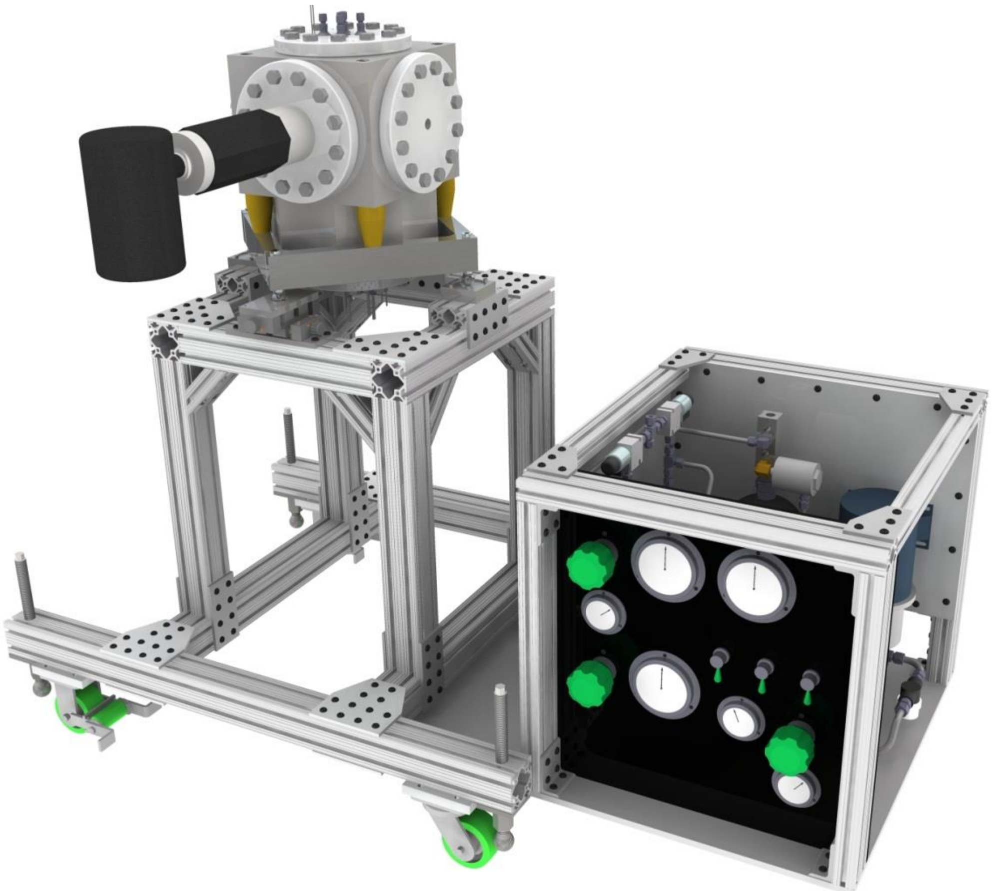
ANL Bubble Chamber Superheated Active Target System



N_2O and C_2F_6 as Active Fluids

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
- Nov 2012 - H_2O Chamber Safety Approval and Testing at ANL
- 2013 - Week Long Campaign at HIγS
- 2014 Approval and Modification of System for Change of Working Fluids
- 2015 Months of Testing and Evaluation @ ANL using Hg, N_2O & C_2F_6
- 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 ESH/QA 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 ______ R.V.F. Janssens, PHY Director 10/22/09 Date

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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.

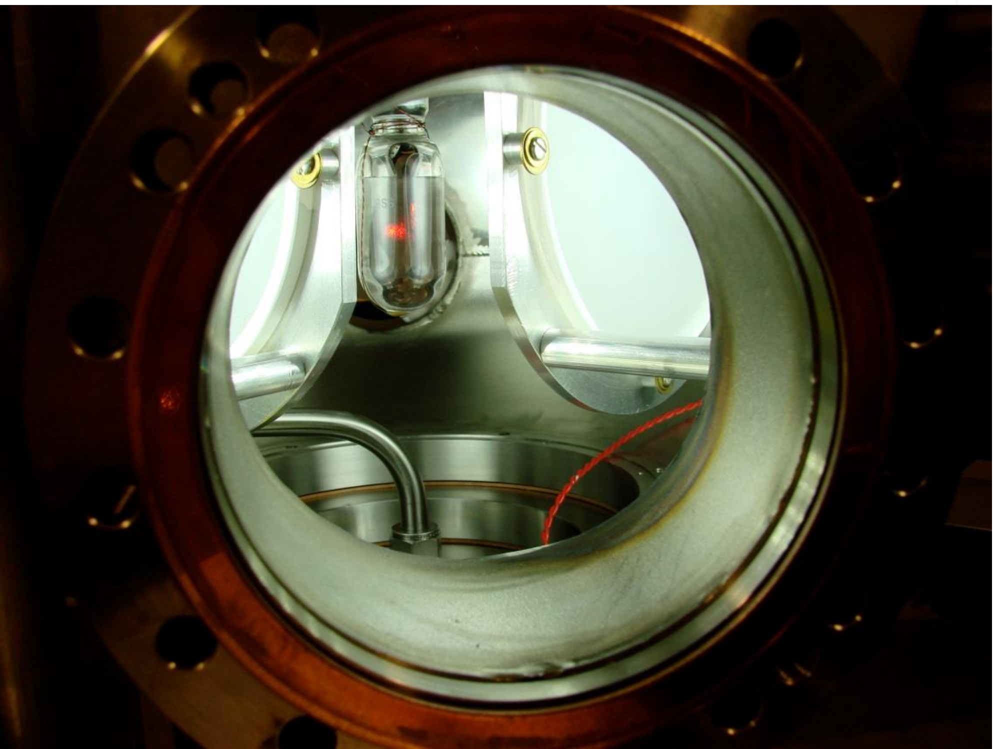
The committee used the document: Upgraded Bubble Chamber, Hazard Analysis and Project Review Form in their review of this device.

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 ______ R.V.F. Janssens 2/16/2010 Date



Argonne NATIONAL LABORATORY

Intra-Laboratory Memo

November 14, 2012

TO: R. V. F. Janssens Director/PHY

FROM: T. P. Mullen PHY ESH/QA Engineer

SUBJECT: Review of the Water Bubble Chamber

A committee made up of members of the Physics Division General Safety Committee and other Argonne employees met on November 13, 2012. The committee consisted of Physics General Safety Committee members Tom Mullen, Frank Curran, and Nancy Van Wermeskerken along with Bruce Nardi, Division DEEI, and Dejan Ristic, ANL Pressure Safety Subject Matter Expert. Also present were Brad DiGiovine, Roy Holt, Ernst Rehm, Claudio Ugalde, Kim Miller and Dale Henderson.

The committee met to review the Water Bubble Chamber constructed for use in an experiment at Duke University in December, 2012 (presentation attached).

Prior to the meeting, the committee was provided with an Equipment Hazard Analysis for the Water Bubble Chamber (attached).

At the meeting Ernst and Brad described the purpose and overview for the Water Bubble Chamber, which included components, control system, heating and safety systems.
The committee found that the complete system is safe to operate as described, when the following questions/concerns are addressed:

1) Bolts need to be inspected to insure they are not suspect/counterfeit items.
2) An Electrical inspection needs to be completed by Bruce Nardi on those items not already inspected.
3) Add the following to the operating procedures: pressure check and the tightening pattern and torque of the chamber bolts.
4) Calculations for stored energy should be added to the Equipment Hazard Analysis.
5) ESH119 (Pressure Safety Orientation) training will need to be completed by all operators.
6) Send MSDS sheets for all chemicals to Jeannie Elkins to be entered into the CMS database.
7) We strongly suggest to create a binder including all component specifications and MSDS sheets for the chemicals used, and keeping it with the chamber.

The committee additionally feels that the pressure cart is safe to operate at this time.

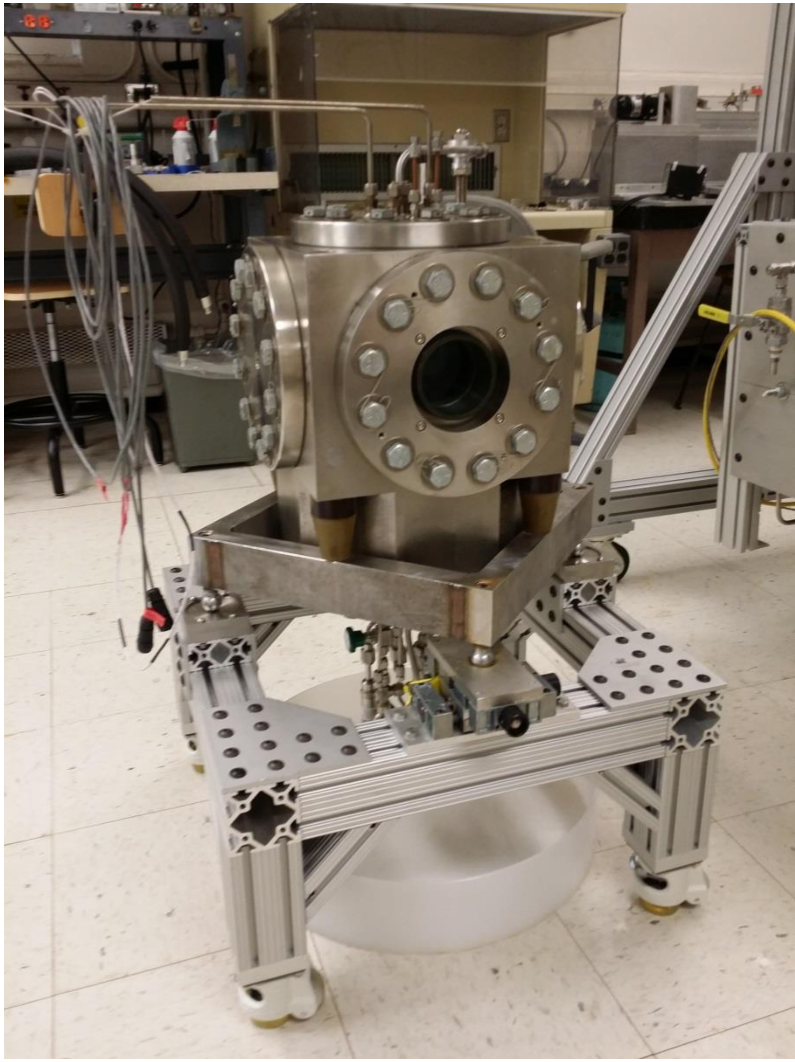
We recommend you authorize testing and operation of this chamber when the above questions and concerns have been addressed.

Authorized: ______ R.V.F. Janssens 11/14/12

ANL-26A (3-06)

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
  - Cooling
  - Control and Instrumentation Chassis
  - Data Acquisition and Systems Integration
- **Safety**
  - Hydraulic Control System
  - Bubble Chamber Pressure Vessel
  - Control Chassis and Remote Overrides
  - Chemical



Theory of Operation

1 Cell is cooled then filled with room temperature gas

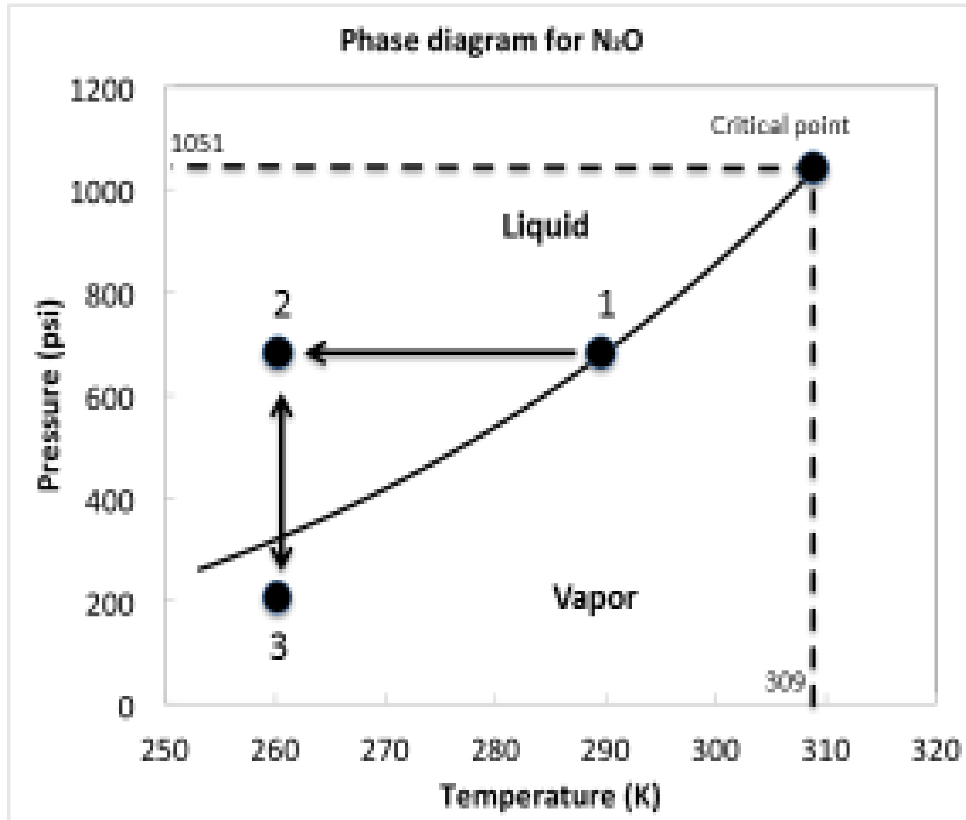
2 Gas is cooled and condenses into liquid

3 Once cell is completely filled with liquid, pressure is reduced creating a superheated liquid

3 Nuclear reactions induce bubble nucleation

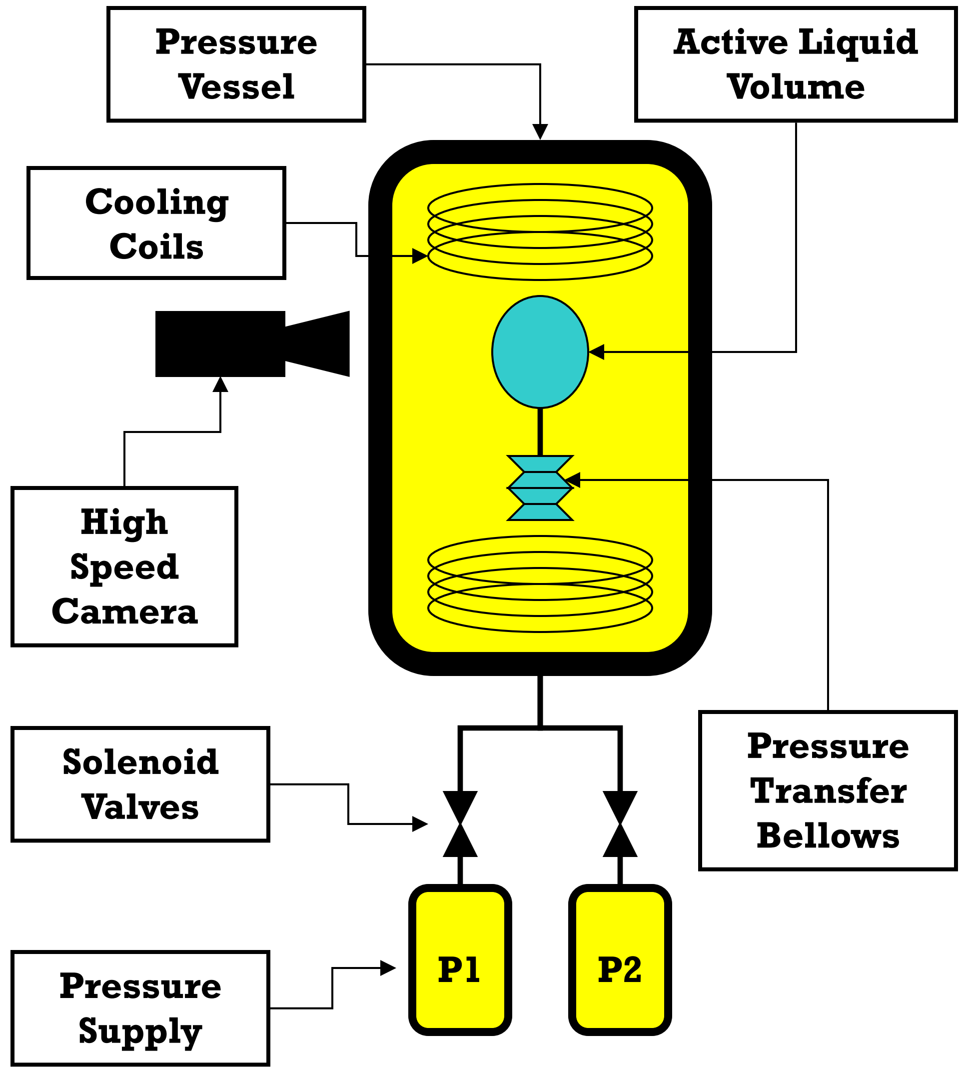
2 High speed camera detects bubble and repressurizes

3 System depressurizes and ready for another cycle



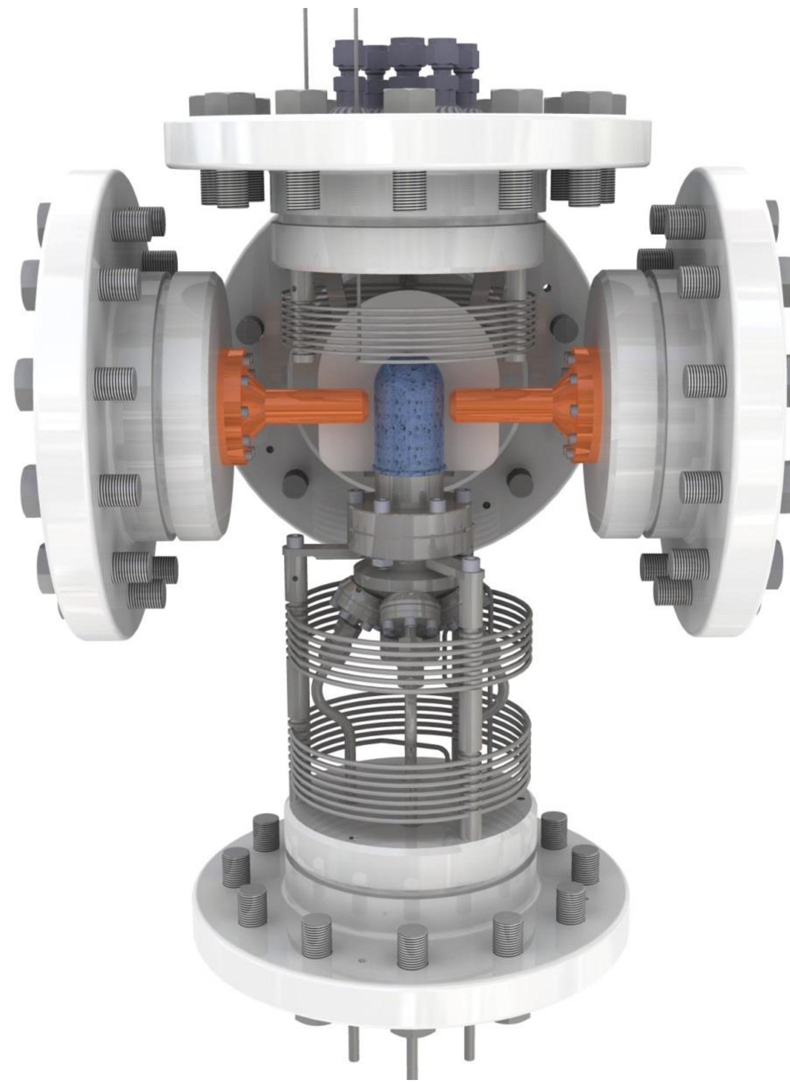
Basic Components

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

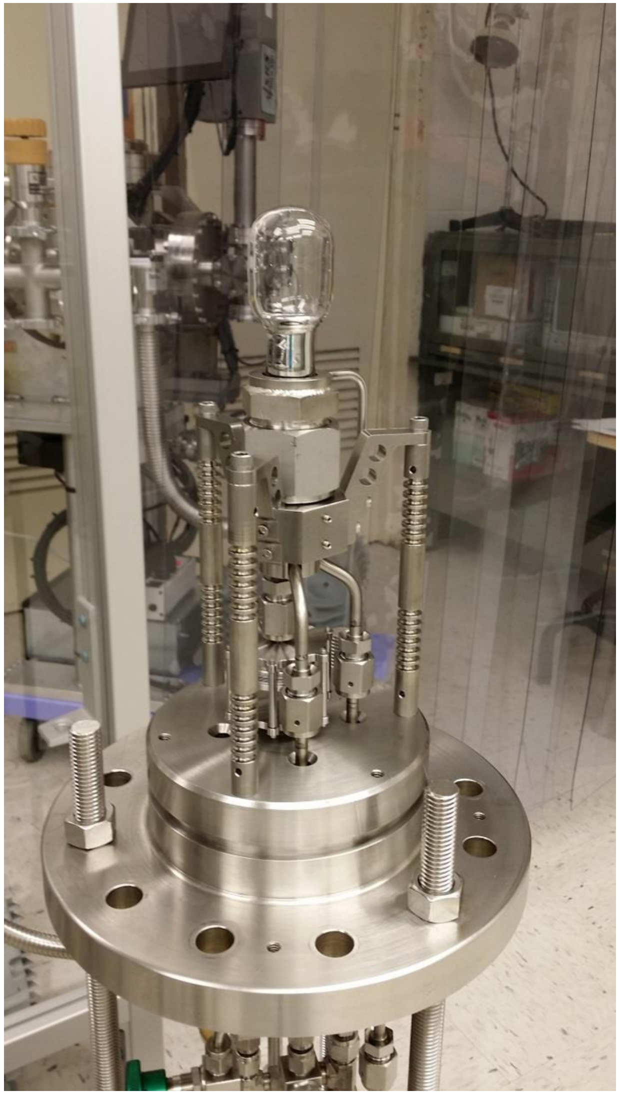


Systems and Components

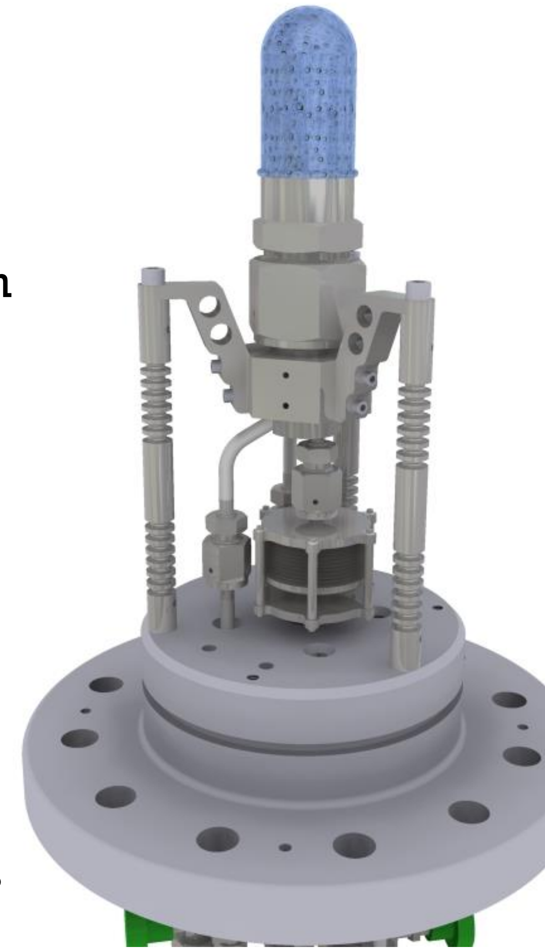
- Bubble Chamber
- Pressure Vessel
- Viewport, Camera and Lighting
- Hydraulic Control
- Cooling
- Control and Instrumentation
- Data Acquisition and Systems Integration



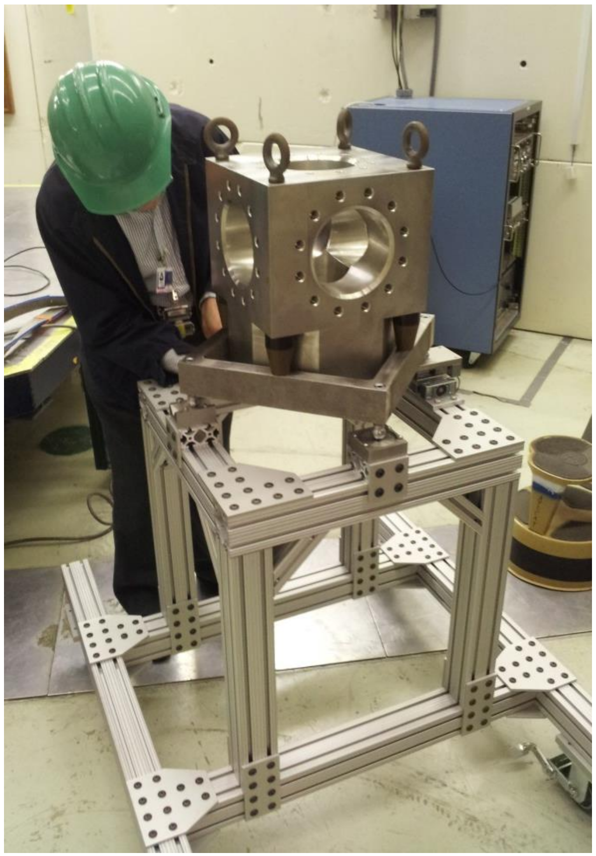
Bubble Chamber



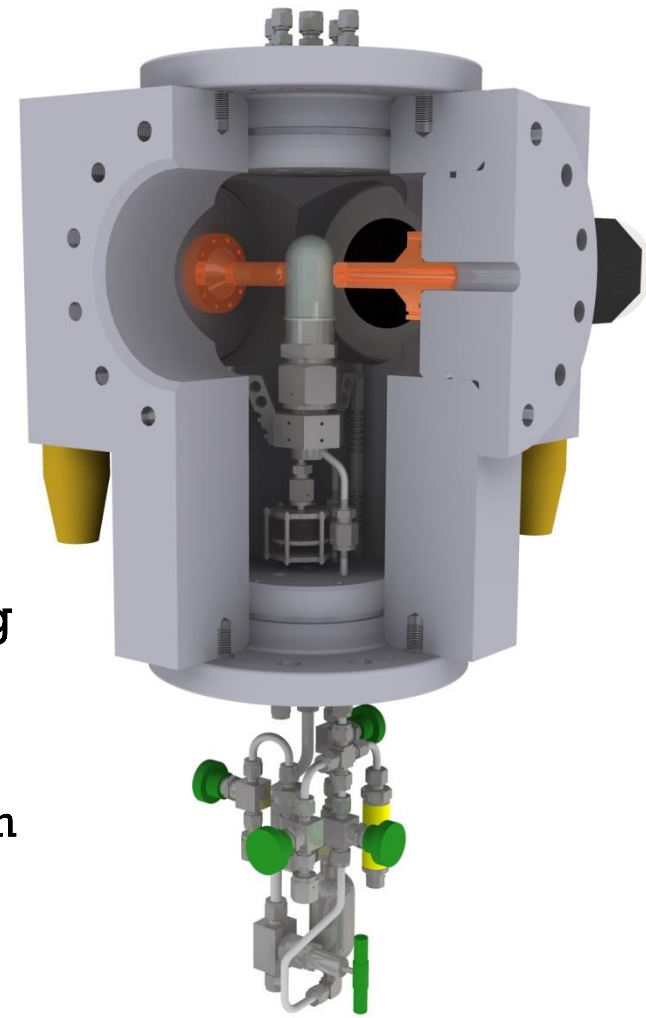
- Thin Glass Vessel Holds Active Liquid, N_2O
- N_2O Floats on Mercury, Which Fills Remaining Inner Volume
- Superheated Liquid Only in Contact With Smooth Surfaces
- Thin Sensitive Edge Welded Bellows Equalize Pressure, Revised
- Stainless Tube Facilitates External Connection of Pressure Transducers and Filling Valves
- Wetted Materials: Stainless Steel, Kovar, Glass



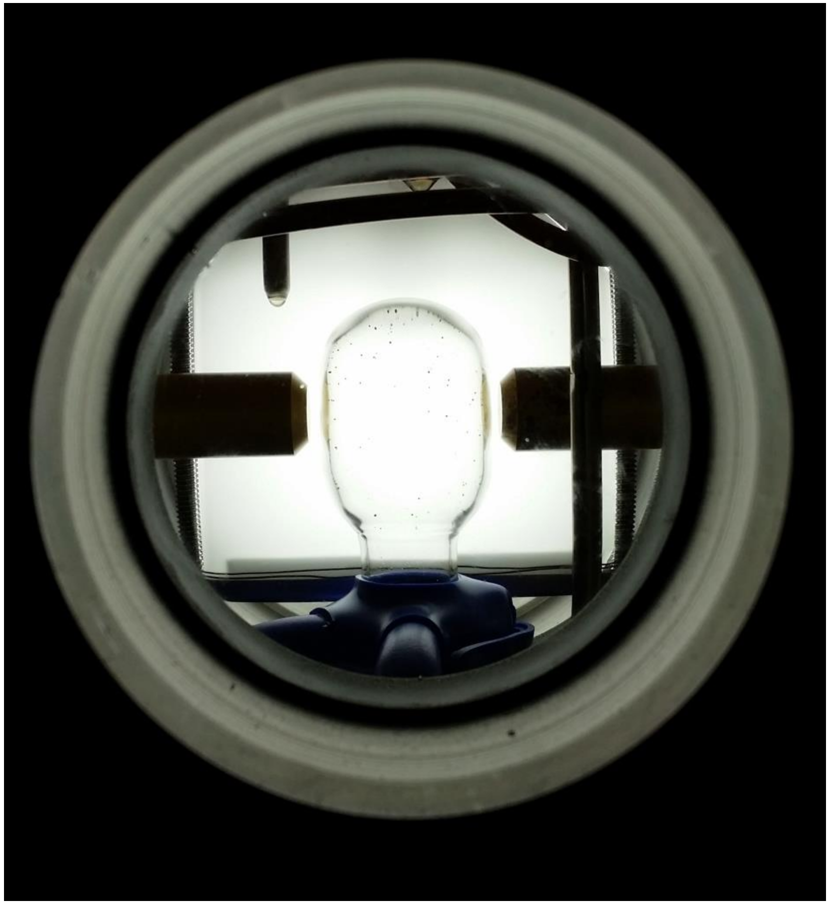
Pressure Vessel



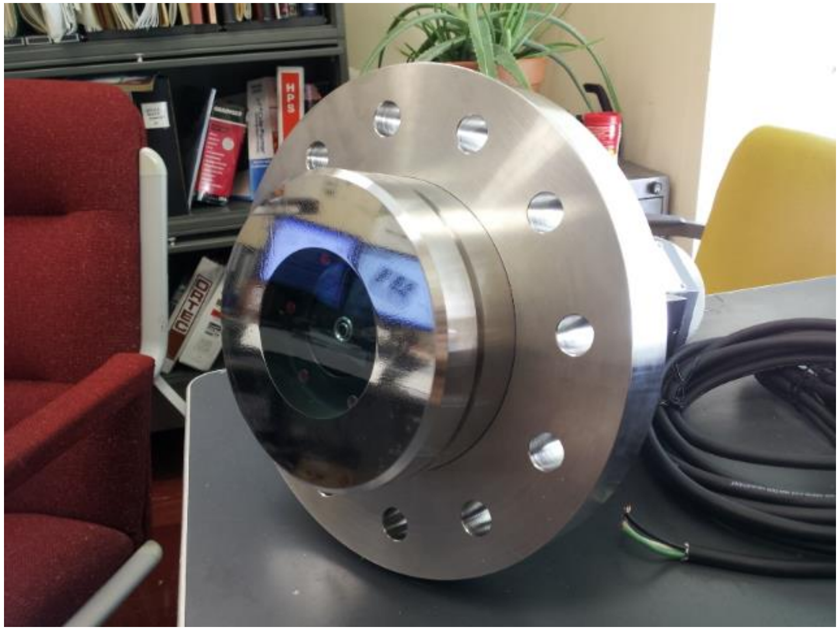
- Houses Bubble Chamber
- One Piece Construction
  - No Welding
  - Minimal Internal Volume
- Machined From a Solid 304 S.S. Forging
- Flanges Machined From 316 S.S.
  - Utilize a Plug Design to Reduce Inner Volume



Viewport, Camera, and Lighting



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

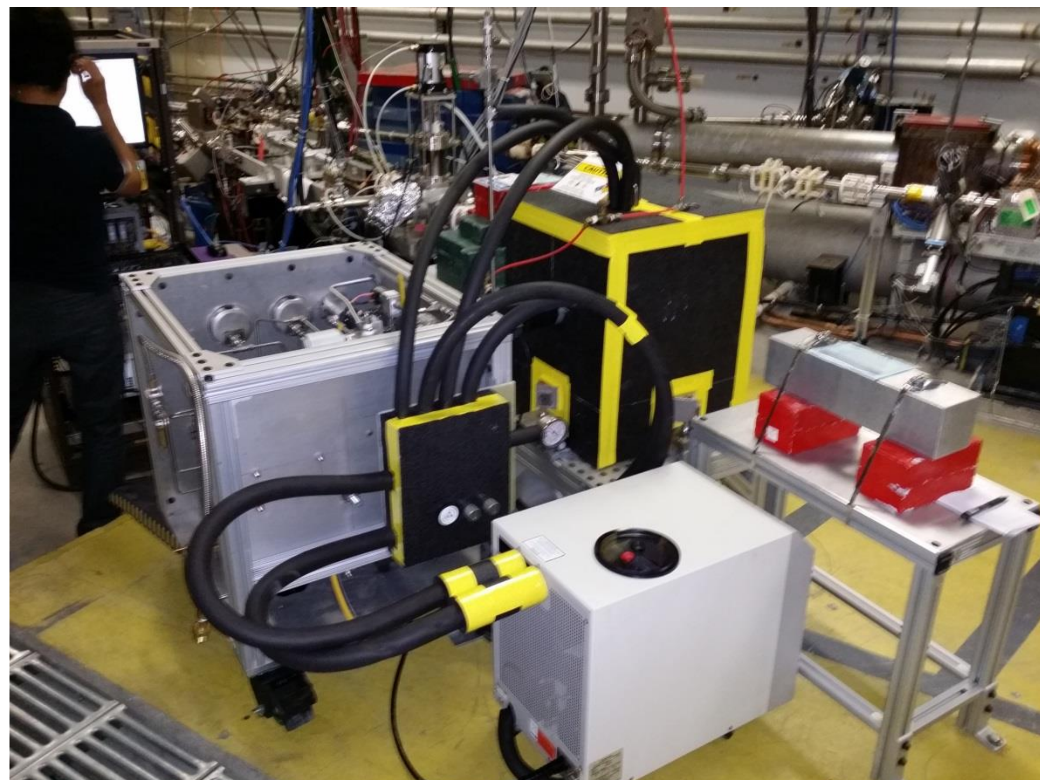


Hydraulic Control System

- 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

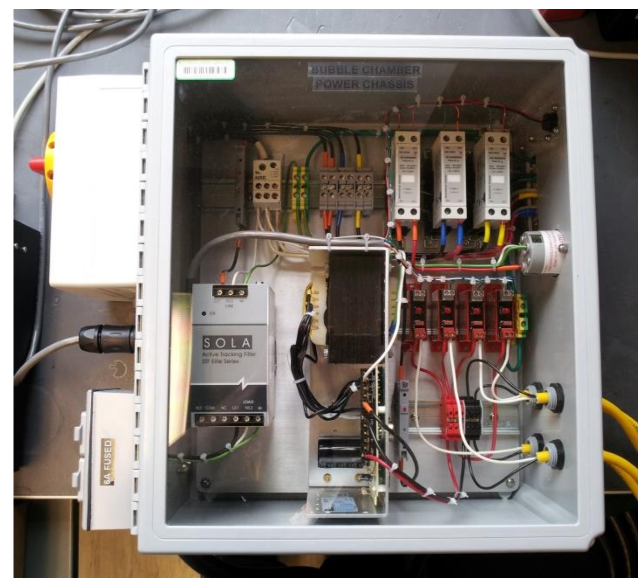
Cooling

- Heavy Wall Copper Cooling Coils Installed
- Bath Operating Temperature   -20C to 20C

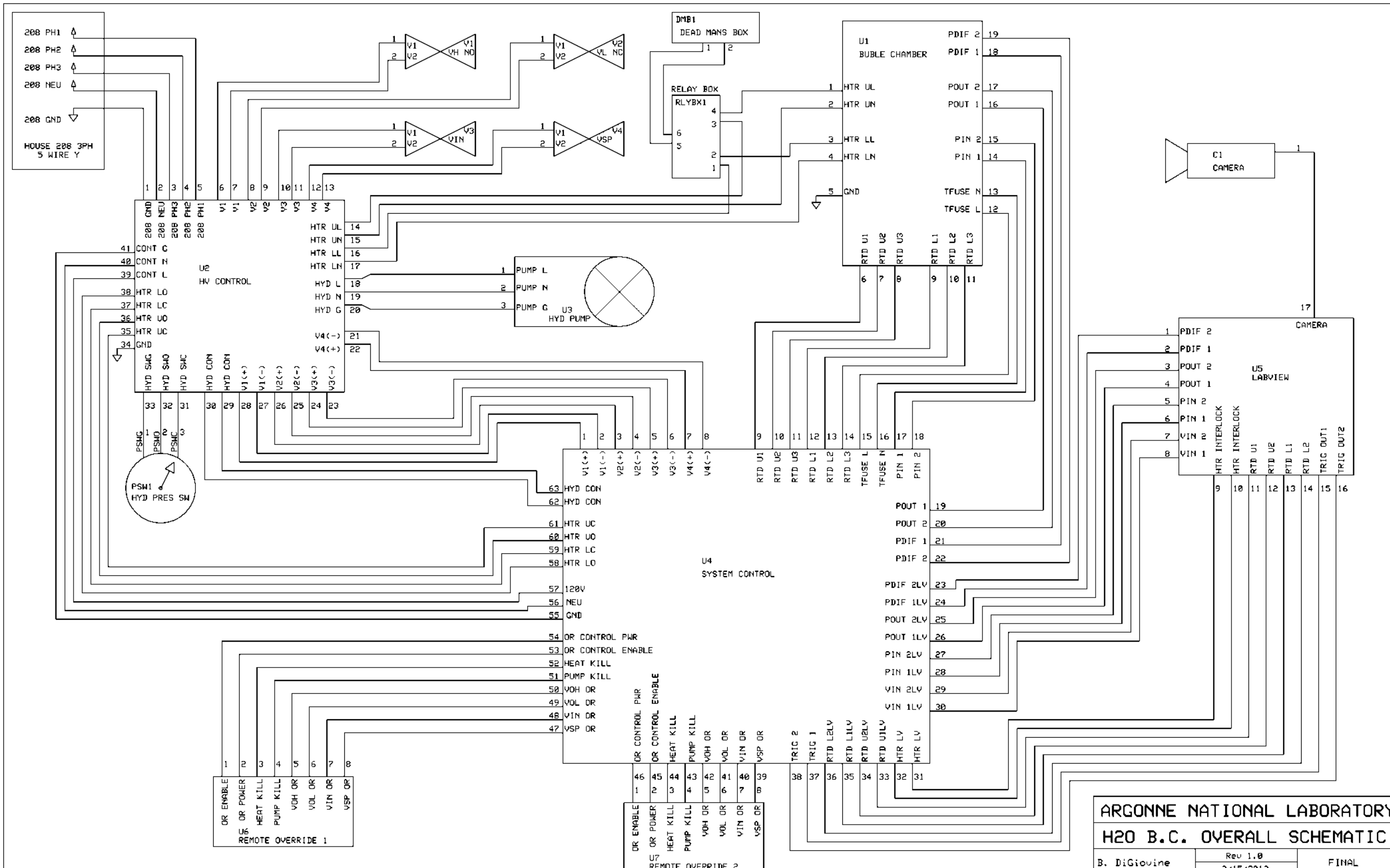


Control and Instrumentation Chassis

- 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

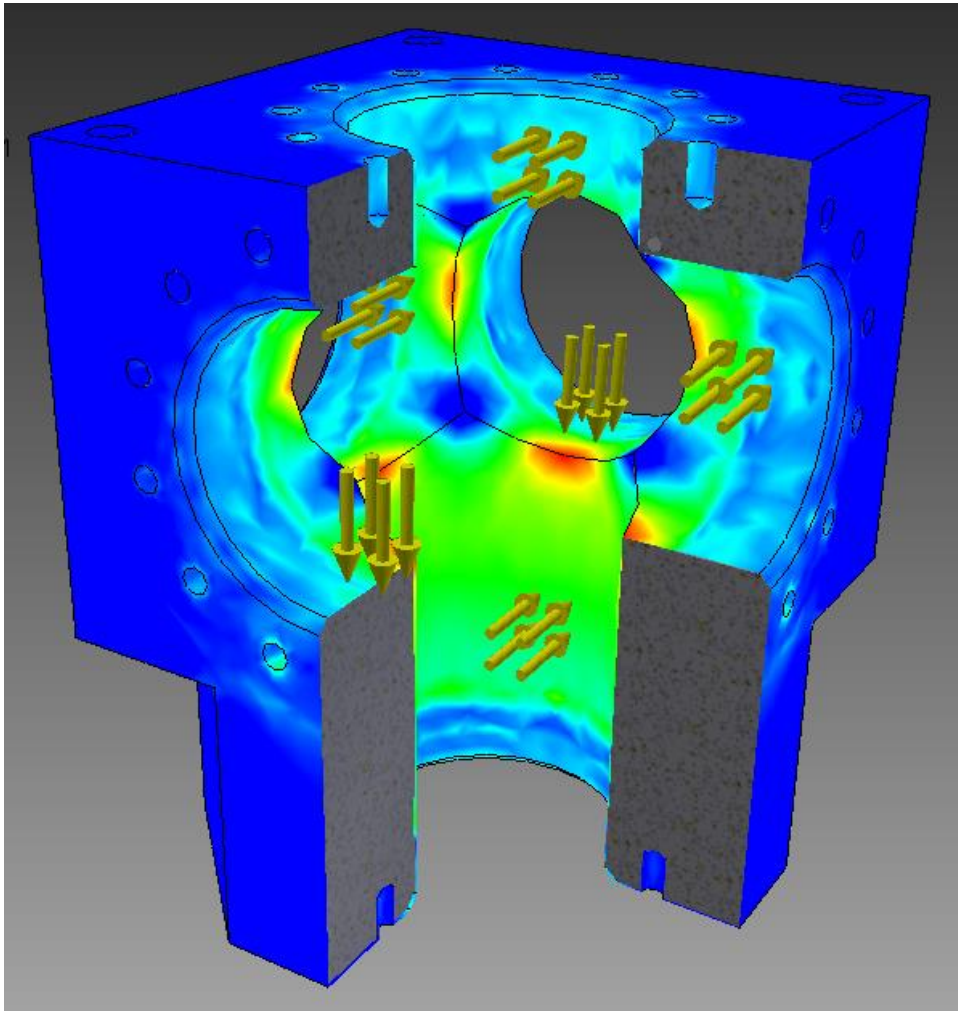


Data Acquisition / System Integration

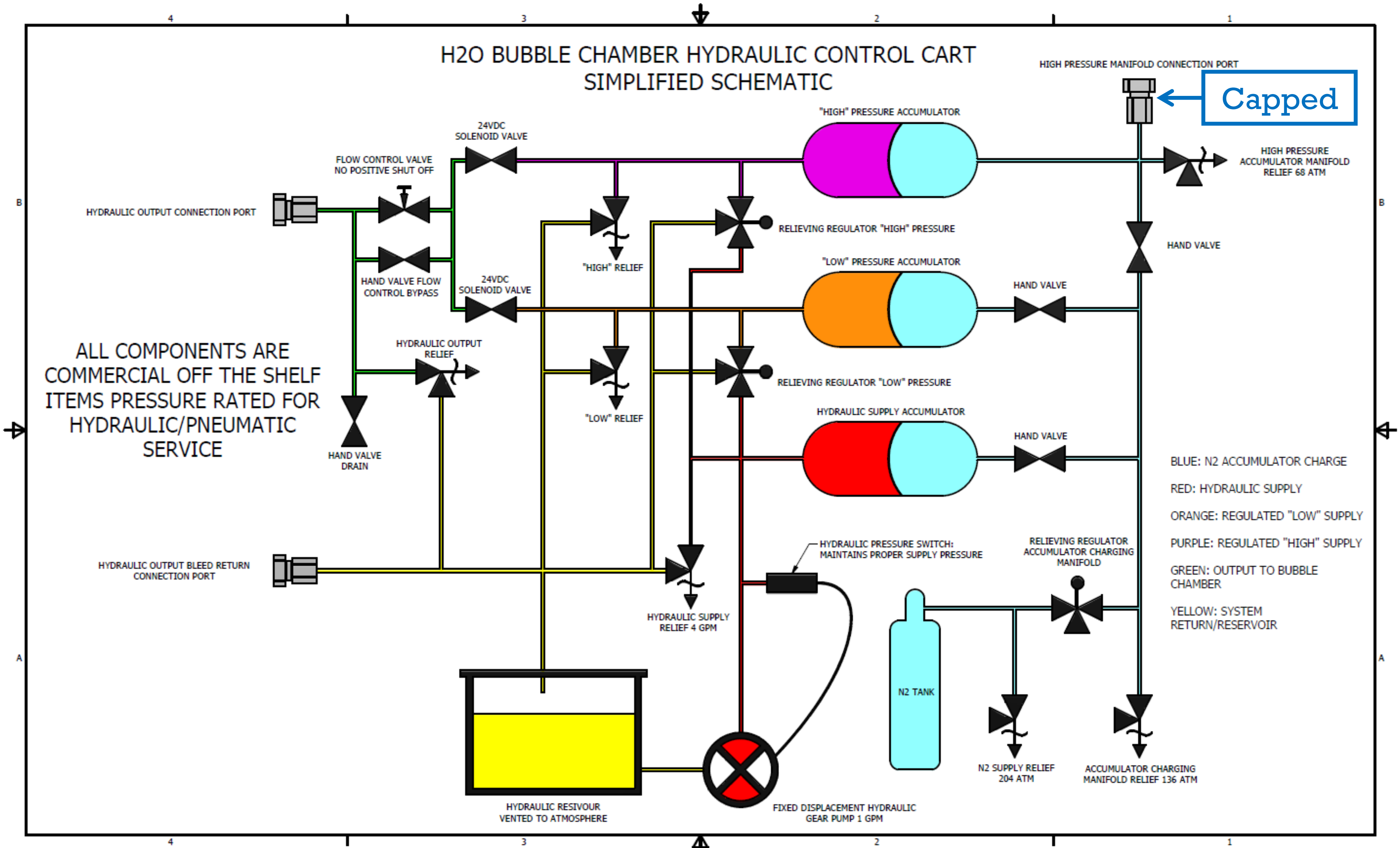


SAFETY

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

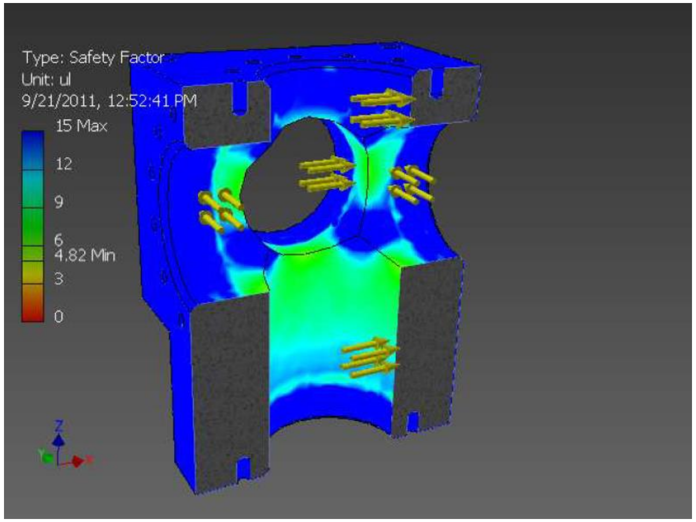


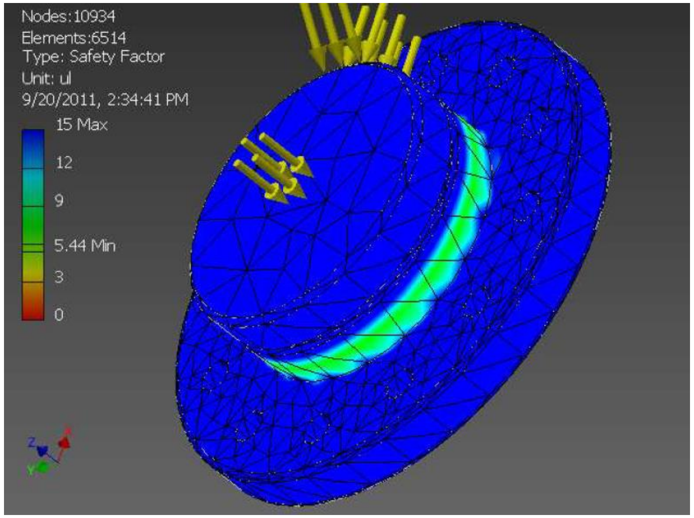
Hydraulic Control System



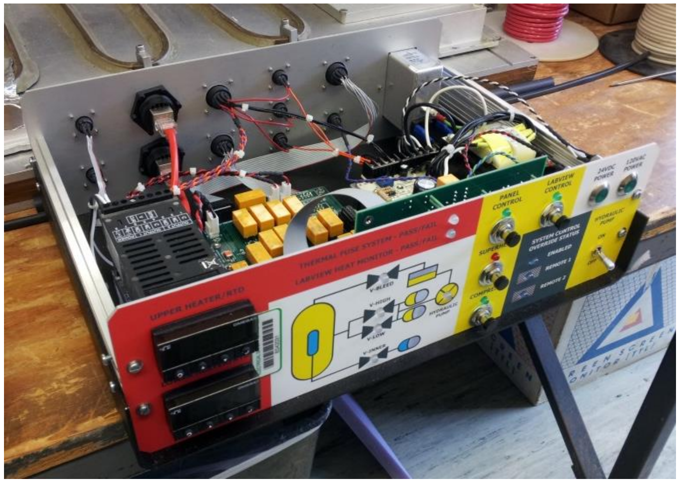
Bubble Chamber Pressure Vessel

- 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



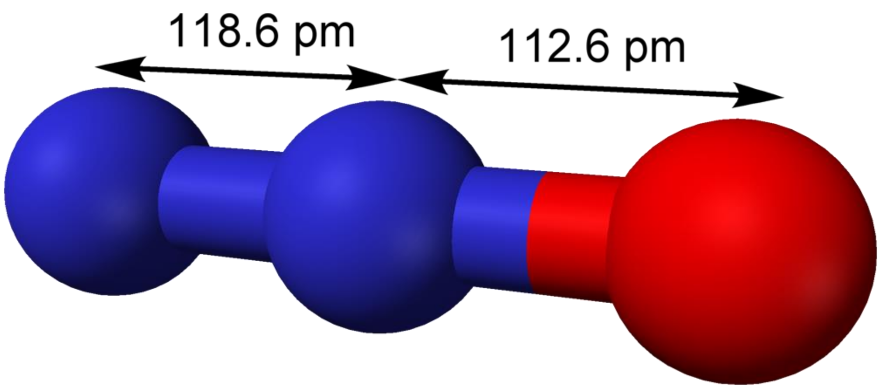


Control Chassis & Remote Overrides



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

Chemical Safety



- Duratherm 450
  - Commercial Heat Transfer Fluid
  - Paraffinic Hydrocarbon
  - Non-Toxic
- Mercury
  - Approx 150ml
  - Secondary Containment for Critical Components
  - Industrial Hygiene Assistance During Fill/Vent/Drain Procedures
- N_2O
  - Approx 40ml liquid
  - 17 liters at STP (0.017 m^3)
- Disposal:
  - D450: Waste Oil Recycler
  - Mercury: ANL Waste Management

Chemical Safety II

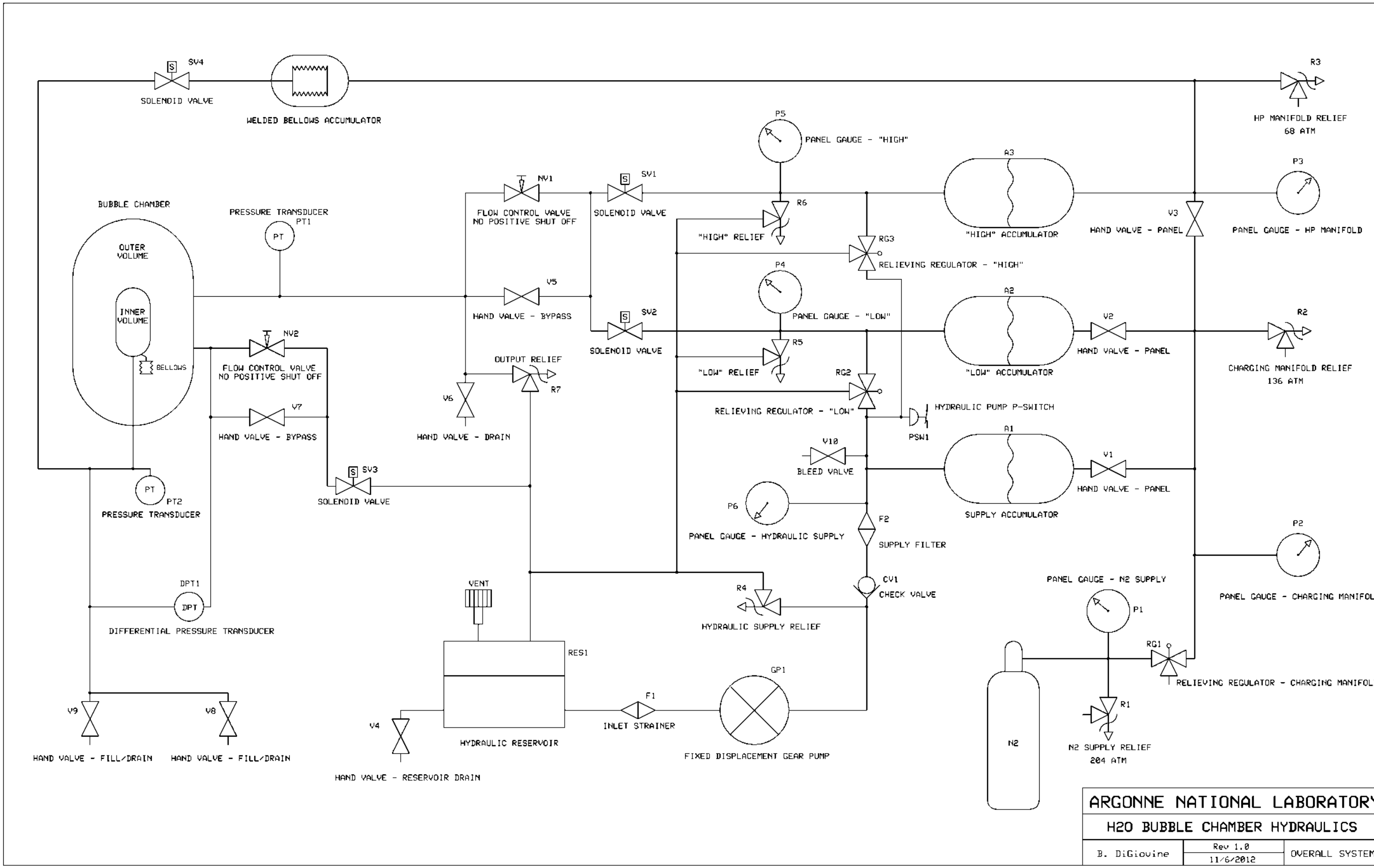
- N_2O
  - Small Amount of Fluid
  - Typical Lab Environment, not an asphyxiant hazard
  - Acute Overexposure:
    - Dizziness
    - Drowsiness
    - Poor Coordination
  - Procedures to limit concentration in area during filling and venting operations, concentrations to be monitored and verified by IH at first until we are satisfied that the procedures adequately limit exposure.
- Mercury
  - Relatively small amount of liquid
  - Saturation concentrations at STP will never be reached because of normal air flow through room, no added heat, and engineering controls put in place.
  - IH will monitor and verify concentrations of mercury vapor in room and surrounding areas during filling and venting operations to be sure procedures and engineering controls limit exposure to acceptable levels.
  - Spill kits on hand to properly respond in the event of a spill
  - Filling, venting, draining procedures to be done over containment pans to prevent spread of material should a spill occur.


JEROME

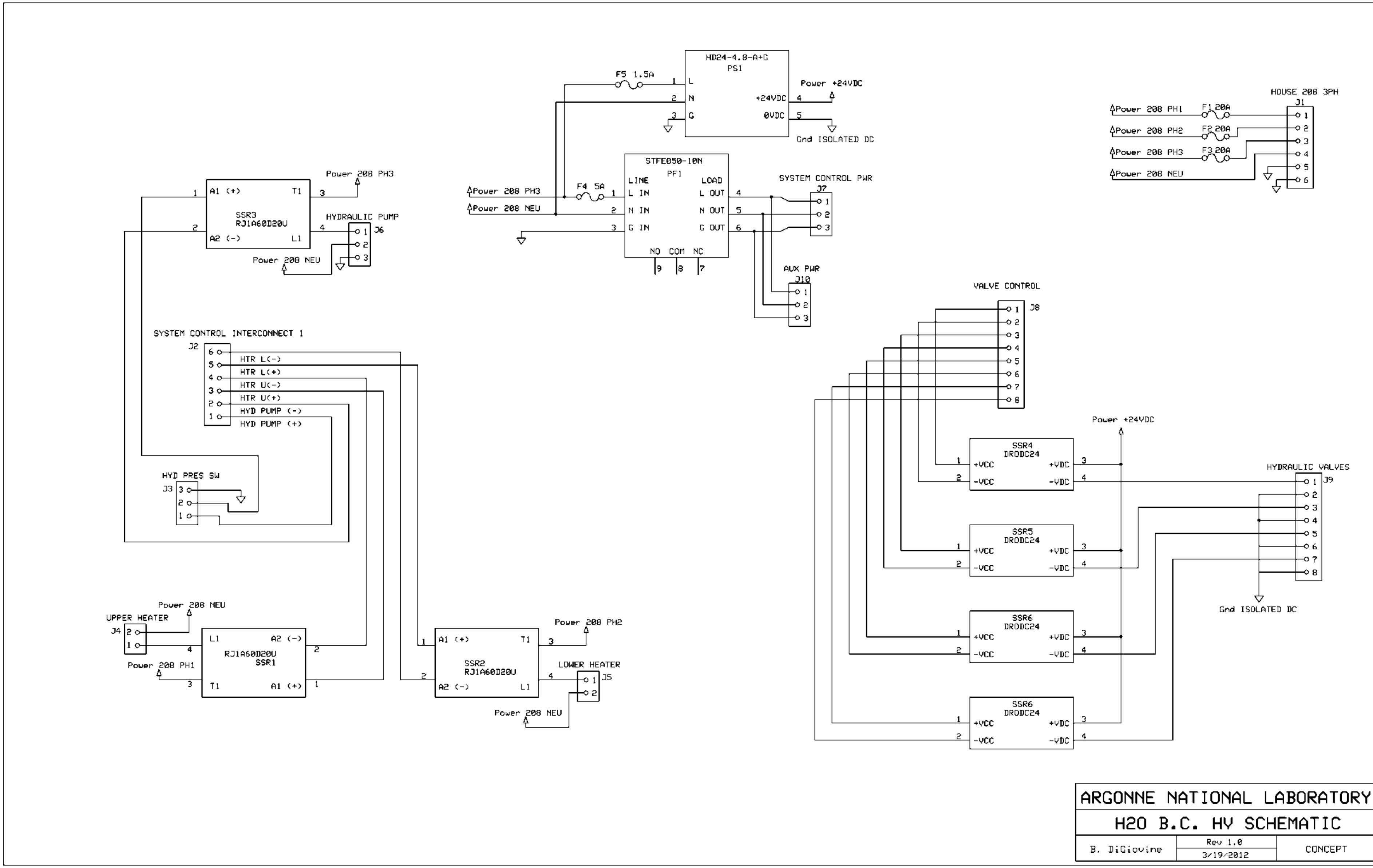
Appendix

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

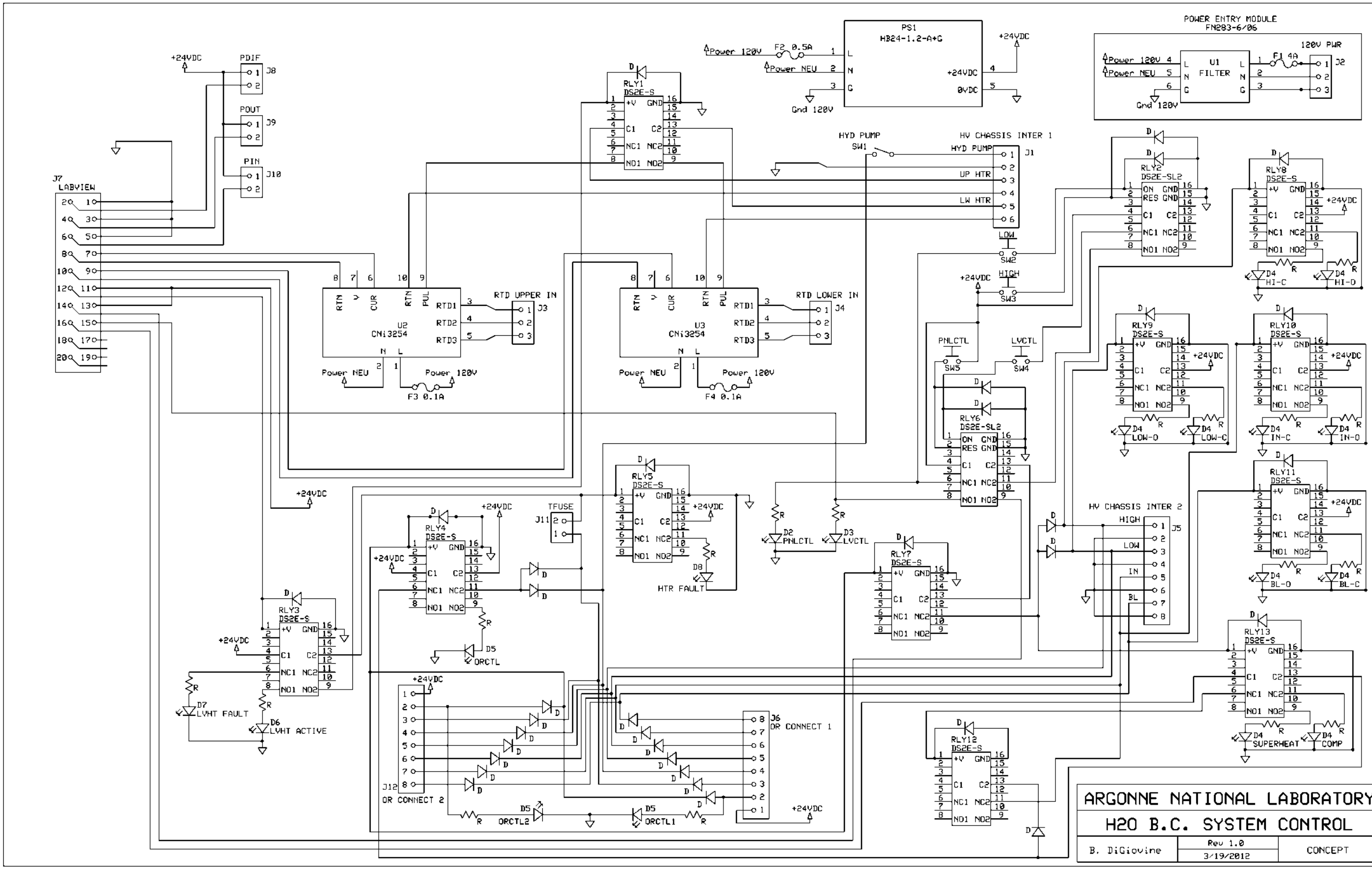
Hydrulic Schematic



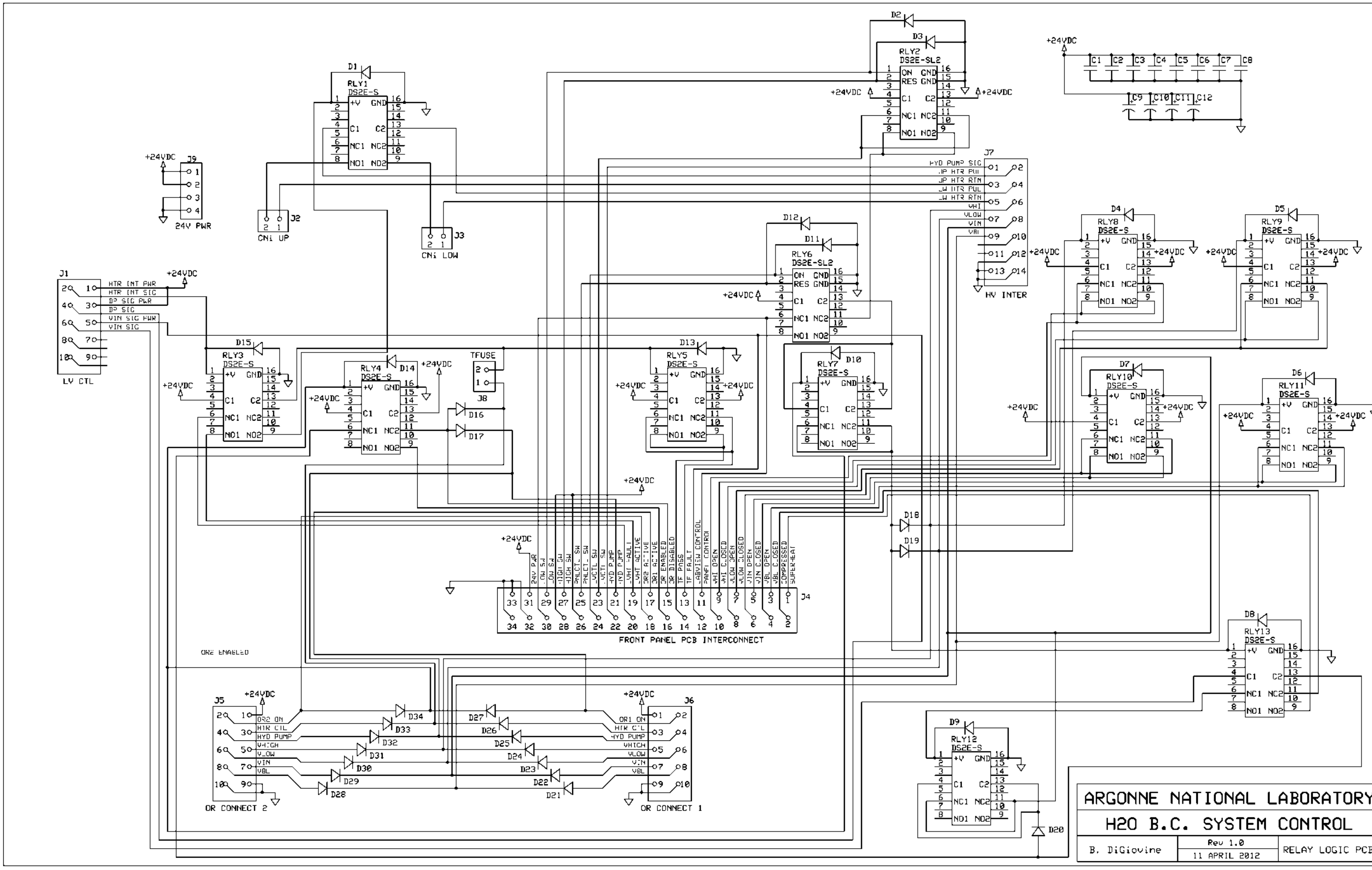
High Voltage Chassis Schematic



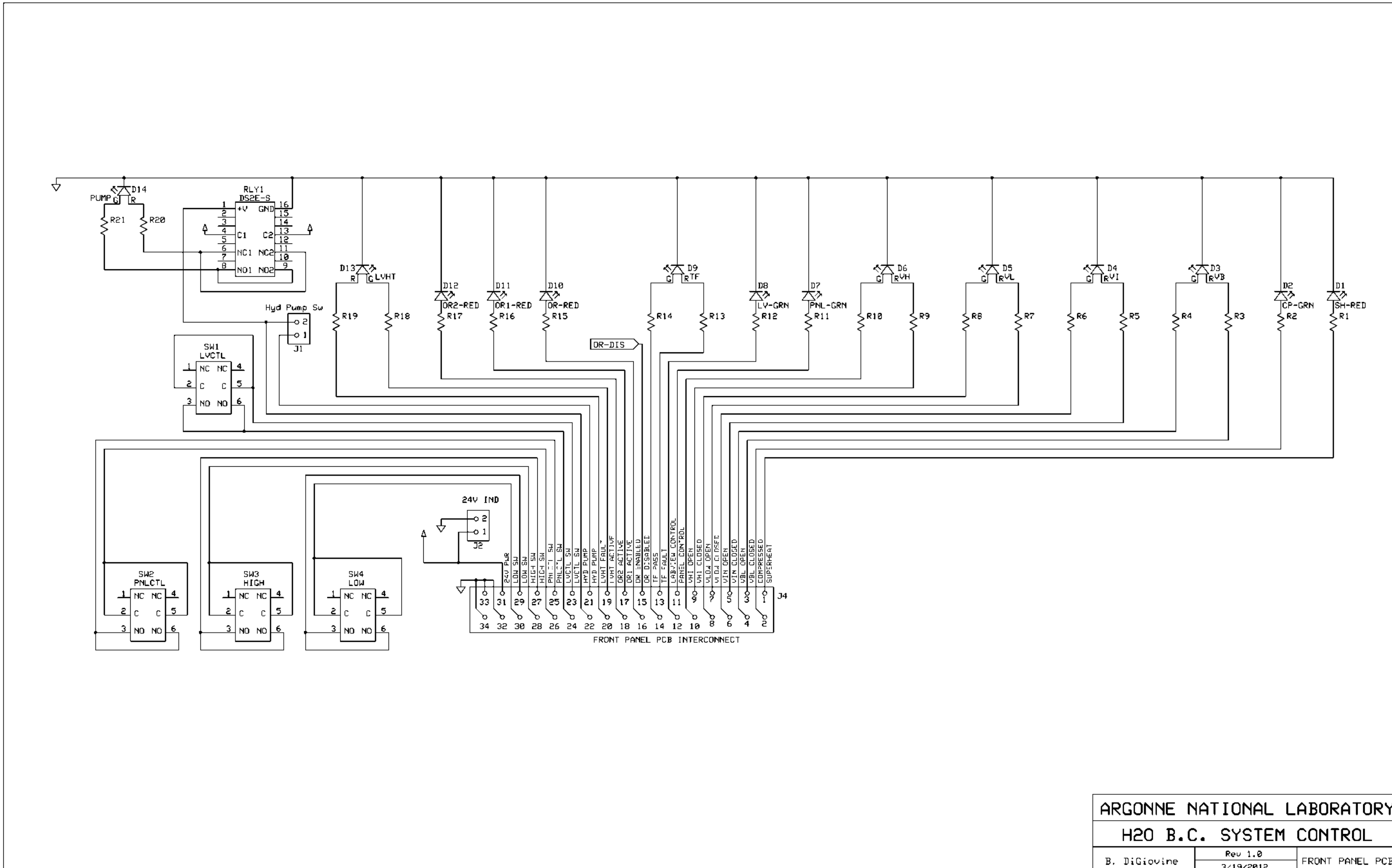
Logic & Instrumentation Chassis Schematic



Relay Logic PCB Schematic



Front Panel Interface PCB Schematic



Energy Storage Calculations

Energy Stored in compressed liquid

$B \sim 1000\ MPa$

Volume $= 460\ in^3$

$.007538\ m^3$

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

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

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

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

equally

Ø of bolt .625"

Cross section Area:

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

Each bolt must carry:

$\frac{(33,761\ lbf)}{12\ bolts} = 2,814\ lbf$

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 Quote and Design Parameters

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

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

Beam Port FEA