STATE OF NEW HAMPSHIRE

Inter-Department Communication

DATE: June 03, 2019
AT (OFFICE): NHPUC

FROM: Jason Morse, Energy Analyst

SUBJECT: **REC 19-103** and RREC 18-0492 North Conway Memorial Hospital – Use of an Alternative Metering Method (Puc 2506.06 and Puc 2506.04 (f) (3)) and Preliminary Designation (Puc 2505.03)

TO: Commissioners
Debra A. Howland, Executive Director

CC: Karen P. Cramton, Director, Sustainable Energy Division
David K. Wiesner, Director, Legal Division
Mary Schwarzer, Staff Attorney

Executive Summary

The Commission has received a request for preliminary designation under N.H. Code Admin. Rules Puc 2505.03 for the Renewable Fuel Oil (RFO) boiler facility at North Conway Memorial Hospital (Memorial Hospital) as a Class I Thermal renewable energy source. As part of the request for preliminary designation, the applicant requested review and approval of a proposed alternative metering method to quantify the useful thermal energy production of the facility, pursuant to Puc 2506.06 and 2506.04 (f) (3).

Memorial Hospital is seeking approval of the proposed alternative metering method and reasonable assurance of facility eligibility through preliminary designation before investing in the installation of metering equipment. After review of the submittal, Commission Staff requested additional information and in subsequent submittals, the applicant provided additional documentation. As of April 23, 2019, Staff had received all information needed to review the proposed alternative metering method and the application for preliminary designation as an eligible renewable energy source.

Staff recommends that the Commission approve the proposed alternative metering method. It further recommends that the applicant be notified that facility certification should be conditioned upon the submission of all required information including a Professional Engineer certification that meters were installed and will be operated to the manufacturer's specifications and, as installed, meet the accuracy requirements of Puc 2506.04 (f) (3).

Background

The Memorial Hospital biomass fuel facility is located at 3073 White Mountain Highway, North Conway, New Hampshire. The facility consists of two 6.695 MMBtu/hour steam boilers with a total combined capacity of 13.39 MMBtu/hour (3.924 MW equivalent). According to Memorial Hospital, over $1 million was invested in equipment enabling the switch from the use of #4 fuel oil to RFO. The facility first operated using RFO as a fuel in 2014 and 2015 for Boiler #1 and Boiler #2 respectively.

Memorial Hospital first applied for eligibility as a Class I Thermal renewable energy source on December 13, 2016 in an application submitted by Innovative Natural Resource Solutions (INRS). The application included an alternative metering proposal. Staff opened Docket REC 16-297, reviewed the application, and requested additional information from the applicant. The applicant requested that Docket REC 16-297 be closed, and it was closed on April 25, 2018.

In a letter received by the Commission on May 31, 2018, INRS submitted a new request for preliminary designation under N.H. Code Admin. Rules Puc 2505.03, on behalf of Memorial Hospital. INRS also requested review and approval of a proposed alternative metering method for the facility. That submittal included a proposed metering method different from the method proposed in the 2016 submittal. Staff reviewed this submittal and requested additional information from the applicant related to both requests, including a more detailed description of the fuel and a more detailed explanation of the alternative metering method. Further, Staff determined that the applicant was a third party (i.e., not the owner of the facility as is required by rule) and requested that the application be re-submitted listing the facility owner as the applicant.

INRS provided supplemental documentation to Staff in multiple submittals. Additional information regarding the eligibility of the fuel was submitted on July 18, 2018 and August 15, 2018. Additional information regarding the ownership of RECs was submitted on July 18, 2018. In a letter received on November 26, 2018, INRS submitted a new request and application listing Memorial Hospital as the facility owner. Additional information regarding the proposed alternative metering method was submitted on June 12, 2018. The final necessary documentation, a more detailed rationale as to why an alternative metering method is necessary, was received on April 23, 2019.

Analysis

Staff confirms that the application submitted as a request for preliminary designation meets all requirements of Puc 2500 for eligibility as a Class I Thermal renewable energy source, other than the metering requirements of Puc 2506.04 (m). Contingent upon approval of the applicant's proposed alternative metering method, Staff will recommend granting a preliminary designation to the Memorial Hospital facility as a Class I Thermal renewable energy source. Staff's review included the following:

- Confirmation that the fuel meets the definition of "biomass fuels" set forth in RSA 362-F:2, II;
- Confirmation that the biomass fuel is being used by the facility as evidenced by delivery records;
- Confirmation that the facility is providing "useful thermal energy" as defined in RSA 362-F:2, XV-a;
- Confirmation that a stack test has been performed by the New Hampshire Department of Environmental Services (NHDES) and that the facility met the particulate matter emissions requirement of 0.10 lbs/MMBtu per RSA 362-F:4, I (l) (1). NHDES also confirmed that the facility meets "best management practices" for control of nitrogen oxides (NOx), as required under Puc 2505.04 (k); and
- Confirmation that the facility, as described in the request for preliminary designation, meets all other applicable requirements of the Puc 2500 rules, other than the metering requirements of Puc 2506.04 (m).

Staff reviewed the proposed alternative metering method for the facility developed by Dan Wilson, P.E., of Wilson Engineering Services (Wilson Engineering). After review, Staff concluded that the request meets the requirements for "Alternative Method for Measuring Thermal Energy," as specified in Puc 2506.06. The information provided by the applicant, and Staff's evaluation of that information, are summarized as follows:

1. *Name, mailing address, daytime telephone number, and email address of the person requesting approval for the alternative method.*

   Eric Kingsley, Innovative Natural Resource Solutions, 63 Federal Street, Suite 5, Portland, Maine 04101. (207) 233-9910; kingsley@inrsllc.com

2. *Name and location of the source at which the alternative method will be implemented.*

   Memorial Hospital, 3073 White Mountain Highway, North Conway, New Hampshire 03860.

3. *A description of the metering method otherwise required by these rules and the reasons it cannot be used with the applicant's facility.*

   As described in detail in the alternative metering request (see Attachment A), there are physical constraints to the installation of the equipment necessary to implement the otherwise required metering method described in Puc 2506.04 (m). There is insufficient open space in the boiler room to enable the installation of steam flow meters with the proper spacing from the boiler in a way that is not cost-prohibitive.

4,5. *A description of the proposed alternative method and technical data and information demonstrating that the accuracy of the proposed alternative method* *will be functionally equivalent to that achieved by the method otherwise required by these rules.*

The alternative metering method proposed requires measuring the mass flow rate of feed water supplied to the boilers from the condensate tank, measuring the incoming feed water temperature and out-going steam pressure, and using these measurement values to determine the net enthalpy added by the boilers, thereby calculating the gross heat delivered by the boilers. Wilson Engineering proposes to account for heat loss due to blowdown and steam leaks by metering the amount and temperature of water provided through the makeup water connection. By determining the amount of Btus required to heat the makeup water to steam, the independent monitor will be able to calculate the total Btus lost through leaks and blowdown. Wilson Engineering certifies that the proposed metering method will achieve an accuracy of +/- 3% and included the calculation demonstrating that level of accuracy. See Attachment A for a more detailed description of the proposed metering method.

Finally, a small portion of the steam generated by the boilers is used to pre-heat the RFO before it is moved into the boiler and combusted. Wilson Engineering suggests calculating the steam used for that process and removing it from the useful thermal energy total. Staff believes that preheating of RFO through use of renewably-powered steam meets the definition of "useful thermal energy," as set forth in RSA 362-F 2, XV-a, namely, that such application represents "energy delivered to an end user in New Hampshire in the form of direct heat, steam, hot water, or other thermal form that is used for heating cooling, humidity control, process use, or other valid thermal end use energy requirements and for which fuel or electricity would otherwise be consumed." The use of steam generated by RFO to pre-heat the fuel product, as opposed to applying electrical pre-heating devices, meets the definition of a process use for which fuel or electricity would otherwise be consumed. Therefore, Staff recommends that Wilson Engineering include the thermal use of steam for preheating RFO fuel as eligible "useful thermal energy."

Given the measurement accuracies described above, the proposed method for calculating useful thermal energy includes appropriate discount factors for meter accuracy as well as for operating energy or parasitic load and thermal energy losses as required by Puc 2506.05 (e) and (f).

6. *A statement from a professional engineer licensed by the state of New Hampshire and in good standing of the meter accuracy rate that will be achieved by the alternative metering method and that the proposed alternative method is technologically sound.*

The alternative metering method request also included a certification by Dan Wilson, P.E. that the total system metering accuracy will meet or exceed +/- 3%. Mr. Wilson is a professional engineer licensed and in good standing in the State of New Hampshire. He certified that the proposed alternative metering method is technologically sound and will exceed the accuracy requirements of Puc 2506.04 (f) (3).

An excerpt was included as a support material from Metering Best Practices, substantiating the proposed metering methods from "A Guide to Achieving Utility Resource Efficiency, Release 3.0," Pacific Northwest National Laboratory, March 2015 (See Attachment B). One particularly relevant section of that document states that "The challenges of metering steam can be simplified [by] measuring the condensed steam, or condensate. The metering of condensate (i.e., high-temperature hot water) is an accepted practice, often less expensive and more reliable than steam metering."

The NHDES also assisted with an informal review of the proposed alternative metering method and concluded that the accuracy will be better than the +/- 5% total combined accuracy level required by Puc 2506.04 (f) (3), and will most likely be within a +/- 3% level of error. The NHDES also stated that the potential sources of error introduced by the proposed alternative metering method would only bias the calculation low, resulting in a reduction in the number of RECs generated rather than an increase in that number.

Conclusion

In conclusion, Staff recommends that the Commission approve the proposed alternative metering method for the Memorial Hospital thermal facility. Puc 2506.06 (c) provides that "[t]he Commission shall approve an alternative metering method that satisfies the requirements of [Puc 2506.06 (b)]." As demonstrated in the analysis summarized above, the proposed alternative metering method meets all requirements of Puc 2506.06 (b).

Staff also recommends that the applicant be notified that final facility authorization will be conditioned upon submission, after meter installation, of all required meter information, including a Professional Engineer certification that meters were installed and will be operated to the manufacturer's specifications, and, as installed, meet the accuracy requirements of Puc 2506.04 (f) (3). In addition, the application must include a description of the method and frequency of reporting production to NEPOOL GIS and any changes to the facility, or preliminary designation application, and all other application materials, which may affect the eligibility of the source.

Attachment A: Alternative Metering Method Description

Wilson Engineering Services, PC
902 Market Street 8430 Rea Road, Suite B
Meadville, PA 16335 Charlotte, NC 28277
(814) 337-8223 (704) 940-1867

WES
Energy · Environment · Enterprise

April 23, 2018

Debra A. Howland
Executive Director
New Hampshire Public Utilities Commission
21 South Fruit Street, Suite 10
Concord, NH 03301-2429

Re: Request for Alternative Metering Method for Class I Thermal RECs for North Conway Memorial Hospital (REC 16-297)

Dear Ms. Howland,

Enclosed is a request for an alternative metering method for measuring useful thermal energy, for Class I Thermal, at North Conway Memorial Hospital in North Conway, NH. This is a new alternative metering request for the eligibility application in docket REC 16-297.

As a professional engineer licensed in the state of New Hampshire and in good standing, I certify that a meter accuracy rate of ±3% or better will be achieved by this alternative metering method, and that this alternative metering method is technologically sound.

Sincerely,
Wilson Engineering Services, PC

Daniel A. Wilson, P.E.
Vice President

enclosures:

Alternative Metering Request and Documentation

Wilson Engineering Services, PC
902 Market Street 8430 Rea Road, Suite B
Meadville, PA 16335 Charlotte, NC 28277
(814) 337-8223 (704) 940-1867

WES
Energy • Environment • Enterprise

MEMORANDUM

Date: April 23, 2018

To: Geoff Hopkins, Ensyn Fuels Inc.

From: Dan Wilson, WES; Peter Oven, WES

CC:

Re: **Alternative Metering Method for North Conway Memorial Hospital**

1.0 BACKGROUND

North Conway Memorial Hospital utilizes two boilers which are able to fire on #4 fuel oil or renewable fuel oil (RFO). The RFO is produced from appropriate woody biomass feedstocks, and this fuel has already been discussed in the previous eligibility application to the PUC (REC 16-297).

Memorial Hospital seeks PUC approval of an alternative metering method for measuring useful thermal energy. This alternative metering method has been developed by WES to provide accuracy comparable to the steam metering method otherwise required by the PUC rules. The source has not yet implemented this metering method, and requests PUC approval of this method prior to investing in this equipment.

2.0 ALTERNATIVE METERING MEHTOD

The following information is provided pursuant to PUC 2506.06(b).

2.1 Requestor

Name: Lee Torrens
Mailing Address: 61 Broadway Ave., Suite 1905, New York, NY 10006
Daytime Telephone Number: (406) 490-9831
E-mail Address: ltorrens@ensyn.com

2.2 Source

The alternative metering method will be implemented at North Conway Memorial Hospital, in North Conway, NH. The source will be two Cleaver-Brooks steam boilers, rated 200 HP each.

2.3 Reason for Alternative Metering Method Request

The metering method otherwise required by the PUC rules would include installation of the following equipment:

- steam mass flow meter as close as possible to the steam distribution header inlet
- steam temperature sensor
- steam pressure sensor
- feedwater flow sensor
- feedwater temperature sensor

- feedwater pressure sensor

The metering method otherwise required is described fully in PUC 2506.04(m).

The reason why the metering method as described in PUC 2506.04(m) cannot be used is that the boiler plant was existing prior to the conversion of the boilers to RFO, and it is difficult to retrofit the existing systems with the required metering equipment. The boiler plant is crowded with pipes and utilities, and presents a challenge for rework. Because the boilers operate at a relatively low steam pressure of 10 psig, the steam headers and boiler piping are sized at 8" and 10". Most steam flow meters, especially retrofit meters, require a certain number of diameters of straight pipe before and after the meter, and the large pipes require a correspondingly large amount of straight run for accurate measurement. This straight run cannot be achieved without expensive retrofits to the boiler plant.

Additionally, any retrofits to the steam piping would require a complete shutdown of the boiler plant, which is the sole source of heat for the hospital. The hospital uses heat year-round for various critical needs, and a shutdown would likely require the use of a mobile rental boiler, at significant expense.

2.4 PROPOSED ALTERNATIVE METHOD

The alternative method is to measure the mass flow rate of feedwater supplied to the boilers, taking into account only those boilers which are operating on RFO. The feedwater temperature and steam pressure are measured to determine the net enthalpy added by the boilers, and thus is calculated the gross heat delivered by the boilers operating on RFO. Then, the heat lost due to blowdown, steam leaks, and RFO heating is subtracted. This method is described on the attached drawing.

The heat lost due to blowdown and steam leaks cannot be directly metered, but it is known that any mass of water lost due to blowdown, steam leaks, and condensate leaks, must eventually be added back into the system via the makeup water connection. Therefore, metering the amount of water provided to the condensate tank via the makeup water valve, and measuring the makeup water temperature, and the steam pressure, allows the calculation of the net heat required to heat the makeup water mass up to steam. This amount of heat is the amount of heat originally lost when the blowdown or steam leaks occurred. Note that if feedwater or condensate is lost, the original amount of heat lost would be less than if steam were lost, however, the losses are assumed to be all steam, in order to be conservative and not underestimate the losses of this non-useful thermal energy. Additionally, direct application of steam is used in certain processes, such as for humidification, where condensate is not able to be recovered due to the type of use. Because these types of uses also contribute to makeup water use they will be netted out of the Btu calculation along with blowdown and steam leaks; however, they are a minor component of the overall steam load.

The RFO requires heating in order to be properly atomized and combusted by the burners. This heating is accomplished using steam, and is considered to be a parasitic load. The heat supplied to the RFO is metered by measuring the volume of RFO combusted, using the tank level sensor, and the starting and ending temperatures of the RFO as it passes through the heater. The specific gravity and specific heat of the RFO are known values, and thus the amount of heat gained by the RFO is able to be calculated, and subtracted from the gross energy output of the boilers.

2.5 TECHNICAL DATA

Cut sheets for the equipment which will be utilized with the proposed alternative metering method have been attached, showing the accuracy of each item.

Additionally, excerpted pages from the US Department of Energy document "Metering Best Practices: A Guide to Achieving Utility Resource Efficiency, Release 3.0"[1] are included, which contain the following statement:

> *The challenges of metering steam can be simplified measuring the condensed steam, or condensate. The metering of condensate (i.e., high-temperature hot water) is an accepted practice, often less expensive and more reliable than steam metering.*

Thus, while the alternative metering method request is due to the difficulty and cost of retrofitting the boiler plant for steam metering, the DOE document indicates that the requested alternative method of metering feedwater (condensate) is an accurate, technologically sound, and accepted method of heat metering.

[1] https://www.energy.gov/sites/prod/files/2015/04/f21/mbpg2015.pdf

Part 3 Table

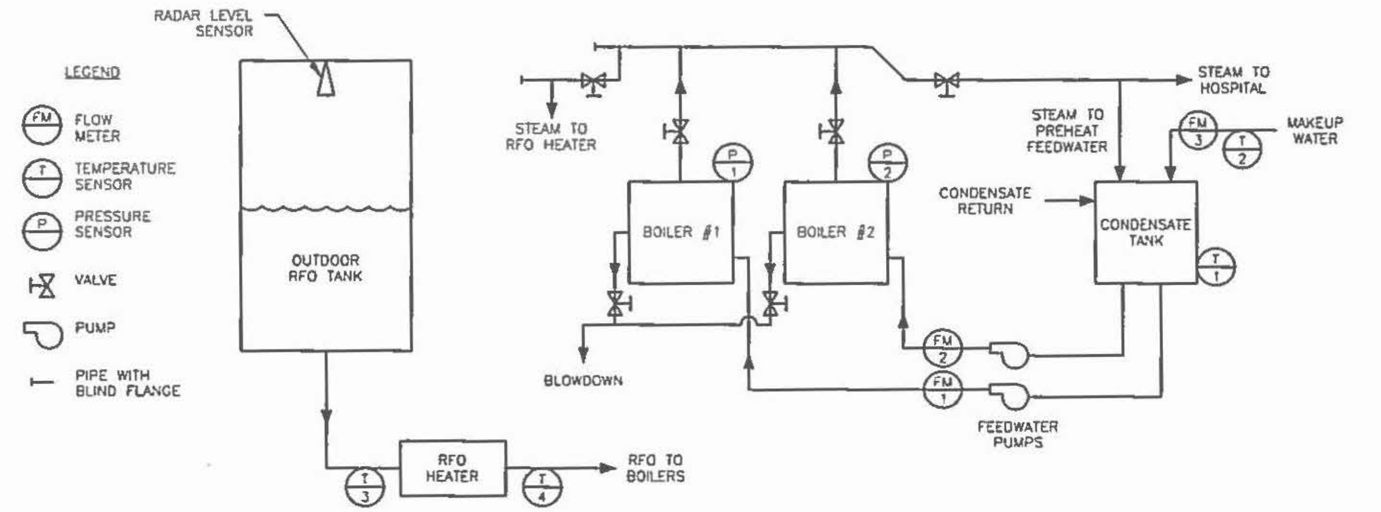
Item	System or Component	Location	Product Name	Product Mfr.	Model No.	Temperature Operating Range	Flow Operating Range	Thermal Energy Operating Range	Pressure Operating Range	Accuracy
1	Flow Meter	FM1, FM2	Multi-Jet Water Meter	ISTEC	1815	n/a	0.7-88 gpm	n/a	n/a	± 1% of reading
2	Flow Meter	FM3	3/4" Water Meter, SS, Pulse Output	EKM	EKM-SPWM-075	n/a	0.9-22 gpm	n/a	n/a	± 2% of reading
3	Temperature Sensor	T1	PT100 RTD and Temperature Transmitter	Omega	PRTX94-3	0-300°F	n/a	n/a	n/a	± (0.27+0.002*|t-32|) °F RTD Accuracy ± 0.1% of full scale transmitter accuracy
4	Temperature Sensor	T2, T3, T4	PT100 RTD and Temperature Transmitter	Omega	SA2C-RTD-3-100-B-40 and TX94-2	0-200°F	n/a	n/a	n/a	± (0.54+0.005*|t-32|) °F RTD Accuracy ± 0.1% of full scale transmitter accuracy
5	Pressure Sensor	P1, P2	Cerabar T	Endress + Hauser	PMC131-A22F1Q4H	n/a	n/a	n/a	0 - 15 psig	± 0.5% of span and ± 0.8% of URL for temperature effects
6	Level Sensor	Radar Level Sensor	Radar Level Sensor	Vega	Vegapuls 62	n/a	n/a	n/a	n/a	± 2 mm or ± 3% of maximum hourly RFO usage

Notes:

Total System Accuracy:
Combined total system accuracy is better than ±3%

Attachment 3-1 (Component Specification Sheets)

Attachments with accuracy and operating ranges are provided on the following pages.



ALTERNATIVE METHOD METERING PLAN

Notes

1. Steam used for blowdown and heating RFO is parasitic load and shall be excluded from the useful thermal energy according to the calculation method.
2. Flow meters FM1 and FM2 shall be ISTEC 1815. No upstream or downstream straight pipe is required.
3. Flow meter FM3 shall be EKM-SPWM-075. No upstream or downstream straight pipe is required.
4. Temperature sensor T1 shall be installed in a thermowell. T1 shall be located in the lower portion of the condensate tank. The right side of the condensate tank has an available 1-1/2" plug or a blind flange which can be used for mounting the thermowell.
5. Temperature sensor T2 shall be a strap on sensor installed on the makeup water pipe prior to the makeup water control valve.
6. Pressure sensors P1 and P2 shall be installed on the boiler instrument headers.
7. Radar level sensor in RFO tank is used to determine hourly RFO usage.
8. Temperature sensors T3 and T4 shall be strap on sensors installed before and after the RFO heat exchanger.

Calculation Narrative for Delivered Useful Thermal Energy to North Conway Memorial Hospital from Renewable Fuel Oil (RFO) Boiler System

Equations 1, 2, and 3 show the proposed method for calculating delivered useful thermal energy.

$Q = (Q_s - Q_f - Q_b - Q_o) \ast 0.98 \ast 0.97 \ast t$	Equation 1
$Q_s = h_s \ast F_f$	Equation 2
$Q_f = h_f \ast F_f$	Equation 3
$Q_b = (h_s - h_m) \ast F_m$	Equation 4
$Q_o = (h_{o4} - h_{o3}) \ast F_o$	Equation 5

Where:

- **Q (Btu/hr):** Net useful energy delivered to the hospital.
- **Qs (Btu/hr):** Energy in steam leaving the boilers, as determined by direct measurement of steam pressure, and assuming that feedwater mass flow equals steam mass flow.
- **Qf (Btu/hr):** Energy returned to the boilers in feedwater, as determined by direct measurement of feedwater temperature and volumetric flow.
- **Qb (Btu/hr):** Steam energy lost due to blowdown and steam leaks, as determined by direct measurement of steam pressure, and assuming that makeup water mass flow equals blowdown and steam leak mass flow.
- **Qo (Btu/hr):** Steam energy used to preheat RFO, which is not considered to be a useful thermal energy load, as determined by level measurement of the RFO tank to determine RFO flow, and direct measurement of RFO temperatures before and after the preheater to determine the change in enthalpy of the RFO.
- **t (hr)** is time in hours. Where readings are taken more frequently, the values are converted to hourly.
- The factor of 0.98 accounts for the discount factor for parasitic load, while the factor of 0.97 accounts for the discount factor for metering accuracy of this alternative metering method.
- **hs, hf, hm (Btu/lb):** The specific enthalpies of the steam, feedwater, and makeup water respectively, are determined based on pressure of the steam measured at each boiler by P1 and P2, the temperature T1 of the feedwater measured in the condensate tank, and the temperature of the makeup water measured at T2. These values are then used to develop the enthalpies based on IAPWS steam tables.
- **Ff (lb/hr):** The feedwater flow is calculated using the sum of the flows measured at FM1 and FM2. If boilers 1 or 2 are not operating on RFO, then the flow to that boiler is not counted. This has the effect of excluding the energy supplied by #4 oil. Volumetric flow is converted to mass flow using the IAPWS steam tables and the temperature measured at T1.
- **Fm (lb/hr):** The makeup water flow is calculated using the flow meter FM3. Volumetric flow is converted to mass flow using the IAPWS steam tables and the temperature measured at T2.
- **ho3, ho4 (Btu/lb):** The specific enthalpy of the RFO is 0.6 Btu/(lb*°F).
- **Fo (lb/hr):** The RFO volume consumed is calculated hourly by multiplying the height difference in the tank measured by the level sensor by the cross sectional area of the tank. The mass of RFO is calculated using the specific gravity of RFO which is 1.2.

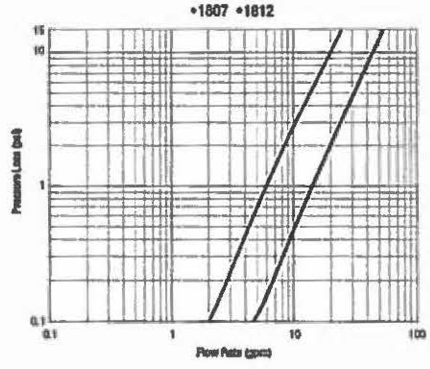
Accuracy

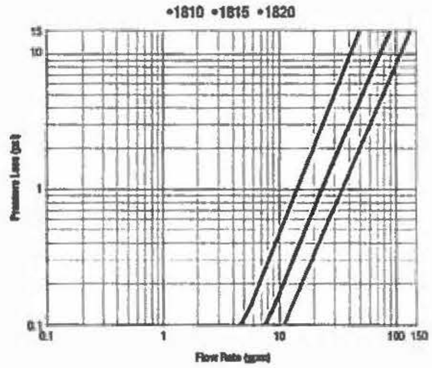
The metering and recording equipment meets the requirements for better than ±5.0% accuracy as called for by PUC 2506.04(f)(3), and a 3.0% penalty is taken for metering equipment accuracy. The 2% discount factor for parasitic load is also taken by the owner per PUC 2506.05(f)(3).

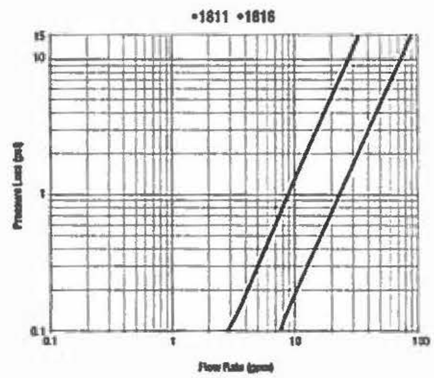
SHEET NO.	REVISIONS					
3-2	Date	Description	Approved	WES Wilson Engineering Services wilsonengineeringservices.com 902 Market St. Meadville, PA 16335	North Conway Memorial Hospital North Conway, NH Alternative Method Metering Plan	Designed PFO 3/16/18 Drawn PFO 3/16/18 Checked Approved ____ Date ____ Title ____ Job Class ____

ISTEC's 1800 Series Multi-Jet Water Meter in 3/4" thru 2"

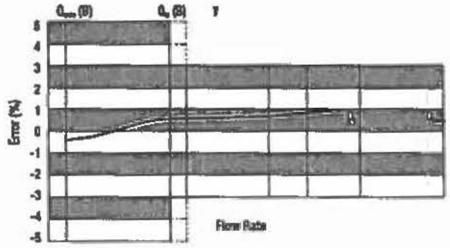
Pressure Loss





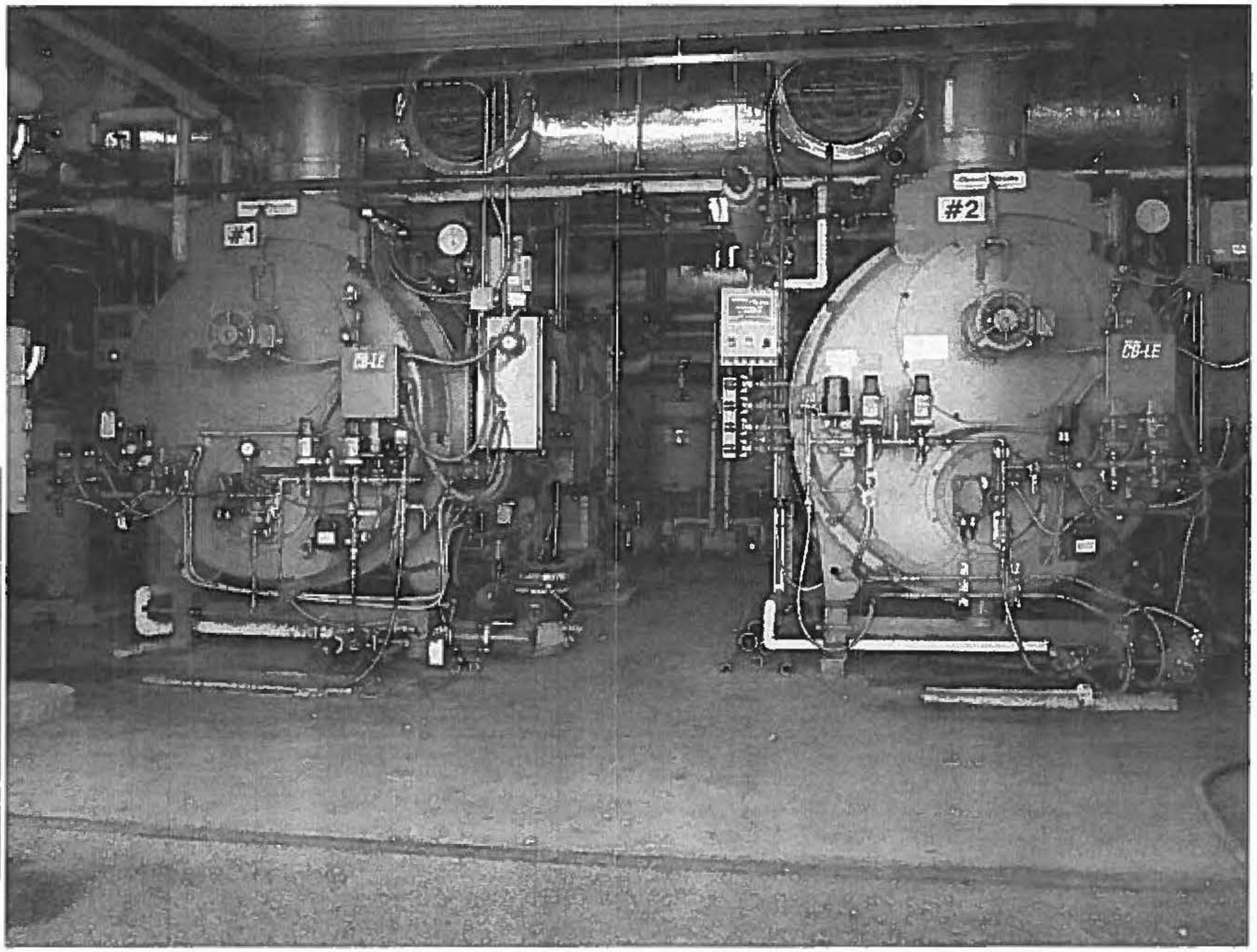


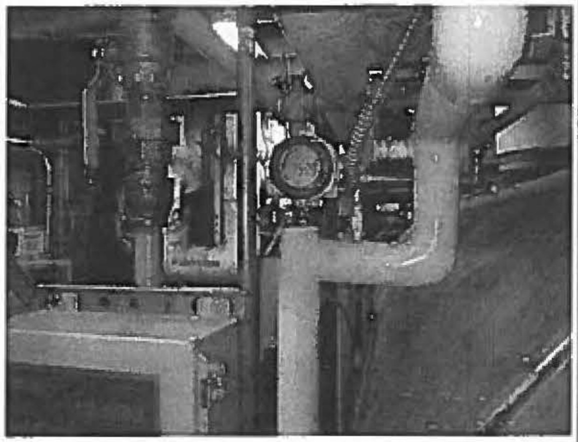
Accuracy



Memorial Hospital Boiler Room
North Conway, NH

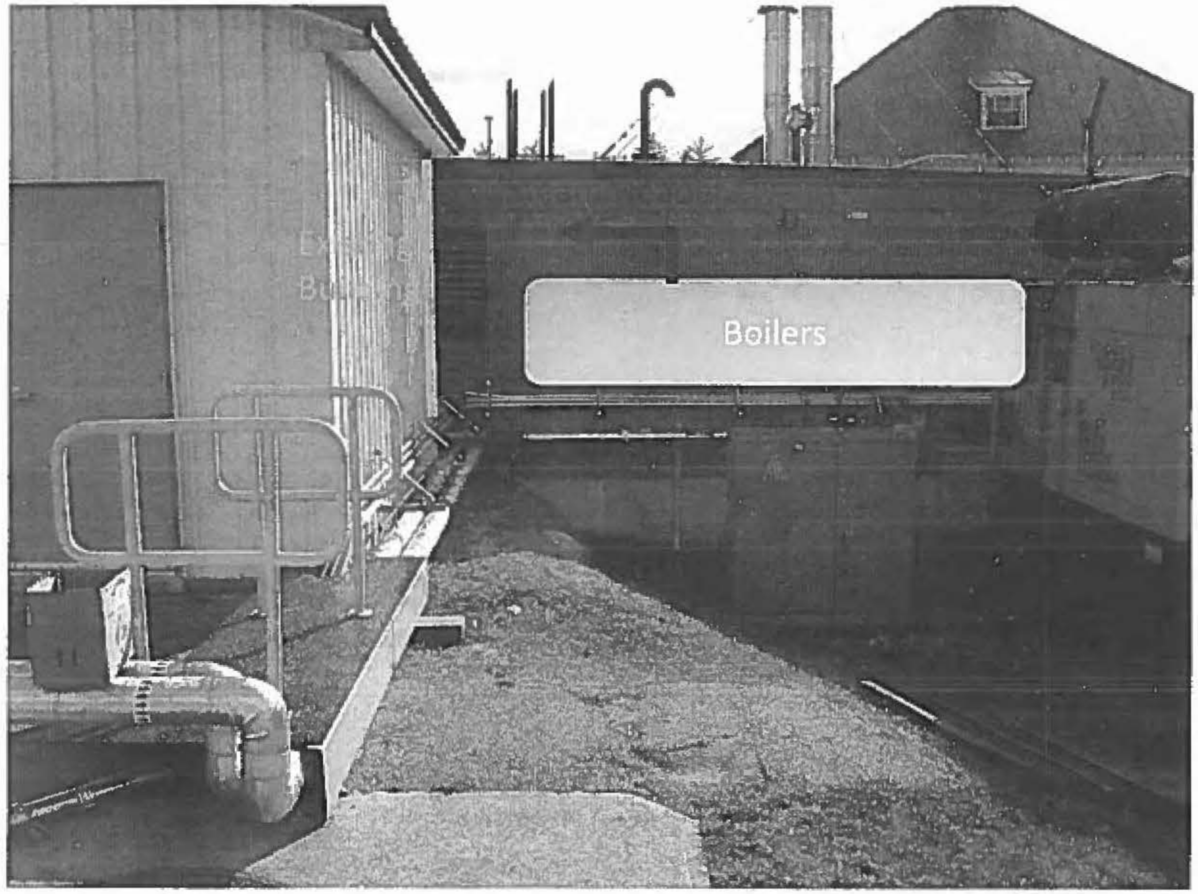
- The photo to the right is of the boilers at site which occupy virtually all of the boiler house.
- All area above the boilers is completely congested with piping, ducting, electrical raceways, etc.
- The photo below illustrates this congestion.





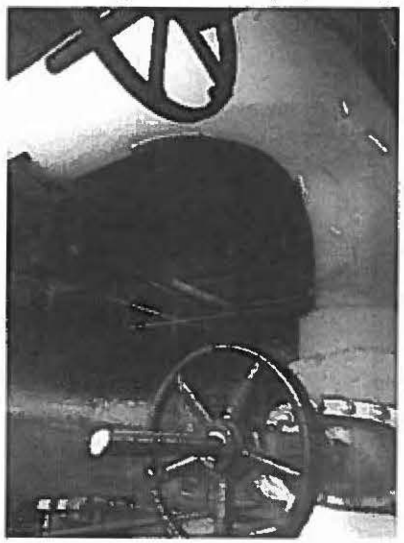
Memorial Hospital Boiler Room
North Conway, NH

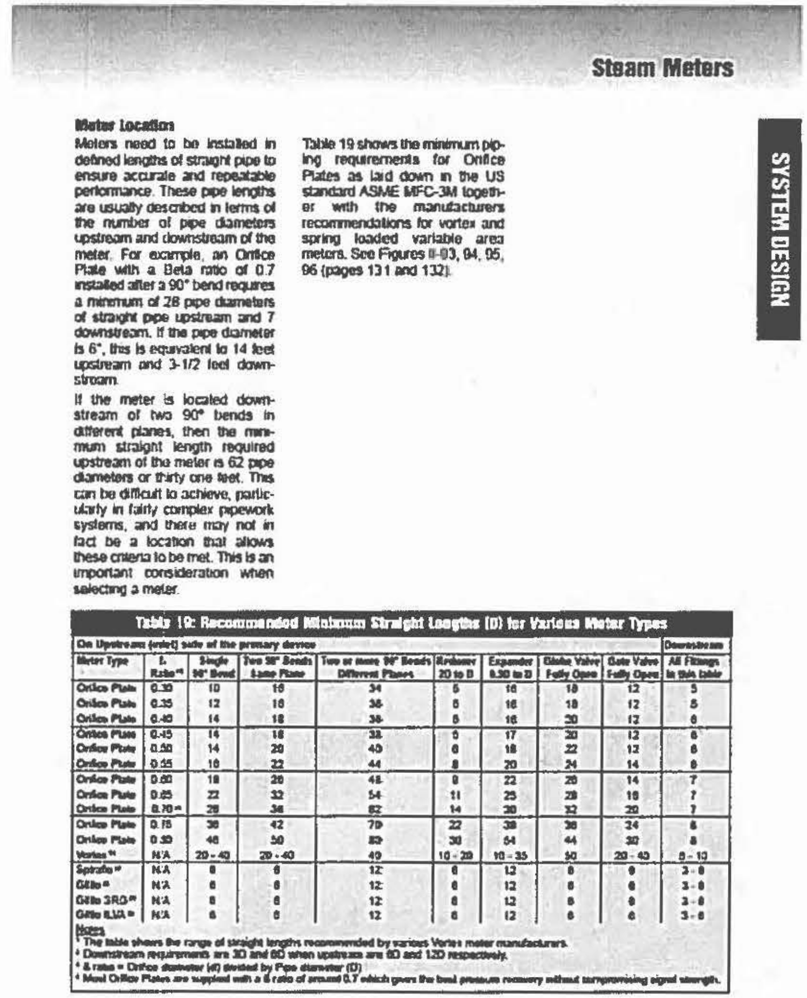
- The photo to the right is of the side of the boiler house, on which we have superimposed the location of the boilers and steam headers.
- In order to measure the steam flow independently in each boiler, the steam flowmeters would have to be installed in an orientation which is parallel to the boilers. It is not possible to extend the boiler house in that direction as the hospital abuts the boiler room.
- A good rule of thumb is that steam flowmeters should have at least 10 upstream plus 5 downstream pipe diameters of straight length pipe to operate correctly. In this case that implies around 12 feet of unobstructed straight pipe length for which space does not physically exist in the boiler house. More detail on this follows.



Memorial Hospital Boiler Room
North Conway, NH

- The image to the right is taken from Spirax Sarco's "Design of Fluid Systems – Hook-Ups" manual. Spirax Sarco is a leading supplier of steam control regulators, valves, traps, meters, etc.
- The sizing of the steam flowmeter could be as large as the existing pipe size, or possibly one pipe size smaller. No significant benefit to required straight pipe length would be realized if a smaller diameter were selected as pipe reducers would add length to the overall pipe network.
- Note that as the steam leaves a boiler, it passes through a gate valve and two elbows (image below); three obstructions after which the flow would have to be conditioned prior to metering. Sufficient physical space for this does not exist.





Steam Meters

SYSTEM DESIGN

Meter Location

Meters need to be installed in defined lengths of straight pipe to ensure accurate and repeatable performance. These pipe lengths are usually described in terms of the number of pipe diameters upstream and downstream of the meter. For example, an Orifice Plate with a Beta ratio of 0.7 installed after a 90° bend requires a minimum of 28 pipe diameters of straight pipe upstream and 7 downstream. If the pipe diameter is 6", this is equivalent to 14 feet upstream and 3-1/2 feet downstream.

If the meter is located downstream of two 90° bends in different planes, then the minimum straight length required upstream of the meter is 62 pipe diameters or thirty one feet. This can be difficult to achieve, particularly in fairly complex pipework systems, and there may not in fact be a location that allows these criteria to be met. This is an important consideration when selecting a meter.

Table 19 shows the minimum piping requirements for Orifice Plates as laid down in the US standard ASME MFC-3M together with the manufacturers recommendations for vortex and spring loaded variable area meters. See Figures II-93, 94, 95, 96 (pages 131 and 132).

Table 19: Recommended Minimum Straight Lengths (D) for Various Meter Types

On Upstream (inlet) side of the primary device									Downstream
Meter Type	β Ratio[3]	Single 90° Bend	Two 90° Bends Same Plane	Two or more 90° Bends Different Planes	Reducer 2D to D	Expander 0.5D to D	Globe Valve Fully Open	Gate Valve Fully Open	All Fittings in this table
Orifice Plate	0.30	10	16	34	5	16	18	12	5
Orifice Plate	0.35	12	16	36	5	16	18	12	5
Orifice Plate	0.40	14	18	36	5	16	20	12	6
Orifice Plate	0.45	14	18	38	5	17	20	12	6
Orifice Plate	0.50	14	20	40	6	18	22	12	6
Orifice Plate	0.55	16	22	44	8	20	24	14	6
Orifice Plate	0.60	18	26	48	9	22	26	14	7
Orifice Plate	0.65	22	32	54	11	25	28	16	7
Orifice Plate	0.70[4]	28	36	62	14	30	32	20	7
Orifice Plate	0.75	36	42	70	22	38	36	24	8
Orifice Plate	0.80	46	50	80	30	54	44	30	8
Vortex[1]	N/A	20 - 40	20 - 40	40	10 - 20	10 - 35	50	20 - 40	5 - 10
Spiraflo[2]	N/A	6	6	12	6	12	6	6	3 - 6
Gilflo[2]	N/A	6	6	12	6	12	6	6	3 - 6
Gilflo SRG[2]	N/A	6	6	12	6	12	6	6	3 - 6
Gilflo ILVA[2]	N/A	6	6	12	6	12	6	6	3 - 6

Notes

[1] The table shows the range of straight lengths recommended by various Vortex meter manufacturers.
[2] Downstream requirements are 3D and 6D when upstream are 6D and 12D respectively.
[3] β ratio = Orifice diameter (d) divided by Pipe diameter (D)
[4] Most Orifice Plates are supplied with a β ratio of around 0.7 which gives the best pressure recovery without compromising signal strength.

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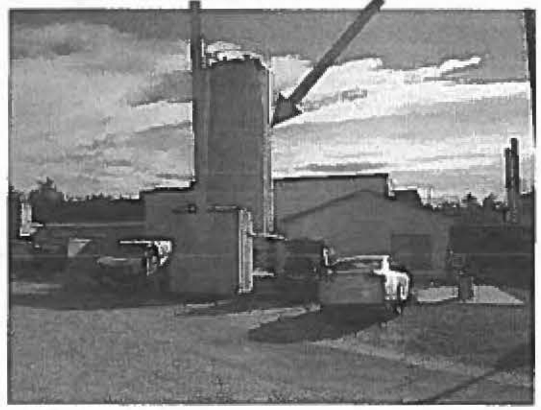
Memorial Hospital Conversion to RFO™

North Conway, NH

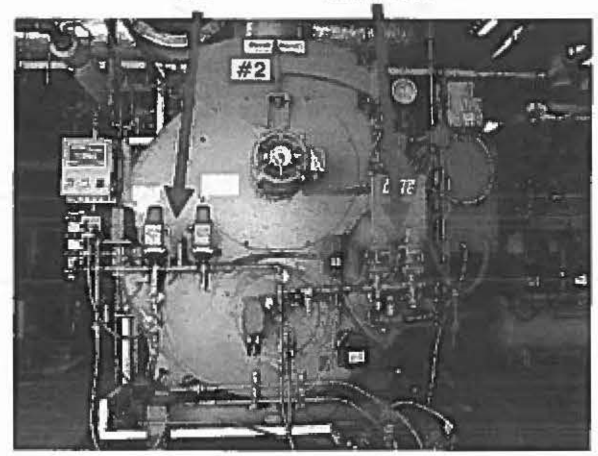
- Significant infrastructure was installed to permit the use of 100% sustainable, RFO™ biofuel prior to 2014. The overall investment was well over $1 million.
- This includes an all stainless steel fuel management system consisting of:
  - Unloading pump/system
  - Insulated fuel tank
  - Piping
  - Redundant pumps
  - RFO™ heater
  - RFO™ burner trains
  - Associated controls and monitoring system
  - Etc.

Unloading System and Tank

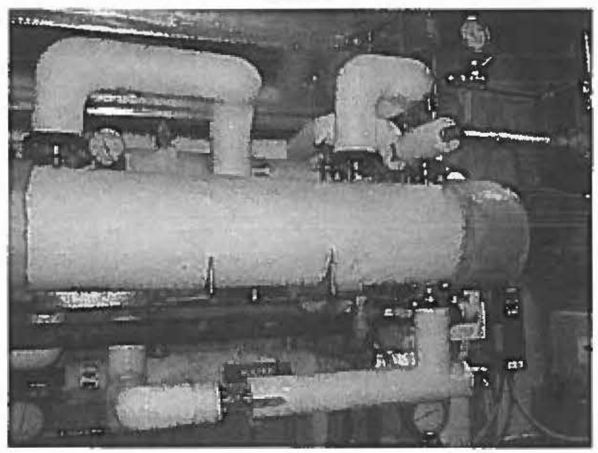


Redundant Fuel Trains

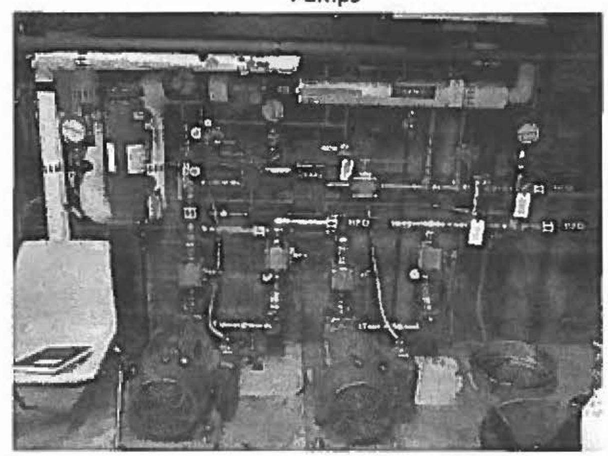
RFO™ Fossil Fuel



Heater



Pumps



Attachment B: U.S. DOE Metering Best Practices

U.S. DEPARTMENT OF ENERGY

PNNL-23892
Release 3.0

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Metering Best Practices: A Guide to Achieving Utility Resource Efficiency, Release 3.0

SA Parker
WD Hunt
KM Fowler
WF Sandusky
GP Sullivan
BK Boyd
KL McMordie Stoughton
TM Koehler
R Pugh

March 2015

Pacific Northwest
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4.5.1 Natural Gas Meter Maintenance

Depending on the meter technology, installation, and quality of gas delivered, natural gas meters generally require limited maintenance. Generally during monthly inspections there is a need to check for gas leaks, noisy operations within the meter, and cleanliness of the equipment. The annual inspections should include calibration according to manufacturer's recommendation or as needed if trended data indicate miscalibration. For Positive Displacement Meters monthly inspections should look for consistent and smooth register operation. For Differential Pressure Meters monthly inspections check for properly connected and sealed pressure taps. During the annual inspections check orifice diameter and edges for wear, roughness, or material buildup, clean and smooth all internal surfaces, and check for well-connected and sealed pressure taps. For Velocity Meters annual inspections check impeller blades and bearings wear or damage.

Depending on the meter technology, installation, and quality of gas delivered, natural gas meters generally require limited maintenance.

4.5.2 Natural Gas Metering Data Output/Communications Considerations

At the building-level, where positive displacement diaphragm and rotary meters are common, calibrated pulses are common data output signals. While other output options are available (4 to 20 milliamp, 0 to 5 volt, Modbus, etc.), calibrated pulses are the most common and are relatively easy to work with.

When specifying the natural gas flow meter, the pulse calibration is a critical parameter.

When specifying the natural gas flow meter, the pulse calibration is a critical parameter. It is important in this specification to understand the range of expected flow and necessary resolution of output. There are situations where too high of a pulse count (i.e., too high of a frequency) can result in saturation of the data collection device. A saturation condition usually results in data loss and erroneous pulse counts. Vendors for the metering equipment, the data communication, and data collection system technology should be consulted when determining the appropriate pulse rate (resolution) and calibration.

4.6 Fluid Metering Technologies – Steam

For steam, energy is primarily contained in the latent heat[7] and, to a lesser extent, the sensible heat[8] of the fluid. The latent heat energy is released as the steam condenses to water. Additional sensible heat energy may be released if the condensate is further lowered in temperature. In steam metering, the energy content of the steam is a function of the steam mass, temperature and pressure. Even after the steam releases its latent energy, the hot condensate still retains considerable heat energy, which may or may not be recovered (and used) in a constructive manner. The energy manager should become familiar with the entire steam cycle, including both the steam supply and the condensate return.

When compared to other liquid flow metering, the metering of steam flow presents one of the most challenging metering scenarios. Most steam meters measure a velocity or volumetric flow of the steam and, unless this is done carefully, the physical properties of steam will impair the ability to measure and define a mass flow rate accurately. *

[7] Latent heat energy refers to the energy absorbed or released with the change in state, or phase, of mass at constant temperature. For example, the energy released when water changes from steam to liquid.

[8] Sensible heat energy refers to the energy absorbed or released with the change in temperature of mass.

Steam is a compressible fluid; therefore, a reduction in pressure results in a reduction in density. Temperature and pressure in steam lines are dynamic. Changes in the system's dynamics, control system operation and instrument calibration can result in considerable differences between actual pressure/temperature and a meter's design parameters. Accurate steam flow measurement generally requires the measurement of the fluid's temperature, pressure, and flow. This information is transmitted to an electronic device or flow computer (either internal or external to the flow meter electronics) and the flow rate is corrected (or compensated) based on actual fluid conditions.

The temperatures associated with steam flow measurement are often quite high and can affect the accuracy and longevity of metering electronics.

The temperatures associated with steam flow measurement are often quite high. These temperatures can affect the accuracy and longevity of metering electronics. Some metering technologies use close-tolerance moving parts that can be affected by moisture or impurities in the steam. Improperly designed or installed components can result in steam system leakage and impact plant safety. The erosive nature of poor-quality steam can damage steam flow sensing elements and lead to inaccuracies and/or device failure.

The challenges of metering steam can be simplified measuring the condensed steam, or condensate. The metering of condensate (i.e., high-temperature hot water) is an accepted practice, often less expensive and more reliable than steam metering. Depending on the application, inherent inaccuracies in condensate metering stem from unaccounted for system steam losses. These losses are often difficult to find and quantify and thus affect condensate measurement accuracy.

Volumetric metering approaches used in steam metering can be broken down into two operating designs: (1) differential pressure and (2) velocity metering technologies. For steam three differential pressure meters are highlighted: orifice flow meter, annubar flow meter, and spring-loaded variable area flow meter. All differential pressure meters rely on the velocity-pressure relationship of flowing fluids for operation.

Differential Pressure – Orifice Flow Meter. Historically, the orifice flow meter is one of the most commonly used meters to measure steam flow. The orifice flow meter for steam functions identically to that for natural gas flow (see previous section). For steam metering, orifice flow meters are commonly used to monitor boiler steam production, amounts of steam delivered to a process or tenant, or in mass balance activities for efficiency calculation or trending.

Differential Pressure – Annubar Flow Meter. The annubar flow meter functions the same way for steam flow as it does for natural gas flow.

Differential Pressure – Spring-Loaded Variable Area Flow Meter. The spring-loaded variable area flow meter is a variation of the rotameter. There are alternative configurations but in general, the flow acts against a spring-mounted float or plug. The float can be shaped to give a linear relationship between differential pressure and flow rate. Another variation of the spring-loaded variable area flow meter is the direct in-line variable area flow meter, which uses a strain gage sensor on the spring rather than using a differential pressure sensor.

The two main type of velocity meters for steam flow, turbine and vortex shedding, both sense some flow characteristic directly proportional to the fluid's velocity.

Turbine meters can be susceptible to wear and resulting inaccuracies because of the mechanical elements in the fluid stream.

Velocity – Turbine Flow Meter. The turbine flow meter functions the same way for steam flow as it does for natural gas flow.

Velocity – Vortex-Shedding Flow Meter. The vortex-shedding flow meter functions the same way for steam flow as it does for natural gas flow.

Table 4-4 presents some common steam metering technologies and key criteria for selection decisions.

Table 4-4. Common Steam Metering Technologies and Key Criteria

Goal	Orifice	Annubar	Turbine	Vortex Shedding
Accuracy	Moderate	Good	Good	Good
Turndown Ratio	<5:1	5:1	10:1	20:1
Repeatability	Good	Good	Low	Very good
Installation Ease	Easy	Easy	Challenging	Moderate
Pressure loss	Moderate	Low	Moderate	Low
Recalibration Needs	Frequent	Infrequent	Frequent	Infrequent
Capital Cost	Low	Low	Moderate	Moderate
Installed Cost	Low	Low	Moderate	Moderate
Maintenance Cost	High	Low	Moderate	Low

4.6.1 Steam Meter Maintenance

Depending on the meter technology, installation, and quality of steam generated, steam meters can require a significant amount of maintenance.

Depending on the meter technology, installation, and quality of steam generated, steam meters can require a significant amount of maintenance. Procedures followed should be those recommended by the manufacturer. For monthly inspections check all connections for steam leakage, listen for abnormally loud or discontinuous sounds internal to the meter, and inspect for general meter cleanliness. Annually the meters need calibration of differential pressure sensors/transmitters according to manufacturer's recommendation or as needed if trended data indicate miscalibration. For differential pressure meters monthly inspections check for properly connected and sealed pressure taps. During annual inspections check orifice diameter, orifice edges, and pressure parts for wear, roughness, or material buildup, and check for properly connected and sealed pressure taps. For velocity meter annual inspections check impeller blades and bearings for wear or damage.

4.6.2 Steam Metering Data Output/Communications Options

The most common outputs of steam metering devices are scalable analog signals of either 4 to 20 mA or 0 to 5 volts dc. In more sophisticated systems, HART™ (Highway Addressable Remote Transducer) protocol systems can be found.[9] The meter outputs are collected and processed using a flow computer/analysis device integral to the meter. The flow computer/analysis device takes the measurement signals (pressure, differential pressure, and temperature) and converts these values to a compensated steam flow rate.

The most common outputs of steam metering devices are scalable analog signals.

When specifying a steam flow meter, the flow computer/analysis device is typically an option with some array of alternatives for analysis and presentation. The output of the flow computer/analysis device is typically a scalable signal or pulse that can be transferred to a data acquisition or energy information system for collection and further analysis or trending.

4.7 Fluid Metering Technologies - Water

Because the metering of water is generally concerned with the quantification of flow volume, lower-cost metering options can be used.

Water is commonly measured and sold in volumetric measurements, which allows for lower-cost metering options. The specific metering option chosen will depend on a number of factors including, but not limited to, current design, budget, accuracy requirements, resolution, minimum flow rate, potable versus non-potable (or at least filtered versus non-filtered water), range of flow rates, and maximum flow rate.

Volumetric water metering designs can be broken down into three general operating designs: (1) positive displacement, (2) differential pressure, and (3) velocity.

Positive Displacement – Nutating-Disk Flow Meter. Nutating-disk flow meters are the most common meter technology used by water utilities to measure potable-water consumption for service connections up to 3-inch. The nutating-disk flow meter consists of a disk mounted on a spherically shaped head and housed in a measuring chamber. As the fluid flows through the meter passing on either side of the disk, it imparts a rocking or nutating motion to the disk. This motion is then transferred to a shaft mounted perpendicular to the disk. It is this shaft that traces out a circular motion – transferring this action to a register that records flow.

There are a variety of differential pressure devices useful for water metering; three of the more common devices include orifice flow meters, venture flow meters, and

Differential Pressure – Orifice Flow Meter. The orifice flow meter functions the same way for water flow as it does for natural gas flow.

Differential Pressure – Venturi Flow Meter. The venturi flow meter functions the same way for water flow as it does for natural gas flow.

[9] HART is a bi-directional communication protocol that provides data access between intelligent field instruments and host systems.

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