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MULTIPLE (TWO) MET BEL 601 IN SERIES ULTIMATE VACUUM TESTING

SRNL Environmental and Chemical Process Technology (E&CPT) was requested to perform testing of vacuum pumps per a verbal request from the Customer, SRNL Hydrogen Processing Technology. Tritium Operations is currently having difficulties procuring the Normetex™® Model 15 m^3/hr (9 CFM) vacuum pump (formerly Normetex Pompes, now Eumeca$_{SARL}$). One possible solution proposed by Hydrogen Processing Technology personnel is to use two Senior Aerospace Metal Bellows MB-601 vacuum pumps piped with the heads in series, and the pumps in series (Figure 1 below). This memorandum documents the ultimate vacuum testing that was performed to determine if this concept was a viable alternate vacuum pump strategy. This testing dovetails with previous pump evaluations documented in references 1 and 2.

Figure 1. MB-601's Pumping System

1.1 Flow Characteristics of the Senior Aerospace Metal Bellows MB-601

The performance of MB-601 pumps is well known at SRS and these pumps can be procured with secondary bellows if needed for secondary process fluid containment. The flow curves for the MB-601 vacuum pump are shown below in Figure 2. Additionally, Table 1 provides the same information in units of Torr. The testing results documented in this memorandum were obtained with the Metal Bellows MB-601 pump heads piped in series, maximizing the ultimate vacuum achievable.

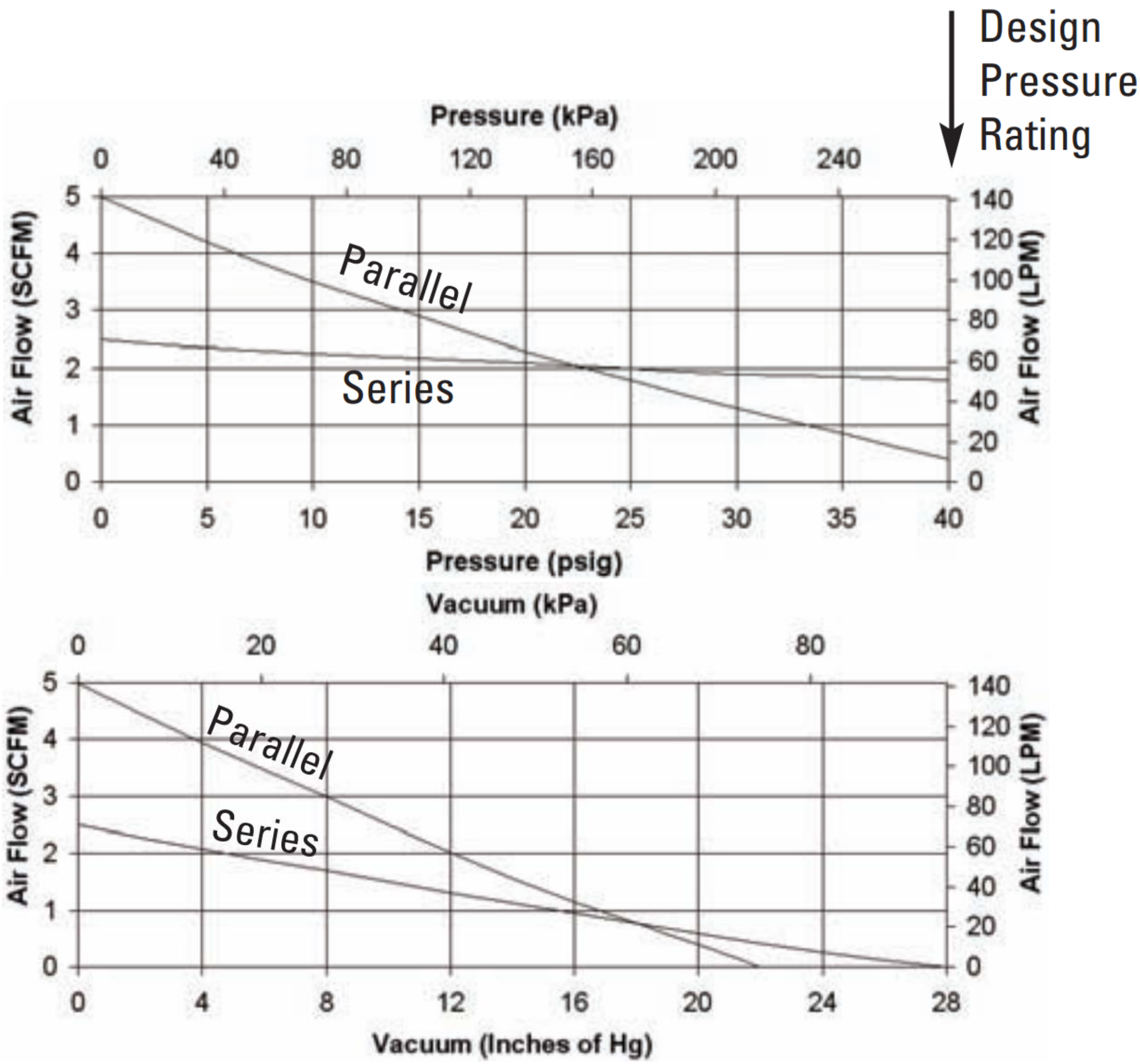


Figure 2. MB-601 Vendor Pump Curves

Table 1. MB-601 Vendor Pump Curves (piped with heads in series), tabular

SERIES PIPED-Vacuum Chart			
Vacuum inches of Hg	Inlet Pressure, in H_2O	Inlet Pressure, Torr	Flow Rate, Air, SCFM
28	**381.1**	**48.8**	0
24	**326.7**	**150.4**	0.28
20	**272.2**	**252.0**	0.61
16	**217.8**	**353.6**	0.97
12	**163.3**	**455.2**	1.33
8	**108.9**	**556.8**	1.75
4	**54.4**	**658.4**	2.14
0	**0.0**	**760.0**	2.50

1.2 Pump Features

Senior Aerospace Metal Bellows MB-601 is a positive displacement, metal bellows pump that can be used both in vacuum service and in pressure service. It uses a single phase, dual voltage (115/230 V) motor. It can optionally be provided with an explosion proof motor, polyphase motor, totally enclosed fan cooled motor, variable speed motor, Aluminum O-ring seals, VCR fittings, Viton valve gaskets, and a high pressure model. It has 3/8" N. P. T. fittings on both the inlet and discharge ports, and can be piped with the heads serially or in parallel. The vendor stated design pressure for the MB-601 is 40 psig, and the vendor warns that damage may occur quickly to the bellows diaphragms if that value is exceeded.

1.3 Pump Test Scope

The pumps were piped in series, with pump heads in series, using ½" Stainless Steel Tubing (0.035" Wall). Stage 4 intake tubing was 3/8" Stainless Steel Tubing. The goal of testing was to determine the ultimate vacuum level achievable for these pumps as configured with the heads and pumps piped in series.

2.0 Experimental Procedure

2.1 Experimental Approach

The following piping and instrument sketch shows the basic testing rig, which was modified as needed for various testing parameter requirements (Note: A protective inlet filter was not used during this testing):

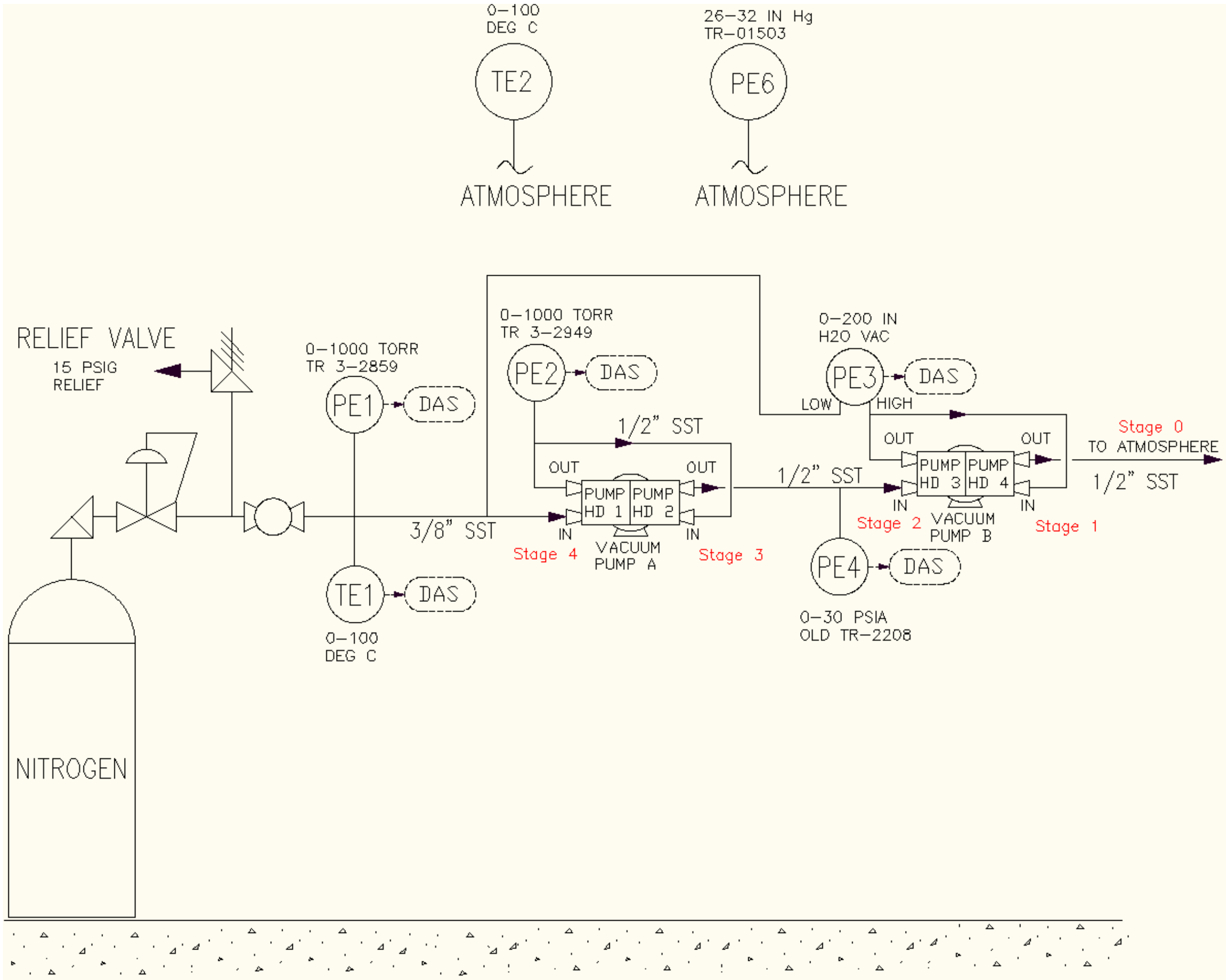


Figure 3. Basic Configuration for Vacuum Testing, MB-601 Series Piped

In Figure 4 are pictures of the rig, including the Data Acquisition System.

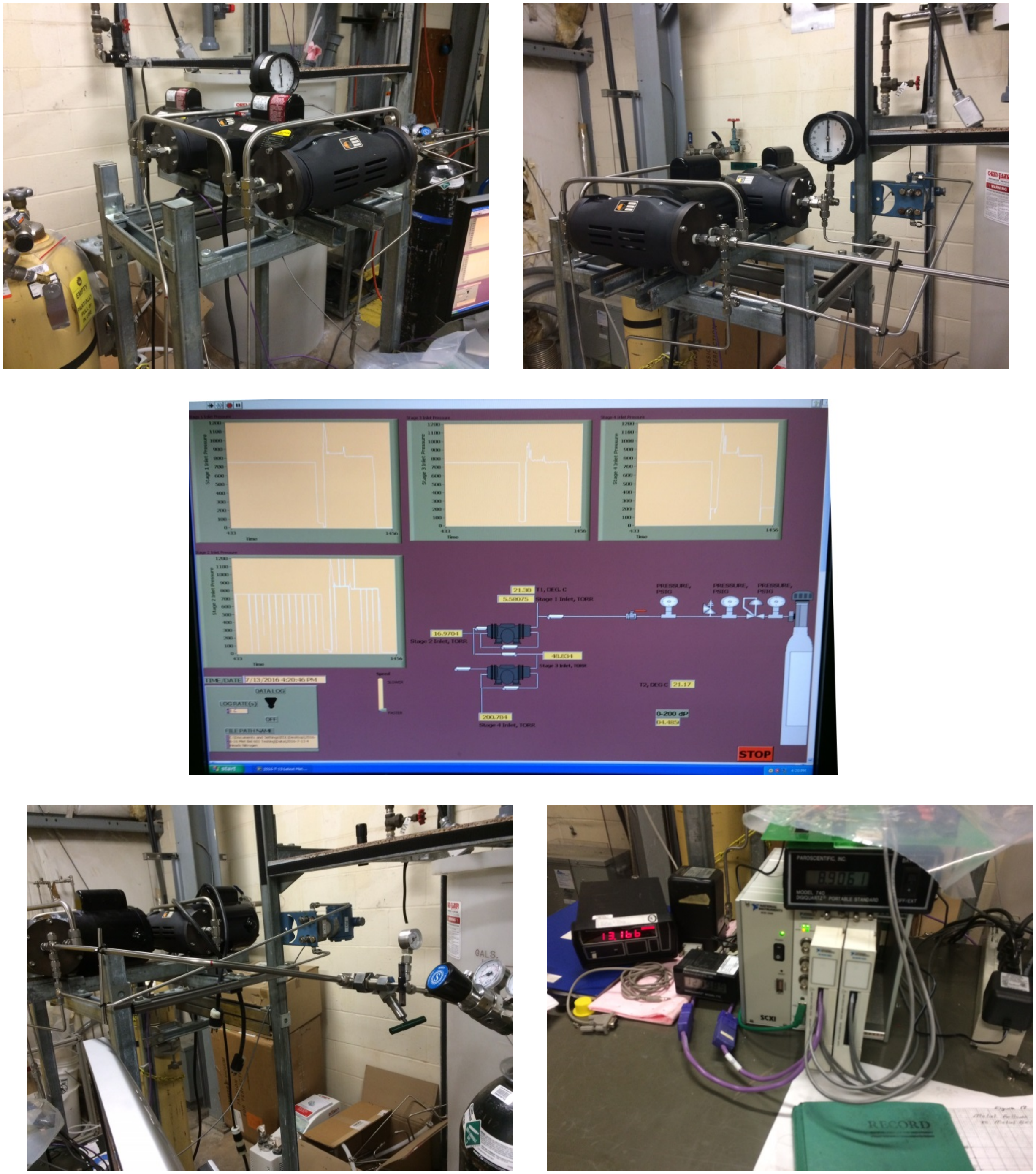


Figure 4. Various Photos of the Test Rig, including the Data Acquisition System

2.2 Equipment Description

The following is a list of the equipment used:

Inlet Stage 1 Pressure Gauge
Rosemount 1151 dP Transducer, M&TE #03713, calibrated 0-200 in H_2O (PE3)
Inlet Stage 2 Pressure Gauge
Heise 901A Pressure Transducer, 0-30 PSIA, Old TR-2208 (PE4)
Inlet Stage 3 Pressure Gauge
Paroscientific Model 710, M&TE #3-2549 (PE2)
Inlet Stage 4 Pressure Gauge
Paroscientific Model 740, M&TE #3-2859 (PE1)
Temperature Instrument
Type E Thermocouple, M&TE #TR-01516, 1/8" body
Type E Thermocouple, M&TE #TR-01510, 1/8" body
Type E Thermocouple, M&TE #TR-40011, 1/16" body
Pumps
Met Bel 601, P/N #29991 Serial #2131 (Pump A)
Met Bel 601, P/N #29991 Serial #2129 (Pump B)
Gas Cylinder Regulator Relief Valve
CLI A-773000-LAB-PSV-6389, 15 psig relief
Pressure Gauge (0-15 psig pressure, 0-30 in Hg Vacuum)
Ashcroft Duragage Model 4513799

Data Acquisition Hardware
Dell 690 Tower running Windows™ XP
National Instruments™ Hardware
SCXI-1000 4-Slot Chassis
SCXI-1600 USB Data Acquisition and Control Module
SCXI-1102 with 1303 Terminal Block, Signal Conditioner for thermocouples and 4-20 mA Instruments
SCXI-1124 6-Channel Isolated Digital-to-Analog Converter Module with SCXI-1325 Terminal Block, used for sending flow meter set points

The equipment/instrument list used for pressure protection concerns is provided in Appendix A (on page 31). Type E thermocouples were used. A 15 psig Relief Valve/Regulator combination was chosen for supplying Nitrogen as the test/purge gas. Additionally, during leak checking, the type E thermocouple was removed (and not reinstalled) from the inlet to the vacuum pumps to eliminate a source of leaks. Informal temperature measurements were made at various operating conditions to determine if temperatures were changing significantly. Temperatures on discharge from the various tests showed less than 2 °C rise.

The pressure transducer for Head #4 suction was a Heise 901A absolute pressure transducer. Vendor stated tolerance is ±0.07% and ±0.035% Full Scale. It was uncalibrated. A non-QA sanity check (documented in the Electronic Notebook ELN #09117-00066-05[4]) was performed against TR 3-2859 pressure transducer, a calibrated instrument. The results are shown below.

TR 3-2859 Rdg, Torr	Heise Rdg, VDC
747.88	2.1547
747.867	2.1546
700.024	2.0032
700.016	2.0027
602.919	1.7044
602.973	1.7053
495.708	1.366
495.951	1.3699
399.857	1.0645
399.814	1.0655
300.669	0.7581
300.888	0.761
197.488	0.4396
197.483	0.4398
97.9013	0.1319
97.877	0.132
67.0833	0.0372
67.0543	0.0374

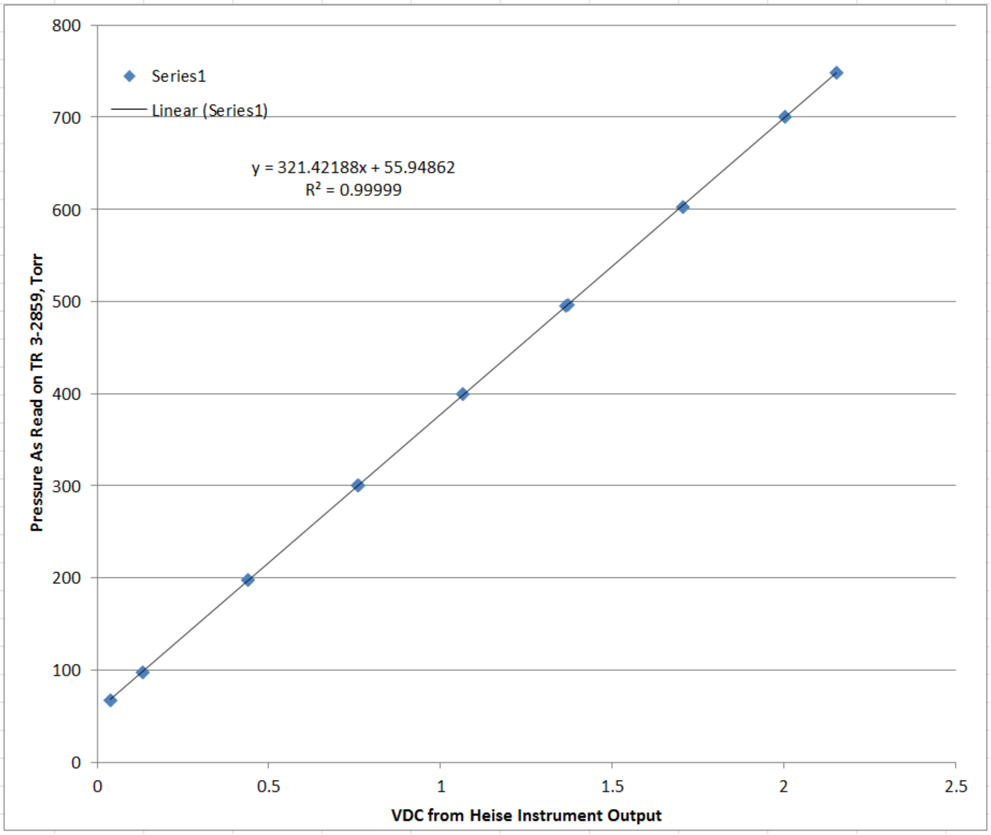


Figure 5. Heise Pressure Indication Check

As the data shows, there was excellent agreement between the output of the Heise and the calibrated pressure transducer. The output (Volts DC) was then corrected in Labview by the linear trend line and used in testing. Various sanity checks against the other calibrated instruments indicated that it was performing appropriately.

To measure Stage 1 inlet pressures, a Rosemount differential pressure transducer was used. It was piped with the high side ported to the Stage 1 piping, and the low side ported to Stage 4 piping. This provided a differential pressure within the range of the instrument, which had been previously calibrated for service on the previous testing rig. The transfer equation was then still valid, and the instrument calibrated.

All instrument impulse lines were constructed of ¼” (0.035”) Stainless Steel Tubing. Data Acquisition Software and programming details are included in the electronic notebook. All work was performed under SRNL eHAP #SRNL-L3100-2015-00025, Rev 1, 786-A Vacuum Pump Testing for SHINE GBSS.[3]

2.3 Leak Checks

Leak checks were provided during the initial installation and subsequent piping changes. The standard formula to determine the leak rate is shown below. The goal was to minimize leakage, and significant work was done to achieve this goal.

$$\text{Leak Rate in SCFM} = \frac{(\Delta P)x(\text{Volume})x(294.26\ K)}{(\Delta t)x(760\ \text{torr})x(\text{temperature})}$$

Leak Rate in Std. CC/Sec=SCFM*28316/60

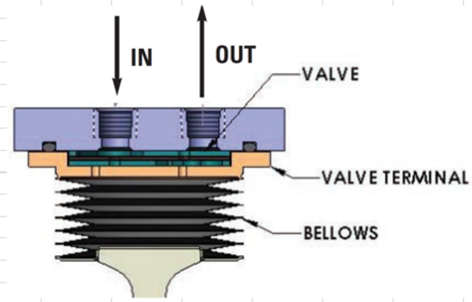
Where there are 28316 cubic centimeters per cubic foot and there are 60 seconds in a minute.

ΔP = Pressure increase in torr (or psi as appropriate)=P_1-P_0
Volume = Internal volume of piping, pump, gauges, etc... (in cubic Feet)
294.26 K=Standard Temperature, Kelvin (Based on industry standard, see attachment B)
Temperature = Room temperature in $^oK = (^oC + 273.15)$
Δt = duration of leak test in minutes=t_1-t_0

The methodology for determining the volume is shown below in Figure 6. At any given time, the volume of the moving pistons, being 180^o out of phase to eachother, would equate to ½ of the swept volume for each head. The volume of the actual pump internals was then taken as ½ the swept volume based on the dimensions below, and then multiplied by two for each pump to arrive at the total pump head volume.

	1/8" 0.028" Wall	1/4" 0.035" Wall	3/8" 0.035" Wall	1/2" 0.049" Wall	
Length, inches	1	128	44	94	
Volume, cubic Inches	0.00	3.26	3.21	11.92	
Total Volume, cubic inches	=sum of tubing, one rosemount (2 cavities), and Met Bel Volumes(2)				
=	30.23	total cubic inches of volume			
	Leak Rate=	ΔPxVolX273 / Δtx760xT	(results in SCFM)		
	ΔP	Change in pressure, torr			
	Vol	Volume, cubic ft		0.017	cubic feet
	Δt	time, minutes			
	T	Temperature of Gas, K			
	P1=	Initial Pressure, Torr		246.62285	
	P2=	Final Pressure, Torr		258.6235	
	ΔP=	P2-P1		12.000654	
	Vol=	Volume of pressure boundary			
	Δt=	Time in minutes		60	
	T=(K)	Temp of rig, deg. C		23.8	
		Leak Rate=	4.56E-06	SCFM	
			0.002153	Std. CC/Sec	

Volume of Rosemount-	1.2	mL		0.0732
	Measured with water			
Volume of Met Bel 601-	5.84	cubic inches		
Measured Shaft Eccentricity"0.75				



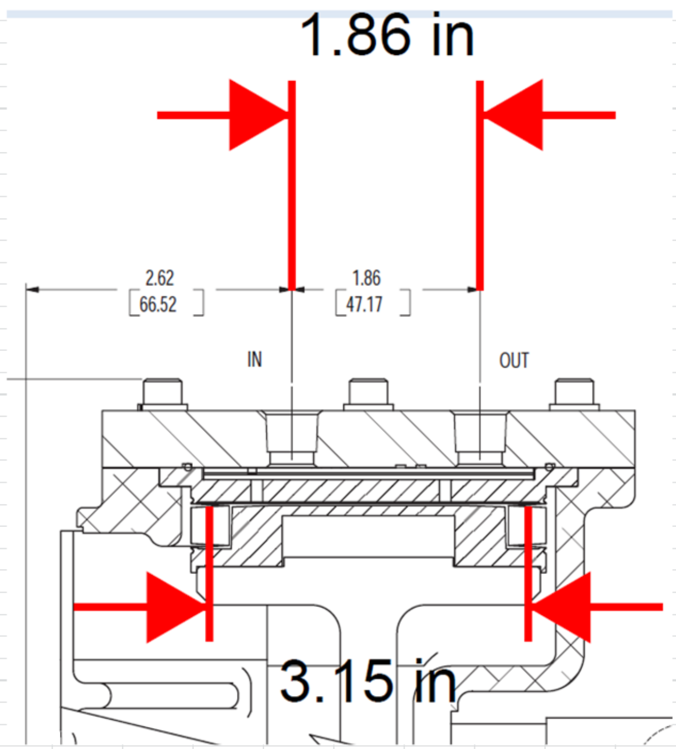


Figure 6. Volume Calculations

The calculated leak rates are recorded in reference 5. Final leak rates for the system are shown below in Figures 7 and 8.

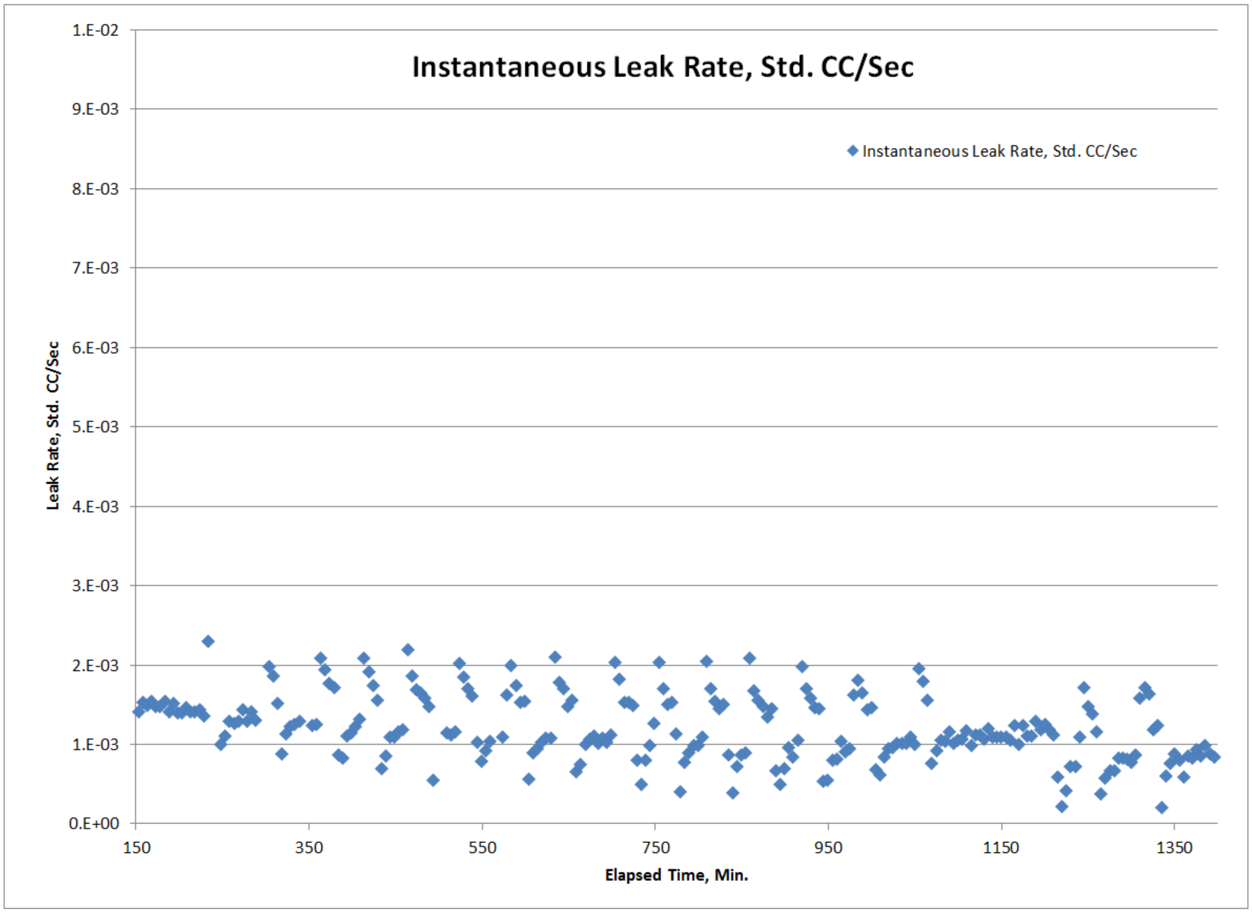


Figure 7. Leak Rate for the Test Rig, std. CC/Sec

The above data is also plotted versus inlet pressure to see if any trends are present. This is shown below.

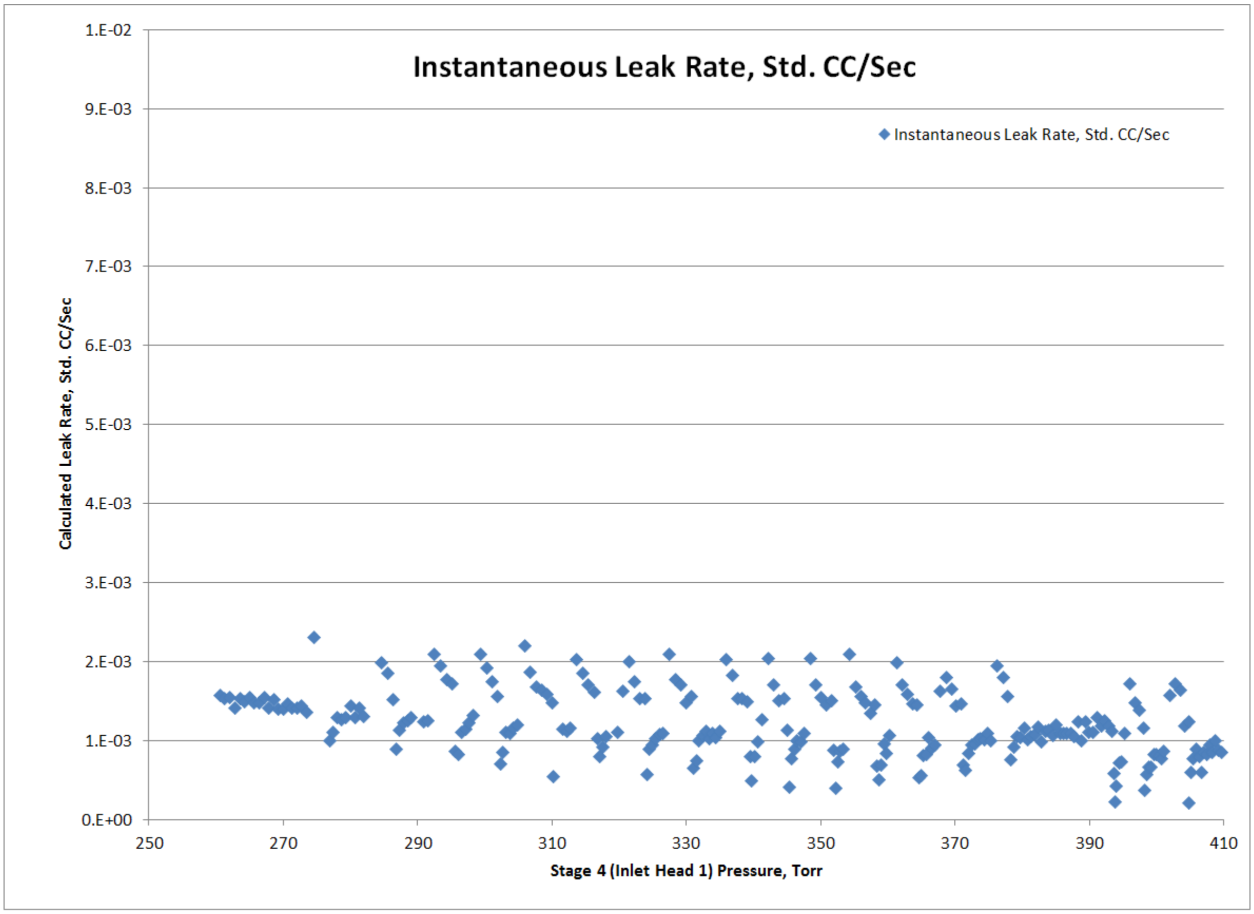


Figure 8. Leak Rate for the Test Rig, std. CC/Sec plotted vs. Stage 4 pressure

2.4 Experimental Testing

Testing was performed by purging for several minutes with Nitrogen, then closing off the inlet valves (an additional block valve was added upstream for leak checking), and recording the ultimate vacuum achieved. This was performed for 4 heads, 3 heads, 2 heads, and one head. Four head testing was repeated twice as a check. All work was documented in ELN #09117-00066-05.[4]

3.0 Results and Discussion

3.1 <u>Experimental Results</u>

This test rig did not have a filter on the inlet, and atmospheric air was used during initial shakedown runs. In reference 5, the author notes that the flapper-type check valves used in the Metal Bellows MB-601 pumps are very sensitive to contamination, which could have had an effect on the testing results. The reference 5 author also notes an ultimate vacuum level achieved during testing of 30 Torr. The testing described in this report produced 40 Torr ultimate vacuum levels for one pump.

The following pages contain data for testing of 4 head, 3 head, 2 head, and one head arrangements.

3.1.1 Four Head Ultimate Vacuum

The first testing was performed with the completed rig, all four heads piped up in series. This test was repeated two times to verify results. Figure 9 below shows the results from all three runs. All discharge pressures (Stage 0) were observed to be 0 psig using a pressure gauge.

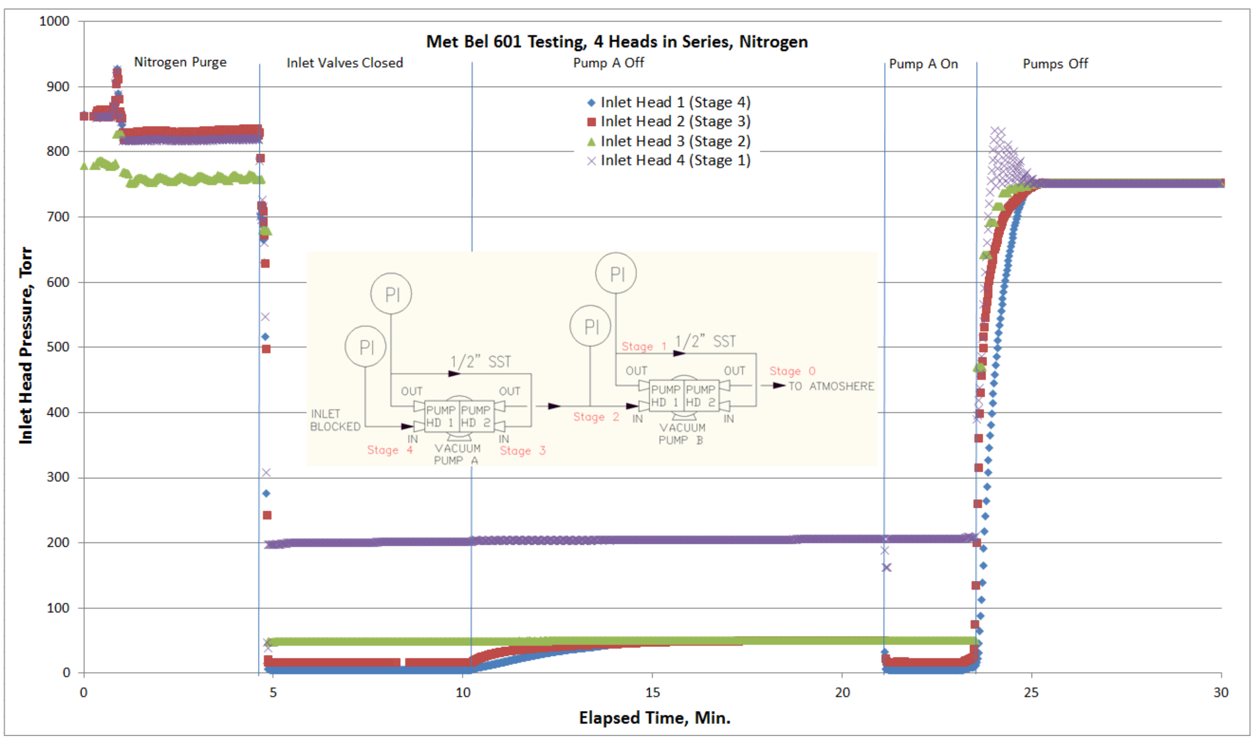


Figure 9. 2016-7-13 Four Head Ultimate Vacuum, Nitrogen Purge

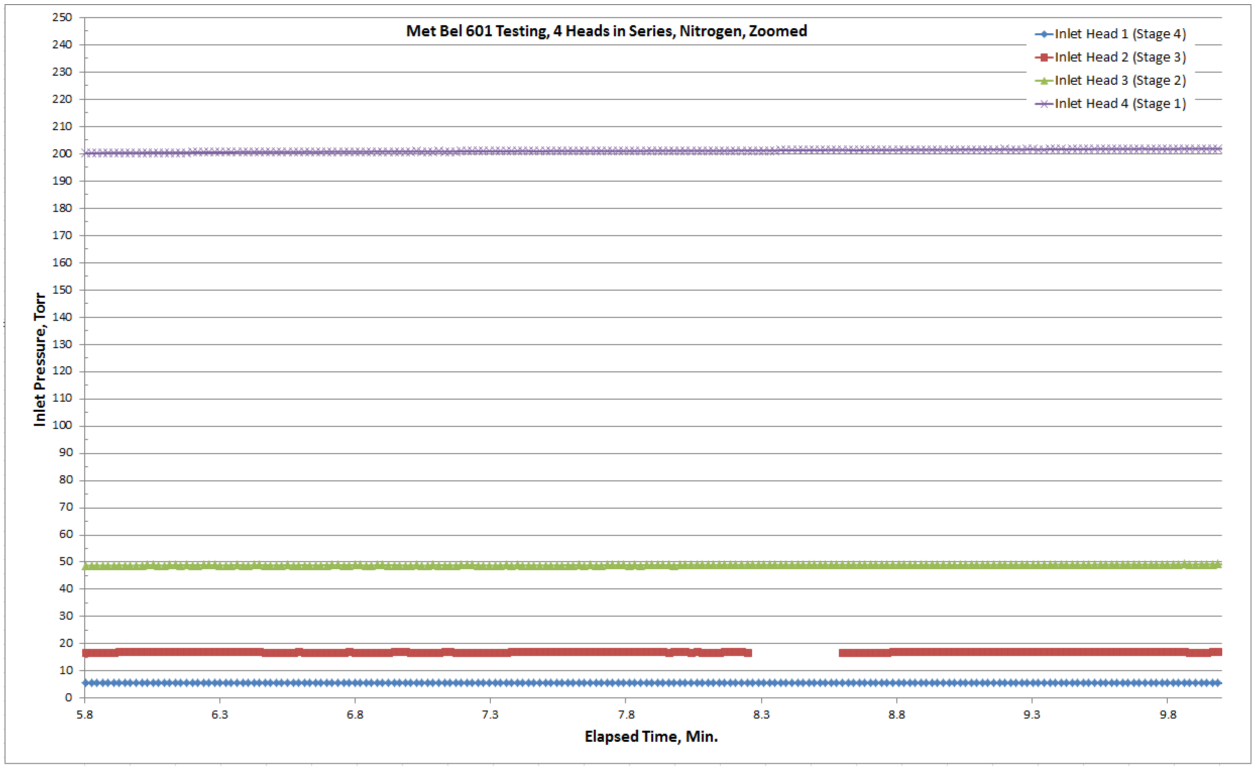


Figure 10. 2016-7-13 Four Head Ultimate Vacuum, Nitrogen Purge, Zoomed

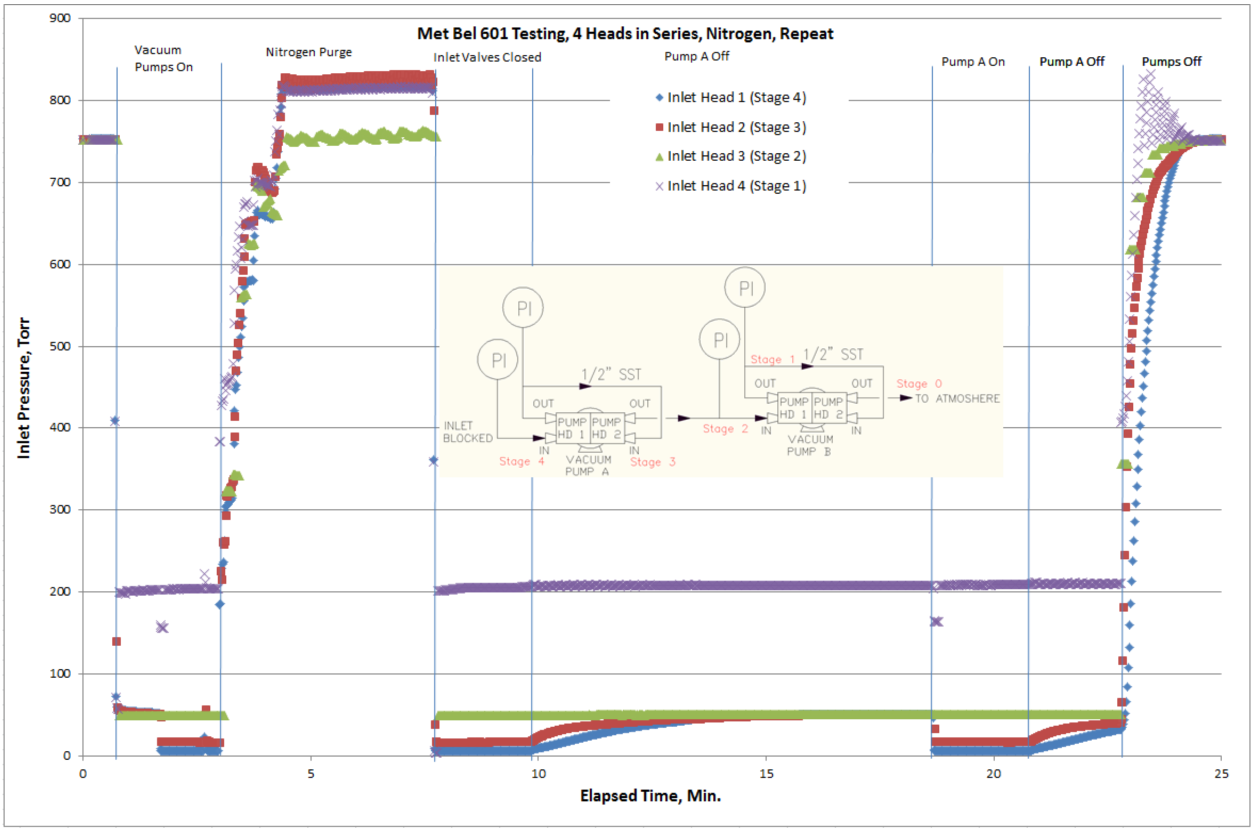


Figure 11. 2016-7-13 Four Head Ultimate Vacuum, Nitrogen Purge, Test 2

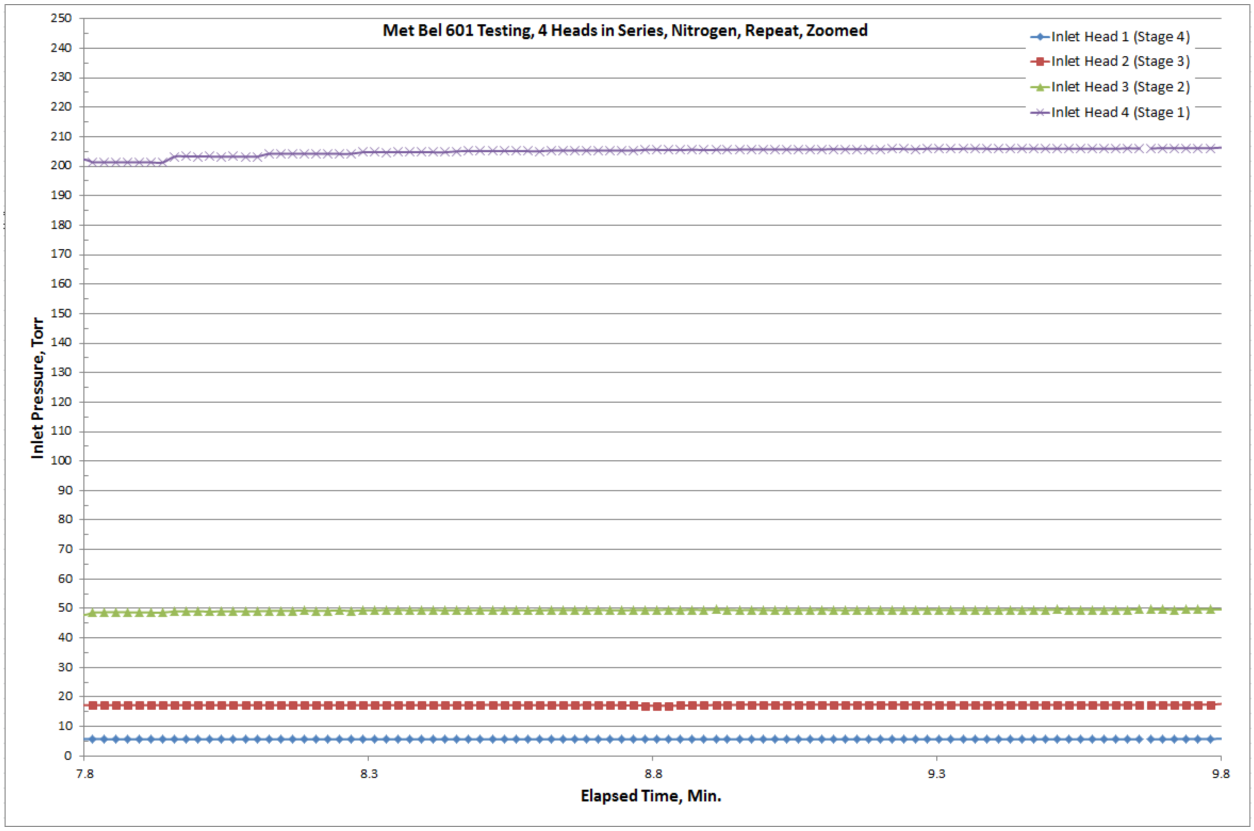


Figure 12. 2016-7-13 Four Head Ultimate Vacuum, Nitrogen Purge, Test 2, Zoomed

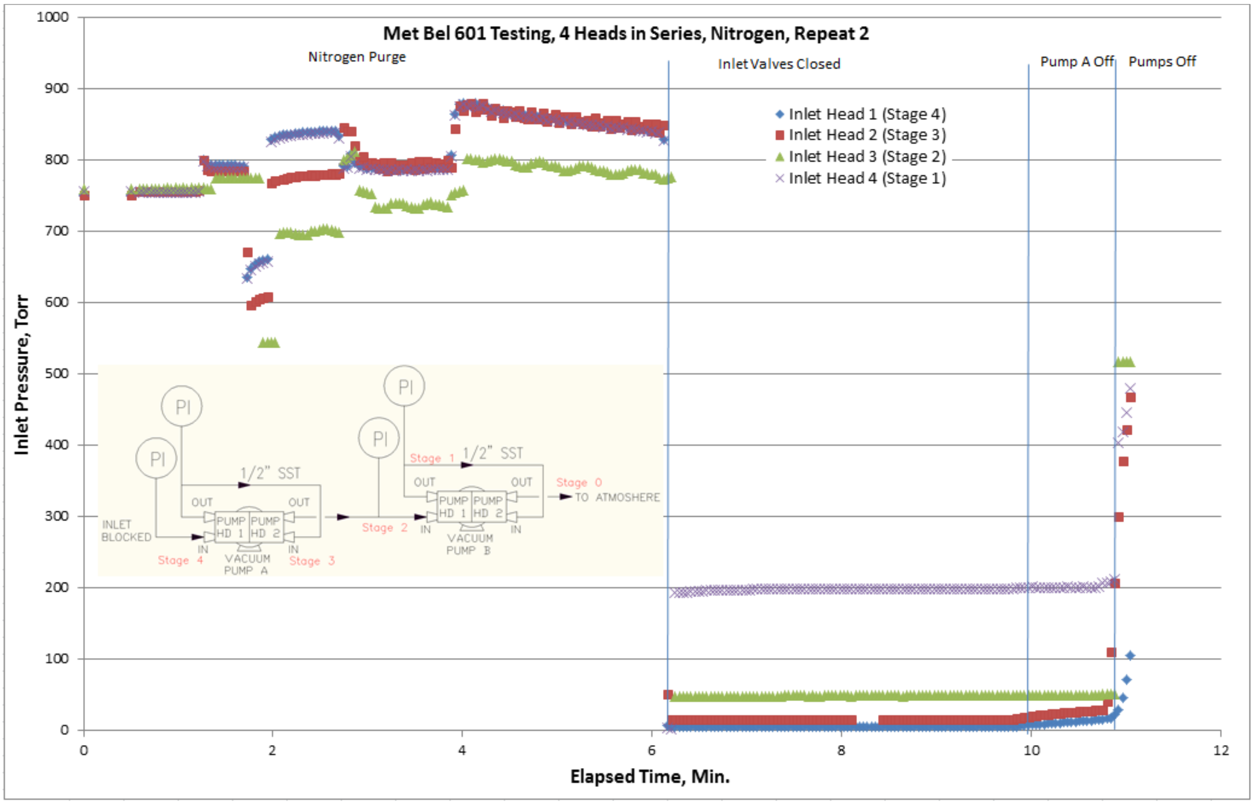


Figure 13. 2016-7-18 Four Head Ultimate Vacuum, Nitrogen Purge, Repeat 2

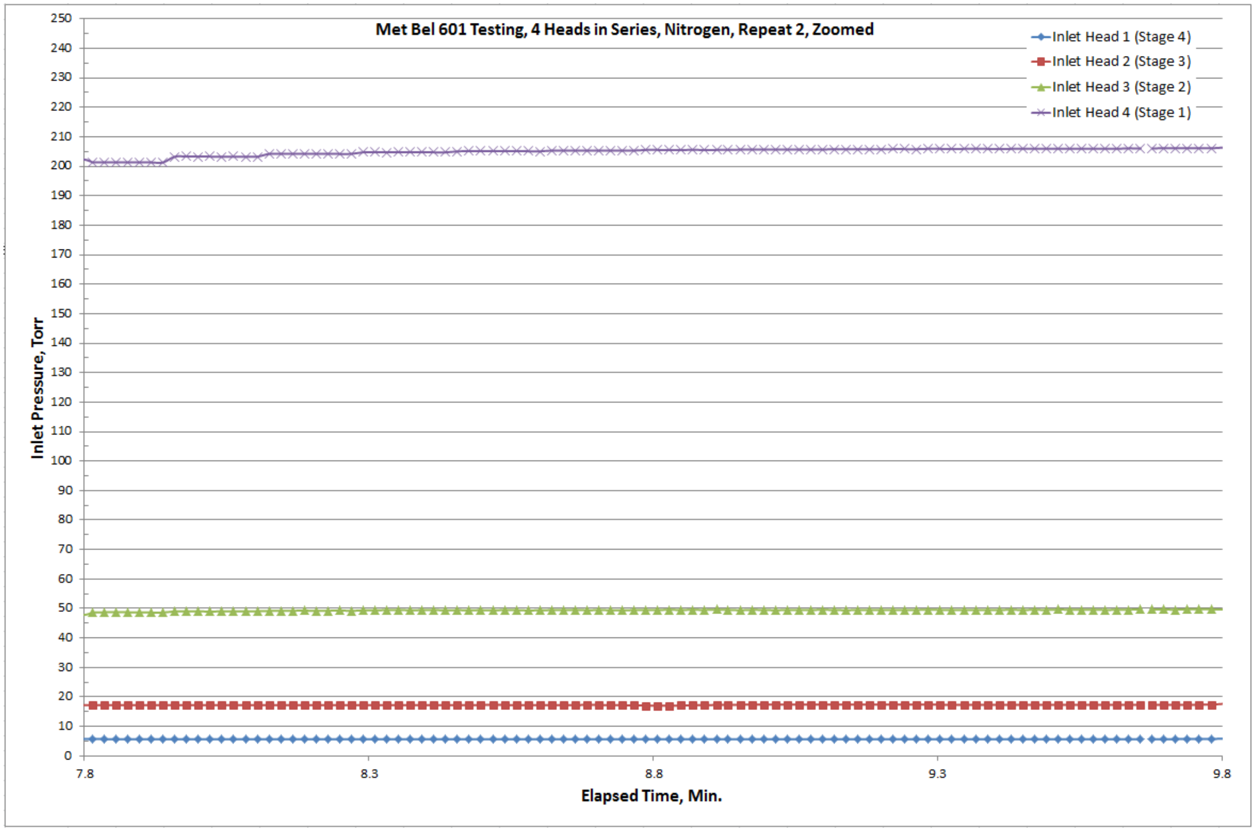


Figure 14. 2016-7-18 Four Head Ultimate Vacuum, Nitrogen Purge, Repeat 2, Zoomed

3.1.2 Three Head Ultimate Vacuum

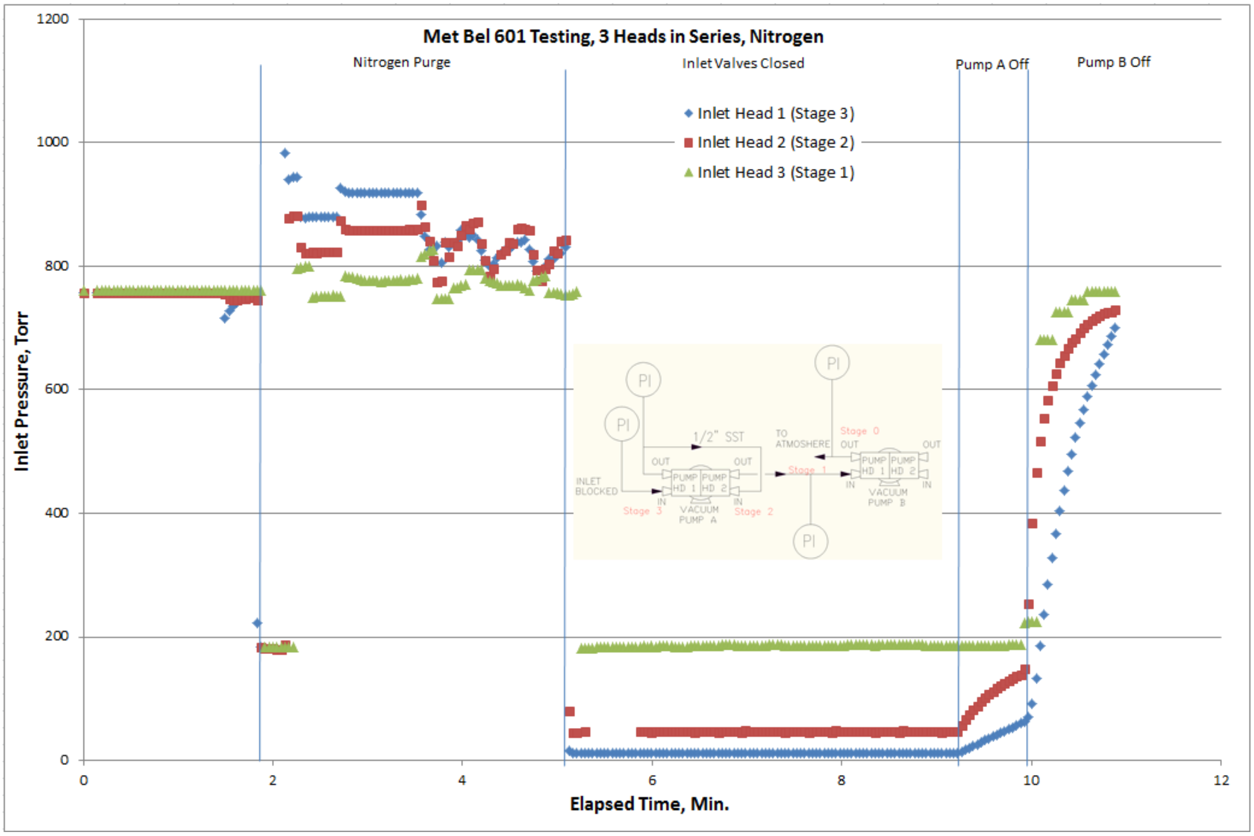


Figure 15. 2016-7-18 Three Head Ultimate Vacuum, Nitrogen Purge

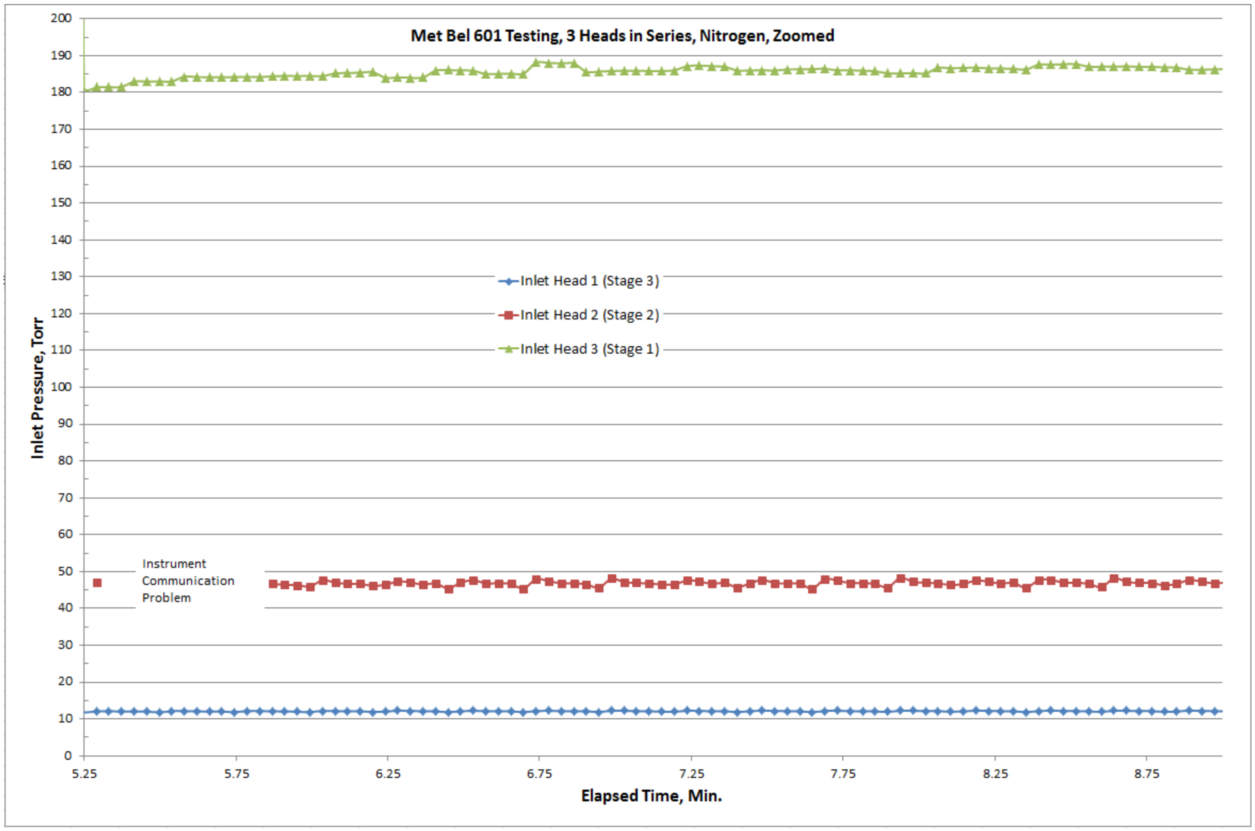


Figure 16. 2016-7-18 Three Head Ultimate Vacuum, Nitrogen Purge, Zoomed

3.1.3 Two Head Ultimate Vacuum

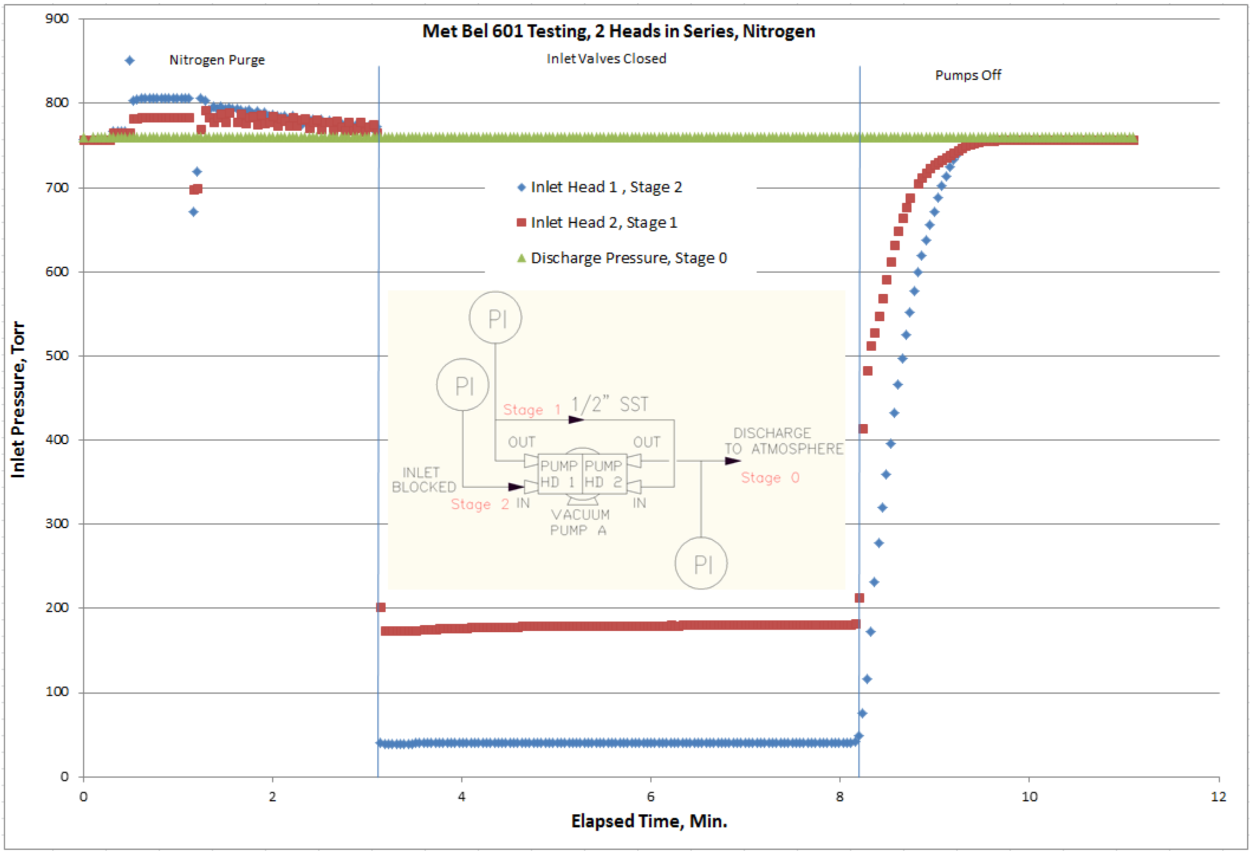


Figure 17. 2016-7-18 Two Head Ultimate Vacuum, Nitrogen Purge

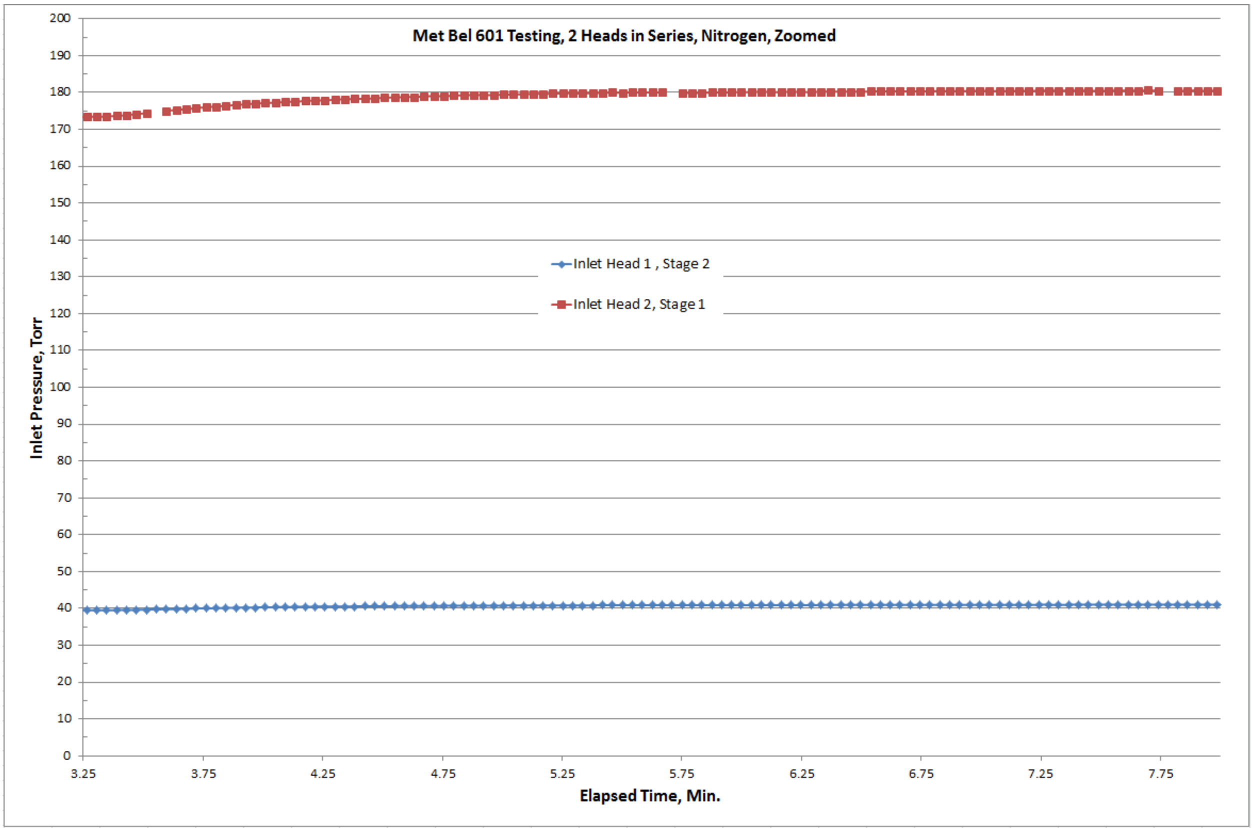


Figure 18. 2016-7-18 Two Head Ultimate Vacuum, Nitrogen Purge, Zoomed

3.1.4 One Head Ultimate Vacuum

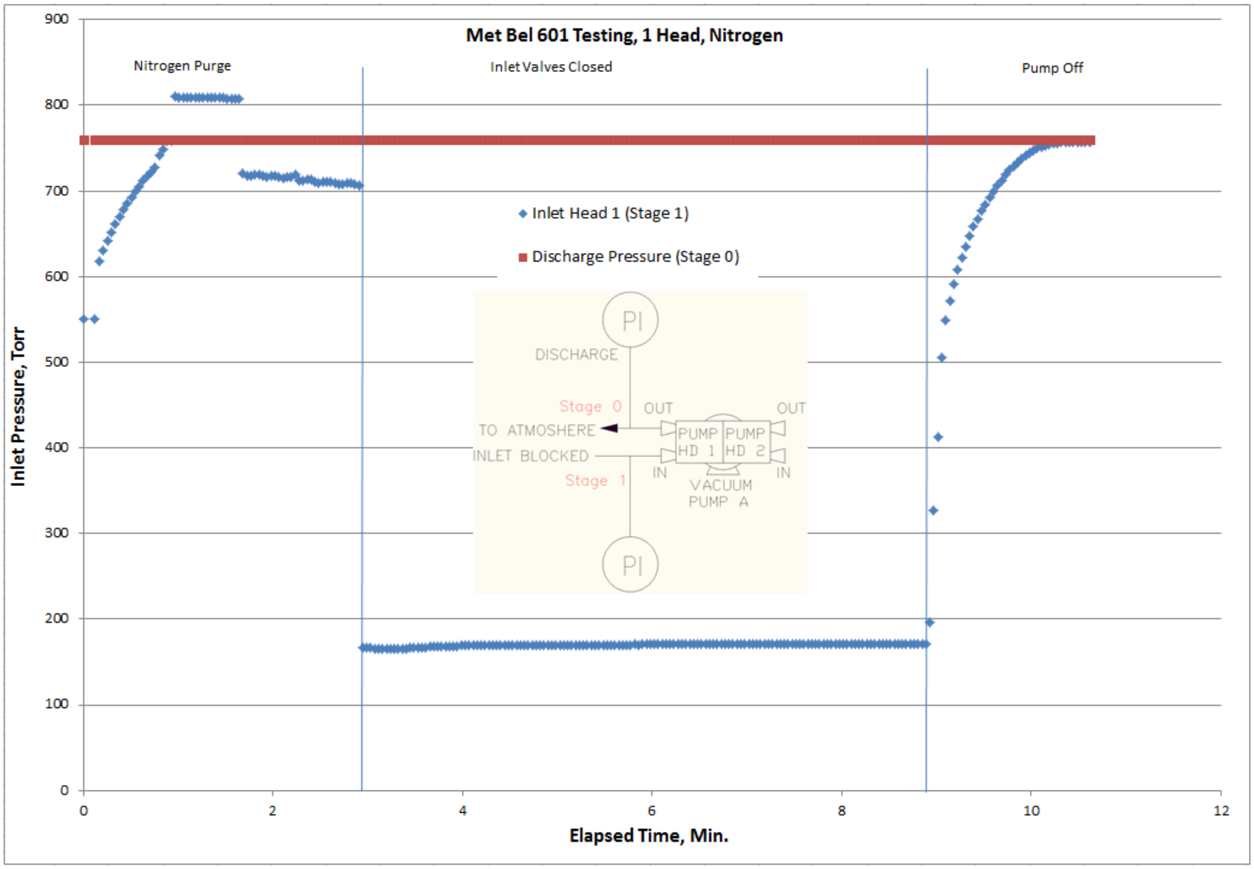


Figure 19. 2016-7-18 One Head Ultimate Vacuum, Nitrogen Purge

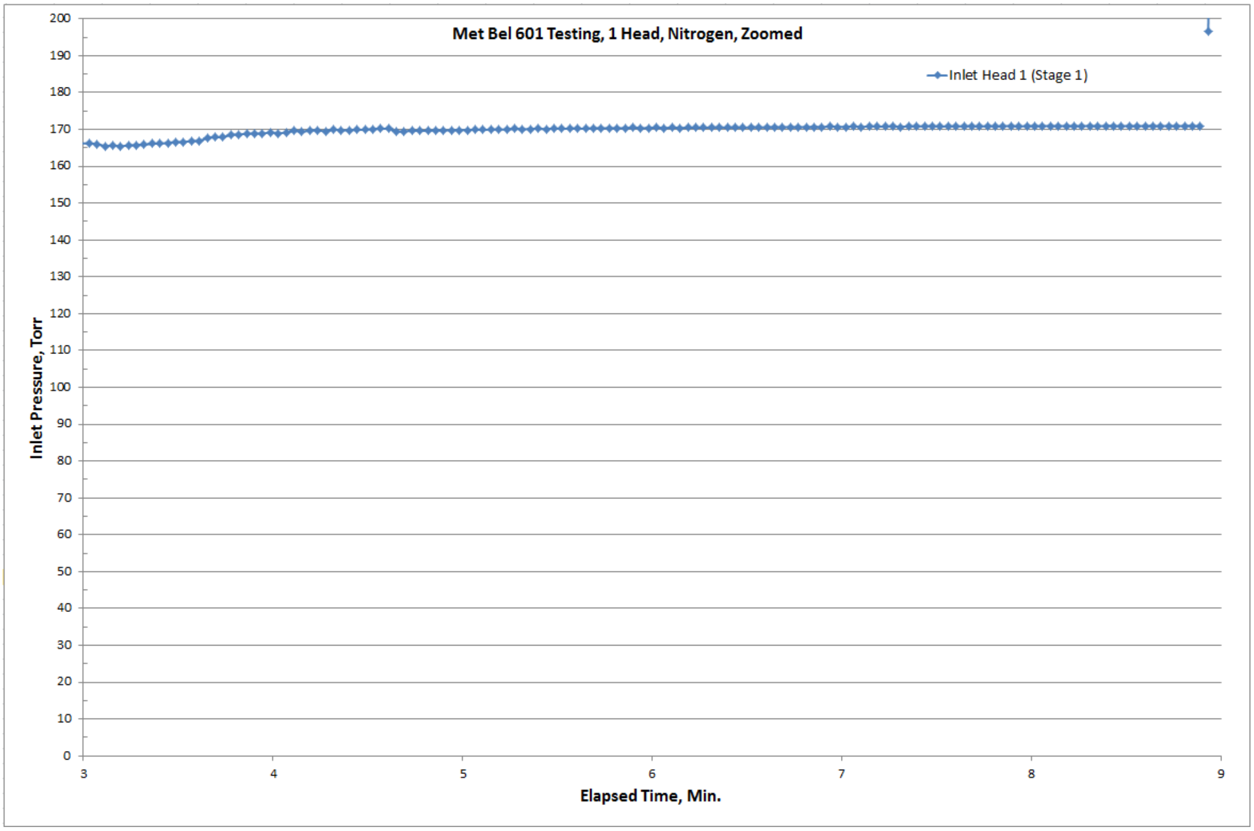


Figure 20. 2016-7-18 One Head Ultimate Vacuum, Nitrogen Purge, Zoomed

It is unclear why there is an observed pressure rise for two and one head testing on the ultimate vacuum at the inlets. The small rise is observed within the first one minute of achieving the lowest vacuum levels, and is approximately 3% to 5% higher than the lowest value. This may be a function of temperature effects.

3.1.5 Compression Ratios

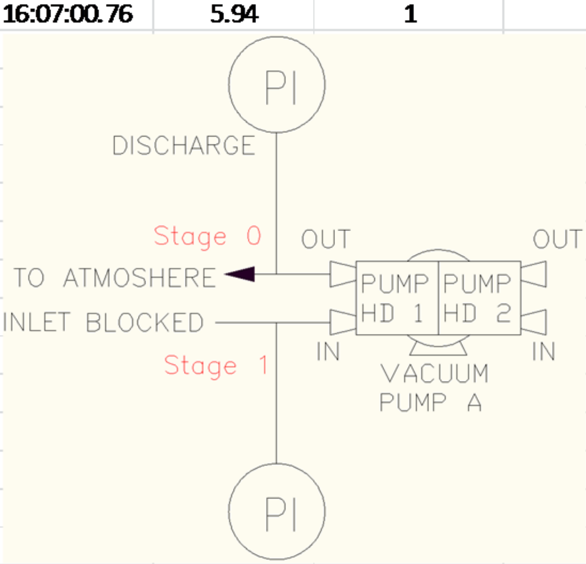
The final data presented is compression ratios for the Met Bel MB-601 at the blocked inlet condition, or ultimate vacuum. These are shown in tabular form in Tables 2 through 5. The compression ratios are shown for one head discharging to atmosphere (Table 2), for one pump discharging to the suction of the next pump (Table 3), one pump discharging to atmosphere (Table 4), and various compression ratios for the full rig (Table 5). The compression ratios for the full rig, two pumps in series, were calculated by taking Stage 0 pressure (approximately atmospheric) divided by stage 4 pressure. The square root of this value was then taken, similar to the methodology used by the author of the reference 5 report[5]. It is assumed his Figure 17 was developed with two Met Bel 601 pumps (in series) backing a Normetex PV-15 vacuum pump. It is believed the square root of his pressure ratios charted was to account for two Met Bel 601 pumps in series, and hence the square root would calculate the average compression ratio of each pump. His value of 4.77 compression ratio per Met Bel pump contrasts with the indicated value of 11.6 achieved during this testing. His Figure 17 shows two data points at atmospheric discharge (his testing obtained data on increasing discharge pressure), with two values of compression ratios. One was square root (760/38) =4.47 and square root (760/30) =5.03.

The reference 5 author mentions in his test report[5] that most testing was performed with the Met Bel pumps in series, but the heads in parallel. If this is correct for Figure 17 of the report (that is, the pumps are in series, but the heads in parallel), than the 4.77 compression ratio he achieved would be very much in line with the 4.5 compression ratios reported in Table 2. Additionally, taking the square root of Table 4 data indicates a compression ratio of 18.6 for a rig equivalent to his two Met Bel pumps piped in series, with the heads in parallel. The reference 5 report[5] compression ratio value was 22.7 before he took the square root.

Table 3 and Table 4 show compression ratios for identical rigs, with Table 3 discharging to the suction of pump B, and Table 4 discharging directly to atmosphere. The compression ratio calculated discharging to the suction of pump B was 8.75, and the compression ratio calculated for discharging to atmosphere, identical rig, was 18.6.

Table 2. Compression Ratio, Blocked Inlet, Nitrogen, Arrangement 1

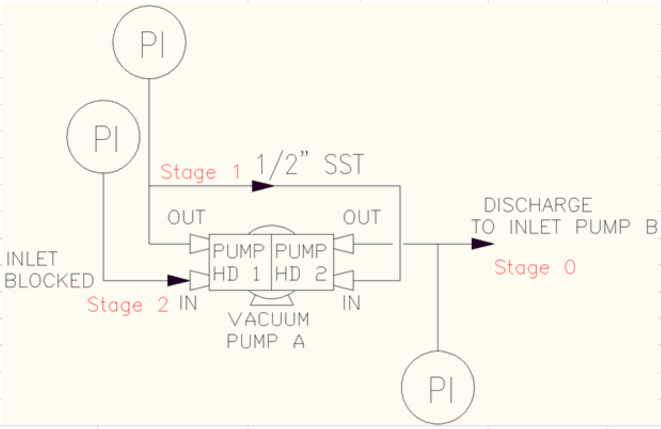
Date	Time	Elapsed Time	Arrangement	Inlet Pressure	Discharge Pressure	Compression Ratio
7/18/2016	16:01:04.26	0	1	166.692988	759.666627	4.56
7/18/2016	16:02:04.09	1.00	1	168.837958	760.353565	4.50
7/18/2016	16:03:06.42	2.04	1	169.850429	760.10823	4.48
7/18/2016	16:04:06.25	3.03	1	170.384343	760.206364	4.46
7/18/2016	16:05:06.09	4.03	1	170.70614	760.10823	4.45
7/18/2016	16:06:05.92	5.03	1	170.951886	760.206364	4.45
7/18/2016	16:07:00.76	5.94	1	170.830824	760.206364	4.45



Arrangement 1

Table 3. Compression Ratio, Blocked Inlet, Nitrogen, Arrangement 2

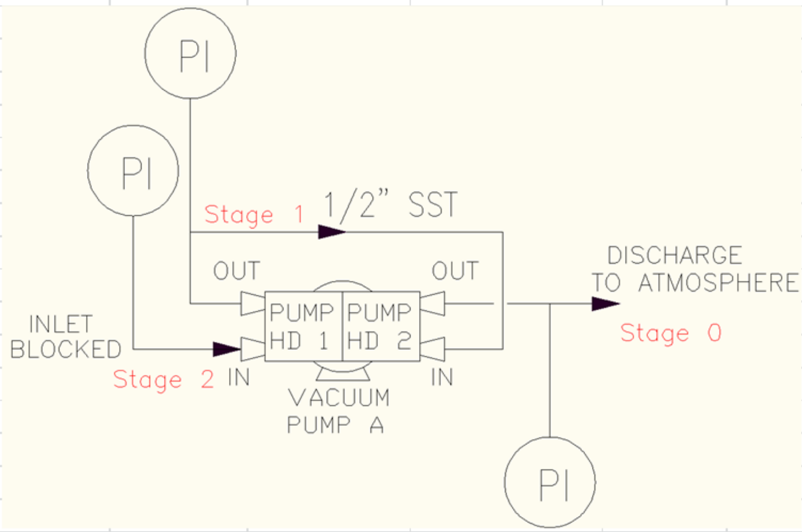
Date	Time	Elapsed Time	Arrangement	Inlet Head 4 Torr	Inlet Head 3 (Stage 0) Heise Voltage Torr	Inlet Head 1 (Stage 2) Torr	Inlet Head 2 (Stage 1) Torr	Pump A Compression Ratio, Stage 0/Stage 2
7/13/2016	16:19:00.39	14.90	2	198.0705549	48.392312	5.592131	16.856065	8.65
7/13/2016	16:20:00.00	15.90	2	200.4422316	48.784847	5.595752	17.092498	8.72
7/13/2016	16:20:59.59	16.89	2	200.8510511	48.932048	5.57661	16.94712	8.77
7/13/2016	16:21:59.20	17.88	2	201.0955558	48.981115	5.607134	16.987992	8.74
7/13/2016	16:23:00.04	18.90	2	201.545323	48.981115	5.600408	17.096637	8.75
7/13/2016	16:23:59.65	19.89	2	201.9355175	49.177383	5.562641	16.899523	8.84



Arrangement 2

Table 4. Compression Ratio, Blocked Inlet, Nitrogen, Arrangement 3

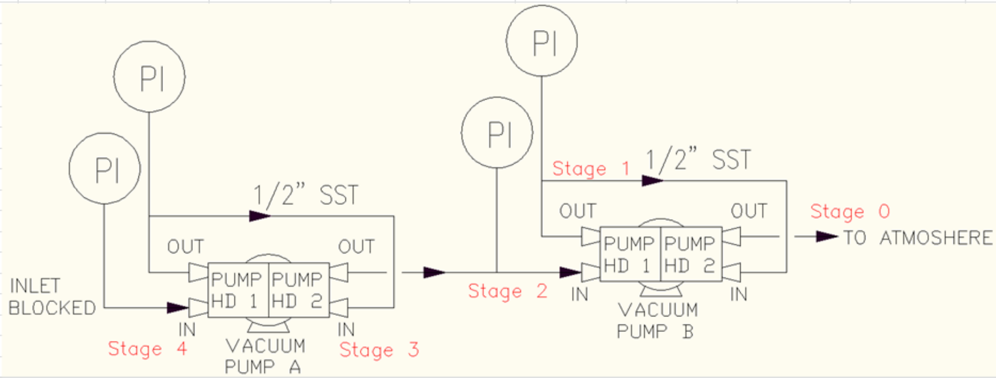
DATE	TIME	Elapsed Time, minutes	Arrangement	Discharge Pressure, Stage 0 Heise Voltage Torr	Inlet Head 1, Stage 2 Torr	Inlet Head 2, Stage 1 Torr	Compression Ratio,Pump A, Stage 0/Stage 2
7/18/2016	15:38:03.98	3.18	3	760.304498	39.6571	173.615248	19.17
7/18/2016	15:39:01.14	4.14	3	760.353565	40.433138	177.531137	18.81
7/18/2016	15:40:00.79	5.13	3	760.255431	40.815466	179.621266	18.63
7/18/2016	15:41:00.45	6.12	3	760.255431	40.927216	180.172771	18.58
7/18/2016	15:42:59.76	8.11	3	760.402631	41.000681	180.530783	18.55



Arrangement 3

Table 5. Compression Ratio, Blocked Inlet, Nitrogen, Arrangement 4

Date	Time	Elapsed Time	Arrangement	Inlet Head 4 (Stage 3) Torr	Inlet Head 3 (Stage 2) Heise Voltage Torr	Inlet Head 1 (Stage 0) Torr	Inlet Head 2 (Stage 1) Torr	Pump A Compression Ratio, Stage 2/Stage 4	Pump B Compression Ratio, Stage 0/Stage 2	Pump Train Compression Ratio, Stage 0/Stage 4	Compression Ratio Per Pump, Sharpe Square Root Function
						752 Torr Atmosphere					
7/13/2016	16:19:06.59	15.01	4	199.1448944	48.588579	5.582301	16.888142	8.70	15.48	134.71	11.61
7/13/2016	16:19:30.18	15.40	4	200.0195191	48.73578	5.572471	16.899006	8.75	15.43	134.95	11.62
7/13/2016	16:20:00.00	15.90	4	200.4422316	48.784847	5.595752	17.092498	8.72	15.41	134.39	11.59
7/13/2016	16:20:29.79	16.39	4	200.6706984	48.882981	5.610238	17.011273	8.71	15.38	134.04	11.58
7/13/2016	16:20:59.59	16.89	4	200.8510511	48.932048	5.57661	16.94712	8.77	15.37	134.85	11.61
7/13/2016	16:21:30.64	17.41	4	200.9775914	48.882981	5.589027	17.107502	8.75	15.38	134.55	11.60
7/13/2016	16:22:00.45	17.90	4	201.0974047	48.981115	5.594717	17.002478	8.75	15.35	134.41	11.59
7/13/2016	16:22:30.25	18.40	4	201.3391782	49.030182	5.579714	16.918666	8.79	15.34	134.77	11.61
7/13/2016	16:23:00.04	18.90	4	201.545323	48.981115	5.600408	17.096637	8.75	15.35	134.28	11.59
7/13/2016	16:23:29.85	19.39	4	201.731807	49.079249	5.601443	17.035589	8.76	15.32	134.25	11.59
7/13/2016	16:23:59.65	19.89	4	201.9355175	49.177383	5.562641	16.899523	8.84	15.29	135.19	11.63



Arrangement 4

4.0 Conclusions

Senior Aerospace Metal Bellows MB-601 is a positive displacement, metal bellows pump that can be used both in vacuum service and in pressure service. It uses a single phase, dual voltage (115/230 V) motor. As discussed, the MB-601 is offered with secondary bellows containment. It can optionally be provided with an explosion proof motor, polyphase motor, totally enclosed fan cooled motor, variable speed motor, Aluminum O-ring seals, VCR fittings, Viton valve gaskets, and a high pressure model. It has 3/8” N. P. T. fittings on both the inlet and discharge ports, and can be piped with the two heads in series or in parallel.

Experimental results demonstrate that the Met Bel MB-601 performed appropriately based on vendor data. The data indicates that the Met Bel MB-601 pumps piped in series, with the heads in series, does not achieve the ultimate pressure of the Normetex/Eumeca Model 15 backed by a MB-601 Metal Bellows pump, and thus may not be an appropriate replacement for the Normetex Model 15’s (PV-15) currently in use in Tritium Operations.

5.0 References

[1]**M. Restivo,** Memo, "SHINE GBSS Vacuum Pump Testing on Adixen™ ACP28", SRNL-L3100-2015-00045, Rev. 0, March 2015

[2]**M. Restivo**, Report, "Vacuum Pump Testing for Potential Application in a Tritium Glovebox Stripper System," SRNL-STI-2015-00657, November 2015

[3]**M. Restivo**, eHAP, "786-A Vacuum Pump Testing for SHINE GBSS," SRNL-L3100-2015-00025, Rev. 0, February 2015

[4]**M. Restivo**, Electronic Notebook (ELN), "SHINE Glove Box Stripping System," ELN #O9117-00066-05, March 2015

[5]**C. L. Sharpe**, Memo, "Report on RTA-9-T Normetex Pump Tests," Rev. 0, October 1984 (Scanned and attached to ELN)

6.0 Acknowledgements

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Appendix A-Equipment/Instrument List for Pressure Protection Concerns

Description	Size	Rated Press (psig)	Design Pressure (psig)	Vendor & Model Number	Comments
Relief Valve	1/4"	15	15		See CLI-7773000-LAB-PSV-6389
3/8" Ball Valves	3/8"	3000	50	Swagelok SS-43S6	
Met Bel 601 Pump	3/8"	40	50	Met Bel 601	
1/4" SS Tubing	1/8"	8500	50	Swagelok SS-T2-S-028-19	1/8" x 0.028" wall 304 SS Tube
1/4" SS Tubing	1/4"	5100	50	Swagelok SS-T4-S-035-20	1/4" x 0.035" wall 304 SS Tube
1/2" SS Tubing	1/2"	2600	50	Swagelok SS-T8-S-035-20	1/2" x 0.035" wall 304 SS Tube
3/4" SS Tubing	3/4"	3300	50	Swagelok SS-T12-S-065-20	3/4" x 0.065" wall 304 SS Tube
Pressure Indicator	1/4"	90	50	Ashcroft Q-Duragage 451379	Stage 4 Pressure Gauge
Pressure Transducer	1/4"	54	50	Paroscientific Model 740	Stage 0 Pressure Transducer, TR 3-2859
Pressure Transducer	1/4"	54	50	Paroscientific Model 710	Stage 1 Pressure Transducer, TR 3-2549
Pressure Transducer	1/4"	15.3	15.3	Heise 901A	Stage 2 Pressure Transducer, OLD TR 2208
Pressure Transducer	1/4"	2000	2000	Rosemount 1151 dP	Stage 3 Pressure Transducer, TR 03713

Appendix B-Email, Mitch Shikowitz (Senior Aerospace Metal Bellows Pump Flow Curve Standard Conditions), to Jim Klein, SRNL, dated 7/27/2016

From:	Mitch Shikowitz <mshikowitz@metalbellows.com>
To:	"james.klein@srnl.doe.gov" <james.klein@srnl.doe.gov>
Date:	07/27/2016 02:49 PM
Subject:	RE: Metal Bellows Pump Flow Curve Standard Conditions [Savannah River National Laboratory - Fielded Item Question on SCFM]

Hi James –

So nice to hear from you.

For our SCFM measurements on the pump / compressor product line the “standard” refers to flow at 14.7 PSIA at 70°F.

I hope this helps answer your question for our catalog / custom pump configurations.

Please let me know if you have any additional questions.

Best regards –

Mitch

Mitch Shikowitz
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