Thermoacoustic Quality Factor Measurement in a Helmholtz Resonator

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For a driven-damped spring-mass system:

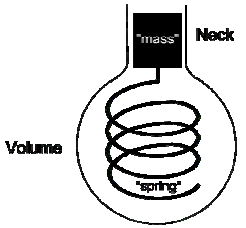
$$m\frac{d^2x}{dt^2} + R\frac{dx}{dt} + kx = SPe^{j\omega t}$$

Assuming a solution of the form:

$$x_p(t) = xe^{j\omega t}$$

Inserting this solution into the equation:

$$\frac{x}{x_0} = \frac{1}{\sqrt{1+(f^2/f_0^2)Q^2[1-(f_0^2/f^2)]^2}}$$



The resonance frequency f_o and the quality factor Q are defined as:

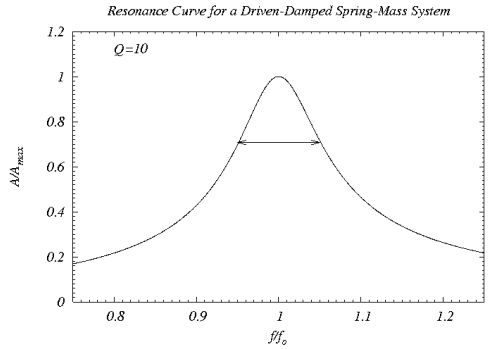
$$f_0 = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{c}{2\pi}\sqrt{\frac{S_{neck}}{L'V_{flask}}} \quad \text{and} \quad Q = \frac{\omega_0 m}{R}$$

The displacement in the flask is related to the pressure by:

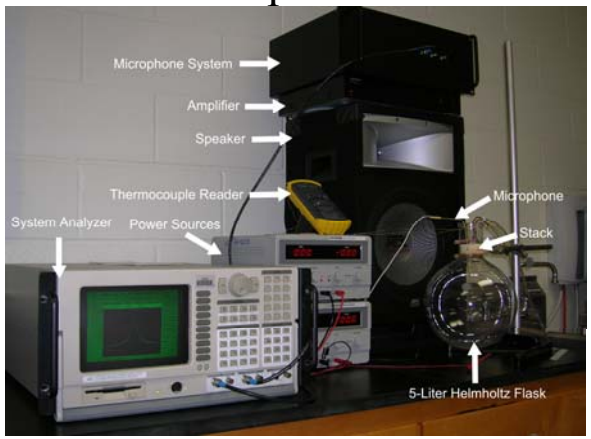
$$x = \frac{V_{flask}}{\rho_0 c^2 S_{neck}} P$$

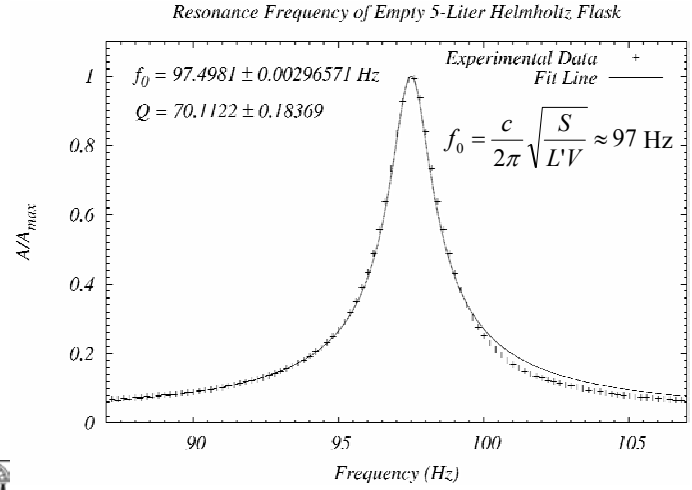
The equation for the driven-damped system becomes:

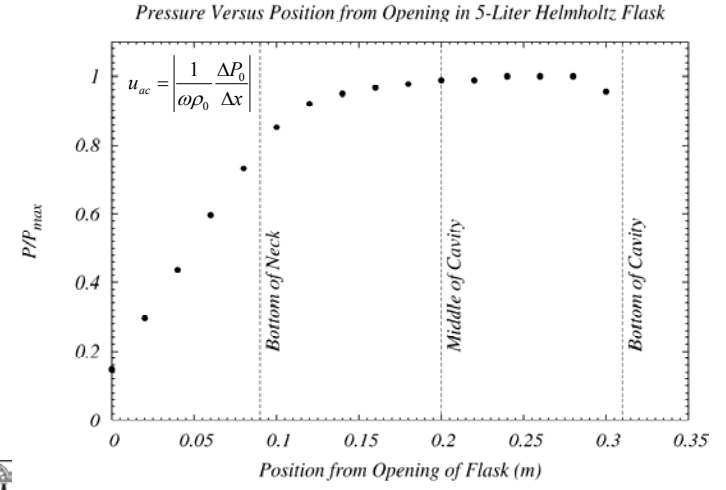
$$\frac{A}{A_{\max}} = \frac{1}{\sqrt{1+(f^2/f_0^2)Q^2[1-(f_0^2/f^2)]^2}}$$



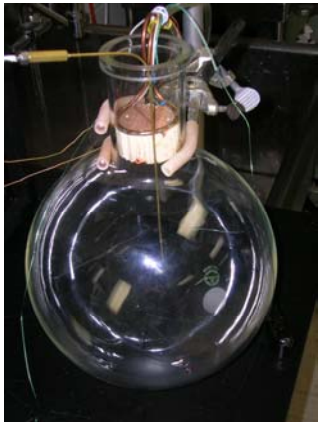
Experimental Setup

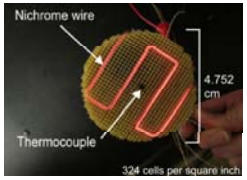


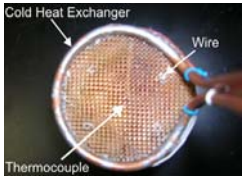


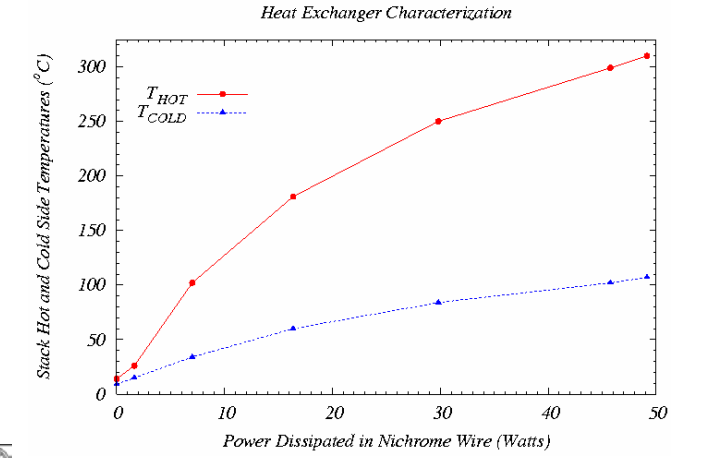


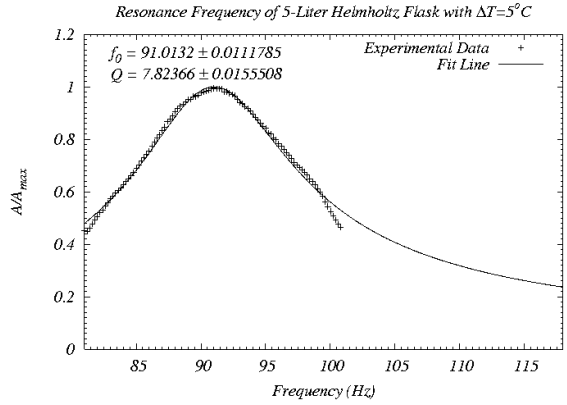
Ceramic Substrate

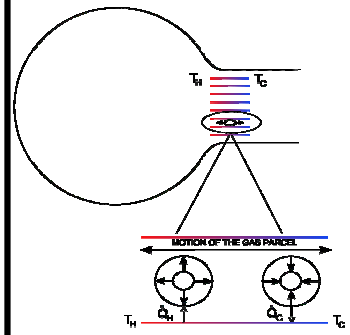






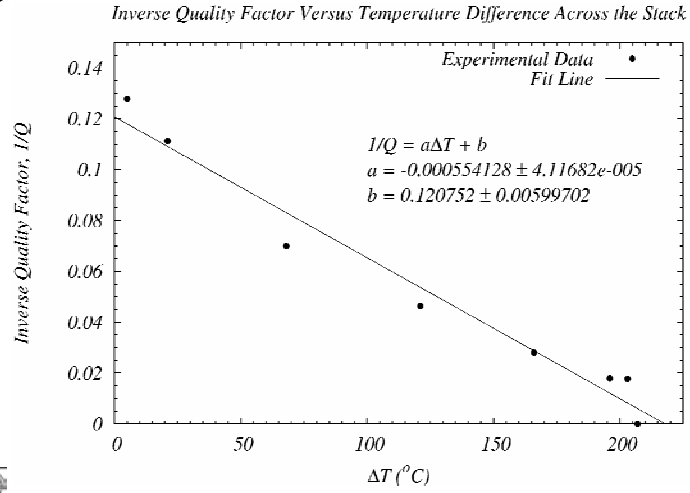






ΔT (°C)	Resonance Frequency	Quality Factor
5	91.0132 ± 0.0111785	7.82366 ± 0.0155508
21	92.2596 ± 0.0161504	8.98896 ± 0.0273673
68	95.5556 ± 0.0104956	14.2907 ± 0.0361752
121	99.72 ± 0.00322041	21.5922 ± 0.0218019
166	104.856 ± 0.00344855	35.6377 ± 0.0554797
196	108.316 ± 0.00330435	52.7626 ± 0.107727
203	109.041 ± 0.00375164	56.3187 ± 0.137585

$$Q = \frac{\omega_0 m}{R}$$



Future Investigation

- Theoretical modeling of the 1/Q vs. ΔT data

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