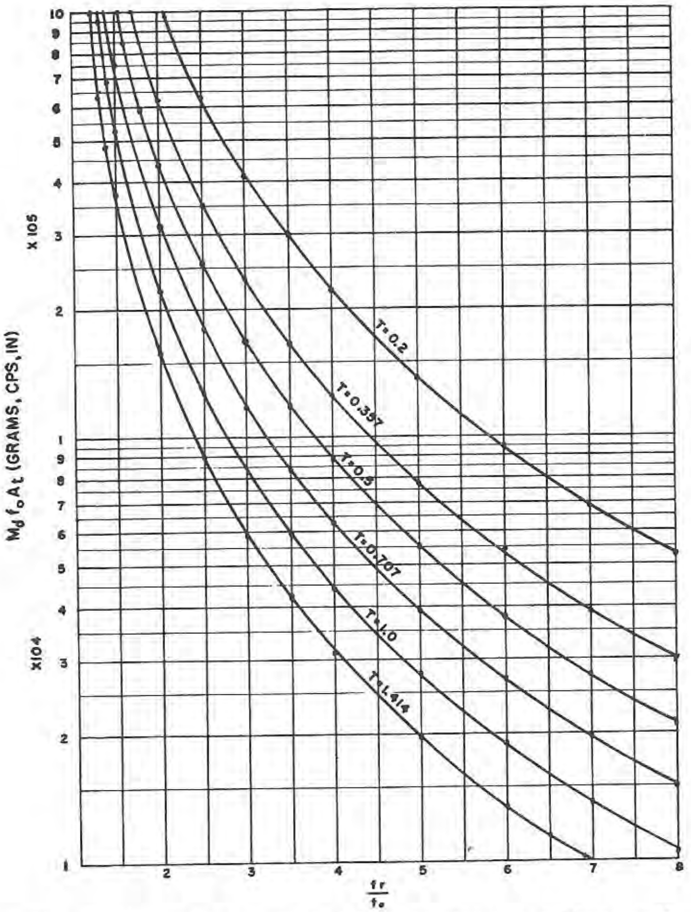

FIG. 6. Hyperbolic-exponential horn reactance annulling conditions.

This type of horn arrangement is capable of yielding the highest possible lf efficiency, since a conjugate match is possible between horn cutoff frequency and driver resonance. The disadvantage of this arrangement in lf corner horns is the rapid attenuation and response roughness that occur at frequencies above a few hundred cycles, necessitating a very low crossover frequency.

With enclosures that combine horn back-loading with front radiation maximum efficiency cannot generally be achieved, since the speakers used in this application have a relatively low resonant frequency which may be close to cutoff, making a conjugate match impossible. Improved efficiency may be achieved by designing around a woofer with a relatively high resonance or by treating the cone annulus with a stiffening lacquer to raise the resonance.

EFFICIENCY

A knowledge of the efficiency characteristics of a horn unit is important. If the driver constants and the nature of the terminating impedance are known, the efficiency may be calculated. The efficiency may also be determined by measurement of the driver impedance in its horn enclosure, in vacuum, and in its blocked state for every frequency where information is required.

The energy efficiency, sometimes referred to as the initial efficiency, is defined as the ratio of acoustic power output to electrical power input and is given by

$$\eta_e = \frac{(Bl)^2 R_h \times 10^{-9}}{R_c (R_m + R_h)^2 + (R_m + R_h)(Bl)^2 \times 10^{-9}}$$

The energy efficiencies for a properly designed horn unit may exceed values of 80%. Since the impedance of a unit is not constant, cognizance must be taken of its ability to draw power from a source. The energy efficiency multiplied by the loss due to impedance mismatch is the actual measure of horn performance. This type of efficiency is designated as the absolute efficiency and is the ratio of acoustical power output to the maximum power available from a matched source, given by the expression

$$\eta_a = \frac{\dfrac{4 R_g R_h (Bl)^2 \times 10^{-9}}{(R_m + R_h)^2 + (\omega M_d)^2}}{\left[R_g + R_c + \dfrac{(Bl)^2 \times 10^{-9} (R_m + R_h)}{(R_m + R_h)^2 + (\omega M_d)^2}\right]^2 + X_e^2}$$

where X_e includes the motional reactance and voice coil reactance. The efficiency as determined in this manner may be appreciably less than the energy efficiency. For a properly designed horn unit the reactive component is small compared to total mechanical resistance, and the losses above cutoff are negligible compared to total resistance. The expression may then be simplified to

$$\eta_a = \frac{4R_g (Bl)^2 \times 10^{-9}}{R_h \left[R_g + R_c + \dfrac{(Bl)^2 \times 10^{-9}}{R_h}\right]^2}$$

Differentiation of η with respect to $(Bl)^2/R_h$ yields the condition for maximum efficiency given by

$$\frac{(Bl)^2 \times 10^{-9}}{R_h} = R_g + R_c$$

Since R_h varies with frequency, the matching requirement is generally satisfied somewhat above cutoff where the load presented by the horn is close to the ultimate value. The required throat area is then given by

$$A_t = \frac{267 A_d^2 (R_g + R_c)}{(Bl)^2 \times 10^{-9}}$$

If this condition is satisfied, the efficiency is relatively independent of throat impedance variations, since an increase in resistance by four times or a reduction by the same factor results in a loss of less than 2 db.