

Beam Tube Qualification Test

- Vacuum test results
 - ›› Outgassing rates after bake out
 - ›› Temperature dependence of outgassing post bake
 - ›› Sensitivity of air signature leak assay pre and post bake
 - ›› Power required and temperature distribution during bake
 - ›› Time required for bake
 - ›› Upper limits for weld leak statistics
 - ›› Upper limits to hydrogen bursts

- Ancillary test results
 - ›› Optical properties of the beam tube
 - ›› Vibrational transfer functions of the beam tube

QT System Parameters

- Geometric

Volume 5.12×10^4 liters

Area 1.71×10^6 cm²

- Vacuum

Pumping speeds H₂ 570 ±30 liters/sec

N₂ 246 ±15

H₂O 690 ±35 (LN₂ trapped)

RGA sensitivity H₂ $2.5 \pm 0.3 \times 10^{-15}$ torr/(count/sec)

N₂ $9.7 \pm 1.0 \times 10^{-15}$

He $3.9 \pm 0.2 \times 10^{-15}$

Absolute calibration: N₂, H₂ leaks

Relative calibration: CO, CO₂, Kr

QT Outgassing Data

PREBAKE OUTGASSING RATES

$$\text{H}_2\text{O} \quad \frac{1.2 \times 10^{-8}}{t(\text{hours})} \text{ torr liters/sec cm}^2$$

$$\text{H}_2 \quad 2.9 \pm 0.2 \times 10^{-14}$$

$$\text{CO} \quad < 2 \times 10^{-13}$$

$$\text{CO}_2 \quad < 3 \times 10^{-13}$$

$$\text{CH}_4 \quad < 1 \times 10^{-13}$$

- BAKE AT 140 - 150 C for 670 hours

POST BAKE OUTGASSING RATES

$$\text{H}_2\text{O} \quad < 8 \times 10^{-18}$$

$$\text{H}_2 \quad 8.6 \pm 0.2 \times 10^{-14} \text{ (increase from welds)}$$

$$\text{CO} \quad 2.5 \pm 0.1 \times 10^{-16}$$

QT Outgassing Data (cont)

CO₂ 1.6±0.3×10⁻¹⁶ torr liters/sec cm²

CH₄ 3.0±0.3×10⁻¹⁶

Sum amu > 45 < 4×10⁻¹⁸

POST BAKE OUTGASSING TEMPERATURE DEPENDENCE

- Temperature increase to double outgassing at 300K

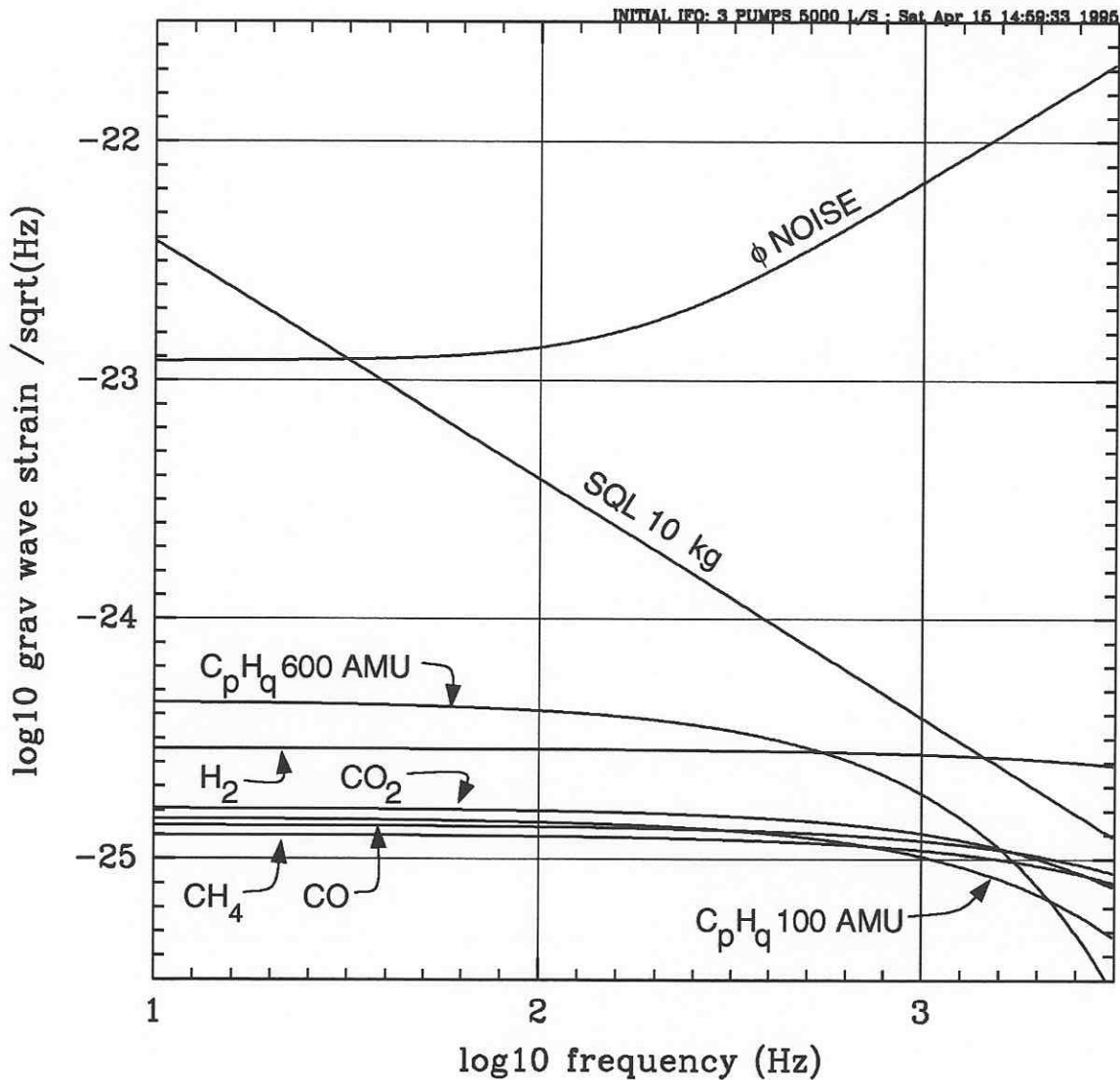
H₂ : From room temperature fluctuations 4.9 K

From outgassing ratio 413K/300K 8.9

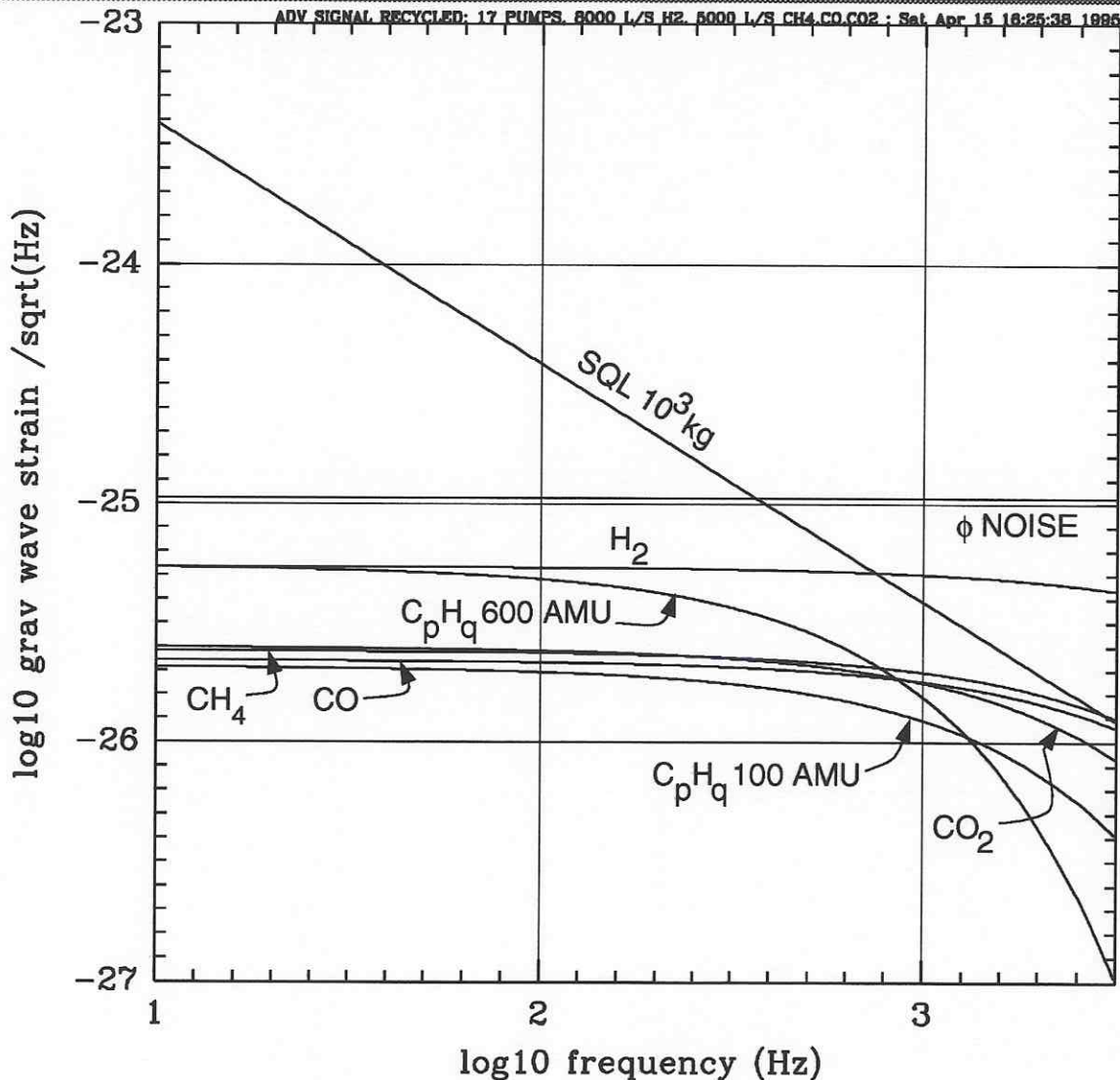
H₂O 4.8

CO₂ 6.5

Initial Interferometer Noise Budget



Advanced Interferometer Noise Budget



Advanced amplitude recycled interferometer parameters:

$$A_m = 10^{-5}$$

$$P_{in} = 100 \text{ W}$$

$$P_{circ} \sim 1 \text{ MW}$$

$$\epsilon_{opt} = 0.3$$

$$\lambda = 1.06 \mu$$



SUMMARY

- TEST RESULTS SATISFY THE LIGO REQUIREMENTS FOR INITIAL INTERFEROMETERS AND THE GOALS FOR ADVANCED INTERFEROMETERS

OTHER TEST RESULTS TO BE PRESENTED TOMORROW

QT Weld and Leak Statistics

- No He leaks measured $Q_{leak} < 10^{-10}$ torr liters/sec
- Leak rate confirmed by air signature assay

	m weld	repairs/m weld	leaks/m weld	leaks/m tube
circumferential	23	0.043	$<4.3 \times 10^{-2}$	$<2.5 \times 10^{-2}$
stiffening and support rings	188	0.027	$<5.3 \times 10^{-3}$	
spiral welds	377	0.12	$<2.6 \times 10^{-3}$	

QT Air Signature Limits

PREBAKE

LIGO requirement	$Q_{\text{leak}} < 10^{-5}$ torr liters/sec
QT demonstration requirement	$< 10^{-7}$

- METHOD

Air calibration LNT2: 77K

Minimum of N ₂ , O ₂ , A	$< 8 \times 10^{-8}$
χ^2 minimization 21 gases, 42 amu	$< 1 \times 10^{-9} \frac{\chi^2}{\nu} = 2.1$

POSTBAKE

LIGO assay requirement	$< 10^{-9}$
LIGO localization requirement	$< 10^{-10}$
QT demonstration assay requirement	$< 10^{-11}$
QT demonstration localization reqmnt	$< 10^{-12}$

QT Air Signature (cont)

- METHOD

Air calibration LNT2: 300K

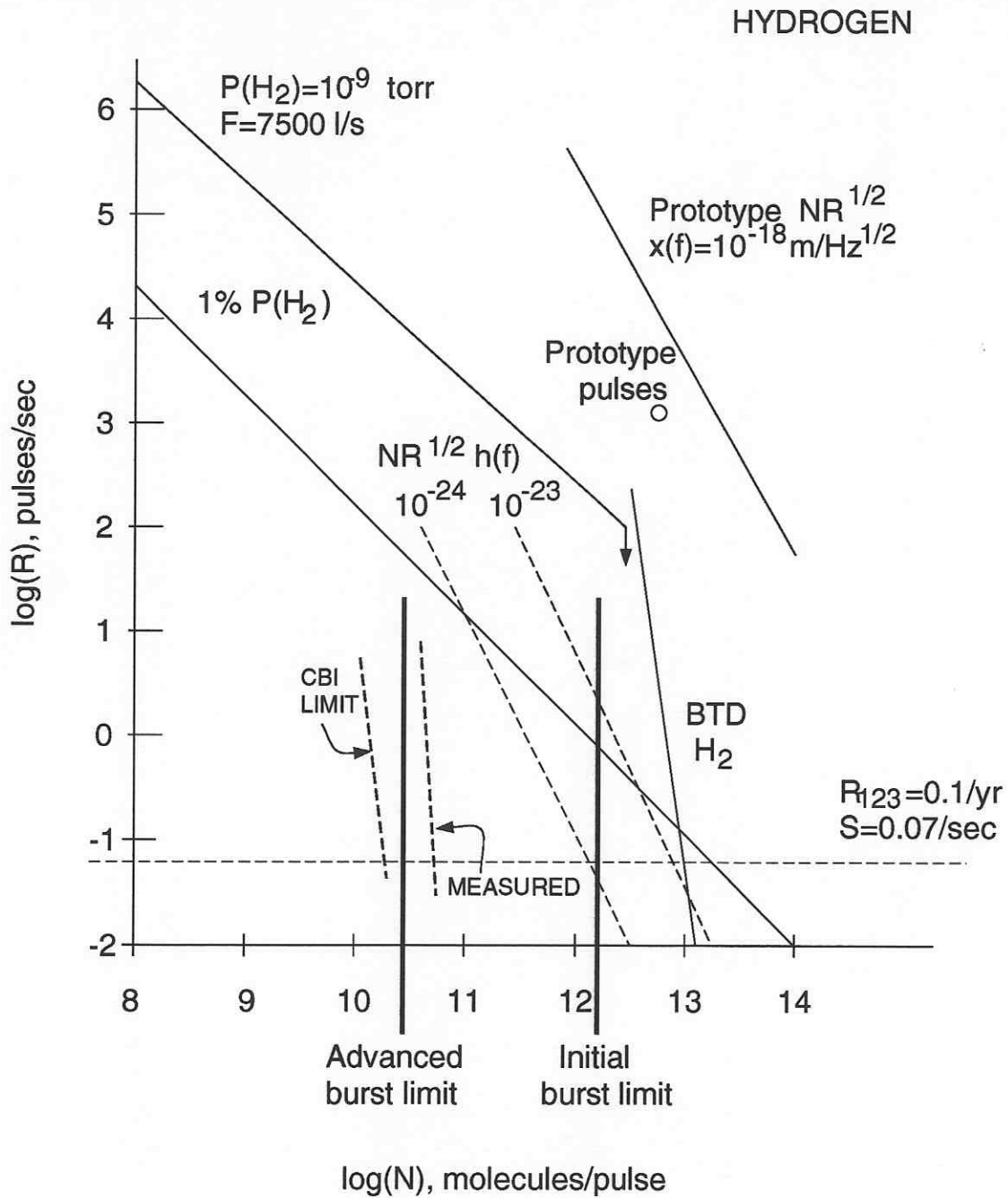
Total amu 28 $<10^{-11}$

χ^2 minimization 21 gases, 42 amu $<8 \times 10^{-12} \frac{\chi^2}{\nu} = 110$

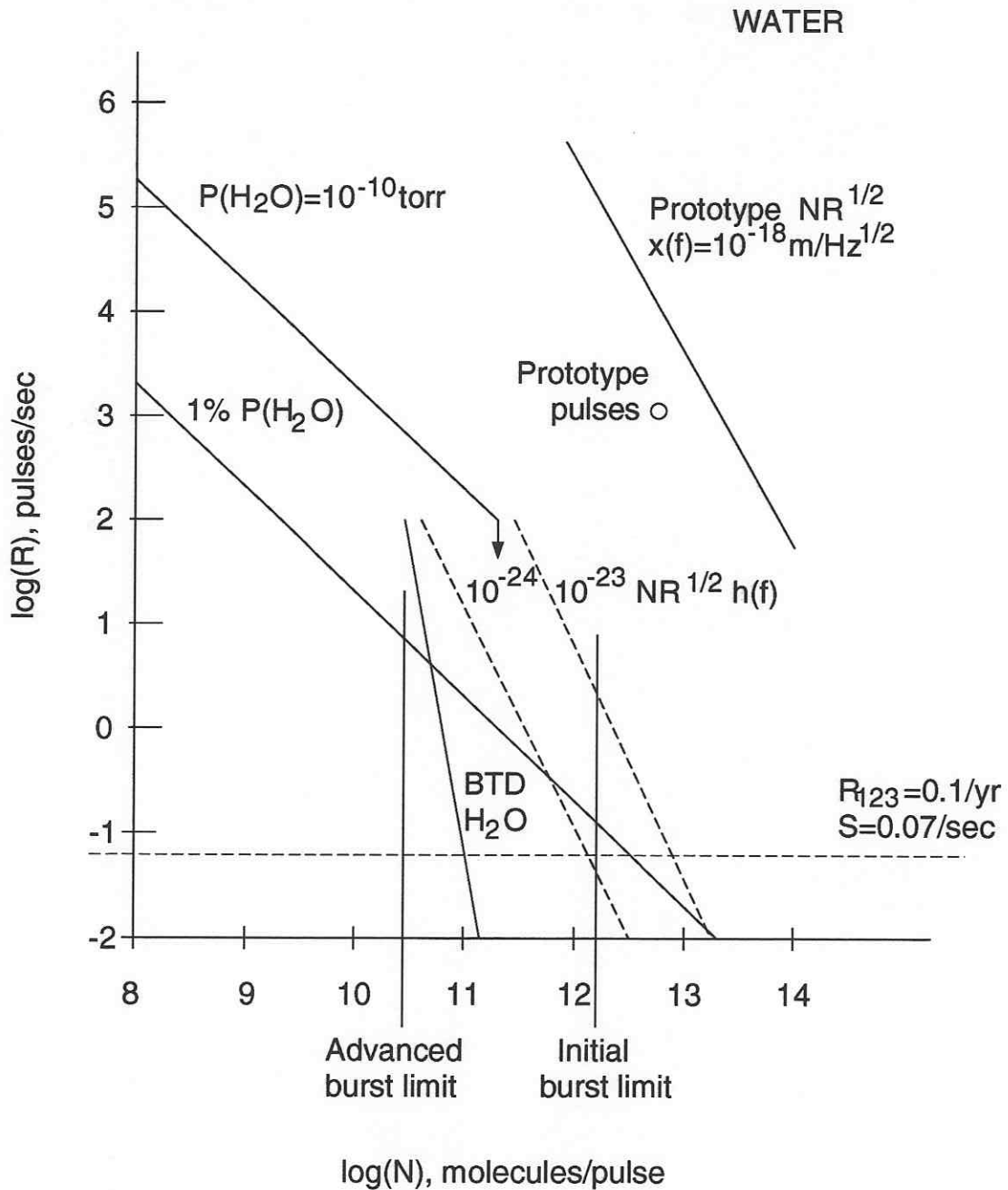
χ^2 minimization 21 gases, 42 amu $<2 \times 10^{-12} \frac{\chi^2}{\nu} = 3$

CH₄ cracking fractions allowed to exceed literature uncertainties

Hydrogen Burst Limits



Water Burst Limits



Beam Tube Optical Properties at 6328A

- Back scatter

$$\frac{dP_{scat}/d\Omega}{P_{inc}} \sim 10^{-2} \text{ sr}^{-1} \quad \text{grazing angle} < 1.7 \times 10^{-2} \text{ radians}$$

- Forward scatter

$$\frac{dP_{scat}/d\Omega}{P_{inc}} \sim 3.5 \times 10^2 \text{ sr}^{-1} \quad \text{grazing angle} < 1.7 \times 10^{-2} \text{ radians}$$

$$\Delta\theta_{hw} = 0.08 \text{ radians}$$

- Absorption

$$A = 0.49 \pm 0.04$$

$$\text{grazing angle} = \frac{\pi}{2}$$