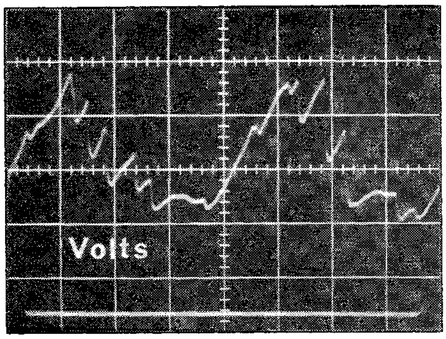

Fig. 4 Another mode of the unstable nitrogen operation; $\dot{m}$ = 0.128 lb/min, $\bar{V}$ = 64 v; sweep speed is 0.1 msec/cm

100 v and then falls very suddenly to the initial value; measurements of the decay time indicate values of the order of 1.0 μsec. This sudden drop in voltage is reflected as a peak in the arc current, seen in the upper trace of Fig. 3c. The lower trace of this figure shows the photodiode output, which indicates that a peak in the light intensity occurs in-phase with the current maxima, although the effects of diffusion appear to have broadened the intensity pulse. When operating with nitrogen, the test section becomes filled with a luminous gas, which probably accounts for the apparent shift of the intensity curve away from the zero.

It has been noticed that the nature of the voltage instability for nitrogen changes to that shown in Fig. 4 when the mass flow rate is reduced. Comparing Fig. 4 with Fig. 3a, it can be seen that the voltage follows a similar trend while increasing, but instead of falling suddenly from the peak value, it decreases in a series of steps. Despite the radical change in voltage characteristic, the frequency of the fluctuations remains almost unaltered.

It has been proposed that the arc instability results from a mechanism indicated in Fig. 5a. The arc initially strikes at position 1 and then moves down the anode through the subsequent positions. This movement results from both the downstream convection of the lower conductivity gas, initially at position 1, and the self-induced magnetic force caused by the curvature in the current path. For simplicity, any representation of the gas swirl has been omitted; however, the inherent stability of the vortex tends to localize the arc along the axis of the anode. When the arc reaches position 5, the voltage drop along it has increased to a value sufficiently high for breakdown to recur at position 1, so that the process is cyclic. Such a behavior is compatible with the voltage trace shown in Fig. 3a; however, it cannot explain the mode shown in Fig. 4. An explanation for this mode is that, before breakdown occurs, the arc column between C and B in Fig. 5a itself becomes unstable. This is possible because a radial perturbation of the column will produce an outward magnetic force, which under unfavorable conditions could overcome the inward aerodynamic force resulting from the gas swirl. This type of instability could lead to the column configuration shown in Fig. 5b. If the amplitude of the waves shown increases, the arc path will be shortened due to successive earlier contacts with the anode, and a voltage trace similar to that of Fig. 4 could be expected.

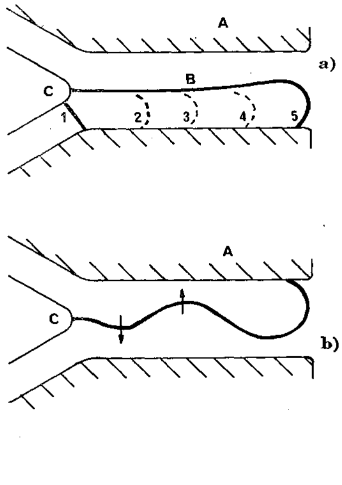

Fig. 5 Proposed arc column configurations

Conclusions

The results of these investigations show that for this type of arc generator it is possible to have a stable arc column configuration for argon. This is contrary to the inference of Ref. 1, in which the gas being used was not stipulated.

Stable operation has not yet been achieved when running with nitrogen, even though the mass flow, open circuit voltage, and electrode geometry were varied. The measurements of the light intensity, taken downstream of the nozzle, indicate that the settling chamber and nozzle did not smooth the fluctuations. Thus, the interpretation of results taken in such a facility must be made with caution, since time-averaged measurements for the unsteady flow are not necessarily the same as those that would be measured in an equivalent steady flow.

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Blast-Wave Correlation of Pressures on Blunt-Nosed Cylinders in Perfect- and Real-Gas Flows at Hypersonic Speeds

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It is shown that the blast-wave parameter that includes a function of the isentropic exponent γ offers the possibility of correlating blunt-nosed cylinder pressures obtained by theoretical solutions and experiment for both perfect and real gases. The result of the correlation is a single equation, in blast-wave form, which should approximate the pressures on blunted cylinders in both real and perfect gases for a wide range of nose drag and Mach number.

The blast-wave theory has been used in many investigations to correlate the surface pressures for blunted, stream-aligned cylinders. The parameter $(x/d)/M_\infty{}^2C_D{}^{1/2}$ has been used for both perfect and real gases (e.g., see Refs. 1 and 2). Pressures on cylinders with different nose-drag coefficients C_D and freestream Mach numbers M_∞ obtained by the method of characteristics are correlated in Ref. 1 for each of two perfect gases. The parameter worked very well for constant isentropic exponent γ but is inadequate for correlating pressures for various values of γ.

The generalized first-order blast-wave theory for axisymmetric flow[2,3] contains a parameter for the effects of the isen-

Received by ARS November 13, 1962.
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tropic exponent in addition to the effects of nose drag and Mach number. This parameter has not been exploited in the correlation of cylinder pressures. The correlating parameter is immediately evident from the following equation[2] for the ratio of surface pressure to freestream pressure:

$$p/p_\infty = f_1(\gamma)\ [M_\infty{}^2 C_D{}^{1/2}/(x/d)] \qquad (1)$$

where

$$f_1(\gamma) = \tfrac{1}{8}(\gamma/J_0)^{1/2} g_0{}^0$$

The blast-wave constants J_0 and $g_0{}^0$ are discussed in Refs. 2 and 3. Values of the γ function are shown in Table 1.

The perfect-gas characteristics solutions of Van Hise were correlated[1] by using the blast-wave parameter that does not include the effects of γ. The following equations resulted:

$$\frac{p}{p_\infty} = 0.060\,\frac{M_\infty{}^2 C_D{}^{1/2}}{x/d} + 0.55 \qquad (\gamma = 1.40) \quad (2)$$

$$\frac{p}{p_\infty} = 0.075\,\frac{M_\infty{}^2 C_D{}^{1/2}}{x/d} + 0.55 \qquad (\gamma = 1.67) \quad (3)$$

These equations reduce to the following single equation when the γ function is included:

$$\frac{p}{p_\infty} = 0.89\,\frac{M_\infty{}^2 C_D{}^{1/2} f_1(\gamma)}{x/d} + 0.55 \qquad (4)$$

The parameter with the γ function thus correlates the characteristics solutions for these two perfect-gas cases.

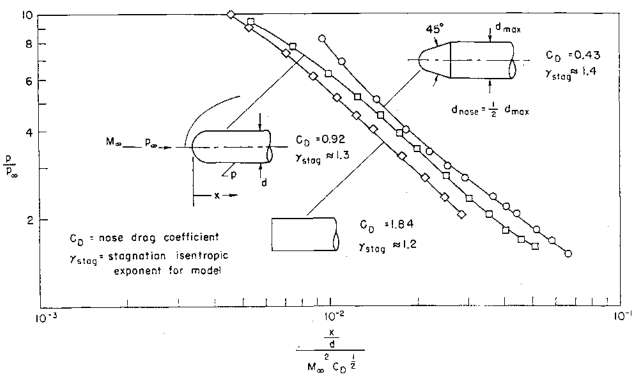

Fig. 1 Correlation using blast-wave parameter without γ function; experimental data from tests in air at M = 14.4

The application of the blast-wave parameter which includes the γ function to real-air flows presents a problem because of the variation of γ within the flow fields about blunt bodies. The question thus arises whether a single value of γ can be used to characterize a particular flow field. Bradford Wick of the NASA Ames Research Center has suggested that the value of γ in the stagnation region should be used, since the blast-wave analogy described the flow in terms of a blast that originates at the nose of a blunt body. This hypothesis can be checked with the author's unpublished experimental pressure distributions measured in air at a Mach number of 14.4 for three blunt cylinders. The total temperature, 3600°R, and the total pressure, 1000 psia, of the freestream would produce in the stagnation region of the model a value of γ of about 1.2 for equilibrium flow and 1.4 for frozen flow. Comparison of theoretical and experimental pressure distributions and shock standoff distances indicates that the former value of γ should apply for the flat-faced cylinder and the latter for the conical nose. For the hemispherical nose, an intermediate value of γ should apply. The data are shown in Fig. 1 as a function of the blast-wave parameter based on freestream Mach number and nose drag computed by modified Newtonian impact theory. The pressure distributions do not correlate. It should be emphasized that freestream conditions were identical for the three models. The variation in stagnation γ shown in Fig. 1 is the result of a variation in the extent of vibrational relaxation. The experimental pressure distributions correlated with the blast-wave parameter generalized to include the γ function are shown in Fig. 2, along with the curve representing the correlated characteristics solutions given by Eq. (4). The experimental data correlate very well; furthermore, the correlated experimental data are in very good agreement with the correlated characteristics solutions.

Table 1 γ function described by blast-wave theory

γ	$f_1(\gamma)$
1.15	0.046
1.2	0.052
1.3	0.061
1.4	0.067
1.67	0.084

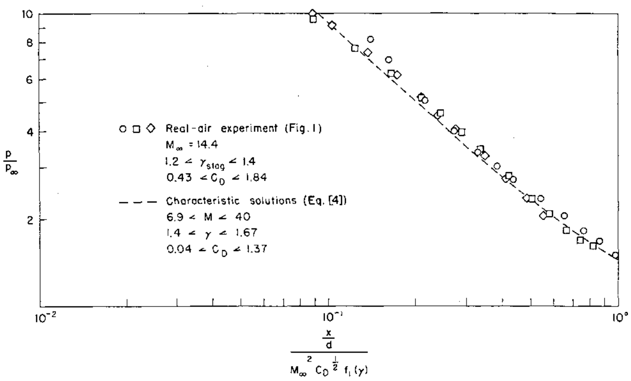

Fig. 2 Correlation using blast-wave parameter with γ function; experimental data from tests in air at M = 14.4

Although the foregoing correlation is by no means definitive, it does indicate the possibility of using a single correlation equation for surface pressures on blunted cylinders in perfect and real gases for a wide range of nose drag and Mach number. Further evaluation of this type of correlation is necessary, in particular, for real-gas flows for which stagnation values of γ are used. In this regard, it is interesting to note that for the present tests the local γ for equilibrium expansion around the nose of the flat-faced cylinder varies rapidly from about 1.2 to 1.35 because the total enthalpy was in the region where γ changes very rapidly with enthalpy. In contrast, γ changes much more slowly with enthalpy at the high total enthalpies associated with entry flight conditions. For such flight conditions, the choice of γ will, of course, be less questionable.

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