ference was attributed to the ring airfoil-fuselage interference.

In the case of the lift, a semiempirical relation has been found which seems to account for the difference; the extra lift due to interference was assumed to be produced by a straight wing that is the horizontal projection of the inner half of the ring wings plus the connecting portion of the fuselage. This "auxiliary wing" is thus assumed to have an NACA 0015 airfoil with a span of 19 in. and a chord of 5 in. (aspect ratio of 3.8).

With this correction and the use of Eq. (1), the expression for C_L becomes

$$C_L = 0.102\alpha^0 + 0.576C_{L0015} \tag{3}$$

In the case of the drag coefficient, the experimental data can be curve-fitted by the following equation:

$$C_D = 0.03 + (C_L^2/25.2) \tag{4}$$

The second term in Eq. (4) corresponds to an airplane efficiency factor of 1.212 based on an aspect ratio (over-all wing span/chord) of 6.6. Equations (3) and (4) are based upon a reference area equal to the horizontal projected area of both wings plus the connecting portion of the fuselage.

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Thrust Performance of Suppressor Nozzles

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Nomenclature

c_v = velocity coefficient
c_{vs} = velocity coefficient of standard nozzle at critical pressure ratio
c_{vp} = maximum velocity coefficient of suppressor nozzle configuration
D = diameter of standard nozzle
D_e = diameter of equal area circle for suppressor configuration
D_h = hydraulic diameter = 4 area/perimeter
D_{he} = equivalent hydraulic diameter = D_h/D_e = $(4\pi\text{area})^{1/2}$/perimeter
θ = momentum boundary-layer thickness
ρ^* = local fluid density at nozzle throat
V^* = sonic velocity at nozzle throat
g = standard gravity
C_f = local skin-friction coefficient
St = Stanton number
Nu = Nusselt number
Re = Reynolds number based on hydraulic diameter
Pr = Prandtl number

THE suitability of a suppression device as a propulsion nozzle depends upon the level of the thrust performance required for the airplane mission. The thrust performance is presented as a semiempirical correlation of velocity coefficient with a function of the hydraulic diameter at the nozzle throat (Fig. 1). The suppressor applications considered are the reduction of soundpower level generated in the exhaust jet wake and the reduction of ground surface deterioration from VTOL lift jets.[1]

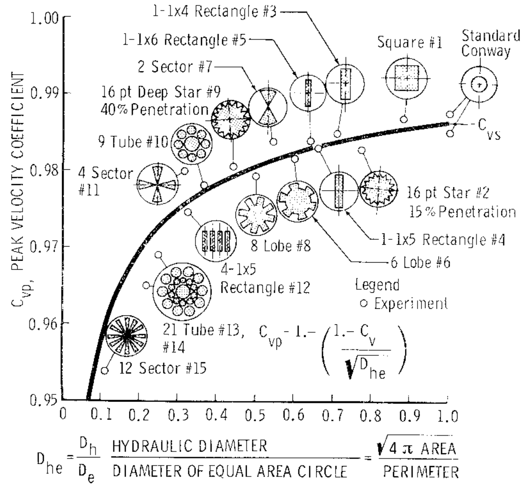

Fig. 1 Convergent nozzle performance maximum velocity coefficient for noise suppressor and jet mixing configurations.

The nozzle performance is shown in terms of the maximum value that the velocity coefficient can achieve for a convergent nozzle on a static test stand. The velocity coefficient is defined as the ratio of the measured thrust divided by the thrust of a fully expanded isentropic flow process at the measured nozzle pressure ratio and flow rate. The maximum value of the velocity coefficient occurs at a pressure ratio such that the convergent nozzle is choked but does not exhibit any underexpansion loss. Ideally, the condition occurs at the critical pressure ratio for sonic flow. The correlation was obtained by separating the measured thrust term into an ideal thrust and the aerodynamic drag at the critical pressure ratio.

Consider this aerodynamic drag as consisting of three parts: the internal flow losses caused by eddies in wakes of internal struts and irregular contours in the flow passage, a negative pressure drag on the external surface caused by unventilated base areas, and the skin-friction losses in the boundary layer.

In developing suppressor nozzles, an attempt is made to keep the internal losses to a minimum by providing smooth, continuous, streamlined contours. The pressure drag is kept to a minimum by eliminating blunt base areas and by providing smoothly converging exterior passageways for the induced secondary or ventilation air flow.

The peak velocity coefficient can be reduced to a simple equation if the convergent nozzle losses can be assumed to be represented in terms of a boundary-layer momentum thickness.

Velocity coefficient is calculated with the measured flow as

$$c_v = \frac{F_{\text{measured}}}{F_{\text{ideal}}} = \frac{F_{\text{ideal}} - \text{drag}}{F_{\text{ideal}}} = 1 - \frac{\text{drag}}{F_{\text{ideal}}} \tag{1}$$

Peak velocity coefficient for a standard round convergent nozzle[2] is

$$c_{vp} = 1 - \frac{\pi D\theta(\rho^* V^{*2}/g)}{(\pi D^2/4)(\rho^* V^{*2}/g)} = 1 - \frac{4\theta}{D} \tag{2}$$

The hydraulic diameter D_h is introduced to account for nozzles of different cross-sectional geometry. In order to compare all configurations on the basis of equal size, the hydraulic diameter is divided by the diameter D_e of a circular nozzle of equal area. This equivalent hydraulic diameter

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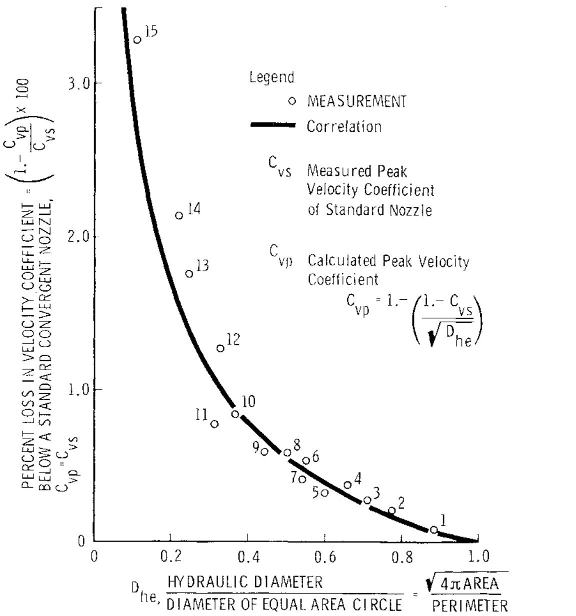

Fig. 2 Effect of hydraulic diameter on convergent nozzle performance.

D_{he} places the emphasis for comparison on the wetted perimeter for the same exit area. For nozzles of noncircular cross section, the internal surfaces are not all scrubbed at the free-stream velocity, and thus the momentum thickness varies over the perimeter. To account for this variation in skin friction and still use the standard round nozzle for a basis of comparison, dimensional analysis will be employed. Reynolds' analogy defines a relation between the skin-friction coefficient C_f and the Stanton number St[3]:

$$C_f/2 = St = Nu/RePr \tag{3}$$

where $Nu = Re^{1-n}Pr^m$.

Thus,

$$C_f/2 = Re^{-n}Pr^{m-1} \tag{4}$$

Since the boundary layer is to be evaluated at the nozzle throat for the same fluid flow conditions, then the skin friction varies only with the characteristic dimension term in the Reynolds number Re to some power n. The characteristic dimension used in this type of correlation is the hydraulic diameter D_h. Then the exponent n depends upon the turbulence level of the boundary layer. Here n varies from 0.5 for laminar flow to 0.2 for turbulent flow.

If the momentum thickness is assumed to be directly proportional to the local skin-friction coefficient at the nozzle exit, then

$$\theta \alpha C_f \alpha D_{he}^{-n} \tag{5}$$

The peak velocity coefficient of Eq. (2) is represented in terms of the maximum velocity coefficient $c_{vs} = 1$ and 4 with $1 = c_{vs}/(D_{he})^n$. Thus,

$$c_{vp} = 1 - [(1 - c_{vs})/(D_{he})^n] \tag{6}$$

The exponent n is found from the correlation to be 0.5.

As the nozzle perimeter is increased, the performance of nozzles with equivalent hydraulic diameters less than 0.3 (Fig. 1) falls below the correlation. This performance loss can be attributed to significant base pressure drag caused by an inability to ventilate this base region properly.

The data are presented in Fig. 2 as percent loss in velocity coefficient below the standard nozzle. This places the data in a comparative frame of reference and eliminates the universal problem of absolute magnitude of the standard nozzle performance. The accuracy of the data as presented in Fig. 2 is within 0.25%, which is the range of the data from the correlation to an equivalent hydraulic diameter of 0.3.

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Using Maintenance Float to Measure the Value of Maintainability and Reliability

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One of the problems associated with product design is to measure the value of increased reliability or maintainability; that is, how much more maintainability and reliability to work for, or, conversely, to determine the value of the levels achieved. This note describes an analytic method for doing this quickly and with reasonable accuracy, using the amount of equipment in the "maintenance float" as the criterion.

Maintenance Float as a Measuring Unit

A fleet of trucks, radios, or other devices must not only operate but keep on operating. To support it, some extra equipment is usually made available. Maintenance float is a kind of "revolving fund" of extra equipment. Equipment that fails is replaced by a unit from the float, and the old unit is repaired and returned to the float. It is this feature of replacement and concurrent repair which is unique to the float system. The amount of float required, F, is usually computed from the equipment population Q_0 and the float factor f as $F = Q_0 f$. For equipment that has an exponential failure distribution, f is shown[1] to be

$$f = 1 - [e^{-g}(Q_0 - 1)/Q_0] \tag{1}$$

where g is the ratio of mean time to repair (MTTR) to the mean time between failures (MTBF). This expression has been plotted in Fig. 1 for several representative populations. In army practice, f ranges from 0.03 to 0.35.

Equation (1) can be used to show how much improvements in maintainability and reliability reduce the maintenance

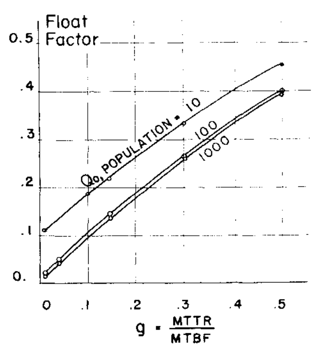

Fig. 1 Maintenance float.

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