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Title: Production Facility Prototype Blower Installation Report with 1000 Hour Test Results

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6/24/2015

Updated with Appendix B on 3/16/2016 with 1000 Hr. Test Results

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LA-UR-

Introduction

The roots blower in use at ANL for in-beam experiments and also at LANL for flow tests was sized for 12 mm diameter disks and significantly less beam heating. Currently, the disks are 29 mm in diameter, with a 12 mm FWHM Gaussian beam spot at 42 MeV and 2.86 μA on each side of the target, 5.72 μA total. The target design itself is reported elsewhere. With the increased beam heating, the helium flow requirement increased so that a larger blower was need for a mass flow rate of 400 g/s at 2.76 MPa (400 psig). An Aerzen GM 12.4 blower was selected, and is currently being installed at the LANL facility for target and component flow testing. This report describes this blower/motor/pressure vessel package and the status of the facility preparations.

The blower has been operated for 1000 hours as a preliminary investigation of long term performance, operation and possible maintenance issues. The blower performed well, with no significant change in blower head or mass flow rate developed under the operating conditions. Upon inspection, some oil had leaked out of the shaft seal of the blower. The shaft seal and bearing race have been replaced. Test results and conclusions are in Appendix B.

Blower Selection

The blower currently being used for the accelerator experiments at ANL and the flow visualization loop at LANL is a Tuthill 3206 PDplus. At 2.07 MPa (300 psi) and, we are limited to 100 g/s with about 138 kPa (20 psi) head. In order to achieve the heat transfer requirement of the new target, we need 400 g/s at 2.76 MPa (400 psig) as stated above. Tuthill has no blower that can achieve this. Aerzen offered 2 blower options, the performance of which is summarized in Figure 1. The GM 12.4 was chosen because it is physically smaller, fitting into a smaller pressure vessel. The 180 icfm in the 3rd column corresponds to 400 g/s, at blower speed 1737 rpm. Blower displacement is 0.14 ft^3/rev. The drive motor is a 30 hp WEG with maximum speed 1800 rpm.

Pressure Vessel

The motor and blower are mounted inside a pressure vessel rated for the 2.76 MPa. The vessel is designed to ASME BPVC. Appendix A below shows the code calculations for the pressure vessel, as well as the calculations for the loop piping and the pressure rating of the instruments. The vessel fabricated by AA Tanks. AA Tanks makes their own drawings from LANL drawings and requirements. They then make their own ASME code validation calculations, fabricate the vessel, and pressure test to ASME required load (1.3 times design pressure).

As with the earlier designs, the pressure vessel made of essentially 2 parts: A bell that rides on a rail to expose the blower and motor inside, and a fixed flange with all the penetrations for power, instrumentation, and helium inlet and outlet.

AERZEN

Aerzen USA Corporation Quotation nº: PG-130

09/26/2013

Aerzen Rotary Lobe Blower

Performance data:

		GM 13.6	GM 13.6	GM 12.4	GM 12.4
medium		Helium	Helium	Helium	Helium
operating case		Given	Current dP	Given	Current dP
MW	lb/lbM	4.00	4.00	4.00	4.00
K = Cp/Cv	./.	1.660	1.660	1.660	1.660
volumetric flow at intake conditions	icfm	180	150	180	150
volumetric flow at standard conditions	MMscfd	7.225	6.021	7.225	6.021
volumetric flow at standard conditions	scfm	5,017	4,181	5,017	4,181
specific weight at intake conditions	lb/ft³	0.294	0.294	0.294	0.294
intake pressure (absolute)	psia	414.5	414.50	414.50	414.50
discharge pressure (absolute)	psia	436.3	432.50	436.25	432.50
differential pressure	psi	21.8	18.0	21.8	18.0
intake temperature	°F	66.2	66.2	66.2	66.2
discharge temperature	°F	83	81	81	79
blower speed	rpm	1,019	877	1,737	1,482
motor speed	rpm	1,019	877	1,737	1,482
power required at blower shaft	BHP	28	20	24	18
motor rating	HP	40	25	30	20

Tolerances:

for volume handled at intake conditions	± 5 %
for power consumption at blower shaft	± 5 %

Machine noise:

sound pressure level without hood approx.	dB(A)				
sound pressure level with hood approx.	dB(A)				

Figure 1. Performance Table for the Aerzen blowers.

Blower/Motor/Pressure Vessel Assembly

The assembly is best described with the drawing and photographs in Figures 2 through 5. Not shown, but waiting for install, is a sound-proofing box procured from Industrial Noise Control to reduce the blower noise from the 90 dB range to closer to 70 dB.

Additional Loop Components

Blower heating of the helium will be removed with a plate type heat exchanger from GEA, part number FP10X20L-90. This is sized to keep the helium pressure drop to less than 1 psi in the exchanger. This is shown in Figure 6 along with connected helium and water piping and some instruments.

Helium flow rate will be measured using a turbine type meter, Omega PN FTB-939. Also installed for flow measurement is a vortex flow meter from Sierra Instruments. This flow meter has been used unsuccessfully on an earlier loop but has been reinstalled here for more cross-comparison with the turbine type under different conditions.

Temperature is measured at numerous locations around the loop with Type K thermocouples. Pressure is measured by gages and transducers acquired from Omega. A motor driven ball valve will be used to characterize the blower output curve mass flow rate vs pressure drop, as a function of motor speed. Although the blower is intended to run at full speed in the plant, this test facility has the motor on a variable frequency drive for flexibility and adaptability to a variety of test and experiment conditions. A P&ID is shown in Figure 7.

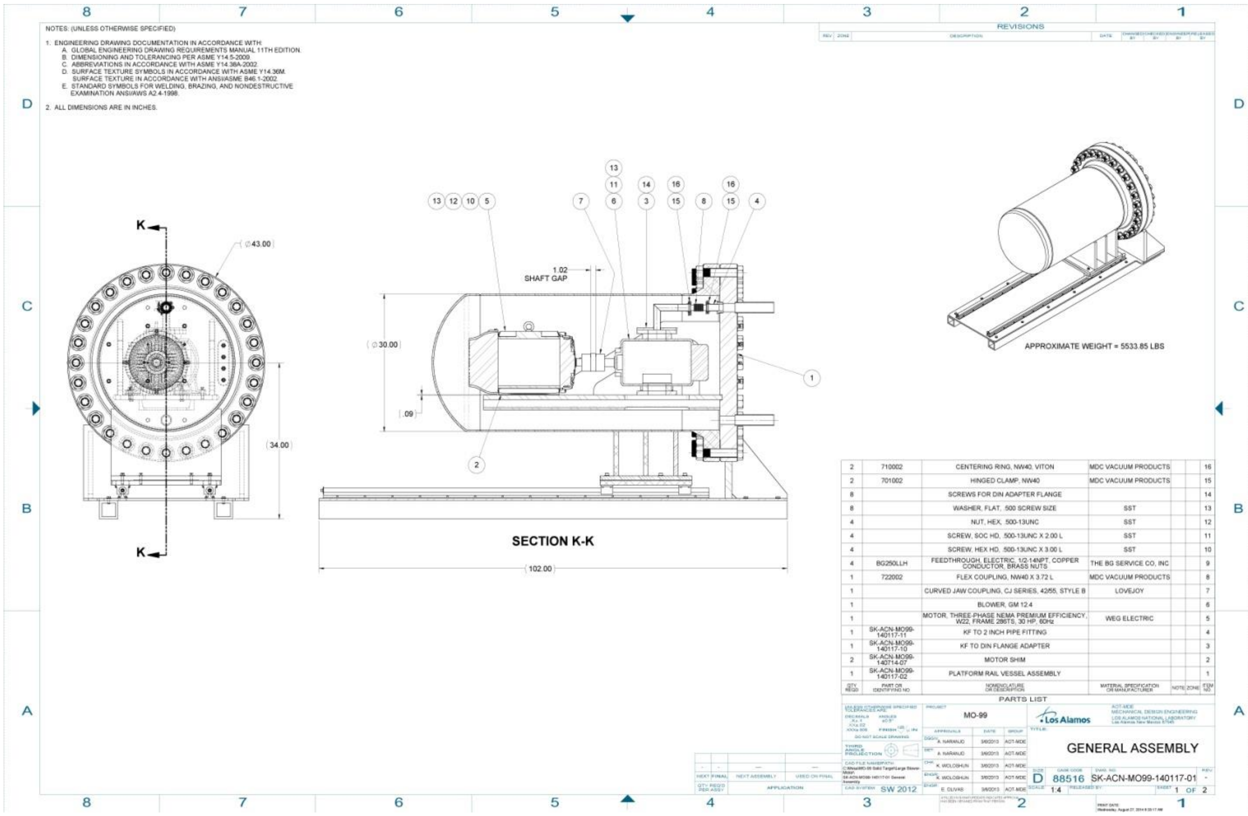

Figure 2. Drawing of the blower and motor in the pressure vessel, indicating overall dimensions.

Figure 3. Vessel open, showing blower and motor.

Figure 4. Close-up view of the blower, on the left, with motor. Motor is wired and blower exit piping is installed. (top left).

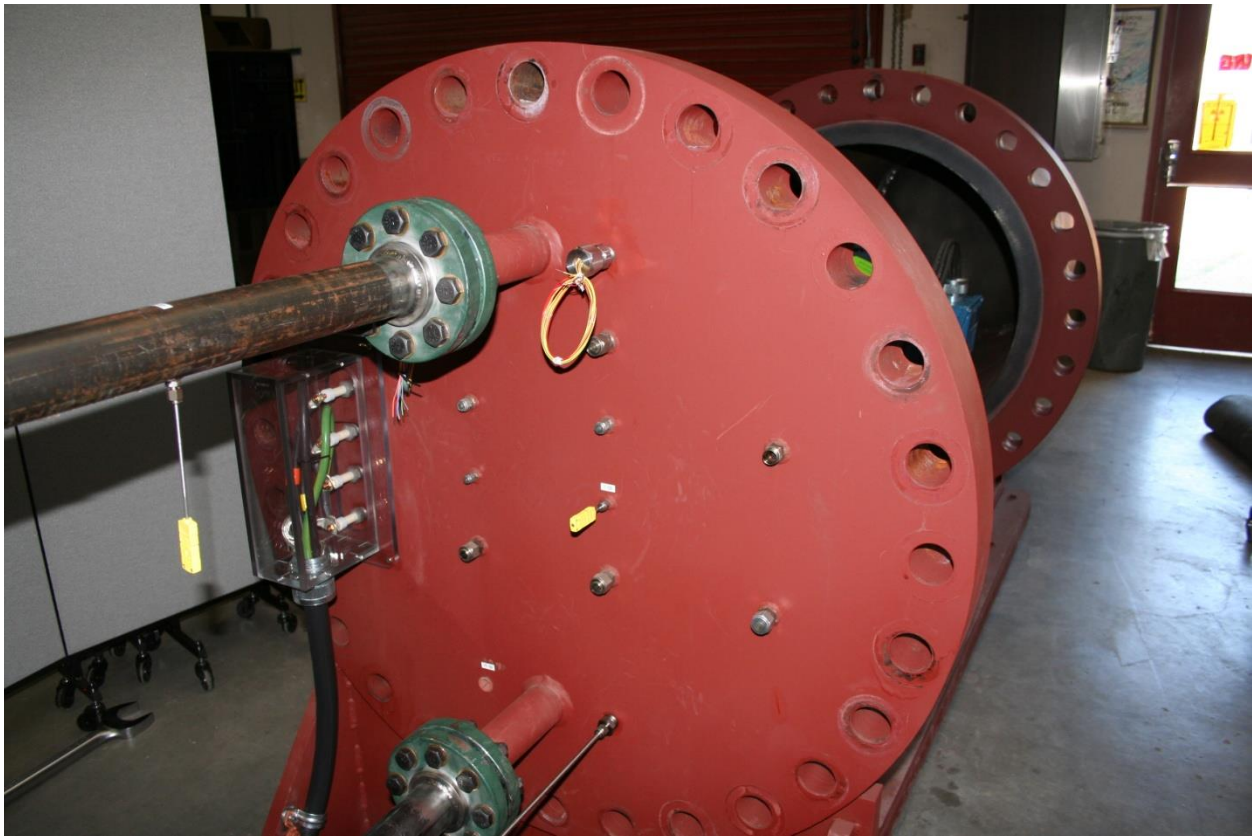

Figure 5. Fixed flange. Motor power inlet feed-throughs at center left. helium discharge pipe at the top, and return helium pipe at the bottom. Some instruments for temperature and accelerometers installed.

Figure 6. Heat exchanger (bottom of photo) along with piping and instruments. A water filter is mounted on the wall near the top.

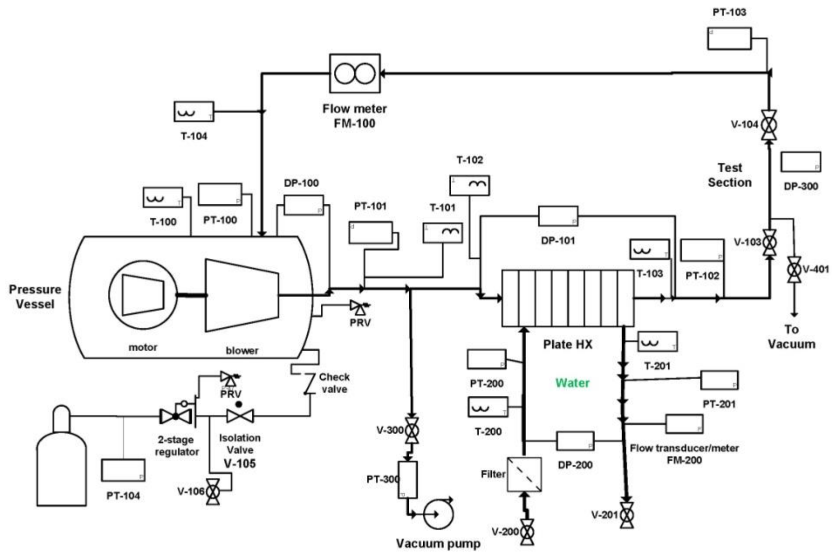

Figure 7. Flow loop Piping and Instrumentation Drawing.

Status and Conclusions

The blower/motor/pressure vessel set-up is installed and ready. After final instrumentation install is complete the sound enclosure can be assembled. The first test section is straight pipe with a motor controlled ball valve for blower characterization. This is ready to install. Final data acquisition software and hook-ups are now being readied. With the exception of a second heat exchanger to remove target heat, and a tritium removal slip stream, this loop is nearly identical to that envisioned for the Northstar production plant.

Appendix A. Pressure Vessel Calculations for Blower/Motor Enclosure.

Cylindrical Shell
$t \geq PR/(2SE+0.4P)$
$P = 400$ psi
SA515-70 steel (or equivalent, 70 ksi UTS or greater), S = 20000 psi
E = 0.6, butt welds
R = 14.625 "
$t \geq 0.242$"
Sch 10 pipe, t = 0.375"

Domed Elliptical Head
$t \geq PD/(2SE-0.2P)$
E= 1, no welds on head
$t \geq 0.293$"
t = 0.375"

Unstayed Flat Head
$t \geq d*\text{sqrt}(CP/SE +1.9Wh_G/SEd^3)$
C = .3 (from UG-34)
$W = W_{m1} = 0.785G^2P+2b3.14GmP$, bolt load
h_g = distance from gasket center to bolt circle = 4
b = gasket width = 2.5
G = gasket OD - 2b = 33.75-2*2.5 = 28.75
m = gasket factor = 2.00 (Appx 2)
W = 620640
$t \geq 3.63$
t = 3.63

Pressure Rating of Instruments and Piping

Flow meter MAWP 500 psi

Heat exchanger MAWP 450 psi

Piping is sch 40 SA-53 carbon steel with allowable stress S = 16000 psi.

Allowable pressure $P = SEt/(R+0.6t)$

E = weld allowance, taken as 0.5. Flange welds are slip on flanges welded both sides. Other weldments are small Swagelok fittings for pressure and temperature measurements, fillet welds.

Sch 40 pipe has R = 1.03", t = 0.155"

Allowable P = 1104 psi.

Pressure stress calculations are for design guidance but the ultimate qualification is the pressure test. The vessel was factory tested and stamped. The piping, with instruments, was tested 1/22/14, as per attached record. System design pressure is 400 psig, with pressure relief valve set at 400 psig. Pressure test was conducted at 530 psig, greater than the required 130% of MAWP.

Appendix B. 1000 Hour Operations Test

The goal of the 1000 hr. test was to operate the blower in a closed loop configuration with the flow conditions anticipated in plant operation with a target in line. Neglecting temperature effects that will be experienced in actual plant operation, a throttling valve was used to mimic the flow pressure drop expected from a target.

The procedure for initiating the test and setting the operating conditions was as follows:

1. Starting with a closed pressure vessel and closed loop, consisting of 2" pipe, a heat exchanger, a throttle valve and instrumentation, eliminate air by vacuum pump and purging.
2. Set fill with helium to the desired pressure, 2.5 MPa (365 psig) (Figure B1).
3. Ramp up blower speed to maximum (1800 rpm).
4. Adjust throttling valve to achieve a pressure drop consistent with the plant target design at the desired flow rate.

In practice, ramping up the blower and adjusting the throttle valve for flow and pressure drop, steps 2 through 4, was an iterative process.

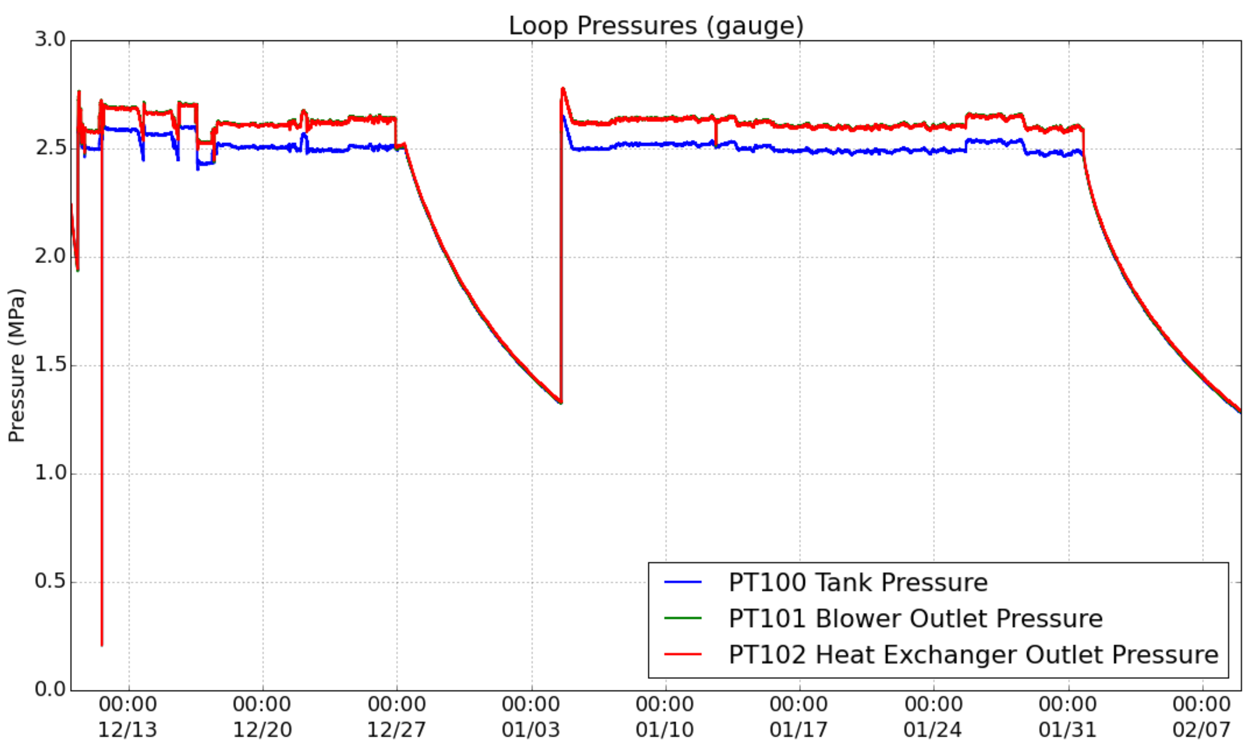

Figure B1. System pressures. The lines for PT 101 and PT 102 overlap. Inlet pressure is nominally 2.5 MPA for the test, or 365 psig or 26 bar.

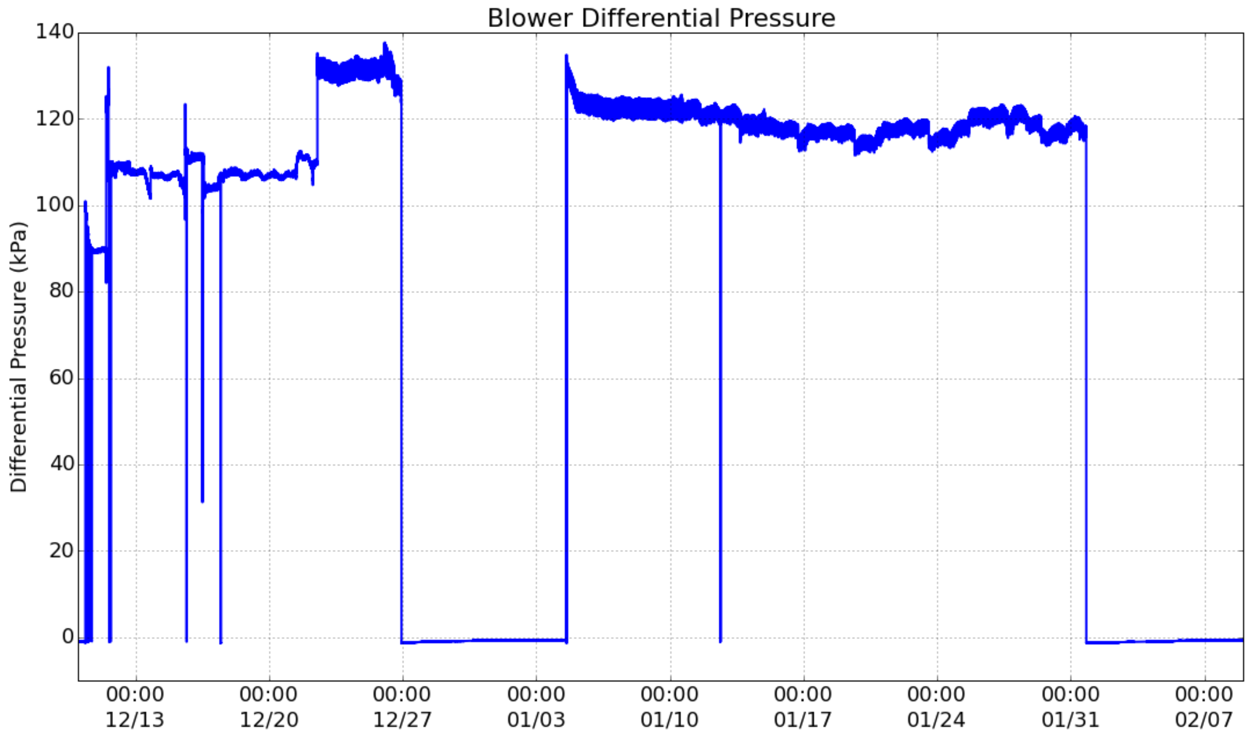

Figure B2. Pressure head developed by the blower. Differential pressure was nominally 120 kPa (17.4 psi).

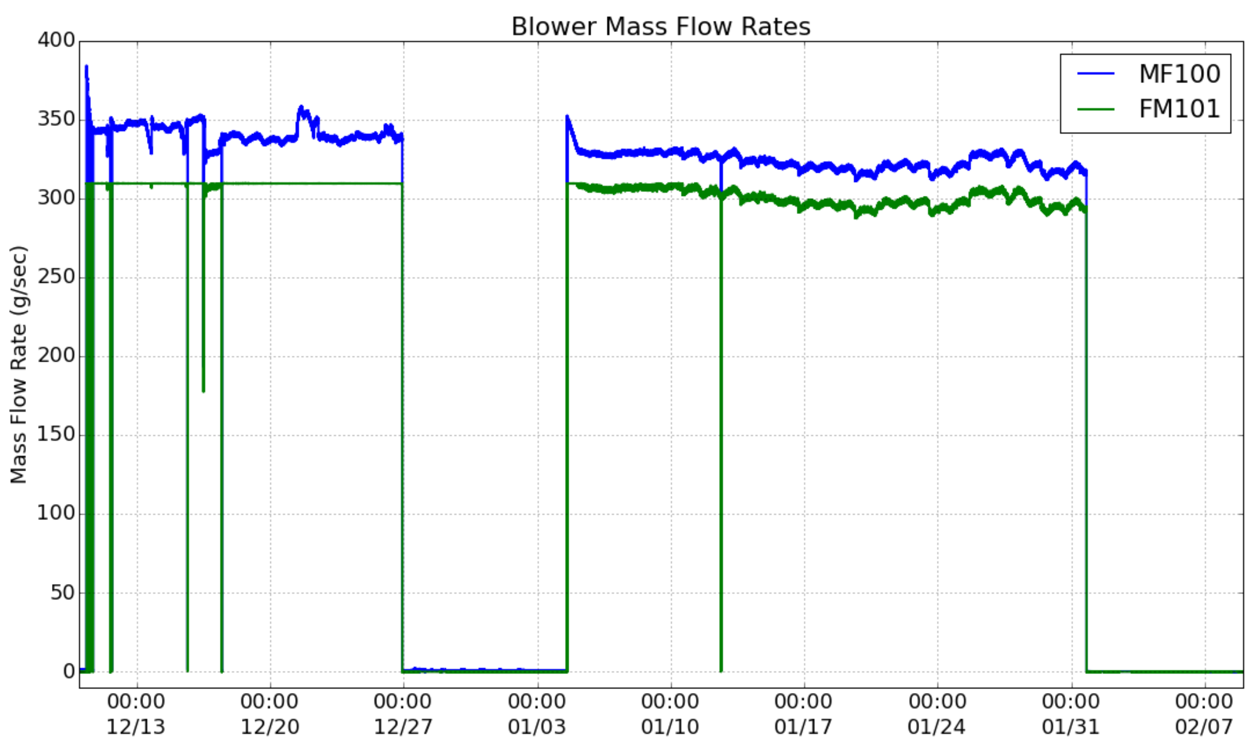

Figure B3. Mass flow rate of helium during the test.

The Aerzen performance calculations for this blower under these conditions is shown in Figure B4. The operating conditions for this test correspond well to the first column in the chart below, with a mass flow rate of 34 g/s and inlet pressure of 26.7 bar. However, the head developed by the blower, as measured, is significantly lower than expected.

AERZEN

Rotary Lobe Blower Performance Data: SI Units

Project :	Helium Blower
Proposal- / Job-No :	PG-130
Customer :	Los Alamos National Labs
Date / User :	11/02/2015 Grady

Operating Case :			180 kPa	147 kPa	113 kPa	80 kPa
Name of Process Gas :			Helium	Helium	Helium	Helium
AERZEN Rotary Lobe Blower Size :			**GM 12.4**	**GM 12.4**	**GM 12.4**	**GM 12.4**
Mole Weight	R :	kg/kgM	4.0	4.0	4.0	4.0
Isentropic Exponent, K = Cp/Cv	κ :	./.	1.66	1.66	1.66	1.66
Intake Volume Flow (actual)	Q_{1act} :	m^3/min	4.64	4.87	5.13	5.44
Standard Volume Flow	V_N :	Nm^3/min	114.31	120.05	126.48	133.96
Standard Volume Flow	V_N :	Nm^3/h	6,859	7,203	7,589	8,038
Specific Weight at Intake Conditions	ρ_1 :	kg/m^3	4.40	4.40	4.40	4.40
Mass Flow	$\dot{m}$:	g/sec	340	357	376	398
Intake Pressure (absolute)	p_{1abs} :	bar	26.70	26.70	26.70	26.70
Discharge Pressure (absolute)	p_{2abs} :	bar	28.50	28.17	27.83	27.50
Differential Pressure	Δp :	kPa	180	147	113	80
Intake Temperature	t_1 :	°C	19.0	19.0	19.0	19.0
Discharge Temperature	t_2 :	°C	31	28	26	24
Blower Speed	n_R :	rpm	1,775	1,775	1,775	1,775
Motor Speed	n_{Mot} :	rpm	1,775	1,775	1,775	1,775
Power at Blower Shaft	P_k :	BkW	22	18	14	10
Motor Rating		kW	27	22	17	12

Tolerances:		Standard Conditions:
for Intake Volume Flow	± 10 %	Temperature = 0° C
for Power at Blower Shaft	± 10 %	Pressure = 101.325 kPa

Figure B4. Expected blower performance.

Gas temperatures are shown in Figure B5. Because of problems controlling the cooling water temperature as low as desired, the run was at a considerably higher temperature than that used in the Aerzen calculations.

Motor power and blower torque are shown in Figures B6 and B7. The temperature rise of the helium across the blower is shown in Figure B8. The total power taken up by heating the gas is Q_{th} = mass flow rate X specific heat X temperature rise, or Q_{th} = 0.325 X 5200 X 10 = 16900 W. The useful work performed on the gas is Qw = pressure rise X mass flow rate / density, or Qw = 118000 X 0.325 / 4 =

9750 W. Total power into the helium is then 26.7 kW. This compares well with the power as shown in Figure B6.

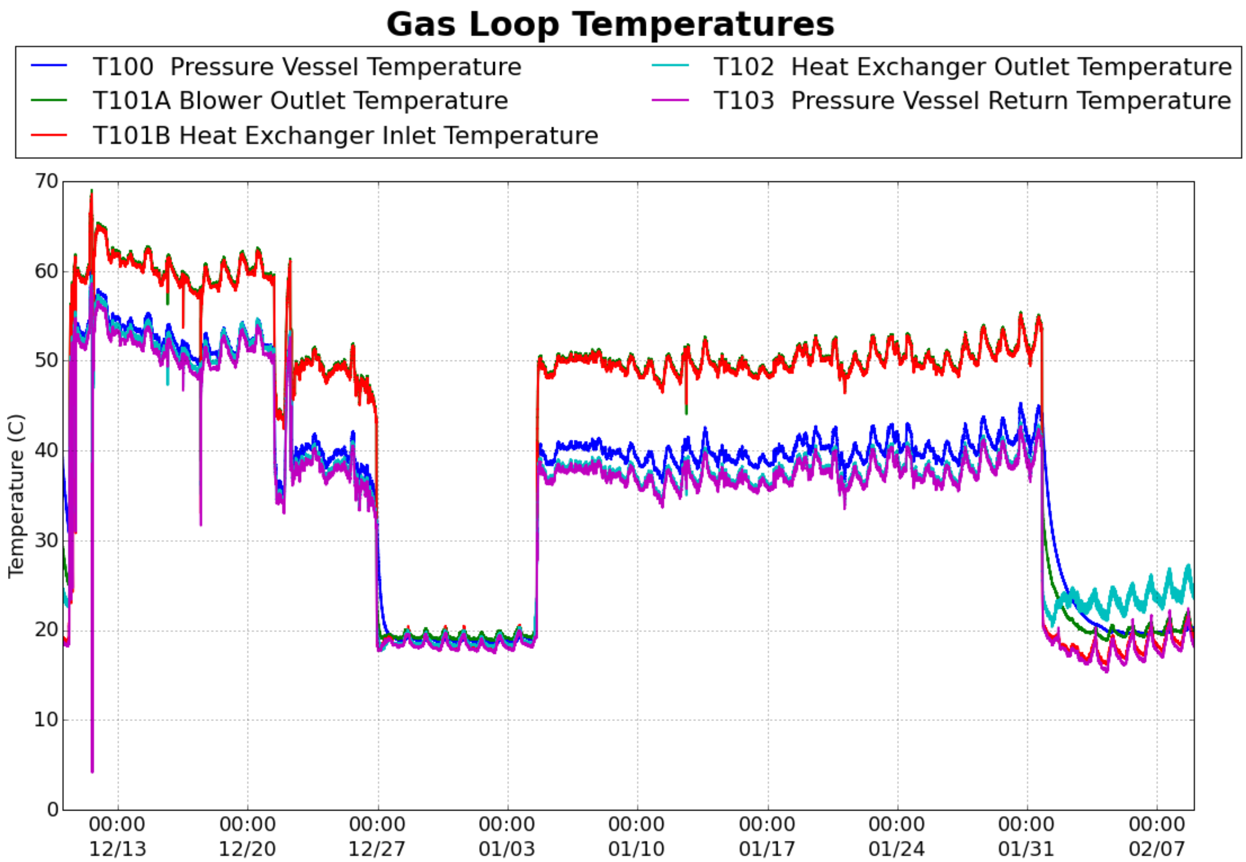

Figure B5. Helium temperatures during the test.

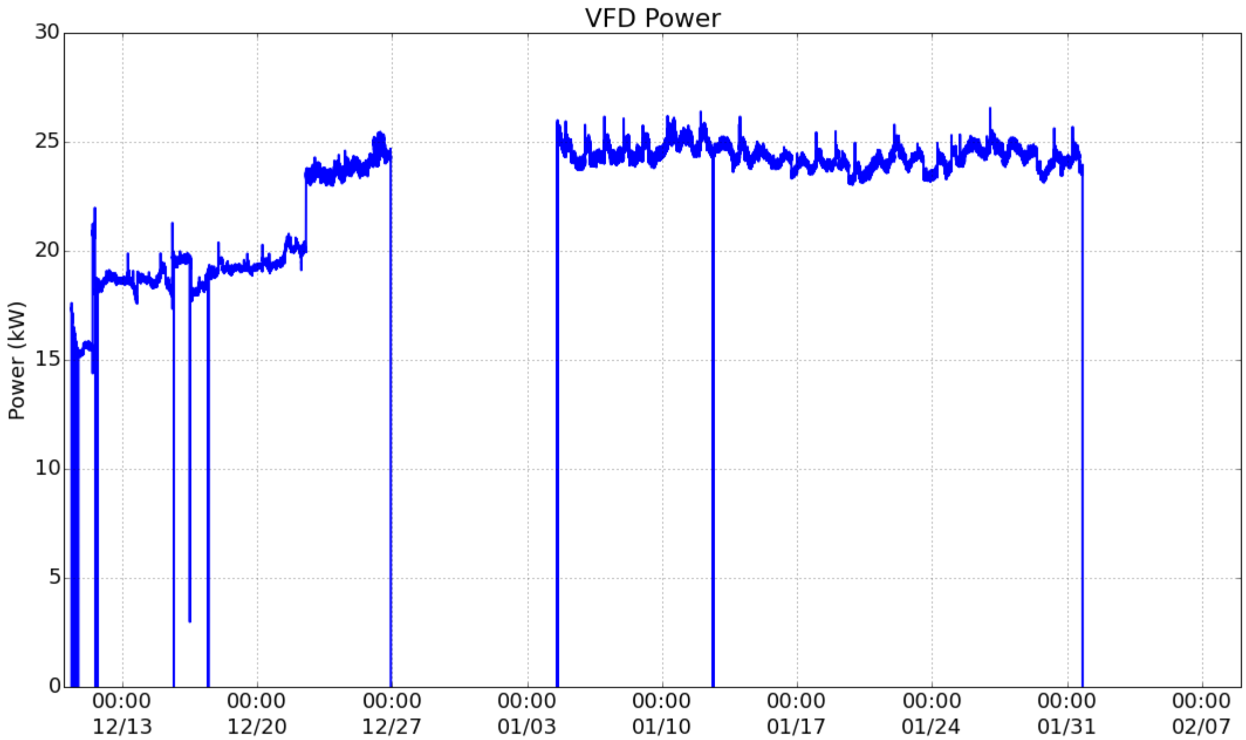

Figure B6. Power to the motor, as measured at the Variable Frequency Drive (VFD).

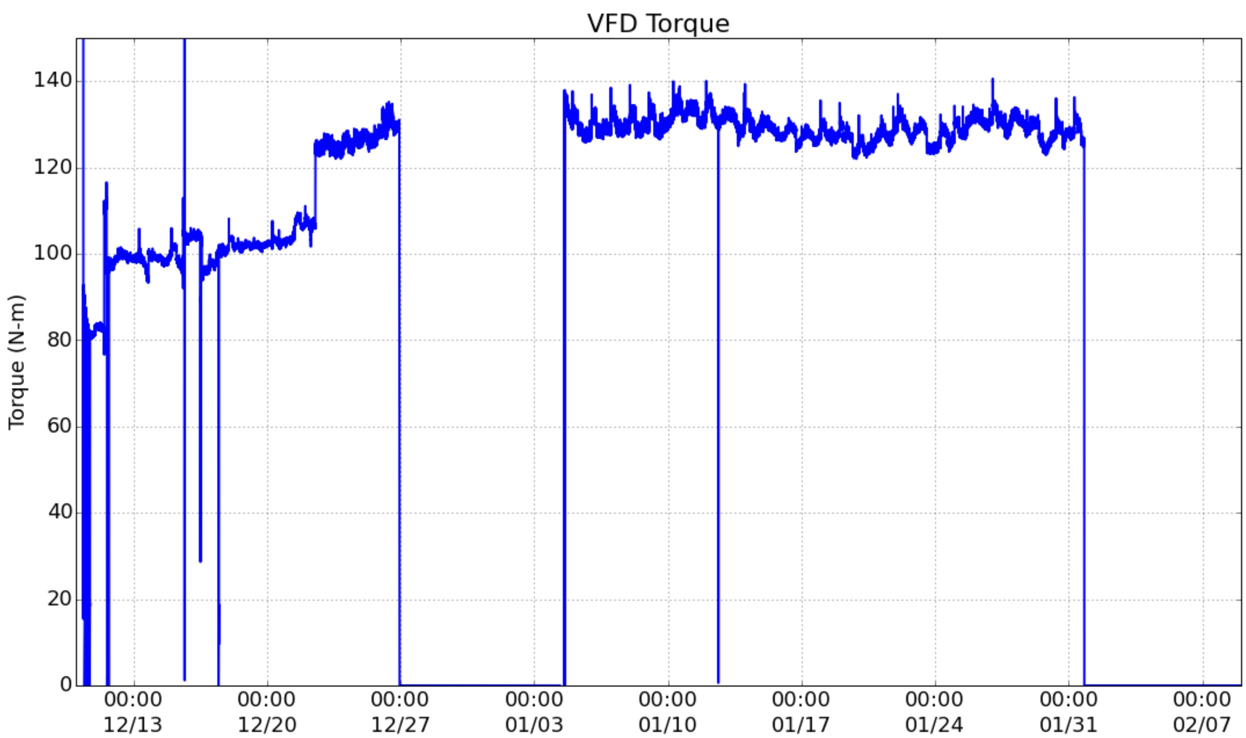

Figure B7. Blower torque.

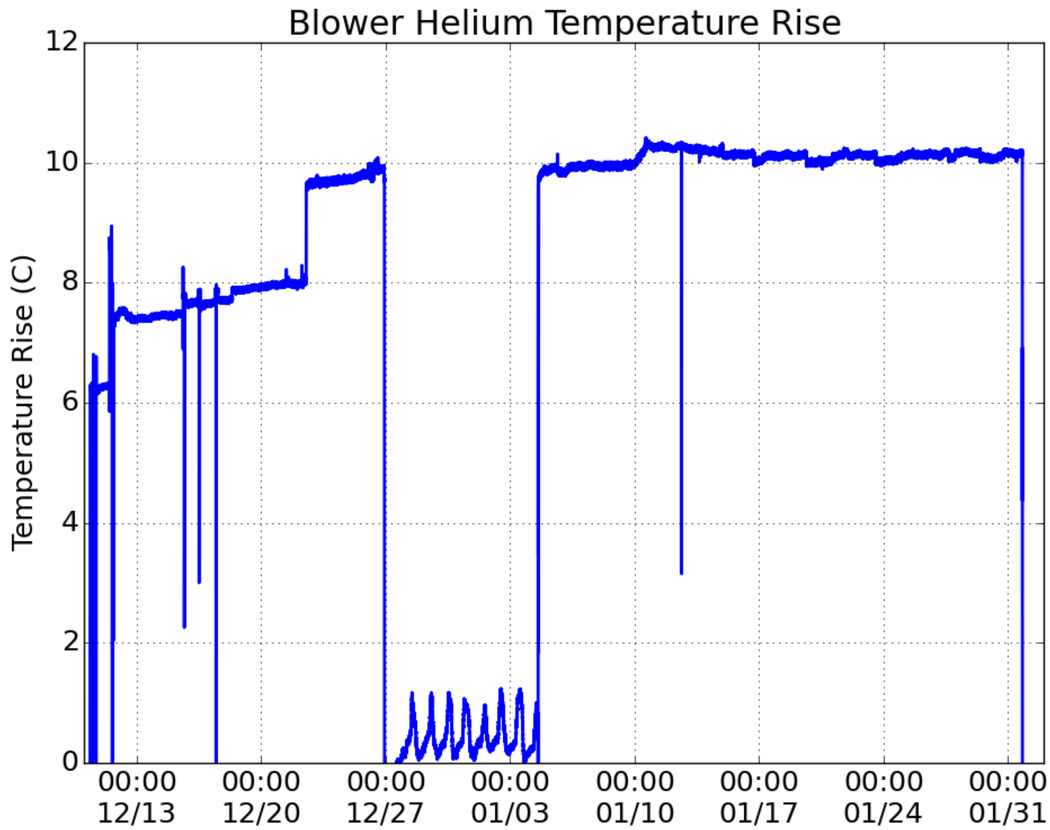

Figure B8. Helium temperature rise across the blower.

Oil Leak

Upon opening the tank, some oil leakage from the shaft seal was evident. Fig B9 shows the reduced oil level in the sight glass and Figures B10 and B11 show some of the escaped oil. The oil was a thinly distributed coating over much of the interior of the tank. After investigation, it was discovered that the sealing covers had not been removed. These are vent ports that allow for pressure equalization between the oiled bearing housing and atmospheric conditions, in this case pressurized helium.

Figure B9. Oil level sight glass, showing some loss.

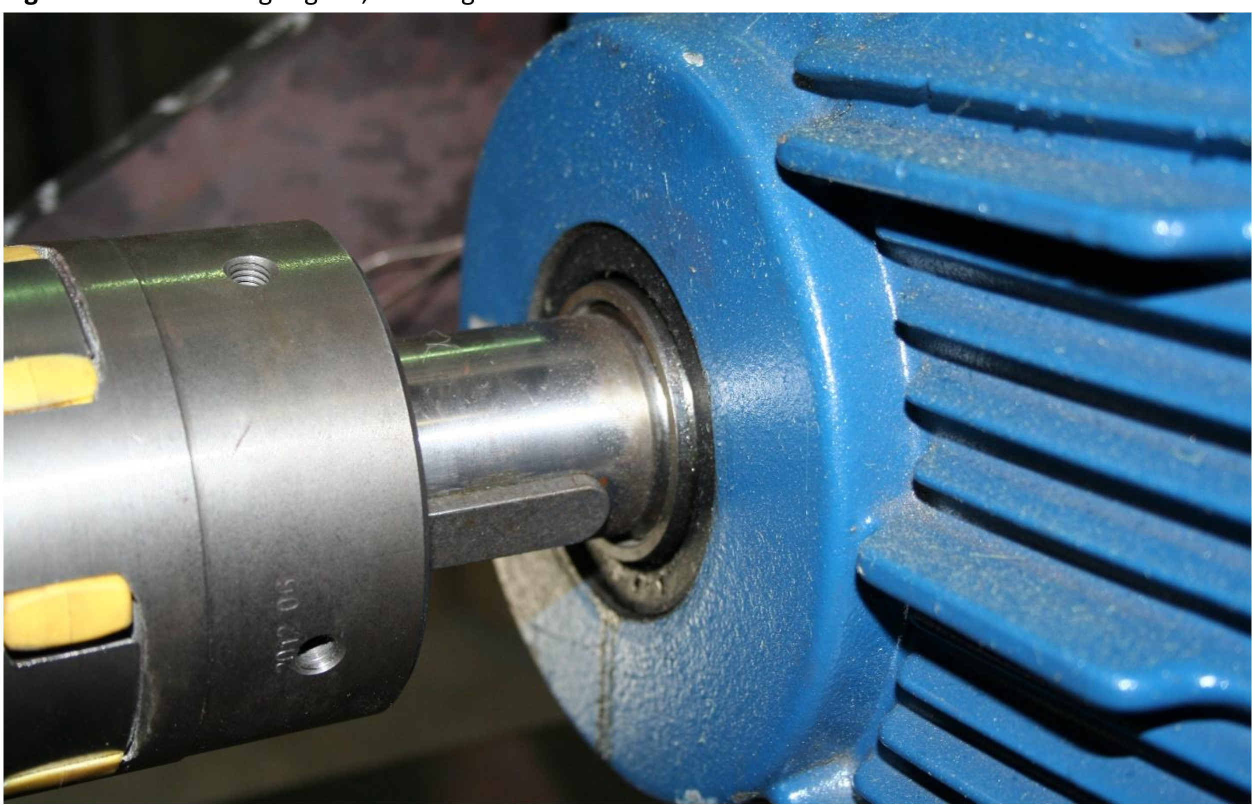

Figure B10. Oil drip trace at the shaft seal.

Figure B11. Oil on the vessel bulkhead, and dripping to the platform below after opening the tank.

Conclusions

The blower has performed well, and should be sufficient to the task of providing the required helium flow to the target. The apparent underperformance of the blower head generated, as compared with the vendor calculated numbers, needs to be investigated and understood. This will be systematically studied in the next test. The 4 calculated run points will be replicated as closely as possible and discussed with the vendor.