research report

WYLE LABORATORIES
TESTING DIVISION, HUNTSVILLE FACILITY

WYLE LABORATORIES - RESEARCH STAFF

TECHNICAL MEMORANDUM 69-1

DIGITAL COMPUTATION OF DOWNSTREAM MODES GENERATED BY THE INTERACTION OF A SHOCK WAVE WITH AN UPSTREAM FLOW CONTAINING THE THREE DISTURBANCE MODES (VORTICITY, ENTROPY AND SOUND)

By

D. M. Lister

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WYLE LABORATORIES
RESEARCH DIVISION, HUNTSVILLE FACILITY

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SUMMARY

A Fortran computer program has been written for the CDC 3300 which computes the values of the modes of the perturbed downstream flow field resulting from the interaction of an infinite, plane shock wave with an upstream flow containing perturbations in all three modes: vorticity, entropy and sound.

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1.0 INTRODUCTION

A Fortran computer program has been written for the CDC 3300 which computes the values of the modes of the perturbed downstream flow field resulting from the interaction of a field of turbulence and sound waves with an infinite shock plane. Various other quantities associated with the flow are computed and output. This program supersedes the one reported in Reference 1, which was able to accommodate only one of the possible upstream modes -- the entropy mode -- as an input disturbance, and only for specified values of δ, the inclination angle of the incoming disturbance wavefront. In the present program, the effects of the upstream entropy, pressure and vorticity modes on the downstream entropy, pressure and vorticity modes are computed, and the downstream intensities and levels are obtained for a random field of upstream perturbations, by numerically integrating over all wavefront inclination angles. The output is designed to exhibit not only the resulting downstream intensities of vorticity and entropy, plus the overall sound pressure level, but also to show the proportion that is due to each of the upstream modes, and to show the portion of the generated near field pressure flucutation level that will be radiated to the far field as sound. The theoretical model, and justification of the mathematical expressions used, are given in Reference 2. Schematic representation of the basic flow coordinate system and the interaction process are given in Figures 1 and 2, respectively.

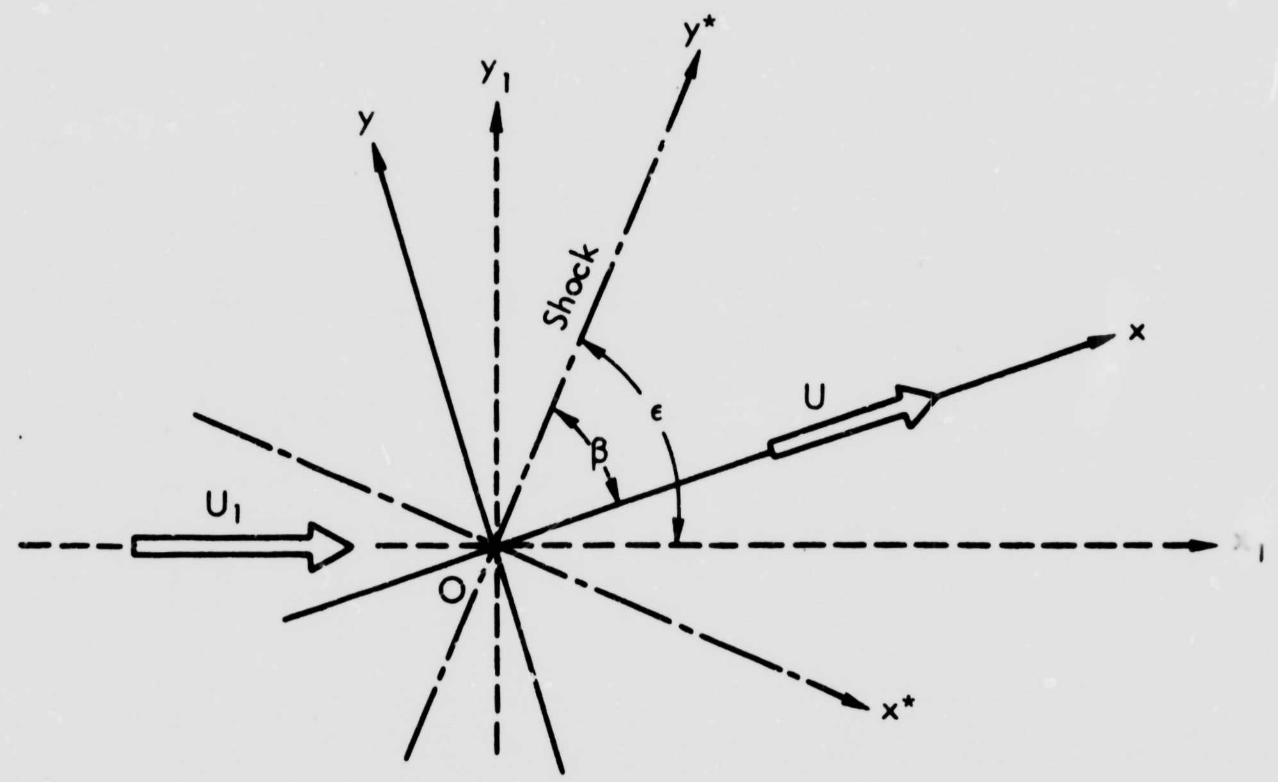


Figure 1. Basic Flow Coordinate Systems

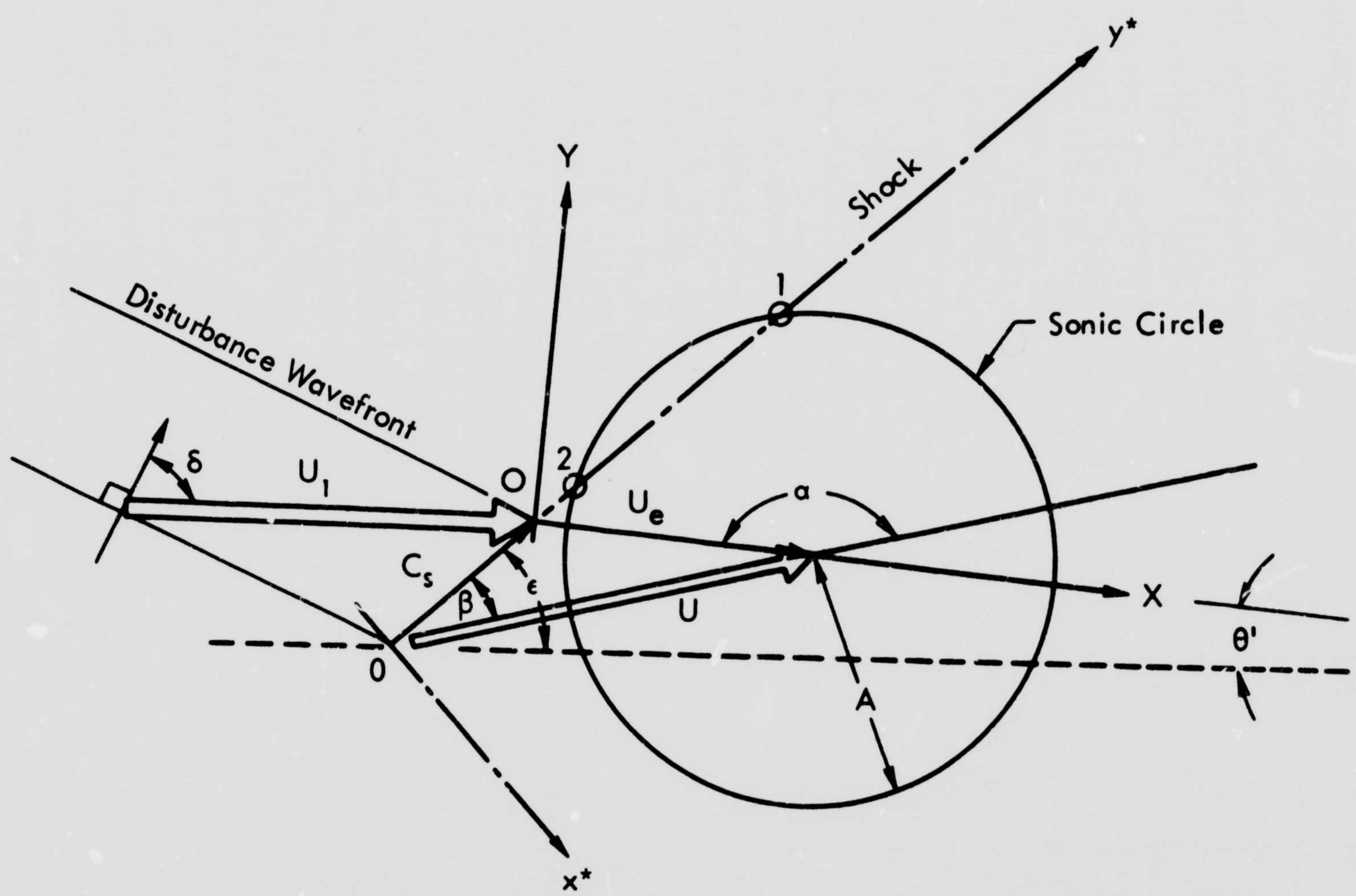


Figure 2. Intrinsic Frame of Reference with Respect to Downstream Flow Field

2.0 LIST OF SYMBOLS

These are best exhibited in tabular form: -

TABLE OF SYMBOLS, THEIR COMPUTER CODE EQUIVALENTS, AND DEFINITIONS

Symbol	Computer Code		Definition
ϵ	EPI EPIR	(degrees) (radians)	Shock wave angle, referenced to the x_1 - axis.
β	BETA BETAR	(degrees) (radians)	Angle between the shock wave and the downstream flow velocity vector.
δ	DELTA DELTAR	(degrees) (radians)	Inclination of upstream disturbance wave with respect to mean flow direction.
	DB DBR	(degrees) (radians)	The initial values of δ; i.e., the lower limit of integration.
	DS DSR	(degrees) (radians)	The step length of δ for the numerical integration.
	DE DER	(degrees) (radians)	The final value of δ; i.e., the upper limit of integration.
α	ALPHA ALPHAR	(degrees) (radians)	Inclination of U_e with respect to the downstream mean flow direction U (exterior angle).
μ_e	EMEWE EMEWER	(degrees) (radians)	Effective Mach angle corresponding to M_e
γ	GAMMA		Ratio of specific heats.
M_1	EM1		Upstream flow Mach number.
M	EM		Downstream flow Mach number.
N_1	EN1		Upstream Mach number corresponding to a normal shock of equivalent strength.
N	EN		Downstream Mach number corresponding to a normal shock of equivalent strength.
M_e	EME		Effective Mach number corresponding to U_e.
A_1	A1		Speed of sound in the flow field upstream of the shock.

Symbol	Computer Code	Definition
A	A	Speed of sound in the flow field downstream of the shock.
$A/A1$	ARAT	Ratio of acoustic velocities across the shock, downstream to upstream.
U_1	U1	Mean flow velocity upstream of the shock.
U	U	Mean flow velocity downstream of the shock.
U_e	UE	Apparent mean flow velocity downstream of the shock with respect to an observer moving with C_s.
u^*_-	USM	Dimensionless magnitude of the upstream velocity perturbation along the x*-axis.
v^*_-	VSM	Dimensionless magnitude of the upstream velocity perturbation along the y*-axis.
u_1	UL1	Dimensionless magnitude of the downstream velocity perturbation along the x_1-axis.
v_1	VL1	Dimensionless magnitude of the downstream velocity perturbation along the y_1-axis.
VORT	VORT	$\sqrt{(UL1^2 + VL1^2)}$
u^*_+	USP	Dimensionless magnitude of the downstream velocity perturbation along the x*-axis.
v^*_+	VSP	Dimensionless magnitude of the downstream velocity perturbation along the y*-axis.
U_+	UP	Dimensionless magnitude of the downstream velocity perturbation component along downstream mean flow velocity vector.
V_+	VP	Dimensionless magnitude of the downstream velocity perturbation component normal to downstream mean flow velocity vector.
I_{U1}	EYEU1	The upstream turbulence intensity along the x_1-axis.
I_{V1}	EYEV1	The upstream turbulence intensity, normal to the x_1-axis.

Symbol	Computer Code	Definition
I_u	TIU	The downstream turbulence intensity along the x_1-axis.
I_v	TIV	The downstream turbulence intensity normal to the x_1-axis.
C_s	CS	Drift speed of the upstream disturbance wave along the shock.
C_{s1}	CS1	Intersection of shock plane and sonic circle lying farthest from the origin.
C_{s2}	CS2	Intersection of shock plane and sonic circle lying nearest the origin.
χ	CHI	Shock strength in terms of the ratio of pressure of the unperturbed flow across the shock
p_-	PM	Dimensionless magnitude of upstream pressure perturbation.
$p]_{x^*=0}$	PCS	Dimensionless pressure perturbation immediately behind the shock.
p_+	PP	Dimensionless magnitude of the downstream generated pressure perturbation.
pm	PM1	The ambient static upstream pressure.
SPL_1	SPL1	The overall upstream sound pressure level.
SPL	TSPL	The overall downstream sound pressure level.
q	Q	A dimenionless parameter related to the downstream pressure perturbation, one member of the pair making up the Riemann invariants.
ρ_n/ρ_{1m}	RORAT	Density ratio across the shock, downstream to upstream.
I_{T1}	EYET1	The upstream entropy fluctuation intensity; i.e., the r.m.s. fluctuation in static temperature, referenced to the local total temperature.
S_-	SM	The dimensionless magnitude of the upstream entropy perturbation.
S_+	SP	The dimensionless magnitude of the downstream entropy perturbation.
I_T	TIT	The downstream entropy fluctuation intensity.

Symbol	Computer Code	Definition
π_{ij}	PIE(I)	Transfer coefficients for the interaction.
λ_{ij}	ALAM(I,J)	Transfer coefficient for the interaction.
D C	D C }	Convenient groupings of parameters in the solution for the equivalent source function $g(y^*)$; see Reference 2.
$g(y^*)$	GYS	A function related to the strength of an equivalent source located on the shock plane. See Reference 2, Case $M_e < 1$.
$P(x^* = 0)$	PCS	Dimensionless pressure perturbation immediately behind the shock, for the case $M_e > 1$.

3.0 LIST OF EQUATIONS

The following equations were used in the model to express the downstream modal values in terms of the upstream modal values. Many of the equations are the same as those used in Reference 1. The principal equation which is the basis of the model is Equation 3.38. Most of the remainder of the equations were used to supply values of the parameters used in Equation 3.38.

3.1 $$N_1 = M_1 \sin \epsilon$$

3.2 $$M = \left[\frac{N_1^2 + 5}{(7 N_1^2 - 1) \sin^2 \beta} \right]^{1/2}$$

3.3 $$N = M \sin \beta$$

3.4 $$X = \left(\frac{P_m}{P_{1m}} \right) = \frac{7 N_1^2 - 1}{6}$$

3.5 $$\left(\frac{\rho_m}{\rho_{1m}} \right) = \frac{6X + 1}{X + 6}$$

3.6 $$\begin{cases} \Lambda_{11} = \left(\frac{\rho_m}{\rho_{1m}} \right)^2 \left(\frac{N}{N_1} \right)^2 - (\gamma - 1) \left(1 - \frac{\rho_m}{\rho_{1m}} \right) N^2 \\ \Lambda_{21} = \frac{N^2}{1 - N^2} \left\{ \left(1 - \frac{\rho_m}{\rho_{1m}} \right) \left[1 + (\gamma - 1) N^2 \right] + \left[1 - \left(\frac{\rho_m}{\rho_{1m}} \right)^2 \left(\frac{N}{N_1} \right)^2 \right] \right\} \\ \Lambda_{31} = \frac{-N}{1 - N^2} \left\{ \left[1 - \left(\frac{\rho_m}{\rho_{1m}} \right)^2 \left(\frac{N}{N_1} \right)^2 \right] + \left(1 - \frac{\rho_m}{\rho_{1m}} \right) \gamma N^2 \right\} \\ \Lambda_{12} = (\gamma - 1) \left(1 - \frac{\rho_m}{\rho_{1m}} \right) \left(1 - \frac{1}{N_1^2} \frac{\rho_m}{\rho_{1m}} \right) N^2 \end{cases}$$

$$\Lambda_{22} = \frac{-N^2}{1-N^2}\left\{\left(1-\frac{\rho_m}{\rho_{1m}}\right)+\left(1-\frac{1}{N_1^2}\,\frac{\rho_m}{\rho_{1m}}\right)\left[1+(\gamma-1)\left(1-\frac{\rho_m}{\rho_{1m}}\right)N^2\right]\right\}$$

$$\Lambda_{32} = \frac{N}{1-N^2}\left\{\left[1-\left(\frac{\rho_m}{\rho_{1m}}\right)^2\left(\frac{N}{N_1}\right)^2\right]+\gamma\left(1-\frac{\rho_m}{\rho_{1m}}\right)\left(1-\frac{1}{N_1^2}\,\frac{\rho_m}{\rho_{1m}}\right)N^2\right\}$$

$$\Lambda_{13} = (\gamma-1)\left(1-\frac{\rho_m}{\rho_{1m}}\right)^2\frac{N^2}{N_1}$$

$$\Lambda_{23} = \frac{-N}{1-N^2}\left(1-\frac{\rho_m}{\rho_{1m}}\right)\left\{2+(\gamma-1)\left(1-\frac{\rho_m}{\rho_{1m}}\right)N^2\right\}\frac{N}{N_1}$$

$$\Lambda_{33} = \frac{1}{1-N^2}\,\frac{N}{N_1}\left\{1-\left(\frac{\rho_m}{\rho_{1m}}\,N\right)^2+\gamma\left(1-\frac{\rho_m}{\rho_{1m}}\right)^2N^2\right\}$$

$$\Lambda_{44} = \left(\frac{\rho_m}{\rho_{1m}}\right)\frac{N}{N_1}$$

3.7

$$\Pi_{11} = -(\gamma-1)\left(1-\frac{\rho_{1m}}{\rho_m}\right)^2\left(\frac{\rho_m}{\rho_{1m}}\right)N$$

$$\Pi_{21} = \frac{-N}{1-N^2}\left(1-\frac{\rho_{1m}}{\rho_m}\right)\left[2+(\gamma-1)\left(1-\frac{\rho_m}{\rho_{1m}}\right)N^2\right]$$

$$\Pi_{31} = \frac{1}{1-N^2}\left(1-\frac{\rho_{1m}}{\rho_m}\right)\left[1+N^2+(\gamma-1)\left(1-\frac{\rho_m}{\rho_{1m}}\right)N^2\right]$$

$$\Pi_{41} = \left(\frac{\rho_m}{\rho_{1m}}-1\right)N$$

3.8 $$\left(\frac{A}{A_1}\right) = \left[\frac{(7N_1^2 - 1)(N_1^2 + 5)}{36 N_1^2}\right]^{1/2}$$

3.9 $$A = \left(\frac{A}{A_1}\right) \cdot A_1$$

3.10 $$U_1 = M_1 A_1$$

3.11 $$U = MA$$

3.12 $$S_- = I_{t1} \left(1 + \frac{(\gamma - 1)}{2} M_1^2\right)$$

3.13 $$P_- = \frac{1.45 \times 10^{-5}}{\gamma p_{m1}} \text{ antilog} \left[\frac{SPL_1 - 74}{20}\right]$$

3.14 $$u_- = I_{u1} M_1$$

3.15 $$v_- = I_{v1} M_1$$

3.16 $$u_-^* = u_- \sin\epsilon - v_- \cos\epsilon$$

3.17 $$v_-^* = u_- \cos\epsilon + v_- \sin\epsilon$$

3.18 $$C_s = \frac{\cos\delta}{\cos(\delta - \epsilon)} \cdot U_1$$

3.19 $$\alpha = \arctan\left[\frac{C_s \sin\beta}{C_s \cos\beta - U}\right]$$

3.20 $$U_e = \frac{U \sin\beta}{\sin(\alpha-\beta)}$$

3.21 $$M_e = \frac{U_e}{A}$$

3.22 $$\mu_e = \arc\sin\left(\frac{1}{M_e}\right)$$

3.23 $$C_{s1} = \sqrt{\left[U^2 + A^2 - 2U\left[U\sin^2\beta - \cos\beta\sqrt{A^2 - U^2\sin^2\beta}\right]\right]}$$

3.24 $$C_{s2} = C_{s1} - 2\sqrt{A^2 - U^2\sin^2\beta}$$

3.25 $$D = \frac{M_e K_1}{2\sqrt{1 - M_e^2}}$$

3.26 $$C = K_2 s_- + K_3 p_- + K_4 u_-^* + K_5 v_-^*$$

3.27 $$K_1 = \frac{-\left[\Pi_{31}(M\cos\beta - C_s/A)\cos(\alpha-\beta) - \Pi_{41}\sin(\alpha-\beta)\right]}{\Pi_{21}\left(M\cos\beta - \frac{C_s}{A}\right)}$$

3.28 $$K_2 = -\Lambda_{31}\cos(\alpha-\beta) + \Lambda_{21} K_1$$

3.29 $$K_3 = -\Lambda_{32}\cos(\alpha-\beta) + \Lambda_{22} K_1$$

3.30 $$K_4 = -\Lambda_{33}\cos(\alpha-\beta) + \Lambda_{23} K_1$$

3.31 $$K_5 = -\Lambda_{44}\sin(\alpha-\beta)$$

3.32 $$g(Y^*) = \frac{D \cdot C}{1 + D^2}$$

3.33 $$p\Big]_{x^*=0} = \frac{0.5\, M_e}{\sqrt{1 - M_e^2}}\, g(Y^*)$$

3.34 $$q = \left\{ - \left[(\Lambda_{31} s_- + \Lambda_{32} p_- + \Lambda_{33} u_-^*) \cos(\alpha-\beta) + \Lambda_{44} v_-^* \sin(\alpha-\beta) \right] \middle/ \left[1 - \frac{\left[\Pi_{31} (M\cos\beta - C_s/A) \cos(\alpha-\beta) - \Pi_{41} \sin(\alpha-\beta) \right]}{\Pi_{21} (M\cos\beta - C_s/A) \cos\mu_e} \right] \right\} -$$

$$- \left\{ \left[(\Lambda_{21} s_- + \Lambda_{22} p_- + \Lambda_{23} u_-^*) \cos\mu_e \right] \times \right.$$

$$\times \frac{\left[\Pi_{31} (M\cos\beta - C_s/A) \cos(\alpha-\beta) - \Pi_{41} \sin(\alpha-\beta) \right]}{\left[\Pi_{21} (M\cos\beta - C_s/A) \cos\mu_e \right]} \Bigg/$$

$$\left. \Bigg/ \left[1 - \frac{\left[\Pi_{31} (M\cos\beta - C_s/A) \cos(\alpha-\beta) - \Pi_{41} \sin(\alpha-\beta) \right]}{\Pi_{21} (M\cos\beta - C_s/A) \cos\mu_e} \right] \right\}$$

Note that the above equation is used for $M_e > 1$ and $C_s \leq C_{s2}$.

3.35
$$q = \left\{ \left[(\Lambda_{31} s_- + \Lambda_{32} p_- + \Lambda_{33} u_-^*) \cos(\alpha-\beta) + \Lambda_{44} v_-^* \sin(\alpha-\beta) \right] \Big/ \right.$$

$$\left. \Big/ \left[1 + \frac{\left[\Pi_{31} (M\cos\beta - C_s/A)\cos(\alpha-\beta) - \Pi_{41}\sin(\alpha-\beta)\right]}{\Pi_{21} (M\cos\beta - C_s/A)\cos\mu_e} \right] \right\} +$$

$$+ \left\{ \left[(\Lambda_{21} s_- + \Lambda_{22} p_- + \Lambda_{23} u_-^*) \cos\mu_e \right] \times \right.$$

$$\times \frac{\left[\Pi_{31} (M\cos\beta - C_s/A)\cos(\alpha-\beta) - \Pi_{41}\sin(\alpha-\beta)\right]}{\left[\Pi_{21} (M\cos\beta - C_s/A)\cos\mu_e\right]} \Big/$$

$$\left. \Big/ \left[1 + \frac{\left[\Pi_{31} (M\cos\beta - C_s/A)\cos(\alpha-\beta) - \Pi_{41}\sin(\alpha-\beta)\right]}{\left[\Pi_{21} (M\cos\beta - C_s/A)\cos\mu_e\right]} \right] \right\}$$

Note that the above equation is used for $M_e > 1$ and $C_s \geq C_{s1}$.

3.36
$$\psi_y = - \left[\frac{q + (\Lambda_{21} s_- + \Lambda_{22} p_- + \Lambda_{23} u_-^*) \cos\mu_e}{\Pi_{21} (M\cos\beta - C_s/A)\cos\mu_e \sin(\alpha-\beta)} \right]$$

Note that the above equation is used for $M_e > 1$.

3.37
$$\psi_y = \frac{p\big]_{x=0} - (\Lambda_{21} s_- + \Lambda_{22} p_- + \Lambda_{23} u_-^*)}{\Pi_{21} (M\cos\beta - C_s/A)\sin(\alpha-\beta)}$$

Note that the above equation is used for $M_e < 1$.

3.38

$$
\begin{bmatrix} s_+ \\ p_+ \\ U_+ \\ V_+ \end{bmatrix} = \begin{bmatrix} \Lambda_{11} \\ \Lambda_{21} \\ \Lambda_{31} \sin(\alpha-\beta) \\ \Lambda_{31} \cos(\alpha-\beta) \end{bmatrix} s_- + \begin{bmatrix} \Lambda_{12} \\ \Lambda_{22} \\ \Lambda_{32} \sin(\alpha-\beta) \\ \Lambda_{32} \cos(\alpha-\beta) \end{bmatrix} p_- +
$$

$$
+ \begin{bmatrix} \Lambda_{13} \\ \Lambda_{23} \\ \Lambda_{33} \sin(\alpha-\beta) \\ \Lambda_{33} \cos(\alpha-\beta) \end{bmatrix} u_-^* + \begin{bmatrix} 0 \\ 0 \\ -\Lambda_{44} \cos(\alpha-\beta) \\ \Lambda_{44} \sin(\alpha-\beta) \end{bmatrix} v_-^* +
$$

$$
+ \begin{bmatrix} \Pi_{11}\ (M\cos\beta - C_s/A) \\ \Pi_{21}\ (M\cos\beta - C_s/A) \\ \Pi_{31}\ (M\cos\beta - C_s/A)\sin(\alpha-\beta) - \Pi_{41}\cos(\alpha-\beta) \\ \Pi_{31}\ (M\cos\beta - C_s/A)\cos(\alpha-\beta) - \Pi_{41}\sin(\alpha-\beta) \end{bmatrix} \sin(\alpha-\beta)\ \Psi_y
$$

3.39 $$u_+^* = \sin(\alpha-\beta)\cdot U_+ + \cos(\alpha-\beta)\cdot V_+$$

3.40 $$v_+^* = -\cos(\alpha-\beta)\cdot U_+ + \sin(\alpha-\beta)\cdot V_+$$

3.41 $$u_1 = \sin\epsilon \cdot u_+^* + \cos\epsilon\ v_+^*$$

3.42 $$v_1 = -\cos\epsilon \cdot u_+^* + \sin\epsilon\ v_+^*$$

3.43 $$\mathrm{vort} = \sqrt{\left[u_1^2 + v_1^2\right]}$$

3.44 $$I_u = \langle u_+^* \rangle / M$$

3.45 $$I_v = \langle v_+^* \rangle / M$$

3.46 $$I_t = \langle s_+ \rangle / \left[1 + \frac{\gamma - 1}{2} \cdot M^2 \right]$$

3.47 $$SPL = 20 \log_{10} \left[\langle p_+ \rangle \gamma p_{ml} X / (1.45 \times 10^{-5}) \right] + 74$$

Note that in the above four equations $\langle \; \rangle$ implies root-mean square values, (summed over delta).

The theoretical justification for all the above equations is given in Reference 2.

4.0 OBJECT OF THE PROGRAM

Consider a turbulent fluid flow, plus a field of sound waves, passing through a shock wave. Then given certain of the upstream parameters of the flow the object of the program is to predict the downstream values of certain of these parameters. In particular it is of interest to find the individual contributions of the upstream values of entropy, pressure and vorticity to the downstream values of entropy, pressure and vorticity, and the total resulting downstream intensity or level for each of the three modes. The principal equation involved in this process is Equation (3.38). As α is a function of δ then this equation applies for only one particular value of δ. To find the total effect, the equation is numerically integrated over the range $0 \leq \delta \leq \pi/2$.

Two methods of integration are used and the results of both printed. The first method merely computes the root-mean-square values of the various parameters involved. The second method is best illustrated by example:

$$\langle p_+ \rangle = \sqrt{\left[\sum_{\delta_i} \left(\sum_j (p_{ij}^2) \cos \delta_i \right) \times \Delta \delta_i \right]}$$

where

$\langle p_+ \rangle$ is the downstream pressure

p_{ij}^2 is the downstream pressure for a particular jth modal upstream change at a particular value of δ.

$\Delta \delta_i$ is the step length in δ in radians.

Note that for the downstream pressure due to upstream entropy (say) then the summation over j will contain one value only.

In practice $\Delta\delta$ was taken as one degree but this is an input parameter and can therefore be changed. The summation for both methods was taken from:

$$\delta = \frac{\Delta\delta}{2} \quad \text{up to} \quad \delta = \left[N\,\Delta\delta + \frac{\Delta\delta}{2} \right]$$

where

$$\left[N\,\Delta\delta + \frac{\Delta\delta}{2} \right] \leq \frac{\pi}{2} \quad \text{but} \quad \left[(N+1)\,\Delta\delta + \frac{\Delta\delta}{2} \right] > \frac{\pi}{2}$$

The results produced by the above two methods compare very well. In fact in many cases there is agreement to three significant figures.

The author refers the reader to Reference 2 for a more detailed discussion of the methods used herein.

5.0 INPUT TO THE PROGRAM

Card	Parameter	Description	Format	Columns
1	DATE	The date of the run	A8	1-8
1	JN	The job number	I5	11-15
1	NN	The number of sets for this job	I5	16-20
1	DB	The initial value of delta-degrees (Usually Zero)	F10.0	21-30
1	DS	The step length in delta-degrees (Usually Unity)	F10.0	31-40
1	DE	The final value of delta-degrees (Usually 90)	F10.0	41-60
2	EMI	M_1 the upstream flow Mach number	F10.0	1-10
2	EPI	The shock wave angle - degrees	F10.0	11-20
2	BETA	The angle between shock wave and the downstream near flow velocity vector - degrees	F10.0	21-30
2	A1	Speed of sound in the flow field upstream of the shock, ft/sec	F10.0	31-40
2	EYEU1	The upstream turbulence intensity along x_1-axis, r.m.s. velocity fluctuation referenced to the upstream mean velocity	F10.0	41-50
2	EYEV1	The upstream turbulence intensity along y_1-axis, r.m.s. velocity fluctuation referenced to the upstream mean velocity	F10.0	51-60
2	SPL1	The overall upstream sound pressure level, dB re: 0.0002 dyne/cm^2	F10.0	61-70
2	EYET1	The upstream entropy fluctuation intensity, r.m.s. fluctuation in static temperature, referenced to the local total temperature, $^{\circ}$R	F10.0	71-80

Card	Parameter	Description	Format	Columns
3	GAMMA	Ratio of specific heats of fluid	F10.0	1-10
3	PM1	The ambient static upstream pressure, psi	F10.0	11-20

Repeat cards two and three NN times in all, then input another card type one. To end run NN should be less than unity.

6.0 OUTPUT FROM THE PROGRAM

The output from the program is well annotated. The results for method 1 described in Section 4.0 are given at the top of the second page of output for each set. The results from method 2 described in Section 4.0 are given at the bottom of the second page of output for each set and are referred to as the "alternative method of integration."

ACKNOWLEDGEMENTS

The author wishes to thank Mrs. Elizabeth Cuadra of Wyle Laboratories for assembling the equations for the model used herein and for her guidance and critique throughout this project. Thanks are also offered to Mr. Jack Robertson, Dr. Sam Radcliffe and Dr. Paul Pao for their help and comments during the early stages of the project.

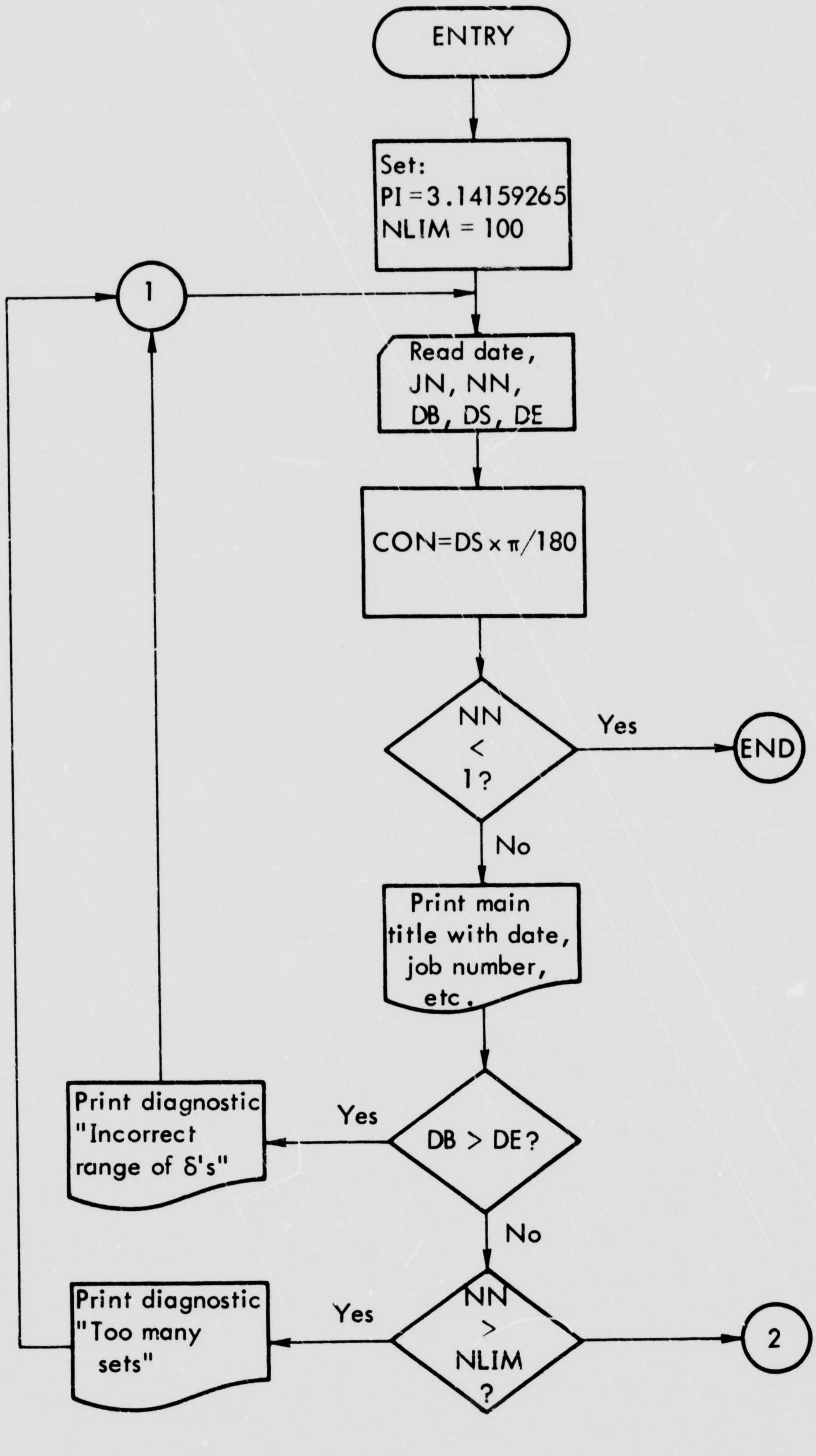
REFERENCES

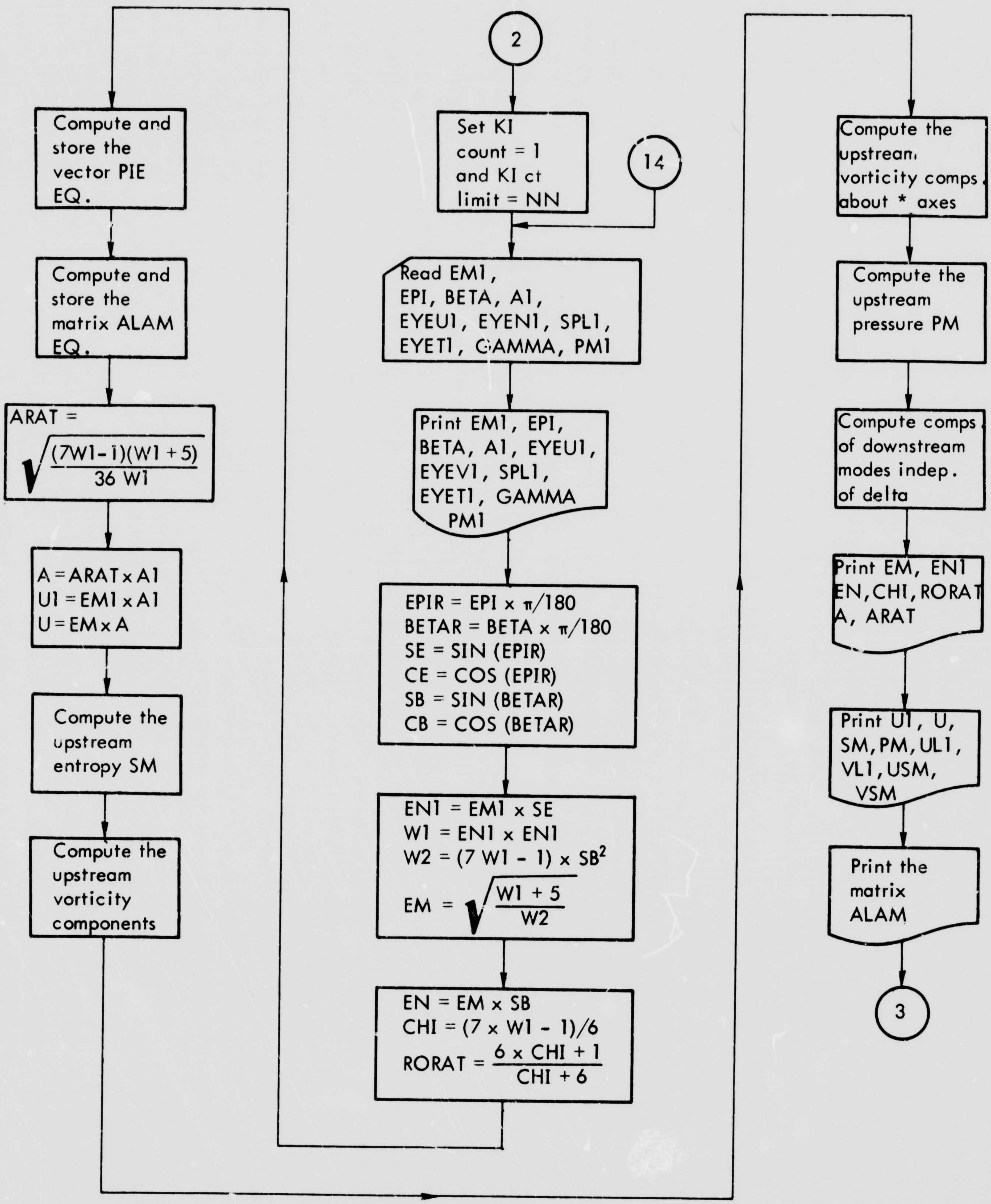
1. Cuadra, Elizabeth, "Flow Perturbations Generated by a Shock Wave Interacting with an Entropy Wave," Proceedings of the AFOSR-UTIAS Symposium on Aerodynamic Noise, Toronto, May 1968. (Same as Wyle Laboratories Research Staff Report WR 67-17, "Interactions of a Shock Wave with an Entropy Discontinuity," February 1968).

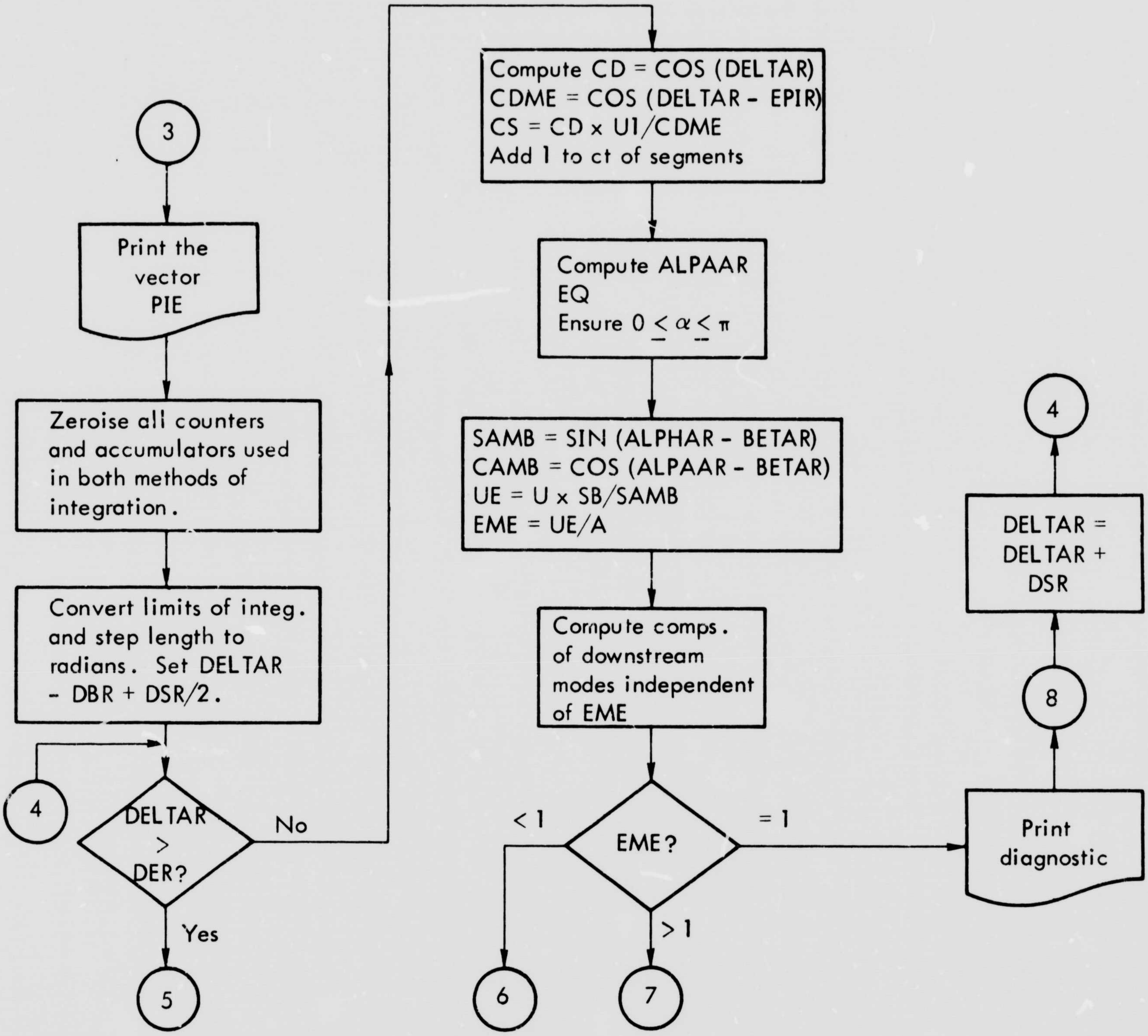
2. Cuadra, Elizabeth, "Flow Perturbation Intensities and Noise Levels Downstream of a Shock Wave Interacting with a Random Upstream Field Containing Turbulence, Entropy Fluctuations, and Sound Waves," Wyle Laboratories Research Staff Report WR 69-5, March 1969.

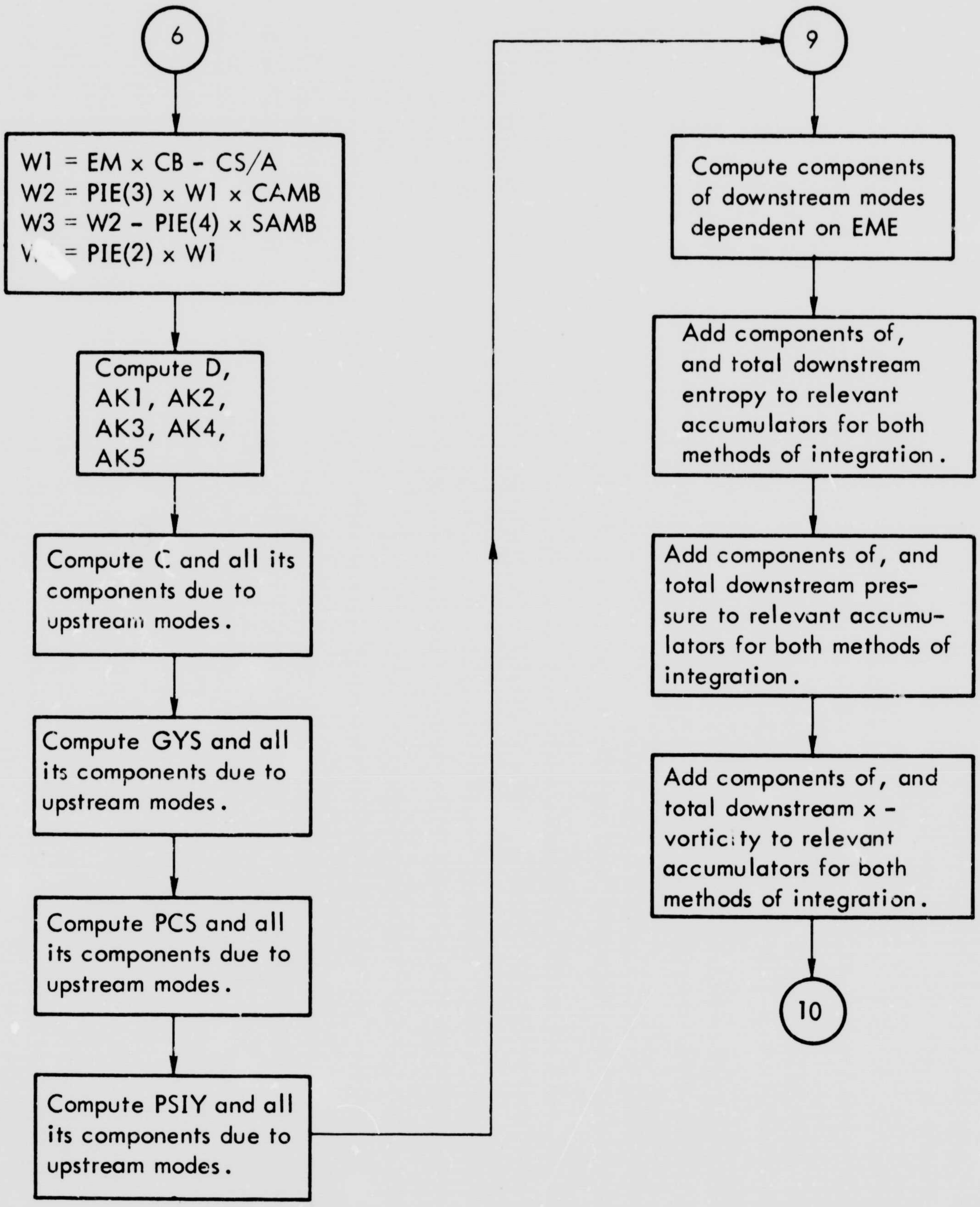
APPENDIX A

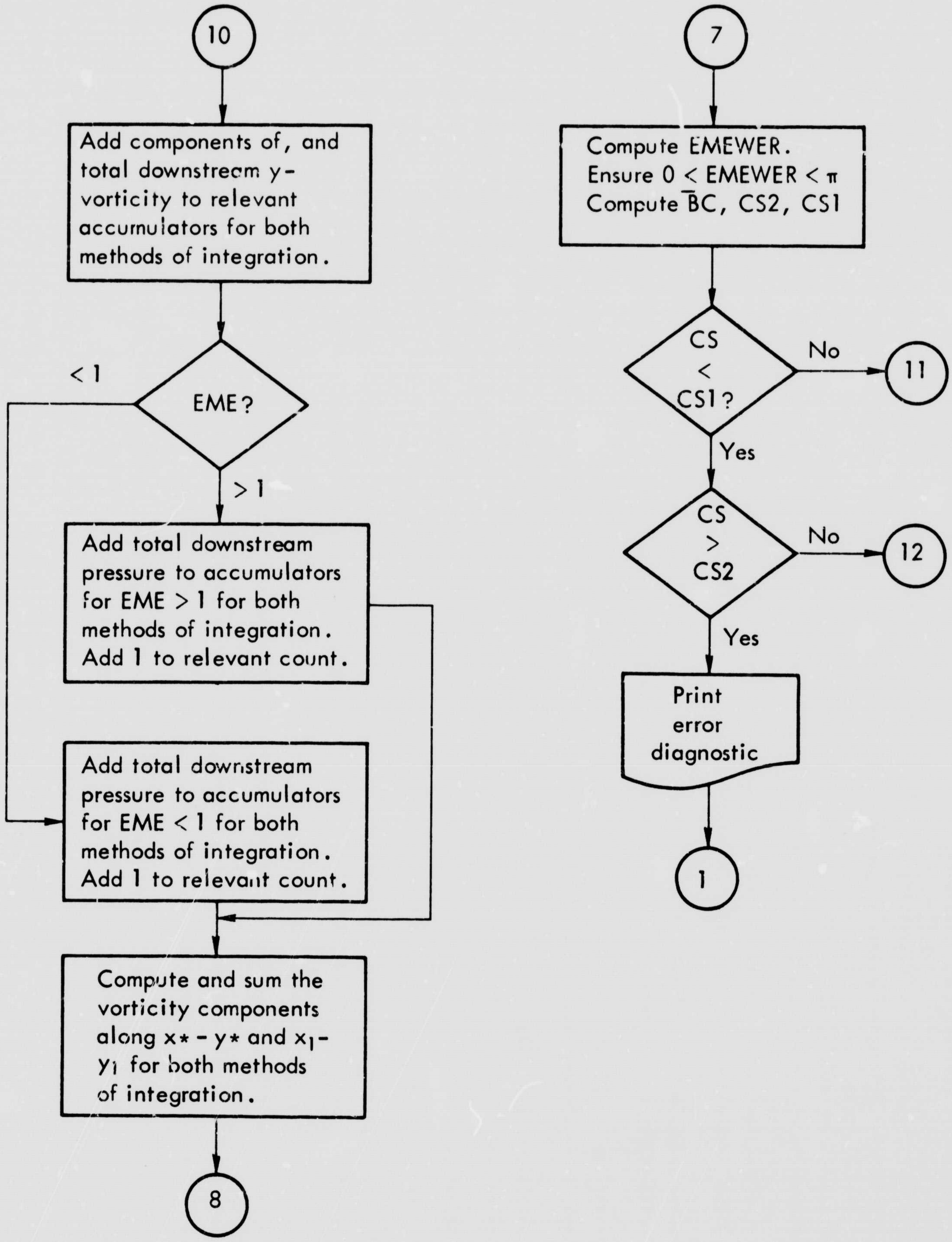
Flow Diagrams
of
Program DIONE

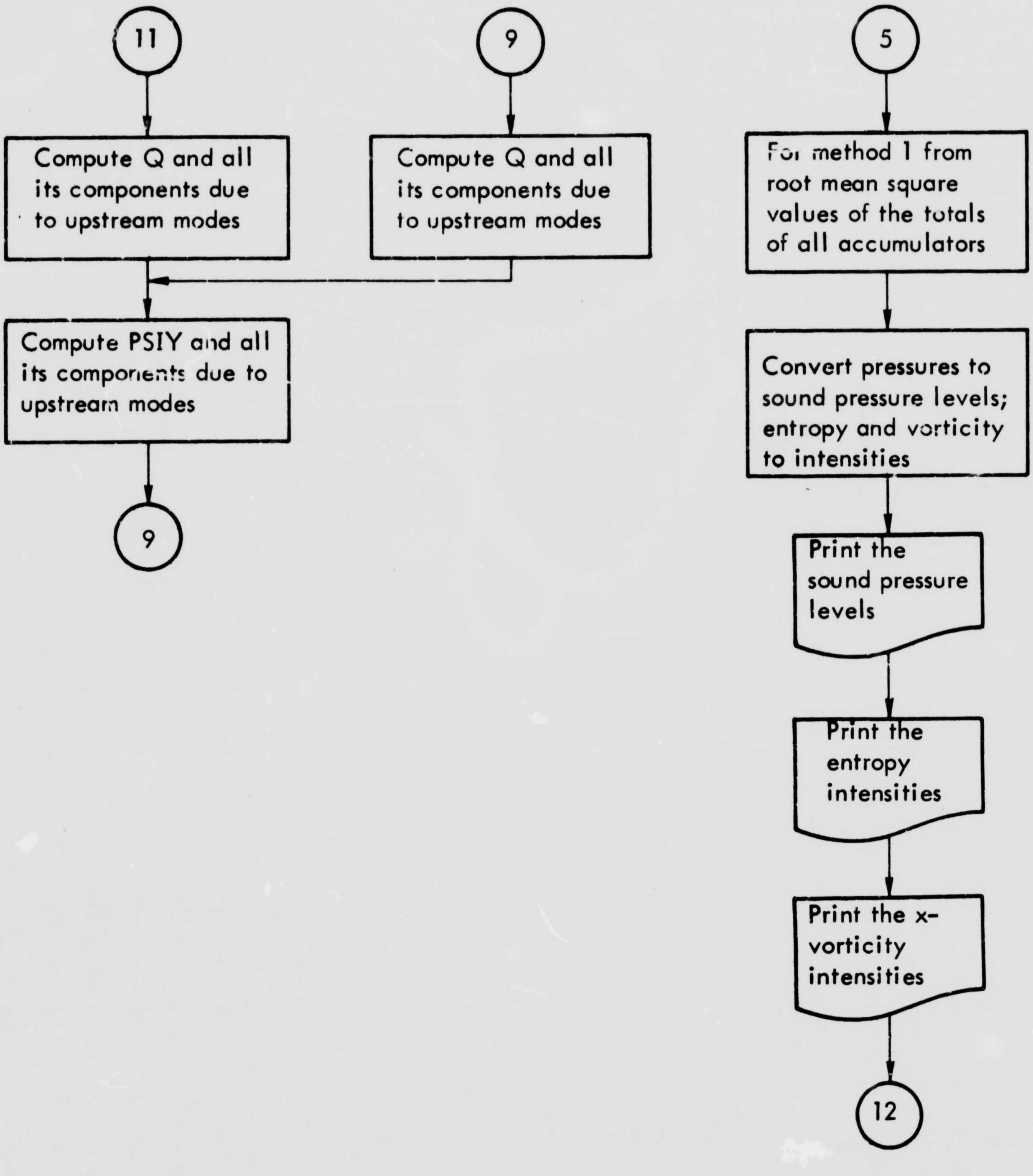

ENTRY
Set:
PI = 3.14159265
NLIM = 100
1
Read date,
JN, NN,
DB, DS, DE
CON=DS x π/180
NN
<
1?
Yes
END
No
Print main
title with date,
job number,
etc.
Print diagnostic
"Incorrect
range of δ's"
Yes
DB > DE?
No
Print diagnostic
"Too many
sets"
Yes
NN
>
NLIM
?
2

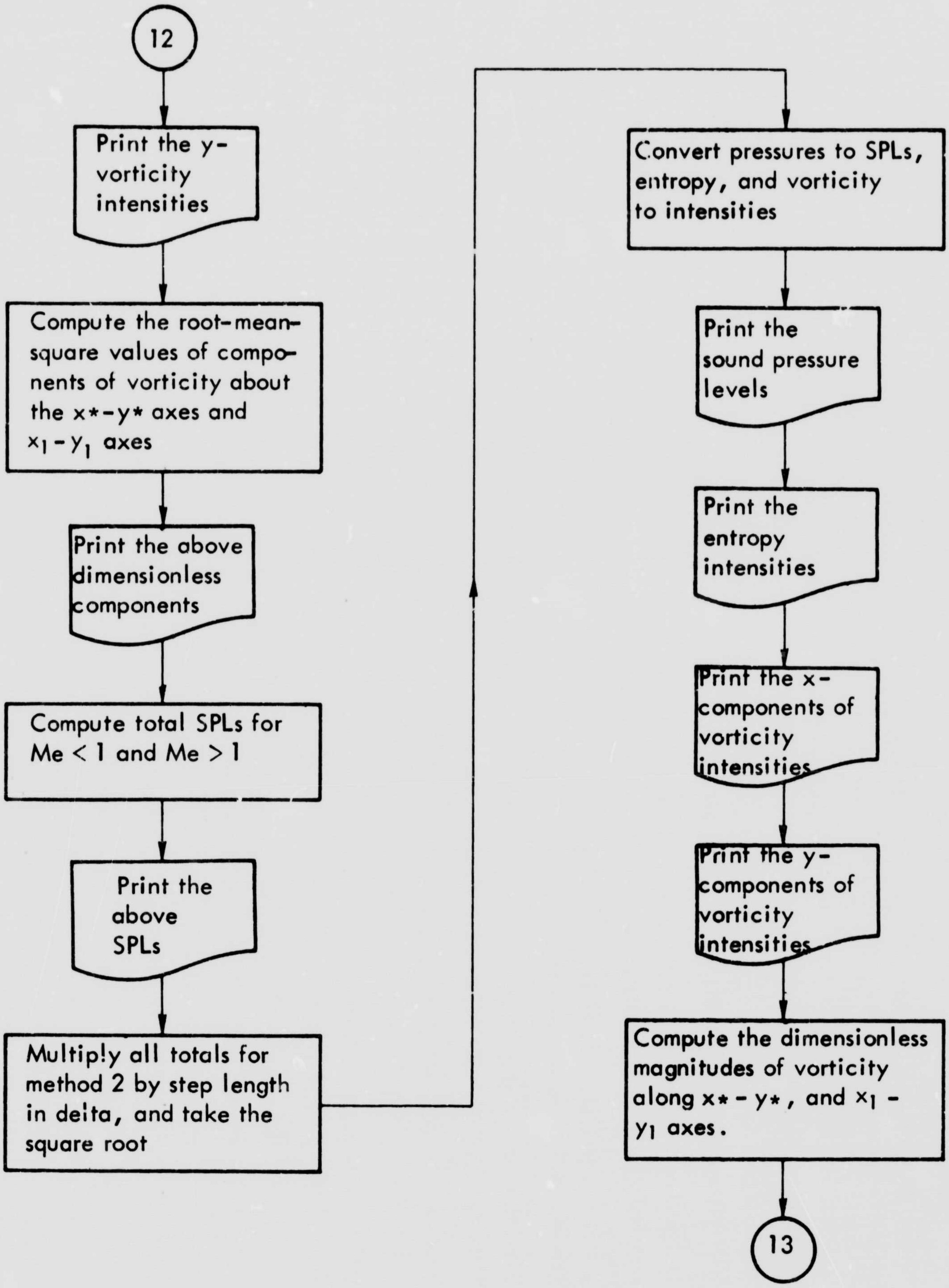

2
Set KI count = 1 and KI ct limit = NN
14
Read EM1, EPI, BETA, A1, EYEU1, EYEN1, SPL1, EYET1, GAMMA, PM1
Print EM1, EPI, BETA, A1, EYEU1, EYEV1, SPL1, EYET1, GAMMA PM1
EPIR = EPI x π/180
BETAR = BETA x π/180
SE = SIN (EPIR)
CE = COS (EPIR)
SB = SIN (BETAR)
CB = COS (BETAR)
EN1 = EM1 x SE
W1 = EN1 x EN1
W2 = (7 W1 - 1) x SB²
EM = √((W1 + 5)/W2)
EN = EM x SB
CHI = (7 x W1 - 1)/6
RORAT = (6 x CHI + 1)/(CHI + 6)
Compute and store the vector PIE EQ.
Compute and store the matrix ALAM EQ.
ARAT = √((7W1-1)(W1+5)/(36 W1))
A = ARAT x A1
U1 = EM1 x A1
U = EM x A
Compute the upstream entropy SM
Compute the upstream vorticity components
Compute the upstream vorticity comps about * axes
Compute the upstream pressure PM
Compute comps of downstream modes indep. of delta
Print EM, EN1 EN, CHI, RORAT A, ARAT
Print U1, U, SM, PM, UL1, VL1, USM, VSM
Print the matrix ALAM
3

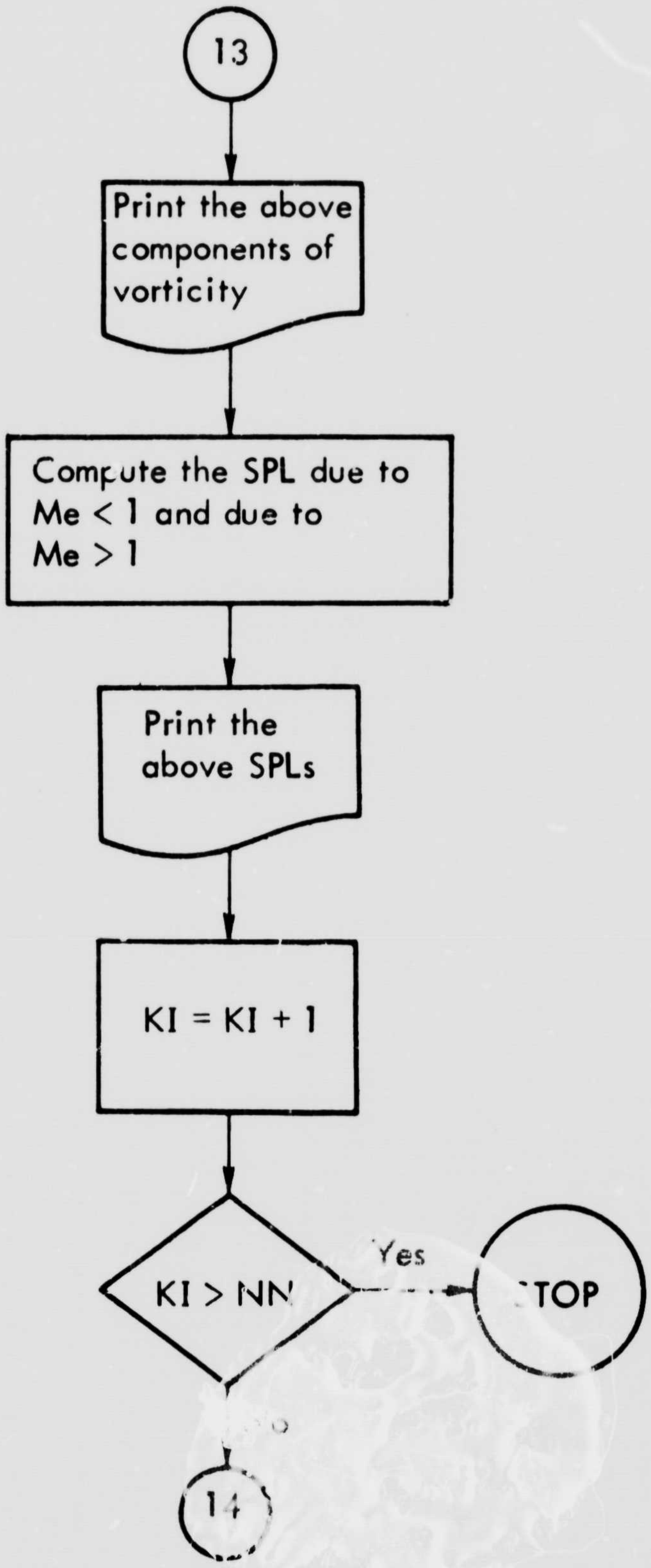

3
Print the vector PIE
Zeroise all counters and accumulators used in both methods of integration.
Convert limits of integ. and step length to radians. Set DELTAR - DBR + DSR/2.
4
DELTAR > DER?
No
Yes
5
Compute CD = COS (DELTAR)
CDME = COS (DELTAR - EPIR)
CS = CD x U1/CDME
Add 1 to ct of segments
Compute ALPAAR
EQ
Ensure 0 ≤ α ≤ π
SAMB = SIN (ALPHAR - BETAR)
CAMB = COS (ALPAAR - BETAR)
UE = U x SB/SAMB
EME = UE/A
Compute comps. of downstream modes independent of EME
EME?
< 1
= 1
> 1
6
7
Print diagnostic
8
DELTAR = DELTAR + DSR
4


6
W1 = EM x CB - CS/A
W2 = PIE(3) x W1 x CAMB
W3 = W2 - PIE(4) x SAMB
V. = PIE(2) x W1
Compute D, AK1, AK2, AK3, AK4, AK5
Compute C and all its components due to upstream modes.
Compute GYS and all its components due to upstream modes.
Compute PCS and all its components due to upstream modes.
Compute PSIY and all its components due to upstream modes.
9
Compute components of downstream modes dependent on EME
Add components of, and total downstream entropy to relevant accumulators for both methods of integration.
Add components of, and total downstream pressure to relevant accumulators for both methods of integration.
Add components of, and total downstream x - vorticity to relevant accumulators for both methods of integration.
10


10
Add components of, and total downstream y-vorticity to relevant accumulators for both methods of integration.
EME?
< 1
> 1
Add total downstream pressure to accumulators for EME > 1 for both methods of integration. Add 1 to relevant count.
Add total downstream pressure to accumulators for EME < 1 for both methods of integration. Add 1 to relevant count.
Compute and sum the vorticity components along x* - y* and x1 - y1 for both methods of integration.
8
7
Compute EMEWER. Ensure 0 < EMEWER < π Compute BC, CS2, CS1
CS < CS1?
No
11
Yes
CS > CS2
No
12
Yes
Print error diagnostic
1


11
9
5
Compute Q and all its components due to upstream modes
Compute Q and all its components due to upstream modes
For method 1 from root mean square values of the totals of all accumulators
Compute PSIY and all its components due to upstream modes
Convert pressures to sound pressure levels; entropy and vorticity to intensities
9
Print the sound pressure levels
Print the entropy intensities
Print the x-vorticity intensities
12


12
Print the y-vorticity intensities
Compute the root-mean-square values of components of vorticity about the x*-y* axes and $x_1 - y_1$ axes
Print the above dimensionless components
Compute total SPLs for Me < 1 and Me > 1
Print the above SPLs
Multiply all totals for method 2 by step length in delta, and take the square root
Convert pressures to SPLs, entropy, and vorticity to intensities
Print the sound pressure levels
Print the entropy intensities
Print the x-components of vorticity intensities
Print the y-components of vorticity intensities
Compute the dimensionless magnitudes of vorticity along x* - y*, and $x_1 - y_1$ axes.
13


13
Print the above components of vorticity
Compute the SPL due to Me < 1 and due to Me > 1
Print the above SPLs
KI = KI + 1
KI > NN
Yes
STOP
14

APPENDIX B

Fortran Listing
of
Program DIONE

```
      PROGRAM DIONE
      COMMON ALAM(4,4),PIE(4)
      COMMON/DATA/PI
      DATA (PI=3.14159265)
      NLIM=100
 9999 WRITE(61,19)
      READ(60,2)DATE,JN,NN,DB,DS,DE
 2    FORMAT(A8,2X,2I5,3F10.0)
      CON=DS*PI/180.0
      IF(NN.LT.1)999,998
 998  WRITE(61,3)DATE,JN,NN,DB,DS,DE
 3    FORMAT (10X,A8,37X,26HSHOCK          INTERACTION.,37X,10HRUN NUMBER
     1,I4/10X,8(1H-),37X,26(1H-),37X,14(1H-)///10X,22HNUMBER OF SETS OF
     2DATA,70X,2H= ,I5/10X,22HINITIAL VALUE OF DELTA,70X,2H= ,E12.4,2X,8
     3HDEGREES./10X,20HSTEP LENGTH IN DELTA,72X,2H= ,E12.4,2X,8HDEGREES.
     4/10X,20HFINAL VALUE OF DELTA,72X,2H= ,E12.4,2X,8HDEGREES.)
      IF(DB.GT.DE)4,6
 4    WRITE(61,5)
 5    FORMAT(///10X,19HLOOK AT THE DELTAS./10X,11HEND OF RUN.)
      GO TO 9999
 6    IF(NN.GT.NLIM)7,9
 7    WRITE(61,8)
 8    FORMAT (10X,20HNN IS TOO MUCH BABY.///10X,11HEND OF RUN.)
      GO TO 9999
 9    DO 921 KI=1,NN
      READ(60,10)EM1,EPI,BETA,A1,EYEU1,EYEV1,SPL1,EYET1,GAMMA,PM1
 10   FORMAT(8F10.0)
      WRITE(61,11)EM1,EPI,BETA,A1,EYEU1,EYEV1,SPL1,EYET1,GAMMA,PM1
 11   FORMAT (10X,33HEM1 THE UPSTREAM FLOW MACH NUMBER,59X,2H= ,E12.4/10
     1X,54HEPSILON THE SHOCK WAVE ANGLE REFERENCED TO THE X1 AXIS,38X,2H
     2= ,E12.4/10X,62HBETA THE ANGLE BETWEEN THE SHOCK WAVE AND THE DOWN
     3STREAM MEAN FLOW VELOCITY VECTOR,10X,2H= ,E12.4/10X,61HA1 THE SPEE
     4D OF SOUND IN THE FLOW FIELD UPSTREAM OF THE SHOCK,31X,2H= ,E12.4/
     510X,55HIU1 THE UPSTREAM TURBULENCE INTENSITY ALONG THE X1 AXIS,37X
     6,2H= ,E12.4/10X,59HIV1 THE UPSTREAM TURBULENCE INTENSITY NORMAL TO
     7 THE X1 AXIS,33X,2H= ,E12.4/10X,37HSPL1 THE OVERALL UPSTREAM SOUND
     8 FIELD,55X,2H= ,E12.4/10X,46HIT1 THE UPSTREAM ENTROPY FLUCTUATION
     9INTENSITY,46X,2H= ,E12.4/10X,33HGAMMA THE RATIO OF SPECIFIC HEATS,
     A59X,2H= ,E12.4/10X,40HPM1 THE AMBIENT STATIC UPSTREAM PRESSURE,52X
     B,2H= ,E12.4///)
      EPIR=EPI*PI/180.0
      BETAR=BETA*PI/180.0
      SE=SINF(EPIR)
      CE=COSF(EPIR)
      SB=SINF(BETAR)
      CB=COSF(BETAR)
      EN1=EM1*SE
      W1=EN1*EN1
      W2=(W1*7.0-1.0)*SB*SB
      EM=SQRT((W1+5.0)/W2)
      EN=EM*SB
      CHI=(W1*7.0-1.0)/6.0
      RORAT=(CHI*6.0+1.0)/(CHI+6.0)
      DO 12 I=1,4
```

```
      PIE(I)=0.0
      DO 12 J=1,4
      ALAM(I,J)=0.0
12    CONTINUE
      ALAM(1,1)=(RORAT*RORAT/EN1/EN1-(GAMMA-1.0)*(1.0-RORAT))*EN*EN
      ALAM(2,1)=EN*EN/(1.0-EN*EN)*((1.0-RORAT)*(1.0+(GAMMA-1.0)*EN*EN)+(
     11.0-RORAT*RORAT*EN*EN/EN1/EN1))
      ALAM(3,1)=-EN/(1.0-EN*EN)*((1.0-RORAT*RORAT*EN*EN/EN1/EN1)+(1.0-RO
     1RAT)*GAMMA*EN*EN)
      ALAM(1,2)=(GAMMA-1.0)*(1.0-RORAT)*(1.0-RORAT/EN1/EN1)*EN*EN
      ALAM(2,2)=-EN*EN/(1.0-EN*EN)*((1.0-RORAT)+(1.0-RORAT/EN1/EN1)*(1.0
     1+(GAMMA-1.0)*(1.0-RORAT)*EN*EN))
      ALAM(3,2)=EN/(1.0-EN*EN)*((1.0-RORAT*RORAT*EN*EN/EN1/EN1)+GAMMA*(1
     1.0-RORAT)*(1.0-RORAT/EN1/EN1)*EN*EN)
      ALAM(1,3)=(GAMMA-1.0)*(1.0-RORAT)*(1.0-RORAT)*EN*EN/EN1
      ALAM(2,3)=-EN/(1.0-EN*EN)*(1.0-RORAT)*(2.0+(GAMMA-1.0)*(1.0-RORAT)
     1*EN*EN)*EN/EN1
      ALAM(3,3)=1.0/(1.0-EN*EN)*EN/EN1*(1.0-RORAT*RORAT*EN*EN+GAMMA*(1.0
     1-RORAT)*(1.0-RORAT)*EN*EN)
      ALAM(4,4)=RORAT*EN/EN1
      PIE(1)=-(GAMMA-1.0)*(1.0-1.0/RORAT)*(1.0-1.0/RORAT)*RORAT*EN
      PIE(2)=-EN/(1.0-EN*EN)*(1.0-1.0/RORAT)*(2.0+(GAMMA-1.0)*(1.0-RORAT
     1)*EN*EN)
      PIE(3)=1.0/(1.0-EN*EN)*(1.0-1.0/RORAT)*(1.0+EN*EN+(GAMMA-1.0)*(1.0
     1-RORAT)*EN*EN)
      PIE(4)=(RORAT-1.0)*EN
      ARAT=SQRT((W1*7.0-1.0)*(W1+5.0)/W1/36.0)
      A=ARAT*A1
      U1=EM1*A1
      U=EM*A
      SM=EYET1*(1.0+(GAMMA-1.0)/2.0*EM1*EM1)
      UL1=EYEU1*EM1
      VL1=EYEV1*EM1
      USM=UL1*SE-VL1*CE
      VSM=UL1*CE+VL1*SE
      PM=1.0/GAMMA/PM1*1.45E-5*10.0**((SPL1-74.0)/20.0)
      SPDTSM1=ALAM(1,1)*SM
      PPDTSM1=ALAM(2,1)*SM
      SPDTPM1=ALAM(1,2)*PM
      PPDTPM1=ALAM(2,2)*PM
      SPDTUM1=ALAM(1,3)*USM
      PPDTUM1=ALAM(2,3)*USM
      WRITE(61,13)EM,EN1,EN,CHI,RORAT,A,ARAT
13    FORMAT (10X,33HM THE DOWNSTREAM FLOW MACH NUMBER,59X,2H= ,E12.4/10
     1X,82HM1 THE UPSTREAM MACH NUMBER CORRESPONDING TO A NORMAL SHOCK O
     2F EQUIVALENT STRENGTH,10X,2H= ,E12.4/10X,83HN THE DOWNSTREAM MACH
     3NUMBER CORRESPONDING TO A NORMAL SHOCK OF EQUIVALENT STRENGTH,9X,2
     4H= ,E12.4/10X,85HCHI SHOCK STRENGTH IN TERMS OF RATIO OF PRESSURE
     5OF UNPERTURBED FLOW ACROSS THE SHOCK,7X,2H= ,E12.4/10X,64HRORAT TH
     6E DENSITY RATIO ACROSS THE SHOCK, DOWNSTREAM TO UPSTREAM,28X,2H= ,
     7E12.4/10X,60HA THE SPEED OF SOUND IN THE FLOW FIELD DOWNSTREAM  OF
     8 SHOCK,32X,2H= ,E12.4/10X,78HARAT THE RATIO OF ACOUSTIC VELOCITIE
     9S ACROSS THE SHOCK, DOWNSTREAM TO UPSTREAM,14X,2H= ,E12.4)
      WRITE(61,14)U1,U,SM,PM,UL1,VL1,USM,VSM
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14    FORMAT (10X,47HU1 THE MEAN FLOW VELOCITY UPSTREAM OF THE SHOCK,45X
     1,2H= ,E12.4/10X,48HU THE MEAN FLOW VELOCITY DOWNSTREAM OF THE SHOC
     2K,44X,2H= ,E12.4/10X,66HSM THE DIMENSIONLESS MAGNITUDE OF THE UPST
     3REAM ENTROPY PERTUBATION,26X,2H= ,E12.4/10X,67HPM THE DIMENSIONLES
     4S MAGNITUDE OF THE UPSTREAM PRESSURE PERTUBATION,25X,2H= ,E12.4/10
     5X,84HUL1 THE DIMENSIONLESS MAGNITUDE OF THE DOWNSTREAM VELOCITY PE
     6RTUBATION ALONG X1 AXIS,8X,2H= ,E12.4/10X,84HVL1 THE DIMENSIONLESS
     7 MAGNITUDE OF THE DOWNSTREAM VELOCITY PERTUBATION ALONG Y1 AXIS,8X
     8,2H= ,E12.4/10X,82HUSM THE DIMENSIONLESS MAGNITUDE OF THE UPSTREAM
     9 VELOCITY PERTUBATION ALONG X* AXIS,10X,2H= ,E12.4/10X,82HVSM THE
     ADIMENSIONLESS MAGNITUDE OF THE UPSTREAM VELOCITY PERTUBATION ALONG
     B Y* AXIS,10X,2H= ,E12.4////)
      WRITE(61,15)
15    FORMAT (10X,62HMATRIX LAMBDA(I,J)  TRANSFER COEFFICIENTS FOR THE I
     1NTERACTION,/10X,62(1H-)/)
      DO 16 I=1,4
      WRITE(61,17)(ALAM(I,J),J=1,4)
16    CONTINUE
17    FORMAT (10X,4(E12.4,5X))
      WRITE(61,18)
18    FORMAT (///10X,58HVECTOR OF PI(I)  TRANSFER COEFFICIENTS OF THE IN
     1TERACTION,/10X,58(1H-)/)
      WRITE(61,17)(PIE(I),I=1,4)
19    FORMAT(1H1)
      SUSP=SVSP=SUL1=SVL1=SVORT=0.0
      SSP=SSP1=SSP2=SSP3=SSP4=0.0
      SPP=SPP1=SPP2=SPP3=SPP4=0.0
      SUP=SUP1=SUP2=SUP3=SUP4=0.0
      SVP=SVP1=SVP2=SVP3=SVP4=0.0
      SSP1A=SSP2A=SSP3A=SSP4A=0.0
      SPP1A=SPP2A=SPP3A=SPP4A=0.0
      SUP1A=SUP2A=SUP3A=SUP4A=0.0
      SVP1A=SVP2A=SVP3A=SVP4A=0.0
      SUSPA=SVSPA=SUL1A=SVL1A=SVORTA=0.0
      NCP=NCM=0
      SPPP=SPPM=0.0
      SPPPA=SPPMA=0.0
      NCOUNT=0
      DBR=DB*PI/180.0
      DSR=DS*PI/180.0
      DER=DE*PI/180.0
      DELTAR=DBR+DSR*0.5
20    IF(DELTAR.GT.DER)21,22
21    WRITE(61,19)
      AN=FLOAT(NCOUNT)
      SPP=SQRT(SPP/AN)
      SPP1=SQRT(SPP1/AN)
      SPP2=SQRT(SPP2/AN)
      SPP5=SQRT((SPP4+SPP3)/AN)
      SSP=SQRT(SSP/AN)
      SSP1=SQRT(SSP1/AN)
      SSP2=SQRT(SSP2/AN)
      SSP5=SQRT((SSP3+SSP4)/AN)
      SUP=SQRT(SUP/AN)
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      SUP1=SQRT(SUP1/AN)
      SUP2=SQRT(SUP2/AN)
      SUP5=SQRT((SUP3+SUP4)/AN)
      SVP=SQRT(SVP/AN)
      SVP1=SQRT(SVP1/AN)
      SVP2=SQRT(SVP2/AN)
      SVP5=SQRT((SVP3+SVP4)/AN)
      SPL1T=74,0+20,0*ALOG10(SPP*GAMMA*PM1*CHI/1,45E-5)
      SPL1S=74,0+20,0*ALOG10(SPP1*GAMMA*PM1*CHI/1,45E-5)
      SPL1P=74,0+20,0*ALOG10(SPP2*GAMMA*PM1*CHI/1,45E-5)
      SPL1U=74,0+20,0*ALOG10(SPP5*GAMMA*PM1*CHI/1,45E-5)
      TIT=SSP/(1,0+(GAMMA-1,0)/2,0*EM*EM)
      SIT=SSP1/(1,0+(GAMMA-1,0)/2,0*EM*EM)
      PIT=SSP2/(1,0+(GAMMA-1,0)/2,0*EM*EM)
      UIT=SSP5/(1,0+(GAMMA-1,0)/2,0*EM*EM)
      TIU1=SUP/EM
      SIU1=SUP1/EM
      PIU1=SUP2/EM
      UIU1=SUP5/EM
      TIV1=SVP/EM
      SIV1=SVP1/EM
      PIV1=SVP2/EM
      UIV1=SVP5/EM
      WRITE(61,100)SPL1T,SPL1S,SPL1P,SPL1U
  100 FORMAT (5X,41HTHE TOTAL DOWNSTREAM SOUND PRESSURE LEVEL,56X,2H= ,E
     112,4/5X,73HTHE DOWNSTREAM SOUND PRESSURE LEVEL DUE TO UPSTREAM ENT
     2ROPY PERTURBATIONS,24X,2H= ,E12,4/5X,74HTHE DOWNSTREAM SOUND PRESS
     3URE LEVEL DUE TO UPSTREAM PRESSURE PERTURBATIONS,23X,2H= ,E12,4/5X
     4,75HTHE DOWNSTREAM SOUND PRESSURE LEVEL DUE TO UPSTREAM  VELOCITY
     5PERTURBATIONS,22X,2H= ,E12,4/)
      WRITE(61,101)TIT,SIT,PIT,UIT
  101 FORMAT (5X,38HTHE TOTAL DOWNSTREAM ENTROPY INTENSITY,59X,2H= ,E12,
     14/5X,70HTHE DOWNSTREAM ENTROPY INTENSITY DUE TO UPSTREAM ENTROPY P
     2ERTURBATIONS,27X,2H= ,E12,4/5X,71HTHE DOWNSTREAM ENTROPY INTENSITY
     3 DUE TO UPSTREAM PRESSURE PERTURBATIONS,26X,2H= ,E12,4/5X,72HTHE D
     4OWNSTREAM ENTROPY INTENSITY DUE TO UPSTREAM  VELOCITY PERTURBATION
     5S,25X,2H= ,E12,4/)
      WRITE(61,102)TIU1,SIU1,PIU1,UIU1
  102 FORMAT (5X,53HTHE TOTAL DOWNSTREAM VORTICITY COMPONENT ALONG X-AXI
     1S,44X,2H= ,E12,4/5X, 85HTHE DOWNSTREAM VORTICITY COMPONENT ALONG X
     2-AXIS DUE TO UPSTREAM ENTROPY PERTURBATIONS,12X,2H= ,E12,4/5X,90HT
     3HE DOWNSTREAM VORTICITY COMPONENT ALONG THE X-AXIS DUE TO UPSTREAM
     4 PRESSURE PERTURBATIONS,7X,2H= ,E12,4/5X,81HTHE DOWNSTREAM VORTICI
     5TY ALONG THE X-AXIS DUE TO UPSTREAM  VELOCITY PERTURBATIONS,16X,2H
     6= ,E12,4/)
      WRITE(61,103)TIV1,SIV1,PIV1,UIV1
  103 FORMAT (5X,57HTHE TOTAL DOWNSTREAM VORTICITY COMPONENT ALONG THE Y
     1-AXIS,40X,2H= ,E12,4/5X,89HTHE DOWNSTREAM VORTICITY COMPONENT ALON
     2G THE Y-AXIS DUE TO UPSTREAM ENTROPY PERTURBATIONS,8X,2H= ,E12,4/5
     3X,90HTHE DOWNSTREAM VORTICITY COMPONENT ALONG THE Y-AXIS DUE TO UP
     4STREAM PRESSURE PERTURBATIONS,7X,2H= ,E12,4/5X,91HTHE DOWNSTREAM V
     5ORTICITY COMPONENT ALONG THE Y-AXIS DUE TO UPSTREAM  VELOCITY PERT
     6URBATIONS,6X,2H= ,E12,4/)
      SUSP=SQRT(SUSP/AN)
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      SVSP=SQRT(SVSP/AN)
      SUL1=SQRT(SUL1/AN)
      SVL1=SQRT(SVL1/AN)
      SVORT=SQRT(SVORT/AN)
      WRITE(61,200)SUSP,SVSP,SUL1,SVL1,SVORT
  200 FORMAT (5X,83HDIMENSIONLESS MAGNITUDE OF DOWNSTREAM VELOCITY PERTU
     1RBATION COMPONENT ALONG X*-AXIS,14X,2H= ,E12.4/5X,83HDIMENSIONLESS
     2 MAGNITUDE OF DOWNSTREAM VELOCITY PERTURBATION COMPONENT ALONG Y*-
     3AXIS,14X,2H= ,E12.4/5X,83HDIMENSIONLESS MAGNITUDE OF DOWNSTREAM VE
     4LOCITY PERTURBATION COMPONENT ALONG X1-AXIS,14X,2H= ,E12.4/5X,83HD
     5IMENSIONLESS MAGNITUDE OF DOWNSTREAM VELOCITY PERTURBATION COMPONE
     6NT ALONG Y1-AXIS,14X,2H= ,E12.4/5X,41HDOWNSTREAM VORTICITY BASED O
     7N UL1 AND VL1,56X,2H= ,E12.4/)
      ANP=FLOAT(NCP)
      ANM=FLOAT(NCM)
      SPPP=SQRT(SPPP/ANP)
      SPPM=SQRT(SPPM/ANM)
      SPLP=74.0+20.0*ALOG10(SPPP*GAMMA*PM1*CHI/1.45E-5)
      SPLM=74.0+20.0*ALOG10(SPPM*GAMMA*PM1*CHI/1.45E-5)
      WRITE(61,403)SPLP,SPLM
  403 FORMAT (5X,44HDOWNSTREAM SOUND PRESSURE LEVEL FOR ME GT. 1,53X,2H=
     1 ,E12.4/5X,44HDOWNSTREAM SOUND PRESSURE LEVEL FOR ME LT. 1,53X,2H=
     2 ,E12.4/)
      WRITE(61,201)
  201 FORMAT(1H0,107HNOTE THAT THE FOLLOWING RESULTS HAVE BEEN COMPUTED
     1BY USING AN ALTERNATIVE METHOD OF NUMERICAL INTEGRATION.//)
      SSP1A=SSP1A*CON
      SSP2A=SSP2A*CON
      SSP3A=SSP3A*CON
      SSP4A=SSP4A*CON
      SSPA=SSP1A+SSP2A+SSP3A+SSP4A
      SPP1A=SPP1A*CON
      SPP2A=SPP2A*CON
      SPP3A=SPP3A*CON
      SPP4A=SPP4A*CON
      SPPA=SPP1A+SPP2A+SPP3A+SPP4A
      SUP1A=SUP1A*CON
      SUP2A=SUP2A*CON
      SUP3A=SUP3A*CON
      SUP4A=SUP4A*CON
      SUPA=SUP1A+SUP2A+SUP3A+SUP4A
      SVP1A=SVP1A*CON
      SVP2A=SVP2A*CON
      SVP3A=SVP3A*CON
      SVP4A=SVP4A*CON
      SVPA=SVP1A+SVP2A+SVP3A+SVP4A
      SPPA=SQRT(SPPA)
      SPP1A=SQRT(SPP1A)
      SPP2A=SQRT(SPP2A)
      SPP5A=SQRT (SPP4A+SPP3A)
      SSPA=SQRT(SSPA)
      SSP1A=SQRT(SSP1A)
      SSP2A=SQRT(SSP2A)
      SSP5A=SQRT (SSP4A+SSP3A)
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      SUPA=SQRT(SUPA)
      SUP1A=SQRT(SUP1A)
      SUP2A=SQRT(SUP2A)
      SUP5A=SQRT (SUP4A+SUP3A)
      SVPA=SQRT(SVPA)
      SVP1A=SQRT(SVP1A)
      SVP2A=SQRT(SVP2A)
      SVP5A=SQRT (SVP4A+SVP3A)
      SPL1TA=74.0+20.0*ALOG10(SPPA*GAMMA*PM1*CHI/1.45E-5)
      SPL1SA=74.0+20.0*ALOG10(SPP1A*GAMMA*PM1*CHI/1.45E-5)
      SPL1PA=74.0+20.0*ALOG10(SPP2A*GAMMA*PM1*CHI/1.45E-5)
      SPL1UA=74.0+20.0*ALOG10(SPP5A*GAMMA*PM1*CHI/1.45E-5)
      TITA=SSPA/(1.00+(GAMMA-1.0)/2.0*EM*EM)
      SITA=SSP1A/(1.0+(GAMMA-1.0)/2.0*EM*EM)
      PITA=SSP2A/(1.0+(GAMMA-1.0)/2.0*EM*EM)
      UITA=SSP5A/(1.0+(GAMMA-1.0)/2.0*EM*EM)
      TIU1A=SUPA/EM
      SIU1A=SUP1A/EM
      PIU1A=SUP2A/EM
      UIU1A=SUP5A/EM
      TIV1A=SVPA/EM
      SIV1A=SVP1A/EM
      PIV1A=SVP2A/EM
      UIV1A=SVP5A/EM
      WRITE(61,100) SPL1TA,SPL1SA,SPL1PA,SPL1UA
      WRITE(61,101) TITA,SITA,PITA,UITA
      WRITE(61,102) TIU1A,SIU1A,PIU1A,UIU1A
      WRITE(61,103) TIV1A,SIV1A,PIV1A,UIV1A
      SUSPA=SQRT(SUSPA*CON)
      SVSPA=SQRT(SVSPA*CON)
      SUL1A=SQRT(SUL1A*CON)
      SVL1A=SQRT(SVL1A*CON)
      SVORTA=SQRT(SVORTA*CON)
      WRITE(61,200) SUSPA,SVSPA,SUL1A,SVL1A,SVORTA
      SPPPA=SQRT(SPPPA*CON)
      SPPMA=SQRT(SPPMA*CON)
      SPLPA=74.0+20.0*ALOG10(SPPPA*GAMMA*PM1*CHI/1.45E-5)
      SPLMA=74.0+20.0*ALOG10(SPPMA*GAMMA*PM1*CHI/1.45E-5)
      WRITE(61,403) SPLPA,SPLMA
921   CONTINUE
      GO TO 9999
22    CD=COSF(DELTAR)
      CDME=COSF(DELTAR-EPIR)
      CS=CD*U1/CDME
      NCOUNT=NCOUNT+1
      ALPHAR=ATAN(CS*SB/(CS*CB-U))
      IF(ALPHAR)23,24,24
23    ALPHAR=ALPHAR+PI
24    ALPHA=ALPHAR*180.0/PI
      SAMB=SINF(ALPHAR-BETAR)
      CAMB=COSF(ALPHAR-BETAR)
      LE=U*SB/SAMB
      EME=LE/A
      UPDTSM2=ALAM(3,1)*SAMB*SM
```

27692

```
      VPDTSM2=ALAM(3,1)*CAMB*SM
      LPDTPM2=ALAM(3,2)*SAMB*PM
      VPDTPM2=ALAM(3,2)*CAMB*PM
      LPDTUM2=ALAM(3,3)*SAMB*USM
      VPDTUM2=ALAM(3,3)*CAMB*USM
      LPDTVM2=-ALAM(4,4)*CAMB*VSM
      VPDTVM2=ALAM(4,4)*SAMB*VSM
      IF(EME-1,0)33,30,35
30    WRITE(61,31)
31    FORMAT (10X,41HME = 1,0   WILL IGNORE THIS AND CONTINUE,)
32    DELTAR=DELTAR+DSR
      GO TO 20
33    W1=EM*CB-CS/A
      W2=PIE(3)*W1*CAMB
      W3=W2-PIE(4)*SAMB
      W4=PIE(2)*W1
      AK1=-W3/W4
      D=0,5*EME*AK1/SQRT(1,0-EME*EME)
      AK2=-ALAM(3,1)*CAMB+ALAM(2,1)*AK1
      AK3=-ALAM(3,2)*CAMB+ALAM(2,2)*AK1
      AK4=-ALAM(3,3)*CAMB+ALAM(2,3)*AK1
      AK5=-ALAM(4,4)*SAMB
      CSM=AK2*SM
      CPM=AK3*PM
      CUM=AK4*USM
      CVM=AK5*VSM
      C=CSM+CPM+CUM+CVM
      W7=D/(1,0-D*D)
      GYSSM=W7*CSM
      GYSPM=W7*CPM
      GYSUM=W7*CUM
      GYSVM=W7*CVM
      GYS=W7*C
      W8=0,5*EME/SQRT(1,0-EME*EME)
      PCSSM=W8*GYSSM
      PCSPM=W8*GYSPM
      PCSUM=W8*GYSUM
      PCSVM=W8*GYSVM
      PCS=W8*GYS
      DEN=W4*SAMB
      PSIYS=(PCSSM-ALAM(2,1)*SM)/DEN
      PSIYP=(PCSPM-ALAM(2,2)*PM)/DEN
      PSIYU=(PCSUM-ALAM(2,3)*USM)/DEN
      PSIYV=PCSVM    /DEN
      PSIY=PSIYS+PSIYP+PSIYU+PSIYV
34    W5=W1*SAMB
      W6=W5*PIE(1)
      SPDTSM3=W6*PSIYS
      SPDTPM3=W6*PSIYP
      SPDTUM3=W6*PSIYU
      SPDTVM3=W6*PSIYV
      W6=W5*PIE(2)
      PPDTSM3=W6*PSIYS
      PPDTPM3=W6*PSIYP
```

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```
      PPDTUM3=W6*PSIYU
      PPDTVM3=W6*PSIYV
      W6=(PIE(3)*W5-PIE(4)*CAMB)*SAMB
      UPDTSM3=W6*PSIYS
      UPDTPM3=W6*PSIYP
      UPDTUM3=W6*PSIYU
      UPDTVM3=W6*PSIYV
      W6=(PIE(3)*W1*CAMB-PIE(4)*SAMB)*SAMB
      VPDTSM3=W6*PSIYS
      VPDTPM3=W6*PSIYP
      VPDTUM3=W6*PSIYU
      VPDTVM3=W6*PSIYV
      TSPSM=SPDTSM3+SPDTSM1
      SSP1=SSP1+TSPSM*TSPSM
      SSP1A=SSP1A+TSPSM*TSPSM*CD
      TSPPM=SPDTPM3+SPDTPM1
      SSP2=SSP2+TSPPM*TSPPM
      SSP2A=SSP2A+TSPPM*TSPPM*CD
      TSPUM=SPDTUM3+SPDTUM1
      SSP3=SSP3+TSPUM*TSPUM
      SSP3A=SSP3A+TSPUM*TSPUM*CD
      TSPVM=SPDTVM3
      SSP4=SSP4+TSPVM*TSPVM
      SSP4A=SSP4A+TSPVM*TSPVM*CD
      SSP=SSP+(TSPSM+TSPPM+TSPUM+TSPVM)*(TSPSM+TSPPM+TSPUM+TSPVM)
      TPPSM=PPDTSM3+PPDTSM1
      SPP1=SPP1+TPPSM*TPPSM
      SPP1A=SPP1A+TPPSM*TPPSM*CD
      TPPPM=PPDTPM3+PPDTPM1
      SPP2=SPP2+TPPPM*TPPPM
      SPP2A=SPP2A+TPPPM*TPPPM*CD
      TPPUM=PPDTUM3+PPDTUM1
      SPP3=SPP3+TPPUM*TPPUM
      SPP3A=SPP3A+TPPUM*TPPUM*CD
      TPPVM=PPDTVM3
      SPP4=SPP4+TPPVM*TPPVM
      SPP4A=SPP4A+TPPVM*TPPVM*CD
      SPP=SPP+(TPPSM+TPPPM+TPPUM+TPPVM)*(TPPSM+TPPPM+TPPUM+TPPVM)
      TUPSM=UPDTSM3+UPDTSM2
      SUP1=SUP1+TUPSM*TUPSM
      SUP1A=SUP1A+TUPSM*TUPSM*CD
      TUPPM=UPDTPM3+UPDTPM2
      SUP2=SUP2+TUPPM*TUPPM
      SUP2A=SUP2A+TUPPM*TUPPM*CD
      TUPUM=UPDTUM3+UPDTUM2
      SUP3=SUP3+TUPUM*TUPUM
      SUP3A=SUP3A+TUPUM*TUPUM*CD
      TUPVM=UPDTVM3+UPDTVM2
      SUP4=SUP4+TUPVM*TUPVM
      SUP4A=SUP4A+TUPVM*TUPVM*CD
      SUP=SUP+(TUPSM+TUPPM+TUPUM+TUPVM)*(TUPSM+TUPPM+TUPUM+TUPVM)
      TVPSM=VPDTSM3+VPDTSM2
      SVP1=SVP1+TVPSM*TVPSM
      SVP1A=SVP1A+TVPSM*TVPSM*CD
```

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```
      TVPPM=VPDTPM3+VPDTPM2
      SVP2=SVP2+TVPPM*TVPPM
      SVP2A=SVP2A+TVPPM*TVPPM*CD
      TVPUM=VPDTUM3+VPDTUM2
      SVP3=SVP3+TVPUM*TVPUM
      SVP3A=SVP3A+TVPUM*TVPUM*CD
      TVPVM=VPDTVM3+VPDTVM2
      SVP4=SVP4+TVPVM*TVPVM
      SVP4A=SVP4A+TVPVM*TVPVM*CD
      SVP=SVP+(TVPSM+TVPPM+TVPUM+TVPVM)*(TVPSM+TVPPM+TVPUM+TVPVM)
      IF(EME.GT.1.0)400,401
  400 SPPP=SPPP+(TPPSM+TPPPM+TPPUM+TPPVM)*(TPPSM+TPPPM+TPPUM+TPPVM)
      SPPPA=SPPPA+(TPPSM*TPPSM+TPPUM*TPPUM+TPPVM*TPPVM+TPPPM*TPPPM)*CD
      NCP=NCP+1
      GO TO 402
  401 SPPM=SPPM+(TPPSM+TPPPM+TPPUM+TPPVM)*(TPPSM+TPPPM+TPPUM+TPPVM)
      SPPMA=SPPMA+(TPPSM*TPPSM+TPPUM*TPPUM+TPPVM*TPPVM+TPPPM*TPPPM)*CD
      NCM=NCM+1
  402 CONTINUE
      UP1=UPDTSM3+UPDTPM3+UPDTUM3+UPDTVM3+UPDTSM2+UPDTPM2+UPDTUM2+UPDTVM
     12
      UP1A=SQRT(((UPDTSM3+UPDTSM2)*(UPDTSM3+UPDTSM2)+(UPDTPM3+UPDTPM2)*(
     1UPDTPM3+UPDTPM2)+(UPDTUM3+UPDTUM2)*(UPDTUM3+UPDTUM2)+(UPDTVM3+UPDT
     2VM2)*(UPDTVM3+UPDTVM2))*CD)
      VP1=VPDTSM3+VPDTPM3+VPDTUM3+VPDTVM3+VPDTSM2+VPDTPM2+VPDTUM2+VPDTVM
     12
      VP1A=SQRT(((VPDTSM3+VPDTSM2)*(VPDTSM3+VPDTSM2)+(VPDTPM3+VPDTPM2)*(
     1VPDTPM3+VPDTPM2)+(VPDTUM3+VPDTUM2)*(VPDTUM3+VPDTUM2)+(VPDTVM3+VPDT
     2VM2)*(VPDTVM3+VPDTVM2))*CD)
      USP=UP1*SAMB+VP1*CAMB
      VSP=VP1*SAMB-UP1*CAMB
      USPA=UP1A*SAMB+VP1A*CAMB
      VSPA=VP1A*SAMB-UP1A*CAMB
      UL1=USP*SE+VSP*CE
      VL1=VSP*SE-USP*CE
      UL1A=USPA*SE+VSPA*CE
      VL1A=VSPA*SE-USPA*CE
      VORT=SQRT(UL1*UL1+VL1*VL1)
      VORTA=SQRT(UL1A*UL1A+VL1A*VL1A)
      SUSP=SUSP+USP*USP
      SUSPA=SUSPA+USPA*USPA
      SVSP=SVSP+VSP*VSP
      SVSPA=SVSPA+VSPA*VSPA
      SUL1=SUL1+UL1*UL1
      SUL1A=SUL1A+UL1A*UL1A
      SVL1=SVL1+VL1*VL1
      SVL1A=SVL1A+VL1A*VL1A
      SVORT=SVORT+VORT*VORT
      SVORTA=SVORTA+VORTA*VORTA
      GO TO 32
   35 EMEWER=ATAN(1.0/SQRT(EME*EME-1.0))
      IF(EMEWER)25,26,26
   25 EMEWER=EMEWER+PI
   26 EMEWE=EMEWER*180.0/PI
```

```
      CMEWE=COSF(EMEWER)
      BC=SQRT(A*A-U*U*SB*SB)*2,0
      CS1=SQRT(U*U+A*A-2,0*U*(U*SB*SB-CB*SQRT(A*A-U*U*SB*SB)))
      CS2=CS1-BC
      W1=EM*CB-CS/A
      DEN1=PIE(2)*W1*CMEWE
      DEN2=PIE(3)*W1*CAMB-PIE(4)*SAMB
      DEN3=DEN2/DEN1
      DEN4=1,0+DEN3
      IF(CS.LT.CS1)36,39
36    IF(CS.GT.CS2)37,41
37    WRITE(61,38)CS2,CS,CS1
38    FORMAT (10X,23HCS IN PROHIBITED RANGE,,3(5X,E14.4))
      GO TO 9999
39    GSM=ALAM(3,1)*SM*CAMB/DEN4+ALAM(2,1)*SM*CMEWE*DEN3/DEN4
      GPM=ALAM(3,2)*PM*CAMB/DEN4+ALAM(2,2)*PM*CMEWE*DEN3/DEN4
      GUM=ALAM(3,3)*USM*CAMB/DEN4+ALAM(2,3)*USM*CMEWE*DEN3/DEN4
      GVM=ALAM(4,4)*VSM*SAMB/DEN4
40    G=GSM+GPM+GUM+GVM
      DEN5=DEN1*SAMB
      PSIYS=-(GSM+ALAM(2,1)*SM*CMEWE)/DEN5
      PSIYP=-(GPM+ALAM(2,2)*PM*CMEWE)/DEN5
      PSIYU=-(GUM+ALAM(2,3)*USM*CMEWE)/DEN5
      PSIYV=-GVM/DEN5
      PSIY=PSIYS+PSIYP+PSIYU+PSIYV
      GO TO 34
41    DEN4=1,0-DEN3
      GSM=-ALAM(3,1)*SM*CAMB/DEN4-ALAM(2,1)*SM*CMEWE*DEN3/DEN4
      GPM=-ALAM(3,2)*PM*CAMB/DEN4-ALAM(2,2)*PM*CMEWE*DEN3/DEN4
      GUM=-ALAM(3,3)*USM*CAMB/DEN4-ALAM(2,3)*USM*CMEWE*DEN3/DEN4
      GVM=-ALAM(4,4)*VSM*SAMB/DEN4
      GO TO 40
999   CONTINUE
      END
```

FORTRAN DIAGNOSTIC RESULTS FOR DIONE

NO ERRORS

DIONE P 10575 C 00050 D 00002

27696

```
FORTRAN (3.0)/MASTER                                                    02/21/69

       FUNCTION ALOG10( X )
 C
       TENLOGE = 0.43429448192
       ALOG10 = TENLOGE * ALOG(X)
 C
       RETURN
       END

         FORTRAN DIAGNOSTIC RESULTS FOR       ALOG10

NO ERRORS

   ALOG10      P   00042   C   00000   D   00000
X.LGO
```

7697

APPENDIX C

Typical Set of Results
from
Program DIONE

```
02/19/69                         SHOCK       INTERACTION,                                   RUN NUMBER   5
--------                         --------------------------                                 -------------

NUMBER OF SETS OF DATA                                                              =      1
INITIAL VALUE OF DELTA                                                              =           0  DEGREES,
STEP LENGTH IN DELTA                                                                =   1,0000E 00  DEGREES,
FINAL VALUE OF DELTA                                                                =   9,0000E 01  DEGREES,
EM1 THE UPSTREAM FLOW MACH NUMBER                                                   =   2,4000E 00
EPSILON THE SHOCK WAVE ANGLE REFERENCED TO THE X1 AXIS                              =   3,5000E 01
BETA THE ANGLE BETWEEN THE SHOCK WAVE AND THE DOWNSTREAM MEAN FLOW VELOCITY VECTOR  =   2,3000E 01
A1 THE SPEED OF SOUND IN THE FLOW FIELD UPSTREAM OF THE SHOCK                       =   1,1200E 03
IU1 THE UPSTREAM TURBULENCE INTENSITY ALONG THE X1 AXIS                             =   1,0000E-01
IV1 THE UPSTREAM TURBULENCE INTENSITY NORMAL TO THE X1 AXIS                         =   1,0000E-01
SPL1 THE OVERALL UPSTREAM SOUND FIELD                                               =   1,2000E 02
IT1 THE UPSTREAM ENTROPY FLUCTUATION INTENSITY                                      =   5,0000E-02
GAMMA THE RATIO OF SPECIFIC HEATS                                                   =   1,4000E 00
PM1 THE AMBIENT STATIC UPSTREAM PRESSURE                                            =   1,4600E 01


M THE DOWNSTREAM FLOW MACH NUMBER                                                   =   1,9189E 00
N1 THE UPSTREAM MACH NUMBER CORRESPONDING TO A NORMAL SHOCK OF EQUIVALENT STRENGTH  =   1,3766E 00
N THE DOWNSTREAM MACH NUMBER CORRESPONDING TO A NORMAL SHOCK OF EQUIVALENT STRENGTH =   7,4978E-01
CHI SHOCK STRENGTH IN TERMS OF RATIO OF PRESSURE OF UNPERTURBED FLOW ACROSS THE SHOCK = 2,0441E 00
RORAT THE DENSITY RATIO ACROSS THE SHOCK, DOWNSTREAM TO UPSTREAM                    =   1,6490E 00
A THE SPEED OF SOUND IN THE FLOW FIELD DOWNSTREAM  OF  SHOCK                        =   1,2470E 03
ARAT THE RATIO OF ACOUSTIC VELOCITIES ACROSS THE SHOCK, DOWNSTREAM TO UPSTREAM      =   1,1134E 00
U1 THE MEAN FLOW VELOCITY UPSTREAM OF THE SHOCK                                     =   2,6880E 03
U THE MEAN FLOW VELOCITY DOWNSTREAM OF THE SHOCK                                    =   2,3929E 03
SM THE DIMENSIONLESS MAGNITUDE OF THE UPSTREAM ENTROPY PERTUBATION                  =   1,0760E-01
PM THE DIMENSIONLESS MAGNITUDE OF THE UPSTREAM PRESSURE PERTUBATION                 =   1,4154E-04
UL1 THE DIMENSIONLESS MAGNITUDE OF THE DOWNSTREAM VELOCITY PERTURBATION ALONG X1 AXIS = 2,4000E-01
VL1 THE DIMENSIONLESS MAGNITUDE OF THE DOWNSTREAM VELOCITY PERTURBATION ALONG Y1 AXIS = 2,4000E-01
USM THE DIMENSIONLESS MAGNITUDE OF THE UPSTREAM VELOCITY PERTUBATION ALONG X* AXIS  =  -5,8936E-02
VSM THE DIMENSIONLESS MAGNITUDE OF THE UPSTREAM VELOCITY PERTUBATION ALONG Y* AXIS  =   3,3425E-01


MATRIX LAMBDA(I,J)  TRANSFER COEFFICIENTS FOR THE INTERACTION,
--------------------------------------------------------------

  9,5264E-01     -1,8944E-02      6,8607E-02           0
 -7,7252E-01      6,9099E-01      1,1224E 00           0
  5,4372E-01      2,1749E-01     -2,4528E-01           0
           0               0               0      8,9816E-01


VECTOR OF PI(I)  TRANSFER COEFFICIENTS OF THE INTERACTION,
----------------------------------------------------------

 -7,6608E-02     -1,2496E 00      1,2731E 00      4,8662E-01
```

```
THE TOTAL DOWNSTREAM SOUND PRESSURE LEVEL                                                              =   1.9094E 02
THE DOWNSTREAM SOUND PRESSURE LEVEL DUE TO UPSTREAM ENTROPY PERTURBATIONS                              =   1.9112E 02
THE DOWNSTREAM SOUND PRESSURE LEVEL DUE TO UPSTREAM PRESSURE PERTURBATIONS                             =   1.2626E 02
THE DOWNSTREAM SOUND PRESSURE LEVEL DUE TO UPSTREAM  VELOCITY PERTURBATIONS                            =   1.9322E 02

THE TOTAL DOWNSTREAM ENTROPY INTENSITY                                                                 =   6.3427E-02
THE DOWNSTREAM ENTROPY INTENSITY DUE TO UPSTREAM ENTROPY PERTURBATIONS                                 =   6.5617E-02
THE DOWNSTREAM ENTROPY INTENSITY DUE TO UPSTREAM PRESSURE PERTURBATIONS                                =   7.9120E-06
THE DOWNSTREAM ENTROPY INTENSITY DUE TO UPSTREAM  VELOCITY PERTURBATIONS                               =   1.1196E-02

THE TOTAL DOWNSTREAM VORTICITY COMPONENT ALONG X-AXIS                                                  =   1.3982E-01
THE DOWNSTREAM VORTICITY COMPONENT ALONG X-AXIS DUE TO UPSTREAM ENTROPY PERTURBATIONS                  =   1.0977E-01
THE DOWNSTREAM VORTICITY COMPONENT ALONG THE X-AXIS DUE TO UPSTREAM PRESSURE PERTURBATIONS             =   9.3271E-05
THE DOWNSTREAM VORTICITY ALONG THE X-AXIS DUE TO UPSTREAM  VELOCITY PERTURBATIONS                      =   2.0557E-01

THE TOTAL DOWNSTREAM VORTICITY COMPONENT ALONG THE Y-AXIS                                              =   2.4743E-01
THE DOWNSTREAM VORTICITY COMPONENT ALONG THE Y-AXIS DUE TO UPSTREAM ENTROPY PERTURBATIONS              =   1.4278E-01
THE DOWNSTREAM VORTICITY COMPONENT ALONG THE Y-AXIS DUE TO UPSTREAM PRESSURE PERTURBATIONS             =   1.1472E-04
THE DOWNSTREAM VORTICITY COMPONENT ALONG THE Y-AXIS DUE TO UPSTREAM  VELOCITY PERTURBATIONS            =   2.3537E-01

DIMENSIONLESS MAGNITUDE OF DOWNSTREAM VELOCITY PERTURBATION COMPONENT ALONG X*-AXIS                    =   3.9230E-01
DIMENSIONLESS MAGNITUDE OF DOWNSTREAM VELOCITY PERTURBATION COMPONENT ALONG Y*-AXIS                    =   3.7884E-01
DIMENSIONLESS MAGNITUDE OF DOWNSTREAM VELOCITY PERTURBATION COMPONENT ALONG X1-AXIS                    =   3.1434E-01
DIMENSIONLESS MAGNITUDE OF DOWNSTREAM VELOCITY PERTURBATION COMPONENT ALONG Y1-AXIS                    =   4.4566E-01
DOWNSTREAM VORTICITY BASED ON UL1 AND VL1                                                              =   5.4536E-01

DOWNSTREAM SOUND PRESSURE LEVEL FOR ME GT. 1                                                           =   1.9384E 02
DOWNSTREAM SOUND PRESSURE LEVEL FOR ME LT. 1                                                           =   1.8721E 02

NOTE THAT THE FOLLOWING RESULTS HAVE BEEN COMPUTED BY USING AN ALTERNATIVE METHOD OF NUMERICAL INTEGRATION.

THE TOTAL DOWNSTREAM SOUND PRESSURE LEVEL                                                              =   1.9099E 02
THE DOWNSTREAM SOUND PRESSURE LEVEL DUE TO UPSTREAM ENTROPY PERTURBATIONS                              =   1.8581E 02
THE DOWNSTREAM SOUND PRESSURE LEVEL DUE TO UPSTREAM PRESSURE PERTURBATIONS                             =   1.2237E 02
THE DOWNSTREAM SOUND PRESSURE LEVEL DUE TO UPSTREAM  VELOCITY PERTURBATIONS                            =   1.8941E 02

THE TOTAL DOWNSTREAM ENTROPY INTENSITY                                                                 =   6.2596E-02
THE DOWNSTREAM ENTROPY INTENSITY DUE TO UPSTREAM ENTROPY PERTURBATIONS                                 =   6.2178E-02
THE DOWNSTREAM ENTROPY INTENSITY DUE TO UPSTREAM PRESSURE PERTURBATIONS                                =   5.4278E-06
THE DOWNSTREAM ENTROPY INTENSITY DUE TO UPSTREAM  VELOCITY PERTURBATIONS                               =   7.2249E-03

THE TOTAL DOWNSTREAM VORTICITY COMPONENT ALONG X-AXIS                                                  =   1.6303E-01
THE DOWNSTREAM VORTICITY COMPONENT ALONG X-AXIS DUE TO UPSTREAM ENTROPY PERTURBATIONS                  =   7.0590E-02
THE DOWNSTREAM VORTICITY COMPONENT ALONG THE X-AXIS DUE TO UPSTREAM PRESSURE PERTURBATIONS             =   7.381[illegible]E-05
THE DOWNSTREAM VORTICITY ALONG THE X-AXIS DUE TO UPSTREAM  VELOCITY PERTURBATIONS                      =   1.4695E-01

THE TOTAL DOWNSTREAM VORTICITY COMPONENT ALONG THE Y-AXIS                                              =   2.3935E-01
THE DOWNSTREAM VORTICITY COMPONENT ALONG THE Y-AXIS DUE TO UPSTREAM ENTROPY PERTURBATIONS              =   7.8173E-02
THE DOWNSTREAM VORTICITY COMPONENT ALONG THE Y-AXIS DUE TO UPSTREAM PRESSURE PERTURBATIONS             =   7.7994E-05
THE DOWNSTREAM VORTICITY COMPONENT ALONG THE Y-AXIS DUE TO UPSTREAM  VELOCITY PERTURBATIONS            =   2.2623E-01

DIMENSIONLESS MAGNITUDE OF DOWNSTREAM VELOCITY PERTURBATION COMPONENT ALONG X*-AXIS                    =   2.8624E-01
DIMENSIONLESS MAGNITUDE OF DOWNSTREAM VELOCITY PERTURBATION COMPONENT ALONG Y*-AXIS                    =   4.7633E-01
DIMENSIONLESS MAGNITUDE OF DOWNSTREAM VELOCITY PERTURBATION COMPONENT ALONG X1-AXIS                    =   4.3139E-01
DIMENSIONLESS MAGNITUDE OF DOWNSTREAM VELOCITY PERTURBATION COMPONENT ALONG Y1-AXIS                    =   3.5032E-01
DOWNSTREAM VORTICITY BASED ON UL1 AND VL1                                                              =   5.5572E-01

DOWNSTREAM SOUND PRESSURE LEVEL FOR ME GT. 1                                                           =   1.8984E 02
DOWNSTREAM SOUND PRESSURE LEVEL FOR ME LT. 1                                                           =   1.8464E 02
```

27710