Shuttle Valve Design

Team #17

Date
April 17th, 2014

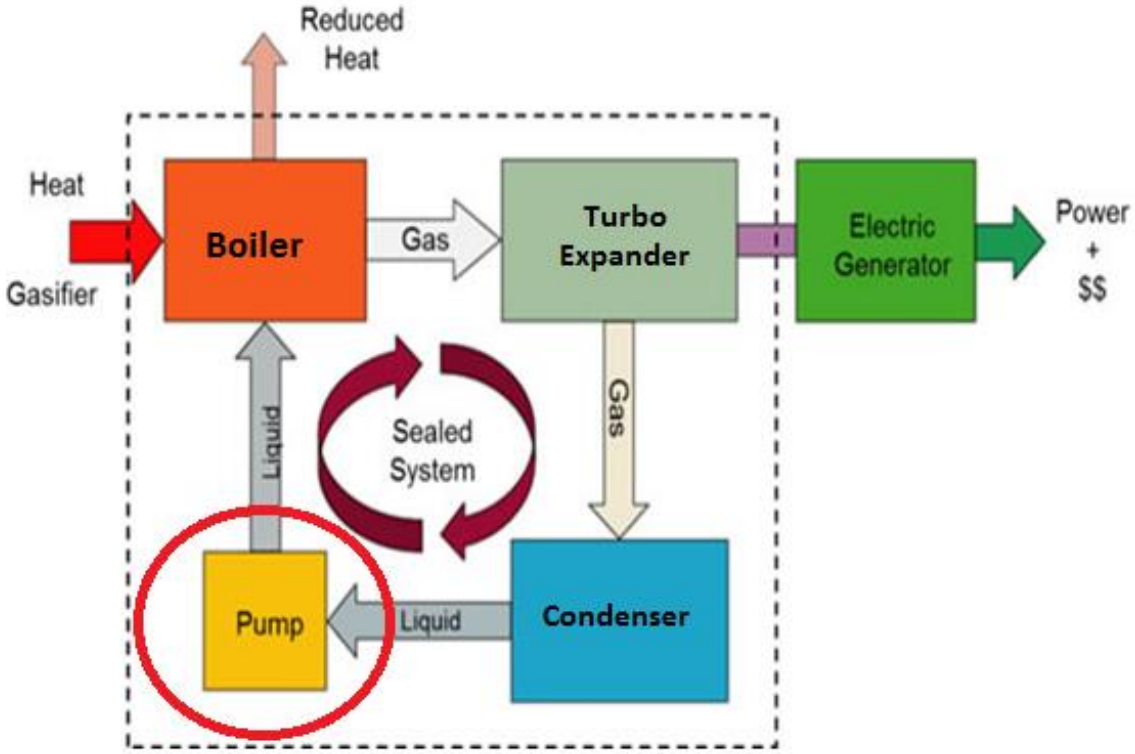
Group Members
Ryan Laney – Team Leader
Billy Ernst – Team Webmaster
Samantha Zeidel – Team Treasurer

Instructor
Dr. Kamal Amin

Sponsor
Verdicorp Inc.
Robert Parsons

Project Overview

- Verdicorp Environmental Technologies has developed a revolutionary Organic Rankine Cycle (ORC)
- ORC uses waste heat from a low grade source and converts it to useful power
- The ORC systems have somewhat low efficiency (~10-14%); Special concern within the company to maximize this efficiency in any way possible
- ORC is cable of producing ~125 kW
- Parasitic losses consume ~20 kW
  - (Pump ~10 kW)
- Senior Design Team 17 has been tasked with increasing the efficiency of the system
  - (Removal and replacement of the pump)



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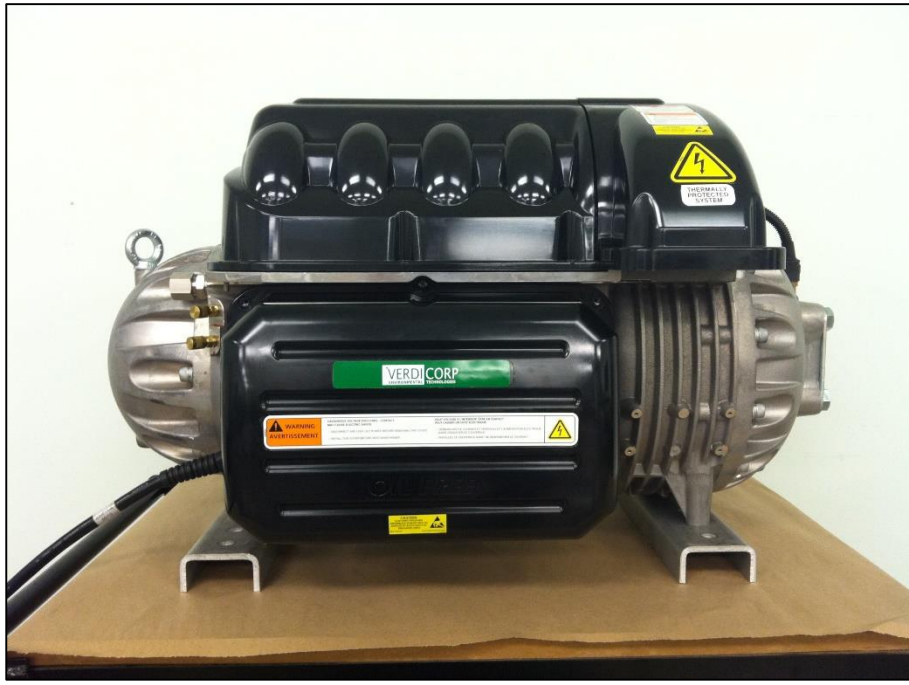
Project Overview



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Project Objectives

- Design and construct a prototype of the shuttle valve system that will replace the pump
- Maintain the continuous flow of liquid within the system (~ 3 gpm)
- Using solenoid valves, to balance pressure difference of 50 psi, and the aid of gravity, transfer the fluid in the system from the low pressure side to the high pressure side
- Minimize the parasitic losses in the system (electrical consumption)
- Design and confirm on a final prototype concept by the end of the fall semester
- Maintain the prototype's allocated budget of $2000
- Completion of prototype and presentation to MEAC Open House by April 17th, 2014

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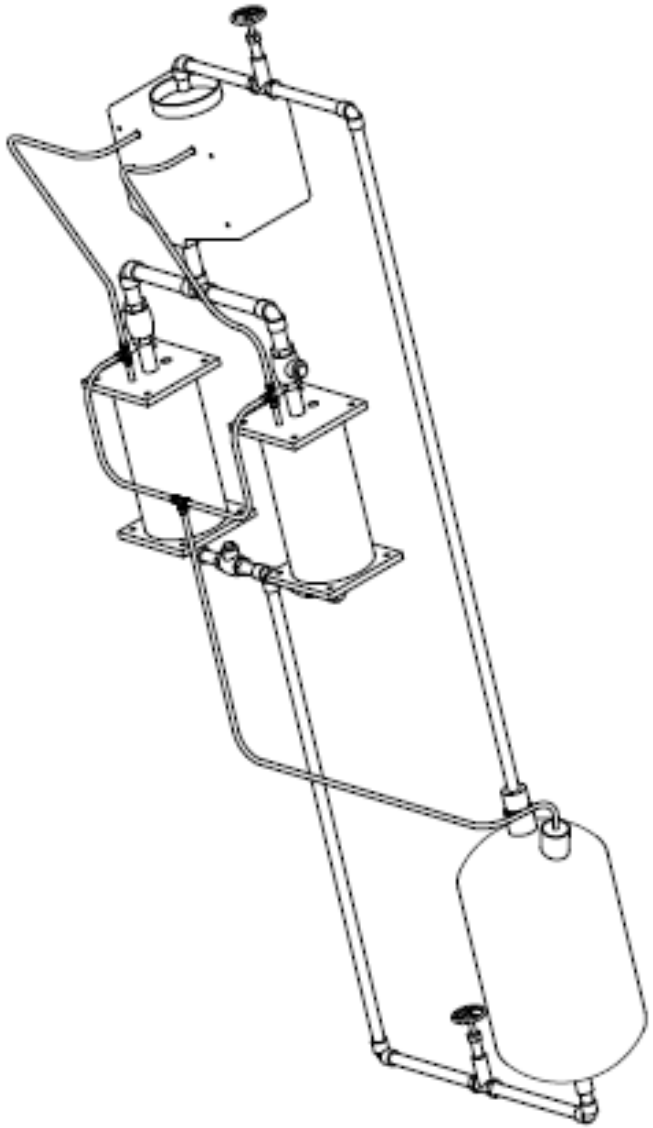
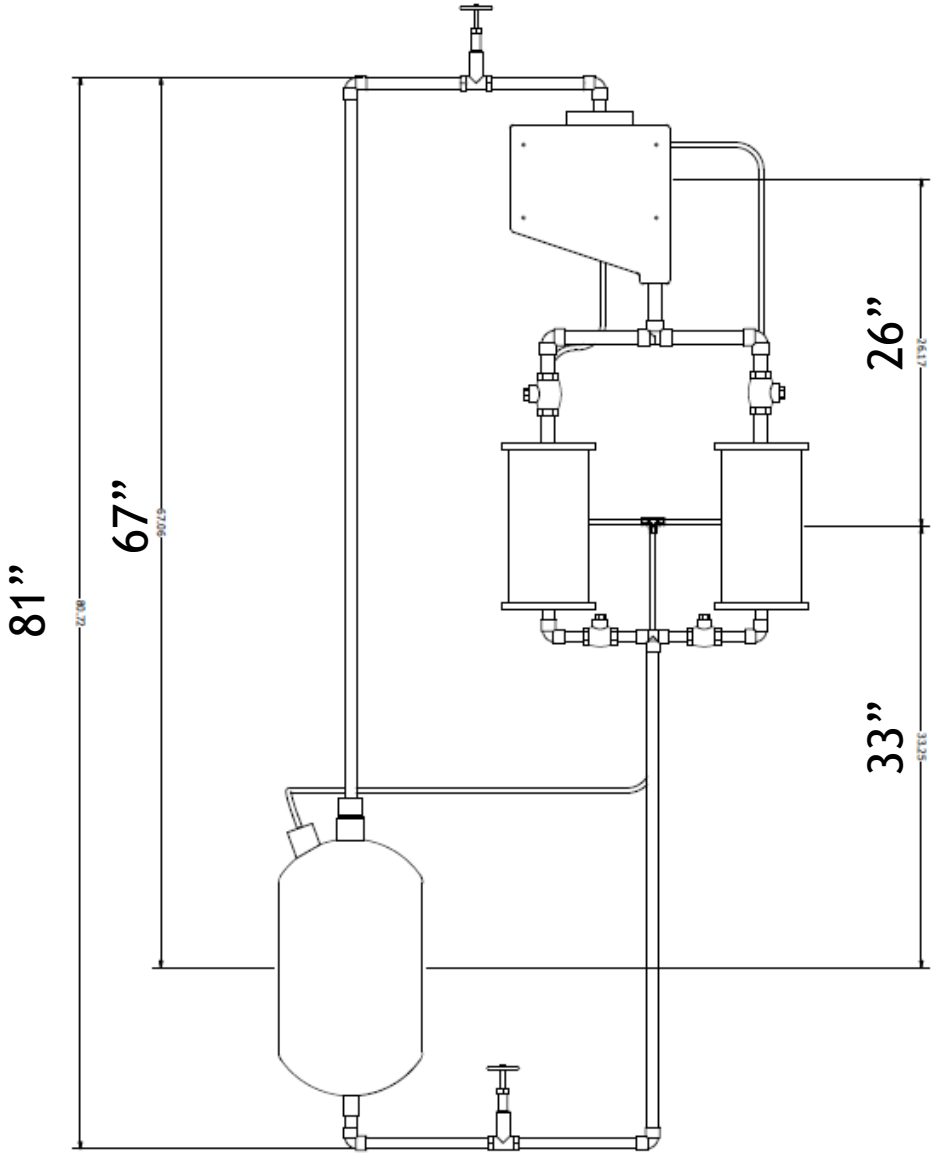
Final Design Concept





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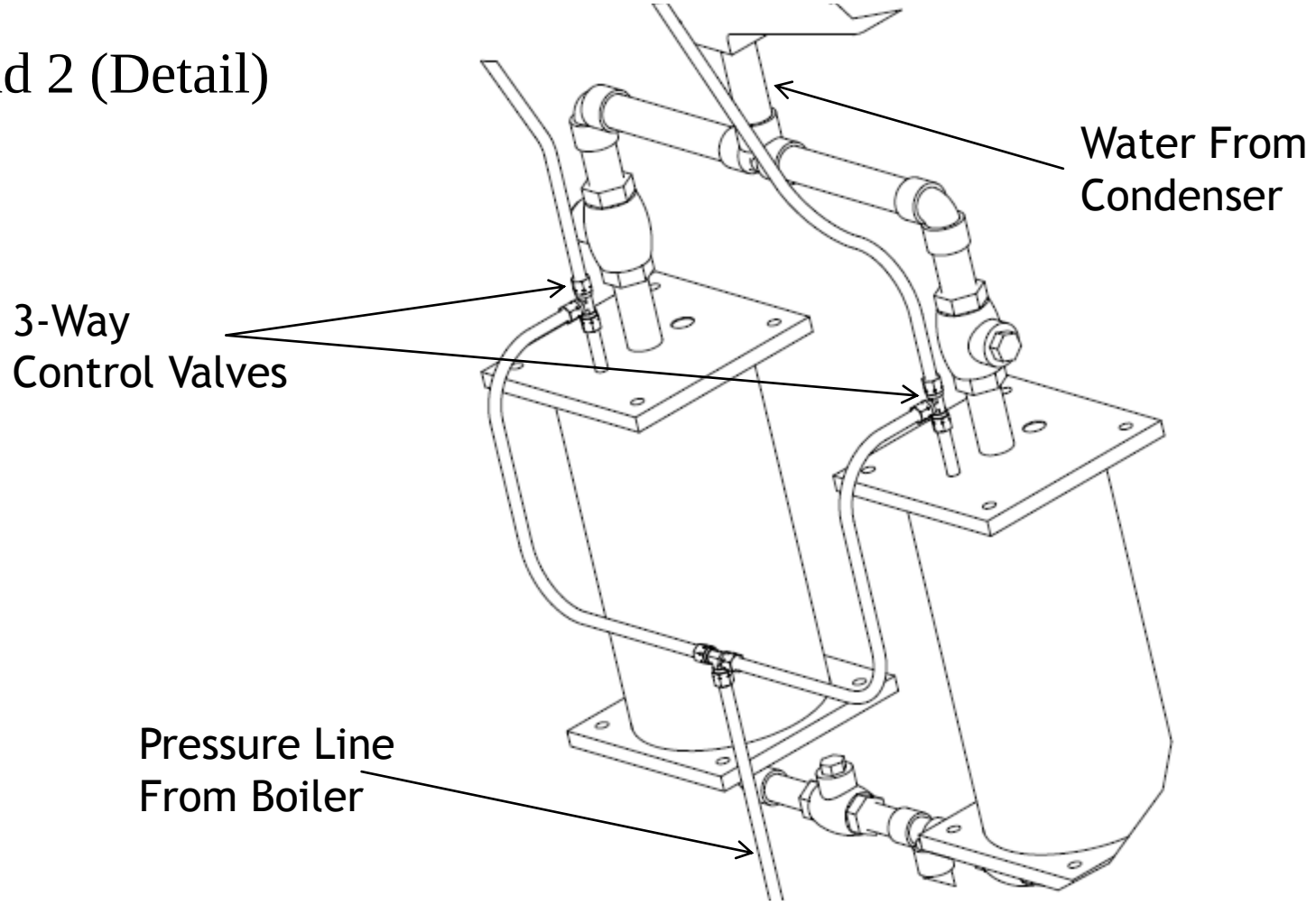
Final Design Concept

- Holding Tanks 1 and 2 (Detail)



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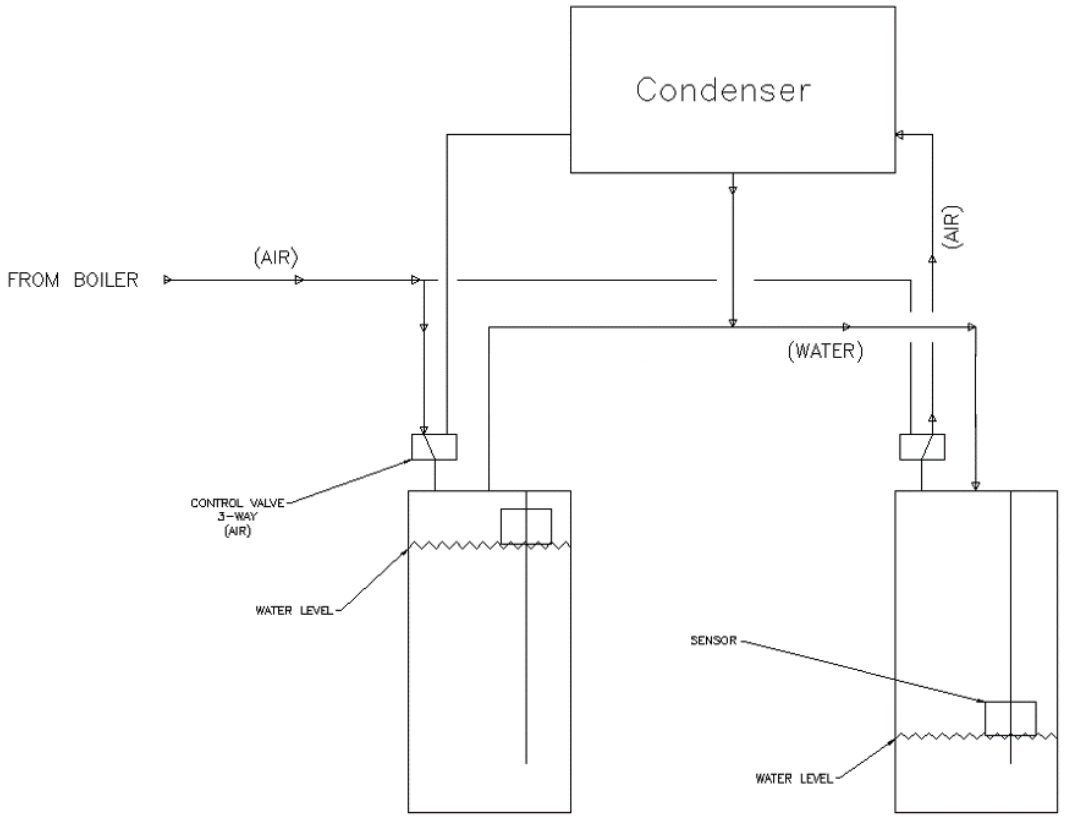
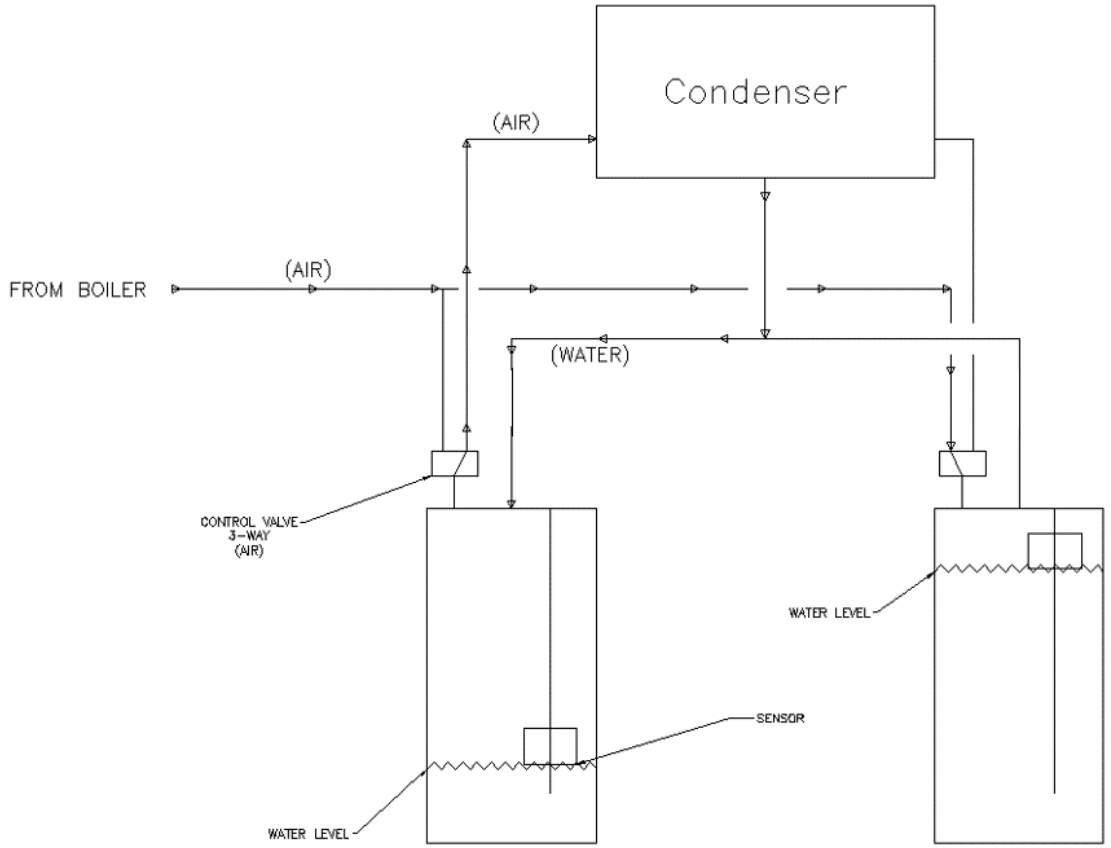
Final Design Concept

- Execution of Holding Tank 1



- Execution of Holding Tank 2



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PIPE-FLO Software Calculations

EngineeredSoftware, Inc.

PIPE-FLO®

Boiler to Condenser

- With an internal pressure in the boiler of 50 psi and using ½” PVC, the flow rate will be 39.04 gpm
- A throttling valve will be used to model the turbo expander and provide the pressure drop and decrease the flow rate to the desired 3 gpm

Condenser to Holding Tanks

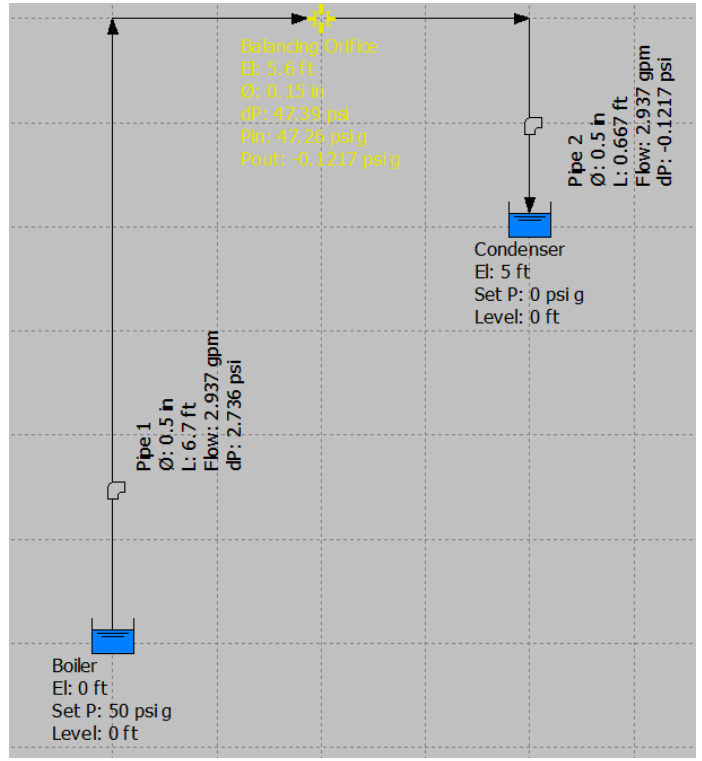
- Using ¾” PVC, gpm (max) = 7.4 gpm

Greater than 3 gpm which is acceptable; Tanks will fill faster than they empty

Holding Tanks to Boiler

- Using ½” PVC, gpm (max) = 4 gpm

Therefore ½” PVC must be used along with a throttling valve to restrict the flow down to 3 gpm



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Major Design Components

- **Condenser**
  - Non-pressurized vessel in our system
  - Holes were drilled into the top and the side of the tank for the insertion of piping
- **Holding Tanks**
  - Pressurized vessel in our system (50 psi)
  - 1 ft. segments of 6 in. polycarbonate tubing were cut
  - 3/4 in. aluminum stock end caps were machined and press fitted to the tubing by 3/8 in. tie rods
- **Boiler**
  - Pressurized vessel in our system (50 psi)
  - Water level tube attached on outside of tank
  - Two caps were machined for the two holes on top of the boiler
  - Bottom of tank was modified to insert ½ in. PVC from holding tanks

Presented by: Samantha Zeidel

Electrical Components

Air Control Valves

- Air: 24VDC Pneumatic Single Solenoid, 3-way, 1/8 in. NPT

Power Supply

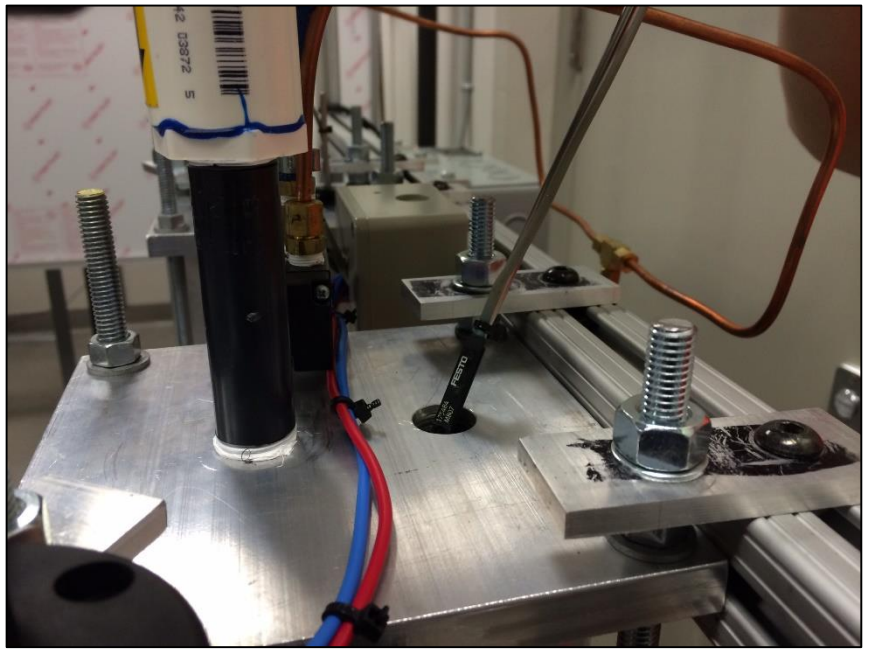
- Siemens 6EP1332-1SH31
- AC 230/120V to DC 24V converter

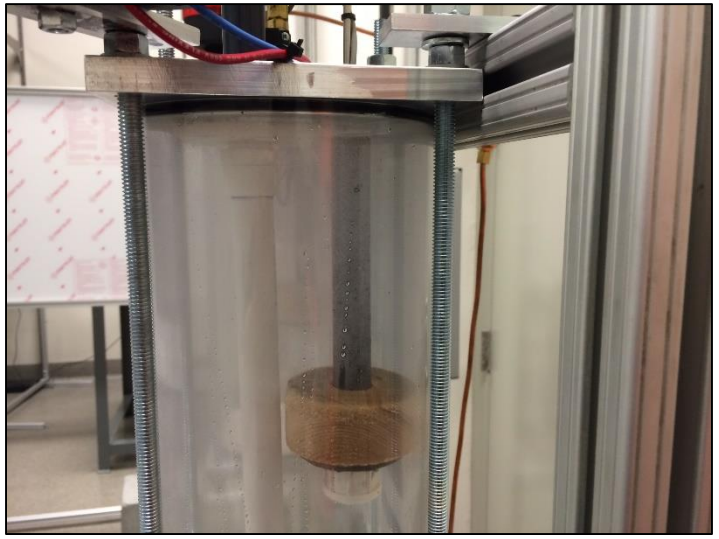
Sensor

- Entirely constructed by the design team; ½ in. PVC pipe
- Outside: Magnet with wood attached to it (floats with water level)
- Inside: Salvaged magnet sensors (24VDC) adjustable to proper heights

Relay

- Purchased from McMaster-Carr
- Voltage: 24 VDC (Voltage for all electrical components)
- No coding required for electrical components





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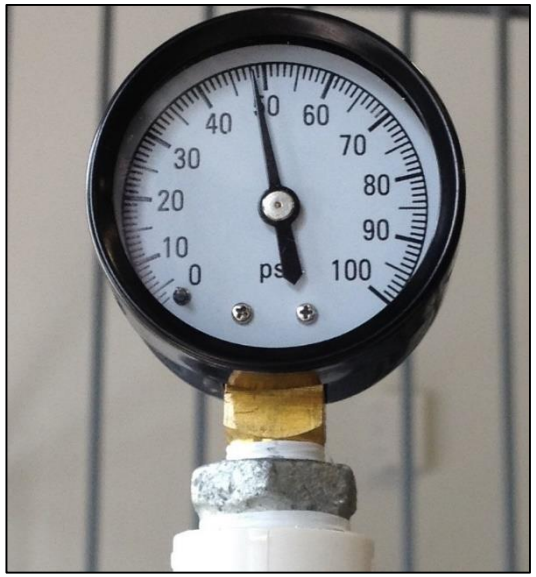
Analytical Components

- **Pressure Gauges**
  - 0-100 psi Pressure Gauges

- **Flow Meter**
  - Orange Research Liquid Variable Flow Meter 0-5 gpm



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Remaining Components

- **Piping**
  - **Water Pipes:** ½ in. and ¾ in. PVC Schedule 40
  - **Pressure Pipes:** 3/16 in. Copper Tubing and ¼ in. Air Hose
  - **The majority of the piping components are threaded to allow for easy modification**

- **Valves**
  - ½ in. and ¾ in. Brass Swing Check Valves
  - ½ in. Plastic Globe Valve (throttling)
  - ½ in. Brass Gate Valves
  - Pressure Relief Valve (65 psi)

- **Pipe Fittings**
  - ½ in. and ¾ in. PVC SCH 40 fittings







Presented by: Samantha Zeidel

Project Procurement

Component	Product Description	Vendor	Total Cost	Status
Boiler	6.25 Gallon Oil Extractor	Harbor Freight Tools	$145.11	Received
Condenser	Ace / DenHartog 3 Gallon Rectangular Specialty Rinse Tank	The Tank Depot (Online)	$54.15	Received
Holding Tanks (Walls)	6” Acrylic Tubing (Walls) Purchased a 6 ft. segment of tube	U.S. Plastics (Online)	$88.20	CHANGED
Control Valve (Air)	Parker Air Control Valve Single Solenoid, 3-way, 2-pos, 1/8” NPT	Global Industrial (Online)	$116.86	Received
Control Valve (Liquid)	Pilot Operated Solenoid Valves 2-way, 2-pos, 3/4” FPT	Zoro Tools (Online)	$99	CHANGED
PVC Piping, Components, and Fittings	PVC Piping: 1/2” and 3/4” Piping Pipe Components: 1/2” Throttle Valves PVC Fittings: Tees, 90° Elbows	The Home Depot	$32.23	Received
PVC Fittings, Pressure Relief	Pipe Components: Plug Valves, PVC Fittings: Male Fittings for PVC	ACE Hardware	$15.00	Received
Flow Meter	Orange Research In-Line 2320 Series Flow Meter, 0-5 GPM	Harbor Freight Tools	$106.00	Received

Presented by: Ryan Laney

Project Procurement

Component	Product Description	Vendor	Total Cost	Status
Air Compressor, Sensors, Outer Frame, Pressure Piping	3.5 Gallon Pancake Air Compressor, Sensors, and Outer Frame from old machines in Verdicorp machine shop	Verdicorp	$0	Received
Holding Tanks (End Caps)	3/4” aluminum stock, O-ring, and threaded rods	Purchased through Verdicorp	$114.52	Received
Holding Tanks (Walls)	Reordered 6” polycarbonate tubing for walls	Purchased through Verdicorp	$61.52	Received
PVC and Copper Components, Pressure Gauges	Additional PVC and Copper components and fittings. 0-100 PSI Pressure Gauges	ACE Hardware, Lowes	$130.56	Received
Relays	24 VDC Relay That’s Stays Switched, Sockets	Purchased through Verdicorp	$43.17	Received
PVC and Copper Components	Additional PVC and Copper components, fittings, and piping.	ACE Hardware	$100	Received

Presented by: Ryan Laney

Financial Analysis

- **Overall Budget: $2000**

- **Expenditure (Purchased Components): $1006.32**
  - Air and Liquid Control Valves: $116.86 ($99)
  - Heat Exchanger: $145.11
  - Condenser: $54.15
  - Holding Tanks (Walls): $61.52 ($88.20)
  - Holding Tanks (End Caps): $114.52
  - Relays: $43.17
  - PVC Piping, PVC Fittings, Standard Valves: $47.23
  - Air Compressor, Sensors, Outer Frame, Pressure Line Piping: $0
  - Flow Meter: $106.00
  - Pressure Gauges, PVC and Copper Components: $130.56
  - Additional PVC and Copper components: $100

- **Total Expenses: $1106.32**
- **Remaining Budget: $893.68**

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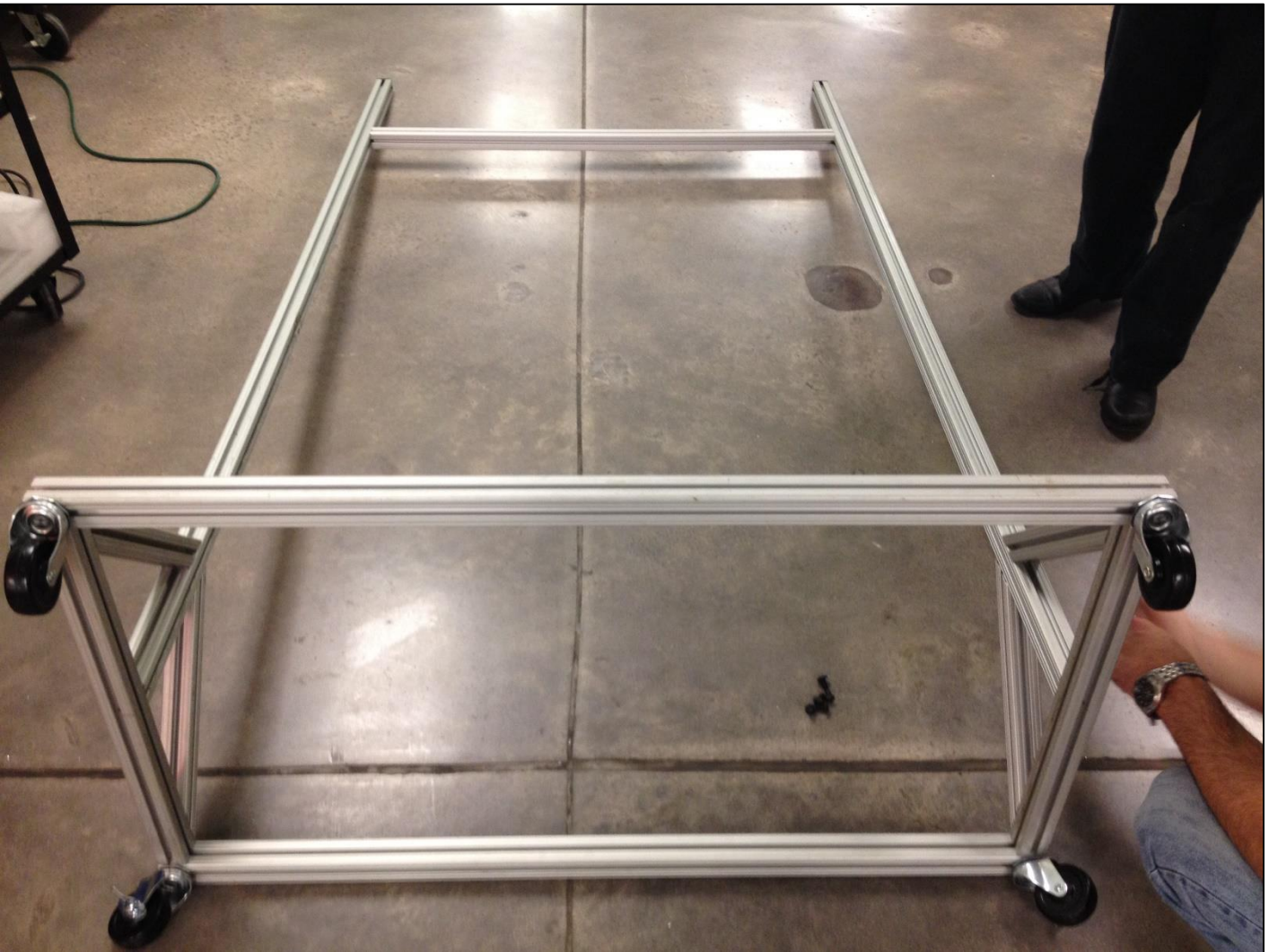
Prototype Construction

Presented by: Ryan Laney



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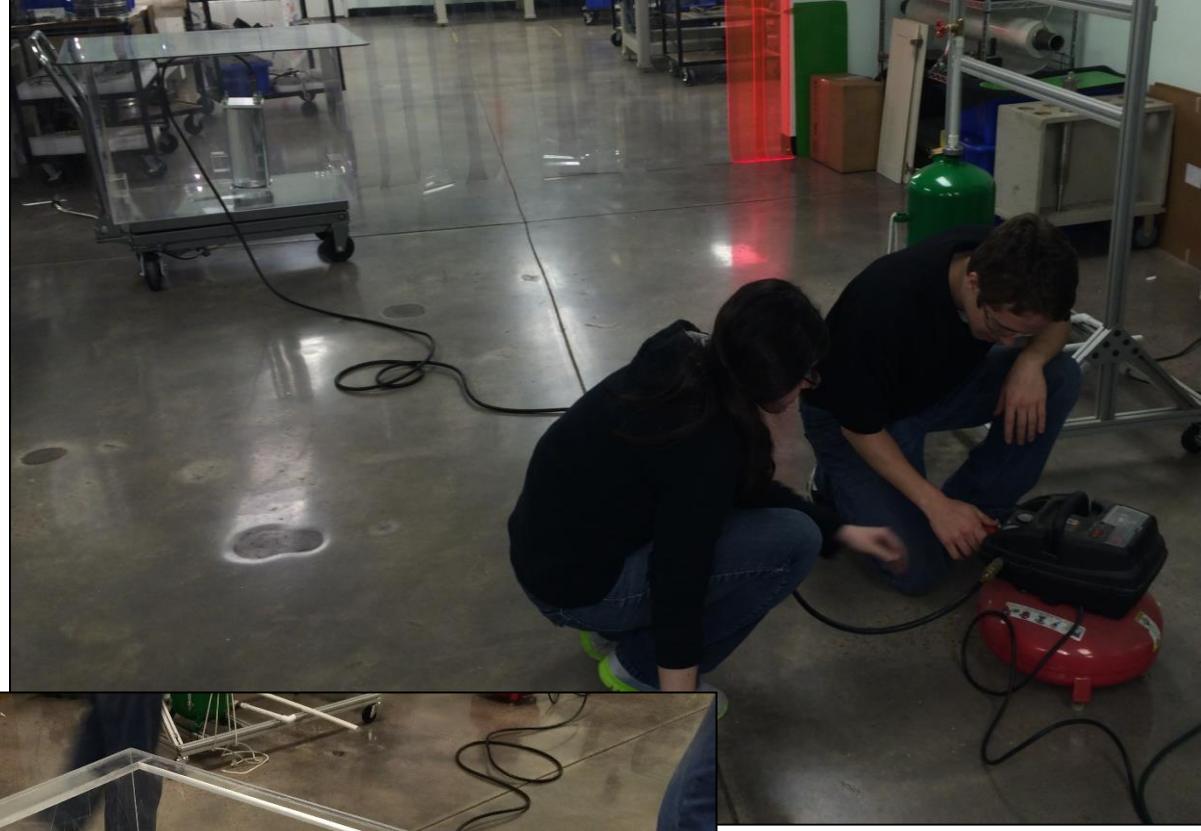

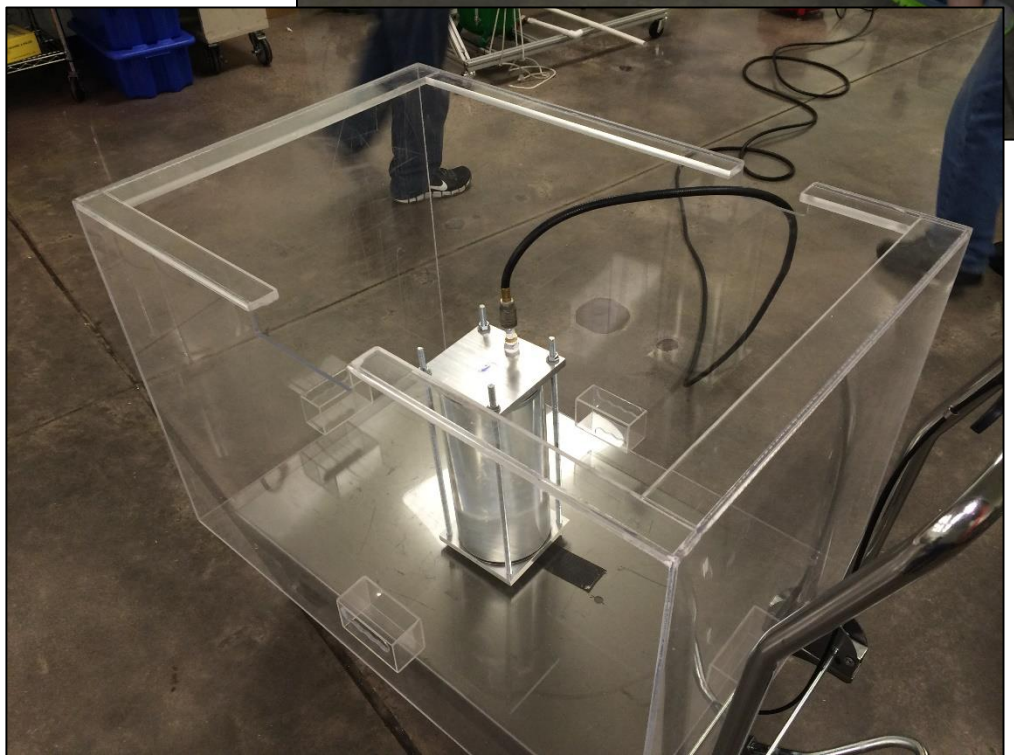

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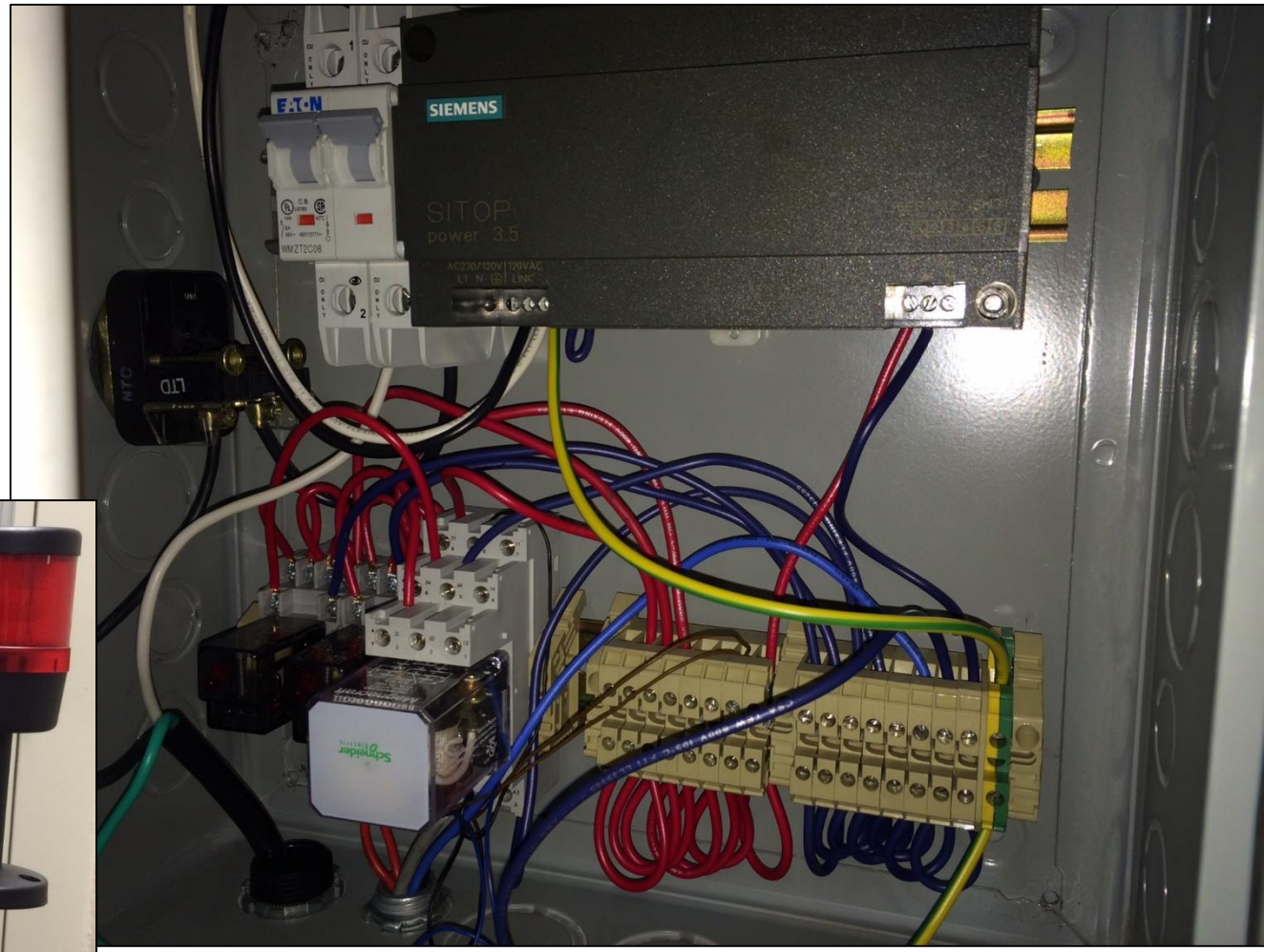

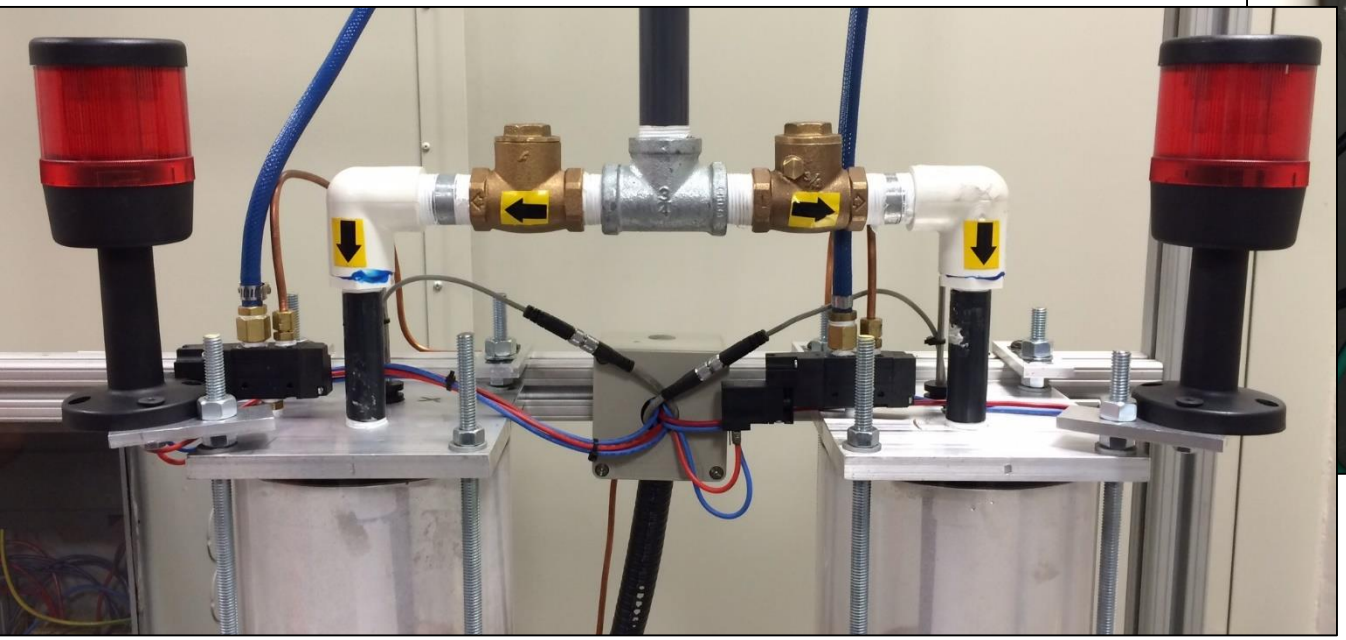

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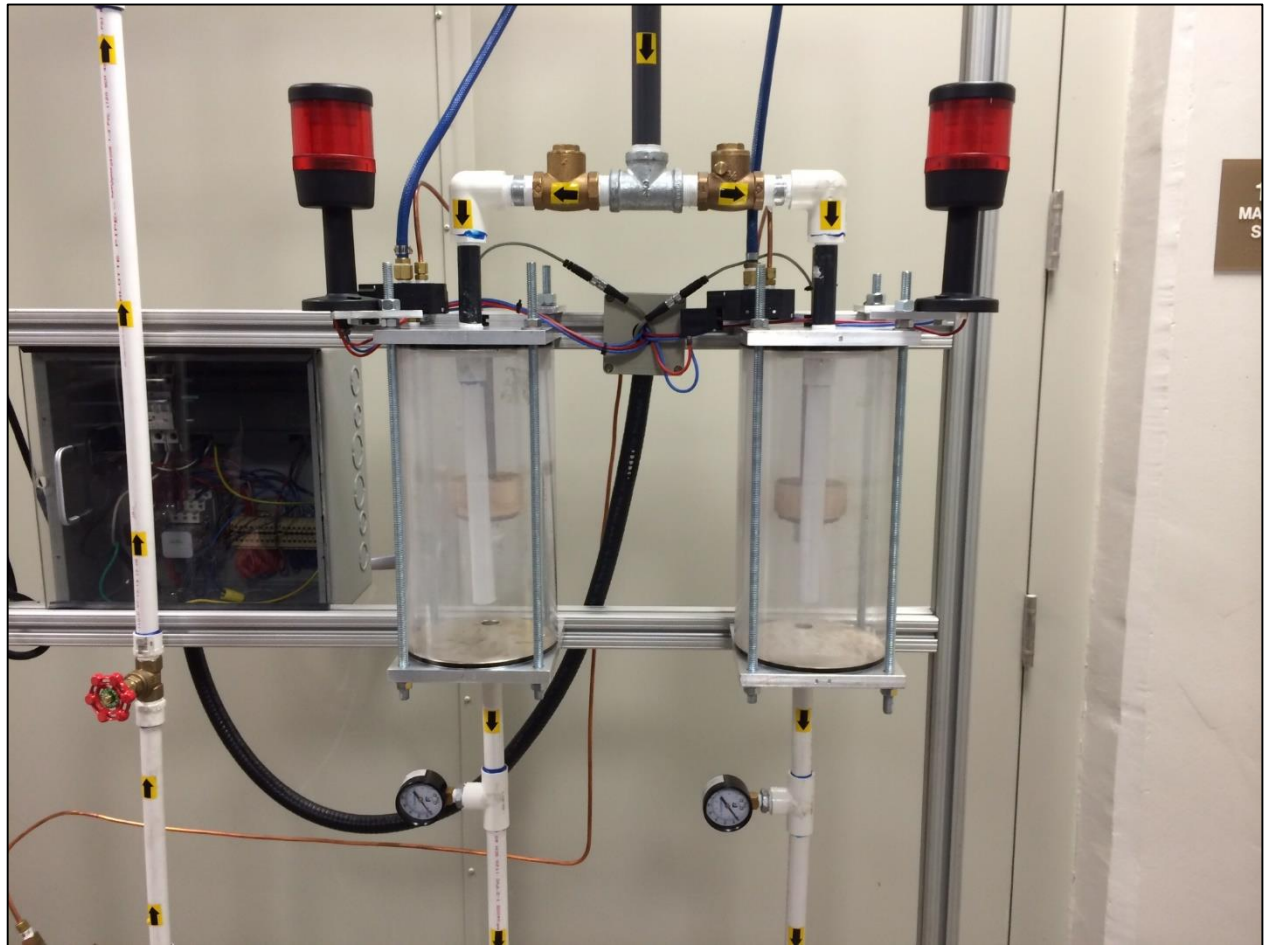
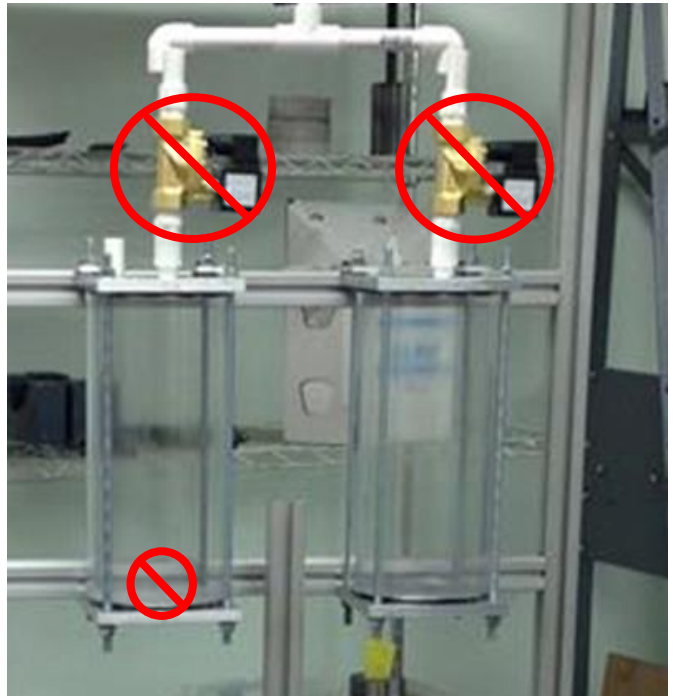


Prototype Challenges

- **Holding Tanks (Walls)**
  - 6 in. acrylic tubing cracked; replaced by 6 in. polycarbonate tubing
- **Liquid Control Valves**
  - Valves wouldn't open because the were diaphragm piloted; required 5 psi.
  - Valve removal led to air leaks into the water piping. Fixed by adding a ½ in. PVC pipe inside the tanks that would remain below the water level.
- **Magnetic Floats for Sensors**
  - The buoyant material attached to the magnet continuously changed from Styrofoam to cork and finally to wood.
  - The pressurizing of the holding tank also compressed and deformed the first two materials attempted. Wood is nearly an incompressible material.



Presented by: Samantha Zeidel

Prototype Testing

Presented by: Billy Ernst

Prototype Results and Analysis

Results

- Achieved a continuous flow rate of 1.5 gpm ✓
- Achieved a pressure differential of 50 psi ✓
- Constructed the prototype using approximately half of the allocated budget ($1106.32) ✓
- Proved the overall theory that by using solenoid valves and the aid of gravity, fluid can be transferred from the low pressure side to the high pressure side of the system without the use of a centrifugal pump ✓

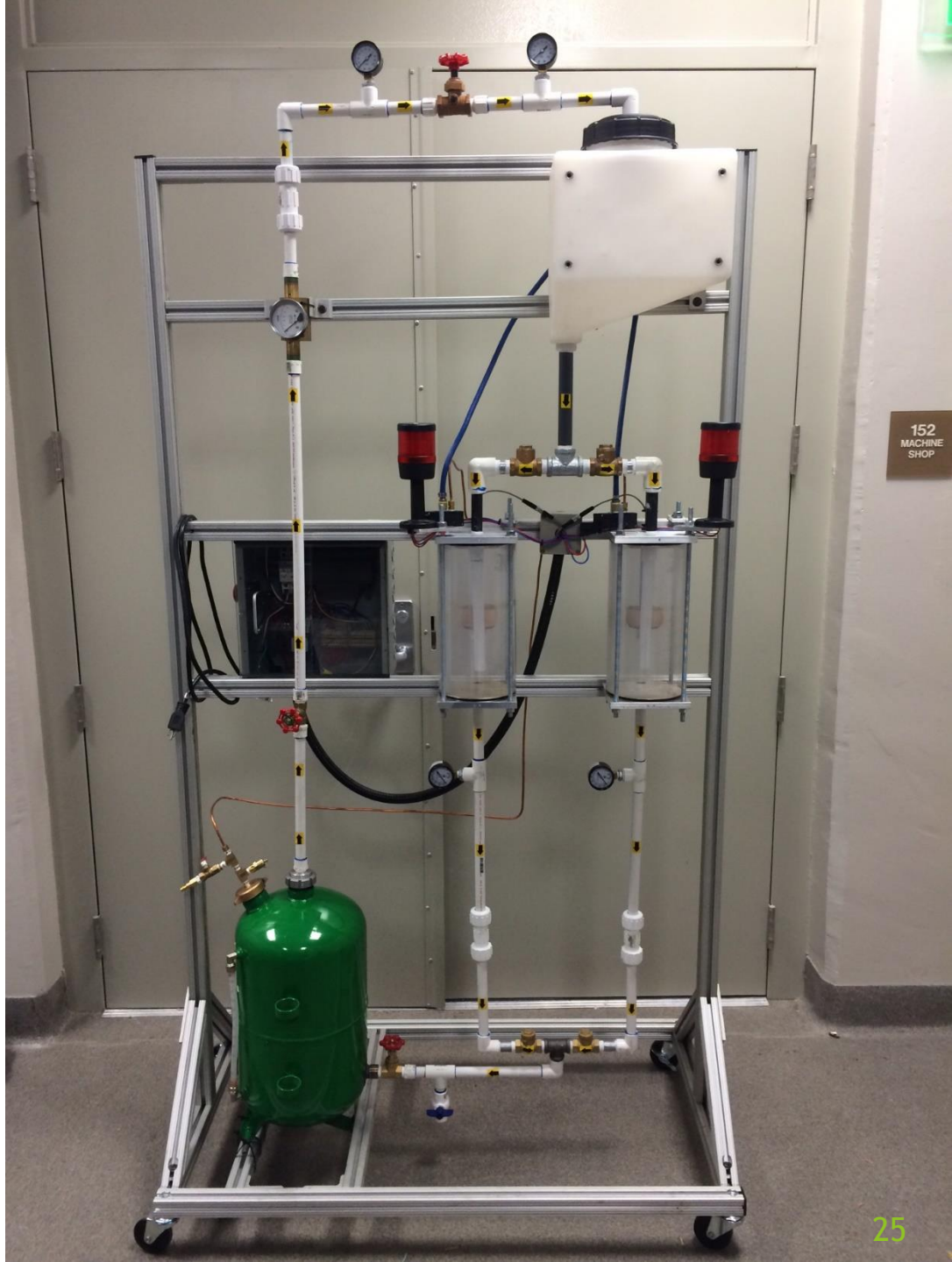
Prototype Modifications

- To achieve the desired flow rate of 3 gpm, the ½” PVC piping segment from the holding tanks to the boiler needs to be increased to ¾” PVC ✓

Presented by: Ryan Laney

Future Work

- **In depth calculations**
  - Refrigerant 245fa
  - Operating temperatures and pressures
  - Increase or decrease in efficiency
  - Cost effectiveness of using a larger-scale version of the prototype in place of the pump



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Acknowledgements

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COLLEGE OF ENGINEERING 1982

Dr. Chiang Shih

Dr. Kamal Amin

Presented by: Ryan Laney

Questions, Comments, or Advice?