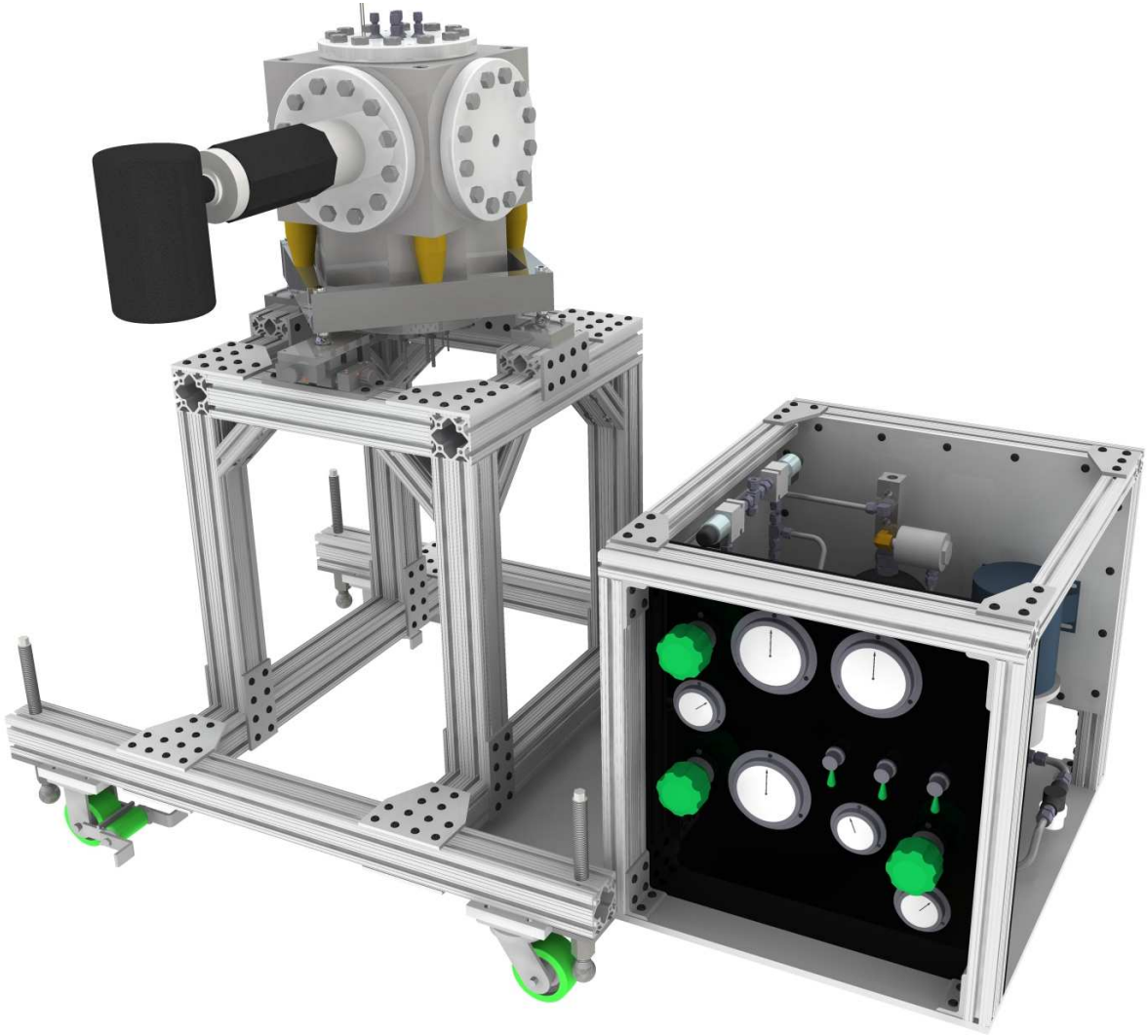
H_2O Bubble Chamber
Superheated Active Target System



Safety and Systems Overview

B. DiGiovine

Physics Division and Bubble Chambers

- April 2009
  - First Bubble Chamber Received Full Operation Authorization (C_4F_{10})
- February 2010
  - First Bubble Chamber Received Upgrade Authorization for Superheated H_2O
- Two Campaigns at HIγS
- Months of Testing and Calibrations at ANL
- Operation at ANL Open House Detecting Cosmic Rays
- Months of Operation by FERMI Collaborators for Calibration of COUPP Bubble Chambers
- Zero Incidents/Accidents

Physics Division and Bubble Chambers

Argonne NATIONAL LABORATORY

Intra-Laboratory Memo

October 21, 2009

TO: R.V.F. Janssens Dir., PHY

FROM: T. Mullen ESHQA Engineer, PHY

SUBJECT: Recommendation to Authorize Full Operation of the Bubble Chamber

At the recommendation of the Physics Division General Safety Committee, you authorized room temperature testing of the Bubble Chamber on April 6, 2009 (see attached.)

The Committee felt that additional actions needed to be taken before it could approve and recommend that you authorize full operation of that apparatus. The actions that needed to be taken were:

1. Add over temperature switches to the body of the vacuum chamber
2. Revise the vent to point down to eliminate the possibility of gas striking someone.

I have reviewed the apparatus today, and witnessed that both of those actions had been accomplished.

Therefore, on behalf of the committee I am now approving, and recommend that you authorize, the full operation of this equipment. B. DiGiovine has requested that the he be allowed to operate the Bubble Chamber at room temperature.

Authorized _____ 10/22/09
R.V.F. Janssens, PHY Director Date

Argonne NATIONAL LABORATORY

Intra-Laboratory Memo

February 16, 2010

TO: R.V.F. Janssens

FROM: T.P. Mullen

SUBJECT: Recommendation to Authorize Use of the Bubble Chamber Upgrade

A committee was formed to review the safety aspects when operating the upgraded Bubble Chamber. The original Bubble Chamber was reviewed and approved and also received your authorization to operate previously.

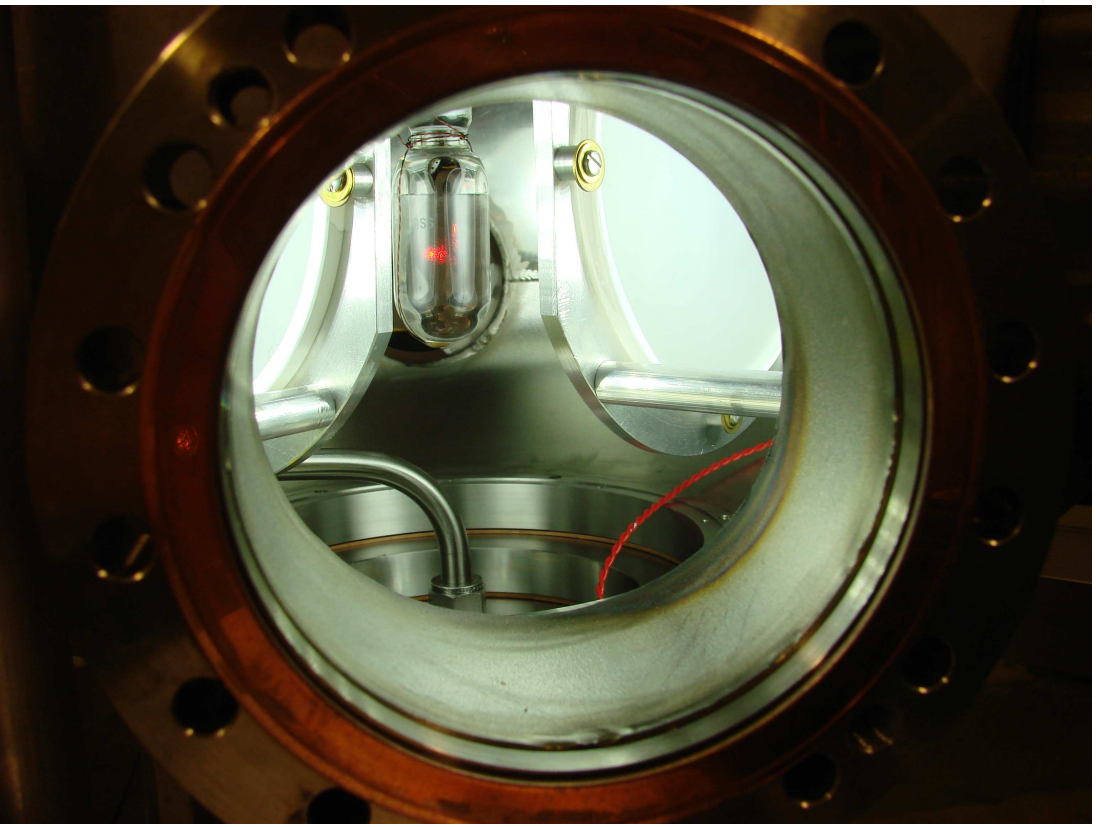
The committee used the document: Upgraded Bubble Chamber, Hazard Analysis and Project Review Form in their review of this device.

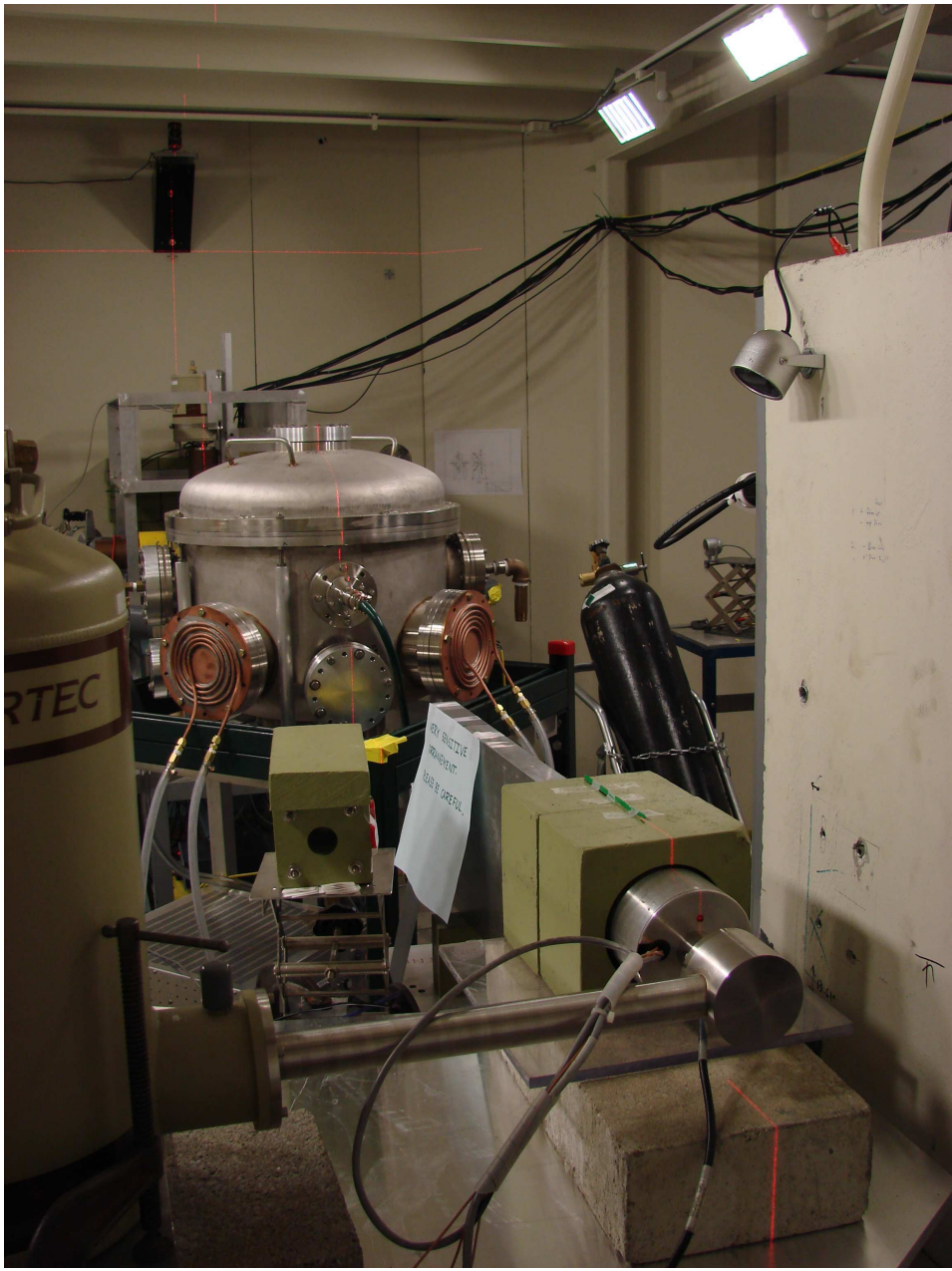
The committee found that the chamber itself was adequately safeguarded against any potential hazard, and that when properly used, would not be a danger to users, employees or the general public.

The committee recommended that a requirement be added to the work description to insure that the chamber top be fully attached before operations begin. That requirement has now been added to the description.

Therefore, the committee has approved use of this equipment and recommends that you authorize its use.

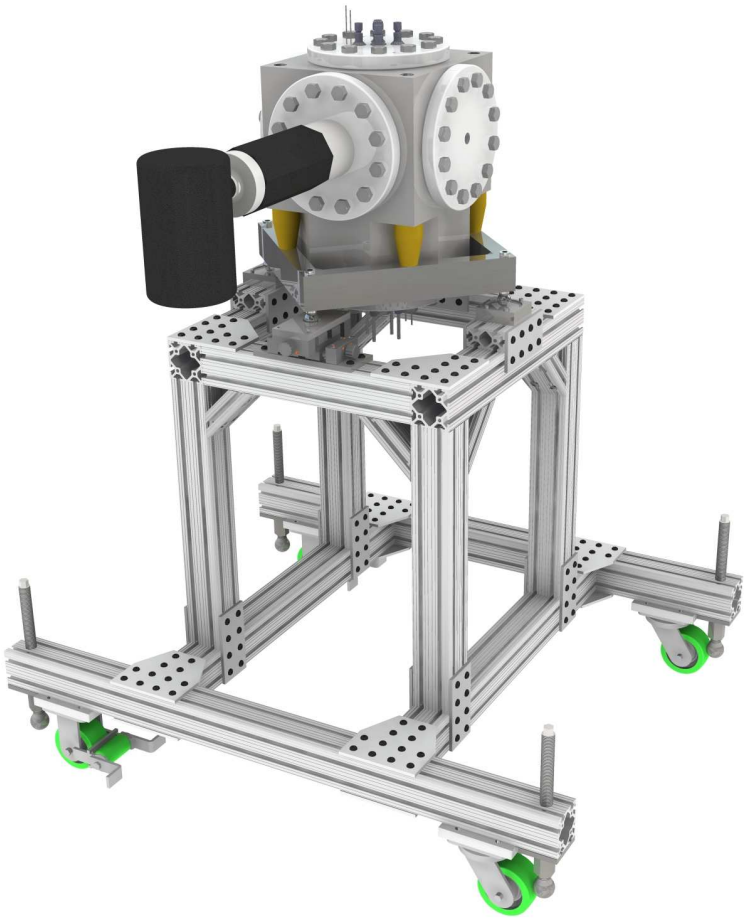
Authorized: _____ 2/16/2010
R.V.F. Janssens Date





Safety and Systems

- **Basic Operation and Phase Diagrams**
  - Theory of Operation
  - Basic Components of the Detector
- **Overview of Systems and Components**
  - Bubble Chamber
  - Pressure Vessel
  - Viewport, Camera, and Lighting
  - Hydraulic
  - Heating
  - Control and Instrumentation Chassis
  - Data Acquisition and Systems Integration
- **Safety**
  - Hydraulic Control System
  - Bubble Chamber Pressure Vessel
  - Control Chassis and Remote Overrides
  - Heating
  - Chemical



Theory of Operation

1 → 2

Active liquid is pressurized

2 → 3

Active liquid is heated

3 → 4

Pressure is reduced creating a superheated liquid

4

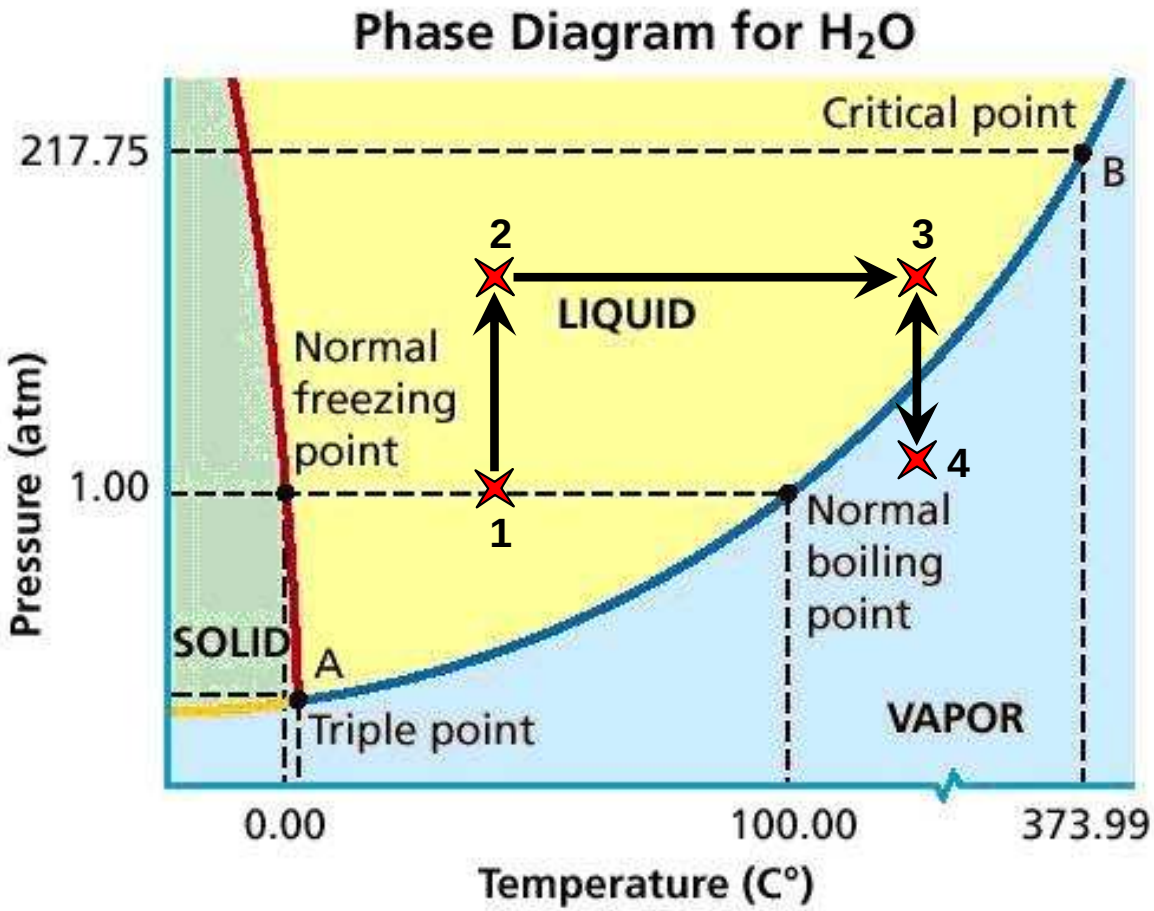
Nuclear reactions induce bubble nucleation

4 → 3

High speed camera detects bubble and repressurizes

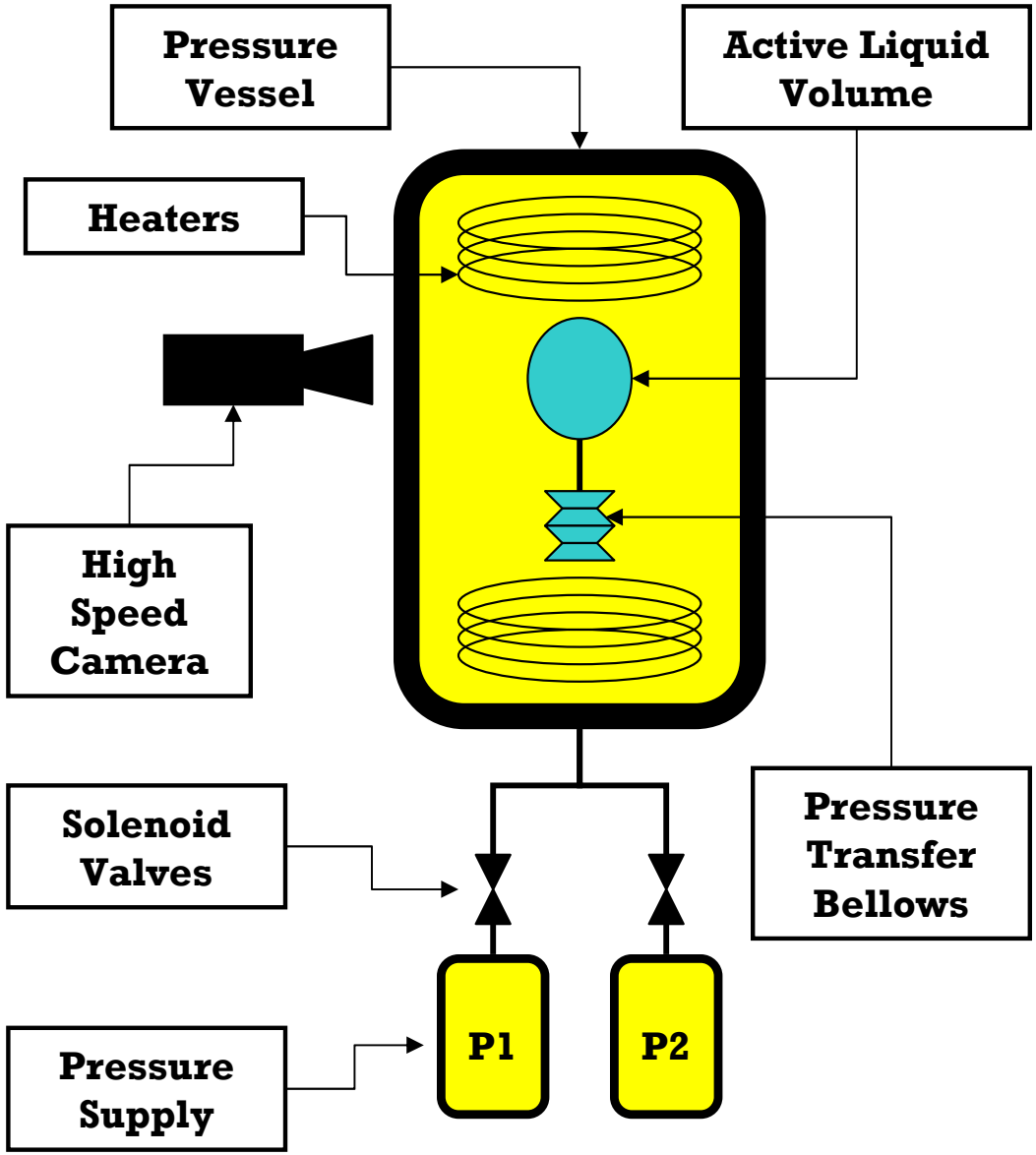
3 → 4 → 3

System is now prepared for another cycle.



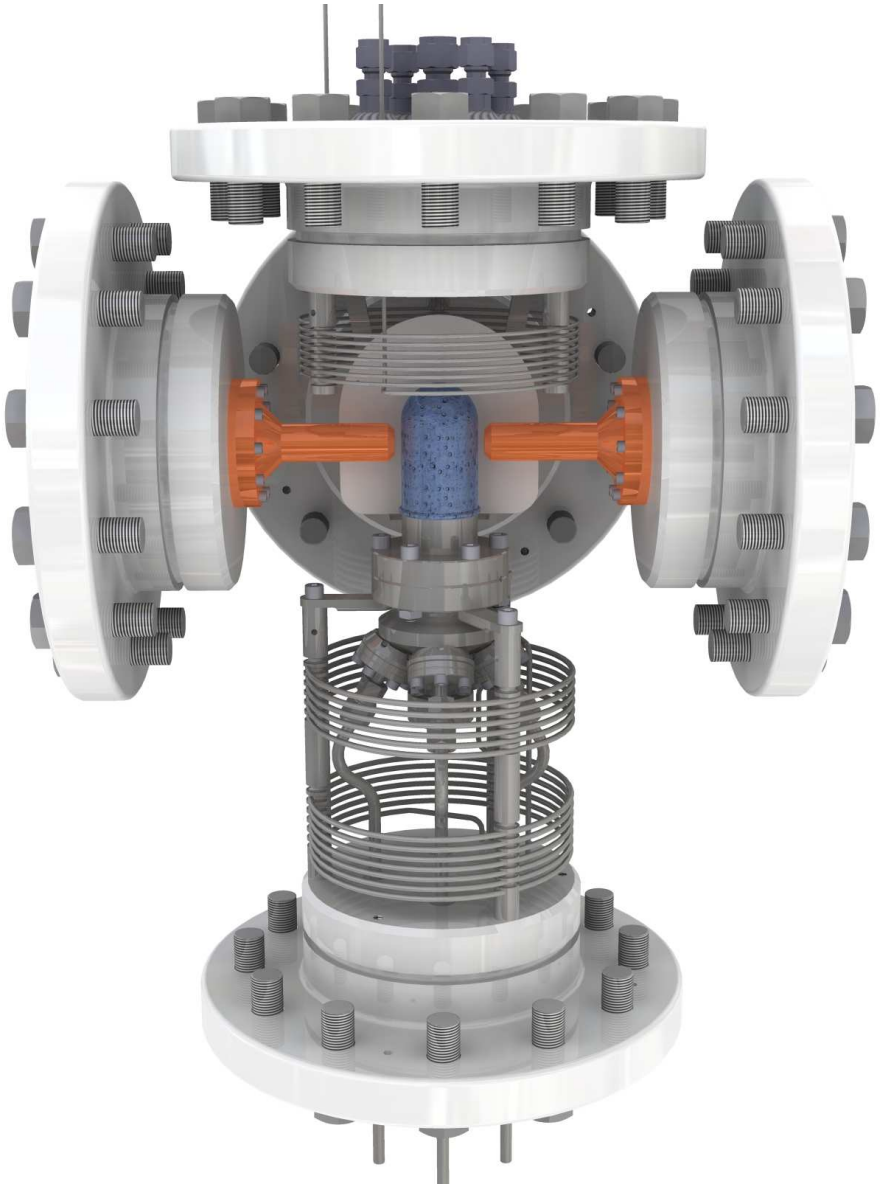
Basic Components

- Heavy Wall Stainless Steel Pressure Vessel
- Thin Wall Glass Active Liquid Volume
- Thin Pressure Transfer Bellows
- Heaters
- Pressure Supply
- Solenoid Valves
- High Speed Camera

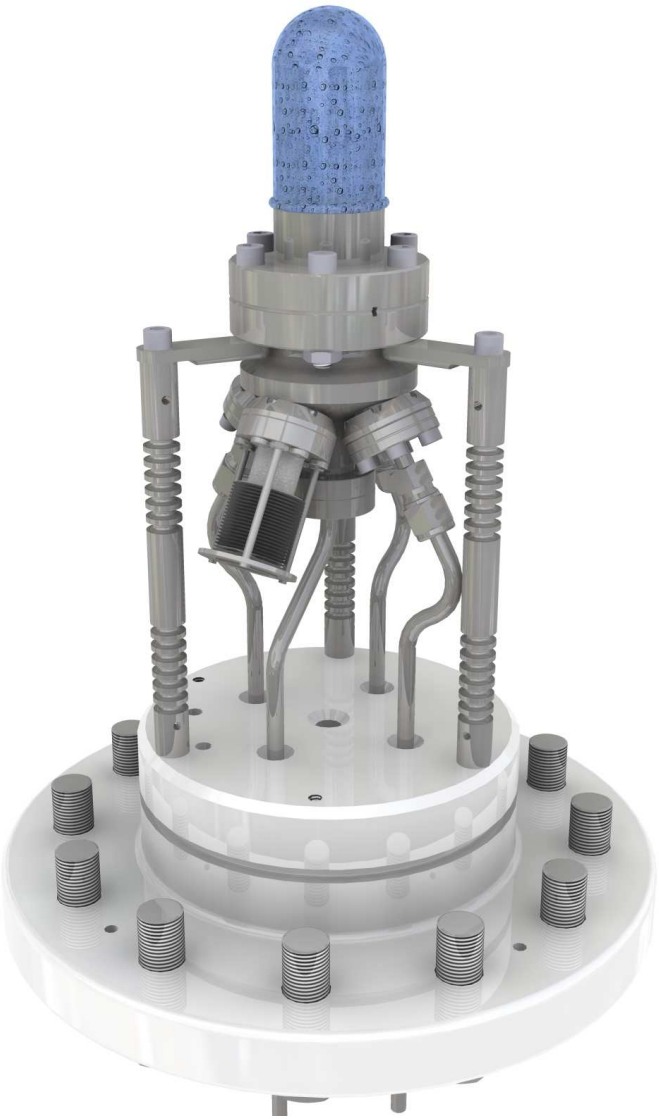


Systems and Components

- Bubble Chamber
- Pressure Vessel
- Viewport, Camera and Lighting
- Hydraulic Control
- Heating
- Control and Instrumentation
- Data Acquisition and Systems Integration

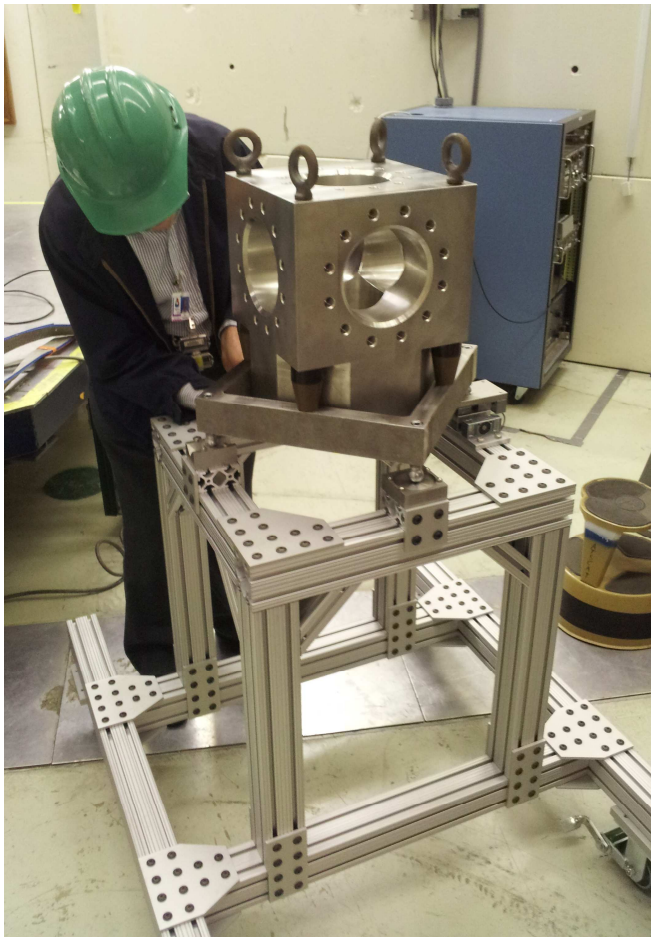


Bubble Chamber

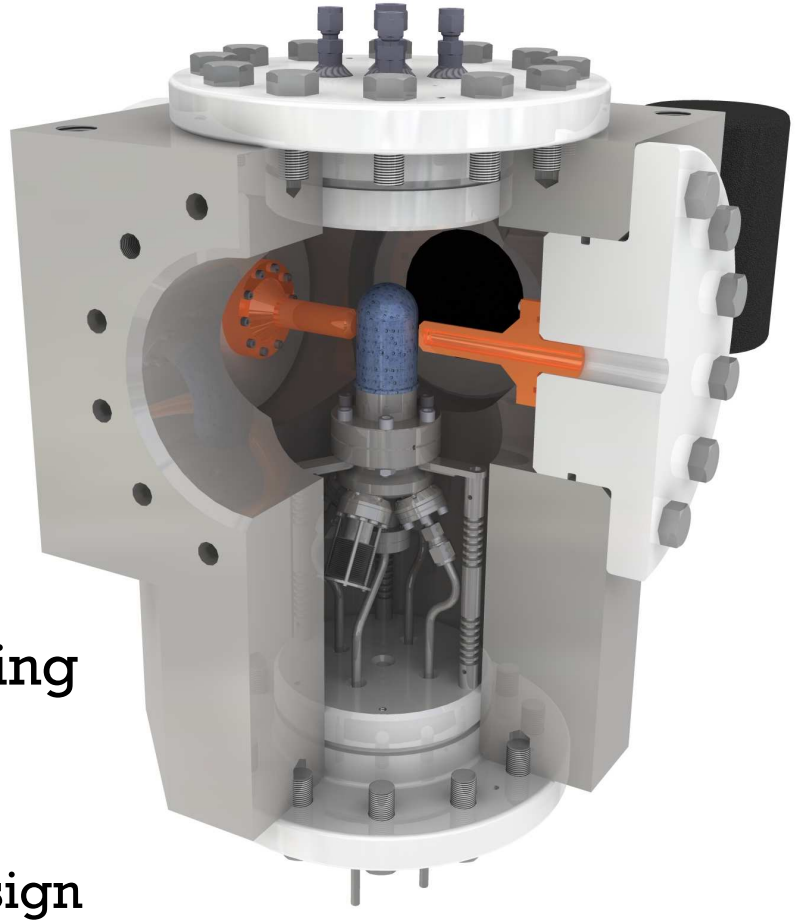


- Thin Glass Vessel Holds Active Liquid, H_2O
- H_2O Floats on Diffusion Pump Oil
- Oil Fills Remaining Inner Volume
- Superheated Liquid Only in Contact With Smooth Surfaces
- Thin Sensitive Edge Welded Bellows Equalize Pressure
- Stainless Tube Facilitates External Connection of Pressure Transducers and Filling Valves

Pressure Vessel

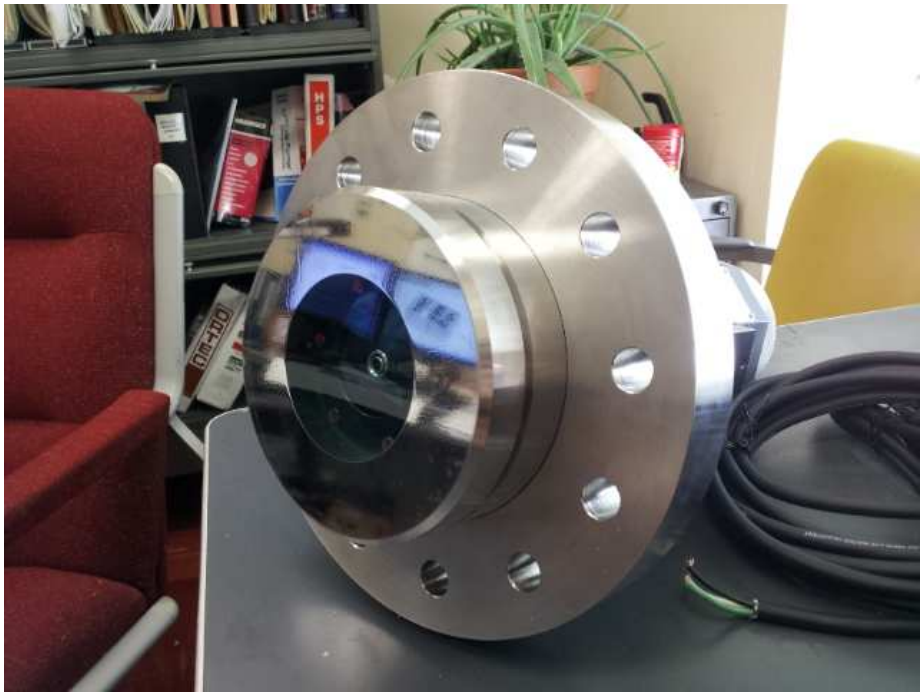


- Houses Bubble Chamber
- One Piece Construction
  - No Welding
  - Minimal Internal Volume
- Machined From a Solid 304 S.S. Forging
- Flanges Machined From 316 S.S.
  - Utilize a Plug Design to Reduce Inner Volume



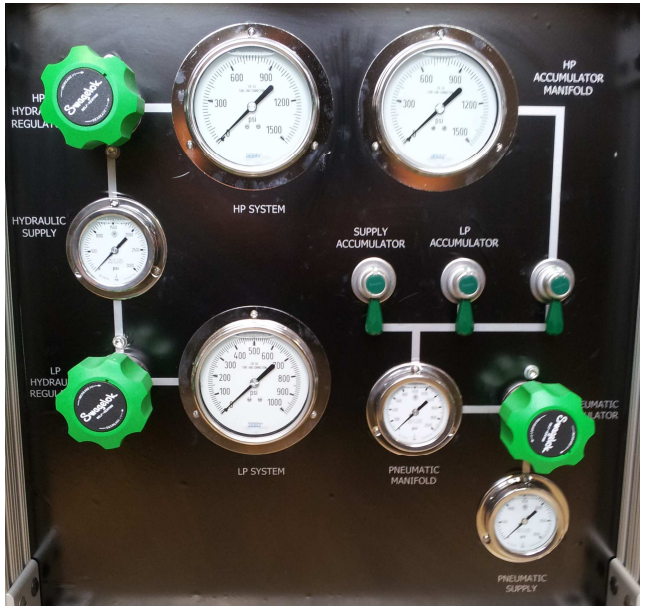
Viewport, Camera, and Lighting

- Custom Designed and Fabricated by Industry Leader in High P&T Viewports
- Design Paramaters:
  - 260°C
  - 88 ATM
- High Speed 100FPS Camera
- High Intensity Fiber Optic Lighting

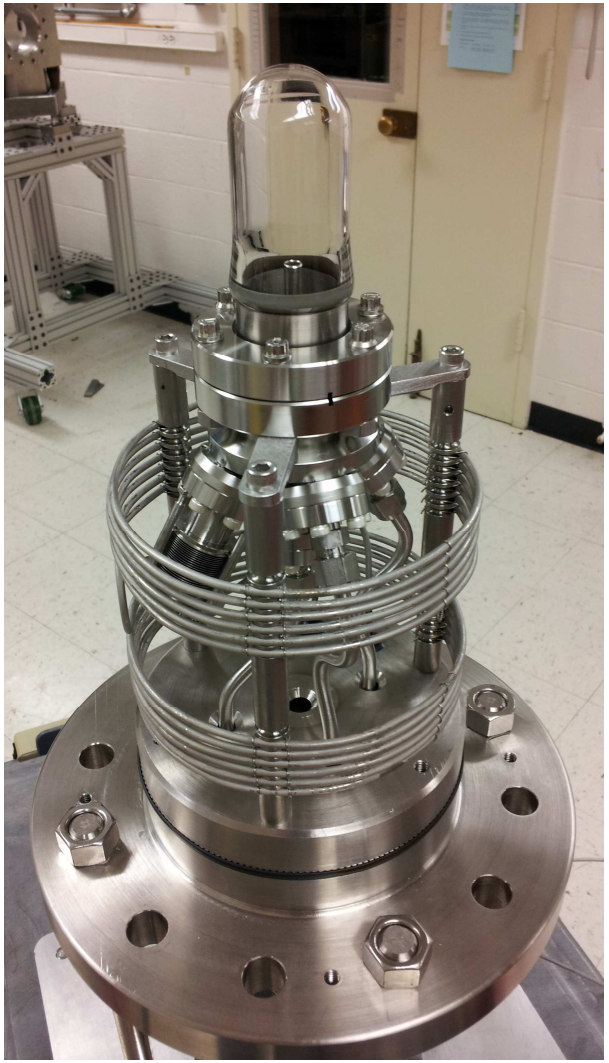


Hydraulic Control System

- Constructed of Commercially Available Off-the-Shelf Components
  - Pressure Rated for Hydraulic Service
- Provides Regulated Hydraulic Pressure
- Solenoid Valve Output Control
- Output Flow Control and Relief
- Vented Reservoir System



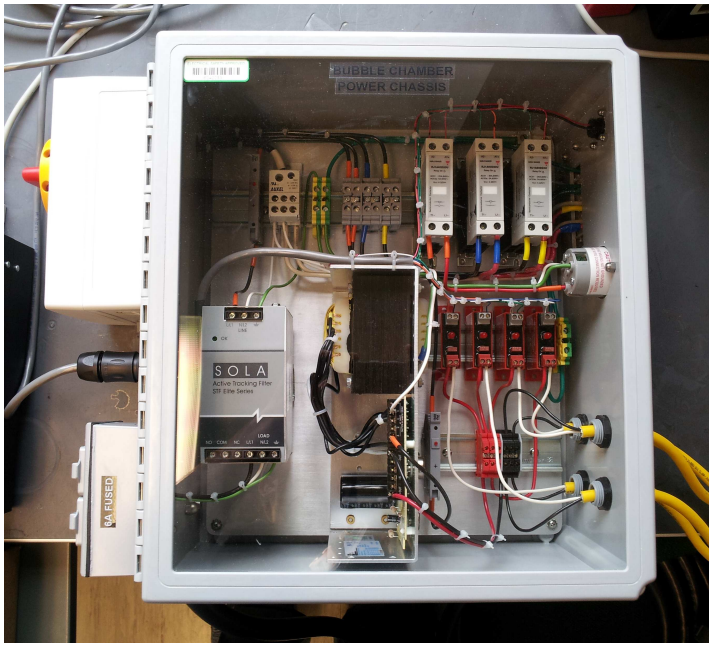
Heating



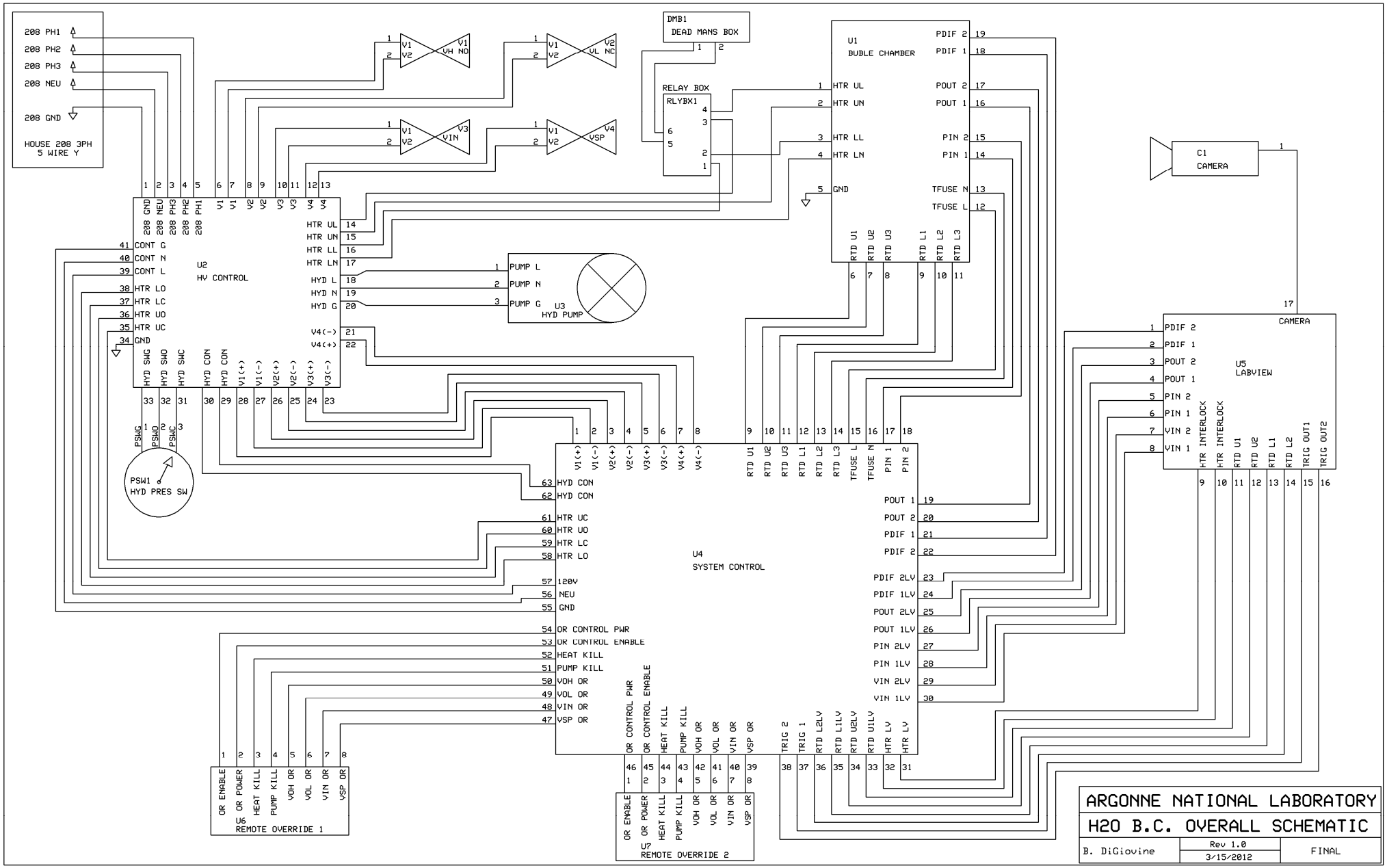
- Thermocoax: Commercial Off-the-Shelf Heating Elements
- Mineral Insulated Stainless/Inconel Sheath Coaxial Heating Elements
- Electrical Connections Made Externally
- 3.5kW Total Heating

Control and Instrumentation Chassis

- Temperature Monitoring and Heater Control
- Pressure and Temperature Transducer Retransmission to Computer
- Solenoid Valve Manual Operation and Computer Interface
- Hydraulic System Logic and Interlocks
- Two Remote Override Control Interfaces
- Electrical Safety Inspection Completed on All Chasses

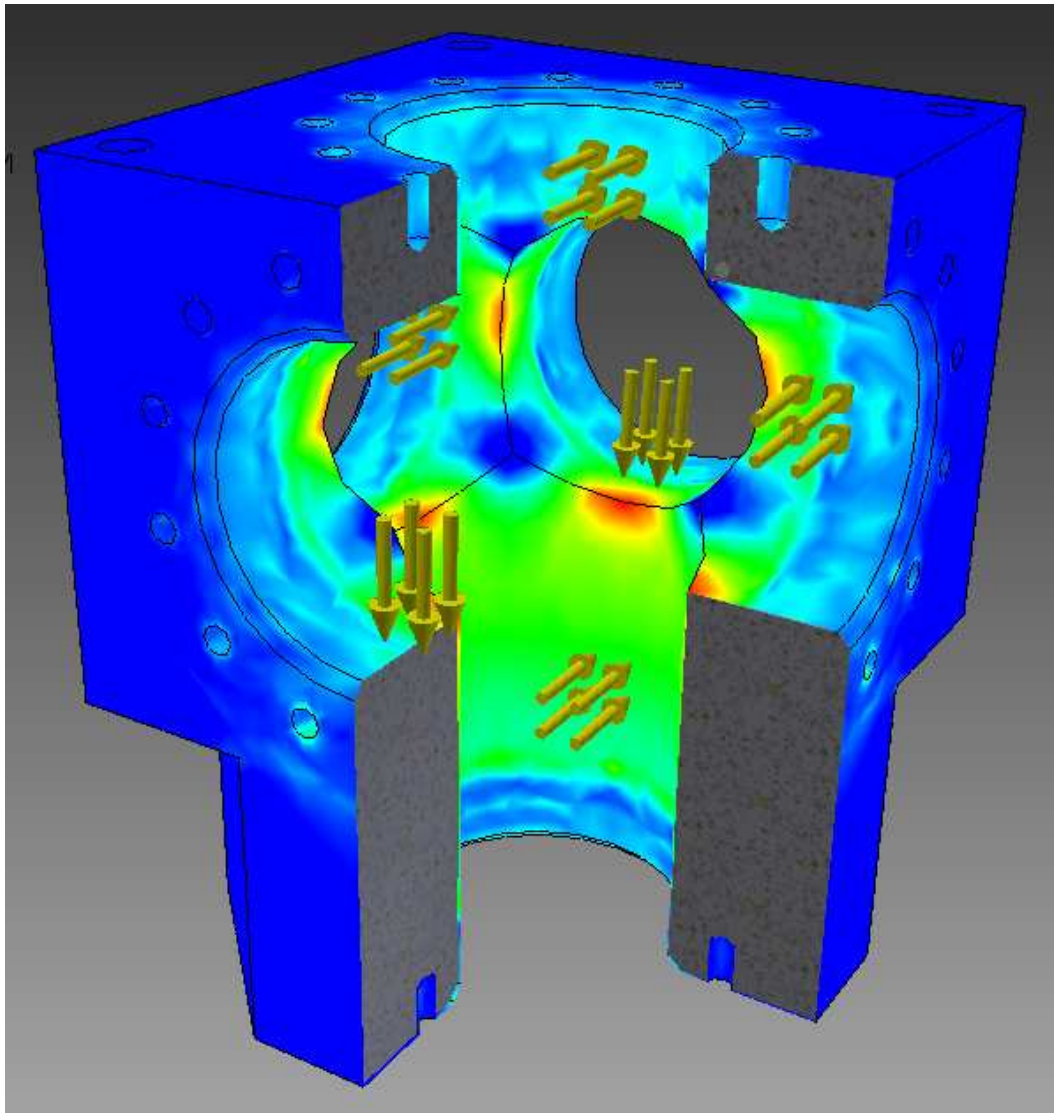


Data Acquisition / System Integration

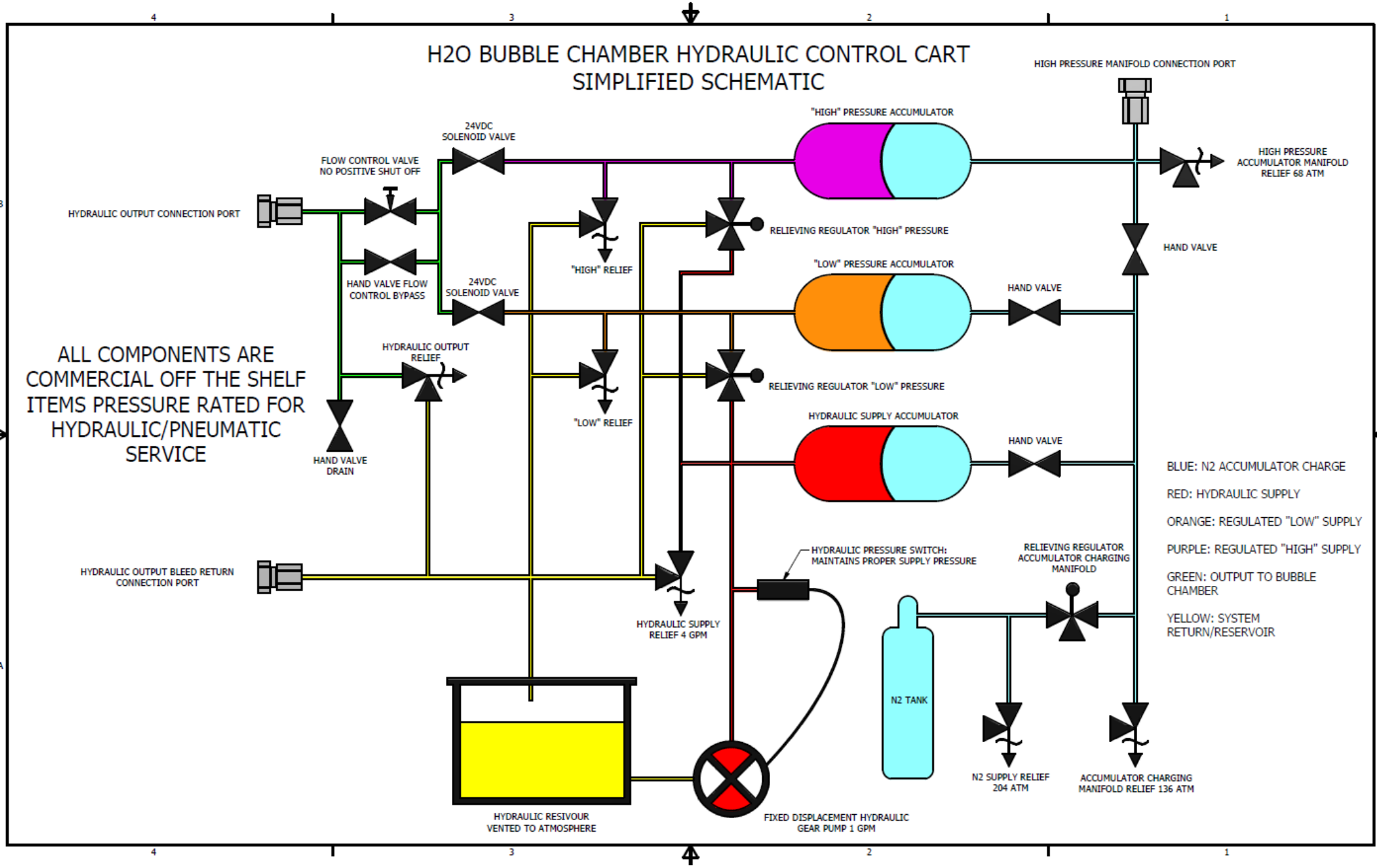


SAFETY

- Hydraulic Control System
- Bubble Chamber Pressure Vessel
- Control Chassis and Remote Overrides
- Heating
- Chemical

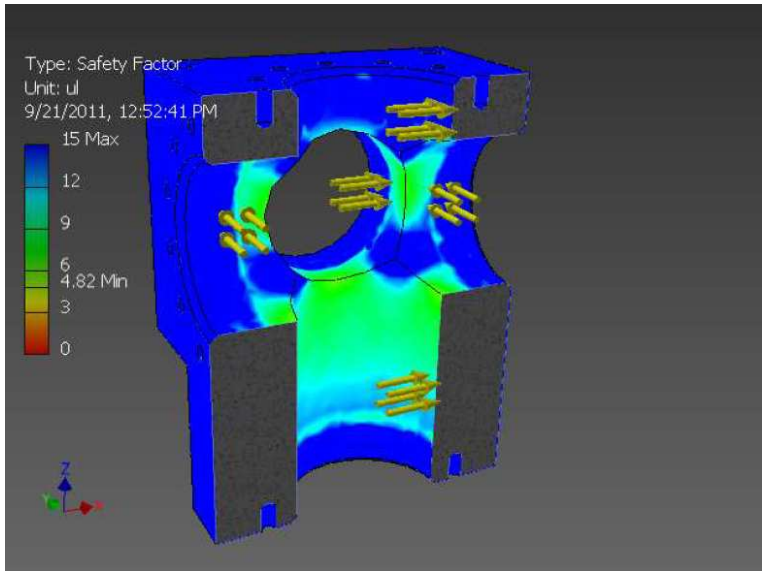


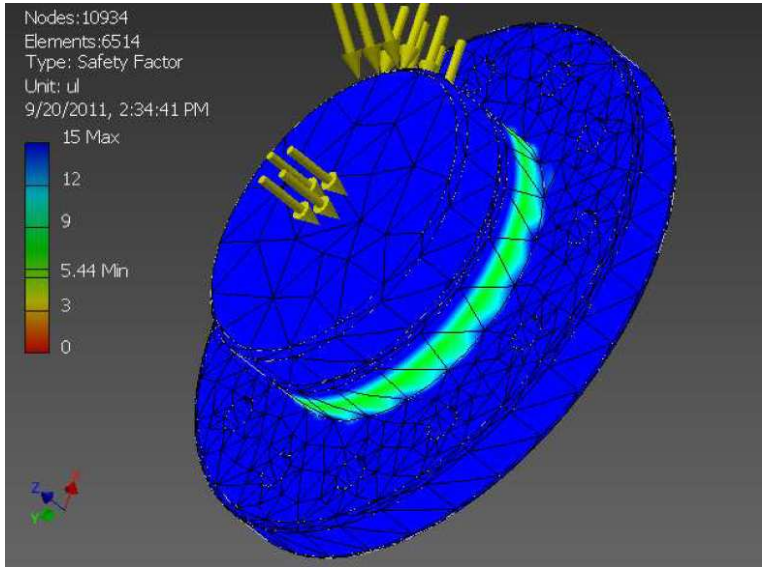
Hydraulic Control System



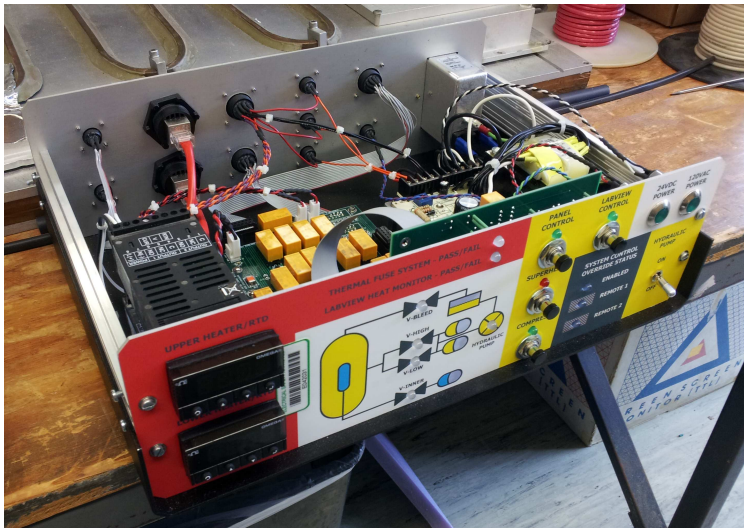
Bubble Chamber Pressure Vessel

- FEA Used for Verification of Production Design, Pressure of 88 ATM
- Material Properties @ 250°C Used for Simulations and Analysis
- S.F. Based on Material **Yield Strength**, *Not* Ultimate Tensile Strength
  - Pressure Vessel Safety Factor: 4.8
  - Pressure Flange Safety Factor: 5.4
- @ 88 ATM, Force on Flange = 34klbf
  - Each Bolt Must Carry 2.8klbf
  - 5/8-18 Grade 5 Bolt Rated to 36klbf
  - Bolts Safety Wired to Prevent Loosening
- Max Operating Conditions to be Limited to 68 ATM, 250°C





Control Chassis & Remote Overrides



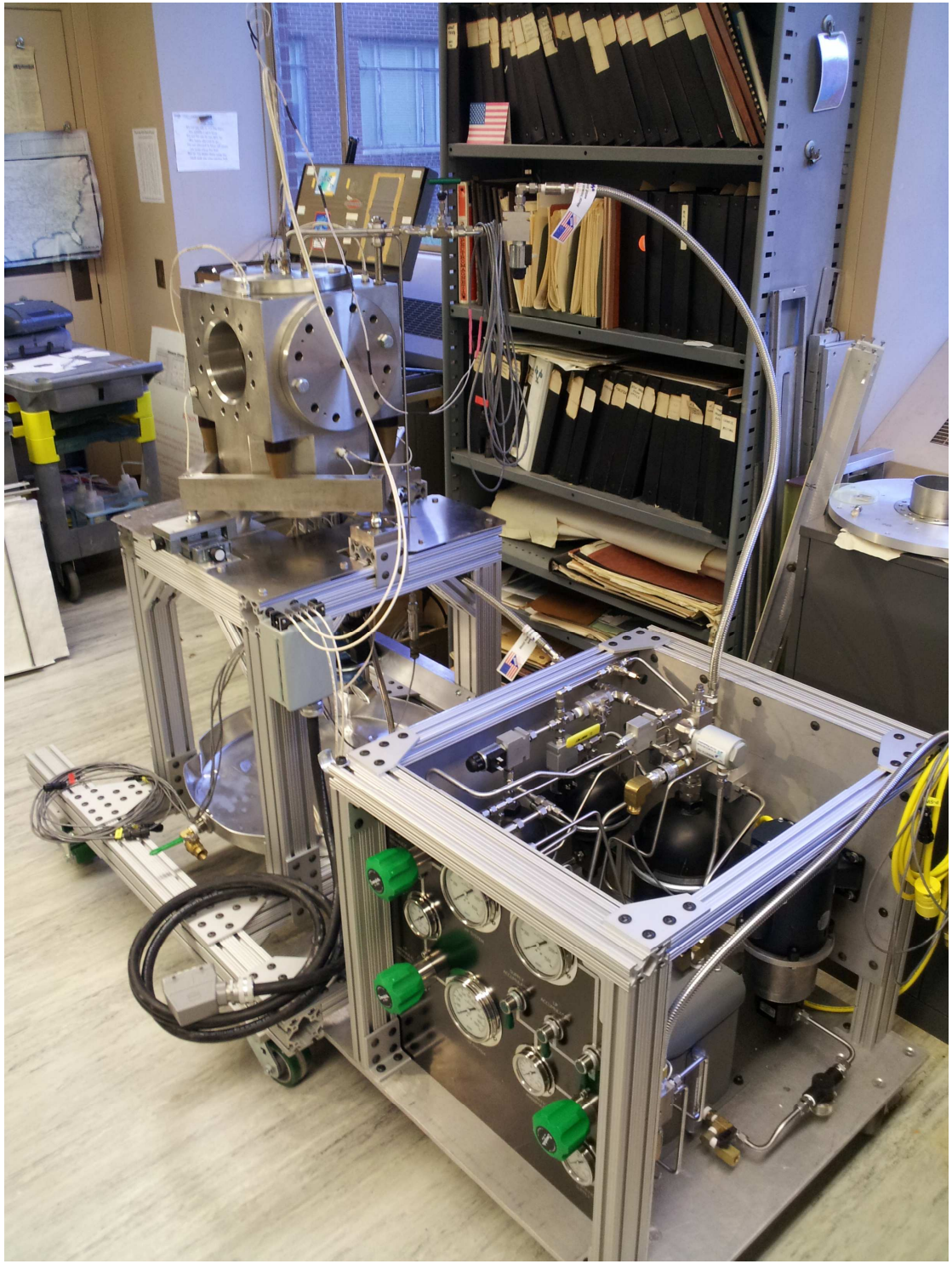
- Control Chassis Designed with Safety Interlocks
  - Heating
  - Solenoid Valves
- Two Remote Override Interfaces Allow for Complete Control of System
  - Solenoid Valves
  - Hydraulic Pump
  - Heaters

Heating Safety

- Commercial Heating Controllers Integrated into System
- Retransmission of Temperature Values to Computer
  - Logging Values
  - Heater Interlock
- Thermal Switch Network Installed on Pressure Vessel
- Heater Override on Remote Interface
- Redundant and Independent Remote Heat Kill System
- Thermal Insulation Housing
  - Reduce Heat Loss
  - Protect Personnel

Chemical Safety

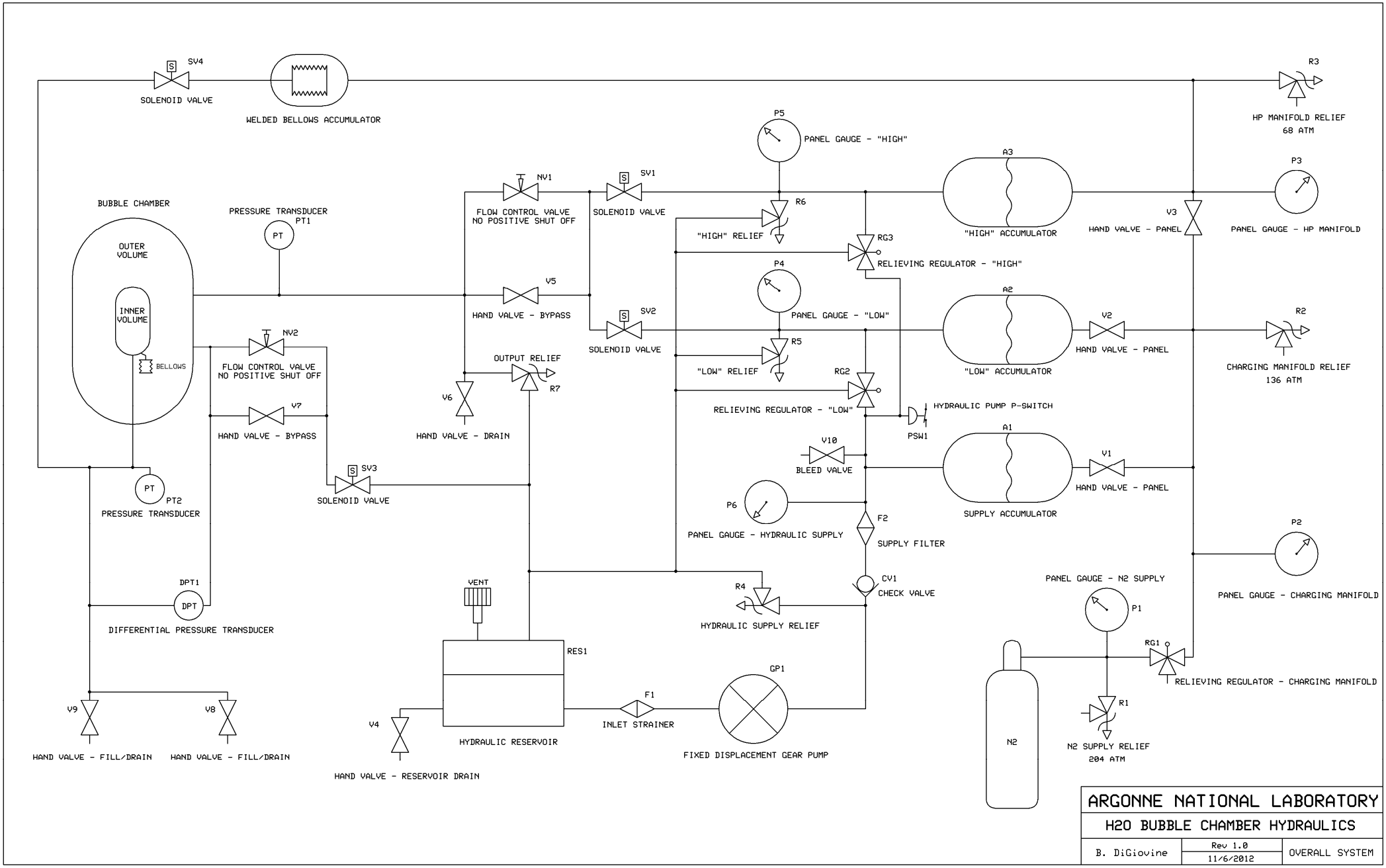
- Paratherm NF
  - Commercial Heat Transfer Fluid
  - Max Operating Temp 332°C
  - Food Grade, Mineral Oil Based
- Fomblin 14/6
  - Diffusion Pump Oil
  - Chemically Inert
  - Wide Temperature Operating Range (-100°C to 290°C)
- Distilled Water
- No Serious Hazards
  - Standard PPE: gloves, safety glasses
- Disposal:
  - NF: Waste Oil Recycler
  - Fomblin: Landfill, Not Hazardous



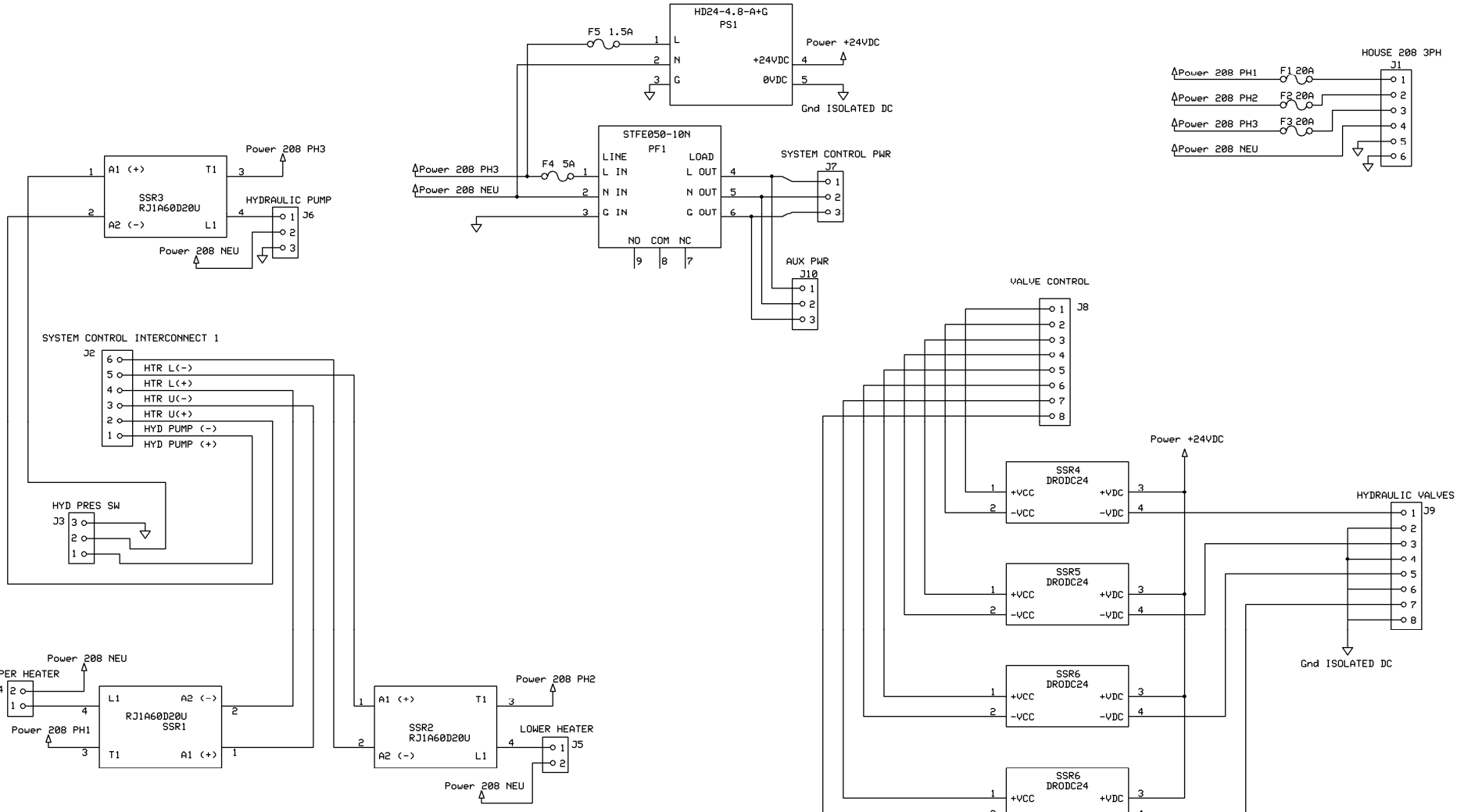
Appendix

1. Complete Hydraulic Schematic
2. High Voltage Control Chassis Schematic
3. Logic and Instrumentation Chassis Schematic
4. Relay Logic PCB Schematic
5. Front Panel Interface PCB Schematic
6. Compressed Liquid Energy Stored Calculations
7. Flange Loading and Bolt Strength Calculations
8. Canty Quote With Design Parameters
9. Beam Entry Port FEA

Hydrulic Schematic

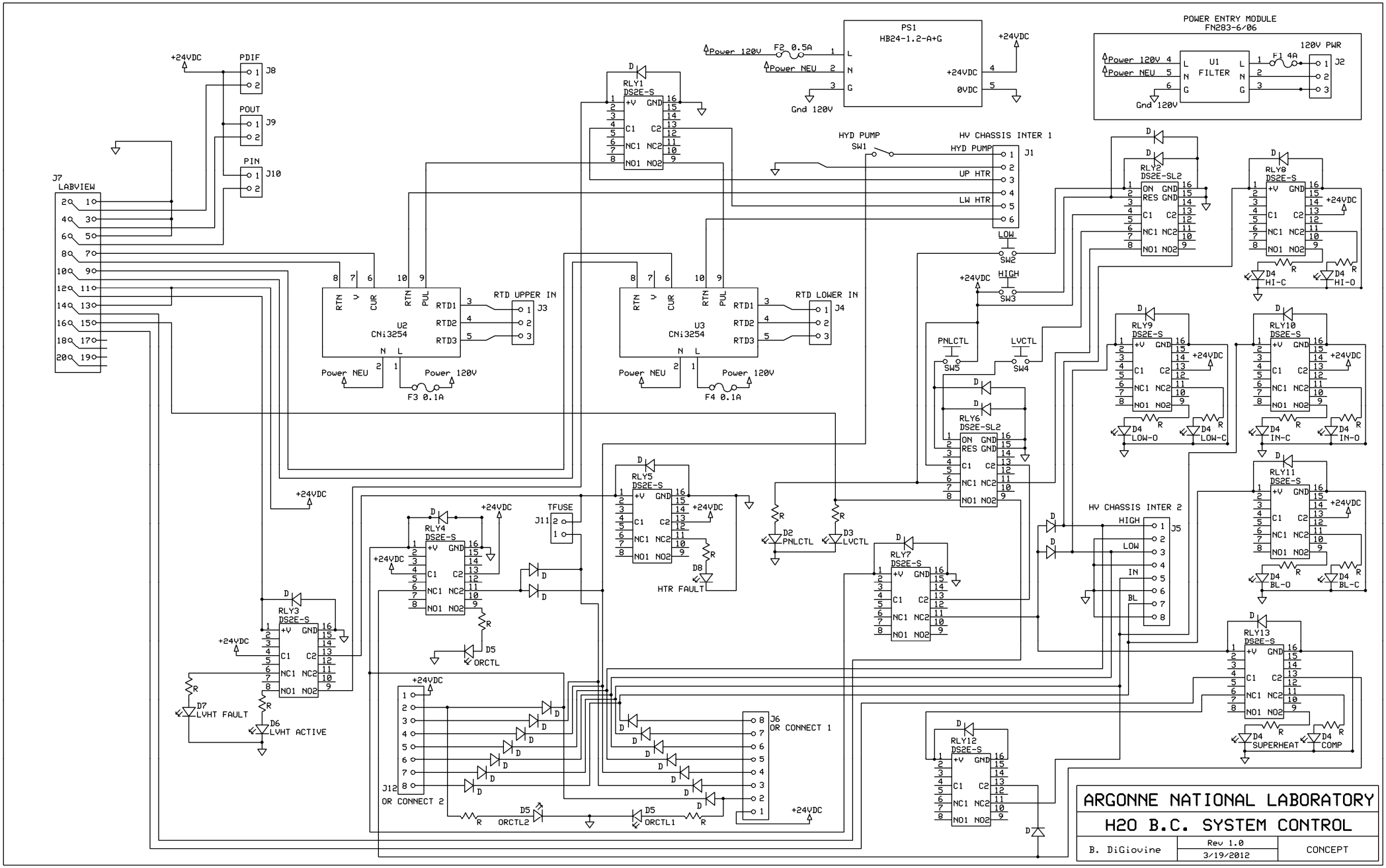


High Voltage Chassis Schematic

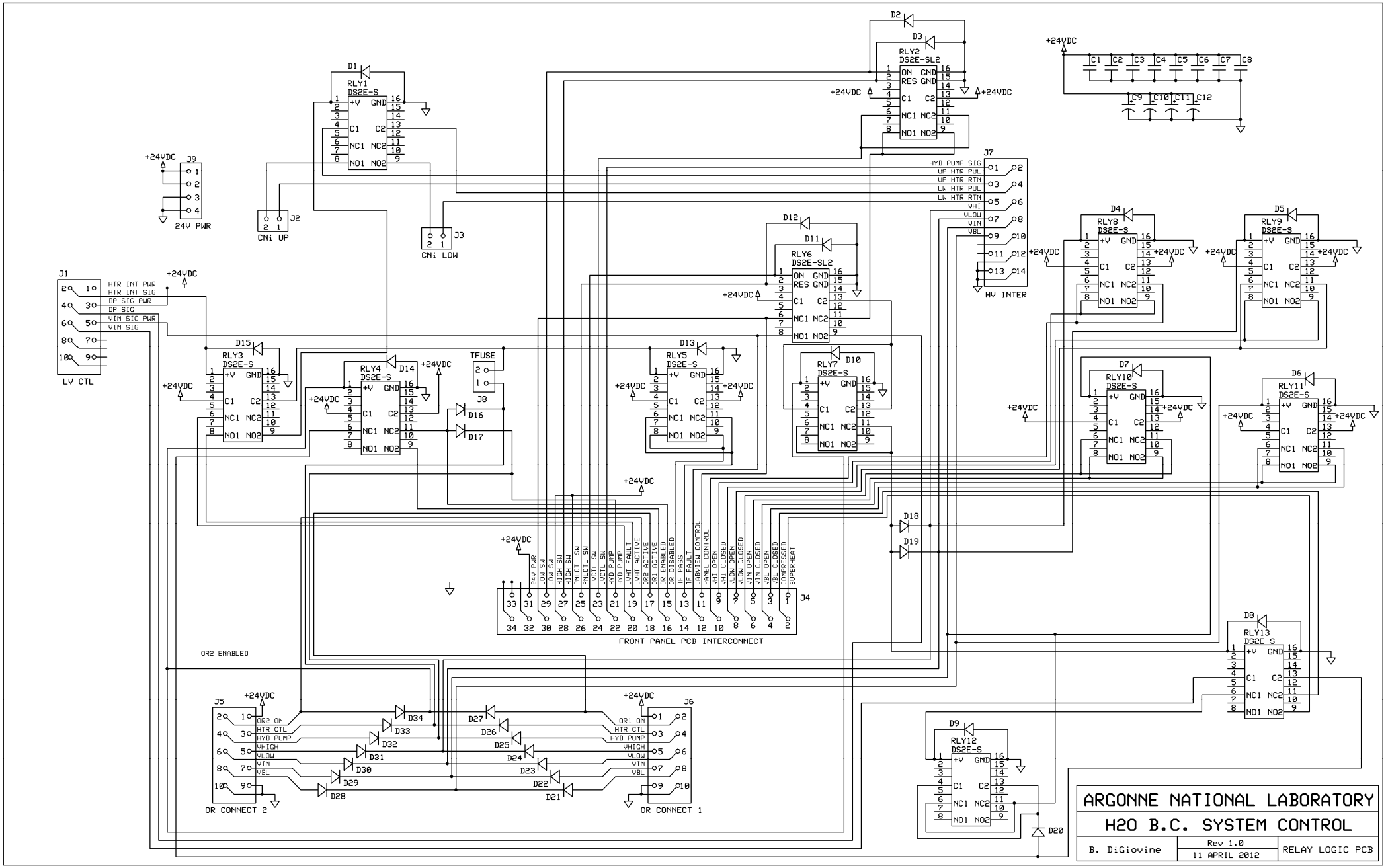


ARGONNE NATIONAL LABORATORY		
H2O B.C. HV SCHEMATIC		
B. DiGiovine	Rev 1.0 3/19/2012	CONCEPT

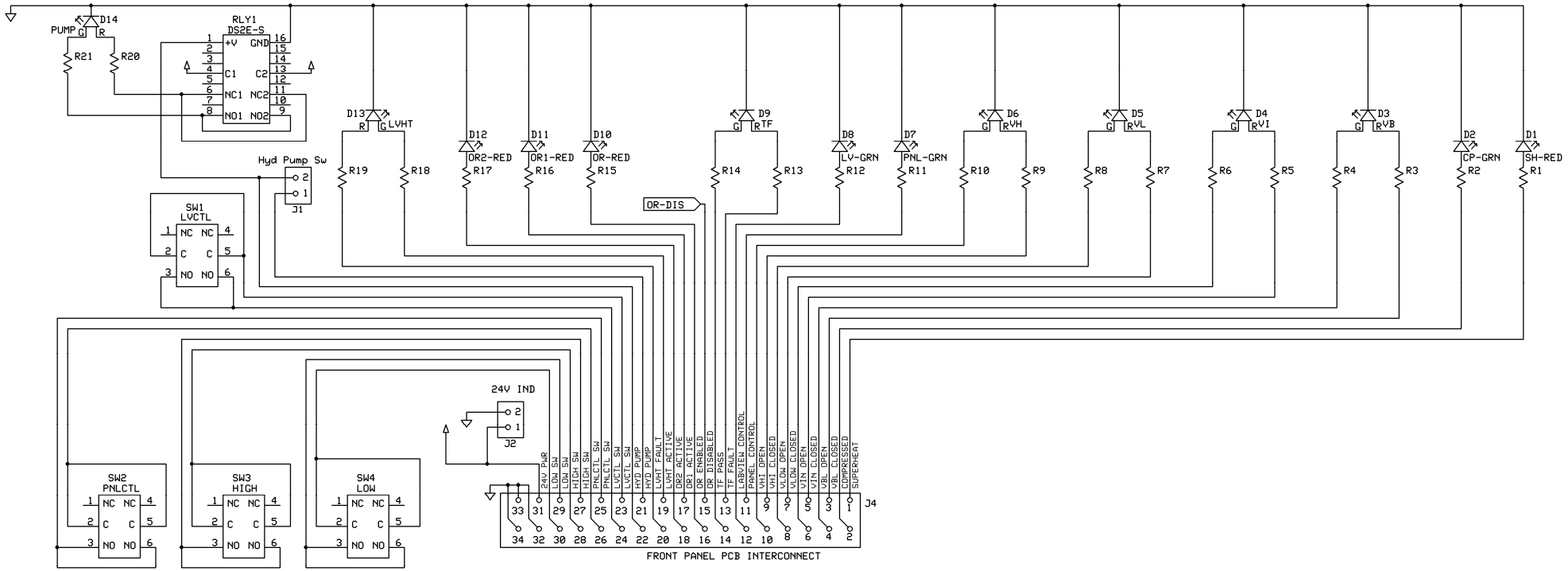
Logic & Instrumentation Chassis Schematic



Relay Logic PCB Schematic



Front Panel Interface PCB Schematic



ARGONNE NATIONAL LABORATORY		
H2O B.C. SYSTEM CONTROL		
B. DiGiovine	Rev 1.0 3/19/2012	FRONT PANEL PCB

Energy Storage Calculations

Energy Stored in compressed liquid

$B \sim 1000\ MPa$

Volume $= 460\ in^3 \cdot .007538\ m^3$

$$U_{liq} = \frac{1}{2}\left(\frac{(P_{sys})^2 V_{sys}}{B}\right) = \frac{1}{2}\left(\frac{(9\ MPa)^2 (0.007538\ m^3)}{1000\ MPa}\right) = 1\ \frac{N}{m^2}(m^3)$$

$$\boxed{U_{liq} = 306\ J}$$

All stored potential energy given to single flange (All bolts break simultaneously)
Seal friction neglected

Mass of flange $= 16\ kg$

$$306\ J = U_{liquid} = K_{flange} = \frac{1}{2}mv^2$$

$$\sqrt{\frac{2(306\ J)}{16\ kg}} = v = 6.18\ m/s = 14\ mph$$

Flange Loading & Bolt Strength Calculations

5/8 - 18 Bolts X 12 equally

SS 70,000 PSI

Grade 5 120,000 PSI

Grade 8 150,000 PSI

Flange - Area to see pressure

Ø 5.75"

$\pi(2.875")^2 = 25.97 in^2$

Force on flange

$(1300 psi)(25.97 in^2) =$

33,761 lbs Force

Ø of bolt .625"

Cross section Area:

$\pi(.3125)^2 = 0.3067 in^2$

Each bolt must carry:

$\frac{(33,761 lbf)}{12 bolts} = 2814 lbf$

Bolt data

SS $(70,000 psi)(0.3067 in^2) = 21,469 lbf$

Grade 5 $(120,000 psi)(0.3067 in^2) = 36,804 lbf$

Grade 8 $(150,000 psi)(0.3067 in^2) = 46,005 lbf$

CANTY
PROCESS TECHNOLOGY

JM CANTY
6100 DONNER ROAD
LOCKPORT, NY 14094
716-625-4227
Fax: 716-625-4228
HTTP://WWW.JMCANTY.COM

Quotation

Quote Date: **9/14/2010**
Quote ID: **08471**
Sales Representative: **R100**

Quote To: **ARGONNE NATIONAL LABORATORY**
9700 S. CASS AVE.
ARGONNE, IL 60439
USA

Ship To:

Contact:

Customer Reference	Lead Time	Desired Ship Date	Quote Expiration Date

Terms	Tax Status	FOB Point	Ship Via	Preferred Carrier	Freight
NET 30	Exempt, Tax ID: 161077555	LOCKPORT	GROUND	UPS	Billed

Line	Quantity	Part - Description	UM	Unit Price	Extension
1	1.0000	**CUSTOMQUOTE Custom Camera System, as per below notes**	EACH	14,980.0000	$14,980.00

Ethernet Camera light combination
Nema 4
A602F Camera
56 degree lens
Power Supply in non WP or EXP enclosure
316L/Hastelloy wetted
Mounting Connection - Custom Flange NPD-20-002
HYL 80 1SRDO integral light

Vessel operates up to 260C at pressure up to 1300 psig.

Delivery would be approximately 10 - 12 weeks from receipt of signed approval drawing.

sds

QUOTES ARE VALID FOR 30 DAYS FROM DATE OF ISSUE.

Line Item Sub Total:	**$14,980.00**
Service Charge Total:	**$0.00**
Total Before Tax:	**$14,980.00**

Canty Quote and Design Parameters

Beam Port FEA