MEASUREMENT AND VERIFICATION PLAN

FOR

DG/CHP SYSTEM
AT
ST JOSEPH'S HOSPITAL

December 29, 2014

Submitted to:

New York State Energy Research and Development Authority
17 Columbia Circle
Albany, NY 12203-6399

Submitted by:

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1. Introduction

A 4.6 MW CHP consisting of a Solar Mercury 50 natural gas fired combustion turbine and a Rentech heat recovery steam generator (HRSG) producing up to 45,000 lb/h of 75-psig steam are being installed at the St. Joseph's Hospital in Syracuse, NY. Clough Harbor and Associates and Cogen Power Technologies (CHA/CPT) are providing a design-build installation of the system.

St. Joseph's Hospital is installing a Mercury 50-6000R natural gas fired turbine CHP system that will produce 4.5 MW net of electrical power. The turbine is outfited with a heat recovery steam generator (HRSG) that can produce 13,000 lb/h of steam at 75-psig using only the turbine exhaust, or up to 45,000 lb/h of 75-psig steam when the HRSG duct burner is firing. The turbine and HRSG duct burner are fueled by natural gas at a rate of 45.4 MMBtu/h LHV (44,115 CFH) for the turbine alone, and 82.7 MMBtu/h (80,291 CFH) with the turbine and duct burner operating. Based on the supplied energy balance, the system has a rated CHP efficiency of 63.6% LHV without the duct burner firing, and 76.5% LHV with the duct burner firing.

Based on the DEA submittal, the system is anticipated to displace 3,957 kW of peak demand, and provide 33,465,530 kWh/year of electricity. This performance equals 7,436 EFLH of turbine operation. The projected performance incentive for the project reaches the program cap of $2,000,000, with $1,200,000 tied to annual performance as determined by monitoring and verification (M&V). The project has a 2,800 kW contract demand reduction (kWspc).

2. Instrumentation

In order to quantify the performance of the proposed CHP system, the CHP system fuel input, net electrical output, and useful thermal output must be measured. To capture these energy flows, an instrumentation plan was developed by CDH Energy and reviewed with the developer Cogen Power and system integrator Rovisys. The instrumentation plan covers the location and type of sensors necessary to provide the appropriate measurements of the energy flows of the system.

Data Logger

No dedicated data logger is used for the St Joseph's Hospital CHP system. The Rovisys data integration platform, will collect information from the remote PLCs located at each major component, assemble the data into a report conforming with the NYSERDA requirements, and deliver the report daily to the CDH energy servers. The Rovisys system interfaces with PLCs at the turbine skid, heat recovery steam generator (HRSG), deaerator/feedwater system, balance of plant (BOP) PLCs including electrical switchgear monitoring, and gas compressor skid, using the appropriate protocol for each PLC (e.g. Modbus, BACnet, HART, etc).

In accordance to the instrumentation plan, Cogen Power will supply the instrumentation listed below for use in meeting the NYSERDA CHP program monitoring requirements. The table provides a description of the data points monitored, sensors, and their host PLC.

Table 1. Instrumentation Supplied By Cogen Power

Data Point	Description	PID Label	Drawing Number	Sensor	Notes
WG_kW	Gas Turbine Gross Electrical Output	DMMF-G1	E1-101	Schweitzer Engineering Laboratories SEL-734 Power Meter	13 kV meter located in protection relay, true power output
WG_kWh				Schweitzer Engineering Laboratories SEL-734 Power Meter	13 kV meter located in protection relay, Accumulated Energy Production
WPAR1_kW	Parasitic Load MCC-1 GTG/HRSG	DMMF-MCC1	E1-103	Squared D PMQ 800	480 V meter, 3-phase demand
WPAR1_kWh					480 V meter, Accumulated energy
WPAR2_kW	Parasitic Load MCC-3 Gas Compressor	DMMF-MCC3	E1-103	Squared D PMQ 800	480 V meter, 3-phase demand
WPAR2_kWh					480 V meter, Accumulated energy
FS_gross	CHP Gross Steam Flow	FE-1	M-112	Veris V150-8-10-H-R-XX-XX	Gross steam flow from HRSG
FS_DA	CHP DA Steam Flow	FE-116	M-112	ABB Orifice Plate FPD500.V1.60.S.B1.A1.H.3.H.0.H.1.H1.AY.CW.C2.EN.M5	Steam flow directed to deaerator
TS	CHP Steam Temeprature	TE-1	M-112	3-wire RTD 100 Ohm JMS Southeast 3EDBNK9BSPZZYZM3	
PS	CHP Steam Pressure	PIT-2	M-112	From HRSG skid	Steam drum pressure
TC	Condensate Temperature	TE-118	M-114	ABB J-type thermocouple sensor	
FC	Condensate Flow	FE-117	M-114	Rosemount Orifice Plate	
FG	Turbine Gas Consumption	FM-586	M-116	Micromotion Coriolis Meter F200S419CCAAEZZZZ	Temperature and pressure compensated mass flow meter
FGB	Duct Burner Gas Consumption	FE-20	M-117	Veris V150-2-05-H-R-XX-XX	Temperature compensated differential pressure meter

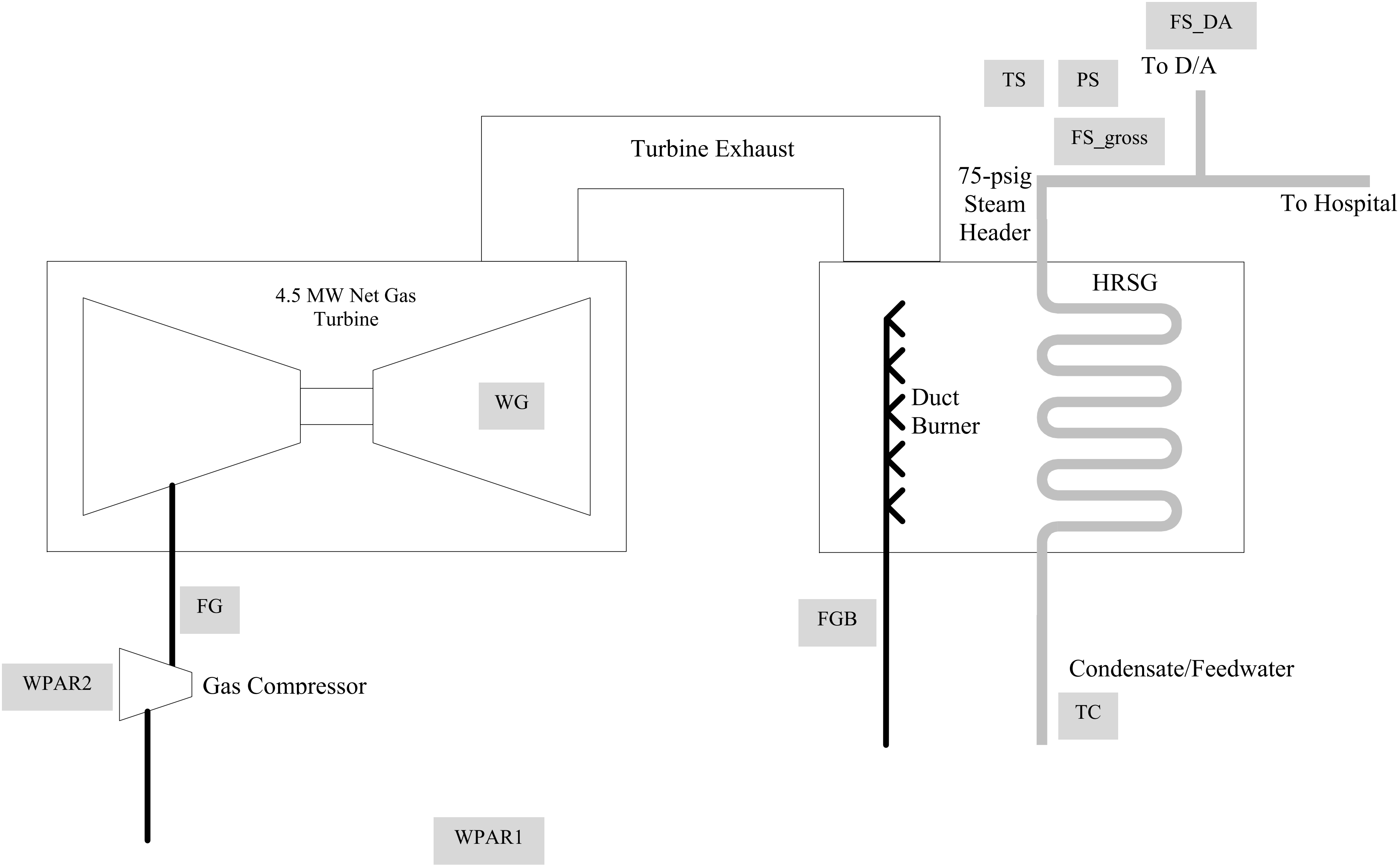


Figure 1. St Josephs Hospital CHP System Schematic

Onsite Installation

No onsite installation work is performed by CDH Energy.

Communications

All communications from the Rovisys system to the internet are supplied via St Joseph's internal network. The Rovisys system will upload the data report once per day to the CDH Energy server via sFTP using the following credentials:

- Protocol: sFTP (port 22)
- Server: data.cdhenergy.com
- Username: stjoes
- Password: stjoes_nyserda

On Site Support

The site will be responsible for providing access to all areas necessary for verification of sensors.

3. Data Analysis

The collected data will be used to determine the net power output of the system as well as the fuel conversion efficiency (FCE).

Peak Demand or Peak kW

The peak electric output or demand for each power reading will be taken as the average kW in a fixed 15-minute interval (0:00, 0:15, 0:30, etc), or

$$\text{kW} = \sum_{15\text{min}} \frac{\text{kWh}}{\Delta t} = \sum_{15\text{min}} = \frac{\text{kWh per interval}}{0.25\ \text{h}}$$

and the net power output from the CHP system is defined as:

$$\mathbf{WG_{net} = WG - (WPAR1 + WPAR2)}$$

Where: **WG_{net}** - Net output from gas turbine (kWh or kW)
WG - Gas turbine gross output (kWh or kW)
WPAR1 - Parasitic load MCC-1 GTG1/HRSG-1 (kWh or kW)
WPAR2 - Parasitic load MCC-4 Gas Compressor (kWh or kW)

Heat Recovery Rates

Heat recovery from the CHP system is achieved in the form of steam production from the HRSG. Steam conditions (temperature and pressure) are monitored leaving the HRSG to set the enthalpy of steam delivered, and determine the amount of superheat delivered. Useful heat recovery in the form of 75-PSIG steam is calculated by:

$$\mathbf{QU = (h_g(TS) - h_f(TC)) \times FS / 1000.}$$

Where: QU - Useful heat recovery (MBtu or MBtu/h)
$h_g(TS)$ - Enthalpy of HRSG steam at 75-psig (stipulated) and steam temperature TS (Btu/lb)
TS - HRSG steam temperature (deg F)
$h_f(TC)$ - Enthalpy of HRSG condensate (before deaerator) at 75-psig and temperature TC (Btu/lb)
TC - Condensate temperature (deg F)
FS - Net Steam Flow (lb/h) (FS_gross – FS_DA)

Fuel Input

Fuel input to the CHP system is measured by two gas meters. The first meter is a corilois meter that measures the high pressure gas leaving the gas compressor and entering the turbine. The second meter is a temperature compensated differential pressure meter that measures the low pressure gas to the HRSG duct burner.

Total gas input to the CHP system is:

$$\mathbf{FG_{tot} = FG + FGB}$$

Where: FG_{tot} - Total natural gas input (CF or CF/h)
FG - Gas turbine natural gas input (CF or CF/h)
FGB - Duct burner natural gas input (CF or CF/h)

Calculated Quantities

The fuel conversion efficiency of the CHP system, based on the lower heating value of the fuel, will be defined as:

$$FCE = \frac{QU + 3{,}413 \cdot (WG)}{0.9 \cdot HHV_{gas} \cdot FG_{tot}}$$

Where:
QU = Useful heat recovery (Btu) (QUD+QUB)
WG = Engine generator net output (kWh)
FG_{tot} = Generator gas consumption (Std CF)
HHV_{gas}= Higher heating value for natural gas (~1030 Btu per CF).
Where 0.9 is the conversion factor between HHV and LHV

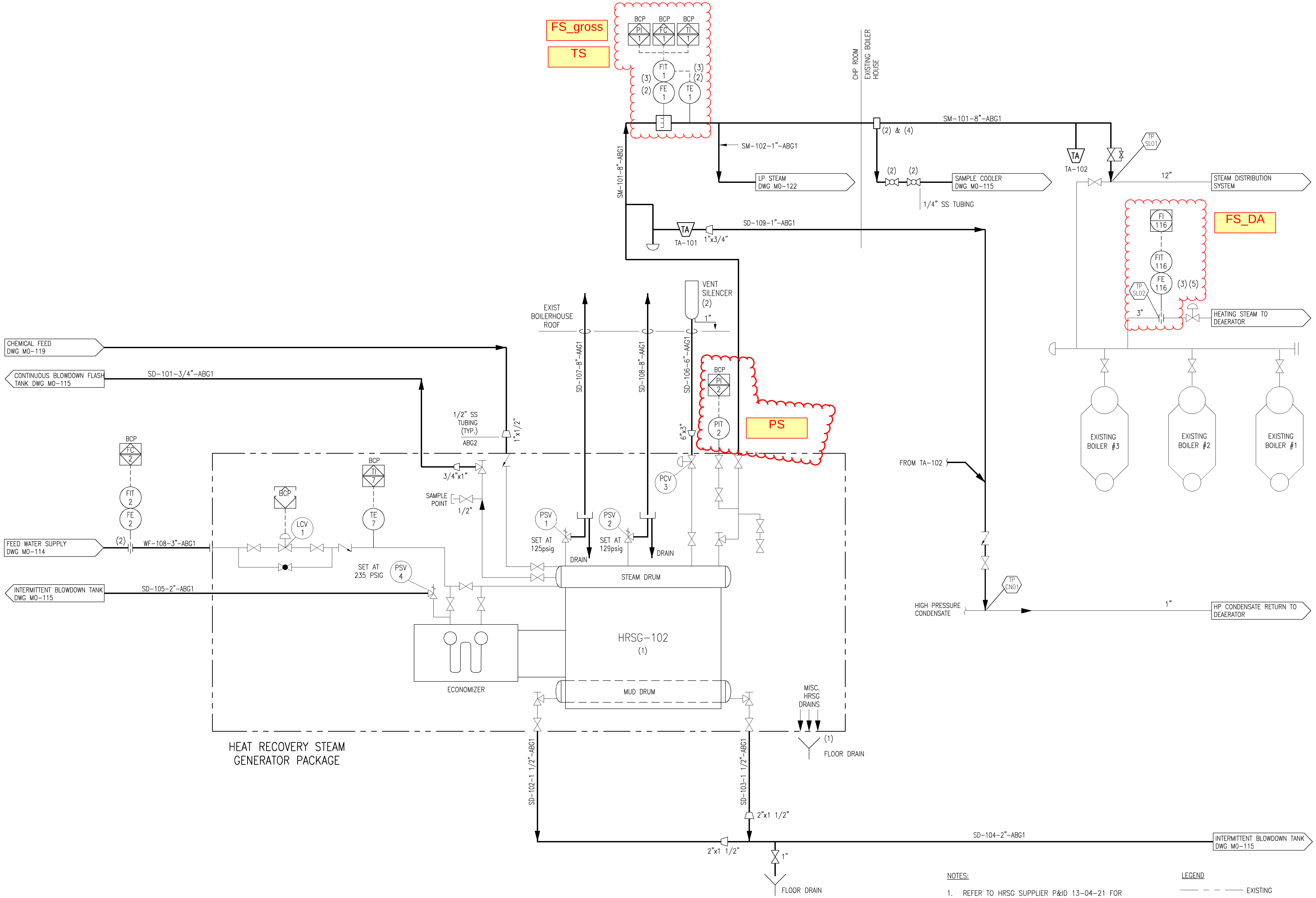
The FCE can be calculated for any time interval. When converting to daily, monthly, or annual values, the each value is summed and then the formula is applied:

$$FCE = \frac{\sum^{N} QU + 3{,}413 \cdot \sum^{N} (WG)}{0.9 \cdot HHV_{gas} \cdot \sum^{N} FG}$$

Where N is equal to the number of intervals in the period of interest.

Appendix A

System Schematic and Cut Sheets for Key Sensors and Instruments



NOTES:

1. REFER TO HRSG SUPPLIER P&ID 13-04-21 FOR HRSG PIPING, INSTRUMENTS, VENTS & DRAINS.
2. SUPPLIED LOOSE BY HRSG SUPPLIER
3. NYSERDA METERING POINT
4. STEAM SAMPLE NOZZLE BY HRSG SUPPLIER.
5. CONTRACTOR TO VERIFY PIPE SIZE WHERE FLOWMETER FE-116 TO BE INSTALLED.

00

LEGEND

— — —	EXISTING
TP XXX	TIE-POINT

File: \\SCON57FS1\GRYDATA\24391\DWG\PID\M0-112.DWG
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00	ISSUED FOR CONSTRUCTION	AL	CRG	10/11/13

COGEN POWER TECHNOLOGIES
BETTE CRING CONSTRUCTION GROUP

JOSEPH JOHN THOMSON 070662
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THE CHA POWER TEAM

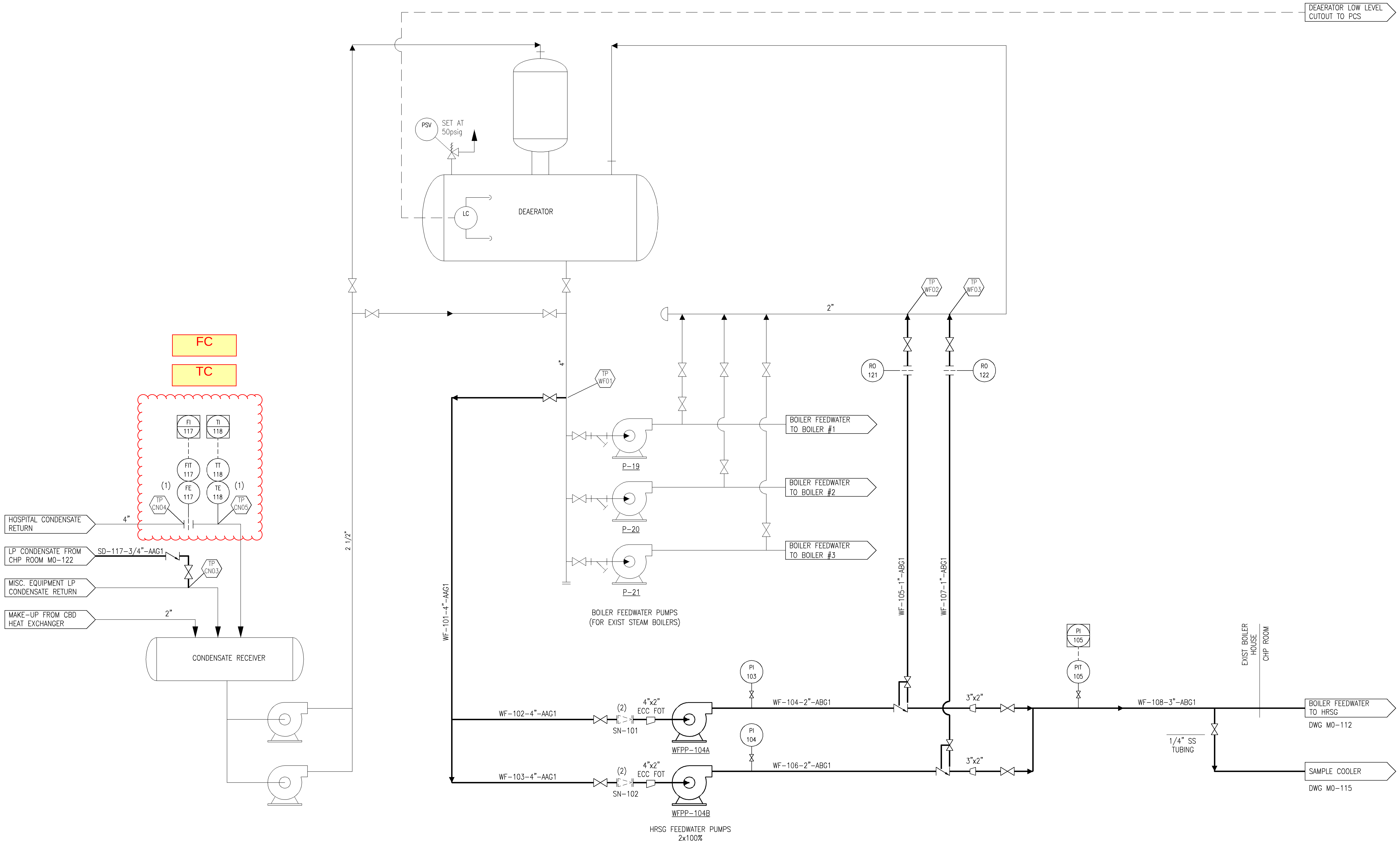
Designed:
Drawn: CRG
Checked: AL

ST. JOSEPH'S HOSPITAL
SYRACUSE, NEW YORK
COMBINED HEAT AND POWER PROJECT

P&ID
HRSG AND STEAM SYSTEM

Issue Date: 12/14/12
Project No.: 24391
Scale: NONE

M0-112



LEGEND

EXISTING

TP XXX TIE-POINT

NOTES:

1. NYSERDA METERING PLANT
2. SN-101 & SN-102 ARE TEMPORARY FILTERS. REMOVE FILTERS AFTER COMMISSIONING OF THE FEEDWATER SYSTEM TO HRSG.

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SYRACUSE, NEW YORK
COMBINED HEAT AND POWER PROJECT

P&ID
FEEDWATER SYSTEM

Issue Date: 12/14/12
Project No.: 24391
Scale: NONE

M0-114

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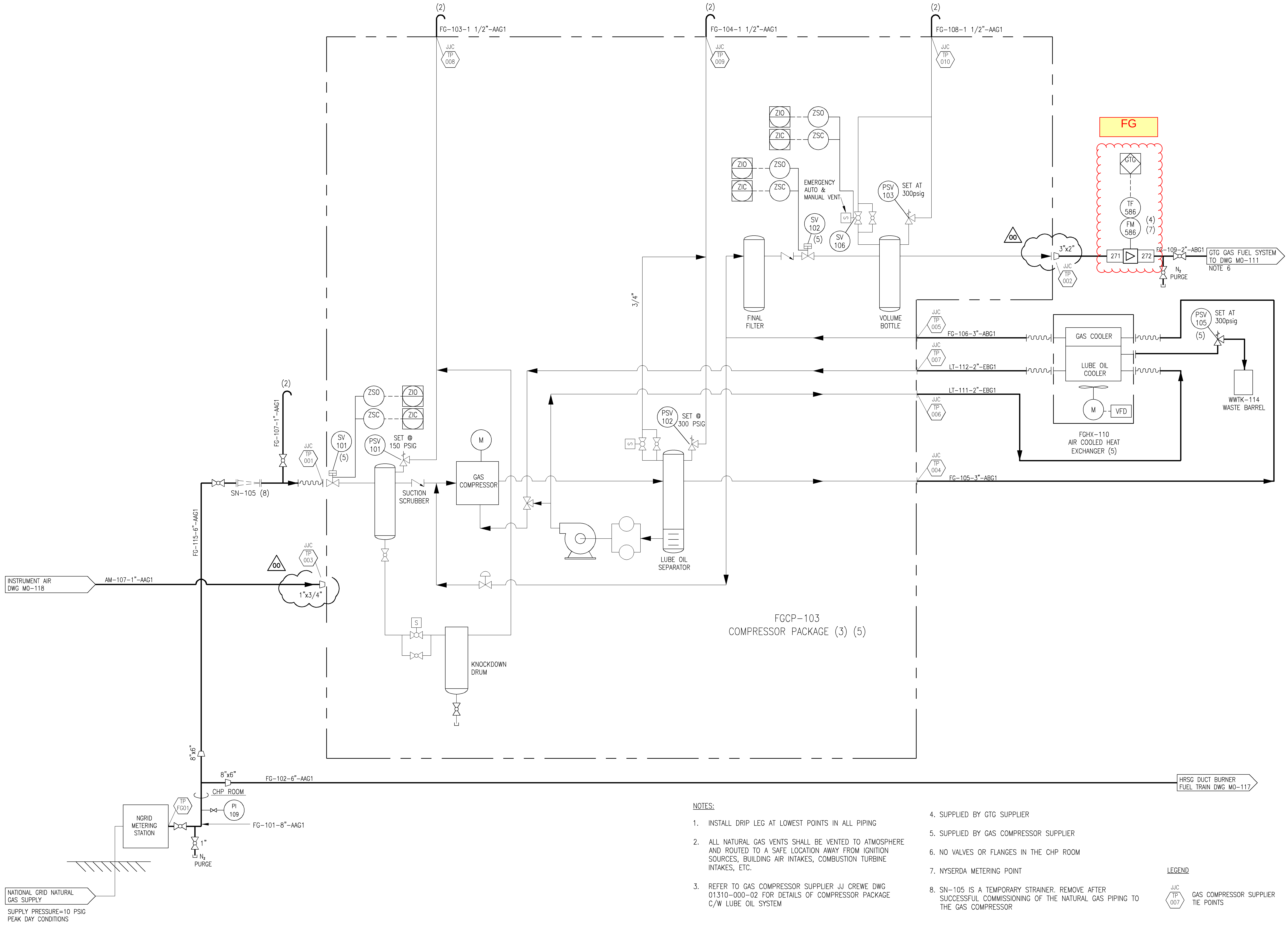

NOTES:

1. INSTALL DRIP LEG AT LOWEST POINTS IN ALL PIPING
2. ALL NATURAL GAS VENTS SHALL BE VENTED TO ATMOSPHERE AND ROUTED TO A SAFE LOCATION AWAY FROM IGNITION SOURCES, BUILDING AIR INTAKES, COMBUSTION TURBINE INTAKES, ETC.
3. REFER TO GAS COMPRESSOR SUPPLIER JJ CREWE DWG 01310–000–02 FOR DETAILS OF COMPRESSOR PACKAGE C/W LUBE OIL SYSTEM
4. SUPPLIED BY GTG SUPPLIER
5. SUPPLIED BY GAS COMPRESSOR SUPPLIER
6. NO VALVES OR FLANGES IN THE CHP ROOM
7. NYSERDA METERING POINT
8. SN–105 IS A TEMPORARY STRAINER. REMOVE AFTER SUCCESSFUL COMMISSIONING OF THE NATURAL GAS PIPING TO THE GAS COMPRESSOR

LEGEND

JJC TP 007 GAS COMPRESSOR SUPPLIER TIE POINTS

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ST. JOSEPH'S HOSPITAL
SYRACUSE, NEW YORK
COMBINED HEAT AND POWER PROJECT

P&ID
NATURAL GAS SYSTEM

Issue Date: 12/14/12 | Project No.: 24391 | Scale: NONE

M0-116

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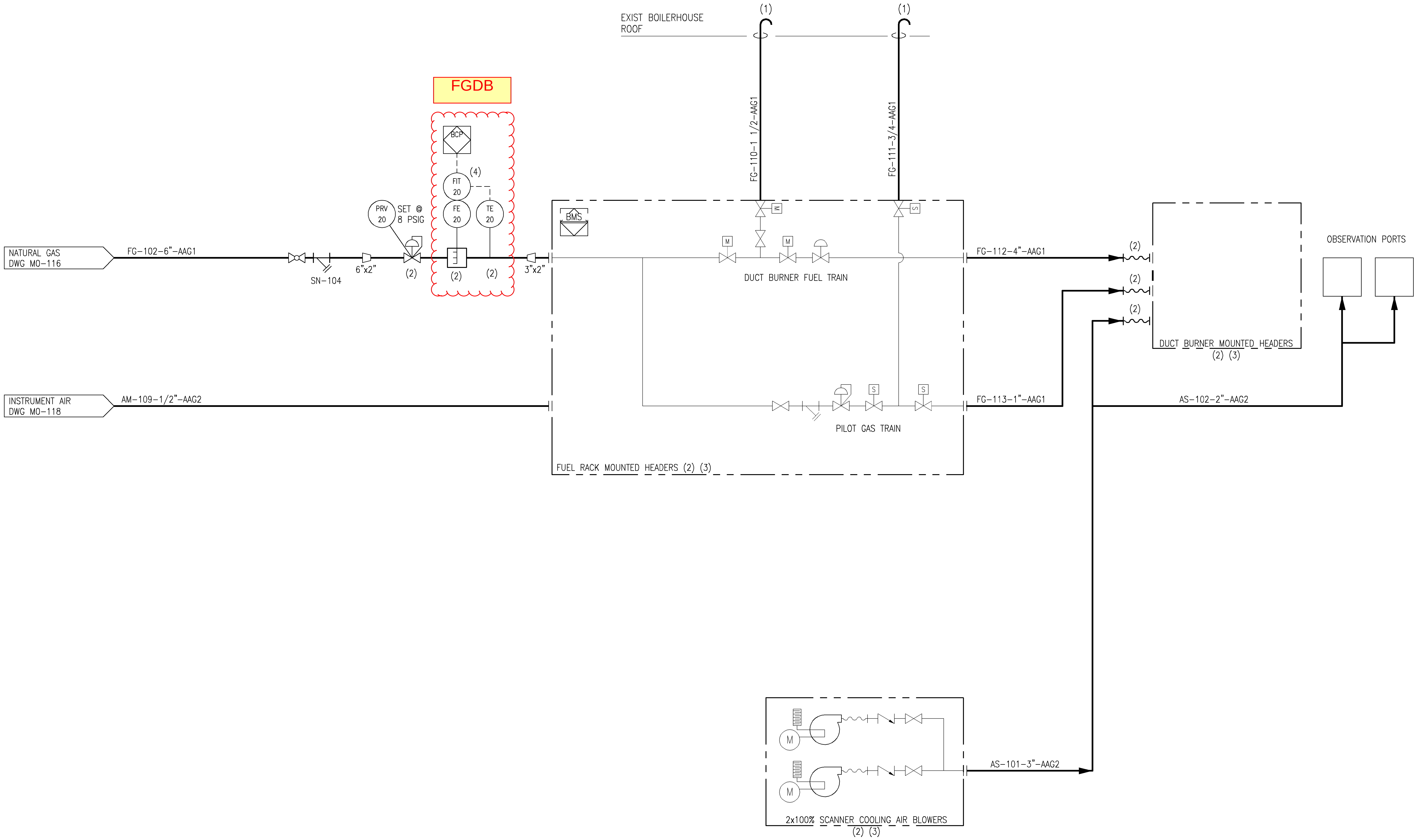

NOTES:

1. ALL NATURAL GAS VENTS SHALL BE VENTED TO ATMOSPHERE AND ROUTED TO A SAFE LOCATION AWAY FROM IGNITION SOURCES, BUILDING AIR INTAKES, COMBUSTION TURBINE INTAKES, ETC.
2. SUPPLIED BY HRSG SUPPLIER
3. REFER TO DUCT BURNER SUPPLIER DWG # DB-9135624-150 FOR DETAILS OF DUCT BURNER PACKAGE.
4. NYSERDA METERING POINT

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ST. JOSEPH'S HOSPITAL
SYRACUSE, NEW YORK
COMBINED HEAT AND POWER PROJECT

P&ID
NATURAL GAS SYSTEM-DUCT BURNER

Issue Date: 12/14/12
Project No.: 24391
Scale: NONE

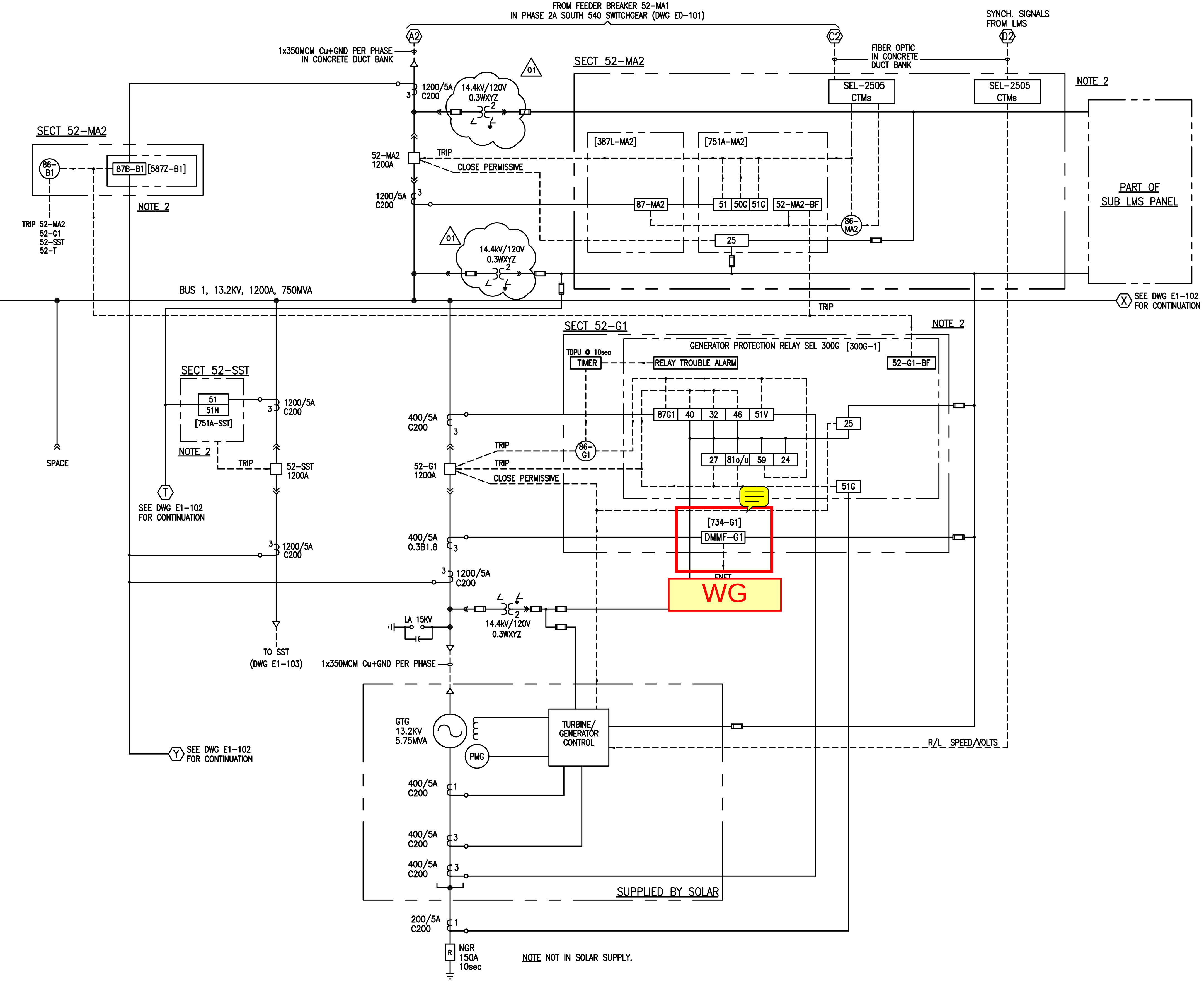
M0-117

LEGENT

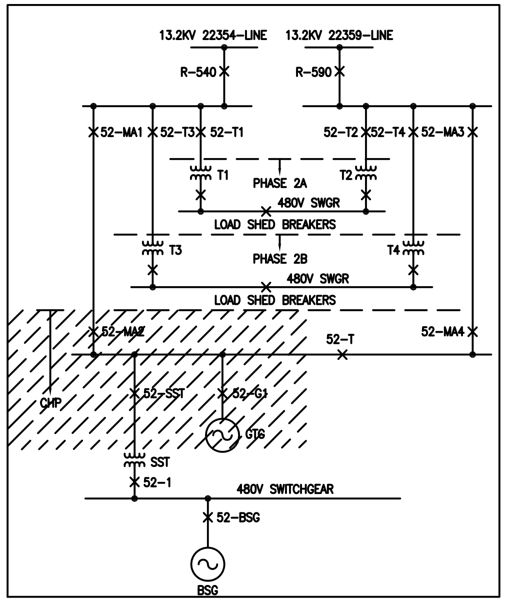
CTM	CONTACT TRANSER MODULE
DMMF	DIGITAL MULTIFUNCTION METER
NGR	NEUTRAL GROUND RESISTER
SST	STATION SERVICE TRANSFORMER
PMG	PERMANENT MAGNET GENERATOR
T/CI	TRIP & CLOSE INHIBIT CONTACTS
24	VOLTS/FREQUENCY
25	SYNC CHECK
27	UNDERVOLTAGE
32	DIRECTIONAL POWER
46	REVERSE PHASE CURRENT
50	INSTANTANEOUS OVERCURRENT
51	TIME DELAY OVERCURRENT
51G	GROUND TIME DELAY OVERCURRENT
51V	TIME OVERCURRENT VOLTAGE RESTRAINED
59	OVERVOLTAGE
81	FREQUENCY
86	LOCKOUT RELAY
87	DIFFERENTIAL PROTECTION

NOTES

1. RELAY TYPE AND MANUFACTURE ARE SHOWN AS TYPICAL.
2. RELAY PROTECTION & METERING PART OF 13.2KV SWITCHGEAR LINE UP.
3. 13.2KV SWITCHGEAR SUPPLIED BY CPT.



KEY SINGLE LINE DIAGRAM



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01	ISSUED FOR CONSTRUCTION	SK	HL	04/22/14

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ST. JOSEPH'S HOSPITAL
SYRACUSE, NEW YORK
COMBINED HEAT AND POWER PROJECT

COGEN - ELECTRICAL SINGLE LINE DIAGRAM
13.2KV BUS 1 PROTECTION & METERING

Issue Date: 11/05/12
Project No.: 24391
Scale: NONE

E1-101

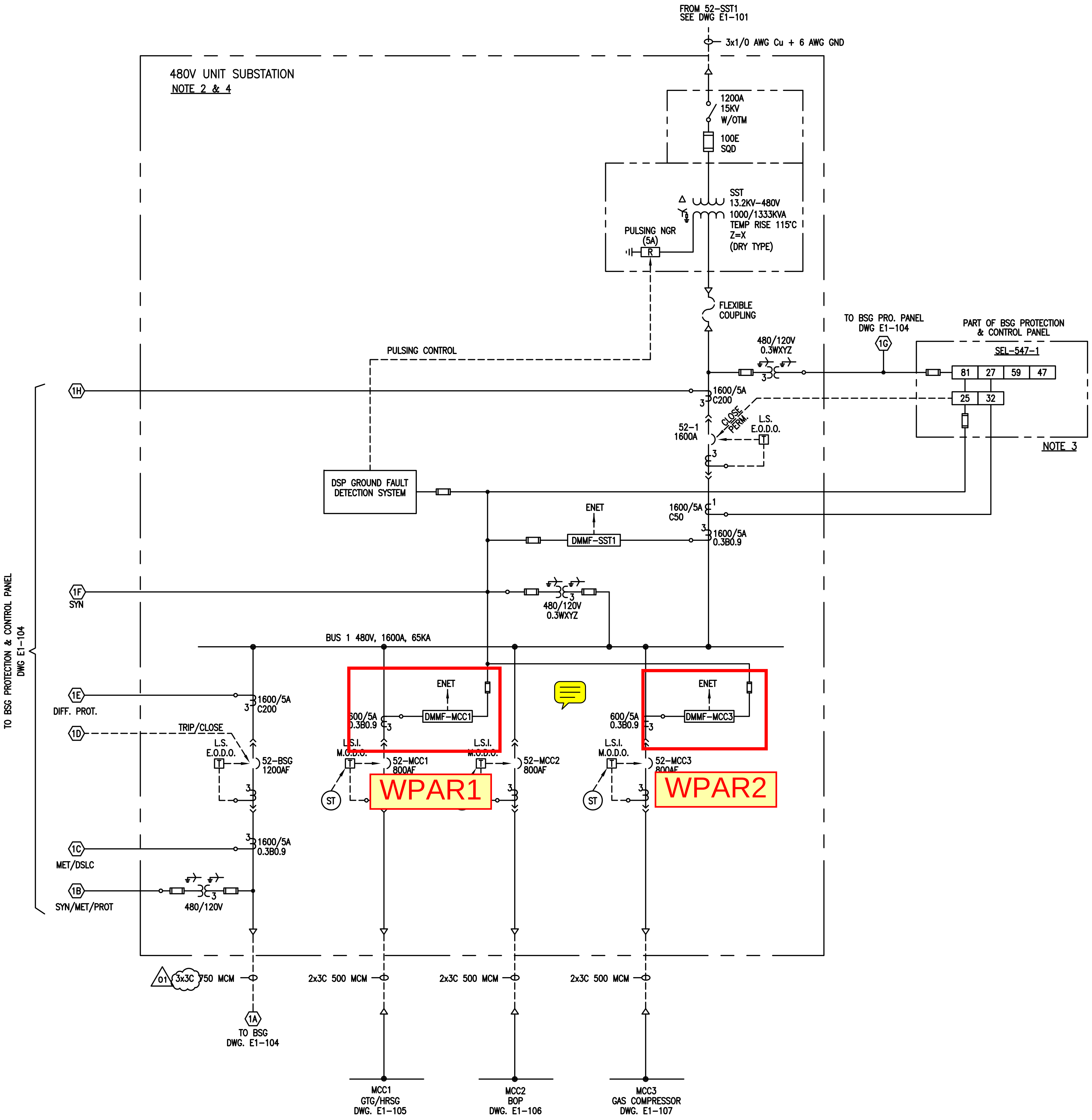
LEGEND

E.O.D.O.	ELECTRICALLY OPERATED, DRAWOUT
L.S.I.	SOLID STATE TRIPPING LONG TIME, SHORT TIME, INSTANTANEOUS
M.O.D.O.	MANUALLY OPERATED, DRAWOUT
DMMF	DIGITAL MULTIFUNCTION METER
DSP	DISPLAY
HRSG	HEAT RECOVERY STEAM GENERATOR
BSG	BLACK START GENERATOR
GTG	GAS TURBINE GENERATOR
BOP	BALANCE OF PLANT
SST	STATION SERVICE TRANSFORMER
NGR	NEUTRAL GROUNDING RESISTOR
[547–1]	DENOTES SCHWEITZER (SEL) RELAY MODEL AND CIRCUIT DESIGNATION – 547 DISTRIBUTED GENERATOR INTERCONNECTION RELAY
OTM	OVER TOGGLE MECHANISM

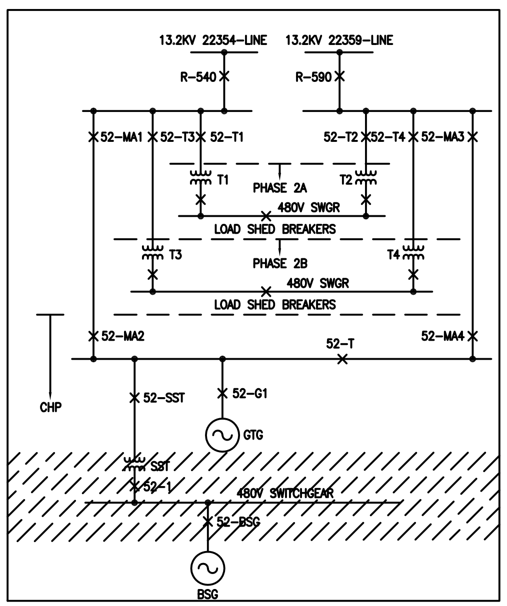
01

NOTES

1. RELAY TYPE AND MANUFACTURE ARE SHOWN AS TYPICAL.
2. RELAY PROTECTION & METERING PART OF 480V UNIT SUBSTATION EQUIPMENT SUPPLIED BY CPT.
3. RELAY PROTECTION PART OF BLACK START DIESEL GENERATOR EQUIPMENT SUPPLIED BY CPT.
4. 480V UNIT SUBSTATION SUPPLIED BY CPT.



KEY SINGLE LINE DIAGRAM



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01	ISSUED FOR CONSTRUCTION	SK	HL	2/27/14

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ST. JOSEPH'S HOSPITAL
SYRACUSE, NEW YORK
COMBINED HEAT AND POWER PROJECT

COGEN - ELECTRICAL SINGLE LINE DIAGRAM
480V SST & BUS 1 SWITCHGEAR

Issue Date: 11/05/12
Project No.: 24391
Scale: NONE

E1-103

SEL-734 Advanced Metering System

Advanced Power Quality and Revenue Metering

Accurate, comprehensive, and reliable metering for new installations and retrofits.

Extended Memory

- *32 MB on SEL-734*
- *128 MB on SEL-734P*

Features and Benefits

Power Quality Monitoring

Record voltage sag, swell, and interruption (VSSI); monitor harmonics to the 50th order; capture waveforms; measure flicker; and record sequential events.

Accurate, Bidirectional Metering

Exceeds ANSI C12.20 0.2 and IEC 62053-22 0,2 S accuracy class bidirectional, with full four-quadrant energy metering for generation, interchange, transmission, distribution, or industrial applications.

Standard Software Tools

Easily configure, test, monitor, and retrieve data using ACSELERATOR QuickSet® SEL-5030 Software. ACSELERATOR QuickSet quickly programs, retrieves, plots, and exports billing data to .HHF or .CSV formats.

Time-of-Use (TOU) Metering

Provides flexible, time-differentiated energy and demand registers, with multiple day types, rates, seasons, and a 20-year programmable calendar. Automation functions include programmable self-reads and peak demand resets.

High-Speed Load Profile (LDP) Data Recorders

Multiple LDP recorders store billing and power quality data in separate records with a maximum update rate of once every three seconds. ACSELERATOR QuickSet quickly retrieves, plots, and stores LDP data to a laptop computer or remotely over any communications port.

Transformer and Line-Loss Compensation

Enter transformer nameplate and line impedance information directly into the meter to automatically compensate for transformer or line losses and move the billing point.

Instrument Transformer Compensation

Increase the metering accuracy of your installation with instrument transformer compensation (ITC). Six calibration points allow you to correct ratio and phase errors over the entire measurement range. Decrease replacement and maintenance costs by compensating for each sensor individually.

Industry-Standard Compliance

Fully comply with ANSI and IEC standards with voltage and current ranges of: 57–132 V, 132–277 V; CL2, CL20, IEC 1A, and 5 A I_{NOM}.

Making Electric Power Safer, More Reliable, and More Economical®

SEL-734 Advanced Metering System

Power Quality and Recording Options

The SEL-734 is available with two different power quality and recording feature set levels: standard and advanced. With the advanced power quality and recording option, the SEL-734P can replace a high-end power quality instrument costing thousands of dollars more. This allows economical power quality monitoring at more locations.

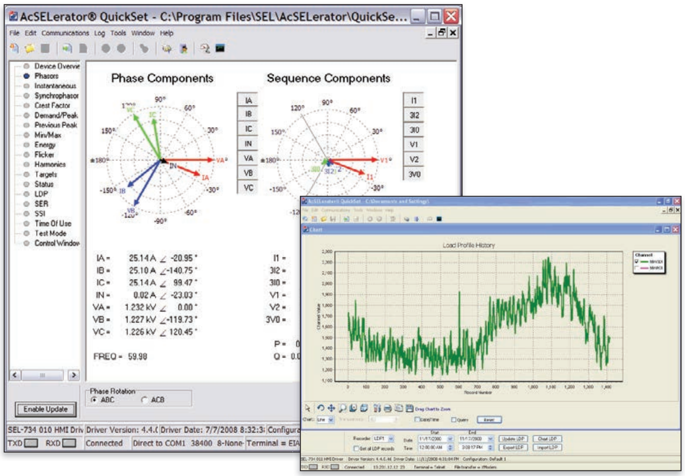
Advanced PQ Option
SEL-734P benefits as compared to the SEL-734

Memory	4X
Load Profile Capacity	4X
Harmonic Measurements	3X
Waveform Captures	**48X**
Flicker Measurement	**Yes**
Harmonic Phase Angles	**Yes**
Variable Event Report Length	**Yes**
Event Report Dial-Out	**Yes**
Outstanding Value!	**Only $500***

* Price adder over SEL-734 price

Simplified Setup and Troubleshooting

- Use ACSELERATOR QuickSet to customize your metering. Set and edit meter configuration, settings, and logic.
- View the HMI screens in ACSELERATOR QuickSet to check wiring connections, phase rotation, and power flow direction.



IA = 25.14 A ∠ -20.95°
IB = 25.10 A ∠-140.75°
IC = 25.14 A ∠ 99.47°
IN = 0.02 A ∠ -23.03°
VA = 1.232 kV ∠ 0.00°
VB = 1.227 kV ∠-119.73°
VC = 1.226 kV ∠ 120.45°
FREQ = 59.98

SEL-734 010 HMI Driv | Driver Version: 4.4.(| Driver Date: 7/7/2008 8:32:3 | Configura
TXD RXD | Connected | Direct to COM1 38400 8-None- | Terminal = EIA

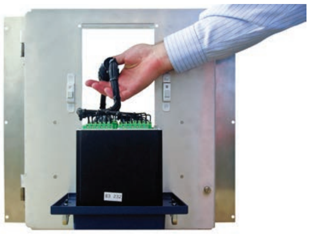
Feature Overview

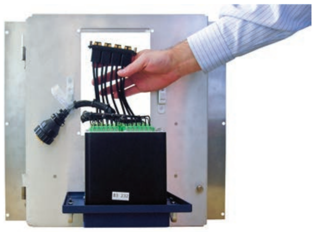
- Form 5 and Form 9 metering connections
- ANSI C12.20 0.2 and IEC 62053-22 0,2 S accuracy class
- Rack-mount, panel-mount, wall-mount, and NEMA enclosure options available
- Ethernet, EIA-485, EIA-232, telephone modem, and optical probe communications
- Fast message synchrophasors
- Enhanced SELOGIC® control equations
- Communications protocols
  - SEL ASCII
  - Modbus® RTU/TCP
  - MV-90®
  - SEL Fast Operate/Fast Meter
  - MIRRORED BITS® communications
  - SEL Distributed Port Switch (LMD)
  - DNP3 Serial LAN/WAN
- Inputs/outputs
  - 2 digital inputs, 3 electromechanical outputs
  - 4 digital inputs, 4 KY outputs
  - 4 digital inputs, 4 electromechanical outputs
  - 4 analog outputs, 4 KY outputs

See model option table for available configurations and options.

Easily Extractable Meter (EXM)

Remove the SEL-734 from service in just seconds with the EXM option. This innovative mounting and wiring solution allows rapid removal while safely shorting connected CTs. Safe, economical, and flexible, this option easily retrofits legacy draw-out meters with a vertical retrofit bezel.





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How Do You Reduce Energy Costs And Prolong The Life Of Your Equipment?

PowerLogic® PM800 series power meters

Buildings

Industry

Data Center

SQUARE D

by Schneider Electric

Features and options	PM820	PM850	PM870
Installation			
Fast installation, panel or DIN mount, integrated or remote display	■	■	■
Display (integrated or remote display options)			
Backlit LCD, multilingual, bar graphs	■	■	■
Power and energy metering			
3-phase voltage, current, power, demand, energy, frequency, power factor	■	■	■
Power quality analysis			
THD	■	■	■
Harmonics: individual, up to	31	63	63
Waveform recording		standard	enhanced
EN50160 compliance evaluation[3]		■	■
Disturbance (dip/swell) monitoring			■
Data and event logging			
Memory capacity	80 kB	800 kB	800 kB
Min/max log	■	■	■
Maintenence, alarm and event logs	■	■	■
Billing (energy, demand) log	■	■	■
Energy per interval	■	■	■
Customizable data logs	1	4	4
Trending and forecasting		■	■
GPS Synchronization	■	■	■
Timestamp resolution in seconds	1	1	1
Digital and analog inputs/outputs			
Digital inputs (standard / optional)[1]	1/8	1/8	1/8
Digital outputs (standard / optional)[2]	1/4	1/4	1/4
Analog inputs (standard / optional)	0/4	0/4	0/4
Analog outputs (standard / optional)	0/4	0/4	0/4
Alarms and control			
Setpoint response time, seconds	1	1	1
Single & multi-condition alarms	■	■	■
Boolean alarm logic		■	■
Communications			
Serial ports with Modbus protocol	Standard meter offers one RS-485 port. Optional PM8RDA remote display module offers one RS-485/RS-232 port. Optional PM8ECC Ethernet module offers one RS-485 port.		
Ethernet port with Modbus TCP protocol Embedded web server Ethernet to RS-485 gateway. SNMP object and trap support for host meter utilizing the PM8ECC MIB	Optional PM8ECC module		

1 On-board and optional digital inputs can be used for on/off status monitoring or for pulse counting.
2 On-board digital output is KY type, optional digital outputs are relay type.
3 The PM850 does not include sag or swell detection.

Ordering Information	Part Number		
PM with integrated display	PM820	PM850	PM870
PM with remote display	PM820RD	PM850RD	PM870RD
PM unit only, no display	PM820U	PM850U	PM870U
PM8ECC Ethernet communication card	PM8ECC		
Remote display adapter alone†	PM8RDA		
Remote display kit includes remote display, adapter and 10' cable (3.04m)†	PM8RD		
RJ-11 thru door 12' cable extender for PM800	RJ11EXT		
PM800 Mounting Adapter for CM2000	PM8MA		
PM800 gasket for analog 4' round cutout	PM8G		
2 digital outputs (relays), 6 digital inputs	PM8M26		
2 digital outputs (relays), 2 digital inputs, 2 analog outputs, 2 analog inputs	PM8M2222		
Cable for remote display adapter 1.25 m (4 ft)	CAB4		
Cable for remote display adapter 3.65 m (12 ft)	CAB12		
Cable for remote display adapter 9.14 m (30 ft)	CAB30		

† RS-485/232 port is disabled when a PM8ECC module is installed.

c UL us LISTED CE

Visit www.powerlogic.com for more information on other PowerLogic products, applications and system solutions.

As standards, specifications and designs develop over time, always ask for confirmation of the information given in this publication. PowerLogic, ION, ION Enterprise, System Manager, Square D, MeterM@il, and Modbus are either trademarks or registered trademarks of Schneider Electric.

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10-10

Data Sheet
D-TS-V1018_5

Temperature Measurement Products

Spring Loaded Sensor Assembly - V10186
Welded Sensor Assembly - V10187
Sensor Assembly Without Thermowell - V10188
Sensor Only - V10189

- **Design**
  - Can be built from standardized components
  - Standard lengths for fewer spare parts on stock
  - Immersion lengths can be selected individually
  - Sensor can be replaced during operation
  - No welding seams coming into contact with media
- **Technical Features**
  - Approvals according to FM and ATEX for intrinsically safe installation of the transmitter
  - Thermowell materials and designs adapted to operating conditions
  - Installation of a transmitter in the connection head eliminates the need for multi-wire circuit
  - Interference-immune standard output signal 4 to 20 mA
- **Applications**
  - Chemical process engineering
  - Petroleum/natural gas supply and processing
  - Power generation and heat distribution
- **FM Approved Sensor Assemblies**
  - Sensors approved for Intrinsic Safe Class 1, Div 1
  - Sensors approved for Non-incendive Class 1, Div 2

Spring Loaded Sensor Assembly -V10186
Welded Sensor Assembly - V10187
Sensor Assembly w/o Thermowell - V10188
Sensor Only - V10189

ABB

Sensor Design

All of the sensors assemblies are FM certified for Instrinic Safe Class 1, Div 1; and Non-incendive Class 1, Div 2 applications, as well as, general purpose.

The thermocouple thermometers are used primarily for measuring temperatures in process systems which have corrosive media in the operating range up to 1832 °F (800 °C). RTD thermometers have an operating range up to 752 °F (400 °C).

They are composed of a thermowell made from bar stock material, with an extension and a connection head with a spring loaded or welded exchangeable sensor.

The design of the thermowell matches the mechanical requirements in both measurement and mechanical terms, thus enabling it to withstand high levels of stress caused by pressure (up to 10,000 psi), flow and vibration.

This sensor design is ideal for mating the sensors to virtually any enclosure and assembly. The sensor:

- can be removed while the system is running without dismantling the entire sensor,
- can be calibrated in a standard test facility,
- can be stocked as a universal standard component in order to assure availability of the system during replacement.

Spring Loaded Sensor Assembly
V10186

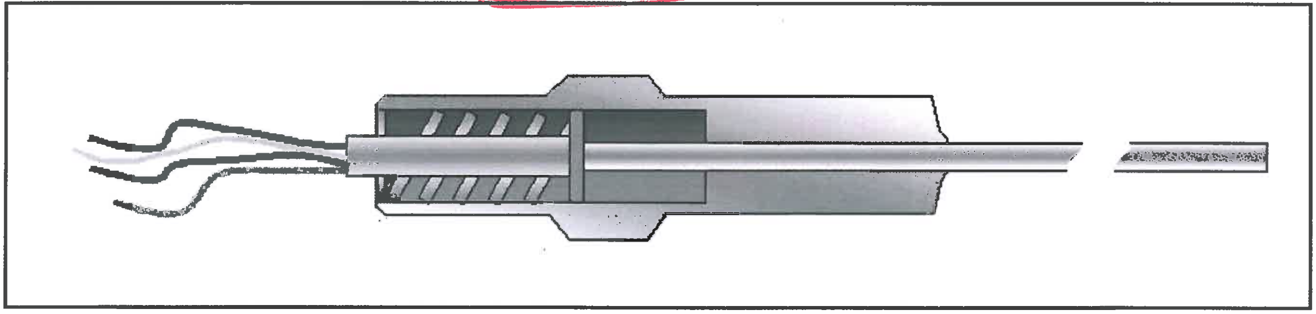


Figure 1

Welded Sensor Assembly
V10187

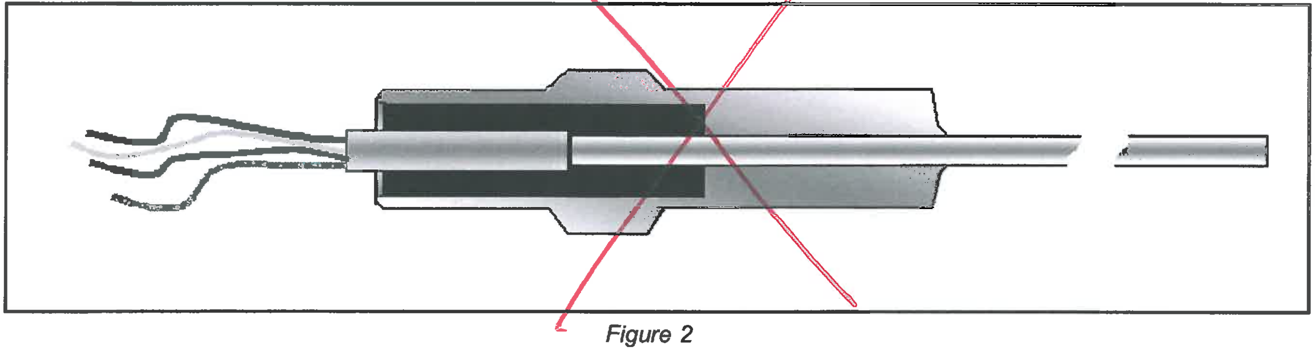


Figure 2

Response times

Apart from the thermowell mass at the measuring point, the factors governing the heat transfers, which are the chief determinants for the response time, are the heat capacity, pressure, density, moisture and flow velocity of the medium. The following table features approximate values, referring to water or air.

Greater flow velocities and heat capacities considerably reduce the time intervals. The values T0.5 and T0.9 give information on the time period after which 50 % or 90 % of a sudden temperature change is displayed.

TABLE 1

<table>
<tr><th rowspan="3">Sensor</th><th colspan="2">Thermowell</th><th colspan="2">In water
1.3 ft/s</th><th colspan="2">In air
10 ft/s</th></tr>
<tr><th rowspan="2">Type</th><th rowspan="2">U-length</th><th colspan="2"></th><th colspan="2"></th></tr>
<tr><th>T 0.5</th><th>T 0.9</th><th>T 0.5</th><th>T 0.9</th></tr>
<tr><td rowspan="2">Resistance Thermometer RTD</td><td>Tapered</td><td>2.5 inch</td><td>20 sec</td><td>63 sec</td><td>300 sec</td><td>900 sec</td></tr>
<tr><td>Tapered</td><td>5 inch</td><td>14 sec</td><td>44 sec</td><td>235 sec</td><td>706 sec</td></tr>
<tr><td rowspan="2">Thermocouple</td><td>Tapered</td><td>2.5 inch</td><td>16 sec</td><td>50 sec</td><td>235 sec</td><td>705 sec</td></tr>
<tr><td>Tapered</td><td>5 inch</td><td>10 sec</td><td>40 sec</td><td>150 sec</td><td>500 sec</td></tr>
</table>

Resistance Temperature Detectors (RTD)

Nominal resistance/Standard/Tolerance

Resistance elements with platinum measurement windings are used. In accordance with DIN EN 60 751 the nominal resistance is defined as follows:

- 100 ohms at 0 °C
- Temperature coefficient 3.85 x $10^{-3}(K^{-1})$ - Averaged between 0 °C and 100 °C.

For your quick reference some typical permissible values are shown in the table below for Class A and B.

For practical reasons we recommend a maximum long-term operating temperature of max. 400 °C for Class A tolerance.

Operational temperature

The temperature range is from -392 to +1110°F
(-200 to +600°C)

Sheath material

The standard material used for all resistance thermometer measuring insets is 316 Ti.

Number of lead wires/measuring circuits/sheath diameters

Sensors can be supplied with:

- 1 or 2 measurement RTD's and in 2, 3 and 4-wire circuits.

However, in some particular cases the combinations are restricted.

TABLE 2

<table>
<tr><th colspan="8">Resistance of platinum RTD according to IEC 60 751</th></tr>
<tr><th>Temperature</th><td>0°C/32°F</td><td>100°C/212°F</td><td>200°C/392°F</td><td>300°C/572°F</td><td>400°C/852°F</td><td>500°C/932°F</td><td>600°C/1112°F</td></tr>
<tr><th>Ω</th><td>100</td><td>138.51</td><td>175.86</td><td>212.05</td><td>247.09</td><td>280.98</td><td>313.71</td></tr>
<tr><th colspan="8">Allowed Deviation for platinum RTD according to IEC 60 751</th></tr>
<tr><th>Class B</th><td>0.3°C/2.1°F</td><td>0.8°C/2.6°F</td><td>1.3°C/3.1°F</td><td>1.8°C/3.6°F</td><td>2.3°C/4.1°F</td><td>2.8°C/4.6°F</td><td>3.3°C/5.1°F</td></tr>
<tr><th>Class A</th><td>0.15°C/1.95°F</td><td>0.35°C/2.15°F</td><td>0.55°C/2.35°F</td><td>0.75°C/2.55°F</td><td>0.95°C/2.75°F</td><td>1.15°C/2.95°F</td><td>N/A</td></tr>
</table>

Resistance vs. Temperature Tables

The condensed Resistance VS Temperature Tables on the following pages are provided to aid in the proper RTD element selection.

Notice that the tables for the various platinum curves are for the standard 100 ohm @ 0°C sensor.

To calculate the resistance of:

50 ohm multiply the values by .5
200 ohm multiply the values by 2
500 ohm multiply the values by 5
100 ohm multiply the values by 10

Table C100 for the 100 ohm @ 25°C Copper (90.35 ohms @ 0°C) is published. To calculate the resistance of the 10 ohm at 25°C (9.035 ohms @ 0°C) multiply the value shown by .1.

100Ω PLATINUM (.00385 Ω/Ω/°C) @ 0°C (DIN 43760)

TEMP. °C	-100	-0	TEMP. °C	0	100	200	300	400	500	600
-0	60.25	100.00	0	100	138.50	175.84	212.03	247.06	280.90	313.59
-10	56.19	96.09	10	103.90	142.29	179.51	215.58	250.50	284.22	316.80
-20	52.11	92.16	20	107.79	146.06	183.17	219.13	253.93	287.53	319.99
-30	48.00	88.22	30	111.67	149.82	185.82	222.65	257.32	290.83	323.18
-40	43.67	84.27	40	115.54	153.58	190.46	226.18	270.72	294.11	326.35
-50	39.71	80.31	50	119.40	157.32	194.08	229.69	264.11	297.39	329.51
-60	35.53	76.33	60	123.24	161.04	197.69	233.19	267.49	300.65	332.66
-70	31.32	72.33	70	127.07	164.76	201.30	236.67	270.86	303.91	335.79
-80	27.08	68.33	80	130.89	168.47	204.88	240.15	274.22	307.15	338.92
-90	22.80	64.30	90	134.70	172.16	288.46	243.61	277.56	310.38	342.03
-100	18.49	60.25	100	183.50	175.84	212.03	247.05	280.90	313.59	345.13

Table 3

Thermocouples

Standard/Tolerance

For thermocouples conforming to DIN EN 60 584 various different classes are defined for the permissible deviation from the e.m.f. reference table. The measured thermoelectric emf. corresponds to the temperature difference between hot junction and reference junction. The reference table conforming to DIN EN 60 584 relates to a reference temperature at 0 °C. Because of the fact that, as the temperature rises, the effects of oxidation can have significant adverse effects on the characteristics and service life of a measuring inset, the specified operating temperatures (dependent on thermocouple type, tolerance class and sheath diameter) should never be exceeded.

Accessories, components

Many of the components of the models listed in the catalog can be ordered as separate components or modules. In this respect, please consult your nearest representative.

TABLE 4

Thermoelectric Voltage (mV) acc. to IEC 60584 / ASTM 230						
Temperature	200°C	350°C	500°C	700°C	900°C	1100°C
Temperature	392°F	662°F	932°F	1292°F	1652°F	1832°F
Type J (mV)	10.78	19.09	27.39	39.13	51.88	63.79
Type K (mV)	8.14	14.29	20.64	29.13	37.33	45.12
Type N (mV)	5.91	11.14	16.75	24.53	32.37	40.09
Allowed Deviation for Type K thermocouple acc. to IEC 60584						
Class 2	2.5°C/4.3°F	2.6°C/4.4°F	3.8°C/5.6°F	5.3°C/7.1°F	6.8°C/8.6°F	8.3°C/10.1°F
Class 1	1.5°C/3.3°F	1.5°C/3.3°F	2.0°C/3.8°F	2.8°C/4.6°F	3.6°C/5.4°F	N/A

TABLE 5

Standard and special combinations				
Type of thermocouple		Standards	Tolerance	
Type	Special	Standard Type	Standard Type	Special Type
J (Fe-CuNi)	E (NiCr-CuNi)	IEC 60584	Class 2	Class 1
K (NiCr-Ni)	T (Cu-CuNi)	IEC 60584	Standard	Special
N (NiCrSi-NiSi)	R (Pt13Rh-Pt)	IEC 60584	See Std	See Std
S (Pt10Rh-Pt) B (Pt30Rh-Pt6Rh)	L (Fe-CuNi) U (Cu-CuNi)	DIN43 710	DIN	½ DIN

TABLE 6

Operating temperature, lead resistance, sheath material				
Type	Measuring inset 6 mm ∅			Sheath material
	Long-term temperature for tolerance		Lead resistance	
	Class 1	Class 2	Ω/m with Rt	
T	-	500°C / 932°F	0.7	321
E	-	800°C / 1472°F	1.8	316 Ti
J	600°C / 1112°F	700°C / 1292°F	0.9	316 Ti
K	800°C / 1472°F	1000°C / 1832°F	1.5	INCONEL 600
N	800°C / 1472°F	1000°C / 1832°F	1.5	INCONEL 600
L	600°C / 1112°F	700°C / 1292°F 400°C / 752°F	0.9	321
U	-		0.7	321

Other versions
This data sheet contains only a small selection of our range of thermometers with thermowells and transmitter. Please consult your nearest representative for other models.

Other options:

- *Special Insertion Length*
- *Special process connection*
- *Thermowell material*
- *Design style of thermowell*
- *Conduit connections*
- *Connection head painting*
- *Tests and certificate*

Application and Technical Data

TABLE 7 - Limit of Error - Reference Junction at 32ºF

Thermocouple Calibration	Temperature Range	Limits of Error			
		Standard (Whichever is Greater)		Special (Whichever is Greater)	
T	-200 to 350ºC	± 1ºC	or 0.759% above 0ºC	± .5ºC	or ± .4%
	-328 to 852ºF	± 2ºF	or 1.5º below 0ºC	± 1ºC=F	
J	0 to 750ºC	± 2.2ºC	or ± .75%	± 1.1ºC	or ± .4%
	32 to 1382ºF	± 4ºF		± 2ºF	
E	-200 to 900ºC	± 1.7ºC	or 0.5% above 0ºC	± 1ºC	or ± .4%
	-328 to 1652ºF	± 3ºF	or 1.0% below 0ºC	± 2ºF	
K	-200 to 1250ºC	±2.2ºC	or 0.75% above 0ºC	± 1.1ºC	or ± .4%
	-328 to 2282ºF	± 4ºF	or 2.0% below 0ºC	± 2ºF	
R,S	400 to 1400ºC	±1.5ºC	or ± .25%	Or ± .1%	
	752 to 2550ºF	± 3ºF			
B	800 to 1800ºC	±0.5%	or ± .50%	Or ± .25%	
	1475 to 3270ºF	over 900ºC (1470ºF)			
N	0 to 1250ºC	±2.2ºC	or 0.75% above 0ºC	± 1.1ºC	or ± .4%
	32 to 2282ºF	± 4.0ºF	or 2.0% below 0ºC	± 2ºF	
When the limit of error is given in %, the percentage applies to the temperature being measured, not the range.					

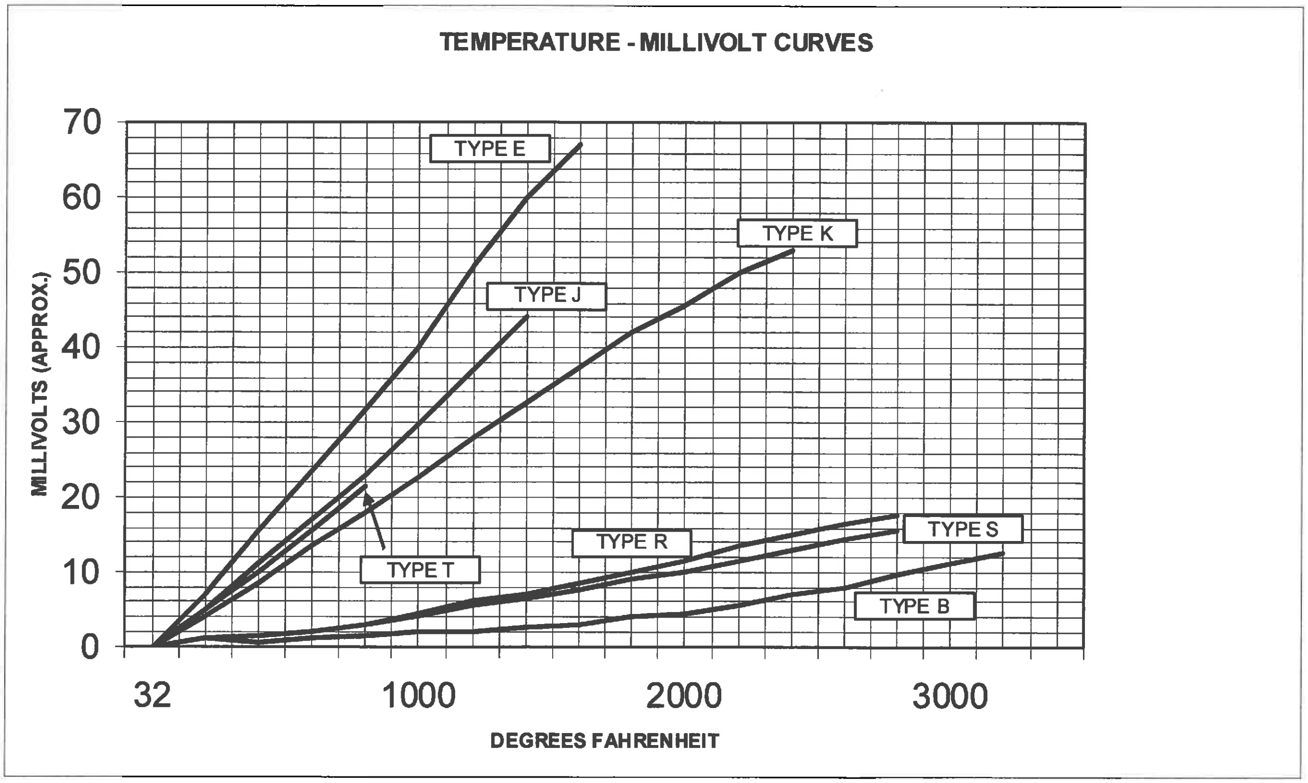


Figure 3

OriMaster Calculation Report

Generated by CompMast V1.0.9

Client	Gryphon
Company	Gryphon
Your Reference	St Joseph's Hospital
ABB Reference	
Quote Reference	
Item Number	**1** qty 1
Tag Number	

FPD500.V1.60.S.B1.A1.H.3.H.0.H.1.H1.AY.CW.C2.EN.M5

Input Data

Fluid	Steam (Saturated)	
Operating Pressure	125	psi [G]
Operating Temperature	352.95	°F
Operating Density	0.30969	lb/ft³
Meter Max Flow	5200	lb/h
Maximum Flow	5200	lb/h
Normal Flow	3300	lb/h
Minimum Flow	600	lb/h
Pipe Schedule	6"/40	
Pipe Internal Diameter	6.06496062992126	in
Outside Diameter	6.6248	in
Pipe Wall Thickness	0.279921	in
Material	Carbon Steel Pipe	
Beta Ratio	0.4	

Calculated Results

DP @ Meter Max Flow	52.377	in wg		
DP @ Max Flow	52.377	in wg		
DP @ Normal Flow	20.974	in wg		
DP @ Min Flow	0.68517	in wg		
Pressure Loss @ Meter Max	43.094	in wg	17.72%	recovery
Pressure Loss @ Max	43.094	in wg		
Pressure Loss @ Normal	17.254	in wg		
Pressure Loss @ Min	0.56317	in wg		
Estimated mass	14	kg		
Reynolds	361,163			

Product Code breakdown

Item	Description
FPD500	OriMaster
V1	Volume Flow Fixed Plate (364DS)
60	6"
S	Saturated steam
B1	0.4
A1	ASME CL 150
H	Horizontal Pipe
3	Integral 3-valve manifold
H	1.6 ... 160 kPa / 16 ... 1600 mbar / 6.4 ... 642 in. H2O
0	Without seal
H	AISI 304L SST / 1/2-14 NPT
1	LCD display
H1	HART digital communication and 4 ... 20 mA
AY	None
CW	Standard water calibration at reference conditions
C2	Material monitoring with inspection certificate 3.1 acc. EN 10204
EN	ATEX + FM + CSA
M5	English

OriMaster FPD500
Compact orifice flowmeter

Ordering Information

V1 60 S 1 A1 H

Main code

OriMaster compact orifice flowmeter	**FPD500**	**XX**	**XX**	**X**	**X**	**XX**	**X**	**X**	**X**	**X**	**X**	**X**	**XX**

Optional code

XX	**XX**	**XX**	**XX**	**XX**	**XX**

See page 22

Model and design level	
[✓ Volume flow fixed plate (364DS)]	V1
Volume flow fixed plate (266DSH)	V2
Volume flow removable plate (364DS)	V3
Volume flow removable plate (266DSH)	V4
Mass flow fixed plate (267CS)	M1
Mass flow removable plate (267CS)	M3
Meter size	
25 mm. (1 in.)	10
40 mm (1¹/₂ in.)	15
50 mm (2 in.)	20
80 mm (3 in.)	30
100 mm (4 in.)	40
[✓ 150 mm (6 in.)]	60
200 mm (8 in.)	80
250 mm (10 in.)	90
300 mm (12 in.)	92
Fluid	
Liquid	L
Gas	G
[✓ Saturated steam]	S
Beta ratio	
[✓ 0.4]	B 1
0.65	2
Pressure rating	
[✓ ASME CL 150]	A1
ASME CL 300	A3
ASME CL 600	A6
PN 10	D1
PN 16	D2
PN 25	D3
PN 40	D4
PN 63	D5
PN 100	D6
Pipeline orientation	
[✓ Horizontal pipe]	H
Vertical pipe *	V

Continued on next page …

* Not available for steam applications

3 H 0 H 1 H1

		Main code													Optional code					
OriMaster compact orifice flowmeter	FPD500	XX	XX	X	X	XX	X	X	X	X	X	X	XX		XX	XX	XX	XX	XX	XX
		See page 20													See next page …					

Manifold	
Integral 3-valve manifold	[✓ 3]
Integral 5-valve manifold	5
DP span limits	
0.05 … 1 kPa / 0.5 … 10 mbar / 0.2 … 4 in. H_2O	A
0.2 … 4 kPa / 1.4 … 40 mbar / 0.56 … 16 in. H_2O	B
0.2 … 6 kPa / 2 … 60 mbar / 0.8 … 24 in. H_2O [2]	C
0.27 … 16 kPa / 2.7 … 160 mbar / 1.08 … 64 in. H_2O [1]	E
0.4 … 40 kPa / 4 … 400 mbar / 1.6 … 160 in. H_2O [2]	F
0.65 … 65 kPa / 6.5 … 650 mbar / 2.6 … 260 in. H_2O [1]	G
1.6 … 160 kPa / 16 … 1600 mbar / 6.4 … 642 in. H_2O [1]	[✓ H]
2.5 … 250 kPa / 25 … 2500 mbar / 10 … 1000 in. H_2O [2]	L
Transmitter seal material	
Without seal [1]	[✓ 0]
Viton [2]	3
PTFE [2]	4
EPDM [4]	5
Perbunan [4]	6
Electronic housing material / electrical connection	
Aluminium Alloy ½ –14 NPT [2]	A
Aluminium Alloy M20 x 1.5 [2]	B
AISI 304L SST ½ –14 NPT [1]	[✓ H]
AISI 304L SST M20 x 1.5 [1]	L
AISI 316L SST ½ –14 NPT	S
AISI 316L SST M20 x 1.5	T
Integrated digital display (LCD)	
None (blind)	0
Integrated LCD display	[✓ 1]
Integrated LCD display (backlit) [4]	2
TTG (through-the-glass) controlled LCD display [3]	5
Output signal	
HART digital communications and 4 … 20 mA	[✓ H1]
HART digital communications and 4 … 20 mA, SIL2 and SIL3 certified to IEC 61508 [3]	H2
PROFIBUS PA [3]	P1
FOUNDATION Fieldbus [3]	F1
Modbus RS485 [4]	M1
Wireless HART	W1

[1] Model and design level V1 and V3 only

[2] Model and design level V2, V4, M1 and M3 only

[3] Model and design level V2 and V4 only

[4] Model and design level M1 and M3 only

OriMaster FPD500
Compact orifice flowmeter

AY CWC2 EN

		Main code													Optional code					
OriMaster compact orifice flowmeter	**FPD500**	XX	XX	X	X	XX	X	X	X	X	X	X	XX		XX	XX	XX	XX	XX	XX
		See page 20					See page 21													

Temperature element	
Integral [2]	AT
Remote [2]	AR
None [1]	[✓ AY]
Calibration	
Standard water calibration at reference conditions	[✓ CW]
Other	CZ
Certificates	
Material monitoring with inspection certificate 3.1 in accordance with EN 10204	[✓ C2]
Material monitoring NACE MR 01-75 with inspection certificate 3.1 in accordance with EN 10204	CN
PED certificate (Pressure Equipment Directive 97/23/EC)	CP
Explosion protection certification	
ATEX + FM + CSA [1]	[✓ EN]
Factory Mutual (FM) – Intrinsically Safe [2]	EA
Factory Mutual (FM) – Explosion Proof [2]	EB
Canadian Standard Association – Explosion Proof [2]	EE
ATEX II 1/2 GD, EEx ia + ATEX II 1/2 GD EEx d + ATEX EEx nL [2]	EW
Documentation language	
German	M1
Italian	M2
Spanish	M3
French	M4
English	[✓ M5]
Chinese	M6
Special applications	
Degreased (oil and grease free) with inert capsule filling for oxygen applications	P1
Gold plated diaphragm (silicone oil filled) for hydrogen applications	P2

[1] Model and design level V1, V2, V3 and V4 only

[2] Model and design level V2, V4, M1 and M3 only

VERIS Verabar

Flow Calculation

VeraCalc
Version: VP190-REV 6.0.0

Model No.: V150 (8 in SCH 40) -10-H-R-XX-XX

Serial No.:

Tag No.: 13-04-FE-1

Pipe Size: 8 in SCH 40
ID = 7.981 Wall = 0.322

Process: Main Steam

Customer: St. Joseph's Hospital

Customer PO: 15800-01

Processed By: SPH

Veris Ref.:

Process Date: 04-30-2013 10:21:13

File Name: 13-04-FE-1 verabar.vfc

Fluid Name: Saturated

I. Flow Equation

Mass Flow Rate for Steam

$$Q_m = C' \cdot \sqrt{h_w} \qquad h_w = \left[\frac{Q_m}{C'}\right]^2$$

$$C' = N \cdot K \cdot Y_v \cdot F_a \cdot D^2 \cdot \sqrt{\rho_f}$$

II. Constants

Term	Description	Value	Units
N	Numeric Constant	358.9265681	
K	Flow Coefficient	0.7425	
D	Pipe ID	7.981	in
P_a	Atmos Pressure	14.70	psi

III. Flow Rate and Differential Pressure

Term	Description	Maximum	Nominal	Minimum	Units
Q_m	**Mass Flow Rate**	**53000**	**45000**	**9425**	**lbm/hr**
C'	Flow Constant	7668.24	7673.27	7685.64	
P_f	Flowing Pressure	75	75	75	psi G
T_f	Flowing Temperature	320.04	320.04	320.04	F
ρ_f	Flowing Density	0.2036	0.2036	0.2036	lbm/ft^3
Y_v	Expansion Factor	0.9977	0.9983	0.9999	
F_a	Thermal Expansion Factor	1.003	1.003	1.003	
h_w	**Differential Pressure**	**47.771**	**34.393**	**1.504**	**in H2O(68F)**

IV. Structural Limits

Term	ANSI Eq	at User's Maximum	Ultimate Maximum	Limiting Component at Ultimate
Max Temp	ANSI 600	800 F at 75 PSI G	800 F at 825 PSI G	Mounting Assembly
Max Press	ANSI 600	1101 PSI G at 320 F	1440 PSI G at 100 F	Instrument Head

Maximum Allowable Flow Rate at Maximum Column: 173008.52 lbm/hr (534.269 in H2O(68F))
Maximum Insert/Retract Flow Rate at Maximum Column:

V. Notes

Up and Downstream lengths depend on type of disturbance.
See attached chart. (annubar)

VERIS Verabar®

Structural Calculation

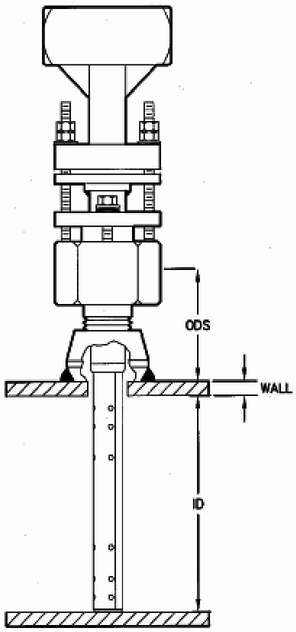
VeraCalc
Version: VP190-REV 6.0.0

Model No.: V150 (8 in SCH 40) -10-H-R-XX-XX
Serial No.:
Tag No.: 13-04-FE-1

Customer: St. Joseph's Hospital
Customer PO: 15800-01
File Name: 13-04-FE-1 verabar.vfc

Dimensions

Term	Description	Value	Units
D	Internal Pipe Diameter	7.981	in
t	Pipe Wall Thickness	0.322	in
l	Unsupported length	10.626	in
ODS	OD to support point	2.323	in
y	OD to oposite support	0.000	in



Maximum Allowable

Term	Description	Value	Units
Vmax	Maximum allowable velocity	677.11	ft/sec
Qmax	Maximum Flow Rate	173008.52	lbm/hr
hmax	Maximum allowable differential pressure	534.269	in H2O(68F)
σmax	Stress at Maximum Flow Rate	14360	psi
Cl	Sensor lift coefficient (Nonfrequency)	3.56	

At Natural Frequency

Term	Description	Value	Units
fn	Natural Frequency	462.34	Hz

VERIS Verabar.

Flow Calculation

VeraCalc
Version: VP190-REV 6.0.0

Model No.: V150 (2 in SCH 80) -05-H-R-XX-XX

Serial No.:

Tag No.: 13-04-FE-20

Pipe Size: 2 in SCH 80
ID = 1.939 Wall = 0.218

Process: Fuel Gas

Customer: St. Joseph's Hospital

Customer PO: 15800-01

Processed By: SPH

Veris Ref.:

Process Date: 04-30-2013 10:37:13

File Name: 13-04-FE-20 verabar.vfc

Fluid Name: Natural Gas

I. Flow Equation

Mass Flow Rate for Gases

$$Q_m = C' \cdot \sqrt{\frac{h_w \cdot P_{fa}}{T_{fa} \cdot Z_f}} \qquad h_w = \left[\frac{Q_m}{C'}\right]^2 \cdot \left[\frac{T_{fa} \cdot Z_f}{P_{fa}}\right]$$

$$C' = N \cdot K \cdot Y_v \cdot F_a \cdot D^2 \cdot \sqrt{\frac{G_r \cdot Z_b}{Z_{airbase}}}$$

Tfa = Tf + 459.67

Pfa = Pf + 14.7

II. Constants

Term	Description	Value	Units
N	Numeric Constant	589.6482333	
K	Flow Coefficient	0.7017	
D	Pipe ID	1.939	in
P_a	Atmos Pressure	14.70	psi
Z_b	Base Compress	0.998	

III. Flow Rate and Differential Pressure

Term	Description	Maximum	Nominal	Minimum	Units
Q_m	**Mass Flow Rate**	**2000**	**1525**	**150**	**lbm/hr**
C'	Flow Constant	1197.83	1200.54	1204.24	
P_f	Flowing Pressure	9	9	9	psi G
T_f	Flowing Temperature	70	70	70	F
G_r	Real Gas Specific Gravity	0.6002	0.6002	0.6002	S.G. Real
Y_v	Expansion Factor	0.9946	0.9969	1.0000	
Z_f	Flowing Compressibility	0.996708	0.996708	0.996708	
F_a	Thermal Expansion Factor	1.000	1.000	1.000	
h_w	**Differential Pressure**	**62.101**	**35.943**	**0.346**	**in H2O(68F)**

IV. Structural Limits

Term	ANSI Eq	at User's Maximum	Ultimate Maximum	Limiting Component at Ultimate
Max Temp	ANSI 600	800 F at 9 PSI G	800 F at 825 PSI G	Mounting Assembly
Max Press	ANSI 600	1440 PSI G at 70 F	1440 PSI G at 100 F	Instrument Head

Maximum Allowable Flow Rate at Maximum Column: 13231.56 lbm/hr (2877.19 in H2O(68F))
Maximum Insert/Retract Flow Rate at Maximum Column:

V. Notes

Up and Downstream lengths depend on type of disturbance.
See attached chart. (annubar)

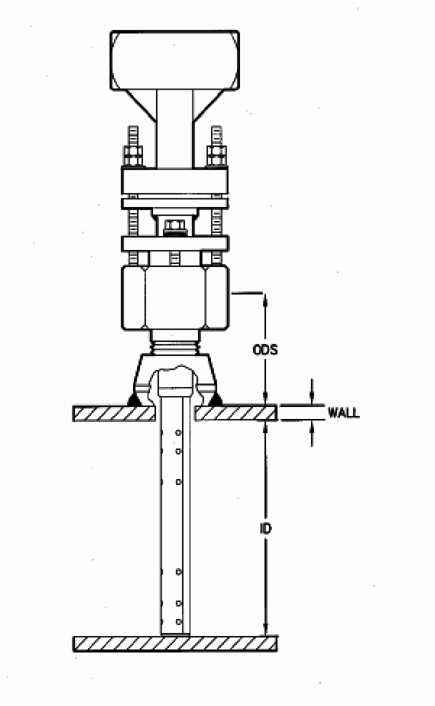
Structural Calculation

VeraCalc
Version: VP190-REV 6.0.0

Model No.:	V150 (2 in SCH 80) -05-H-R-XX-XX	Customer:	St. Joseph's Hospital
Serial No.:		Customer PO:	15800-01
Tag No.:	13-04-FE-20	File Name:	13-04-FE-20 verabar.vfc

Dimensions

Term	Description	Value	Units
D	Internal Pipe Diameter	1.939	in
t	Pipe Wall Thickness	0.218	in
l	Unsupported length	3.987	in
ODS	OD to support point	1.830	in
y	OD to oposite support	0.000	in



Maximum Allowable

Term	Description	Value	Units
Vmax	Maximum allowable velocity	2468.36	ft/sec
Qmax	Maximum Flow Rate	13231.56	lbm/hr
hmax	Maximum allowable differential pressure	2877.19	in H2O(68F)
σmax	Stress at Maximum Flow Rate	18800	psi
Cl	Sensor lift coefficient (Nonfrequency)	3.52	

At Natural Frequency

Term	Description	Value	Units
fn	Natural Frequency	1548.05	Hz

Model No.:	V150 (2 in SCH 80) -05-H-R-XX-XX	Customer:	St. Joseph's Hospital
Serial No.:		Customer PO:	15800-01
Tag No.:	13-04-FE-20	File Name:	13-04-FE-20 verabar.vfc

Supplemental Notes, Assumptions & Methods of Calculation (For Natural Gas):

Method of calculation:

NX-19 (American Gas Association Determination of Super compressibility Factors for Natural Gas, PAR Research Project NX-19, December 1962)

Method used to determine natural gas density:

Veracalc default value used (0.6). Units of Density: S.G. Real

Method used to determine natural gas compressibility:

NX-19 (Methane Method)

Value Used in Calculation	Units
1.000	
2.000	

Isentropic exponent method used & values used in flow calculations:

Maximum	Nominal	Minimum
1.300	**1.300**	**1.300**

Other terms used in natural gas calculations:

Value	Units

Structural Limitations:

Max Allowable Flow Rate at the flowing conditions given:

Maximum	Nominal	Minimum	Units
13231.56	**13230.92**	**13223.06**	**lbm/hr**

Energy Savings Calculation:

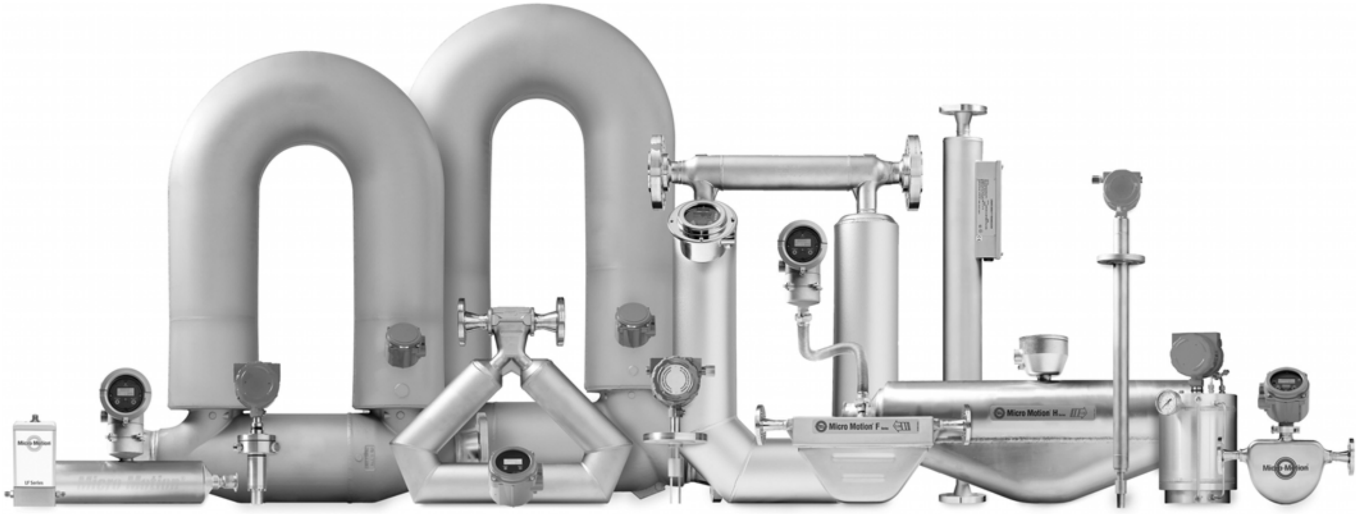
Permanent Pressure loss at the flowing conditions given:

Maximum	Nominal	Minimum	Units
1.863	**1.078**	**0.01**	**in H2O(68F)**

Product Data Sheet
PS-00232, Rev. L
August 2012

Micro Motion®
Technical Overview and Specification Summary

Emerson's world-leading Micro Motion® Coriolis flow and density measurement devices have set the standard for superior measurement technology. Micro Motion truly offers the best measurement solutions for any process challenge.



Technology leadership
Micro Motion is committed to technology innovations that deliver the highest-performing solutions for your complex measurement challenges.

Widest breadth of products
Micro Motion has the widest range of flow and density measurement devices for virtually any process, application, or fluid. A wide variety of wetted materials, line sizes, and an extensive range of output options enable optimal system integration.

Unparalleled value
Benefit from expert field and technical application service and support made possible from more than 750,000 meters installed worldwide and over 30 years of flow and density measurement experience.

Micro Motion®

EMERSON™
Process Management

Micro Motion Coriolis flow and density meters

	ELITE®	F-Series	H-Series	T-Series	R-Series	LF-Series	7835 7845 7847	7826 7827 7828 7829	7812 3098
Application type									
Continuous control	●	●	●	●	●	●	●	●	●
Batching / loading / blending	●	●	●	●	●	●	●	●	●
Custody transfer	●	◐	◐				●		●
Measurement accuracy									
Liquid & slurry – Flow	±0.05%	±0.10%	±0.10%	±0.15%	±0.50%	±0.50%			
Liquid & slurry – Density	±0.0002 g/cm^3 (±0.2 kg/m^3)	±0.001 g/cm^3 (±1.0 kg/m^3)	±0.001 g/cm^3 (±1.0 kg/m^3)	±0.002 g/cm^3 (±2.0 kg/m^3)		±0.005 g/cm^3 (±5.0 kg/m^3)	±0.0001 g/cm^3 (±0.1 kg/m^3)	±0.001 g/cm^3 (±1.0 kg/m^3)	
Liquid – Viscosity								±1% FS	
Gas – Flow	±0.35%	±0.50%	±0.50%	±0.50%	±0.75%	±0.50%			
Gas – Density/SG									±0.10%
Capabilities									
Self-draining	◐	●	●	●	●		●	●	
Sanitary / hygienic	◐	◐	●	●			◐		
Two-phase flow / Entrained gas	●	◐	◐				◐		
Smart Meter Verification	●	●	●						
High temperature*	◐	◐							
High pressure**	◐	◐						●	◐
Cryogenic*	●	◐							
Wetted materials									
300-series stainless steel	●	●	●		●	●	●	●	●
Super Duplex	◐								
Nickel Alloy C22	●	●						●	
Nickel Alloy B3								●	
Ni-Span-C®							●		●
Titanium				●				●	
Monel®								●	
Zirconium								●	
Fits nominal line sizes									
Inches	1/10–16	1/4–4	1/4–4	1/4–2	1/4–2	1/32–1/4	1	1 or larger	1/4 or larger
Millimeters	32–406	6–100	6–100	6–50	6–75	0.8–6	23	25 or larger	6 or larger

* Standard temperature is –148 to +400 °F (–100 to +204 °C)
High temperature is above +400 °F (+204 °C)
Cryogenic is below –148 °F (–100 °C)

** Above 1494 psi (103 bar)

● Supported on all models

◐ Supported on some models

Product comparison Pages 2–3

Product details Pages 4–5

Performance Pages 6–8

Line size and flow rate Page 10

Gas flow specifications Pages 11–12

Temperature ratings Page 14

Pressure ratings Page 15

Micro Motion transmitters and controllers

	1500	1700	2200S	2400S	2500	2700	FMT	3300	3350	3500	3700	7950 7951
Output variables												
Mass / volume flow	●	●	●	●	●	●	●	●	●	●	●	
Net product content / flow[‡]				●	●	●				●	●	
Temperature			●	●	●	●	●			●	●	●
Density			●	●	●	●	●			●	●	●
Concentration				●	●	●				●	●	●
Viscosity / referred viscosity												●
Local display												
2-line		●	●	●		●						
Multi-line								●	●	●	●	●
Power												
AC		●		●		●		●	●	●	●	●
DC	●	●		●	●	●	●	●	●	●	●	●
Loop powered			●									
Outputs												
4–20 mA	●	●	●	●	●	●	●	●	●	●	●	●
10 kHz pulse	●	●		●	●	●	●	●	●	●	●	
Discrete	●	●		●	●	●	●	●	●	●	●	●
HART® / WirelessHART®	●	●	●	●	●	●		●	●	●	●	
Modbus®	●	●			●	●	●	●	●	●	●	●
FOUNDATION™ fieldbus						●						
PROFIBUS-PA						●						
PROFIBUS-DP				●			●					
DeviceNet™				●								
Inputs												
10 kHz pulse								●	●			
Discrete				●	●	●	●	●	●	●	●	
4–20 mA												●
HART										●	●	
2-wire density sensor												●
3-wire density sensor												●
4-wire Coriolis sensor	●	●			●	●				●	●	
9-wire Coriolis sensor	●	●			●	●				●	●	
Mounting												
Integral – Field		●	●	●		●	●					
Remote – Field		●				●			●		●	●
Remote – Control room	●				●			●		●		●
Remote – Rack / panel mount								●		●		
Special application types												
Batch controller								●	●	●	●	
Custody transfer						●		●	●	●	●	
Two-phase flow / entrained gas	●	●		●	●	●				●	●	
Filling & dosing	●						●					
Meter verification	●	●		●	●	●				●	●	
SIS Certified		●				●						
Hazardous approvals												
C1D1		●	●			●						
C1D2		●	●	●		●	●		●		●	
Zone 1		●	●			●			●		●	
Zone 2		●	●	●		●			●		●	

[‡] Flow rate of product based on concentration. For example, in a dissolved sugar solution, the measurement is the flow rate of the sugar alone and in a net oil application the measurement is water alone or oil alone.

Appendix B

Site Photos

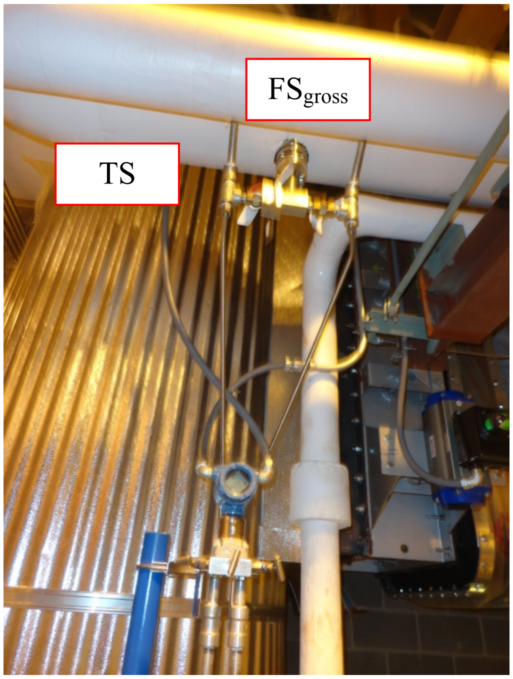
Gas Turbine

Heat Recovery Steam Generator (HRSG)

Gas Compressor (in enclosure on roof)

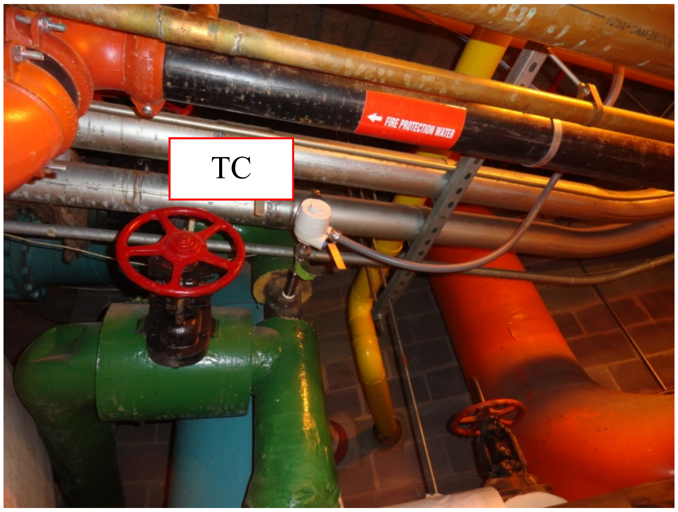
Turbine Gas Meter (FG)

Duct Burner Gas Meter (FGB)

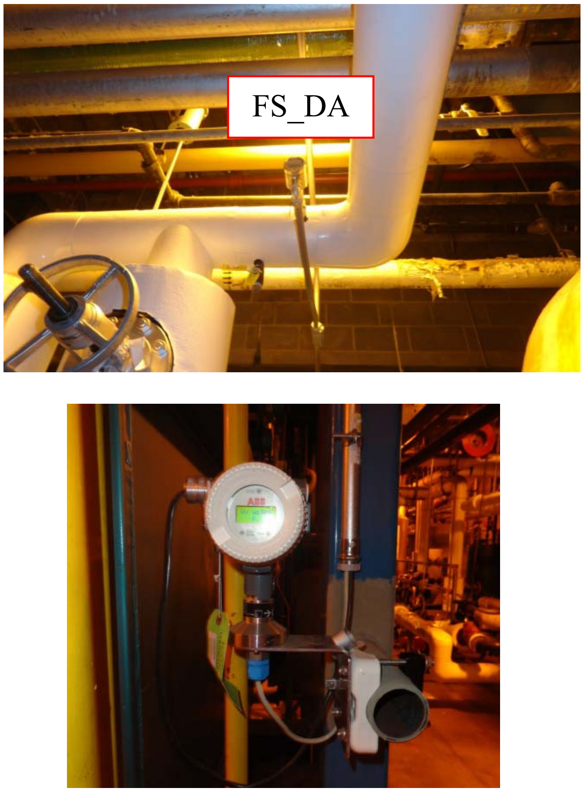


HRSG Gross Steam Meter (FS_{gross}) and Temperature (TS)

HRSG Gross Steam Meter (FS_{gross})



Condensate Return Temperature (TC)



Deaerator Steam Flow (FS_DA)

Gas Compressor Power Transducer MCC-3 (WPAR2)

CHP Parasitic Loads MCC-1 (WPAR2)

Gas Turbine Gross Output Power Transducer SEL-734B (WG)