Inviscid fluid flow in a compressible liquid or gas occurs whenever the magnitude of ***inertial*** forces $\vec{F}_{inertial}(\vec{r},t)$ acting on an infinitesimal volume element V of the fluid centered on the point $\vec{r}$ in the fluid are ***large*** in comparison to the ***dissipative*** forces $\vec{F}_{viscous}(\vec{r},t)$ acting on that fluid, *e.g.* a fluid with high Reynolds number: $R_e = \left|\vec{F}_{inertial}(\vec{r},t)\right| / \left|\vec{F}_{viscous}(\vec{r},t)\right| \gg 1$. "Free" air, well away from any bounding/confining ***surfaces*** is one such example of an inviscid fluid.

In analogy with electric charge conservation, the ***mass continuity equation*** for fluid flow describes ***conservation*** of ***mass*** at every space-time point $(\vec{r},t)$ within the volume V of the fluid:

$$\boxed{\frac{\partial\tilde{\rho}(\vec{r},t)}{\partial t} + \vec{\nabla}\bullet\left(\tilde{\rho}(\vec{r},t)\vec{\tilde{u}}(\vec{r},t)\right) = 0} \quad \text{or:} \quad \boxed{\frac{\partial\tilde{\rho}(\vec{r},t)}{\partial t} + \vec{\nabla}\bullet\vec{\tilde{J}}_a(\vec{r},t) = 0}$$

where: $\vec{\tilde{J}}_a(\vec{r},t) \equiv \tilde{\rho}(\vec{r},t)\vec{\tilde{u}}(\vec{r},t)\ \left(kg/m^2\text{-}s\right)$ is the 3-D vector acoustic mass current density.

For "everyday" complex sound fields $\tilde{S}(\vec{r},t)$ in air (at NTP) that we are considering in this course (in the audio frequency range: $20\,Hz \le f \le 20\,KHz$), typical sound pressure levels are:

$$SPL(\vec{r},t) = L_p(\vec{r},t) = 20\log_{10}\left(\left|\tilde{p}(\vec{r},t)\right|/p_o\right) \ll 134\,dB.$$

The ***reference*** sound over-pressure amplitude is $p_o \equiv 2\times10^{-5}\,RMS\ Pascals\left(= RMS\ N/m^2\right)$ in {bone-dry} air at NTP, and we have shown in a previous P406POM lecture note that a sound over-pressure amplitude of $|\tilde{p}| = 1.0\ RMS\ Pascals$ corresponds to a sound pressure level of $SPL = L_p = 20\log_{10}\left(|\tilde{p}|/p_o\right) = 94\,dB \ll 134\,dB$ in {bone-dry} air at NTP. Note that a sound over-pressure amplitude of $|\tilde{p}| = 1.0\ RMS\ Pascals$ is $\ll$ than the ambient atmospheric pressure $P_{atm} = 1.013\times10^5\ Pascals$ at NTP, or: $|\tilde{p}|/P_{atm} \simeq 10^{-5}$. A sound over-pressure *amplitude* that is as large as the atmospheric pressure itself, $\left|\tilde{p}(\vec{r},t)\right| = P_{atm} = 1.013\times10^5\ RMS\ Pascals$ corresponds to an almost unimaginable sound pressure level of $SPL = L_p = 20\log_{10}\left(p_{atm}/p_o\right) = 194\,dB$! {Note that an over-pressure amplitude of $\left|\tilde{p}_{pain}(\vec{r},t)\right| = 20\ RMS\ Pascals$ corresponds to a sound pressure level of $SPL = L_p = 20\log_{10}\left(\left|\tilde{p}_{pain}\right|/p_o\right) = 120\,dB$, which is the threshold for pain... }

Non-linear effects in air become increasingly noticeable at over-pressure amplitudes greater than $\left|\tilde{p}_{nl}(\vec{r},t)\right| \simeq 100\ RMS\ Pascals \ll P_{atm} = 1.013\times10^5\ Pascals$, which corresponds to a sound pressure level of $SPL = L_p = 20\log_{10}\left(\left|\tilde{p}_{nl}\right|/p_o\right) \simeq 134\,dB$ (See graph below).

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