REC 19-103

Innovative Natural Resource Solutions LLC
63 Federal Street, Suite 5, Portland, Maine 04101
Phone 207-233-9910, www.inrsllc.com

31 MAY '18 AM9:36

May 29, 2018

NHPUC 29MAY'19PM3:30

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

Re: Alternative Metering Method Request and Request for Preliminary Designation for Class I Thermal Renewable Energy Source Eligibility for North Conway Memorial Hospital

Dear Ms. Howland,

Enclosed is a request for an alternative metering method and preliminary designation as an eligible Class I Thermal source for North Conway Memorial Hospital in North Conway, NH. This large thermal source is already in commercial operation using renewable biomass fuels and has demonstrated that it meets the emissions limits specified in PUC 2502.38(a).

The source is requesting preliminary designation as described by PUC 2505.03 because the source wishes to utilize an alternative metering method which has not been approved by the commission. PUC 2506.06(a) states that a "source shall not use an alternative metering method until that alternative metering method is approved by the commission." Accordingly, the source has not yet installed the proposed alternative metering method, in order that any changes requested by the commission may be incorporated into the metering design prior to purchase of the metering equipment.

The source requests both approval of the proposed alternative metering method, as well as preliminary designation as an eligible source. Please do not hesitate to contact me with any questions or clarifications on this application.

Sincerely,

Eric Kingsley
kingsley@inrsllc.com

Attachments:

- Thermal REC Application
- Alternative Metering Method Request

State of New Hampshire
Public Utilities Commission
21 S. Fruit Street, Suite 10, Concord, NH 03301-2429

DRAFT

APPLICATION FORM FOR
RENEWABLE ENERGY SOURCE ELIGIBILITY FOR CLASS I THERMAL SOURCES WITH RENEWABLE THERMAL ENERGY CAPACITY GREATER THAN 150,000 BTU/HR

Pursuant to New Hampshire Administrative Code PUC 2500 Rules

- Please submit one (1) original and two (2) paper copies of the completed application and cover letter* to:

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

- Send an electronic version of the completed application and the cover letter electronically to executive.director@puc.nh.gov.

* The cover letter must include complete contact information and identify the renewable energy class for which the applicant seeks eligibility. Pursuant to PUC 2505.01, the Commission is required to render a decision on an application within 45 days of receiving a completed application.

If you have any questions please contact Barbara Bernstein at (603) 271-6011 or Barbara.Bernstein@puc.nh.gov.

Only facilities that began operation after January 1, 2013 are eligible.

Is this facility part of a Commission approved aggregation?

Yes X No ____

Aggregator's Company Name: WES Energy & Environment LLC

Aggregator Contact Information: Dan Wilson, dan@wesenergyandenvironment.com
(814) 336-1284

Contents

Attachment Labeling Instructions

Please label all attachments by Part and Question number to which they apply (e.g. Part 3-7). For electronic submission, name each attachment file using the Owner Name and Part and Question number (e.g. Pearson Part 3-7).

Part 1. General Application Information

Please provide the following information:

Applicant

Name: Ensyn Fuels Inc.

Mailing Address: 61 Broadway Avenue, Suite 1905

Town/City: New York State: NY Zip Code: 10006

Primary Contact: Lee Torrens

Telephone: (406) 490-9831 Cell: (406) 490-9831

Email Address: ltorrens@ensyn.com

Facility

Name: Memorial Hospital

Physical Address: 3073 White Mountain Highway

Town/City: North Conway State: NH Zip Code: 03860

If the facility does not have a physical address, the Latitude: ______ & Longitude ______

Installer

Name: Blake Equipment

Installer License Number: MBE1000400

Mailing Address: 7 Ingersol Drive, Unit 1

Town/City: Portland State: ME Zip Code: 04103

Primary Contact: Dan Burnell

Telephone: 800-308-2213 Cell: ______

Email Address: Dan.burnell@bghusa.com

If the equipment was installed by the facility owner, check here: ☐

Facility Operator

If the facility operator is different from the owner, please provide the following:

Name: Memorial Hospital Joseph Bubar Jbubar@memorialhospitalnh.or

Facility Operator Telephone Number: 603-356-5461 x 2122

Independent Monitor

Name: GWA Research, LLC

Mailing Address: 7 Masa Morey Lane

Town/City: Lyme State: NH Zip Code: 03768

Primary Contact: Gary Phetteplace

Telephone: 603-795-4920 Cell:

Email Address: garyp@gwaresearch.com

NEPOOL/GIS Asset ID and Facility Code

In order to qualify your facility's thermal energy production for RECs, you must register with the NEPOOL – GIS. Contact information for the GIS administrator follows:

James Webb

Registry Administrator, APX Environmental Markets

224 Airport Parkway, Suite 600, San Jose, CA 95110

Office: 408.517.2174

jwebb@apx.com

Mr. Webb will assist you in obtaining a GIS facility code and an ISO-New England asset ID number.

GIS Facility Code # NON58396 Asset ID # NON58396

1. Has the facility been certified under another non-federal jurisdiction's renewable portfolio standards?

Yes [ ] No [X]

If you selected yes, *please provide proof of certification in the form of an attached document as Attachment 1-1.*

2. Attach any supplementary documentation that will help in classification of the facility as Attachment 1-9

Part 2. Technology Specific Data

All Technologies

Fuel type (solar, geothermal, or biomass): Biomass

Rated Thermal Capacity (Btu/hr): 2 units at ~~8.45~~ MMBtu/hour each = 16,900,000 btu / 3412 btu/kw = 4,953 kw = ~~4.95~~ MW

See email – 6.695 mmbtu each = 13.39 mmbtu / 3412 = 3,924.4 kw = 3.92 MW

Date of initial operation using renewable fuels: Boiler 1 – July 2, 2014; Boiler 2 – May 6, 2015

Biomass

If a thermal biomass facility, provide proof of New Hampshire Department of Environmental Services approval that the facility meets the emissions requirements set forth in Puc 2500, as Attachment 2-1.

Solar Thermal

If a solar thermal facility, please provide the Solar Rating and Certification Corporation rating based on Mildly Cloudy C (kBtu/day): ____________________

Geothermal

If a geothermal facility, please provide the following:

The coefficient of performance (COP): ____________________

The energy efficiency ratio of the system: ____________________

Part 3. Metering and Measurement of Thermal Energy and REC Calculations

This section deals with the thermal metering system including methods for calculation and reporting useful thermal energy. **A copy of PUC 2506.04 of the RPS rules is included as Appendix A.**

Using the table below, identify the thermal metering system or custom components (e.g., heat meters, flow meters, pressure and temperature sensors) used to measure the useful thermal energy and enter the accuracy of measurement for the entire system:

System or Component	Product name	Product Manufacturer	Model No.
see alternative metering method			
request for details on equipment			
Total System Accuracy (Percent)	97%		

Attach component specification sheets (Accuracy, Operating Ranges) as Attachment 3-1. X

Attach a simple schematic identifying the location of each sensor that is part of the metering system as Attachment 3-2. X

Check the applicable standard for meter accuracy prescribed in Puc 2506.04 among the six choices below (compliance with Puc 2506.04 shall be certified by a professional engineer licensed by the state of New Hampshire and in good standing):

If the facility is a large thermal source using a liquid or air based system, check the method that applies:

A. Installation and use of heat meters capable of meeting the accuracy provisions of European
Standard EN 1434 published by CEN, the European Committee for Standardization. The heat meter shall have the highest Class flow meter that will cover the design flow range at the point of measurement and a temperature sensor pair of Class 5K or lower. [ ]

B. Installation and use of meters that do not comply with European Standard EN 1434, provided that the manufacturers' guaranteed accuracy of the meters is ±5.0% or better, [ ]

C. Use of an alternative metering method approved pursuant to Puc 2506.06. [ ]

If the facility is a large thermal source using a steam-based system, check the method that applies:

D. Installation and use of meters with accuracy of ±3.0% or better. [ ]

E. Installation and use of meters with system accuracy that do not meet D but are ±5% or better. [ ]

F. Use of an alternative metering method approved pursuant to Puc 2506.06. [X*]

* Alternative metering method pending, see attachment 3-3, 3-4 and 3-5

Please summarize the manufacturer's recommended methods and frequency for metering system calibration and provide reference for source document (e.g. owners/operators manual):

see alternative metering method request for details

REC Calculation Discount factor for meter accuracy (Enter 0 if no discount is required): 3 %

If the meters used to measure useful thermal energy comply with the accuracy of the European

REC Calculation Discount factor for operating energy and thermal energy losses: 2 %

Check the method used for determining the operating energy and thermal loss factor among the choices below:

[ ]

Default Factor [X]

- For sources using solar thermal technology, the discount factor shall be 3.0% of the useful thermal energy produced;
- For sources using geothermal technology, the discount factor shall be 3.6% of the useful thermal energy produced;
- For sources using thermal biomass renewable energy technology, the discount factor shall be 2.0% of the useful thermal energy produced.

Actual Metering ☐

- Include a simple schematic identifying the operating energy and thermal energy losses and placement of the meters.

Interim Alternative Metering Method

Until such time as the Puc 2500 rule is finalized applicants may utilize an alternative method as described in the draft rule 2505.02(e)(2):

> *In lieu of the information required by Puc 2505.02 (d) (11) through (13), a thermal source may submit a detailed explanation of the methodology used to measure and calculate thermal energy and an attestation by a professional engineer that is licensed in New Hampshire and in good standing that the methodology for measuring useful thermal energy and calculating certificates is sound.*

Please see attachments:

Part 4. Affidavits

Owners Affidavit

The following affidavit must be completed by the owner attesting to the accuracy of the contents of the application pursuant to PUC 2505.02 (b) (14).

AFFIDAVIT

I, Lee Torrens have reviewed the contents of this application and attest that it is accurate and is signed under the pains and penalties of perjury.

Applicant's Signature [signature] **Date** 5.25.18

Applicant's Printed Name Lee Torrens

Subscribed and sworn before me this 25th **Day of** May **(month) in the year** 2018

County of Missoula **State of** Montana

JENNIFER J COTE
NOTARY PUBLIC for the
State of Montana
Residing at Missoula, MT
My Commission Expires
November 11, 2018

JENNIFER J COTE NOTARIAL SEAL STATE OF MONTANA

Jennifer J. Cote

Notary Public/Justice of the Peace Seal

My Commission Expires Nov. 11, 2018

NH Professional Engineer Affidavit

AFFIDAVIT

I, __________ attest that this facility meets the requirements of the thermal REC eligibility requirements of Puc 2500, including the thermal metering and measurement methodologies and standards and REC calculation methodologies.

Professional Engineer's Signature __________ **Date** __________

Professional Engineer's Printed Name __________

NH Professional Engineer License Number __________

PE Stamp

Part 4. Affidavits

Owners Affidavit

The following affidavit must be completed by the owner attesting to the accuracy of the contents of the application pursuant to PUC 2505.02 (b) (14).

AFFIDAVIT

I, Lee Torrens ______________________ have reviewed the contents of this application and attest that it is accurate and is signed under the pains and penalties of perjury.

Applicant's Signature ______________________ Date ______________

Applicant's Printed Name Lee Torrens ______________________

Subscribed and sworn before me this ________ Day of __________ (month) in the year __________

County of ______________________ State of ______________________

____
Notary Public/Justice of the Peace Seal

My Commission Expires ______________________

NH Professional Engineer Affidavit

AFFIDAVIT

I, Daniel A. Wilson ______________________ attest that I have reviewed the contents of this request for preliminary designation, and I attest that this facility would meet the thermal REC eligibility requirements of PUC 2500, including the thermal metering and measurement methodologies and standards and REC calculation methodologies. This application is being submitted as a request for preliminary designation. If this system is constructed, I will approve it only after such time the system has been inspected to verify that it has been constructed in accordance with this request for preliminary designation and any approved modifications.

Professional Engineer's Signature [signature] Date 5/22/18

Professional Engineer's Printed Name Daniel A. Wilson

NH Professional Engineer License Number 13688

PE Stamp

STATE OF NEW HAMPSHIRE
DANIEL A. WILSON
No. 13688
LICENSED
PROFESSIONAL ENGINEER

5/22/18

Attachment 2-1: New Hampshire Department of Environmental Services approval that the facility meets the emissions requirements set forth in PUC 2500

NHDES

The State of New Hampshire
DEPARTMENT OF ENVIRONMENTAL SERVICES

Thomas S. Burack, Commissioner

November 2, 2015

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

Re: Recommended Certification as a Class I Thermal Renewable Energy Source
Memorial Hospital
North Conway, NH

Dear Ms. Howland:

The New Hampshire Department of Environmental Services (DES) was contacted by Eric Kingsley of Innovative Natural Resource Solutions on behalf of Memorial Hospital requesting certification of the wood-fired boilers located at Memorial Hospital as a Class I thermal renewable energy source. DES recommends that the Public Utilities Commission (PUC) grant conditional approval to Memorial Hospital as a Class I thermal renewable energy source eligible to generate renewable energy certificates (RECs). A summary of the facility description, DES's review of particulate and NOx emission rates and monitoring requirements, and a recommendation for approval are presented below.

Facility Description

Facility Name:	Memorial Hospital
Facility Location:	3073 White Mountain Highway North Conway, NH 03860
Gross Nameplate Capacity:	2 Cleaver Brooks boilers; 8.45 MMBtu/hr each
State Permit to Operate:	SP-0046
Issue Date:	March 19, 2014
Primary Fuel:	Renewable Fuel Oil (RFO), a liquid biomass fuel derived from wood products

Particulate Matter (PM) Emissions

By definition, *"Thermal biomass renewable energy technologies"*, requires units rated between 3 and 30 MMBtu/hr gross heat input to meet a particulate matter (PM) emission rate limit of 0.10 pounds/million British thermal units (lb/MMBtu). Permit SP-0046 issued by DES contains boiler operation requirements (see Table 3). In addition to the permit requirements, DES herein establishes the following quarterly reporting requirements in order to demonstrate continued REC eligibility by Memorial Hospital:

1. Certification that RFO was the primary fuel combusted in the boilers and that no #4 light residual petroleum fuel oil was combusted, and report the actual thermal output based upon the amount of RFO combusted;
2. Certification that the timing of the soot-blow system was a two-second cycle every 90 minutes, resulting in 16 2-second soot blow cycles, for a total of 32 seconds of soot blowing, per 24-hour period; and
3. Because testing was conducted at less than 90% of rated capacity, report the hours of operation and the calculated maximum quarterly thermal output, in addition to the actual thermal output.
    a. Tests were conducted at 87.2% of boiler #1 capacity and 81.7% of boiler #2 capacity.
    b. Alternative maximum rated thermal capacity = 0.872 x 8.45 MMBtu/hr + 0.817 x 8.45 MMBtu/hr = 14.27 MMBtu/hr.
    c. Calculated maximum quarterly thermal output = quarterly hours of operation x Alternative maximum rated thermal capacity.
4. Certification that the reported actual thermal output is less than or equal to the calculated maximum quarterly thermal output. RECs shall be calculated based on the lower of the reported actual thermal output or the calculated maximum quarterly thermal output.

Emission Rate Confirmation

A PM emission test has been performed for Memorial Hospital, and the test results have been reported in writing to DES. The emission test was performed for PM in accordance with the pre-test protocol reviewed by DES. The results of the emission test indicate the actual PM emission rate in lb/MMBtu meets the required 0.10 lb/MMBtu.

Nitrogen Oxides (NOx) Emissions

By definition, "*Thermal biomass renewable energy technologies*", requires units rated less than 100 MMBtu/hr gross heat input to meet best management practices (BMP) as established by DES for control of nitrogen oxides (NOx) emissions. DES herein establishes BMP as conducting boiler tune-ups annually and conducting combustion efficiency testing initially and annually demonstrating results equal to or greater than 99%.

BMP Confirmation

Memorial Hospital measured actual carbon monoxide (CO) and carbon dioxide (CO_2) concentrations in the exhaust gas using a hand-held portable analyzer (or alternative method approved by DES) to determine combustion efficiency using the following equation:

$CE(\%) = 100 \times CO_2 / (CO_2 + CO)$

Where:

CE = combustion efficiency

CO_2 = % by volume of carbon dioxide in the flue gas, and

CO = % by volume of carbon monoxide in the flue gas.

The results of the initial test indicate that the combustion efficiency meets the required 99%. DES anticipates that Memorial Hospital will be able to meet ongoing BMP annually.

Conclusion and Recommendation for Approval

DES believes that Memorial Hospital currently meets, and annually will meet, the requirements to be certified as a Class I - New Biomass thermal renewable energy source. DES recommends that the PUC certify Memorial Hospital as a Class I thermal renewable energy source eligible to generate thermal renewable energy certificates beginning the fourth calendar quarter 2015 (October 1, 2015), because Memorial Hospital has demonstrated that the following conditions have been met:

1) Memorial Hospital emits PM at an average rate less than or equal to 0.10 lb/MMBtu; and
2) Memorial Hospital currently maintains CE equal to or greater than 99%.

If you have any questions, please contact me at joseph.fontaine@des.nh.gov or (603) 271-6794.

Sincerely

Joseph T. Fontaine
Technical Programs Manager
Air Resources Division

Attachment 2-2

Renewable Fuel Oil

Memorial Hospital is currently using Renewable Fuel Oil (RFO) to fire their boilers. As described on Ensyn's website[1], RFO is a liquid fuel manufactured through the process of fast pyrolysis using residual woody feedstocks. Feedstocks are primarily sawmill residues such as sawdust, bark, and wood chips. All of these are qualify as "biomass fuel "under both NH PUC 2502.03 and NH RSA 362-F:2.

There is no construction and demolition debris used as feedstock for RFO.

New Hampshire PUC rules define biomass as:

> PUC 2502.03 "Biomass fuels" means "biomass fuels" as defined in RSA 362-F:2, II, namely "plant derived fuel including clean and untreated wood such as brush, stumps, lumber ends and trimmings, wood pallets, bark, wood chips or pellets, shavings, sawdust and slash, agricultural crops, biogas, *or liquid biofuels*, but shall exclude any materials derived in whole or in part from construction and demolition debris."

Using this definition, the Renewable Fuel Oil (RFO) fuel used at Memorial Hospital clearly qualifies as "biomass fuel".

RFO contains 76,000 BTU per gallon. An analysis of RFO (as delivered to Memorial Hospital) follows.

[1] http://www.ensyn.com/technology/overview/ and http://www.ensyn.com/technology/feedstocks/

Wilson Engineering Services, PC
902 Market Street
Meadville, PA 16335
(814) 337-8223

8430 Rea Road, Suite B
Charlotte, NC 28277
(704) 940-1867

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

ENSYN

1 Innovation Drive
Renfrew, Ontario
Canada, K7V 0B5
1-613-433-9508

Customer: Memorial Hospital
3073 White Mountain Highway
North Conway, NH
3860

Delivery Instructions: None

Certificate of Analysis		
Product Name:		Shipping Date: 08-Feb-16
Product Code: 7100-203-100		Customer PO #:
Reference Number:		BOL #: 2677
Parameter	**Test Method**	**Result**
Water Content, wt% as is	ASTM E203	22.3%
Viscosity @ 40°C, cSt	ASTM D445	50.1
Solids Content, wt% as is	ASTM D7579	0.08%
Ash Content, wt% as is	EN 055	0.11%
Density @ 20°C, kg/dm^3	EN 064	1.19
HHV (as is), cal/g	ASTM D240	4324
HHV (as is), MJ/kg	ASTM D240	18.1
HHV (as is), BTU/lb	ASTM D240	7783
Quantity Shipped: 5900 Gallons		

This product conforms to specifications:	Yes
Technician Signature:	PS
Name:	Paula Sevigny
Date:	27-Jan-16

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

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.

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

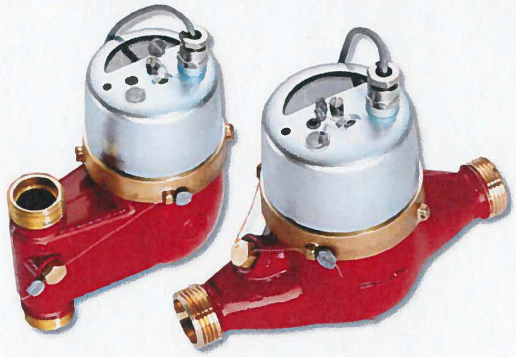
Part 3 Table (for ease of reference, same as previous table with Attachment 3-1)

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

Attachment 3-3 (Manufacturer's Recommendations for Maintenance and Calibration)

Item	System or Component	Manufacturer's Recommendation	Manufacturer's Information Included	Application Page
1	Flow Meter	no recommendations	no	n/a
2	Flow Meter	no recommendations	no	n/a
3	Temperature Sensor	no recommendations	no	n/a
4	Temperature Sensor	no recommendations	no	n/a
5	Pressure Sensor	no recommendations	no	n/a
6	Level Sensor	no recommendations	no	n/a

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

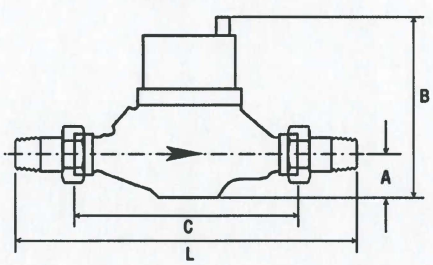


- Multi-Jet Design with only the impeller operating in the flow chamber for reliable performance
- No Straight Pipe required before or after the meter
- Hermetically-sealed Counter is dust and waterproof preventing internal condensation
- Roller Counter can be rotated for easy reading
- Built-in Reed Switch is cast into a waterproof enclosure and can be field replaced (Contact Rating 24V, 0.2A)
- Compact Design for easy installation
- Unique Design allows easy maintenance and repair
- Calibration Test Certification available on request

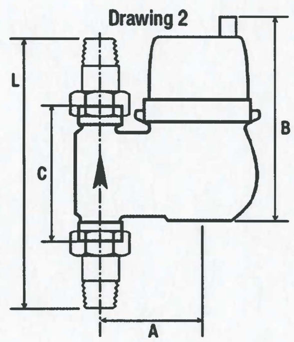
Model Number	1807	1810	1811	1812	1815	1816	1820
Pipe Size	3/4"	1"	1"	1"	1-1/2"	1-1/2"	2"
Min. Flow Rate (gpm)	0.22	0.4	0.4	0.4	0.7	0.7	2.64
Continuous Flow Rate (gpm)	11	26.4	26.4	26.4	44	44	66
Max. Flow Rate (gpm)	22	52.8	52.8	52.8	88	88	132
Max. Operation Temperature (°F)	248	248	248	248	248	248	248
Max. Operation Pressure (psi)	232	232	232	232	232	232	232
Design	Multi-Jet	Multi-Jet	Multi-Jet	Multi-Jet	Multi-Jet	Multi-Jet	Multi-Jet
Mounting Connections	NPT	NPT	NPT	NPT	NPT	NPT	Flanged
Mounting Position	U	H	D	U	H	D	H
Pulse (gal/pulse)	1	1	1	1	1	1	10
Weight (pounds)	5.25	7.5	8.1	8.1	14.2	15.5	27.5

H : Horizontal Installation, D : Vertical Downflow Installation, U : Vertical Upflow Installation

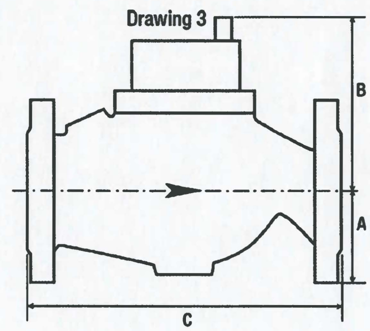
Drawing 1



Drawing 2

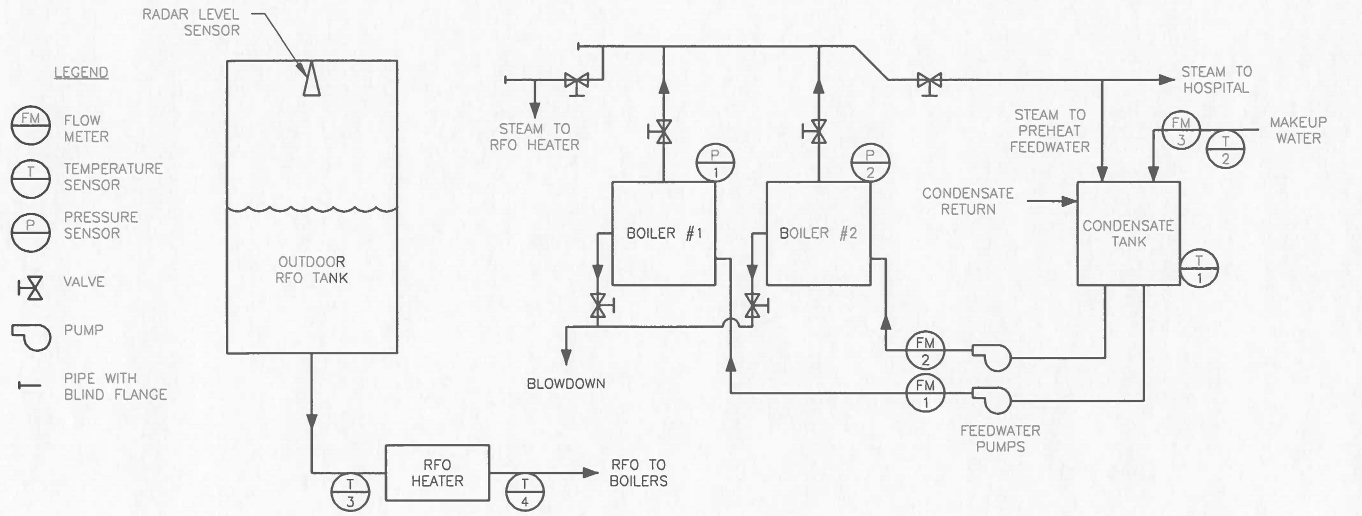


Drawing 3



Dimensions	1807	1810	1811	1812	1815	1816	1820
Pipe Size	3/4"	1"	1"	1"	1-1/2"	1-1/2"	2"
A	3-1/4"	2"	3-3/4"	3-3/4"	2-1/4"	4-3/4"	3-1/4"
B	6-1/2"	7"	7-1/4"	7-1/4"	8"	8-1/4"	6-1/4"
C	4-1/4"	10-1/4"	6"	6"	11-7/8"	8"	10-1/2"
L	9-1/4"	15-1/2"	11-1/4"	11-1/4"	17-1/2"	13-3/4"	N/A
Drawing	2	1	2	2	1	2	3

See Next Page for Pressure Loss and Accuracy



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.

$Q = (Qs - Qf - Qb - Qo) * 0.98 * 0.97 * t$ Equation 1

$Qs = hs * Ff$ Equation 2

$Qf = hf * Ff$ Equation 3

$Qb = (hs - hm) * Fm$ Equation 4

$Qo = (ho4 - ho3) * Fo$ 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.

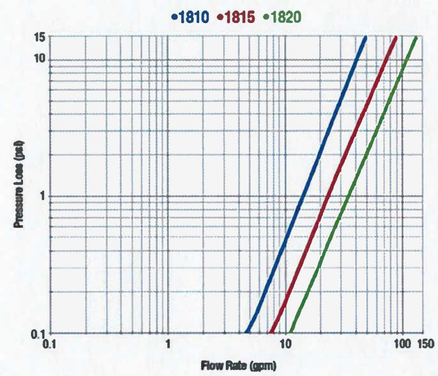
Accuracy

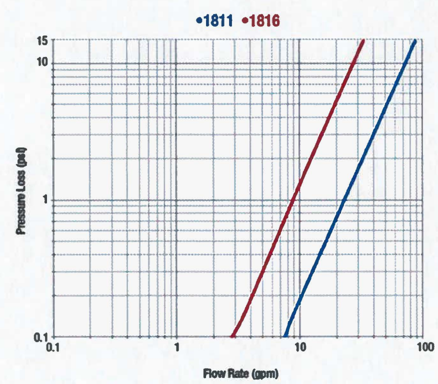
The metering and recording equipment meets the requirements for better than ±5.0% accuracy as called for by PUC 2506.04(f)(3), and a 3.0% penalty is taken for metering equipment accuracy. The 2% discount factor for parasitic load is also taken by the owner per PUC 2506.05(f)(3).

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 ____

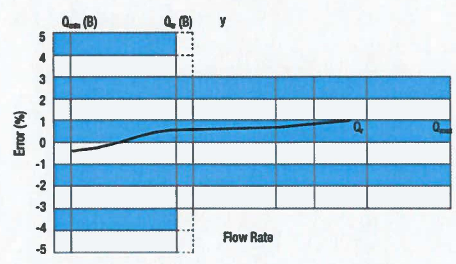
ISTEC's 1800 Series Multi-Jet Water Meter in 3/4" thru 2"

Pressure Loss





Accuracy



EKM METERING INC.

3/4" Water Meter - Stainless Steel, Pulse Output Spec Sheet

I. Functions and characteristics

1.) Model: EKM-SPWM-075
2.) 3/4" water flow meter for measuring water flow in cubic feet.
3.) With pulse-output communication for remote reading.
4.) No power source required.
5.) Has received California Type Approval for revenue grade accuracy from the California Department of Weights and Measures.

II. Technical specifications

1.) Class B
2.) Dimensions: 300mm long x 82mm wide x 116mm tall
3.) Weight: 3 lbs., 8 oz.
4.) Casing: Stainless Steel 201
5.) Pulse rate: 1 pulse / 0.1 cu. ft; 1 pulse = approx. 0.75 gal.
6.) Accuracy: 5% from Qmin to Qt, 2% from Qt to Qs
7.) Maximum reading before zeroing: 9,999,999.99 cu. ft (Approx. 75,000,000 gal.)
8.) Minimum reading: 0.0035 cu. ft
9.) Maximum operating pressure: 140 psi
10.) Minimum flow (Qmin): 1.77 cu. ft/hr
11.) Overload flow (Qs):176.5 cu. ft/hr
12.) Nominal flow (Qp): 88 cu. ft/hr
13.) Transitional Flow (Qt): 7 cu. ft/hr
14.) Temperature range: 0-40 deg C / 32-104 deg F
15.) 3/4 Inch NPT male threads

III. Operation

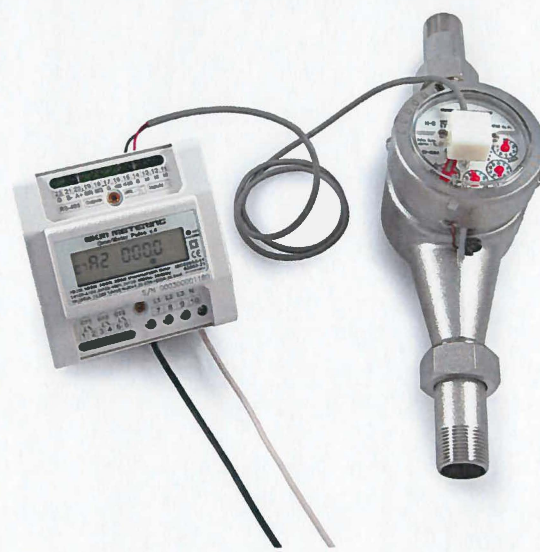
This meter can be used as a traditional water meter where the water consumption is read off of the face of the meter. It also has the added functionality of being able to connect the pulse-output wires to a pulse counting device. This meter produces a pulse for every 1/10 cubic foot (approx 0.75 gallon, or 2.83 liters) that flows by the meter. This pulse-output water meter can be connected to our EKM-Omnimeter Pulse v.4*(Fig 1)*. The pulse counting devices can then be connected to a computer, either locally or over the internet.

IV. Installation

1.) We recommend that this meter be installed by a qualified plumber.
2.) Install horizontally with the dial facing upwards. *(Fig 2)*
3.) Use teflon tape or pipe dope when connecting pipe fittings to the meter's NPT pipe threads.
**Note: You do not need to use dialectric unions when connecting dissimilar metal fittings to the stainless fittings provided with the meter.*

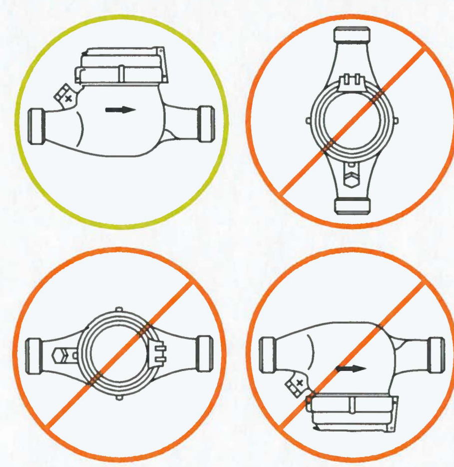
V. Pulse Output

1.) Use in conjuction with our pulse counter to se a digital diplay of the total pulse counts.
2.) Use in conjunction with our EKM-Omnimeter Pulse v.4 for remote metering applications.
3.) The EKM-Omnimeter Pulse v.4 has ports for three separate pulse inputs (ports 11, 12 and 13). All of the pulse input devices share a common ground wire (Port 14). These wires can be up to 200 feet long.
4.) Connect the red wire from the water meter to either port 11, 12, or 13. Connect the black wire to port 14. See *(Fig. 1)*
5.) The easiest way to power the EKM-Omnimeter Pulse v.4 is with 110v AC. Connect a hot leg into port 7 and the neutral into port 10.
6.) For more information on how to read this meter remotely, please refer to the various communication devices that we offer on our website.



(Fig. 1)

Install Horizontally with the Dial Facing Up

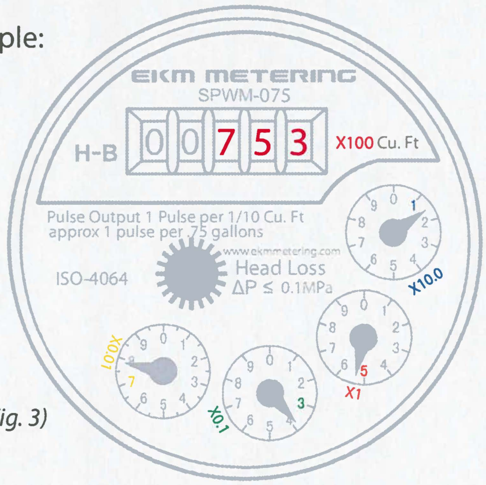


(Fig. 2)

EKM METERING INC.

V. Reading Your Meter

Example:



(Fig. 3)

(753 x 100)
+ (1 x 10)
+ (5 x 1)
+ (3 x 0.1)
+ (7 x 0.01)
= **75,315.37** ft^3

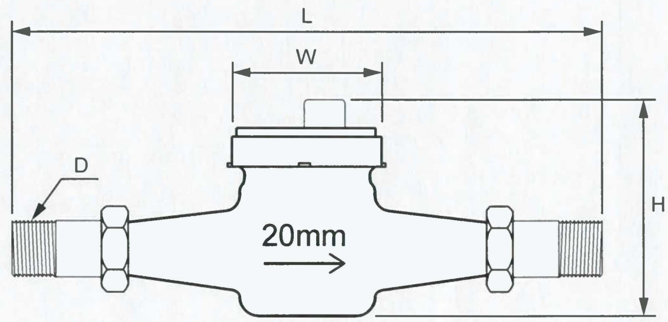
75,315.37 x 1 = 75,315.37 cubic feet
75,315.37 x 10 = 753,153 pulses
75,315.37 x 7.48052 = 563,398.09 gallons
75,315.37 x 0.0283168 = 2,132.69 cubic meters
75,315.37 x 28.3168 = 2,132,693.78 Liters

Conversion Multipliers:
Cubic Feet: x1
Pulses: x10
Gallons: x 7.48052
Cubic Meters: x 0.0283168
Liters: x 28.3168

*** Note:** Most Utilities in the United States round to the nearest 100 cubic feet. So in this case, only the red portion above, showing 75,300, would be necessary for determining usage.

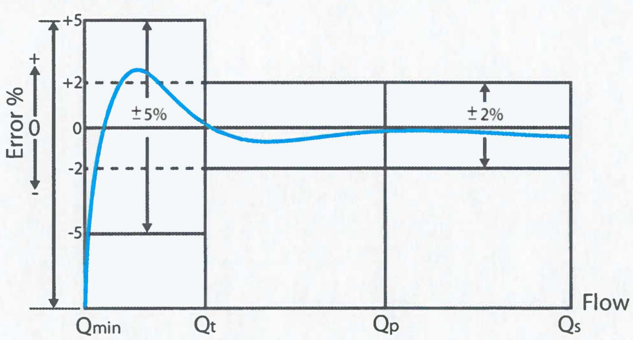
VI. Dimensions and Weight

Model	Size	L	W	H	D	Weight
SPWM-075	20mm	300mm	82mm	116mm	3/4" NPT	3.5 lbs.



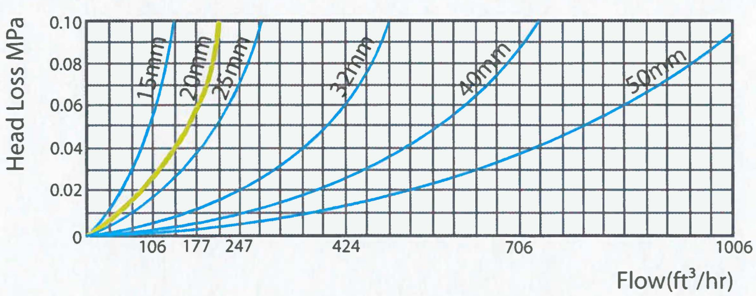
(Fig. 4)

VII. Error Curve:



(Fig. 5)

VIII. Head Loss Curve:



(Fig. 6)

Miniature Temperature Transmitters

Thermocouple, RTD (Pt100) or Voltage Input

NB1TX93-K3 thermocouple RTD. Smaller than actual size.

TX93

5 YEAR WARRANTY

TX93-J4, shown actual size.

- Ultra-Low Profile Design Only 19 mm (¾") High (Including Terminal Strip)
- 4 to 20 mA Output
- ±0.1% FS Accuracy
- Non-Isolated
- Mounts in Protection Head

Models TX93, TX94 and TX95 transmitters can eliminate long runs of costly field wiring in a variety of applications. A stable 4 to 20 mA output signal is provided proportional to the transmitters specific input type and calibrated temperature range (see Range Code table below). Adjustability of ±25% for zero and span is provided to facilitate some rangeability. The transmitted signal eliminates noise pickup, voltage drops, multiple cold junction errors and requires only a twisted pair of copper wire for loop connections. TX93, TX94 and TX95 are ultra-low profile transmitters at an economical price.

Specifications

Output Range: 4 to 20 mA dc

Zero and Span Adjustment Range: ±25%

Accuracy: ±0.1% FS (includes effects of linearity, hysteresis and repeatability)

Frequency Response: 3 dB @ 3Hz

Ambient Temperature Range: -25 to 85°C (-13 to 185°F)

Storage Temperature Range: -65 to 125°C (-85 to 257°F)

Supply Voltage: 8 to 35 Vdc; 24 Vdc recommended

Maximum Loop Resistance: $\frac{Vs - 8V}{0.020}$

Dimensions: 1.90 H x 4.45 cm D (0.75 x 1.75") (height includes terminal strip)

Weight: 30 g (1 oz)

To Order

Model No.	Description
TX93-(*)	Thermocouple transmitter (J, K, T, or E)
TX94-(*)	RTD transmitter (100 Ω Pt, alpha = 0.00385)
TX95-(*)	Voltage input transmitter
NB1TX93-(*)	NB1 thermocouple probe, 305 mm (12") L, 6 mm (¼") OD, ungrounded junction, 304 SS sheath, with TX93 transmitter
PRTX94-(*)	PR-12 RTD probe, 305 mm (12") L, 6 mm (¼") OD, 304 SS sheath, with TX94 transmitter

** Insert range code from chart below.*

Range Codes

Model Number						
TX93				TX94	TX95	
J	K	T	E	RTD†	Voltage	Range °C (°F)
J1			E1	1		-40 to 49 (-40 to 120)
J2	K2	T2	E2	2		-18 to 93 (0 to 200)
J3	K3	T3	E3	3		-18 to 149 (0 to 300)
J4	K4	T4	E4	4		-18 to 260 (0 to 500)
J5	K5	T5	E5	5		-18 to 399 (0 to 750)
J6	K6		E6	6		-18 to 538 (0 to 1000)
					V1	0 to 60 mV dc
					V2	0 to 10 Vdc

Comes complete with operator's manual.

† 2-lead RTD configuration

***Notes:** (1) Thermocouple models output proportional to mV output of thermocouple. Not linearized to temperature. (2) Non-Isolated unit for use with ungrounded probes.*

***Ordering Example: TX93-J4,** Type J, transmitter with -18 to 260°C (0 to 500°F) range.*

Accessories

Model No.	Description
TX90-DIN	DIN rail mounting adaptor
RT	1.2 m (48") mounting track
TX90-BR	Mounting track mounts up to 2 transmitters of the TX90 series
PSR-24S	Regulated power supply, 24 Vdc, 400 mA, screw terminal
PSR-24L	Regulated power supply, 24 Vdc, 400 mA, UL, stripped leads
PSR-24L-230	Regulated power supply, 24 Vdc, 400 mA, stripped leads, 230 Vac input
PSU-93	Unregulated power supply, 16 to 23 Vdc, 300 mA max, screw terminal
TX82B	Process loop indicator (see omega.com)
RAIL-35-2	2 m (6.6') section 35 mm DIN rail

Level | Pressure | Flow | Temperature | Liquid Analysis | Registration | Systems Components | Services | Solutions

Technical Information

Cerabar T PMC131, PMP131, PMP135

Process pressure measurement
Pressure transducer with ceramic and metallic sensors
For absolute pressure and gauge pressure measurement up to 400 bar (6000 psi); Extremely stable, overload-resistant and reliable

Application
The Cerabar T is a pressure transducer for measuring absolute pressure and gauge pressure in gases, vapors, liquids and dusts.
Hygienic and threaded connections are available as process connections.

Your benefits
This compact pressure transducer impresses with its well-engineered construction:

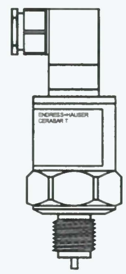
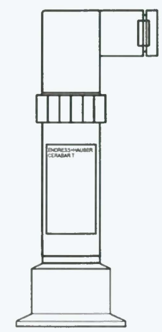
- High reproducibility and long-term stability.
- Finely graduated measuring ranges from vacuum up to 400 bar (6000 psi)
- Ceraphire® ceramic sensor: corrosion-proof, abrasion-proof and extremely overload-resistant
- Deployed for pressure monitoring up to SIL 2 as per IEC 61508/IEC 61511-1
- Sensors
  - Dry capacitance ceramic sensor (Ceraphire®) for measuring ranges up to 40 bar (600 psi): overload-resistant, vacuum-proof, stable against alternating load
  - Piezoresistive sensor with metallic process isolating diaphragm for measuring ranges up to 400 bar (6000 psi)

TI00415P/00/EN/19.15
No. 71289985

Endress+Hauser
People for Process Automation

Function and system design

Device selection

Cerabar T - Product family	**PMC131**	**PMP131**	**PMP135**
	 P01-PMC131xx-14-xx-xx-xx-000 With capacitive measuring cell and ceramic process isolating diaphragm (Ceraphire®)	 P01-PMP131xx-14-xx-xx-xx-000 With piezoresistive measuring cell and metallic process isolating diaphragm	 P01-PMP135xx-14-xx-xx-xx-000 With piezoresistive measuring cell and metallic process isolating diaphragm for hygienic applications
Field of application	Absolute pressure and gauge pressure	Absolute pressure and gauge pressure	Absolute pressure and gauge pressure in hygienic processes
Output	– Current output 4 to 20 mA	– Current output 4 to 20 mA – Voltage output 0 to 10 V – Switch output PNP	– Current output 4 to 20 mA – Switch output PNP
Process connections	Thread: – G ½ – ½ MNPT and ¼ FNPT – G ½, bore 11 mm (0.43 in)	Thread: – G ½ – ½ MNPT and ¼ FNPT – ½ MNPT, bore 11.4 mm (0.45 in) – G ¼ – ¼ MNPT, bore 3.5 mm (0.14 in) – M 20 x 1.5	Hygiene: – Clamp DN 22 (¾") – Tri-Clamp DN 25 to 38 (1" to 1½") – Tri-Clamp DN 40 to 51 (2") – G 1 – SMS 1½"
Measuring ranges	from –1 to 0 bar (–15 to 0 psi) / –100 to 0 kPa up to 0 to 40 bar (0 to 600 psi) / 0 to 4 MPa	0 to 1 bar (0 to 15 psi) / 0 to 100 kPa up to 0 to 400 bar (0 to 6000 psi) / 0 to 40 MPa	0 to 1 bar (0 to 15 psi)/0 to 100 kPa up to 0 to 40 bar (0 to 600 psi) / 0...4 MPa
Process temperature range	–20 to +100 °C (-4 to +212 °F)	–25 °C to +70 °C (-13 to +158 °F)	–25 to +100 °C (-13 to +212 °F), +135 °C (275 °F) for max. 1 hour

Measuring principle

PMC131

The process pressure causes a slight deflection of the ceramic process isolating diaphragm of the sensor. The pressure-proportional change in capacitance is measured at the electrodes of the ceramic sensor. The ceramic sensor is a dry sensor, i.e. no fill fluid is required for the pressure transfer. This makes the sensor completely suitable for vacuums. Extremely high stability, comparable with the material Alloy, is achieved by using ultrapure Ceraphire® as the ceramic.

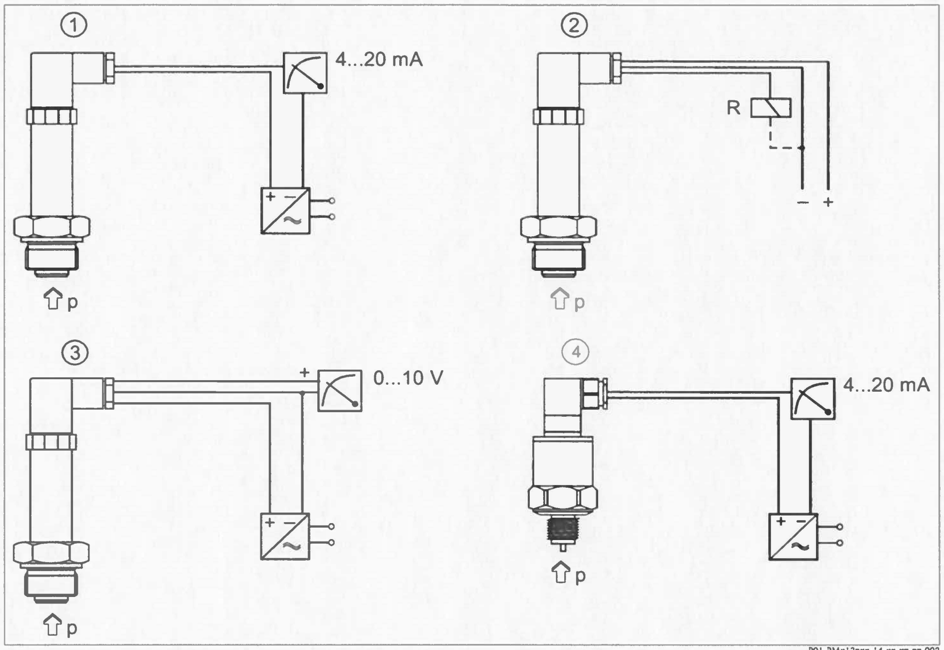
PMP131 and PMP135 with analog output

The process pressure acting upon the metallic process isolating diaphragm of the sensor is transmitted to a resistance bridge via a fluid. The pressure-proportional change of the bridge output voltage is measured and processed further.

PMP131 and PMP135 with switch output

The process pressure acting upon the metallic process isolating diaphragm of the sensor is transmitted to a resistance bridge via a fluid. A differential amplifier creates a standard signal from the pressure-proportional change in output voltage of the bridge. A comparator with an adjustable hysteresis compares this signal with the pre-set switch point and then activates the transistor output.

Measuring system



1 *PMP131, PMP135: current output with transmitter power supply unit, e.g. RN 221N from Endress+Hauser*
2 *PMP131, PMP135: switch output with load, e.g. PLC, DCS, relay*
3 *PMC131: voltage output with transmitter power supply unit, e.g. RIA452 from Endress+Hauser*
4 *PMC131: current output with transmitter power supply unit, e.g. RN 221N from Endress+Hauser*

Input

Measured variable	Absolute pressure or gauge pressure
Measuring range	up to 400 bar (6000 psi), → 🖹 21, "Ordering information" section

Output

Analog output (PMC131, PMP131, PMP135)

Output signal

Current output 4...20 mA, 2-wire version (PMC131, PMP131, PMP135)
Voltage output 0...10 V, 3-wire version (PMP131)

Load

PMC131
R_{Lmax} [Ω] ≤ (U_S – 11 V) / 0.02 A

PMP131 and PMP135 (current output)
R_{Lmax} [Ω] ≤ (U_S – 12 V) / 0.02 A (R_{Lmax}: Maximum load resistance, U_S: Supply voltage)

PMP131 (voltage output)
Load resistance RLmax ≥5 kΩ, current consumption ≤6 mA

Switch output (PMP131, PMP135)

Output signal	PNP switch output (positive voltage signal), rate depends on power supply voltage
Output current	▪ Switch status ON: I_a ≤ 500 mA

- Switch status OFF: $I_a \leq 1$ mA

Power max. 6 W

Switch frequency max. 10 Hz

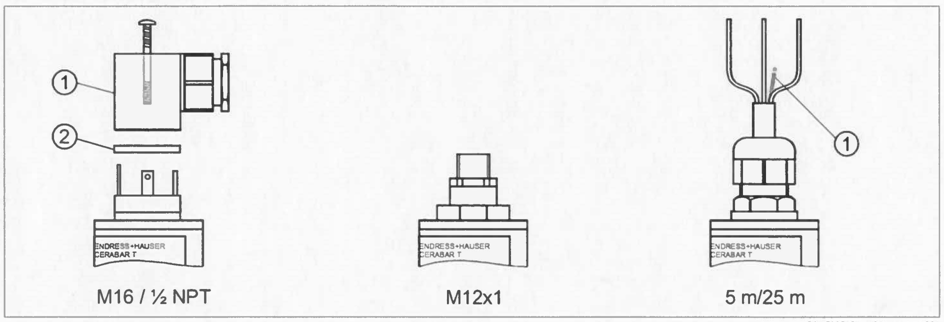
Input PLC
- Input resistance $R_i \leq 2$ kΩ
- Input current $I_i \geq 10$ mA

Inductive loads To prevent electrical interference, only operate an inductive load (relays, contactors, solenoid valves) when directly connected to a protective circuit (free-wheeling diode or capacitor).

Power supply

PMC131

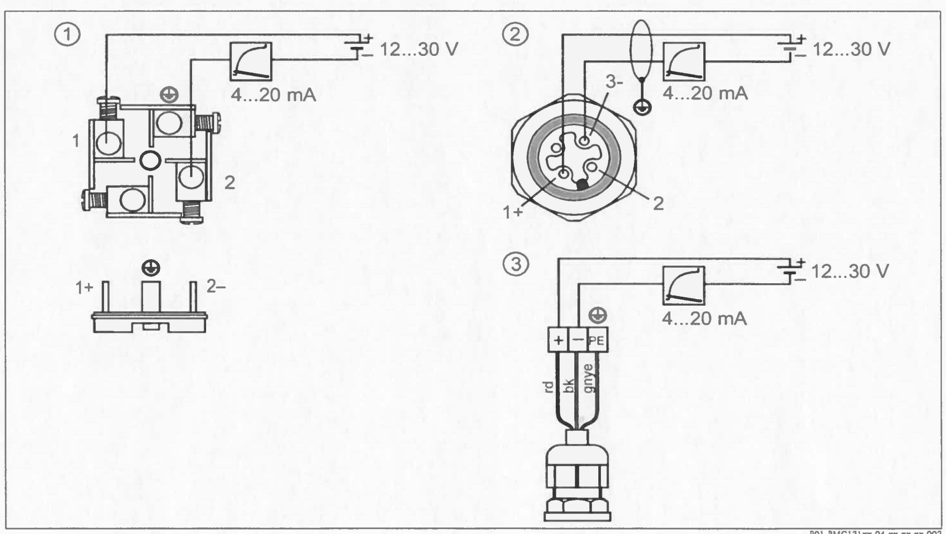
Plug/cable connection



P01-PMC131xx-04-xx-xx-xx-001

Plug M 16 x 1.5 (DIN 43650/A), ½ NPT	Plug M 12x1	5 m (16 ft) / 25 m (82 ft) cable
① Plug-in housing		① Reference pressure line
② Gasket		

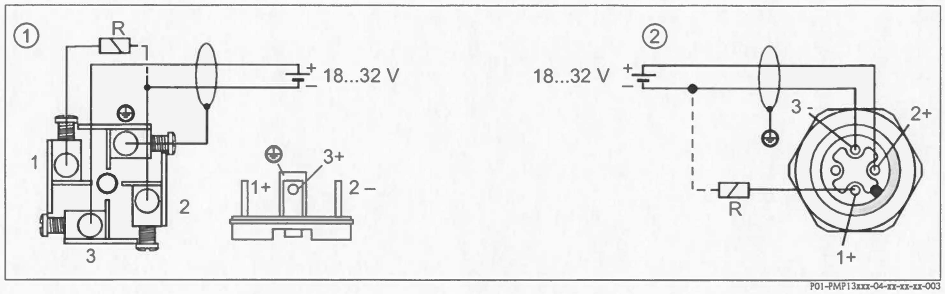
Electrical connection: Analog/current output



P01-PMC131xx-04-xx-xx-xx-002

1 Plug M 16 x 1.5 (DIN 43650/A), ½ NPT
2 Plug M 12 x 1
3 Cable (rd = red, bk = black, gnye = green-yellow)

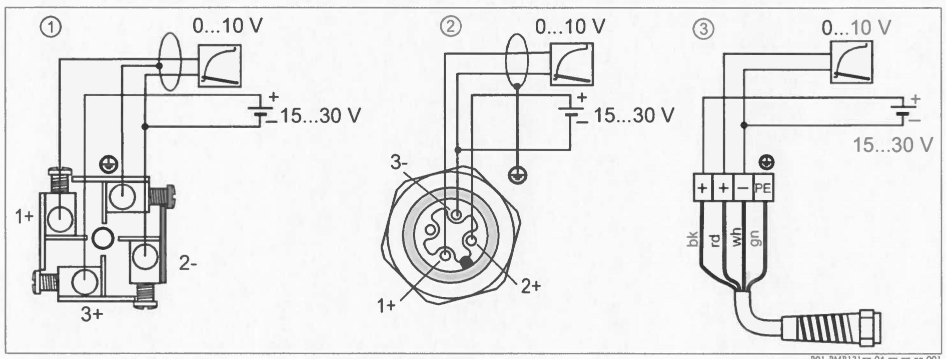
Electrical connection (switch output)



1 Plug M 16 x 1.5 (DIN 43650/A), ½ NPT
2 Plug M 12 x 1
R External load, e.g. relay, programmable logic controller, distributed control system

For electrical connection provided by customer use only shielded cable

PMP131 Electrical connection: Analog-/voltage output



1 Plug M 16 x 1,5 (DIN 43650/A), ½ NPT and plug DIN 43 650/C
2 Plug M 12 x 1
3 Cable (rd = red, wh = white, gn = green)

For electrical connection provided by customer use only shielded cable

Supply voltage

PMC131
11 to 30 V DC

PMP131 and PMP135 (current output, 2-wire version)

- For non-hazardous areas: 12 to 30 V DC
- Ex i: no-load voltage ≤ 26 V DC, short-circuit current ≤ 100 mA, power consumption ≤ 0.8 W

PMP131 (voltage output, 3-wire version)

- 15...30 V DC

PMP131 and PMP135 (switch output)

- 18 to 32 V DC, current consumption without load < 20 mA, with reverse polarity protection

Residual ripple

- Analog output: max. 5 % of supply voltage
- Switch output: max. 10 % of supply voltage

Cable entry

→ 🗎 21, "Ordering information" section.

Performance characteristics

Reference operating conditions

as per DIN IEC 60770, T_U = 25 °C (77 °F)

Long-term stability

≤ 0.15 % of URL per year

Reference accuracy Analog output

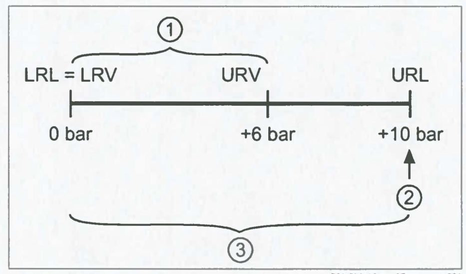
The reference accuracy comprises the non-linearity according to limit point setting, hysteresisand non-reproducibility as per IEC 60770.

PMC131

- ≤ 0.5 % of nominal value x TD
  (extended specifications apply to customer-specific measuring ranges)

Example: PMC131 version "A1R"
- Nominal value = 10 bar (150 psi)
- Upper range value (URV) = 6 bar (90 psi)
- Lower range value (LRV) = 0 bar

Turn down (is set at factory):
- Nominal value / (URV – LRV) | =
  10 bar (150 psi)/6 bar (90 psi) = 10:6



Example: PMC131 version "A1R"
set span: 0 to 6 bar (0 to 90 psi);
nominal value = 10 bar (150 psi)

1 Span set and calibrated at the factory (measuring range)
2 Nominal value ≙ Upper Range Limit (URL)
3 Sensor measuring range
LRL Lower Range Limit
URL Upper Range Limit
LRV Lower Range Value
URV Upper Range Value

PMP131 and PMP135

- ≤ 0.5 % of URL

Switch point

PMP131 and PMP135

- Deviation: ≤ 1 % of URL
- Non-reproducibility: ≤ 0.5 % of URL

Rise time (T90)

PMC131
20 ms

PMP131 and PMP135
2 to 5 ms

Thermal change in the zero output and the output span

PMC131

For customer-specific measuring-ranges: values are doubled

Zero output, –20 to +85 °C (-4 to +185 °F):
- typically 1.5 % of nominal value

Output span, –20 to +85 °C (-4 to +185 °F):
- Nominal value 0.4 to 40 bar (6 to 600 psi): typically 0.8 % of nominal value
- Nominal value 0.1 to 0.2 bar (1.5 to 3 psi): typically 1.0 % of nominal value

Temperature coefficient (T_K) for lower range value and span

PMP131 and PMP135 (analog output)

Zero output:
- typically: 0.2 % of URL/10 K
- max.: 0.5 % of URL/10 K
- Nominal value ≤ 6 bar (90 psi): by 0.1 % of URL/10 K higher

Output signal:
- typically: 0.2 % of URL/10 K
- max.: 0.5 % of URL/10 K

PMP131 and PMP135 (switch output)

Switch point:
- typically: 0.2 % of URL/10 K
- max.: 0.5 % of URL/10 K

Operating conditions (installation)

Orientation

anywhere

Installation instructions

PMP131
Process connection G ½ flush-mounted, max. torque 40 Nm (29.5 lbf ft)

Location dependence

PMC131
without influence

PMP131 and PMP135
Position-dependent zero point shift can be corrected by potentiometer setting, → 🗎 17.

Operating conditions (environment)

Ambient temperature range

PMC131
–20 to +85 °C (-4 to +185 °F)

PMP131 and PMP135
- For non-hazardous areas: –25 to +70 °C (-13 to +158 °F)
- Ex i: –25 to +65 °C (-13 to +149 °F)

Storage temperature range

PMC131
–50 to +100 °C (-58 to +212 °F)

PMP131 and PMP135
–40 to +85 °C (-40 to +185 °F)

Climate class

PMC131
4K4H as per DIN EN 60721-3

PMP131 and PMP135
4Z
with Z = 70 °C (158 °F) as per VDI/VDE 3540

Degree of protection

PMC131
- Plug M 16 x 1,5 (DIN 43650/A), ½ NPT: IP 65/NEMA 4X
- Plug M12x1: IP 65/ NEMA 4
- Cable: IP 68/NEMA 6P (1 mWS/24 h)

PMP131 and PMP135
- Plug M 16 x 1,5 (DIN 43650/A), ½ NPT: IP 65/NEMA 4X
- Plug M 12x1 and gauge pressure sensors: IP 65/NEMA 4X
- Plug M 12x1 and absolute pressure sensors: IP 68/NEMA 6P (1 mWS/24 h)
- Cable: IP 68/NEMA 6P (1 mWS/24 h)

Vibration resistance

4M5 as per DIN EN 60721-3

Electromagnetic compatibility

EMC in accordance with all the relevant requirements of the EN 61326 series. Details are provided in the Declaration of Conformity.

Operating conditions (process)

Process temperature range

PMC131

- –20 to +100 °C (-4 to 212 °F)
- Devices for oxygen application: –10 to +60 °C (14 to 140 °F)
  (Version "S" for feature 30 "Sensor gasket")

PMP131
–25 to +70 °C (-13 to +158 °F)

PMP135
–25 to +100 °C (-13 to 212 °F), +135 °C (275 °F) for max. 1 hour

Extreme jumps in temperature can result in temporary measuring errors. Temperature compensation takes effect after several minutes. Internal temperature compensation is faster the smaller the temperature jump and the longer the time interval.

Overload resistance

→ 21, "Ordering information" section.

Vacuum resistance

PMC131

URV	Vacuum resistance	Version
0...100 mbar (0...1.5 psi)	700 $mbar_{abs}$ (10.5 psi_{abs})	D10
20 mbar (0.3 psi)		D3W
100 mbar (1.5 psi)		D31
1.5 psi (100 mbar)		V6F
0...1.5 psi (0...100 mbar)		Q4D
15 inH_2O		W6N
30 inH_2O		W6R
0...200 mbar (0...3 psi)	500 $mbar_{abs}$ (7.5 psi_{abs})	D12
200 mbar (3 psi)		D38
50 inH_2O		S4N
80 inH_2O		W6O
all other versions	0 $mbar_{abs}$	

PMP131 and PMP135
10 $mbar_{abs}$ (0.15 psi_{abs})
The vacuum resistance applies for the measuring cell under reference operating conditions.

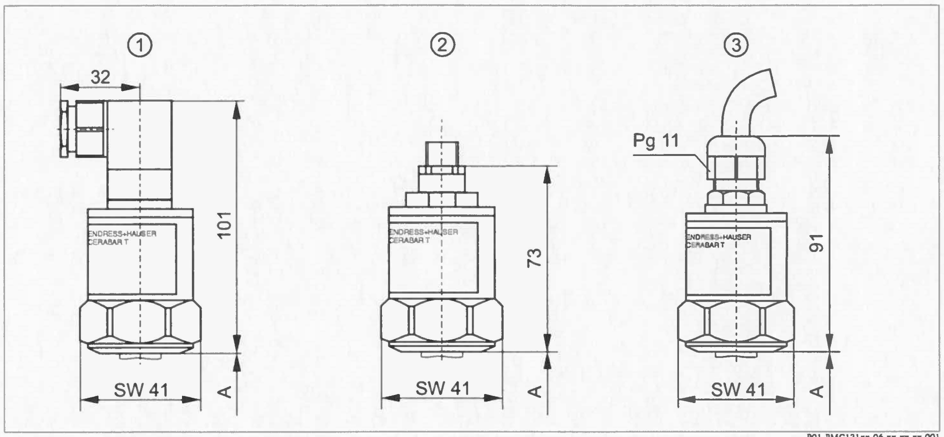
Pressure specifications

- The MWP (maximum working pressure) of the device is specified on the nameplate. It depends on the weakest element, with regard to pressure, of the selected components. See the following sections:
  - → 21 ff, "Ordering information" section, feature 50 "Measuring range; MWP; Nominal value; OPL" or "Sensor range; MWP; OPL".
  - → 12 ff, "Mechanical construction" section.

  The MWP specification on the nameplate is based on a reference temperature of +20 °C (68 °F) and can be present over an unlimited period of time.
- The test pressure corresponds to the overload limit of the measuring device (Over Pressure Limit OPL) and must only be present for a limited period of time.

Mechanical construction

PMC131 Housing

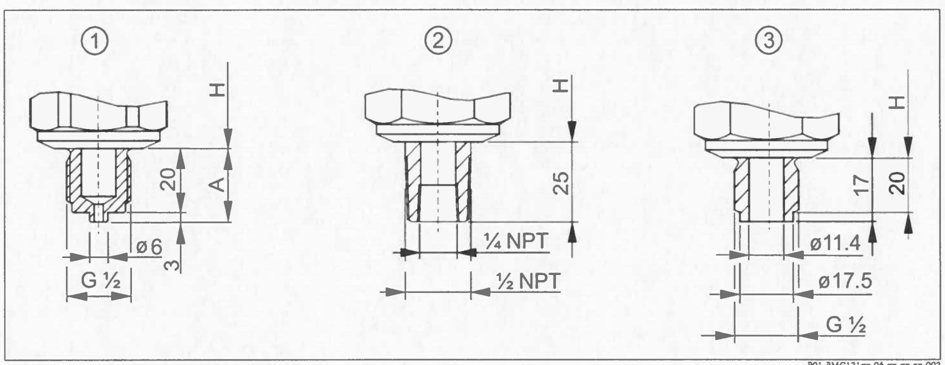


Housing PMC131; Material AISI 304 (1.4301)

1 Versions A1, A2, B1, C1, C2: Plug M 16 or ½ NPT (ISO 4400), IP 65
2 Versions A5, B5, C5: Plug M 12, IP 65
3 Versions A3, A4, B3, C3: 5 m (16 ft) or 25 m (82 ft) cable, IP 68

→ See the following diagram for the height of process connection A

PMC131 Process connections



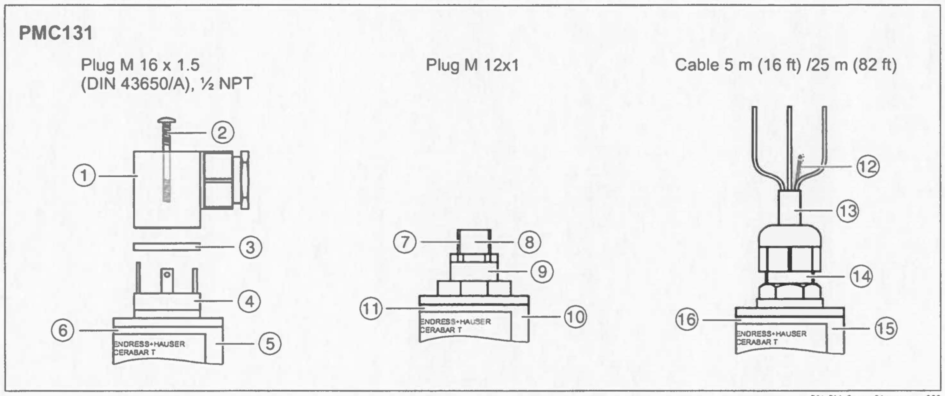
Process connections PMC131; Material AISI 304 (1.4301)

1 Version 1: Thread ISO 228 G ½
2 Version 2: Thread ANSI ½ MNPT ¼ FNPT
3 Version 5: Thread ISO 228 G ½, bore 11.4 mm (0.45 in)

→ See respective housing for installation height H (previous figure)

Material (not wetted)

Housing



P01-PMx3xxxx-06-xx-xx-en-002

Item number	Component part	Material
1	Plug housing	PA6 GF
2	Flat sealing	NBR
3	Screw M3 x 35	A2
4	Connection cover	PBT-FR
5	O-ring	NBR
6	Housing	1.4301
7	O-ring for connector	FKM
8	Inner connector	PA
9	M12 connector	GD-Zn, nickel-plated
10	O-ring	NBR
11	Housing	1.4301
12	Hose	PA
13	Cable	PE
14	Gland	PBT
15	O-ring	NBR
16	Housing	1.4301

Ordering information

PMC131

This overview does not mark options which are mutually exclusive.

10	Electrical connection:
A1	Plug ISO 4400, M 16, IP 65/NEMA 4X
A2	Plug ISO 4400, ½ NPT, IP 65/NEMA 4X
A3	5 m cable, IP 68/NEMA 6P
A4	25 m cable, IP 68/NEMA 6P
A5	Plug M 12, IP 65/NEMA 4
B1	Plug ISO 4400, M 16, IP 65, ATEX II 3 G EEx nA II T4
B3	5 m cable, IP 68, ATEX II 3 G EEx nA II T4
B5	Plug M 12, IP 65, ATEX II 3 G EEx nA II T4
C1	Plug ISO 4400, M 16, NEMA 4X, CSA GP
C2	Plug ISO 4400, ½ NPT, NEMA 4X, CSA GP
C3	5m cable, IP 68/NEMA 6P, CSA GP
C5	Plug M12, IP 65/NEMA 4, CSA GP

20	Process connection:
1	Thread ISO 228 G ½, AISI 304
2	Thread ANSI ½ MNPT ¼ FNPT, AISI 304
5	Thread ISO 228 G ½ bore 11 mm, AISI 304

30	Sensor seal:
E	EPDM
F	FKM Viton
S	FKM Viton, oxygen application

40	Additional options:
1	Without additional equipment
S	GL (German Lloyd) marine certificate
2	Final inspection report

50	Measuring range; MWP; Nominal value; OPL:			
	Measuring range	MWP (Maximum Working Pressure)	Nominal value	OPL (Over Pressure Limit)
	Sensors for gauge pressure			
A1G	0 to 1 bar / 0 to 100 kPa	6.7 bar	1 bar	10 bar / 1 MPa
A1H 1)	0 to 1.6 bar / 0 to 160 kPa	12 bar	2 bar	18 bar / 1.8 MPa
A1K	0 to 2 bar / 0 to 200 kPa	12 bar	2 bar	18 bar / 1.8 MPa
A1Q	0 to 4 bar / 0 to 400 kPa	16.7 bar	4 bar	25 bar / 2.5 MPa
A1R 1)	0 to 6 bar / 0 to 600 kPa	26.7 bar	10 bar	40 bar / 4 MPa
A1S	0 to 10 bar / 0 to 1 MPa	26.7 bar	10 bar	40 bar / 4 MPa
A1T 1)	0 to 16 bar / 0 to 1.6 MPa	26.7 bar	20 bar	40 bar / 4 MPa
A1V	0 to 20 bar / 0 to 2 MPa	26.7 bar	20 bar	40 bar / 4 MPa
A1W 1)	0 to 25 bar / 0 to 2.5 MPa	40 bar	40 bar	60 bar / 6 MPa
A1X	0 to 40 bar / 0 to 4 MPa	40 bar	40 bar	60 bar / 6 MPa
A3C 1)	–1 to 0 bar / –100 to 0 kPa	6.7 bar	2 bar	10 bar / 1 MPa
A3E 1)	–1 to 1 bar / –100 to 100 kPa	6.7 bar	2 bar	10 bar / 1 MPa
A3G 1)	–1 to 3 bar / –100 to 300 kPa	16.7 bar	4 bar	25 bar / 2.5 MPa
A3K 1)	–1 to 9 bar / –100 to 900 kPa	26.7 bar	10 bar	40 bar / 4 MPa
A3N 1)	–1 to 15 bar / –0.1 to 1.5 MPa	26.7 bar	20 bar	40 bar / 4 MPa
D10	0 to 100 mbar / 0 to 10 kPa	2.7 bar	0.1 bar	4 bar / 400 kPa
D12 1)	0 to 200 mbar / 0 to 20 kPa	3.3 bar	0.2 bar	5 bar / 500 kPa
D14	0 to 400 mbar / 0 to 40 kPa	5.3 bar	0.4 bar	8 bar / 800 kPa
D3W	–20 to 20 mbar / –2 to 2 kPa	2.7 bar	0.2 bar	4 bar / 400 kPa
D31 1)	–100 to 100 mbar / –10 to 10 kPa	3.3 bar	0.2 bar	5 bar / 500 kPa
D38 1)	–200 to 200 mbar / –20 to 20 kPa	3.3 bar	0.4 bar	5 bar / 500 kPa
D39 1)	–300 to 300 mbar / –30 to 30 kPa	5.3 bar	1 bar	8 bar / 800 kPa

PMC131					Order code

→ For continuation of ordering information of PMC131, see the following page.

1) Span set and calibrated at the factory

PMC131 (continued)

50	Measuring range; MWP; Nominal value; OPL:			
	Measuring range	MWP (Maximum Working Pressure)	Nominal value	OPL (Over Pressure Limit)
	Sensors for gauge pressure			
Q4D	0 to 1.5 psi	40 psi	1.5 psi	60 psi
Q4F 1)	0 to 5 psi	80 psi	6 psi	120 psi
Q4H	0 to 15 psi	100 psi	15 psi	150 psi
Q4K	0 to 30 psi	180 psi	30 psi	270 psi
Q4N 1)	0 to 50 psi	250 psi	60 psi	375 psi
Q4R	0 to 150 psi	400 psi	150 psi	600 psi
Q4S	0 to 300 psi	400 psi	300 psi	600 psi
Q4T 1)	0 to 500 psi	600 psi	600 psi	900 psi
V6F 1)	–1.5 to 1.5 psi	50 psi	3 psi	75 psi
V6N 1)	–15 to 15 psi	100 psi	30 psi	150 psi
V6R 1)	–15 to 30 psi	250 psi	60 psi	375 psi
V6S	–15 to 60 psi	250 psi	60 psi	375 psi
V6V	–15 to 150 psi	400 psi	150 psi	600 psi
S4N 1)	0 to 50 inH_2O	50 psi	3 psi	75 psi
S4Q 1)	0 to 100 inH_2O	80 psi	6 psi	120 psi
W6N 1)	–15 to 15 inH_2O	40 psi	3 psi	60 psi
W6O 1)	–80 to 80 inH_2O	50 psi	6 psi	75 psi
W6R 1)	–15 to 30 inH_2O	50 psi	3 psi	75 psi
	Sensors for absolute pressure			
A2G	0 to 1 bar / 0 to 100 kPa	6.7 bar	1 bar	10 bar / 1 MPa
A2H 1)	0 to 1.6 bar / 0 to 160 kPa	12 bar	2 bar	18 bar / 1.8 MPa
A2K	0 to 2 bar / 0 to 200 kPa	12 bar	2 bar	18 bar / 1.8 MPa
A2Q	0 to 4 bar / 0 to 400 kPa	16.7 bar	4 bar	25 bar / 2.5 MPa
A2R 1)	0 to 6 bar / 0 to 600 kPa	26.7 bar	10 bar	40 bar / 4 MPa
A2S	0 to 10 bar / 0 to 1 MPa	26.7 bar	10 bar	40 bar / 4 MPa
A2T 1)	0 to 16 bar / 0 to 1.6 MPa	26.7 bar	20 bar	40 bar / 4 MPa
A2V	0 to 20 bar / 0 to 2 MPa	26.7 bar	20 bar	40 bar / 4 MPa
A2W 1)	0 to 25 bar / 0 to 2.5 MPa	40 bar	40 bar	60 bar / 6 MPa
A2X	0 to 40 bar / 0 to 4 MPa	40 bar	40 bar	60 bar / 6 MPa
D20 1)	0 to 100 mbar / 0 to 10 kPa	3.3 bar	0.2 bar	5 bar / 500 kPa
D22	0 to 200 mbar / 0 to 20 kPa	3.3 bar	0.2 bar	5 bar / 500 kPa
D24	0 to 400 mbar / 0 to 40 kPa	5.3 bar	0.4 bar	8 bar / 800 kPa
R4D 1)	0 to 1.5 psi	50 psi	3 psi	75 psi
R4F 1)	0 to 5 psi	80 psi	6 psi	120 psi
R4H	0 to 15 psi	100 psi	15 psi	150 psi
R4K	0 to 30 psi	180 psi	30 psi	270 psi
R4N 1)	0 to 50 psi	250 psi	60 psi	375 psi
R4R	0 to 150 psi	400 psi	150 psi	600 psi
R4S	0 to 300 psi	400 psi	300 psi	600 psi
R4T 1)	0 to 500 psi	600 psi	600 psi	900 psi

995	Marking
1	Tagging (TAG), see additional spec.
PMC131	Complete order code

1) Span set and calibrated at the factory

Specification sheet

VEGAPULS 62

4 … 20 mA/HART - four-wire

Radar sensor for continuous level measurement of liquids

Application area

The VEGAPULS 62 sensor can be used universally for continuous level measurement in liquids.
It is suitable for level measurement in storage containers, reactors and process vessels, even under difficult process conditions. With its various antenna versions and materials, VEGAPULS 62 is the optimal solution for almost all applications and processes. Its wide temperature and pressure range makes project planning simple.

Your benefit

- Maintenance-free operation thanks to non-contact measuring principle
- High plant availability, because wear and maintenance free
- Exact measuring results independent of pressure, temperature, gas and steam

Function

Extremely short microwave pulses are emitted by the antenna system in the direction of the measured product, reflected by the product surface and received back again by the antenna system. The time from emission to reception of the signals is proportional to the level in the vessel. A special time stretching procedure allows reliable and precise measurement of the extremely short signal running times.

Technical data

Measuring range up to	35 m (114.8 ft)
Deviation	±2 mm
Process fitting	Thread from G1½; 1½ NPT; flanges from DN 40, 1½"
Process pressure	-1 … +160 bar/-100 … +16000 kPa (-14.5 … +2320 psig)
Process temperature	-196 … +450 °C (-321 … +842 °F)
Ambient, storage and transport temperature	-40 … +70 °C (-40 … +158 °F)
Operating voltage	
– Version for low voltage	9.6 … 48 V DC, 20 … 42 V AC, 50/60 Hz
– Version for mains voltage	90 … 253 V AC, 50/60 Hz
SIL qualification	Optionally up to SIL2

Materials

The wetted parts of the instrument are made of 316L, Alloy C22 (2.4602), Alloy 400 (2.4360), stainless steel precision casting (1.4848) or PTFE, PP, PEEK. The process seal is made of FKM, FFKM or graphite.
You will find a complete overview of the available materials and seals in the "*Configurator*" at www.vega.com and "*VEGA Tools*".

Housing versions

The housings are available as double chamber version in plastic, stainless steel or Aluminium. They are available in protection class IP 66/ IP 67.

Electronics versions

The instruments are available in different electronics versions.
Apart from 4 … 20 mA/HART in two and four-wire version, there are also digital versions with Profibus PA, Foundation Fieldbus and Modbus protocols. Another HART version is available with integrated accumulator.

Approvals

The instruments are suitable for use in hazardous areas and are approved e.g. according to ATEX and IEC. The instruments also have various ship approvals such as e.g. GL, LRS or ABS.
You can find detailed information at www.vega.com/downloads and "*Approvals*".

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
NATIONAL LABORATORY

Proudly Operated by Battelle Since 1965

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.

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

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.

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

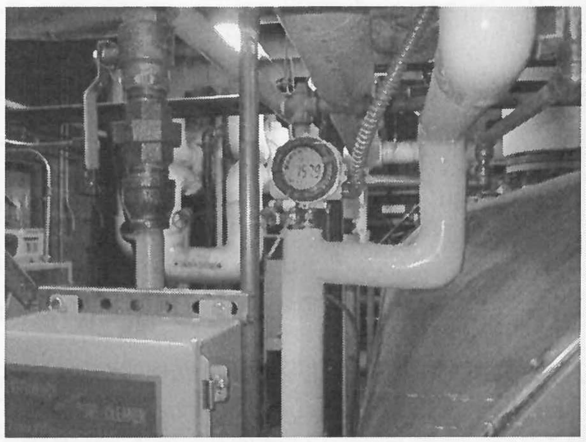
Differential Pressure – Orifice Flow Meter. The orifice flow meter functions the same way for water flow as it does for natural gas flow.

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.

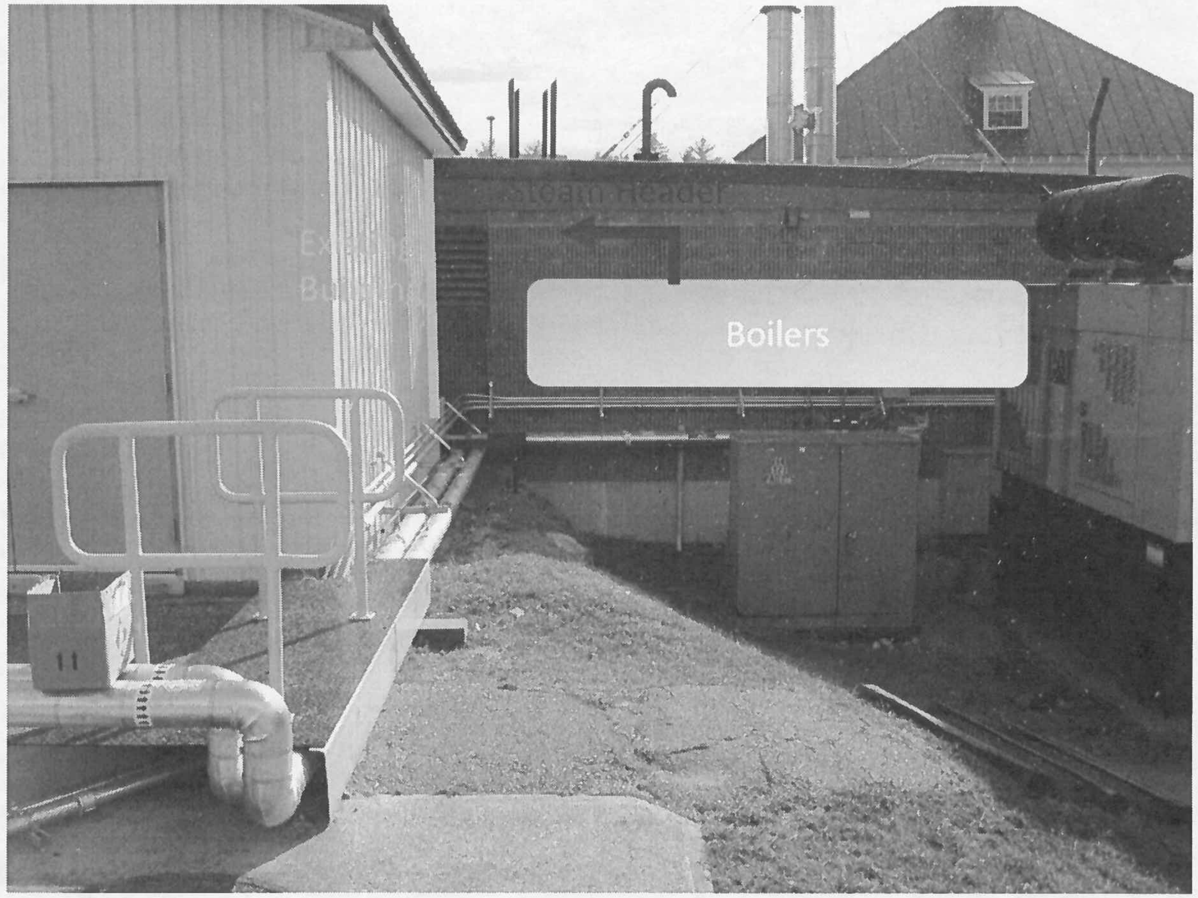
Memorial Hospital Boiler Room
North Conway, NH

- 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

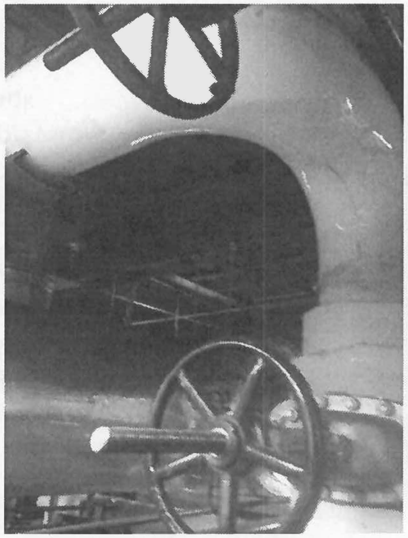
- The photo to the right is of the side of the boiler house, on which we have superimposed the location of the boilers and steam headers.
- In order to measure the steam flow independently in each boiler, the steam flowmeters would have to be installed in an orientation which is parallel to the boilers. 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.



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	ß Ratio[3,4]	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

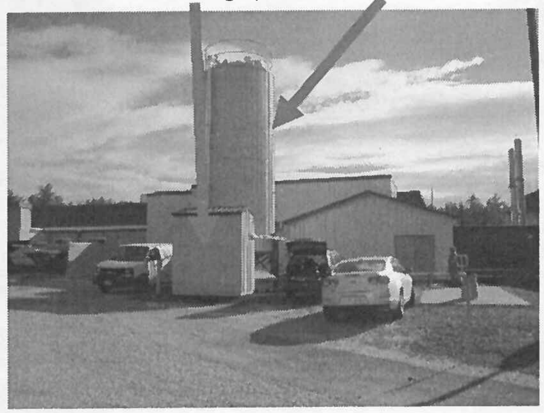
Notes:

[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] ß ratio = Orifice diameter (d) divided by Pipe diameter (D)
[4] Most Orifice Plates are supplied with a ß ratio of around 0.7 which gives the best pressure recovery without compromising signal strength.

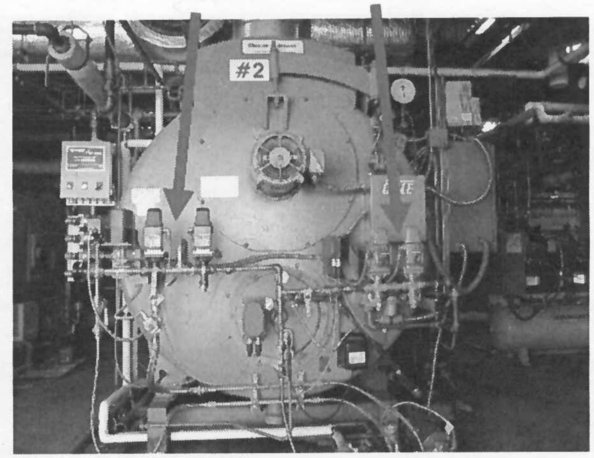
Memorial Hospital Conversion to RFO™
North Conway, NH

- 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.

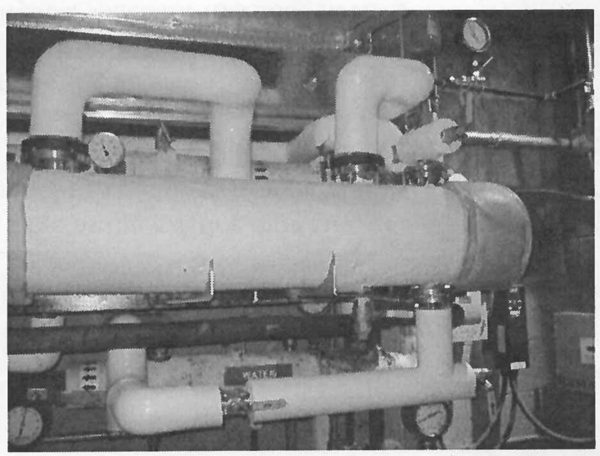
Unloading System and Tank



Redundant Fuel Trains
RFO™ Fossil Fuel



Heater



Pumps