

FIG. 2. Throat resistance characteristics for horns of various  $T$  values.

sented by an inductance shunted by a resistance. The impedance presented to a driver by a horn is

$$Z_h = 267 \frac{A_d^2}{A_t} \left[ \frac{\left(1 - \frac{1}{u^2}\right)^{1/2} + jT/u}{1 - \left(\frac{1-T^2}{u^2}\right)} \right]$$

It will be noted that as  $u$  approaches infinity the asymptotic resistance presented to the driver is independent of the value of  $T$  and approaches  $267(A_d^2/A_t)$  mechanical ohms and the reactive component  $T/u$  approaches zero. Near cutoff, where  $u$  has values near unity, the throat impedance is dependent on the parameter  $T$ . A normalized plot of throat resistance as a function of frequency with  $T$  as a parameter is shown in Fig. 2. If the driver unit is operated under constant-velocity conditions, these curves also indicate the relative acoustic output. By the choice of the parameter  $T$  practically any desired characteristic near cutoff may be obtained. Variation of mouth resistance can be partially compensated by the use of a hyperbolic-exponential horn having the appropriate throat resistance rise near cutoff.

Although resistance considerations will generally dictate the particular value of  $T$  to be used, the reactance characteristics may be an important factor in some cases. A plot of normalized reactance of a horn is given in Fig. 3. It is seen that small values of  $T$  result in a higher reactive component at cutoff, the reactance being  $1/T$  times the reactance of an exponential horn. The reactance, however, is seen to drop more rapidly above cutoff for smaller  $T$  values. For a horn having a  $T$  of zero there is no reactive component above cutoff.

The preceding discussion applied to the characteristics of

infinite horns. In practice a horn has a finite length and mouth area, so deviation from the characteristics of the infinite horn is to be expected. Since a horn is essentially a tapered acoustic transmission line, it must be properly terminated in order to avoid reflections which would cause large variations of the throat resistance above and below its asymptotic value, with consequent irregularities in radiated power. If a horn is expanded until its circumference is equal to or greater than a wavelength at the lowest frequency to be passed, the effects of reflections are minimized. This condition is satisfied when

$$D_m \geq \frac{4,300}{f}$$

An equivalent expression on an area basis yields

$$A_m \geq \frac{1.45 \times 10^7}{f^2}$$

These figures apply for operation in free space. When radiation occurs into smaller solid angles, the required area can be reduced. Figure 4 is a plot of required mouth size against frequency for various modes of operation. Curve A would be applicable to any units designed for operation in free space. Operation of 1f horns at the intersection of a wall and floor reduces the area requirement by a factor of 4, as shown in curve B. For corner operation the area can be reduced by a factor of 8 as compared to free space, and curve C applies. When the horn is operated under matched conditions, the area may be further reduced as the driver then becomes relatively insensitive to fairly large impedance variations.

At this point we will consider the behavior of a horn when coupled to a driver unit. Figure 5 represents the equivalent circuit of this system.

To obtain maximum power transfer between a driver and horn requires that the driver impedance be a conjugate of the impedance of the horn. If this condition is satisfied,

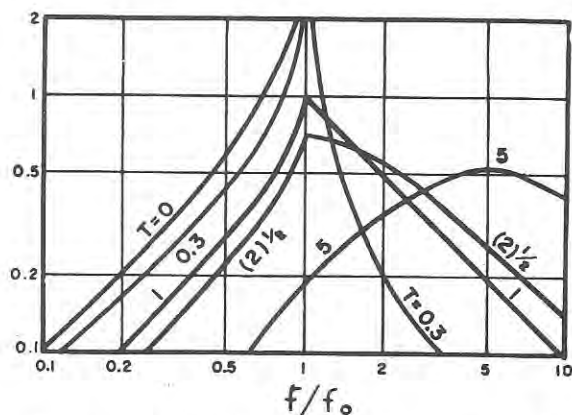


FIG. 3. Frequency dependence of throat reactance for horns of various  $T$  values.