A Gasdynamic/Acoustic Model of a Bird Scare Gun

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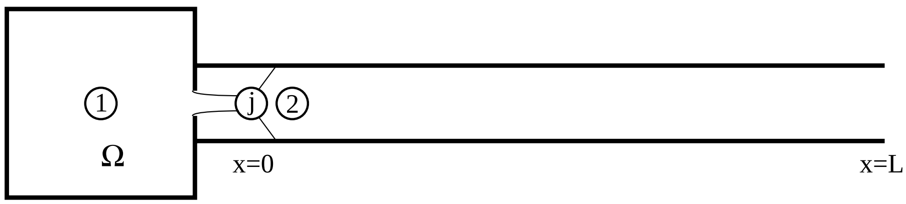
The Problem

A bird scare gun is a relatively simple device, producing impulsive noise by gas explosion. It is used for scaring birds away from areas where their presence is unwanted, like orchards, airfields, or oil-fields. It consists of a pot connected via an iris to an open pipe. In the pot (1) a mixture of butane or propane gas



and air is ignited. From the pressure difference between (2) and (1) a hot jet (j) is formed from the iris into the pipe, which initiates a pressure wave in the pipe ($x = 0$). The wave steepens up and reflects at the open end ($x = L$), where an almost spherical sound pulse is generated that radiates away to the far field. To investigate the effect of various problem parameters on the resulting noise level (Sound Pressure Level, SPL) we analysed the following model.

The Model

We modelled the increase of thermal energy in the pot (the explosion) by an increase of entropy

$$\beta(t) = \frac{p_1}{\rho_1^\gamma}, \qquad \text{with a suitably chosen function } \beta(t).$$

For small enough iris any flow *in* the pot is negligible. From the pot to the jet we have continuity of mass, Bernoulli's law for compressible isentropic flow, and isentropy (with a constant γ)

$$\Omega \frac{\mathrm{d}}{\mathrm{d}t}\rho_1 = -\rho_j v_j S_j, \qquad \frac{\gamma}{\gamma-1}\frac{p_1}{\rho_1} = \tfrac{1}{2}v_j^2 + \frac{\gamma}{\gamma-1}\frac{p_j}{\rho_j}, \qquad \frac{p_1}{\rho_1^\gamma} = \frac{p_j}{\rho_j^\gamma}.$$

Further downstream the jet becomes turbulent and widens from a cross section S_j to the size of the pipe S_2. This transition is described by crosswise averaged conservation of mass, momentum, and energy

$$S_j\rho_j v_j = S_2\rho_2 v_2, \quad S_2 p_j + S_j\rho_j v_j^2 = S_2 p_2 + S_2\rho_2 v_2^2, \quad \tfrac{1}{2}v_j^2 + \frac{\gamma}{\gamma-1}\frac{p_j}{\rho_j} = \tfrac{1}{2}v_2^2 + \frac{\gamma}{\gamma-1}\frac{p_2}{\rho_2}.$$

The transition from the hot jet to the cold air of the pipe is quasi-stationary described by continuity of pressure and mass flux

$$p_2 = p_0, \qquad \rho_2 v_2 = \rho_0 v_0.$$

In the pipe we assume the generated pressure wave (and its reflections) of weakly non-linear type, such that the wave (with $p(L,t) = p_\infty$)

$$p = p_\infty + \rho_\infty c_\infty^2 \Big[f(t - \tfrac{x}{c_\infty}) - f(t + \tfrac{x-2L}{c_\infty}) \Big]$$

is corrected for the effect of steepening by the relation

$$x - x_0 = [c(t_0) + \tfrac{1}{2}(\gamma+1)v_0(t_0)](t - t_0),$$

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saying that the perturbation that starts at x_0 at time t_0 arrives at x at time t.
The radiated field is assumed to be due to a monopole, the varying mass flux at the pipe exit, and so

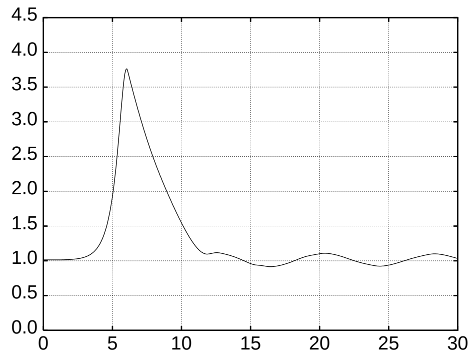
$$p(r,t) = \frac{\rho_\infty c_\infty S_2}{2\pi r} f'(t - L/c_\infty).$$

The noise level at distance r is defined by $SPL = 20 \log_{10} \Big[\Big\{ \frac{1}{T_{\rm ref}} \int_0^{T_{\rm ref}} p(r,t)^2 \, {\rm d}t \Big\}^{1/2} / 2 \cdot 10^{-5} \Big]$.

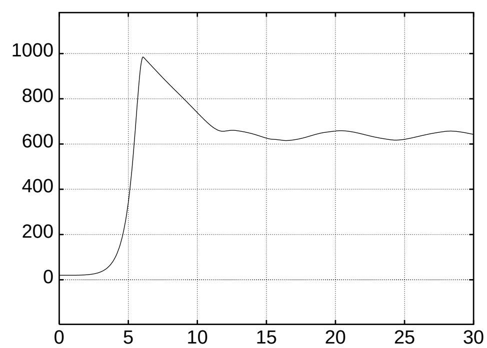
The Results

The pipe length is very important to the noise level, because steepening immediately increases f' and so the radiated pressure. In the same way the explosion time (inherent in $\beta(t)$) is important.

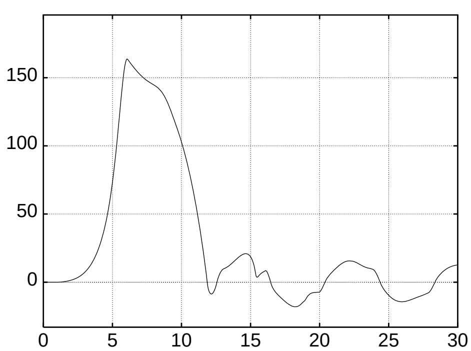
The present model can be solved up to the determination of the zero of an algebraic function, which can further be processed numerically. For typical values of the parameters ($\beta(\infty)$=4.5, explosion time 2.44 ms, Ω=2092 cm^3, L=60 cm, S_j=9.5 cm^2, S_2=63.6 cm^2, p_∞=1 bar, ρ_∞=1.2 kg/m^3, T_∞=20°C, γ=1.4, r=1 m) a noise level SPL = 114.2 dB is found, with the following time histories (in milliseconds):



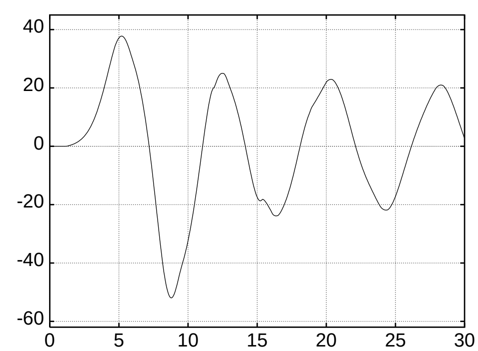
pressure in pot (bar)



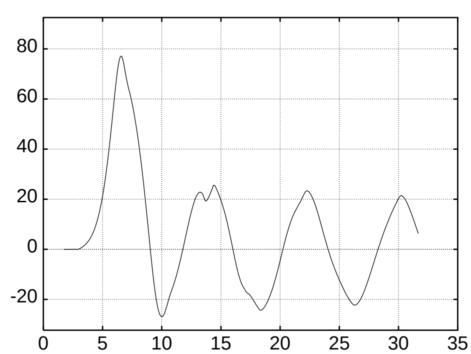
temperature in pot (°C)



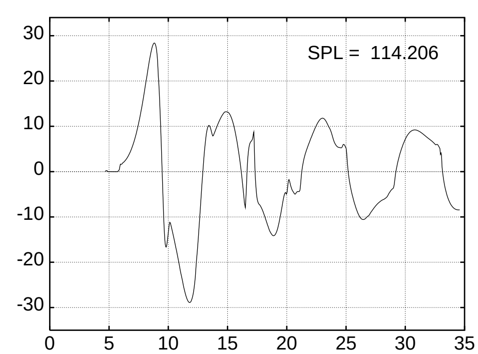
hot velocity v_2 (m/s)



cold velocity v_0 (m/s)



velocity at pipe exit (m/s)



radiated pressure (Pa)