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

Bubble Chamber Detector Upgrade

HAZARD ANALYSIS
&
Project Review Form

PHYSICS DIVISION
ARGONNE NATIONAL LABORATORY
9700 SOUTH CASS AVENUE
ARGONNE, ILLINOIS 60439

Table of Contents

Bubble Chamber Detector Upgrade

Hazard Analysis
&
Project Review Form

1. Experiment Program Description:

Our safety approved, and successfully tested bubble chamber detector will be upgraded. It is necessary to extend its detection threshold of ionizing radiation down to a lower energy level, therefore higher temperatures and pressures must be used. Our upgraded detector will utilize all existing and approved control and safety systems from our previous version. The detector will operate in the same fashion as its predecessor utilizing most of the old components which have been proven to work.

2. Organization and Responsibilities:

DiGiovine, Brad :	Engineering, design, assembly, and fabrication.
Holt, Roy:	Physicist
Rehm, Ernst:	Physicist
Ugalde, Claudio:	Physicist

3. Facility Description:

3.1. Initial testing to be done in building 203 G-018.

3.2. Experimental equipment

3.2.1. Description of upgrade

Previously approved and successfully tested superheated water bubble chamber detector will be upgraded based on findings with previous version. Operating conditions must be changed to allow the detection of ionizing radiation at lower energies. Our detector system must now operate at a max temperature of 230C and max pressure of 840psig as compared to 150C and 150psig of the present system. Our previously proven control system will be utilized. The previous pneumatic system will be left intact. The previous heating system will be utilized as designed. The hydraulic system is identical in design (ie. pressure monitored, relieved into a phase separator, ect.) All of the above systems are fully capable of operating at the new design limits for this chamber. The only critical components which have been changed are as follows:

1. A new containment vessel. This vessel is larger and made of thicker stainless steel, it is relieved identical to previous vessel to prevent pressurization in the event of a failure.

2. The pneumatic to hydraulic system interface has changed. Previously it was a balanced cylinder arrangement - equal areas on either side of the piston which pressurized the hydraulic system to the same value as the pneumatic system. The new interface is now an unbalanced cylinder. This allows the pneumatic system to pressurize the hydraulic system to higher values. It has a 5.3:1 pressure conversion ratio. The reliefs in the pneumatic system limit the hydraulic system pressure to 840psig. The hydraulic system will be relieved to a phase separator as with our previous setup.

Our current glass vessel was hydrostatically tested to 1200psig in central shops, upon reaching this pressure our o-ring slightly extruded from its seat where the glass vessel interfaces with the plumbing - essentially preventing our vessel from being pressurized to the point of failure, our hydraulic system relief will be set to 900psig, well below this level.

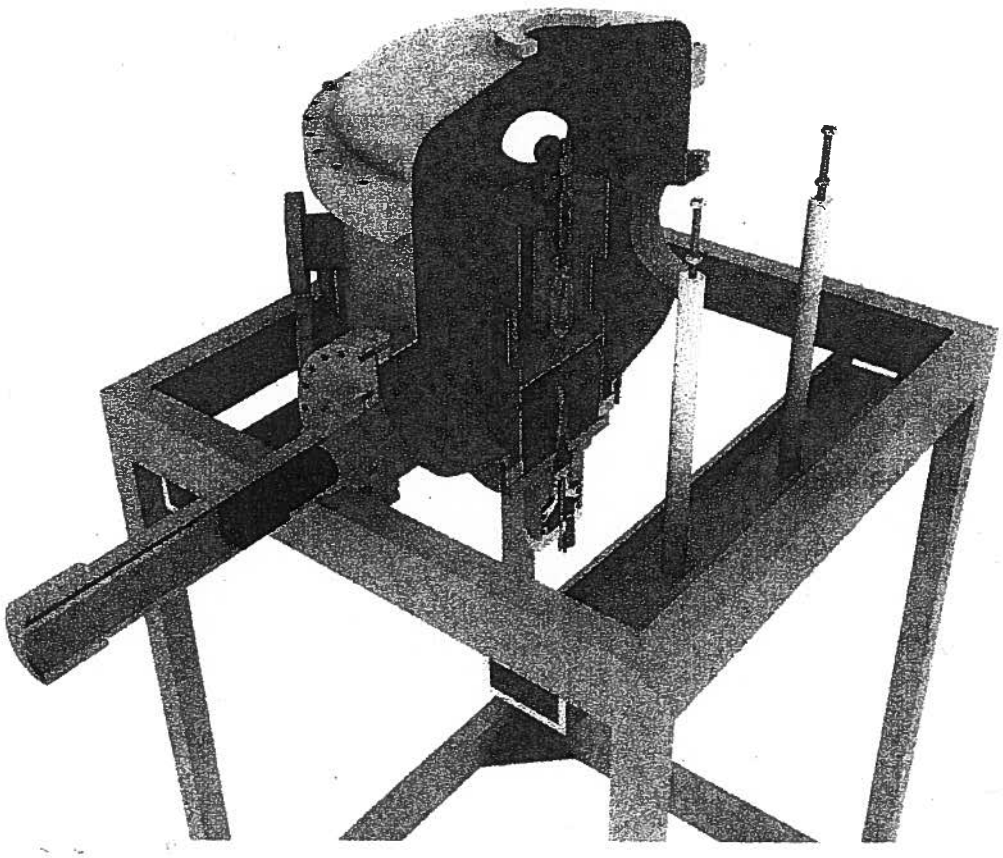


Figure 1

3.2. Controls

All previously approved controls will be implemented. Their function are identical in this application and are not modified by the increased temperature and pressure limits.

3.3. Support and service equipment

In addition to the equipment mentioned above, the following will be used:

No new support or service equipment will be needed.

4. Operating and Maintenance Procedures:

4.1. Operating Procedures

This system consists of all of our previous controlling components; therefore nothing has changed in this respect.

4.2. Maintenance Procedures

Maintenance must be done by a person who has a very thorough understanding of the detector and its accompanying systems. The following personnel have exhibited this understanding:

- Brad DiGiovine

4.3 Experiment Procedure

5. Training:

Training required is the same as our previous detector.

6. Hazards for Normal Operations

TABLE 6-1
POTENTIAL HAZARDS CHECKLIST
(ANL-E ES&H Manual Section 21.2, Appendix A)

POTENTIAL HAZARD	YES	NO	REMARKS
Radiation and Electromagnetic Fields			
Ionizing Radiation			
Alpha		X	
Beta		X	
Gamma and/or X-Ray	X		Experiment conducted at γ facility
Neutron	X		Initial testing using neutron source
Proton		X	
Subatomic		X	
Nonionizing Radiation			
Laser		X	
Visible Light		X	
Ultraviolet		X	
Microwave		X	
Radiofrequency		X	
Electric Fields		X	
Magnetic Fields		X	
Chemicals and/or Materials			
Health and Injury Hazards			
Carcinogens		X	
Mutagens		X	
Teratogens		X	
Toxins		X	
Corrosives		X	
Irritants, Allergens, and/or Sensitizers		X	
Volatile Solvents		X	
Combustion and Injury Hazards			
Flammable Liquids and/or Solvents		X	
Metallic Combustibles		X	
Flammable Gases		X	
Compressed Oxygen		X	
Open Flame or Sparks		X	
Combustible Materials		X	
Explosives		X	
Flammable Suspended Dust Particles		X	
Pyrophoric Chemicals		X	
Respiratory or Contact Injury Hazards			
Cryogenics		X	
Thermal (High or Low)	X		Interior of detector operates at 230C
Dust, Particulates, and Fibers		X	

POTENTIAL HAZARD	YES	NO	REMARKS
Asbestos		X	
Explosives		X	
Reactive Chemicals		X	
Compressed Gases	X		Pneumatic controlling system
Pressure and/or Vacuum Systems	X		Pneumatic controlling system
Steam		X	
Asphyxiation		X	
Stored Energy Not Elsewhere Addressed			
Hydraulic Energy	X		Closed hydraulic system of detector
Kinetic Energy		X	
Mechanical Energy		X	
Potential Energy		X	
Other		X	
Biohazards			
Virus		X	
Bacteria		X	
Human Tissues and/or Body Fluids		X	
Animals and Animal Tissue		X	
Electrical			
High Voltage Devices		X	
Storage Devices		X	
Static Charge		X	
Lightning Protection		X	
Grounding		X	
Exposed Conductors		X	
Mechanical			
Lifting Devices		X	
Low Friction Surfaces		X	
Load-Bearing Components		X	
Vibration		X	
Sharp Points or Edges		X	
Moving Parts		X	
Pinch Points		X	
Ladders, Scaffolds, and/or Platforms		X	
Work Environment			
Activities at Known or Suspected Hazardous Waste Sites		X	
Use of Self-Contained Breathing Apparatus		X	
Temperature or Other Climatic Extremes		X	
Severe Weather		X	

POTENTIAL HAZARD	YES	NO	REMARKS
Noise		X	
Confined Spaces		X	
Others (Tripping Hazards)		X	

6.1.

I. Gamma Radiation:

This device does not emit gamma radiation, rather it detects the interaction between gamma rays from a source and the oxygen atoms contained within the water molecules. All safety procedures in place at the gamma ray facility will be followed.

II. Neutron Radiation:

This device does not emit neutron radiation; we will be using a neutron source for initial testing of our detector here at ATLAS. Depending on the source chosen, all applicable rules and procedures will be followed.

III. Thermal contact injury hazards:

The interior portion of this device will be operated at 230C. Using multiple types of thermal insulation, we are trying to reduce the amount of heat transferred to our detector's containment vessel. Regardless of our rate of heat transfer, there will be warnings placarded to inform any nearby persons as well as a thermal cut off switch which will deactivate our heater systems if the containment vessel reaches 60C. Vessel lid will be installed before operation.

IV. Compressed Gasses:

The pneumatic system of our detector will be supplied by a high pressure cylinder of dry nitrogen using a newly purchased regulator.

V. Pressure and Vacuum systems:

The pneumatic system of this detector has been engineered and built with safety factors exceeding a value of nine; a pressure relief valve is in place to prevent over pressurization of our pneumatic system.

VI. Stored Hydraulic Energy:

Using an overestimate of our hydraulic system volume ($12in^3$) the stored energy in our hydraulic system is in the area of 1 ft-lbf. Vessel lid will be installed before operation.

7. Hazards for Postulated Accidents:

1. Upon the creation of a bubble in our superheated water, pressure must be applied to stop further boiling. Failure of pneumatic system will prevent

application of pressure to prevent a run away boil.
2. Vacuum vessel, hydraulic system, and pneumatic system over pressurization.
3. Failure of the heating system.
4. Failure of the pressure rated glass vessel containing superheated water.

8. Safety Systems and Equipment:

The Hazards for postulated accidents listed above are identical to our previously approved system. All previous controls will be in place in our upgraded detector system.

9. Safety Procedures

1. This device must be operated by a competent person with a thorough understanding of its systems and design.
2. The exposed detector components may be hot, avoid contact with skin. A thermal cut out switch is on the containment vessel preventing exposed components from exceeding a temperature of 60C (safe to touch). Placards are also installed in plain view warning of the elevated temperatures present while operating.

10. Environmental Compliance Procedures:

Does this experiment or equipment meet the definition of the NEPA bench scale exemption YES **X** *NO*☐

If NO, NEPA documentation is required. Contact Tom Mullen 2-2879

List any procedures you needed to create (if any) for environmental compliance purposes.

11. Emergency Procedures:

The engineered and active safety systems contained in section 8 will automatically initiate in the event that any of the postulated accidents occur, they will prevent the system from heating or pressurizing to an unsafe level. The only thing that is required of the experimenter is to power down the control chassis in the event of an accident. Once the system is powered down and allowed to cool, pressure systems should be vented and a thorough investigation must be performed by someone with an intimate understanding of the detector and its systems.

12. Waste Management Considerations

Waste management procedures from previous safety review still apply.

13. List of Applicable Documents

Components found in "high temperature" area of detector see documents listed:

Argonne NATIONAL LABORATORY

Work Planning and Control Worksheet

Div. ID #: WCD-PHY-00034-2010	Revision No.: 0	Date: 2/16/2010

SECTION 1 SUMMARY

Project Title:	Bubble Chamber Detector Upgrade
WCD Preparer Name	Brad DiGiovine
Approving Division:	
Authorizing Division (Lead Division):	
Lead Division Reference No. (if applicable):	
Work Location (Building/Room, etc.):	203 G-018
Designated Person in Charge (TBA [to be assigned] if unknown)	TBA
Overall hazard level for this work	
Moderate	

Approving Department/Section:	
Lead Department/Section (if applicable):	
Rev. No.:	
Estimated Start Date:	ASAP
Estimated End Date:	Dec-12

Work Control Document Type (Choose One)		Required Sections
No	Type 1 (skill of the worker)	1, 3, 4
Yes	Type 2 (ANL-886 as the WCD)	1, 2, 3, 4, 5, 6
No	Type 3 (procedure-controlled)	1, 3, 4

Work Scope Summary (attach or reference work instructions or procedures):

See Bubble Chamber Detector UpgradeHazard Analysis and Project Review Form, attached.

SECTION 2 APPROVAL

NOTE: This section is not required if this document being used for skill of the worker (Type 1) or as a hazard analysis and control selection for procedures (Type 3). Review and approval signatures not appearing here must appear on the higher level document (e.g., procedure or skill of the worker classification form).

Through my signature below, I assert that extensive and systematic hazard identification relating to this work has been performed. The hazard boundaries have been defined by this document and by abiding within the controls stated herein, the risk associated with the work is deemed acceptable. Signatures denote that all comments and issues have been addressed.

Concurrence	Badge	Print Name	Signature	Date
WCD Preparer:	57920	Brad DiGiovine		16-Feb-10
ESH Coordinator*:	42931	Tom Mullen		16-Feb-10

Approval	Badge	Print Name	Signature	Date
Approval Authority	31610	R.V.F. Janssens		16-Feb-10

*For VH, H, and M WCDs, the division ESH Coordinator signature is required. For all WCDs, the division may add rows to this section for division-specific review signatures.

NOTE: This Work Control Document expires three years after the date of approval and must be reviewed and affirmed annually (see Section 5, below)

A current copy of the approved and authorized Work Control Document (WCD) must be available to those conducting work activities; electronic or paper copies are acceptable. Work may not be performed until the Work Control Document has been completed and approved, procedures have been approved, and the work has been authorized.

SECTION 3 REQUIRED PERMITS

Activities requiring Permits -- A Yes answer requires contacting SME per permit procedures

Yes/No	
No	ANL-206 Radiological Work Permit
No	ANL-211 Energized Electrical Work Permit
No	ANL-499 Occupancy Permit Request
No	ANL-609A ANL Laser Operating Permit
No	ANL-609B ANL Temporary Laser Operating Permit
No	ANL-612 Movable Structure and Storage Trailer/Container Siting Permit
No	ANL-614 Confined Space Entry Permit
No	ANL-780 Confined Space Entry Permit for PRCS that Requires Lockout/Tagout Only
No	FD-48 Open Flame Operating Permit
No	FMS-006 Digging Permit
No	Institutional Biosafety Committee (IBC) Approval
No	Institutional Review Board (IRB) Forms/Approval (Human subjects in research)

SECTION 4 HAZARD ANALYSIS, CONTROLS, AND SME SIGNATURES

Task	Description	Controls for Task	Separate HA?
1	Construction of apparatus	Since most components will be reused only simple hand tools will be needed for the upgrade of our detector - skill of the worker.	No
2	Testing and operation of apparatus	All previously approved controls will continue to be implemented to assure the safe operation of this upgraded system.	No
3			No
4			No
5			No
6			No
7			No
8			No
9			No
10			No

For SMEs providing signatures: Through my signature below, I certify that extensive and systematic hazard identification relating to this work has been performed, within the area of my expertise (e.g., electrical safety). By following the procedures contained within this document, the work will be within acceptable hazard boundaries. Signatures denote that all comments have been resolved.

Hazard Present? (Y/N)	Hazard	Task/Hazard Relationship and Hazard Description	Hazard Level	Graded Approach – Hazard Levels (select one)	Hazard-Specific Application of Controls	SME Signature/Date (for HL = VH or H)
Physical Hazards						
Yes	Electrical	120VAC and 240VAC systems	L	Not energized and disconnected, as when being built or unplugged, plug controlled, and no stored energy	System will be powered down prior to any inspection, disassembly, or repair.	
No	Elevated Work			select hazard level descriptor.		
No	Ergonomics			select hazard level descriptor.		
No	Fire			select hazard level descriptor.		
Yes	Hand tools	Standard hand tools for construction, adjustment or repairs	L	Non-powered hand tools; common hand tools, portable electric tools <240V or battery powered tools.	Skill of the worker	

Hazard Present? (Y/N)	Hazard	Task/Hazard Relationship and Hazard Description	Hazard Level	Graded Approach – Hazard Levels (select one)	Hazard-Specific Application of Controls	SME Signature/Date (for HL = VH or H)
Yes	High or low Temperature	Operating temperature of interior most components will be 230C max	M	≥ 100°C (212°F);	Heated components are insulated to minimize heat transfer and contained within larger vessel - not accessible while in operation. Temperature switch is also utilized to prevent containment vessel from becoming too hot. Vessel lid will be installed before operation.	
Yes	High Pressure	Hydraulic system contains around 1 ft-lbf at 840 psig max	M	Stored energy less than 7,500 ft-lbf exclusive	Pressurized vessel is relieved and completely contained within a stainless steel containment vessel. Vessel lid will be installed before operation.	
No	High vacuum			select hazard level descriptor.		
No	Hoisting/rigging			select hazard level descriptor.		
No	laser			select hazard level descriptor.		
No	limited egress			select hazard level descriptor.		
No	machine tools/rotating parts			select hazard level descriptor.		
No	non-ionizing radiation			select hazard level descriptor.		
No	Overhead work or obstructions			select hazard level descriptor.		
No	protruding or falling objects			select hazard level descriptor.		
No	sharps-non-biological			select hazard level descriptor.		
No	Vision			select hazard level descriptor.		
No	welding/cutting/brazing			select hazard level descriptor.		
No	Other					
Hazardous Working Environment						
No	Confined Spaces			select hazard level descriptor.		
No	Cryogenic Materials			select hazard level descriptor.		
No	Ground penetrations			select hazard level descriptor.		
No	Blind penetrations of walls, floors, and ceilings			select hazard level descriptor.		
No	Excavations deeper than 5 feet			select hazard level descriptor.		
No	Exhaust or toxic gas generating equipment			select hazard level descriptor.		
No	Noise			select hazard level descriptor.		
No	Outdoor exposure or unconditioned Indoor space with temperature extremes			select hazard level descriptor.		

Hazard Present? (Y/N)	Hazard	Task/Hazard Relationship and Hazard Description	Hazard Level	Graded Approach – Hazard Levels (select one)	Hazard-Specific Application of Controls	SME Signature/Date (for HL = VH or H)
Yes	Stored energy – hydraulic, thermal, pneumatic, mechanical	150 psig pneumatic system, 840 psig hydraulic system	M	Capable of being easily isolated; no disassembly required	Valves allow for isolation, system will be completely depressurized before any disassembly, inspection, or repair.	
No	Dust			select hazard level descriptor.		
No	Sewage and waste			select hazard level descriptor.		
No	Other hazardous working environment hazard not listed above					
Radiological Hazards - Contact HP for all work involving radiological hazards, regardless of hazard level.						
No	Airborne radioactivity/ cutting, welding, grinding, etc. on radiological material: inhalation, skin			select hazard level descriptor.		
Yes	Radiation exposure: beta, gamma, x-ray, neutron absorption, uptake		L	expected dose < 100 mrem/y	Depending on which neutron source will be used for testing, all applicable rules and procedures will be followed.	
No	Removable contamination: alpha, beta/gamma			select hazard level descriptor.		
No	Other ionizing radiation hazard not listed above					
Chemical Hazards						
No	Asbestos			select hazard level descriptor.		
Yes	Asphyxiant gas (simple)	Nitrogen bottle used for pneumatic system supply	L	Use of inert gases in well ventilated areas such as high bays, outdoors or laboratories	System is leak checked, and while in operation system discharges very small amounts of N2	
No	Beryllium			select hazard level descriptor.		
No	Carcinogenic chemicals			select hazard level descriptor.		
No	Explosives or highly reactive (e.g., alkali metals) chemicals			select hazard level descriptor.		
Yes	Flammable and combustible chemicals (liquid or solid)	Buffer oil used in hydraulic system is a heat transfer fluid, it is rated for the temperatures at which we wish to operate. Being an oil, it is flammable.	L	Incidental use of small quantities (<1 L) of common solvents	System is temperature controlled with redundant controllers, each being capable of recognizing an overheat situation and shutting down the entire heating system. System will be brought to room temperature before any venting or disassembly.	
No	Flammable gas			select hazard level descriptor.		
No	Hydrofluoric acid			select hazard level descriptor.		
No	Hydrogen gas above 1% concentration			select hazard level descriptor.		

Hazard Present? (Y/N)	Hazard	Task/Hazard Relationship and Hazard Description	Hazard Level	Graded Approach – Hazard Levels (select one)	Hazard-Specific Application of Controls	SME Signature/Date (for HL = VH or H)
Yes	Industrial chemicals such as: solvents, strippers, paints, adhesives, industrial cleaners, pesticides, etc.	Alcohol and detergents are used for cleaning components	L	Occasional use, unconfined area, latex paint, good ventilation	Used in well ventilated areas, with proper PPE	
No	Oxidizers			select hazard level descriptor		
No	Perchloric acid or perchlorate salts			select hazard level descriptor		
No	Toxic metals			select hazard level descriptor		
No	Silica dust generation			select hazard level descriptor		
No	Strong acids or bases			select hazard level descriptor		
No	Toxic chemicals			select hazard level descriptor		
No	Toxic gas			select hazard level descriptor		
No	Other chemical hazard not listed above					
Engineered Nanomaterials						
No	Engineered Nanomaterials (ENM)			select hazard level descriptor		
Biological Hazards						
No	Etiologic agents			select hazard level descriptor		
No	Bloodborne pathogens			select hazard level descriptor		
No	Contaminated materials-biological			select hazard level descriptor		
No	Other biological hazard not listed above					
Other						
No	Human subjects as research participants			select hazard level descriptor		
Yes	Measuring & Test Equipment Used?	VOMs, dial calipers, data acquisition system			Calibrate M&TE as required per LMS-PROC-50	
No	Special Considerations? (complex)?					
Environmental Impacts						
No	New or Revised Environmental Review Form Needed?					
No	Waste generation?			select waste descriptor		
Emergency Management						
No	Chemicals where any NFPA 704 rating is 3 or 4 and the liquid quantity is ≥5 gal or solid quantity is ≥ 40 lbs					
No	Use of or work with radioactive materials in quantities where the Hazard Category 3 sum of the fractions exceeds 1 per LMS-PROC-45?					

Hazard Present? (Y/N)	Hazard	Task/Hazard Relationship and Hazard Description	Hazard Level	Graded Approach – Hazard Levels (select one)	Hazard-Specific Application of Controls	SME Signature/Date (for HL = VH or H)
No	Biological hazards requiring IBC review?					
No	High pressure hazards at hazard level high or very high?					
Nuclear Safety Review						
No	Work in Building 200, 205, 212, 306, or 331.				No further action required.	

SECTION 5 ANNUAL REVIEW

Annually, this WCD must be reviewed and affirmed by the approval authority to document that the WCD is current (Type 2 Work only). Signature denotes that the approval authority has reviewed the package, that it is current, and that no revisions are required.

End of Year 1 Reviewed and Affirmed	
Signature	**Date**

End of Year 2 Reviewed and Affirmed	
Signature	**Date**

SECTION 6 FINAL STATUS/END OF WORK

Close out work package at the discretion of the designated authority (after a one time use, at the end of three years, or when the work package requires significant modification). Work is completed. Area is clean and safe and waste generated has been appropriately processed for disposition. Required for Type 2 work only.

PIC (Print Name)	Signature	Date

Designated Person (Print Name)	Signature	Date

ESH Coordinator (Print Name)	Signature	Date
Tom Mullen		2/12/2010

Hazard Present? (Y/N)	Hazard	Task/Hazard Relationship and Hazard Description	Hazard Level	Graded Approach – Hazard Levels (select one)	Hazard-Specific Application of Controls	SME Signature/Date (for HL = VH or H)

SECTION 7 WORK AUTHORIZATION

Work is within safety boundaries, and facility/area configuration and mode of operation allows work. Personnel access requirements have been met, pertinent hazards communicated to co located personnel, work does not conflict with other work, and the appropriate permits are completed. Controls have been implemented to reduce the hazard level, where applicable.

Work is authorized for the time period(s) specified. All work authorizations are valid for a defined period not to exceed one year. If changes are made to the work package, the work must be re-authorized.

Start Date	End Date	Badge #	Print Name	Signature of Work Authorization Authority
2/16/2010	12/31/2012	31610	R.V.F. Janssens	

SECTION 8 PRE-JOB BRIEFING DOCUMENTATION

Documentation of Pre-Job Briefing(s) given for the work should be inserted into the table below. A pre-job briefing is required for very high and high hazard level activities. Pre-job briefings must be repeated if (a) the work control document changes, (b) the work control document is generic in nature and requires specific tailoring for each instance of implementation of the work activity (e.g., work activities conducted in campaigns such as waste packaging), or (c) if required by local procedures (e.g., plan of the day meetings) or the work package itself.

Date	Instructor Name	Badge #	Signature

SECTION 9 WORKER SIGNATURES[1]

The work control document (WCD) is required reading for all participants in the project. All participants must sign the work control document. Additional pages may be attached as needed.

I have read and understand the WCD and will work within the established controls. I have attended a pre-job briefing if the hazard level of this work is high or very high (as documented on the work control document).

I understand that I not only have stop work authority, but also an obligation to stop work and notify the person in charge (e.g., job supervisor) in the event that the work cannot be completed as required by the work control documents or if an unanticipated event occurs.

Worker Name (Printed)	Signature	Badge #	Date Signed	Date Pre-Job Brief Attended[2]
KARL E. REHM	K. E. Rehm	26459	2-16-10	2-16-10
Claude Daviide		58723	2/16/10	2/16/10
Brad Dickerson		57920	2-16-10	2-16-10

Hazard Present? (Y/N)	Hazard	Task/Hazard Relationship and Hazard Description	Hazard Level	Graded Approach – Hazard Levels (select one)	Hazard-Specific Application of Controls	SME Signature/Date (for HL = VH or H)

1 This list must be signed by all participants in the work before the work starts.
All new participants are required to sign before working to a WCD.
New signatures are required annually and when significant changes are made to a WCD.
2 If pre-job not required, enter "NA" in this column.

SECTION 10 WORKER FEEDBACK

Documentation of worker feedback, required when the overall hazard level is High or Very High may be written in this space. Divisions may also choose to use this space to record the results of post-job briefings, if used. Attach additional pages if necessary.

Date	Feedback Documented by (Print Name)	Signature

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 _____ 10/22/09

R.V.F. Janssens, PHY Director Date

Argonne NATIONAL LABORATORY

Intra-Laboratory Memo

April 6, 2009

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

FROM: T. Mullen ESH/QA Engineer, PHY

SUBJECT: Recommendation to Authorize Room Temperature Testing of the Bubble Chamber

The Physics Division General Safety Committee met this month to review the operation of the Bubble Chamber.

During that review, the committee felt several actions needed to be taken before it could recommend that you authorize full operation of the Bubble Chamber.

The recommended actions were:

1. Involve Industrial Hygiene Subject Matter Expert on the safety of working with R134A
2. Add over temperature switches to the body of the vacuum chamber
3. Revise the vent to point down to eliminate the possibility of gas striking someone.

Only the first of those recommendations would be relevant when tests are run at room temperature. That step has been competed. B. DiGiovine has requested that the he be allowed to operate the Bubble Chamber at room temperature. The committee believes that is acceptable and that safety is not compromised by that operation.

We therefore recommend that you authorize operation of the Bubble Chamber at room temperature only. Operation at elevated temperatures will require an additional authorization.

Authorized _____
R.V.F. Janssens, PHY Director

Bubble Chamber Detector

HAZARD ANALYSIS
&
Project Review Form

PHYSICS DIVISION
ARGONNE NATIONAL LABORATORY
9700 SOUTH CASS AVENUE
ARGONNE, ILLINOIS 60439

Table of Contents

Bubble Chamber Detector

Hazard Analysis
&
Project Review Form

1. Experiment Program Description:

A bubble chamber type detector using superheated water as the detecting medium is being built for the study of gamma-16O reactions.

2. Organization and Responsibilities:

DiGiovine, Brad :	Engineering, design, assembly, and fabrication.
Holt, Roy:	Physicist
Rehm, Ernst:	Physicist
Ugalde, Claudio:	Physicist

3. Facility Description:

3.1. Location

Initial testing to be done at the ATLAS facility.

3.2. Experimental equipment

Bubble chamber type detector, with its associated support systems.

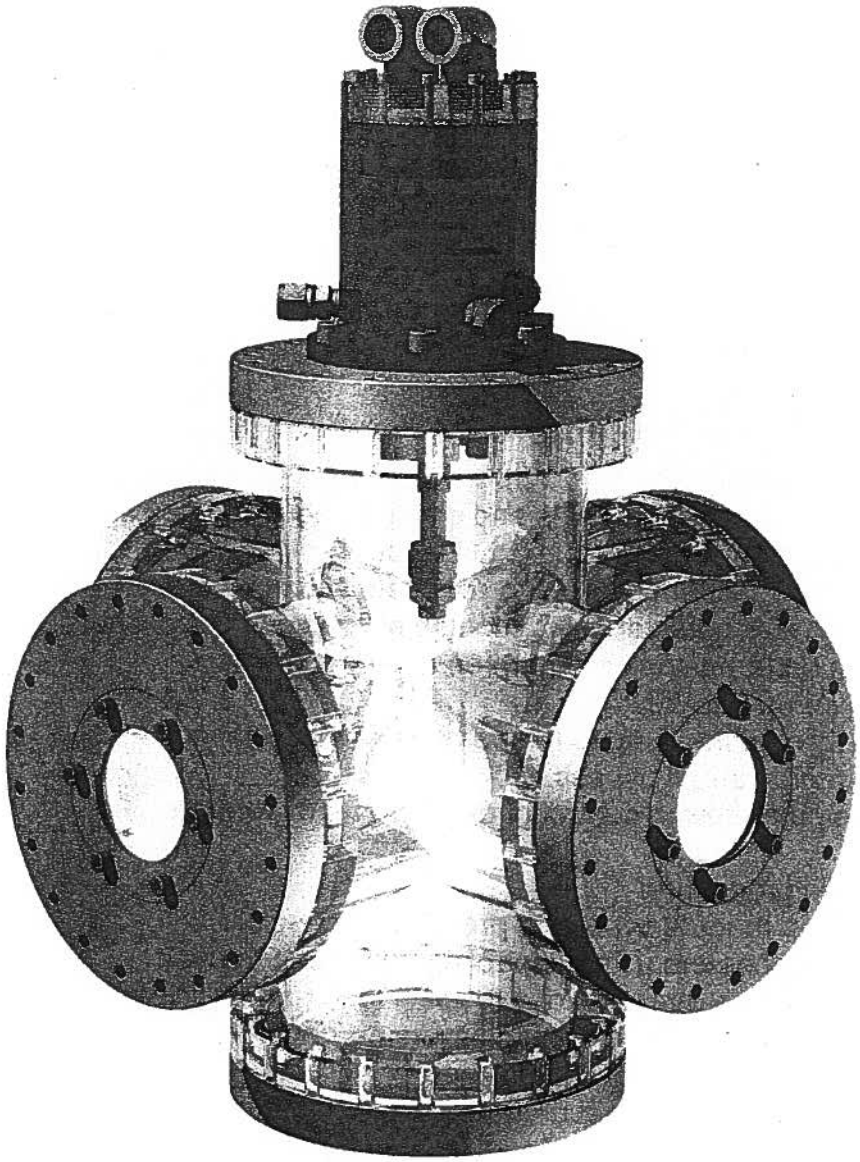
3.2.1. Item 1

Bubble chamber detector.

3.2.2. Item 2

Control chassis, dry nitrogen (pneumatic system), PC running LabView.

Figure 1



3.3. Controls

A control chassis has been built to regulate the temperature of our detector, as well as to provide an interface between our sensors and equipment, and our LabView control and data acquisition software. Manual bypass controls are also available on the front panel of our control chassis.

3.4. Support and service equipment

In addition to the equipment mentioned above, the following will be used:

A vacuum pump is needed to provide our vacuum jacket around our detector, as well as 120V60Hz power for our associated equipment.

4. Operating and Maintenance Procedures:

4.1. Operating Procedures

Start-up procedure:

1. Power on control chassis and connect regulated gas supply.
2. Adjust regulated pressure to 150 psi.
3. Connect vacuum pump and evacuate vacuum cross.
4. Pressurize detector using manual bypass on control chassis.
5. Turn on ramp/soak program on heater controllers.
6. Power up LabView.
7. Verify detector is up to temperature and regulating.
8. Turn off manual bypass.
9. Computer now in control of detector, ready for use.

Shut-down procedure:

1. Turn on manual bypass to pressurize detector.
2. Turn off heaters using controller, allow time to cool.
3. Once temperature is close to room temperature, close nitrogen supply.
4. Vent pneumatic and vacuum systems slowly.
5. Power down control chassis.
6. Once systems are secured, detector is ready for storage.

4.2. Maintenance Procedures

No regular maintenance is needed for this detector system, however if maintenance is needed, it is imperative to have a very thorough understanding of the operation of this detector, and to make sure if disassembling the detector itself, that none of the systems are still pressurized.

4.3 Experiment Procedure

5. Training:

The only training that may apply is ESH119 Pressure Safety Orientation, since a high pressure bottle of dry nitrogen will be used to supply pressure to our pneumatic system.

6. Hazards for Normal Operations

The checklist below is derived from the ES&H Manual. While it appears to be rather extensive, it is a handy listing of the types of hazards that may be present when we work. Use it to list any hazards present in the set-up, running and removal of the project. Mark the AYES@ or ANO@ column for each hazard listed.

For each YES marked, explain below the form what the hazard consists of. Use the REMARKS column to direct the reader to the sub-section explaining the hazard.

Note that this section addresses the hazards associated with normal operations of the Project or Facility. The hazards associated with postulated accidents are addressed in Section 7.

TABLE 6-1
POTENTIAL HAZARDS CHECKLIST
(ANL-E ES&H Manual Section 21.2, Appendix A)

POTENTIAL HAZARD	YES	NO	REMARKS
Radiation and Electromagnetic Fields			
Ionizing Radiation			
Alpha		X	
Beta		X	
Gamma and/or X-Ray	X		Experiment conducted at γ facility
Neutron	X		Initial testing using neutron source
Proton		X	
Subatomic		X	
Nonionizing Radiation			
Laser		X	
Visible Light		X	
Ultraviolet		X	
Microwave		X	
Radiofrequency		X	
Electric Fields		X	
Magnetic Fields		X	
Chemicals and/or Materials			
Health and Injury Hazards			

POTENTIAL HAZARD	YES	NO	REMARKS
Carcinogens		X	
Mutagens		X	
Teratogens		X	
Toxins		X	
Corrosives		X	
Irritants, Allergens, and/or Sensitizers		X	
Volatile Solvents		X	
Combustion and Injury Hazards			
Flammable Liquids and/or Solvents		X	
Metallic Combustibles		X	
Flammable Gases		X	
Compressed Oxygen		X	
Open Flame or Sparks		X	
Combustible Materials		X	
Explosives		X	
Flammable Suspended Dust Particles		X	
Pyrophoric Chemicals		X	
Respiratory or Contact Injury Hazards			
Cryogenics		X	
Thermal (High or Low)	X		Interior of detector operates at 150C
Dust, Particulates, and Fibers		X	
Asbestos		X	
Explosives		X	
Reactive Chemicals		X	
Compressed Gases	X		Pneumatic system of detector
Pressure and/or Vacuum Systems	X		Vacuum jacket and pneumatic sys.
Steam		X	
Asphyxiation		X	
Stored Energy Not Elsewhere Addressed			
Hydraulic Energy	X		Closed hydraulic system of detector
Kinetic Energy		X	
Mechanical Energy		X	
Potential Energy		X	
Other		X	
Biohazards			
Virus		X	
Bacteria		X	
Human Tissues and/or Body Fluids		X	
Animals and Animal Tissue		X	
Electrical			
High Voltage Devices		X	
Storage Devices		X	
Static Charge		X	
Lightning Protection		X	
Grounding		X	
Exposed Conductors		X	

POTENTIAL HAZARD	YES	NO	REMARKS
Mechanical			
Lifting Devices		X	
Low Friction Surfaces		X	
Load-Bearing Components		X	
Vibration		X	
Sharp Points or Edges		X	
Moving Parts		X	
Pinch Points		X	
Ladders, Scaffolds, and/or Platforms		X	
Work Environment			
Activities at Known or Suspected Hazardous Waste Sites		X	
Use of Self-Contained Breathing Apparatus		X	
Temperature or Other Climatic Extremes		X	
Severe Weather		X	
Noise		X	
Confined Spaces		X	
Others (Tripping Hazards)		X	

6.1. First hazard listed

I. Gamma Radiation:

This device does not emit gamma radiation, rather detects the interaction between gamma rays from a source and the oxygen atoms contained within the water molecules. All safety procedures in place at the gamma ray facility will be followed.

II. Neutron Radiation:

This device does not emit neutron radiation; we will be using a neutron source for initial testing of our detector here at ATLAS.

III. Thermal contact injury hazards:

The interior portion of this device will be operated at 150C upon successful completion of our room temperature testing. Using a vacuum jacket, we are trying to reduce the amount of heat transferred to the exterior housing of our detector. Regardless of our rate of heat transfer, there will be warnings placarded to inform any nearby persons.

IV. Compressed Gasses:

The pneumatic system of our detector will be supplied by a high pressure cylinder of dry nitrogen using a newly purchased regulator just for this experiment.

V. Pressure and Vacuum systems:

The pneumatic system of this detector has been engineered and built to withstand significantly higher pressures than those being used, a pressure relief valve is in place to prevent over pressurization of our pneumatic system.

Our vacuum system consists of a pump and vacuum cross which houses the sensitive part of our detector. All sealing components are vacuum rated and appropriate for the elevated temperatures which are possible. Also our vacuum space will be fitted with a blow-off disk to prevent the possibility of over pressurization.

VI. Stored Hydraulic Energy:

Using an overestimate of our hydraulic system volume (20 in^3) the stored energy in our hydraulic system is in the area of .081 Joules.

6.2. Second hazard listed, etc.

7. Hazards for Postulated Accidents:

1. Upon the creation of a bubble in our superheated water, pressure must be applied to stop further boiling. Failure of pneumatic system will prevent application of pressure to prevent a run away boil.

2. Vacuum vessel, hydraulic system, and pneumatic system over pressurization.

3. Failure of the heating system.

4. Failure of the pressure rated glass vessel containing superheated water.

8. Safety Systems and Equipment:

1. A mechanical stop has been designed into the system for the control piston, where if a pneumatic system failure occurs, the steam generated by the boiling will force the piston against its stop, allowing the pressure to rise within its operating conditions to a point around 70psia (vapor pressure of water at 150C), preventing further boiling. If for some unforeseen reason it continues to boil (heater malfunction) a two phase pressure relief valve is in place to vent the water/oil/steam mixture.

2. The vacuum vessel, hydraulic system, and pneumatic system will be relieved in case of over pressure, preventing damage to systems, surrounding equipment, and anyone standing nearby. Special care must be taken in the relieving of the hydraulic system, since there can be both liquid and gas escaping at 150 C. Routing the exit of the relief apparatus into a phase separation system will allow the hot oil and water to collect within a container while allowing unrestricted venting of steam.

3. Failure of the heating system, causing uncontrolled heating of our water will cause the activation of our hydraulic relief system, allowing the excess pressure to be safely relieved. Two independent temperature sensors/heater controllers are in place for redundancy. Their alarm systems are connected to the heater safety relays. Therefore if one system malfunctions and overheats, the other system will reach its alarm point and shut down power to both heaters.

4. Thermodynamic calculations show that in the event of a failure at 165 C, which is 15 degrees above normal operation, there is only enough heat energy stored in the water to cause 10% to flash to vapor. This equates to roughly 8.6 liters of steam at atmospheric pressure. Our vacuum vessel's interior volume is around 12 liters, so such a failure will not cause the pressure in the vessel to reach atmospheric pressure. Furthermore, since the walls of the vacuum vessel will be similar in temperature to its surrounding environment, further cooling of the liquid will occur upon contact with the vacuum vessel, further reducing the amount of liquid that will flash to steam. Even with these precautions, the vacuum vessel itself will be equipped with a blow off disk in the upper portion which will facilitate the venting of the vacuum vessel in case of over pressurization, while allowing the liquid to collect in the lower portion of the containment vessel.

9. Safety Procedures

1. This device must be operated by a competent person with a thorough understanding of its systems and design.
2. The detector itself may be hot, avoid contact with skin.

10. Environmental Compliance Procedures:

Does this experiment or equipment meet the definition of the NEPA bench scale exemption YES ☐ *NO* ☐

If NO, NEPA documentation is required. Contact Tom Mullen 2-2879

List any procedures you needed to create (if any) for environmental compliance

purposes.

11. Emergency Procedures:

The safety systems contained in section 8 will automatically initiate in the event that any of the postulated accidents occur. The only thing that is required of the experimenter is to power down the control chassis in the event of an accident. Once the system is powered down and allowed to cool, pressure and vacuum systems should be vented and a thorough investigation must be performed by someone with an intimate understanding of the detector and its systems.

12. Waste Management Considerations

On occasion we may produce a quart or two of waste heat transfer oil, this will be disposed of properly through waste management operations using form EWM-197

13. List of Applicable Documents

Analysis of 110030

Author:	B. DiGiovine
Analysis Created:	Wednesday, October 15, 2008 1:52:13 PM
Analysis Last Modified:	Wednesday, October 15, 2008 1:55:14 PM
Report Created:	Monday, March 16, 2009 9:25:24 AM
Database:	*C:\Documents and Settings\digiovine\My Documents\Inventor\Brad\NPD-10 (Bubble Chamber)\110030\110030.ipa*
Software:	Autodesk Inventor Professional 2009 ANSYS Technology

Autodesk® ANSYS

Introduction

Autodesk Inventor Professional Stress Analysis was used to simulate the behavior of a mechanical part under structural loading conditions. ANSYS technology generated the results presented in this report.

Do not accept or reject a design based solely on the data presented in this report. Evaluate designs by considering this information in conjunction with experimental test data and the practical experience of design engineers and analysts. A quality approach to engineering design usually mandates physical testing as the final means of validating structural integrity to a measured precision.

Additional information on AIP Stress Analysis and ANSYS products for Autodesk Inventor is available at http://www.ansys.com/autodesk.

Geometry and Mesh

The Relevance setting listed below controlled the fineness of the mesh used in this analysis. For reference, a setting of -100 produces a coarse mesh, fast solutions and results that may include significant uncertainty. A setting of +100 generates a fine mesh, longer solution times and the least uncertainty in results. Zero is the default Relevance setting.

TABLE 1
110030.ipt Statistics

Bounding Box Dimensions	7.97 in 7.97 in 0.88 in
Part Mass	11.33 lbm
Part Volume	38.77 in^3
Mesh Relevance Setting	0
Nodes	79401
Elements	44667

Bounding box dimensions represent lengths in the global X, Y and Z directions.

Material Data

The following material behavior assumptions apply to this analysis:

- Linear - stress is directly proportional to strain.
- Constant - all properties temperature-independent.
- Homogeneous - properties do not change throughout the volume of the part.
- Isotropic - material properties are identical in all directions.

TABLE 2
Stainless Steel

Young's Modulus	2.799e+007 psi
Poisson's Ratio	0.3
Mass Density	0.2921 lbm/in^3
Tensile Yield Strength	3.626e+004 psi
Tensile Ultimate Strength	0.0 psi

Loads and Constraints

The following loads and constraints act on specific regions of the part. Regions were defined by selecting surfaces, cylinders, edges or vertices.

TABLE 3
Load and Constraint Definitions

Name	Type	Magnitude	Vector
Pressure 1	Surface Pressure	164.9 psi	N/A
Fixed Constraint 1	Surface Fixed Constraint	0.0 in	0.0 in 0.0 in 0.0 in

TABLE 4
Constraint Reactions

Name	Force	Vector	Moment	Moment Vector
Fixed Constraint 1	1204 lbf	8.855e-007 lbf 1.513e-006 lbf -1204 lbf	3.326e-006 lbf·in	2.677e-006 lbf·in 8.218e-008 lbf·in 1.972e-006 lbf·in

Note: vector data corresponds to global X, Y and Z components.

Results

The table below lists all structural results generated by the analysis. The following section provides figures showing each result contoured over the surface of the part.

Safety factor was calculated by using the maximum equivalent stress failure theory for ductile materials. The stress limit was specified by the tensile yield strength of the material.

TABLE 5

Structural Results

Name	Minimum	Maximum
Equivalent Stress	10.1 psi	2591 psi
Maximum Principal Stress	-518.1 psi	2771 psi
Minimum Principal Stress	-1776 psi	920.3 psi
Deformation	0.0 in	3.191e-004 in
Safety Factor	13.99	N/A

Figures

FIGURE 1
Equivalent Stress

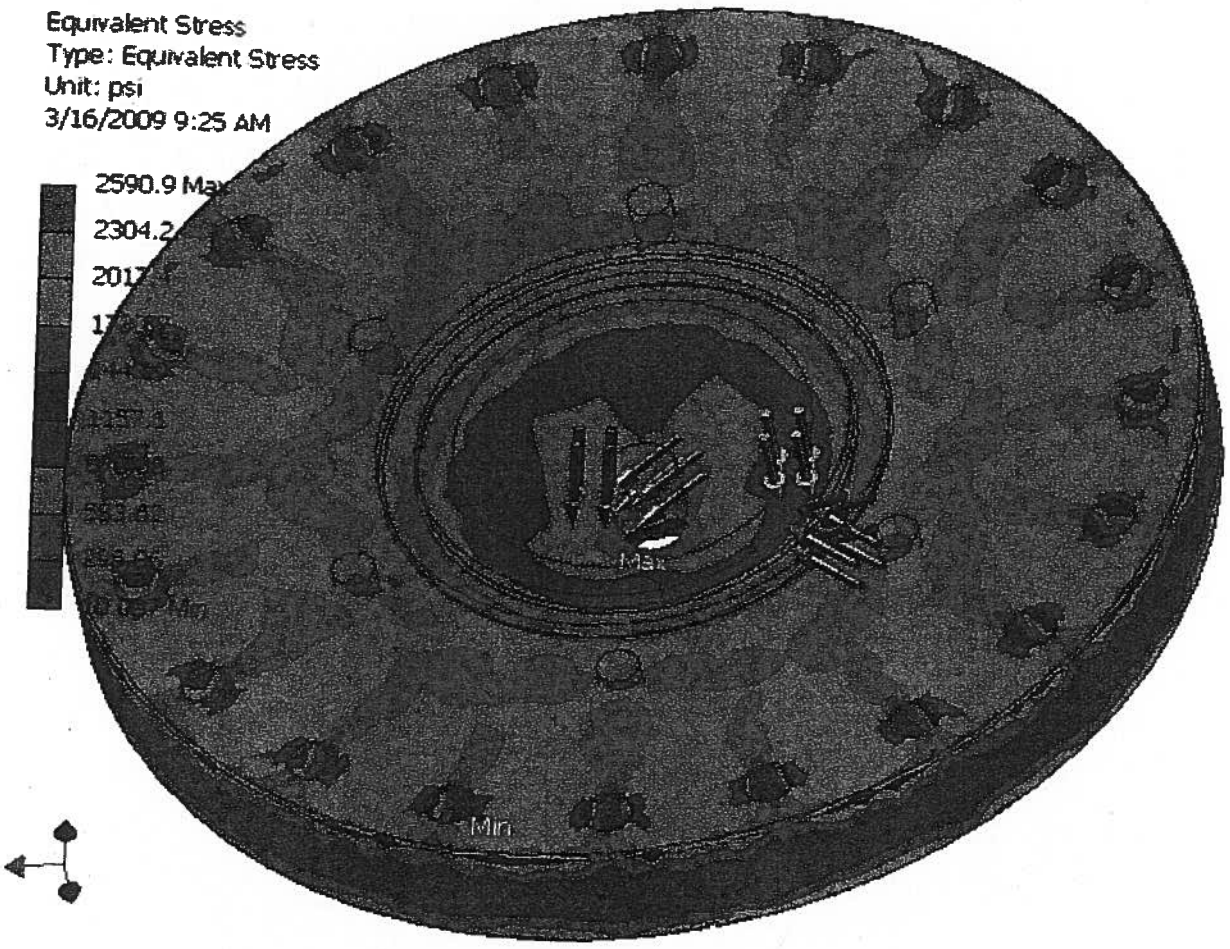


FIGURE 2
Maximum Principal Stress

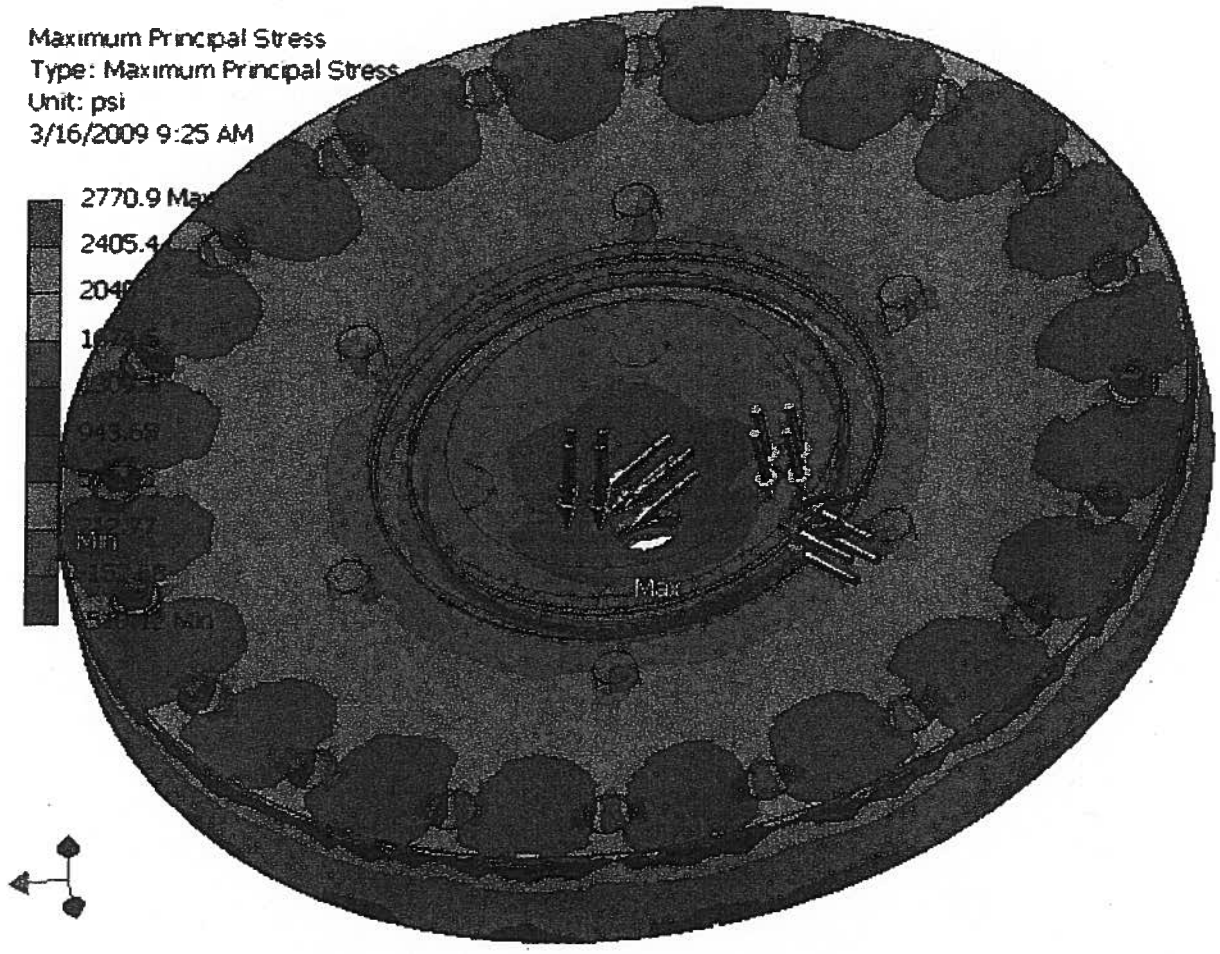


FIGURE 3
Minimum Principal Stress

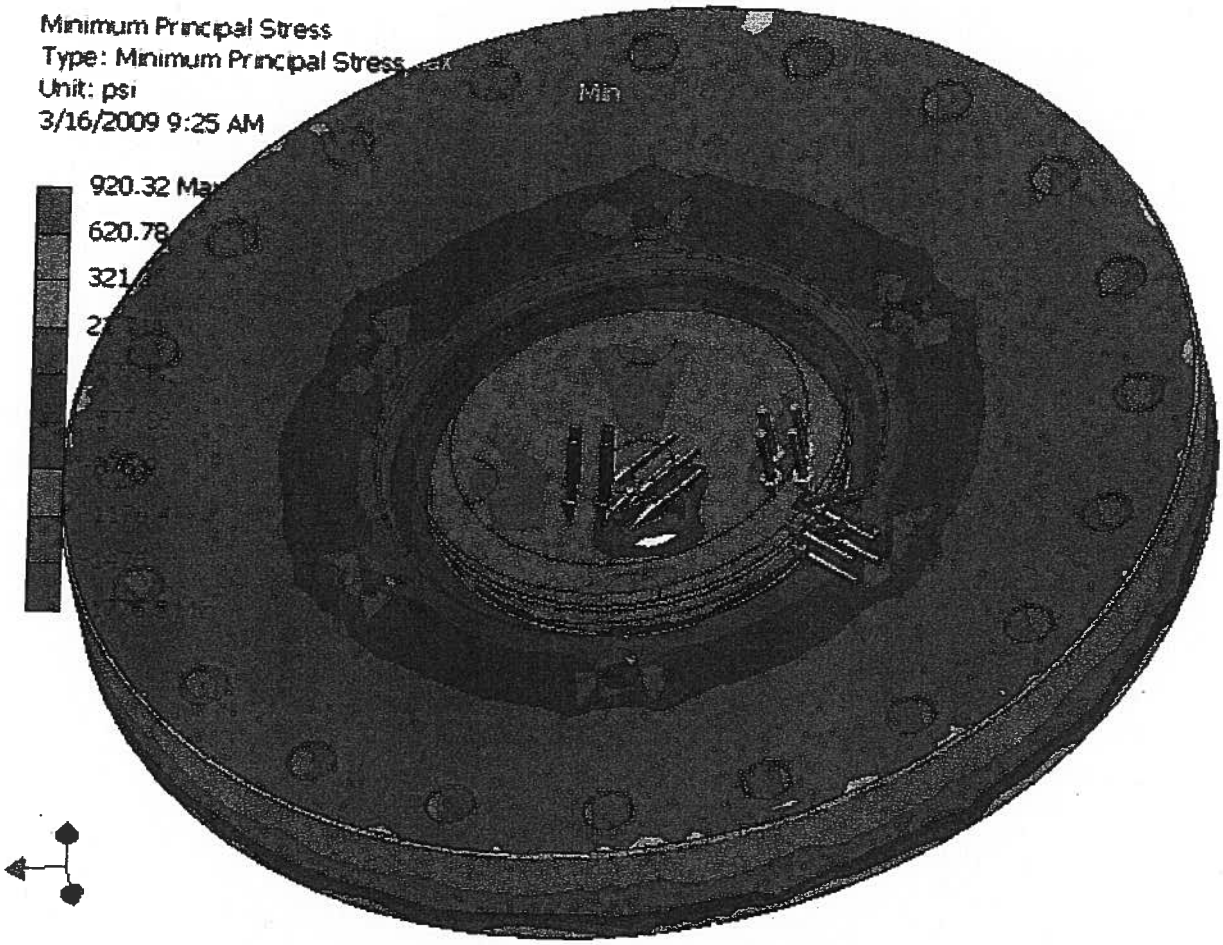


FIGURE 4
Deformation

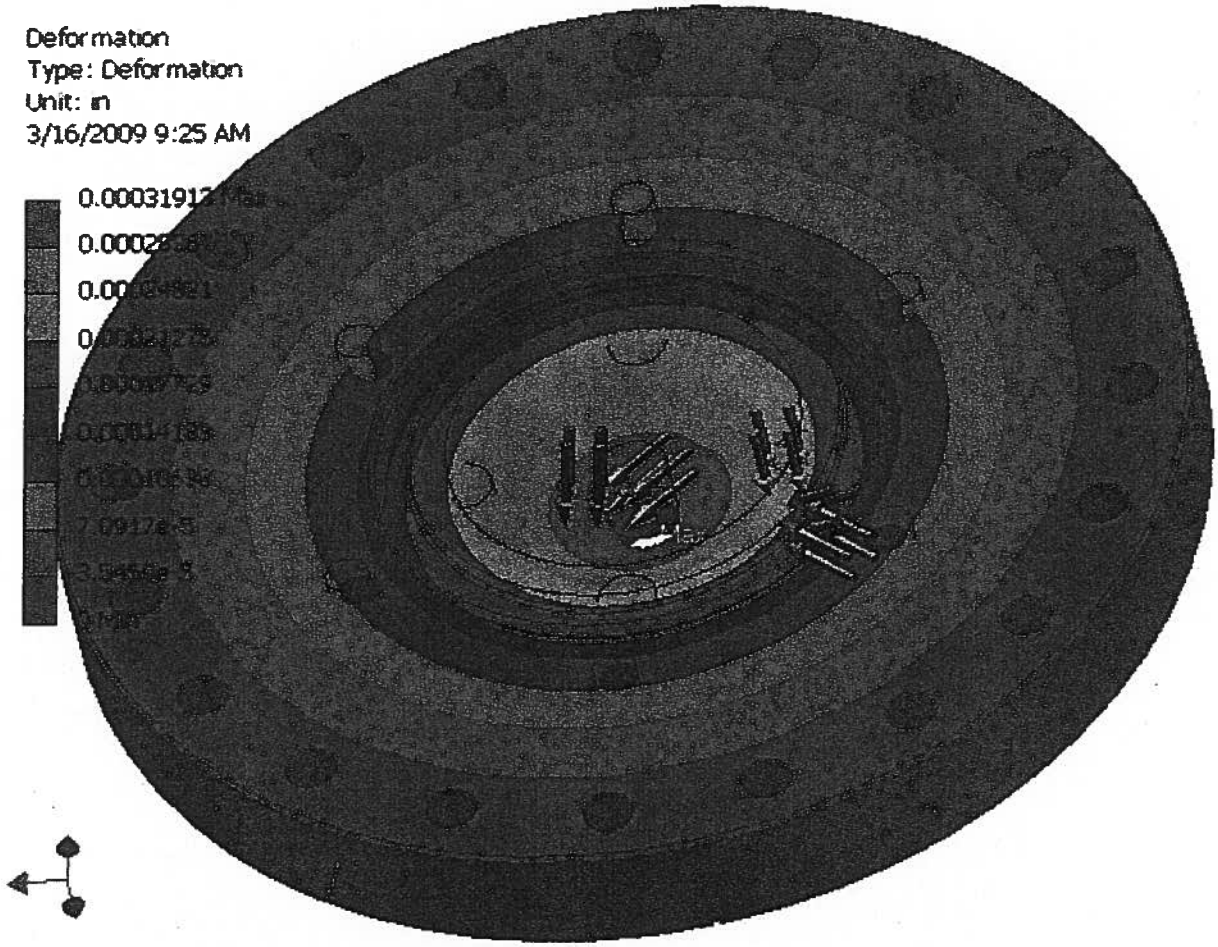
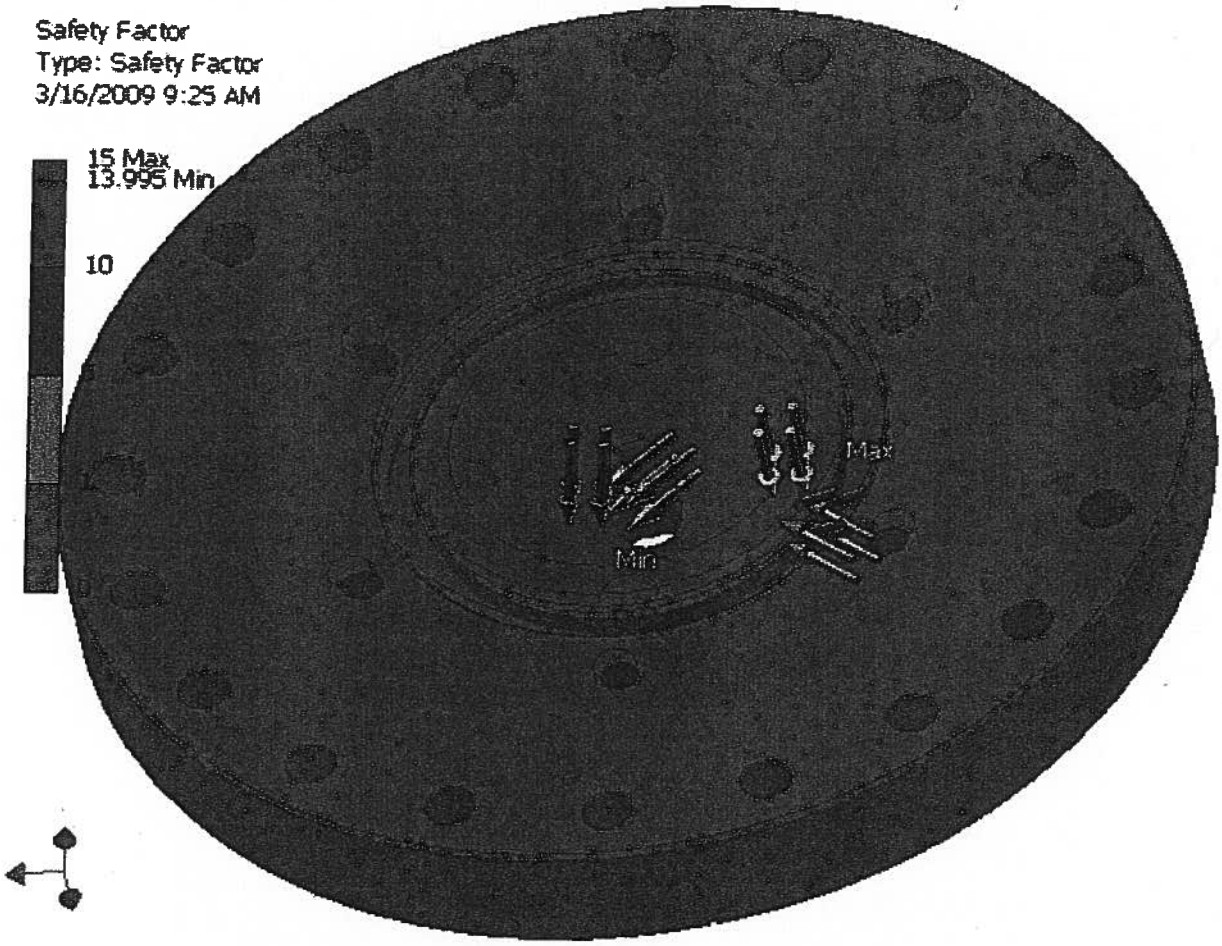


FIGURE 5
Safety Factor



Analysis of CylinderHead2

Author:	B. DiGiovine
Analysis Created:	Wednesday, October 15, 2008 1:45:20 PM
Analysis Last Modified:	Wednesday, November 19, 2008 2:21:03 PM
Report Created:	Monday, March 16, 2009 9:15:33 AM
Database:	*C:\Documents and Settings\digiovine\My Documents\Inventor\Brad\NPD-10 (Bubble Chamber) \CylinderHead2.ipa*
Software:	Autodesk Inventor Professional 2009 ANSYS Technology

Introduction

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Geometry and Mesh

The Relevance setting listed below controlled the fineness of the mesh used in this analysis. For reference, a setting of -100 produces a coarse mesh, fast solutions and results that may include significant uncertainty. A setting of +100 generates a fine mesh, longer solution times and the least uncertainty in results. Zero is the default Relevance setting.

TABLE 1
CylinderHead2 Statistics

Bounding Box Dimensions	3.75 in 1.75 in 3.75 in
Part Mass	2.953 lbm
Part Volume	10.11 in^3
Mesh Relevance Setting	0
Nodes	11532
Elements	6199

Bounding box dimensions represent lengths in the global X, Y and Z directions.

Material Data

The following material behavior assumptions apply to this analysis:

- Linear - stress is directly proportional to strain.
- Constant - all properties temperature-independent.
- Homogeneous - properties do not change throughout the volume of the part.
- Isotropic - material properties are identical in all directions.

TABLE 2
Stainless Steel

Young's Modulus	2.799e+007 psi
Poisson's Ratio	0.3
Mass Density	0.2921 lbm/in³
Tensile Yield Strength	3.626e+004 psi
Tensile Ultimate Strength	0.0 psi

Loads and Constraints

The following loads and constraints act on specific regions of the part. Regions were defined by selecting surfaces, cylinders, edges or vertices.

TABLE 3
Load and Constraint Definitions

Name	Type	Magnitude	Vector
Pressure 1	Surface Pressure	164.9 psi	N/A
Fixed Constraint 2	Edge Fixed Constraint	0.0 in	0.0 in 0.0 in 0.0 in

TABLE 4
Constraint Reactions

Name	Force	Vector	Moment	Moment Vector
Fixed Constraint 2	752.8 lbf	4.835e-007 lbf -752.8 lbf -4.339e-007 lbf	3.138e-003 lbf·in	7.135e-008 lbf·in 2.698e-007 lbf·in 3.138e-003 lbf·in

Note: vector data corresponds to global X, Y and Z components.

Results

The table below lists all structural results generated by the analysis. The following section provides figures showing each result contoured over the surface of the part.

Safety factor was calculated by using the maximum equivalent stress failure theory for ductile materials. The stress limit was specified by the tensile yield strength of the material.

TABLE 5

Structural Results

Name	Minimum	Maximum
Equivalent Stress	7.375 psi	1273 psi
Maximum Principal Stress	-190.1 psi	1431 psi
Minimum Principal Stress	-423.6 psi	313.5 psi
Deformation	0.0 in	5.361e-005 in
Safety Factor	15.0	N/A

Figures

FIGURE 1
Equivalent Stress

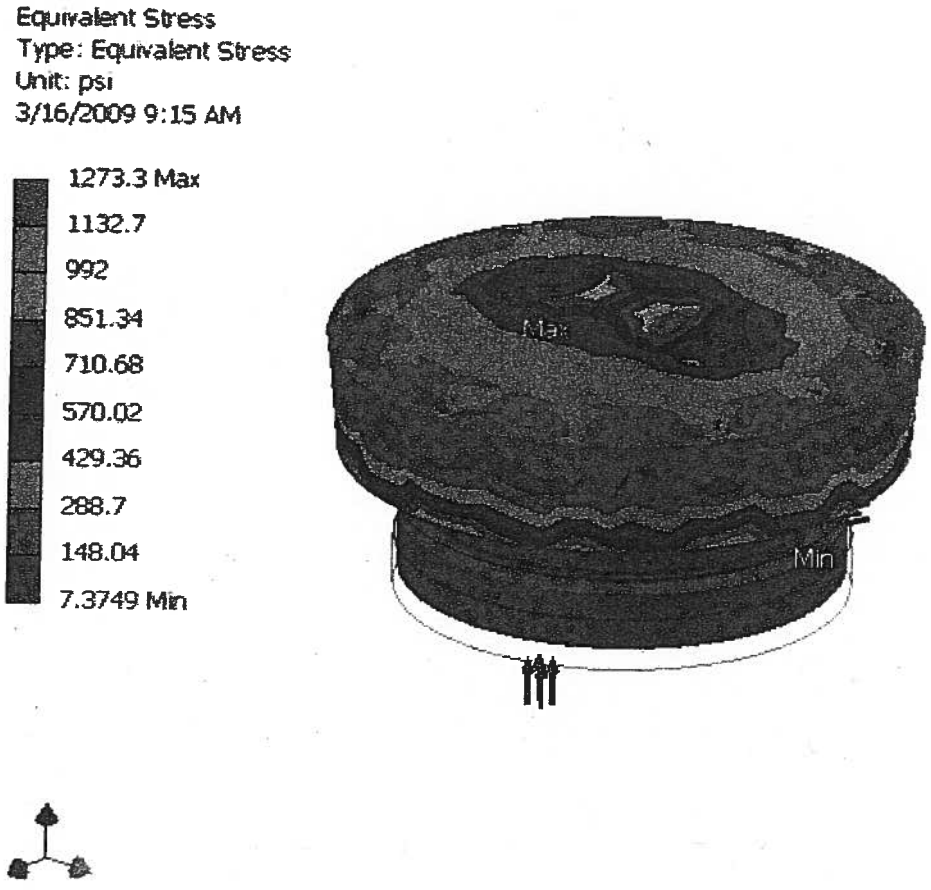


FIGURE 2
Maximum Principal Stress

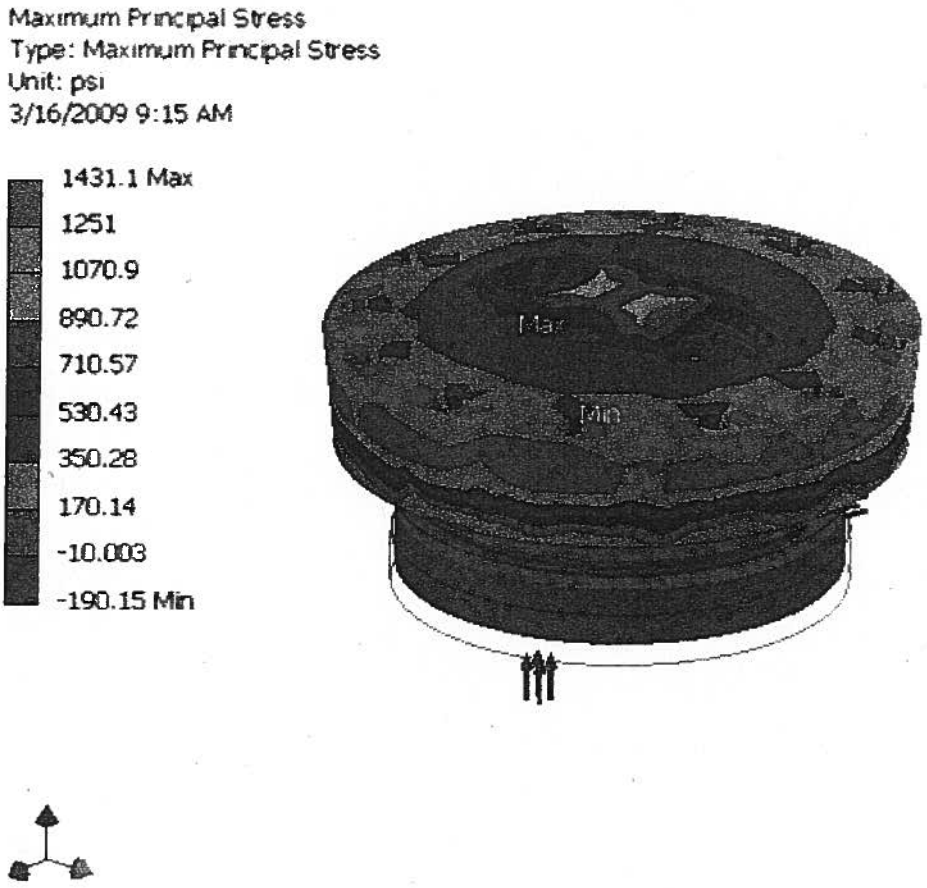


FIGURE 3
Minimum Principal Stress

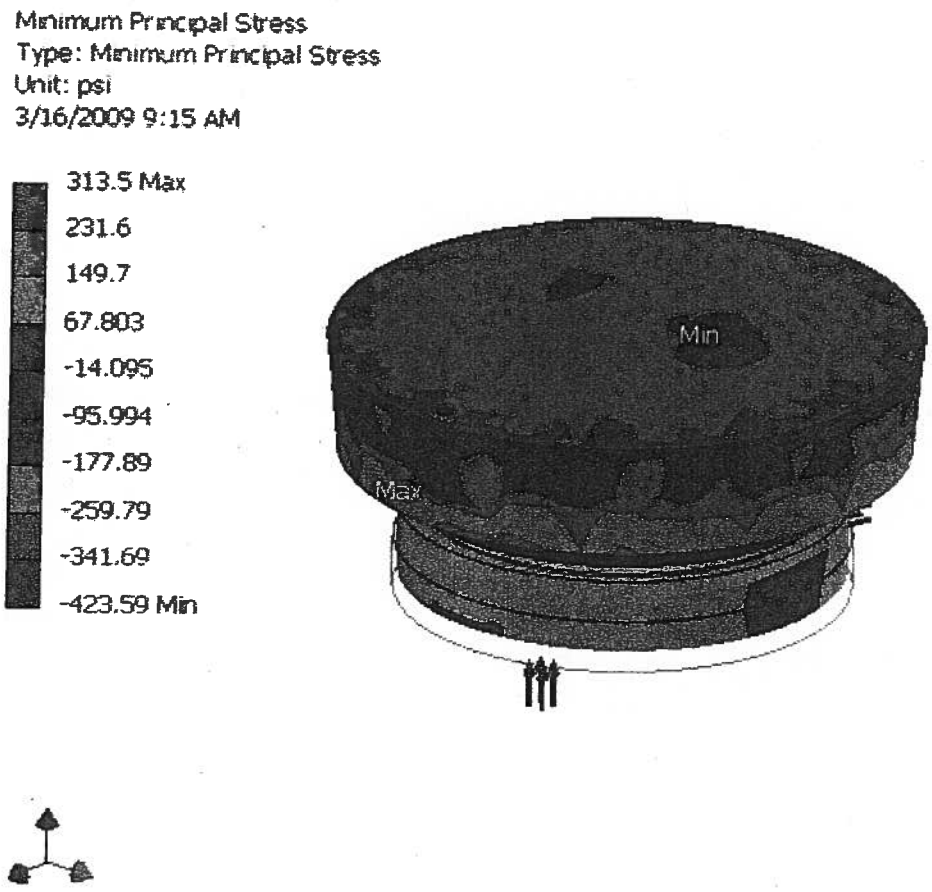


FIGURE 4
Deformation

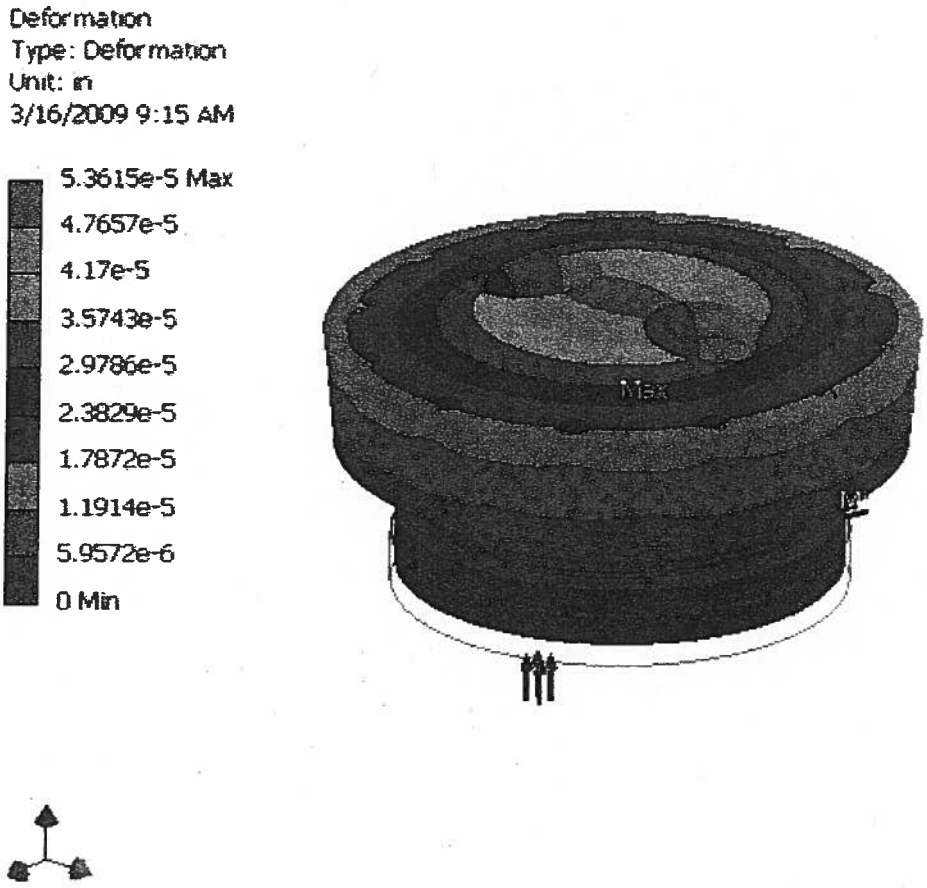
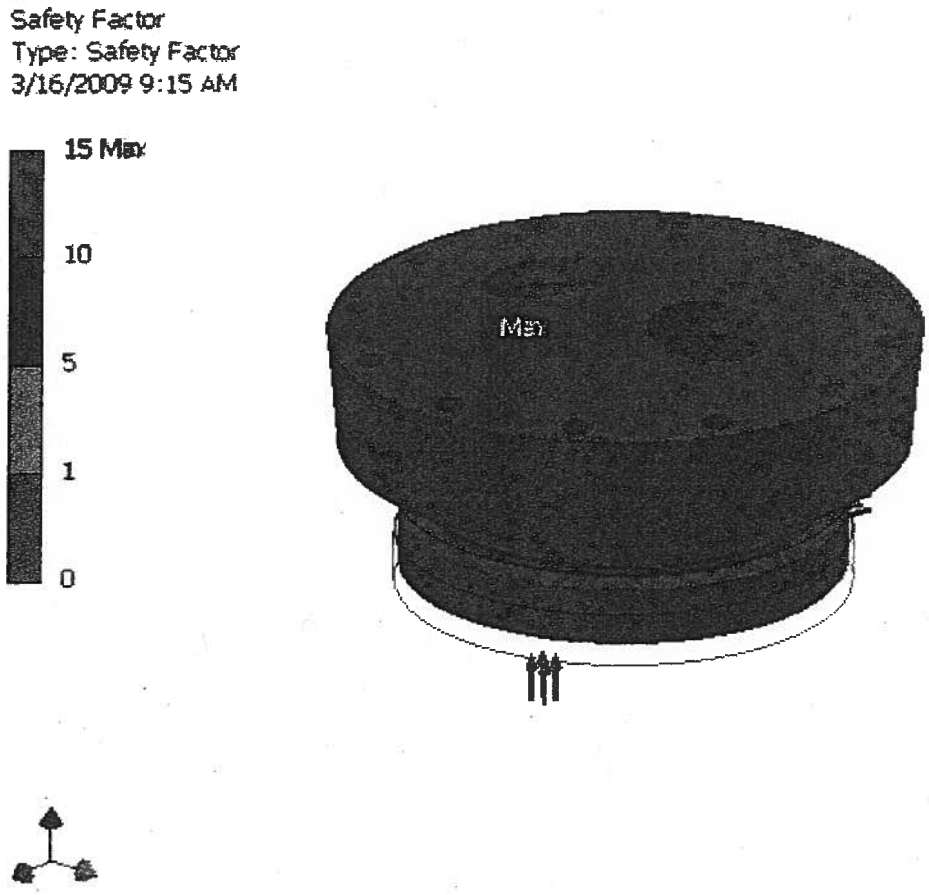


FIGURE 5
Safety Factor



Analysis of cylinder

Author:	B. DiGiovine
Analysis Created:	Wednesday, October 15, 2008 1:35:15 PM
Analysis Last Modified:	Monday, March 16, 2009 9:19:39 AM
Report Created:	Monday, March 16, 2009 9:21:00 AM
Database:	*C:\Documents and Settings\digiovine\My Documents\Inventor\Brad\NPD-10 (Bubble Chamber)\cylinder.ipa*
Software:	Autodesk Inventor Professional 2009 ANSYS Technology

Autodesk® ANSYS

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Geometry and Mesh

The Relevance setting listed below controlled the fineness of the mesh used in this analysis. For reference, a setting of -100 produces a coarse mesh, fast solutions and results that may include significant uncertainty. A setting of +100 generates a fine mesh, longer solution times and the least uncertainty in results. Zero is the default Relevance setting.

TABLE 1
cylinder Statistics

Bounding Box Dimensions	5.0 in 5.0 in 4.5 in
Part Mass	6.919 lbm
Part Volume	23.68 in^3
Mesh Relevance Setting	0
Nodes	9138
Elements	4551

Bounding box dimensions represent lengths in the global X, Y and Z directions.

Material Data

The following material behavior assumptions apply to this analysis:

- Linear - stress is directly proportional to strain.
- Constant - all properties temperature-independent.
- Homogeneous - properties do not change throughout the volume of the part.
- Isotropic - material properties are identical in all directions.

TABLE 2
Stainless Steel

Young's Modulus	2.799e+007 psi
Poisson's Ratio	0.3
Mass Density	0.2921 lbm/in³
Tensile Yield Strength	3.626e+004 psi
Tensile Ultimate Strength	0.0 psi

Loads and Constraints

The following loads and constraints act on specific regions of the part. Regions were defined by selecting surfaces, cylinders, edges or vertices.

TABLE 3
Load and Constraint Definitions

Name	Type	Magnitude	Vector
Pressure 1	Surface Pressure	164.9 psi	N/A
Fixed Constraint 1	Surface Fixed Constraint	0.0 in	0.0 in 0.0 in 0.0 in
Fixed Constraint 2	Surface Fixed Constraint	0.0 in	0.0 in 0.0 in 0.0 in

TABLE 4
Constraint Reactions

Name	Force	Vector	Moment	Moment Vector
Fixed Constraint 1	12.83 lbf	0.1616 lbf 0.1445 lbf -12.83 lbf	0.79 lbf·in	-0.6949 lbf·in 0.2963 lbf·in -0.2311 lbf·in
Fixed Constraint 2	369.0 lbf	-0.1616 lbf -0.1445 lbf 369.0 lbf	0.4678 lbf·in	7.16e-002 lbf·in 0.4004 lbf·in 0.2311 lbf·in

Note: vector data corresponds to global X, Y and Z components.

Results

The table below lists all structural results generated by the analysis. The following section provides figures

showing each result contoured over the surface of the part.

Safety factor was calculated by using the maximum equivalent stress failure theory for ductile materials. The stress limit was specified by the tensile yield strength of the material.

TABLE 5
Structural Results

Name	Minimum	Maximum
Equivalent Stress	12.44 psi	1527 psi
Maximum Principal Stress	-455.4 psi	2316 psi
Minimum Principal Stress	-1366 psi	695.0 psi
Deformation	0.0 in	4.386e-005 in
Safety Factor	15.0	N/A

Figures

FIGURE 1
Equivalent Stress

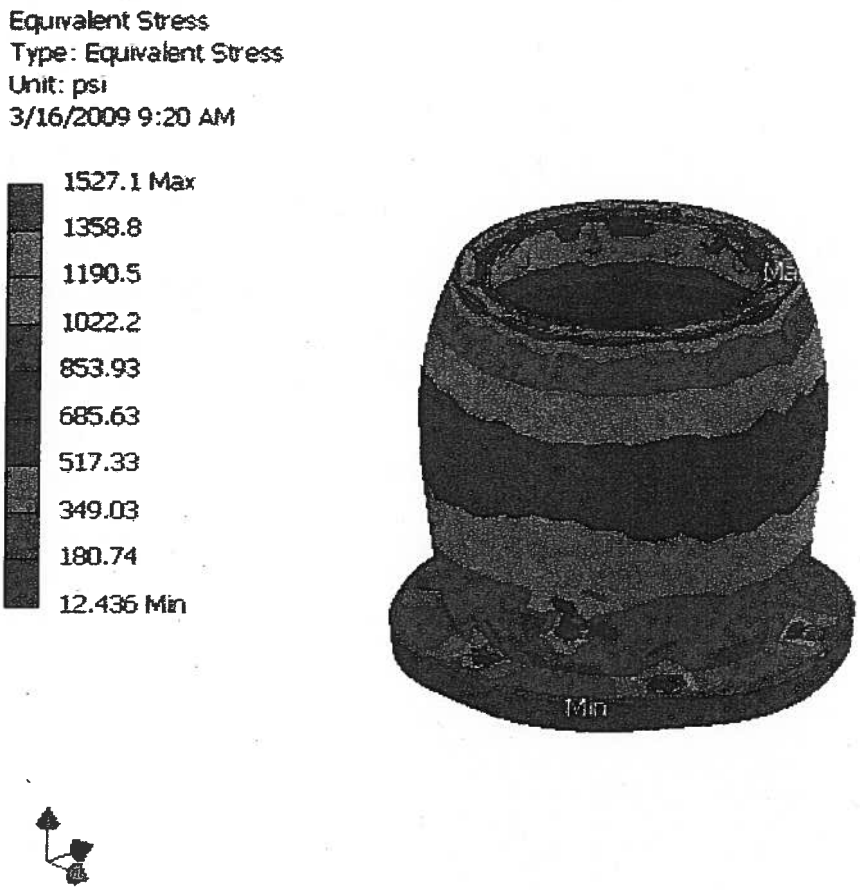


FIGURE 2
Maximum Principal Stress

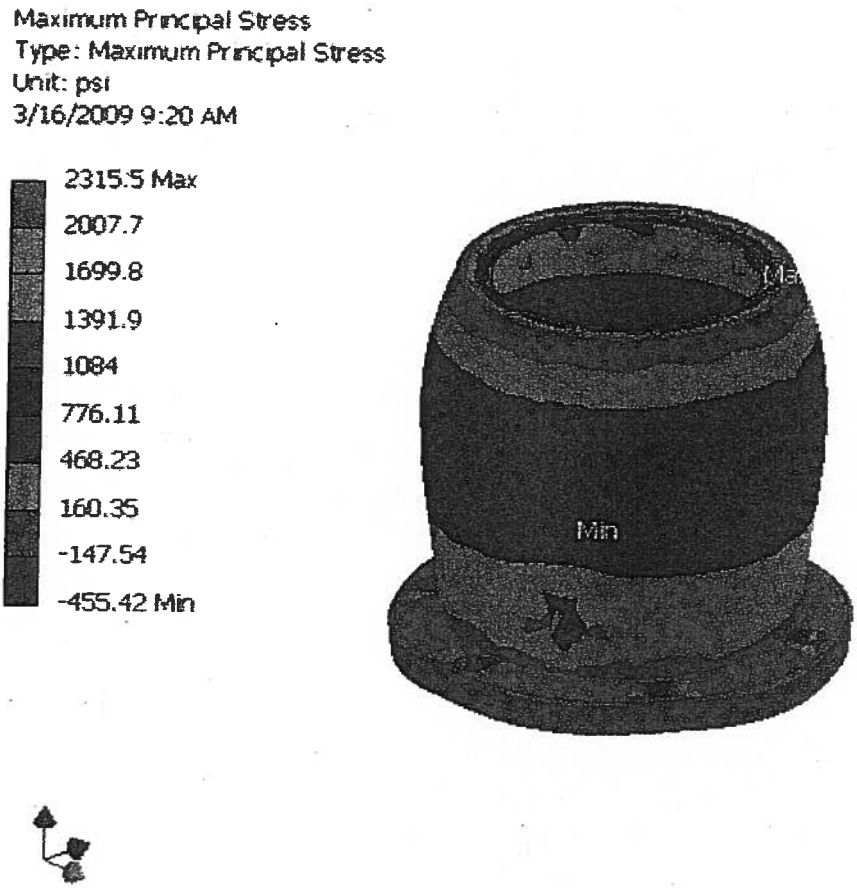


FIGURE 3
Minimum Principal Stress

FIGURE 4
Deformation

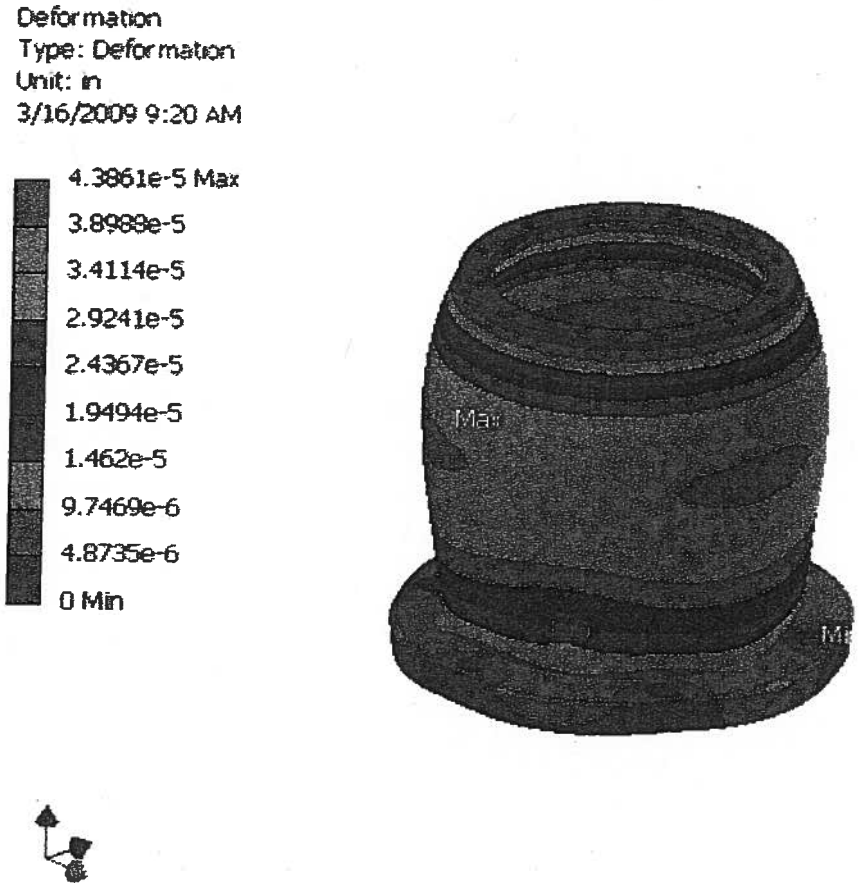
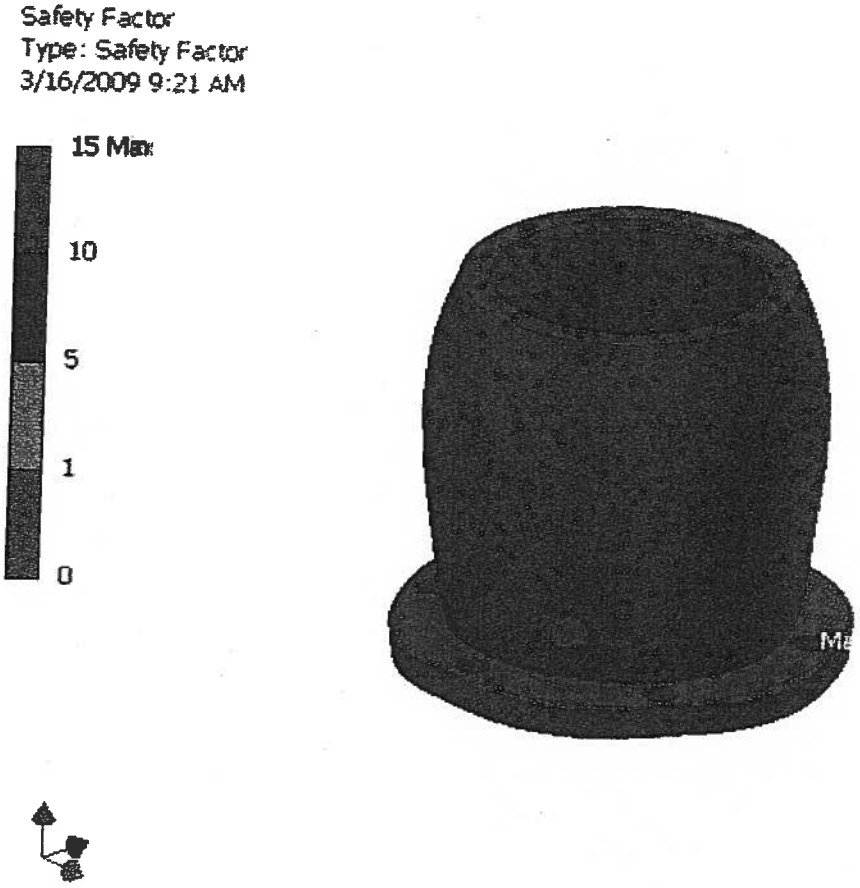


FIGURE 5
Safety Factor



Analysis of Cylinder2

Author:	B. DiGiovine
Analysis Created:	Wednesday, October 29, 2008 11:53:22 AM
Analysis Last Modified:	Wednesday, November 19, 2008 4:37:19 PM
Report Created:	Monday, March 16, 2009 9:45:16 AM
Database:	*C:\Documents and Settings\digiovine\My Documents\Inventor\Brad\NPD-10 (Bubble Chamber)\Cylinder2.ipa*
Software:	Autodesk Inventor Professional 2009 ANSYS Technology

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Autodesk Inventor Professional Stress Analysis was used to simulate the behavior of a mechanical part under structural loading conditions. ANSYS technology generated the results presented in this report.

Do not accept or reject a design based solely on the data presented in this report. Evaluate designs by considering this information in conjunction with experimental test data and the practical experience of design engineers and analysts. A quality approach to engineering design usually mandates physical testing as the final means of validating structural integrity to a measured precision.

Additional information on AIP Stress Analysis and ANSYS products for Autodesk Inventor is available at http://www.ansys.com/autodesk.

Geometry and Mesh

The Relevance setting listed below controlled the fineness of the mesh used in this analysis. For reference, a setting of -100 produces a coarse mesh, fast solutions and results that may include significant uncertainty. A setting of +100 generates a fine mesh, longer solution times and the least uncertainty in results. Zero is the default Relevance setting.

TABLE 1
Cylinder2 Statistics

Bounding Box Dimensions	1.496 in 3.986 in 1.496 in
Part Mass	0.192 lbm
Part Volume	2.381 in^3
Mesh Relevance Setting	0
Nodes	2614
Elements	1273

Bounding box dimensions represent lengths in the global X, Y and Z directions.

Material Data

The following material behavior assumptions apply to this analysis:

- Linear - stress is directly proportional to strain.
- Constant - all properties temperature-independent.
- Homogeneous - properties do not change throughout the volume of the part.
- Isotropic - material properties are identical in all directions.

TABLE 2
Glass

Young's Modulus	9.282e+006 psi
Poisson's Ratio	0.2
Mass Density	8.063e-002 lbm/in³
Tensile Yield Strength	1.45e+004 psi
Tensile Ultimate Strength	7252 psi

Loads and Constraints

The following loads and constraints act on specific regions of the part. Regions were defined by selecting surfaces, cylinders, edges or vertices.

TABLE 3
Load and Constraint Definitions

Name	Type	Magnitude	Vector
Pressure 1	Surface Pressure	164.9 psi	N/A
Fixed Constraint 1	Surface Fixed Constraint	0.0 in	0.0 in 0.0 in 0.0 in

TABLE 4
Constraint Reactions

Name	Force	Vector	Moment	Moment Vector
Fixed Constraint 1	42.05 lbf	-3.474e-014 lbf 42.05 lbf -2.82e-012 lbf	7.493e-009 lbf·in	6.209e-009 lbf·in 4.184e-009 lbf·in 3.056e-010 lbf·in

Note: vector data corresponds to global X, Y and Z components.

Results

The table below lists all structural results generated by the analysis. The following section provides figures showing each result contoured over the surface of the part.

Safety factor was calculated by using the maximum equivalent stress failure theory for ductile materials. The stress limit was specified by the tensile yield strength of the material.

TABLE 5

Structural Results

Name	Minimum	Maximum
Equivalent Stress	82.88 psi	826.6 psi
Maximum Principal Stress	-11.3 psi	751.0 psi
Minimum Principal Stress	-206.7 psi	44.63 psi
Deformation	0.0 in	6.801e-005 in
Safety Factor	15.0	N/A

Figures

FIGURE 1
Equivalent Stress

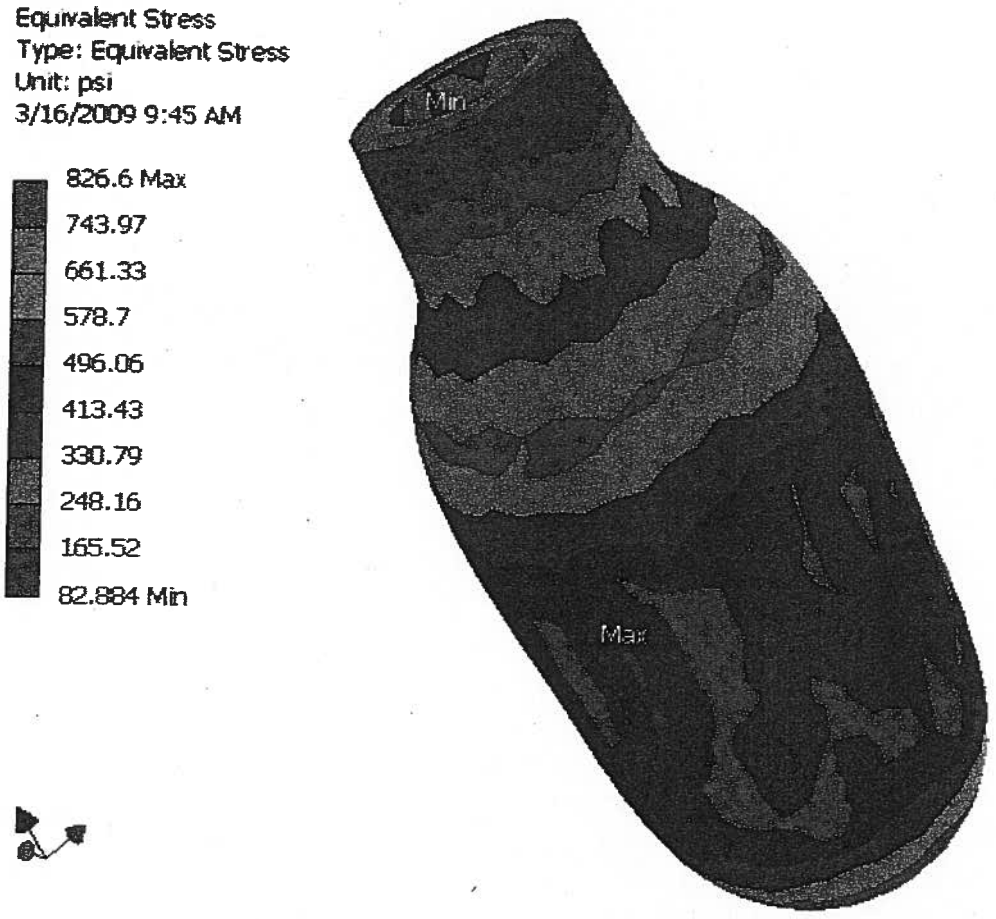


FIGURE 2
Maximum Principal Stress

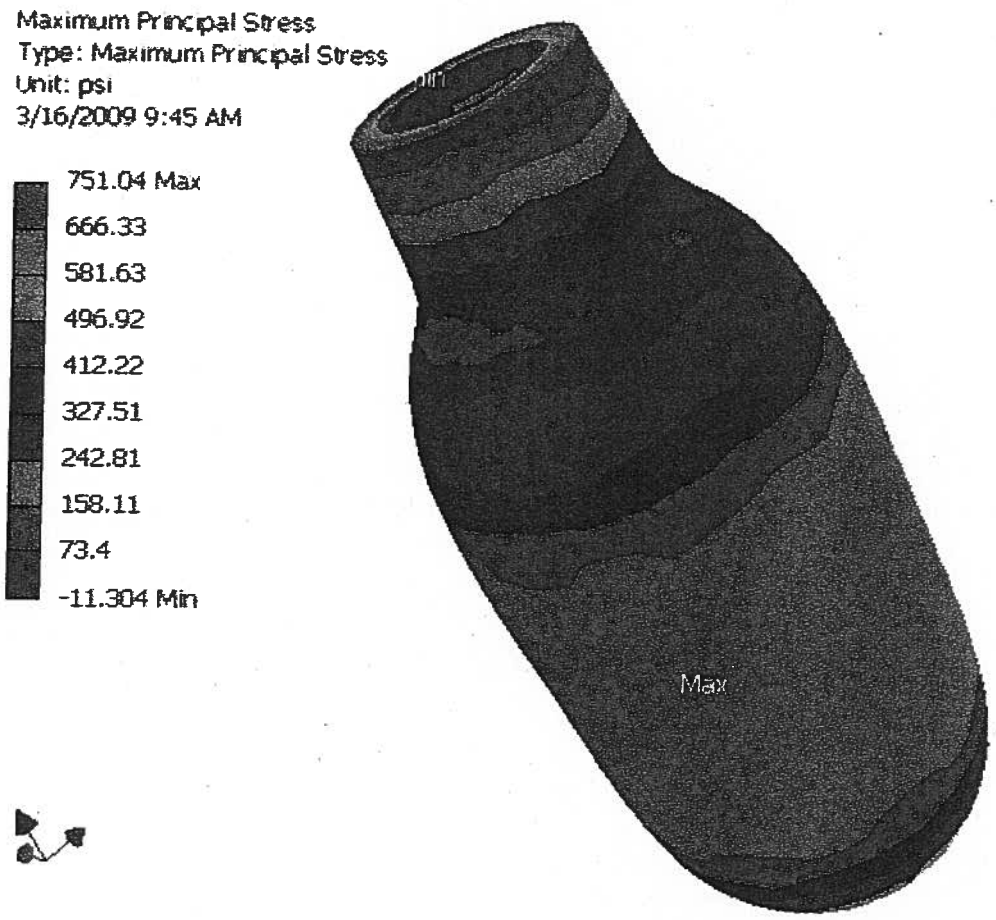


FIGURE 3
Minimum Principal Stress

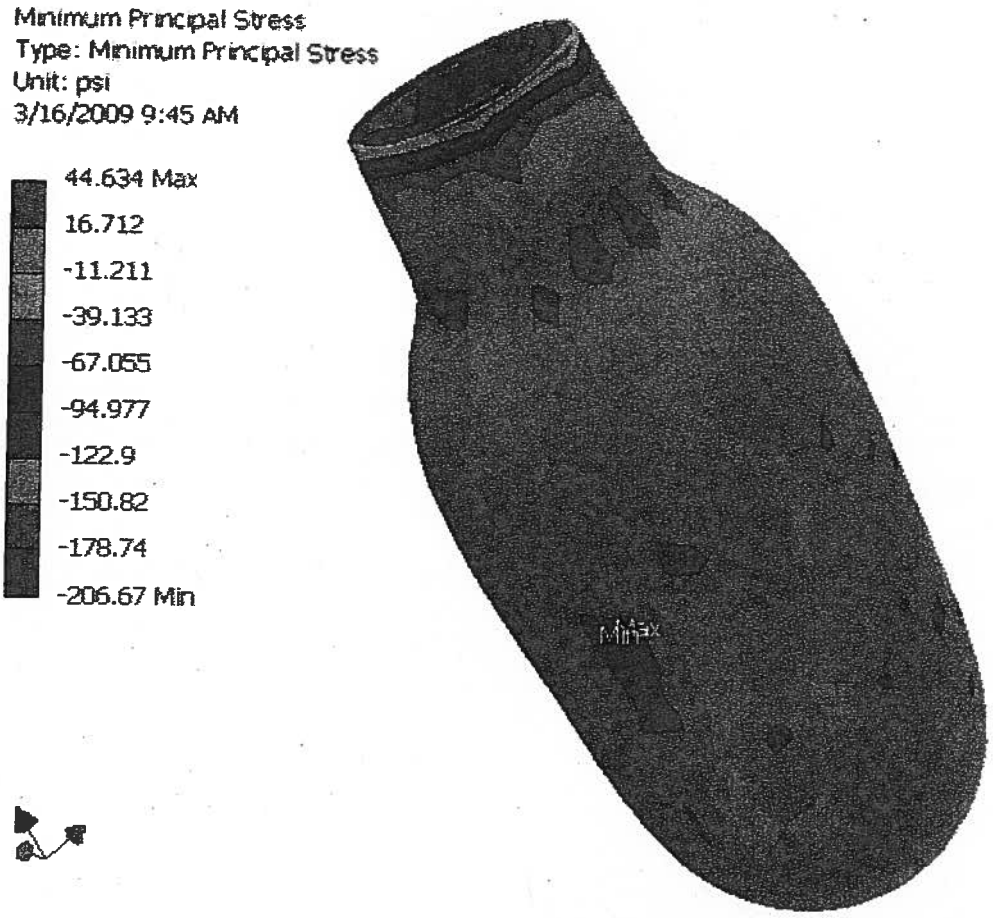


FIGURE 4
Deformation

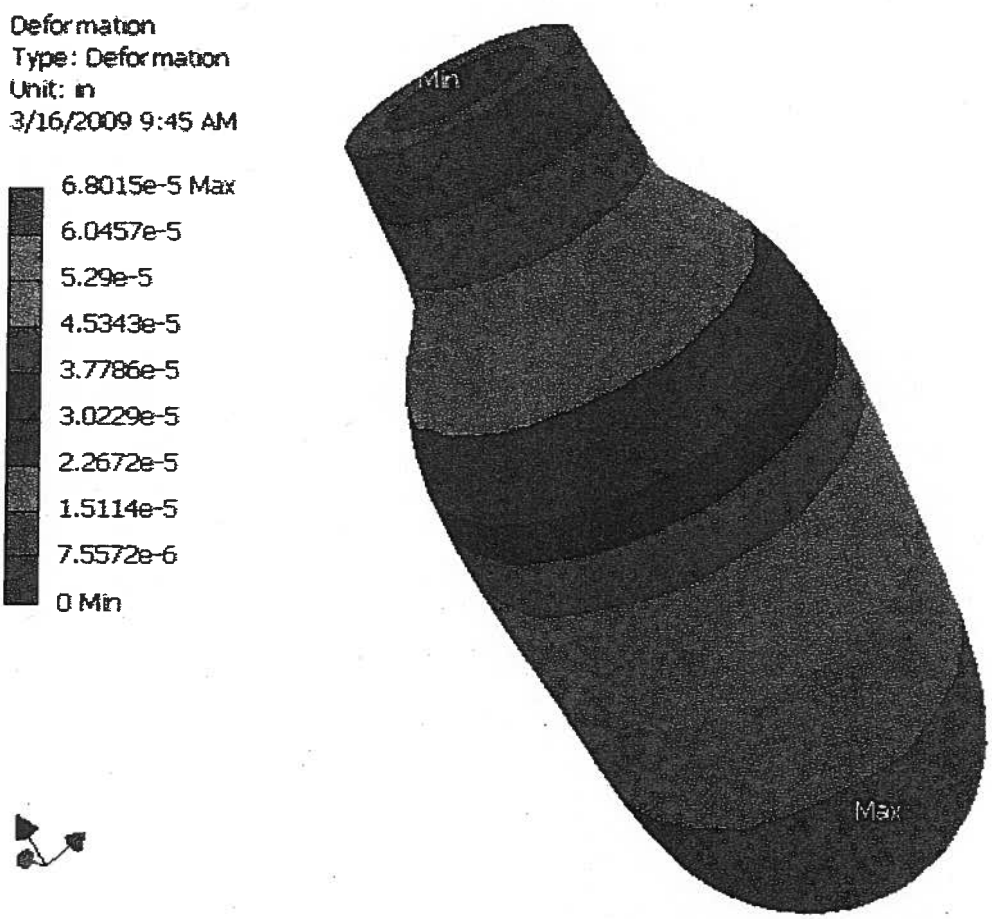
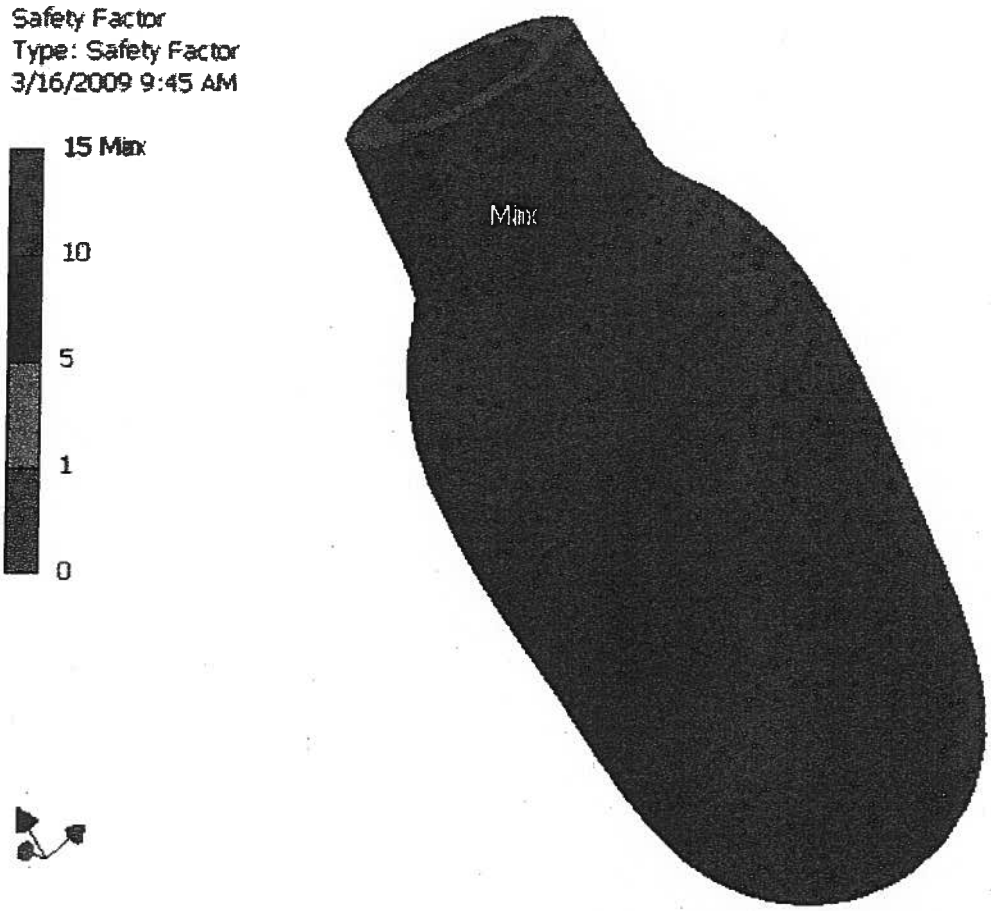


FIGURE 5
Safety Factor



Brad DiGiovine

From: Ristic, Dejan [dristic@anl.gov]
Sent: Wednesday, February 11, 2009 1:00 PM
To: DiGiovine, Brad J.
Cc: Mullen, Thomas
Subject: RE: Help needed

Brad,
Contrary to previous piece if info, ACE Glass QA Manager advised that elevated temperature will not affect mechanical properties (he didn't indicate to what point, but from previous communication it seems that 150 C is within the range). Thanks,
Dejan

From: Brad DiGiovine [mailto:digiovine@phy.anl.gov]
Sent: Tuesday, February 03, 2009 3:42 PM
To: Ristic, Dejan
Cc: Mullen, Thomas
Subject: RE: Help needed

Hi Dejan,

Thats great, I will put this in my file for future reference. This gives us a max allowable interior working pressure of 210.5 psig, which is well above our operating pressure. Now, is this valid for elevated temperatures? I see the 2000 value is for borosilicate glass, which is what we are using. Does this value change when we raise the temperature of our glass to 150C?

Thanks again!

Brad

From: Ristic, Dejan [mailto:dristic@anl.gov]
Sent: Tuesday, February 03, 2009 3:29 PM
To: DiGiovine, Brad J.
Cc: Tom Mullen
Subject: RE: Help needed

Brad,
I followed up with a vendor (ACE Glass) about the conservative formula for calculating max allowable working pressure:

max interior allowable working pressure [psig] = (minimum wall thickness in mm **/ actual vessel's OD** in mm**)*(2000)**
based on cylindrical tubing 300 mm max length

It seems that your part is shorter than 300 mm. It is important for ends to be rounded which seems to be the case according to a drawing I got from you. It reads "minimum" wall thickness in formula in case that wall thickness is not equal due to imperfection in manufacturing.

This 2,000 value (stress) is valid for borosilicate glass Type I Class A, which has coeff. of linear thermal expansion (in 0-300C range): 32 to 33E-07 cm/cm per C (per ASTM E438 from 1992).

I hope this helps,
Dejan

From: Brad DiGiovine [mailto:digiovine@phy.anl.gov]
Sent: Tuesday, January 20, 2009 3:43 PM
To: Ristic, Dejan; Mullen, Thomas
Subject: RE: Help needed

Hi Dejan,

I have run an analytical approach (FEA) on our glass vessel, but I am aprehensive as to the results. First the dimensions of the vessel are very hard to get, the manufacturer will not supply drawings. I made a solid model of it in autodesk inventor using outer measurements and measuring the displacement of the glass walls. Second, and perhaps the most influential aspect that makes me apprehensive, are the large variations in tensile strength that I have found among the literature I have researched. The values for borosilicate glass that I have found so far vary by as much as a factor of 10. Some of my calculations show the vessel failing at 600 psi, some over 2000 psi. We now know that the lower values are wrong, but it just reinforces my aprehension. What I would really like to know is, for my operating conditions of 150psi at 150C, what pressure/temperature test values need to be met in order for this glass vessel to be approved for use under our normal operating conditions?

Thank you,
Brad

From: Ristic, Dejan [mailto:dristic@anl.gov]
Sent: Tuesday, January 20, 2009 2:20 PM
To: DiGiovine, Brad J.
Cc: Mullen, Thomas
Subject: RE: Help needed

Brad,
Have you run an analytical approach (calculation) prior to experimental - testing (or have some paperwork from the manufacturer/fabricator) to show that the glass component should continuously withstand simultaneous p and T at safety factor 10 (used for brittle material like glass)? Normally, if calc shows that it's OK, pneumatic testing is done. When both analytical and experimental are "pass", that component of the system is good to go. The other components need to withstand p&T as well. Thanks,
Dejan

From: Brad DiGiovine [mailto:digiovine@phy.anl.gov]
Sent: Tuesday, January 20, 2009 2:08 PM
To: Ristic, Dejan
Cc: Mullen, Thomas
Subject: RE: Help needed

Hi Dejan,

Thanks for the quick reply. So what I gather is that if I conduct a hydrostatic test at 248psi and at our operating temperature of 150C and it passes, our vessel will be deemed safe enough to use for our purposes?

Thanks for your help,

Brad

From: Ristic, Dejan [mailto:dristic@anl.gov]
Sent: Tuesday, January 20, 2009 1:34 PM
To: DiGiovine, Brad J.
Cc: Mullen, Thomas
Subject: RE: Help needed

Hi Brad,

Most importantly, special precautions measures need to be implemented when performing a pneumatic test due to mush higher level of stored energy compared to hydrostatic testing (depending on several factors can be thousands of times larger), and especially when (trying to) test to failure. Maybe you already did some/all of them, but just in case I'm attaching a document ("PneumTesting") that explains it in more details (it's an excerpt from a Manual I'm working on).

Test pressure should be 1.1 times maximum allowable working pressure (MAWP). If MAWP is not known, then design pressure = MAWP at the same temperature. If max operating pressure (MOP) is 150 psi, MAWP 50% higher = 225 psi, and test pressure (225 psi)(1.1) = 248 psi, it looks like that glas part is good to go if it withstood 1200 psi (which is very risky to try without putting a glass part in the chamber prior to pressurizing or using physical barrier/safe distance precaustions (see attachment).

Another thing that should be considered is leak test. There are several types of leak testing, depending primarily on how small leak needs to be detected.

I will take a look at ASTM refernce book for glass to try to find some applicable standards.

Thanks,
Dejan

From: Brad DiGiovine [mailto:digiovine@phy.anl.gov]
Sent: Tuesday, January 20, 2009 11:48 AM
To: Ristic, Dejan; Mullen, Thomas
Subject: RE: Help needed

Hi Dejan,

It has been a while since we have met, and there has been some progress made. The reason I am contacting you is that we have completed some preliminary hydrostatic testing on our glass pressure vessel. We had initially planned to test to failure. Upon reaching 1200 psi our o-ring began extruding and leaking, but the glass never failed. This test was at ambient temperature. We are now planning a second test. What I need to know is for our operating pressure, what pressure do we need to test to to prove that our vessel is indeed safe enough for use? Also, since our seal began leaking, preventing our pressure from rising further, it would seem that our vessel as it is, is not capable of being pressurized to failure. Any help/input would be greatly appreciated.

Thank you,
Brad DiGiovine

From: Ristic, Dejan [mailto:dristic@anl.gov]
Sent: Tuesday, October 28, 2008 3:35 PM
To: DiGiovine, Brad J.; Mullen, Thomas
Subject: RE: Help needed

Tom and Brad,

To recoup yesterday's first preliminary *H2O Bubble Chamber Detector* design meeting (that I attended):

- regarding pressure relief valve, it shall prevent the pressure from rising more than 10% or 3 psi, whichever is greater (in your case 10% of 150 psi = 15 psi is greater than 3 psi) above the MAWP (max. allowable working pressure) - ASME Code, UG-125.
- glass part CG-1880 from Chemglass is rated for 60 psi - it would burst before reaching desired MOP (max operating pressure) = 150 psi. MAWP is usually 10-20% higher than MOP. However, in this case due to a specific design and possibility of hazardous consequence of bursting glass pressure vessel, I recommend higher-rated glass part (higher than usual 10-20%), i.e. 50% higher MAWP than MOP: 150 psi x 150% = 225 psi. The idea is to minimize the possibility of glass part bursting. The use of impact-resistive and vacuum-rated (assuming that calc shows that flashing all the fluid will still keep the interior of 6-way manifold under atmospheric pressure in case of bursting glass) glass for 6"-diameter viewports is recommended in addition to spiking MAWP/MOP ratio up. In that case pressure relief device could be rated at: 225 psi x 1.05 = 235 to 240 psi.
- I understand that finding glass part for this application can be a problem; try contacting James King, Midwest area sales manager from *ACE Glass* @ acejfk@aol.com, 1.800.445.1219 Ext 13212, www.aceglass.com I met him at lab equipment show at Bld 205 last summer.
- ASME Code Case 2564 (*Impulsively Loaded Pressure Vessels*) addresses impulsive internal loadings that may originate from a detonation source and would fall under Sec. VIII, Div. 3. However, quoted section provides rules for boilers, pressure vessels, and nuclear components, and glass component would fall under pressure accessory, so I wouldn't go this route for designing glass part.

Thanks,
Dejan

From: Brad DiGiovine [mailto:digiovine@phy.anl.gov]
Sent: Thursday, October 16, 2008 1:44 PM
To: Mullen, Thomas; Ristic, Dejan
Cc: Ernst Rehm; Ugalde, Claudio
Subject: RE: Help needed

Tom, Dejan,

This zip file contains what I have so far on our design. The hazard evaluation contains a description of the operation of this detector, it may be helpful to read through it first. The components in the FEA folder are those that are to be fabricated by us (Central shops?), the reports contained there are evaluations at 165PSI, 10% over our intended operating pressure. There is a drawing with labeled parts corresponding to literature contained within the parts folder. Parts of our detector will operate at 150 C and 0 - 150 psig. A pneumatic system will consist of a pressure source (air compressor or air bottle) a regulator to give us 150psig of air, a 5 gallon air tank for our working reservoir, and a 3 way pneumatic valve for pressurizing and depressurizing the top side of our cylinder. The fluids in our hydraulic section consist of water and Dynalene SF (data sheet in .zip). I have not done calculations on relief valves for several reasons. On our pneumatic section we have not decided on a pressure source yet (either compressor or high pressure bottle). Concerning the vacuum and hydraulic sections, I am not sure how to handle those since there is a possibility of two phases in our hydraulic system, and I am unfamiliar with vacuum system reliefs. Pressure and temperature sensors still need to be selected from my list of possibilities, their compatibility with labview must be evaluated. Please do not hesitate to ask me questions, and If you could describe how to calculate reliefs needed, it would be greatly appreciated, and I will gladly do the work.

Thank you very much,

Brad DiGiovine

From: Mullen, Thomas [mailto:tpmullen@anl.gov]
Sent: Tuesday, October 14, 2008 4:28 PM
To: DiGiovine, Brad J.

Subject: FW: Help needed

Brad,

Are you able to do this? Or do we need to talk to him first?

Tom

From: Ristic, Dejan
Sent: Tuesday, October 14, 2008 3:40 PM
To: Mullen, Thomas
Cc: DiGiovine, Brad J.; Jonas, Gregory P.
Subject: RE: Help needed

Hi Tom,

I think we already talked ~ 2 weeks ago about a pressure vessel that one of your engineers is designing? Anyway, please send me all available documentation (write-ups, drawings) related to the vessel. I am particularly interested in type and grade of material, thickness calculation, max operating working pressure and temperature, working fluid, size of relief valve calculation, who is planned to fabricate it - a list of ASME "U" stamp holders in IL can be found at:

http://cstools.asme.org/holdersearch/index.cfm
After I review all the pertaining documentation, we can schedule an appointment for a walk down, perform a review & fill out the review list, etc.

Thanks,
Dejan

From: Mullen, Thomas
Sent: Tuesday, October 14, 2008 3:28 PM
To: Ristic, Dejan
Cc: DiGiovine, Brad J.
Subject: Help needed

Dan,

I left you a voice mail this afternoon, but am writing this just in case you don't get that.

I am with the physics division. An engineer in the division is working on a project, and we need your pressure vessel help - basically figuring out what we need to do.

If you could call me (at 2-2879) or reply to this note and let me know when you might have some time, I would like to set up a meeting.

Thanks,

Tom Mullen

1/15/09 Hydrostatic testing of chemglass 48mL cylindrical glass pressure vessel and teflon fitting.

0399100-109-304

13:15 → . Hydrostatic test
- leak @ 1200 psi
- appears o-ring was extruding

5.831 .969"
.46

Witnesses -

Brad DiGiovine 1-15-09 2.5 2.326in
1.5

[redacted]

Kristi [redacted] 1-15-09 3 2.12 in
.3

Bellofram Rolling Piston

1/16/09 → Energy calculations —

→ Safety engineer → windows

→ air valve

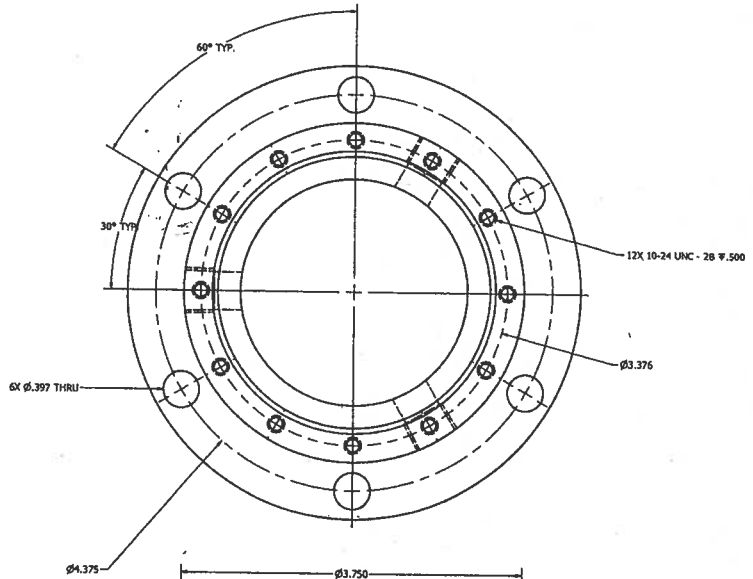
→ Hydraulic system volume

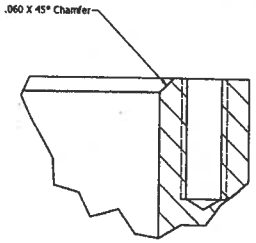
Bruce Zakarski SF_6

Pop-off valve ~750 psi -
hydraulic =
exhaust - hood

O_2 deficiency alarm - Don Phillips

hood → volume of gas
60% or greater → disposal





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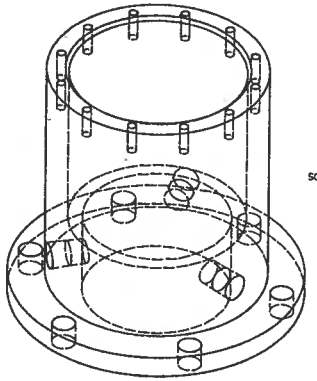

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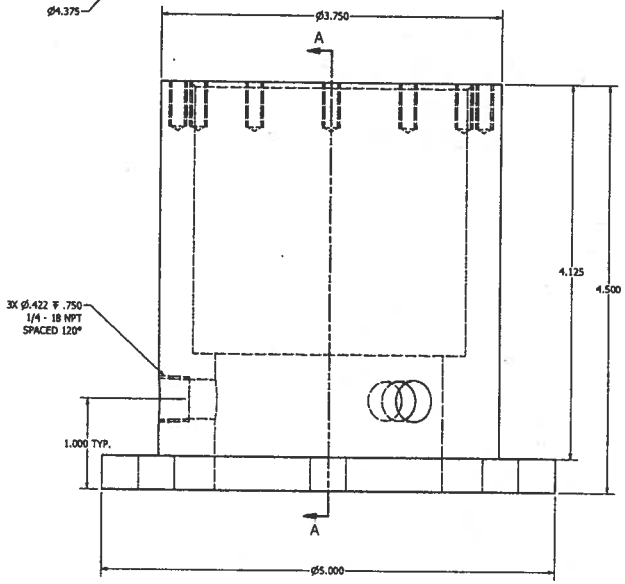

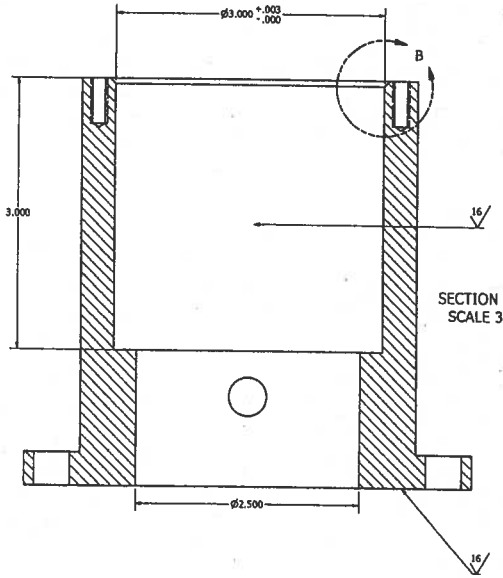

SECTION A-A
SCALE 3:2

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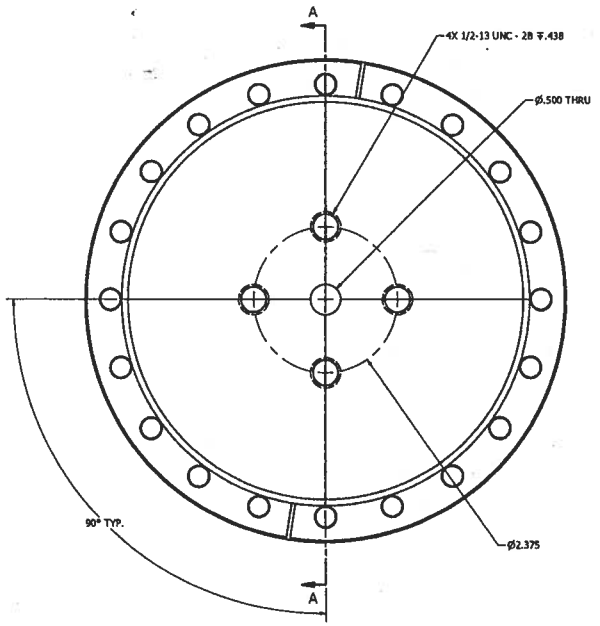
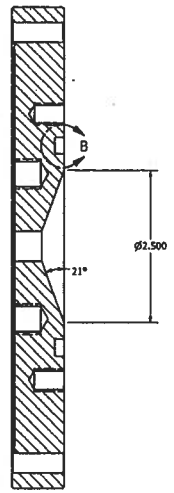
Material 304 Stainless Steel

DRAWN B. DiGiovine	11/18/2008	Argonne National Laboratory
CHECKED		TITLE: PRESSURE TRANSFER CYLINDER
QA		
MFG		
APPROVED		
SIZE D	DWG NO NPD-10-003	REV
SCALE 3:2	SHEET 1 OF 1	





SECTION A-A
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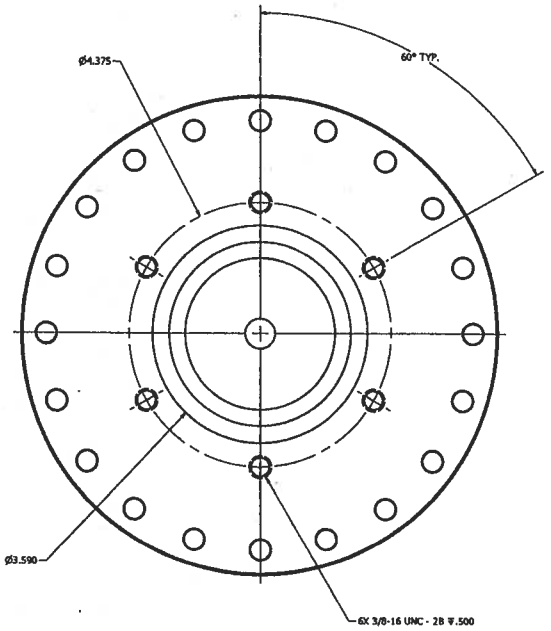
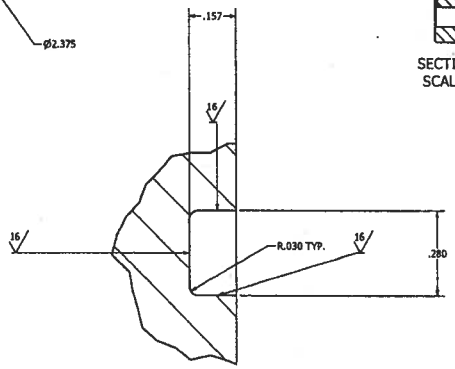
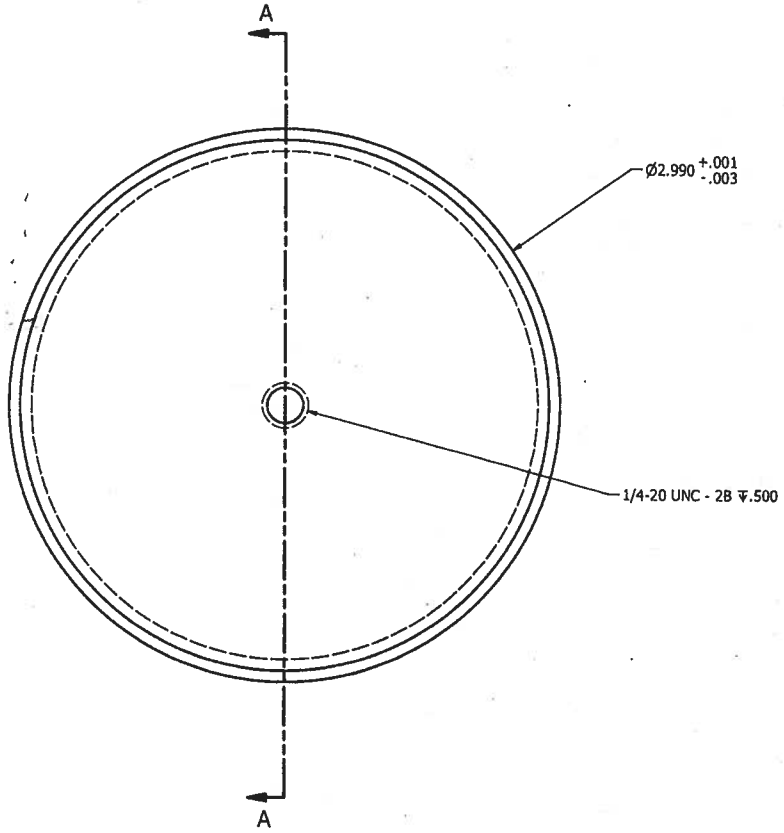
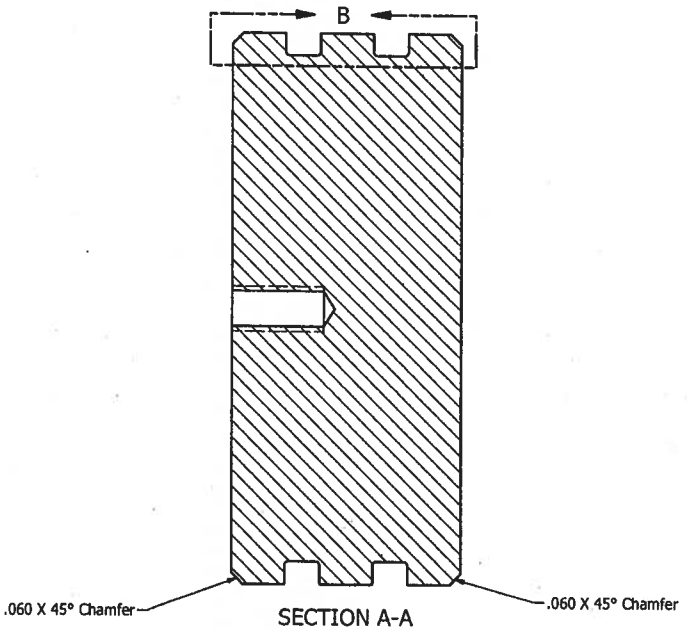




DETAIL B
SCALE 5 : 1

Unless Otherwise Noted All Dimensions - Inches Surface Roughness - 63 Decimal Tolerance .X +/- .1 .XX +/- .01 .XXX +/- .003 Angular Tol. +/- 1/4 deg. Remove all burns and break sharp edges .03 max Material Supplied Blank 8" S.S. C.F. Flange	DRAWN B. DiGiovine CHECKED QA MFG APPROVED	11/14/2008	Argonne National Laboratory TITLE BUBBLE CHAMBER TOP FLANGE SIZE D DWG NO NPD-10-001 REV SCALE 1:1 SHEET 1 OF 1





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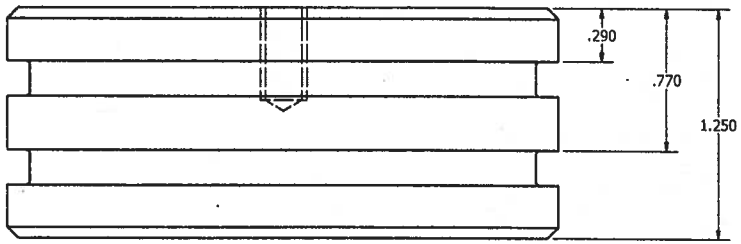

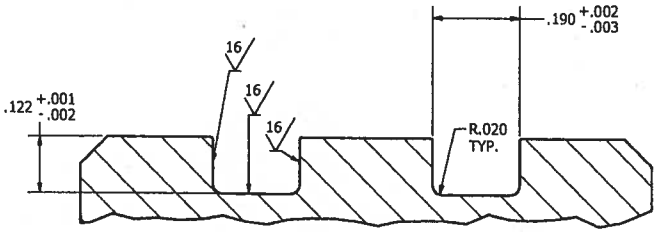

BOTH O-RING GLANDS ARE IDENTICAL
BREAK CORNERS APPROX. .005" RAD.

DETAIL B
SCALE 5 : 1

Unless Otherwise Noted	DRAWN	11/18/2008	Argonne National Laboratory
All Dimensions - Inches Surface Roughness - 63 Decimal Tolerance .X +/- .1 .XX +/- .01 .xxx +/- .003 Angular Tol. +/- 1/4 deg. Remove all burrs and break sharp edges .03 max	B. DiGiovine		
	CHECKED		TITLE: PRESSURE TRANSFER PISTON
	QA		
	MFG		
	APPROVED		
Material Aluminum 6061 T-6			SIZE: C · DWG NO: NPD-10-002 · REV
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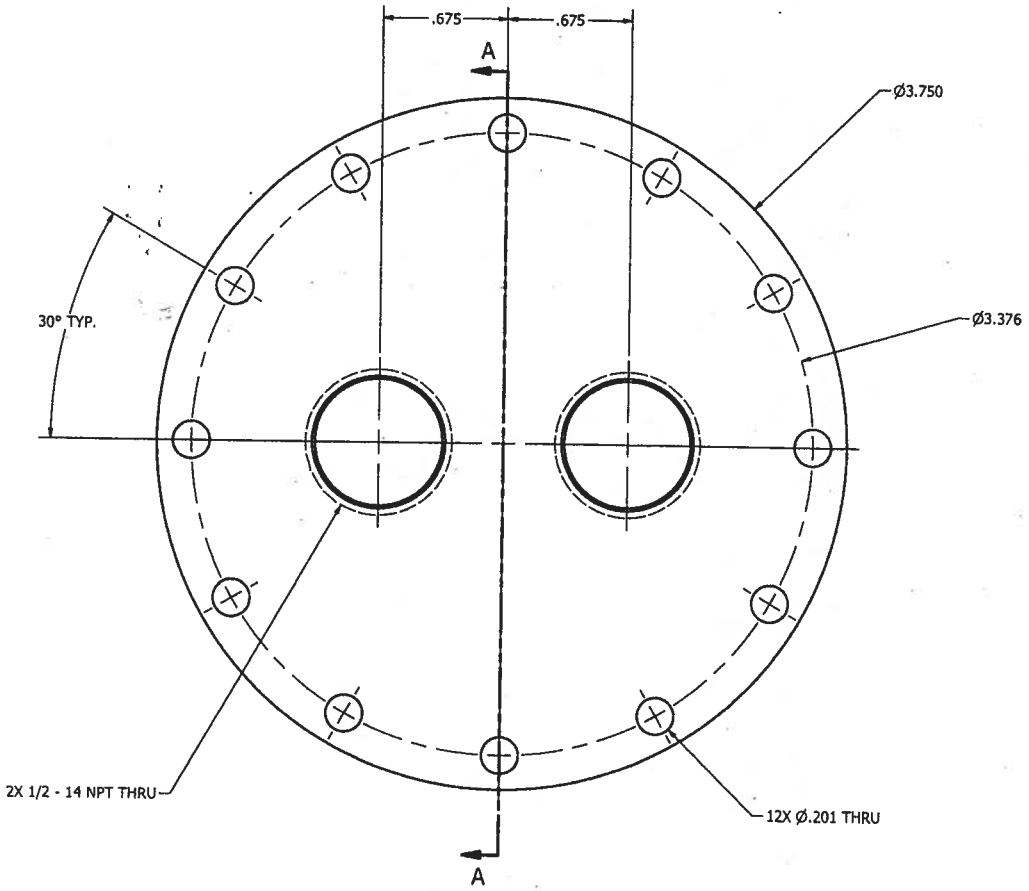
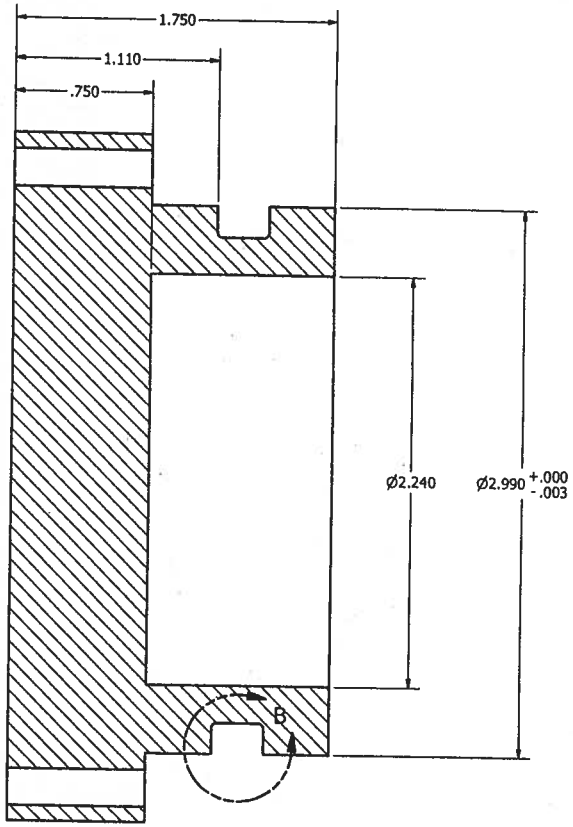
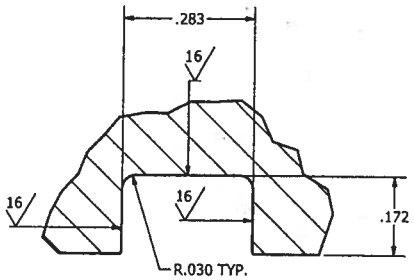




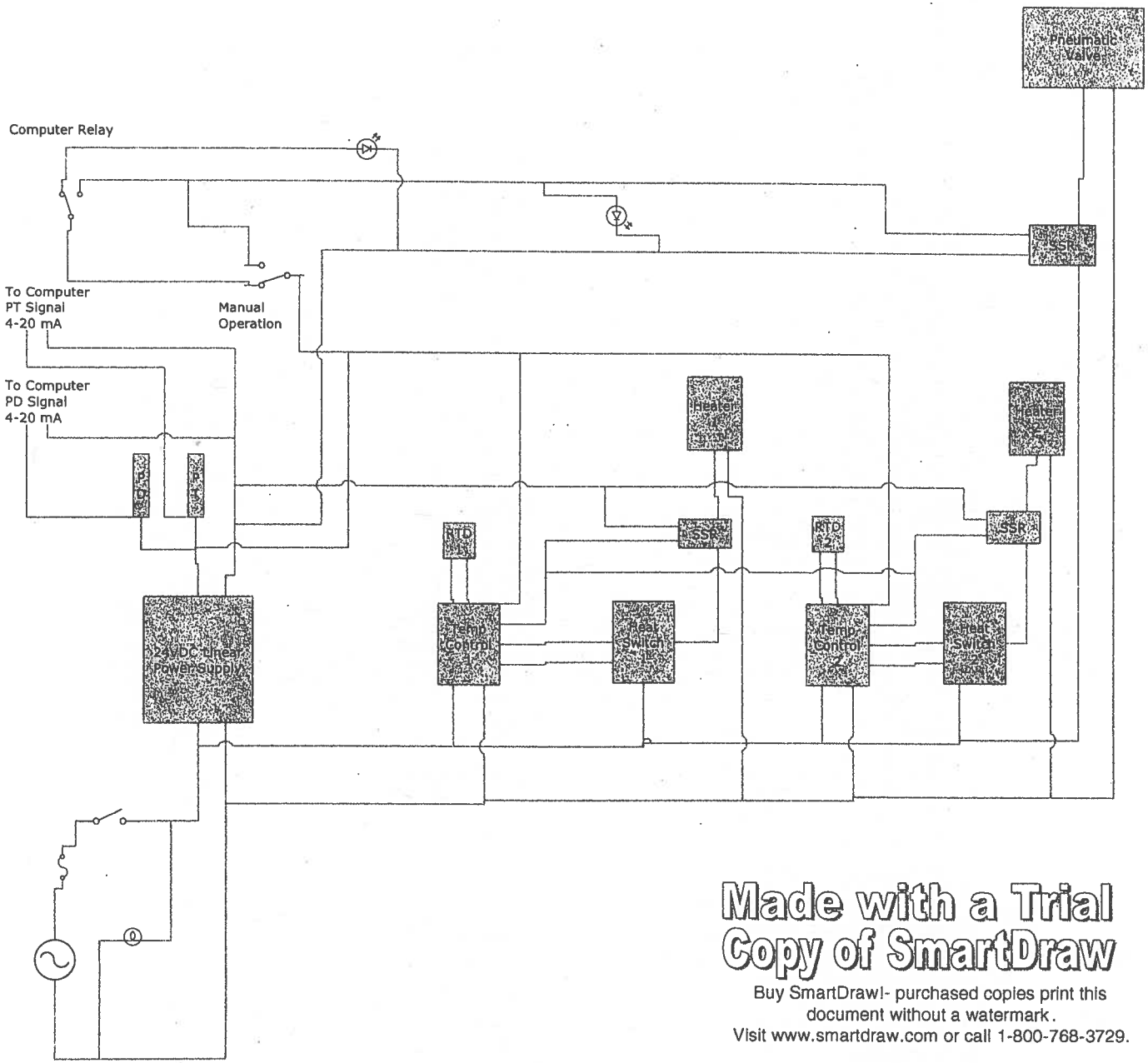
SECTION A-A
SCALE 2 : 1



DETAIL B
SCALE 5 : 1

BREAK CORNERS APPROX. .005" RAD.

Unless Otherwise Noted All Dimensions - Inches Surface Roughness - 63 Decimal Tolerance .X +/- .1 .XX +/- .01 .xxx +/- .003 Angular Tol. +/- 1/4 deg. Remove all burrs and break sharp edges .03 max	DRAWN B. DiGiovine	11/18/2008	Argonne National Laboratory
	CHECKED		TITLE: PRESSURE TRANSFER CYLINDER HEAD
	QA		
	MFG		
	APPROVED		
Material Aluminum 6061 T-6			SIZE C · DWG NO NPD-10-004 · REV
			SCALE 2:1 · SHEET 1 OF 1



Dynalene SF

High Temperature Heat Transfer Fluid Information

Dynalene® SF offers the process industry a versatile, practically nontoxic heat transfer fluid proven to be cost effective and thermally stable at temperatures up to 315°C (600°F).

Dynalene SF, an alyklated aromatic, is known to be particularly stable throughout it's wide temperature range and will not compromise your system's integrity.

Unlike mineral oils, **Dynalene SF** has demonstrated excellent performance over a wide range of temperatures without compromising system reliability or integrity – important factors in choosing a fluid with confidence for long-term use.

Typical Properties of Dynalene SF

Composition: Alyklated Aromatics
Appearance and Color: Clear, Light Brown, oily liquid
Odor: Bland

Property	SI units	US units
Boiling Point:	>330°C	>626°F
Fire Point:	210°C	410°F
Flash Point:	180°C	356°F
Autoignition Temp:	330°C	626°F
Max. Film Temp:	340°C	644°F
Max. Film Outlet Temp:	315°C	600°F

Recommended Temperature Ranges:

Closed System: 0°C (32°F) to 315°C (600°F)
Open System: 20°C (68°F) to 150°C (300°F)

Prime Applications

- Pharmaceuticals
- Plastics
- Metals
- Flooring/ Roofing
- Energy
- Chemical Manufacturing
- General Process
- Asphalt
- Food
- Rubber
- Textiles
- Paper & Pulp

Benefits of using Dynalene SF

- Safe to use
- Excellent performance
- Wide temperature range
- Affordable

For more technical, health and safety information or to request a Material Safety Data Sheet (MSDS), contact our Dynalene sales representative at:
Phone:610-262-9686 Fax:610-262-7437 E-mail: info@dynalene.com

Temperature °F	Viscosity cP	Thermal Conductivity Btu/hr•ft•°F	Specific Heat Btu/lb•°F	Density lb/ft³
32	159.991	0.0801	0.453	55.5
40	108.332	0.0799	0.456	55.3
60	48.536	0.0794	0.466	54.8
80	26.612	0.0789	0.476	54.3
100	16.624	0.0785	0.486	53.9
120	11.321	0.0780	0.495	53.4
140	8.189	0.0775	0.505	52.9
160	6.192	0.0770	0.515	52.5
180	4.843	0.0765	0.524	52.0
200	3.890	0.0760	0.534	51.6
220	3.192	0.0755	0.544	51.1
240	2.667	0.0750	0.553	50.6
260	2.260	0.0745	0.563	50.2
280	1.940	0.0740	0.573	49.7
300	1.684	0.0735	0.583	49.2
320	1.475	0.0730	0.592	48.8
340	1.302	0.0724	0.602	48.3
360	1.158	0.0719	0.612	47.8
380	1.037	0.0714	0.621	47.4
400	0.934	0.0708	0.631	46.9
420	0.845	0.0703	0.641	46.4
440	0.769	0.0697	0.650	46.0
460	0.702	0.0692	0.660	45.5
480	0.644	0.0686	0.670	45.0
500	0.592	0.0681	0.680	44.6
520	0.547	0.0675	0.689	44.1
540	0.507	0.0669	0.699	43.6
560	0.471	0.0664	0.709	43.2
580	0.438	0.0658	0.718	42.7
600	0.409	0.0652	0.728	42.2

Temperature °C	Viscosity mPa•s	Thermal Conductivity W/m•K	Specific Heat kJ/kg•K	Density kg/m³
0	159.991	0.1361	1.894	890
10	70.339	0.1354	1.930	884
20	37.424	0.1347	1.967	877
30	22.851	0.1340	2.003	870
40	15.305	0.1332	2.040	863
50	10.934	0.1325	2.076	857
60	8.189	0.1318	2.113	850
70	6.357	0.1310	2.150	843
80	5.076	0.1303	2.186	836
90	4.144	0.1295	2.223	830
100	3.447	0.1287	2.259	823
110	2.912	0.1280	2.296	816
120	2.492	0.1272	2.332	810
130	2.157	0.1264	2.369	803
140	1.884	0.1256	2.405	796
150	1.661	0.1248	2.442	789
160	1.475	0.1240	2.478	783
170	1.318	0.1232	2.515	776
180	1.185	0.1224	2.552	769
190	1.071	0.1216	2.588	763
200	0.973	0.1208	2.625	756
210	0.888	0.1200	2.661	749
220	0.813	0.1191	2.698	742
230	0.748	0.1183	2.734	736
240	0.690	0.1174	2.771	729
250	0.638	0.1166	2.807	722
260	0.592	0.1157	2.844	715
270	0.551	0.1149	2.880	709
280	0.514	0.1140	2.917	702
290	0.481	0.1131	2.954	695
300	0.451	0.1123	2.990	689
310	0.423	0.1114	3.027	682
315	0.410	0.1109	3.045	678

Dynalene Inc

MATERIAL SAFETY DATA SHEET

DYNALENE SF

SECTION 1: PRODUCT IDENTIFICATION

TRADE NAME (AS LABELED):	**DYNALENE SF™**
CHEMICAL NAME/CLASS:	Heat Transfer Fluid
SYNONYMS:	Mixture: None applicable.
DISTRIBUTOR'S NAME:	**Dynalene Inc**
ADDRESS:	5250 West Coplay Road Whitehall, PA 18052
EMERGENCY PHONE:	1-800-424-9300 (CHEMTREC)
BUSINESS PHONE:	610-262-9686
DATE OF PREPARATION:	August 29, 2004
REVISION DATE:	January 7, 2008

SECTION 2: COMPOSITION AND INFORMATION ON INGREDIENTS

CHEMICAL NAME	% v/v	EXPOSURE LIMITS IN AIR					
		ACGIH		OSHA			
		TLV	STEL	PEL	STEL	IDLH	OTHER
		mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3
Hydrocarbon Mixture	> 95%	NE	NE	NE	NE	NE	NE
Other components present in less than 1% concentration (or 0.1% for carcinogens, reproductive toxins, or respiratory sensitizers).	Balance	None of the other ingredients has established exposure limits or contributes any significant, additional hazard to this product. All pertinent hazard information has been provided in this Material Data Sheet, per the requirements of the Federal OSHA Hazard Communication Standard (29 CFR 1910.1200), U.S. State equivalent standards, and the requirements of the Canadian Workplace Hazardous Materials Information System.					

NE = Not Established **C** = Ceiling Level (See Section 16 for Definitions of Terms Used.)
NOTE (1): All WHMIS required information is included in appropriate sections based on the ANSI Z400.1-1993 format.
NOTE (2): Information on this product is being claimed as proprietary. All Pertinent hazard information has been provided, per the Trade Secret requirements of U.S. Federal Occupational Safety and Health Administration Standards (29 CFR 1910.1200) and Canadian WHMIS (CPR 12 and 19). Information on this mixture will be released when the conditions specified in these Standards are met.

SECTION 3: HAZARD IDENTIFICATION

EMERGENCY OVERVIEW: This product is a light brown, oily liquid, with a slight, hydrocarbon odor. Mists from this product may be slightly irritating if inhaled. The product may also be slightly irritating to contaminated eyes. The product must be substantially preheated before ignition can occur. This product is not reactive under typical emergency response conditions. Emergency responders must wear proper personal protective equipment for the situation to which they are responding.

SYMPTOMS OF OVER-EXPOSURE BY ROUTE OF EXPOSURE:

The most significant routes of exposure to this product are by inhalation of mists from product and contact with skin and eyes. The symptoms of overexposure are as follows.

INHALATION:

Due to low volatile, this product is not generally an inhalation hazard. In heated form, vapors may be irritating to the upper respiratory tract.

CONTACT WITH SKIN or EYES:

Irritation may occur with exposure to vapors. In the skin no hazard expected in normal use. Repeated or prolonged contact can cause redness, irritation, and scaling of the skin. Normal care and personal hygiene should prevent skin effects.

INGESTION:

No hazard under normal industrial use. Ingestion of large quantities may lead to discomfort, nausea, and vomiting.

INJECTION:

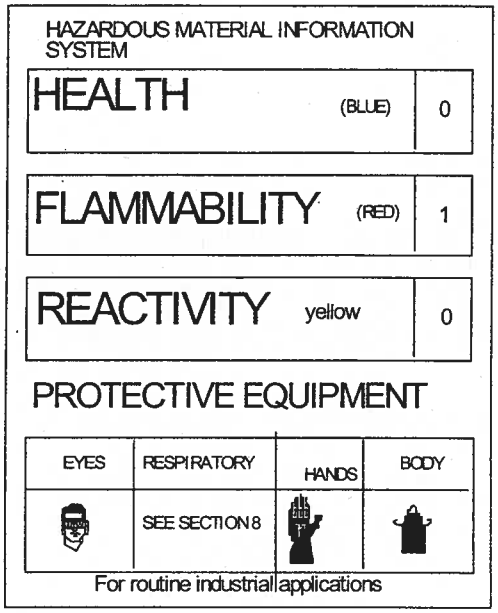
Though not an expected rout of occupational exposure for this product, injection (via punctures or lacerations in the skin) may cause local reddening, tissue swelling and discomfort.

HEALTH HAZARD:

Irritation to eyes and upper respiratory tract may occur with exposure to concentrated vapors. Irritation of eyes or skin may occur when in contact with product. This product is a negligible inhalation hazard due to its low volatility.

FIRE and EXPLOSION:

Material may burn, but does not readily ignite.



SECTION 4: FIRST-AID MEASURES

SKIN EXPOSURE

If the product is spilled the skin, immediately begin decontamination with running water. Contaminated individual must seek immediate medical attention, especially if irritation or redness develops. Wash contaminated clothing and shoes before reuse.

EYE EXPOSURE

If the product enter the eyes, open victim's eyes while under gentle running water. Use sufficient force to open eyelids. Have victim "roll" eyes. Minimum flushing is for 15 minutes. Contaminated individual must seek immediate medical attention, especially if symptoms persist.

INHALATION

If mists of the product are inhaled, removed victim to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call physician immediately.

INGESTION

If the product is swallowed, CALL PHYSICIAN immediately. ONLY induce vomiting at the instruction of a physician. Never give anything by mouth to an unconscious person.

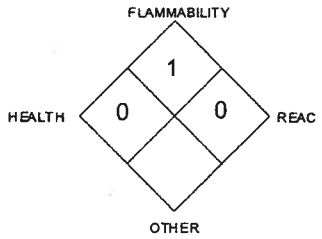
SECTION 5: FIRE-FIGHTING MEASURES

NFPA RATING

FLASH POINT (Pensky-Martens Closed Cup): 180°C (356°F)

AUTOIGNITION TEMPERATURE: 330°C (626°F)

FLAMMABLE LIMITS (in air by volume, %): Lower (LEL): Not available.
Upper (UEL): Not Available.



FIRE EXTINGUISHING MATERIALS:

Water Spray: YES (cooling only) Carbon Dioxide: YES Foam: YES
Dry Chemical: YES Halon: YES Other: Any "B" Class.

FIRE & EXPLOSION: Can burn in fire forming carbon dioxide (CO_2) and some carbon monoxide.

SPECIAL FIRE-FIGHTING PROCEDURES:

Cool exposed equipment with water spray until well after fire is out. Use full protective clothing and self-contained breathing apparatus (SCBA) if fighting fire. Containers can build up pressure if exposed to heat (fire).

SECTION 6: ACCIDENTAL RELEASE MEASURES

SPILL AND LEAK RESPONSE:

In case of a spill, clear the affected area, protect people. Uncontrolled releases should be responded to by trained personnel using pre-planned procedures. Proper protective equipment should be used. Absorb spilled liquid with polypads or other suitable sorbent materials. Decontaminate the area thoroughly. Do not contaminate any lakes, streams, ponds, groundwater, or soil. Dispose of in accordance with Federal, State, and local hazardous waste disposal regulations (see Section 13, Disposal Considerations).

SECTION 7: HANDLING AND STORAGE

WORK PRACTICES AND HYGIENE PRACTICES:

As with all chemicals, avoid getting this product ON YOU or IN YOU. Wash hands after handling this product. Do not eat or drink while handling this material. Use ventilation and other engineering controls to minimize potential exposure to the aerosols and mists of this product.

STORAGE AND HANDLING PRACTICES:

Carbon steels (without coating), carbon steels with baked phenolic or epoxy coating. Store in a cool, dry place; keep container closed when not in use. Open the container with caution. Avoid breathing vapor or mist. Avoid contact with eyes, skin and clothing.

ELECTROSTATIC ACCUMULATION HAZARD:

When transferring this product, there is a potential for the accumulation of static electricity. Consideration should be given to bonding and grounding of equipment during loading, unloading and transfer of this product.

STORAGE/TRANSPORT TEMPERATURE:

Ambient

STORAGE/ TRANSPORT PRESSURE:

Ambient

LOAD/ UNLOAD TEMPERATURE:

Ambient

SECTION 8: EXPOSURE CONTROLS - PERSONAL PROTECTION

VENTILATION AND ENGINEERING CONTROLS:

Mechanical ventilation may be necessary if working with the product in enclosed areas or at elevated temperatures.

RESPIRATORY PROTECTION:

Respiratory protection is normally not required except in emergencies or when conditions cause excessive airborne levels, mist, or vapors. Select the appropriate NIOSH-approved organic vapor air-purifying respirator, self-contained breathing apparatus, or air supplied respirators in situations where there may be potential for overexposure.

EYE PROTECTION:

Safety glasses with side shields or chemical goggles

HAND PROTECTION:

Wear chemical resistant gloves.

BODY PROTECTION:

If potentials for significant exposure to liquid exist, use full protective clothing and chemical boots.

PERSONAL PROTECTIVE EQUIPMENT LEVEL: C

SECTION 9: PHYSICAL AND CHEMICAL PROPERTIES

RELATIVE VAPOR DENSITY (air = 1): > 1.0

SPECIFIC GRAVITY (water = 1): 0.877 g/cm^3 @ 20°C

SOLUBILITY IN WATER: Insoluble.

VAPOR PRESSURE, mm Hg @ 20 °C: 3.6 @ 70°F/21°C

ODOR: Mild hydrocarbon odor

COEFFICIENT WATER/OIL DISTRIBUTION: Not Available.

EVAPORATION RATE (n-BuAc=1): < 1.0

MELTING POINT or RANGE: Aprox. - 81°F (-63°C)

BOILING POINT: >626°F (>330°C)

VISCOSITY: 1872 cSt @ -40°C

PHYSICAL STATE: Liquid

pH: Not applicable.

APPEARANCE AND COLOR: This product is light brown, oily liquid.

SECTION 10: STABILITY AND REACTIVITY

STABILITY:

Stable

DECOMPOSITION PRODUCTS:

None expected.

MATERIALS WITH WHICH SUBSTANCE IS INCOMPATIBLE:

May react with strong oxidizers

HAZARDOUS POLYMERIZATION:

Should not occur

CONDITIONS TO AVOID:

Material is chemically stable. Avoid high temperatures.

SECTION 11: TOXICOLOGICAL INFORMATION

TOXICITY DATA: Additional toxicology information for components greater than 1 percent in concentration is provided below.

Alkylated benzenes:

EYES:	Primary Eye Irritation Index (Rabbits): 3.7 unwashed. (Maximum score is 110)
SKIN:	Acute Dermal LD_{50} (Rabbits): > 2000 mg/kg
	24 – hr primary skin irritation index (Rabbits): 0.8 (max score is 8.0)
INHALATION:	No specific data available.
INGESTION:	Acute Oral LD50 (Rat) > 5000mg/kg (OECD 401)

SECTION 12: ECOLOGICAL INFORMATION

ALL WORK PRACTICES MUST BE AIMED AT ELIMINATING ENVIROMENTAL CONTAMINATION.

ECOTOXICOLOGICAL INFORMATION:

Not available.

EFFECT OF MATERIAL ON PLANTS or ANIMALS:

This product may be harmful to contaminated plant and animal life (especially if large quantities are released). Refer to Section 11 (Toxicological Information) for specified information regarding effects of this product's components on test animals.

EFFECT OF CHEMICAL ON AQUATIC LIFE:

This product may be harmful to aquatic life if large quantities are released into bodies of water.

SECTION 13: DISPOSAL CONSIDERATIONS

PREPARING WASTES FOR DISPOSAL:

Waste disposal must be in accordance with appropriate Federal, State, and local regulations or those of Canada and its Provinces.

WASTE CLASSIFICATION:

Any unused product or empty containers may be disposed of as non-hazardous in accordance with state and federal requirements. Re-evaluation of the product may be required by the user at the time of disposal, since the product uses, transformations, mixture, contamination, and spillage may change the classification to hazardous. If the resulting material is determined to be hazardous, please dispose in accordance with state and federal (40 CFR 264) hazardous waste regulations.

EMPTY CONTAINERS:

Empty containers retain product residue (liquid and/or vapor) and can be dangerous. DO NOT pressurize, cut, weld, braze, solder, drill, grind, or exposed such containers to heat, flame, sparks, static electricity, or others sources of ignition. Empty drums should be completely drained, properly bunged and promptly returned to a drum reconditioner, or properly disposed of.

U.S. EPA WASTE NUMBER:

This product meets the criteria for synthetic used oil under the USEPA Waste Oil Regulation (40 CFR 219). Recycle or burn in accordance with applicable state and local regulations.

SECTION 14: TRANSPORTATION INFORMATION

THIS MATERIAL IS NON- HAZARDOUS , PER 49 CFR 172.101 (THE U.S. DEPARTMENT OF TRANSPORTATION).

PROPER SHIPPING NAME:	Not Applicable.
HAZARD CLASS NUMBER and DESCRIPTION:	Not Applicable.
UN IDENTIFICATION NUMBER:	Not Applicable.
PACKING GROUP:	Not Applicable.
DOT LABEL (S) REQUIRED:	Not Applicable.

NORTH AMERICAN EMERGENCY RESPONSE GUIDEBOOK NUMBER (1996):

Not Applicable.

MARINE POLLUTANT:

No component of this product is classified as a Marine Pollutant, as listed in Appendix B to 49 CFR 172.101.

TRANSPORT CANADA TRANSPORTATION OF DANGEROUS GOODS REGULATIONS:

THIS MATERIAL IS NOT CONSIDERED AS DANGEROUS GOODS.

SECTION 15: REGULATORY INFORMATION

UNITED STATE REGULATIONS:

SARA 302 STATUS:

Contains no chemicals subject to SARA 302 reporting

SARA 311/312:

Non-hazardous

SARA 313 CHEMICALS:

Contains no chemicals subject to SARA 313 reporting

TSCA INVENTORY STATUS:

The components of this product are listed on the TSCA Inventory.

CERCLA REPORTABLE QUANTITY (RQ):

Not Applicable.

OSHA:

Non-hazardous as defined by the OSHA Hazard Communication Standard

CALIFORNIA PROPOSITION 65:

No component of this solution is on the California Proposition 65 (California Safe Drinking Water Act Listing).

ADDITIONAL CANADIAN REGULATIONS:

CANADIAN DSL/NDSL INVENTORY STATUS:

The components of this product are the DSL or NDLS Inventory.

OTHER CANADIAN REGULATIONS:

Not Applicable.

CANADIAN ENVIROMENTAL PROTECTION (CEPA) PRORITIES SUBSTANCES LISTS:

The components of this product are not on the CEPA Priorities Substances Lists.

CANADIAN WHMIS SYMBOLS:

Not Applicable.

SECTION 16: OTHER INFORMATION

PREPARED BY:

DYNALENE INC
5250 West Coplay Road
Whitehall, PA 18052
610-262 - 9686

Date of Printing: January 7, 2008.

Material Safety Data Sheet

1,1,1,2-Tetrafluoroethane (Halocarbon 134a)

Airgas

Section 1. Chemical product and company identification

Product name : 1,1,1,2-Tetrafluoroethane (Halocarbon 134a)

Supplier : AIRGAS INC., on behalf of its subsidiaries
259 North Radnor-Chester Road
Suite 100
Radnor, PA 19087-5283
1-610-687-5253

Product use : Synthetic/Analytical chemistry.Refrigeration.

Synonym : Norflurane; 1,1,1,2-Tetrafluoroethane; Norfluran; R 134a; 1,2,2,2-Tetrafluoroethane; CF3CH2F; HFA-134a

MSDS # : 001055

Date of Preparation/Revision : **9/4/2008.**

In case of emergency : 1-866-734-3438

Section 2. Hazards identification

Physical state : Gas.

Emergency overview : WARNING!
CONTENTS UNDER PRESSURE.
Do not puncture or incinerate container.
Contact with rapidly expanding gases can cause frostbite.

Routes of entry : Inhalation

Potential acute health effects

Eyes : Contact with rapidly expanding gas may cause burns or frostbite.

Skin : Contact with rapidly expanding gas may cause burns or frostbite.

Inhalation : Acts as a simple asphyxiant.

Ingestion : Ingestion is not a normal route of exposure for gases

Potential chronic health effects : **CARCINOGENIC EFFECTS**: Not available.
MUTAGENIC EFFECTS: Not available.
TERATOGENIC EFFECTS: Not available.

Medical conditions aggravated by over-exposure : Acute or chronic respiratory conditions may be aggravated by overexposure to this gas.

See toxicological information (section 11)

Section 3. Composition, Information on Ingredients

Name	CAS number	% Volume	Exposure limits
1,1,1,2-Tetrafluoroethane (Halocarbon 134a)	811-97-2	100	**AIHA WEEL (United States, 1/2007).** TWA: 1000 ppm 8 hour(s).

Section 4. First aid measures

No action shall be taken involving any personal risk or without suitable training.If it is suspected that fumes are still present, the rescuer should wear an appropriate mask or self-contained breathing apparatus.It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation.

Eye contact : Check for and remove any contact lenses. Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical attention immediately.

Skin contact : In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Clean shoes thoroughly before reuse. Get medical attention immediately.

1,1,1,2-Tetrafluoroethane (Halocarbon 134a)

Frostbite : Try to warm up the frozen tissues and seek medical attention.

Inhalation : Move exposed person to fresh air. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention immediately.

Ingestion : As this product is a gas, refer to the inhalation section.

Section 5. Fire fighting measures

Flammability of the product : Non-flammable.

Products of combustion : Decomposition products may include the following materials:
carbon dioxide
carbon monoxide
halogenated compounds

Fire-fighting media and instructions : Use an extinguishing agent suitable for the surrounding fire.

Apply water from a safe distance to cool container and protect surrounding area. If involved in fire, shut off flow immediately if it can be done without risk.

Contains gas under pressure. In a fire or if heated, a pressure increase will occur and the container may burst or explode.

Special protective equipment for fire-fighters : Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode.

Section 6. Accidental release measures

Personal precautions : Immediately contact emergency personnel. Keep unnecessary personnel away. Use suitable protective equipment (section 8). Shut off gas supply if this can be done safely. Isolate area until gas has dispersed.

Environmental precautions : Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers.

Methods for cleaning up : Immediately contact emergency personnel. Stop leak if without risk. Note: see section 1 for emergency contact information and section 13 for waste disposal.

Section 7. Handling and storage

Handling : High pressure gas. Do not puncture or incinerate container. Use equipment rated for cylinder pressure. Close valve after each use and when empty. Protect cylinders from physical damage; do not drag, roll, slide, or drop. Use a suitable hand truck for cylinder movement.

Storage : Cylinders should be stored upright, with valve protection cap in place, and firmly secured to prevent falling or being knocked over. Cylinder temperatures should not exceed 52 °C (125 °F).

Section 8. Exposure controls/personal protection

Engineering controls : Use only with adequate ventilation. Use process enclosures, local exhaust ventilation or other engineering controls to keep worker exposure to airborne contaminants below any recommended or statutory limits.

<u>Personal protection</u>

Eyes : Safety eyewear complying with an approved standard should be used when a risk assessment indicates this is necessary to avoid exposure to liquid splashes, mists or dusts.

Skin : Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.

Respiratory : Use a properly fitted, air-purifying or air-fed respirator complying with an approved standard if a risk assessment indicates this is necessary. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator.

The applicable standards are (US) 29 CFR 1910.134 and (Canada) Z94.4-93

1,1,1,2-Tetrafluoroethane (Halocarbon 134a)

Hands : Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary.

Personal protection in case of a large spill : Self-contained breathing apparatus (SCBA) should be used to avoid inhalation of the product.

Product name

norflurane

AIHA WEEL (United States, 1/2007).
TWA: 1000 ppm 8 hour(s).

Consult local authorities for acceptable exposure limits.

Section 9. Physical and chemical properties

Molecular weight : 102.04 g/mole

Molecular formula : C2-H2-F4

Boiling/condensation point : -26.5°C (-15.7°F)

Melting/freezing point : -92.5°C (-134.5°F)

Critical temperature : 100.9°C (213.6°F)

Vapor pressure : 81.3 (psig)

Vapor density : 3.6 (Air = 1)

Specific Volume (ft^3/lb) : 3.7078

Gas Density (lb/ft^3) : 0.2697

Section 10. Stability and reactivity

Stability and reactivity : The product is stable.

Hazardous decomposition products : Under normal conditions of storage and use, hazardous decomposition products should not be produced.

Hazardous polymerization : Under normal conditions of storage and use, hazardous polymerization will not occur.

Section 11. Toxicological information

Toxicity data

Other toxic effects on humans : No specific information is available in our database regarding the other toxic effects of this material to humans.

Specific effects

Carcinogenic effects : No known significant effects or critical hazards.

Mutagenic effects : No known significant effects or critical hazards.

Reproduction toxicity : No known significant effects or critical hazards.

Section 12. Ecological information

Aquatic ecotoxicity

Not available.

Environmental fate : Not available.

Environmental hazards : No known significant effects or critical hazards.

Toxicity to the environment : Not available.

Section 13. Disposal considerations

Product removed from the cylinder must be disposed of in accordance with appropriate Federal, State, local regulation.Return cylinders with residual product to Airgas, Inc.Do not dispose of locally.

Section 14. Transport information

Regulatory information	UN number	Proper shipping name	Class	Packing group	Label	Additional information
DOT Classification	UN3159	1,1,1,2-TETRAFLUOROETHANE OR REFRIGERANT GAS R 134A	2.2	Not applicable (gas).		**Limited quantity** Yes. **Packaging instruction** **Passenger aircraft** Quantity limitation: 75 kg **Cargo aircraft** Quantity limitation: 150 kg **Special provisions** T50
TDG Classification	UN3159	REFRIGERANT GAS R 134A; OR 1,1,1,2-TETRAFLUOROETHANE	2.2	Not applicable (gas).		**Explosive Limit and Limited Quantity Index** 0.125 **Passenger Carrying Road or Rail Index** 75
Mexico Classification	UN3159	1,1,1,2-TETRAFLUOROETHANE OR REFRIGERANT GAS R 134A	2.2	Not applicable (gas).		-

Section 15. Regulatory information

United States

U.S. Federal regulations : **United States inventory (TSCA 8b):** This material is listed or exempted.

SARA 302/304/311/312 extremely hazardous substances: No products were found.
SARA 302/304 emergency planning and notification: No products were found.
SARA 302/304/311/312 hazardous chemicals: No products were found.
SARA 311/312 MSDS distribution - chemical inventory - hazard identification: No products were found.

Clean Water Act (CWA) 307: No products were found.

Clean Water Act (CWA) 311: No products were found.

Clean Air Act (CAA) 112 accidental release prevention: No products were found.

Clean Air Act (CAA) 112 regulated flammable substances: No products were found.

Clean Air Act (CAA) 112 regulated toxic substances: No products were found.

1,1,1,2-Tetrafluoroethane (Halocarbon 134a)

State regulations : **Connecticut Carcinogen Reporting:** This material is not listed.
Connecticut Hazardous Material Survey: This material is not listed.
Florida substances: This material is not listed.
Illinois Chemical Safety Act: This material is not listed.
Illinois Toxic Substances Disclosure to Employee Act: This material is not listed.
Louisiana Reporting: This material is not listed.
Louisiana Spill: This material is not listed.
Massachusetts Spill: This material is not listed.
Massachusetts Substances: This material is not listed.
Michigan Critical Material: This material is not listed.
Minnesota Hazardous Substances: This material is not listed.
New Jersey Hazardous Substances: This material is not listed.
New Jersey Spill: This material is not listed.
New Jersey Toxic Catastrophe Prevention Act: This material is not listed.
New York Acutely Hazardous Substances: This material is not listed.
New York Toxic Chemical Release Reporting: This material is not listed.
Pennsylvania RTK Hazardous Substances: This material is not listed.
Rhode Island Hazardous Substances: This material is not listed.

Canada

WHMIS (Canada) : Class A: Compressed gas.
CEPA Toxic substances: This material is not listed.
Canadian ARET: This material is not listed.
Canadian NPRI: This material is not listed.
Alberta Designated Substances: This material is not listed.
Ontario Designated Substances: This material is not listed.
Quebec Designated Substances: This material is not listed.

Section 16. Other information

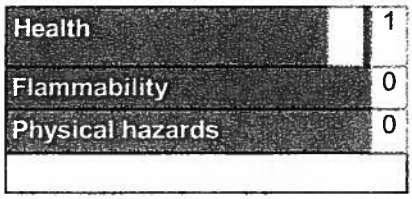
United States

Label requirements : CONTENTS UNDER PRESSURE.

Canada

Label requirements : Class A: Compressed gas.

Hazardous Material Information System (U.S.A.) :



National Fire Protection Association (U.S.A.) :

Notice to reader

To the best of our knowledge, the information contained herein is accurate. However, neither the above-named supplier, nor any of its subsidiaries, assumes any liability whatsoever for the accuracy or completeness of the information contained herein.
Final determination of suitability of any material is the sole responsibility of the user. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards that exist.

MATERIAL SAFETY DATA SHEET

3M
3M Center
St. Paul, Minnesota
55144-1000
1-800-364-3577 or (651) 737-6501 (24 hours)

DIVISION: 3M SPECIALTY MATERIALS
TRADE NAME:
PFC-5040 3M (TM) SPECIALTY GAS
ID NUMBER/U.P.C.:
98-0211-8851-5 - - - 98-0211-8852-3 - - -
98-0211-8853-1 00-51135-10966-3 98-0211-8892-9 00-51135-11000-3
ISSUED: February 20, 2001
SUPERSEDES: December 13, 1999
DOCUMENT: 07-3459-0

1. INGREDIENT

INGREDIENT	C.A.S. NO.	PERCENT
Perfluorobutane (C4F10).....	355-25-9	> 99.5

The components of this product are in compliance with the chemical notification requirements of TSCA. All applicable chemical ingredients in this material are listed on the European Inventory of Existing Chemical Substances (EINECS), or are exempt polymers whose monomers are listed on EINECS.

2. PHYSICAL DATA

BOILING POINT:..... ca. -2 C
Typical
VAPOR PRESSURE:..... ca. 1680 mmHg
@ 20 C
VAPOR DENSITY:..... ca. 8.4 Air=1
EVAPORATION RATE:..... > 1 BuOAc=1
SOLUBILITY IN WATER:..... neglig.
SPECIFIC GRAVITY:..... ca. 1.5 Water=1
PERCENT VOLATILE:..... 100 %
pH:..... N/A
VISCOSITY:..... < 10 centipoise
MELTING POINT:..... N/D

Abbreviations: N/D - Not Determined N/A - Not Applicable CA - Approximately

2. PHYSICAL DATA (continued)

APPEARANCE AND ODOR:
Liquefied Gas

3. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT:..... None
FLAMMABLE LIMITS - LEL:..... Nonflammable
FLAMMABLE LIMITS - UEL:..... Nonflammable
AUTOIGNITION TEMPERATURE:..... Nonflammable

EXTINGUISHING MEDIA:
Nonflammable.

SPECIAL FIRE FIGHTING PROCEDURES:
When fire fighting conditions are severe and total thermal decomposition of the product is possible, wear full protective clothing, including helmet, self-contained, positive pressure or pressure demand breathing apparatus, bunker coat and pants, bands around arms, waist and legs, face mask, and protective covering for exposed areas of the head. No unusual effects are anticipated during fire extinguishing operations. Avoid breathing the products and substances that may result from the thermal decomposition of the product or the other substances in the fire zone. Keep containers cool with water spray when exposed to fire to avoid rupture.

UNUSUAL FIRE AND EXPLOSION HAZARDS:
Exposure to extreme heat can give rise to thermal decomposition. See section 8, Health Hazard Data.

NFPA HAZARD CODES: HEALTH: 1 FIRE: 0 REACTIVITY: 0
UNUSUAL REACTION HAZARD: none

4. REACTIVITY DATA

STABILITY: Stable

INCOMPATIBILITY - MATERIALS/CONDITIONS TO AVOID:
Finely divided active metals, Alkali and alkaline earth metals.

HAZARDOUS POLYMERIZATION: Hazardous polymerization will not occur.

HAZARDOUS DECOMPOSITION PRODUCTS:
See Health Hazard Data section.

5. ENVIRONMENTAL INFORMATION

SPILL RESPONSE:
Observe precautions from other sections. Ventilate area. Close cylinder or if necessary vent in hood or remote area. Place leaking containers in a well-ventilated area, preferrably in an exhaust hood, if available, or outdoors.

RECOMMENDED DISPOSAL:
Incinerate at a facility equipped to handle gaseous waste. Facility must be capable of handling aerosol cans. Combustion products will include HF. Dispose of empty cans in a sanitary landfill. Reclaim if feasible.

ENVIRONMENTAL DATA:
No data available.

REGULATORY INFORMATION:
Volatile Organic Compounds: N/A.
VOC Less H2O & Exempt Solvents: N/A.

Since regulations vary, consult applicable regulations or authorities before disposal. U.S. Clean Water Act, Section 307, Toxic Pollutants = None. U.S. EPA Hazardous Waste Number = None (Not U.S. EPA Hazardous).

Components are in compliance with TSCA, EINECS, and MITI.

Transportation Information:
Regulated for ground, air and ocean transport (UN3163).

OTHER ENVIRONMENTAL INFORMATION:
EPCRA 311/312 Reportable Quantity = Not Reportable.

EPCRA HAZARD CLASS:
FIRE HAZARD: No PRESSURE: Yes REACTIVITY: No ACUTE: No CHRONIC: No

6. SUGGESTED FIRST AID

EYE CONTACT:
Immediately flush eyes with large amounts of water. Get immediate medical attention.

SKIN CONTACT:
No need for first aid is anticipated.

INHALATION:
Remove person to fresh air. If not breathing, give artificial respiration. If breathing is difficult, get immediate medical attention.

6. SUGGESTED FIRST AID (continued)

IF SWALLOWED:
No need for first aid is anticipated.

OTHER FIRST AID INFORMATION:
NOTE TO PHYSICIANS: Exposure to high concentration may increase "myocardial irritability." Do not administer sympathomimetic drugs (i.e. adrenaline) unless absolutely necessary. No specific antidote. Supportive care and treatment based on the judgement of physician in response to the patient are recommended.

7. PRECAUTIONARY INFORMATION

EYE PROTECTION:
Wear safety glasses with side shields.

SKIN PROTECTION:
Avoid skin contact. Wear appropriate gloves when handling this material.

RECOMMENDED VENTILATION:
Use with adequate dilution ventilation.

RESPIRATORY PROTECTION:
Avoid prolonged breathing of vapors.

PREVENTION OF ACCIDENTAL INGESTION:
Not applicable.

RECOMMENDED STORAGE:
Store in a cool place. Keep container closed when not in use. Store in explosion-proof containers.

FIRE AND EXPLOSION AVOIDANCE:
Nonflammable.

Nonflammable.

OTHER PRECAUTIONARY INFORMATION:
No smoking: Smoking while using this product can result in contamination of the tobacco and/or smoke and lead to the formation of the hazardous decomposition products mentioned in the Reactivity Data section of this MSDS.

HMIS HAZARD RATINGS: HEALTH: 0 FLAMMABILITY: 0 REACTIVITY: 0
PERSONAL PROTECTION: X (See precautions, section 7.)

Abbreviations: N/D - Not Determined N/A - Not Applicable CA - Approximately

7. PRECAUTIONARY INFORMATION (continued)

EXPOSURE LIMITS

INGREDIENT	VALUE	UNIT	TYPE	AUTH	SKIN*
Perfluorobutane (C4F10).....	NONE	NONE	NONE	NONE	

* SKIN NOTATION: Listed substances indicated with 'Y' under SKIN refer to the potential contribution to the overall exposure by the cutaneous route including mucous membrane and eye, either by airborne or, more particularly, by direct contact with the substance. Vehicles can alter skin absorption.

SOURCE OF EXPOSURE LIMIT DATA:
- NONE: None Established

8. HEALTH HAZARD DATA

EYE CONTACT:
Eye contact is not expected to occur during normal use of the product.

Frostbite: signs/symptoms can include pain, clouding of the cornea, redness, swelling and blindness.

SKIN CONTACT:
Frostbite: signs/symptoms can include firm blanched areas, redness, pain, tissue destruction, swelling and scar tissue formation.

INHALATION:
Simple Asphyxiation: signs/symptoms can include light-headedness, rapid heart beat, a feeling of suffocation and blue color. Unconsciousness and death may occur if oxygen deprivation is severe or prolonged. Simple asphyxiation results from the displacement of oxygen in air to a concentration which is less than that necessary to maintain life.

IF SWALLOWED:
Ingestion is not a likely route of exposure to this product.

No information was found regarding effects from swallowing.

OTHER HEALTH HAZARD INFORMATION:
If the product is exposed to extreme conditions of heat from misuse or equipment failure, toxic decomposition products that include hydrogen fluoride can occur.

Hydrogen fluoride has an ACGIH threshold limit value of 3 parts per million parts of air, ppm, of fluoride as a ceiling limit and an OSHA PEL of 3 ppm of fluoride as an eight hour time-weighted average and

8. HEALTH HAZARD DATA (continued)

6 ppm of fluoride as a Short Term Exposure Limit.

A 3M Product Toxicity Summary Sheet is Available.

EXPOSURE ROUTE	SUMMARY OF TOXICITY FINDINGS
Oral	Practically Non-Toxic
Inhalation	Simple Asphyxiant

Not a cardiac sensitizer where tested.

SECTION CHANGE DATES

HEADING	SECTION CHANGED SINCE December 13, 1999 ISSUE

Abbreviations: N/D - Not Determined N/A - Not Applicable CA - Approximately

Worst Case → Rupture @ 165 psia
≈ 150 psig

Runaway Heat with Piston stop + H_2O 50 ml

Under 50 V

Oil, Digital Media

internal energy 0.15090 kcal/g
150°C 165 psia
.91739 g/ml

Pressure relief Valve and burst disc → yearly testing

50 ml (.91739 g/ml) = 45.8695 g

(.15090 kcal/g)(45.8695 g) = 6.9217 kcal

(45.8695 g)(1880.9 ml/g)
= 86275.9 ml

internal energy
150°C 15 psia Vapor
.61730 kcal/g
(45.8695 g)(.61730 kcal/g)
= 28.315 kcal

From (Gas) 150° 165 psia to 150° Vapor 15 psia

$\Delta U = -21.39$ kcal

$\frac{86275.9 \text{ ml}}{50 \text{ ml}} = 1725.5 : 1$

Heat of Vaporization 2270 kJ/kg

1 kJ = .239 kcal

(.0458 kg)(2270 kJ/kg)(.239 kcal/kJ) = 24.85 kcal

Physics Est

Hazard analysis Process review

Pressure vessel safety Guy

electrical + fan away Heating control

15 Psia @ 99°C

Water in liquid phase

45.8 g H_2O

→ Point where heating will stop

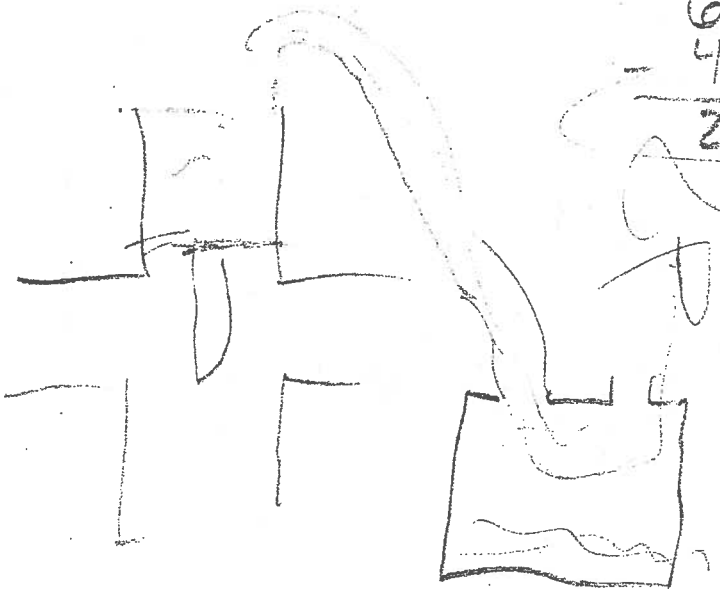
internal energy

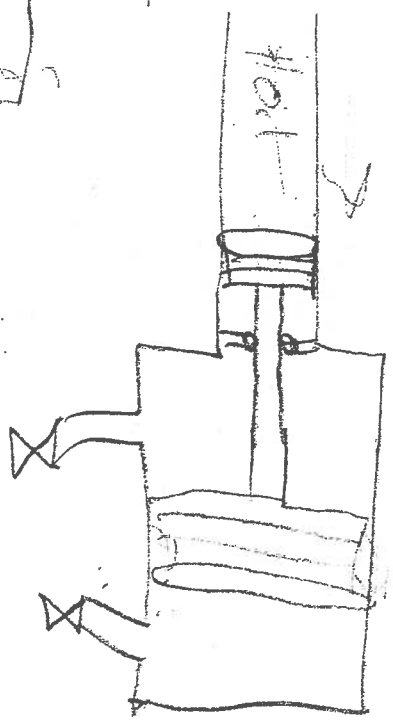
$(.10006\ \text{Kcal/g})(45.8\text{g}) = 4.583\ \text{kcal}$

45.8g internal energy 150°C liquid
6.9217 kcal 155 Psia

6.9217
− 4.583
2.3387 kcal

24.85 Kcal to vaporize 45.8g of H_2O





7-01-5

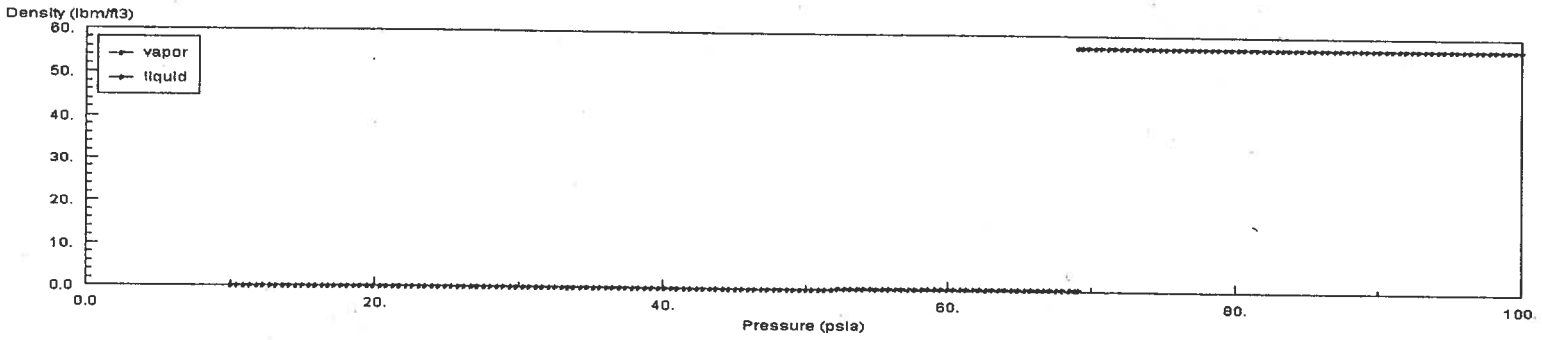
Isothermal Properties for Water

The following adjustments were made to the specified data range:

- The specified increment was adjusted to limit the number of points calculated.

Fluid Data

Isothermal Data for T = 150.00 C



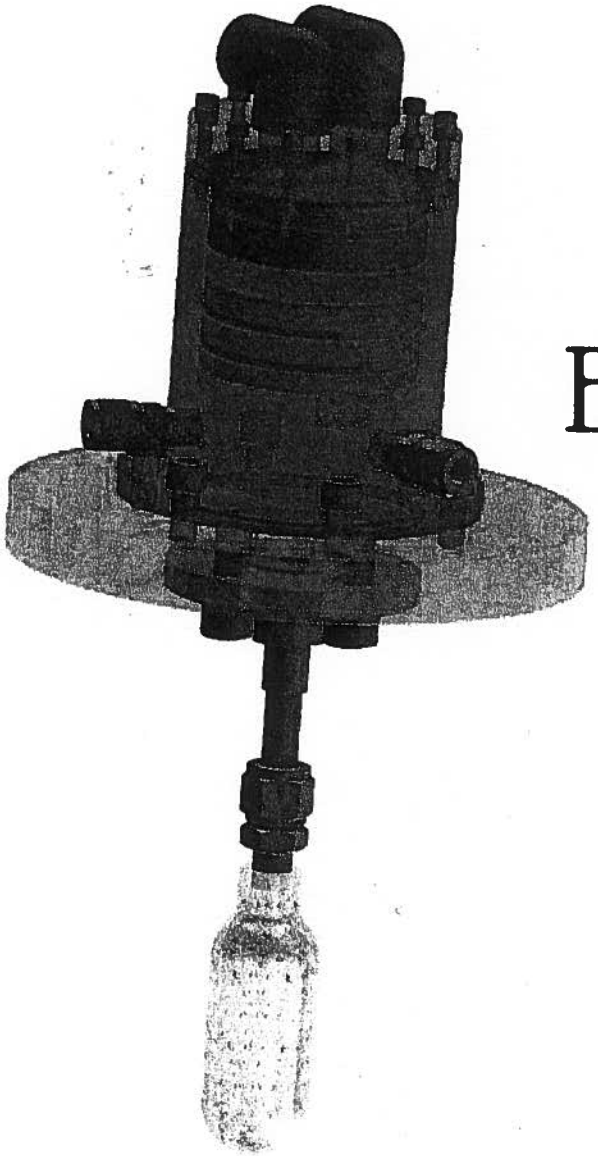
Auxiliary Data

Reference States

Internal energy	U = 0 at 273.16 K for saturated liquid.
Entropy	S = 0 at 273.16 K for saturated liquid.

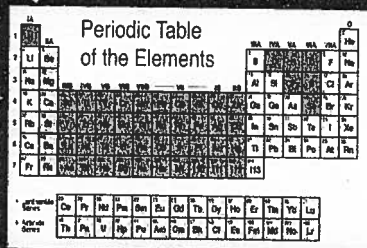
Additional fluid data

Critical temperature (T_c)	373.946 C
Critical pressure (P_c)	3200.11 psia
Critical density (D_c)	20.101808 lbm/ft3
Acentric factor	0.3443
Normal boiling point	99.9743 C
Dipole moment	1.855 Debye

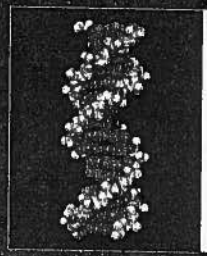


Bubble Chamber Detector

Safety Review

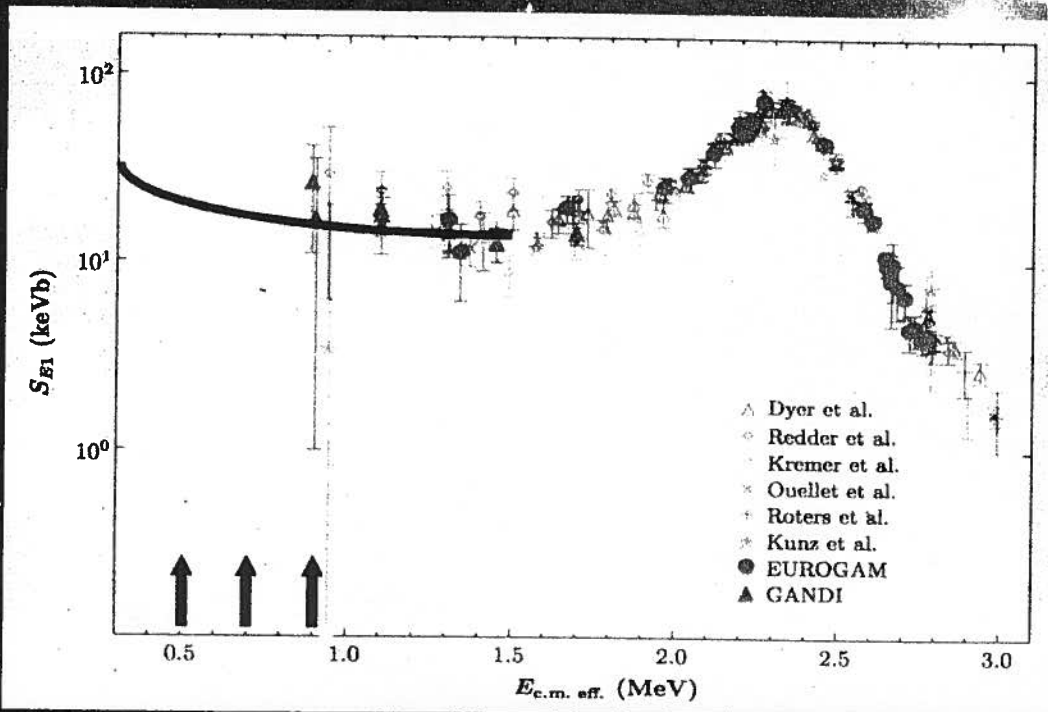


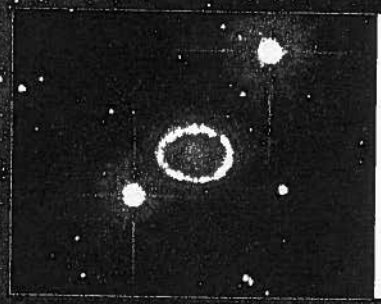
Affects the synthesis of most of the elements of the periodic table



Sets the C to O ratio in the universe

$^{12}C(\alpha,\gamma)^{16}O$





Determines the minimum mass a star requires to become a supernova

Extraction of the required experimental information is extremely challenging. We need better data for extrapolations.

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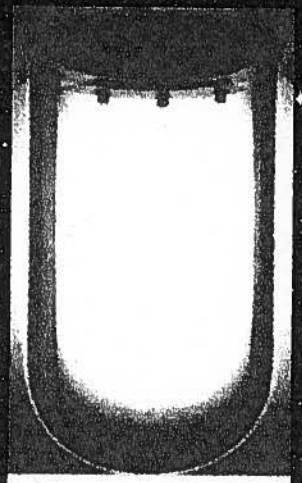
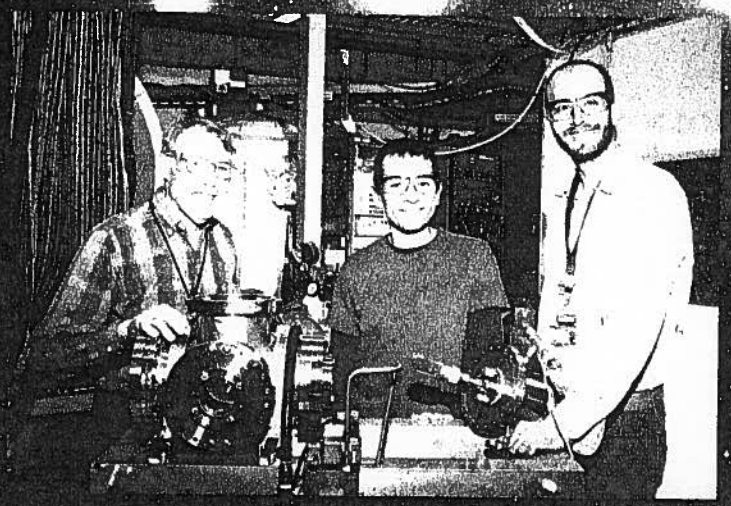
bea target bubbles

$^{m}\gamma + {}^{16}O \rightarrow {}^{12}C + \alpha$

- Superheated water will nucleate from α and ^{12}C recoils
- The detector is insensitive to γ-rays from the beam.
- The target density is 1000x higher than that of previous experiments.



COUPP/FNAL



Milestones $^{12}C(\alpha,\gamma)^{16}O$:

Feb 08 decision to use water
Aug 08 design of prototype
Dec 08 assembly started

Mar 09 produce superheated liquid
Apr 09 write proposal for HIGS
Jun 09 test prototype at ATLAS

Fall 09 tests with ^{16}O-enriched water
End 09 background measurements
2010 run with prototype at HIGS
design full size detector
write proposal to DoE

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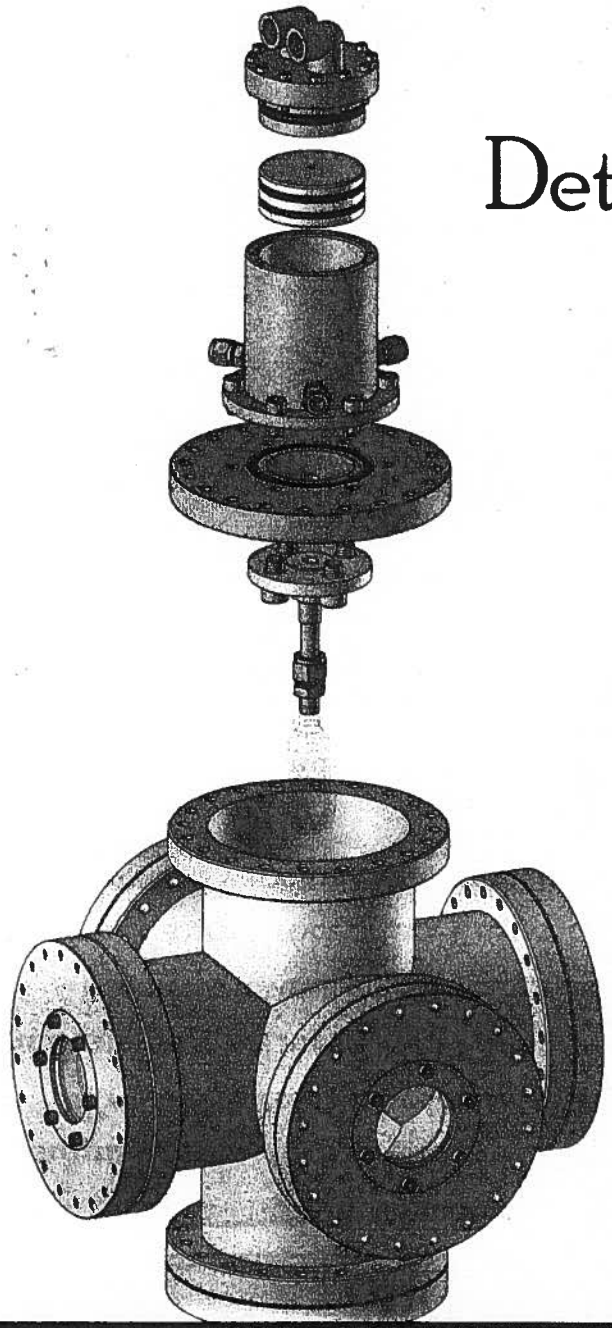
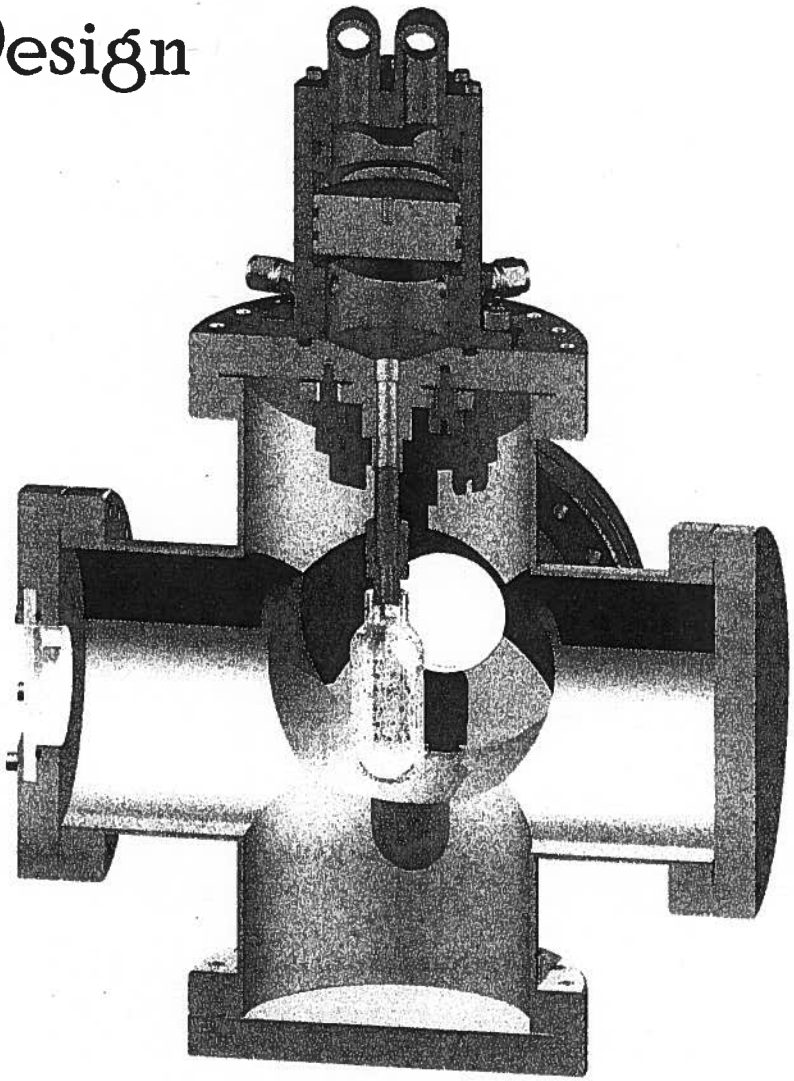
Overview of Detector Systems

- Vacuum System
  - Provides thermal insulation for sensitive volume of detector
- Pneumatic System
  - Provides pressure necessary to reset detector
- Hydraulic System
  - Contains the sensitive volume and buffer fluid
- Temperature Control System
  - Monitors and regulates the temperature of the sensitive volume of the detector
- Data Acquisition/Control System - LabView
  - Machine vision to identify a reaction in our sensitive volume
  - After an event has been identified, the software will reset the detector

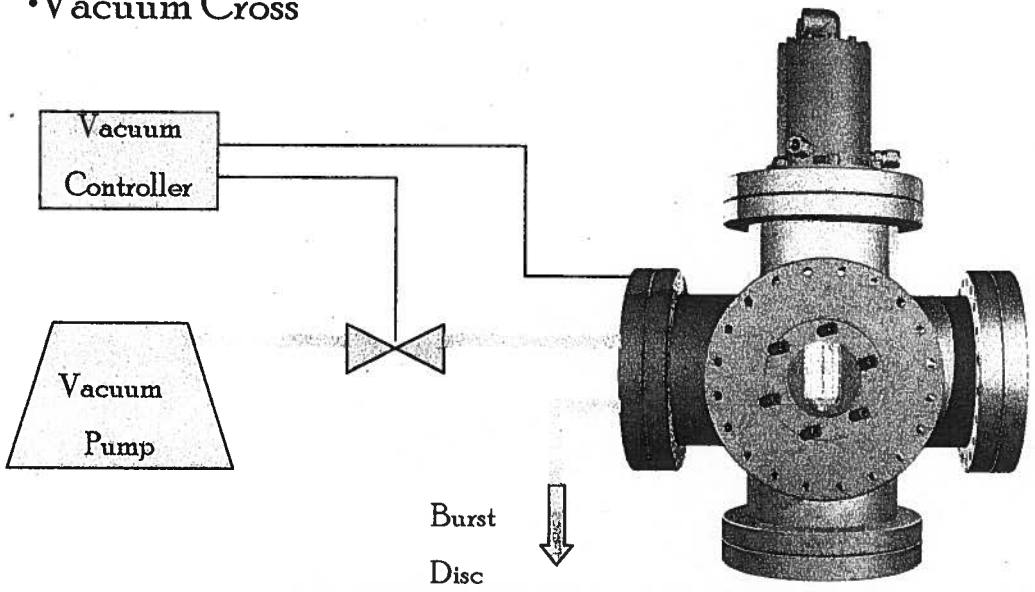
Detector Design





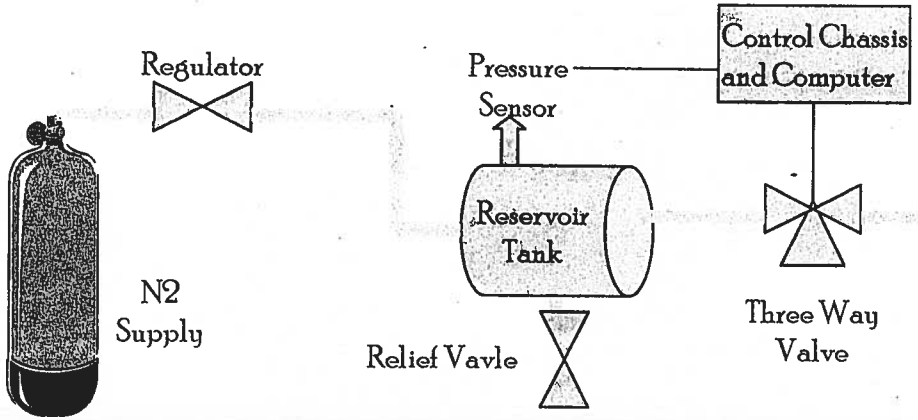
Vacuum System

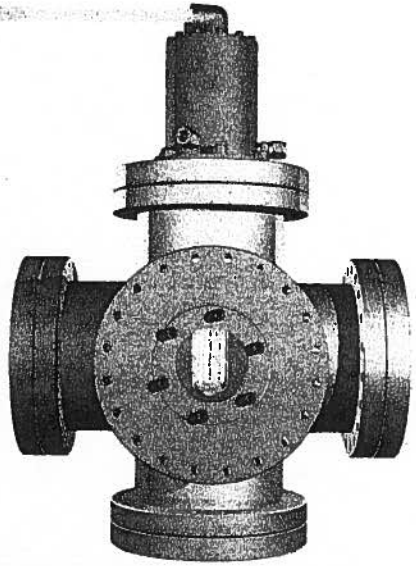
- Vacuum Pump
  - Provides insulating vacuum to keep heating power down and vacuum cross temperature down.
- Vacuum Controller
  - Monitors insulating vacuum, and closes safety valve in case of leak/rupture.
- Vacuum Pump Protection Valve
  - Protects vacuum pump from ingesting liquids/solids in case of sudden hydraulic system failure.
- Burst Disk
  - Prevents vacuum cross from becoming pressurized in the event of a failure.
- Vacuum Cross



Pneumatic System

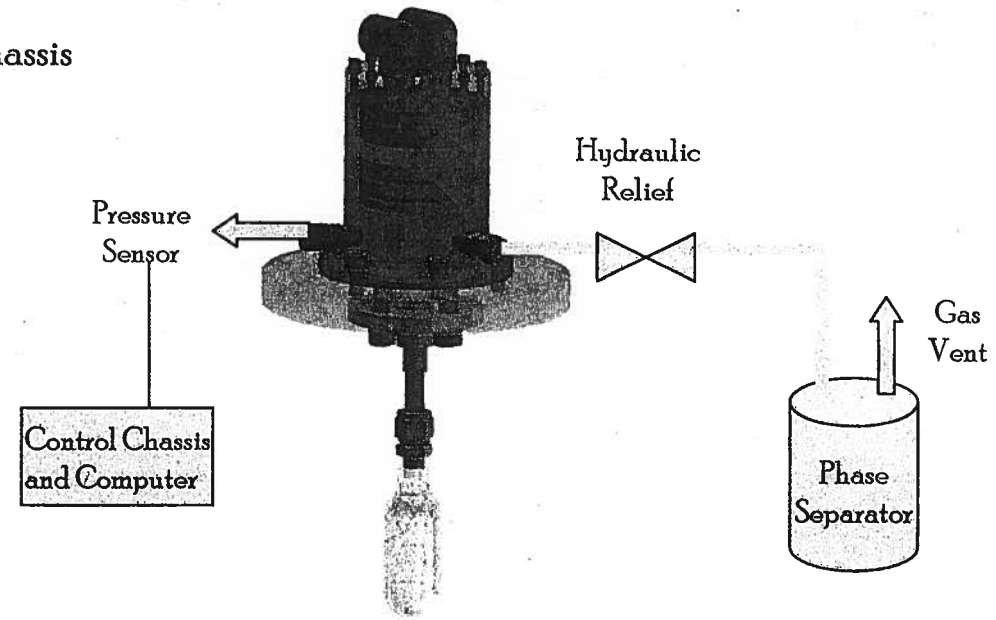
- N2 Supply and Regulator
- Reservoir Tank
- Relief Valve
- Pressure Sensor
  - Read by computer through control chassis
- Control Chassis and Computer
  - Chassis is the interface between detector system and computer.
- Three Way Valve
  - Controlled by computer with a manual bypass on chassis





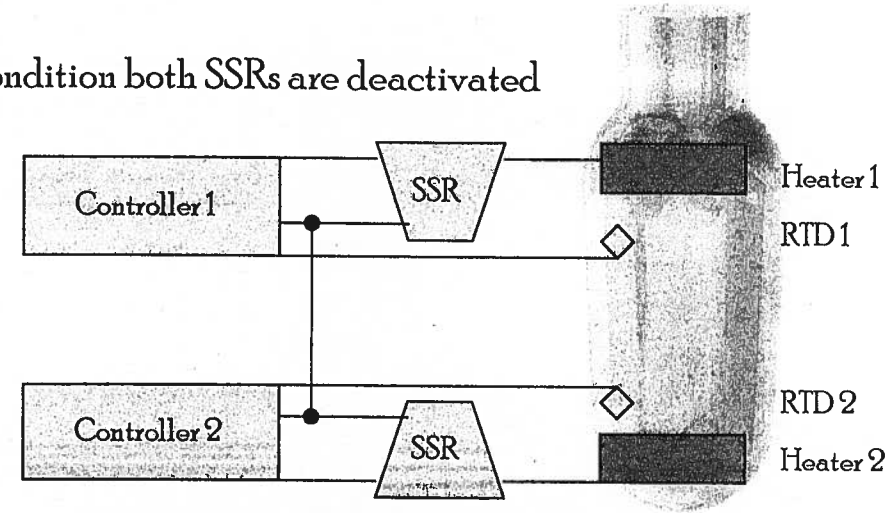
Hydraulic System

- Detector Sensitive Volume and Buffer Fluid
- Pressure Sensor
  - Read by computer through control chassis
- Hydraulic Relief
  - For venting two phase fluid
- Phase Separator
  - Allows liquid to collect while gas can pass through unimpeded
- Control Chassis and Computer



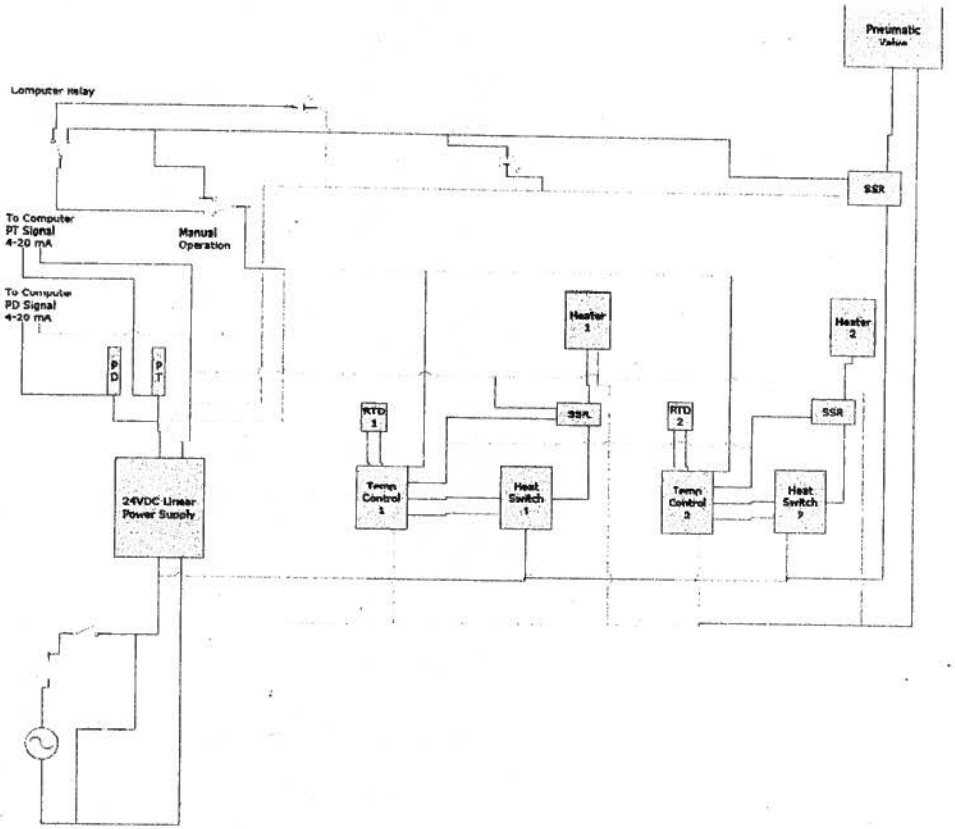
Temperature Control System

- RTDs
  - Pt100 RTD sensors, one for each temperature controller
- Heaters
  - Flexible heaters to match contour of vessel
  - Each is operated independently
- Temperature Controllers
  - Two independent temperature controllers
  - Alarm output of both controllers are connected in parallel to both SSRs
- Solid State Relays
  - If either controller sees an over temperature condition both SSRs are deactivated
- Heater Operation
  - 120VAC
  - All exposed connections are shielded inside grounded cases



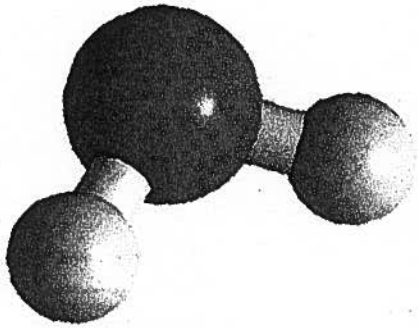
Data Acquisition and Control System

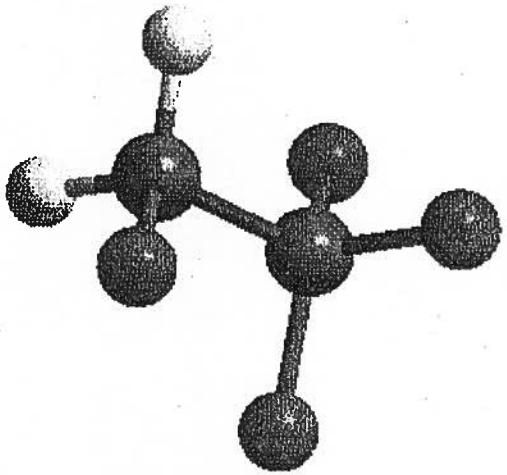
- High Frame Speed Video Cameras
  - Run by LabView
- Low Voltage Background Lighting
  - LEDs with a diffuser
- Redundancy in Control Chassis
  - Two separate heating systems have the ability to "monitor" each other
  - Control Chassis has passed its electrical safety inspection.
- Manual Bypass for Detector Pressurization
  - Ability to operate the pneumatic valve manually and to override computer input



Initial Testing

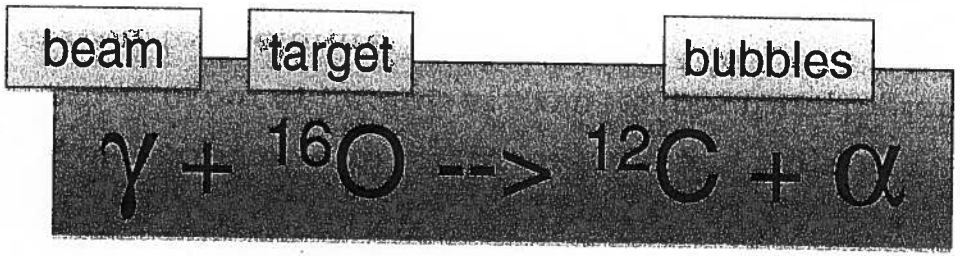
- In order to properly develop software and to work out any bugs in our system we have decided to begin testing of our apparatus at room temperature, therefore a superheated liquid is needed at room temperature
- R-134A has been chosen as our initial testing liquid
  - Vapor pressure at room temperature is around 85psi
  - Non-toxic
  - Oxygen monitors must be worn during filling as the only danger from this substance is asphyxiation
- Water will be used as our buffer fluid
- Testing with neutron source at ATLAS facility





Final Testing

- Once detector is operating as intended at room temperature, final testing can begin
- Using water as our detecting fluid and high temperature oil as our buffer
- Operating Conditions:
  - 150° C
  - Pressure ranging from atmospheric to 150 psig
  - Vapor pressure of water at this temperature is 70 psia
- Initial testing with neutron source at ATLAS facility
- Once proven to work, final testing will take place at a gamma ray facility



Postulated Accidents 1

- Pneumatic System Failure
  - Failure to quench bubbles may result in a runaway boil
  - A mechanical stop for the piston is incorporated into the design
    - Expanding gas will force the piston against its stop and allow pressure to build
    - Pressure in hydraulic system will reach the vapor pressure of the liquid and prevent further boiling
    - If this does not stop the boiling (heater malfunction) a relief is incorporated.

- Vacuum Vessel, Hydraulic System, and Pneumatic System Over Pressurization
  - All three systems are fitted with over pressurization protection mechanisms
  - Hydraulic system has a special phase separator, allowing liquid and gas to safely vent

Postulated Accidents 2

- Heating System Failure
  - Failure of heating system , causing uncontrolled heating will result in over pressurization of the hydraulic system
    - Hydraulic relief and venting system will allow for safe discharge of excess pressure
    - Two separate heater control units add redundancy, each controller is capable of turning both heaters off if the device begins overheating due to one heating system failure

- Failure of Glass Pressure Vessel
  - Thermodynamic calculations show that there is only enough heat contained in the water to cause 10% of it to flash to vapor
  - That is approximately 8 liters of steam, our vacuum vessel has an interior volume of approximately 12 liters
  - The hot oil may cause additional water to change phase into steam, but this will be counter acted by coming in contact with the vacuum vessel walls which should remain close to room temperature
  - It is hard to say exactly how much steam will be produced, but in case it is capable of pressurizing our vacuum vessel, it will be fitted with a blow off disk in the middle portion to allow liquids to collect at the bottom of the vessel and gas to vent