

STAR - sTGC
Gas System and Interlock System
f2f – April 2021

S. Prashanth
for the STAR-BNL Group

Gas system

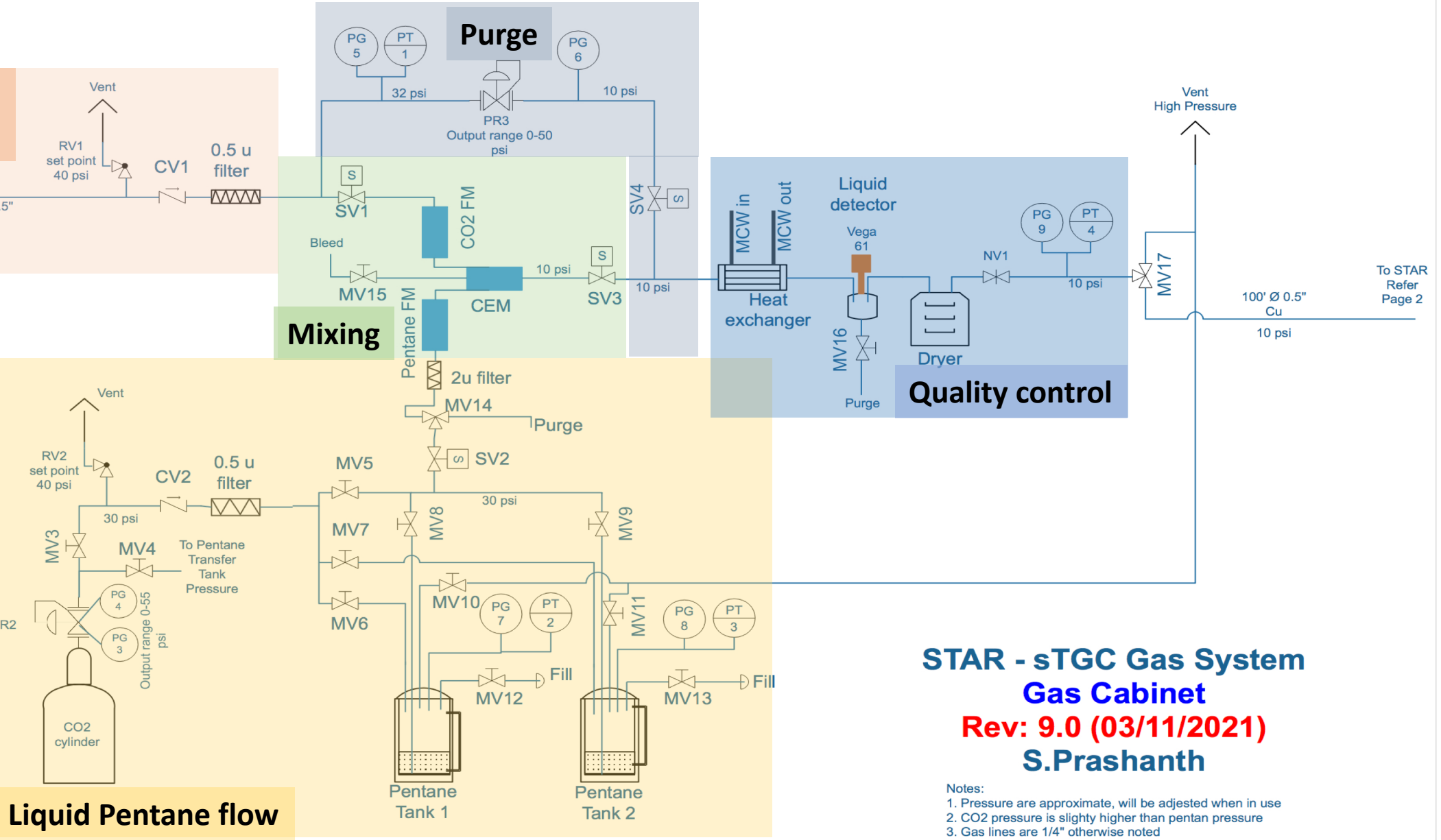
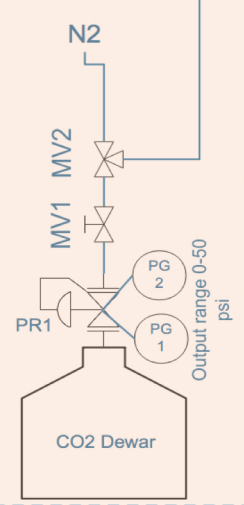
- Gas system consists of three sub-systems
 - **Gas mixing**
 - **Gas delivery, distribution and venting**
 - **Pentane refill system**

Gas mixing system

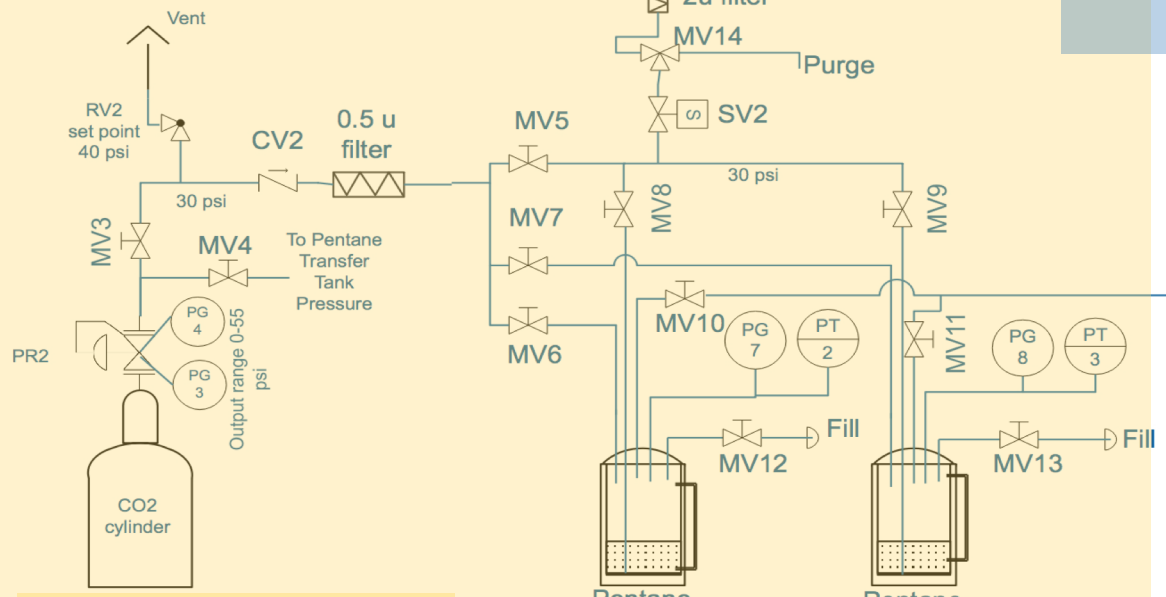
Page 1

CO2 delivery for 55% of mixing

Gas pad



Liquid Pentane flow



**STAR - sTGC Gas System
Gas Cabinet
Rev: 9.0 (03/11/2021)
S.Prashanth**

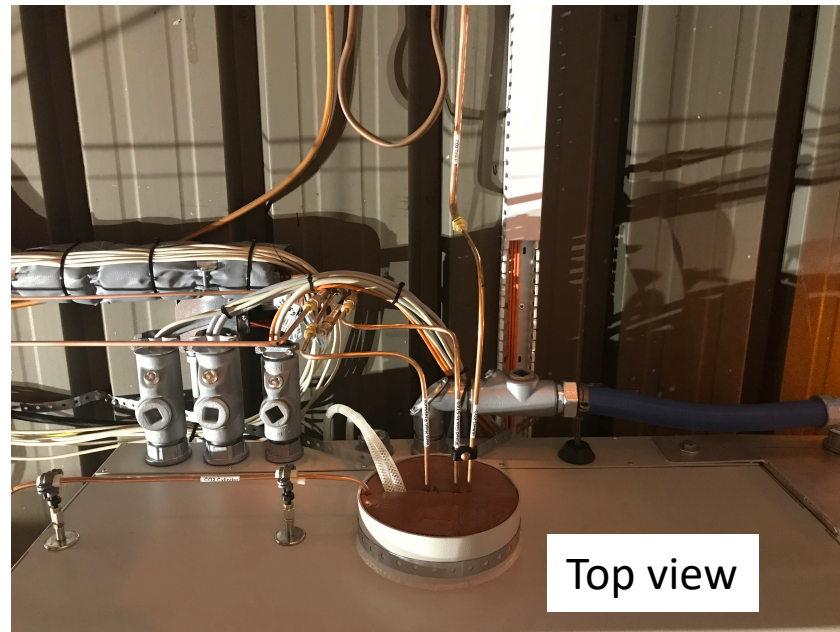
- Notes:
1. Pressure are approximate, will be adjusted when in use
 2. CO2 pressure is slightly higher than pentan pressure
 3. Gas lines are 1/4" otherwise noted
 4. Dewar/Cylinder valves are not shown

To STAR Refer Page 2

Gas cabinet



Controls and indicators in the gas cabinet



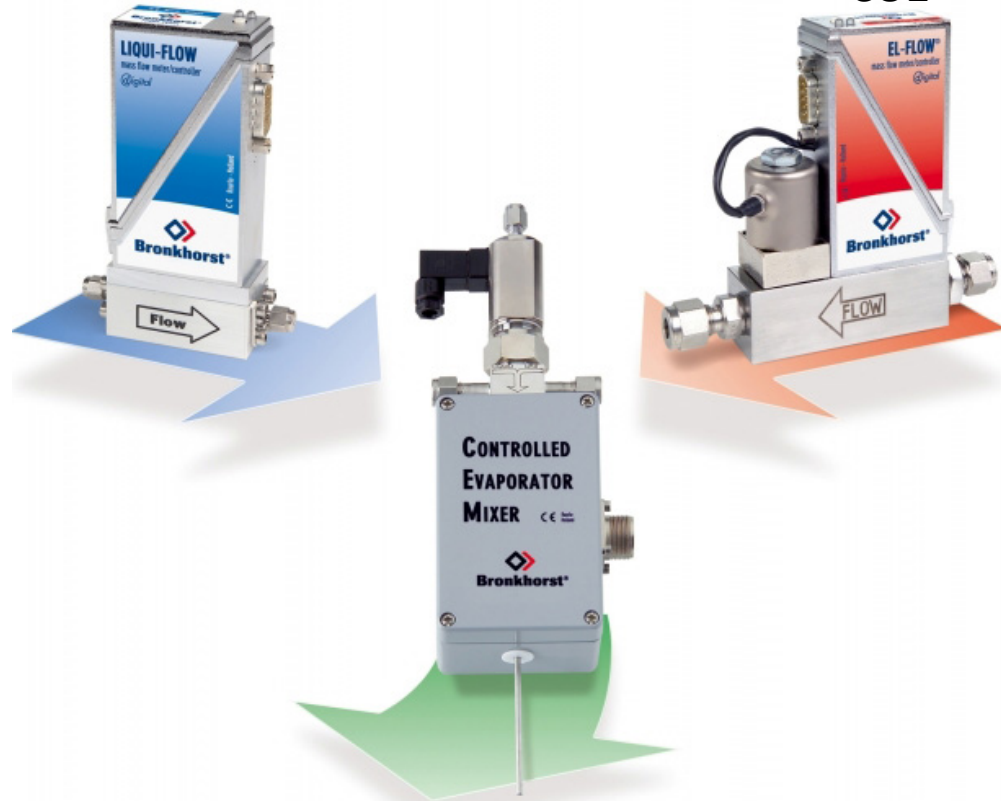
Top view



Bronkhorst gas mixing components

Pentane

CO2



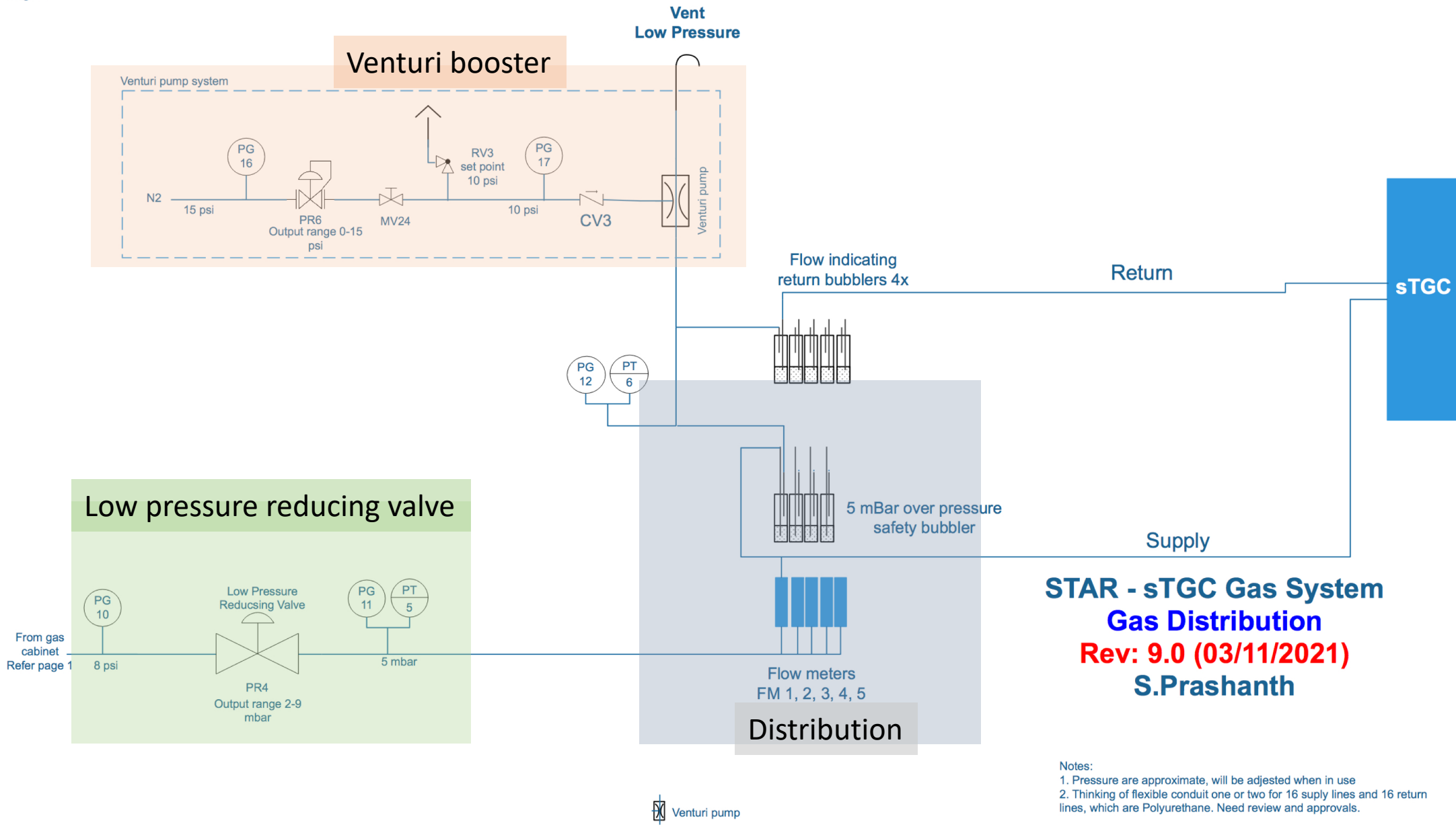
Bronkhorst components assembled in the gas cabinet

Heat Exchanger and MCW



Gas delivery, distribution and venting

Page 2



Briskheat heat tape

- Heated copper lines are wrapped around supply and vent line to prevent pentane to liquify
- Supply line is read via two thermocouples (with two spares) and vent line is read via single thermocouple (one spare)
- Supply line 22 – 40°C
- Vent line is 22 – 40°C
- Temperature range is monitored and interlocked

Your Heating Specialist since 1949

CLOTH HEATERS AND INSULATORS

Silver-Series Cloth Insulators

Silver-Series Insulators are a configurable system of cloth insulators that feature durable high-temperature cloth, 1"-thick needle-punched fiberglass insulation, and hook & loop closures for easy installation and removal. This cost-effective solution improves thermal efficiency for hot and cold pipes, tanks, and vessels in industrial and commercial environments. Custom designs can be manufactured for unique requirements.

Product Highlights

- ✓ Configurable system
- ✓ Easy-to-install
- ✓ Removable and reusable
- ✓ Durable and long service life
- ✓ Economical solution
- ✓ Cut-to-length pipe insulators
- ✓ Moisture and chemical resistant cloth
- ✓ High-temperature
- ✓ Fire-retardant
- ✓ Asbestos-free



Specifications:

- Operating Temperature: Up to 450°F (232°C)
- Cloth: FRC 1650 polymer-coated fiberglass
- Insulation: 1" (25mm) needle-punch fiberglass
- Thermal Performance: R3.3, K0.21@75°F (24°C)

Uses and Applications:


- Self-Regulating Heating Cable
- Constant-Watt Heating Cable
- Heating Tapes
- General Purpose Insulation

1 Quality Construction 2 Cut-to-Length Versatility 3 Improved Thermal Efficiency

XtremeFLEX® BSO-G Grounded Silicone Rubber Heating Tapes

Product Highlights

- ✓ Grounded for your safety
- ✓ Moisture and chemical resistant
- ✓ Exceptional flexibility
- ✓ Rapid thermal response
- ✓ Exceptional durability
- ✓ CE, RoHS, C-UL US compliant


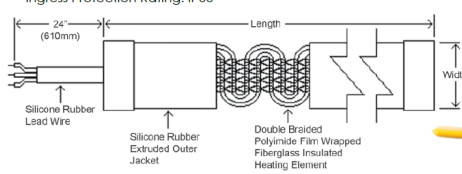


Specifications:

- Maximum exposure temperature: 450°F (232°C)
- Silicone rubber extruded outer sheath
- Polyimide film wrapped fiberglass knitted and braided construction
- Patented grounded heating element
- Minimum Bend Radius: 0.250in (6mm)
- Nominal Thickness: 0.125in (3mm)
- Power density: 4.3 W/in² (0.007 W/mm²)
- Suitable for electrically conductive surfaces
- 120 or 240VAC
- 24" (610mm) lead wire
- Electrical leads same end
- Ingress Protection Rating: IP66

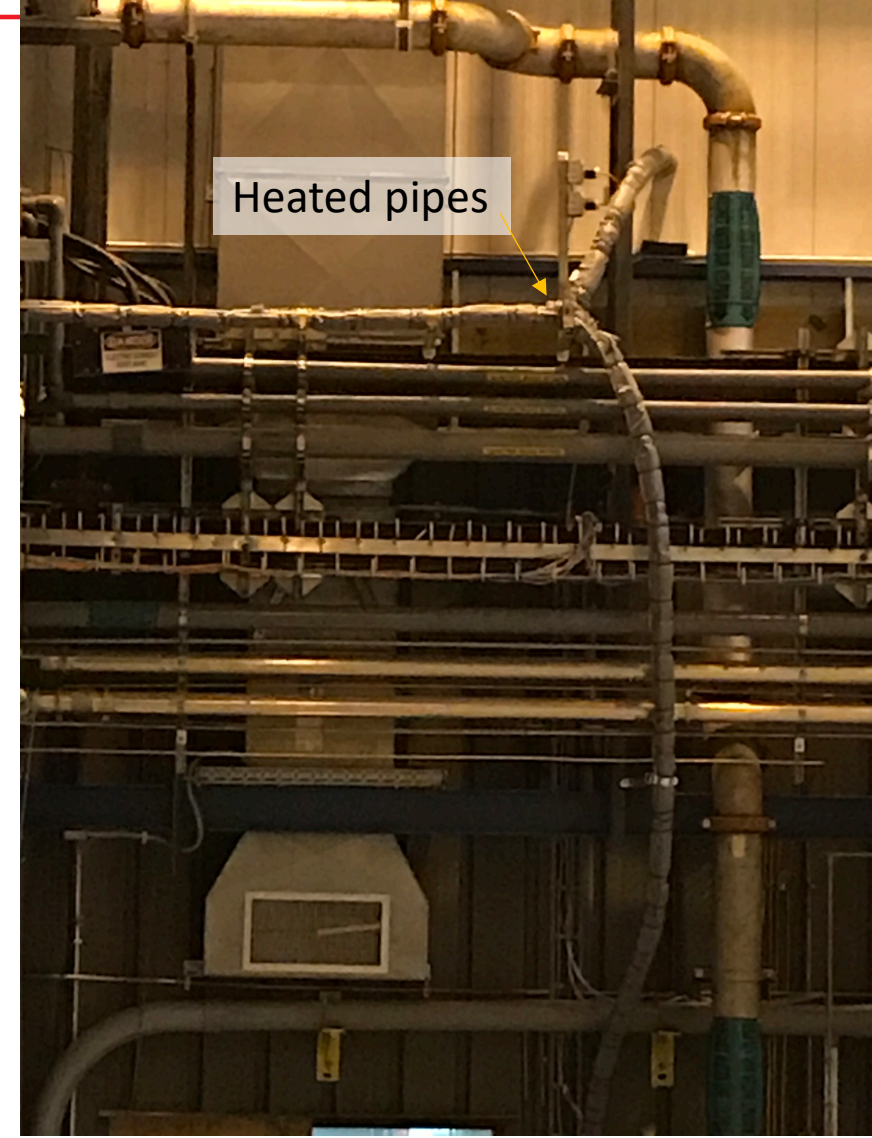
With Ground

Moisture and Chemical Resistant

Ordering Information:

Width	Length	Total	Part No.	Part No.
		



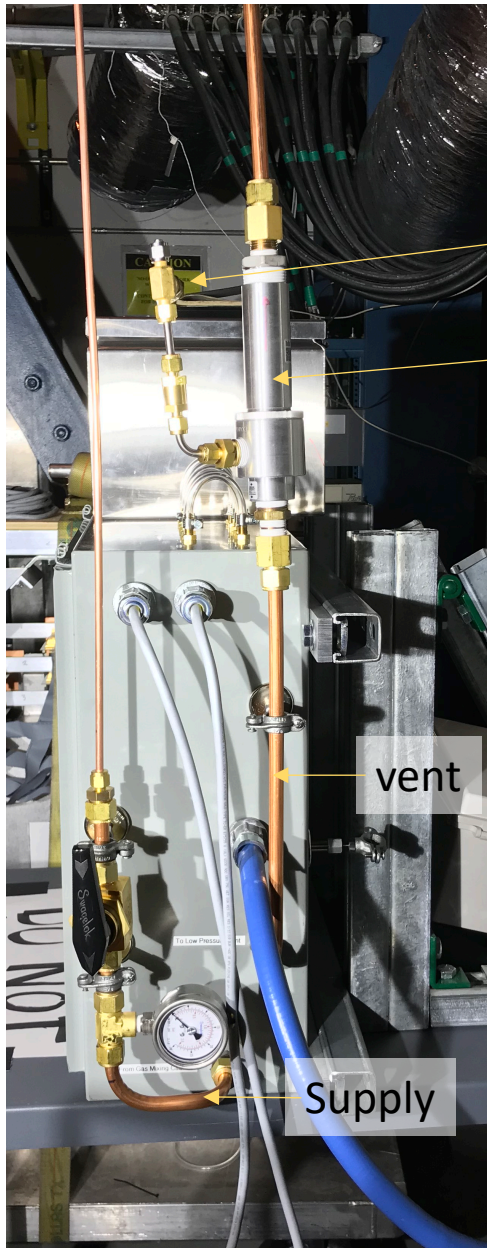
Venting



On the roof of STAR control room

Gas distribution panel

Side view



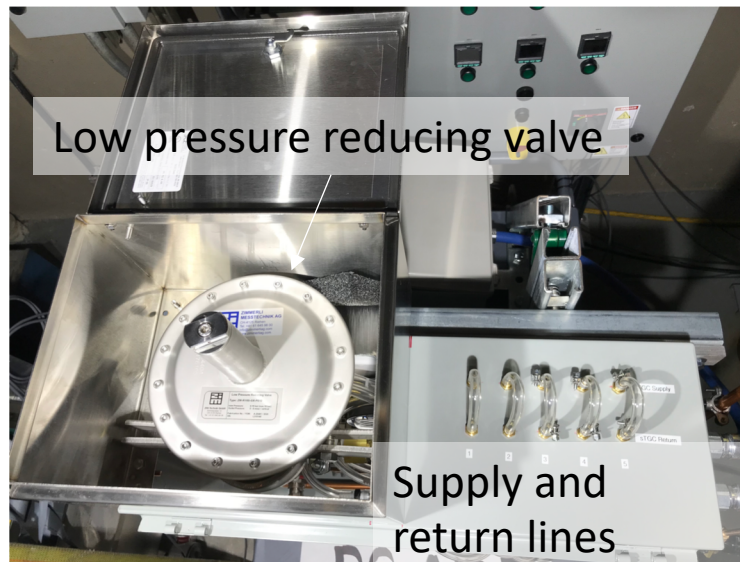
N2 supply for Venturi

Venturi pump

vent

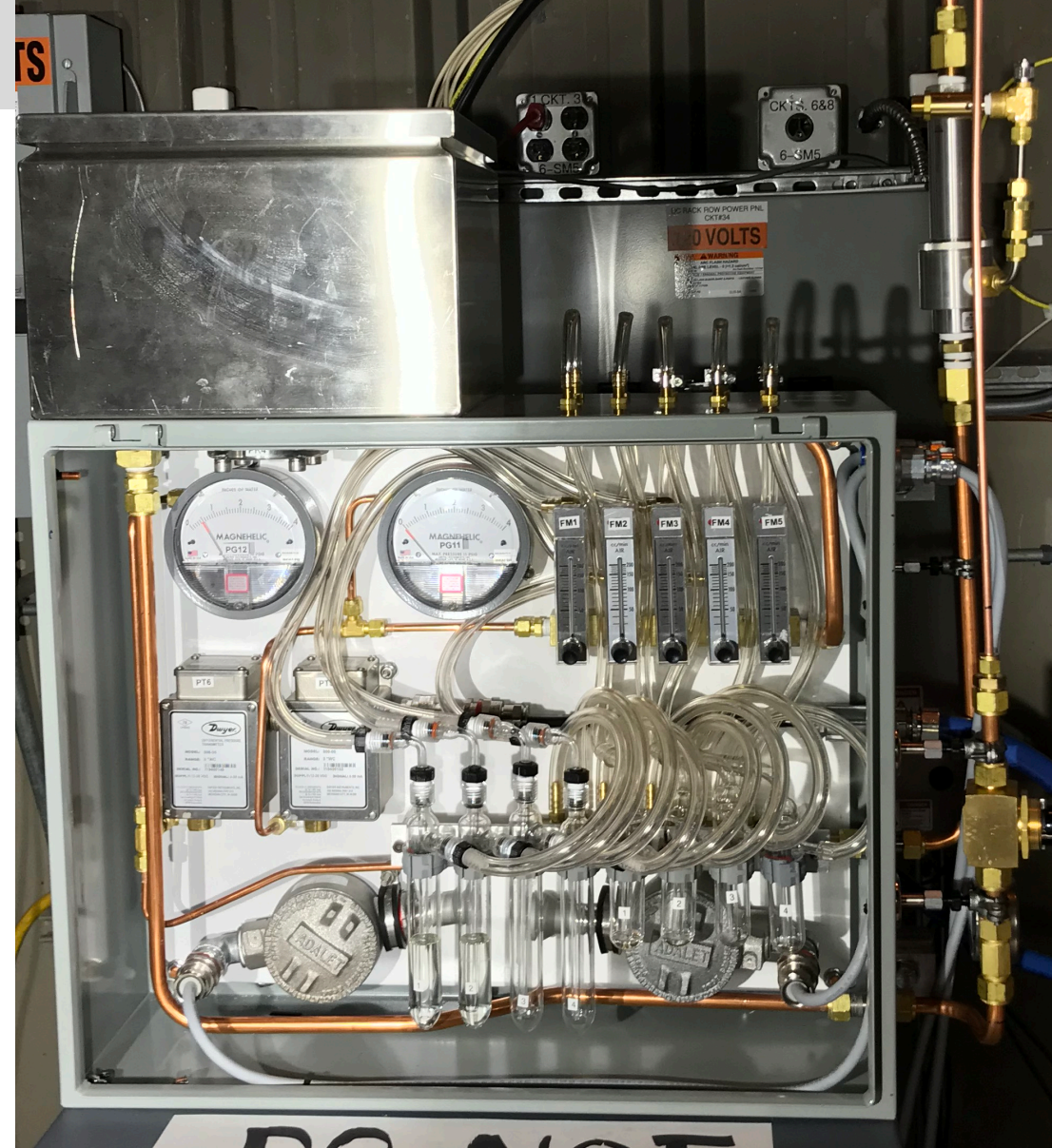
Supply

Top view



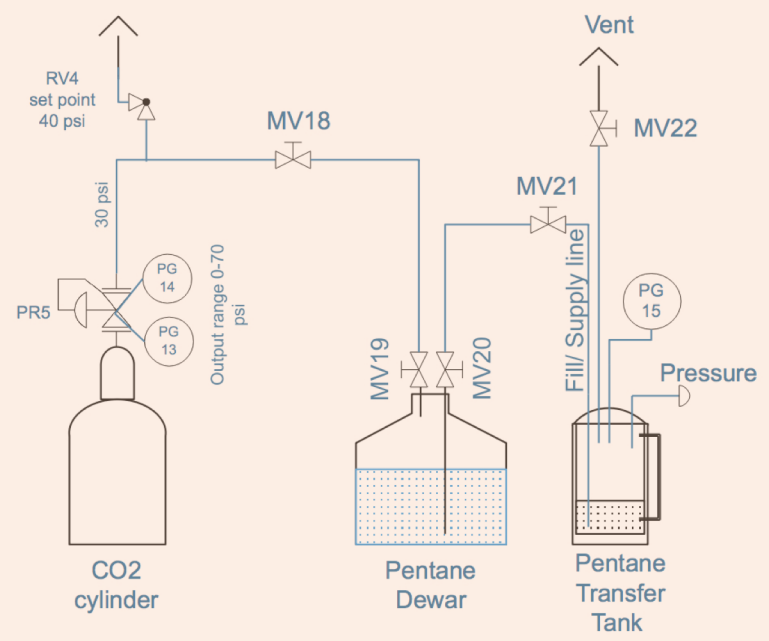
Low pressure reducing valve

Supply and return lines



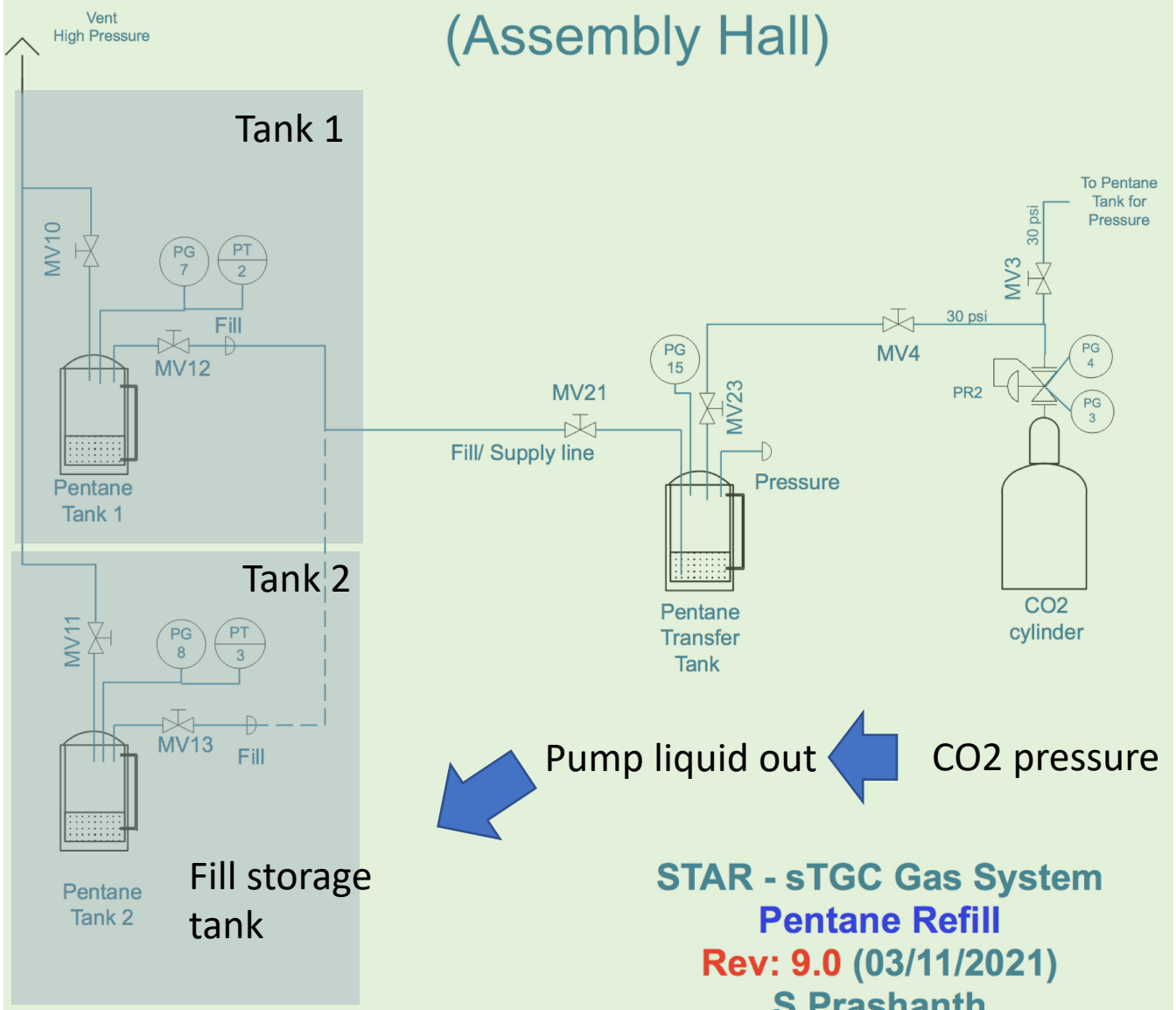
Pentane refill system

Fill Tranfer Tank (Gas Pad)



CO2 pressure → Pump liquid out → Fill transfer tank

Fill Cabinet Tanks (Assembly Hall)



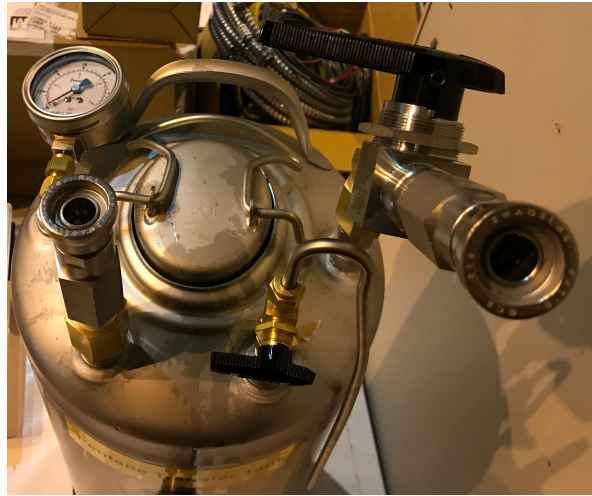
CO2 pressure → Pump liquid out

STAR - sTGC Gas System
Pentane Refill
 Rev: 9.0 (03/11/2021)
 S.Prashanth

Pentane refill system

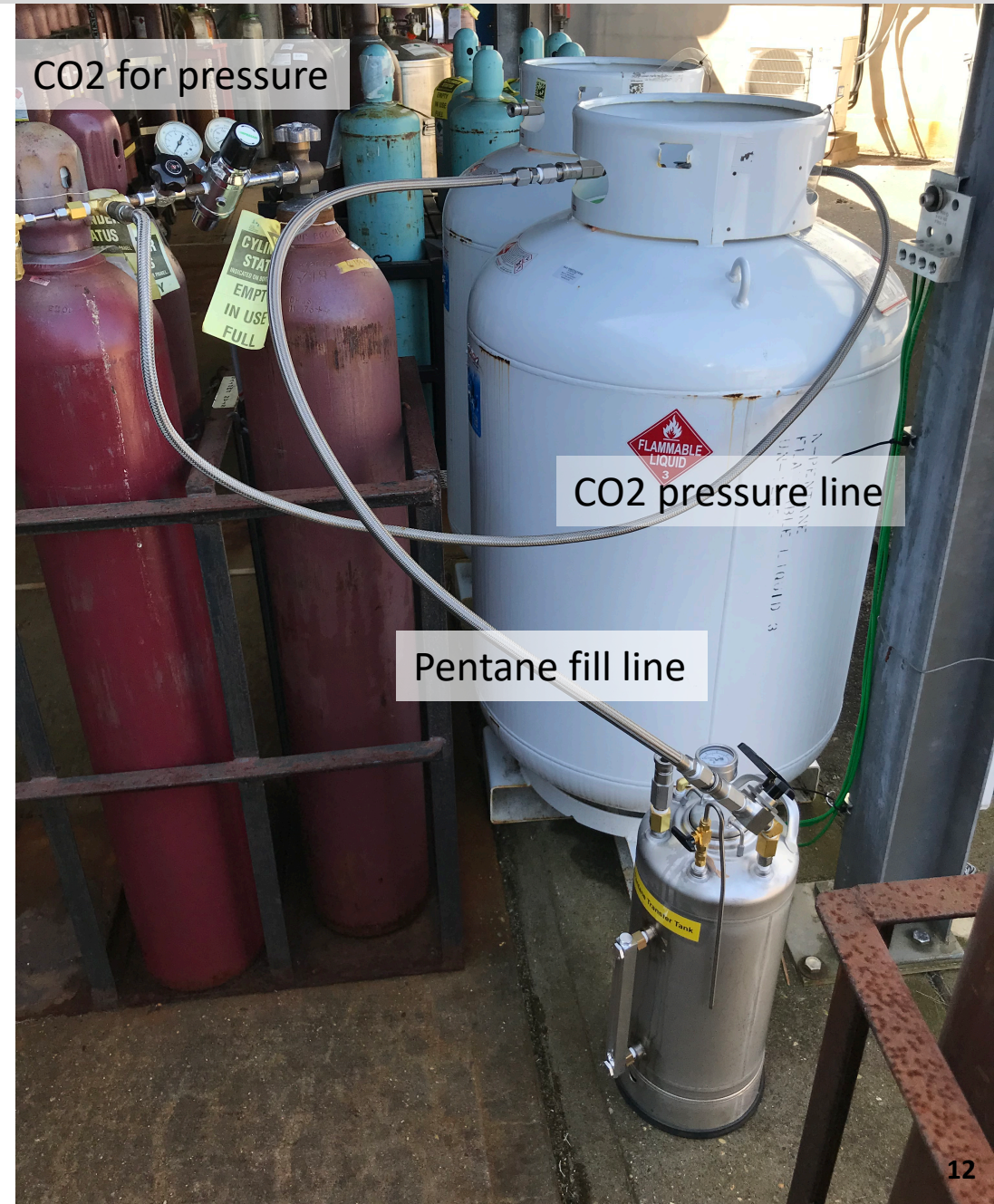


Transfer tank



Top view of transfer tank

Transfer pipe



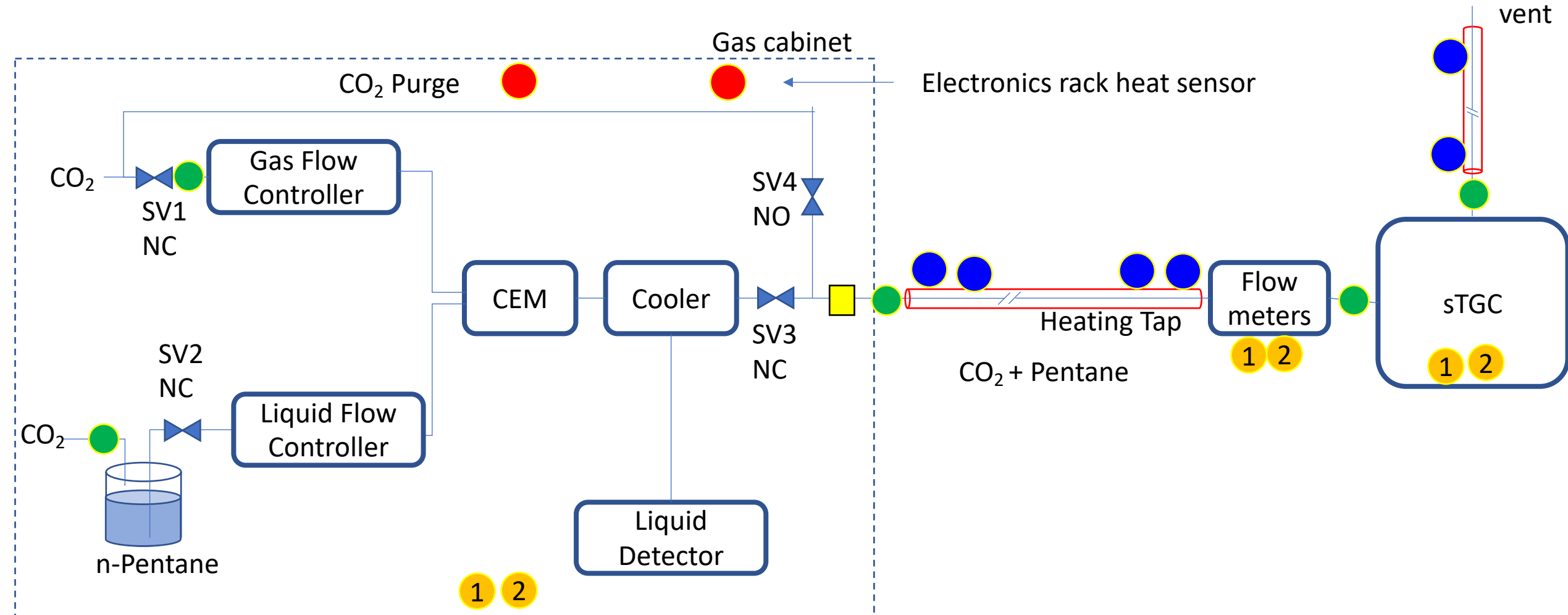
CO2 for pressure

CO2 pressure line

Pentane fill line

System Safety and Interlocks

Location of the safety actuators and sensors



SV – Solenoid valves
 NC – Normally closed
 NO – Normally open

● Pentane Sniffer,
 1 & 2 are independent monitoring
 ● Heat sensor

● Thermocouple
 ● Pressure transmitter

■ Liquid detector

Location of the safety actuators and sensors



- Heat detector
- Pressure relief valves
- Pressure transmitters
- Solenoid valves
- Liquid detector
- Pentane sniffers



- Pressure transmitters
- Pentane sniffers



Prototype pentane sniffers

Solenoid valve operation - I

- Solenoid valves have 3 modes of operation
- **Purge mode**
 - This mode isolates the pentane
 - CO2 flow for purging the gas lines outside the cabinet, detectors and vent
 - During most of the alarms and summer shutdown
- **Mixing mode**
 - Valves enables gas mixing
- **No-Flow mode**
 - No flow of any gas
 - All valves closed
 - Not safe for the detectors for long running
 - In case low pressure reducing valve fails and detector sees inlet pressure high
 - In addition there are safety bubblers
 - Provides redundancy to avoid over pressuring the sTGC chambers

Solenoid valves



List of alarms - I

Type	Message	Comments	Safety action delay	
1	Pentane leak detected	Pentane leak detected in the gas cabinet (1)	(1) and (4) are redundant pentane sniffers in the gas cabinet	In 1.5 min to purge
		Pentane leak detected in the gas cabinet (4)		In 1.5 min to purge
		Pentane leak detected in the gas distribution cabinet (2)	(2) and (5) are redundant pentane sniffers in the gas distribution cabinet	In 1.5 min to purge
		Pentane leak detected in the gas distribution cabinet (5)		In 1.5 min to purge
		Pentane leak detected near sTGC chambers (3)	(3) and (6) are redundant pentane sniffers near sTGC chambers	In 1.5 min to purge
		Pentane leak detected near sTGC chambers (6)		In 1.5 min to purge
		Gas sniffer controller 1 failed	Pentane sniffers 1, 2, 3 are connected to controller 1. If the controller fails, this alarm activates	In 10 min to purge
		Gas sniffer controller 2 failed	Pentane sniffers 4, 5, 6 are connected to controller 2. If the controller fails, this alarm activates	In 10 min to purge
2	Liquid present after mixing	Pentane liquid present after mixing	If the CEM not functioning properly or the temperature is not set correct, liquid pentane will be in the mixed gas. About 15 ml of accumulated pentane in LD chamber can trigger this alarm	In 1.5 min to purge
		Liquid detector malfunction (<4mA)	If the LD is not functioning properly the current from LD will be less than 4 mA	In 10 min to purge
3	Heat Detections	Heat/Fire detected in the gas cabinet		In 1.5 min to purge
		Heat detector faulted in the gas cabinet	Heat detector SWAM dry contact faulted	In 10 min to purge
		Heat/Fire detected in the controls cabinet	Power for the controls cabinet dropped. No alarms generated from sTGC interlocks.	Immediate purge
4	Heat tape	Temperature at location x reads high	x= 1,2,3,4,5,6 Upper limit for supply = xx °C Upper limit for vent = xx °C	In 5 min to purge
		Temperature at location x reads low	x= 1,2,3,4,5,6 Lower limit for supply = xx °C Lower limit for vent = xx °C	In 5 min to purge

Pentane leak alarms

Pentane not evaporated after mixing alarms

Heat/fire alarms

Supply/vent pipe heating issues

List of alarms - II

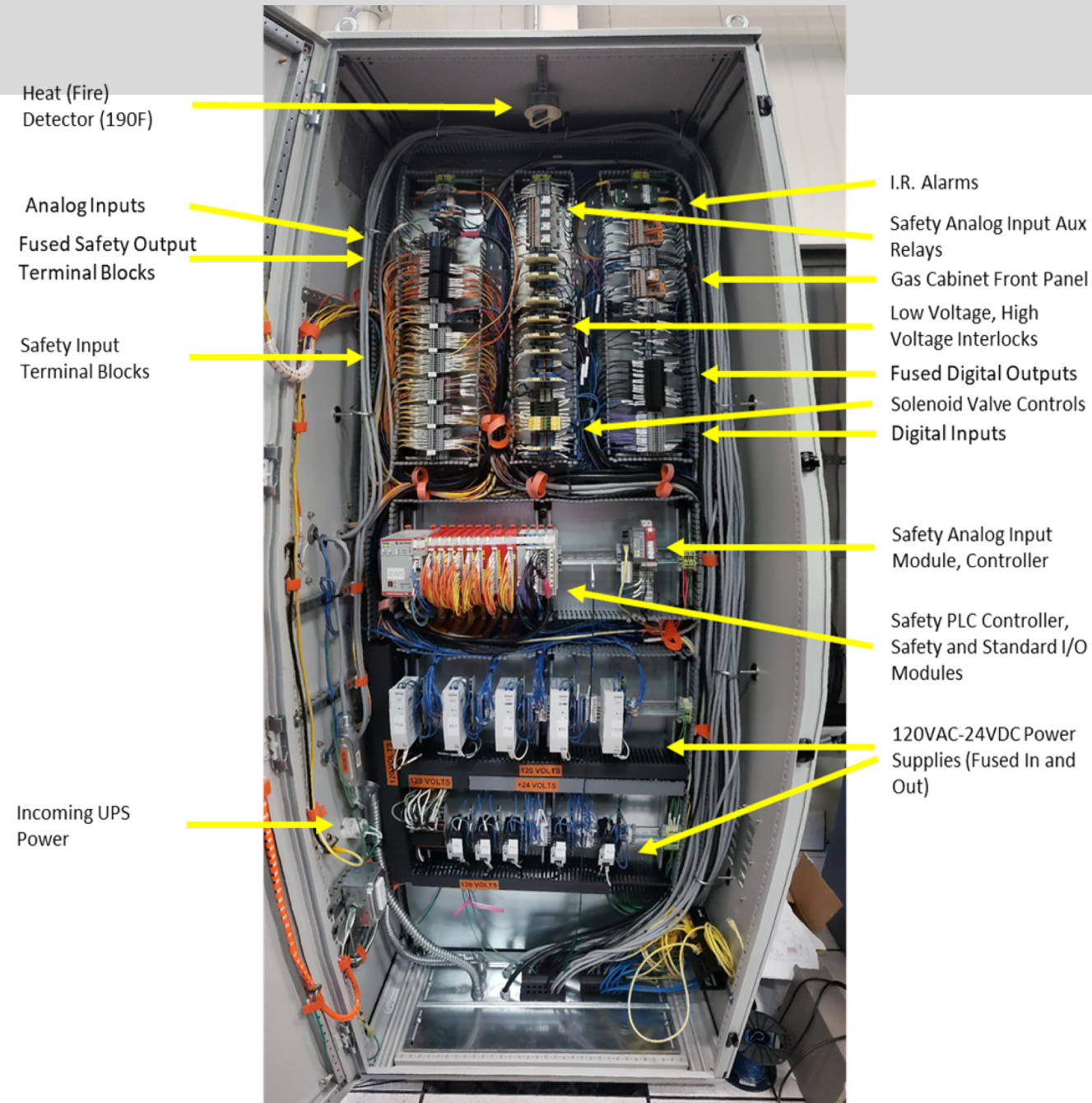
Type	Message	Comments	Safety action delay		
5	Pressure	PTx has a fault (sensor or isolator)	x= 1,2,3,4,5,6 Sensor fault current < 4mA Or the intrinsic safety isolator is failed	Only sensor 5 is in the safety logic for high pressure. In 30 sec to No-flow	Pressure alarms
		PTx pressure high Or PTx pressure low	30 < PT1 < 34 (psi) 28 < PT2 < 32 (psi) 28 < PT3 < 32 (psi) 1 < PT4 < 15 (psi) 1 < PT5 < 10 (mbar) 0 < PT6 < 10 (mbar)	Only sensor 5 is in the safety logic for high pressure. In 5 sec to No-flow	
6	High Voltage	HV enable power fail to turn on	Safety relay is not closed	No safety action	HV/LV control alarms
		HV enable power fail to turn off	Safety relay is not opened		
		HV module x fails to turn on	Safety relay is not closed		
		HV module x fails to turn off	Safety relay is not opened		
7	Low Voltage	LV enable power fail to turn on	Safety relay is not closed	No safety action	HV/LV control alarms
		LV enable power fail to turn off	Safety relay is not opened		
		LV module x fails to turn on	Safety relay is not closed		
		LV module x fails to turn off	Safety relay is not opened		
8	Solenoid Valves	Mix valves fault	Valve status is checked using safety relay	In 1 min to purge	Solenoid valves control alarms
		Purge valves fault		In 10 sec to purge	
		No-flow valves fault		In 1 sec to No-flow	

State table for interlock testing

Status During Interlock		sTGC Purge		sTGC No Flow		sTGC LV Permissive		sTGC HV Permissive		UPS Power for Control Cabinet		Audible & Visible Alarm	
		Mixing	Mixing	Enable	Enable	On	Off						
1	Normal status												
Interlocks													
Fire/Heat Detection													
2	Heat in gas cabinet	X		X	X							X	
3	Heat in electronic cabinet	X		X	X			X					
Pentane Gas Leak Detection													
4	15% of LEL in pentane sniffer 1 - Gas cabinet	X		X	X							X	
5	15% of LEL in pentane sniffer 1 - Flow meters	X		X	X							X	
6	15% of LEL in pentane sniffer 1- sTGC chambers	X		X	X							X	
7	15% of LEL in pentane sniffer 2 - Gas cabinet	X		X	X							X	
8	15% of LEL in pentane sniffer 2 - Flow meters	X		X	X							X	
9	15% of LEL in pentane sniffer 2 - sTGC chambers	X		X	X							X	
10	Pentane sniffer 1 malfunction w/5 min delay	X		X	X							X	
11	Pentane sniffer 2 malfunction w/5 min delay	X		X	X							X	
Gas mixing and Delivery													
12	Liquid pentane present after mixing	X		X	X							X	
13	Supply line heat tap -LOW/HIGH	X		X	X							X	
14	Vent line heat tap -LOW/HIGH	X		X	X							X	
Pressure													
15	sTGC Supply over pressure (PT5)		X	X	X							X	
STAR global interlock (SGIS)													
16	From SGIS	Appropriate action to be determined, not implemented for Run21											
17	To SGIS	Appropriate action to be determined, not implemented for Run21											

Controls cabinet

- The equipment was planned and built to be in compliance with the 2017 National Electric Code, as well as Brookhaven's electrical standards
- All equipment that is in contact with n-Pentane or inside the gas cabinet is either part of
 - an engineered system (Bronkhorst gas mixing equipment)
 - is wired to a Class 1 Division 2 wiring standard for potentially explosive atmospheres, a standard which exceeds the requirements issued by BNL Fire Protection Engineering
- Intrinsically Safe equipment were used for pressure transducers and heat detectors
 - These devices are incapable of providing enough energy to ignite flammable vapors or liquids even if shorted
- The system has been inspected by C-AD EEI/EMI Inspector Dennis Donaldson prior to powering up
- Powered by UPS
 - UPS is interlocked to fire detector in the cabinet



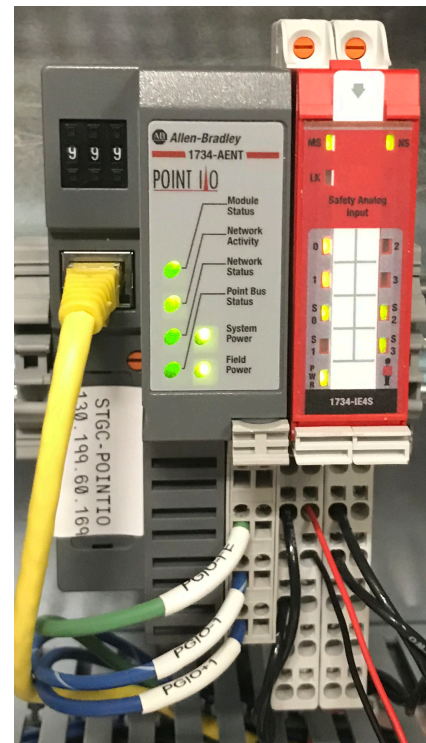
PLC and Modules

- Compact GuardLogix 5380
 - Safety PLC
 - SIL2/PLd certification
- Safety input module - 5069-IB8S
 - 8...32V DC 8-point, safety sinking input module
 - SIL2
- Safety analog input module 1734-IE4S
 - AB Point I/O System - a 1734-AENT Field expandable I/O Adapter with a 1734-IE4S
 - Configured for 4-20 mA life zero transducers
- Standard analog input - 5069-IF8
 - For pressure transmitters
- Safety output module - 5069-OBV8S
 - For solenoid valves and HV
 - SIL2
- Standard output module - 5069-OX4I
 - For alarms and sirens
- HMI (Human Machine Interface)- PanelView 5310, 9"



PLC and modules

Safety analog input module



Interlock user interface – Home screen

This screenshot shows the Home screen of the Interlock user interface. The top navigation bar includes tabs for Home, Active Alarms, Bypass, Pressure, and Alarm History. The main display area shows a schematic diagram of the system with various components like solenoid valves (SV1, SV2, SV3, SV4), pressure transmitters (PT1-PT5), and flowmeters. A large blue box labeled 'sTGC' is visible on the right. At the bottom, there are four large circular buttons: Start Mixing (green), Start Purging (blue), Stop Flow (yellow), and Alarm Silence (red). A legend at the bottom left identifies alarm icons for Heat tape temperature, Liquid level alarm, Heat detected, and Gas leak detected. A 'Login button' is indicated at the top right, and a 'Login required' message is shown at the bottom.

Labels and annotations:

- Screen tabs: Home, Active Alarms, Bypass, Pressure, Alarm History
- Message window: Valves Purging
- Solenoid valves: Blue closed, Green opened
- Alarm icons: Heat tape temperature, Liquid level alarm, Heat detected, Gas leak detected
- User buttons: Start Mixing, Start Purging, Stop Flow, Alarm Silence
- High/low voltage permissive indicator: HV, LV
- Pressure transmitter reading: 35 (8 PSI)
- Login button
- Login required

This screenshot shows the Home screen in a 'Valves Mixing' state. The top navigation bar is the same. The main display area shows the same schematic diagram. A large red box labeled 'sTGC' is visible on the right. At the bottom, the four large circular buttons are present. A legend at the bottom left identifies alarm icons. A 'Heat alarm is active' message is shown in the top right. A 'Mixing button is disabled' message is shown at the bottom right. A 'Time to purge 1:22' is displayed in red text.

Labels and annotations:

- Heat alarm is active
- Mixing button is disabled
- Valves Mixing
- Alarm(s) Active
- Time to purge 1:22
- High/low voltage permissive indicator: HV, LV

This screenshot shows the Home screen in a 'Please wait, Valves changing state...' state. The top navigation bar is the same. The main display area shows the same schematic diagram. A large blue box labeled 'sTGC' is visible on the right. At the bottom, the four large circular buttons are present. A legend at the bottom left identifies alarm icons. A 'Busy indicator' is shown as a green circle with the number '35' in the center of the schematic.

Labels and annotations:

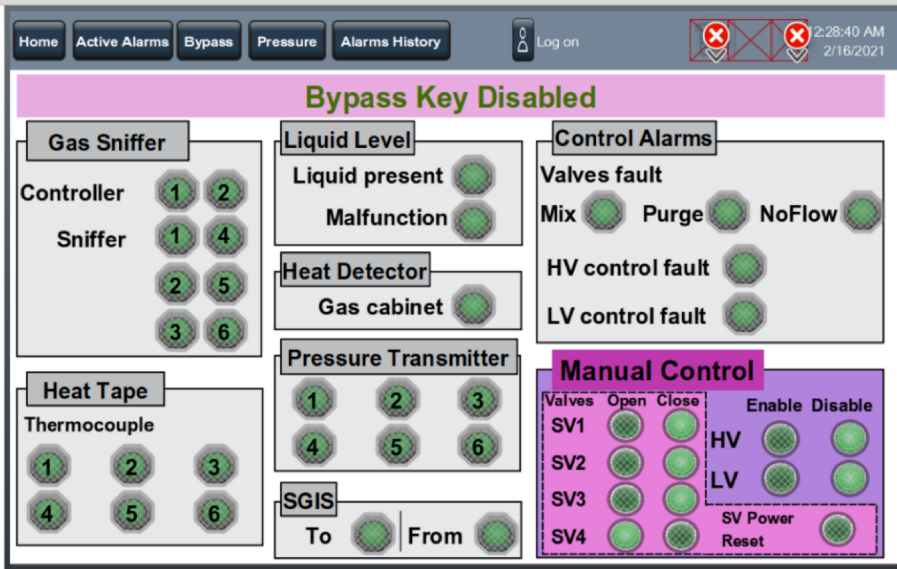
- Valves changing state from purging to mixing
- Busy indicator
- Please wait, Valves changing state...
- Buttons are disabled, while changing state

This screenshot shows the Home screen in a 'Valves Purging' state with bypassed alarms. The top navigation bar is the same. The main display area shows the same schematic diagram. A large blue box labeled 'sTGC' is visible on the right. At the bottom, the four large circular buttons are present. A legend at the bottom left identifies alarm icons. A 'One or more alarms are bypassed' message is shown in red text.

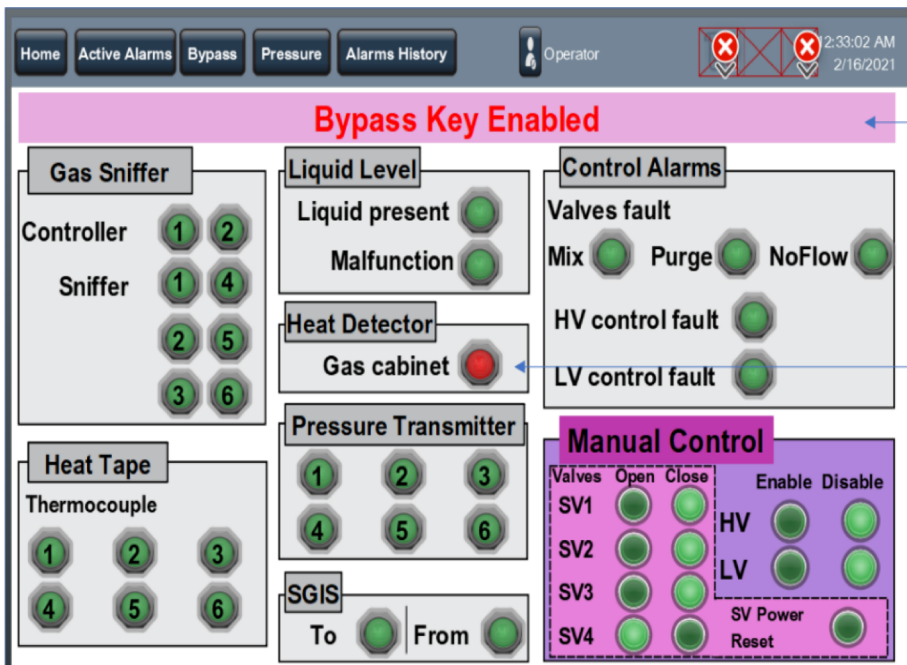
Labels and annotations:

- Valves Purging
- Alarm(s) Active
- One or more alarms are bypassed

Interlock user interface – Bypass screen



- Bypass is disabled
- Login and key is required for bypass operation



Bypass is enabled

Heat/fire in the gas cabinet alarm is bypassed

Manual control for solenoid valves and enable/disable the HV/LV permissive



Interlock user interface – Alarms/History/Pressure

Home Active Alarms Bypass Pressure Alarm History Operator 2:54:05 AM 2/15/2021

Event Time	Message
1/31/1998 06:56:24 AM	LV_OFF_fault_N
1/31/1998 06:56:24 AM	LV_OFF_fault_N
1/31/1998 06:56:24 AM	LV_OFF_fault_N
1/31/1998 06:56:24 AM	LV_OFF_fault_N
1/31/1998 06:54:54 AM	Heat/fire detected in the gas cabinet.

Active alarms window

Event time of the alarm

Alarm message

Home Active Alarms Bypass Pressure Alarm History Operator 2:39:23 AM 2/15/2021

PT1 (psi) PT4 (mBAR)

PT2 (psi) PT5 (psi)

PT3 (psi) PT6 (mBAR)

Pressure reading window

Home Active Alarms Bypass Pressure Alarm History Operator 2:38:48 AM 2/15/2021

Event Time	Message
1/31/1998 06:37:54 AM	Fault when closing all valves for no flow.
1/31/1998 06:37:53 AM	Fault when closing all valves for no flow.
1/31/1998 06:37:42 AM	Fault when closing all valves for no flow.
1/31/1998 06:36:28 AM	PT6 has a fault (sensor or isolator)
1/31/1998 06:36:16 AM	PT5 has a fault (sensor or isolator)
1/31/1998 06:36:02 AM	PT4 has a fault (sensor or isolator)
1/31/1998 06:35:46 AM	PT3 has a fault (sensor or isolator)
1/31/1998 06:35:43 AM	PT2 has a fault (sensor or isolator)

Alarms history window

Time when the alarm disappeared

Time when the alarm is created

Switches, Sirens and Strobes

Controls cabinet



Control room



In the experiment



Gas cabinet



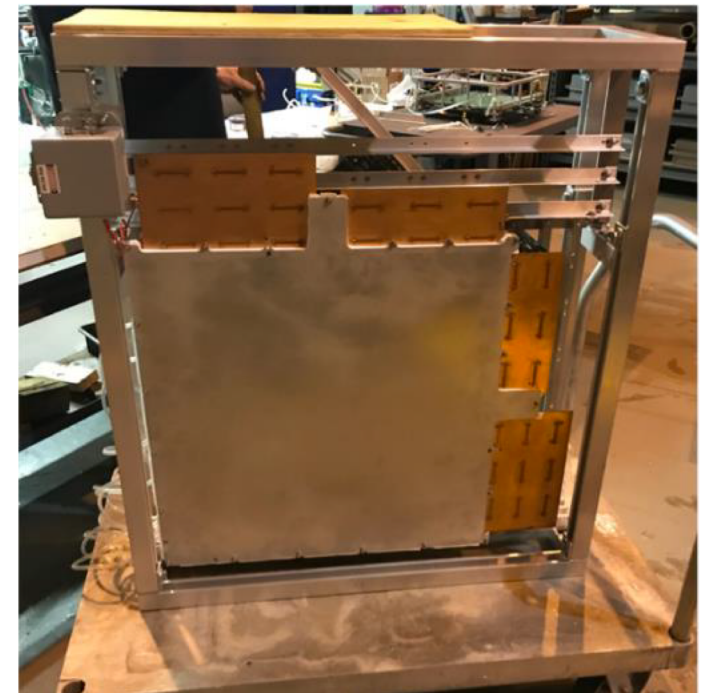
Prototype assembly

Test plan for gas and interlock system in the STAR assembly hall (Run21)

Final installation in the STAR west platform (Run21)

Prototype assembly for Run21

- 60 by 60 cm prototype for run 21
- Mounted to a frame with chamber to collect gas if there is any leak
- Two pentane sniffers are placed inside the chambers for sniffing any gas leak
- One of the chamber is leaking, will not be used
- One ROB (RDO) and FEB (FEE card) will be used
 - Rest are TPX electronics
- Goals for Run21:
 - Evaluate the gas system
 - Evaluate new electronics and DAQ
 - Slow controls, monitoring plots, trips,...

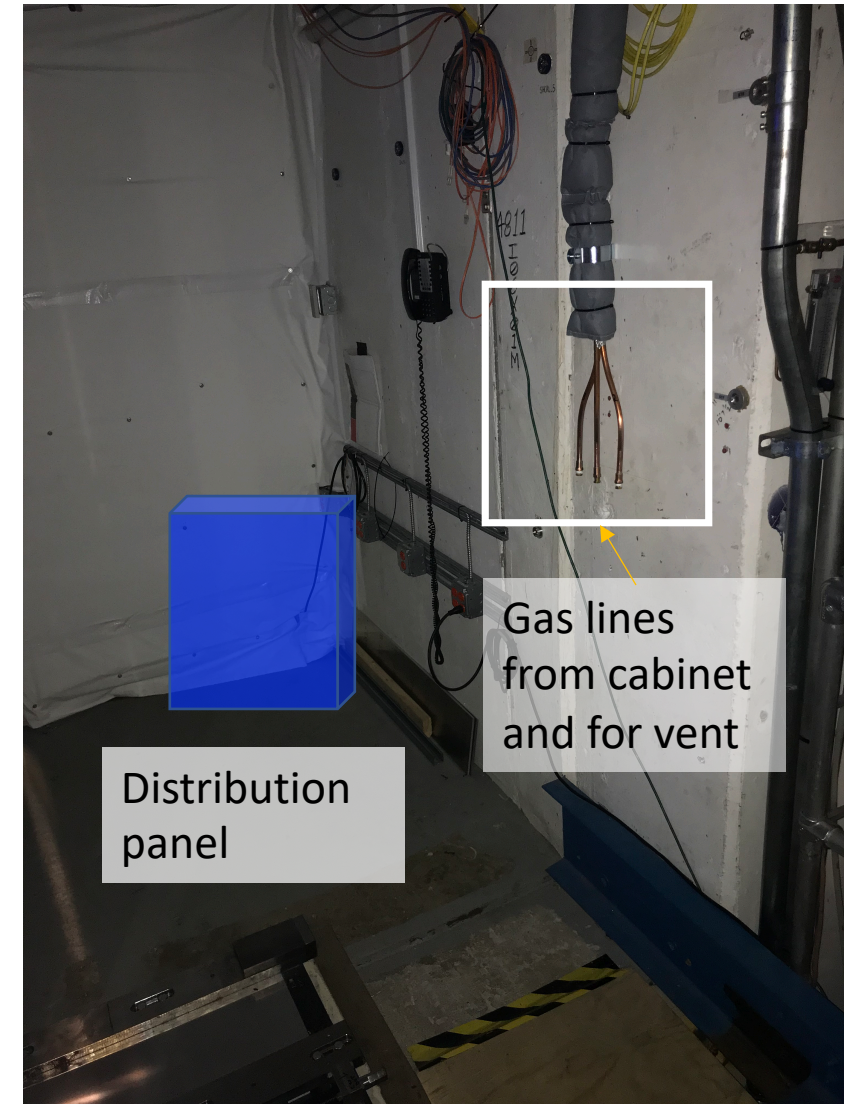


Testing in the assembly hall

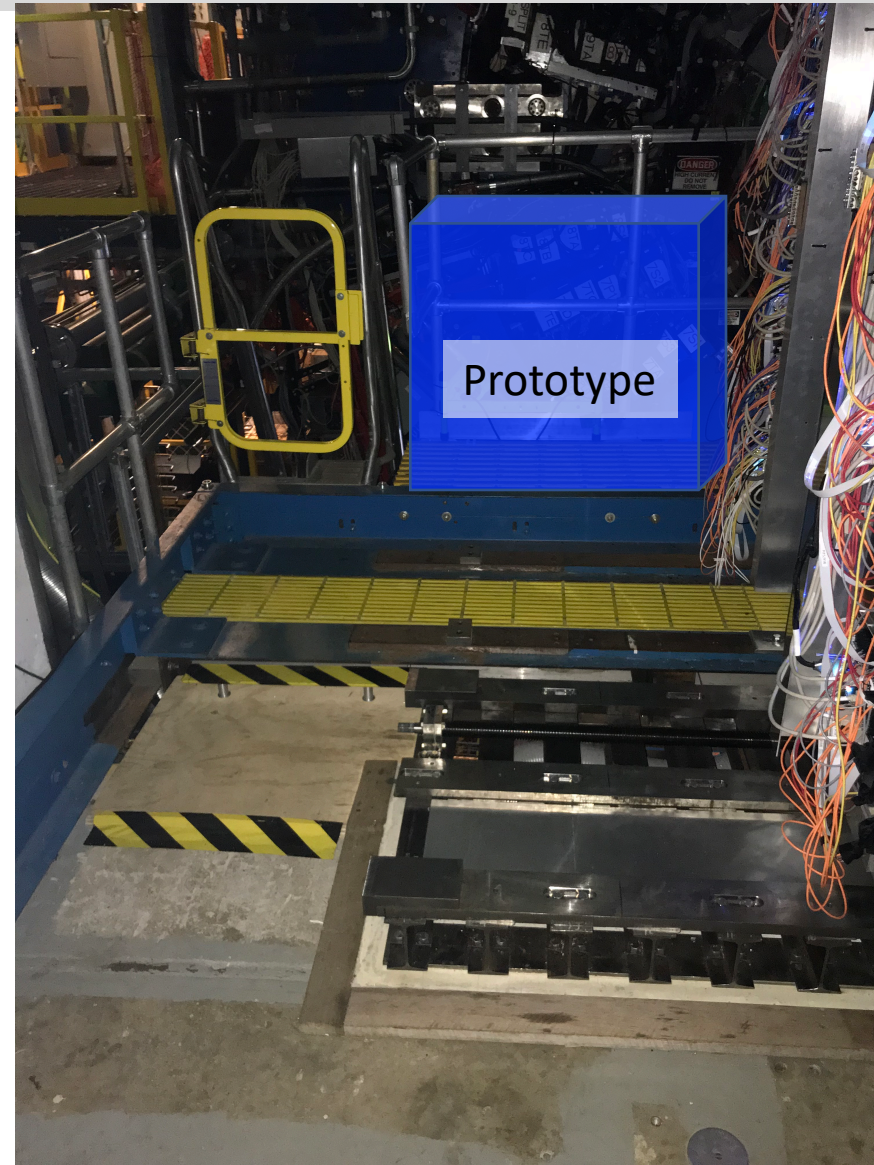
- Gas cabinet and interlock cabinet are in the permanent location
- Prototype and the gas distribution panel are temporarily placed in the assembly hall
 - Temporary wiring for all the electronics and gas lines for prototype and the gas distribution panel
 - Venting to atmosphere outside
- Since most of the time STAR experimental hall is closed, full setup outside allows to test the gas system and interlocks without need of an access
- Easy for the reviewers and for the safety walk through for system outside the hall
- 100 % supervised by system expert when pentane is used



Installation in the west platform



North-west platform



Procedures and Documentation

- Written procedures available to operate the gas system and the interlock system
- Documents, manuals and schematics
 - Gas system operation manual
 - Interlock system operation manual
 - Leak test documentation
 - Schematics of interlock and electrical wiring
 - Schematics of the gas system