Michigan MDT Chamber Certification

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April 28, 2002

1. Chamber Certification

The UM ATLAS group started installing and certifying chamber gas systems at the beginning of 2001. By Summer 2001, four chambers had certified gas systems. And by Fall 2001, we included this work into a seven-day production cycle. We first pre-assemble the gasbars on a special jig and certify them (Figure 1), then mount the gasbars onto the chambers and certify the chamber (Figure 2-4). In certifying both pre-assembled gasbars and chambers, we use: (1) a differential gauge to detect leaks at rate of a few mbar/hour; (2) a Qualitek 196 leak detector to detect leaks at rate $\geq 10^{-5}$ ml/sec; and (3) a mass spectrometer (VEECO), sensitive to leaks with rate $\geq 6\times10^{-7}$ ml/sec (air equivalent).

Figures 1 and 2 show some of the key steps of our gasbar pre-assembly and leak testing, and chamber certification. *All 16 EMS4* and 7 *EML3 chambers certified satisfy ATLAS specification*, as shown in Figure 5. The certification time for each chamber is longer than 24 hours. Most of them were certified over 60 hours during the weekend in the chamber gluing room, where the temperature is stable to within $\pm0.5\ ^{0}$C.

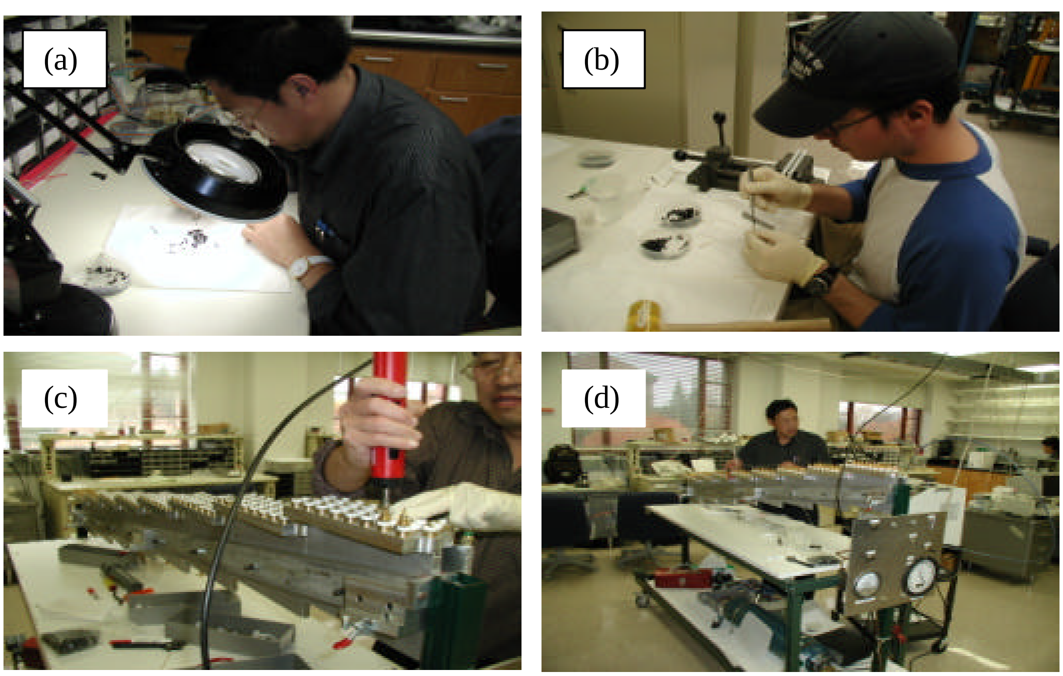

Figure 1. Gasbar pre-assembly and leak test. (a) O-ring pre-selection; (b) tubelet assembly; (c) assembly of gas manifold on jig; (d) leak checking and repairing.

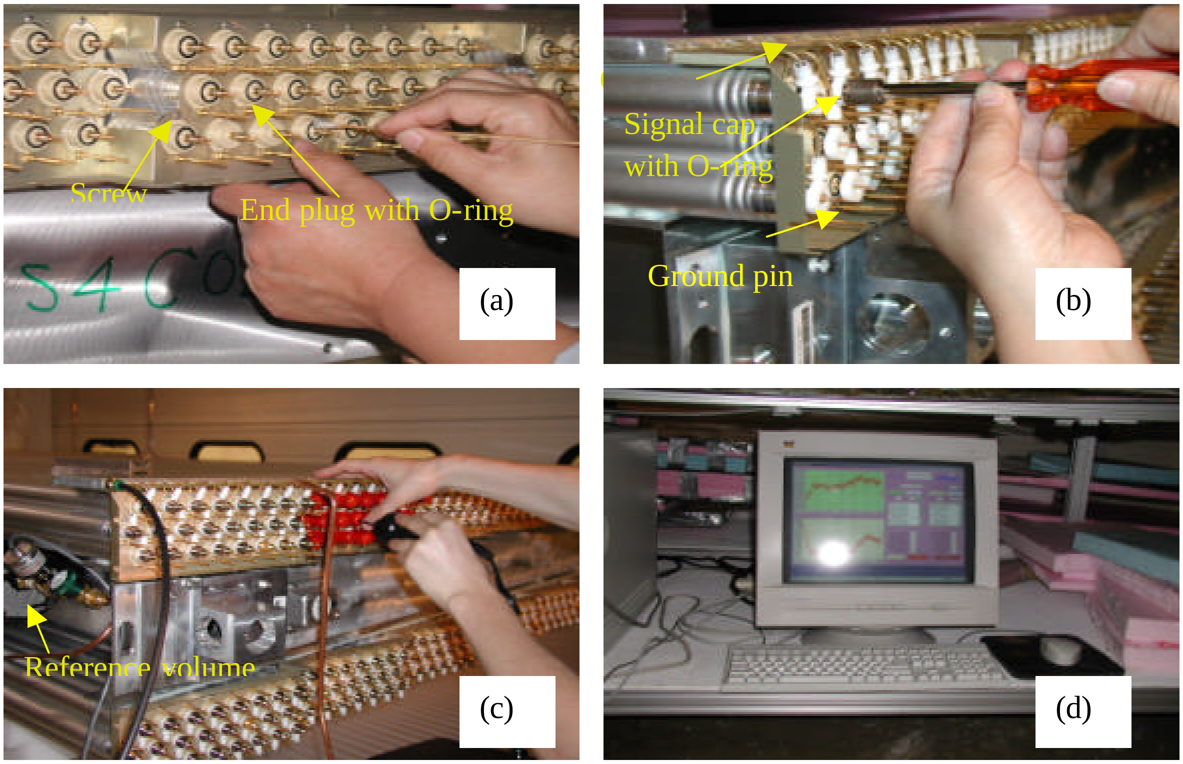

Figure 2. (a) Installation of Farady cage and cleaning of O-rings on endplugs. (b) Installation of gasbars onto chamber. (c) Leak checking. (d) DAQ system to certify the chamber. Chamber pressures, differential pressures and temperature from 16 T sensors (6 for each multiplayer, and 2 for each reference volume) are recorded every 5 minutes.

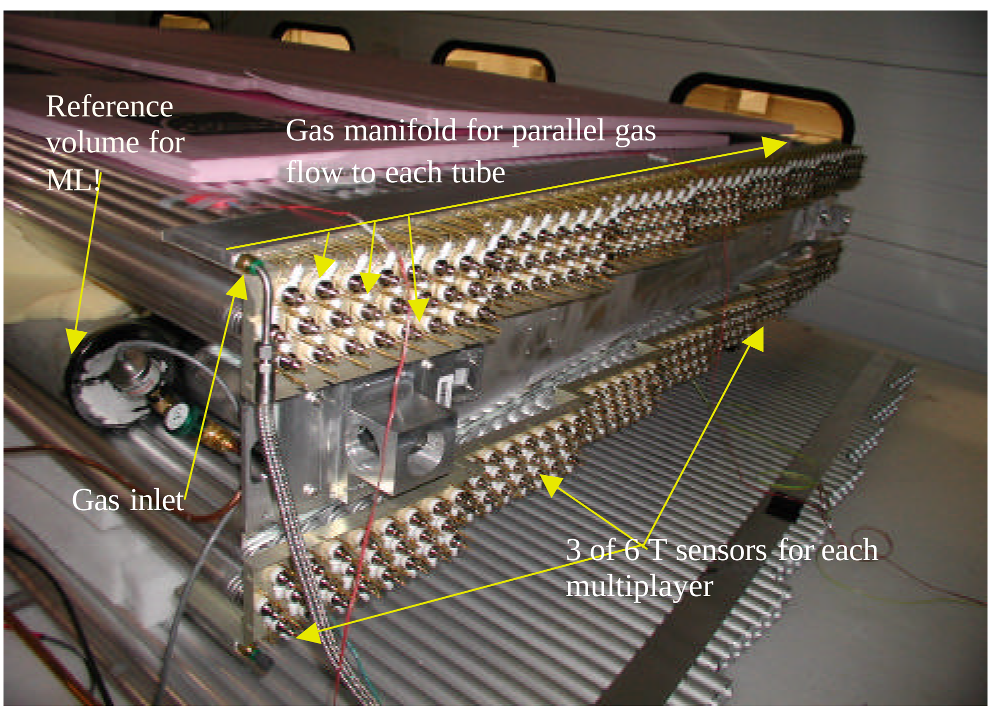

Figure 3. Overview of a chamber that is ready for certification.

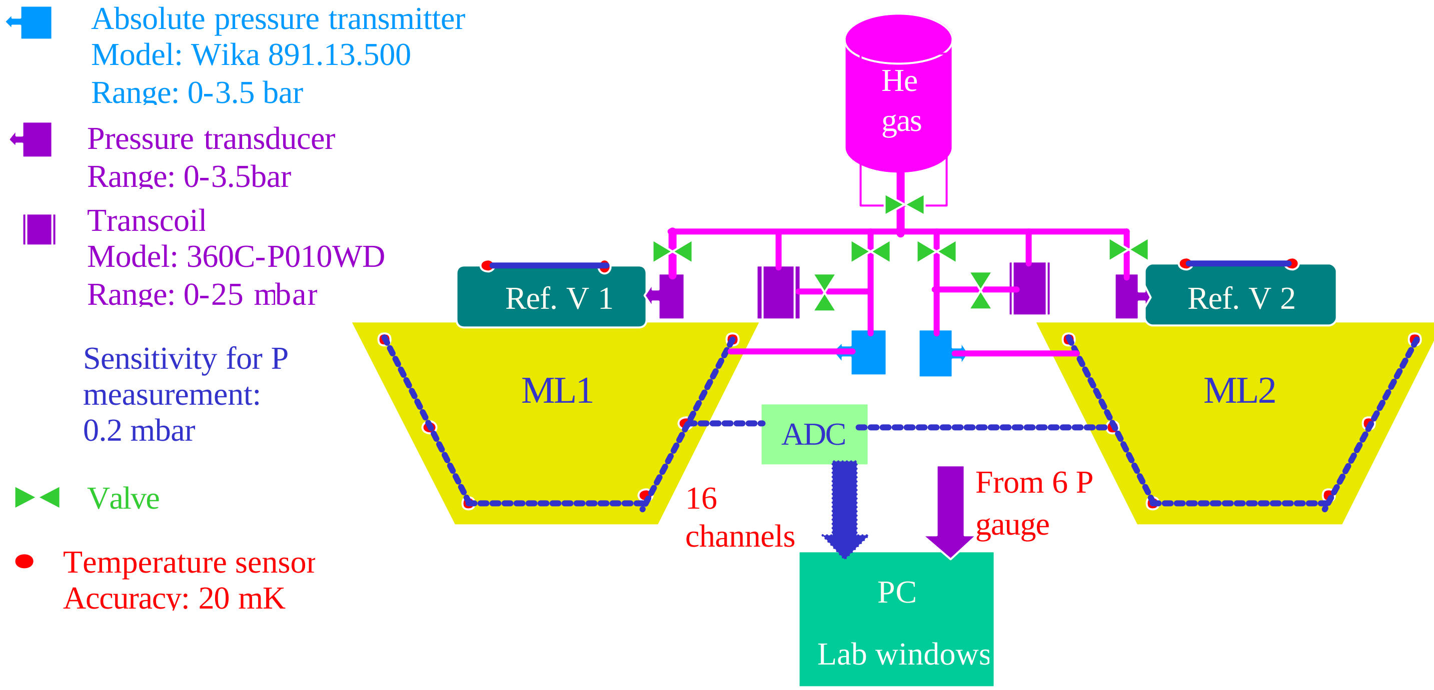

Figure 4. Diagram of MDT leak rate certification system at University of Michigan. A reference volume is attached to each multiplayer to measure the differential pressure. Six temperature sensors are mounted on the HV and RO ends of each multi-layer to monitor temperature. Absolute pressure, differential pressure and temperature of each multi-layer are recorded at periodic intervals.

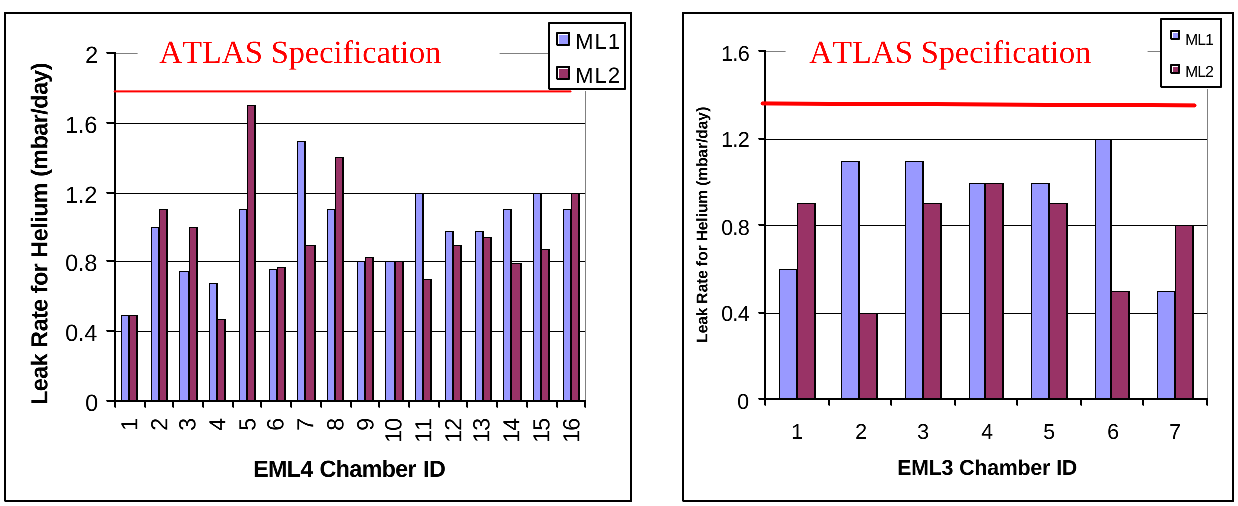

Figure 5. Leak rate for (a) 16 EMS4 chambers and (b) 7 EML3 chambers certified at U of M. The ATLAS leak rate for EMS4 and EML3 chambers are about 1.8 mbar/day and 1.4 mbar/day for helium respectively. The measured leak rate for helium gas is about twice as large as that for Ar(97%)+CO_2(3%).

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2. Final Work Before Shipping

After measuring the leak rate, a sequence of final tasks must be performed before the chambers are ready for shipping. 1) The chamber is depressurized so that we can transfer the extension tube (ET) to the next chamber. 2) Continuity of the anode wires is checked by measuring the resistance between the signal caps of the HV and RO sides of the tube. *No broken wires were found* for the 13 chambers we certified since EMS4C06.

To prevent the chamber thickness distortions observed for some EMS4 chambers, we fixed aluminum strips (width×thickness = 13mm × 1mm) by screws, as shown in Figure 6, on the gasbars of the two multi-layers.

Beginning with EML3, 20 temperature sensors (also see Figure 6) are glued onto pre-selected locations around the perimeter of the chamber.

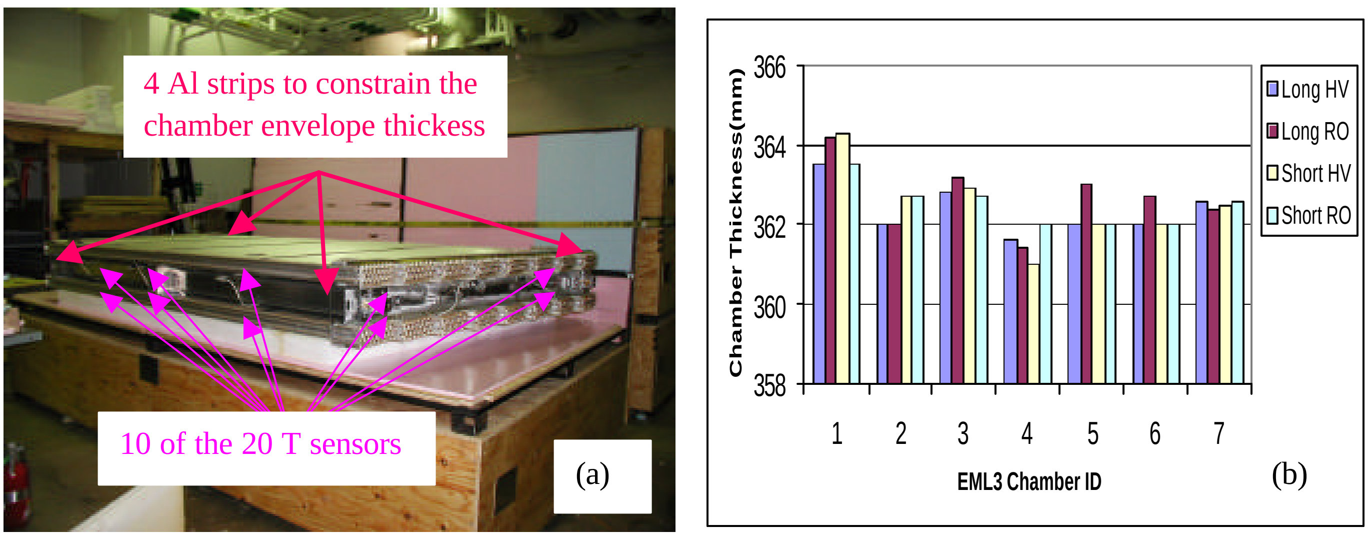

Figure 6. (a) Shown are aluminum strips screwed onto the gasbars of the two multi-layers at the four corners of the chamber, and temperature sensors glued on the chamber tubes and spacer frame. (b) Measured EML3 chamber envelope thickness.

3. Leak Rate Stability Study

Our experience with the chamber leak test shows that, to reach the stringent ATLAS gas leak specification, we must identify and *reject any single leak at the level of* 6×10^{-7} *ml/sec*, which is about two times as high as the helium background. This is possible only by means of using a highly sensitive gas leak detector, such as a *mass spectrometer*.

In EMLS4 series chambers, we discovered that some of the previously certified chambers developed new leaks with rates ranging from 10^{-6} to 10^{-4} ml/sec. These leaks appeared after depressurizing and re-pressurizing the chamber, or when the chamber was continuously certified at 3 bar for more than 24 hours. We have been paying great attention to this problem for EML3 chambers and have implemented the following tests to understand the pressure stability of certified chambers:

1. Pressure recycle the *certified* chambers and scan for leaks with a mass spectrometer.
2. Certify one chamber for a few days and then scan for leaks.

3.1. Pressure Recycle Test with Certified Chambers

Test 1 was done with chambers EMLA0x (x=5, 7, 9, 11), and EMLA07 was tested twice. Figure 7 plots the results of test 1. We find that the leaks with rates from 10^{-6} to 10^{-4} ml/sec are from the locations between signal cap/endplug and 10 mm O-rings, half jumper and 1.8 mm O-ring, and gasbar and 2 mm O-ring, as shown in Figure 8 (d). In one chamber, one tubelet had a *pinhole* and one had a *crack*. Both pinhole and crack had leak rates of about 10^{-4} ml/sec, were at the location of the bend (Figure 8 (d)), and can be seen with a times 10 magnifier. We also found that the leak from the pinhole/crack disappeared after marking the pinhole/crack location with a felt tipped marker of alcohol soluble ink. This indicates that some sealant can be used to fix the pinhole/crack on tubelets. Leaks reappeared after the ink was cleaned off with alcohol.

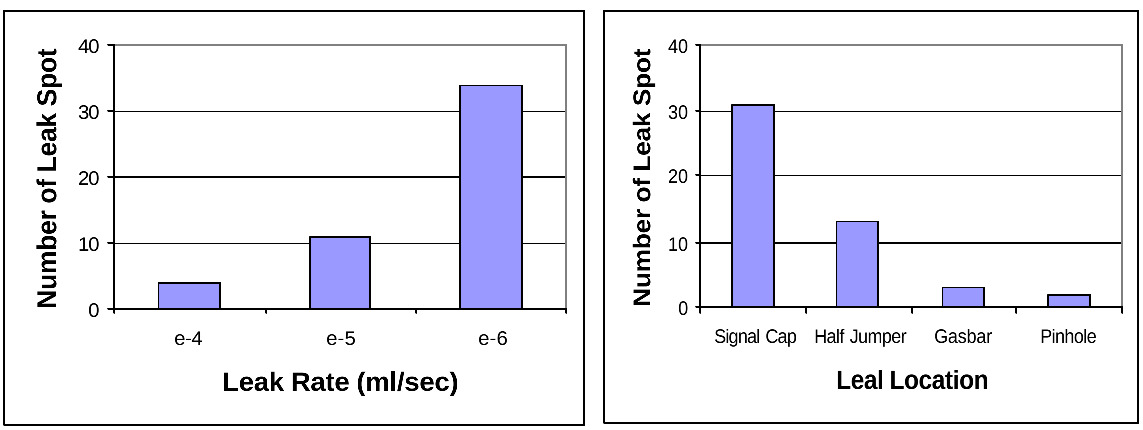

Figure 7. Shown are number of leaks for (a) different leak rate, (b) different leak locations. A total of 49 new leaks were found in four leak-certified chambers (EML3A0x, x=5, 7, 9, 11, and 7 was tested twice).

The most serious leaks identified for this series chambers have rates at 10^{-4} ml/sec. Two are found on the half jumper O-rings (Figure 8 (b) and (d)) due to deep cuts on the O-rings, and two result from pinhole/cracks on tubelets near the bend, as described previously.

Three leaks with rate at 10^{-6} ml/sec were identified on gasbar O-rings (Figure 8 (a)). Aluminum specks/chips were observed on the O-rings, which are assumed to be the reason for the leaks.

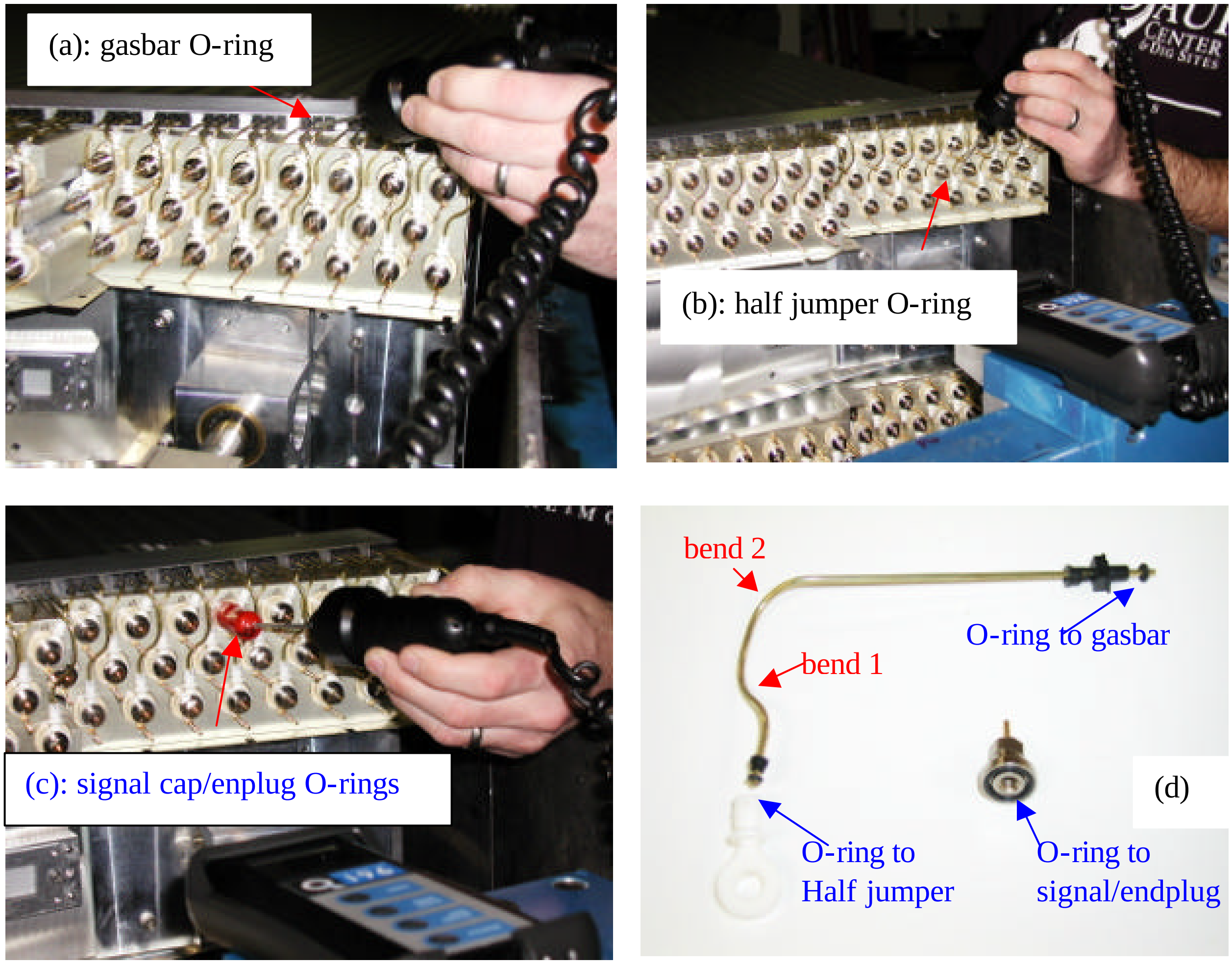

Figure 8. (a)-(c) Areas checked for leaks. (d) O-rings to half jumper/gasbar/signal cap.

For the leaks between the signal cap/endlug and O-rings, the rate is at the level of 10^{-6} ml/sec. We identify them with the mass spectrometer by covering the signal cap with a plastic cap shown in Figure 8 (c). Inspection at the O-rings revealed the presence of metal specks. It's almost impossible to identify whether the leak comes from the location between the O-ring and signal cap or endplug since the two locations are very close. In this case, both O-rings are replaced and both signal cap and endplug are cleaned. Signal caps are ultrasonically cleaned prior to use, but were then screwed onto the tube endplug after wiring room assembly. This screwing action generates metal chips, so the signal cap must be recleaned before mounting gasbars onto the chamber.

The leaks from the half jumper O-rings are due to fiber from the material of the half jumper and from flashing and specks on O-rings.

3.2. Long Term Leak Rate Tightness Test with Chambers

We used certified chambers EML3A09 for Test 2. After four days under pressure at 3 bar, the chambers had 6 and 13 leaks at a rate of 10^{-5} and 10^{-6} ml/sec respectively.

They were located between O-rings to signal cap/endplug; two out of these 19 leaks have a rate at 10^{-6} ml/sec and are from the half jumper O-ring. All the others are from O-rings between signal cap and endplug.

We emphasize that the method used to find leaks around the signal cap/endplug is very sensitive since the plastic cap accumulates the leaked gas. The leak rate measured depends on how long the cap has been in place and how tightly the cap seals the signal cap.

We also certified chamber EML3A13 in a room that controls temperature to ±0.5 ^{0}C, and monitored the chamber temperature and pressure every 5 minutes by our DAQ system as shown in Figure 4. Figure 9 shows the change of pressure as a function of time for about 65 hours.

The ML1 and ML2 layers satisfy ATLAS specification for about 30 and 20 hours respectively. Then large leak rates appeared as indicated in the plots. We use the mass spectrometer to sniff the leak spots and found: ML1 has four leaks, two at rate of 10^{-2} ml/sec and two at 10^{-4} ml/sec; ML2 has two leaks at rates of 10^{-3} ml/sec. *All 6 leaks were from the half jumper O-ring location*. In two of these fibers of delrin material were seen, but for the remaining four no obvious leaks were seen.

We replaced these six tubelets and pressurized the chamber step by step through 0.5 bar, 2.0 bar 3.0 bar within about one hour. We then sniffed the chamber and found six leaks from #3 tubelets in bend locations at rates around 10^{-6} ml/sec. Four of these six tubelets show streams of bubbles when they are pressurized to 1.5 bar and immersed in alcohol. Pin holes/cracks cannot be observed with a microscope that can resolve micro level structures. After we replaced these six tubelets, we repressurized the chamber to 3 bar and monitored the chamber temperature and pressure in the temperature controlled room. We found ML1 satisfies ATLAS specification, but ML2 had a leak rate about 2 mbar/day, which is slightly worse than the specification. We use the mass spectrometer to scan ML2 again and found nine leaks, of which three had rates of 10^{-6} ml/sec from half jumper O-ring locations (two O-rings were pinched and one O-ring had fibers from the half jumper material), and six from pin hole/cracks on #3 tubelets in bend locations. (three at a rate of 10^{-5} ml/sec and three at rate of 10^{-6} ml/sec). Four out of these six tubelets were suspected to have pinhole/cracks, which was later verified in a bubble test.

We did a test to study how these leaks develop by observing the leak rate for three days. Figure 10 shows the observed result. Visually the five leaks were observed bubbling in four tubelets, and generally appeared larger after the 3-day test. The measured rates at two leak sites decreased somewhat or were unstable, although they were at times large enough to probably cause a certification test to fail. Leaks at three sites increased dramatically to 10^{-4} and 10^{-3} ml/sec levels. All leaks occurred at one or the other of the bends. From this observation, we conclude that there is no assurance that a tiny pinhole ($<10^{-5}$ ml/sec) will not, in a fairly short time, expand to a severe leak impacting chamber performance.

We also measured chamber leak rates for one multilayer having

a) one known leak spot at half jumper with rate of 10^{-4} ml/sec
b) two known leaks on gasbar O-ring with rates of 10^{-6} ml/sec
c) five known leaks on the location between O-ring and signal cap/endplug at the rate 10^{-6} ml/sec.

For case (a), the overall chamber leak rate reached 4 mbar/day, about two times greater than the ATLAS specification. Both case (b) and (c) reached ATLAS specification, indicating that we can afford a few leaks at rates of 10^{-6} ml/sec for each multilayer.

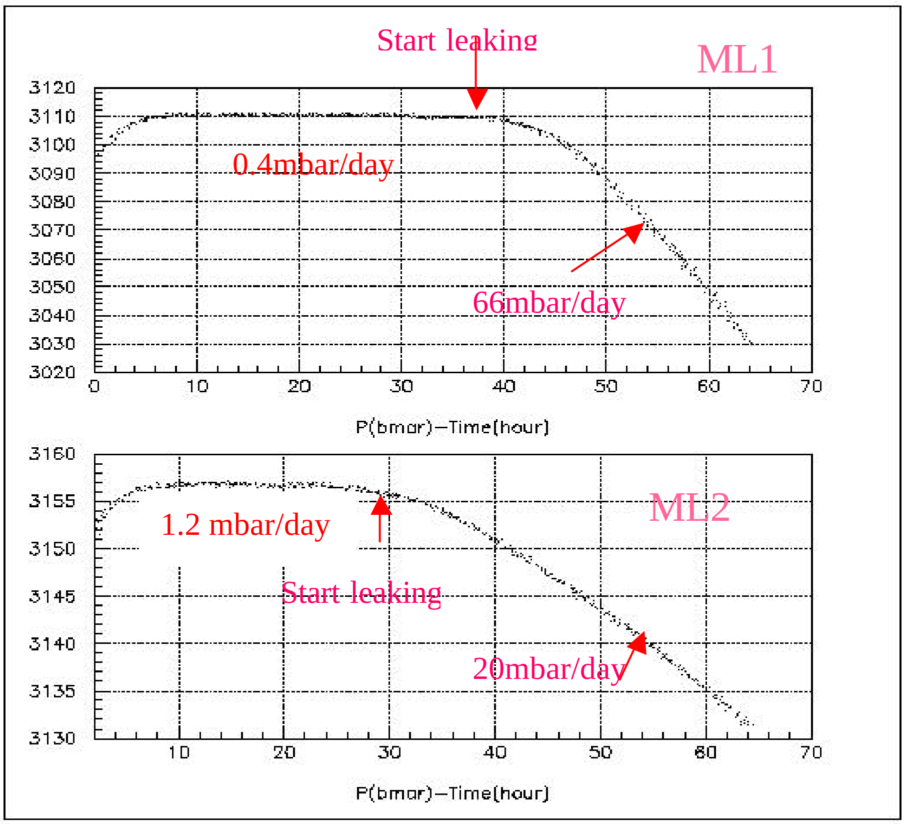

Figure 9. The monitored pressures of ML1 and ML2 in chamber EML3A13.

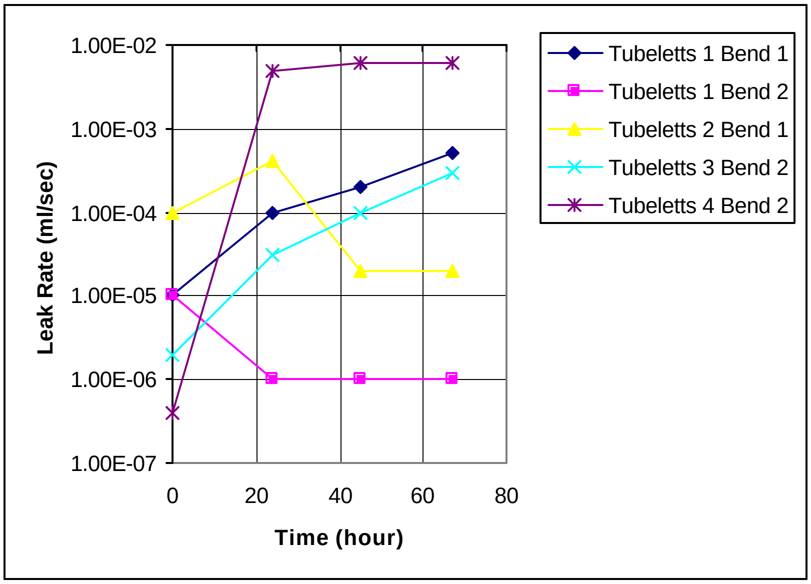

Figure 10. Observation of leak rates for four tubelets that have pinhole/cracks on them.

3.3. Long Term Leak Rate Tightness with Gasbars

We performed tests with ten pre-assembled gasbars. These gasbars have no leaks larger than 6×10^{-7} ml/sec. We pressurized the gasbars to 4 bars and kept the pressure over night (~15 hours), and then sniffed with the mass spectrometer over all the possible leak spots. We found 117 newly developed leaks from these gasbars with total possible leak spots $10\times192\times5=9600$, giving a ratio of 117/9600=*1.2%*. This ratio is about ten times greater than on the chambers, demonstrating that pre-assembly and gas leak tests of gasbar is an effective way to isolate and repair the leaks. Among these 117 leak spots, more than 40% have no visible O-rings defect. About 25% are due to fibers from half jumper material on O-rings; 13% and 5% come from the specks and flashing on O-ring, respectively. Another 5% are due to deep cuts on the O-rings. Pinhole/cracks are also found on two tubelets around the bend region with leak rates around 10^{-4}-10^{-3} ml/sec.

Figure 12 shows the number of leaks at different rates and locations for the gasbar leak rate stability test.

3.4. Gasbar Pressure Recycle Test

To further investigate the sources of leaks of the certified chambers due to pressure recycling, we did a test with the leak tested pre-assembled gasbars. The tests are done according to following procedure

(a) pressurize the gasbar to 4 bar and sniff all possible leak spots (indicated as *before* in Figure 12)
(b) keep the gasbar pressure at 4 bar for about one hour
(c) repeat (a)-(b) three times
(d) sniff the leak spots with the mass spectrometer, replace leaking parts and ensure no leaks with rates greater than 6×10^{-7} ml/sec (denoted as *after*).

(e) keep the gasbar at 4 bar for 15 hours and then scan the leak spots again with mass spectrometer (denoted as *over night*)

Figure 12 shows the results of the tests for eight gasbars. After three pressure recycles, some new leaks at rates from 10^{-6} to 10^{-5} ml/sec levels are produced. The over-night pressure test also shows new leaks at these level. We inspected each leak spot and found that the major reasons were due to pinches, metal specks and fibers on O-rings to signal caps, half jumpers and gasbars. About 15% of these newly produced leaks have no observable reason. Pinhole/crack are found on two #3 tubelet bend locations.

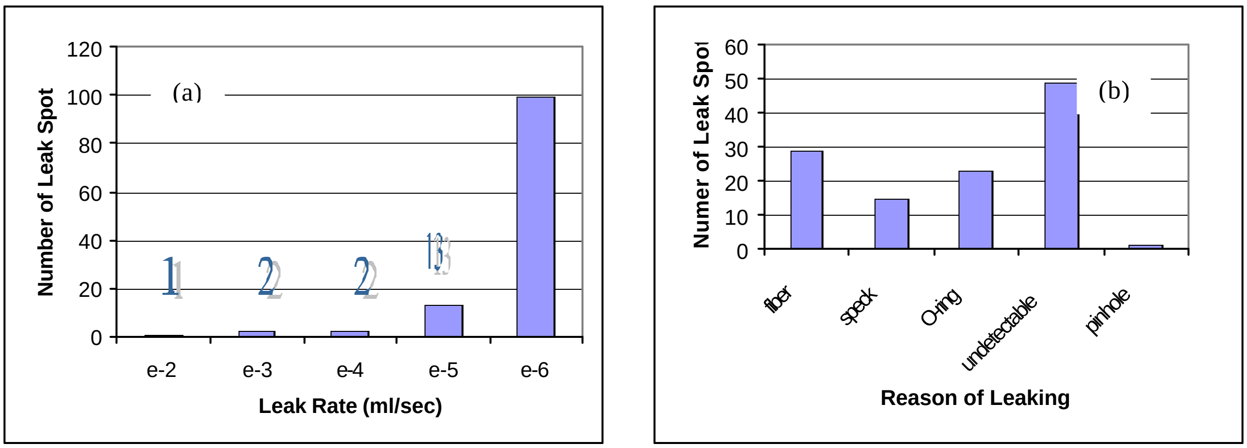

Figure 11. Number of leaks for (a) different leak rates, (b) different leak locations. A total of 117 new leaks were found on ten gasbars that were leak sniffed and pressurized to about 4 bar over-night.

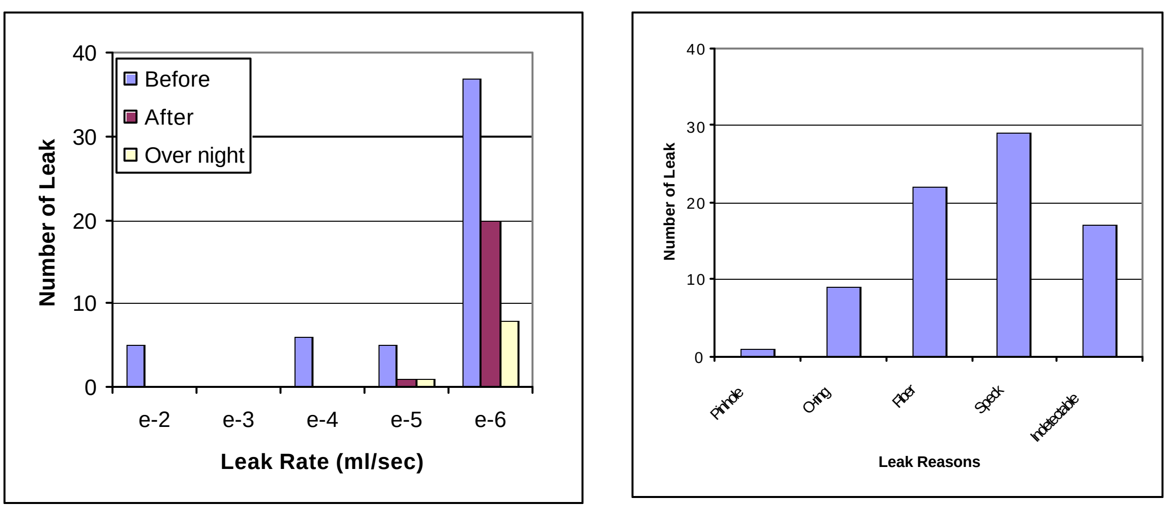

Figure 12. Number of leaks with different rates and different reasons from re-pressure tests of eight gasbars re-pressure tests. “Before”, “After” and “Over night” are defined in the previous paragraph.

4. Conclusions

From the study of pressure recycling and long term leak rate tightness for both chambers and gasbars, we conclude:

1) To reach ATLAS gas leak specification, one must identify and repair leaks with rates greater than 6×10^{-7} ml/sec. A solitary leak at the rate of 10^{-4} ml/sec will cause a multilayer to fail certification. However a few steady leaks at the rate of 10^{-6} ml/sec are acceptable.

2) The major leak sites are at the O-rings of the half jumpers and signalcap/endplugs, and a small fraction on the gasbar O-rings. Half jumper locations appeared to be the weakest from the leak rate stability point of view. The principal reasons of the leak are metal specks, flashing and fibers (from the half jumper material) on the O-rings.

3) Pinholes/cracks are found on twelve #3 tubelets at bend locations from two certified chambers. It's unknown yet how and when these pinholes/cracks are produced and how they develop. A tiny pinhole/crack on tubelets at leak rates $<10^{-5}$ ml/sec may, in a fairly short interval, expand to a severe leak impacting chamber performance.

4) Pressure recycling the chambers may cause new leaks at rates of 10^{-6}-10^{-4} ml/sec.

5) Long term pressurization of chambers at 3 bars may also develop leaks at rates of 10^{-6}-10^{-4} ml/sec.

6) All EML3 type chambers produced at U of M have satisfied ATLAS specification for the 24-hour certification time, and gas leak certification has been included in our routine chamber production cycle.