DRAGON Technical Note

Performance of DRAGON's Gas Target Recirculation System

D.F. Ottewell, G. Roy, D.A. Hutcheon

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1 Orientation of central gas cell

The design of the mounting and collimation of 2 elastic scattering monitor counters would be less complicated if the bevelled ends of the central gas cell could be slanted to point "up" instead of "down" (the direction of the tests in spring 2000). The effect of such a design change on end-of-target pressures was investigated.

Unlike the spring 2000 tests which were in flow-through mode, these tests mostly were in recirculation mode, initially bypassing the cleaning trap, and EPICS control of pumps, valves and gauges. The cell was unchanged from spring, namely 20° and 30° bevels on the ends (directing the jets downwards) with one dummy monitor detector mounted at 45° above the cell and one below it. Gas was let in and the return valve adjusted until the cell pressure and the return line pressure matched the 4.5 Torr and 50 Torr, respectively, of previous tests.

Figure 1 indicates schematically the recirculation systems of the windowless target.

Pressures in the central cell, the surrounding manifold, upstream and downstream ion gauges and the return line are given in Table 1.

The net increase in pressure at the ends of the target system is about 1.5×10^{-6} Torr, very close to what was measured in spring 2000.

Table 1: Pressures (Torr) measured for jets directed “down”.

Cell	Manifold	IGU3	IGD4	IGD1	TRIN
He gas, flow through					
0.00	0.007	2.0(-6)	8.3(-7)	7.4(-7)	0.64
1.93	0.098	2.3(-6)	1.3(-6)	1.1(-5)	12.7
4.51	0.198	2.4(-6)	1.4(-6)	2.2(-5)	22.3
He gas, recirc.(bypass)					
2.62	0.127	2.4(-6)	1.3(-6)	1.4(-5)	28.2
4.54	0.205	2.4(-6)	1.4(-6)	2.3(-5)	43.0
H gas, flow through					
0.00	0.007	1.4(-6)	6.8(-7)	6.1(-7)	0.39
2.00	0.127	1.7(-6)	1.3(-6)	3.0(-5)	12.5
4.57	0.269	2.4(-6)	1.8(-6)	8.2(-5)	21.9
H gas, recirc.(bypass)					
0.00	0.007	1.3(-6)	6.3(-7)	5.8(-7)	0.49
2.47	0.161	1.7(-6)	1.4(-6)	3.8(-5)	24.8
4.52	0.310	2.6(-6)	1.9(-6)	9.6(-5)	40.1
4.52	0.325	2.6(-6)	2.1(-6)	1.0(-4)	45.6
4.52	0.359	2.8(-6)	2.2(-6)	1.2(-4)	51.9

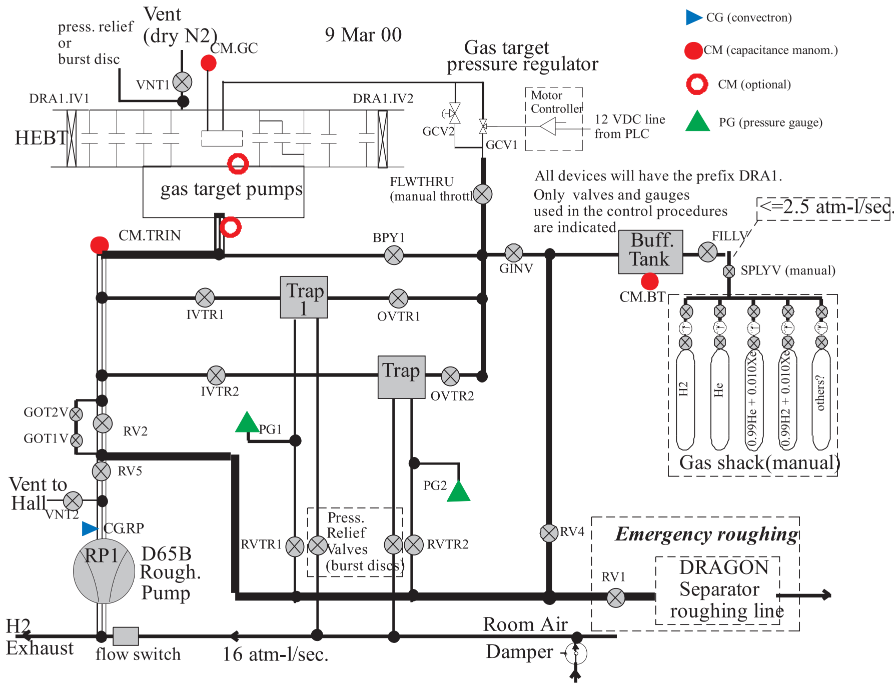

Figure 1: Gas target recirculation and roughing.

The ends of the central cell then were rotated 180° so that the bevelled ends directed the supersonic jets of escaping gas upwards, away from the direction leading to the Roots blowers. For a pressure of 4.54 Torr in the central cell and 48 Torr in the return line, the net increase in end pressures upstream and downstream were 2.6(-6) and 2.2(-6) or an increase by factors 1.7 and 1.4, respectively, over the "downward jet" orientation.

The upper dummy monitor counter was removed and a baffle placed immediately above the cell, simulating a "lowered roof" on the vacuum box. There was essentially no change in end pressure compared to the previous configureation (both with jets directed upwards).

2 Impedance of the cleaning trap

The runs in recirculation mode with the cleaning trap bypassed showed (Table 1) that 40.1 Torr in the return line was needed to achieve a cell pressure of 4.5 Torr with throttle valve wide open. If the final Roots blower is to run at not more than 50 Torr, only 10 Torr would be available to overcome the flow impedance of the cleaning trap.

For an initial run at room temperature, the trap was filled with 20 l of molecular sieve (X13). To inhibit migration of X13 dust, the neck of the trap was blocked by twisted kimwipes with a 1-cm thick felt pad at each end. A test with He gas obtained only a cell pressure of 3.93 Torr for trap inlet pressure (TRIN) of 55.7 Torr, substantially less than the 4.54 Torr for TRIN of 43 Torr obtained in bypass mode. One of the two felt pads was removed, but this gave only a modest improvement (3.87 Torr for TRIN=51 Torr). Switching to H gas, still with the trap at room temperature, gave a cell pressure of 4.25 Torr at trap inlet pressure of 48.4 Torr. This is slightly sub-marginal, but our technical advisor (D. Healey) suggested that the impedance would decrease at LN2 temperature.

3 Hydrogen adsorption by cold zeolite

Bench tests with 0.25 l of zeolite (X13) molecular sieve (D. Healey note, March 24/99) indicated that a trap filled with 20 l of X13 at LN2 temperature should adsorb 70 atm$\cdot l$ of hydrogen gas. To confirm this estimate, a buffer volume of 6 l was mounted between the hydrogen supply cylinder and the recirculation system. The SRS residual gas analyzer (RGA) was mounted at the upstream pumping stage.

Before addition of hydrogen, the RGA registered a total pressure of 3.3E-7 and a mass scan showed peaks at A=2 (2.0E-8), A=17 (4.4E08), A=18 (1.7E-7), A=28

(2.0E-8), A=29 (1.5E-8) and a number of smaller peaks including several at A=41–44 and A=55–57 which are ascribed to isobutane.

Hydrogen was added to the recirculation system in 19 “shots” from the buffer tank, to bring the TRIN pressure up to 47 Torr and the cell pressure to 4.6 Torr. The buffer tank filling initially was to 50 Torr only, but that was soon increased to 300 Torr per “shot” and the total gas supplied amounted to about 30 atm$\cdot l$. At this time the A=2 peak (1.0E-6) dominated the RGA mass spectrum.

However, it was observed that the TRIN pressure dropped steadily (about 20% per 5 minutes). More hydrogen was added, until a total of 100 atm$\cdot l$ was reached at which point no more hydrogen was added. The TRIN pressure dropped from 45.9 Torr to 14.8 Torr in 1 hour, to 8.7 Torr after another hour. A prior measurement excluded the possibility of loss through a leaky valve, so it was concluded that the zeolite was adsorbing hydrogen with a time constant of $\approx$30 minutes, to a much greater loading that was estimated from the (11-minute) bench test. Assuming exponential approach to equilibrium, a final pressure of 6 Torr is estimated.

The 20-litre load of zeolite was removed from the trap using a vacuum cleaner and replaced by a load of 2 litres. The trap was cooled to LN2 temperature and loading via the 6-litre buffer tank commenced. The first loading of 350 Torr raised TRIN to 25.2 Torr, the second to 41.6 Torr. Subsequent “shots” were timed to keep TRIN between about 35 Torr and 45 Torr; the observed rate of pressure drop was approximately 10 Torr per 5 minutes. Filling continued until 50 atm$\cdot l$ of loading, when the trap saturated at 44 Torr. The resulting cell pressure was 3.7 Torr.

The hydrogen loading results may be summarized as follows:

- there is a “fast” adsorption of H_2 by X13, the amount of which is approximately proportional to the gas pressure and amounts to about 3.7 atm·l of gas per litre of X13 when loaded to 50 Torr.

- there is a "slow" adsorption, also (very) roughly proportional to gas pressure, amounting to 25 atm·l per litre X13 at 50 Torr.

4 Adsorption of air by cold zeolite

D. Healey measured adsorption of 17 Torr·l of air by 0.25l of X13 molecular sieve and deduced a partial pressure of 0.13 mT. at that loading. He also estimated that a trap containing 20 l of X13 should be able to keep the air pressure below 0.9 mT (18 ppm) in the face of a leak of 1200 Torr·l/week. (Initial experience is that over a week-end the pressure in the target system rises by well under 1 Torr in a volume of order 125 l, substantially less than the above estimate, but with pumps turned off.)

We looked into the ability of just 2 l of X13 to handle 1200 Torr·l of air.

Following the hydrogen uptake measurements, the trap was allowed to warm up to room temperature and pumped on overnight. Three days later it was again pumped out, isolated, and cooled to LN2 temperature. The blowers and turbos were turned on and recirculation allowed through the Bypass valve.

The buffer tank was filled to 50 Torr with air (300 Torr·l). When it was released into the recirculations system the initial reading of TRIN was 16.0 Torr and at the cell CMGC was 1.8 Torr. There was no sign of increased pressure at ion gauges U3 (8.3E-7) or D4 (7.4E-7), while the residual gas analyzer showed a very slight increase in the A=28 peak (6E-8 to 7E-8).

The Bypass was closed and the trap opened to the recirculation lines. Within 45 seconds the pressure TRIN dropped from 16 to 2 Torr and after 300 seconds to 1.17

Torr. Additional loadings of 300 and 600 Torr·l were added in quick succession to bring the total air inventory to 1200 Torr·l. The last loading raised TRIN to 8.3 Torr but after 10 s it had decreased to 2.3 Torr. At this time the cell reading was CMGC=0.659 T and the RGA A=28 peak 4E-8. After 100 minutes the TRIN reading was 0.635 T, very close to the offset which was observed before addition of any gas. The LN2 dewar was lowered and after 20 minutes the pressure had risen to TRIN=2.4 Torr. At this point the dewar was again raised (trap cooled) and the pumps turned off overnight.

Turning on the Roots blowers the next morning caused the cell pressure reading to drop from 36 mT to 15 mT, the TRIN pressure reading to rise from 560 mT to 586 mT. The ion gauge IGD1 (essentially the manifold pressure because turbos were off) read 2E-4 Torr (calibrated for air). A repeat of the exercise the next day saw CMGC drop from 71 mT to 15 mT and TRIN rise from 586 mT to 660 mT. However, within minutes TRIN had fallen below 600 mT — evidently the zeolite is able to hold an additional 5 Torr·l of air/water/... with a pressure increase of, at most, a few milliTorr.

Some conclusions from the air adsorption tests:

- firm conclusions are hard to make because pressures of interest are small and comparable to uncertainties in zero-offset of the capacitance manometers

- 2 l of X13 molecular sieve at LN2 temperature can hold 1200 Torr·l of air at a partial pressure of 20–50 mT. This is 400–1000 ppm relative to hydrogen at 50 Torr, assuming the loading of the trap with hydrogen does not interfere with its ability to hold air.

- the present setup of the residual gas analyzer (upstream box U3) limits the sensitivity to air in the gas cell to about 1 Torr. A “simple” change (moving to the volume of turbo D3) might improve the sensitivity by a factor ≈100 but the RGA would have to operate at a pressure of 2E-4.

5 Summary

1. There is a substantial penalty (1.5 to 1.7 increase in pressure at the ends of the target system) in orienting the cell ends to direct the gas jets above the entrance/exit differential pumping tubes rather than below them.

2. The impedance of the cleaning trap may force operation at 55–60 Torr inlet pressure to obtain 4.5 Torr cell pressure.

3. X13 molecular sieve at LN2 temperature must be saturated with 25 atm·l of hydrogen per litre of X13 to achieve a gas pressure of 44 Torr. The first 15% of the uptake is very rapid but the rest takes place with a time-constant of order 30 minutes.

4. Measurement of the partial pressure of air (or other contaminants) in the target gas is not easy. Moving the RGA to operate in the volume pumped by the D3 turbo might detect impurities at the part-per-thousand level.

5. No good value was obtained for the ability of X13 to remove air contamination. The best estimate is that 1200 Torr·l load into 2 l of sieve would produce contamination at the 400–1000 ppm level in hydrogen gas at 50 Torr.