M&V Plan for DG/CHP System

Cubit Power

April 30, 2019

Submitted to:

New York State Energy Research and Development Authority

17 Columbia Circle

Albany, NY 12203-6399

Submitted by:

Frontier Energy, Inc.

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Cazenovia, NY 13035

315-655-1063

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Introduction

Cubit Power is in the process of installing a combined heat and power (CHP) system at the Staten Island Ice facility located at 4534 & 4532 Victory Boulevard in Staten Island, New York. The CHP system is based on two 5.4 MW natural gas fueled, reciprocating engine-generator sets manufactured by Hyundai Heavy Industries. Two auxiliary (400 kW and 736 kW) natural gas fueled, reciprocating engine-generators are utilized to support the host plant prior to start of the main engine gensets. Once operating, the facility will operate as a merchant generation plant, exporting excess energy to the utility grid. Energy used on site will support the ice-production process.

Heat from the main 10.8 MW CHP system will be recovered in the form of hot water from the engine jacket, and heat from the engine exhaust stream. Hot water loads consist of a 790-ton hot-water absorption chiller (CH3000), which is installed in parallel with a plate frame heat exchanger to reject heat when required (typically only at plant startup). The exhaust heat recovery system is configured in two parallel streams. After leaving the engines, exhaust passes through individual SCR emissions control for each engine, and a pair of induction air damper boxes that allow for bypassing exhaust directly to individual stacks.

During normal operation, the exhaust from both units is combined into a common plenum, and then separated into parallel heat recovery streams. One exhaust stream is used to drive an 831-ton exhaust-fired absorption chiller (CH3100). The other exhaust stream is used to drive a 165-ton exhaust-fired low-temperature ammonia-water chiller (CH3200 or HRVG) for ice production. After thermal heat recovery is performed on the chillers, the split exhaust streams combine and head through a spray cooler and a water condensing tank, where moisture from combustion is condensed out, sent through a RO and polishing system, and used as the feedstock for ice. Exhaust leaves the condensing tank and head to a stack for exhaust.

A set of 1,136 kW plant support natural gas generators are used to operate process electrical loads at the plant. These generators do not recovery any heat for process use and are considered parasitic natural gas loads.

Instrumentation

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 Frontier Energy based on system configuration and information provided by the applicant, Cubit Power as documented in the final PIDs dated 04/19/2019. These data points are consistent with the observed system configuration during the July 2018 site inspection. All point names have been renumbered for consistency with the as-built design configuration.

In accordance to the instrumentation plan, Cubit Power has supplied the instrumentation listed below in Table 1 for use in meeting the NYSERDA CHP program monitoring requirements.

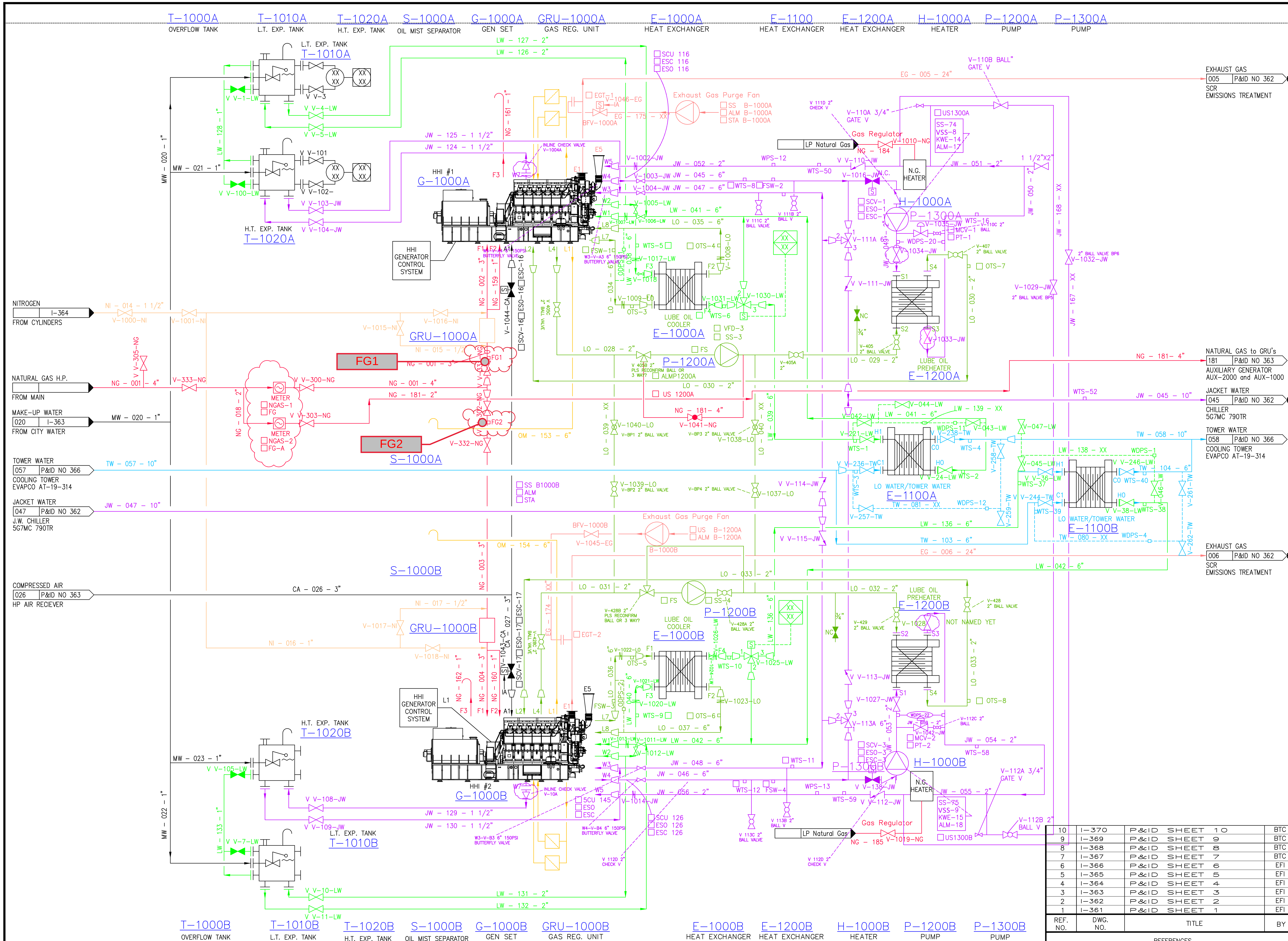
The following issues require addressing, prior to finalizing the M&V plan. **These issues shall be addressed during the onsite visit, and a remediation plan developed and executed.**

M&V Deficiency #1: Sensor model numbers cut sheets must be provided for all sensors shown in Table 1**Error! Reference source not found.**. Minor deficiency - needed to complete documentation.

Table 1. Instrumentation Supplied by Cubit Power for CHP Analysis

No	Data Point	Description	Eng Units	Location (from PIDs & 1-Line)	Energy Stream	Notes
1	WEXP	Power/Energy - Exported Power/Energy - Plant	kWh / kW	13.8kV side of transformer before paralleling switchgear / Utility	Net Plant Electrical Output	From RTAC data source for NYISO - suitable data source
2	WG1	Gross Power/Energy - Genset 1	kWh / kW	At Generator 1	Electrical Diagnositc	From Generator - Diagnositc only
3	WG2	Gross Power/Energy - Genset 2	kWh / kW	At Generator 2		From Generator - Diagnositc only
4	WGAUX1	Power/Energy - Aux Gen MCC1	kWh / kW	MCC-1 Main		From Generator - Diagnositc only
5	WGAUX2	Power/Energy - Aux Gen MCC2	kWh / kW	MCC-2 Main		From Generator - Diagnositc only
6	FG1	Main Engine #1 Gas Consumption	cf	NG-001	Natural Gas Input	Site supplied rotary gas meter +/-1%
7	FG2	Main Engine #1 Gas Consumption	cf	NG-018		Site supplied rotary gas meter +/-1%
8	FG3	750 kW Aux Engine Gas Consumption	cf	NG-181		Site supplied rotary gas meter +/-1%
9	FG4	400 kW Aux Engine Gas Consumption	cf	NG-186		Site supplied rotary gas meter +/-1%
10	TCHJWS	CH-3000 Jacket Water Entering	deg F	At chiller branch piping	CH-3000 Heat Recovery	From Thermax modbus
11	TCHJWR	CH-3000 Jacket Water Leavings	deg F	At chiller branch piping		From Thermax modbus
12	FCHJW	CH-3000 Jacket Water Flow	GPM	At chiller branch piping		From manufacturer delta-P curve
13	TE1A	Exhaust After SCR - Unit A	deg F	EG-170	Engine A - Exhaust	
14	PO2A	Percent O2 - Unit A	%	EG-170		
15	FE1A	Exhaust Flow - Unit A	lb/h	EG-170		
16	TE1B	Exhaust After SCR - Unit B	deg F	EG-007	Engine B - Exhaust	
17	PO2B	Percent O2 - Unit B	%	EG-007		
18	FE1B	Exhaust Flow - Unit B	lb/h	EG-007		
19	TE2	CH-3100 Exhaust Entering	deg F	EG-171	CH-3100 Heat Recovery	
20	TE3	CH-3100 Exhaust Leaving	deg F	EG-013		
21	FE2	CH-3200 Exhaust Flow	lb/h	EG-008	CH-3200 Heat Recovery	
22	TE4	CH-3200 Exhaust Entering	deg F	EG-008		
23	TE5	CH-3200 Exhaust Leaving	deg F	EG-009		
24	FE3	Combined Exhaust to CH-3100 & CH-3200	lb/h	EG-171	Combined Heat Recovery	Installed at location shown due to ductwork configuration - calculate CH-3100 exhaust flow from FE3-FE2
25	TE6	Exhaust Entering Spray Cooler	deg F	EG-010	Diagnostic Exhaust Temps	
26	TE7	Exhaust at Discharge Fan	deg F	EG-11		
27	QJWC	CH-3000 Jacket Water Chiller Output	tons	n/a	Chiller Output	Diagnositc - proof of CH-3000 operation
28	QEGC	CH-3100 Exhaust Chiller Output	tons	n/a		Diagnositc - proof of CH-3100 operation
29	QAC	CH-3200 Ammonia Chiller Output	tons	n/a		Diagnositc - proof of CH-3200 operation

Locations of all measurement are shown on the following PIDs and one-line diagrams.



REF. NO.	DWG. NO.	TITLE	BY
10	I-370	P&ID SHEET 10	BTC
9	I-369	P&ID SHEET 9	BTC
8	I-368	P&ID SHEET 8	BTC
7	I-367	P&ID SHEET 7	BTC
6	I-366	P&ID SHEET 6	EFI
5	I-365	P&ID SHEET 5	EFI
4	I-364	P&ID SHEET 4	EFI
3	I-363	P&ID SHEET 3	EFI
2	I-362	P&ID SHEET 2	EFI
1	I-361	P&ID SHEET 1	EFI

REFERENCES

EFI Engineering For Industry
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www.salemengineering.com

DATE	REV.	REVISIONS	BY	APP'D BY
2017/12/21	H	UPDATED PIPING & VALVES	BTC	SALEM
2017/11/13	G	UPDATED PIPING & VALVES	BTC	SALEM
2016/03/16	F	ADDED E-4000	DP	GC
2016/02/09	E	UPDATED PROCESS	CS	GC
2016/02/01	D	PROCESS/NYSERDA UPDATES	DP	GC
2016/01/13	C	UPDATED PROCESS	TN	GC
2015/09/09	B	UPDATED PROCESS	AP	GC
2015/04/20	A	–	AP	GC

DRAWING ISSUED FOR:

DATE: 2016 APRIL 01

■ CLIENT REVIEW ☐ BID/TENDER ☐ CONSTRUCTION
☐ INFORMATION ☐ PERMIT ☐ OTHER

Cubit

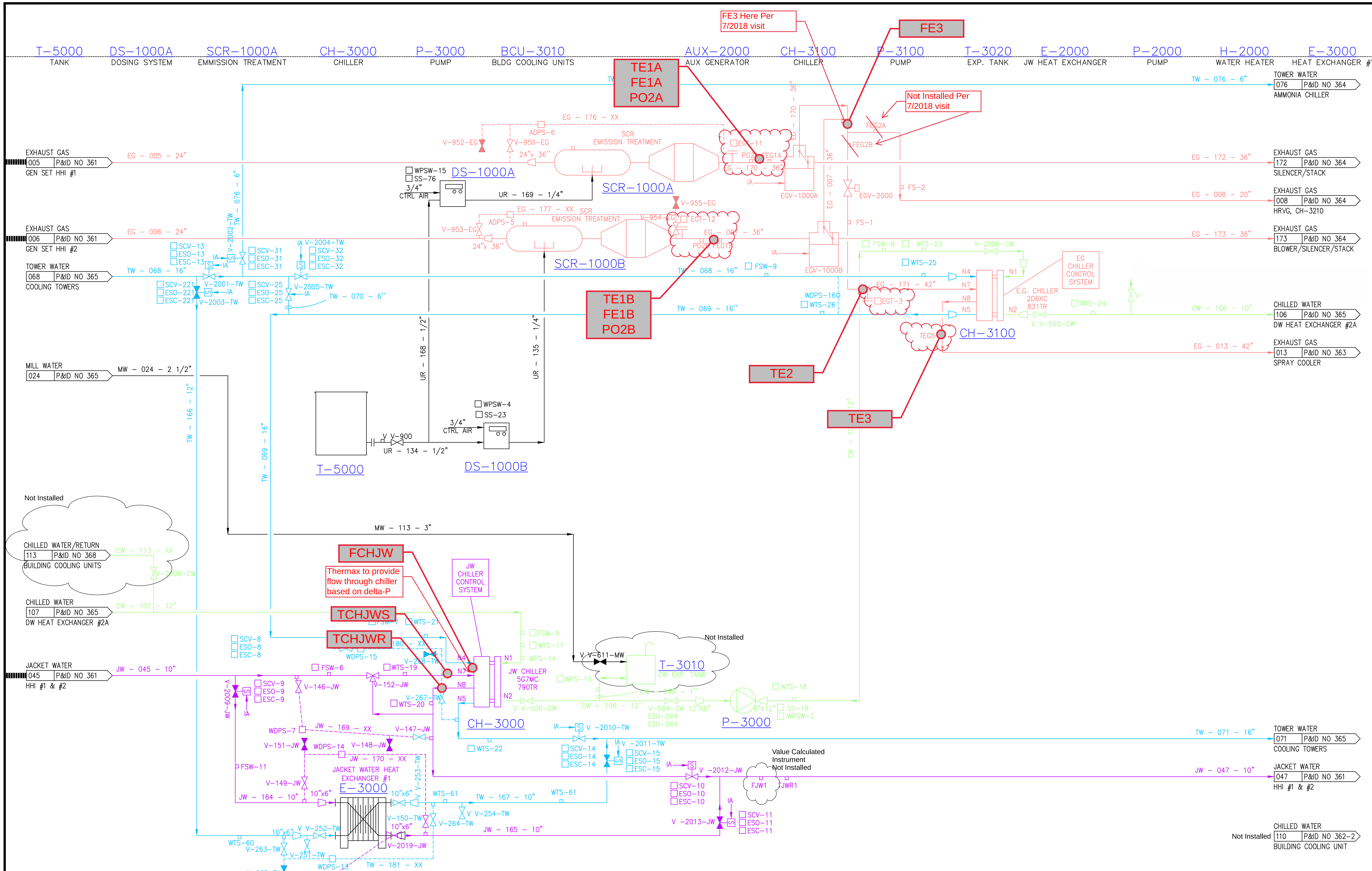
STATEN ISLAND ICE CHP & ICE PRODUCTION FACILITY P&ID SHEET 1

DRAWN: ACP
DATE: 2015/06/11 CHKD: G.C.
SCALE: N.T.S.

APPROVED BY: NAME
DATE: YYYY/MM/DD
SHEET:

PROJECT NO.	DISCIPLINE	DRAWING NO.	REVISION
5000	I	361	H

I-361-H



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2016/02/01	D	PROCESS/NYSERDA UPDATES	DP	GC
2016/01/13	C	UPDATED PROCESS	TN	GC
2015/09/09	B	UPDATED PROCESS	AP	GC
2015/04/20	A	–	AP	GC

DRAWING ISSUED FOR:

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STATEN ISLAND ICE
CHP & ICE PRODUCTION FACILITY
P&ID SHEET 2

REF. NO.	DWG. NO.	TITLE	BY
10	I-370	P&ID SHEET 10	BTC
9	I-369	P&ID SHEET 9	BTC
8	I-368	P&ID SHEET 8	BTC
7	I-367	P&ID SHEET 7	BTC
6	I-366	P&ID SHEET 6	EFI
5	I-365	P&ID SHEET 5	EFI
4	I-364	P&ID SHEET 4	EFI
3	I-363	P&ID SHEET 3	EFI
2	I-362	P&ID SHEET 2	EFI
1	I-361	P&ID SHEET 1	EFI

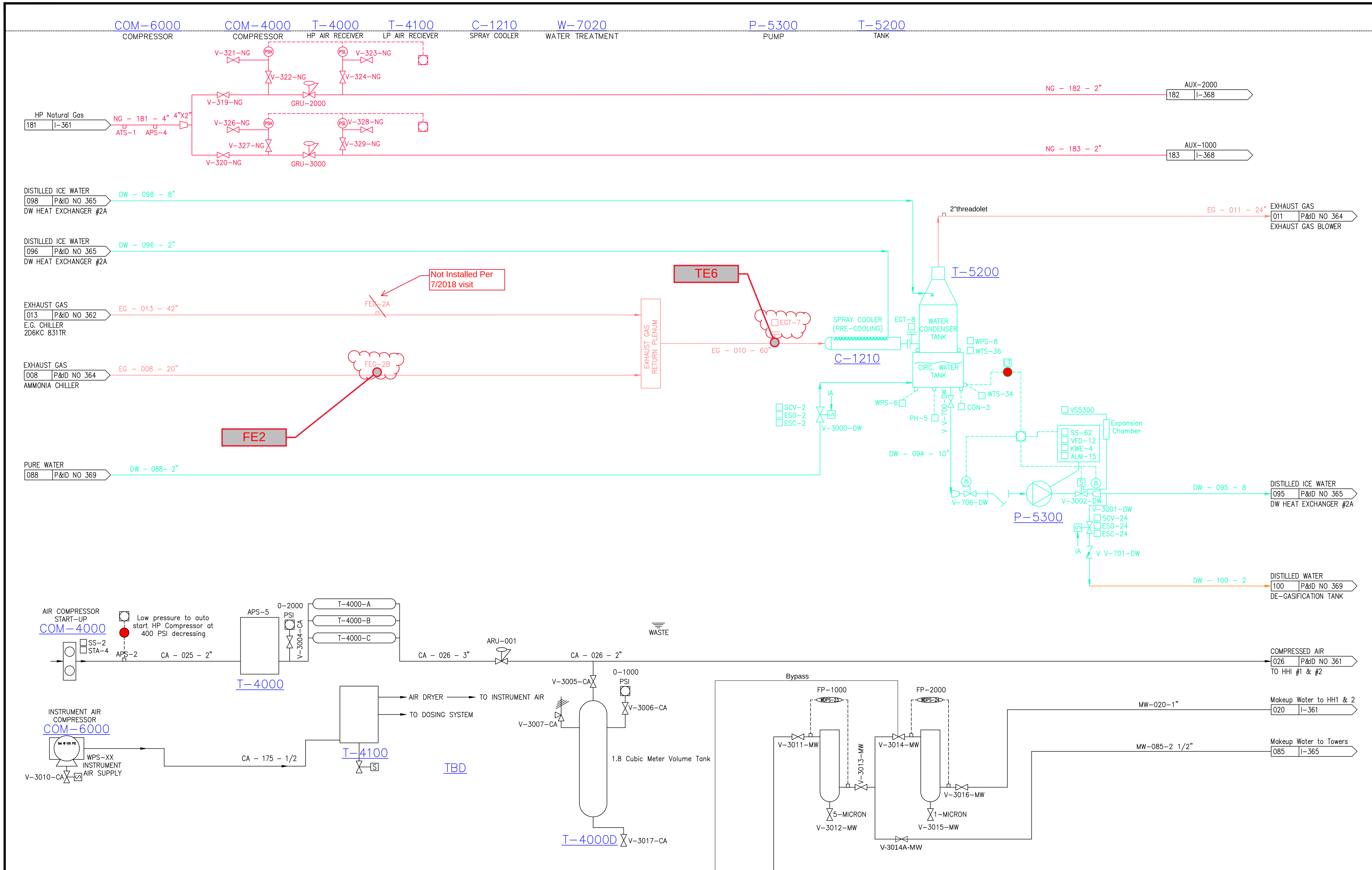
REFERENCES

DRAWN: ACP
DATE: 2015/06/11 CHKD: G.C.
SCALE: N.T.S.

APPROVED BY: NAME
DATE: YYYY/MM/DD
SHEET:

PROJECT NO.	DISCIPLINE	DRAWING NO.	REVISION
5000	I	362	H

I-362-H



REF. NO.	DWG. NO.	TITLE	BY
10	I-370	P&ID SHEET 10	BTC
9	I-369	P&ID SHEET 9	BTC
8	I-368	P&ID SHEET 8	BTC
7	I-367	P&ID SHEET 7	BTC
6	I-366	P&ID SHEET 6	EFI
5	I-365	P&ID SHEET 5	EFI
4	I-364	P&ID SHEET 4	EFI
3	I-363	P&ID SHEET 3	EFI
2	I-362	P&ID SHEET 2	EFI
1	I-361	P&ID SHEET 1	EFI

REFERENCES

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2016/02/09	E	UPDATED PROCESS	CS	GC
2016/02/01	D	PROCESS/NYSERDA UPDATES	DP	GC
2016/01/13	C	UPDATED PROCESS	TN	GC
2015/09/09	B	UPDATED PROCESS	AP	GC
2015/04/20	A	–	AP	GC

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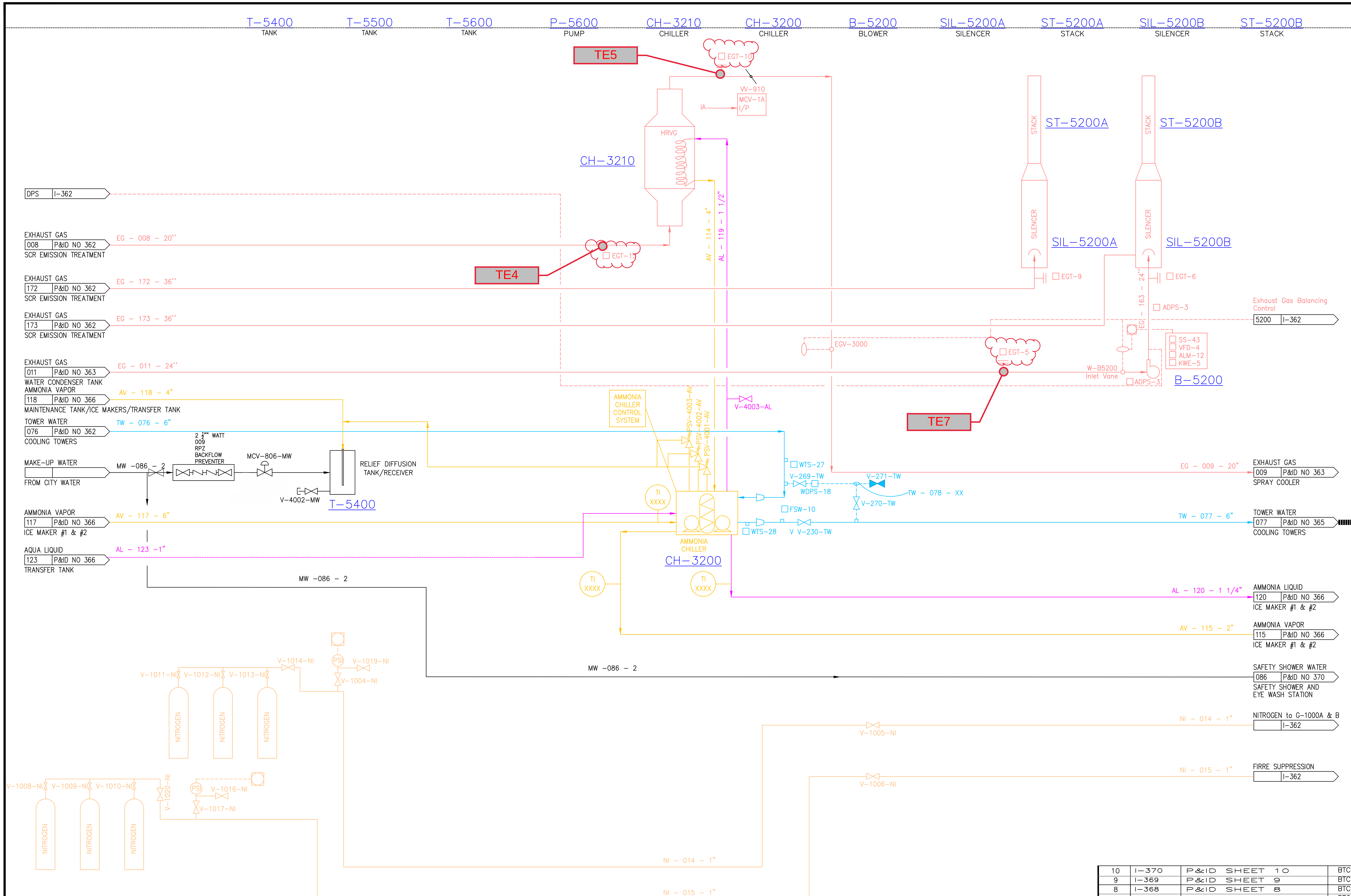
STATEN ISLAND ICE
CHP & ICE PRODUCTION FACILITY
P&ID SHEET 3

DRAWN: ACP
DATE: 2015/06/11 CHKD: G.C.
SCALE: N.T.S.

APPROVED BY: NAME
DATE: YYYY/MM/DD
SHEET:

PROJECT NO.	DISCIPLINE	DRAWING NO.	REVISION
5000	I	363	H

I-363-H



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2017/12/21	H	UPDATED PIPING & VALVES	BTC	SALEM
2017/11/13	G	UPDATED PIPING & VALVES	BTC	SALEM
2016/03/16	F	ADDED E-4000	DP	GC
2016/02/09	E	UPDATED PROCESS	CS	GC
2016/02/01	D	PROCESS/NYSERDA UPDATES	DP	GC
2016/01/13	C	UPDATED PROCESS	TN	GC
2015/09/09	B	UPDATED PROCESS	AP	GC
2015/04/20	A	–	AP	GC

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DATE: 2016 APRIL 01

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- ☐ BID/TENDER
- ☐ CONSTRUCTION
- ☐ INFORMATION
- ☐ PERMIT
- ☐ OTHER

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STATEN ISLAND ICE
CHP & ICE PRODUCTION FACILITY
P&ID SHEET 4

DRAWN: ACP
DATE: 2015/06/11 CHKD: G.C.
SCALE: N.T.S.

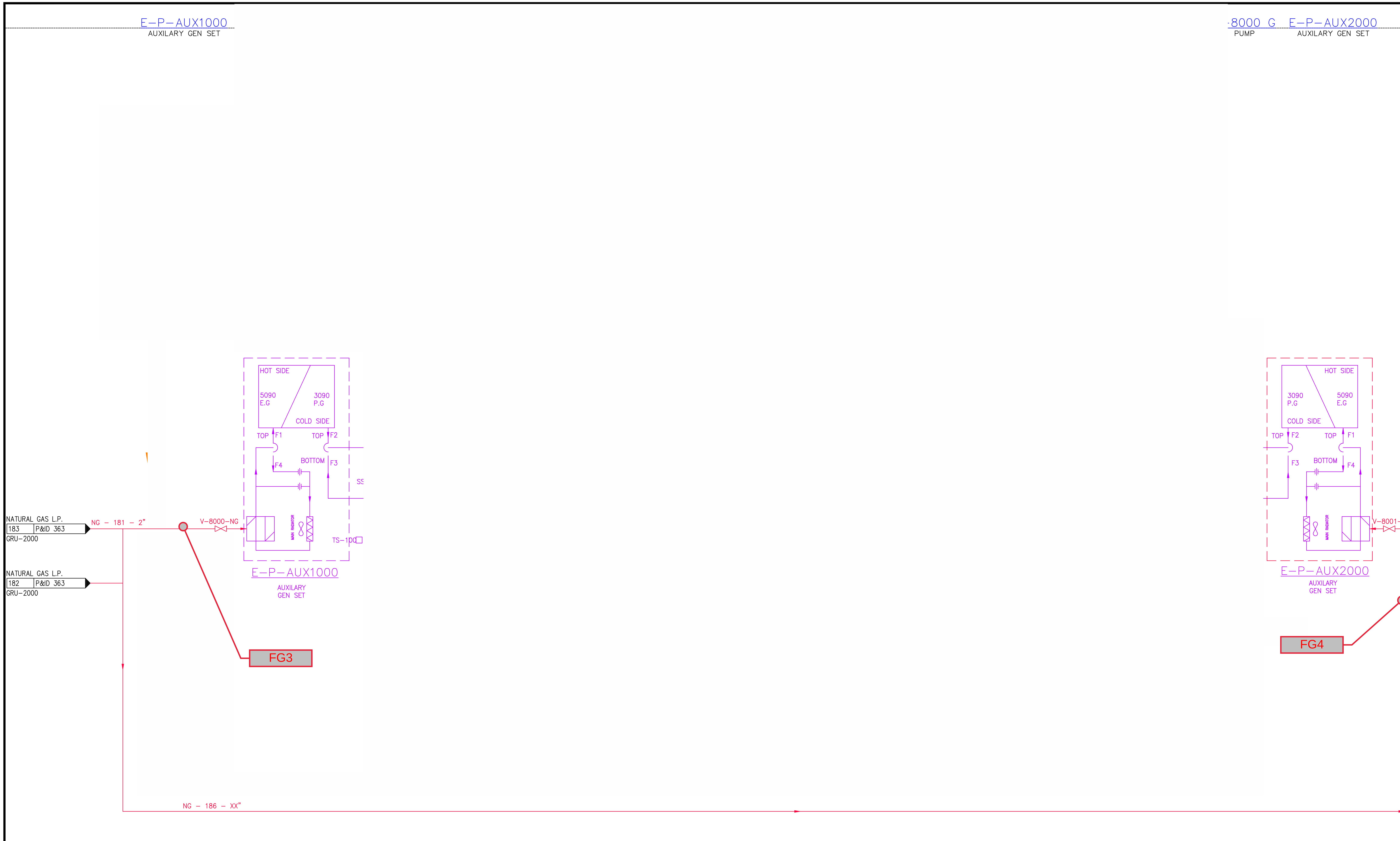
APPROVED BY: NAME
DATE: YYYY/MM/DD
SHEET:

PROJECT NO.	DISCIPLINE	DRAWING NO.	REVISION
5000	I	364	H

REF. NO.	DWG. NO.	TITLE	BY
10	I-370	P&ID SHEET 10	BTC
9	I-369	P&ID SHEET 9	BTC
8	I-368	P&ID SHEET 8	BTC
7	I-367	P&ID SHEET 7	BTC
6	I-366	P&ID SHEET 6	EFI
5	I-365	P&ID SHEET 5	EFI
4	I-364	P&ID SHEET 4	EFI
3	I-363	P&ID SHEET 3	EFI
2	I-362	P&ID SHEET 2	EFI
1	I-361	P&ID SHEET 1	EFI

REFERENCES

I-364-H



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DATE	REV.	REVISIONS	BY	APP'D BY
2017/11/19	A	ISSUE NEW SYSTEM	BTC	GC

DRAWING ISSUED FOR:

DATE: 2016 APRIL 01

- [x] CLIENT REVIEW
- [ ] BID/TENDER
- [ ] CONSTRUCTION
- [ ] INFORMATION
- [ ] PERMIT
- [ ] OTHER

STATEN ISLAND ICE
CHP & ICE PRODUCTION FACILITY
P&ID SHEET 8

REF. NO.	DWG. NO.	TITLE	BY
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8	I-368	P&ID SHEET 8	BTC
7	I-367	P&ID SHEET 7	BTC
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5	I-365	P&ID SHEET 5	EFI
4	I-364	P&ID SHEET 4	EFI
3	I-363	P&ID SHEET 3	EFI
2	I-362	P&ID SHEET 2	EFI
1	I-361	P&ID SHEET 1	EFI

REFERENCES

DRAWN: BTC
DATE: 2018/10/28 CHKD: G.C.
SCALE: N.T.S.

APPROVED BY: NAME
DATE: YYYY/MM/DD
SHEET:

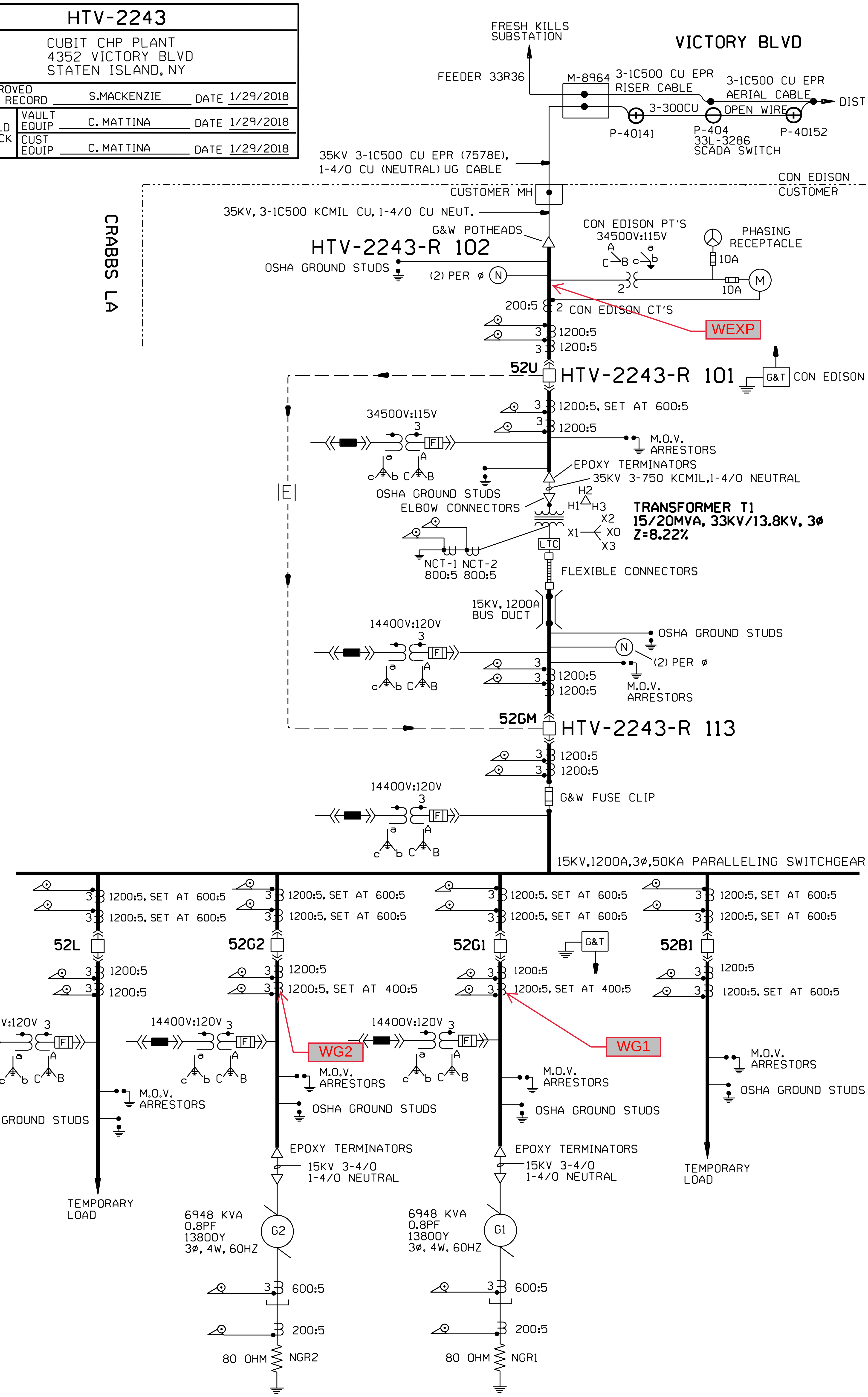
PROJECT NO.	DISCIPLINE	DRAWING NO.	REVISION
5000	I	368	A

I-368-A

HTV-2243

CUBIT CHP PLANT
4352 VICTORY BLVD
STATEN ISLAND, NY

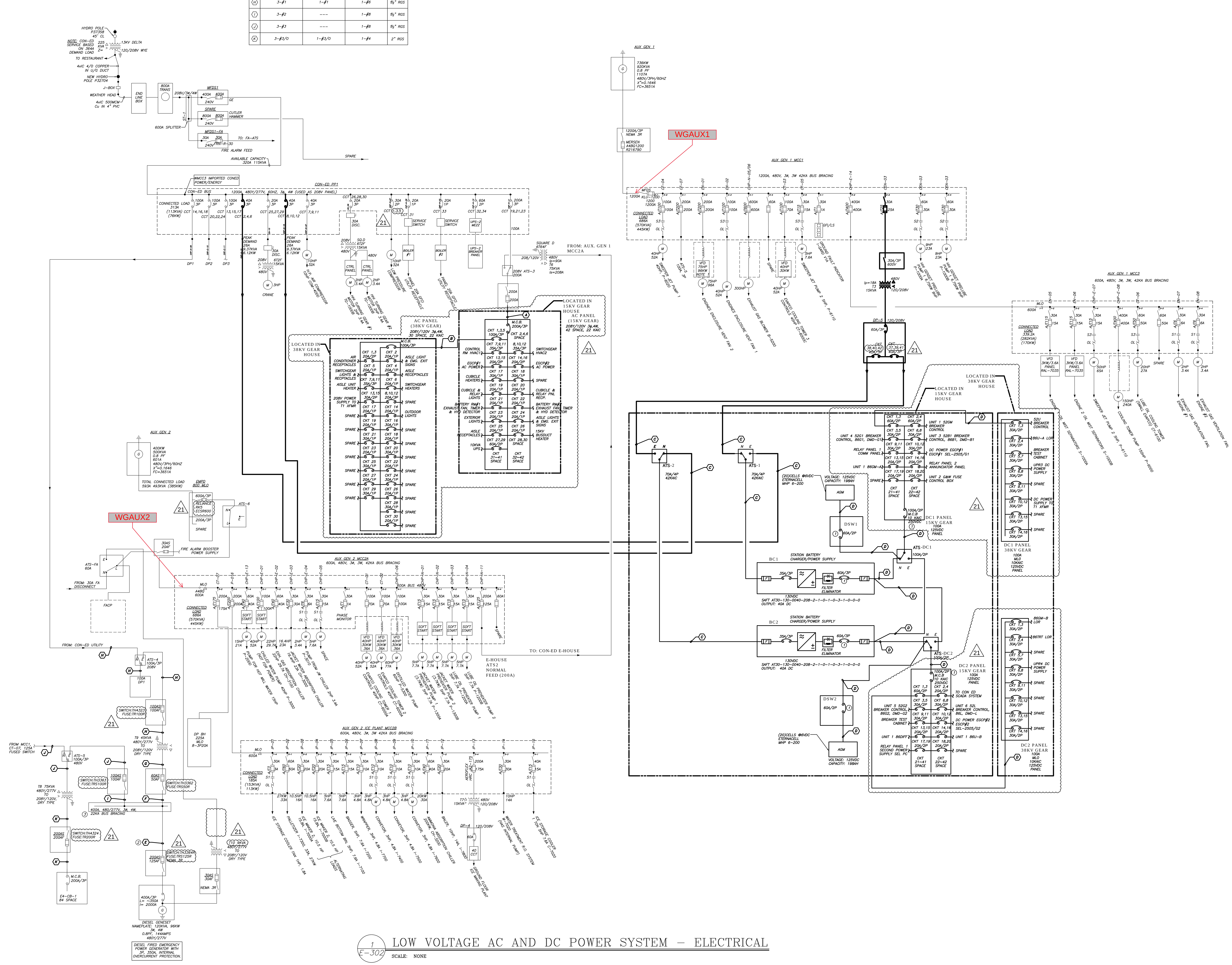
APPROVED FOR RECORD	S.MACKENZIE	DATE	1/29/2018
FIELD CHECK — VAULT EQUIP	C. MATTINA	DATE	1/29/2018
FIELD CHECK — CUST EQUIP	C. MATTINA	DATE	1/29/2018



FEEDER SCHEDULE WIRE SIZE IN AWG				
NO.	PHASE	NEUTRAL	GROUND	CONDUIT
A	3-#3/0	1-#3/0	1-#6	2" RGS
B	3-#2	1-#2	1-#8	1½" RGS
C	3-#8	1-#8	1-#10	1" RGS
D	1-#6	---	---	¾" FRE
	1-#6	---	---	¾" FRE
E	3-#1	1-#1	---	2" RGS
F	3-#4	---	1-#8	1½" RGS
G	3-#6	---	1-#10	1" RGS
H	3-#1	1-#1	1-#6	1½" RGS
I	3-#2	---	1-#8	1½" RGS
J	3-#3	---	1-#8	1½" RGS
K	3-#3/0	1-#3/0	1-#4	2" RGS

INSTALLATION NOTES:

1. DC CIRCUIT BREAKER SHALL BE PROVIDED WITH (2) 125VDC FORM 'C' AUXILARY CONTACTS
2. PROVIDE (1)-2" RGS CONDUIT FOR EMERGENCY POWER FEEDERS, (4)-1" RGS CONDUITS FOR CONTROL CIRCUIT, FROM EMERGENCY GENERATOR LOCATION TO EMERGENCY POWER ELECTRICAL ROOM. RACK ON SIDE OF STRUCTURE, CAREFUL TO NOT IMPACT ACOUSTICAL PROPERTIES OF ENGINE ROOM WALL MATERIAL.
3. PROVIDE NEW 6"X6"X36" WIREWAY/GUTTER ON INSIDE WALL OF EMERGENCY ELECTRICAL ROOM. USE TO TAP CONDUCTORS FOR AUTO TRANSFER SWITCH USING ISLCO TAP BLOCKS OR APPROVED EQUIVALENT.



1 E-302 LOW VOLTAGE AC AND DC POWER SYSTEM – ELECTRICAL

SCALE: NONE

ENERGY CONCEPTS

INTEGRATED ENERGY CONCEPTS ENGINEERING, P.C.

3445 Winton Place, Suite 240
Rochester, NY 14623
Phone: (585) 272-4650
www.nrg-concepts.com

Combined Heat & Power, Energy, Mechanical and Electrical - Consultants

CLIENT INFORMATION

Cubit

REVISIONS		
NO.	DATE	DESCRIPTION
5	7/31/2015	PRELIMINARY EQUIPMENT LIST
6	8/4/2015	ELECTRICAL GEAR BID SET
7	9/30/2015	UPDATED ELECTRICAL GEAR BID SET
8	11/19/2015	CONED CONTRACT SUBMISSION
9	1/8/2016	ISSUED FOR BIDDING
10	6/7/2016	ISSUED FOR CONSTRUCTION
11	8/23/2016	ISSUED FOR CONSTRUCTION VERIFICATION
12	3/24/2017	RESUBMISSION TO CON EDISON
13	5/12/2017	RESUBMISSION TO CON EDISON
14	7/18/2017	RESUBMISSION TO CON EDISON
15	8/21/2017	RESUBMISSION TO CON EDISON
16	9/11/2017	RESUBMISSION TO CON EDISON
17	9/27/2017	REVISED PER CON ED COMMENTS
18	11/6/2017	REVISED PER PER AS-BUILT CONDITIONS
19	11/13/2017	REVISED PER CON ED COMMENTS
20	12/18/2017	OWNER PROGRESS SET
21	2/20/2018	AS-BUILT UPDATES

CUBIT CHP PLANT

4352 VICTORY BLVD.
STATEN ISLAND, NY

PROJECT NAME

SCALE | PHASE

LOW VOLTAGE AC AND DC POWER SYSTEM - ELECTRICAL

DRAWING TITLE

SEAL & SIGNATURE

DATE: 1/7/2015
PROJECT No.: 14027
DRAWING BY: YR
CHK BY: CPC
DWG No: E-302.00
CADO FILE No: J: | of

saved on 2/20/2018 4:47 PM by yruan, plotted on 2/20/2018 4:48 PM by yruan

Readings for the installed instrumentation will be recorded by the plant control system (PCS). All field point sensors will report to the PCS at least once per minute and the PCS shall record 15-minute sums and/or averages as appropriate for the measurement type. Integrated heat transfer calculations shall be performed by the PCS for comparison to the values calculated by the fundamental flow and temperature difference measurements. If the PCS cannot provide true integrated values, then shorter time step data, such as 1-minute sums and averages shall be provided.

The PCS shall have sufficient memory to store 30-days of data if communications with the logger are interrupted. The data will be uploaded from the PCS to CDH Energy once per day via an internet connection provided by the site/applicant. The data will be loaded into a database, checked for validity, and posted on the NYSERDA web site.

The following table is used to map the data file columns to the database points used for analysis.

Data Point	Description	Units	Data File Column Header
WEXP	Power/Energy - Exported Power/Energy - Plant	kW	WEXP Total Engine Power Exported A1M1AV6
WG1	Gross Power/Energy - Genset 1	kW	WG1 Gross power Engine 1 B6M1AV1
WG2	Gross Power/Energy - Genset 2	kW	WG2 Gross power Engine 2 B6M100
WGAUX1	Power/Energy - Aux Gen MCC1	kW	WGA-400 3412 400kW Power Output C3M1
WGAUX2	Power/Energy - Aux Gen MCC2	kW	WGA-700 3516 700kW Power Out C3M1
FG1_ACC	Main Engine #1 Gas Accumulator	CF	FG-1 Acumulated Gas Consumption HHI 1 B5M2 AV01
FG2_ACC	Main Engine #1 Gas Accumulator	CF	FG-2 Accumulated Gas Consump HHI 2 B5M1 AV10
FG3_ACC	750 kW Aux Engine Gas Accumulator	CF	FGA 400 Gas Consump AV-1
FG4_ACC	400 kW Aux Engine Gas Accumulator	CF	FGA 750 Gas Consump AV-3
TCHJWS	CH-3000 Jacket Water Entering	deg F	TJWS1_JW Chiller Supply In B2M1 MOD4 AcV07
TCHJWR	CH-3000 Jacket Water Leaving	deg F	TJWR1 JW Chiller Supply Out B2M1 MON4 AcV08
FCHJW	CH-3000 Jacket Water Flow	gpm	FJW2 Jacket Water Heat Flow C3M1 AV05
TE1A	Exhaust After SCR - Unit A	deg F	TEG 1A D1M1 AV10
PO2A	Percent O2 - Unit A	%	PO2-A Oxygen Analyzer Engine 1
FE1A	Exhaust Flow - Unit A	lb/h	FEG1A Engine 1 EG Flowrate B6M1AV12
TE1B	Exhaust After SCR - Unit B	deg F	TEG-1B D1M1AV06
PO2B	Percent O2 - Unit B	%	PO2-B Oxygen Analyzer B1M3
FE1B	Exhaust Flow - Unit B	lb/h	FEG1B Engine 2 EG Flowrate B6M1AV13
TE2	CH-3100 Exhaust Entering	deg F	TEG-4 Gas Temp in EG Chiller B2M1 AV35
TE3	CH-3100 Exhaust Leaving	deg F	TEG-5 Gas Temp EG Out B2M1AV36
FE2	CH-3200 Exhaust Flow	lb/h	FEG2A EG Flow into Chillers C4M1AV11
TE4	CH-3200 Exhaust Entering	deg F	TEG-2 Gas Temp in NH3 AV6
TE5	CH-3200 Exhaust Leaving	deg F	TEG-3 EG NH3 Chiller Out C4M1-AV07
FE3	Combined Exhaust to CH-3100 & CH-3200	lb/h	FEG3 EG Flow Out NH3 Chiller
TE6	Exhaust Entering Spray Cooler	deg F	TEG 7 Spray Inlet Temp AV 8
TE7	Exhaust at Discharge Fan	deg F	TEG 8 EG Cond Tank Out B22M1 AV01
QJWC	CH-3000 Jacket Water Chiller Output	tons	QJW_Tons B2M1AV14
QEGC	CH-3100 Exhaust Chiller Output	tons	QEGC_TONS B2M1 AV18
QAC	CH-3200 Ammonia Chiller Output	tons	QAC_TONS D1M1 AV08

On Site Installation

All equipment site supplied – no on-site work needed at this time.

Communications

Internet connectivity shall be provided to the PCS to allow for routine, automated data transfer to Frontier Energy. Data shall be emailed nightly to data_collection@frontierenergy.com.

On Site Support

Frontier Energy will communicate with the site and applicant for access to all areas necessary to verify the monitoring installation, as well as any return trips for verification of sensors or resolve questions with the PCS.

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

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

The CHP system is operated to provide thermal resource for the production of ice, with the resulting electricity production being exported to the utility. During periods of plant downtime, a small amount of power is required to be imported from the utility for various lighting and building circuit loads, and fire suppression system. This imported energy is not metered, however an average annual power will be established from the billing data.

The net electricity production of the CHP system is:

$$WG = WEXP - Utilty\ import\ during\ downtime\ (stipulated\ from\ bills)$$

The plant cannot operate without running the two auxiliary generators, however because that electricity generation is consumed on premises. This auxiliary generator electricity production will not be counted toward the net electricity production of the plant.

Heat Recovery Rates

The heat recovery rates will be calculated by the PCS based on the measurements collected each 1-minute scan interval and integrated into 15-minute data. The fundamental flow and temperature difference data will be used to verify these integrated heat transfer calculations.

The only useful heat load on the main genset jacket water is CH-3000 chiller, therefore useful heat from the main genset jacket water (**QJW**) is defined as:

$$QJW = \sum k \cdot FCHJW \cdot (TCHJWS - TCHJWR) \cdot \frac{N}{60}$$

No heat rejection measurement is available. The main generators will reject heat during startup only.

No heat is recovered from the auxiliary gensets.

"N" is the timestep of the recording interval (e.g., with 15-minute data, N=15). This converts the heat transfer rate calculation to a heat quantity per interval, which is summed to hourly data used on the NYSERDA Integrated Data System website. The heat transfer fluid for the high temperature loop is expected to be a glycol water mixture, which has a k-factor of $488\ \mathrm{Btu/h \cdot gpm \cdot {}^{\circ}F}$ at an operating temperature of 180°F.

Heat transfer to the exhaust driven equipment is based on the overall temperature difference of the exhaust stream across the ammonia chiller and exhaust fired absorption chiller. The exhaust flow sensors are located in the trunks entering both the ammonia chiller (CH-3200) and exhaust fired chiller (CH-3100) combined (FE3) and exiting the ammonia chiller (CH-3200) (FE2).

Flow to the exhaust chiller is therefore defined as:

$$\frac{lb}{h} = FE4 = FE3 - FE2$$

Heat recovery to each chiller can be calculated directly:

$$QEXH_{CH3100} = \sum k \cdot FE4 \cdot (TE2 - TE3) \cdot \frac{N}{60}$$
$$QEXH_{CH3200} = \sum k \cdot FE2 \cdot (TE4 - TE5) \cdot \frac{N}{60}$$
$$QEXH = QEXH_{CH3200} + QEXH_{CH3100}$$

There is no single supply temperature measurement for use with the FE3 combined flow to calculate the exhaust heat recovery in a single calculation.

The k-factor is specific heat of engine combustion products, based on the following table:

Component	**Percent**	**Cp (Btu/lb ° F)**	**Weighted Cp**
N_2	74%	0.250	0.185
CO_2	14%	0.210	0.029
H_20	12%	0.470	0.056
	100%		**0.271**

Each chiller (jacket water, exhaust fired, and ammonia) will provide a capacity value representing the output of the chiller. This is used to provide evidence of beneficial operation of each heat recovery load.

Calculated Quantities – CHP Performance

The fuel conversion efficiency of the CHP system, based on the higher heating value of the fuel, is defined in the NYSERDA CHP Systems Manual 2013 as:

$$FCE = \frac{\frac{QU}{0.8} + 3{,}413 \cdot WG}{HHV_{gas} \cdot FG}$$

Where:

QU	-	Useful heat recovery (Btu) (QJW1 + QJW2 + QEXH)
0.8	-	Nominal boiler efficiency displaced by useful heat
WG	-	Net generator output (kWh)
FG	-	Generator gas consumption (Std CF)
HHV_{gas}	-	Higher heating value for natural gas (~1,030 Btu/CF).