

the beamtubes and chambers are that the residual gas noise is a factor of ten below the design sensitivity at all frequencies. In the absence of a malfunction or poor vacuum practice, such as leaks in the vacuum system or inadequate cleaning of vacuum components, achieving the low partial pressures necessary to meet these requirements will be most challenging for hydrogen, water, nitrogen, and oxygen. We thus allow these four species to saturate these requirements with each contributing one quarter to the total. Hydrocarbons could potentially make a large contribution to the noise since they are massive and have large polarizabilities. Keeping their pressures low enough to have a negligible contribution to the total noise also ensures that they do not contaminate the mirror and cause excess optical loss. These pressure requirements and goals are summarized in Table 8.3.

Species	Beamtubes			Chambers	
	Req / torr	Goal / torr	LIGO Achvd / torr	Req / torr	Goal / torr
He	1.3×10^{-9}	3.4×10^{-10}		8.8×10^{-10}	7.9×10^{-11}
H ₂	3.3×10^{-10}	8.3×10^{-11}	3.4×10^{-9}	3.1×10^{-9}	2.8×10^{-10}
Ne	1.8×10^{-10}	4.5×10^{-11}		3.9×10^{-10}	3.5×10^{-11}
H ₂ O	3.0×10^{-11}	7.6×10^{-12}	2.3×10^{-12}	1.0×10^{-9}	9.4×10^{-11}
O ₂	2.1×10^{-11}	5.3×10^{-12}	2.0×10^{-13}	7.8×10^{-10}	7.0×10^{-11}
N ₂	1.9×10^{-11}	4.7×10^{-12}	1.0×10^{-13}	8.3×10^{-10}	7.5×10^{-11}
Ar	6.7×10^{-12}	1.7×10^{-12}	9.0×10^{-14}	2.8×10^{-10}	2.5×10^{-11}
CO	5.8×10^{-12}	1.4×10^{-12}	2.0×10^{-12}	3.3×10^{-10}	3.0×10^{-11}
CH ₄	4.8×10^{-12}	1.2×10^{-12}	2.2×10^{-11}	4.4×10^{-10}	4.0×10^{-11}
CO ₂	2.8×10^{-12}	6.9×10^{-13}	4.0×10^{-13}	2.7×10^{-10}	2.4×10^{-11}
Xe	6.3×10^{-13}	1.6×10^{-13}		1.5×10^{-10}	1.4×10^{-11}
100 u H _n C _m	8.9×10^{-14}	2.2×10^{-14}		1.8×10^{-10}	1.6×10^{-11}
200 u H _n C _m	1.7×10^{-14}	4.2×10^{-15}		1.2×10^{-10}	1.1×10^{-11}
300 u H _n C _m	6.2×10^{-15}	1.5×10^{-15}		1.0×10^{-10}	9.2×10^{-12}
400 u H _n C _m	3.1×10^{-15}	7.6×10^{-16}		8.8×10^{-11}	7.9×10^{-12}
500 u H _n C _m	1.7×10^{-15}	4.3×10^{-16}		7.9×10^{-11}	7.1×10^{-12}
600 u H _n C _m	1.1×10^{-15}	2.8×10^{-16}		7.2×10^{-11}	6.5×10^{-12}

Table 8.3: Cosmic Explorer residual gas requirements and goals. The requirements are that the total gas scattering noise is a factor of five below the design sensitivity and that the total gas damping noises are a factor of three below the design sensitivity. The goals are that the total residual gas noise is a factor of ten below the design sensitivity everywhere. See text for details. The pressures achieved in the Advanced LIGO beamtube are also shown for comparison.⁴¹³ The H₂ pumping speed can easily be augmented by titanium sublimation or non-evaporable getter pumps to reach the required pressures in both the chambers and beamtubes.

Ultrahigh-vacuum beamtubes The vacuum tubing for Cosmic Explorer will be separated into 10 km sections, which are independently pumped. Each section is further divided into 2 km subsections for outgassing and leak hunting as shown in Fig. 8.3. The ends of the 10 km sections