Thoughts for the VRB on Backfilling the ISI pods with Tracer Gasses
Brian Lantz, March 25, 2009, T0900127-v1

Several ideas have been suggested for the filler gas for the pods. I will try to briefly discuss the pros and cons of each, and then turn to the VRB for advice. First, it is useful to review the requirements for the pods and their filler gasses:

Highest Priority:
1) Don't leak anything awful into the LIGO vacuum (oil, paint, magic smoke from electrolytic capacitors, etc).
2) Allow good performance and reliability of the ISI sensors.

Very important:
3) Allow pod-by-pod confirmation of good seal performance.
4) Don't leak anything annoying into the LIGO vacuum.

Also useful:
5) Be able to tell if one of the ISI pods is, or is not, responsible for a measured leak in the LIGO vacuum. Alternatively, we AdLIGO installation team detects a leak, allow them to rule out either a bad external flange or a bad ISI pod. Since checking all the pods is very difficult, being able to rule out the pods will save much head scratching if there are problems.
6) Simplify the pod assembly and testing. There are about 126 HAM pods (1) plus spares and about 225 BSC pods (2) plus spares, so each hour we add to the pod assembly is worth about 9 person-weeks. Plus, more steps means more handling with more risk of contamination and damage. This should act as a moderating influence on 'cool ideas'.

With these in mind, several filling strategies have been suggested: vacuum, traceable mix of noble gasses, all Neon, clean air with a tracer, dry nitrogen with a tracer, dry nitrogen, clean air.

For HAM6, we sprayed neon into the pod with a hose, and sealed it. This gives a pod mostly filled with neon with the remainder being clean air. This seems a good option. The best variant I see is to get a bottle filled with a mix of (mostly) nitrogen and (a little) neon tracer, and spray that into the pod. Praxair and Airgas can both provide such, but they are custom mixes. As evidence of feasibility, Airgas has a standard mix of 10% helium with the balance as nitrogen.

Vacuum: not a realistic option.
Cons: Difficult to test pod seals, and difficult to detect leaking pods in the system. Nanometrics says that the Trillium T240 should be run in air. We have run STS-2s, L-4Cs and GS-13s at vacuum, on and off, in the Tech Demo for many years, with no evidence of damage. One worries about heat dissipation, outgassing damaging components, greases and plastics doing weird stuff and damaging the instruments. Plus, you still need a sealed pod.
Pros: Nasty goo not impressed into a jet of gas in the event of leak.

Traceable mix of nobel gasses: not believed to have any benefit over all neon.
Pros: It was suggested that various mixes of nobel gasses (e.g. one mix for L-4Cs, another for GS-13s, etc) would allow us to start tracing which pod was generating the leak.
Cons: I'm told there is a calculation showing that such fingerprinting is not achievable with reasonable equipment and pumping speeds, so this offers no advantage over an all-neon pod. I think Mike Zucker did this?

All Neon: reasonable
Pros: Allows simple leak checking of the pod prior to installation, and will distinguish between pod leaks and chamber door leaks.
Cons: Vern gave a nice discussion of this in an email on Dec. 19, 2008 (included below as (3)). I will summarize those points here and add a few of my own. Neon is hard to pump out of the LIGO tanks, and the residual time with ion pumps is quite long. Neon is much more likely to leak from the pod than air or nitrogen, so there may be neon leaks which don't really leak anything noxious. Neon is slightly lighter than air (molecular weight of 20 vs 29 for air), so some care should be taken to be sure the pod is actually filled with neon.

Clean air with a tracer: similar to all neon, but easier.
Pros: A large partial pressure of neon mixed in with clean air gives pretty much the same advantages and disadvantages as all neon, but could be done with a hose on a clean bench, rather than a special glove box. This is what was done with HAM6 pods
Cons: Air has water and oxygen, which may cause some long term reliability issues. This seems a more likely a red herring than a real threat. If we spray in with a hose, we don't really know what the neon concentration is.

Dry nitrogen with neon tracer: I like this:
Pros: similar pros to all neon, but leaks will cause less total neon in the vacuum system. minimizes water and oxygen. If we allow a bit of air, we could probably do this with a pre-mixed bottle of, say, 90% clean, dry nitrogen and 10 % Neon, and spray it in as was done with the HAM6 pods, which would be pretty easy, and give us reasonable estimate of the neon concentration. Since neon is more expensive than nitrogen, this might even save us money. Leaks into the vacuum can be seen, but there is less total neon to pump out.
Cons: This requires some way to load the pod which is more difficult than using clean air. To achieve no air would require a glove box, but seems unnecessary. The ability to measure leak rates on pods not as good as all neon, both for pod testing and for detection of installed leaks.

Clean air: not as easy as it sounds
Pros: Simple to put together, can be done on a bench.
Cons: Makes a good leak test of the pod difficult. Dennis suggests a 'bomb-test' whereby we put the sealed pod in a helium atmosphere and try to drive helium through the seals, then put the pod in a vacuum and look for an outgassing helium signature. This

means the pod-by-pod leak checking is much more work than air with a tracer. In addition, we lose then ability to distinguish pod leaks from vacuum system leaks after installation.

Dry nitrogen: harder than clean air
Pros: easy to pump leaking gas from the LIGO system.
Cons: leak testing difficult as clean air, and indistinguishablity of pod leaks and system leaks still a problem. Gas could be sprayed in with a hose, pure nitrogen would require a glove box.

Notes:
(1) AdLIGO needs 14 new HAM ISIs = 5 HAM ISIs per IFO + 1 at LASTI, and we have 2 already. Each has 6 GS-13s. In addition, HAMs 4&5, 10 & 11, and LASTI will (probably) have 6 feedforward L4Cs. 14 * 6 + 7* 6 = 126 + spares.

(2) AdLIGO needs 15 new BSCs, 5 per IFO. Each BSC has 3 Trilliums, 6 L-4Cs, and 6 GS-13s. 15 * (3+6+6) = 225 + spares.

(3) Vern's email of Dec 19, 2008:

1. I have raised and discussed the issue of the use of filler gas and its composition with several people and it is not a resolved issue. I understand that the GS-13 needs the viscosity and heat transport properties of a filler gas, but I don't know how detailed the SEI team has examined this. Taking a conservative position and assuming there will be a slow leak of the pod, I would lobby for a gas that can be pumped with our ion pumps and is not reactive with the optics, suspension components, etc. Something like N2 (diatomic nitrogen) as a filler gas. The use of argon or a similar noble gas will stay in the vacuum chamber forever. Looking at the RGA scans from the days of the bakeout of the beam tubes, the data indicates that it would be practically impossible to resolve a mixture of noble gases (or other gases for that matter) to the degree necessary to distinguish a chamber platform let alone have the resolution to identify an individual pod. To locate a slowly leaking pod (answer the question, "Which one?") perhaps it would be better to examine the flow of gas down the tube across many RGAs or gauges and construct a "wind pattern" inside the vacuum environment. This could be DMT monitor and a good project for an LSC group.

The case for an in-pod pressure sensor has to be made to only detect large leaks and to aid in identifying the culprit. The pressure change the sensor can resolve sets the threshold. (It better have a temperature monitor on it, too. We do not want false alarms.) To see a small leak on a large pressure background is very difficult and the pressure sensors available just do not seem to be up to it. A large leak would require opening the volume and making repairs. Speed would be of the essence, so maybe a simple pressure sensor has value. A sensor that indicated a drop of say 1/10th an atmosphere could be used to identify the leak, but we have to weigh the complexity of the system against redoubling the effort to test (e.g., pre-qualify a filled pod in a test vacuum chamber) and prevent leaks in the first place.