Beam Tube Leak Detection

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Requirements on Beam Tube

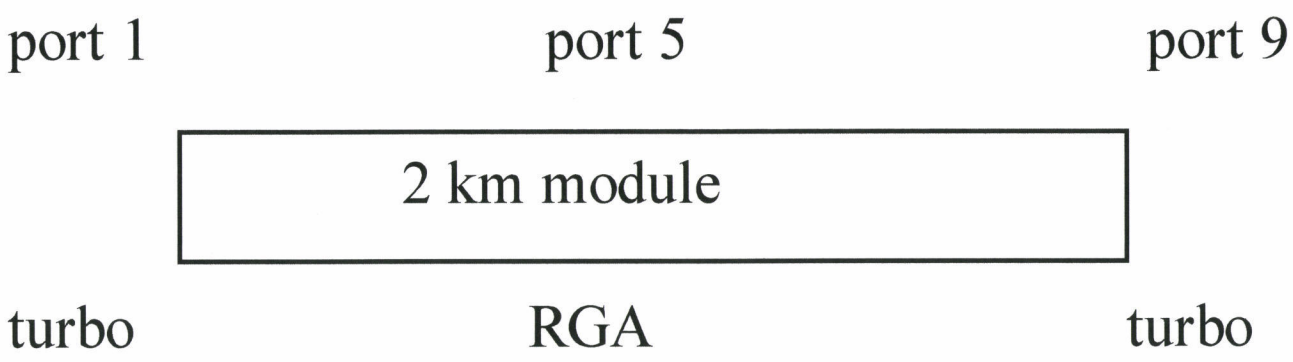
- Science
  - » attenuation and phase noise
    - – **$H_2 < 10^{-6}$ torr initial LIGO, 10^{-9} torr ultimate**
    - – **$H_2O < 10^{-7}$ torr initial, 10^{-10} ultimate**
- Lifetime
  - » Hydrocarbons produce less than a monolayer on optics
- Economics
  - » 10,000 m^2 vacuum system highly underpumped
    - – **2 km modules in initial LIGO are end-pumped only**

Steps

- Tubes
  - » 20 m tube sections - He leak checked to 10^{-10}
- Modules
  - » 2 km long and all girth welds He leak checked to 10^{-10}
- Prebake leak check *(LIGO acceptance of module!)*
  - » one 2 km module at a time
    - – **to < 10^{-5} atm-cc/sec or 2x sensitivity of instrument but no less than ~2x10^{-8} atm-cc/sec (He leak rate, not air)**
- Bakeout for water/hydrocarbon reduction
  - » Executed by LIGO post-acceptance

Leak Detection

Leak Detection



Leak Measurement

- Leak *Detection*
  - » bag module and use He leak detection
    - – **very difficult**
  - » use RGA and search for air signature of leak
    - – **execute with one RGA at central port 5**
- Leak *Location*
  - » instrument all 9 pump ports and measure leak air signature rates at all ports and solve simultaneous equations
    - – **human can outpace gas migration in tube**
    - – **should locate leak to 100 feet**
  - » VERY EXPENSIVE!

Qualification Test

- 40 meters of real size tube
- Carried out at CB&I Illinois in 1995 in basement laboratory
  - » temperature pretty stable
- Included the water bakeout
- All metal system! (No viton O-rings)
- Led to prebake expected leak detection sensitivity of about 2 x 10^{-8} atm-cc/sec

New Factors

- Outdoor field conditions
  - » Day-night temperature swings
- Viton O-rings on gate valves, flanges
- Viton discovered since QT to absorb Nitrogen and other species (air?)
- Quality assurance needed at every step

Pumpdown/Leak Detection

- LIGO X2 module pumped down in May
  - » 800 hours of pumping leads to pressure < 5 x 10^{-7} torr
- Turbopumps at ports 1 and 9 valved off and RGA accumulation carried out at port 5
- H_2O and condensibles pumped out between module and RGA by cold trap
- Instrument was contaminated and pump port system required bakeout
- RGA accumulation repeated June 14-15

First Results and Questions

- Air signature measured to be ~ 1 x 10^{-7} torr liters/sec
  - » factor 2 accuracy
  - » large temperature variation swings CO and CO_2 outgassing
- Is this from a leak or from outgassing of system constituent?
  - » viton O-rings in 48" and 10" gate valves totals 1270 cm^2
  - » Nitrogen outgassing should give gas load of ~ 1 x 10^{-7} torr liters/sec
  - » Is it air? What about oxygen, argon, etc.? Does viton absorb these and release at same rate as nitrogen? Oxygen gettering by baked stainless steel could distort proportions
  - » PSI study leads to conclusion that our air signature may be from viton outgassing

Likely Conclusion

- Viton outgassing is likely source of air signature
- Not accepting module from CB&I and requesting 9 RGA leak location will be expensive in money and schedule and may fail in these prebake conditions
  - » temperature variations and water load may make solving Rai's equations infeasible
- Accept module and move on to 7 more modules
- Opposing view
  - » Definitively determine if there is a leak or if viton is source
  - » Heat gate valves, etc.
- Will do RGA accumulation during pumpdown in future

Latest Status

- Calibration and reproducibility are troublesome
- RGA sensitivity is varying by factor ~2
  - » electron multipliers in all 9 RGA's are contaminated
    - – **QUALITY ASSURANCE**
- Temperature variability makes it hard to compare reasonable length accumulations
- Calibration using calibrated leaks is not very useful given swings
- Outgassing "appears" to vary by factor 3-4
- Review Board to meet on module acceptance