

INVISCID SUPERSONIC FLOW PAST CONES AT ZERO INCIDENCE: (ii) SURFACE PRESSURE COEFFICIENT AND SHOCK ANGLE FOR CIRCULAR CONES

1. NOTATION AND UNITS (see sketch on Figure 1)

		SI	British
C_{pc}	cone surface pressure coefficient, $\left(\frac{p_c}{p_1} - 1\right) / \left(\frac{1}{2}\gamma M_1^2\right)$		
M_c	Mach number at surface of cone		
M_1	Mach number in uniform flow upstream		
p_c	static pressure on surface of cone	N/m ²	lbf/ft ²
p_1	static pressure in uniform flow upstream	N/m ²	lbf/ft ²
γ	ratio of specific heat capacity at constant pressure to specific heat capacity at constant volume, taken as 1.4 for air		
δ	semi-vertex angle	deg	deg
ζ	shock angle	deg	deg

2. NOTES

When a supersonic air stream encounters a sharp-pointed conical obstruction which causes the stream to be deflected, as shown in the sketch on Figure 1, a shock wave is formed. If the Mach number in the uniform flow upstream is less than a certain critical value, particular to the cone angle, the flow is not wholly supersonic; this Item applies only when the flow is wholly supersonic (*i.e.* $M_c > 1$), the shock wave then being conical in form. Through this shock wave there is a rapid compression and decrease in speed of the air.

Figure 1 presents the surface pressure coefficient, C_{pc} , and shock angle*, ζ , for a sharp-nosed right-circular cone at zero incidence in a uniform supersonic flow of air considered as a perfect gas ($\gamma = 1.4$). The data are given in terms of the Mach number in the uniform flow upstream, M_1 , and the cone semi-vertex angle, δ . The flow is assumed to be inviscid throughout.

The data were derived from calculations made by Professor C.W. Jones of Imperial College for use in Derivation 2. These calculations were made in order to adjust the data given in Derivation 1 from $\gamma = 1.405$ to $\gamma = 1.4$.

Item No. Aero S.00.03.10 gives similar information for the flow past two-dimensional wedges. An essential difference between wholly supersonic flow past a wedge and a cone is that in the former case all streamlines after the shock wave are parallel to the surface and the flow there is uniform. In the case of a cone, due to

* See also Item No. 70008.

the different requirements for continuity, the streamlines after the shock wave are not parallel to the surface and consequently there is a variation in Mach number along a normal to the surface. Details of the flow in this region are given in Item Nos 70009 and 70010. It may be noted, however, that the flow conditions are constant along any line lying between the shock and the cone surface and passing through the cone vertex. Such a flow is usually referred to as being conical.

At some value of M_c less than unity, the shock wave will become detached from the nose of the cone. For conditions under which this will occur see Item Nos Aero S.00.03.16, 70008, 70009 and 70010.

In real flows viscosity causes a boundary layer on the cone surface which increases the effective vertex angle of the cone. Allowance for this effect, which is generally insignificant for Reynolds numbers greater than about 10^5 , may be made using the method of Reference 6.

The data presented in this Item are for cones at zero incidence in airflows with Mach numbers up to 4. For the effects of incidence, and Mach numbers up to 20, detailed tabulations are given in References 4, 5 and 7 while Reference 3 contains some useful graphical correlations.

3. DERIVATION AND REFERENCES

3.1 Derivation

1. KOPAL, Z. Tables of supersonic flow around cones. Massachusetts Institute of Technology, tech. Rep. 1, 1947.
2. ROSENHEAD, L. *A selection of graphs for use in calculations of compressible airflow*. Clarendon Press, 1954.

3.2 References

3. BERTRAM, M.H. Correlation graphs for supersonic flow around right circular cones at zero yaw in air as a perfect gas. NASA tech. Note D-2339, 1964.
4. SIMS, J.L. Tables for supersonic flow around right circular cones at zero angle of attack. NASA spec. Publ. 3004, 1964.
5. SIMS, J.L. Tables for supersonic flow around right circular cones at small angle of attack. NASA spec. Publ. 3007, 1964.
6. PETER, R.A.
HIGH, M.D.
BLICK, E.F. Viscous flow properties on slender cones. *AIAA J.*, Vol. 3, No. 3, p. 572, March 1965.
7. JONES, D.J. Tables of inviscid supersonic flow about circular cones at incidence, $\gamma = 1.4$. AGARDograph 137, Parts I and II, 1969.