

# Beam Tube Qualification Test

LIGO-T960125-00-D

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- 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

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- Geometric

Volume  $5.12 \times 10^4$  liters

Area  $1.71 \times 10^6$  cm<sup>2</sup>

- Vacuum

Pumping speeds H<sub>2</sub> 570 ±30 liters/sec

N<sub>2</sub> 246±15

H<sub>2</sub>O 690±35 (LN<sub>2</sub> trapped)

RGA sensitivity H<sub>2</sub>  $2.5 \pm 0.3 \times 10^{-15}$  torr/(count/sec)

N<sub>2</sub>  $9.7 \pm 1.0 \times 10^{-15}$

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

Absolute calibration: N<sub>2</sub>, H<sub>2</sub> leaks

Relative calibration: CO, CO<sub>2</sub>, Kr

# QT Outgassing Data

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## 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)

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CO<sub>2</sub>     $1.6 \pm 0.3 \times 10^{-16}$  torr liters/sec cm<sup>2</sup>

CH<sub>4</sub>     $3.0 \pm 0.3 \times 10^{-16}$

Sum amu > 45     $< 4 \times 10^{-18}$

## POST BAKE OUTGASSING TEMPERATURE DEPENDENCE

- Temperature increase to double outgassing at 300K

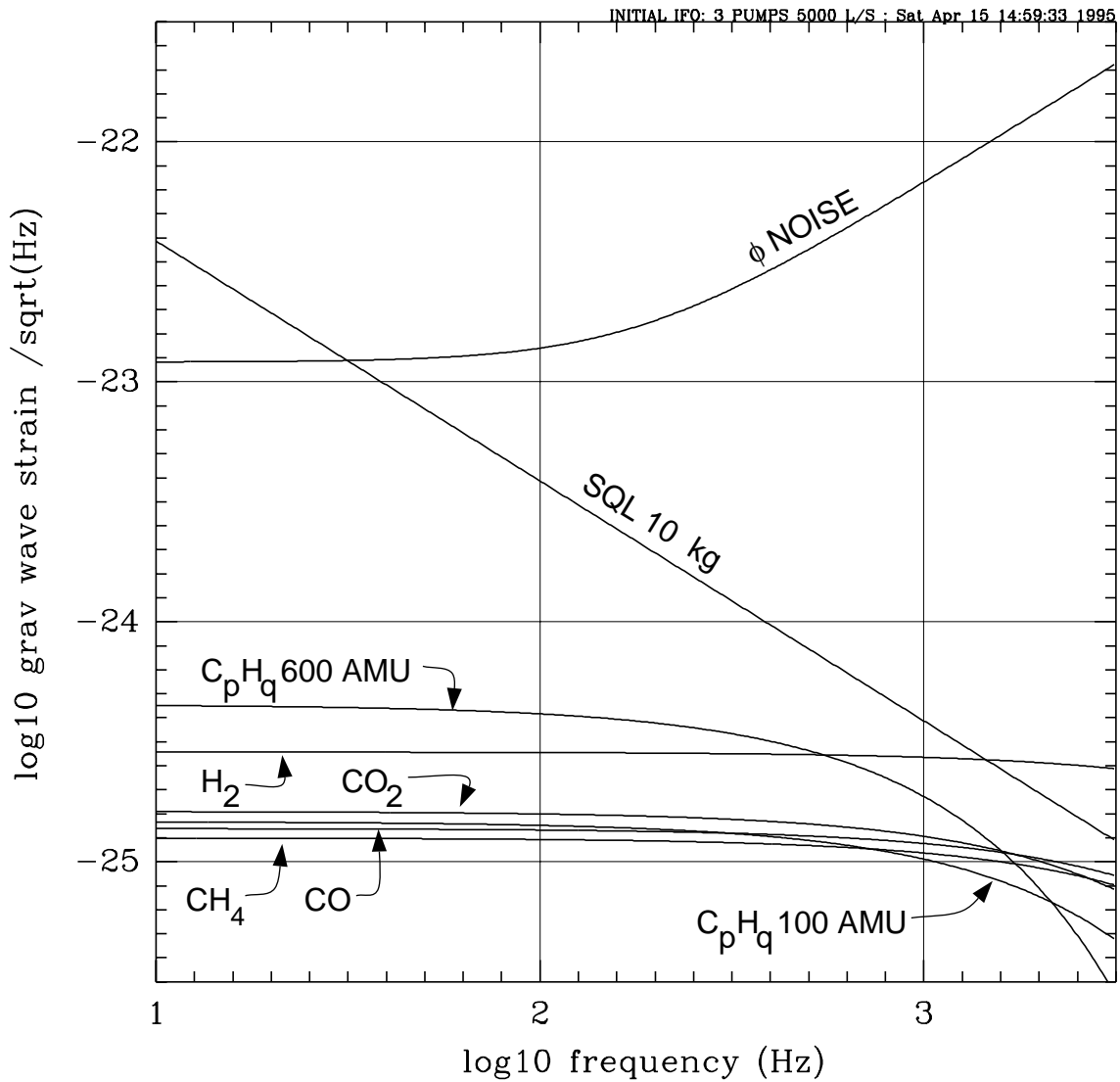
H<sub>2</sub> : From room temperature fluctuations    4.9 K

From outgassing ratio 413K/300K    8.9

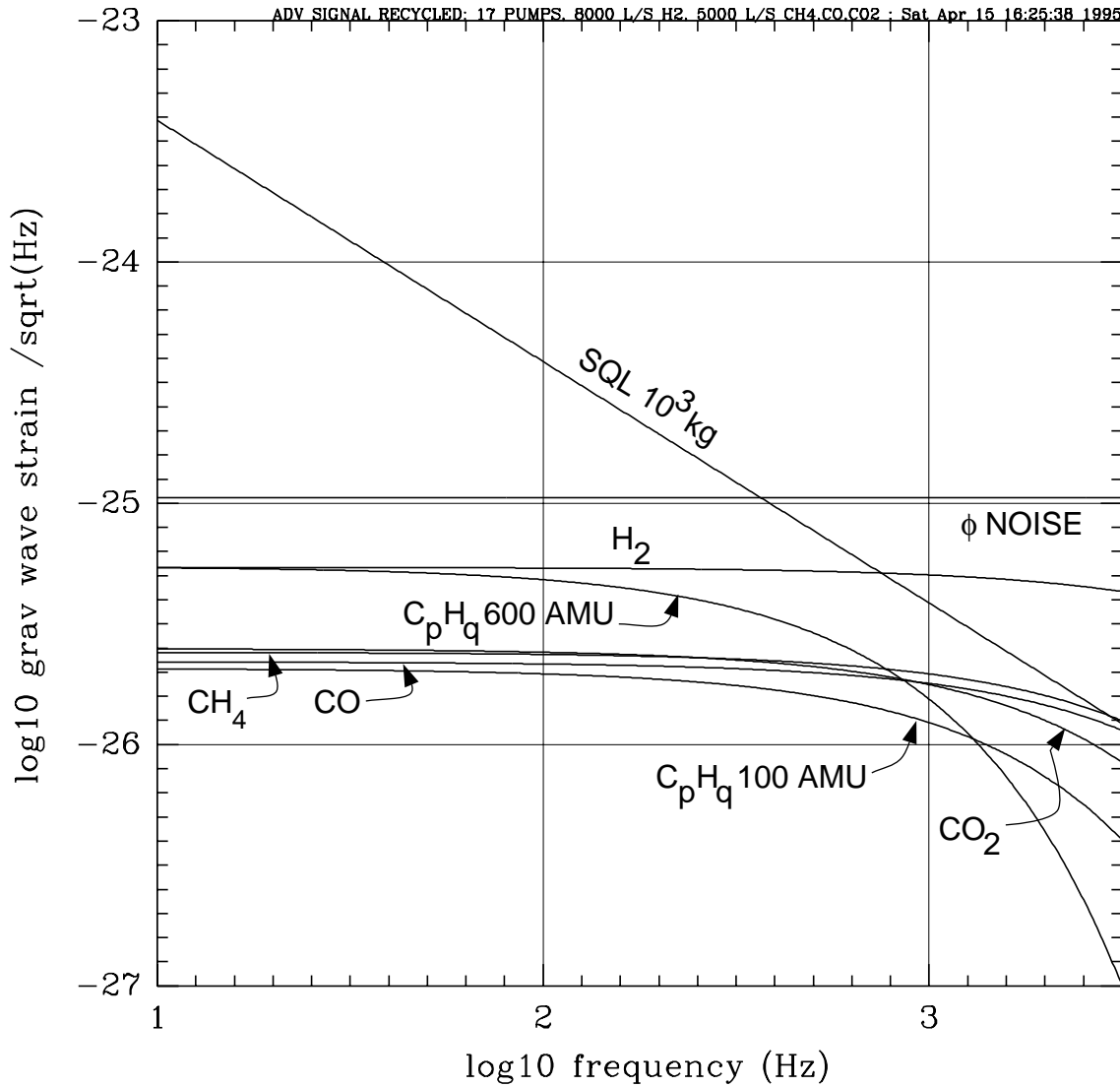
H<sub>2</sub>O    4.8

CO<sub>2</sub>    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

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- 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

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

	<b>m weld</b>	<b>repairs/m weld</b>	<b>leaks/ m weld</b>	<b>leaks/ m tube</b>
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

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## PREBAKE

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

- ## METHOD

Air calibration LNT2: 77K

Minimum of N <sub>2</sub> , O <sub>2</sub> , A	$< 8 \times 10^{-8}$
$\chi^2$ 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)

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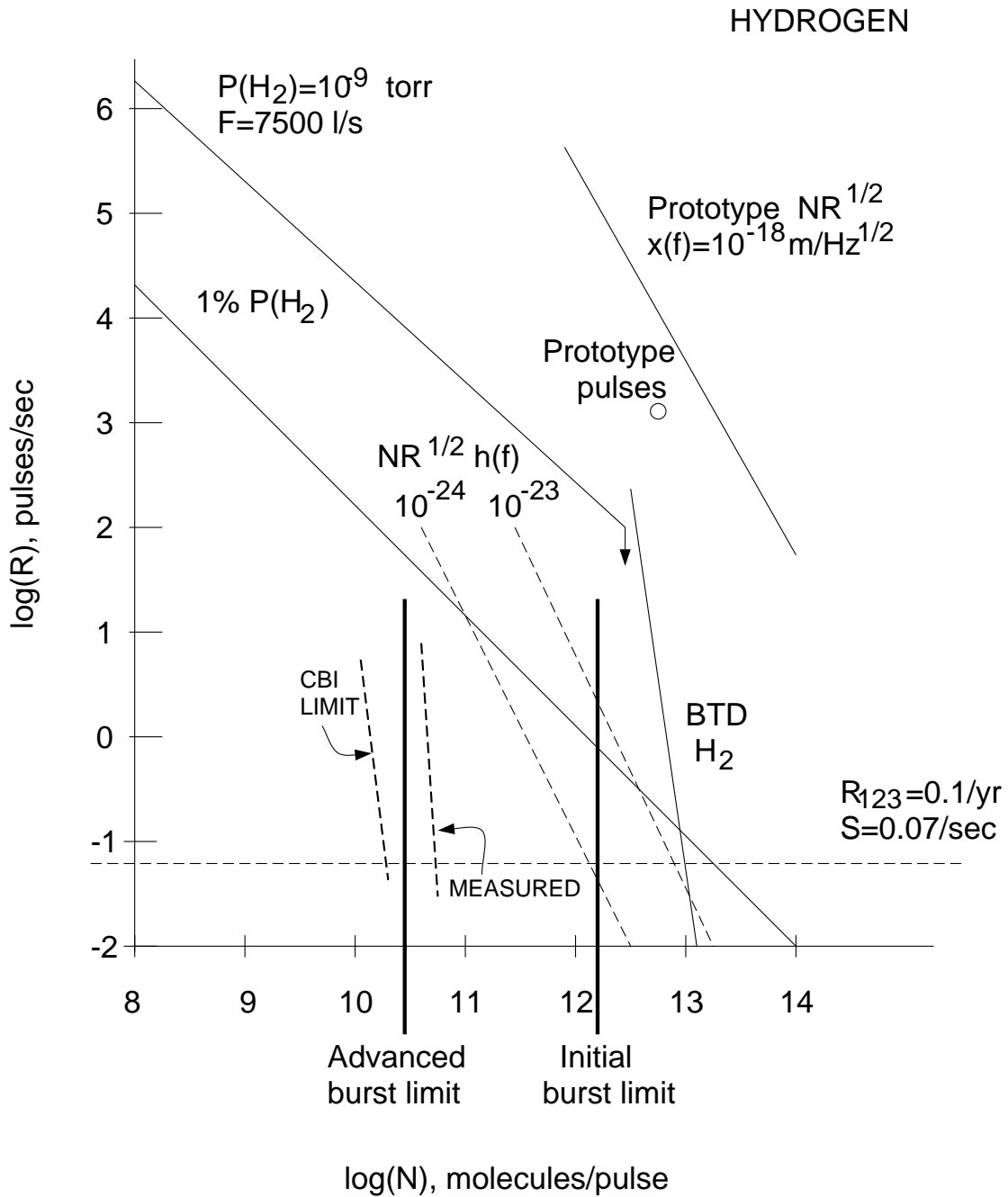
- METHOD

Air calibration LNT2: 300K

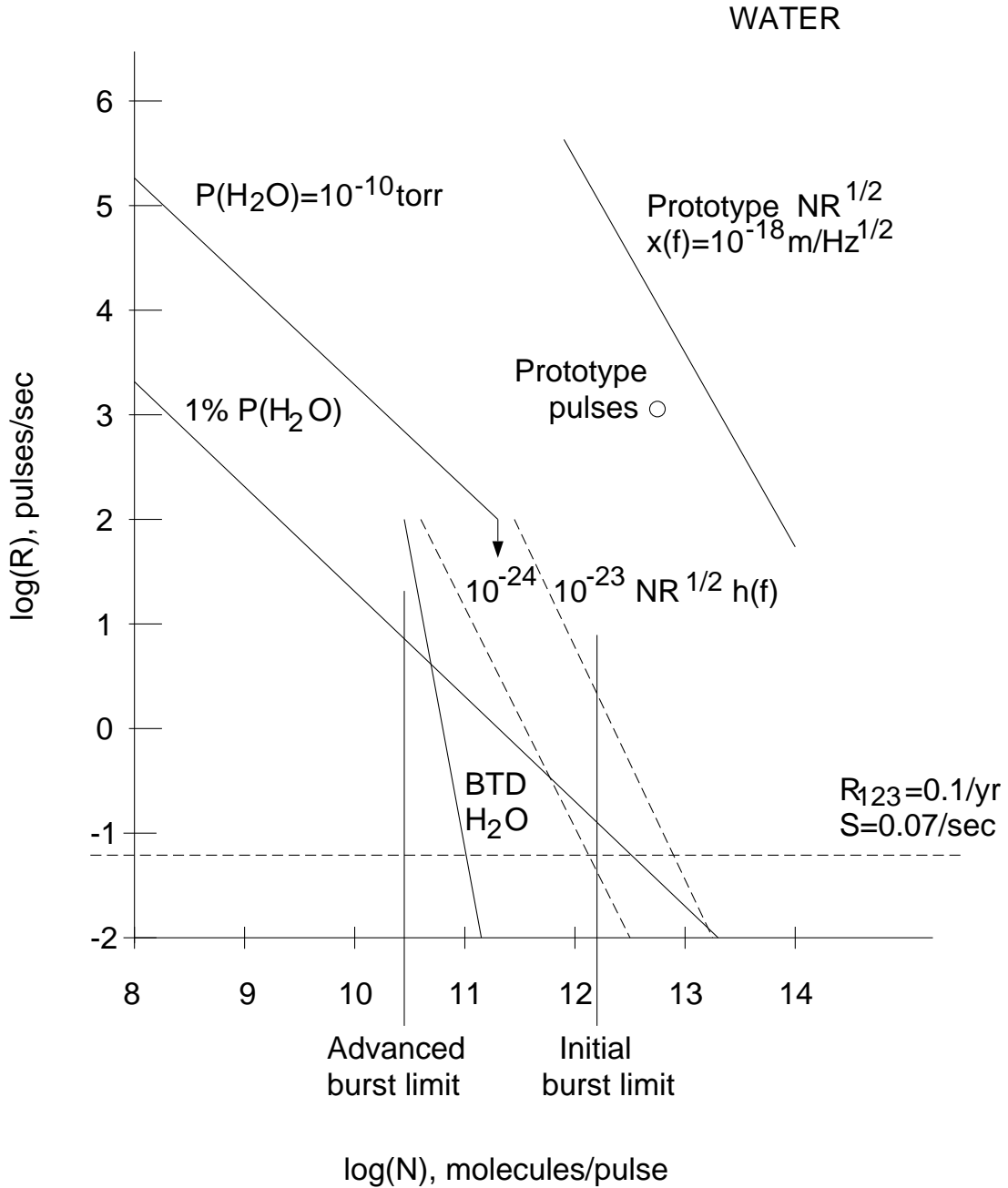
Total amu 28	$<10^{-11}$
$\chi^2$ minimization 21 gases, 42 amu	$<8 \times 10^{-12} \frac{\chi^2}{\nu} = 110$
$\chi^2$ minimization 21 gases, 42 amu	$<2 \times 10^{-12} \frac{\chi^2}{\nu} = 3$

CH<sub>4</sub> cracking fractions allowed to exceed literature uncertainties

# Hydrogen Burst Limits



# Water Burst Limits



# Beam Tube Optical Properties at 6328A

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- 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

$$A = 0.49 \pm 0.04$$

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