Operational Readiness Clearance for roots pumps in NM4

Anchit Arora

August 2020

1 Description

The system to be tested is a vacuum pump system for the E1039 experiment. The system consists of four large vacuum pumps connected in series, which are connected via a support manifold. The system will eventually be used to cause the liquid helium in a test chamber to reach a low enough vapor pressure such that the temperature of the helium, and thus the chamber, reach one degree Kelvin. The system was designed,manufactured, and purchased from Oerlikon Leybold Vacuum Inc.

The pumping assembly in NM4 consists of 3 roots booster pumps, RUVAC WH 7000 and 1 backing pump, Sogavak SV630. The RUVAC WH are Roots Boosters driven by water cooled hermetically sealed motors.The assembled pumpstack is $4' \times 10'$ in area and about $15'$ high and the total weight of the assembly is 2000 kg. This document contains information regarding the operational readiness of the pump stack.

Figure 1: Image of Root Pump Stack installed at NM4

2 Specifications of the pumps and instrumentation

There are two types of pumps in this pump stack, roots pumps and backing pump. Attached with this document are techincal specification tables for the roots pumps and the rotary vane(backing) pump.

2.1 Roots pumps: Oerlikon RUVAC WH7000

These are the three roots booster pumps. These are manufactured by Oerlikon Leybold, the ones we use are model named: RUVAC WH7000. They operate at electrical power of 480V @ 34A. Following table outlines the technical specifications of the roots pumps as per the manual provided by the manufacturer.

en0.7en

Figure 2: Technical Data: RUVACWH7000

SV630 BF US WATER (60 Hz)

Technical data		60 Hz
Pumping speed [1]	cfm	444
Ultimate partial pressure without gas ballast [1]	Torr	0.06
Ultimate total pressure with 1 gas ballast EM [1] 24 VDC	Torr	≤ 0.5
Ultimate total pressure with 2 gas ballasts EM [1] 24 VDC	Torr	≤ 1.5
Antisuckback valve 24 VDC		OUI
Water vapour tolerance:	Torr	
▪ without gas ballast		
▪ with 1 gas ballast [3]		22,5
▪ with 2 gas ballasts [3]		30
Water vapour capacity:	qt/hr	
▪ without gas ballast		
▪ with 1 gas ballast [2] [3]		15
▪ with 2 gas ballasts [1] [3]		20
Cooling		H2O
Thermostatic valve		YES
Water quality	TH (°F)	4 - 8
Water pressure min./max.	PSI	29/114
Noise level [2]	dB (A)	72
Motor power	HP	25
Type of protection/Isolation		TEFC / F
Rated rotational speed pump	rpm	1000
Weight (with oil filling)	lb	1678
Oil capacity min./max.	qt	21/24
Intake connection		DIN 160 Roots adapter 2001
Exhaust connection		DN 100 ISOK
Thermal switch Pump		YES
Thermal switch Motor		YES

1) to DIN 28400 and following numbers, with standard gas ballast
2) operated at the ultime pressure without gas ballast, free-field measurement at a distance of 1 m
3) please contact Oerlikon Leybold Vacuum

Figure 3: SV 630 Technical Data

2.2 Sogavac SV 630

Electrical power of the rotary vane pump: 1x 480V @ 29A The maximum pressure of the cooling water should be 6 bar. The pump must only be operated between 10 and 40 C. Do not operate RUVAC WH pumps in connection with

backing pumps where an ultimate pressure exceeding 10 bar is specified. This will prevent excessively high temperatures when the RUVAC is running idle.

3 Wiring diagrams of the system:

3.1 AC

480 VAC and 200 amp, power source: PHP-NM4-1, wire size: AWG- , fuse or circuit breaker size. The 480V power is provided in the building from panel PHP-NM4-1(circuit number). 5 conductor 3 phase. The AC frequency is 60 Hz The panel for the 24DC sensors consists of connections for the following:

3.2 Sensor cable dimensions

3.3 DC

:24 VDC Instrument spec sheets The following sensors and transducers are part of the DC wiring system:

- DI 2000 vacuum transducer
- Kobold PSR 5115 flow switch
- M4 Oil Temp switch
- M4 Oil Level switch
- intempco MS25 Sanitary temp sensor
- M4 Anti suckback valve
- Ceravac transmitter CTR-100
- vacuum transducer: oerlikon DI2000

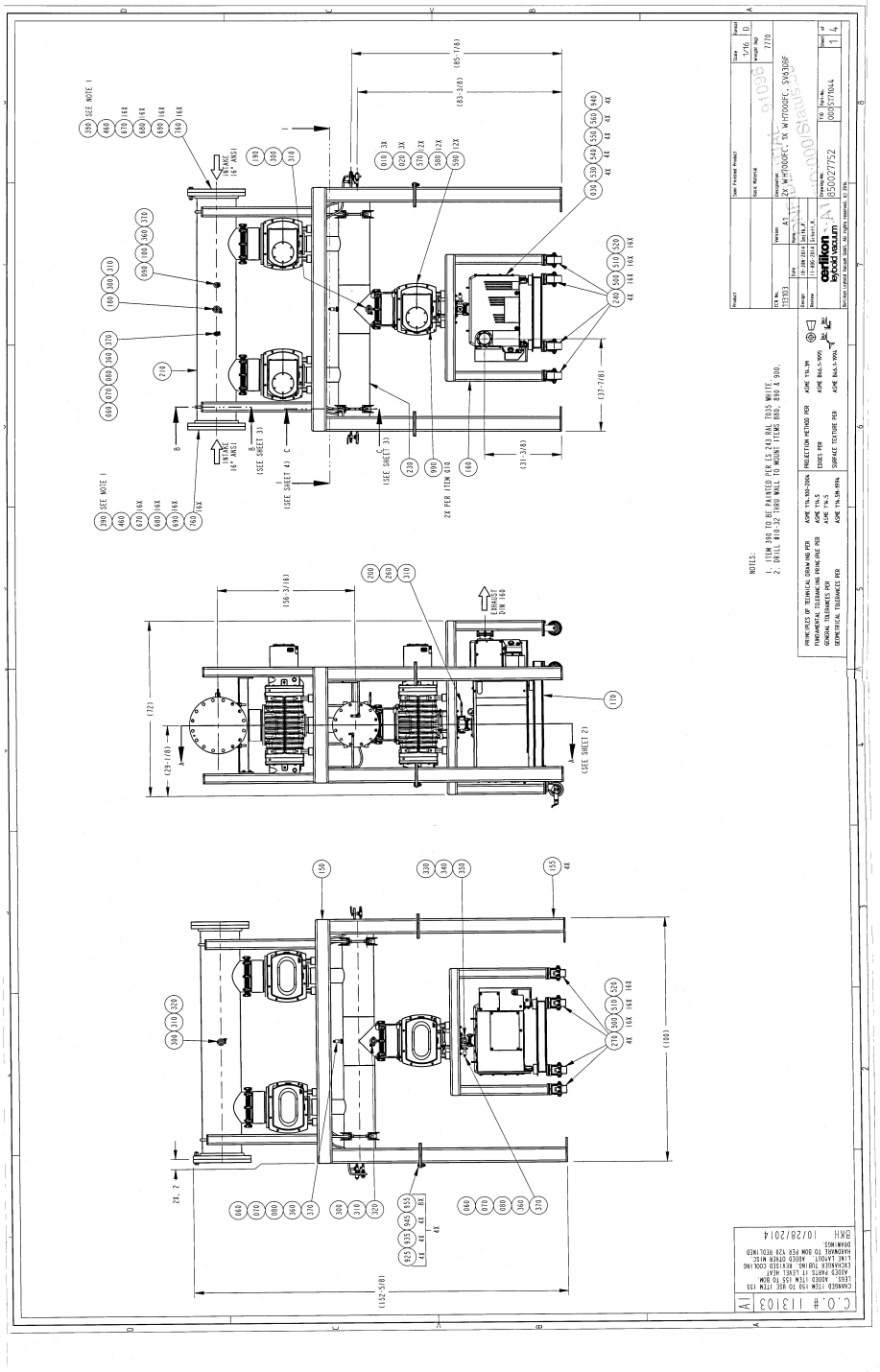
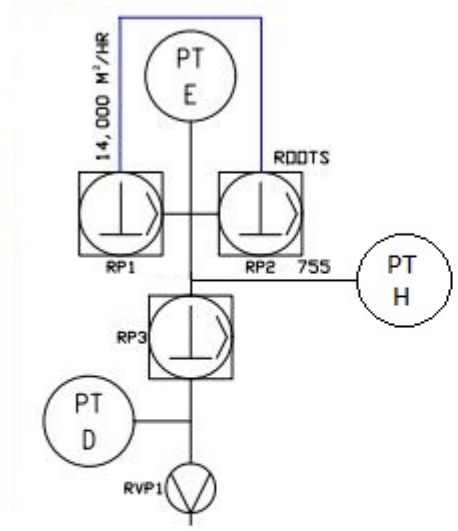


Figure 4: Pump stack dimensions



P&ID for the Roots Pump Stack

Figure 5: PID for roots pump stack

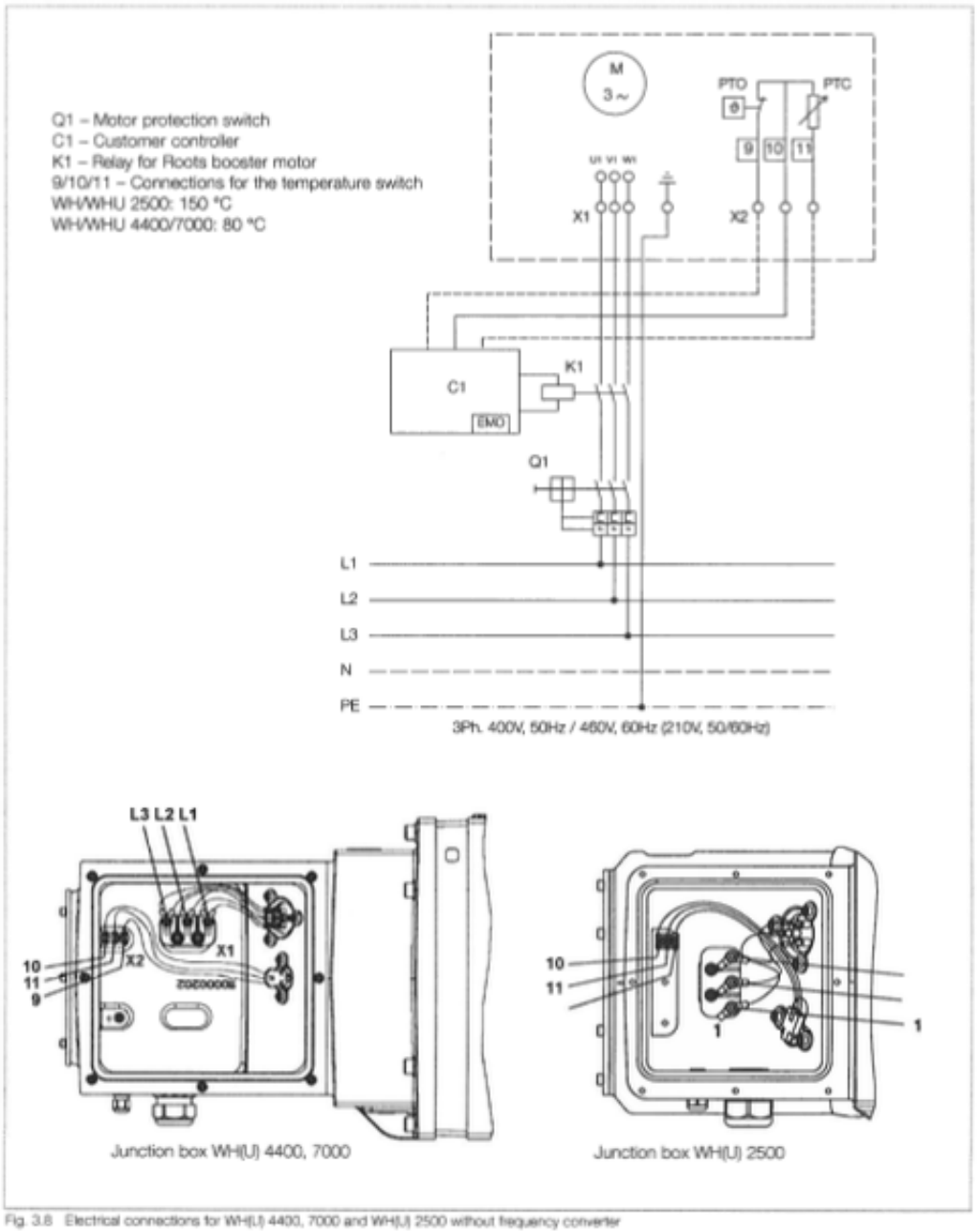


Fig. 3.8 Electrical connections for WH(U) 4400, 7000 and WH(U) 2500 without frequency converter

Figure 6: Electrical supply for roots

Switch heater wiring diagram

Figure 7: Switch heater wiring diagram

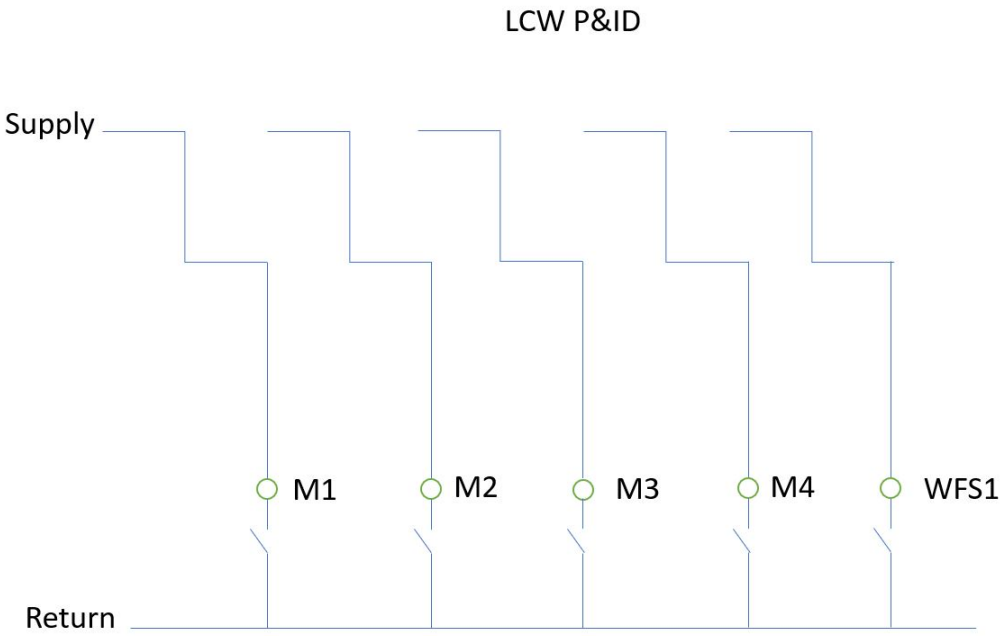


Figure 8: Low conductivity water PID

Figure 9: 24 VDC feedthrough panel

3.3.1 Wire Specification

The specification of wires connecting different sensors on the root pump stack to the 24 VDC pannel is as follows:

- Wire gauge: 18 AWG
- Standard: AWM(Appliance wire material) 2661 22/4
- Make: INTEM PCO
- 4 conductor wire
- M2 micro female controller PT-100
- Untwisted pair cable

4 Piping and instrumentation diagram

Piping and instrumentation diagram indicating nominal flows and pressures for the water system. The hose used for the connections is:3/4" inner diameter polyurethane hose supply/return lines (only up to the water supply/return connections).

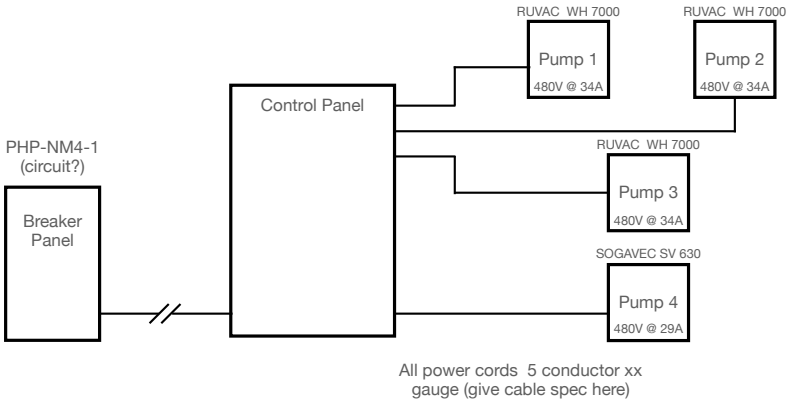


Figure 10: Roots AC Wiring Diagram

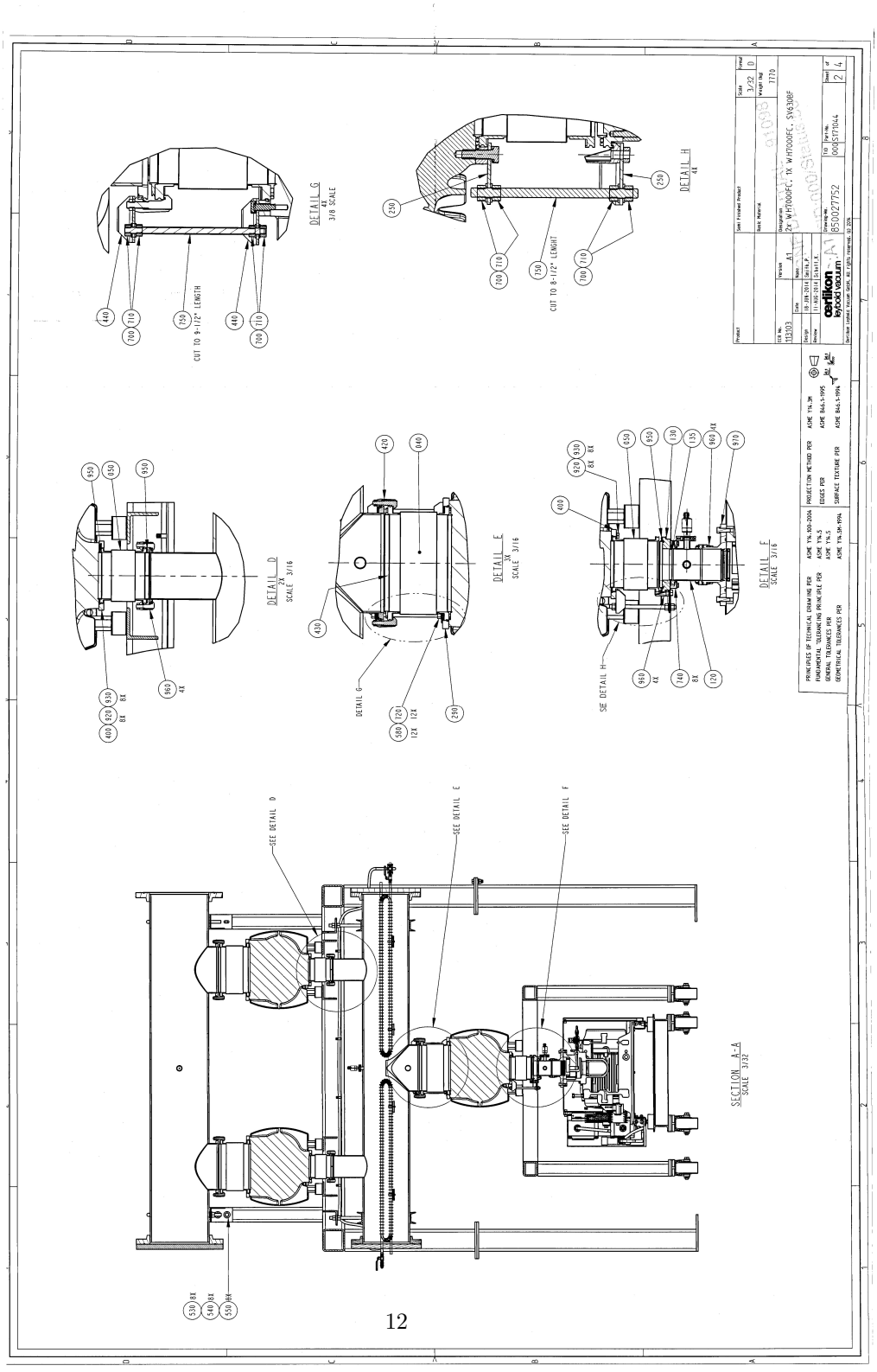


Figure 11: Piping and instrumentation diagram

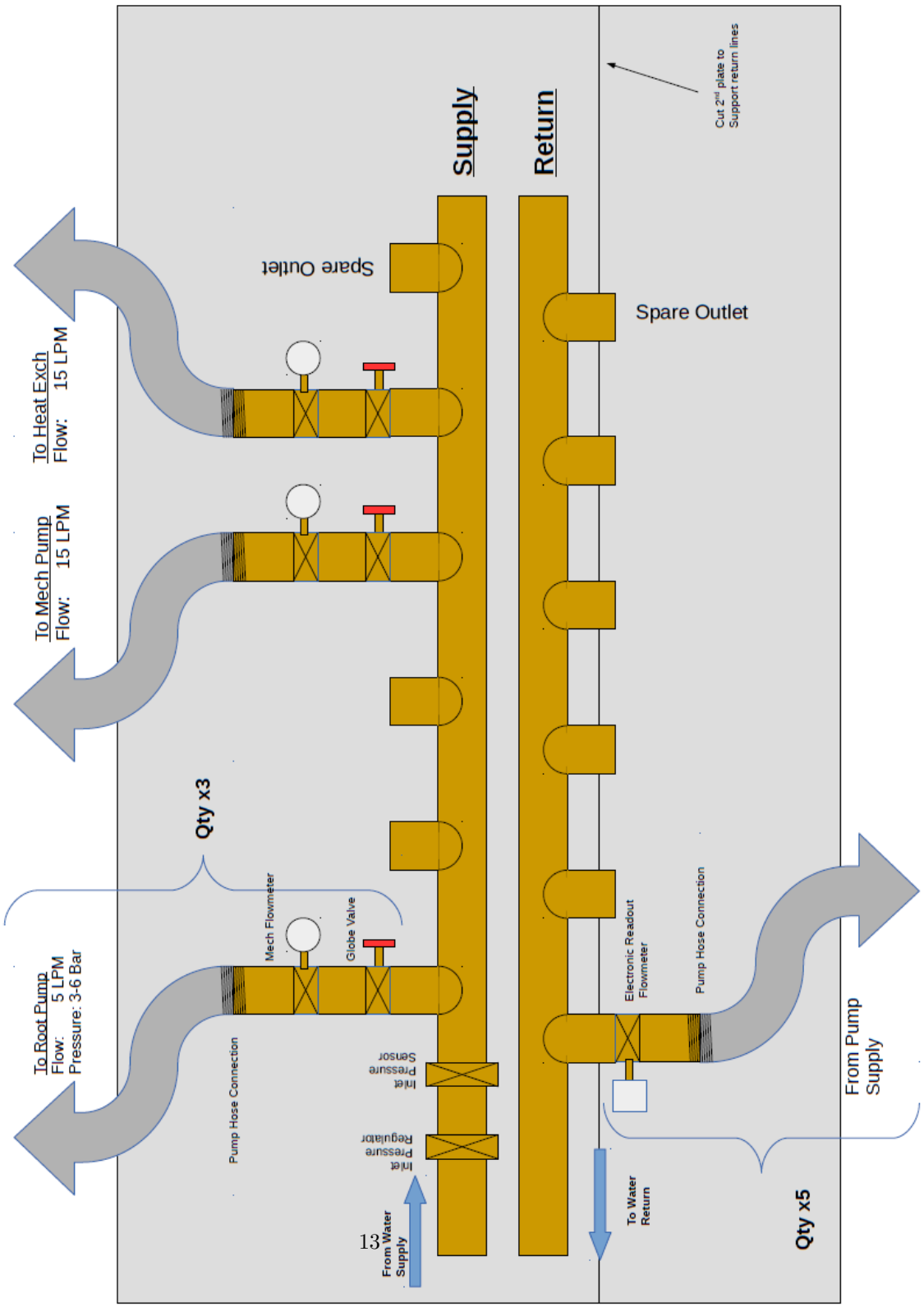


Figure 12: Water flow in and out of the pumps

Figure 13: Piping and instrumentation diagram for LCW

Figure 14: Electrical control panel

Full Scale (FS) / Measurement range		1 Torr / 1 x 10^{-4} - 1 Torr Pressure Units: 1 Torr = 1.33 mbar = 133 Pascal	10 Torr / 1 x 10^{-3} - 10 Torr 100 Torr / 0.01 - 100 Torr 1000 Torr / 0.1 - 1000 Torr Pressure Units: 1 Torr = 1.33 mbar = 133 Pascal
Materials exposed to gases		ceramic (Al_2O_3), stainless steel 316, Vacon 70	ceramic (Al_2O_3), stainless steel 316, Vacon 70
Max. overrange pressure		2000 Torr for 1/10/100 Torr sensors, 3000 Torr for 1000 Torr sensors	2000 Torr for 1/10/100 Torr sensors, 3000 Torr for 1000 Torr sensors
Measurement uncertainty		0.2% of reading ± temperature effect	0.2% of reading ± temperature effect
Resolution		0.003% of FS for 0.1/1 Torr sensors	0.003% of FS for 10/100/1000 Torr sensors
Temperature effects			
Zero coefficient	**%/°C**	0.015 of Full scale	0.005 of Full scale
Span coefficient	**%/°C**	0.01 of reading	0.01 of reading
Response time	**ms**	≤ 30	≤ 30
Nominal temperatur range	**°C**	+5 to +50	+5 to +50
Supply voltage	**V DC**	+14 to +30	+14 to +30
Power consumption	**W**	≤ 1	≤ 1
Signal Output	**V**	0 - 10; linear	0 - 10; linear
Interface		0.26 (0.57)	0.26 (0.57)
Weight approx.	**kg (lbs)**	RS 232 C	RS 232 C
Dead Volume	**cm^3**	6	6
Connection cable		see section "Connection Cable for active Sensors"	see section "Connection Cable for active Sensors"
Calibration		see section "Miscellaneous", para. "Oerlikon Leybold Vacuum Calibration Service"	see section "Miscellaneous", para. "Oerlikon Leybold Vacuum Calibration Service"

Figure 15: Ceravac Transmitter technical data

Piping and instrumentation diagram for the vacuum system. SeaQuest-Doc-5834 contains the PID for the cryogenic system.

Water supply and return lines at 70psi and 4gpm are also needed. E1039 480V Vacuum Pump System 3 The second step is to provide power to the system. The system requires a 480VAC, 200 Amp power supply. Power is fed into an electrical box provided by the manufacturer. 480VAC lines will go from the electrical box to the four vacuum pumps to supply power to each individual pump. 24VDC Feedthrough panel wires exit the electrical box to various readout sensors on the system.

4.1 Pressure sensor

Ceravac CTR 100 used for absolute pressure measurement for gases. Pressure measurement is independent of the gas type. The aluminium oxide ceramics diaphragm of the CERAVAC sensors is capable of returning precisely to its initial position with respect to a certain pressure so that the measurements will be highly reproducible. Since the diaphragm is not impaired by overpressures or frequent pressure changes, no blocking valves will be required.

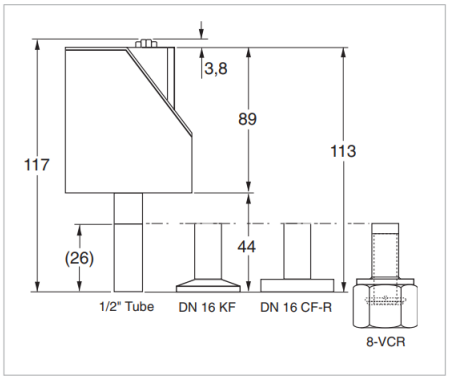


Figure 16: Ceravac CTR100 dimensions

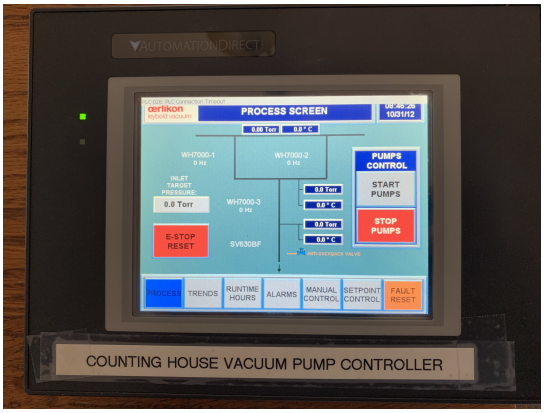


Figure 17: Counting house vacuum pump controller

4.2 Counting House Vacuum Pump Controller

Make: Automation Direct Surrounding Air temperature: 50 C Input :12-24V Max. 16W Class2 for use in pollution degree 2 environment comunication: Ethernet/USB/RS485

4.3 Vacuum Transducer

The vacuum transducer is

4.4 Paddle type Flow switch

Model: Kobold PSMaterial: brass
Maximum pressure: 1450PSIG
Media Temperature

Measuring principle	piezo-resistive
Measuring range	2000 - 1 mbar (1500 - 1 Torr)
Max. overload	5 bar abs.
Uncertainty Reproducibility	0.25 % FS (linearity, hysteresis, reproducibility) 0.05 % FS
TC* Zero TC* Sensitivity	0.1 % FS/10K 0.15 % FS/10K
Materials in contact with media	stainl. steel 1.4305, Al_2O_3 ceramic, FPM (DI2000, DU2000), EPDM (DI2001, DU2001)
Operating temperature	0 ... +60 °C
Storage temperature	-40...+70 °C
Response time	< 20 ms
Voltage supply	DI: 12 – 30 VDC (two-wire) DU: 14,5 - 30 VDC (four-wire)
Electrical connection	DI: 5m cable with diode plug, 7pin, male DU: 5m cable with plug type FCC68, 8pin
Output signal	DI: 4 - 20 mA, linear max. load in Ω: (supply voltage – 12V) / 0.02A DU: 2 - 10 VDC, linear
Dead volume	1.8 cm^3
Vacuum connection	small flange DN16 ISO KF with G1/4 female thread
Protection class	IP 54
Weight	DI: 260 g DU: 240 g

* Temperature coefficient

Figure 18: Vacuum Transducer techincal data

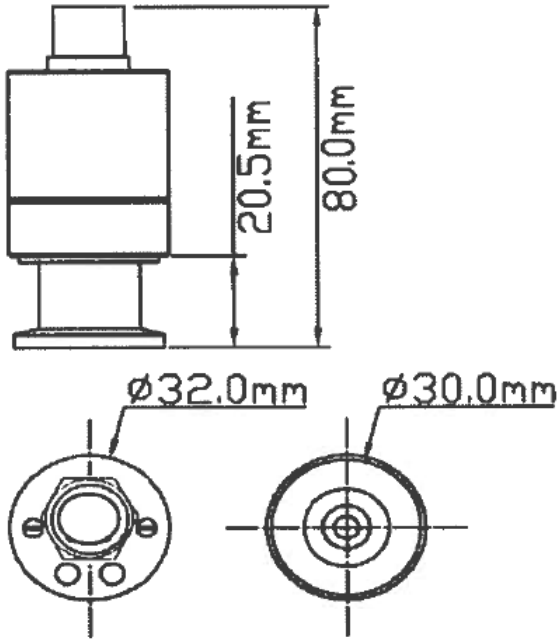


Figure 19: cross-section of vacuum transducer

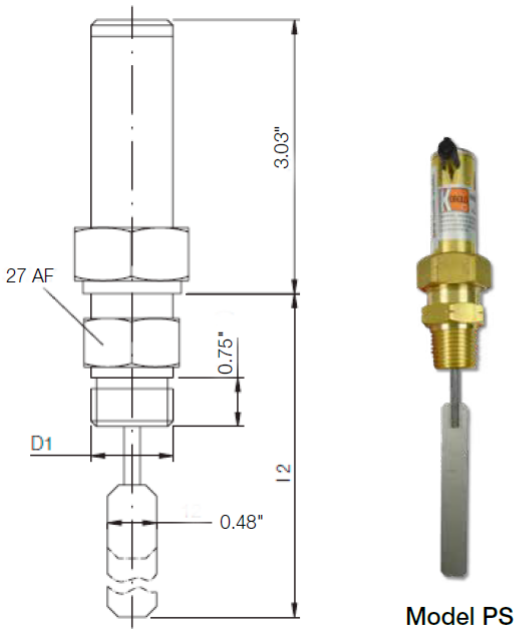


Figure 20: Flow switch

Max. Pressure
1-1/4"...1-1/2" = 360 PSIG
SS: 1/4"...1" = 3600 PSIG
1-1/4"...1-1/2" = 580 PSIG
Ingress Protection: IP 65
Mounting Orientation: Horizontal Flow Preferred
Max Flow Rate: 5x Switching Range, Increasing
Maximum Contact Ratings (cCSAus):
SPST Contact: 2A, 20 VAC, 0.18 A, 230 VAC, max. 40 W
SPDT Contact: 0.13 A, 150 VAC, 0.5 A, 40 VAC, max. 20 W
Cable: PVC Jacketed
Cable Length: Standard: 5 Ft. (1.5m), Optional (SPST only): 10, 15 or 21 Ft.

480VAC power has already been supplied to the electrical box at LANL, and approved by LANL electrical safety personnel. However, only the 24VDC readouts were tested at the LANL facility. FNAL electrical safety personnel will be needed to guide the 480VAC power supply connections in the NM4 area.

The system is controlled via an LED touch screen on the front of the electrical box.

Electrical power: Roots: 3x 480V @ 34A Rotary Vane pump: 1x 480V @ 29A

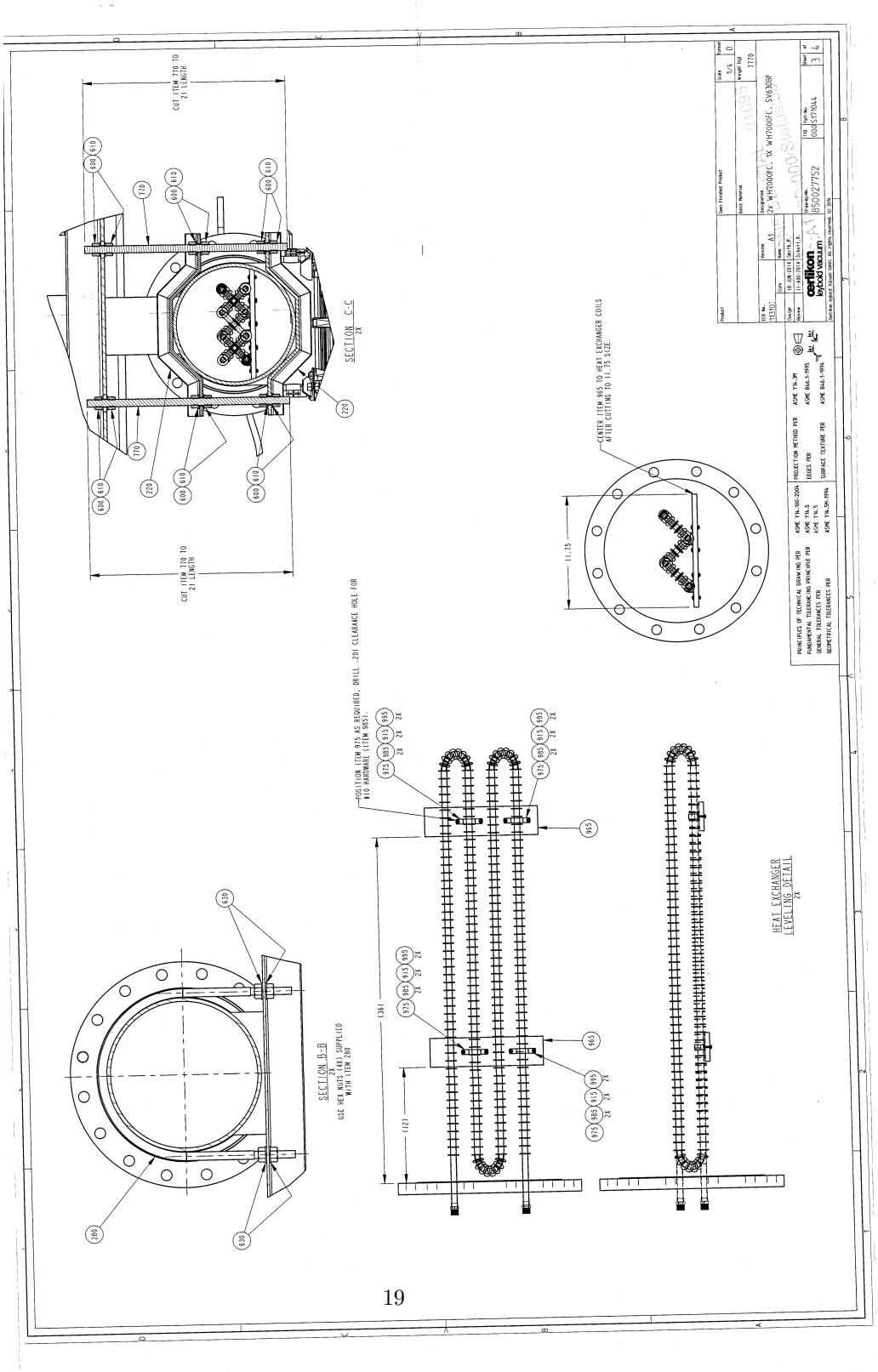


Figure 21: Heat exchanger for cooling water coming out from the pumps

Water Cooling: 3 liters/min @ 5 C to 35 C

Water supplied by FNAL low conductivity water system.

Each wiring diagram should include wire specification (eg 5 conductor 600VAC rated 10AWG-stranded, PVC jacketed, Belden part number: xxxxxxx). What people will want to know is whether the wire has the capacity to carry the current and that the insulation won't break down (short) at the operating voltage.

We need a similar wiring diagram the instruments (pressure transducers, etc). Also, the instruments are powered. Does this power come from a supply in the main control panel or is the supply separate? There is a box attached to the north side of the roots frame that, I think serves as 24V power distribution for the sensors and perhaps combines the signals for presenting to the control panel.

Hazard ID Checklist

Flammables (Gases or Liquids)		**Gases**		**Hazardous Chemicals**		**Other Hazardous /Toxic Materials**
Type:		Type:			Cyanide plating materials	List any other hazardous/toxic materials planned for use:
Flow rate:		Flow rate:			Hydrofluoric Acid	
Capacity:		Capacity:			Methane	
Radioactive Sources		**Metals of Concern**			photographic developers	
	Permanent Installation		Beryllium (Be)		PolyChlorinated Biphenyls (PCBs)	
	Temporary Use		Lithium (Li)		Scintillation Oil	
Type:			Mercury (Hg)		Triethylamine (TEA)	
Strength:			Lead (Pb)		Tri-MethylaMino Ethyl (TMAE)	
Nuclear Materials*			Tungsten (W)		Other: (Activated Water?)	
Name:			Uranium (U)			
Weight:			Other:	**Lasers**		
Mechanical Structures		**Electrical Equipment**			Permanent installation	
	Lifting Devices		Cryo/Electrical devices		Temporary installation	
	Motion Controllers		Capacitor Banks		Alignment	
	Scaffolding/ Elevated Platforms		High Voltage/High Amperage		Calibration	
	Other:		Exposed Equipment over 50 V	Type:		
			Non-commercial/Non-PREP	Wattage:		
			Modified Commercial/PREP	MFR Class:		
Vacuum Vessels		**Pressure Vessels**		**Cryogenics**		
Inside Diameter:		Inside Diameter:			Inert cryogenic liquids	
Operating Pressure:		Operating Pressure:			Hydrogen cryo liquids	
Window Material:		Window Material:			Other cryo liquids	
Window Thickness:		Window Thickness:				

Figure 22: Hazard ID checklist