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Vulcan TAW upgrade – vacuum system design

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Introduction

2008 saw the completion of the TAW upgrade project [1] which was to incorporate a second high-intensity beamline alongside existing functionality. Integrated into this project was the need to replace the vacuum system supporting the compression and interaction chambers. The new short pulse large aperture beam brought with it dielectric gratings. These are more susceptible to damage caused by vacuum oil and other contaminates. This forced a re think away from existing conventional oil sealed rotary vacuum pumps to dry technologies such as screw and scroll pumps. Additionally with the increase in gas experiments capacitance gauges were fitted along side conventional pirani and penning gauges for evaluation. The capacitance gauges promise gas independence due to their construction. A permanent (Residual Gas Analyser) RGA has been fitted to the interaction chamber to verify the level of contamination before permitting the opening of the pendulum valves between the interaction and compression chambers.

Vacuum specification

Compression chamber

- Ultimate vacuum 1×10^{-5} mbar.
- Time from atmosphere to reach ultimate, 1 day.
- Expected operating cycle 2/yr.

Interaction chamber

- Ultimate vacuum 1×10^{-5} mbar.
- Time from atmosphere to reach 5×10^{-3} mbar 20 mins.
- Expected operating cycle 6/day.

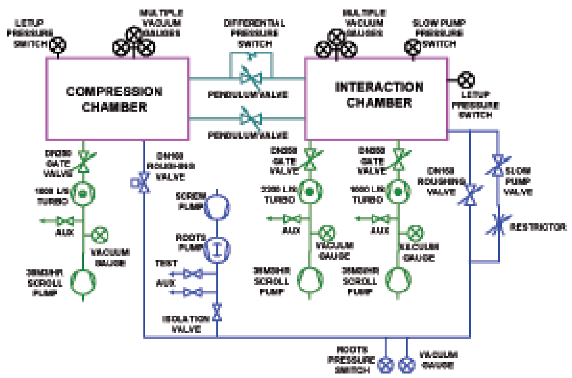

Figure 1. Vacuum system diagram

Vacuum system diagram

Figure 1 shows the main vacuum components in the TAW vacuum system.

Vacuum logic

Pumping from atmosphere

1. All pumps are started and allowed to run up to full speed.
2. DN160 roughing valve on interaction or compression chamber opens. (Interaction chamber retains slow pump down option).
3. On interaction chamber if roughing pumps do not reduce vacuum to 600 mbar in 5 minutes, roughing is stopped and error message displayed.
4. At 100 mbar roots pump starts.
5. At 8×10^{-2} mbar the roughing cycle ends and the DN160 roughing valve closes. The DN250 gate valve then opens above turbo pump(s).
6. Turbo pump(s) run continuously.

To prevent the pendulum valve on the beam pipes from being opened before the pressure is equalised in both chambers a differential pressure switch is fitted. This gives an electrical signal which limits the available options on the control panel and protects the laser hardware.

The pendulum valves have sapphire windows fitted which are Ø280 mm and 12 mm thick. This allows alignment to be carried out whilst the valves are closed. Test ports and auxiliary ports are fitted to allow vacuum diagnostics to be fitted quickly such as a leak detector or additional gauging to help fault finding.

Pump selection

Roughing

The main roughing pump is a Leybold SP250 (figure 2) screw pump which provides roughly 250 m^3/hr pumping speed dropping off at 10^{-2} mbar. It replaced a SOGEVAC SV200 oil sealed rotary pump and offers a very modest performance improvement and one decade lower ultimate. The SP250 comes with a diagnostic tool which is interfaced with the control system. The diagnostic tool monitors conditions such as gearbox oil level, pump temperature and vibration. Signals warn or stop the pump depending on pre determined set points. This reduces planned intervention/maintenance to a yearly gearbox oil change.

Figure 2. Leybold SP250 roughing pump.

Roots

The screw pump is supplemented by a Leybold WAU501 (500 m^3/hr) roots pump, similar to those shown in figure 3. The roots pump can be up to 5 times larger than the main pump and this is currently under spec. Roots pumps do not start to work until the vacuum is below 100 mbar and attain a one decade improvement over the primary pump.

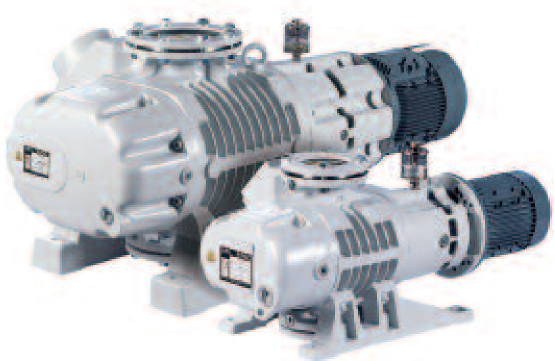

Figure 3. Leybold 250 m^3/hr and 1000 m^3/hr roots pumps.

Backing

Edwards XDS35i (35 m^3/hr) scroll pumps are used to back the three turbo pumps (Figure 4). These replace a range of smaller oil sealed rotary pumps. As well as being dry a second benefit of the scroll pump is low

Figure 4. Edwards XDS35i scroll pump.

maintenance. The oil sealed rotary requires regular inspection of oil level and oil quality, servicing is also time consuming. The scroll pump requires a yearly tip seal replacement and taking less than 30 minutes is a significant time saving. The internal surfaces of large vacuum chambers do attract much moisture when open. The scroll pumps do see a water build up in a short period of time and require to be set on a constant purge.

Turbo pumps

Both chambers are fitted with existing standard bearing Leybold 1000 l/s turbo pumps. To cope with gas experiments and a larger interaction chamber we also purchased a Leybold 2200 l/s magnetically levitated pump (figure 5). Standard bearing turbo pumps require biannual servicing where as magnetic bearing pumps are maintenance free. They also offer reduced vibration and improved control.

Figure 5. Leybold 2200 and 2800 turbo pumps.

Vacuum performance

During commissioning the pump time was confirmed and approved with an empty chamber. Experiments rarely run with a near empty chamber. Figure 6 shows a pump down curve with experimental hardware installed consisting of many optics, mounts and diagnostics. The chamber was leak tested before this test. The blue curve shows the chamber letup to N_2 and then pumped without opening the chamber. The red curve shows the impact of opening the doors for 10 minutes before pumping the chamber. From the diagram it is clear that out gassing and moisture are significant problems with the current configuration.

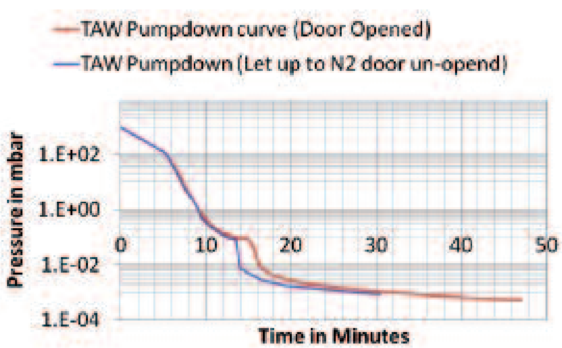

Figure 6. TAW pump down curve with experimental hardware.

Developments underway

To reduce turnaround time a dry air letup system running at 10 barg is under construction. Much of the hardware is in place and it should be running in the summer. This will replace a current N_2 only or N_2 and room air system. Figure 7 compares the different methods and shows the dry air to be at least 1/3 faster than the current fastest method.

Letup Method	10 barg dry air	6 barg N_2 with manual recharge at 500 mbar	6 barg N_2 automatically switching to room air
Let up time (minutes)	4	14	26

Figure 7. Comparing the different let-up options and the time to reach atmosphere.

With increased use of MCP's and streak cameras requiring a vacuum level of 10^{-5} mbar to operate, pumping time is becoming more critical. We will shortly embark on a project to heavily characterise the current facility and determine the most suitable course of action to reduce pumping time. We will report our findings next year.

References

1. C. Hernandez-Gomez, CLF Annual Report, 260-262, (2007-2008).