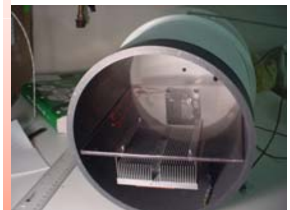
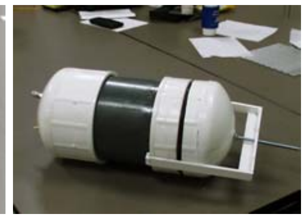
Pressure Vessel

Data Sciences International, Inc.





Engineering 481: Senior Design Clinic

Spring 2003

Faculty Advisor: Dr. Camille George

Francis Ssennoga, Ryan Beck, Jason Wain, Cheri Logan, Meghan O'Brien

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Background

- DSI
  - global leader in manufacturing telemetry transmitter products for physiologic monitoring in animals
  - customers: research organizations, pharmaceutical manufacturers, academic research institutions
- Pressure Vessel
  - tool offered to customers that allows calibration of DSI telemetry transmitter products
  - provides a temperature and pressure controlled environment
  - verify data outputs and ensure products are calibrated before implanting for next experiment

Problem Statement & Customer Requirements

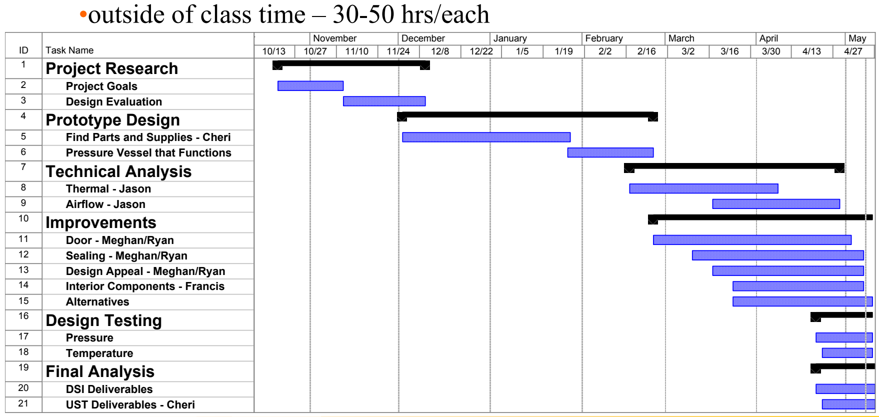
- Redesign the current pressure vessel
- Provide a first-run concept, not a finished product
- Address several key design issues:
  - eliminate the leaks through the door and passthroughs
  - find new material that is less brittle and easier to machine
  - design a door that functions reliably & is safe
  - decrease overall cost of the device ($1800+)
  - decrease the number of components

Team Member Assignments

- Research: materials, latches, doors, pressure vessels – Team
- Procurement of materials – Cheri
- ANSYS – Jason
- Prototype assembly – Team
- Prototype testing – Francis
- Prototype presentation – Meghan
- Final design machining/assembly – Ryan, Meghan
- Building alternate design - Francis
- Final design testing – Francis
- Project management & ANSYS – Jason
- Final presentation – Cheri
- Paper – Team

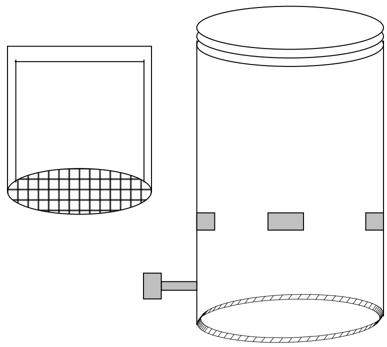
Project Management

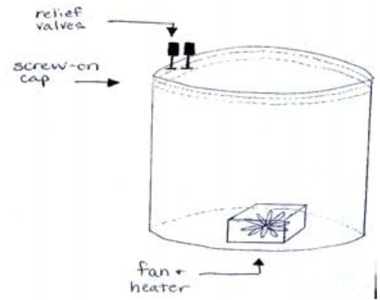
- Time Schedule:
  - weekly meetings – 40 hrs/each
  - work on tasks – 75 hrs/each
  - outside of class time – 30-50 hrs/each

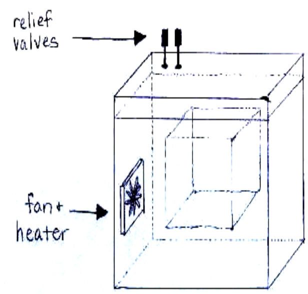


Concept Generation

- Brainstorming prior to prototype
- Main components: fan, heater, door, shelf, valves

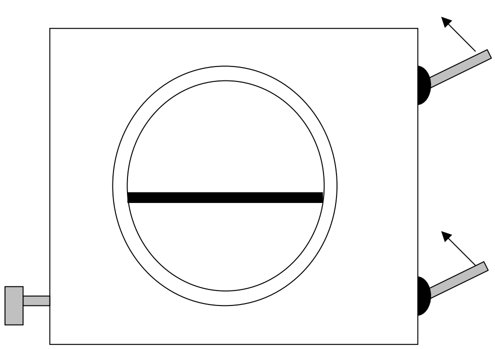


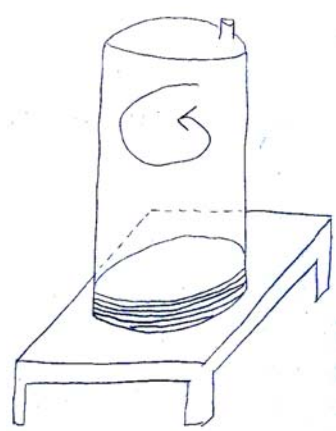




Concept Generation

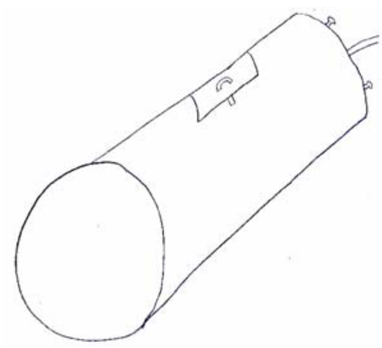
- Brainstorming

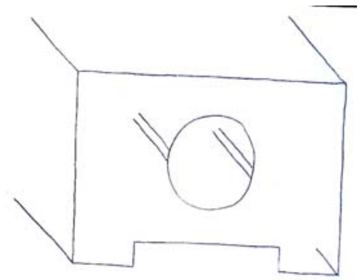




Concept Generation

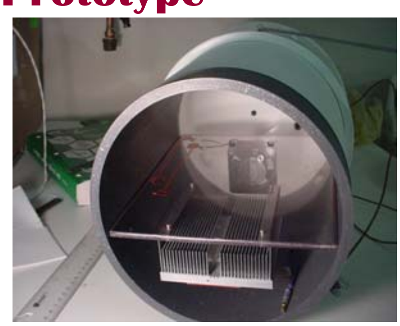
- Brainstorming





Concept Generation – Prototype

- Basic design
  - horizontal
- Shelf
  - fan & heater attached
    - – removable, easy maintenance
- Materials
  - PVC tube – cheap, correct shape
- Leaks/Door
  - small latches
    - – cheap, little machining
  - PVC end caps
    - – cheap, no machining, few components



Prototype - Test Results

Temperature

#1	Before starting heater	70°F
#2	After running heater for 3 minutes	72°F
#3	8 minutes later	73°F
#4	After stopping the heater; 1 minute later	72°F

Pressure

	Gauge #1 (outlet)	Gauge #2 (pressure vessel)
#1	10 psi	4.8 psi
#2	14 psi	5.1 psi
#3	20 psi	5.3 psi

Prototype - Testing Analysis

- Slow temperature increase
  - inadequate power supply
- Leaks
  - caulked thermocouple wire pass through
  - latch/door interface
- Improvements for final design testing
  - correct wattage power supply (50 watts)
  - thermocouple – buy probe thermocouple & fitting
  - door – o-ring/gasket

Prototype Assessment

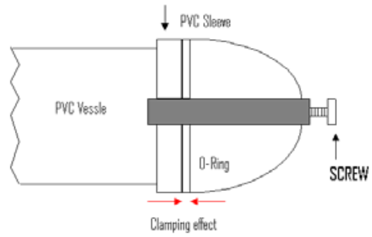
- Other concerns:
  - latches – not user friendly, tedious assembly, require extensions
  - PVC end caps – bulky
  - door/latch interface requires alignment
  - overall appearance

Final Concept Designs

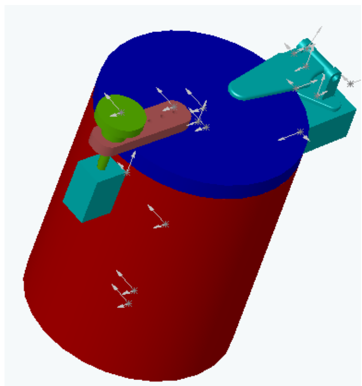
- Two approaches for door – speculation on possible success
- Basic requirements for each version:
  - V1 & V2 – no need for door/end cap alignment
  - V1 – eliminate end caps
  - V1 – cleaner appearance
  - V2 – easier assembly
  - V2 – limited extra components & machining
- Two versions for door:
  - V1: similar to original
    - – smaller hinge, fastening knob
  - V2: compression seal
    - – screw-down U-bar, even sealing from two directions

Final Concept Designs

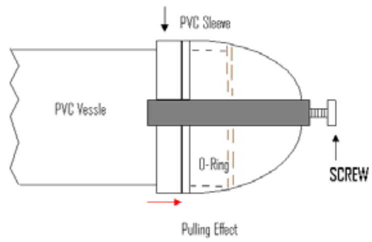
V2 – Clamp-Lock Door: Squeezing Effect



V1 – Double-Sealed Door



V2 – Clamp-Lock Door: Pulling Effect



Final Designs – Test Results Technical Analysis

- Heat Transfer Analysis
  - Difference in heaters
  - Effects of air
  - Optimizing heater and fan from DSI for radiation & convection
  - Reiterate process for results-Spreadsheet
    - Are materials durable?
    - Component requirement attainable?

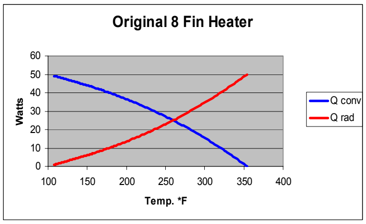
Qin = Qrad+Qconv+Qcond

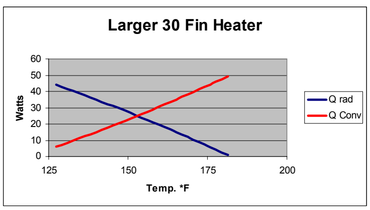
- Finite Element Analysis
  - Transient conduction of heater
  - Time to get up to 98.6°F?
  - Fluid Flow
    - Velocity of air
    - Air flow distribution at end
  - Reiterate process – ANSYS
    - Vary component placement
    - Change boundary conditions
  - Attain Results

Heat Transfer Analysis

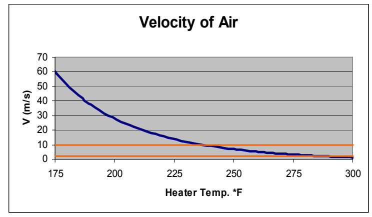
Ambient Air Temperature in vessel @ 98.6°F

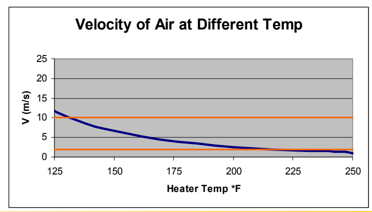
- Heater
  - Heat out @ varying temp.





- Air Flow
  - Vair necessary for 98.6°F



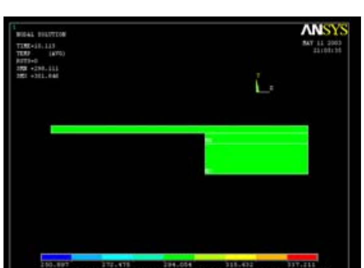


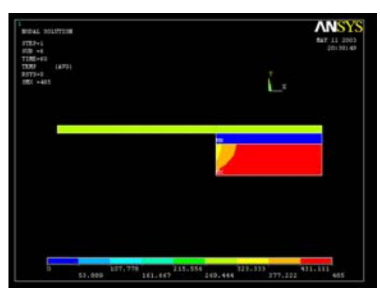
Finite Element Analysis

- Transient Conduction of Heater

1. Start of model

To get air temperature in vessel to 98.6°F in 60 seconds HEATER NEEDS TO BE 410 °F !!!!





2. Find reasonable time

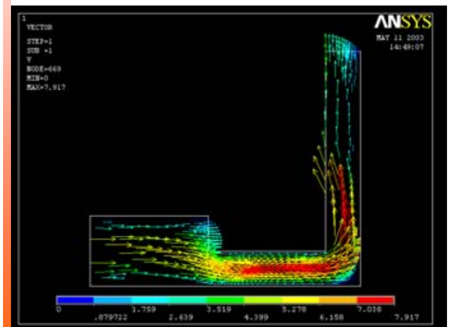
Reiteration down to 150 °F

<u>Actually takes 263 seconds</u>

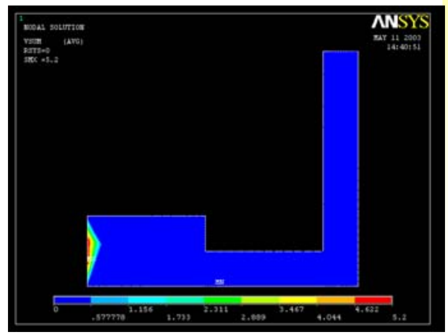
Finite Element Analysis

- Fluid Flow – Horizontal Cross Section
  - Demonstrates flow around heater thru end of vessel
  - Reiterate varying component placement and air velocity
  - Shows maximum airflow at different component placement
  - Ideally fan should should be 3 inches from heating element

V in = 4.6 m/s



V in = 2.4 m/s



Results

- 30 fin heater allows us to run a much lower T
- Air flow (V) required by fan inverse of Heater T
- Heater will not melt shelf T_melt=266°F
- Heater should not effect PVC walls T_melt=145°F
- Average h=38.4 W/m^2°K
- Air velocity required by fan attainable
- Lumped Capacitance shows thermocouple response = 2.94 sec
- IDEAL CONDITIONS
  - T_heater ≈ 150 °F
  - V air ≈ 4 - 6 m/s (12V)
  - Heater 3” from fan (Fan to center of heating element)

Final Designs - Testing Results

- Temperature, Pressure – V1
  - Probe position: center of vessel above shelf

#1	Before Starting heater	80°F
#2	After running heater 6 minutes	98°F
#3	40 seconds after switching off heater	97.5°F
#4	30 seconds – turned back on	98°F

#1	8 psi -> 2 psi	7 minutes
#2	8 psi -> 5 psi	4 minutes, 30 sec
#3	8 psi -> psi	9 minutes

Final Designs – Testing Results

- Temperature, Pressure – V2
  - Probe position: center of vessel above shelf

#1	Before Starting heater	79°F
#2	After running heater 19 minutes	98°F
#3	40 seconds after switching off heater	97°F
#4	30 seconds	97°F -> 98°F

#1	8 psi -> 2 psi	8 minutes, 30 sec
#2	8 psi -> 5 psi	6 minutes, 15 sec
#3	8 psi -> psi	10 minutes

Manufacturability - Components

- Both vessels:
  - PVC – round stock & easily machined, CNC to square up
  - shelf – cut acrylic to vessel size, drill holes for better flow, little assembly for components, some wiring
  - fan, heater & passthrough components – basic models, internal threads necessary
  - PVC cement, screws, washers & nuts – general components
  - simple tools required – saw, drill, screwdriver

Manufacturability – Assembly/Time

- V1
  - door – lathe disks, concentricity difficult, lathe o-ring groove
    - our time: 45 hours, estimated outsource time: < 3 hours (CNC)
  - components – grinding curvature on aluminum parts, difficult to line up & ensure correct motion, internal threads necessary
    - our time: 20 hours, estimated outsource time: 3 hours (CNC)
- V2
  - door – trim down end cap, cut PVC sleeve
    - our time: 1.5 hours, estimated outsource time: 30 minutes
  - components – cut steel, weld U-bar
    - our time: 1.5 hours, estimated outsource time: 45 minutes

Cost Comparison

Part Name	Cost for Old Vessel	V1 Cost	V2 Cost	V1: Cost Change (%)	V2: Cost Change (%)
Cylinder	$410.50	$12.00	$12.00	97.08%	97.08%
Base Plate	$61.83	$10.00	$26.28	83.83%	57.50%
Front Door	$168.90	$20.00	$26.28	88.16%	84.44%
Door Components	$298.03	$59.47	$10.00	80.05%	96.64%
Shelf	$62.35	$3.00	$3.00	95.19%	95.19%
Chamber Stand	$57.30	$50.00	$50.00	12.74%	12.74%
Receiver Stop Block	$21.65	$0.00	$0.00	100.00%	100.00%
COMPONENT COST	**$1,080.56**	**$154.47**	**$127.56**	**85.70%**	**88.20%**
Miscellaneous:					
Screws, fittings, etc.	N/A	$134.00	$134.00		
MISC. COST:	N/A	*$134.00*	*$134.00*		
TOTAL COST:	**$1,058.91**	**$288.47**	**$261.56**		

Estimated Cost Savings = 85.70% - 88.20%

Completion of Design Requirements

- Better material – PVC
- Door
  - V1 – hinged, user friendly, bleeds
  - V2 – safe, easy to use
- Components
  - V1 – less hardware, smaller size
  - V2 – minimal hardware, fewer components
- Leaks
  - V1 – used o-ring & gasket, glued in rear plate
  - V2 – sealing from two directions, more uniform seal, o-ring
- Estimated cost savings
  - V1 = 85.70% ≅ $288.47
  - V2 = 88.20% ≅ $261.56

Final Designs - Assessment

- Strengths/Weaknesses of design
  - V1 – inexpensive, less cumbersome door, knob
  - V1 – difficult to make front cap, extra machining required, leaks
  - V2 – inexpensive, apply uniform pressure, no hinges, easier assembly
  - V2 – bulky end cap, extra machining/welding for clamp, hard to compress & center, leaks
- Recommendations for improvement
  - ***we believe in design concepts – our lack of machining skills causes leaks***
  - V1 – concentric disks for door, curvature on components, torque knob,
  - V2 – even surface on end cap, less material for caps, attach clamp to a stand, one large o-ring instead of two small o-rings
  - assembly time needs to be reduced
  - would have combined best of both versions, testing performed too late

Conclusions

- Reflections on the process
  - concentrate on the door earlier
  - order materials earlier
- Team performance
  - all ideas considered – reason for V1 & V2
  - helped others with their tasks
  - continually made progress