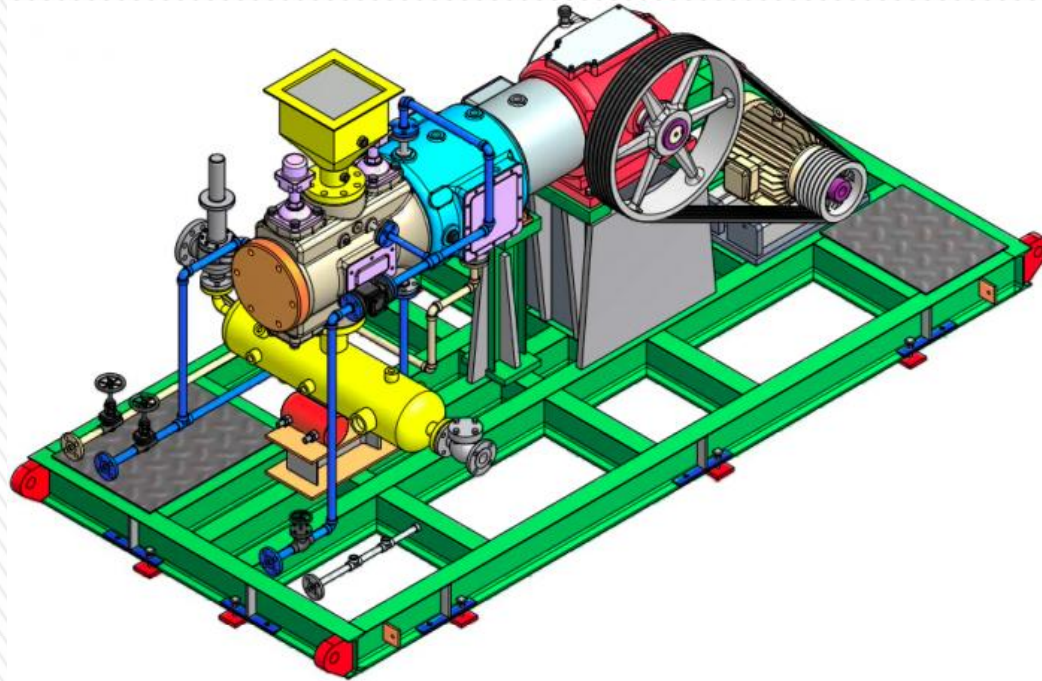


Reciprocating Compressor Installation and Validation



- John Blamer – Team Leader
- Promit Bagchi
- Elliot Kendall
- Matthias Purvis

MSD I - 11452

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» Agenda

- **Finalized Designs:**
 - Customer Needs
 - Compressor Mounting
 - Cooling System
 - Data Acquisition
 - T-zero & “Life” Test Plans
 - Labs
 - Bill of Materials

- **Arrival Task Plan**
 - Risk Mitigation (Plan A, B, and C)
 - MSD II Schedule
 - Delivery Check List
 - Power Up Check List
 - Complete Installation Checklist

- **Post Delivery**
 - Maintenance Hints
 - Safety Recommendations

» Finalized Design - Customer Needs

Stakeholders

Stakeholder Groups	Representative Stakeholders	Raw Data from Stakeholder Interactions
Faculty Researchers	Dr. Kolodziej	Interview with Dr. Kolodziej - Sept. 17th, 2010
RIT Faculty	Dr. Lam, Dr. Ogut, Mr. Wellin, Dr. Day	Wellin Interview - Sept. 23rd, 2010 Dr. Lam Interview - October 7th 2010
Corporate Sponsors	Dresser-Rand, Lord Corp.	Interview with Dresser-Rand - Sept. 24th 2010
KGCOE Department Heads	Dr. Edward Hensel (ME)	Interview with Dr. Hensel

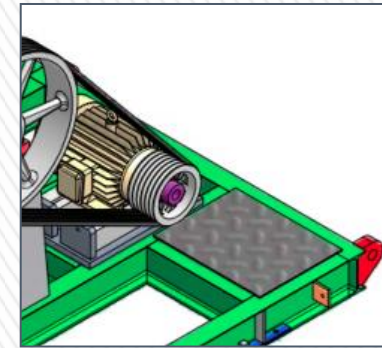
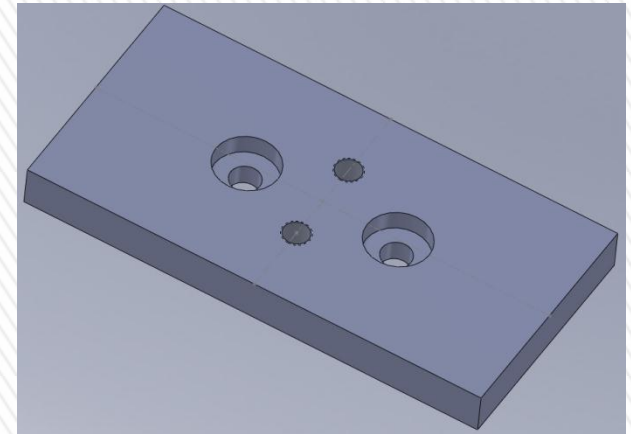
Needs Summary

CN #	Need	Customer	Importance
CN1	Get compressor fully operational by the end of SD1	Dr. Kolodziej	9
CN2	Create simple easy-to-use guide	Dr. Kolodziej, Dr. Hensel	3
CN3	Begining of life characterization of compressor performance for diagnostic research	Dr. Kolodziej, Dresser Rand	9
CN4	Compare baseline data to provided specifications	Dr. Kolodziej	9
CN5	Clean, organized, and professional looking room	Dr. Kolodziej	1
CN6	Implement Existing DAQ system	Dr. Hensel, Dr. Kolodziej	9
CN7	Safety	All	9
CN8	Educational: Labs (Vibrations and Thermodynamics)	Dr. Hensel	9

» Finalized Design - Mounting

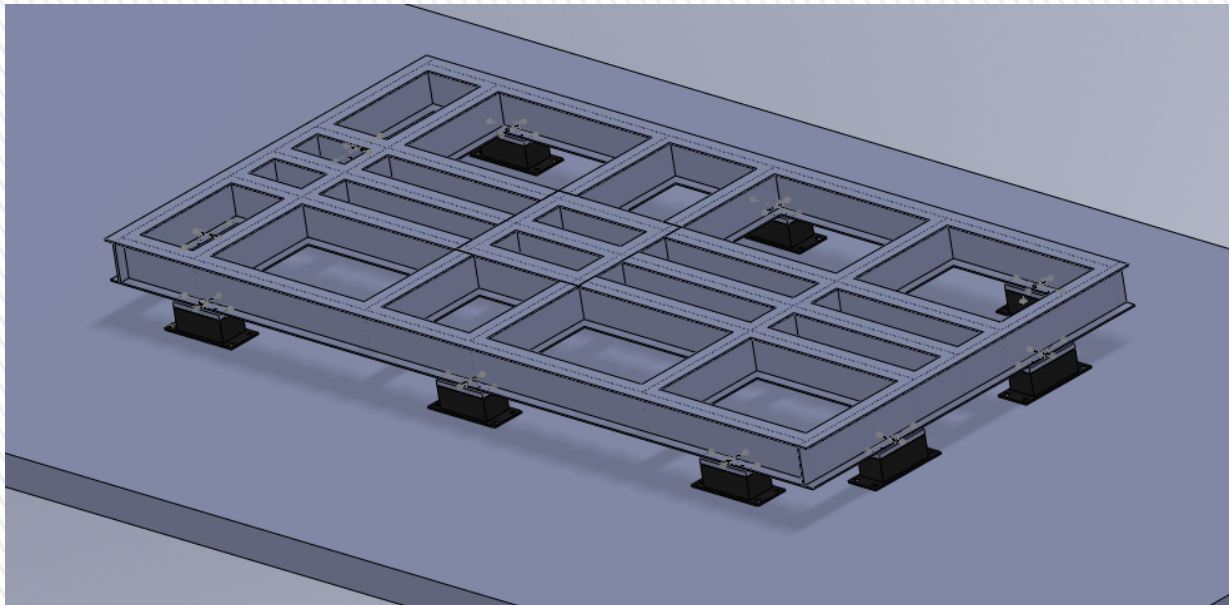
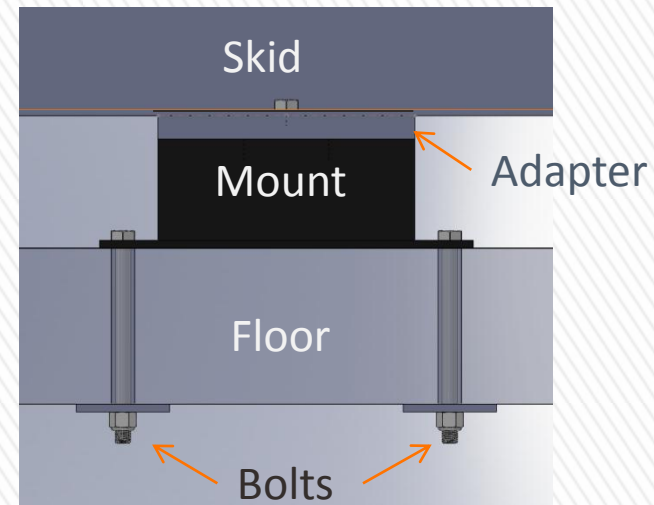
- Attaching vibration mounts → skid
 - Adapter plate
 - Method of attachment
 - Welding, bolts, clamps
 - Access to inner I-beam flange

- Attaching vibration mounts → floor
 - Bolts through floor
 - Epoxy
 - Concrete anchors
 - Combination

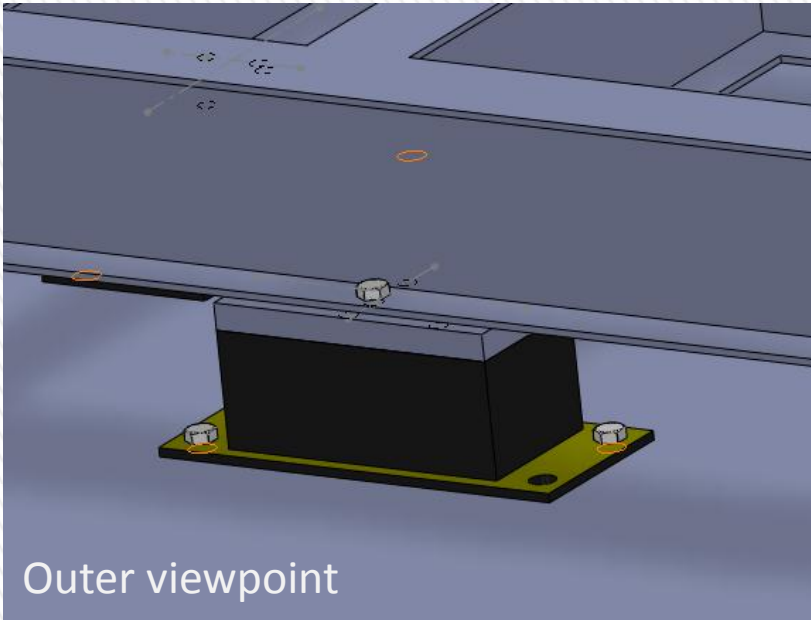


» Finalized Design - Mounting - Selected Mounting Method

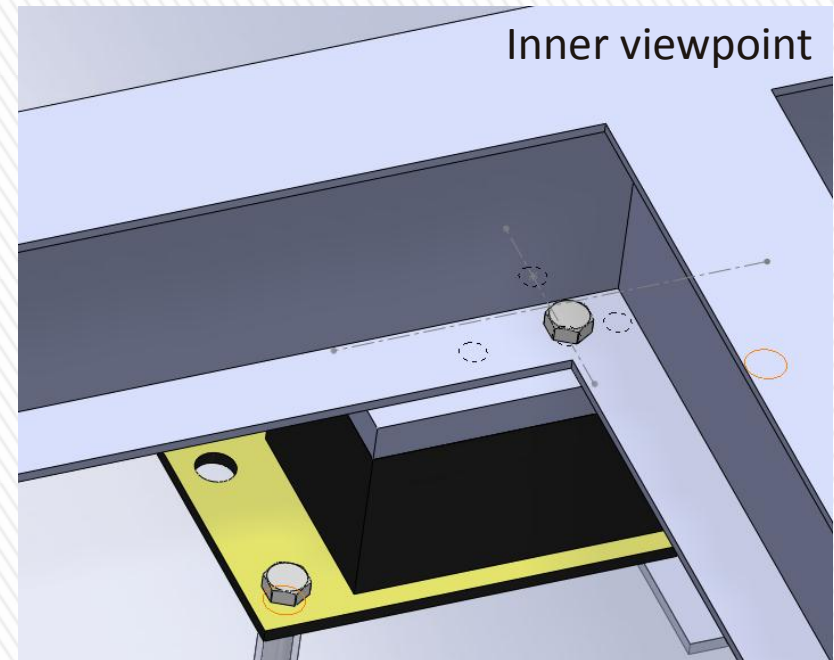
- Steel adapter plates
 - Counter-bored bolts → vibration mount
 - Threaded holes → I-beam flange
- Attaching mounts to floor
 - Two bolts per mount
 - Bolt through floor slab



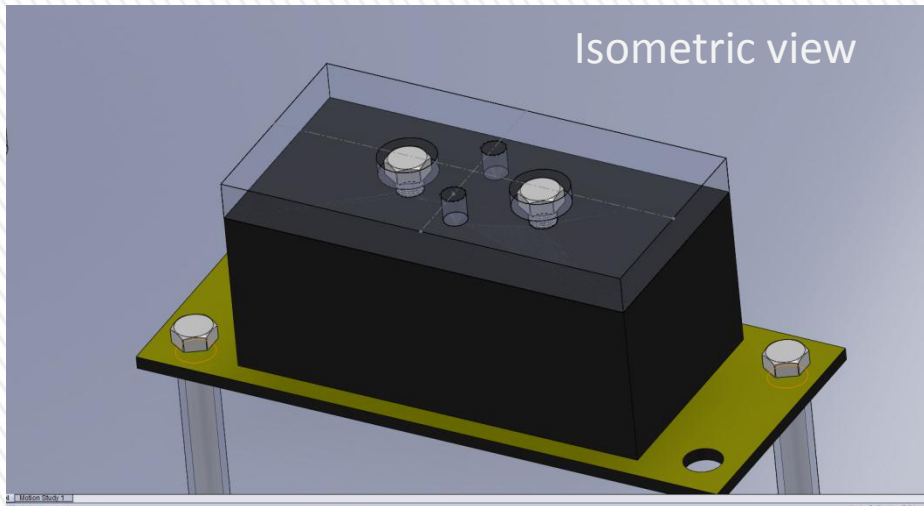
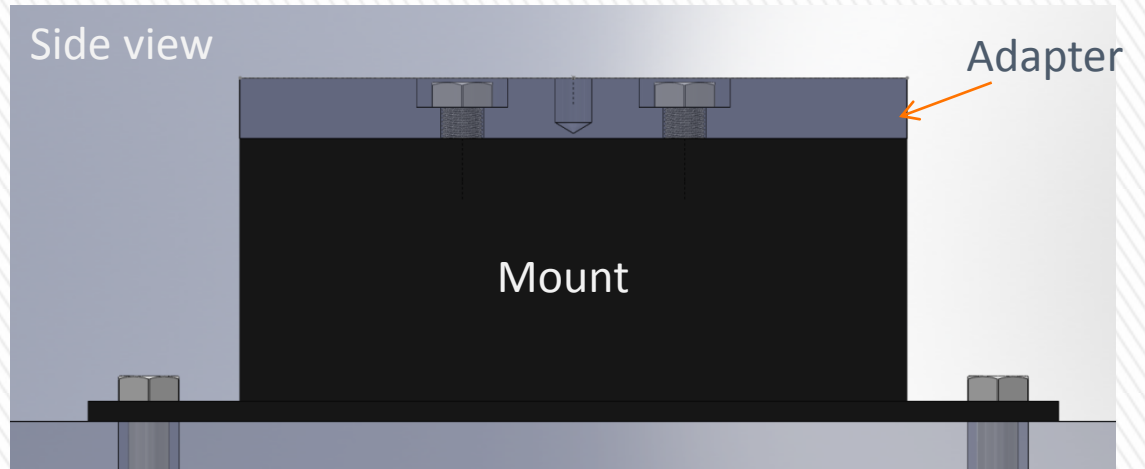
» Finalized Design - Mounting - Adapter Plates



- $\frac{1}{2}$ -20 x $\frac{3}{4}$ " Grade 8 Bolts
 - 4 per mount
 - 4 x 10 mounts = 40 bolts
- 40 Washers

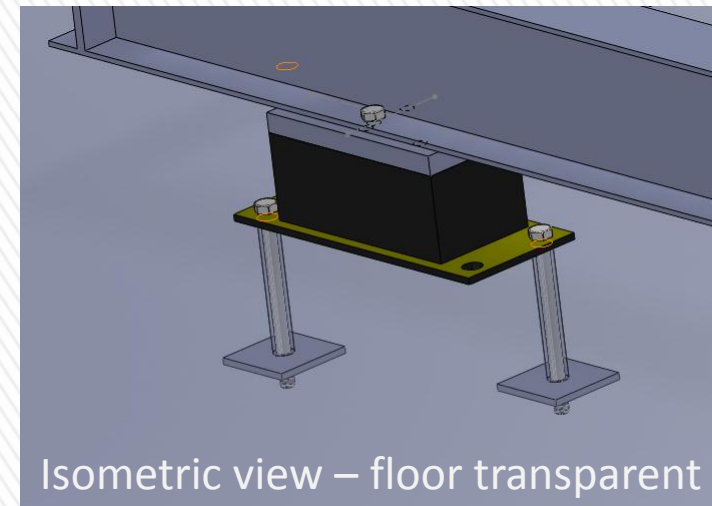
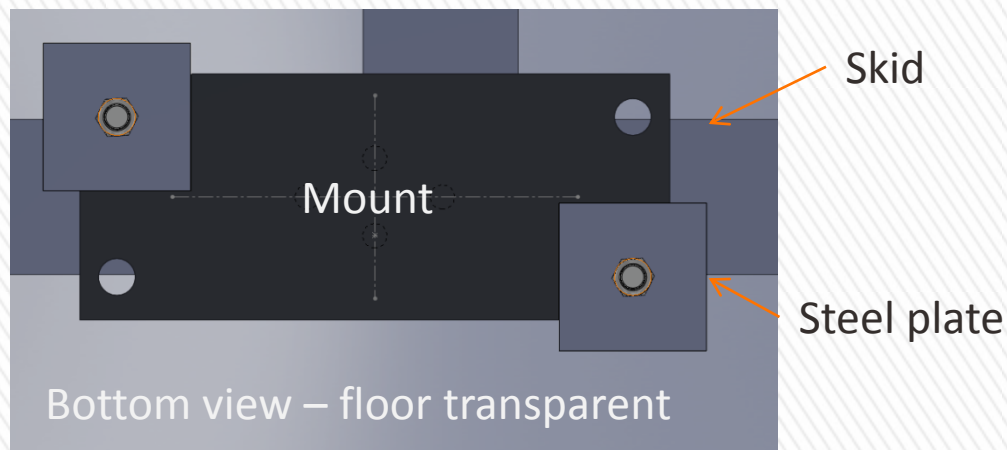
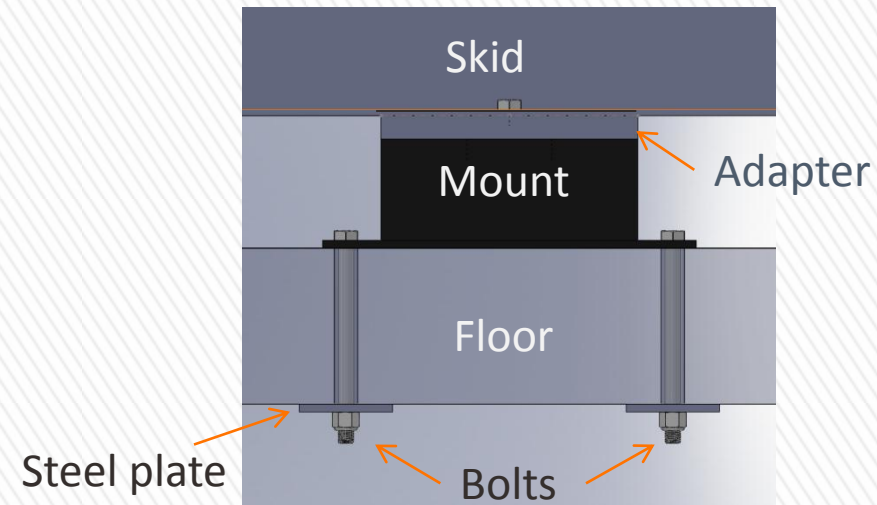


» Finalized Design - Mounting - Adapter Plates cont.



» Finalized Design - Mounting – Bolting to floor

- ½-20 x 6.5” bolts
- 2 Bolts per mount
 - 2 x 10 mounts = 20 bolts
- 20 Washers, 20 locknuts
- 5/8” – ¾” holes drilled in floor



» Finalized Design - Cooling System – Development Process

- Construct new cooling system
 - High head - multi stage - Industrial Booster Pump
 - Spa pump
 - Multi-stage centrifugal pump
 - Time consuming, expensive
- Utilize Mr. Wellin's existing system
 - Insufficient head
 - Replace electric motor, 2X RPM
 - Reusing existing Dept. materials
 - Saving money



High Head – multi stage pump



Spa pump



Multi-stage centrifugal pump



Wellin's pump system



Construction Process

Acquire Components:

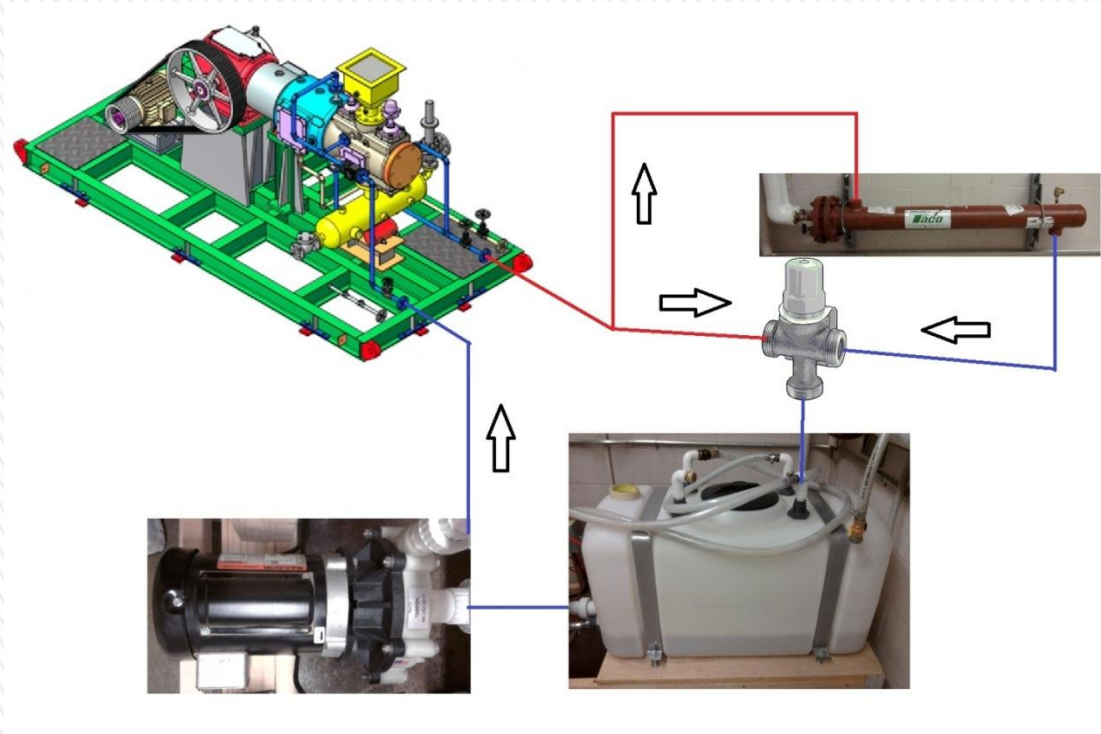
- Pump
- Tubing
- Fittings
 - Barbed connectors
 - Flange adapters
- Mixing valve
- Wood for frame
- Bolts
- Wheels
- Tank
- Flow meter

Construct Cooling Unit:

- Construct frame
- Bolt compressor and tank to frame
- Attach tubing, control valve, and flow meter
- Attach to compressor

» Finalized Design - Cooling System – System Diagram

- » Pump - .33 hp, 3450 RPM, 92 psi
- » Mixing Valve - 70° to 100°F thermostatic valve
- » Tank - 50 gallon Polyethylene tank



Calibration and Testing

- ❑ Initial flow rate Adjustment:
 - ❑ Start coolant circulation pump and read flow rate from flow meter.
 - ❑ Adjust flow control valve to achieve a flow of 4 gpm.

- ❑ Temperature Calibration:
 - ❑ Measure mixing valve output temperature with thermocouple and data logger or thermometer.
 - ❑ Adjust mixing valve to produce an output temperature of 80° F
 - ❑ Use a thermocouple and data logger to record mixing valve output temperature from cold startup to steady state operation to verify accurate operation.

» Finalized Design - Data Acquisition System - Details

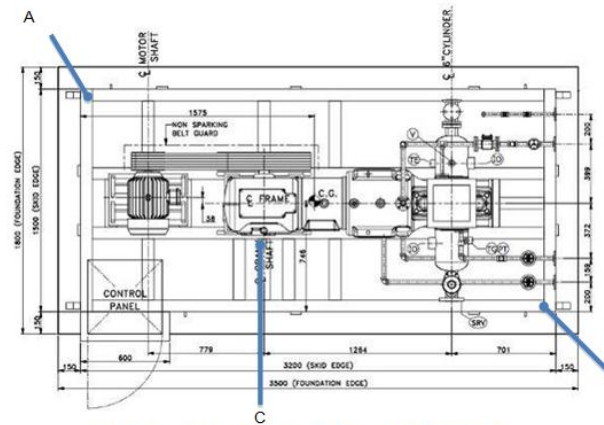


Figure 6 - Top view Schematic of Dresser-Rand Compressor

Position	Sensor	Model #	Mounting
A	X-axis Accelerometer	PCB 623C00	Stud/Magnetic Mount
C	Z-axis Accelerometer	PCB 623C00	Stud/Magnetic Mount
D	Y-axis Accelerometer	PCB 623C00	Stud/Magnetic Mount

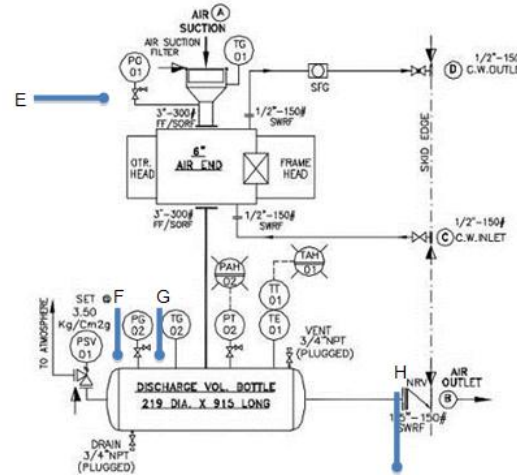
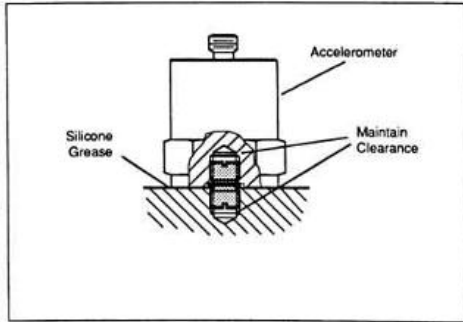


Figure 7 - Air and Cooling Water Schematic

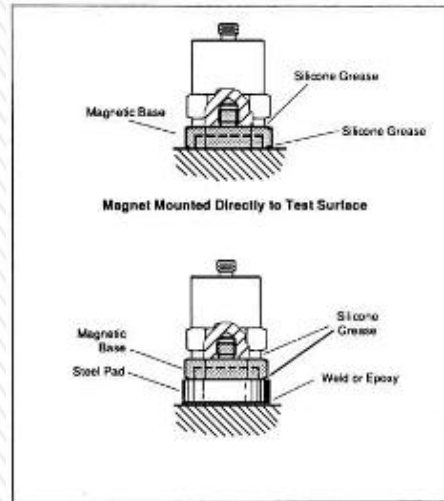
Position	Sensor	Model #	Mounting
E	Inlet Air Pressure	PCB 101A05	Stud Mount
F	Tank Air Pressure	PCB 102A21	Bore Hole
G	Tank Air Temperature	Omega RTD-NPT-72-E-DUAL-MTP	Bore Hole
H	Outlet Air Temperature	Omega RTD-805	Adhesive Mount
H	Air flow meter	Omega FTB-936	Pipe Fitting



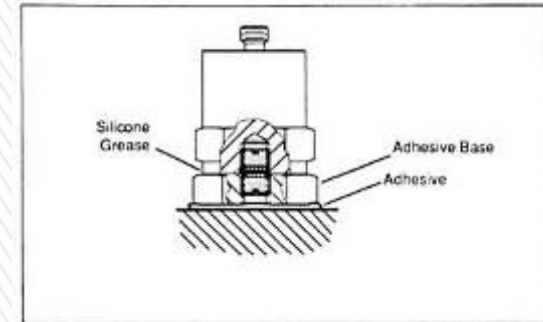
» Finalized Design - Data Acquisition System - Details



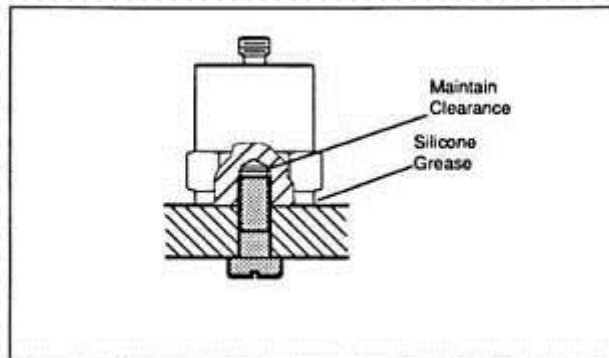
Stud Mount



Magnetic Mount



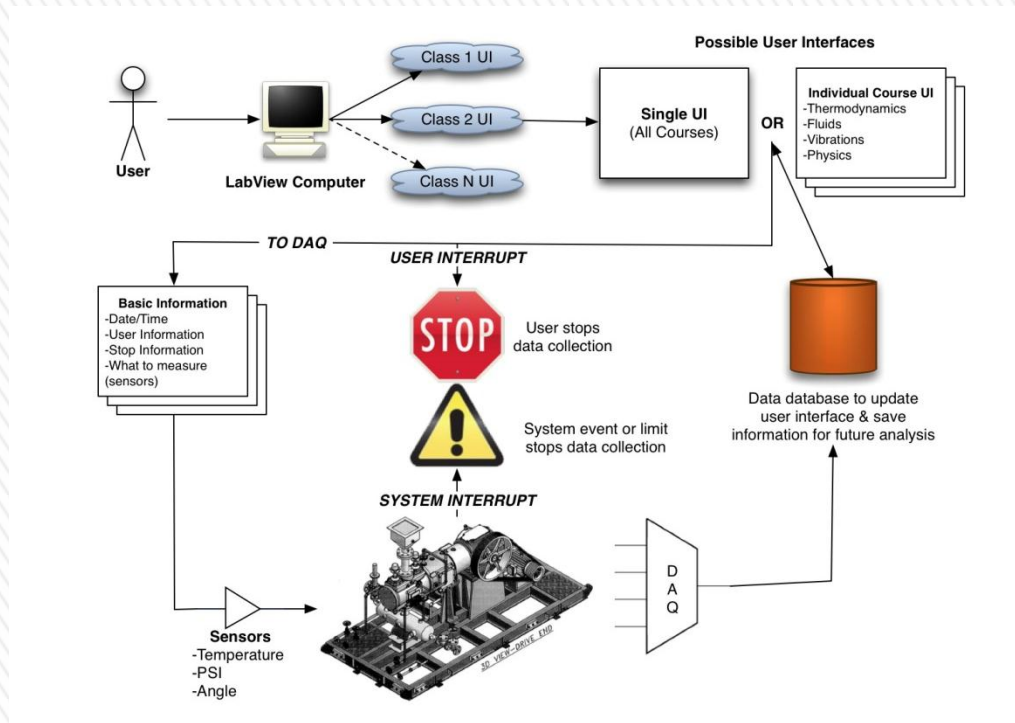
Adhesive Mount



Screw Mount

Adhesives	Mounting Surface Condition		Temperature		Availability	
	Flat & Smooth Surfaces	Rough Surfaces (Casting, etc.)	Room Temp. Only	Elevated Temp. (see Mtg. Spec.)	Commercial	PCB Piezotronics (request sample)
TEMPORARY/EASILY REMOVED						
Petro Wax	•	•	•			•
Bee's Wax	•	•	•		•	
Duct Putty	•	•	•		•	
Two-sided Sticky Tape	•	•	•		•	
SEMI-PERMANENT/PERMANENT						
Super Glue (Thin one part quick dry)						
Loctite® 403 Super Bonder	•			-65°F to +175°F	•	•
Eastman 910	•			-65°F to +180°F	•	
Super Glue-Gap Filling (thick liquid & gel)						
Powr RX-50 "Gel"		•		-114°F to +180°F	•	•
Loctite® 488 Super Bonder		•		-40°F to +223°F	•	
Loctite® 422 "Gap Filling"		•		-65°F to +175°F	•	
Hot Glue (apply with hot glue gun)	•	•		Various Grades from +150°F	•	
PERMANENT						
Two Part Std Commercial Epoxies	•	•		to +250°F	•	
Loctite® 325 Speed Bonder	•	•		-65°F to +350°F	•	

» Finalized Design - Data Acquisition System



- Research sensor's listed from P09452.
 - Make sure that the sensor's do not exceed the 8 analog input slots in the existing DAQ system.
- Install the existing DAQ system onto the LabView Computer
- Run and secure all cabling to sensors/signal conditioners to the LabView computer.
- On the Labview computer, configure the LabView Compressor Project to accept all the sensors. All the random number generators will have to be replaced, and all the sensors will need to be calibrated.
- Test the DAQ to ensure it is measuring the correct information.

» Post Delivery - T-zero and “life” Test Plans

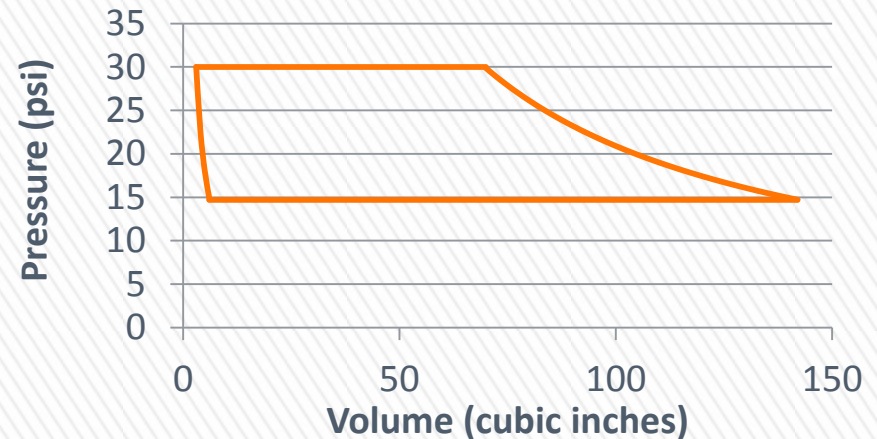
- Turn on computer and DAQ System.
- Turn on compressor
- Wait for the compressor to reach operating temp.
- Measure each parameter at least 3 times.
 - Flow at discharge
 - Temperature at discharge
 - Pressure at discharge
 - Transmissibility
- Take an average of each parameter.
- Calculate BHP.
- Record averages and plot results.
 - Beginning of life characterization of compressor performance data - complete
- Compare with Dresser Rand’s Specifications.
 - Calculate percent difference between P11452’s experimental results and given specifications.
 - Validation of specifications - complete
- Give results to Dr. Kolodziej
 - Dr. Kolodziej may start his research

» Finalized Design - Labs

Thermodynamics

- Lab procedure:
 - Become familiar with safety procedures
 - Run compressor for 5 minutes
 - Record data with LabView interface
 - Plot data in Excel
- Tasks:
 - Create theoretical P-V diagram
 - Compare experimental data to theoretical
 - What are possible sources of error
 - Calculate compressor efficiency
 - Identify sources of inefficiency
- Improvements:
 - New P-V diagram

P-V Diagram (Outer Side Cylinder)



Vibrations Lab – Needs to be completely re-evaluated

- A new ANSYS model needs to be fabricated
- Might be converted into a homework instead
- Will be determined in SD2

» Finalized Design - Bill of Materials

Bill of Materials

	Part Name	Material	Manufacturer	Manufacturer Part #	Distributor	Distributor Part #	Quantity Needed	Unit MFG Time (hrs)	Total MFG Time (hrs)	Quantity Ordered	Unit Price	Total Price	Lead Time	Owner	Status	Comments
Cooling System	Coolant Circulation Pump Motor		Baldor	JL3405A	Baldor	JL3405A	1	0	0	1	\$263.00	\$ 263.00	1 wk	Elliot	arrived	
	Barbed Tubing Fittings	copper			Home Depot		2	0	0				0	Elliot		
	Mixing Valve	Bronze	Honeywell	AM-101	McMaster-Carr	9156K12	1	0	0	1	\$107.12	\$ 107.12	1 wk	Elliot	arrived	
	Flange Connectors	Forged Steel	McMaster-	68095K122	McMaster-Carr	68095K122	2	0	0	2	\$15.27	\$ 30.54	1 wk	Elliot	arrived	
Safety	Signs													Matt		
	Glasses													Matt		
	Ear Plugs													Matt		
Mounting	Steel for Adapters	3/4" Hot Rolled	Rochester Steel		Rochester Steel		2			2	\$79.67	\$ 159.34	2 days	Promit	arrived	
	Nuts (floor to mount)				McMaster-Carr	90630A160								Promit		
	Bolts (floor to mount)				McMaster-Carr	91257A490								Promit		
	Nuts				McMaster-Carr									Promit		
	Bolts				McMaster-Carr									Promit		
DAQ	X-axis Accelerometer			PCB 623C00										John		
	Y-axis Accelerometer			PCB 623C00										John		
	Z-axis Accelerometer			PCB 623C00										John		
	Inlet Air Pressure			PCB 101A05										John		
	Tank Air Pressure			PCB 102A21										John		
	Tank Air Temperature			Omega RTD-NPT-72-E Dual-MTP										John		
	Outlet Air Temperature			Omega RTD-805										John		
	Air Flow Meter			Omega FTB-936										John		
Misc	Tool Chest													All		
	Boulter Services													All		

Legend

	Ordered
	Ready to order
	Do not know all info.

» **Arrival Task Plan** - Risk Mitigation (Plan A, B & C)

~~Plan A – Compressor Arrives in Fall Quarter~~

Plan B – Compressor Arrives in Winter Quarter

~~Plan C – Compressor Does Not Arrive~~

» Post Delivery – MSD II Schedule

	A	B	C	CF	CG	CH	CI	CJ	CK	CL	CM	CN	CO	CP	CQ	CR	CS	CT	CU	CV	CW
1	KEY																				
2		Task Complete																			
3		Goal Date to Complete																			
4		Final Due date																			
5		In Process																			
6		Date of most recent update																			
7		Main Task	Detailed Tasks	Week 1				Week 2						Week 3							
8				1-Dec	2-Dec	3-Dec	4-Dec	5-Dec	6-Dec	7-Dec	8-Dec	9-Dec	10-Dec	11-Dec	12-Dec	13-Dec	14-Dec	15-Dec	16-Dec	17-Dec	18-Dec
20			Contact Boulter: Explain delivery procedures																		
21			Schedule delivery date & time																		
34			Flow control valve																		
35			Misc																		
36		5 Electricity																			
37			Contact Electrician: Schedule/Verify Date and Time																		
38			Install E-Stops (3)																		
39		6 Hardware																			
40			Research/ calculate proper bolt grade																		
41			Order bolts																		
42			Delivered: Bolts																		
43		7 Back-pressure system																			
44			Research and analyze back-pressure needs																		
45			Contact suppliers for valve and tube & place orders																		
46			Delivered: Back-pressure valve																		
47			Orvis tube																		
52		12 Installation																			
53			Contact FMS: Provide ncessary project details																		
54			Submit project/work order																		
55			Schedule date & time for installation																		
56			Bolt to floor with dampers																		
57			Thermocouples																		
58			Pump																		
59			Piping & fittings																		
60			Heating blanket																		
61			Flow control valve																		
62			Back-pressure valve																		
63			Orvis tube																		
64		13 DAQ system																			
65			Research DAQ systems																		
66			Research sensors																		
67			Contact suppliers & place orders																		
68			Install sensors																		
69			Install DAQ system																		
70		14 Baseline Data																			
71																					
72		15 Validation Tests																			

» Arrival Task Plan - Delivery Checklist

- Ensure that all crates and cartons are correct in accordance with the shipping waybill
- Ensure that there is no obvious physical or water damage

NOTE: If there are damages or missing items, make proper notation on the waybill and inform Boulter and notify Dresser-Rand.

- Open all crates and cartons
- Remove all shipping paper and packaging



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» Arrival Task Plan - Boulter Installation Checklist

- Remove rust preventative with an acceptable solvent
- Assemble compressor components
- Purge the entire gas piping system and compressor with nitrogen or other dry inert gas

NOTE: There should be a slight positive pressure charge left on the piping system at all times to keep the system free of air.

- Measure and compare spacing of bolts, damper holes, and skid holes.
- Align and level the compressor
- Mark holes on floor
- Move compressor, drill holes, move compressor back in
- Hold the final position by snugging the bolts evenly against the skid base.

NOTE: Check with a level to make sure the machine does not shift. Do not attempt to level the unit by tightening to the foundation bolt nuts as this can distort the skid.

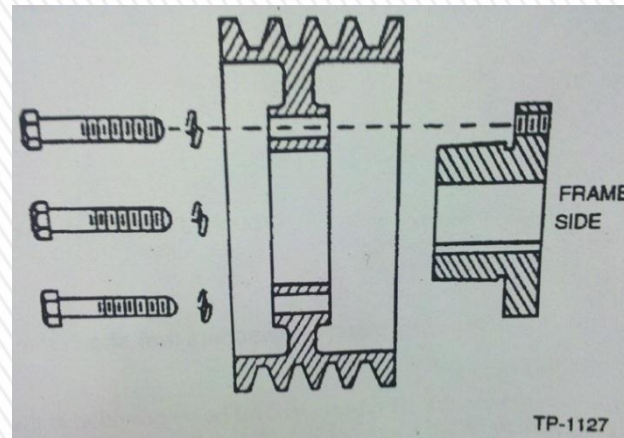
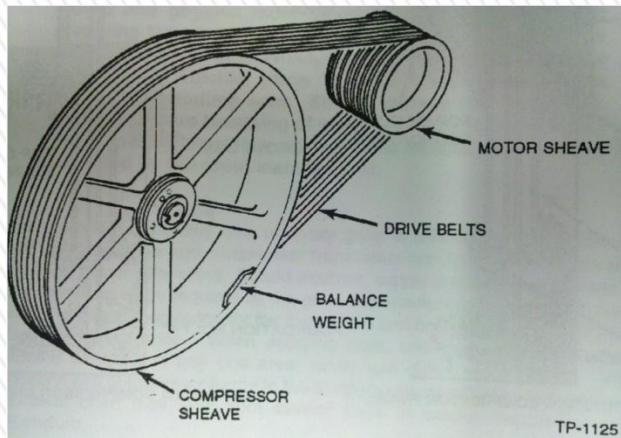


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» Arrival Task Plan - Boulter Installation Checklist

- Recheck the alignment of the drive arrangement
- Adjust motor position for proper V-belt tensioning
- Securely tighten foundation bolts
- Install sheave
 - Inspect the bushing diameter and crankshaft; surface must be clean and free of all substances
 - Assemble the tapered bushing and sheave
 - Properly set key in crankshaft key-seat
 - Slide the sheave and bushing assembly onto to crankshaft

CAUTION: The tightening force of the sheave bushing is multiplied many times by the wedging action of the taper sheave bore. If extreme tightening force is used, bursting pressures may be created in the sheave hub. *Tighten bushing cap screws evenly and progressively.* Never allow the sheave to be drawn into contact with the bushing flange. **DO NOT** lubricate cap screw threads or any other part of the assembly.



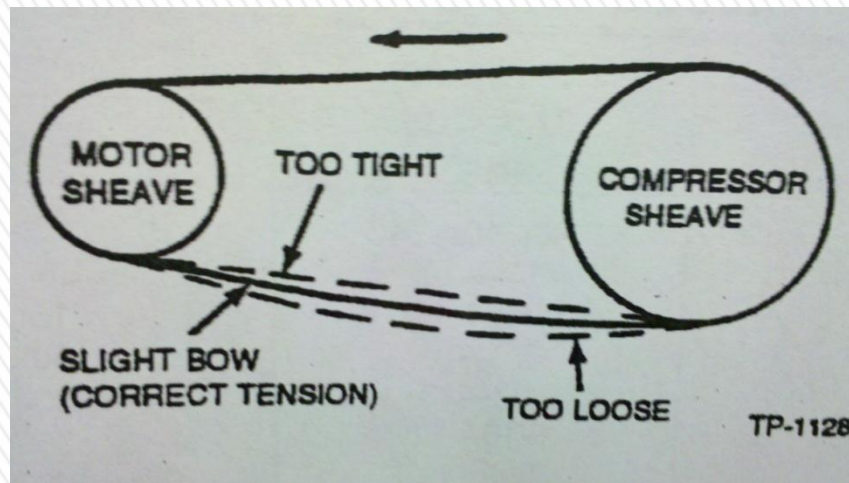
» Arrival Task Plan - Boulter Installation Checklist

CAUTION: Before installing or adjusting drive belts, make sure the drive motor has been shut off and locked out to prevent accidental start up.

- Make sure the motor and compressor belt sheaves are properly aligned. Use a straightedge across the sheave faces
- Move motor toward compressor as far as the slide base will permit
- Install the belts in the sheave grooves

NOTE: DO NOT pry the belts over the sheave rims with a screwdriver or similar tool, as this will damage the belts and greatly reduce the belt service life.

- Reposition the motor the slack until the belts are fairly taut

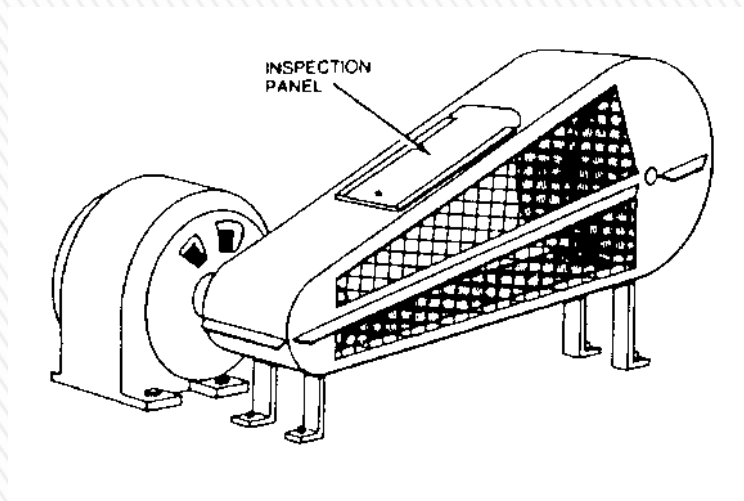


NOTE: DO NOT start and operate the compressor until the equipment has been prepared for its initial start.

» Arrival Task Plan - Boulter Installation Checklist

- Install the belt guard
- Start the drive motor and observe the belt tension. There should be a slight “bow” on the slack side of the drive.
- If adjustment is required, shut off and lock out the motor, then reposition the motor.

The belts may need readjusting after a few days of operation after they seat themselves in the sheave grooves



» Arrival Task Plan - Power up Checklist

» *Prior to First Run*

E-Stops

- Ensure power is connected to the control unit by using a voltmeter to check power supply to the control unit.
- Press the E-Stop button located in the front of the room.
- Ensure that the control unit has lost power.
- Reset the circuit breaker.
- Press the E-Stop button located in the back of the room.
- Ensure that the control unit has lost power.
- Reset the circuit breaker.
- Press the E-Stop button located outside of the room.
- Check that the control unit has lost power.
- Reset the circuit breaker.



» Arrival Task Plan - Power up Checklist

» Lock-Out Tag-Out for Control Panel

- Pull down the power lever to shut down the main circuit breakers.
- Use the lock-out tag-out lock to ensure the lock-out lever is restricted from moving.
- Turn on the control panel.
- Use a multi-meter to check that the control panel is not receiving power.
- Turn off the control panel.
- Un-lock the lock-out lever.
- Pull the power lever up to return power to the main circuit breakers.



» Arrival Task Plan – Complete Installation Checklist

A	B	C	D	E
1	CHECK	TASK	WHO	DATE
2		Delivery	Boulter	
3		Ensure that all crates and cartons are correct in accordance with the shipping waybill		
4		Ensure that there is no obvious physical or water damage		
5		Open all crates and cartons		
6		Remove all shipping paper and packaging		
7		Remove rust preventative with an acceptable solvent		
8		Assemble compressor components		
9		Purge the entire gas piping system and compressor with nitrogen or other dry inert gas		
10		Mounting	-----	----
11		Measure the and compare spacing of bolts, damper holes, and skid holes.		
12		Align and level the compressor		
13		Hold the final position by snugging the bolts evenly against the skid base.		
14		Recheck the alignment of the drive arrangement		
15		Adjust motor position for proper V-belt tensioning		
16		Securely tighten foundation bolts		
17		Sheave and Belts	-----	----
18		Install sheave		
19		Make sure the motor and compressor belt sheaves are properly aligned. Use a straightedge across the sheave faces		
20		Move motor toward compressor as far as the slide base will permit		
21		Install the belts in the sheave grooves		
22		Reposition the motor the slack until the belts are fairly taut		
23		Install the belt guard		
24		Start the drive motor and observe the belt tension. There should be a slight "bow" on the slack side of the drive.		
25		E-Stops	-----	----
26		Ensure power is connected to the control unit by using a voltmeter to check power supply to the control unit.		
27		Press the E-Stop button located in the front of the room.		
28		Ensure that the control unit has lost power		
29		Reset the circuit breaker		
30		Press the E-Stop button located in the back of the room		
31		Ensure that the control unit has lost power		
32		Reset the circuit breaker		
33		Press the E-Stop button located outside of the room		
34		Ensure that the control unit has lost power		
35		Reset the circuit breaker		
36		Lock-Out Tag-Out for Control Panel		

» Post Delivery - Maintenance Hints

- Idle belts should appear snug. In motion and under load, they should have a slight bow on the slack side.
- Avoid excessive heat. Above 140°F (60°C) rubber is over cured and belt life is shortened. Keep belts well ventilated to avoid heat buildup.
- Never intermix belts or replace less than a complete set of belts.

CAUTION: Always replace drive belts as a complete matched set, since a new unstretched belt installed independently will carry an unequal share of the load and possibly break.

- Never use belt dressing.
- Worn and/or misaligned sheaves reduce belt life. Check sheaves periodically.

» Post Delivery - Maintenance Hints

- Periodically examine the belts for fraying, cracking, or softening. Press on each belt to see if all the belts have the same tension. If one or more belts are defective, the entire belt set must be replaced.
- Keep belts oil-free. Excessive oil on belts causes rubber to swell and belts to fail prematurely.
- Never force belts onto sheaves; release the belt take-up by moving the motor toward the compressor.
- Equalize belt slack before tensing, either all on the top or all on the bottom.

CAUTION: If left on equipment during an extended shutdown, the belts can acquire a permanent “set” which may greatly increase the possibility of failure.

» Post Delivery - Maintenance Hints

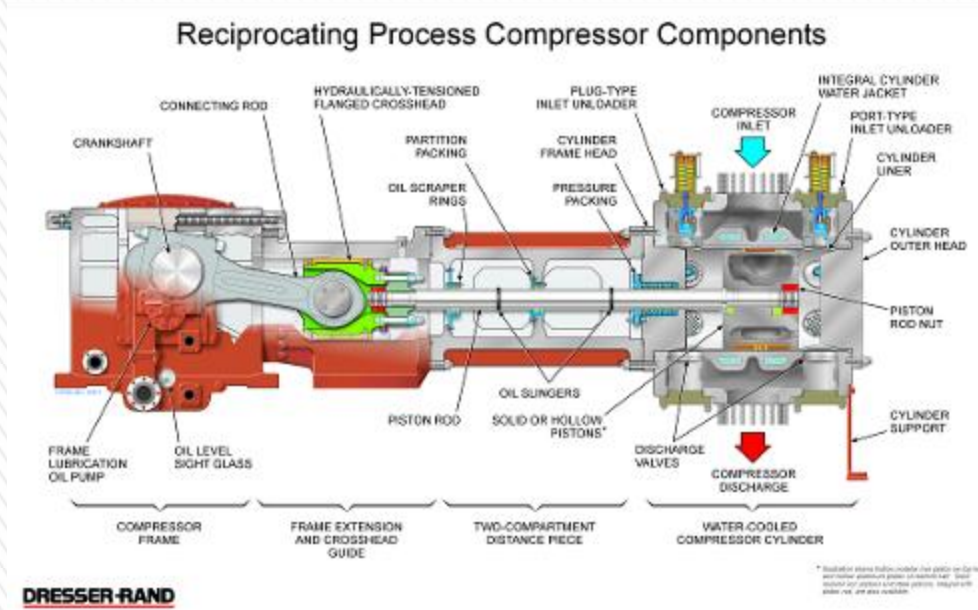
- If the compressor is shut down and is to remain idle for an extended period, the drive belts should be removed and stored in a cool, dry location. The best method of storing belts is to hang them uncoiled over pegs on a wall or rack. If belts become water-soaked, or are piled on a damp floor, undue shrinking may occur.

WARNING: NEVER operate belt driven equipment without adequate guarding installed in conformance with OSHA, State and/or local standards and codes in effect at the compressor site

CAUTION: It is extremely important that the compressor intake piping be thoroughly cleaned. If metal pieces, pipe scale, rust, welding spatter, dirt, and all foreign material are not carefully and completely removed, they will be loosened by the flow of air or gas and will cause serious damage. Blow the piping out with high pressure air after cleaning.

» Post Delivery - Safety Recommendations

- » Review all safety procedures in operating manual.
- » Identify all reciprocating components, electrical hazards, pinch-points, rotating parts, and pressurized equipment.
- » Maintain daily operating procedures



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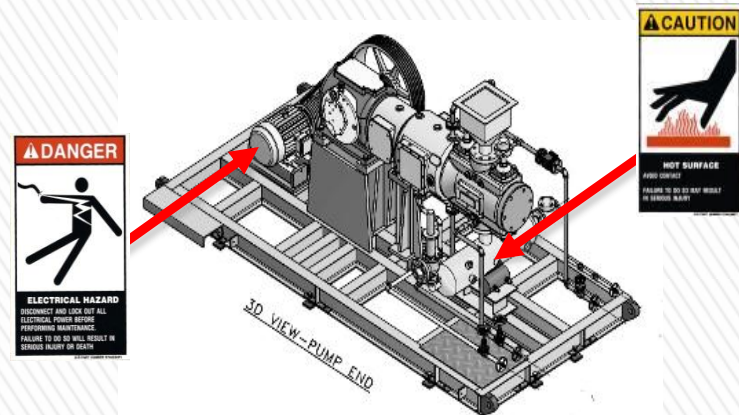
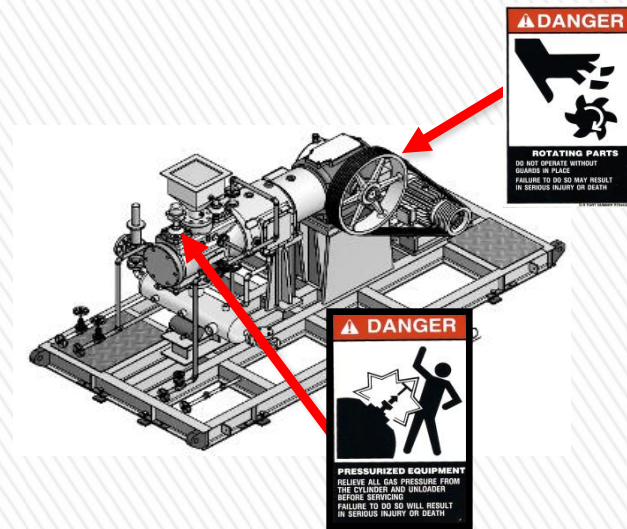
» Post Delivery - Safety Recommendations

» Post hazard and Warning Labels



- » Pinch-Point Electric Motor Drive Belts
- » Pressurized Valve Cover

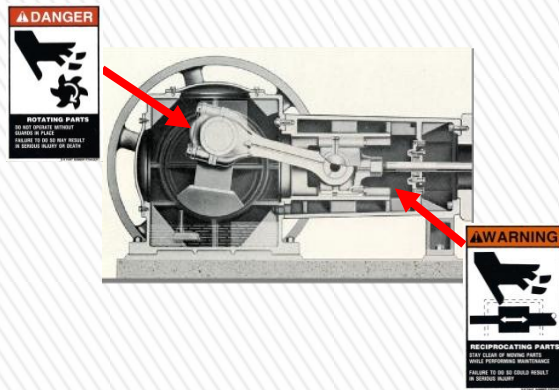
- » Hot Discharge Temperatures: Compressor Cylinder & Discharge Bottle
- » Electric Motor Shock Hazard



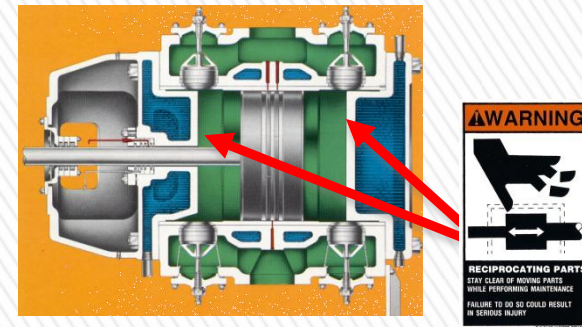
» Post Delivery - Safety Recommendations

» Post hazard and Warning Labels

» Running Gear Pinch-Points



» Cylinder Pinch-Points



» Depressurize Before Valve Cover Removal



» Post Delivery - Safety Recommendations

» LOCKOUT, TAG-OUT ELECTRICAL POWER



» Appropriate Safety Gear

- > Safety glasses or goggles
- > Gloves
- > Ear protection

» Post Delivery - Safety Recommendations

- » Be careful where you place your hands and finger when tightening the piston rod jam-nut with hammer wrench



Questions?

