Lessons Learned using a PLC for Process Control

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NIST Center for Neutron Research

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Lessons Learned using a PLC for Process System Control

Introduction to NIST NCNR Cold Source

PLC control of the Cold Neutron Source

Basic understanding of PLC Data Input and Output

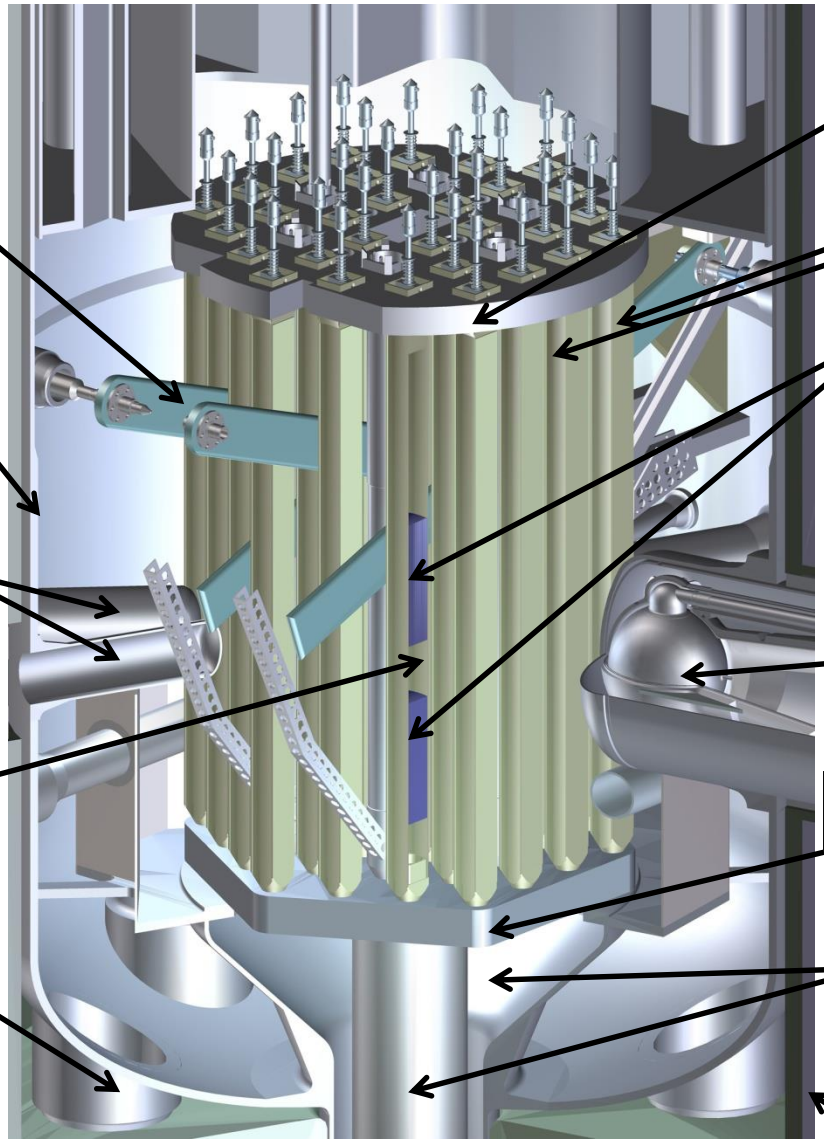
Reactor Rundown Associated with Cold Neutron Source

Regulatory Issue Summary 2016-05, Embedded Digital Devices

Communication Fault

Software Common Cause Failure

Cut-away View of the NBSR Core



Cd Shim Safety Arms (4)

Reactor Vessel

Radial Beam Tubes (9)

18-cm Unfueled Gap – Flux Trap

Primary Outlet (2)

Top Grid Plate

Fuel Elements (30)

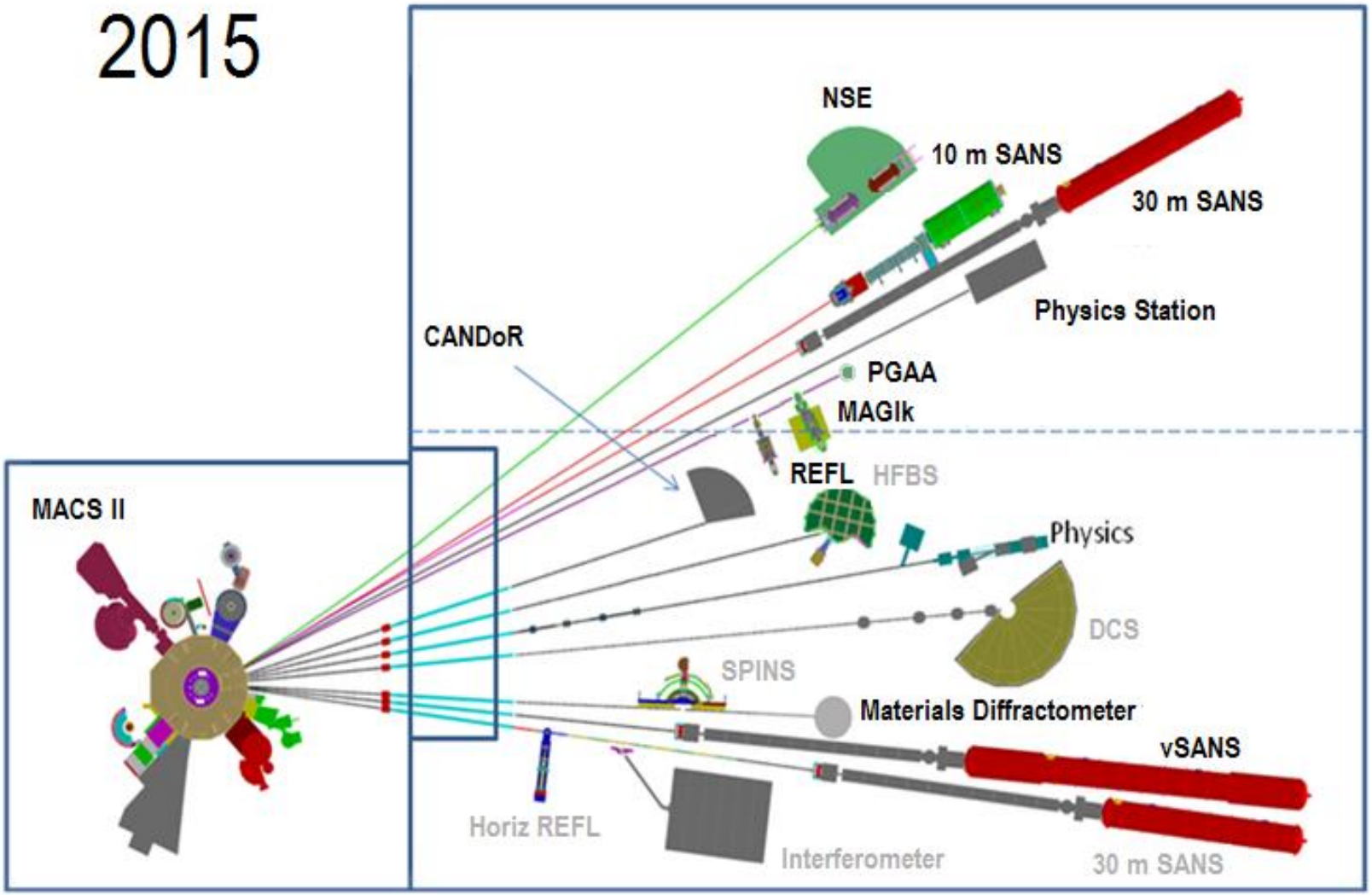
Fuel Plates

Liquid Hydrogen Cold Neutron Source

Bottom Grid Plate

D_2O Primary Inlet Plenums

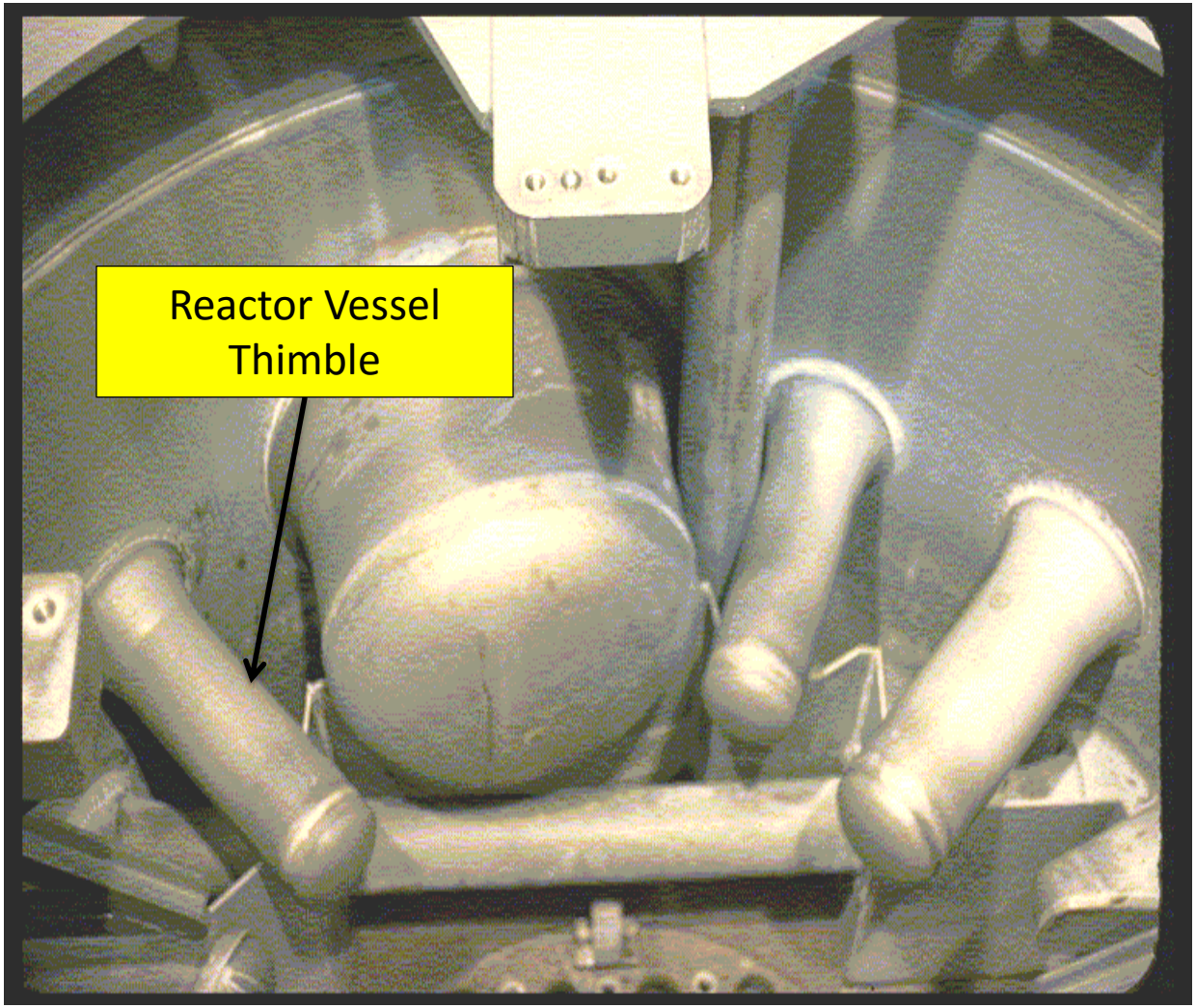
Thermal Shield



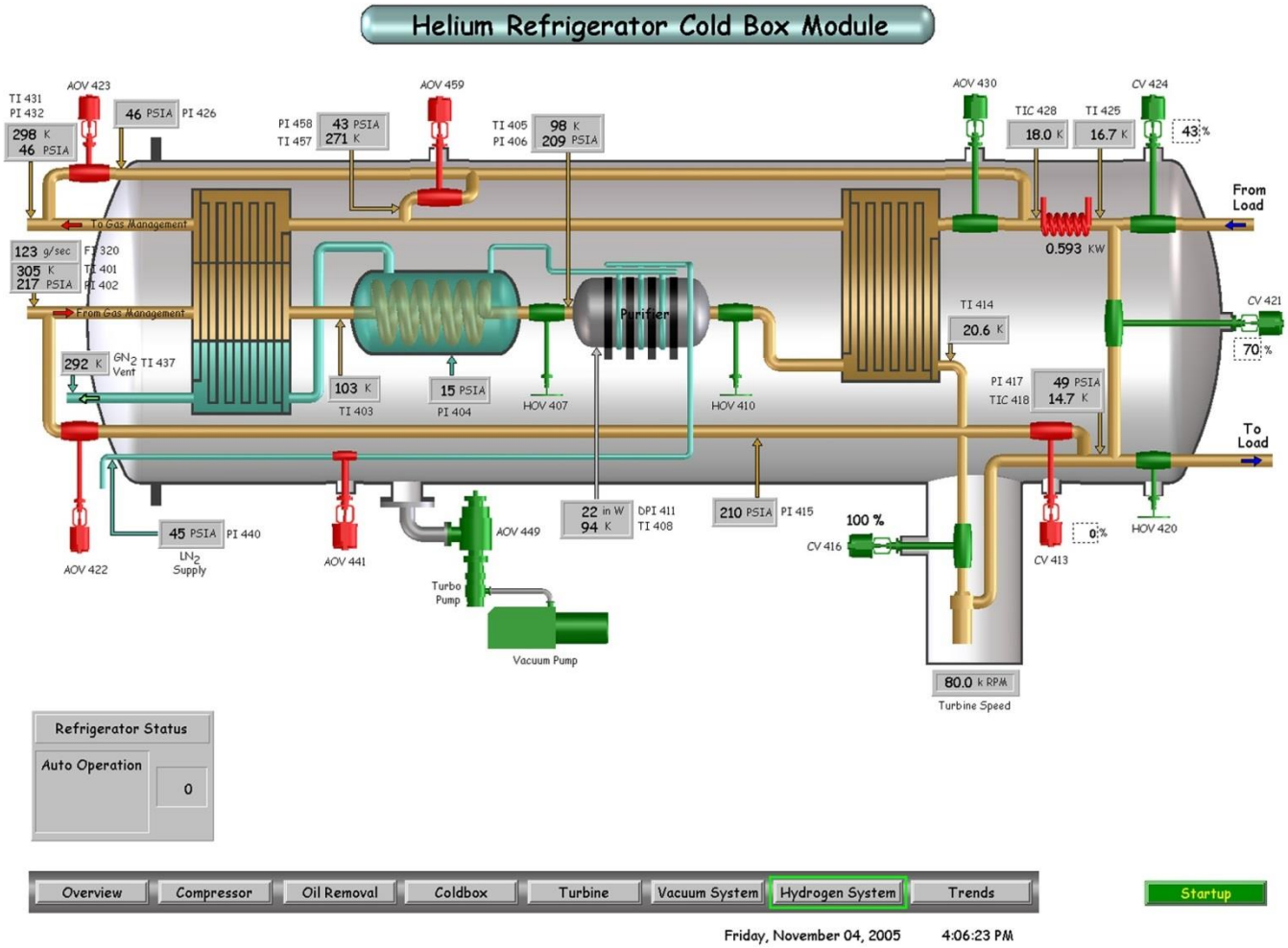
Bold indicates new or re-located, upgraded instruments.

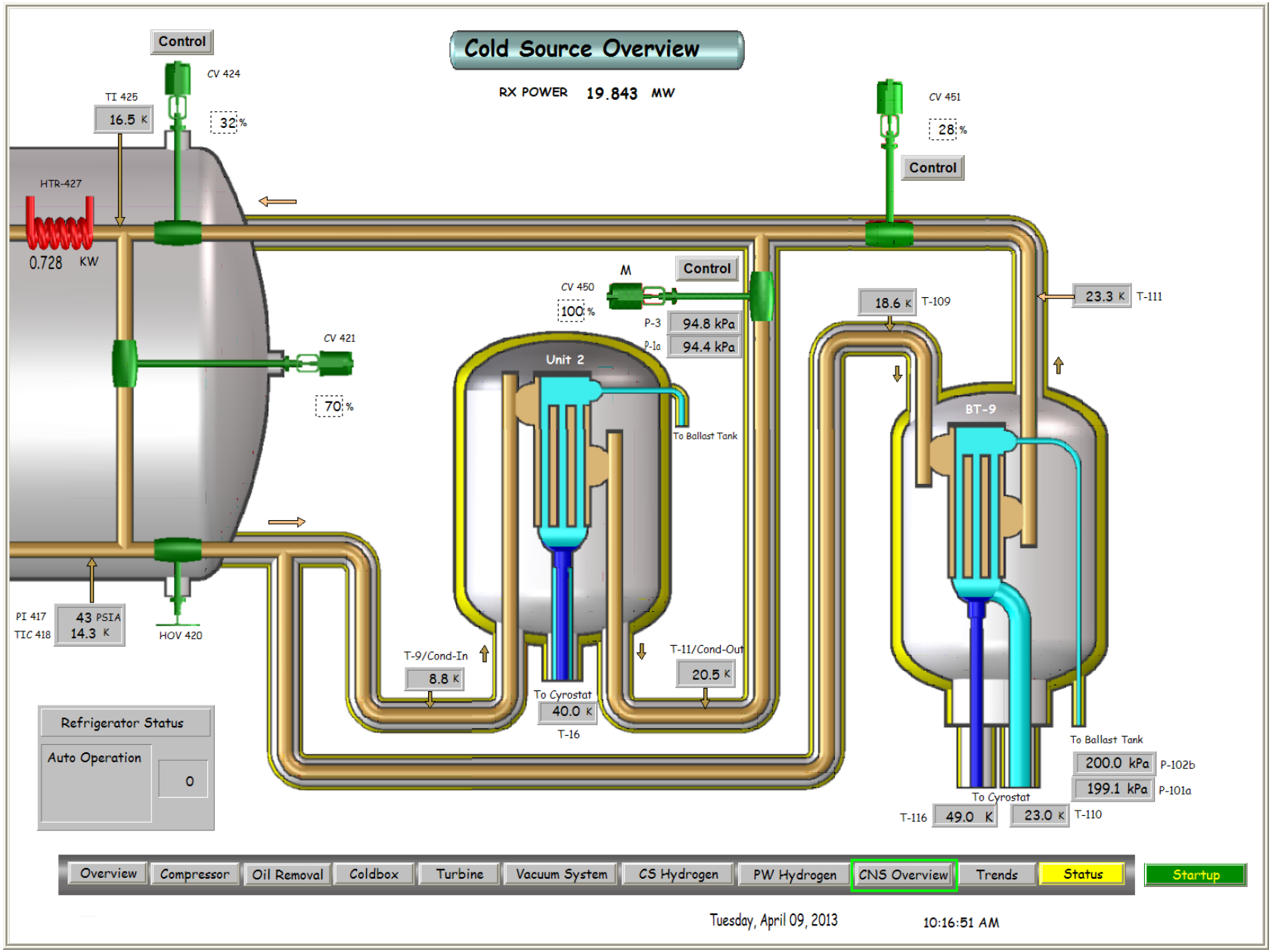
NRC OVERSIGHT

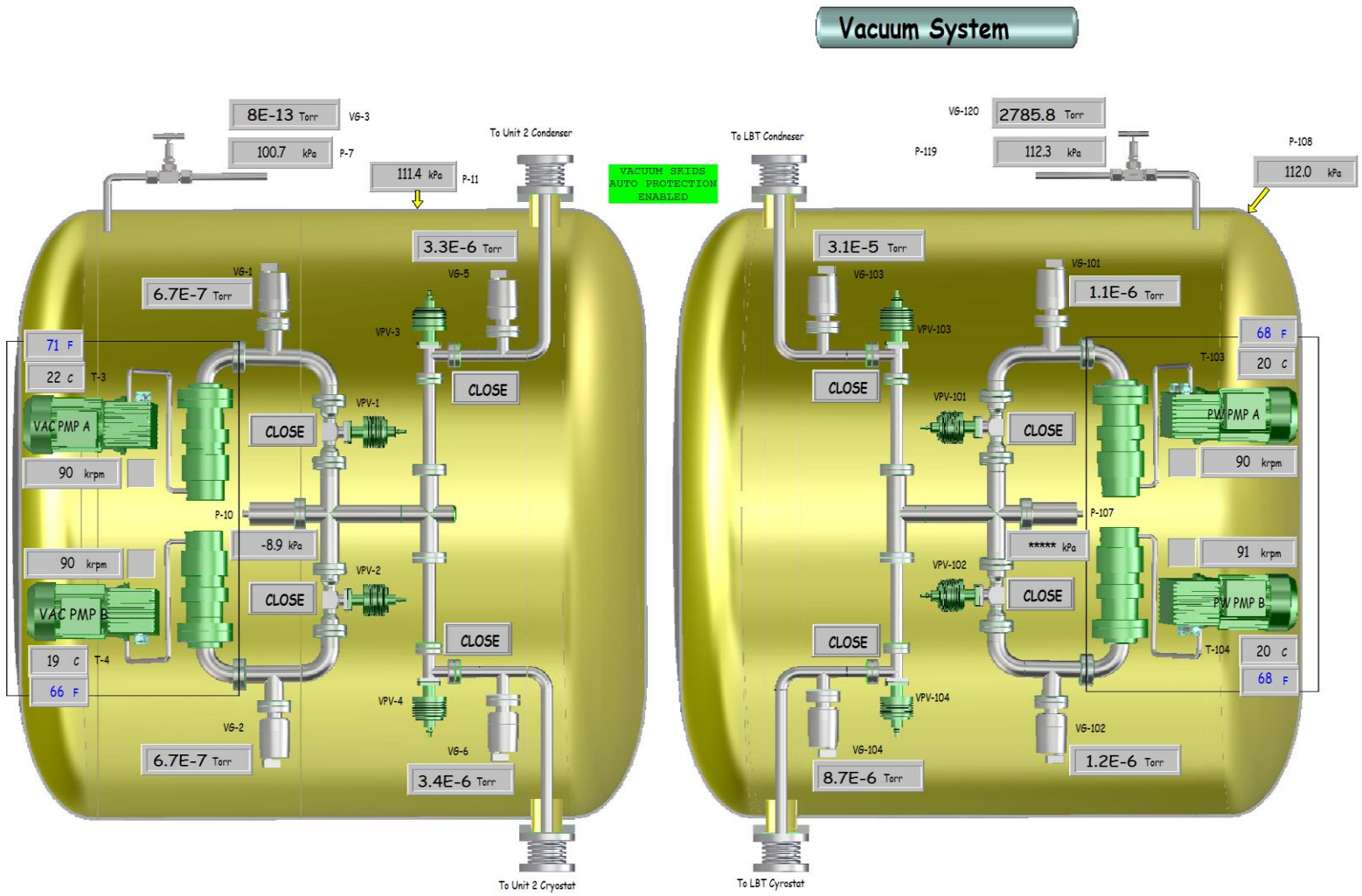
An NRC Inspector was present to observe much of the process.

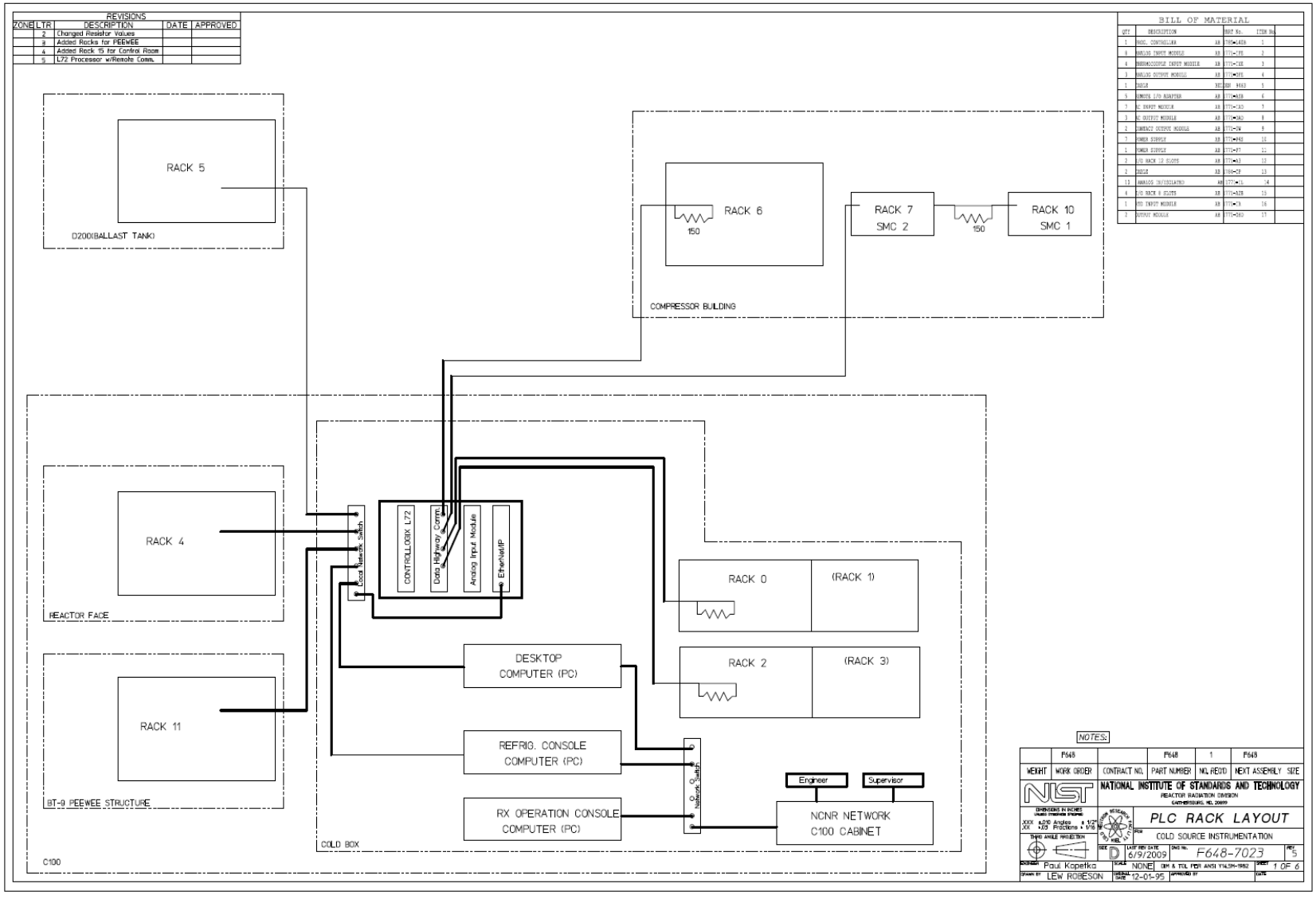


The NBSR was designed with a 55-cm diameter cryogenic beam port and smaller diameter beam ports


Helium Refrigerator Cold Box Module
AOV 423
TI 431
PI 432
298 K
46 PSIA
46 PSIA PI 426
AOV 459
PI 458
TI 457
43 PSIA
271 K
TI 405
PI 406
98 K
209 PSIA
AOV 430
TIC 428
18.0 K
TI 425
16.7 K
CV 424
43 %
From Load
To Gas Management
123 g/sec FT 320
305 K TI 401
217 PSIA PI 402
From Gas Management
0.593 KW
TI 414
20.6 K
CV 421
70 %
292 K
GN2 Vent
TI 437
103 K
TI 403
15 PSIA
PI 404
HOV 407
Purifier
HOV 410
PI 417
TIC 418
49 PSIA
14.7 K
To Load
45 PSIA PI 440
LN2 Supply
AOV 422
AOV 441
AOV 449
Turbo Pump
22 in W
94 K
DPI 411
TI 408
210 PSIA PI 415
100 %
CV 416
CV 413
0 %
HOV 420
Vacuum Pump
80.0 k RPM
Turbine Speed
Refrigerator Status
Auto Operation
0
Overview
Compressor
Oil Removal
Coldbox
Turbine
Vacuum System
Hydrogen System
Trends
Startup
Friday, November 04, 2005
4:06:23 PM


Cold Source Overview
RX POWER 19.843 MW
Control
CV 424
TI 425
16.5 K
32 %
HTR-427
0.728 KW
CV 421
70 %
PI 417
43 PSIA
TIC 418
14.3 K
HOV 420
CV 450
M
Control
100 %
P-3
94.8 kPa
P-1a
94.4 kPa
Unit 2
To Ballast Tank
T-9/Cond-In
8.8 K
To Cyrostat
40.0 K
T-16
T-11/Cond-Out
20.5 K
CV 451
28 %
Control
18.6 K
T-109
23.3 K
T-111
BT-9
To Ballast Tank
200.0 kPa
P-102b
199.1 kPa
P-101a
To Cyrostat
T-116
49.0 K
23.0 K
T-110
Refrigerator Status
Auto Operation
0
Overview
Compressor
Oil Removal
Coldbox
Turbine
Vacuum System
CS Hydrogen
PW Hydrogen
CNS Overview
Trends
Status
Startup
Tuesday, April 09, 2013
10:16:51 AM


Vacuum System
8E-13 Torr
VG-3
100.7 kPa
P-7
111.4 kPa
P-11
To Unit 2 Condenser
VACUUM SKIDS AUTO PROTECTION ENABLED
To LBT Condneser
VG-120
2785.8 Torr
P-119
112.3 kPa
P-108
112.0 kPa
3.3E-6 Torr
VG-5
VPV-3
CLOSE
6.7E-7 Torr
VG-1
71 F
22 C
T-3
VAC PMP A
90 krpm
VPV-1
CLOSE
P-10
-8.9 kPa
90 krpm
VAC PMP B
19 C
66 F
T-4
VPV-2
CLOSE
CLOSE
VPV-4
VG-2
6.7E-7 Torr
VG-6
3.4E-6 Torr
To Unit 2 Cryostat
3.1E-5 Torr
VG-103
VPV-103
CLOSE
VG-101
1.1E-6 Torr
68 F
20 C
T-103
PW PMP A
90 krpm
VPV-101
CLOSE
P-107
***** kPa
91 krpm
PW PMP B
VPV-102
CLOSE
CLOSE
T-104
20 C
68 F
VPV-104
VG-104
8.7E-6 Torr
VG-102
1.2E-6 Torr
To LBT Cyrostat
Overview
Compressor
Oil Removal
Coldbox
Turbine
Vacuum System
CS Hydrogen
PW Hydrogen
CNS Overview
Trends
Status
Startup
Monday, June 13, 2016 10:55:30 AM


REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
2 Changed Resistor Values
3 Added Racks for PEEWEE
4 Added Rack 15 for Control Room
5 L72 Processor w/Remote Comm.
BILL OF MATERIAL
RACK 5
D200(BALLAST TANK)
RACK 6
150
RACK 7
SMC 2
150
RACK 10
SMC 1
COMPRESSOR BUILDING
RACK 4
REACTOR FACE
RACK 11
BT-9 PEEWEE STRUCTURE
C100
COLD BOX
Local Network Switch
CONTROLLOGIX L72
Data Highway Comm.
Analog Input Module
EtherNet/IP
RACK 0
(RACK 1)
RACK 2
(RACK 3)
DESKTOP
COMPUTER (PC)
REFRIG. CONSOLE
COMPUTER (PC)
RX OPERATION CONSOLE
COMPUTER (PC)
Network Switch
Engineer
Supervisor
NCNR NETWORK
C100 CABINET
NOTES:
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
REACTOR RADIATION DIVISION
GAITHERSBURG, MD, 20899
PLC RACK LAYOUT
COLD SOURCE INSTRUMENTATION
F648-7023
Paul Kopetka
LEW ROBESON
12-01-95
1 OF 6

Communication Error,

Cycle power to Unit: Assert in File ApexHW.cpp Line 845

Date	Rack #	Module	Local Error	PLC Error	FactoryTalk Error	Solution
7/17/2014	Rack 4	Comm				Cycle power
7/29/2014	Master	CPU				Reload CPU programming
8/4/2014	??	Comm	Line 845	I/O Fault		Cycle power
8/12/2014	Rack 6	Comm	"Adapter fault"	I/O Fault		Cycle power
2/7/2015	Rack 4	Comm				Cycle power
8/1/2015	Rack 5	Comm	Line 845	I/O Fault	Rack 5 Fault #40 - PW Rack Error	Cycle power
12/19/2015	Master	CPU			All numbers on HMI show blank boxes	Reload CPU programming
2/18/2016	Rack 4	Comm	Line 845	I/O Fault		Cycle power
3/11/2016	Rack 5	Comm	Line 845	I/O Fault		Cycle power
3/20/2016	Rack 5	Comm	Line 845	I/O Fault		Cycle power
3/27/2016	Rack 4	Comm	Line 845	I/O Fault		Cycle power
4/5/2016	Rack 5	Comm	Line 845	I/O Fault		Cycle power

Line 845: "Cycle power to Unit: Assert in File ApexHW.cpp Line 845."
I/O Fault: "NIST I/O Fault Rack 5 #0204 Message Timeout unconnected." *(or similar)*

7/13/2016, Rack 11 Comm Line 845 I/O Fault

The vast majority of the faults has been the “Line 845” failures, a coding fault that appears on the Communication module display, which is believed to be thrown by the internal apex processor on each chassis backplane. The cause of the backplane error could be the communication module, the backplane itself or literally any other component connected to it.

Actions

Check Local Network Cables

Replace Network Switch

Update Firmware on Communication Modules

Change Communication Rates

Installed Wire Shark

“Line 845” fault occurs at 4 AM one week before our next shutdown, resulting in a short rundown during the recovery. Which involves cycling the remote rack’s power supply.

Actions

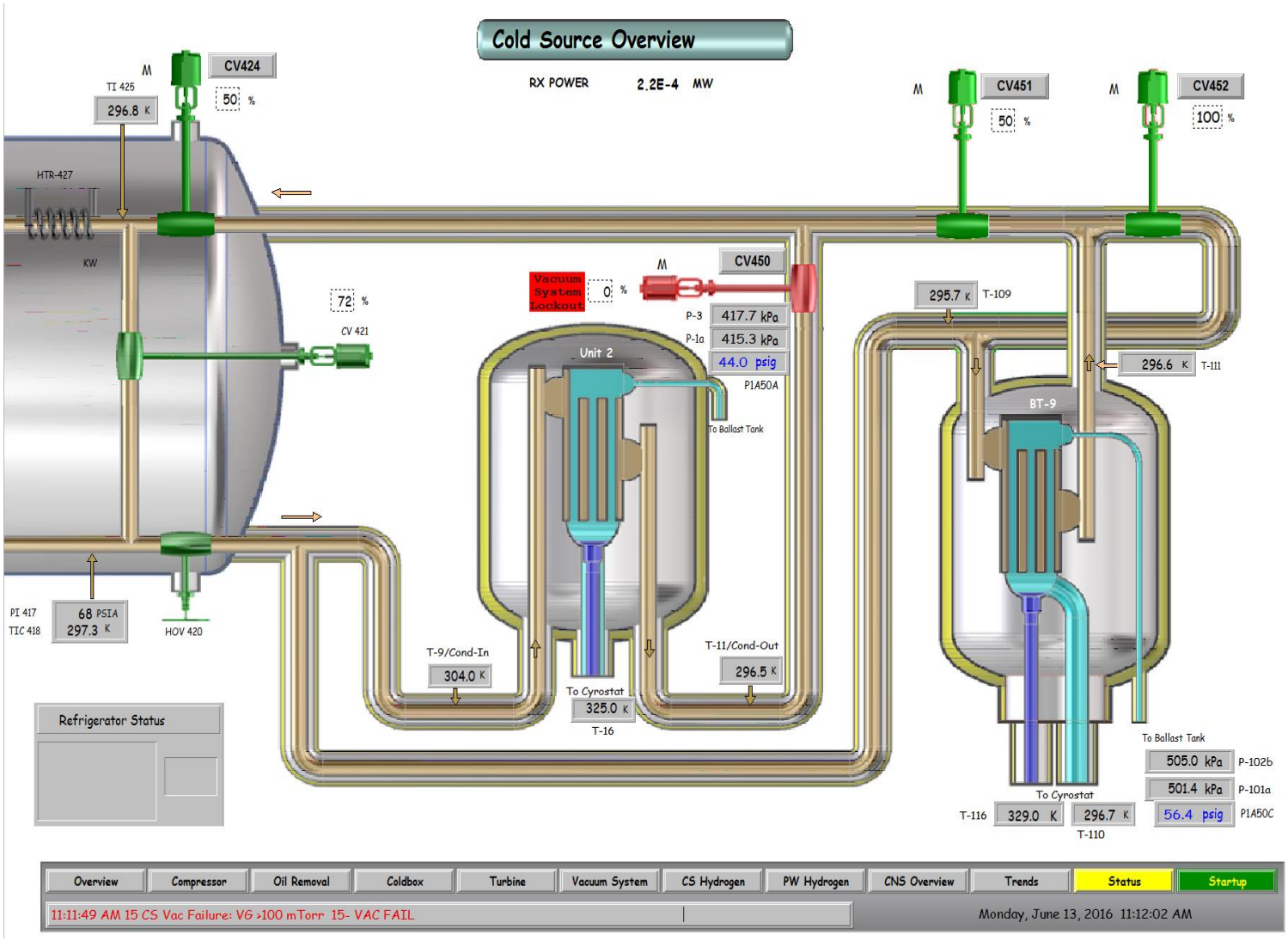
Replace two communication modules

Re-Configure WireShark

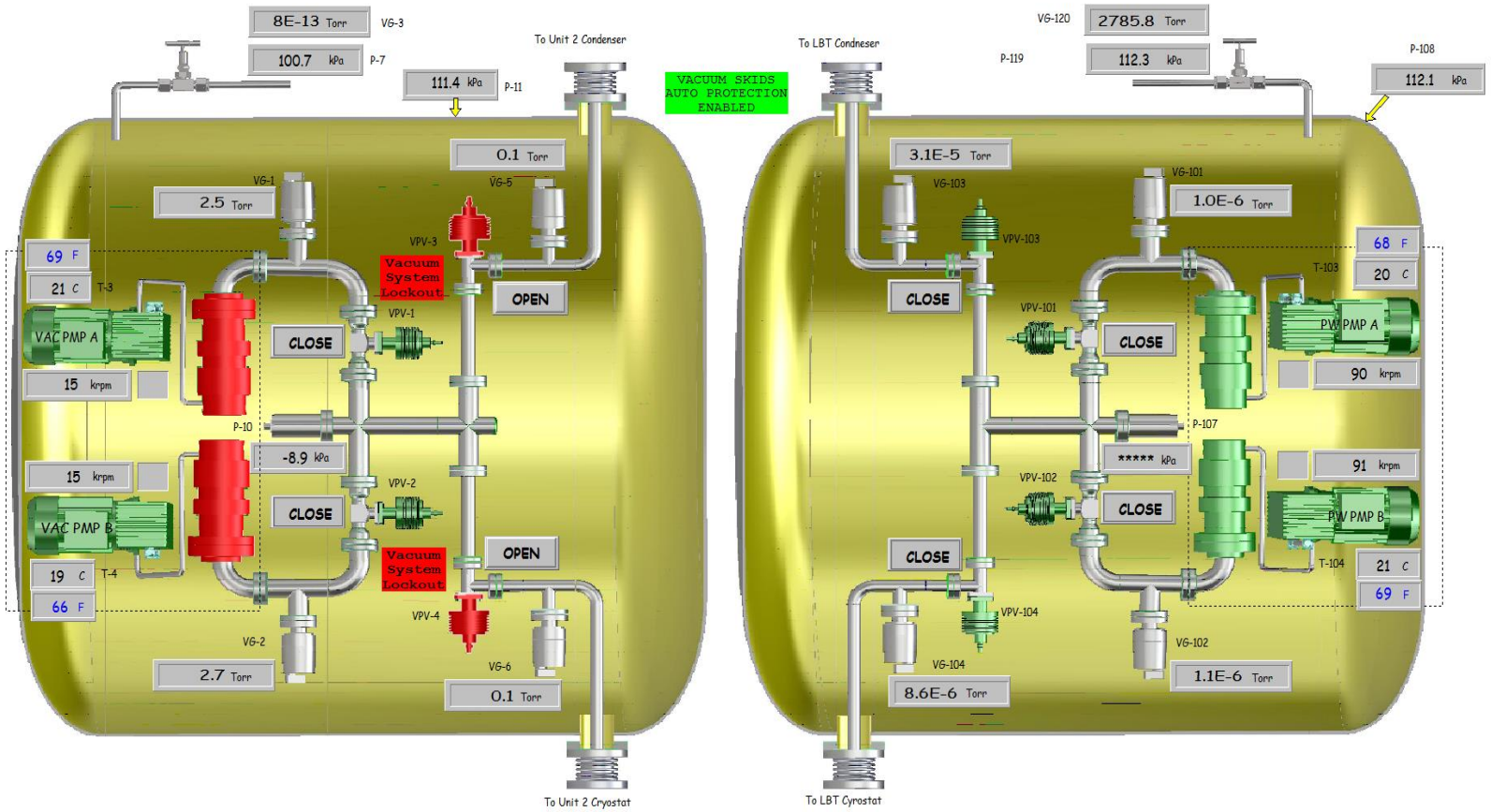
Send Information on SD card to Vendor

Modify PLC Code, minimize rundown during recovery

Place Critical Components on a New Remote PLC Rack


Cold Source Overview
RX POWER 2.2E-4 MW
CV424
50 %
TI 425
296.8 K
HTR-427
KW
72 %
CV 421
PI 417
TIC 418
68 PSIA
297.3 K
HOV 420
Refrigerator Status
Vacuum System Lockout
0 %
CV450
P-3
417.7 kPa
P-1a
415.3 kPa
44.0 psig
P1A50A
To Ballast Tank
Unit 2
T-9/Cond-In
304.0 K
To Cyrostat
325.0 K
T-16
T-11/Cond-Out
296.5 K
CV451
50 %
CV452
100 %
295.7 K
T-109
296.6 K
T-111
BT-9
To Ballast Tank
505.0 kPa
P-102b
501.4 kPa
P-101a
56.4 psig
P1A50C
To Cyrostat
T-116
329.0 K
296.7 K
T-110
Overview
Compressor
Oil Removal
Coldbox
Turbine
Vacuum System
CS Hydrogen
PW Hydrogen
CNS Overview
Trends
Status
Startup
11:11:49 AM 15 CS Vac Failure: VG >100 mTorr 15- VAC FAIL
Monday, June 13, 2016 11:12:02 AM

Vacuum System



Overview | Compressor | Oil Removal | Coldbox | Turbine | Vacuum System | CS Hydrogen | PW Hydrogen | CNS Overview | Trends | Status | Startup

11:11:49 AM 15 CS Vac Failure: VG >100 mTorr 15- VAC FAIL

Monday, June 13, 2016 11:12:13 AM

System Status

Compressor Status

Selected Compressor	UNIT 2
Auxillary Contact	Motor OFF
Compressor Power	No Power
Refrigerator Status	Normal
Cooldown Sequence	

Coldbox Status

Helium Flow	0	g/sec
He Discharge	67	PSIA
Turbine Speed	0	k RPM
Turbine Inlet	295.2	K
Turbine Fault	10	

Cold Source Temperature

C100 20.7 %O2	
C200 20.5 %O2	UNIT 2 / BT-9
Condenser Outlet	296.5 K / 296.6 K
Moderator Vessel	325.0 K / 329.0 K
Cyrostat Assembly	51.0 C

CS CryoWord 1

1 P5 OOR	Clear
2 TCRYO	Clear
3 P11 LO	Clear
4 P12 OOR	Clear
5 P13 OOR	Clear
8 P1A OOR	Clear
9 TD20 HI	Clear
10 P1B OOR	Clear
11 TCOND HI	Clear
12 TCOND HI	Clear
13 TCOND HI	Clear
14 RACK ERR	Not Active

CS CryoWord 2

15 Vac Fail	Active Alarm
16 C100 H2	Clear
17 C100 O2	Clear
18 C200 O2	Clear
19 VAC PWR	Clear
20 FD2O LO	Clear
21 FD2O LO	Clear
22 P1A ERR	Clear
23 P1B ERR	Clear
24 VAC ERR	Not Active
25 HE ERR	Clear
26 VAC TEMP	Clear

PW CryoWord 3

27 P105 OOR	Clear
28 P108 OOR	Clear
29 P106 LO	Clear
30 P112 OOR	Clear
31 P113 OOR	Clear
34 P101A OOR	Clear
35 PW TD2O HI	Clear
36 P101B OOR	Clear
37 PW TCOND HI	Clear
38 PW TCOND HI	Clear
39 PW TCOND HI	Clear
40 PW RACK ER	Clear

PW CryoWord 4

41 PW VAC FAIL	Clear
42 D200 H2	Clear
43 PW VAC PWR	Clear
44 PW FD2O LO	Clear
45 PW FD2O LO	Clear
46 P101A ERR	Clear
47 P101B ERR	Clear
48 PW VAC ERR	Clear
49 PW HE ERR	Clear
50 PW TCRYO	Clear
51 PW VAC TEMP	Clear

Cold Source Status

Reactor Power	2E-4 MW
CS Cryo Status 1	
CS Cryo Status 2	
PW Cryo Status 1	Normal
PW Cryo Status 2	Normal

Unit2 (Hydrogen Pressure) BT-9

P1A 415.3 kPa		P101A 501.5 kPa	
P1A50A 43.98 psig		P1A50C 56.4 psig	
P1B 422.7 kPa		P101B 497.8 kPa	
P1A50B 45.05 psig		P1A50D 55.9 psig	

Unit2 (Vacuum) BT-9

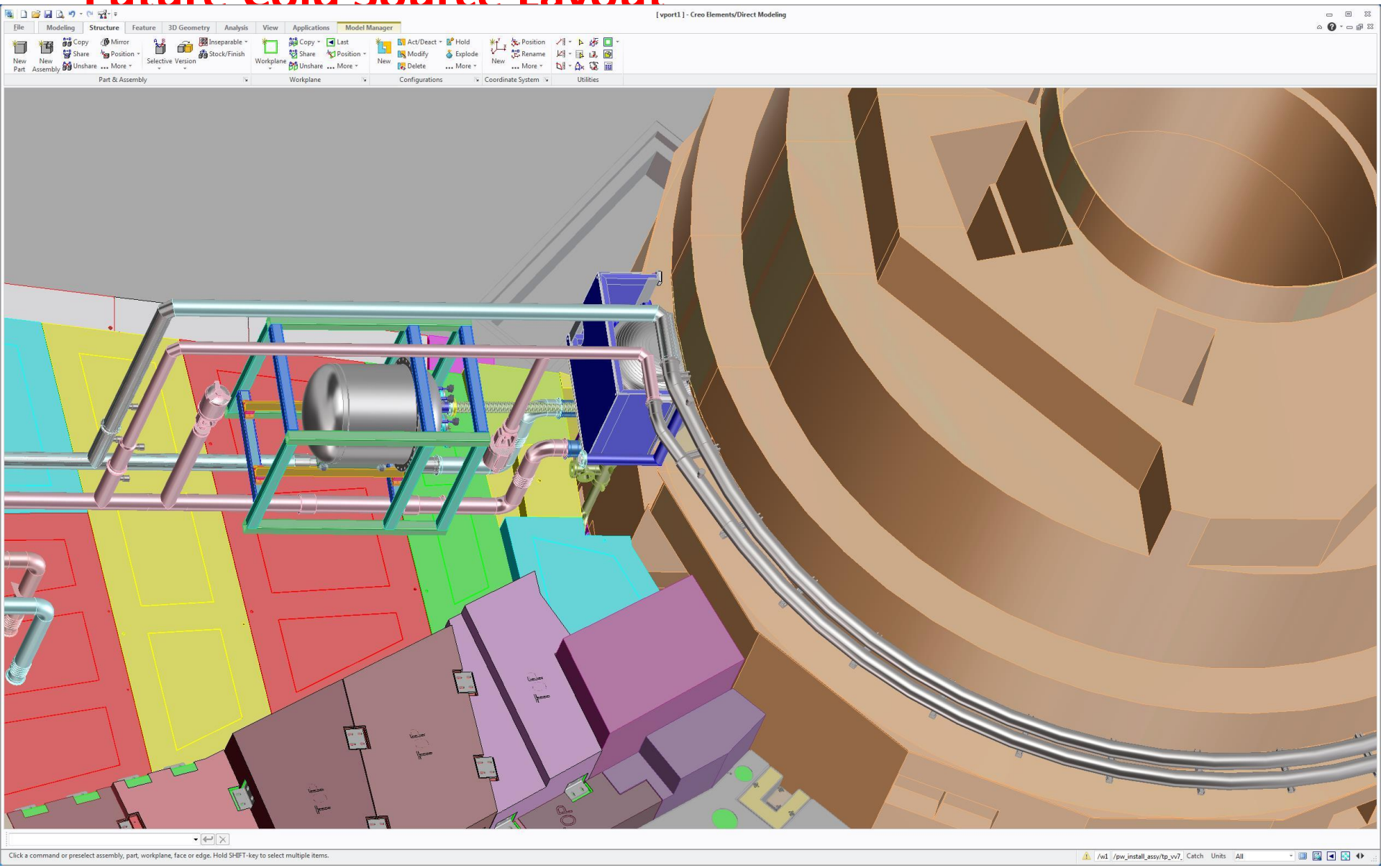
UNIT 2 CS NORMAL VACUUM	Vac. Skid Condenser Cryostat	PEEWEE NORMAL VACUUM

Hydrogen Detectors % LFL

D200	0.0	D100	0.0		
CS	0.0	PW	0.0	PWBT	0.0

Monday, June 13, 2016 11:16:47 AM

Future Cold Source Layout



Embedded Digital Devices, EDD

Manufacturers are increasingly introducing digital technology into non-actuated and actuation devices that in turn are used in applications such as digital displays, motor controllers, sequencers, pumps, valve actuators, breakers, uninterruptable power supplies and emergency diesel generator controls.

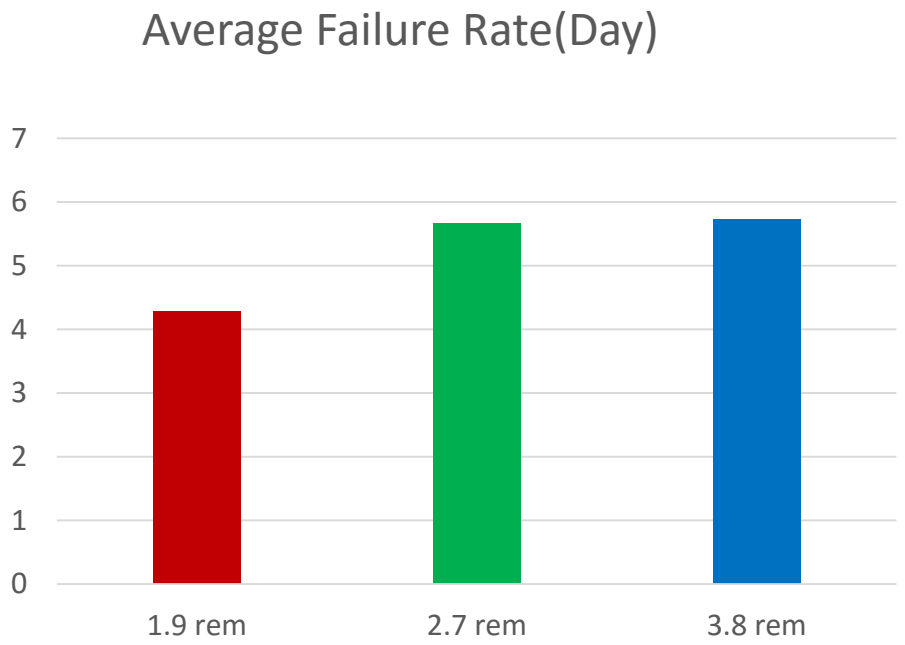
Embedded Digital Devices EDD might exist in procured equipment used in safety related systems without device having been identified in procurement documentation. Related to equipment including instrumentation and controls in safety related systems.

EDDs possibly could fail to function as intended because of a latent defect, as an example in software or firmware. If a trigger results in latent software defect causing the failure of identical functions in redundant but otherwise independent systems or channels, it is a **common cause failure** across the system(channel). Defect free EDDs cannot be guaranteed with a reasonable assurance of safety, despite a quality development process and through testing.

The record of changes to the facility should show that any potential safety issue arising from the use of EDDs has been addressed adequately.

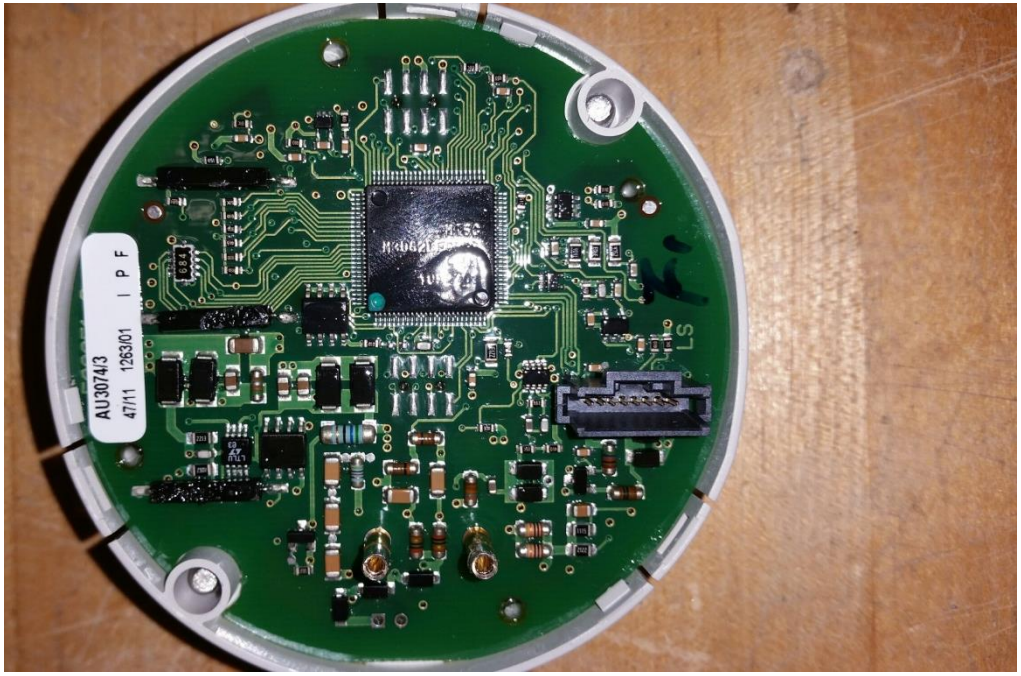
The 10 CFR 50.59 rule contains requirements for the process by which licenses may make changes to their facilities and procedures as described in the FSAR without prior NRC approval.

ABB FLOW TRANSMITTER MODEL #266DSH

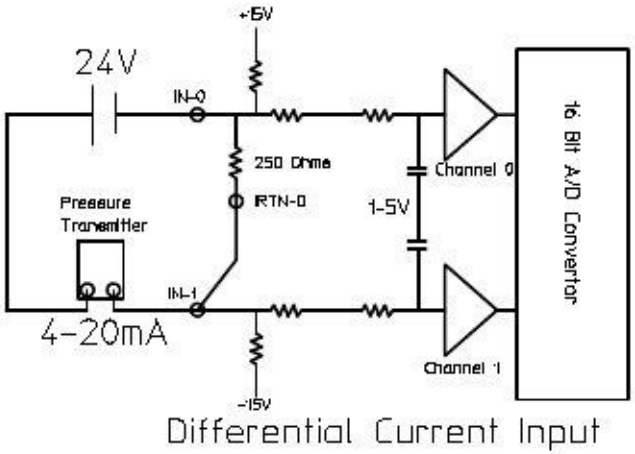


Broad use of safety related equipment with EDDs carries potential safety concerns including the potential increase in a facility's vulnerability to hazards from undetected EDD defects, potential increase in susceptibility to electromagnetic interference and other potential hazards from the in service environment.

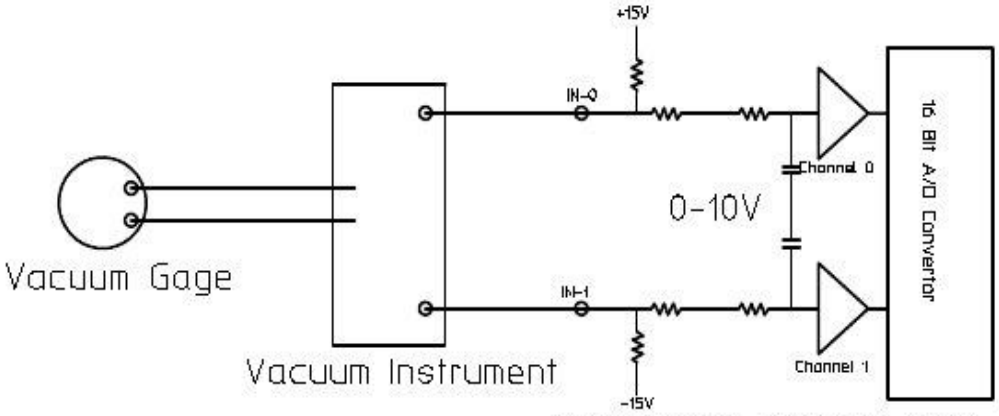
Processor for ABB Flow Transmitter



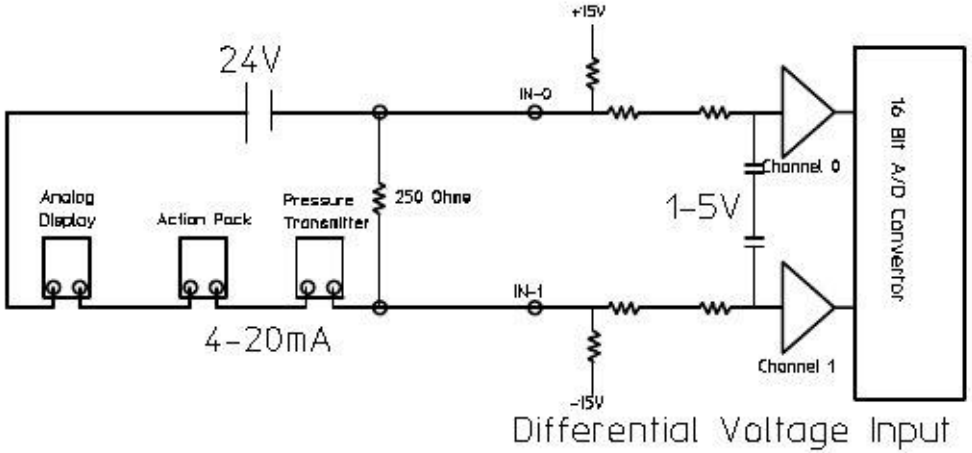
Basic Analog Input Layout



Differential Current Input



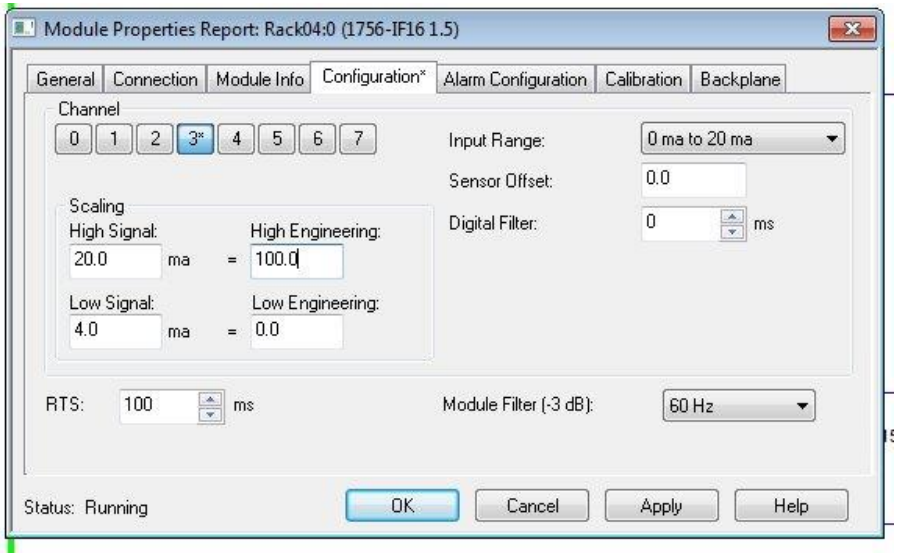
Differential Voltage Input

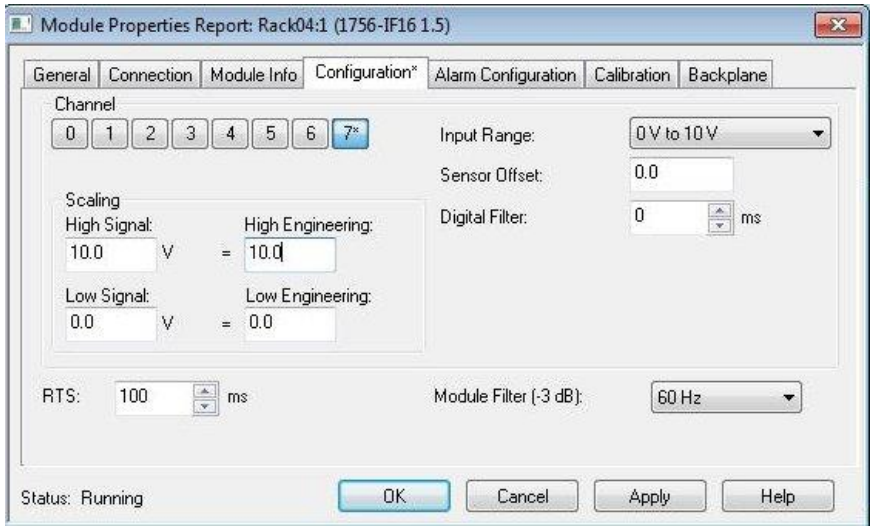


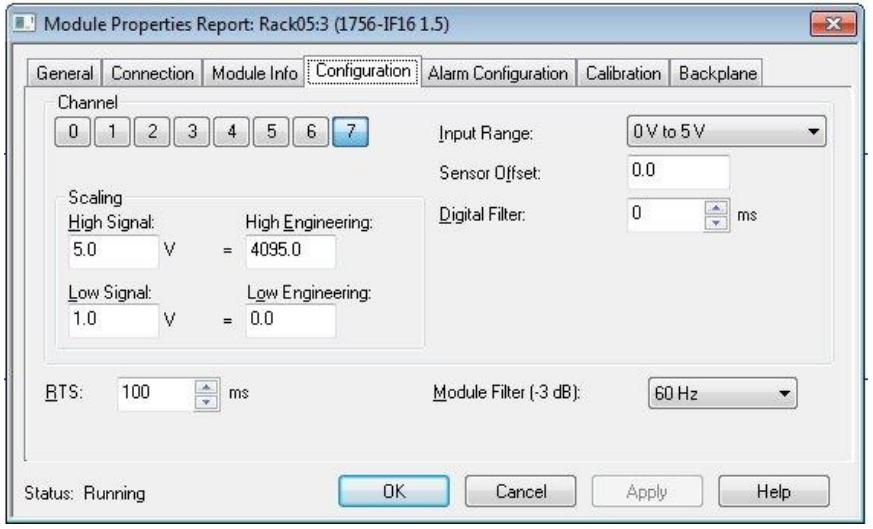
Differential Voltage Input

Basic Analog Input Configuration

-10 to +10 V
0 to +5V
0 to +10V
0 to 20 mA

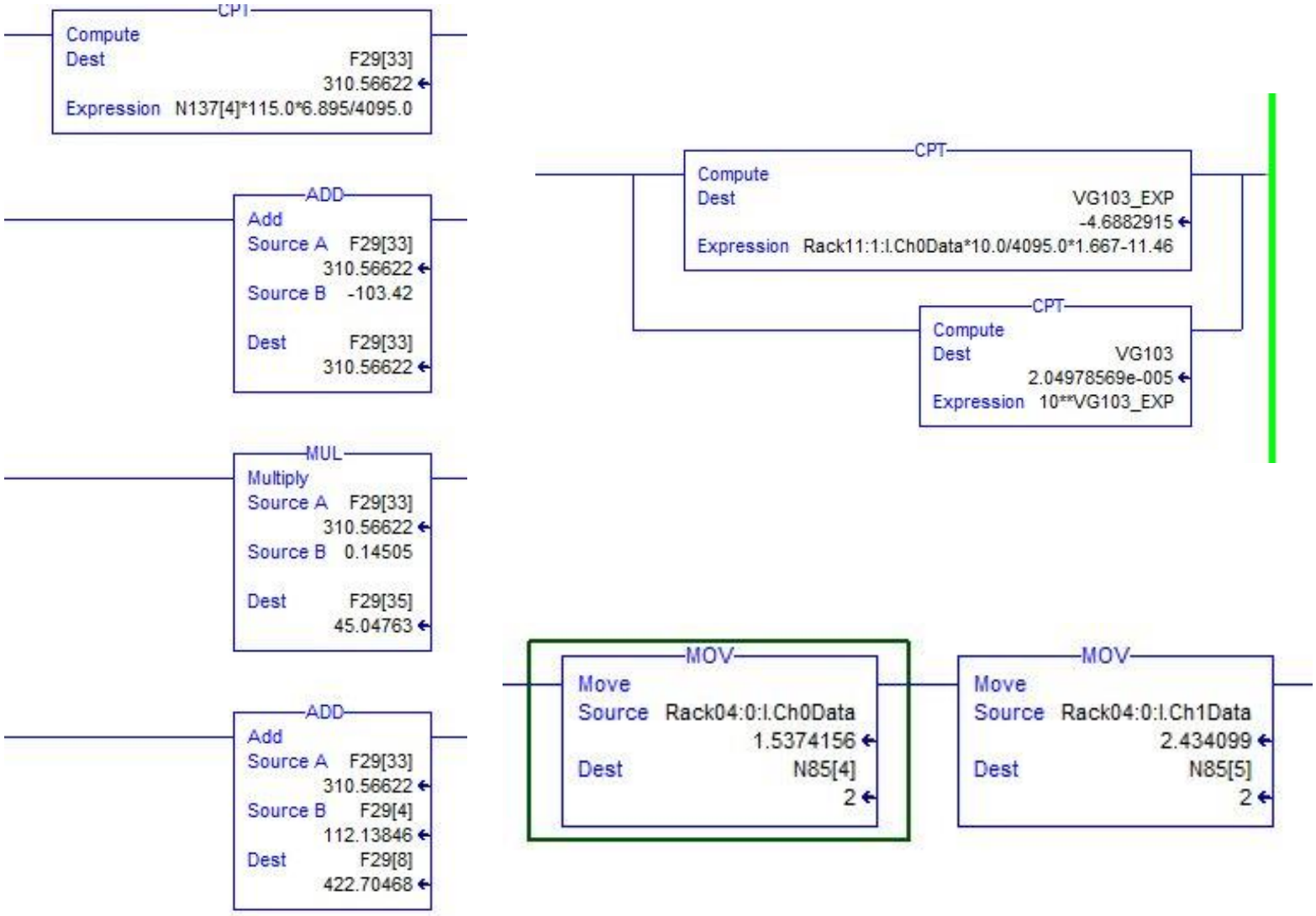




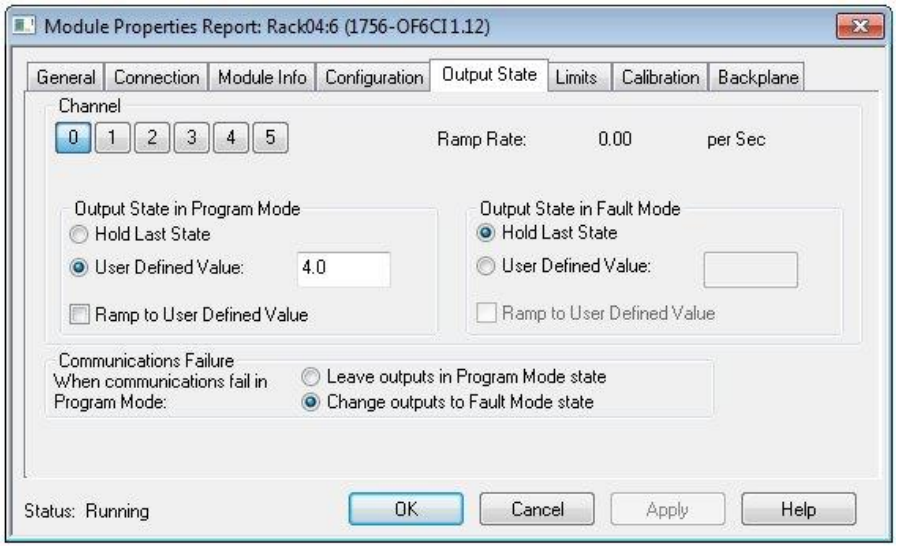


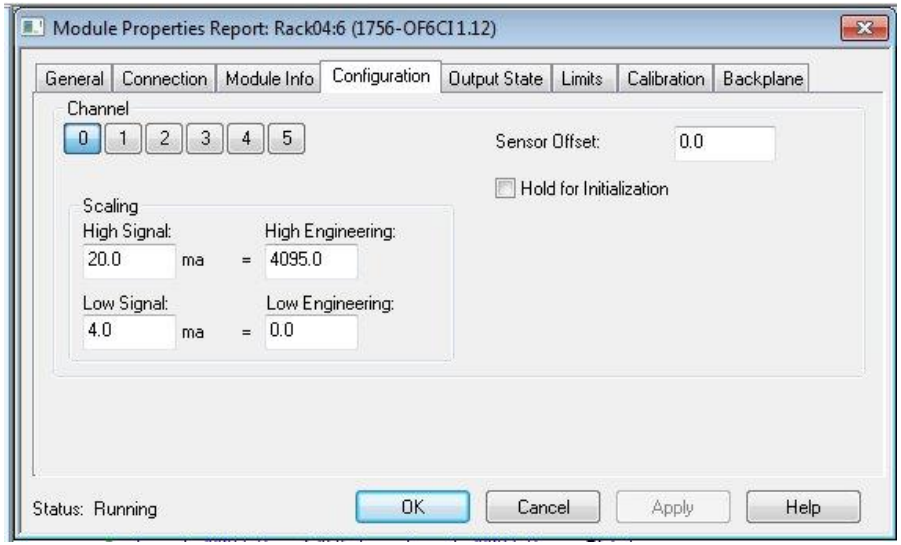
Eng. Units
Input Signal
Counts, 12 Bit

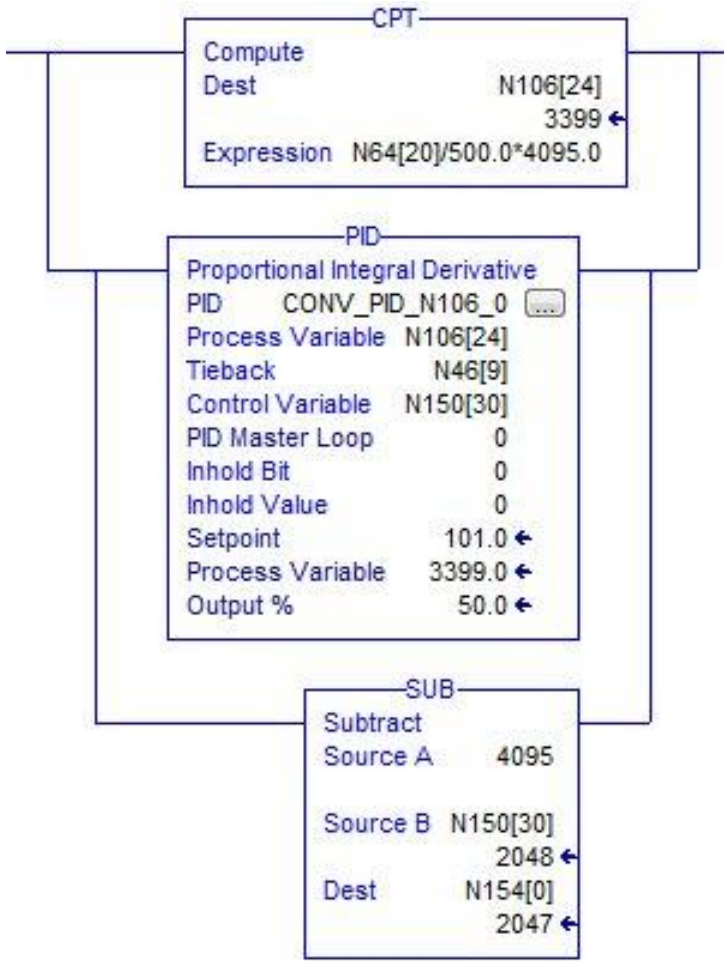
Basic Analog Input Code



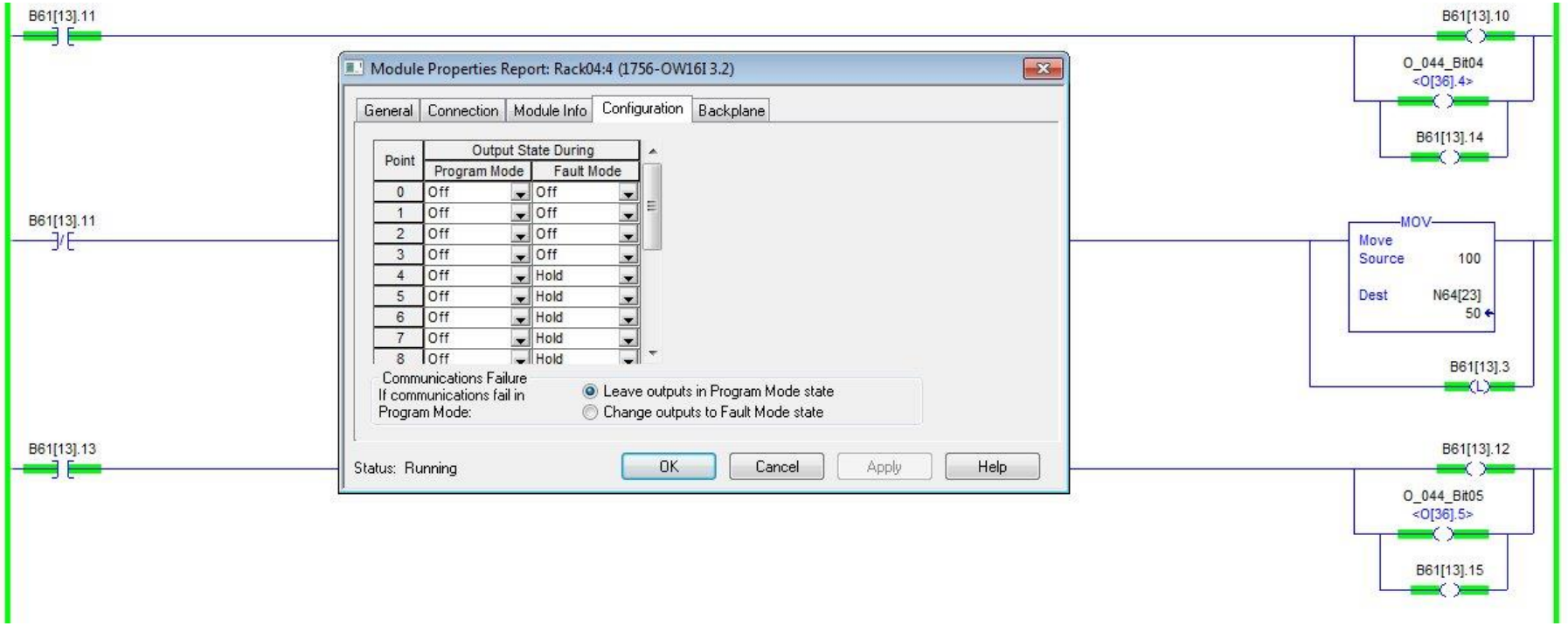
Basic Analog Output Configuration



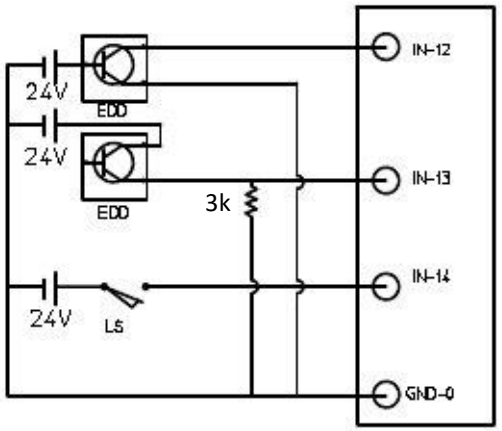


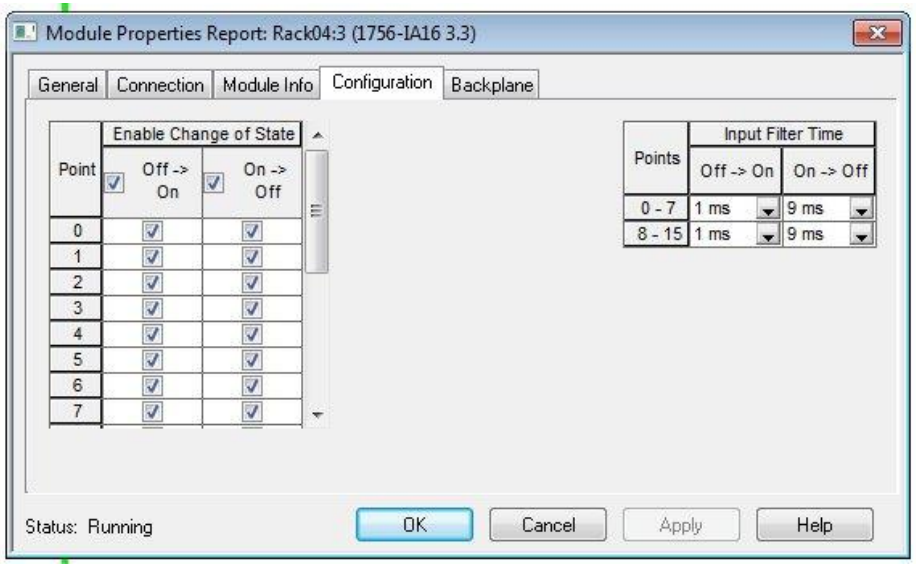


Basic Digital Relay Output



Basic Digital 24 V Input

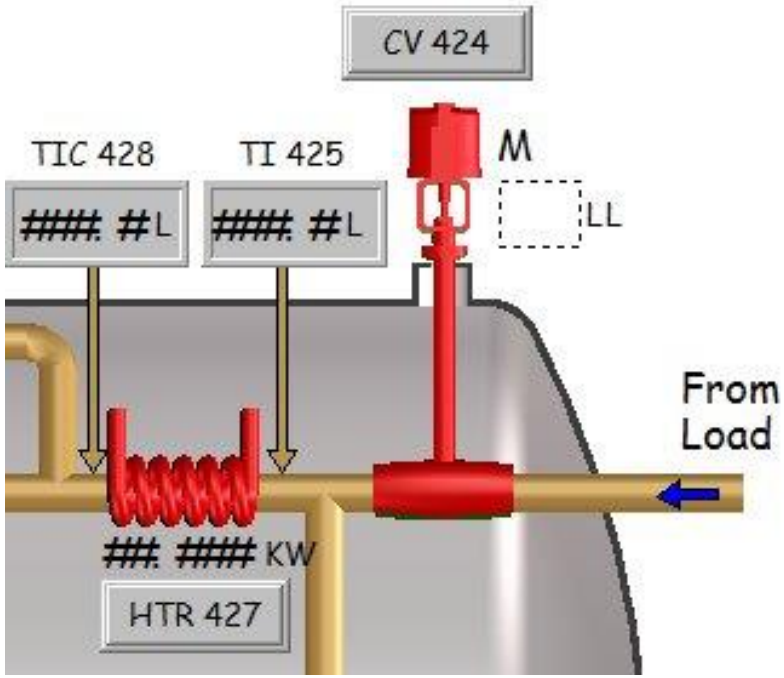


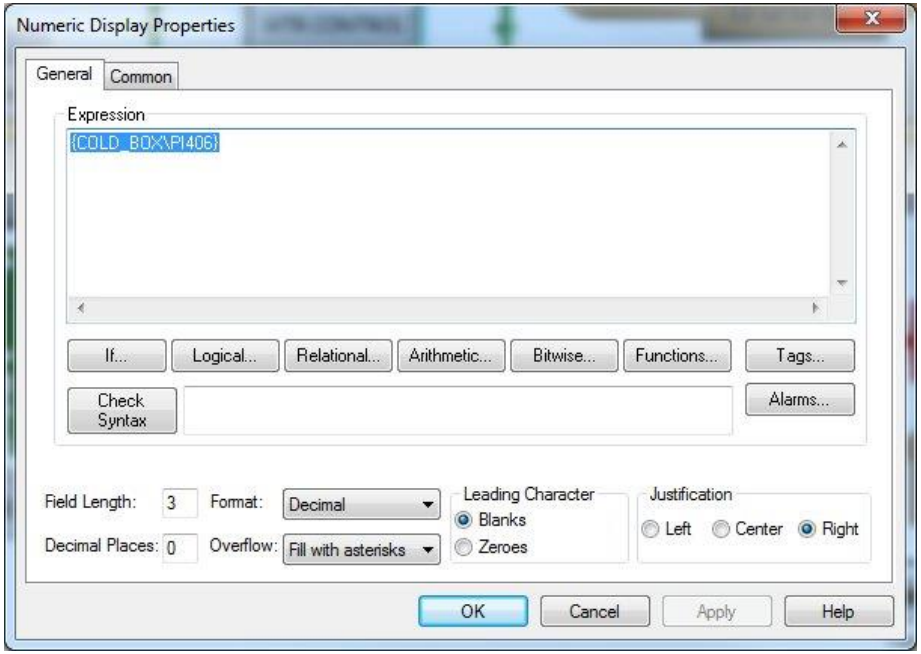


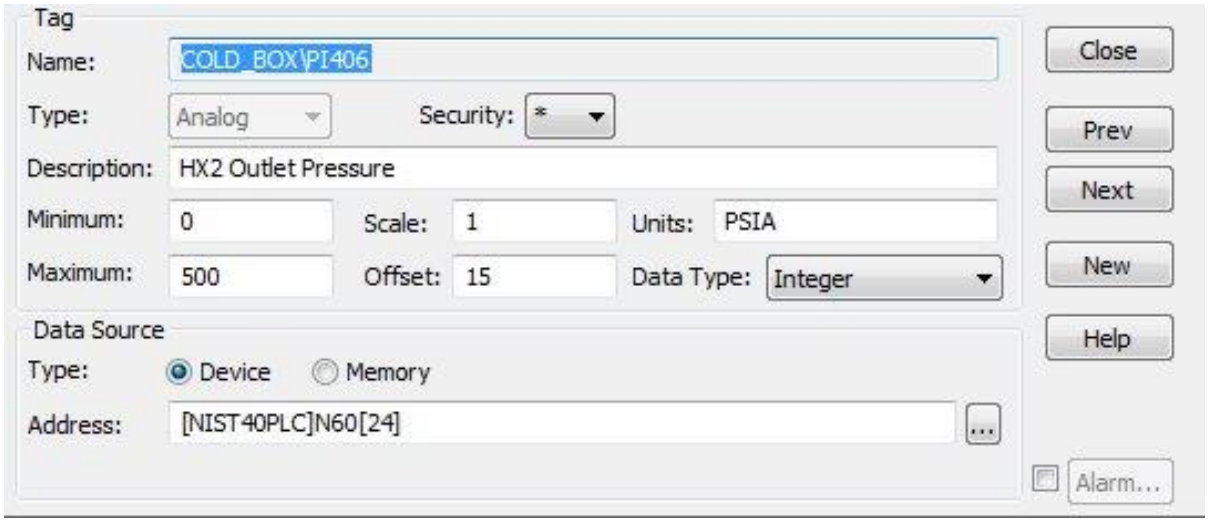
Off State Voltage Max 5 V

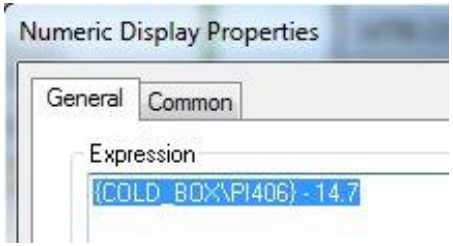
IN-12- OFF, 0V or ON, 24V
IN-13- 1 mA, 3V or 4 mA, 12V,
IN-14- OP, 0V or CL, 24V

Basic HMI Screen Display

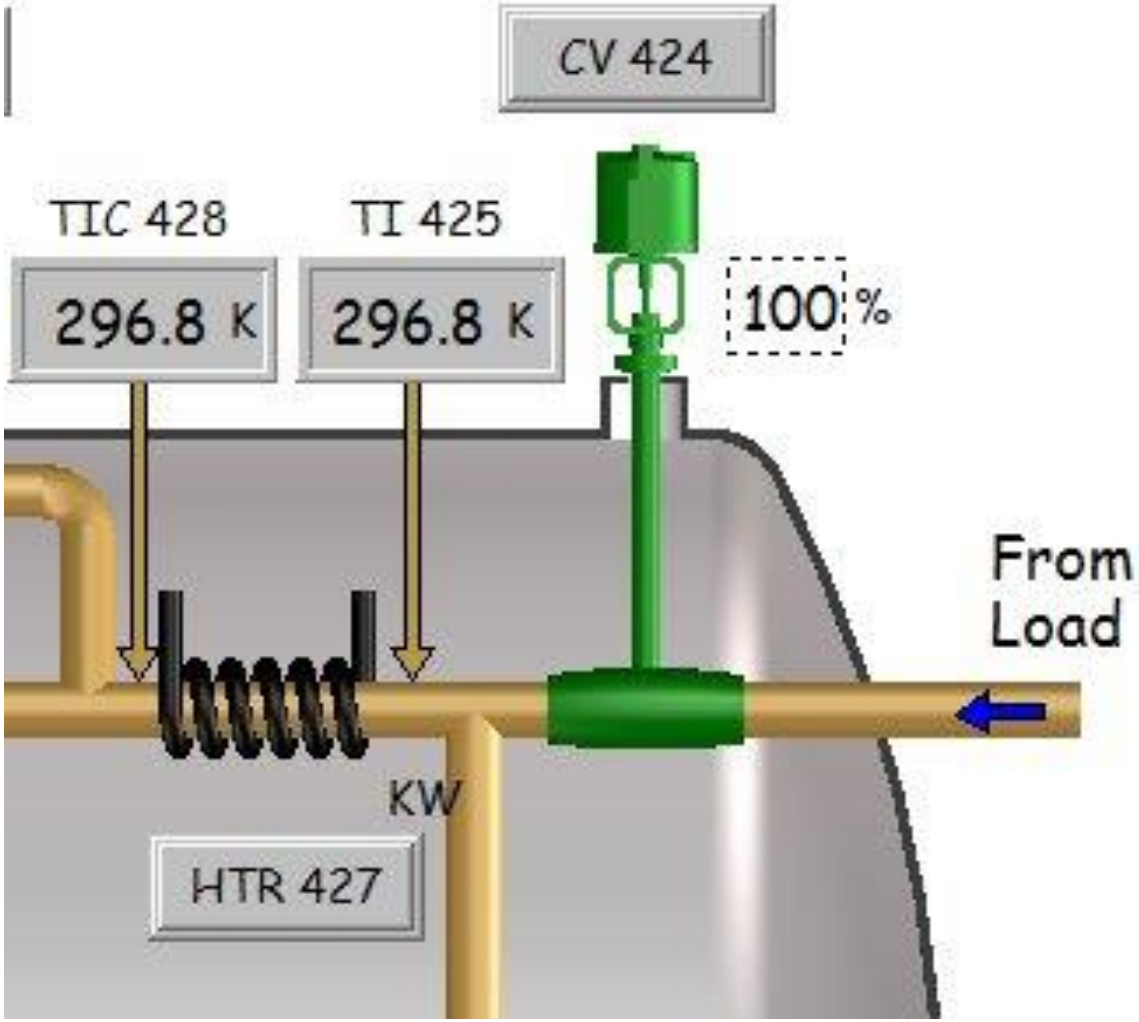








Basic HMI Screen Display



Conclusion

Our Comm Fault appears to be a Common Cause Failure Associated with either Software or Firmware

Cold Source is not a Safety Related System

Use of Embedded Digital Devices Going Forward Will be Unavoidable

Questions?