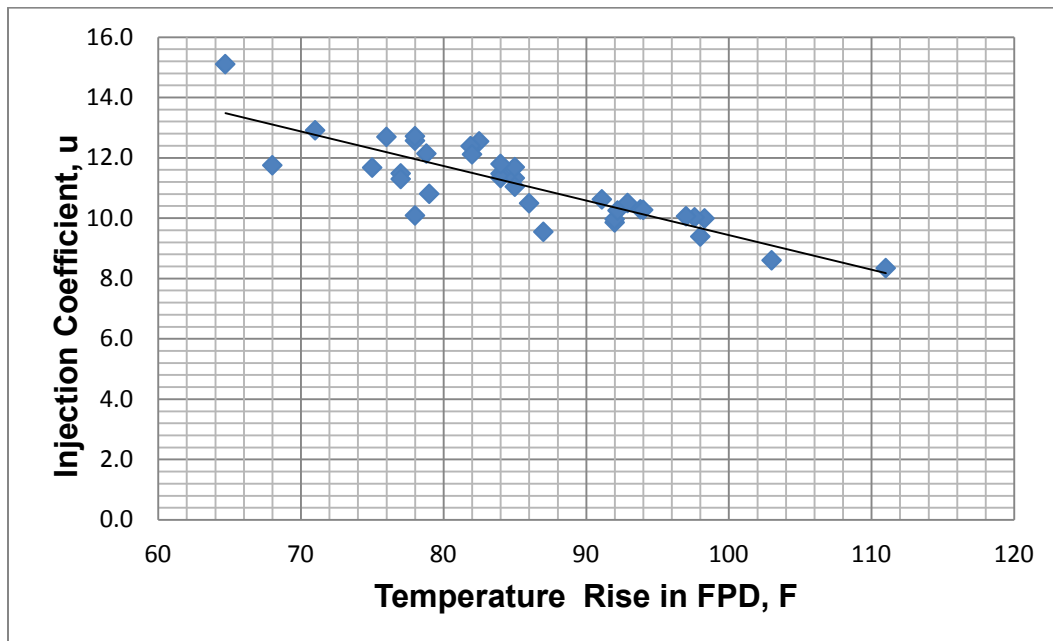
The fourth group of tests was performed with cold water flows ranging between 1.8 and 2.3 gpm. The cold water temperature during those tests was between 76 °F and 81.5 °F. The pressure of the cold water before the FPD ranged between 14.2 psia (vacuum) and 23.8 psig. The pressure of the working steam in front of the FPD ranged between 8.7 psia (vacuum) and 16.7 psig. The discharge pressure from the FPD ranged between 2 psig to 21.6 psig. The temperature of the water discharged from the FPD ranged between 84 °F and 165.4 °F. The tests once again confirmed the capability of the FPD to create discharge pressure higher than the pressure of the working (steam) and injected (cold water) streams, even when the injected cold water and the working steam entering the FPD are under vacuum (Table 3). The dependence of injection coefficient on temperature rise in FPD is presented in Figure 23. A combined dependence of discharge pressure from injection coefficient for all tests is presented in Figure 24.

The influence of the injected water pressures on the injection coefficient is presented in Figure 25. Curves 1-2 present the estimates determined by Equations 8-10 in Section 2 of this report. Our test points are placed on Curve 1. The comparison shows a relatively good agreement between estimated values and actual test results.

The dependence of discharge pressure from injection coefficient for different temperatures of injected water is presented in Figure 26. Curves 1-3 present the estimates by Equations 8-10 in Section 2 of this report. Our test points are placed on Curves 2 and 3. The comparison shows a relatively good agreement between estimated values and actual test results.

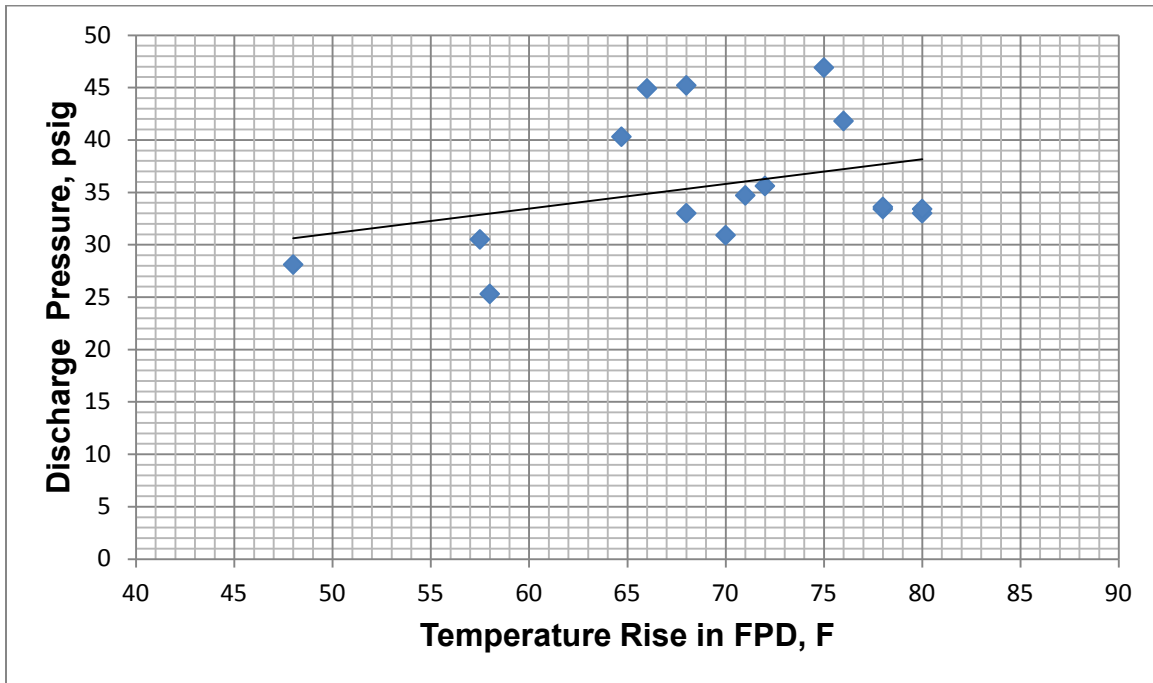**Figure 23. Dependence of Injection Coefficient on Temperature Rise in FPD for the Fourth Group of Tests**
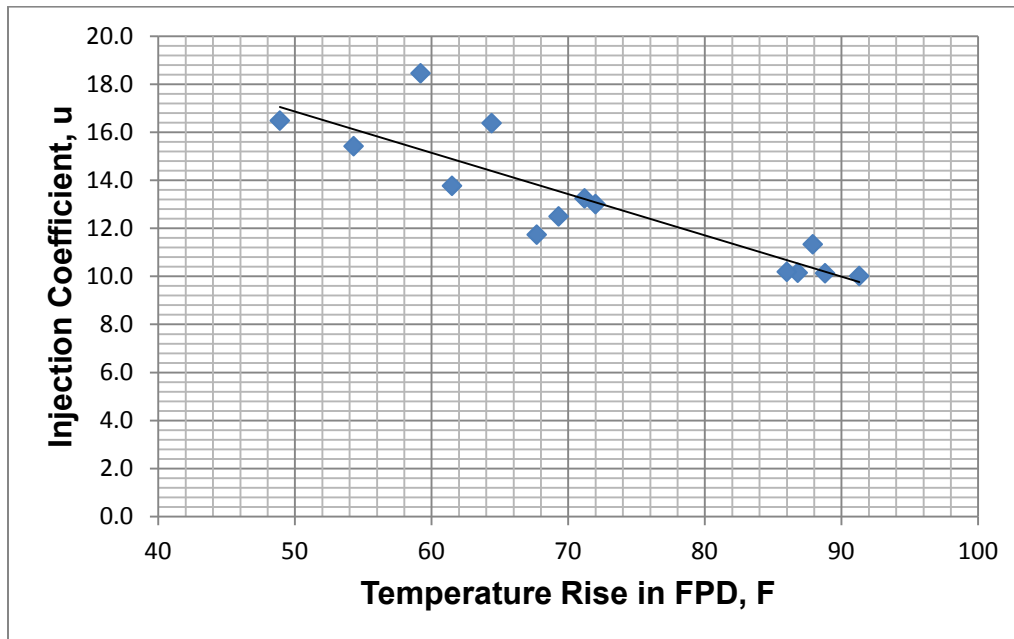
Figure 24. Dependence of Injection Coefficient on Temperature Rise in FPD for all Tests
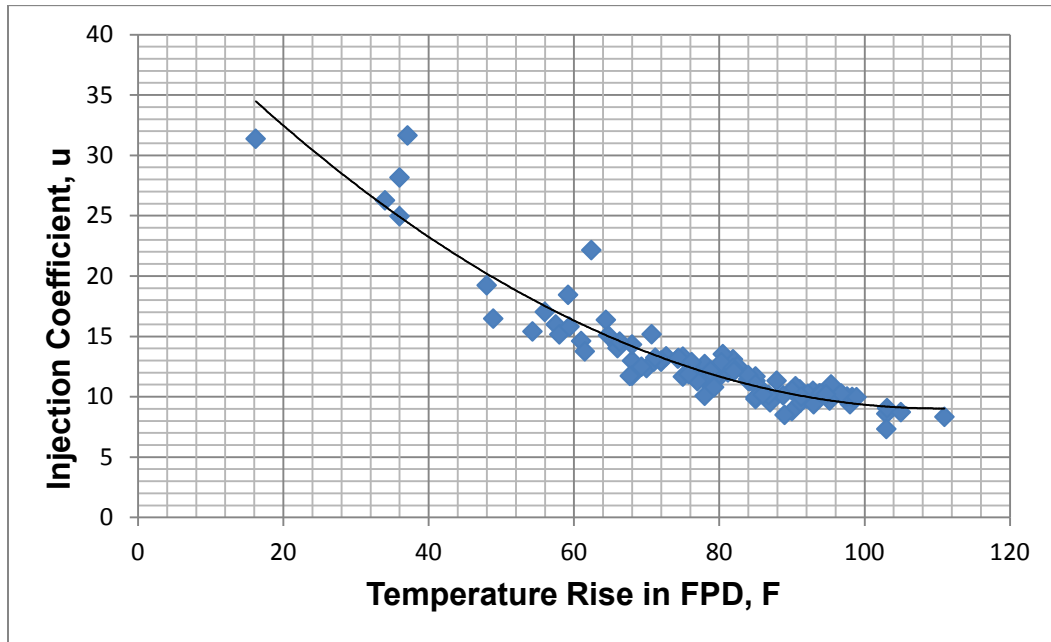
Figure 25. Dependence of Discharge Pressure from Injection Coefficient for Different Pressures of Injected Water

Injection Water Pressure for Test Group 1: 19-22 psig; for Test Group 2: 17.4 psig;

Injected Water Temperature for Test Group 1: 72 °F; for Test Group 2: 68 °F;

Steam Pressure for Test Group 1: 7.5-9.6 psig; for Test Group 2: 87 psig.
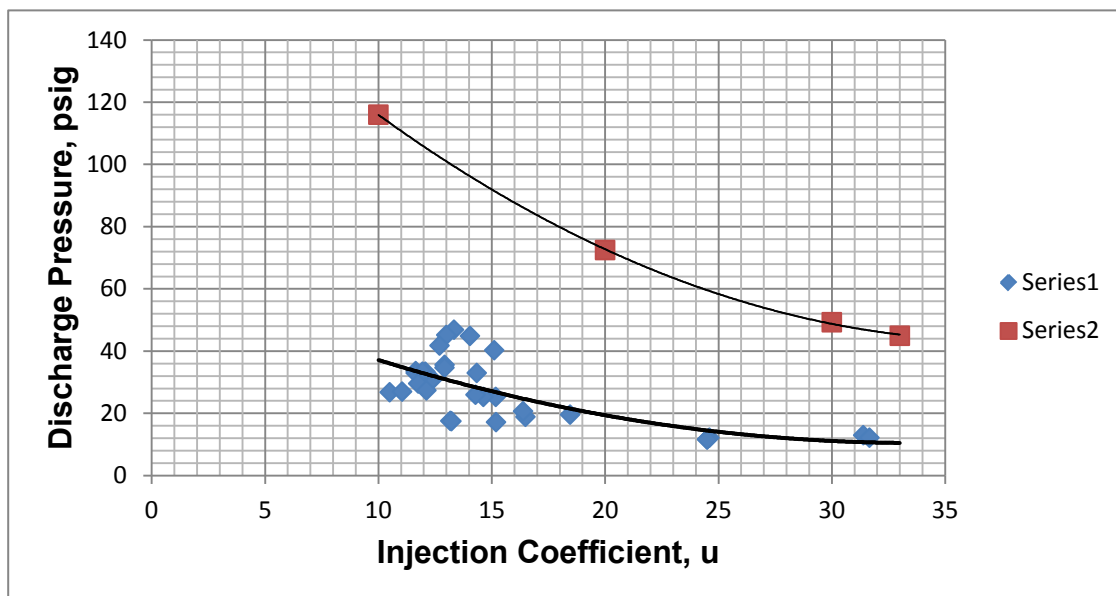
Figure 26. Dependence of Discharge Pressure from Injection Coefficient for Different Temperatures of Injected Water

Injection Water Pressure for Test Series 1: 10.7 psig for Test Series 2: 21 psig; for Test Series 3: 11.6 psig; Injected Water Temperature for Series 1: 76.5F; for Series 2: 72F; for Series 3: 68F;

Steam Pressure for Test Series 1: 11.9-18.3 psig; for Test Series 2: 6.7-9.6 psig; for Test Series 3: 87 psig.
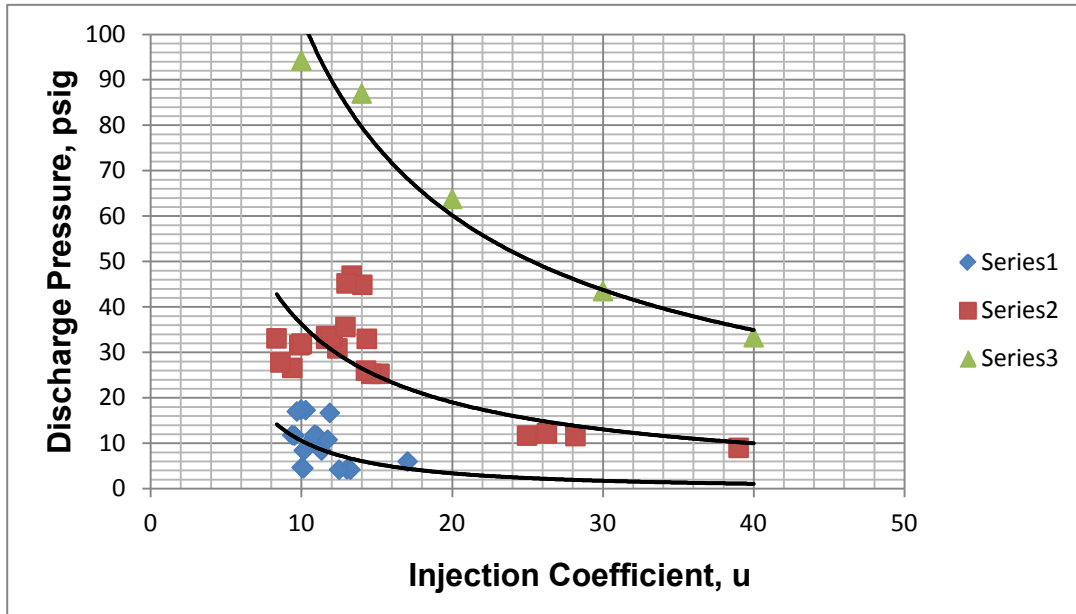
The influence of the injected water temperature on the injection coefficient is presented in Figure 27. Curves 1- 3 present the estimates by Equations 8-10 from Section 2 of this report. Our test points are placed on Curve 1. The comparison shows a relativley good agreement between estimated values and actual test results.

The test results of the FPD reliably demonstrated the capability of the FD to operate as a pump under a wide range of operating parameters, including vacuum pressure of working steam and injected water. The obtained results are in good agreement with certification tests performed independently by the U.S. Underwriters Laboratories global safety science company (Table 3 and Appendix D).

6 Description of the Fisonic Heat Generating Device (FHGD) Test Facility

Testing of FHGD was performed on a pilot test stand (Figure 27). The stand was constructed and installed next to the main test facility described in Section 3 of this report.

Figure 27. Pilot Stand for Testing the FHGD
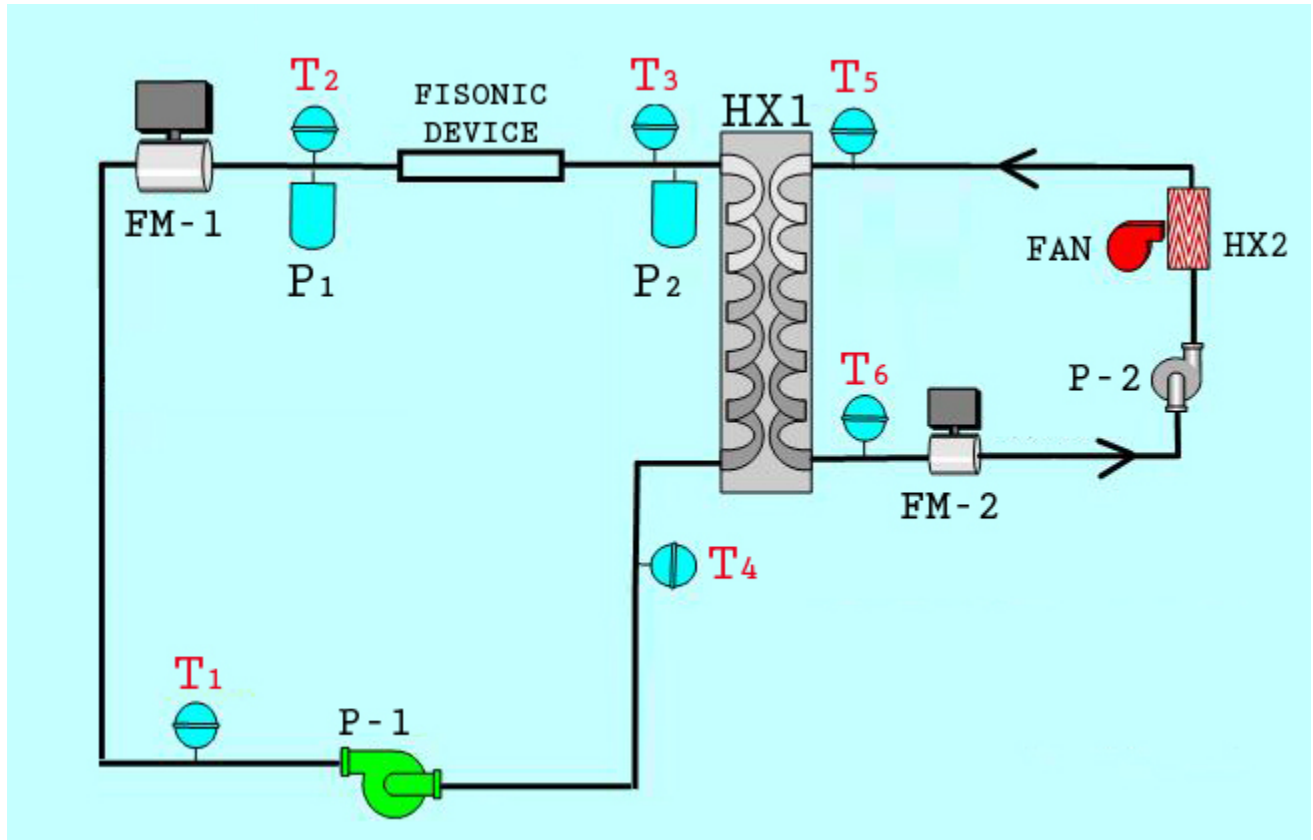
Pictures of the pilot stand and its components are presented in Figures 28 to 34. The FHGD is designed in accordance to the recent Fisenko's patent (Visenko 2012) and has a nozzle size of 4.2 mm (0.165 inch). In the primary loop, a 0.16 horsepower Wilo electric pump circulates water through the FHGD and a brazed plate and frame heat exchanger (HX1) with a heat transfer area of 85 square feet. According to Dr. Fisenko, the Fisonic Device should create in the water a mass of small bubbles that will gradually collapse and release heat. The heat exchanger increases the retention time of the water after the FHGD.

Before the tests, the primary and secondary loops were filled-up with cold potable water with a temperature of 74 °F. The water is not externally heated during the tests, however the water temperature is gradually increasing from internal friction. Through the heat exchanger HX1, the heat is transferred to the secondary loop, where water is recirculated by a Grundfoss 90-watt electric pump.

Figure 28. Pilot Stand for Testing the FHGD
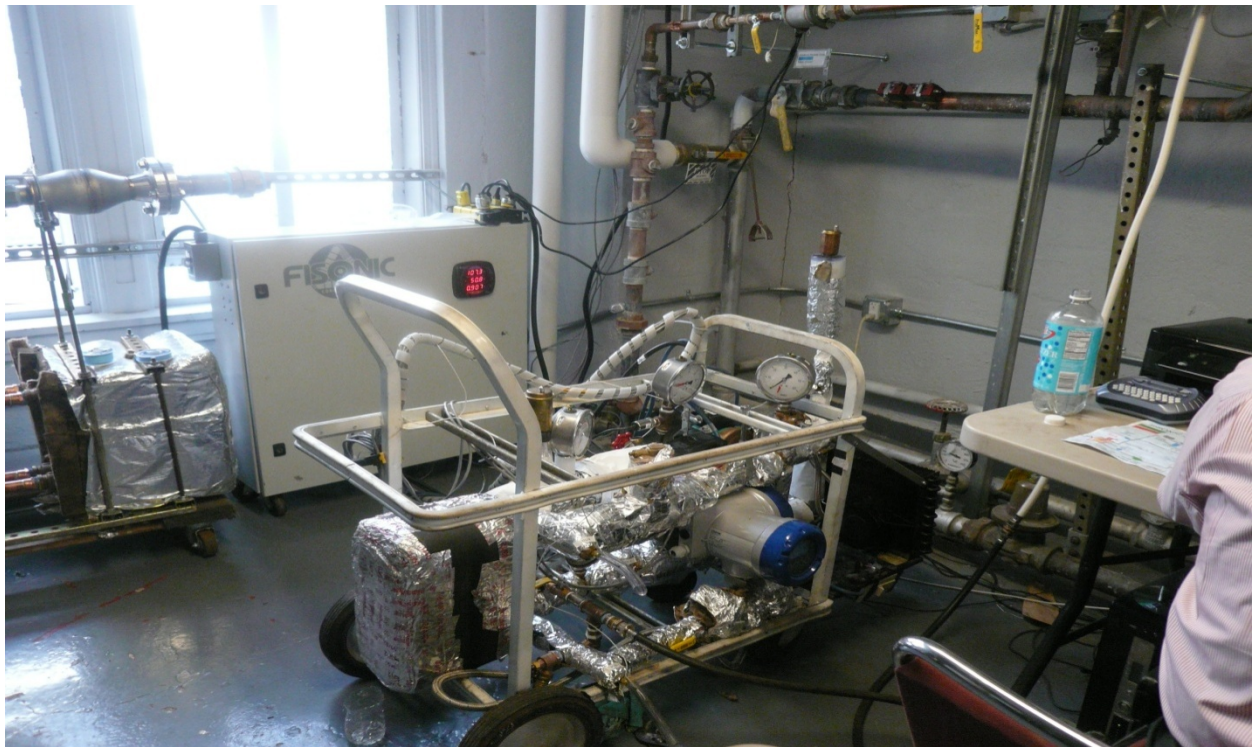
Figure 29. Overall View of the Pilot Test Stand
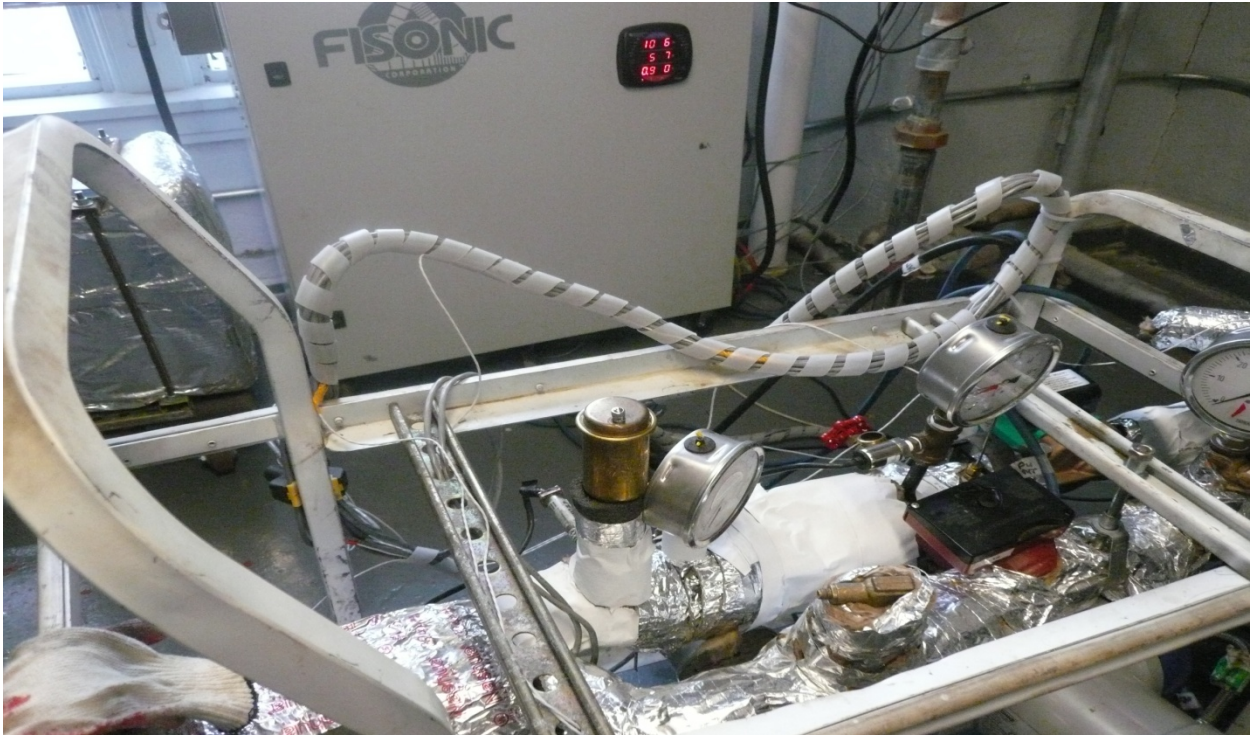
Figure 30.The Main Heat Exchanger (HX1)

Figure 31. The Primary Loop Water Circulating Pump P-1 (Wilo)

Figure 32. Overall View of Heat Rejection Heat Exchanger
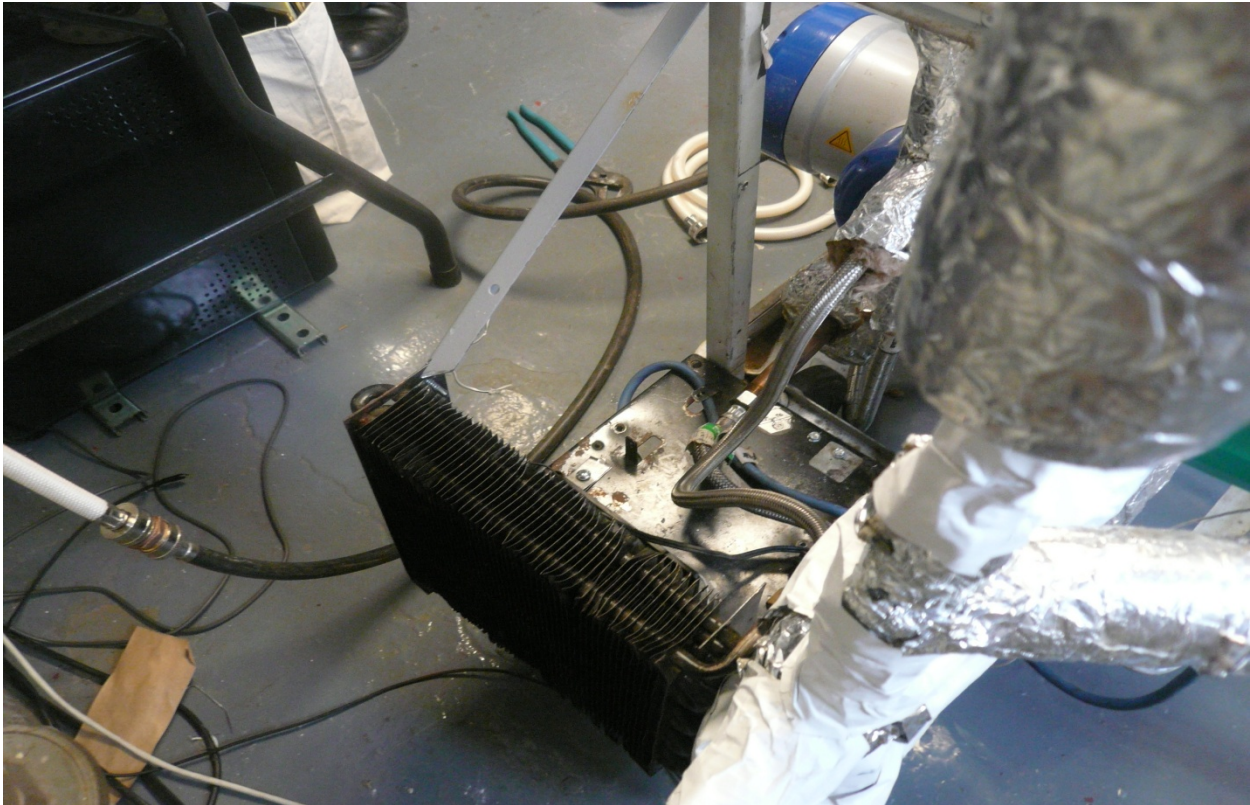
Figure 33. Overall View of the Heat Rejection Heat Exchanger (HX2)
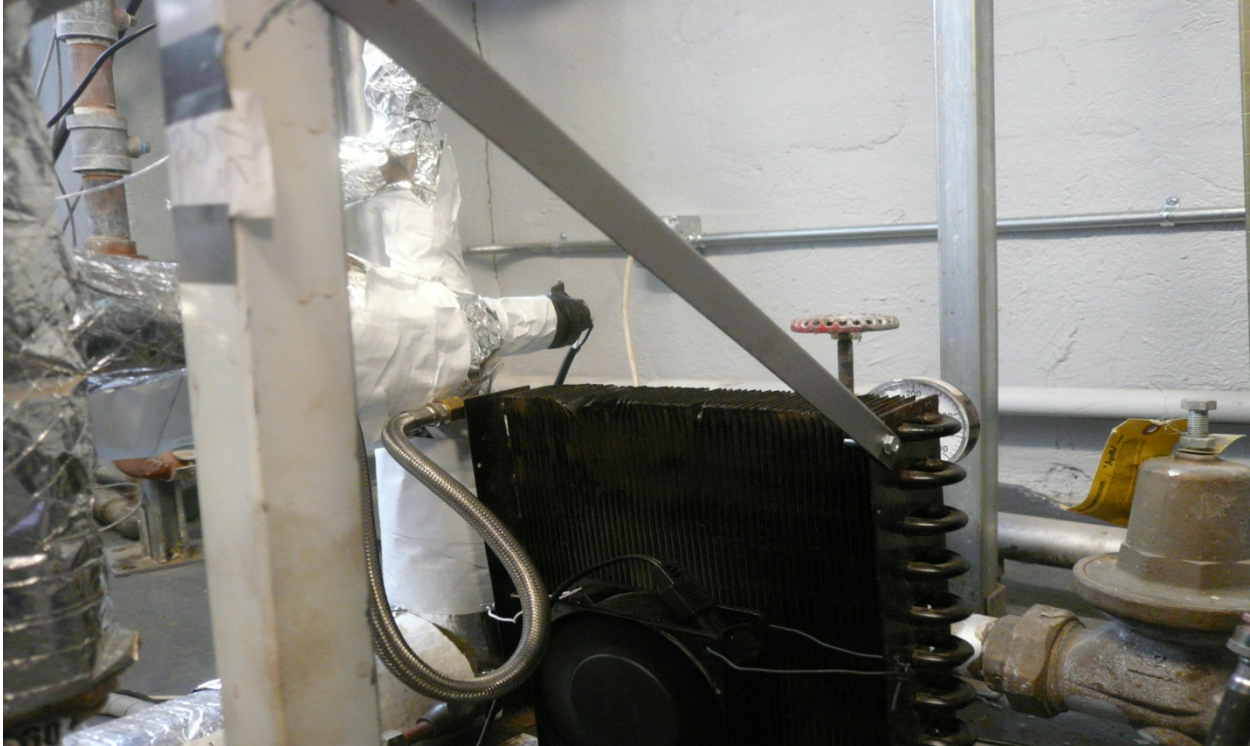
Figure 34. Overall View of the Flow Meter

During water recirculation in the primary loop, the water heated from friction transfers the heat to the secondary loop where the water is circulated by a 90-watt electric pump through a heat exchanger HX2 where the water is cooled by an electric fun blowing ambient air. After the water is cooled, it is recirculated back through the first heat exchanger HX1. The stand is equipped with extensive instrumentations for metering all water temperatures, flow rates, and electric consumption of the pumps. The specifications of the heat exchangers and the pumps are presented in Appendix C.

7 Results of Fisonic Heat Generating Device (FHGD) Tests

During tests, the water was recirculated through the FHGD and the heat exchanger HX1. The water flow rate in the primary loop was 3.2 gpm, and in the secondary loop, the water flow rate was close to 1.0 gpm. The tests indicated that, the water temperature increased by about 0.3 °F after the water circulated through the heat exchanger HX1and in the second loop by about 1.10 °F. The heat released in the heat exchanger is the sum of heat released in both loops (3.2 gpm × 0.3 °F × 500 + 1.0gpm × 1.1 °F × 500=1030 Btu/hr). The tests demonstrated that the heat transferred to the second loop through the HX1 is about 550 Btu/hr or about 60 percent higher than the thermal equivalent of the electric input into the primary loop motor of about 340 Btu/hr. It appears that these preliminary tests are in agreement with Fisenko's theory that the FHGD can generate some heat. However, to obtain conclusive results, the FHGD must be tested in a large commercial building, where the heating system can provide substantial retention time for the water processed in the FHGD and allows harvesting all the heat of the small bubbles generated in the FHGD. Such tests will be performed during the commercialization of the FDs in the Con Edison district for steam customers.

8 Test of Fisonic Pumping Device (FPD) for Domestic Hot Water

According to existing building codes, DHW cannot be heated by direct contact with steam delivered by the Con Edison district steam system. Therefore, DHW is heated in a heat exchanger. Such an installation exists on the 20th floor of the Con Edison Headquarters (Figures 35-38) and is in close proximity to the main test installation. The existing unit heats potable water for the Con Edison Headquarters cafeteria and other hot water usage in the building. As one can see from these figures, DHW is heated in a heat exchanger combined with a hot water storage tank. The hot water temperature is controlled by a steam control valve. The steam condensate is discharged to the condensate tank located in the basement of the building.

Figure 35. Front View of Existing Patterson Kelly 400 Domestic Hot Water Unit

Figure 36. Rear View of Existing Patterson Kelly 400 Domestic Hot Water Unit

Figure 37. Steam Control Valve of the Existing DHW unit

Figure 38. Steam Condensate Drain of the Existing DHW unit

To demonstrate the operation of the FPD for heating DHW, the system presented in Figure 39 was constructed and installed in close proximity to the existing DHW installation. Con Edison steam is directed to a FPD that heats the recirculated water in a primary water loop and discharges it to a vortex deaerator, which releases the noncondensable gases to the atmosphere. After the deaerator, the water enters a brazed plate type heat exchanger where the heat is transferred to potable water. The heated potable water of the secondary loop is used by the cafeteria and other users in the building. Part of the primary loop water cooled in the heat exchanger is discharged to the condensate tank. The FPD DHW unit is instantaneous, and does not have any storage capacity. Various components of the new DHW unit are shown in Figures 40 through 43.

Figure 39. Flow Diagram of the New DHW Unit with the Fisonic Pumping Device
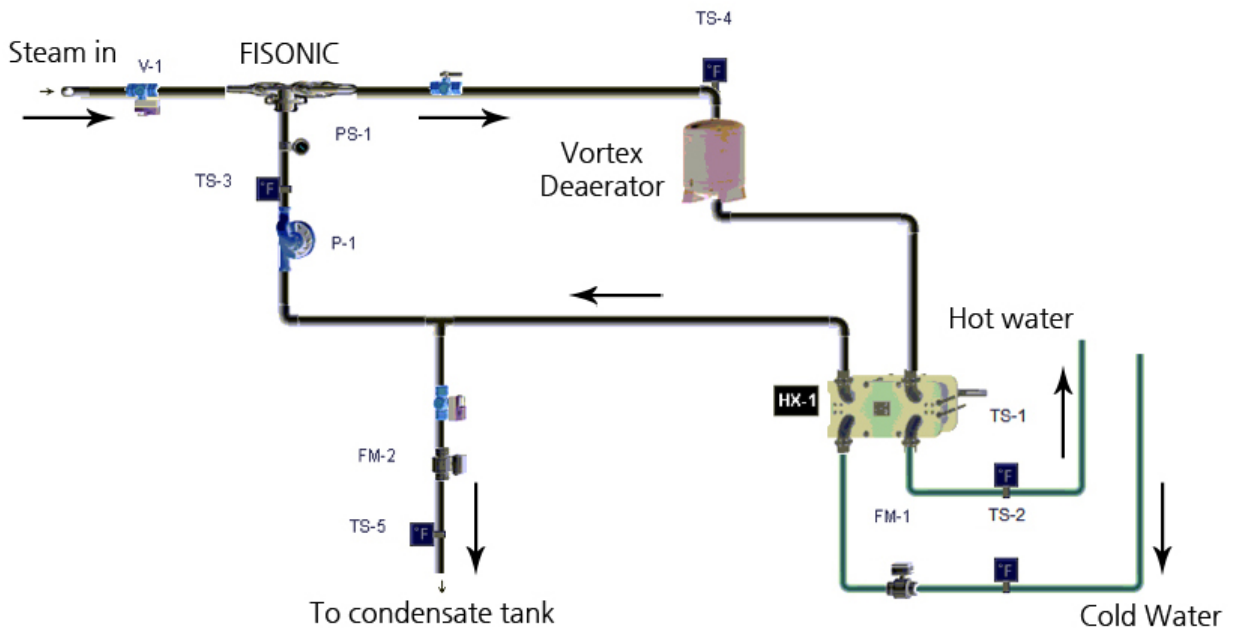
Figure 40. New Domestic Hot Water Unit with the Fisonic Pumping Device

Figure 41. The Fisonic Device and the Modulating Steam Valve of the New Unit

Figure 42. Brazed Plate Heat Exchanger of the New Unit

Figure 43. The Control and Data Recording Package of the New DHW Unit

The new unit was equipped with instrumentation permitting to measure every 15 minutes the cold and hot water temperatures and flows and the temperature of discharged condensate. The unit was put in operation and metered continuously for two weeks. During the tests the average daily cold potable water temperatures ranged between 63.1 and 84.6 °F and the hot water temperatures between 119.1 and 133.1 °F (Figure 44).The test results demonstrated that the hot water and steam consumptions patterns vary daily but have similar signature (Figures 45 and 46). Note the first tested week included a Monday holiday.

Figure 44. Weekly Variation of Cold and Hot Water Temperatures

Series1: First Week Cold Water Temperatures; Series2: Second Week Cold Water Temperatures; Series3: First Week Hot Water Temperatures; Series4: Second Week Hot Water Temperatures.
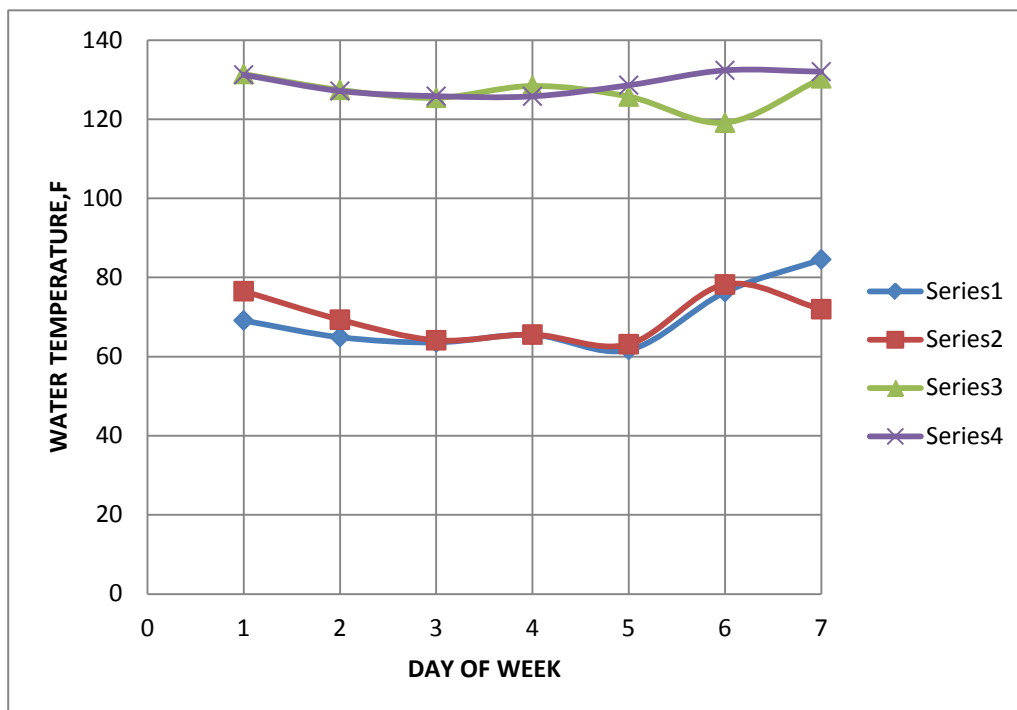
The test results demonstrated that the DHW unit with the FPD operates reliably. The temperature of the condensate rejected from the primary loop varies between 77 and 104 °F, which is much lower than the condensate temperature rejected from the original existing unit.The specific steam consumption for the FPD DHW unit for the metered period was 0.9047 lbs of steam per 1,000 Btu of generated heat. Con Edison disconnected the original DHW unit and is continuosly using the new unit with the FPD for the last years.

Figure 45. Variation of Hot Water Consumption Flow

Series 1: First Week; Series2: Second Week.
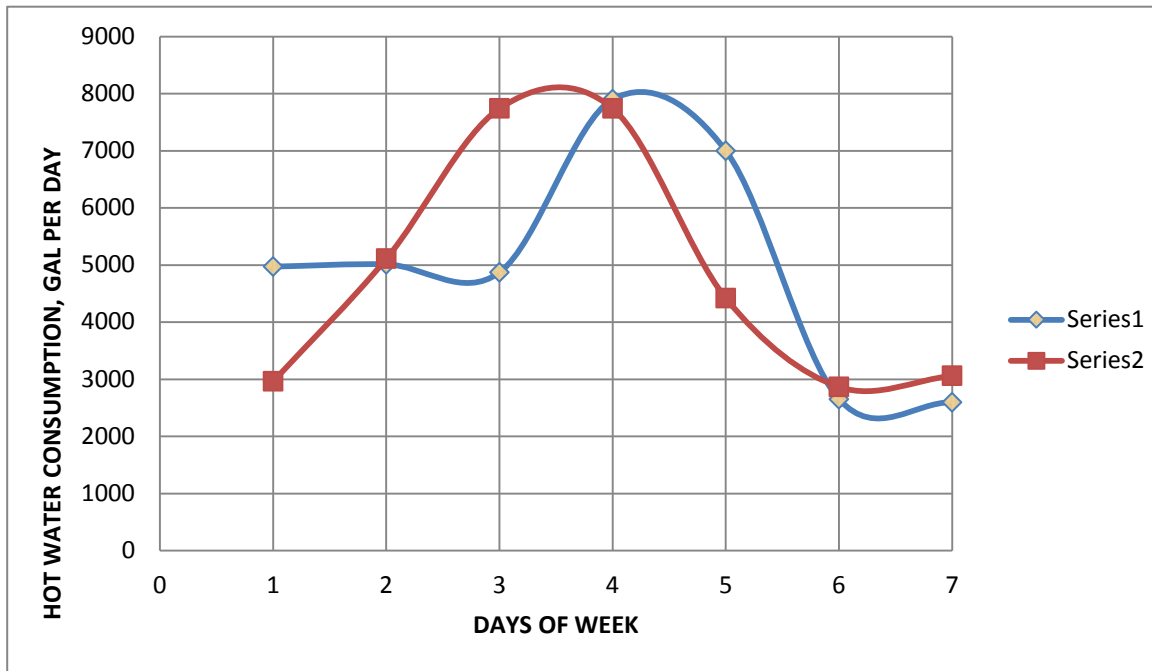
Figure 46. Variation of Steam Consumption Flow

Series 1: First Week; Series 2: Second Week.
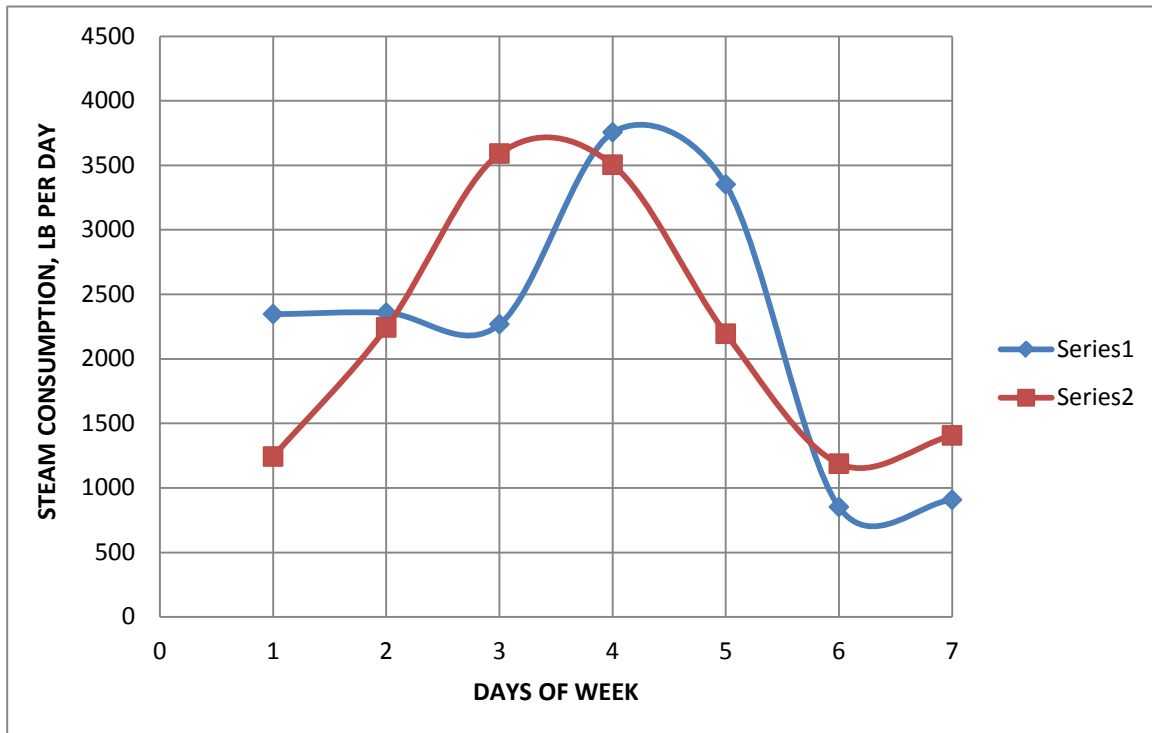
To compare the performance of the old DHW unit with the FPD DHW unit, the old unit was also equipped with monitoring devices. For two weeks, these devices continuously metered the cold water flow, the hot and cold water temperatures, and the steam consumption. The test results demonstrated that the steam consumption of the old DHW unit was 1.0369 lbs of steam per 1,000 Btu of generated heat. The comparison indicated that the old unit consumes 14.6% ([1.0369-0.9047]/0.9047) more steam than the FD DHW unit.

9 Economic Analysis

The economics of the Fisonic Device System is demonstrated for the Con Edison Headquarters building. The Con Edison Headquarters occupies all 27 stories of the building, which totals an area of 1,170,000 square ft. The building is supplied with steam from the Con Edison district steam system with a pressure of 170 to 200 psig. In the building, the steam pressure is reduced by pressure reducing valves to 3 to 5 psig for space heating and DHW. The building is equipped with 54 large fan rooms with switchover steam and cooling coils. The perimeter space hot water radiation is supplied from two tube and shell heat exchangers by four electrically driven pumps. The space hot water temperature is modulating from 90 to 180 °F. Two additional heat exchangers supply the DHW load.

The heating load of the building consists of space heating hot water supply to the building perimeter radiators, space heating steam for ventilation (direct steam supply to the air handler heating coils), and DHW and direct steam supply to the cafeteria kitchen. An assessment of the building heating loads has been performed utilizing the monthly steam consumption obtained from Con Edison. The heat load analysis indicated that the peak heat load of the space heating hot water system as 3.76 MMBtu/hr and the ventilation peak heat load as 3.74 MMBtu/hr. The average DHW and cafeteria kitchen load is 3.93 MMBtu/hr. This information was used to size and select the heat transfer equipment.

Figure 47 shows the hot water system supplying space heating to the building periphery radiators.

Figure 47. Con Edison Space Heating Hot Water System
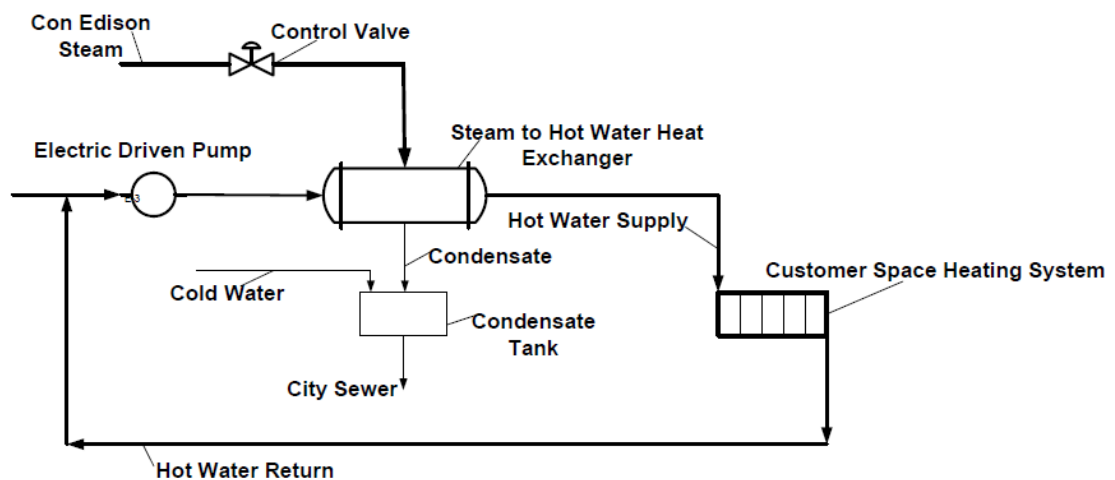
Figure 48 presents the retrofitted space hot water system equipped with the FDs. In this system when compared with the existing system (Figure 47), the heat exchanger is eliminated. The heat exchanger is replaced with the FDs which provide direct contact water heating with steam and water pumping. At very low loads, the FD does not generate the required pumping power. To provide the necessary pumping power at these conditions, a circulating pump is installed on the discharge line from the FD. The pump will operate for a limited number of hours during the year. The estimates show that the total pumping power of the system will be reduced by 80 percent in comparison with conventional system. The hot water return temperature can be reduced by heating the DHW in a plate and frame heat exchanger. Afterwards the return water is discharged to the existing dilution tank.

Figure 48. Space Heating System with the Fisonic Device
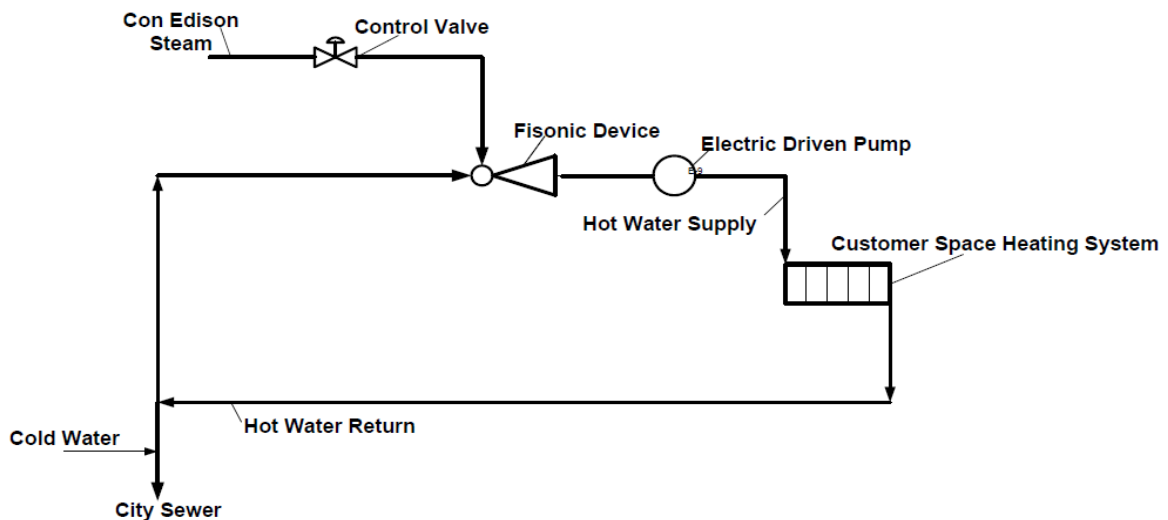
Table 4 presents the capital cost estimates for the retrofit of existing system with FDs. The capital cost includes the material and installation costs. The material cost was provided by HVAC equipment vendors and HFC, and the installation cost was supplied by the New York City mechanical contractors.

Table 5 presents the annual operational parameters of the existing and the FD space heating system. The consumption and peak load data in Table 5 were obtained from the heat load calculations. To determine the potential steam savings with the FD system versus the conventional system, the dependence of supply and return temperatures on the outdoor temperatures was obtained (Figure 49).

Figure 49. Dependence of Water Supply and Return Temperatures from Outdoor Temperature
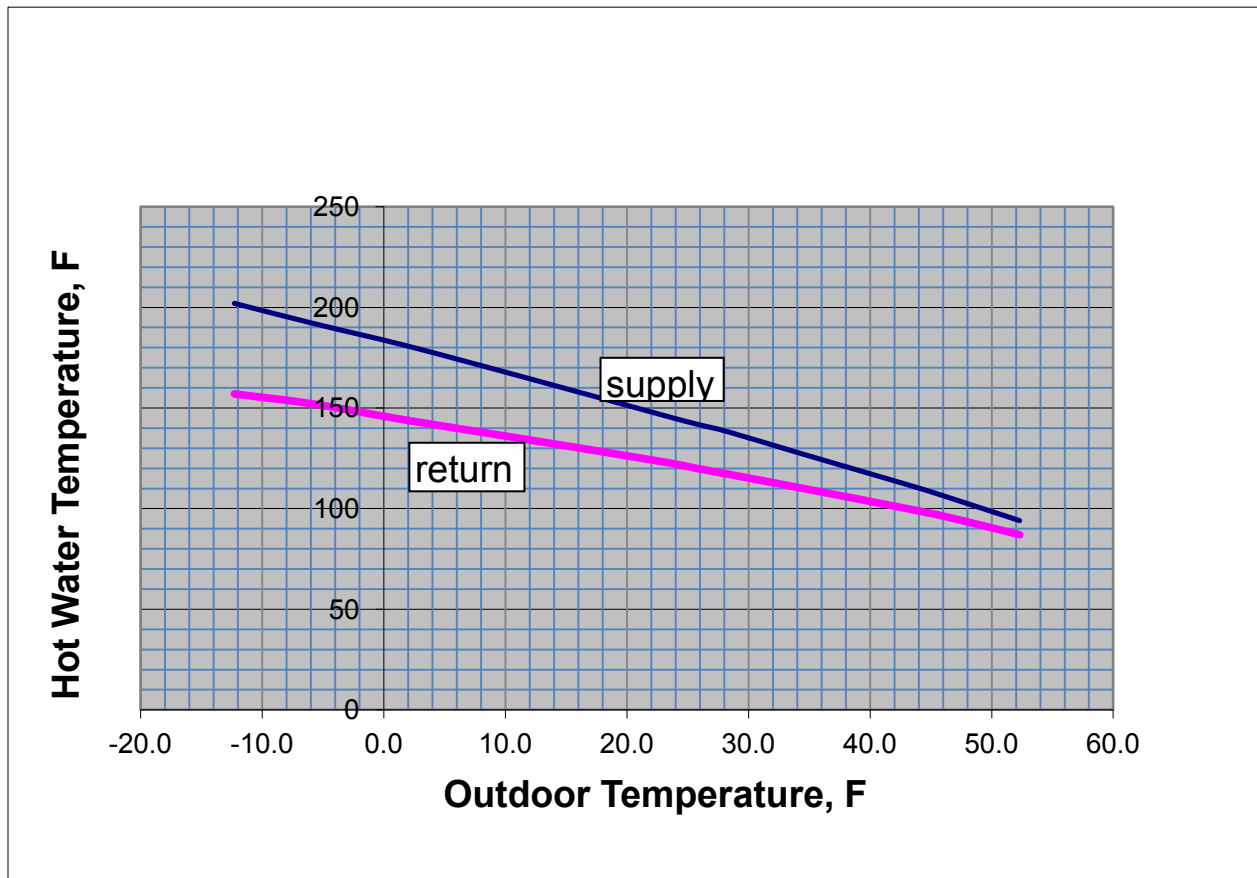
The potential steam savings for each outdoor temperature were determined by the ratio of the difference in enthalpies of the steam and condensate and the steam and the return water. The estimates for the duration for each outdoor temperature during the year demonstrated that the annual potential steam savings with the FD system amounted to 16.4 percent.

Table 4. Capital Cost of Existing System Retrofit with FDs

Items	Capital Cost, $
Fisonic Devices	21,000
Temperature Control Valve	9,000
Pressure Control Valve	5,330
Ball Valves	5,610
Nonreturn Valves	4,100
Piping,Small Valves,Supports, Insulation and Painting	13,910
Temperature and Pressure Sensors,Electric Power Supply,Connection to Graphic Screen	13,000
Subtotal	71,950
Engineering,Permitting,Drawings and Specification	28,780
Contingency	14,390
Total	115,120

Table 5. Annual Operational Parameters

PARAMETERS	Units	Existing System	System with FD
Annual System Heat Consumption	MMBtu	7,743	7,743
Annual Steam Consumption	Mlbs	7,722	6,458
Peak Comfort Heat Load	MMBtu/hr	3.86	3.86
Peak Steam Load	lb/hr	3,850	3,219
Hot Water Peak Flowrate	gpm	386	386
Annual Condensate Flow	Mlbs	7,722	6,458
Annual Make-up Water Flow	Mlbs	66,692	718
Annual Make-up Water Flow	Mgal	802	86
Total Condensate and Make-up Flow	Mlbs	14,414	7,176
Total Condensate and Make-up Flow	Mgal	1,728	860
Annual Electric Cons. For Hot Water Pumps	kWh	62,827	12,565

Table 6 presents the potential operation and maintenance (O&M) savings of the FD system in comparison with the existing system. The following unit costs (obtained during the building survey) were used:

- Average steam unit cost: $23.11/Mlb.
- Average make-up water (city water) unit cost: $2.67/Mgal.
- Average sewer unit cost: $4.28/Mgal.
- Average electricity unit cost: $0.15/kWh.
- Maintenance cost for the existing and the FD systems is 3 percent of capital cost.

Table 6. O&M Cost Comparison

In the Table 6, "cons" is an abbreviation for consumption.

PARAMETERS	Existing System		System with FD'S		Savings,
	Cons.	Cost, $/yr	Cons.	Cost, $/yr	$/year
Annual Steam Consumption,Mlbs	7,722	178,455	6,458	149,244	29,211
Annual Make-up Water Flow, Mgal	802	2,141	86	230	1,912
Total Condensate and Make-up Flow, Mgal	1,728	7,396	860	3,681	3,715
Annual Electric Cons. for Hot Water Pumps,kWh	62,827	9,424	12,565	1,790	7,634
Maintenance		11,483		7,722	3,761
Total		208,899		162,667	46,233

The analysis indicates that the simple payback for the building retrofit with FDs is $115,120/$46,233=2.5 years.

Table 7 presents the capital cost comparison between a conventional space heating system with heat exchangers and a system with FDs for a new construction alternative. Table 7 shows that the capital cost of the space heating system with FDs is about 33 percent less than for a conventional system.

Table 7. Total Capital Cost Estimates for New Conventional and Fisonic Space Heating Systems

Items	Size	Conven. System Qty	Conven. System $	System with FD's Qty	System with FD's $
Shell and Tube Heat Exchanger	4,000 MBH	2	26,600		
Fisonic Devices	4,000 MBH			2	21,000
Steam Pressure Reduction Valves		3	15,980		
Temperature Control Valves	4"	1	9,000	2	18,000
Water Pressure Control Valve	4"			1	5,330
Air Separator	1000 gpm	1	5,700	1	5,700
Expansion tank	1300 gal	1	8,100	1	8,100
Hot Water Circulating Pumps	50 HP	2	27,000	1	13,500
Hot Water Circulating Pumps	40 HP	2	24,000		
Relief Valve	3 "	1	900	1	900
Triple Duty Valves	4 "	4	3,000	1	750
Airtrol Fitting		1	720	1	720
Water Make-up Pressure Reducing Valve	2"	1	340	1	340
Suction Diffusers	4"	4	1,560	1	390
Ball Valves	4"	5	5,610	5	5,610
Gate Valves	4"	4	4,300	4	4,300
Chemical Feed Tank		1	1,370	1	1,370
Water Softener		1	5,700	1	5,700
Nonreturn Valves	4"			4	4,100
Motorized Butterfly Valves	4"	5	11,250	5	11,250
Piping, Small Valves, Supports, Insulation and Painting			44,300		27,820
Temperature and Pressure Sensors, Electric Power Supply, Connection to Graphic Screen			43,800		26,000
Subtotal			239,230		160,880
Engineering, Permitting, Drawings and Specification Preparation, Equipment Procurement, Construction Management			95,692		64,352
Contingency			47,846		32,176
Total			382,767		257,408

10 Potential Benefits and Commercialization of FDs

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

- **Energy Savings:** assuming the implementation of Fisonic devices by 30% of the Con Edison customers (540 buildings with current steam consumption of about 8.4 million Mlbs per year), the potential reduction in steam consumption of 16.4% will result in $32 million of cost savings to the customers: 8.4 million Mlbs × 0.164 × $23.4/Mlb (current average cost of steam to the customers = $32 million). The potential savings of the customers in electric consumption are: 8.4 million Mlbs × $0.80/Mlbs (estimated electric cost) = $6.7 million.
- **Water and Sewer Savings**: for the above assumptions the savings associated with cold water consumption and sewer discharge will be 8.4 million Mlbs × $0.48/Mlbs (estimated water and sewer cost) =$4 million.
- **Job Creation**: using 32 job years per $1 million of energy savings (EPRI, "Guidelines for Assessing the Feasibility of District Energy Projects,"www.epri.com) it is estimated that project implementation will result in creation of 1,580 job years.
- **Environmental Benefits:** using the following emission reduction factors in lbs/yr/Mlb:

    o NO_x:10.74 × 10^{-3}; Particulates : 4.3 × 10^{-3}; VOC : 1.5 × 10^{-3}; CO_2:60
    o The environmental benefits are estimated as the following pollution reductions in lbs/year, except CO_2:
    o NO_x :15,000; Particulates : 5,900; VOC : 2,100; and CO_2:37,600 tons/year.

The potential benefits of use of FDs for the State of New York customers are estimated as follows:

The annual primary energy consumption in NYS for buildings and industry is about 1,316 Tbtu (NYSERDA 2012). Assuming that 5 percent of this energy is supplied by steam with conventional heat exchangers and electric driven pumps, the current steam consumption can be estimated as 66 million Mlbs/year. Applying the previously described methodology for estimating the energy savings with the use of FDs, the potential benefits for the NYS are estimated as follows:

- Energy Savings: $386 million.
- Water and sewer discharge savings: $31 million.
- Environmental Pollution Reductions:

    o NO_x – 116,000 lbs/yr.
    o Particulates – 45,600 lbs/yr.
    o VOC – 16,200 lbs/yr.
    o CO_2 – 290,600 ton/yr.

10.1 Commercialization Plan

To start the FD commercialization, the following actions are planned:

- Under the sponsorship of Hudson Fisonic Corporation (HFC) and NYSERDA in close cooperation with Con Edison, demonstrate the operation of full-scale FDs at the Woolworth building in New York City.
- Taking into account the substantial potential energy savings and reduction of condensate and potable water discharge in the city sewer system, HFC will market FDs to the Con Edison customers, city and state administration, consulting engineers, and HVAC equipment vendors. All entities must be comfortable with the concept of using FDs, and all must be convinced of the cost effectiveness and benefits that they will provide.
- Many existing customers are in the process of replacing or upgrading an existing HVAC system, so local engineers and HVAC contractors are in an ideal position to market FDs by providing technical guidance. The city and state administration can also play an important role in marketing, especially when it comes to renovations of existing buildings and new construction, by passing an ordinance that would require every building in the district steam service area to consider using FDs as a prerequisite for obtaining a construction permit.
- HFC, in close cooperation with Con Edison, will conduct a seminar aimed at providing to potential customers, consulting engineers, and HVAC equipment vendors complete information concerning the benefits of FDs and recommending retrofit procedures and equipment.
- The demonstration of savings achieved by operation of FDs in a large commercial building in Manhattan, and marketing activities will motivate the steam customers into ordering the FDs for their buildings. This demand will allow HFC to planning for FD manufacturing in the NYS. Then, manufacturing start within 9 to 12 months after the completion of the demonstration project. With customer orders for the FDs in hand, the manufacturing facility will be financed by the HFC and a bank loan.
- The results of the demonstration project will be widely disseminated to steam customers in the New York City and NYS via articles in technical magazines and presentations to the Building Owners and Management Association (BOMA) and Manufacturing Association and Industrial Development Agencies.

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Appendix A: Equipment and Installation Specification of the Fisonic Device Test Facility

Section 1

1.1.1 1.01   <u>Introduction</u>

The Fisonic Device (FD) is a supersonic, condensing heat pump with a patented internal geometry which 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.Hudson Fisonic Corporation (HFC) under a contract with NYSERDA and with the support of Con Edison is constructing a demonstration test facility located at the 20th floor of Con Edison headquarters at 4 Irving Place, NY.The FD test facility installation is presented in Figure 1. During the tests Con Edison will supply saturated steam and cold potable water to the facility.

The steam supply for the test facility is branched off with a 2 inch line from the Con Edison building heating system at 50 psi pressure. The steam line is equipped with gate valve and a 1 inch steam flow meter FM1 (Figure 1). The flow meter and other equipment specifications are presented in Appendix A. Con Edison requiested that the test facility will utilize steam with a maximum pressure of 15 psig.Therefore a pressure regulator/emergency shutoff device PRV1 is installed after the gate valve 2. During the start up the condensate which may accumulate in the steam line will be drained.The steam line is also equipped with an additional pressure regulator and the hot water temperature control valve TRV. The steam line is equipped with a steam trap line for drainage of the condensate during facility start-up. Following the TRV 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.

Cold potable water from the existing Con Edison line will pass the water flow meter FM2, the back flow preventer, a check valve and enter the Fisonic Device.

In the Fisonic Device the cold water will be mixed with steam, heated and accelerated to a higher pressure than the mixing streams. The water flow rate discharged from the Fisonic Device is measured by the flow meter FM3 (Figure 1). After the flow meter the hot water is discharged into the condensate tank, from which it is drained to the collection tank located in the basement.

The test facility 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 during the performance of the tests. The instrumentation is also shown on Figure A-1. The detailed description of all equipment and instrumentation is tabulated in Table A-1.

Figure A-1. Installation of Fisonic Device Test Facility
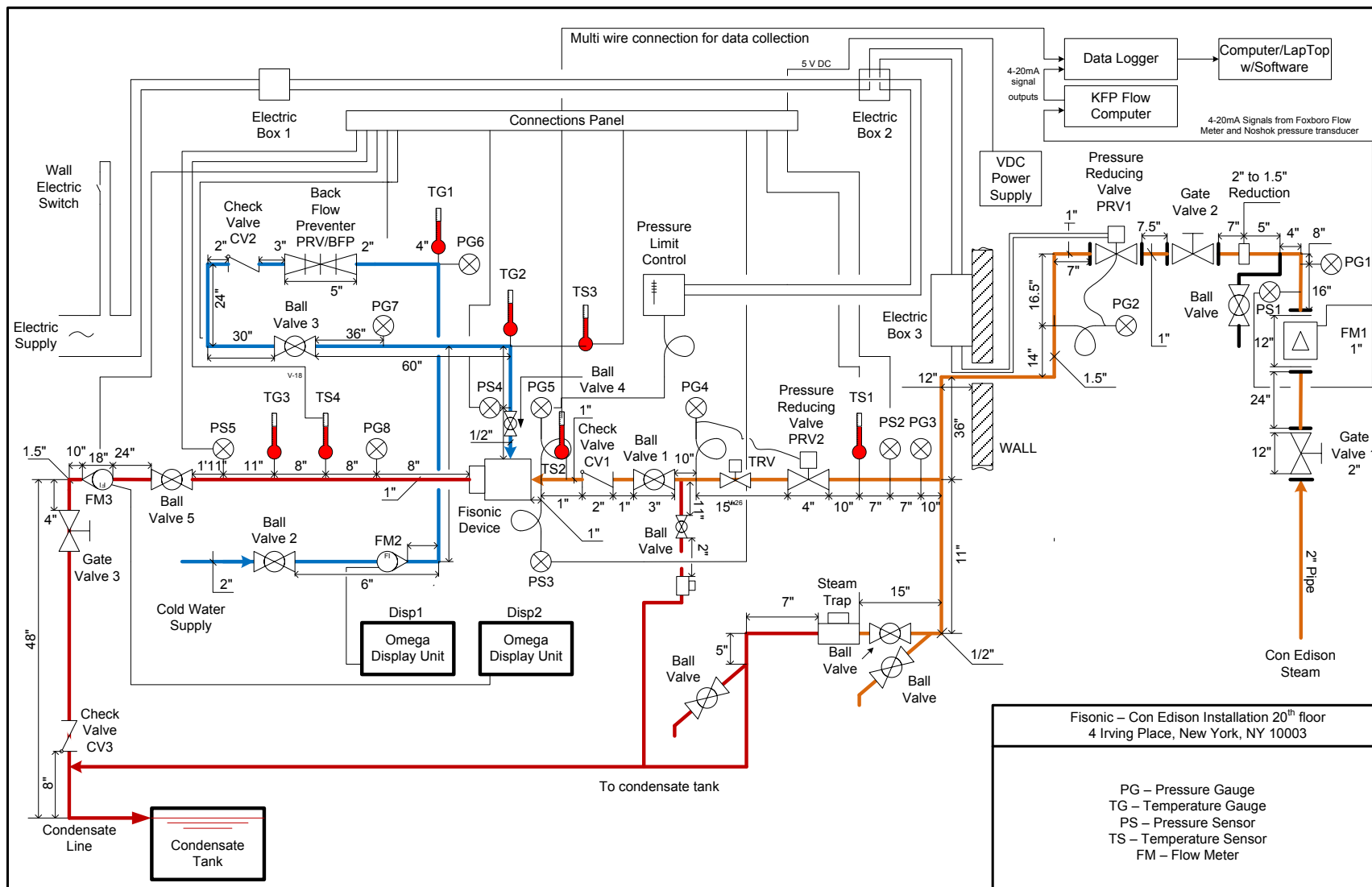
1.1.2   1.02   <u>Definitions</u>

A.   Owner is defined as the Con Edison Company of New York.

   B.   Hudson Fisonic Corporation (HFC) is responsible for purchasing the major

      Equipment, construction management and performance of the tests.

C.   Contractor is defined as the installer of the Fisonic Device (FD) test facility inside the Con Edison building as specified by the HFC. The scope of work, terms and conditions are strictly as mutually agreed to by the Contractor and HFC.

 1.03   Scope Of Work

The installation Contractor (Contractor) shall be responsible to the HFC for satisfactorily completing of the test installation in the Con Edison building. HFC will supervise the installation work. The Contractor and HFC shall comply with the Con Edison Specific Environmental Health and Safety (EH&S) Plan Provided in Appendix A.

The scope of this 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 shall include all labor necessary for installing all equipment, control work, electrical work and services such as:

Valve off and chain the valve on the existing steam supply. Install all necessary components of the test facility in accordance with the Figure 1 and the specification.

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.

Electrical work. All electrical work shall be done with EMT with oil resistant wiring. Separate 15 amp circuit breaker with breaker lock for Btu meter terminated in a 4" square "1900" box with cover located near Btu meter.

The Contractor is responsible for successful hydrostatic test of all installed piping and equipment.

TABLE A-1. LIST OF INSTRUMENTATION AND EQUIPMENT FOR FISONIC DEVICE DEMONSTRATION TEST

DESIGNATION	MFG	Type	Model #	EXPECTED VALUE	RANGE/Rating	ACCURACY	Function
Steam Side							
PG1	Noshok	Hall Effect Pressure Transducer	630C-100-1-13-2-25	50	0-100 psi	1%	Steam Supply Pressure
TG1	Pyromation	Type J Thermocouple	J48G-001-00-6HN3	300	32-1382 deg F	max 3 Deg / .75%	Steam Supply Temperature
WV1			Apollo 64 series	2"	200 psi 450 deg F		Steam Supply Shutoff Valve
FM1	foxboro		CFS10	2500-4500 lb/hr	5000 lb/hr		Flow Meter
FM Processor			3ADI3IA	N/A	N/A		Converts FM1 to 4-20 ma signal
TG2	Pyromation	Type J Thermocouple	J48G-001-00-6HN3	300	32-1382 deg F		Steam Temp after flow meter
PG2	Noshok	Hall Effect Pressure Transducer	630C-100-1-13-2-25	50	0-100 psi	1%	Sream Pressure after flow meter
PRV1	Sarco		SRV2S	70 psi	360psi/410 deg F		Pressure Regulator
PG3	Noshok	Hall Effect Pressure Transducer	630C-100-1-13-2-25	50	0-100 psi	1%	Regulated Pressure
TG3	Pyromation	Type J Thermocouple	J48G-001-00-6HN3	300	32-1382 deg F		Regulated Temperature
Shut Off Emergency Valve	ASCO	ANCI Class 300	8220-G013	15 psi	0-125 psi 350 Deg F	N/A	Emergency 120VAC selenoid valve 2" pipe dia.
TRV	Cashco		Ranger	15 psi	130psi		Process Control Valve
PG4	Noshok	Hall Effect Pressure Transducer	630C-100-1-13-2-25	50	0-100 psi	1%	Steam Pressure to device
TG4	Pyromation	Type J Thermocouple	J48G-001-00-6HN3	300	32-1382 deg F		Steam Temperature to device
Check Valve	Velan		Proquip DP	2", 70 psi	150-2500 psi		Check Valve
PG2 Digital Display	Omega		DP25B-E	50	0-300		Steam Supply Pressure Indication at test room
Safety Valve	Leser	ANCI Class 300	447 - DN 25	50 psi	1.5-230 psi		Safety relief valve
Supply Water Side							
PG6	Noshok	Hall Effect Pressure Transducer	630C-100-1-13-2-25	50	0-100 psi	1%	Water Feed Pressure
TG6	Pyromation	Type J Thermocouple	J48G-001-00-6HN3	300	32-1382 deg F		Water Feed Temperature
PRV2	Sarco		SRV2S	30 psi	360 psi/410 deg F		Water Pressure Regulator
WV2			Apollo 64 series	2"	N/A		Water Supply Shutoff Valve
FM2	Omega		FD400	10-20 gpm	4-200 gpm	0.6 gpm	Water Flow Meter Ultrasonic clamp-on
WV5			Apollo 64 series	2"	N/A		Water Feed to device shutoff
PG5	noshok	Hall Effect Pressure Transducer	630C-100-1-13-2-25	50	0-100 psi	1%	Water Feed to device pressure
TG5	Pyromation	Type J Thermocouple	J48G-001-00-6HN3	70 deg F	32-600 deg F	0.20%	Water Feed to device Temperature
Water Bypass							
TG7	Pyromation	Type J Thermocouple	J48G-001-00-6HN3	140 deg f			Recirc water temperature
PG7	Noshok	Hall Effect Pressure Transducer	630C-30/100-1-13-2-25	70 psi	"-30 - 100" psi	1%	Recirc water pressure / vacuum
WV5			Apollo 64 series	2"	N/A		Recirc Water Valve
Hot Water Side							
EXP-T			J48G-001-00-6HN3	300	32-1382 deg F		Expantion tank for pressure stabilization
TG8	Pyromation	Type J Thermocouple	J48G-001-00-6HN3	140 deg F	60-200 deg F		Device Output Temp
PG8	Noshok	Hall Effect Pressure Transducer	630C-150-1-13-2-25	50	0-150 psi	1%	Device Output Pressure
CASHCO TEMP SENSOR	Cashco		1000 HP	15 deg F	500 deg F		Temperature regulation sensor
FM3	Omega		FD400	3-6 gpm			Device Flow Output Ultrasonic
FM3	Omega		FP-5201	3-6 gpm	4-200 gpm	0.6 gpm	Insertion probe 1500 psi 300 deg F
WV6			Apollo 64 series	2"	N/A		Ball type water valve
TANK			Stainless Collector	N/A	N/A		Collector/drainage tank
AEV	Bell&Gosset		EAS-2	70 psi	150 psi		Tank Drain Valve
WV7			Apollo 64 series	2"	N/A		Tank Pressure Relief Valve
PSV2	Kunkle		19 20 200	70 psi	300 PSI - 300°F		Device Output relief valve
PG9	Noshok	Hall Effect Pressure Transducer	630C-30/100-1-13-2-25	70 psi	"-30 - 100" psi	1%	Tank Pressure/ Vacuum
DRAIN			N/A	N/A	N/A		To City Drain.
TG9	Pyromation	Type J Thermocouple	J48G-001-00-6HN3	140 deg F	32-200 deg F		Tank Temperature
WV3			Apollo 64 series	2"	N/A		Tank Recirc Control Valve
Misc							
DL	Fluke		Hydra				21 Channel. Accepts Thermocouple and Analog Inputs
MC	Panasonic		Toughbook				Windows XP Display Software
FD	Fisonic		FD				Testing Device
PLC	Allen Bradley	micrologix 1400	1766l32bwaa				PLC
	Allen Bradley	thermocouple card	1762it4				4 thermocouple input

1.1.3 1.04 <u>Drawings</u>

Figure 1 indicate the approximate location of all equipment and piping, and shall 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 shall be made by the Contractor without extra charge to the HFC. Figure A-1is made part of this specification. The major Equipment Data Sheets are presented in Attachment.

1.1.4 1.05 <u>Coordination And Supervision</u>

Contractor shall provide adequate competent supervision at all times when work is being performed. Cooperate with all other trades to avoid interference's and delays.

1.1.5 1.06 <u>Local Conditions By The Contractor</u>

A.   Visit site, become familiar with conditions affecting this work. No additional payment will be made on claims that arise from lack of knowledge of existing conditions.

B.   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.

C.   Work includs alterations and connections to existing utilities. When necessary to temporarily interrupt a service, arrange with Owner in advance as to time which will be least disruptive. Consider all work as being performed during normal working hours and in conformity with approved work progress schedule.

D.   Provide temporary services of any nature required to keep building mechanical services functioning. Remove temporary services when permanent facilities are completed.

1.1.6 1.07 <u>Protection By The Contractor</u>

A.   When setting up a pipe shop, cutting, threading machines, protect area against staining, abrasion. Cost of correcting any such condition will be charged against the Contractor.

B.   Protect finished floors from chips and cutting oil by use of chip receiving pan and oil proof cover.

C.   Protect equipment and finished surfaces from welding and cutting spatters with baffles and splatter blankets.

D.   Protect finished surfaces from paint droppings and insulation adhesive, etc.

1.1.7 1.08 <u>Product Handling</u>

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

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

C.   Arrange for packaging of equipment, which must be hoisted, so that there will be no damage or distortion caused by hoisting operation. Protect equipment from any damage during hoisting operation.

D.   Protect equipment from dirt and moisture.

1.1.8 1.09 <u>Damage And Emergency Repairs</u>

A. Assume responsibility for any damage caused by leaks in the piping system being installed or reworked under this contract. Repair this damage without extra cost to HFC.

B. HFC reserves the right to make emergency repairs as required to keep equipment in operation, without voiding Contractor's guarantee or relieving him of responsibility during warranty period.

C. Restore grounds, insulation, piping, building, etc., to their original condition whenever this work causes damage.

1.1.9 1.10 Guarantee And Warranties

A. Warrant that equipment and all work is installed in accordance with good plumbing practice and that all equipment will meet requirements specified.

B. In a reasonable time, the Contractor shall correct any installation component not operating as specified.

1.1.10 1.11 Equipment Supports

The Contractor shall provide all supports, shelving, brackets, inserts, and anchor bolts for all equipment and items supplied and installed by him.

1.1.11 1.12 Cutting and Patching

A. The Contractor shall be responsible for all cutting, patching and fitting of his work that may be required to make its several points come together properly as shown upon or reasonably implied by the Figure 1.

B.   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, shall be done by the Contractor at his expense.

1.1.12 1.13   Material and Workmanship - General Requirements

The Contractor shall carefully examine and check the provided documents before accepting his contract, starting his work or purchasing any materials and shall call attention to any changes or additions which, in his opinion, are necessary to make possible the fulfillment of any guarantees called for; failing which, he shall be deemed to have accepted such guarantees and be bound thereby.

1.1.13 1.14   Codes and Permits

A.   Contractor shall comply with all rules, regulation of New York State, County, and New York City authorities having jurisdiction over the premises.

B.   Secure and pay for all permits and certificates of inspection required.

1.1.14 1.15   Standards

A.   Contractor shall comply with the applicable provisions of latest edition of the following industry standards:

1.   American Society of Testing Material

2.   American Welding Society Code

3.   ASME Boiler and Pressure Vessel Code

4.   ASME Power Piping Code B31.1

5.   National Electrical Code

6.   National Fire Protection Association Standards

            7.   N.Y. State Building and Fire Protection Code

1.1.15

1 Section 2: Products

1.1.1 2.01 <u>Quality of Material</u>

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

1.1.2 2.02 <u>Piping Material and Fittings</u>

A.   Pipe as hereinafter scheduled shall conform to the following ASTM designations:

            1. Steel Schedule 40:   ASTM A-53 Grade A/B

        Note: Seamless Steel Schedule 80 is required for threaded connections for district heating piping.

2. Copper Tube: ASTM B-88

        B.   Fittings as hereinafter scheduled shall conform to the following ASTM designations:

            1.   Cast Iron: A-126

            2.   Malleable Iron: A-197

            3.   Steel Welding: A-234

        4.   Silver Solder: B-88

C. The following manufacturers are acceptable for furnishing materials listed under each group:

       1.   Steel Pipe: National Tube Co. or equal

       2.   Copper Tube: Chase Brass & Copper Co. or equal

3.   Fittings of Cast Iron

Malleable Iron or Brass: Crane Co. or equal

4.   Fittings of Welded Steel: Tube-Turn or equal

D.   Pipe and Fittings Schedule as shown in Table 2.

Table A-2

Pipe and Fittings Schedule

SERVICE	PIPE	JOINT	FITTINGS	RATING psi/^{O}F
Steam and Hot Water	40/80 Black	Welded, Flanged	Steel- 300/3000 lb.	150/300
Secondary Hot Water	40 Black or "L" Copper	Welded, Flanged, Screwed or Soldered 95-5	C.I. - 125 lb.	150/250
			M.I. - 150 lb.	150/250
			Copper	125/225
Cold & Hot Potable Water	"L" Copper	Soldered 95-5, Screwed or Flanged	Wrought	125/225

F.   Strainers shall be "Y" type of the same size and material as the pipe line in which they are installed. Strainer shall be furnished with monel screens with mesh of 1/16" to protect the flow meters. A strainer shall be provided at all equipment that utilizes a precision seat.

G.   Unions shall be as manufactured by E. M. Dart Co. or approved equal:

1.   Non Ferrous: 2 inch and smaller, all bronze body

2. Ferrous: Material compatible with the service pressure and temperature rating.

3. Dielectric unions shall be used on all steel to copper joints "EPOS" or equal.

1.1.3   2.03   Steam and Hot Water Piping

A.   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 shall be used for the threaded portion of the piping system.

1.1.4   2.04   Hot and Cold Potable Water Piping

A.   Piping shall be seamless copper, Type "L", as manufactured by Chase Copper and Brass Co. or equal.

B.   Fittings shall be wrought copper, flanged, sweat or screwed pattern using 95-5 solder. <u>NO OTHER</u> solder shall be used.

C.   Ball valves, sweat ends for water service as shown on the drawings, shall be Watts or approved equal.

2.06   Pressure and Thermometers Gauges

A.   Pressure gauges shall be installed where shown on the drawings.

1.   Pressure gauges shall be 4½" dial, drawn steel case and ring, white face, black figures.

2.   Trerice No. 800 with No. 885 coil siphon for steam service.

B.   Thermometer: 9" red mercury with die cast aluminum case and unbreakable lens, separable sockets, white face with black figures. Ranges shall be as required so normal operation is at about the middle of the face and adjustable angle if necessary.

1.   Thermometers shall be located on the equipment and rotated so that they can be read by a man standing on the floor with normal room illumination.

2.   Thermometer shall be manufactured by Trerice or equal and be industrial series grade.

3.   A 30^OF to 300^OF range thermometer shall be used to measure the steam and water temperature. All other thermometers shall have the standard range of 30^OF to 300^OF unless otherwise specified.

1.1.5 2.07   <u>Water Specialties</u>

A.   Cold water make-up shall 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.

B.   At every high point, provide a manual air vent valve for system air relief.

A-14

C.   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.

D.   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.

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E.   Relief valve(s) shall be designed in accordance to ASME code. Each valve shall be piped separately no closer than 6" to the floor. Relief valve shall be sized to relieve 100% of the heating capacity.

1.1.6   2.08   <u>Heat Exchanger</u>

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

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

1.1.7   2.09   <u>Insulation</u>

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

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

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

1.1.8   2.10   <u>Backflow Preventers</u>

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

1.1.9

2   Section 3: Installation

2.1.1   3.01   <u>Pipe Installation by Contractor</u>

A.   The location of piping, as indicated on the Figure 1 unless otherwise noted, is diagrammatic only, and the exact location shall be responsibility of the Contractor for the correctness of field dimensions and shall check for himself all grades, lines, measurements and other data in any way affecting the work. Make offsets as may become necessary to meet the actual field conditions. Contractor shall not be entitled to any extra compensation for any additional work or expense arising from his failure to do so.

B.   The Contractor shall 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 shall 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 shall 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.

C.   Pipe sleeves, inserts, hangers, and supports as well as equipment supports shall be furnished and set by the Contractor and he shall be responsible for their proper and permanent location. Pipe will not be permitted to pass through footings. The Contractor shall be 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 shall be furnished for all horizontal and vertical piping.

D.   All steel pipe, throughout the job, shall be reamed smooth and all burrs removed before being installed. Pipe or tubing shall not be split, bent, flattened nor otherwise injured, either before or during the installation. Full lengths of pipe shall be used wherever possible.

E.   Reducing fittings shall be utilized in making reductions in size of pipe. Bushings will not be allowed.

F.   Unions or flanges shall 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.

G.   All piping connections to risers or equipment shall be from the top of mains. Particular care shall be used to assure proper air venting.

2.1.2

H.   Piping subject to expansion shall be flexible and installed to safely absorb all defection stresses. All piping shall be erected to insure a perfect and noiseless circulation throughout the system.

2.1.3   3.02   <u>Hangers, Anchors and Supports</u>

A.   Equipment and accessories shall be set level plumb and in proper alignment with walls and floors.

B.   All piping and equipment shall 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 shall be supported to maintain grade and pitch. Hangers, etc. shall permit the piping to expand and move as necessary.

C.   All hangers shall 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 they shall be secured in approved inserts wherever possible and practicable. Field drilling where required, shall be done by the Contractor.

D.   Piping shall be supported at all changes of direction, base of risers and on all branch lines regardless of lengths and at a maximum spacing as shown in Table 3.

Table A-3

Pipe Support Spacing

Maximum Span		
Nominal Pipe Size	Water Service	Steam, Gas or Air Service
in.	Ft.	Ft.
1	7	9
2	10	13
3	12	15
4	14	17
6	17	21
8	19	24
12	23	30
16	27	35

E.   Where two or more lines run parallel, approved type trapeze hangers may be used.

F.   Approved bolts and inserts shall be used for connecting hanger supports, fixtures, or equipment to masonry. Wooden plugs shall not be used. Provide necessary templates and bolts. Set bolts in sleeves of proper length and size.

G.   The use of perforated strap iron will not be permitted. Piping on side walls shall be supported from approved "J" type bracket. No piping shall be hung from piping or equipment of other trades. Hangers shall be wrought iron, malleable iron, copper or steel as manufactured by Grinnell or approved equal. Roller type hangers shall be used on all insulated lines and all piping three (3) inches and larger. Clevis type hangers shall be used on all 2½" inches and smaller pipe size.

2.1.4   3.03   Insulation Installation

A.   General: The work covered by this specification shall consist of furnishing all labor, equipment, material and accessories and performing all work necessary for the installation of all insulation for all piping.

B.   Insulation shall be applied to clean, dry surfaces. Piping shall be tested before insulation is applied or joints shall be left uncovered until tests have been performed. All lumps of plaster, cement, and paint shall be removed before insulation.

C.   All insulation shall be installed in complete accordance with the manufacturer's instructions and recommendations.

D.   All sections of insulation shall be tightly butted together. Laps shall be applied according to manufacturer's published recommendations to maintain a tight seal on the lap, a field coat of vapor barrier adhesive shall be applied. In areas where insulation is run exposed, laps shall face the wall or ceiling to enhance appearance; in concealed areas they shall face downward to facilitate inspection.

H.   The piping may be insulated before testing, leaving all fittings and joints uninsulated until after hydrostatic tests are completed.

2.1.5   3.04   Electrical Installation

The Contractor shall 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 shall match existing wiring, i.e., (conduit, electrical metallic tubing, romex) and be in accordance with the National Electrical Code.

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

2.1.6 3.05 Hydrostatic Tests

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

3.06   Pipe Welding Requirements

Contractor shall use 300/3000 lb. rated welded fittings. Socket welded fittings up to and including 2" pipe shall 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 shall 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 shall be on record with the Engineer prior to the start of any welding.

Appendix B: Con Edison Specific Environmental Health and Safety (EH&S) Plan

Job Description

Testing of Fisonic Device

Location

20th Floor

4 Irving Place

New York, New York 10003

Contracting Company   Robert Kremer

Hudson Fisonic Corporation   917-806-6230

EHS Representative

Mazetta Ford-Medina,Senior Safety Specialist

Facilities EH&S

Phone # (212) 460-3047

Cell # (917) 578-3078

A COPY OF THIS HASP MUST BE PRESENT AT ALL TIMES WHILE DUDSON FISONIC IS ON SITE. WORK WILL BE STOPPED IMMEDIALY IF THIS HASP IS NOT ON LOCATION. THE TIME LOST WILL BE PAID FOR BY THE CONTRACTOR, NOT BY CON EDISON. THIS HASP HAS BEEN REVIEWED BY ALL ON-SITE EMPOYLEES.

Contracting Company:

Hudson Fisonic Corporation

Project Manager:

Robert Kremer

Emergency Contacts:

Robert Kremer

917-806-6230

Job Site Supervisor:

Robert Kremer

917-806-6230

Site EHS (Safety Officer) Representative:

Robert Kremer 917-806-6230

Con Edison Representative:

Mazetta Ford-Medina,Senior Safety Specialist

Facilities EH&S

Phone # (212) 460-3047

Cell # (917) 578-3078

Job Description (scope of work)

Hudson Fisonic Corporation (HFC) is testing a Fisonic Device.The test installation is connected to the building steam and cold potable water piping.The liquid exhaust from the Fisonic Device is discharged to the drain system of the building

2) Emergency Procedures and Notifications

Police Department – 911

Fire department - 911

Ambulance - 911

B-2

Employees will review with the on-site Con Ed Representative all emergency evacuation procedures when assigned to work in any Con Ed facilities.

Site Control (describe how the area and public will be protected)

The testing area will only be accessible by authorized personnel. Appropriate barriers or barricades will be used as necessary to limit access and/or proximity by individuals to moving parts or other hazards.

Before we start any work we will review with Con Edison our work task and ask Con Edison to brief us on any hazards pertaining to the job.

Job Hazard Analysis and Control:

Hazard Identification: Identify and address "all" EH&S hazards present during the course of performing this job activity. Below are general hazard classifications that you are required to select. Additional hazards should be presented below. Reference HASP manual for clarification of each item if needed. Each item must be addressed in the report (see headings below).

1.0 Air Resources   _____

2.0   Asbestos Awareness   _____

3.0   Blood borne Pathogens Exposure Control Plan   _____

4.0   Chemical Safety and Handling   _____

5.0   Confined Space Program (Permit-Required   _____

6.0   Electrical Safety   __X__

7.0   Electrical Enclosed Spaces   _____

8.0   Excavation and Trenching   _____

9.0   Fish, Wildlife and Wetlands   _____

10.0 Fire Protection and Prevention   _____

11.0 Gas Enclosed Spaces   _____

12.0 Hazard Communication Program   _____

13.0 Hearing Conservation   _____

14.0 Job Briefing   _____

15.0 Insulation Materials (Non-Asbestos)   _____

16.0 Lead Management Program   _____

17.0 Management of Change   _____

18.0 Materials Handling   _____

19.0 Mechanical

20.0 Mercury Management Program   _____

21.0 Noise   _____

22.0 Oil and Dielectric Fluid   _____

23.0 PCB Management   _____

24.0 Personal Protective Equipment   __X__

25.0 Pesticide Use, Storage, and Disposal   _____

26.0 Respiratory Protection Program   _____

27.0 Sampling   _____

28.0 Vehicle Management   _____

29.0 Waste Management   _____

30.0 Water Resources   _____

31.0 Welding and Burning   _____

32.0 Work Area Protection   __X__

     33.0 Working at Elevations   _____
     34.0 Drug and Alcohol Program   _____
     35.0 FR Clothing   _____
     36.0 Close Call Program   _____
     37.0 Time Out Program   _____
     39.0 Training   _____

5) Hazard Evaluation

Applicable Potential Hazards to be Addressed:

1.0 Air Resources

2.0 Asbestos Awareness

    If Hudson Fisonic Corporation encounters any ACM/PACM, the employees will stop work in the area and notify Con Edison representative.

3.0 Blood Borne Pathogens exposure control

Con Edison representative will be notified immediately in the event of an incident involving BBP exposures.

4.0 Chemical Safety and Handling

5.0 Confined Space Program

6.0 Electrical Safety

HFC will be testing a Fisonic Device. All testing will be done under the oversight of ConEd following their safety procedures. No decisions will be made without prior approval from ConEd.

7.0 Electrical Enclosed Spaces

8.0 Excavations and Trenching

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9.0 Fish, Wildlife and Wetlands

10.0 Fire Protection and Prevention

Con Edison representative will be notified of all fire or explosion occurrences.

11.0 Gas Enclosed Spaces

12.0 Hazardous Communications

13.0 Hearing Conservation

14.0 Job Briefing

15.0 Insulation Materials (Non-Asbestos)

16.0 Lead Management Program

17.0 Management of Change

Carrier Commercial Services must notify Con Edison representative of any change in working conditions that could affect compliance with environmental or health and safety requirements as soon as the changed conditions are identified.

18.0 Materials Handling

19.0 Mechanical Equipment

HFC Employees will be operating/testing mechanical equipment. This equipment

is located within a separate room on the 20th floor of Con Ed Headquarters building. The installation is protected with safety valves.

20.0 Mercury Management Program

21.0 Noise

22.0 Oil and Dielectric Fluid

23.0 PCB Management

24.0 Personal Protective Equipment (PPE)

HFC employees will wear safety glasses, and hard hats at all times. If additional PPE gear is required, it will be necessary for ConEd to supply this to HFC for the duration of the visit.

25.0 Pesticide Use, Storage, and Disposal

26.0 Respiratory Protection Program

27.0 Sampling

28.0 Vehicle Management

29.0 Waste Management

30.0 Water Resources

31.0 Welding and Burning

32.0 Work Area Protection

Sufficient barriers and/or barricades will be utilized to provide protection to all personnel from hazards during testing. These barriers will be supplied by ConEd and installed per their procedures.

33.0 Working at Elevations

34.0 Drug and Alcohol Program

35.0 FR. Clothing

36.0 Close Call Procedure

37.0 Time Out Program

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38.0 Training

NOTE: We will follow all of Con Edison, New York State, local, and federal government regulations as it pertains to our work for Con Edison.

6) Housekeeping

Our work area is maintained and monitored to assure safety to all workers. Our employee will monitor the work site for any tripping hazards and correct it accordingly. All sites shall be left clean and free of debris.

7) Training and Hazard Communication:

Are all your personnel (including sub-contractors) trained to conduct their job responsibilities in this plan?

Yes   X   No

Are your employees HazCom trained in the hazards they will be confronting for this project?

Yes   X   No

Job Briefings will be conducted with employees at the start of the shift?

Yes   X   No

How often are documented safety talks conducted?

Daily   shift   weekly   As Needed X

Will all visitors be briefed on evacuation/fire/emergency procedures?

Yes X   No

Visitors will be escorted to job sites and made sure all PPE is in place. As most of our jobs are along roads and out in open it is not necessary to brief them on emergency routes since they will be escorted at all times.

Will all Sub-Contractors be covered under this site-specific HASP?

Yes   X   No

24

If Respirators are used, will all employees be medically qualified, clean-shaven and fit-tested in the respirator?

Yes   No   N/A X

8) Environmental Management:

Check off or include any environmental issue that your job presents.

Air Resources _____   Fish, Wildlife and wetlands _____

PCB Management _____   Hazardous Waste Management _____

Waste Management   Spill Management

Water Resources _____   Asbestos Management _____

Other:

9) Contractor Employee Acknowledgement

Contractor site supervision is responsible for assuring the contents of this HASP are known by all contractor employees and are implemented on site during job performance.

Typical Hazards of Concern

2.1.6.1   *Physical*

Heat	Noise	Radiation
Cold _____	Confined Space _____	Excavation
Trenching	Welding	Burning
Electrical __X_____	Fire Protection _____	Road Work
Rotating Equipment _____	Cranes_____	Work in Elevations _____

Scaffolding _____   Rigging _____   Material Handling

Grinding   Hand Tools   Demolition

Ladders   Steel Erection   Concrete

Power Tools___   Mechanical Equipment X   Slippery Surfaces

Chemical

Lead   Asbestos   PCBs

Mercury   Oil   Lubricants

Cement   Dielectric fluid   Solvents

Gasoline   Diesel   Other Fuels

Silica   Carbon Monoxide   Pesticides

Dust-Particulates _____   Hydrogen Sulfide _____   Isocyanates _____

Acids   Caustics   Glues

Adhesives   Epoxies   Detergents

Bleach   Ammonia   Heavy Metals

Benzene   VOCs   Lacquers

_____

Appendix C: Details of the Pilot Stand for Testing the FHGD

Figure C-1 Heat Exchanger for the Pilot Stand

aic SAHARA

2899 Portland Drive
Oakville, Ontario
L6H 5S4 Canada
T: 905-829-4666, F: 905-829-4646

DATE:	2/1/2012
PROJECT:	HEX-1
CONTACT:	Robert
COMPANY:	Fisonic
CALC. NO.:	K120201-15-02
PREPARED BY:	Mo Kazemi
REF:	0082-120201090439-110616

HEAT EXCHANGERS CALCULATION SHEET

PROJECT DATA SHEET

Heat Load	1600032.27 BTU/h	
LMTD	31.9 deg. F	
Min. Oversizing	0 %	
	Hot Side	**Cold Side**
Fluid	water	water
Inlet Temperature	180.00 deg. F	40.00 deg. F
Outlet Temperature	65.00 deg. F	140.00 deg. F
Mass Flow	13915.93 lb/h	15989.53 lb/h
Inlet Volume Flow	28.60 USGal/min	32.00 USGal/min
Outlet Volume Flow	27.83 USGal/min	32.40 USGal/min
Max. Pressure Drop	14.50 psi	14.50 psi

HEAT EXCHANGER SELECTION

Heat Exchanger Type	LC110 – 70X2J	
# of Units Parallel	1.00	
Heat Transfer Area	85.2 ft2	
Fouling Factor	0.0002 ft2hf/BTU	
OHTC Clean	675.9 BTU/ft2hf	
OHTC Fouling	588.2 BTU/ft2hf	
Oversize	14.9 %	
	Hot Side	**Cold Side**
Calculated Pressure Drop	1.90 psi	2.22 psi
Heat Transfer NTU	-	-

PHYSICAL PROPERTIES

	Hot Side	**Cold Side**
Fluid	water	water
Pressure	100.0 psig	100.0 psig
Reference Temperature	122.5 deg. F	90.0 deg. F
Density	61.826 lb/ft3	62.222 lb/ft3
Heat Capacity	1.0 BTU/lbF	1.001 BTU/lbF
Thermal Conductivity	0.365 BTU/fthF	0.353 BTU/fthF
Dynamic Viscosity	0.549 cP	0.764 cP

Dimensions: mm (inches), NP = 'Number of Plates'

A	B	C	D	F	K1	K2	K3	K4
530 (20.9)	248 (9.8)	454.7(17.9)	170.2(6.7)	13.0 + 2.4NP(0.51+ 0.09NP)	2"	2"	2"	2"
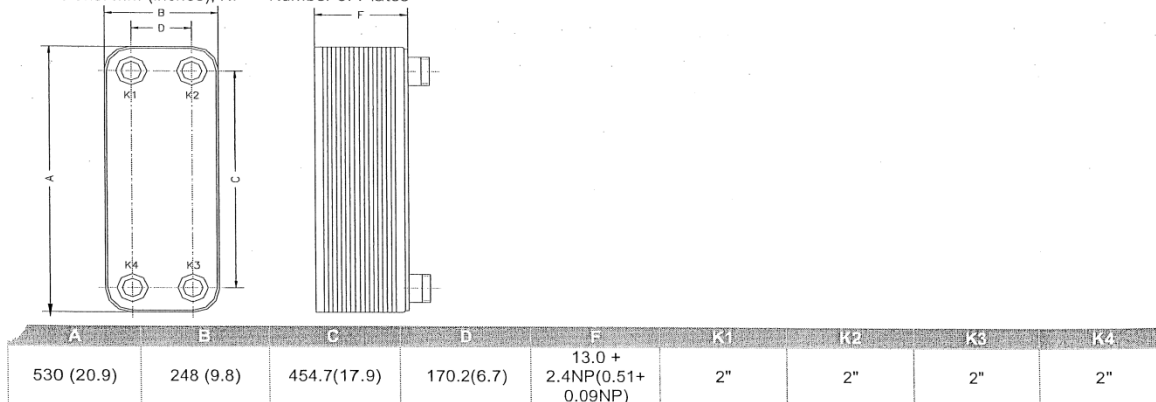
Specifications and dimensional data shall be used as guidelines and may change without notice.
For guaranteed performance, please verify selections with the manufacturer.

Figure C-2. Curve for Primary Loop Pump

WILO USA LLC
1290 North 25th Avenue
Melrose Park, Illinois   60160
USA
Tel.   724 841 3033
Fax

Star 32 B F
System: Standard pump

WILO

Customer	Project	Page 1 / 1
Customer no.	Project no.	
Contact	Position no.	Date 2012-10-23
Care of District Sales Manager Mark Schmittzehlocation		

Requested data

Flow	0	US g.p.m.
Head	0	ft
Fluid	Water, pure	
Fluid temperature	68	°F
Density	62.32	lb/ft³
Kinematic viscosity	1.082E-5	ft²/s
Vapor pressure	0.339	psi

Pump data

Make	WILO	
Type	Star 32 B F	
Pumpe type	Single head pump	
Pressure rating	140 psi	
Min. fluid temperature	14	°F
Max. fluid temperature	230	°F

Hydraulic data (duty point)

Flow		US g.p.m.
Head		ft
Power input P1		hp
Speed	2700	rpm

Minimum suction head

Temperature	122	203	230			°F
Rated voltage	1~		60			
Minimum suction head	1.64	9.84	32.8			ft

Materials / Shaft seal

Pump housing	Bronze
Impeller	PP + G/F 40 %
Shaft	X 40 Cr 13
Bearing	Metal impregnated carbon

Dimensions per pump
inch

A	6³/₈	G	3³/₁₆		
B	5⁷/₈	H	3¹⁵/₁₆		
C	1⁵/₁₆	I	5¹/₁₆		
D	1⁵/₁₆	M	2¹/₁₆		
E	3³/₁₆				

Suction side	-	/ 140 psi
Discharge side	-	/ 140 psi
Weight	7.716	lb

Motordata per Motor/Pump/

Rated power P2	0.05	hp
Power input P1	0.16	hp
Nominal speed	2700	rpm
Rated voltage	115 V , 60 Hz	
Max. current	0.92	A
Degree of protection	IP 44	
Permitted voltage tolerance +/- 10%		

Item no. of standard version	4090779

L   N   PE
1~115 V, 60 Hz

Appendix D: Results of UL Testing of the Fisonic Device

Number of pages in this package _____ [including additional pages _____]
(Fill in when using printed copy as record)

TEST LOCATION:					
[X]UL or Affiliate	[]WTDP	[]CTDP	[]TPTDP	[]TCP	[]PPP
	[]WMT	[]TMP	[]SMT		
Company Name UL Northbrook					
Address 333 Pfingsten Rd. Northbrook, IL 60062					

CLIENT INFORMATION	
Company Name	HFC HUDSON FISONIC CORP
Address	96 Greenwich St New York, NY 10006 United States

AUDIT INFORMATION:

Description of Tests	Per Standard	UL 1995 CAN-CSA C22.2 No. 236	Edition/ Revision Date	4th

[X] Tests Conducted by +		Mike Chieffo/Ken Kingsbury	
		Printed Name	Signature
[] UL Staff conducting or witnessing testing (WTDP, TMP, WMT only) [] UL Staff supervising UL Staff in training []Authorized Signatory (CTDP, TPTDP, TCP, PPP, SMT)		Printed Name	Signature, and include date for CTDP, TPTDP, TCP, PPP, WMT, TMP, SMT
Reviewed and accepted by qualified Project Handler			

TESTS TO BE CONDUCTED:

Test No.	Done +++	Test Name	[] Comments/Parameters []Tests Conducted by ++
1	2012 -07- 02	TEMPERATURE OPERATION TEST (WITHOUT ANY SUPPLEMENTARY HEATING MEANS)	

Instructions -
+ - When all tests are conducted by one person, printed name and signature
can be inserted here instead of including printed name and signature on each
page containing data. Must indicate number of pages in the data package.
++ - When test conducted by more than one person, printed name and signature
of person conducting the test can be inserted next to the test name instead
of including printed name and signature on each page containing data. Must
indicate number of pages in the data package.
+++ - Use of this field is optional and may be employed differently.

Special Instructions –

[ ] Unless specified otherwise in the individual Methods, the tests shall be conducted under the following ambient conditions. Confirmation of these conditions shall be recorded at the time the test is conducted.

~~Ambient Temperature, C~~	±	~~Relative Humidity, %~~	±	~~Barometric Pressure, mBar~~	±

[X] No general environmental conditions are specified in the Standard(s)or have been identified that could affect the test results or measurements.

RISK ANALYSIS RELATED TO TESTING PERFORMANCE:

The following types of risks have been identified. Take necessary precautions. This list is not all inclusive.

~~[ ] Electric shock~~	~~[ ] Radiation~~
[X] Energy related hazards	~~[ ] Chemical hazards~~
~~[ ] Fire~~	~~[ ] Noise~~
[X] Heat related hazards	~~[ ] Vibration~~
~~[ ] Mechanical~~	[X] Other (Specify) steam/pressure

Tested by: _____ Date _____
                    Printed Name   Signature

TEST EQUIPMENT INFORMATION

Inst. ID No.	Instrument Type	Test Number +, Test Title or Conditioning	Function /Range	Last Cal. Date	Next Cal. Date

+ - If Test Number is used, the Test Number must be identified on the data sheet pages or on the Data Sheet Package cover page.

The following additional information is required when using client's or rented equipment, or when a UL ID Number for an instrument number is not used. The Inst. ID No. below corresponds to the Inst. ID No. above.

Inst. ID No.	Make/Model/Serial Number/Asset No.

[X]UL test equipment information is recorded on Meter Use in UL's Laboratory Project Management (LPM) database.

TEST SAMPLE IDENTIFICATION:

The table below is provided to provide correlation of sample numbers to specific product related information. Refer to this table when a test identifies a test sample by "Sample No." only.

Sample Card No.	Date Received	[] Test No.+	Sample No.	Manufacturer, Product Identification and Ratings
~~1395512~~	~~06-07-2012~~	None		[Heating and Heating-Cooling Appliance Accessories] Specialty Heating and Heating-Cooling Appliance Accessories
1413856	2012-07-02	All	2	Steam Test Fixture
1413852	2012-07-02	All	3	Hot Water Test Fixture

+ - If Test Number is used, the Test Number or Numbers the sample was used in must be identified on the data sheet pages or on the Data Sheet Package cover page.

[] Sampling Procedure -

TEMPERATURE OPERATION TEST (WITHOUT ANY   UL 1995, 4th ED., SECTION 4
SUPPLEMENTARY HEATING MEANS)

METHOD

Sample Description

Model No.	T-Fitting
Fan Motor Model No.	n/a
Compressor No.	n/a

The test arrangement and conditions were as follows:

(a)   ~~Voltage -- as specified in Table 39.6.~~ non-electrical

(b)   ~~Inlet air conditions -- 26.7 C (80 F), ±1.1 C (±2 F) DB, wet bulb is~~
      ~~not specified.~~

The unit was operated continuously until temperatures were constant. ~~The~~
~~electrical input to the motor(s) and other electrical loads were measured~~
~~during the test.~~

~~The Operating controls were shunted out of circuit to permit continuous~~
~~operation of unit. If employed, set pressure-limiting devices to maximum~~
~~cutout setting.~~

~~This test is generally conducted after Input Test, and/or the Continuity of~~
~~Operation Test.~~

RESULTS

~~Pressure-limiting device(s) [did] [did not] trip during the test. Motor~~
~~protective device(s) [did] [did not] trip during the test. The maximum~~
~~temperature measured [did] [did not] exceed the values specified in UL 1995,~~
~~Column 1 of Table 39.5.~~ The test ~~[did]~~ [did not] result in ~~refrigerant~~ **water**
leakage or rupture of parts. ~~The maximum pressures developed in the air~~
~~conditioner [did] [did not] exceed those specified in the Strength Tests.~~
~~There [was] [was no] electric shock hazard.~~ Specific results were noted
below.

Tested by: _____   Date _____

             Printed Name   Signature

TEMPERATURE OPERATION TEST (WITHOUT ANY   UL 1995, 4th ED., SECTION 41
SUPPLEMENTARY HEATING MEANS) (CONT'D):

RESULTS

~~The measured load amps were as noted below.~~

~~Sample No.~~	~~2~~			
~~Steam In - Pressure psig~~	~~3.85~~			
~~- Temperature °F~~				
~~City Water In - Pressure psig~~	~~7~~			
~~- Temperature °F~~				
~~Water Out - Pressure psig~~	~~30~~			
~~- Temperature °F~~				
~~Lab Ambient - Temperature °F~~				

~~Outlet Flow Rate: 4.9 gpm~~
~~Test Date and Time: 2012-07-02 12:14pm~~

~~Sample No.~~	~~2~~			
~~Steam In - Pressure psig~~	~~7~~			
~~- Temperature °F~~				
~~City Water In - Pressure psig~~	~~3~~			
~~- Temperature °F~~				
~~Water Out - Pressure psig~~	~~37~~			
~~- Temperature °F~~				
~~Lab Ambient - Temperature °F~~				

Outlet Flow Rate: 5.28 gpm
Test Date and Time: 2012-07-02 12:31pm

~~Sample No.~~	~~2~~			
~~Steam In - Pressure psig~~	~~7~~			
~~- Temperature °F~~				
~~City Water In - Pressure psig~~	~~0~~			
~~- Temperature °F~~				
~~Water Out - Pressure psig~~	~~38~~			
~~- Temperature °F~~				
~~Lab Ambient - Temperature °F~~				

Outlet Flow Rate: 5.9 gpm
Test Date and Time: 2012-07-02, 12:42

NOTE: These three tests are not valid because we didn't follow the
temperature stabilization requirements per UL1995. Ken Kingsbury 2012/7/3

TEMPERATURE OPERATION TEST (WITHOUT ANY   UL 1995, 4ᵗʰ ED., SECTION 41
SUPPLEMENTARY HEATING MEANS) (CONT'D):

Sample No.	2			
Steam In – Pressure psig	7			
– Temperature °F C		113.0	113.5	113.6
City Water In – Pressure psig	2			
– Temperature °F C		16.4	16.5	16.4
Water Out – Pressure psig	36			
Water Out Mixer – Temperature ˚C		53.9	53.9	53.8
Water Out Accumulator – Temperature °F C		53.4	54.1	53.9
Lab Ambient – Temperature °F C		23.4	23.5	23.5

Outlet Flow Rate: 6.4 gpm

Sample No.	2			
Steam In – Pressure psig	7.5			
– Temperature °F C		113.5	113.2	113.7
City Water In – Pressure psig	-12			
– Temperature °F C		16.6	16.6	16.6
Water Out – Pressure psig	0.4			
Water Out Mixer – Temperature ˚C		83.0	82.5	83.8
Water Out Accumulator – Temperature °F C		83.3	82.5	83.7
Lab Ambient – Temperature °F C		23.4	23.5	23.7

Outlet Flow Rate: 3.6 gpm

Sample No.	2			
Steam In – Pressure psig	6			
– Temperature °F C		109.7	109.9	110.1
City Water In – Pressure psig	-9			
– Temperature °F C		16.4	16.5	16.6
Water Out – Pressure psig	32			
Water Out Mixer – Temperature ˚C		65.2	65.1	66.9
Water Out Accumulator – Temperature °F C		65.9	65.6	66.7
Lab Ambient – Temperature °F C		23.6	23.6	23.5

Outlet Flow Rate: 4.3 gpm

TEMPERATURE OPERATION TEST (WITHOUT ANY   UL 1995, 4th ED., SECTION 41
SUPPLEMENTARY HEATING MEANS) (CONT'D):

Sample No.	2			
Steam In - Pressure psig	-5			
- Temperature °F C		94.8	94.3	94.6
City Water In - Pressure psig	-9.5			
- Temperature °F C		16.5	16.4	16.5
Water Out - Pressure psig	14.5			
Water Out Mixer - Temperature °C		44.2	43.3	43.3
Water Out Accumulator - Temperature °F C		44.4	43.7	44.1
Lab Ambient - Temperature °F C		23.5	23.3	24.1

Outlet Flow Rate: 4.7 gpm

ATTACH RAW DATA

(+) - Stabilized temperatures are considered to be achieved when three successive readings taken at 10 min intervals indicate no more than a 1 percent net increase between the last two readings.

If the temperatures measured are within 5 percent of the values specified in Table 39.5, the test shall be continued until two successive 10 min readings indicate constant temperatures.

For temperatures measured constantly over the interval, the raw data is to be attached and last reading is to be recorded in the table.

For cycling type units (such as described in 46.9), peak temperatures are to be recorded until stabilization is obtained per the description above.

Ambient   Relative   Barometric
Temperature, C   N/A   Humidity, %   N/A   Pressure, mBar   N/A

Data for Hot Water unit (Sample#3)-

Voltage				
Amps				
Wattage				
Ambient- °F				
In- °F				
Out- °F				
Flow- GPM				

NOTE: Client couldn't get this sample to work per his specifications. No data recorded. Ken Kingsbury 2012/7/3

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Demonstration of Performance and Energy Efficiency of Fisonic Devices at the Con Edison Test Facility

Final Report
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