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HIGH VELOCITY JET NOISE SOURCE LOCATION AND REDUCTION. TASK 2 S--ETC(U)

MAY 78 P R GLIEBE DOT-OS-30034

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# HIGH VELOCITY JET NOISE SOURCE LOCATION AND REDUCTION



## TASK 2 SUPPLEMENT - COMPUTER PROGRAM FOR CALCULATING THE AEROACOUSTIC CHARACTERISTICS OF JETS FROM NOZZLES OF ARBITRARY SHAPE

TECHNICAL CONTRIBUTOR:

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MAY 1978

FINAL REPORT

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**Washington, D.C. 20590**

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16. Abstract

A computational procedure is presented for predicting the aerodynamic and acoustic characteristics of jets from nozzles of arbitrary shape. The procedure treats the jet plume as a collection of uncorrelated multipole sound sources which convect with the flow. The aerodynamic characteristics of the jet are evaluated utilizing an extension of Reichardt's theory for free turbulent flows. The acoustic radiation from each of the sound sources is evaluated from high-frequency asymptotic solutions of Lilley's equation. The jet plume is subdivided into several hundred elemental volume sources, each roughly the size of a turbulent eddy volume. The correlated sound level spectra of the individual eddy volumes are summed on a mean-square pressure basis to yield the total turbulent mixing noise levels. An auxiliary calculation of shock-cell broadband noise is made and added to the turbulent mixing noise spectrum to give the total farfield noise. A description of the computational model and associated computer program is presented herein, along with a sample of input and output. A FORTRAN listing of the computer program is also included.

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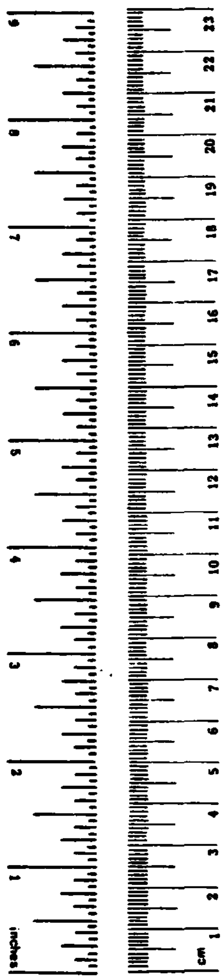
# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

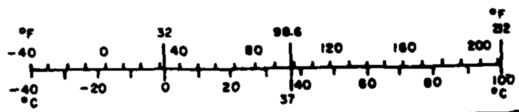
| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | *2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 6.5 | square centimeters | $cm^2$ |
| $ft^2$ | square feet | 0.09 | square meters | $m^2$ |
| $yd^2$ | square yards | 0.8 | square meters | $m^2$ |
| $mi^2$ | square miles | 2.6 | square kilometers | $km^2$ |
| | acres | 0.4 | hectares | ha |
| | | **MASS (weight)** | | |
| oz | ounces | 28 | grams | g |
| lb | pounds | 0.45 | kilograms | kg |
| | short tons (2000 lb) | 0.9 | tonnes | t |
| | | **VOLUME** | | |
| tsp | teaspoons | 5 | milliliters | ml |
| Tbsp | tablespoons | 15 | milliliters | ml |
| fl oz | fluid ounces | 30 | milliliters | ml |
| c | cups | 0.24 | liters | l |
| pt | pints | 0.47 | liters | l |
| qt | quarts | 0.95 | liters | l |
| gal | gallons | 3.8 | liters | l |
| $ft^3$ | cubic feet | 0.03 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.76 | cubic meters | $m^3$ |
| | | **TEMPERATURE (exact)** | | |
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.




## Approximate Conversions from Metric Measures

| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.04 | inches | in |
| cm | centimeters | 0.4 | inches | in |
| m | meters | 3.3 | feet | ft |
| m | meters | 1.1 | yards | yd |
| km | kilometers | 0.6 | miles | mi |
| | | **AREA** | | |
| $cm^2$ | square centimeters | 0.16 | square inches | $in^2$ |
| $m^2$ | square meters | 1.2 | square yards | $yd^2$ |
| $km^2$ | square kilometers | 0.4 | square miles | $mi^2$ |
| ha | hectares (10,000 $m^2$) | 2.5 | acres | |
| | | **MASS (weight)** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.2 | pounds | lb |
| t | tonnes (1000 kg) | 1.1 | short tons | |
| | | **VOLUME** | | |
| ml | milliliters | 0.03 | fluid ounces | fl oz |
| l | liters | 2.1 | pints | pt |
| l | liters | 1.06 | quarts | qt |
| l | liters | 0.26 | gallons | gal |
| $m^3$ | cubic meters | 35 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.3 | cubic yards | $yd^3$ |
| | | **TEMPERATURE (exact)** | | |
| °C | Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | °F |



## PREFACE

This report describes the work performed under Task 2 of the DOT/FAA High Velocity Jet Noise Source Location and Reduction program (Contract DOT-OS-30034). The objectives of the program were:

- Investigation of the aerodynamic and acoustic mechanisms of various jet noise suppressors, including scaling effects
- Analytical and experimental studies of the acoustic source distribution in such suppressors, including identification of source location, nature and strength and noise reduction potential
- Investigation of inflight effects on the aerodynamic and acoustic performance of these suppressors.

The results of these investigations lead to the preparation of a design guide report for predicting the overall characteristics of suppressor concepts from models to full-scale static, to inflight conditions, as well as a quantitative and qualitative prediction of the phenomena involved.

The work effort in this program was organized under the following major Tasks, each of which is reported in a separate final report:

Task 1 - Activation of Facilities and Validation of Source Location Techniques.

Task 2 - Theoretical Developments and Basic Experiments.

Task 3 - Experimental Investigation of Suppression Principles.

Task 4 - Development and Evaluation of Techniques for Inflight Investigation.

Task 5 - Investigation of Inflight Aero-Acoustic Effects on Suppressed Exhausts.

Task 6 - Preparation of Noise Abatement Nozzle Design Guide Report.

Task 1 was an investigative and survey effort designed to identify acoustic facilities and test methods best suited to jet noise studies. Task 2 was a theoretical effort complemented by theory verification experiments which extended across the entire contract period of performance.

This volume is a supplement to the Task 2 report, documenting a general method for predicting the aerodynamic and acoustic behavior of turbulent jets. The objective of the report is to provide users with a description of the method and associated computational procedure in sufficient detail that it can be implemented and utilized as a useful engineering tool.

Task 3 represented a substantial contract effort to gather various test data on a wide range of high velocity jet nozzle suppressors. These data, intended to help identify several "optimum" nozzles for inflight testing under Task 5, provide an extensive high quality data bank useful to preparation of the Task 6 design guide as well as to future studies.

Task 4 was similar to Task 1, except that it dealt with the specific test facility requirements, measurement techniques and analytical methods necessary to evaluate the inflight noise characteristics of simple and complex suppressor nozzles. This effort provided the capability to conduct the "flight" effects test programs of Task 5.

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## SYMBOLS

| | | |
|---|---|---|
| $A_j$ | - | jet nozzle exhaust area |
| AR | - | outer-to-inner stream area ratio |
| $a_{xx}$ | - | (x-x) quadrupole directivity factor |
| $a_{xy}$ | - | (x-y) quadrupole directivity factor |
| $a_{yy}$ | - | (y-y) quadrupole directivity factor |
| $a_{yz}$ | - | (y-z) quadrupole directivity factor |
| $b_h$ | - | enthalpy mixing layer thickness |
| $b_m$ | - | momentum mixing layer thickness |
| C | - | convective amplification factor |
| $C_h$ | - | enthalpy mixing layer spreading parameter |
| $C_j$ | - | jet exit plane speed of sound |
| $C_m$ | - | momentum mixing layer spreading parameter |
| $C_a$ | - | ambient speed of sound |
| $C_p$ | - | specific heat at constant pressure |
| $C_1$ | - | empirical constant in spreading parameter equation |
| $C_2$ | - | empirical constant in spreading parameter equation |
| $D_{eq}$ | - | equivalent area nozzle diameter $\sqrt{4A_j/\pi}$ |
| $D_h$ | - | nozzle hydraulic diameter $4A_j/P_w$ |
| f | - | observed frequency |
| $f_p$ | - | peak-noise observed frequency |
| $g^2(r)$ | - | shielding function |
| H | - | stagnation enthalpy relative to ambient |
| $I(\Omega)$ | - | source intensity spectrum |
| k | - | source wave number $\Omega/C_a$ |
| $L_{avg}$ | - | average shock cell spacing |
| M | - | flow Mach number $U/C_a$ |
| $M_a$ | - | ambient (windtunnel or flight) Mach number |
| $M_c$ | - | eddy convection Mach number $U_c/C_a$ |
| $M_j$ | - | jet nozzle exit plane Mach number $U_j/C_a$ (also $U_j/C_j$ for shock noise prediction) |
| $M_m$ | - | postmerged region potential core Mach number |
| $M_o$ | - | Mach number at source location, $M(r_o)$ |
| N | - | number of shock cells |
| OASPL | - | overall sound pressure level, dB re 0.0002 μ-bar |

| | | |
|---|---|---|
| PNL | - | perceived noise level, dB re 0.0002 μ-bar |
| PR | - | nozzle stagnation-to-ambient static pressure ratio |
| PWL | - | power watt level, dB re $10^{-13}$ watts |
| $P_w$ | - | wetted perimeter of nozzle contour |
| $p_a$ | - | ambient static pressure |
| $\overline{p^2}$ | - | mean-square acoustic pressure |
| R | - | source-to-observer distance |
| $R_o$ | - | flow field calculation transverse coordinate |
| $R_g$ | - | gas constant (1716 $lb_f$-ft/slug-° R) |
| r | - | radial coordinate |
| $r_b(x)$ | - | centerbody radius |
| $r_o$ | - | radial source location |
| $r_\sigma$ | - | radial turning point location |
| SPL | - | sound pressure level, dB re 0.0002 μ-bar |
| $SPL_p$ | - | peak value of SPL 1/3-octave spectrum |
| T | - | flow static temperature |
| $T_a$ | - | ambient static temperature |
| $T_T$ | - | flow stagnation temperature |
| $T_{Tj}$ | - | nozzle exit jet stagnation temperature |
| TR | - | outer-to-inner stream temperature ratio |
| U | - | local mean flow velocity |
| $U_a$ | - | ambient (wind-tunnel or flight) velocity |
| $U_c$ | - | eddy convection speed |
| $U_j$ | - | jet exit plane velocity |
| $U_m$ | - | postmerged potential core velocity |
| $U_o$ | - | mean flow velocity at source location |
| u' | - | axial turbulence velocity (r.m.s. intensity) |
| $V_j$ | - | ideally expanded jet velocity |
| VR | - | outer-to-inner stream velocity ratio |
| x | - | axial coordinate |
| y | - | vector location of eddy volume in jet |
| α | - | coefficient in acoustic calculation; also angular coordinate of nozzle boundary contour |
| $\alpha_t$ | - | turbulent decay parameter in convective amplification factor |

$\beta$ - shock strength parameter

$\beta_{xx}$ - (x-x) quadrupole shielding factor

$\beta_{xy}$ - (x-y) quadrupole shielding factor

$\beta_{yy}$ - (y-y) quadrupole shielding factor

$\beta_{yz}$ - (y-z) quadrupole shielding factor

$\beta_{01}$ - shielding factor for case (c)

$\beta_{02}$ - shielding factor for case (e)

$\beta_{12}$ - shielding factor for case (f)

$\beta_t$ - axial shear stress weighting factor

$\gamma$ - ratio of specific heats

$\Delta r$ - transformed radial coordinate

$\Delta \nu$ - transformed boundary radius

$\delta_t$ - aximuthal shear stress weighting factor

$\theta$ - observer angle relative to jet axis

$\theta_i$ - observer angle relative to inlet axis, $\theta_i = 180° - \theta$

$\mu_t$ - characteristic time-delay azimuthal weighting factor

$\nu_o$ - radial coordinate of nozzle boundary contour

$\rho$ - flow mean density

$\rho_a$ - ambient density

$\rho_j$ - jet exit plane density

$\tau_o$ - characteristic time-delay

$\tau_x$ - axial shear stress

$\tau_r$ - radial shear stress

$\tau_\phi$ - azimuthal shear stress

$\Phi$ - flow field calculation azimuthal coordinate

$\phi$ - azimuthal angular coordinate

$\psi$ - enthalpy function

$\Omega$ - source radian frequency

$\omega$ - observer radian frequency

Subscripts

a - ambient condition

ann - referring to annulus property

b - centerbody parameter

| | | |
|---|---|---|
| c | - | convection property |
| eq | - | equivalent condition |
| g | - | gas property |
| h | - | referring to enthalpy or heat transport |
| i | - | referring to component in i-direction; also, referenced to inlet axis |
| j | - | referring to jet exit plane condition |
| m | - | referring to momentum transport; also, postmerged condition |
| o | - | referring to source location condition |
| p | - | peak noise value |
| r | - | radial component |
| T | - | stagnation condition |
| t | - | referring to a turbulence parameter |
| x | - | axial component |
| xx | - | referring to (x-x) quadrupole property |
| xy | - | referring to (x-y) quadrupole property |
| yy | - | referring to (y-y) quadrupole property |
| yz | - | referring to (y-z) quadrupole property |
| $\sigma$ | - | referring to turning point property |
| $\phi$ | - | azimuthal component |

# 1.0 SUMMARY

This report represents a supplemental Task 2 effort under Contract DOT-OS-30034 documenting the computerized jet noise prediction method. A complete description of the computer program is provided, including examples of input preparation, output cases, and a listing of the FORTRAN computer code. The mathematical model is briefly summarized (it appears in detail in the Task 2 report proper).

A unified aerodynamic/acoustic prediction technique has been developed for assessing the noise characteristics of suppressor nozzles. The technique utilizes an extension of Reichardt's method to provide predictions of the jet plume flow field (velocity, temperature and turbulence intensity distributions). The turbulent fluctuations produced in the mixing regions of the jet are assumed to be the primary source of noise generation, as in the classical theories of jet noise. The alteration of the generated noise by the jet plume itself as it propagates through the jet to the far-field observer (sound/flow interaction or fluid shielding) is modelled utilizing the high-frequency shielding theory based on Lilley's equation.

These basic modelling elements (flow field prediction turbulent mixing noise generation, and sound/flow interaction) have been coupled together in a discrete volume-element formulation. The jet plume is divided into elemental volumes, each roughly the size of a representative turbulence correlation volume appropriate to that particular location in the plume. Each volume element is assigned its own characteristic frequency, spectrum, and acoustic intensity. The sound/flow interaction effects for each volume element are evaluated from the flow environment of the element. The individual volume elements are assumed to be uncorrelated with each other, so that the total contribution to the far field is simply the sum of the individual volume element contributions.

The aero-acoustic model discussed herein is directed toward prediction of high velocity jet noise (1500 - 3000 feet per second), for arbitrary nozzle shapes, including sound pressure level spectra at any observer location.

The model in its present form does have certain limitations. For multielement configurations, all elements must be parallel and non-impinging. In addition, the flow field calculation assumes constant static pressure mixing, so that multichute or multitube nozzles with significant base pressure variations will not be properly simulated. This limitation is important for closely-spaced nozzle elements. Finally, the shock-cell noise portion of the prediction is likely to be inadequate for multielement and/or multiflow configurations.

## 2.0 INTRODUCTION

Many jet noise suppressor nozzles have been designed utilizing intuitive notions of how to suppress jet noise, and have demonstrated substantial noise reduction, although often at the expense of considerable thrust loss, increased engine weight, manufacturing cost and complexity. Seemingly minor changes in suppressor nozzle design, for the purpose of improving thrust performance, often result in substantial loss of noise suppression. It is therefore highly desirable to have available a quantitative prediction technique for estimating the aerodynamic and acoustic characteristics of suppressor-type nozzle configurations, so that design and optimization studies can be made prior to construction and testing in order to minimize the time and cost of development. This technique should ideally be sensitive to the controllable design variables, and should be based on a minimum of empiricism. Any empiricism employed should be tied more or less to physical (flow and acoustic propagation) characteristics rather than geometric parameters, i.e., it should be "universal" in a normalized (but perhaps restricted) sense.

Previous work on modelling of jet aero-acoustic characteristics has been confined to simple round and coannular jets. One of the first attempts at developing a comprehensive aerodynamic acoustic jet model was published by Lee, Kendall, et al., Reference (1), and Grose and Kendall, Reference (2). This approach utilized an extension of Reichardt's method for predicting the jet flow properties (this method is adopted herein and in Reference 3) for round and lobe-type nozzles. Acoustic power spectra are predicted in Reference (1) and (2), based on a "slice-of-jet" model wherein the power per axial slice is computed and related to a certain frequency band by means of empirically-derived frequency versus axial distance relations. Successful predictions are confined to low Mach numbers. A volume-element summation ("lump-of-jet") approach was first developed by Benzakein et al., Reference (4), for round and coannular jets. A finite-difference turbulent-kinetic-energy model was developed therein to predict the jet flow field, while the classical Lighthill (5) and Ffowcs-Williams (6) formulations were employed, with suitable empirical modifications, to predict the noise from each volume element. Extensions of the method of Benzakein et al. (4) to distinguish between self-noise and shear-noise, proposed by Jones (7) and Ribner (8), were developed by Knott (9) and Moon (10). Recently, Chen (11) has applied Kendall's method (2) to predicting power spectra of coannular jets.

The above methods either ignore the sound/flow interaction effects completely, or recognize only source convection in absence of a shrouding flow, which has been shown to give incorrect simulation (see Mani, Reference 12) for all but the lowest jet velocities, especially when predicting sound pressure level spectra at observer angles close to the jet axis. The aero-acoustic model discussed in this report is directed toward prediction of high velocity jet noise (1500 - 3000 fps), for arbitrary nozzle shapes, including sound pressure level spectra at any observer location.

Section 3 summarizes the mathematical model (which is presented in detail in Reference 3) and Section 4 describes the computer program. A description of inputs to the computer program is presented in Appendix A and a description of the outputs is presented in Appendix B. Appendices C and D contain a sample output and a computer source listing for the program, respectively.

# 3.0 ANALYSIS

## 3.1 OUTLINE OF METHOD

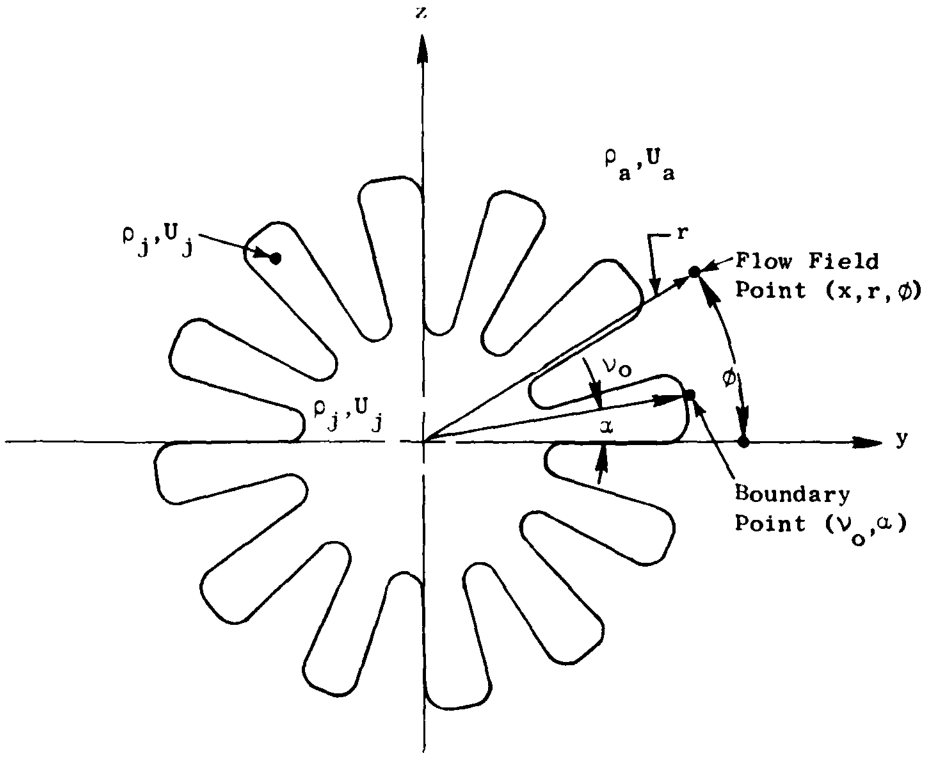
Consider a jet plume exhausting from a nozzle of arbitrary shape, as shown in Figure 1. Utilizing the modified Reichardt theory described in Reference (3), the mean velocity, temperature, density and turbulent shear stress distributions can be computed throughout the jet plume. The required inputs are nozzle shape, nozzle exit plane total pressures and temperatures, and ambient total and static pressures and temperatures.

The jet plume is subdivided into elemental volumes which are approximately the size of a typical turbulent correlation volume or "eddy size". The modified Reichardt theory can provide the aerodynamic properties at any arbitrary point in the plume because of the closed-form solution formulation (the calculation is not a finite-difference method whose grid points are established/ dictated by the accuracy/stability requirements of the numerical procedure). The flow properties are therefore computed at the geometric centers of these eddy volume elements.

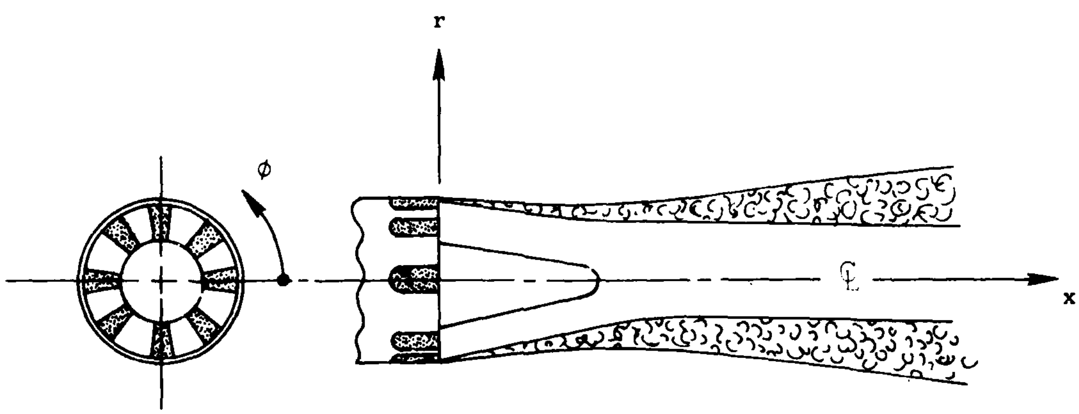
The noise generated by each of the volume elements is estimated from the classical Lighthill (5) expressions for noise produced by free turbulence, assuming that the turbulence can be modeled as locally-isotropic, convecting quadrupole sources of sound, as proposed by Ribner (8). The turbulent structure parameters (intensity, length-scale, characteristic frequency, spectrum) required for computing the generated noise are derived from the calculated mean-flow distributions using previously established empirical similarity relations, developed by Davies et al. (13).

For each volume element, the effect of convection and fluid shielding on the emitted sound of that element is computed. The flow properties in the vicinity of the element, i.e., mean velocity profiles and temperature profiles, determine the amount of flow shrouding or fluid shielding seen by that element. From the generated noise spectrum and the predicted convection and fluid shielding, the net emitted noise level, at each observer angle and 1/3-octave band frequency of interest, is calculated. The contributions from each volume element in the jet are summed on a mean-square pressure basis, assuming that individual volume elements are uncorrelated with each other, to provide the total 1/3-octave spectrum observed in the far field sound pressure.

A typical example of how a jet plume is subdivided into "eddy" volume elements is illustrated in Figure 2. The subdivisions are very small close to the nozzle exit plane where the turbulence length-scales are small, and the volume elements are made progressively larger in the downstream direction, simulating the increasing length-scale with downstream distance.




(b) Typical Suppressor Nozzle Exit Plane Planform Shape and Nomenclature




(a) Jet Plume Coordinate System

Figure 1. Typical Jet Plume Exhausting from a Nozzle of Arbitrary (Noncircular) Planform Shape.

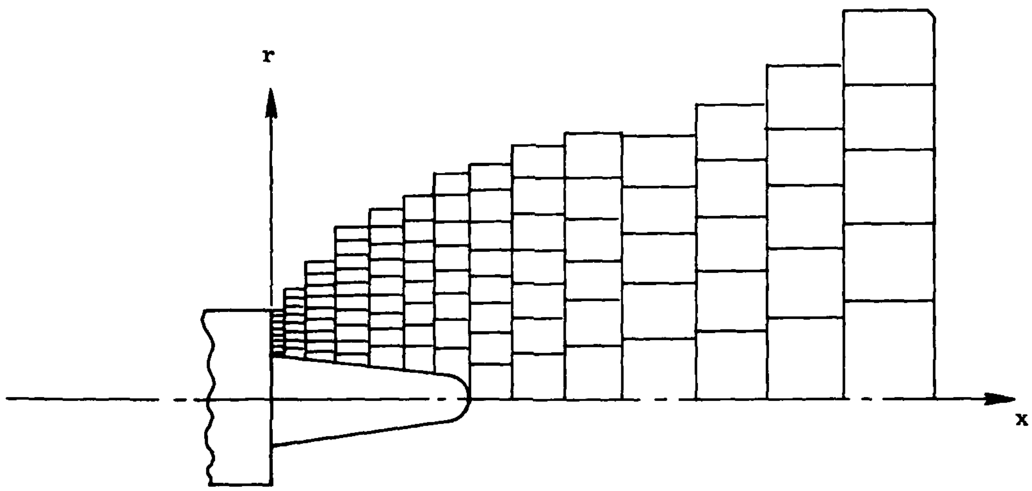



**Figure 2.** Typical Jet Plume Flow Field Subdivision (Not to Scale) into Eddy Volume Elements.

In addition to the calculation of turbulent mixing noise, the shock-cell broadband noise is also computed using a modification of the Harper-Bourne/Fisher method, Reference (14), as described in Reference (3). The mixing noise spectra and the shock-cell noise spectra are summed on a mean-square pressure basis to yield the total jet noise spectra, at each far-field observer angle.

A block diagram of the computation sequence for the jet noise prediction just described is shown in Figure 3. Note also that atmospheric attenuation corrections, using the method of Reference (15), are made to the predicted spectra to account for air attenuation at the appropriate far-field distance. From the far-field sound pressure spectra, the overall sound pressure levels (OASPL), perceived noise levels (PNL) and sound power spectrum (PWL) are also evaluated.

## 3.2 FLOW FIELD PREDICTION

The jet plume flow field is computed using the extension of Reichardt's method developed in Reference (3). The method basically consists of predicting the diffusive transport of momentum flux and enthalpy flux from a specified exit plane distribution to various axial stations along the plume. In addition, the various components of turbulent shear stress are also calculated, being related to directional derivatives of the axial component of momentum flux. From these distributions, the mean axial velocity, density and turbulence intensity distributions are estimated.

A typical suppressor nozzle planform shape at the nozzle exit plane is shown in Figure 1. The nozzle contour can be defined by coordinates ($\nu_o$, $\alpha$). The jet nozzle exit plane conditions are denoted by subscript "j", and ambient field (external flow) conditions by subscript "a". The flow conditions at any flow field point (x, r, $\phi$) are computed from the following equations, taken from Reference (3):

Momentum Transport:

$$\rho U^2 - \rho_a U_a^2 = \frac{1}{2\pi} \int (\rho_j U_j^2 - \rho_a U_a^2) \left[ 1 - e^{-R_o^2/b_m^2} \right] d\Phi \qquad (1)$$

Heat Transport:

$$\rho UH = \frac{1}{2\pi} \int (\rho_j U_j H_j) \left[ 1 - e^{-R_o^2/b_h^2} \right] d\Phi \qquad (2)$$

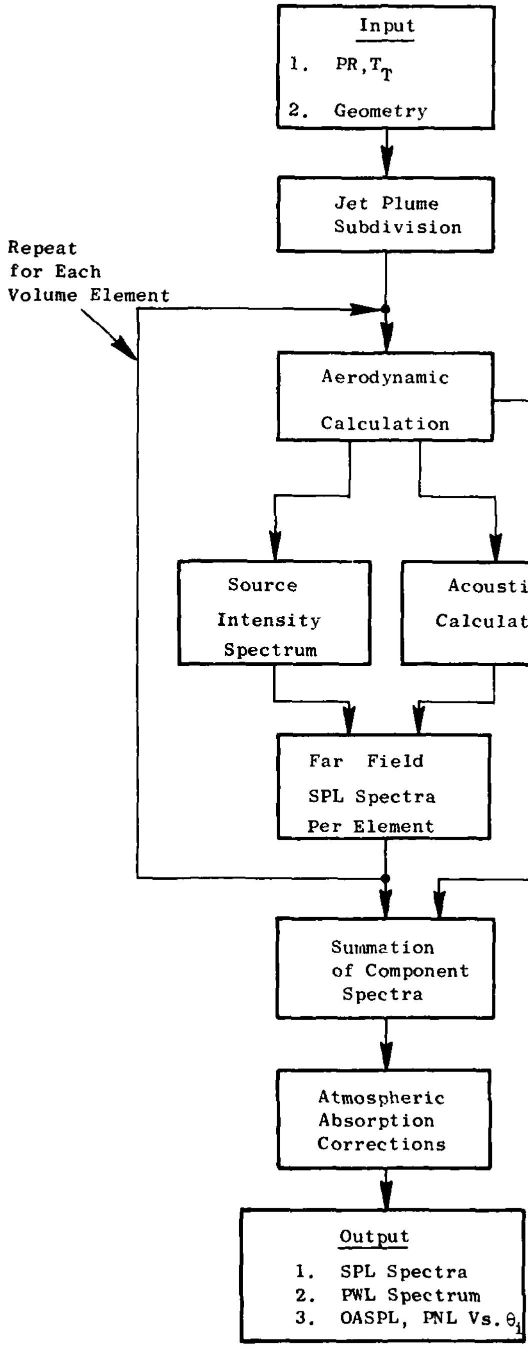



Figure 3. Block Diagram of Jet Noise Aeroacoustic Prediction Model.

Shear Stresses:

$$\frac{\tau_x}{\rho} = -\frac{C_m^2}{2\pi} \oint (U_j^2 - U_a^2) \left[ \frac{R_o^2}{b_m^2} e^{-R_o^2/b_m^2} \right] d\Phi \qquad (3)$$

$$\frac{\tau_r}{\rho} = \frac{C_m}{2\pi} \oint (U_j^2 - U_a^2) \left[ \frac{\sqrt{\pi}}{2} \operatorname{erf}\left(\frac{R_o}{b_m}\right) - \frac{R_o}{b_m} e^{-R_o^2/b_m^2} \right]$$

$$x \cos \Phi d\Phi \qquad (4)$$

$$\frac{\tau_\phi}{\rho} = \frac{C_m}{2\pi} \oint (U_j^2 - U_a^2) \left[ \frac{\sqrt{\pi}}{2} \operatorname{erf}\left(\frac{R_o}{b_m}\right) - \frac{R_o}{b_m} e^{-R_o^2/b_m^2} \right]$$

$$x \sin \Phi d\Phi \qquad (5)$$

where $\oint$ denotes a contour integral around the nozzle planform boundary.

In the above equations, U, $\rho$, and H are the mean velocity, density and enthalpy, respectively, and $\tau_x$, $\tau_r$ and $\tau_\phi$ are the x, r and $\phi$ - components of turbulent shear stress. The coordinates $R_o$ and $\Phi$ are defined by the relations

$$\left.\begin{aligned} R_o^2 &= (r - \nu_o)^2 + 2r\nu_o\,[1 - \cos(\phi-\alpha)] \\ \text{and} \quad R_o\cos\Phi &= r - \nu_o\cos(\phi-\alpha) \end{aligned}\right\} \qquad (6)$$

The turbulent mixing length parameters $b_m = C_m x$ and $b_h = C_h x$ are determined by the momentum spreading rate parameter $C_m$ and enthalpy spreading parameter $C_h$. Empirical expressions for these have been developed in Reference (3), and are as follows:

$$C_m = \frac{0.075}{(1 + C_1 VR)\,(1 + C_2 M_j)} \quad , \quad C_h = 1.15 C_m \qquad (7)$$

where VR = $U_a/U_j$ and $M_j = U_j/C_j$, the jet exit Mach number. The constants $C_1$ and $C_2$ were determined from calibrations with conical nozzle flow field velocity measurements, and values of $C_1 = 0.25$ and $C_2 = 0.08$ were found to give the best agreement with experiments.

The velocity and density are determined from the distributions of $(\rho U^2)$ and $(\rho UH)$ from the following expressions:

$$U = \frac{\rho UH}{2\psi} + \sqrt{\left(\frac{\rho UH}{2\psi}\right)^2 + \frac{C_p T_a (\rho U^2)}{\psi}} \tag{8}$$

where
$$H = C_p T + \frac{1}{2} \rho U^2 - C_p T_a \tag{9}$$

and
$$\psi = \frac{\gamma}{\gamma - 1} p + \frac{1}{2} (\rho U^2) \tag{10}$$

and
$$\rho = \frac{(\rho U^2)}{U^2} \quad ; \quad T = \frac{p}{\rho R_g} \tag{11}$$

In the above expressions, $C_p$ and $R_g$ are the specific heat at constant pressure and universal gas constant, respectively ($R_g = \gamma C_p/(\gamma-1)$), $\gamma$ is the ratio of specific heats, and p is the jet static pressure, assumed to be equal to the ambient static pressure. The local temperature is T, and $T_a$ is the ambient static value.

The axial turbulence intensity u' is computed from the shear stress components utilizing the following expression:

$$(u')^2 = \sqrt{(\tau_r/\rho)^2 + \delta_t \, (\tau_\phi/\rho)^2 + \beta_t \, (10 \, \tau_x/\rho)^2} \tag{12}$$

where $\delta_t$ and $\beta_t$ are empirically - determined constants.

Modifications to the above computation procedure are developed in Reference (3) for nozzles with an axisymmetric centerbody or plug. This modification consists of a coordinate transformation of the variables ($R_o$, $\Phi$) as follows:

$$\left.\begin{aligned} R_o^2 &= (\Delta r - \Delta\nu)^2 + 2\Delta r \Delta\nu\ [1-\cos(\phi-\alpha)] \\ R_o \cos\Phi &= \Delta r - \Delta\nu_o \cos(\phi-\alpha) \\ \text{where}\quad \Delta r &= \sqrt{r^2 - r_b^2\ (x)} \quad \text{and} \quad \Delta\nu = \sqrt{\nu_o^2 - r_b^2\ (o)} \end{aligned}\right\} \quad (13)$$

and $r_b(x)$ is the centerbody/plug contour coordinate specification. For $r_b(x) = 0$, Equation (13) reduce to Equation (6).

Equations (1) through (13) completely define the flow field calculation procedure. As discussed in the previous section, the flow properties are evaluated at all field points corresponding to eddy volume element centers $(x,r,\phi)$

## 3.3 TURBULENT MIXING NOISE PREDICTION

Expressions are developed in Reference (3), for the far-field noise of convected quadrupoles imbedded in a parallel shear flow, utilizing high-frequency asymptotic solutions to Lilley's equation. These expressions, for a source of unit volume and unit strength, when applied to a collection of sources distributed throughout a parallel shear flow model of the jet plume, yield the following equation for the far-field noise spectrum:

$$\overline{p^2}\,(R,\theta,\Omega) = \int_{\vec{y}} \alpha\,(a_{xx} + 4a_{xy} + 2a_{yy} + 2a_{yz})\,\overrightarrow{dy} \qquad (14)$$

where $\int (\ )d\vec{y}$ implies integration over the entire jet plume. The factors $a_{xx}$, $a_{xy}$, $a_{yy}$ and $a_{yz}$ are the directivity factors for each of the contributing quadrupole types contained in each turbulent eddy volume element. The factor $\alpha$ is given by

$$\alpha = \frac{I(\Omega)}{16\pi^2 R^2 C_a{}^4} \left(\frac{\rho_a}{\rho_o}\right)^2 \left(\frac{C_a}{C_o}\right)^2 (1-M_o\cos\theta)^{-2}(1-M_c\cos\theta)^{-2} \qquad (15)$$

where $I(\Omega)$ is given by

$$I(\Omega) = \rho_o^2\ (u')^7 (\Omega\tau_o)^4 \exp\left[-\frac{1}{8}\ (\Omega\tau_o)^2\right] \qquad (16)$$

and $\tau_o$ is the two-point velocity correlation characteristic time delay.

Subscript "o" refers to the volume-element or eddy-center location conditions. The parameters $M_o$ and $M_c$ are defined as

$$M_o = U_o / C_a \qquad M_c = U_c / C_a$$

where $U_c$ is the effective convection velocity of the eddy.

The directivity factors $a_{xx}$, $a_{xy}$, $a_{yy}$ and $a_{yz}$ have different forms, depending on the location of the source and the velocity and temperature profiles in the vicinity of the source. As discussed in Reference (3), these factors depend explicitly upon a shielding function $g^2$, which has the form

$$g^2(r) = \frac{(1-M\cos\theta)^2 (C_a/C)^2 - \cos^2\theta}{(1-M_c\cos\theta)^2} \tag{17}$$

where $C=C(r)$ and $M=M(r)/C_a$. Given a velocity $U(r)$ and temperature profiles $C(r) \sim \sqrt{T(r)}$, the shielding function profile can be computed per Equation (17). Depending on the observer angle $\theta$ and the profile shapes, the profile of $g^2(r)$ may have both positive and negative "zones", or may be positive for all values of r. If a negative region exists, then the possibility of fluid shielding of the sound source exists, depending on the location of the source relative to the negative or shielding zone. The location $r=r_o$ where $g^2(r)$ crosses zero is termed a turning point; practically speaking, more than one turning point can occur, although more than two turning points is very rare.

A maximum of two turning points is considered herein. This allows six possible situations regarding the source location relative to a shielding zone. These are illustrated qualitatively in Figure 4. This figure shows $g^2(r)$ plotted versus radial distance in the jet plume for six cases. In case (a), $g^2(r)$ is positive for all values of r, so no shielding of the source occurs no matter where it is located radially in the jet. In case (b), the source is located outboard of the region where $g^2(r)$ is negative, so still no shielding occurs. In case (c), however, the source is located inboard of the turning point, $r_o < r_{\sigma 1}$, and lies inside the shielding zone. The source will therefore be shielded to some extent.

In cases (d,e,f) shown in Figure 4, there are two turning points $r_{\sigma 1}$ and $r_{\sigma 2} > r_{\sigma 1}$. In case (d), the source lies outside of both turning points and therefore sees no shielding. In case (e), the source lies between the two turning points and thus is shielded by the fluid layer between $r=r_o$ and $r=r_{\sigma 2}$.

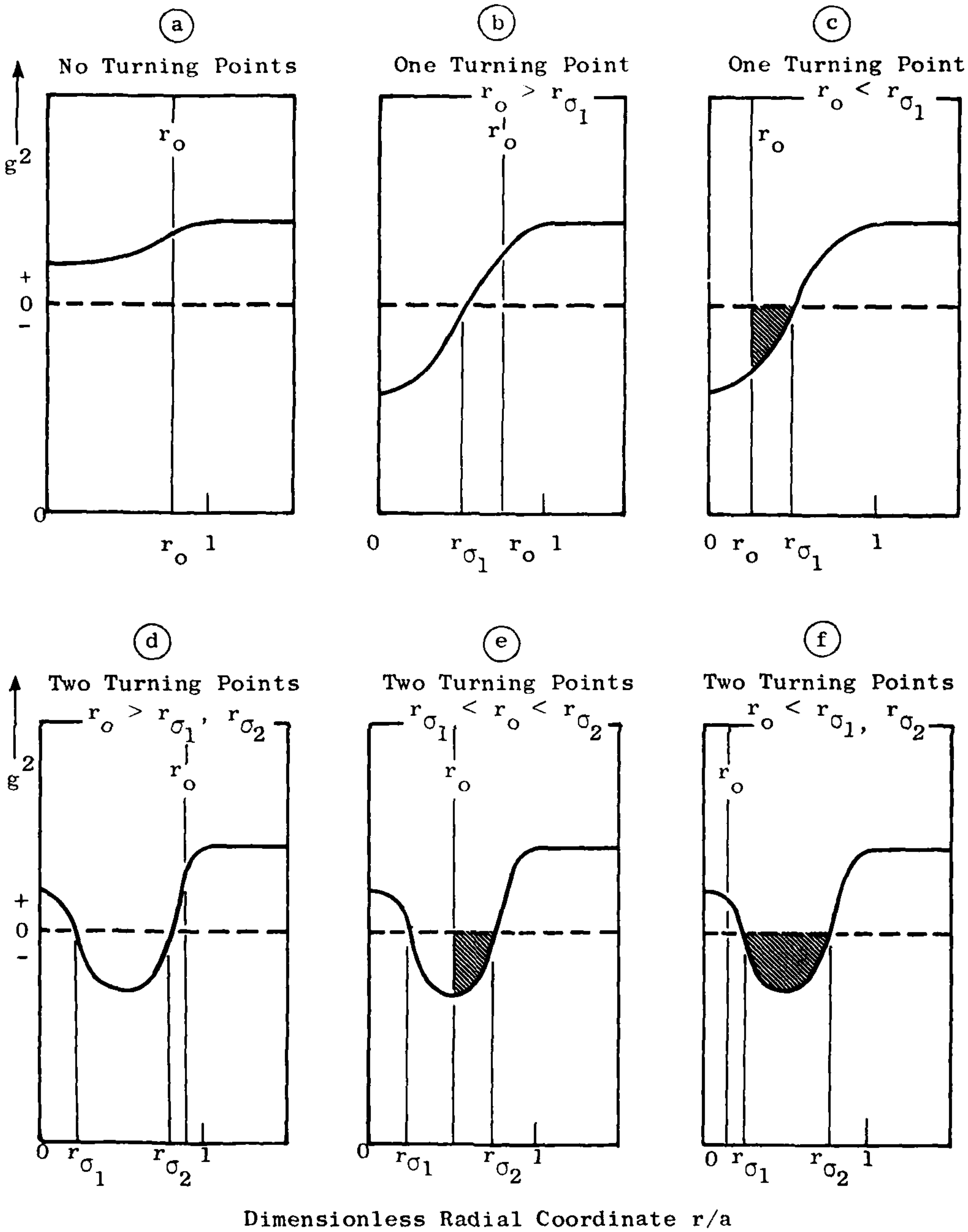



Figure 4. Possible Solution Types for a Maximum of Two Turning Points. Shaded Areas Denote Shielding of Source.

The acoustic radiation solutions for all of the six cases illustrated in Figure 4 are worked out in detail in References (3), and yield different forms for the directivity factors $a_{xx}$, $a_{xy}$, $a_{yy}$ and $a_{yz}$ for each case. These directivity factors have the following forms:

$$a_{xx} = \frac{\cos^4\theta}{(1-M_c\cos\theta)^4}\,\beta_{xx} \tag{18a}$$

$$a_{xy} = \frac{g_o^2\cos^2\theta}{2(1-M_c\cos\theta)^2}\,\beta_{xy} \tag{18b}$$

$$a_{yy} = \frac{3}{8}\,g_o^4\,\beta_{yy} \tag{18c}$$

$$a_{yz} = \frac{1}{8}\,g_o^4\,\beta_{yz} \tag{18d}$$

where $g_o^2$ is the value of $g^2(r)$ at the source radius $r=r_o$. The shielding coefficients $\beta_{xx}$, $\beta_{xy}$, $\beta_{yy}$ and $\beta_{yz}$ depend upon the case encountered in Figure 4. If the parameters $\beta_{01}$, $\beta_{02}$ and $\beta_{12}$ are defined as

$$\beta_{01} = \exp\left\{-2k\int_{r_o}^{r_{\sigma 1}} |g^2(r)|^{1/2}\,dr\right\} \tag{19a}$$

$$\beta_{02} = \exp\left\{-2k\int_{r_o}^{r_{\sigma 2}} |g^2(r)|^{1/2}\,dr\right\} \tag{19b}$$

$$\beta_{12} = \exp\left\{-2k\int_{r_{\sigma 1}}^{r_{\sigma 2}} |g^2(r)|^{1/2}\,dr\right\} \tag{19c}$$

where $k=\Omega/C_a$, the shielding coefficients are then determined from the following table:

Table 1. Shielding Coefficients $\beta_{ij}$.

| Case | $\beta_{xx}$ | $\beta_{xy}$ | $\beta_{yy}$ | $\beta_{yz}$ |
|---|---|---|---|---|
| a | 1 | 1 | 1 | 1 |
| b | 1 | 1 | 1 | 1 |
| c | $\beta_{01}$ | 0 | 0 | 0 |
| d | 1 | 1 | 1 | 1 |
| e | $\beta_{02}$ | 0 | 0 | 0 |
| f | $\beta_{12}$ | $\beta_{12}$ | $\beta_{12}$ | $\beta_{12}$ |

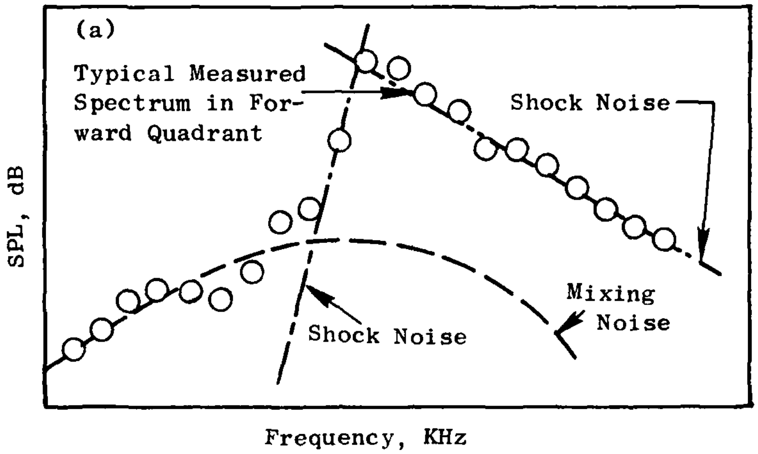
Note that a value of $\beta_{xx}$, etc., of unity indicates no fluid shielding, as in cases (a), (b) and (d). When the source is imbedded within the shielding zone, as in cases (c) and (e), only the x-x quadrupole contributes, for reasons explained in Reference (3).

## 3.4 SHOCK-CELL NOISE PREDICTION

As discussed in Section 3.1, the shock cell broadband noise prediction is based on a modification of the theory of Harper-Bourne and Fisher (14). A thorough discussion of this theory and its application to noncircular nozzles can be found in Reference (3).

Although the analysis of Reference (3) demonstrated that noncircular nozzle shock-cell noise exhibits the same scaling of noise level with operating conditions as that for a conical nozzle, the influence of nozzle shape on noise level and spectrum shape was not quantified to the extent that a verified prediction method could be established. A method for predicting the shock cell structures (number of cells, spacing, etc.) is still required before a general shock noise prediction procedure can be established. An interim shock cell noise prediction method was therefore adopted for incorporation into the unified aeroacoustic prediction model, with the expectation of replacement by a more general method at some future date.

The interim method is essentially that of Deneuville (16), with some modifications to simplify the calculation and incorporate some of the ideas developed in Reference (3). The method consists of modeling the shock cell noise component of the spectrum by two straight lines, as illustrated in Figure 5. The primary variables required are peak sound pressure level $SPL_p$ and the frequency $f_p$ at which this occurs.



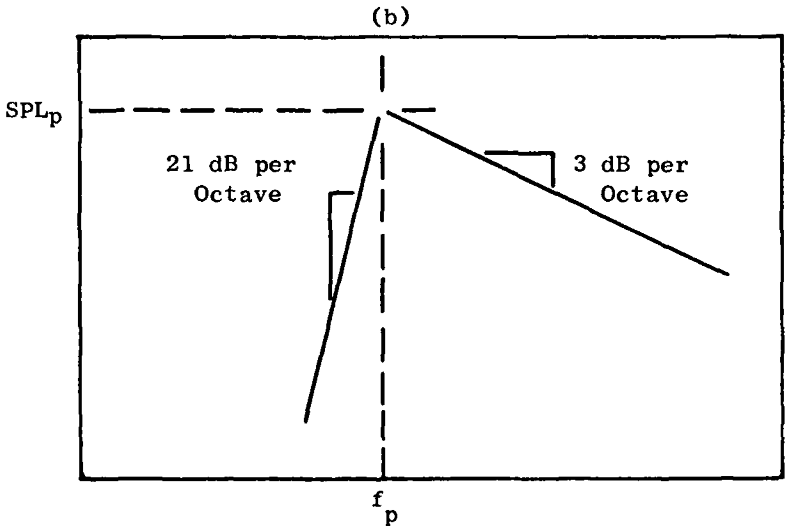




Figure 5. Empirical Model of Shock Cell Noise Component of Spectrum: (a) Shock Cell Component Approximated by Straight Lines; (b) Model Representation of Shock Cell Spectrum and Correlation Parameters.

Given a nozzle operating at pressure ratio PR, jet velocity $V_j$, having total flow area $A_j$, equivalent diameter $D_{eq} = \sqrt{4A_j/\pi}$, and hydraulic diameter $D_h = 4A_j/P_w$ (where $P_w$ is the nozzle boundary wetted perimeter), the parameters $SPL_p$ and $f_p$ can be computed as a function of observer angle $\theta_i$. The computation proceeds as follows:

(1) compute shock strength parameter $\beta$ from

$$\beta = \sqrt{M_j^2 - 1} \tag{20}$$

where

$$M_j^2 = \frac{2}{\gamma-1}\left[PR^{\frac{\gamma-1}{\gamma}} - 1\right] \tag{21}$$

(2) compute average shock-cell spacing $L_{avg}$ from

$$L_{avg} = 1.1 \ \beta D_{eq} \tag{22}$$

(3) Compute peak noise frequency from

$$f_p = \frac{U_c}{L_{avg}} (1 + M_c \cos \theta_i)^{-1} \tag{23}$$

where $U_c = 0.7\ U_j$ and $M_c = U_c/C_a$.

(4) Compute peak SPL from

$$\begin{aligned} SPL_p(\theta_i) = {} & 152.6 + 40 \log_{10}(\beta) + 10 \log_{10}(A_j/R^2) \\ & + 10 \log_{10}(D_h/D_{eq}) - 40 \log_{10}(1-M_a\cos\theta_i) \\ & + 10 \log_{10}(N/8) \end{aligned} \tag{24}$$

where $M_a = U_a/C_a$, the flight Mach number, and N is the number of shock cells (usually N = 8 is assumed). The spectrum shape is then calculated from the assumed two straight-line model shown in Figure 5. The equations are as follows:

$$\left.\begin{aligned} SPL(f,\theta_i) &= SPL_p(\theta_i) - 10 \log_{10}(f/f_p), \ f > f_p \\ SPL(f,\theta_i) &= SPL_p(\theta_i) + 70 \log_{10}(f/f_p), \ f < f_p \end{aligned}\right\} \tag{25}$$

Equations (20 through 25) completely describe the shock cell noise prediction method for obtaining 1/3-octave spectra at any observer angle $\theta_i$.

### 3.5 AEROACOUSTIC MODEL INTEGRATION

An outline of the basic prediction method and a description of the component building blocks have been presented in the preceding sections. This section describes how these building blocks are tied together. Additionally, some practical guidelines are given which were found from experience to be helpful in producing reasonably accurate predictions while maximizing computational efficiency.

The mixing noise spectrum is computed from equation (14), with the integration over the jet plume $\int (\ )\, d\vec{y}$ replaced (or approximated) by a summation over all eddy-volume elements. Since equation (14) represents the narrowband spectrum in terms of source frequency $\Omega$ (emitted frequency in a reference frame moving with the eddy), a conversion is made to 1/3-octave spectrum based on observed center frequency f. It is assumed that the 1/3-octave band level can be approximated by the narrowband level evaluated at the center frequency, multiplied by the bandwidth, rather than integrating the narrowband level distribution over the bandwidth. The standard 1/3-octave center frequencies are used. For each eddy-volume element, at each observer angle $\theta_i = 180° - \theta$, the source frequency is calculated for each 1/3-octave center frequency from the relation

$$\Omega = 2\pi f(1-M_c \cos \theta) \tag{26}$$

The spectrum shape of a given eddy, equation (16), determines the amount contributed by a given eddy at that 1/3-octave frequency. Theoretically, all eddies contribute some amount at all 1/3-octave frequencies, but the rather "peaky" nature of $I(\Omega)$ given by equation (16) dictates that the major contribution of an eddy will be in the vicinity of $\Omega \sim 4/\tau_o$.

Computationally, the integrand of equation (14) can be expressed explicitly in terms of observed frequency, since the source frequency always occurs in the combination $\Omega/(1-M_c\cos\theta)$. The one exception is in the exponent of the spectrum function $I(\Omega)$, equation (16). For example, the product $\alpha a_{xx}$ can be rewritten as

$$\alpha a_{xx} \sim \frac{\rho_a^2 (u')^7 (2\pi f\tau_o)^4 \beta_{xx} \cos^4\theta \ (C_a/C_o)^2}{16\pi^2 R^2 \ C_a^4 \ (1-M_o\cos\theta)^2 (1-M_c\cos\theta)^2} \exp\left[-\frac{1}{8}(\Omega\tau_o)^2\right]$$

Similar expressions can be derived for $\alpha a_{xy}$, etc.

The eddy convection factor $(1-M_c\cos\theta)$ has a singularity at $M_c\cos\theta = 1$. To circumvent this computational difficulty, it is replaced by a modified convection factor as suggested by Ffowcs-Williams (6) and Ribner (8), as follows:

$$C = 1-M_c\cos\theta \rightarrow \sqrt{(1-M_c\cos\theta)^2 + (\alpha_t u'/C_a)^2} \tag{27}$$

where, as Ffowcs-Williams and Ribner have shown, the term $(\alpha_t u'/c_a)$ accounts for the finite life-time of the eddy as it is convected downstream. The constant $\alpha_t$ was determined (from comparison of prediction with experiments) to be approximately 0.5, independent of source location, jet operating conditions and nozzle geometry. An additional assumption was made that the flow convection factor $(1-M_o\cos\theta)$ can be replaced by the modified eddy convection factor C given by equation (27).

The eddy convection Mach number must be a function of the local flow Mach number of the eddy-volume being considered. Several expressions for $M_c$ were tried; the best results (over a wide range of nozzle operating conditions and geometries) were obtained with the following:

$$M_c = \frac{1}{2}(M_o + 0.65\, M_j) \tag{28}$$

where $M_j = U_j/C_a$, the nozzle exit acoustic Mach number. Equation (28) represents a simple average of the classical assumption $M_c = 0.65\, M_j$ and the local Mach number $M_o = M(r_o)$. For suppressor nozzles, equation (28) works best if $M_j$ is replaced by the postmerged potential core Mach number $M_m = U_m/C_a$. This can be evaluated from the results of the flow field calculation described in Section 3.2.

The acoustic theory summarized in Section 3.3 applies only for axisymmetric jets. For nonaxisymmetric nozzles (multilobe, chute, tube, etc.), an assumption is therefore made that a representative average radial profile at each axial station can be derived which, when inserted in the acoustic calculation, will adequately model the acoustic characteristics of the asymmetric jet. The mass-averaged values of U and $\rho$ are calculated from the azimuthal average of the quantities $\rho U^2$ and $\rho UH$. The resulting distributions of $U(x,r)$ and $\rho(x,r)$ are then employed in the acoustic calculation described in Section 3.3.

For axisymmetric jets, the empirical similarity relation $[\tau_o \sim (\partial U/\partial r)^{-1}]$ derived by Davies et al.(13) can be used to calculate the local value of $\tau_o$ from the radial velocity profiles $U(r)$. For a multichute or lobe nozzle, however, there are volume elements close to the nozzle exit plane which have negligible radial gradients $\partial U/\partial r$ but large azimuthal gradients $\partial U/\partial\phi$. It is therefore assumed that $\tau_o$ is a function of both $\partial U/\partial r$ and $\partial U/\partial\phi$. From Reichardt's hypothesis (see Reference 3), the transverse shear stresses are related to $\partial U/\partial r$ and $\partial U/\partial\phi$ by the approximate formulae

$$\frac{\tau_r}{\rho} \approx \lambda \frac{\partial U^2}{\partial r} \quad \text{and} \quad \frac{\tau_\phi}{\rho} \approx \frac{\lambda}{r} \frac{\partial U^2}{\partial \phi}$$

where $\lambda = C_m^2 \, x/2$. Thus the transverse derivatives of U can be expressed in terms of $\tau_r$ and $\tau_\phi$ as follows:

$$\frac{\partial U}{\partial r} \approx \frac{(\tau_r/\rho)}{U \, C_m^2 \, x} \quad \text{and} \quad \frac{1}{r} \frac{\partial U}{\partial \phi} \approx \frac{(\tau_\phi/\rho)}{U \, C_m^2 \, x}$$

A new transverse derivative $\partial U/\partial n$ is therefore defined in terms of the above r and $\phi$ derivatives as follows,

$$\frac{\partial U}{\partial n} = \frac{1}{U \, C_m^2 \, x} \sqrt{\left(\frac{\tau_r}{\rho}\right)^2 + \mu_t \left(\frac{\tau_\phi}{\rho}\right)^2} \tag{29}$$

such that

$$\tau_o \sim \frac{\partial U}{\partial n}^{-1} \tag{30}$$

The parameter $\mu_t$ is an empirical constant which must be evaluated from comparison with experiments.

For prediction of jet noise in flight, the mean square sound pressure level should be multiplied by the dynamic amplification factor $(1 + M_a \cos\theta)^{-1}$, where $M_a = U_a/C_a$. In addition, the convection and flow Mach numbers are replaced by $(M_c - M_a)$ and $(M_o - M_a)$, respectively, where $M_c$ and $M_o$ are evaluated in a reference frame fixed to the nozzle.

Finally, in all predictions of 1/3-octave spectra, the atmospheric attenuation corrections given by Reference (15) are applied, using standard-day corrections (70% relative humidity and 59° F dry-bulb temperature) evaluated at the center frequency.

# 4.0 COMPUTER PROGRAM DESCRIPTION

## 4.1 INTRODUCTION

The central theme of this report has been the development of a general method for predicting the aeroacoustic characteristics of turbulent jets for a wide range of nozzle flow conditions and nozzle geometries. The preceding section describes the analytic, algebraic relationships which have been developed to represent the various physical aspects of the mathematical model. The purpose of this section is to describe the computational algorithms and associated computer program which provides the necessary link between the symbolic representation of the model and the actual numerical results of the prediction method.

The computer program is written in FORTRAN IV language. It has been run on both the GE/Honeywell 6080 and CDC 7600 computers, and can easily be modified for running on other systems. The program subdivides the jet plume utilizing a built-in grid system which requires minimal input for specification. This grid system can be superseded by the user through more complex input if desired. The nozzle geometry is input through discrete point coordinates for each nozzle element boundary, and up to 109 elements can be input for a given case. A maximum of 24 axial stations along the jet plume is permitted, and up to 200 radial points per axial station can be accommodated. These limits can be changed if so desired by modifying the appropriate DIMENSION and COMMON statements in the program logic.

The limiting assumptions made in developing the method have been discussed in Section 3.0, but it is appropriate to summarize them here to warn against indiscriminate violation of these limitations. They are as follows:

1. The exhaust nozzle elements should be co-planar, i.e., each tube or chute of a multielement configuration should exhaust at the same axial plane. However, nozzle element exit planes can be staggered, provided that the mixing layer of a given element does not impinge on the wall of another element.

2. The jet exhaust gases must all be of the same constituent, because the calculation cannot accommodate gas mixtures or species concentrations.

3. Within any nozzle element, the flow is assumed to be uniform at the exit plane.

4. The time-averaged static pressure is assumed to be constant and uniform throughout the jet flow field and surrounding ambient field.

5. The exhaust nozzle elements must discharge axially, radial mean flow and swirl are neglected in the model.

6. The effects of shock formations on mixing and turbulence levels are neglected.

These assumptions and limitations are those which pertain to the types of problems which can be analyzed. There are, of course, additional assumptions which went into the formulation of the model itself which may restrict the accuracy of the model, but not the type of problem which can be analyzed. The user is advised to consult Reference (3) for the details of the model formulation.

## 4.2 PROGRAM NOMENCLATURE AND SYMBOL CONVENTION

The jet plume and nozzle geometry coordinates are computed in the MAIN routine. The jet plume is divided into KX axial slices, specified by KA (1 ≤ KA ≤ KX). The FORTRAN symbol variables for the various coordinate parameters and indices are shown in Figure 6. Note that the radial subdivision, specified by index M (1 ≤ M ≤ NR), proceeds in increments DSIG(KA), from SIG = RMIN(KA) to the maximum value set by NR. The value of NR is determined during the calculation from the location where the axial momentum flux is within a certain tolerance of being equal to the ambient level, i.e.,

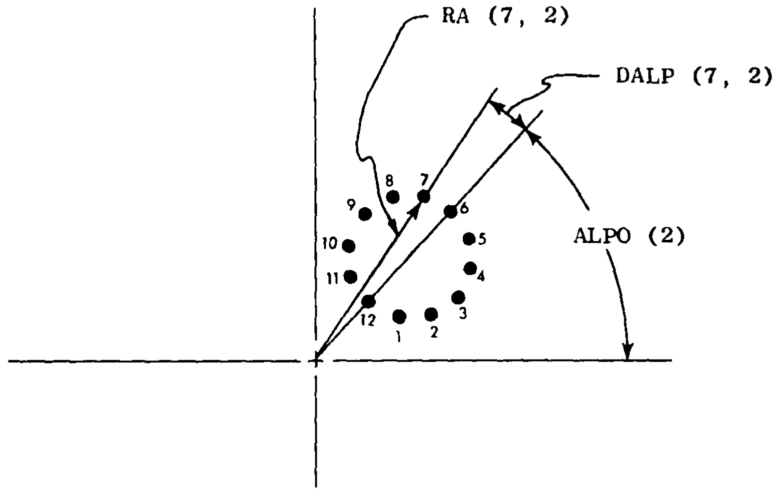
$$|RU2 - RU2E(1)| \leq RU2M$$

where RU2M is a specified input tolerance. The maximum allowable value of NR can be specified by the input variable IQUIT. The program dimension sizes limit KX and IQUIT to the following maximum values:

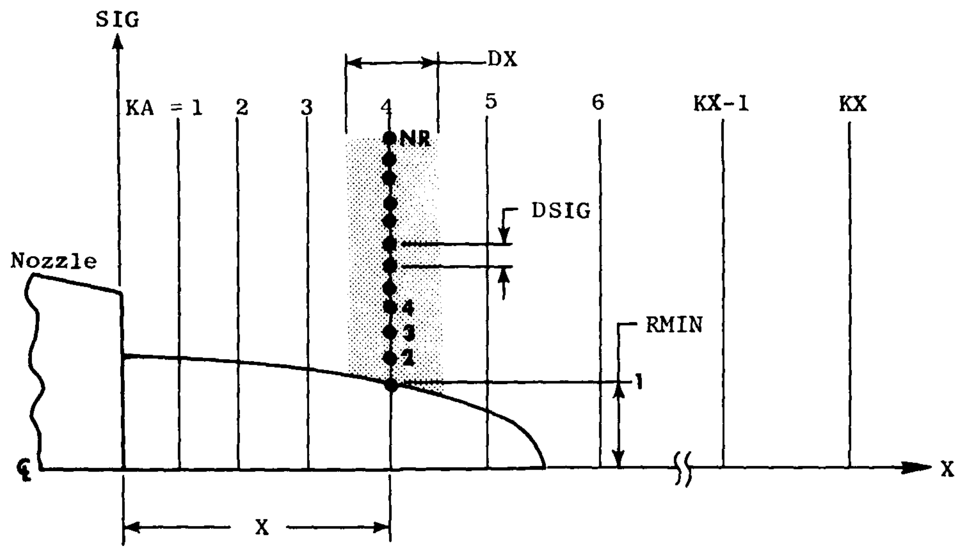
$$KX \leq 24 \qquad IQUIT \leq 200$$

The nozzle geometry itself is input as a number (NEST) of boundary elements. Each element is specified by coordinate pairs RA(I,J) and DALP(I,J), where RA(I,J) denotes the radius and DALP(I,J) denotes the angular increment, as shown in Figure 6. The index I denotes the boundary contour point number, and the index J denotes the boundary number. The reference angular location for each boundary is given by ALPO(J). For each boundary, the exit-plane values of total pressure PT(J) and total temperature TT(J) are also specified. Boundary number one (J=1) is always considered to be the ambient field.

The far field acoustic calculations are performed on either a constant-radius arc or a sideline parallel to the jet axis, according to whether the input variable NUMANG is set equal to 1 or 2, respectively. For NUMANG = 1, the input DIST is the arc radius; for NUMANG = 2, DIST is the sideline distance. The acoustic arena geometry specification in terms of FORTRAN variables is shown in Figure 7. Note that a distinction is made between the source-to-observer distance RSTAR and the nozzle-to-observer distance RADIUS. The observer angle relative to the jet axis THETA is always in units of radians, while the observer angle relative to the inlet axis THETD is in units of degrees. The far-field sound pressure level SPL(I,J) is computed at




(b) Nozzle Exit Plane Example Nozzle Element Coordinates




(a) Radial/Axial Plane

Figure 6. FORTRAN Symbol Convention for Coordinates and Geometric Variables.

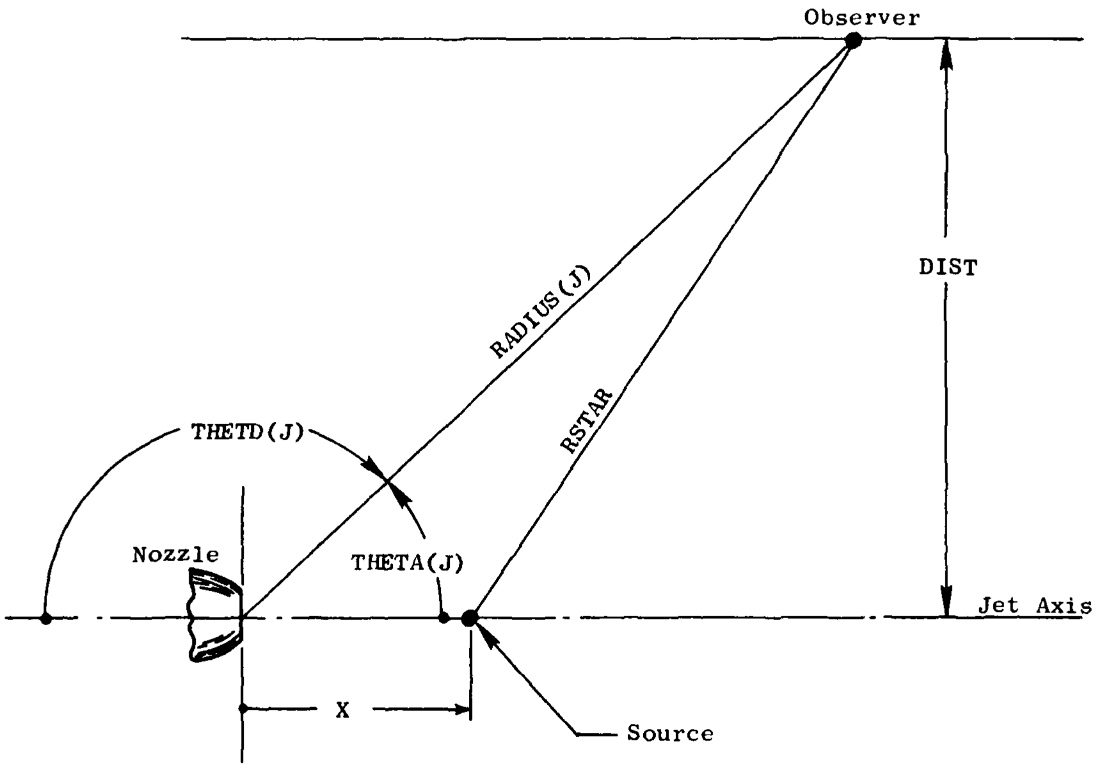



Figure 7. FORTRAN Symbol Convention for Acoustic Arena Variables.

every 1/3-octave frequency from FMIN to FMAX, at ten-degree increments from THETD = 20° to 160°.

A list of the important FORTRAN symbols used in the computer program is given in Table 2, along with their algebraic equivalents where possible. A complete description of all of the input variables and examples of input preparation are given in Appendix A.

## 4.3 DESCRIPTION OF PROGRAM AND SUBROUTINES

A flow chart of the computer program logic is shown in Figure 8. It indicates the sequence of operations, the interconnections of various portions of the program, and their functions. A description of the main program and each of the subroutines is given in the following paragraphs.

### 4.3.1 MAIN

The main program initiates the computation and controls the sequence of operations. It reads the input data, computes the grid system for the aerodynamic flow field, and computes the various required nozzle exit plane flow parameters such as velocities, Mach numbers, momentum and enthalpy fluxes, etc. The main program prints out all input data, nozzle exit conditions, nozzle geometry, and coordinate system parameters.

The main program controls and executes the jet plume flow field computation. After each axial slice has been evaluated, the MAIN program calls subroutine SLICE to perform the requested acoustic calculations. Upon completing the calculations at all axial slices, MAIN then calls OUTPUT to perform some final calculations and print out the far-field noise levels. If additional cases are requested, the entire procedure is repeated, beginning with reading of input data; otherwise the execution is halted.

### 4.3.2 ARCCOS(X)

This is a function subroutine which computes the principal value of the arc cosine of the variable X. It is used in MAIN in evaluating certain angles relating boundary coordinate points and flow field location points.

### 4.3.3 ERF(X)

This function subroutine evaluates the error function of argument X using polynomial approximations as given in Reference (19). It is used in MAIN for evaluating flow field integrands.

Table 2. List of FORTRAN Symbols.

| FORTRAN Symbol | Meaning | Related Subroutines |
|---|---|---|
| AA | Air attenuation factor | ATMOS |
| AAA | Intermediate variable | LSPFIT, MAIN |
| ABDTH | $\|\Delta\Phi\|$ | MAIN |
| ABLE | Intermediate variable | MAIN |
| ABPA | $\|\phi-\alpha\|$ | MAIN |
| ACH | Mach number M | MAIN |
| ACHM | Average mach number | MAIN |
| ACH2 | $M^2$ | MAIN |
| AK | Sound level constant | MAIN, OUTPUT |
| AL | Lighthill parameter | MAIN |
| ALFA | Frequency constant | MAIN |
| ALP | Angle | MAIN |
| ALPHT | Convection constant $\alpha_t$ | SLICE |
| ALPØ | Reference boundary angle | MAIN |
| AMUIN | Input turbulence constant $\mu_t$ | MAIN |
| AMULT | Intermediate value for $\mu_t$ | MAIN |
| AO | Speed of sound $C_a$ | MAIN |
| ATOTAL | Total flow area | MAIN |
| B | Intermediate variable | LSPFIT |
| BETA | Shock strength parameter $\beta$ | SHOCK |
| BETAIN | Input turbulence constant $\beta_t$ | MAIN |
| BETAMC | Convection constant $\beta_{Mc}$ | MAIN, SLICE |
| BK | Intermediate variable | SLICE |
| BKR | Intermediate variable | MAIN |
| BOT | Intermediate variable | LSPFIT |
| BUG | Intermediate variable | MAIN |
| C | Constant | LSPFIT |
| CH | Spreading parameter $C_h/C_m$ | MAIN |
| CHX | Spreading parameter $C_hx$ | MAIN |
| CJOCO | Ratio of $C_j/C_a$ | SLICE |
| CM | Spreading parameter $C_m$ | MAIN |
| CMAX | Intermediate variable | TPNLC |
| CMC | Intermediate variable | MAIN |
| CMMC | Spreading constant $C_1$ | MAIN |
| CMVR | Spreading constant $C_2$ | MAIN |
| CNST | Constant | SLICE |
| CO | Ambient speed of sound $C_a$ | MAIN, SLICE, SHOCK |
| COEF | Conversion factor | OUTPUT |
| CONV | Convection factor | SHOCK |
| CONVF | Flight dynamic factor | SLICE |
| CONVO | Convection factor | SLICE |
| CONV2 | Modified convection factor C | SLICE |
| CON1 | Constant | SLICE |

Table 2. List of FORTRAN Symbols (Continued).

| FORTRAN Symbol | Meaning | Related Subroutines |
|---|---|---|
| CON2 | Constant | SLICE |
| COST | Cos $\Phi$ | MAIN |
| COSTO | Cos $\Phi$ | MAIN |
| CP | Specific heat $C_p$ | MAIN |
| CT | Cos $\theta$ | SLICE, CRD |
| CTSQ | $\text{Cos}^2\ \theta$ | SLICE |
| CTH | Cos $\theta$ | SHOCK |
| CVR | Intermediate variable | MAIN |
| DALP | Boundary coordinate $\Delta\alpha$ | MAIN |
| DDTHE | Tolerance on $\Delta\theta$, radians | SLICE |
| DDTHED | Tolerance on $\Delta\theta$, degrees | SLICE |
| DELRA | Transformed boundary radius $\Delta\nu$ | MAIN |
| DELSIG | Transformed radius $\Delta r$ | MAIN |
| DELTA | Turbulence constant $\delta_t$ | MAIN |
| DELTIN | Input array of $\delta_t$ | MAIN |
| DEQ | Equivalent diameter $D_{eq}$ | MAIN, SLICE, SHOCK |
| DIA | Reference $D_{eq}$ | MAIN |
| DIRECT | Directivity factor | SLICE |
| DIST | Sideline or arc distance | MAIN, SLICE |
| DJET | Reference diameter | MAIN |
| DPHI | $\Delta\phi$ | MAIN |
| DRMIN | $\Delta r$ - minimum value | SLICE |
| DS | Source strength amplitude | SLICE |
| DSIG | $\Delta r$ | MAIN, SLICE |
| DSPL | Mixing noise pressure | SLICE, OUTPUT |
| DSPL1 | Intermediate variable | SHOCK |
| DSPL2 | Intermediate variable | SHOCK |
| DTHED | $\Delta\theta$, degrees | SLICE |
| DTHM | Maximum increment of $\phi$ | MAIN |
| DU | Intermediate variable | MAIN |
| DUDR | $\partial U/\partial r$ | MAIN, SLICE |
| DV | Eddy volume dV | SLICE |
| DX | Axial step size $\Delta x$ | MAIN, SLICE |
| EF | Enthalpy flux | MAIN |
| EFE | Enthalpy flux | MAIN |
| EM | Mach number | SLICE |
| EMACH | Exit Mach number | MAIN, SLICE, OUTPUT |
| F | Intermediate variable | LSPFIT |
| FAC | Intermediate variable | PNLC |
| FC | Center frequency | SLICE |
| FIRSTU | Flight velocity $U_a$ | MAIN, SLICE |
| FIS | Intermediate variable | MAIN |
| FM | Mass flow | MAIN |

Table 2. List of FORTRAN Symbols (Continued).

| FORTRAN Symbol | Meaning | Related Subroutines |
|---|---|---|
| FMAX | Maximum observed frequency | MAIN, OUTPUT |
| FMIN | Minimum observed frequency | MAIN, OUTPUT |
| FO | Observed frequency | SLICE, SHOCK, OUTPUT |
| FP | Peak frequency | SHOCK |
| FR | Frequency ratio | SLICE |
| FRSQ | Intermediate variable | SLICE |
| FS | Source frequency | SLICE |
| GAM | Specific heat ratio $\gamma$ | MAIN, SHOCK |
| GAMA | Gas constant parameter | MAIN |
| GEXP | Gas constant parameter | SHOCK |
| GM | Shielding function | CRD |
| GOSQ | Shielding function | CRD |
| G2 | Shielding function | SLICE, CRD |
| HF | Spectrum function | SLICE |
| HPSI | Intermediate variable | MAIN |
| HTR | Stagnation enthalpy | MAIN |
| I | Index | ALL |
| IC | Index | LSPFIT |
| IDENT | Title (80-characters) | MAIN |
| II | Index | TPNLC |
| IMH | Index | MAIN |
| IQUIT | Maximum number of points | MAIN |
| IS | Index | MAIN |
| ISSY | Index | MAIN |
| ISAVE | Index | LSPFIT |
| ISYM | Symmetry indicator | MAIN |
| IT | Symmetry indicator | MAIN |
| J | Index | ALL |
| JMAX | Maximum band number | OUTPUT, SHOCK, SLICE |
| JMIN | Minimum band number | OUTPUT, SHOCK, SLICE |
| J1 | Index | CRD |
| J11 | Index | CRD |
| J2 | Index | CRD |
| J21 | Index | CRD |
| J211 | Index | CRD |
| K | Index, also wave number | MAIN, SLICE, PNLC |
| KN | Surrounding boundary index | MAIN |
| KNCAS | Case counter | MAIN |
| KNK | Surrounding boundary index | MAIN |
| KX | Number of axial slices | MAIN |
| L | Index | MAIN |
| LAVG | Shock spacing | SHOCK |
| LEAF | Number of boundary leaves | MAIN |

Table 2. List of FORTRAN Symbols (Continued).

| FORTRAN Symbol | Meaning | Related Subroutines |
|---|---|---|
| LEAV | Number of boundary leaves | MAIN |
| LINE | Printout counter | MAIN |
| LPHI | Number of flow field leaves | MAIN |
| LQ | Index | MAIN |
| M | Index | MAIN, SLICE |
| MACH | Mach number | SLICE |
| MAXNOY | Maximum noy value | PNLC |
| MC | Convection Mach number | SLICE, SHOCK, CRD |
| MCIN | Input array of $M_c$ | SLICE |
| MIN | Input array of $M_o$ | CRD |
| MJ | Jet exit Mach number | SHOCK |
| N | Index, also number of shocks | MAIN, SHOCK, LSPFIT |
| NBREF | Reference boundary number | MAIN |
| NCASE | Number of cases | MAIN |
| NCBDY | Number of centerbody points | MAIN |
| NCELL | Number of shock cells | MAIN, SHOCK |
| NCOUNT | Counter | LSPFIT |
| NN | Acoustic calculation selector | MAIN, SLICE |
| NODE | Intermediate variable | MAIN |
| NOV | Minimum number of points | MAIN |
| NOY | Noy value | PNLC |
| NPAGE | Page counter | MAIN |
| NPR | Printout counter | MAIN |
| NPRINT | Printout selector | MAIN, SLICE |
| NPTS | Number of points | LSPFIT |
| NR | Number of points | SLICE, CRD |
| NR1 | Index | SLICE |
| NTP | Number of turning points | SLICE, CRD |
| NUM | Number of boundary points | MAIN |
| NUMANG | Arena selector | MAIN, SLICE |
| NUMK | Number of boundary points | MAIN |
| NXC | Index | LSPFIT |
| OAPWL | Overall power level | OUTPUT |
| OASPL | Overall sound pressure level | OUTPUT, PNLC |
| OBSTN | Observed Strouhal number | OUTPUT |
| OMEGR | Source radian frequency | SLICE |
| PAA | Ambient static pressure | MAIN |
| PC | Intermediate variable | PNLC |
| PGC | Gas constant parameter | MAIN |
| PHI | Angle $\phi$ | MAIN |
| PI | Constant $\pi$ | MAIN, SLICE, OUTPUT |
| PIO2 | $\pi/2$ | CRD |
| PI2 | $2\pi$ | MAIN |

Table 2. List of FORTRAN Symbols (Continued).

| FORTRAN Symbol | Meaning | Related Subroutines |
|---|---|---|
| PNDB | PNdB | PNLC |
| PNL | PNL | OUTPUT, PNLC |
| PNLT | $PNL_t$, tone-corrected PNL | OUTPUT |
| POWER | Exponent | MAIN |
| PS | Ambient static pressure | MAIN, SHOCK |
| PSQ | Square of acoustic pressure | OUTPUT |
| PSQM | Mixing noise $\overline{p^2}$ | SHOCK |
| PSQS | Shock noise $\overline{p^2}$ | SHOCK |
| PSQT | Total noise $\overline{p^2}$ | SHOCK |
| PT | Stagnation pressure | MAIN, SHOCK |
| PWL | Power level | OUTPUT |
| PWR | Sound power, watts | OUTPUT |
| Q | Intermediate variable | MAIN |
| RA | Boundary coordinate radius | MAIN |
| RAD | Flow integration variable $R_o$ | MAIN |
| RADO | Flow integration variable $R_o$ | MAIN |
| RADIUS | Nozzle-to-observer radius R | SLICE, OUTPUT, ATMOS |
| RADX | Argument $R_o/C_m x$ | MAIN |
| RCBDY | Centerbody radial cooordinate | MAIN |
| PRCRIT | Critical pressure ratio | SHOCK |
| RCRC | Intermediate variable | MAIN |
| RFO | Intermediate variable | OUTPUT |
| RHO | Density $\rho$ | MAIN |
| RHOE | Ambient density $\rho_a$ | MAIN, SLICE |
| RHOESQ | $\rho_a^2$ | SLICE |
| RHOR | Azimuthally-averaged $\rho$ | MAIN, SLICE |
| RIN | Input radius | SLICE, CRD |
| RJET | Reference jet density ratio | MAIN |
| RMIN | Minimum value of r | MAIN |
| RMINEX | Exit plane value of RMIN | MAIN |
| RMINSQ | Square of RMIN | MAIN |
| RMNSQE | Square of RMINEX | MAIN |
| RMP | Dummy variable | MAIN |
| RND | Normalized radius $r/D_{eq}$ | MAIN |
| ROOT | Root (zero) of $g^2$ | SLICE |
| ROOT2 | $\sqrt{2}$ | SLICE |
| RO | Source radius $r_o$ | CRD |
| RSIG | Turning point radius $r_\sigma$ | SLICE, CRD |
| RSIG1 | $r_{\sigma 1}$ | CRD |
| RSIG2 | $r_{\sigma 2}$ | CRD |
| RSORSQ | Source location correction $(R*/R)^2$ | SLICE |
| RSTAR | Source-to-observer radius R* | SLICE |

Table 2. List of FORTRAN Symbols (Continued).

| FORTRAN Symbol | Meaning | Related Subroutines |
|---|---|---|
| RU | Mass flux $\rho U$ | MAIN |
| RU2 | Momentum flux $\rho U^2$ | MAIN |
| RU2E | Exit plane value of $\rho U^2$ | MAIN |
| RU2M | Minimum value of $\rho U^2$ | MAIN |
| RU2REF | Reference value of $\rho U^2$ | MAIN |
| R1 | Intermediate variable | CRD |
| R2 | Intermediate variable | CRD |
| S | Intermediate variable | TPNLC |
| SA | Intermediate variable | MAIN |
| SAC | Intermediate value of $\tau_\phi$ | MAIN |
| SACO | Intermediate value of $\tau_\phi$ | MAIN |
| SAR | Intermediate value of $\tau_r$ | MAIN |
| SARO | Intermediate value of $\tau_r$ | MAIN |
| SAX | Intermediate value of $\tau_x$ | MAIN |
| SAXO | Intermediate value of $\tau_x$ | MAIN |
| SBAR | Intermediate variable | TPNLC |
| SDU | Intermediate value of $\partial U/\partial r$ | MAIN |
| SEFE | Integral of enthalpy flux | MAIN |
| SGN | Sign | LSPFIT |
| SGN1 | Sign | CRD |
| SGN2 | Sign | CRD |
| SG1 | Intermediate variable | CRD |
| SG2 | Intermediate variable | CRD |
| SHIELD | Shielding integral | SLICE, CRD |
| SIC | Intermediate value of $\tau_\phi$ | MAIN |
| SIG | Radius r | MAIN |
| SIGN | Sign | ERF |
| SIGSQ | $r^2$ | MAIN |
| SIGR | Radius r | MAIN, SLICE |
| SINT | Sin $\theta$ | MAIN |
| SINTO | Sin $\theta_o$ | MAIN |
| SIR | Intermediate value of $\tau_r$ | MAIN |
| SIX | Intermediate value of $\tau_x$ | MAIN |
| SPL | SPL array | ALL |
| SPLL | Intermediate variable | TPNLC |
| SPLMAX | Maximum SPL | SHOCK |
| SPLP | Intermediate variable | TPNLC |
| SPLPP | Intermediate variable | TPNLC |
| SPLU | Intermediate variable | TPNLC |
| SRU | Mass flux integral | MAIN |
| SRUM | Mass flux integral | MAIN |
| SRU2 | Momentum flux integral | MAIN |
| SRU2M | Momentum flux integral | MAIN |

Table 2. List of FORTRAN Symbols (Continued).

| FORTRAN Symbol | Meaning | Related Subroutines |
|---|---|---|
| SS | SPL array | PNLC |
| SSPL | Shock noise SPL array | SHOCK |
| STC | Azimuthal shear stress $\tau_\phi$ | MAIN |
| STR | Radial shear stress $\tau_r$ | MAIN |
| STRFR | Radial coordinate stretching factor | MAIN |
| STRFX | Axial coordinate stretching factor | MAIN |
| STX | Axial shear stress $\tau_x$ | MAIN |
| SUE | Reference velocity | MAIN |
| SUM | Sum | OUTPUT |
| SUMNOY | Sum of noy value | PNLC |
| SUMSPL | Sum of SPL | PNLC |
| SUM1 | Sum | CRD |
| SUM2 | Sum | CRD |
| SU8 | Integral of source strength | MAIN |
| SU8M | Integral of source strength | MAIN |
| SV2 | Square of velocity | MAIN |
| S1 | Intermediate variable | LSPFIT |
| T | Temperature | ERF, MAIN |
| TA | Intermediate variable | MAIN |
| TAA | Ambient static temperature | MAIN |
| TAO | Intermediate variable | MAIN |
| TAU | Total shear stress $\tau$ | MAIN |
| TAUR | Azimuthal average of $\tau$ | MAIN, SLICE |
| TC2 | Intermediate variable | TPNLC |
| TC3 | Intermediate variable | TPNLC |
| TE | Exit static temperature | MAIN |
| TEMP | Normalized temperature T/Ta | SLICE |
| TERM | Directivity factor | SLICE |
| TH | Angle $\phi$ | MAIN |
| THCR | Critical angle $\theta_{cr}$ | SHOCK |
| TERM | Directivity factor | SLICE |
| THE | Angle $\theta$ | SLICE, CRD |
| THETA | Observer angle $\theta$, radians | SLICE, OUTPUT |
| THETD | Observer angle $\theta_I$, degrees | SLICE, OUTPUT, SHOCK |
| THO | $\phi_o$ | MAIN |
| THT | Observer angle $\theta_I$, radians | SHOCK |
| TI | Intermediate value of enthalpy flux | MAIN |
| TOP | Intermediate variable | LSPFIT |
| TSR | Static temperature | MAIN |
| TSTD | Circumferential asymmetry test parameter | MAIN |
| TSTH | Circumferential asymmetry test parameter | MAIN |
| TSTHL | Circumferential asymmetry test parameter | MAIN |
| TSTL | Circumferential asymmetry test parameter | MAIN |

Table 2. List of FORTRAN Symbols (Concluded).

| FORTRAN Symbol | Meaning | Related Subroutines |
|---|---|---|
| TT | Stagnation temperature | MAIN |
| TTR | Stagnation temperature | MAIN |
| TURBIN | Turbulence intensity, u' | MAIN |
| U | Mean velocity | MAIN |
| UAP | Intermediate variable | MAIN |
| UAVG | Mass-average of U at x | MAIN |
| UC | Convection velocity $U_c$ | SHOCK |
| UE | Exit plane velocity $U_j$ | MAIN, SHOCK |
| UGLY | Intermediate variable | MAIN |
| UJET | Reference exit velocity | MAIN |
| UMAX | Maximum local value of U at x | MAIN |
| UND | Normalized value of U, U/UREF | MAIN |
| UNITS | Constant for units conversion | MAIN, OUTPUT |
| UR | Azimuthal average of U | MAIN, SLICE |
| UREF | Reference exit velocity | MAIN |
| U8 | Intermediate value of source strength | MAIN |
| U8I | Integral of source strength | MAIN |
| VA | Intermediate value of momentum | MAIN |
| VAO | Intermediate value of momentum | MAIN |
| VI | Intermediate value of momentum | MAIN |
| VMAX | Maximum of velocities inside and outside | MAIN |
| VMIN | Minimum of velocities inside and outside | MAIN |
| VO | Flight velocity $U_a$ | SHOCK |
| VR | Velocity ratio VMIN/VMAX | MAIN |
| WITHIN | Dummy variable | LSPFIT |
| X | Axial distance x | MAIN, SLICE |
| XCBDY | Centerbody axial coordinate | MAIN |
| XD | Intermediate variable | LSPFIT |
| XE | Exit plane axial coordinate | MAIN |
| XND | Normalized axial coordinate $X/D_{eq}$ | MAIN |
| XOR | Variable x/R | SLICE |
| X1 | Intermediate variable for curve fitting | LSPFIT |
| X13 | Intermediate variable for curve fitting | LSPFIT |
| X4 | Intermediate variable for curve fitting | LSPFIT |
| X43 | Intermediate variable for curve fitting | LSPFIT |
| Y | Intermediate variable for curve fitting | LSPFIT |
| YC | Intermediate variable for curve fitting | LSPFIT |
| YI | Intermediate variable for curve fitting | LSPFIT |
| Y3 | Intermediate variable for curve fitting | LSPFIT |

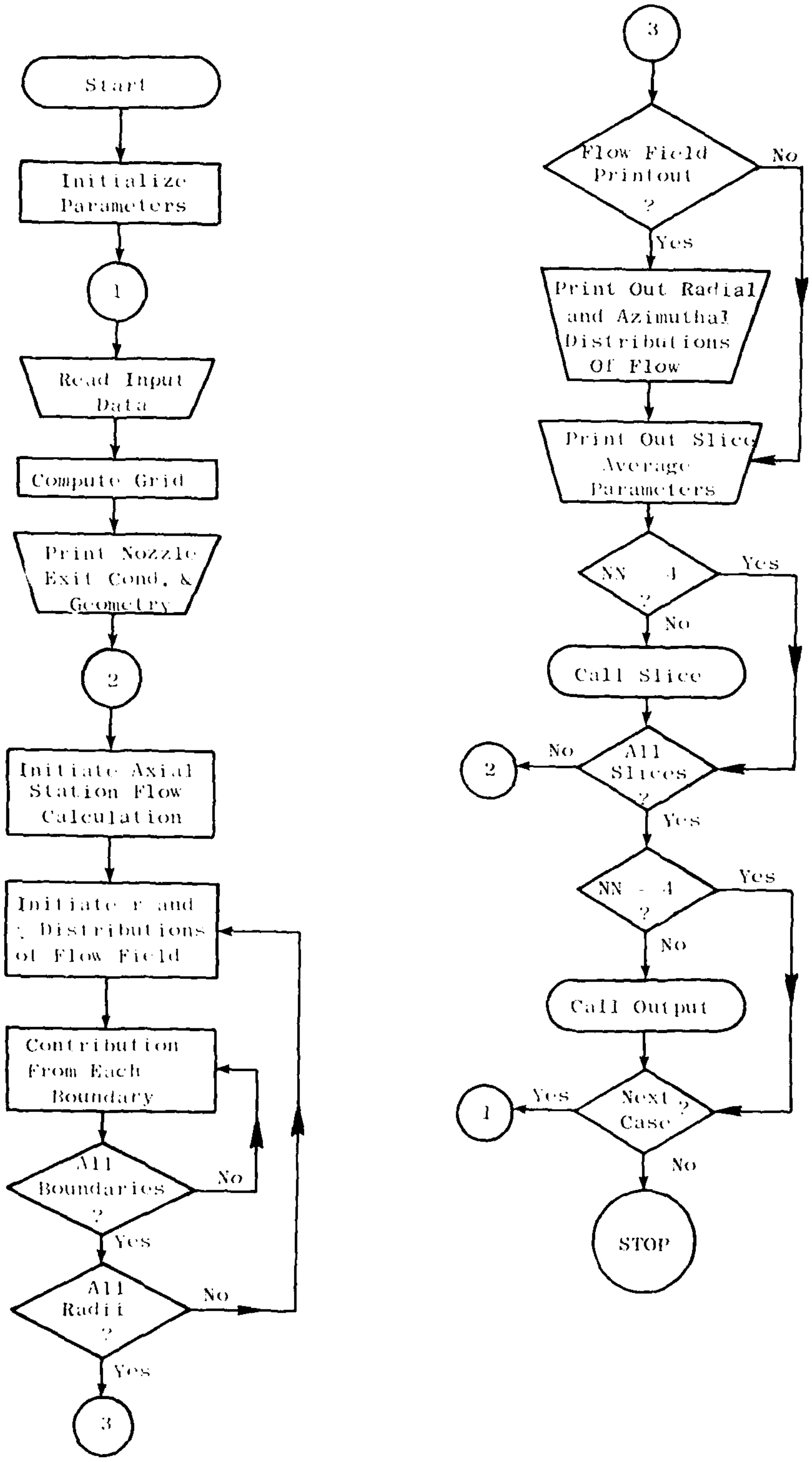
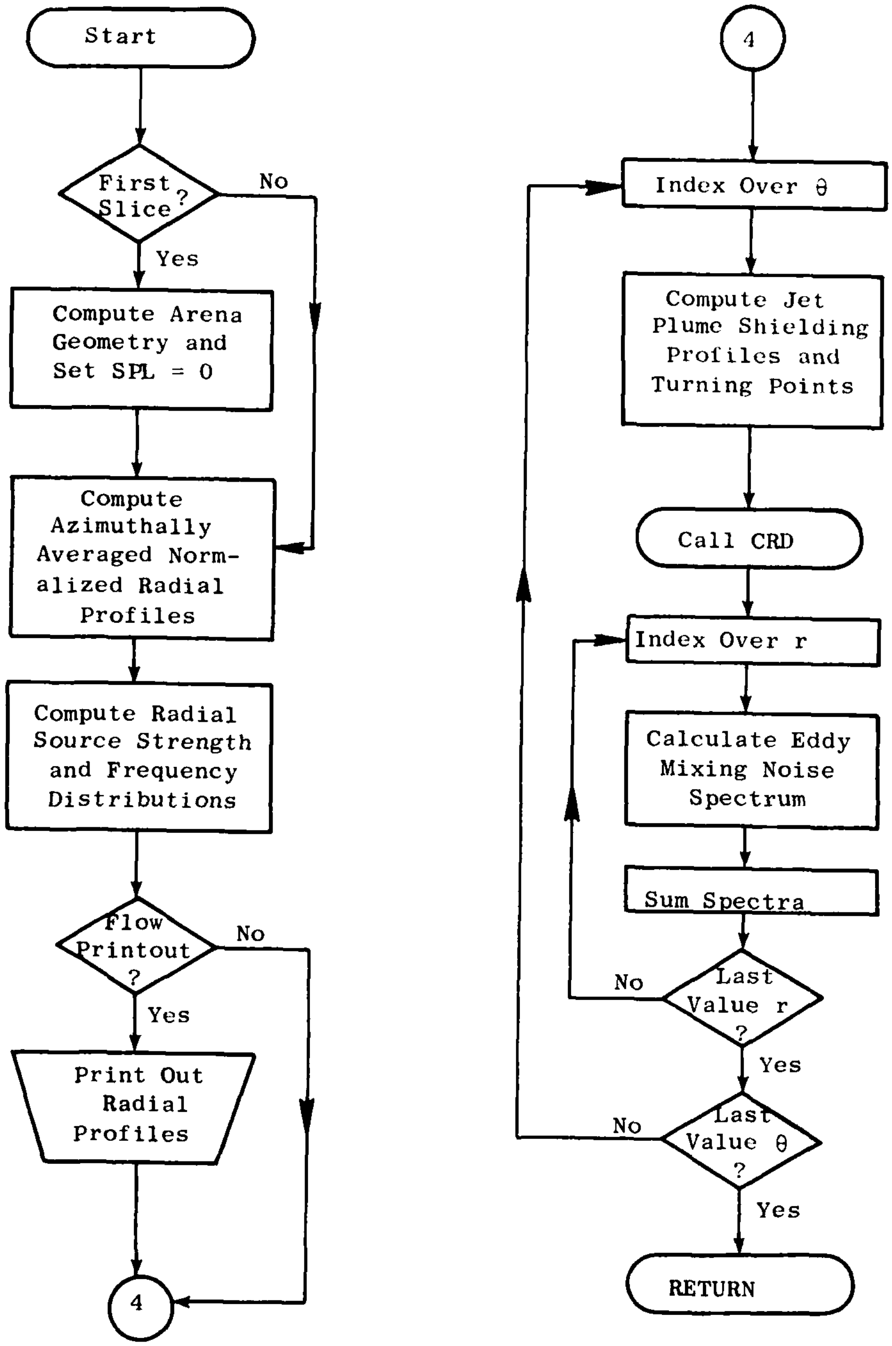
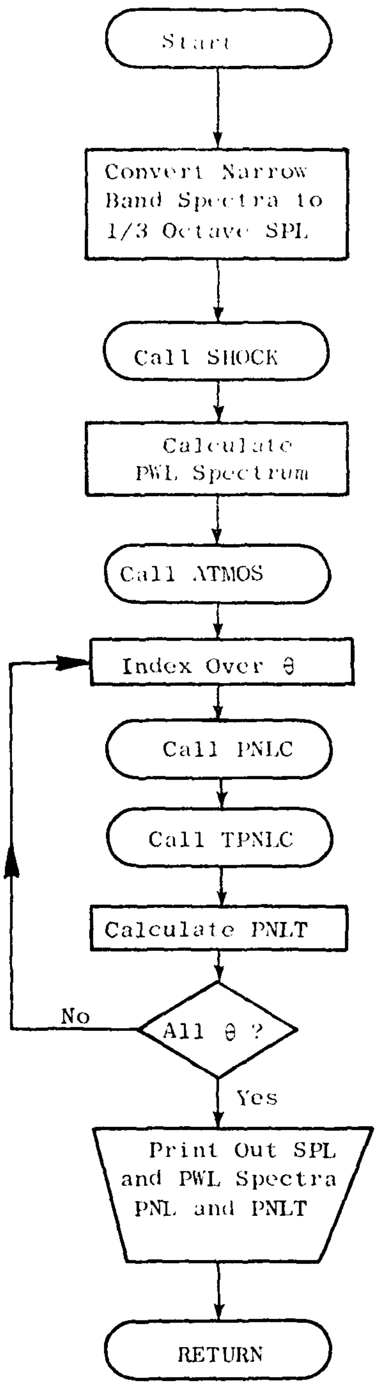



Figure 8. Computer Program Flow Chart.




(b) Subroutine SLICE

Figure 8. Computer Program Flowchart (Continued).




(c) Subroutine OUTPUT

Figure 8. Computer Program Flow Chart (Concluded).

### 4.3.4 LSPFIT

Subroutine LSPFIT is a curve-fitting routine which utilizes least-squares polynomial fits of second order to perform interpolation, differentiation and integration of input discrete-point data. The calling statement is:

```
CALL LSPFIT(X, Y, N, XC, YC, NC, NF, A)
```

where (X, Y) are the input data coordinates (N values of each), XC are the values of X where output is requested, YC are the output functions, NC is the number of output data points, and NF indicates the type of output desired. The coding for NF is as follows:

NF = 0, YC are interpolated values of Y

NF = 1, YC are derivatives of Y

NF = -1, YC is the integral of Y from XC(1) to XC(J), $1 \leq J \leq NC$.

The parameter A is the second derivative of Y. Subroutine LSPFIT is used in MAIN to interpolate input plug/centerbody geometry coordinates at various axial stations in the flow field, and to obtain radial gradients of density from the computed density profiles.

### 4.3.5 SLICE

Subroutine SLICE directs the mixing noise calculation for each axial slice. The calling sequence is as follows:

```
CALL SLICE (X(KA), DSIG(KA), DX, M)
```

where X(KA) is the axial location, DSIG(KA) is the radial step size, DX is the axial slice thickness, and M is the number of radial points in the slice. The flow parameters (which are circumferentially mass-averaged values) are transferred through labeled COMMON statements. Subroutine SLICE computes the acoustic arena geometry parameters THETA, THETD, RADIUS and initializes SPL (I,J) to zero during the first call, skipping this calculation on succeeding calls. The normalized radial profiles of velocity (MACH) and temperature (TEMP) are evaluated, followed by a calculation of source strength amplitude DS and characteristic frequency FS for each radial volume element.

Subroutine SLICE computes the acoustic shielding function profiles G2(J), the number of turning points NTP, and their locations RSIG. Subroutine CRD is then called to calculate the acoustic shielding exponentials and quadrupole directivity functions. Subroutine SLICE then sums up the mixing noise contributions from each radial volume element, factoring in their individual source strengths, characteristic frequencies, spectrum shapes, directivities, and shielding factors. The resulting noise spectra from each slice is stored as the variable DSPL(I,J), where I denotes the observer angle index and J is the 1/3-octave frequency band index. Upon completing the calculation for a given slice, SLICE returns control to MAIN.

#### 4.3.6 CRD

Subroutine CRD computes the shielding function integrals and quadrupole directivity factors for a given axial slice as a function of radial source location. The radial distributions of normalized velocity (MACH) and temperatures (TEMP) and shielding function (G2) are transferred to CRD through labeled COMMON statements. The calling statement is:

```
CALL CRD
```

At each source radius, subroutine CRD interrogates the data to determine which of the six shielding conditions in Figure 4 applies, and computes the appropriate shielding integral ($\beta_{01}$, $\beta_{02}$, or $\beta_{12}$), and the appropriate directivity factors. After all radial source volumes have been evaluated, CRD returns control to SLICE.

#### 4.3.7 OUTPUT

Subroutine OUTPUT performs the final acoustic calculations and prints out the far field SPL spectra, OASPL, PNL and PNLT directivities. The calling sequence is as follows:

```
CALL OUTPUT (EMACH, DJET, RJET, UJET, UNITS)
```

where EMACH, DJET, RJET, and UJET are the characteristic (usually reference) jet Mach number, diameter, density ratio and velocity, respectively. The parameter UNITS is a conversion factor for converting from $lb_f/ft^2$ to $dynes/cm^2$ relative to 0.0002 $dynes/cm^2$. Subroutine OUTPUT converts the narrow-band spectra from SLICE into 1/3-octave levels. Subroutine SLICE then calls SHOCK to compute SSPL spectra (shock noise) and adds these to the turbulent mixing noise spectra to obtain the total noise spectra. The corresponding power spectrum (PWL) is then computed, and subroutine ATMOS is then called to correct all SPL spectra for atmospheric attenuation. Subroutines PNLC and TPNLC are then called to calculate perceived noise level

PNL and tone-corrected noise level PNLT. Finally, overall sound pressure level OASPL is computed, and all of these acoustic parameters are then printed out. Subroutine OUTPUT then returns control to MAIN.

#### 4.3.8 SHOCK

Subroutine SHOCK computes the broadband shock-associated noise spectra at each observer angle. The calling statement is as follows:

```
CALL SHOCK
```

All parameters are transferred into and out of this subroutine through labeled COMMON statements. Subroutine SHOCK computes the 1/3-octave SPL spectra for each nozzle boundary element which has a non-zero shock cell number input, NCELL > 0. The individual boundary contributions are summed on a mean-square pressure basis and added to the mixing noise spectra.

#### 4.3.9 ATMOS

Subroutine ATMOS corrects the input SPL spectra for atmospheric attenuation effects using standard-day atmospheric absorption factors for 70% relative humidity and 59° F ambient conditions. The calling sequence is as follows:

```
CALL ATMOS (SPL, RADIUS)
```

where SPL(I,J) is the sound pressure spectrum array, I denotes the index for observer angle, J denotes the index on frequency, and RADIUS(I) is the nozzle-to-observer distance array. The atmospheric absorption in dB per 1000 ft from reference (15) is corrected to the proper distance RADIUS(J), and the result is subtracted from SPL(I,J). The array of SPL(I,J) returned to OUTPUT is the corrected array.

#### 4.3.10 PNLC

Subroutine PNLC computes the perceived noise level in PNdB at each observer angle from the input 1/3-octave spectra. The calling sequence is as follows:

```
CALL PNLC (SS, FAC, PNDB, OASPL)
```

where SS is the input array of either 1/3-octave or octave SPL values, FAC is a constant equal to 0.15 for 1/3-octave and 0.3 for octave levels, PNDB is the output PNL, and OASPL is the conventional overall level. The method used to calculate PNL is taken from reference (17). The OASPL output from subroutine PNLC is discarded because it only computes the summation for the first 24 values of SS. This is sometimes insufficient for model scale conditions where the frequency range of interest can cover as many as 33 1/3-octave frequency bands.

#### 4.3.11 TPNLC

Subroutine TPNLC determines a pure-tone correction factor to the PNL value as a function of the 1/3-octave SPL spectrum. The calling sequence is as follows:

```
CALL TPNLC (SPL, PTCOR)
```

where SPL is the input 1/3-octave spectrum and PTCOR is the correction to be applied to PNL to account for the presence of tones in the spectrum. Subroutine TPNLC reads in SPL and returns PTCOR. The tone correction and detection procedure is based on the method proposed in reference (18).

### 4.4 PROGRAM USAGE AND LOGIC

A complete description of the program input variables and input format is given in Appendix A. A list of notes and suggestions on running the program is also included. A description of program output format, including warning flags and diagnostics, is given in Appendix B. A sample case listing (including input data card images) is given in Appendix C for a 7-tube suppressor nozzle, one of the data-theory comparison cases presented in Reference (3). A complete FORTRAN source listing of the program logic is given in Appendix D.

Program users should be completely familiar with Appendix A, since there are many pitfalls which can be avoided by giving attention to the recommendations presented therein. The program flexibility permits analysis of nozzle planforms of any imaginable shape, so long as certain input rules and guidelines are followed. When non-axisymmetric nozzles are run, a completely three-dimensional, turbulent, compressible flow field analysis is performed, and input mistakes can be costly in terms of computer processor time. The user should make initial checkout runs for complex nozzles, running just one or two axial slices at first, to ensure that all input is as desired, before running a complete jet plume.

The program is designed to serve as a diagnostic tool, in addition to functioning in the standard jet noise prediction mode. Individual slice calculations can be made by suitable input selection, running each slice (or [illegible] ate case. This mode permits evaluation of the [illegible] each slice at each frequency and observer angle. [illegible] acoustic model can be bypassed to assess, for [illegible] effects of convection, acoustic shielding, etc. The [illegible] used to predict only the jet flow field, if desired.

## 5.0 CONCLUDING REMARKS

A theoretical analysis and associated computer model for the solution of the flow field and the acoustic characteristics of nozzles of arbitrary geometry is presented. A large number of cases have been calculated with this model and compared with appropriate experimental data (Reference 3). The computerized procedure presented herein provides a reasonably accurate method of predicting the aeroacoustic characteristics of a wide variety of exhaust nozzles over the range of flow conditions of interest, at least for those conditions and or observer angles where shock-cell noise does not dominate the spectrum.

# APPENDIX A

## DESCRIPTION OF INPUT

The input data is supplied through NAMELIST input format, with the exception of the alphanumeric title data card, which precedes the input NAMELIST data. Any number of successive cases can be run consecutively, limited only by the user's execution time available. Each successive case requires a title card (80 - character label in columns 1 - 80), followed by the INPUT NAMELIST. The data from preceding cases remains in storage, so only those variables which are to be changed from the preceding case input value need be included in the INPUT file of succeeding cases.

A suggested input preparation format is given in Table A-1. Those variables marked by an asterisk (*) have preset values built into the program, and need not be input unless the user desires to over-ride the preset value with a different one. The definitions of each of the input variables given in Table A-1 are listed in Table A-2. Again, preset variables are marked by an asterisk (*). The values of those variables which are preset are given in Table A-3. The format of Table A-2 is such that a note number (where appropriate) is given for each variable which corresponds to the note number in Section A.1 (Notes on Input). These notes give further elaboration on how to specify and prepare the input data.

Table A-1. Suggested Input Format.

Column
2

(80 - CHARACTER TITLE CARD, COLUMNS 1-80)

$INPUT

KX* = ________, NEST = ________, LPHI* = ________, ISYM = ________,

IQUIT* = ________, NN* = ________, NCASE* = ________, NBREF* = ________,

NPRINT* = ________, NCBDY = ________,

NØV = ________, ________, ________, ________, ________, ________,

X = ________, ________, ________, ________, ________, ________,

DSIG = ________, ________, ________, ________, ________, ________,

BETAIN* = ________, ________, ________, ________, ________, ________,

DELTIN* = ________, ________, ________, ________, ________, ________,

AMUIN* = ________, ________, ________, ________, ________, ________,

RMIN = ________, ________, ________, ________, ________, ________,

XE = ___0___, ________, ________, ________, ________, ________,

ALPØ = ___0___, ________, ________, ________, ________, ________,

LEAV = ___1___, ________, ________, ________, ________, ________,

NUM = ___1___, ________, ________, ________, ________, ________,

KN = ___1___, ________, ________, ________, ________, ________,

DEQ = ________, ________, ________, ________, ________, ________,

DS = ________, ________, ________, ________, ________, ________,

NCELL = ________, ________, ________, ________, ________, ________,

PT = ________, ________, ________, ________, ________, ________,

TT = ________, ________, ________, ________, ________, ________,

Table A-1. Suggested Input Format (Concluded).

Column
2

DALP(1,2) = __________, __________, __________, __________, __________,

DALP(1,3) = __________, __________, __________, __________, __________,
(etc., for boundary 4, 5, 6, .....NEST)

RA(1, 2) = __________, __________, __________, __________, __________,

RA(1, 3) = __________, __________, __________, __________, __________,
(etc., for boundary 4, 5, 6, .....Nest)

CM* = __________, CH* = __________, CMVR* = __________, CMMC* = __________,
GAM = __________, CP = __________, PS = __________, ALFA* = __________,

DTHM* = __________, RU2M* = __________, AK* = __________, BK* = __________,

STRFR* = __________, STRFX* = __________, ATØTAL = __________,

ALPHMC* = __________, BETAMC* = __________,

NUMANG = __________, DIST = __________, FMIN* = __________, FMAX* = __________,

ALPHT* = __________, __________, __________, __________, __________, __________,

XCBDY = __________, __________, __________, __________, __________, __________,
RCBDY = __________, __________, __________, __________, __________, __________,

$

(NEXT CASE, IF ANY)

Table A-2. Input Variable Definitions.

| Variable | Note | Description |
|---|---|---|
| KX* | | Number of axial stations to be analyzed; a maximum of 24 stations is permitted. |
| NEST | 1 | Number of closed boundary contours defining the nozzle exit geometry. A maximum of 110 is permitted. |
| LPHI | 7 | Number of symmetric leaves (repeating segments in the nozzle exit planform. |
| ISYM | | Nozzle symmetry indicator; ISYM = 1 for axsymmetric nozzles or completely asymmetric nozzles, = 0 otherwise. |
| IQUIT | | Maximum number of radii at which flow field is calculated ($\leq$200). |
| NN* | 12 | Acoustic Calculation option indicator. |
| NCASE* | | Number of cases to be run consecutively. |
| NBREF* | | Reference condition boundary number. |
| NPRINT* | 13 | Aerodynamic station printout indicator. |
| NCBDY | 9 | Number of centerbody input coordinate points. A maximum of 40 is permitted. |
| NØV | | Minimum number of radii at which flow field is to be calculated, for each axial station (KX values required). |
| X | 11 | Axial location of each axial station, ft. (KX values required). |
| DSIG | 11 | Radial step size to be taken for flow field calculation at each axial station, ft. (KX values required). |
| BETAIN* | 15 | Axial shear stress turbulence constant (KX values required). |
| DELTIN* | | Azimuthal shear stress turbulence constant (KX values required). |

Table A-2. Input Variable Definitions. (Continued)

| Variable | Note | Description |
| --- | --- | --- |
| AMUIN* | | Azimuthal velocity gradient turbulence frequency constant (KX values required). |
| RMIN | 9 | Minimum radius for flow field calculation at each axial station (KC values required). |
| XE | 8 | Axial location of exit plane of each boundary, ft. (NEST values required). |
| ALPØ | 2 | Reference angle $\alpha_0$ from which the coordinates of each boundary point are specified, radians (NEST values required). |
| LEAV | 1,4 | Number of symmetric leaves (repeating segments) of each boundary (NEST values required). |
| NUM | 1,5 | Number of input points (coordinate pairs) to be supplied for each boundary (NEST values required). |
| KN | 1 | The number of the boundary which encloses a given boundary (NEST values required). |
| DEQ | 16 | Equivalent flow area diameter of each boundary, ft. (NEST values required). |
| DS | 16 | Shock-cell spacing characteristic dimension, usually hydraulic diameter, of each boundary, ft. (NEST values required). |
| NCELL | 16 | Number of shock cells for each boundary element (NEST values required). |
| PT | 6 | Stagnation pressure inside each boundary, $lb_f/ft^2$ (NEST values required). |
| TT | 6 | Stagnation Temperature inside each boundary °R (NEST values required). |
| DALP(I,J) | 2,3,5 | Angular increment $\Delta\alpha$ from preceding boundary point which locates the given boundary point I on boundary J, radians (omit boundary number 1, ambient field). |

Table A-2. Input Variable Definitions (Continued).

| Variable | Note | Description |
|---|---|---|
| RA (I,J) | 2,3,5 | Radial coordinates of boundary point I on boundary J, ft. (omit boundary number 1, ambient field). |
| CM* | 10 | Empirical jet momentum diffusion rate spreading parameter $C_m$. |
| CH* | 10 | Ratio of enthalpy-to-momentum spreading parameters $C_h/C_m$. |
| CMVR* | 10 | Momentum spreading parameter velocity ratio influence coefficient. |
| CMMC* | 10 | Momentum spreading parameter Mach number influence coefficient. |
| GAM | | Specific heat ratio $\gamma = C_p/C_v$. |
| CP | | Specific heat at constant pressure $C_p$, in $(ft\text{-}lb_f)/(slug - °R)$. |
| PS | | Ambient static pressure, $lb_f/ft^2$. |
| ALFA* | | Turbulence characteristic frequency constant. |
| DTHM* | 7 | Maximum allowable increment in angular coordinate, $(d\phi)_{max}$, for flow field calculation. |
| RU2M* | | Minimum value of jet momentum flux, $(\rho U^2)_{min}$, below which the flow is not calculated. |
| AK* | | Sound pressure level proportionality constant for mixing noise calculation. |
| BK* | | Sound pressure level proportionality con- for dipole density-gradient noise calculation. |
| STRFR* | 11 | Radial coordinate stretching factor for use of automatic mesh calculation. |
| STRFX* | 11 | Axial coordinate stretching factor for use of automatic mesh calculation. |

Table A-2. Input Variable Definitions (Concluded).

| Variable | Note | Description |
|---|---|---|
| ATØTAL | | Nozzle Total exit flow area, $ft^2$. |
| ALPHMC* | 14 | Convection Mach number weighting factor. |
| BETAMC* | 14 | Convection Mach number weighting factor. |
| NUMANG | | Arena selection indicator; NUMANG = 1 indicates constant radius arc, NUMANG = 2 indicates sideline parallel to the jet axis. |
| DIST | | Arc or sideline distance, ft. |
| FMIN* | | Minimum frequency for which acoustic calculations are required, Hz ($\geq$50); an integer variable. |
| FMAX* | | Maximum frequency for which acoustic calculations are required, Hz ($\leq$100,000); an integer variable. |
| ALPHT* | | Convective amplification factor turbulence constant $\alpha_t$; 15 values required, one for each observer angle $\theta_I$ from $\theta_I$ = 20° to 160° in 10° increments. |
| XCBDY | 9 | Centerbody input point axial coordinate, NCBDY values required. |
| RCBDY | 9 | Centerbody input point radial coordinate, NCBDT values required. |

Table A-3. Preset Input Values.

| Variable | Value |
|---|---|
| AK | 0.08 |
| ALFA | 1.0 |
| ALPHT | 15* 0.5 |
| ALPHMC | 0.5 |
| AMUIN | 24* 0.2 |
| BETAIN | 24* 4.0 |
| BETAMC | 0.325 |
| BK | 0.0 |
| CH | 1.15 |
| CM | 0.075 |
| CMMC | 0.08 |
| CMVR | 0.25 |
| DELTIN | 24* 4.0 |
| DTHM | 0.1 |
| FMAX | 100000 |
| FMIN | 50 |
| IQUIT | 50 |
| KX | 15 |
| LPHI | 9999 |
| NBREF | 2 |
| NCASE | 1 |
| NN | 0 |
| NPRINT | 1 |
| RU2M | 3.0 |
| STRFR | 0.01 |
| STRFX | 1.259921 |

## A.1 NOTES ON INPUT

1. The jet nozzle geometry is specified by input of the number of component boundaries, NEST, along with pairs of coordinates, RA and DALP, for each boundary element. The ambient field is always treated as the first boundary in the input arrays for UE, PT, TT, LEAV, NUM, KN, XE, and ALPO. This is why some numbers have already been filled in on Table A-1 in the first column for these arrays. A nozzle with N elements has NEST = N + 1 boundaries.

2. The steps to specifying nozzle geometry input are as follows, referring to Figure 6:

   a. Obtain sketch or drawing of nozzle exit cross section and select a coordinate origin which is optimum from the standpoint of symmetry and boundary point specification.

   b. Number each boundary, reserving boundary Number 1 for the ambient field.

   c. With respect to the coordinate origin, select a reference angular location for each boundary, ALPØ.

   d. For each boundary, select points represented by pairs of coordinates. The coordinates used as input are radius, RA(I,J), and angular increment from the preceding point, DALP(I,J). For the first point, DALP(I,J) is the angular increment from the reference angle ALPØ. The index I is the boundary point number, and the index J is the boundary number. Both ALPØ and DALP are to be input in radians, and RA is input in feet.

3. The last point on a given boundary should be located at ALPØ if the boundary has only one leaf. The sum of all DALP(I,J) should equal zero if the boundary has only one leaf.

4. If the boundary is a circle about the origin, only one point on the boundary need be supplied, and the value of LEAV for that boundary is set equal to the number of boundary points desired on the circle.

5. The program uses linear interpolation between input boundary points. If a boundary is made up of or contains straight line segments, only the end-points of the straight line segments need be input.

6. The variables PT and TT refer to stagnation pressure and temperature at the exit plane inside the boundary of interest. Setting the first value of PT equal to PS gives a static ambient field. The first value of PT greater than PS simulates non-zero flight velocity.

7. The variable LPHI determines what angular extent of the flow field needs to be calculated. If the nozzle geometry is axisymmetric, setting LPHI equal to a large number (such that $2\pi$/LPHI is less than DTHM) forces the program to calculate the flow field at only one angular location. The flow field for a nozzle containing two adjacent circular jets, for example, has LPHI = 4, since the flow is the same each quadrant. Several examples of how boundary parameters are specified are shown in Figure A-1.

8. The program can currently only handle coplannar nozzles, i.e., every nozzle element must terminate at the same axial location. Therefore XE must be the same for all input boundaries.

9. The centerbody, if any, is input through coordinates pairs XCBDY(J), RCBDY(J), where $1 \leq J \leq$ NCBDY. A maximum of 40 points can be input. The LSPFIT subroutine uses this input to interpolate for finding the values of RMIN at each axial location X. The LSPFIT routine can treat line segments, both straight and curved. Typical examples of centerbody coordinate input are shown in Figure A-2. If there is no centerbody, the user can avoid automatic computation of the potential core of axisymmetric nozzles (which has no impact on mixing noise) by specifying RMIN as input, but with NCBDY = 0. This option causes the computation to begin at r = RMIN(KA), where KA is the axial station number.

10. The input value of CM is modified for velocity ratio and Mach number effects by the relation

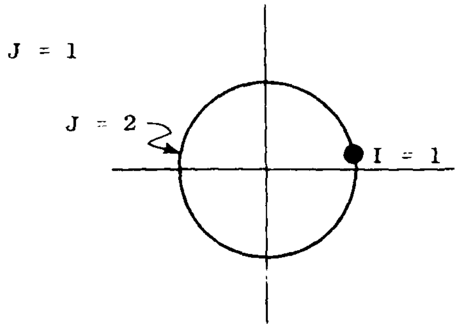
$$\text{DBDX} = \frac{\text{CM}}{(1 + \text{CMVR*VR})(1 + \text{CMMC*ACH})}$$

where DBDX is the modified value of $C_m$, and VR and ACH are the velocity ratio and Mach number, respectively, of a given boundary. The heat transport spreading parameter is then calculated from the relation

$$C_h = \text{CH} * \text{DBDX}$$

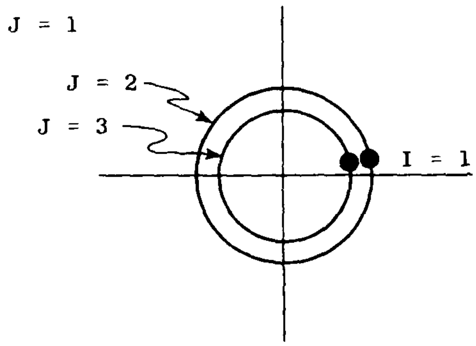
The values of CM, CMMC, CMVR and CH recommended and preset in the program are given in Table A-3. These values can be changed by the user to reflect experimental evidence if so desired.

11. The axial locations of the axial stations can be input by the array X(KA), where $1 \leq KA \leq KX$. The radial mesh step size can also be input by the array DSIG(KA). An automatic grid selection procedure has been devised to obviate the need for supplying all values of X(KA) and DSIG(KA). The only input required is the first axial station X(1), and the grid stretching factors STRFR and STRFX. The grid is then calculated from the following relations:



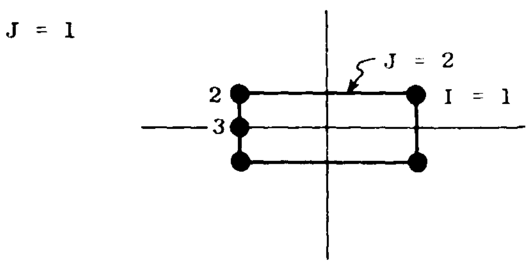

NEST = 2
LPHI = 999
ISYM = 1
LEAV = 1,36
NUM = 1,1,
$ALP_{\phi}$ = 0,0,
KN = 1,1,

(a) Circular Jet




NEST = 3
LPHI = 999
ISYM = 1
LEAV = 1,36,36,
NUM = 1,1,1,
$ALP_{\phi}$ = 0,0,0,
KN = 1,1,2,

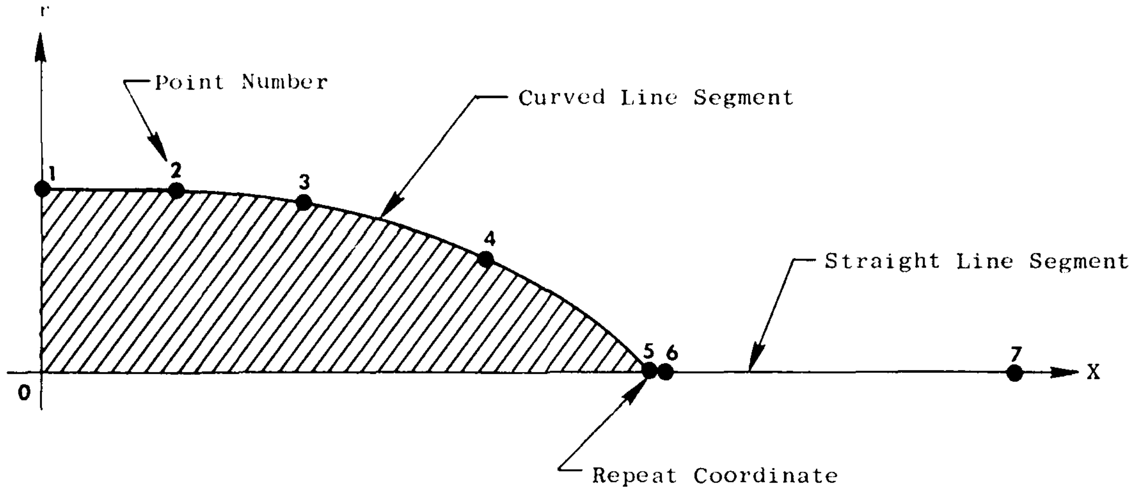
(b) Coannular Jet




NEST = 2
LPHI = 4
ISYM = 0
LEAV = 1,2,
NUM = 1,3,
$ALP_{\phi}$ = 0,0,
KN = 1,1,

(c) Rectangular Jet

Figure A-1. Examples of How Boundary Parameters are Specified.

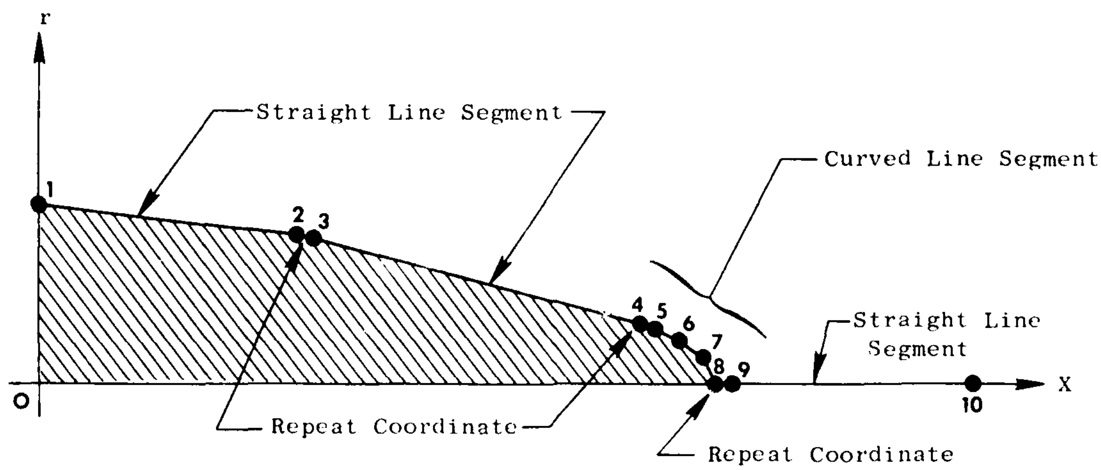



NCBDY = 7,

XCBDY = $X_1, X_2, X_3, X_4, X_5, X_6(=X_5), X_7$,

RCBDY = $R_1, R_2, R_3, R_4, 0, 0, 0$,

(a) Example 1 - Curved Centerbody




NCBDY = 10,

XCBDY = $X_1, X_2, X_3\ (=X_2), X_4, X_5(=X_4), X_6, X_7, X_8, X_9(=X_8), X_{10}$,

RCBDY = $R_1, R_2, R_3(\ R_2), R_4, R_5(=R_4), R_6, R_7, R_8, R_9(=R_8), R_{10}$,

(b) Example 2 - Segmented-Cone Centerbody with Curved Tip

Figure A-2. Centerbody Input Coordinate Examples.

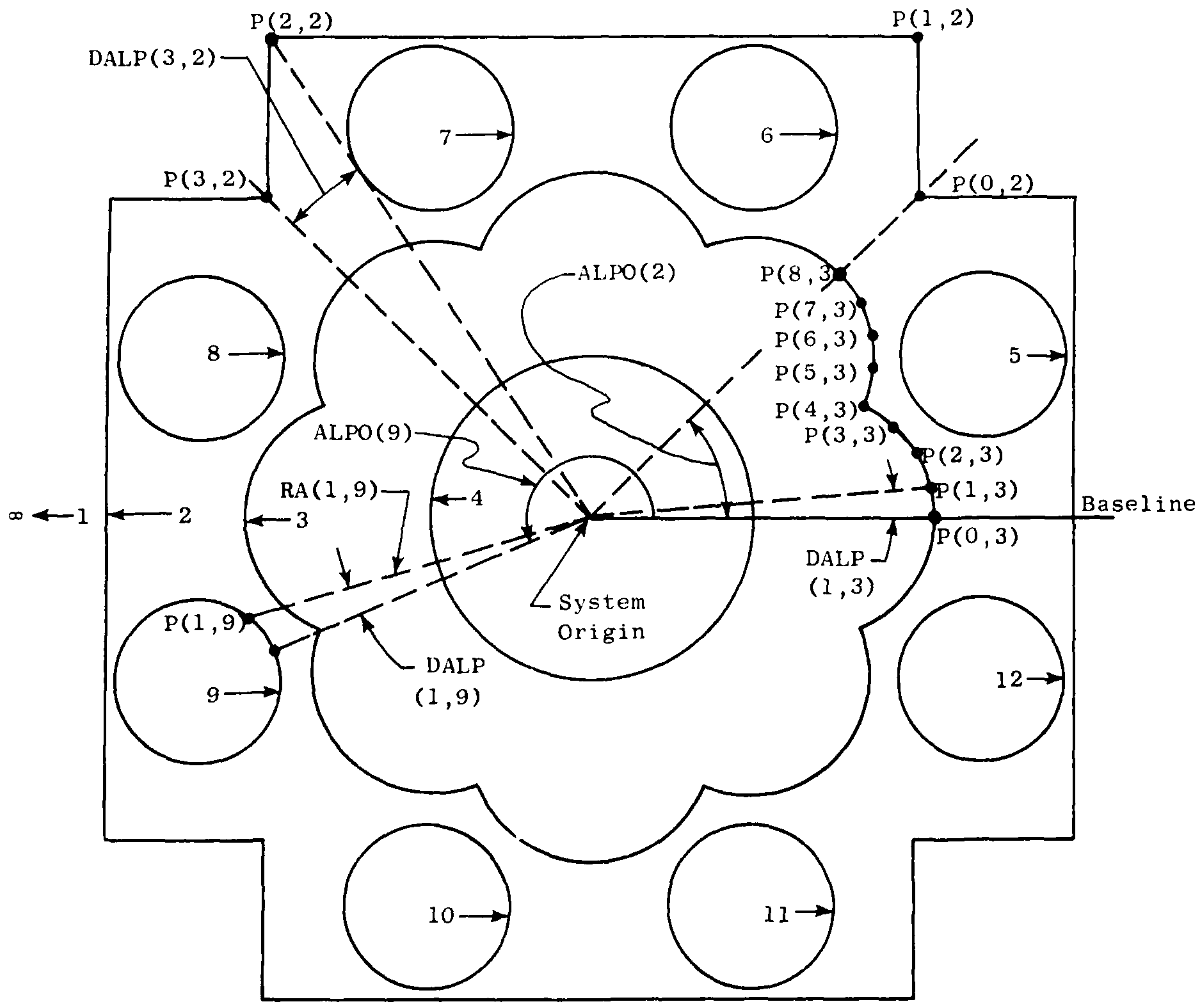



Figure A-3. Example Demonstration of Nozzle Geometry Specification with a Generalized Nozzle Exit Configuration.

$$X(KA) = STRFX * X(KA-1)$$

$$DSIG(KA) = STRFR * X(KA)$$

This provides a grid which exhibits larger and larger step sizes as the plume is developed downstream. Recommended value of STRFR and STRFX are preset and listed in Table A-3.

12. The variable NN determines the type of acoustic calculation desired. Normal (preset) operation is with NN = 0, which give the complete acoustic calculation described in Section 3. The user may desire to perform diagnostic computations to assess the relative importance of convection, shielding, etc. By selecting the appropriate value of NN, the various components of the acoustic calculation can be switched on and off in various combinations. Setting NN = 4 gives only the aerodynamic calculation, and the acoustic calculations are bypassed. The various options for NN are listed below:

    NN = 0 - complete acoustic calculation.

    NN = 1 - convective amplification, no shielding.

    NN = 2 - no convective amplification, no shielding.

    NN = 3 - no convective amplification, with shielding.

    NN = 4 - no acoustic calculation, aerodynamics only.

13. The printout of aerodynamic flow field data is controlled by NPRINT. When NPRINT = 0, no aerodyanmic printout is provided. If NPRINT = 1, aerodynamic printout is provided at every axial station. If NPRINT = 2, aerodynamic printout is provided at every <u>second</u> axial station (i.e., KA = 1, 3, 5, 7, etc). For PRINT = 3, printout is provided at every <u>third</u> station, etc.

14. For dual flow nozzles, if the inner stream has a higher velocity than the outer stream, use ALPHMC = 0.5 and BETAMC = 0.325 (preset values). These variables are weighting factors in the convection Mach number calculation, which is computed from the relation

$$MC = ALPHMC * MACH + BETAMC * EMACH$$

where MACH is the local acoustic Mach number $U/C_a$ and EMACH is the exit plane reference Mach number $U_j/C_a$. If the outer stream has a higher velocity than the inner stream, use ALPHMC = 0.5 and BETAMC = 0.325/VR, where VR = $(U_{outer}/U_{inner})_j$. For multielement suppressor nozzles, VR = $U_j/U_m$, where $U_m$ is the post-merged potential core velocity. If $U_m$ is not known, BETAMC = 0.2 to 0.25 is usually a good approximation.

15. For dual flow nozzles, input BETAIN = 4.0 (preset) for all values of X, provided the inner stream velocity is higher than the outer stream velocity at the exit plane. If the outer stream velocity is higher than the inner stream velocity at the exit plane, input BETAIN = 0 for all axial stations where X $\leq$ 10*DEQ(NBREF), and BETAIN = 4.0 thereafter, where NBREF is the outer stream boundary number. For multielement nozzles, input BETAIN = 0 for axial distances less than 10*DEQ(1), where DEQ(1) is the equivalent diameter based on total flow area at the exit plane.

16. For each boundary element DEQ, DS and NCELL are input. The first value of DEQ is the total flow area equivalent diameter. The first value of NCELL determines whether or not the shock cell noise is computed. If NCELL(1) is input zero, no shock noise is computed; for NCELL(1)>0, the shock cell noise routine is called. The shock noise of each boundary element is computed separately and added to the total noise. If any boundary has a value of NCELL = 0, that boundary element is bypassed in the shock noise calculation. It is recommended that NCELL = 8 be used for each element unless the actual number is known.

## A.2 EXAMPLE CASE INPUT SELECTION

To illustrate how geometric input parameters are selected for a complex nozzle geometry, an example is presented, taken from Reference (1). The example nozzle exit geometry is shown in Figure A-3. Consideration of this figure indicates information over a 45° sector of the flow field will be sufficient to describe the complete flow field. This is one-eighth of a circle, thus LPHI = 8. Neither axial total similarity or dissimilarity exists so ISYM is 0. Counting the number of closed contours indicates a value of NEST of 12, where one is included for the ambient or external field. Values of PT and TT must be provided for the exit state existing just within each of these contours. Values of XE, ALPO, LEAV, NUM, KN, DEQ, DS, and NCELL must be provided for all the contours except the first which is the boundary at infinity. Values of these parameters for the contours shown in Figure A-3 are now considered in the following discussion.

Boundary 2: Description of this boundary starting at 45° to the system baseline is convenient. Thus ALPO = $\pi/4$ radians. Since each 90° sector of the contour is identical with the proceeding one, LEAV = 4. Since the program assumes straight lines to exist between successive boundary points, description of this boundary is possible with only three points for each quadrant. These are P(1,2), P(2,2), and P(3,2). Each point is described by its distance from the system origin and the angle between the line joining it with the origin and the line joining the proceeding point with the origin. Note that no value of RA is given for the point P(0,2) since it will be identical to RA(3,2). The value of NUM for boundary 2 will therefore be 3.

Boundary 3: This contour has eight symmetric leaves, thus LEAV = 8. ALPO of 0.0 is as convenient as any other value. The eight points indicated P(1,3) through P(8,3) probably are sufficient to describe the boundary. Thus NUM = 8.

Boundary 4: Since this is a circle about the origin it can be divided into a convenient number of leaves and only one point given for each (NUM = 1). If a hundred boundary points are desired; set LEAV = 100, DALP(1,4)=$\pi$/50 and RA(1,4) equal to the circle radius.

Boundary 5 through 12: Each of these contours must be described individually unless certain artifical changes are made in the arrangement. A partial representation of Boundary 9 is shown in Figure A-3. Note that successive points on the boundary are obtained by progressing around the boundary in a counter-clockwise fashion. In order to reduce the labor of representing each circle separately, a straight line can be drawn connecting each circle. Two contours can then be visualized, one consisting of the outer halves of the circles and the lines, the other consisting of the inner halves of the circles and the lines. Each contour has eight leaves and only one need be represented by the programmer. Since this technique requires the computer to integrate along each straight line twice in the course of computation, it will definitely increase the computational time over the method wherein each contour is represented separately.

## APPENDIX B

## OUTPUT DESCRIPTION

The output format is generally self-explanatory. The input data is first printed out, using the same nomenclature previously defined in Table 2. Nozzle exit plane flow conditions (static temperature, velocity, Mach number, momentum flux, and enthalpy flux) are then printed out for each boundary contour.

At each axial location specified, the radial and tangential distributions of flow field properties are printed out. After the flow field information, the noise characteristics of that particular axial station are then listed.

Following all of the axial station flow field data, a summary table of the noise characteristics (SPL spectra, PNL, PWL, OASPL) is given.

Appendix C contains an input deck card listing and output printout for a sample case run. This particular case is for a 7-tube nozzle presented in Reference 2. Only a portion of the total output is shown for brevity, but the formats of the various output data are all included.

Two warning flags are built into the program. The first is a case termination flag, which occurs whenever an input total pressure (PT) is less than the input static pressure (PS). The flag message is as follows:

```
****ERROR - MACH NO. SQUARE IS NOT GREATER THAN ZERO - CASE WILL
    TERMINATE****
```

The second flag is a warning detected in subroutine SLICE, which occurs whenever the number of turning points (NTP) is found to be greater than 2. The flag message is as follows:

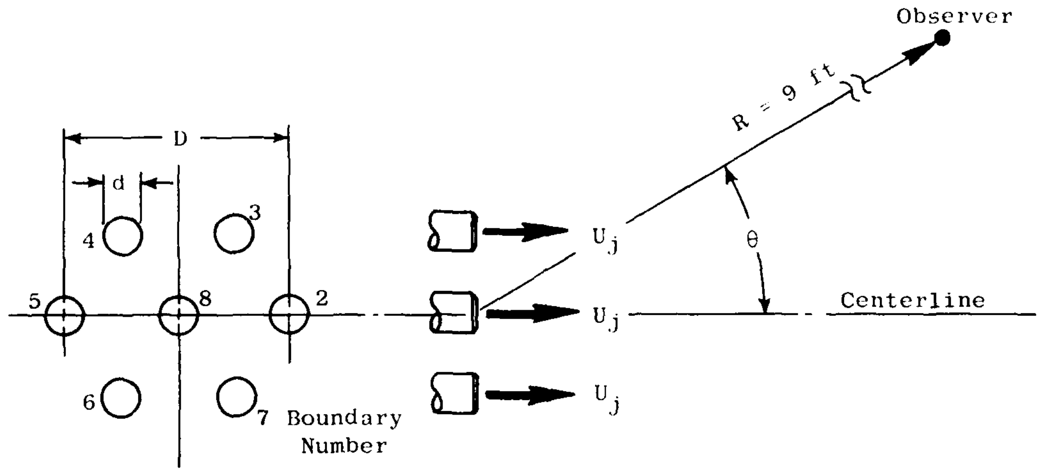
```
WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT

KA = _____, X = _____, ITH = _____, THETA = _____, NTP = _____
```

where KA is the axial station number, X is the axial location, ITH is the observer angle index, THETA is the observer angle in degrees ($\theta_I$), and NTP is the number of turning points found. The two outermost turning points are used and those inboard of these two are discarded in such cases, since the acoustic shielding model can only accommodate up to 2 turning points. The noise output at those values of $\theta_I$ where this warning appears should be treated as suspect, since the acoustic shielding effects are not properly modeled. This is most likely to occur in the initial mixing regions of multitube nozzles where multiple peaks in the aximuthally-averaged velocity profiles are likely to occur.

## APPENDIX C

## SAMPLE OUTPUT LISTING

An example case of a 7-tube multielement nozzle is described herein, selected from one of the data/theory comparison cases presented in Reference (3). The nozzle consists of a hexagonal array of 0.875-inch diameter tubes, with a spacing/diameter ratio of 3. The acoustic arena is a 9 ft. radius arc. The geometry is illustrated in the sketch below.




d = 0.875 in.

D = 3.0 in.

The input data cards for this case are listed in Table C-1. Note that all geometry input lengths are in feet, and all input geometry angles are in radians. The output listing for this case follows Table C-1.

Table C-1. Input Data Card Listing Sample Case.

```
5R329 01   10-06-77    16.471    *** INPUT DATA CARD LISTING -- M*G*B ***
         CRD 7-TUBE AR#2.3 NOZZLE  -  VJ#2200 FPS - TTJ#1600 DEG-R
 $INPUT
 NEST=8, LPHI=12, ISYM=0, IQUIT=100,
 RU2M=3, DTHM=0.1, PS=2116,
 ATOTAL=0.029231, DEQ=8*0.0729167, DS=8*0.0729167, NCELL=8*8,
 KN=8*1, XE=8*0,
 GAM=1.35, CP=6619,

 ALP0=0.0,5.96144,0.725447,1.77264,2.8198,3.8670,4.9142,0.0,
 LEAV=0,6*1,24,    NUM=1,6*24,1, KN=8*1, XE=8*0,
 DALP(1,2)=
 .033596,.045590,.054084,.059862,.063450,.065168,
 .065168,.063450,.059862,.054084,.045590,.033596,
 .017039,-.005317,-.034336,-.068984,-.103591,-.126562,
 -.126562,-.103591,-.068984,-.034336,-.005317,.017039,
 DALP(1,3)=
 .033596,.045590,.054084,.059862,.063450,.065168,
 .065168,.063450,.059862,.054084,.045590,.033596,
 .017039,-.005317,-.034336,-.068984,-.103591,-.126562,
 -.126562,-.103591,-.068984,-.034336,-.005317,.017039,
 DALP(1,4)=
 .033596,.045590,.054084,.059862,.063450,.065168,
 .065168,.063450,.059862,.054084,.045590,.033596,
 .017039,-.005317,-.034336,-.068984,-.103591,-.126562,
 -.126562,-.103591,-.068984,-.034336,-.005317,.017039,
 DALP(1,5)=
 .033596,.045590,.054084,.059862,.063450,.065168,
 .065168,.063450,.059862,.054084,.045590,.033596,
 .017039,-.005317,-.034336,-.068984,-.103591,-.126562,
 -.126562,-.103591,-.068984,-.034336,-.005317,.017039,
 DALP(1,6)=
 .033596,.045590,.054084,.059862,.063450,.065168,
 .065168,.063450,.059862,.054084,.045590,.033596,
 .017039,-.005317,-.034336,-.068984,-.103591,-.126562,
 -.126562,-.103591,-.068984,-.034336,-.005317,.017039,
 DALP(1,7)=
 .033596,.045590,.054084,.059862,.063450,.065168,
 .065168,.063450,.059862,.054084,.045590,.033596,
 .017039,-.005317,-.034336,-.068984,-.103591,-.126562,
 -.126562,-.103591,-.068984,-.034336,-.005317,.017039,
 RA(1,2)=
 .12392,.13145,.13759,.14212,.14489,.14583,
 .14489,.14212,.13759,.13145,.12392,.11529,
 .10596,.09646,.08748,.07991,.07476,.07292,
 .07476,.07991,.08748,.09646,.10596,.11529,
 RA(1,3)=
 .12392,.13145,.13759,.14212,.14489,.14583,
 .14489,.14212,.13759,.13145,.12392,.11529,
 .10596,.09646,.08748,.07991,.07476,.07292,
 .07476,.07991,.08748,.09646,.10596,.11529,
 RA(1,4)=
 .12392,.13145,.13759,.14212,.14489,.14583,
 .14489,.14212,.13759,.13145,.12392,.11529,
 .10596,.09646,.08748,.07991,.07476,.07292,
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Table C-1. Input Data Card Listing Sample Case (Concluded).

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5R329 01   10-06-77    16.471     *** INPUT DATA CARD LISTING -- M*G*8 ***

 .07476,.07991,.08748,.09646,.10596,.11529,
 RA(1,5)=
 .12392,.13145,.13759,.14212,.14489,.14583,
 .14489,.14212,.13759,.13145,.12392,.11529,
 .10596,.09646,.08748,.07991,.07476,.07292,
 .07476,.07991,.08748,.09646,.10596,.11529,
 RA(1,6)=
 .12392,.13145,.13759,.14212,.14489,.14583,
 .14489,.14212,.13759,.13145,.12392,.11529,
 .10596,.09646,.08748,.07991,.07476,.07292,
 .07476,.07991,.08748,.09646,.10596,.11529,
 RA(1,7)=
 .12392,.13145,.13759,.14212,.14489,.14583,
 .14489,.14212,.13759,.13145,.12392,.11529,
 .10596,.09646,.08748,.07991,.07476,.07292,
 .07476,.07991,.08748,.09646,.10596,.11529,
 DALP(1,8)=0.2618, RA(1,8)=0.036453,

 ALPHMC=0.5, BETAMC=0.25,
 FMIN=100, FMAX=80000, NUMANG=1, DIST=9.0,
 KX=24, X=0.0729167, STRFR=0.01,
 DSIG=10*0.00729167, 14*0,  NOV=10*20,14*0,
 BETAIN=15*0.0,
 NPRINT=
 NCASE=1,

 PT=2116,7*5732, TT#540,7*1605,
 $
```

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1    CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

INPUT DATA

KX= 24    NEST= 6    LPHI= 12    ISYM= 0    NPRINT= 6    CM= .075

CH= 1.150    GAM= 1.350    CP= 6619.0    DTHM= .1000    RU2M= 3.0000    PS= 2116.0

COMPUTATION MESH CONTROL PARAMETERS......................../ TURBULENCE CONSTANTS

| SLICE NO. | X | DSIG | RMIN | NOV | BETA | DELTA | MU |
|---|---|---|---|---|---|---|---|
| 1 | .07292 | .00729 | 0.00000 | 20 | 0.00 | 4.00 | .20 |
| 2 | .09187 | .00729 | 0.00000 | 20 | 0.00 | 4.00 | .20 |
| 3 | .11575 | .00729 | 0.00000 | 20 | 0.00 | 4.00 | .20 |
| 4 | .14583 | .00729 | 0.00000 | 20 | 0.00 | 4.00 | .20 |
| 5 | .18374 | .00729 | 0.00000 | 20 | 0.00 | 4.00 | .20 |
| 6 | .23150 | .00729 | 0.00000 | 20 | 0.00 | 4.00 | .20 |
| 7 | .29167 | .00729 | 0.00000 | 20 | 0.00 | 4.00 | .20 |
| 8 | .36748 | .00729 | 0.00000 | 20 | 0.00 | 4.00 | .20 |
| 9 | .46299 | .00729 | 0.00000 | 20 | 0.00 | 4.00 | .20 |
| 10 | .58333 | .00729 | 0.00000 | 20 | 0.00 | 4.00 | .20 |
| 11 | .73495 | .00735 | 0.00000 | 0 | 0.00 | 4.00 | .20 |
| 12 | .92593 | .00926 | 0.00000 | 0 | 0.00 | 4.00 | .20 |
| 13 | 1.16667 | .01167 | 0.00000 | 0 | 0.00 | 4.00 | .20 |
| 14 | 1.46991 | .01470 | 0.00000 | 0 | 0.00 | 4.00 | .20 |
| 15 | 1.85197 | .01852 | 0.00000 | 0 | 0.00 | 4.00 | .20 |
| 16 | 2.33333 | .02333 | 0.00000 | 0 | 4.00 | 4.00 | .20 |
| 17 | 2.93982 | .02940 | 0.00000 | 0 | 4.00 | 4.00 | .20 |
| 18 | 3.70393 | .03704 | 0.00000 | 0 | 4.00 | 4.00 | .20 |
| 19 | 4.66667 | .04667 | 0.00000 | 0 | 4.00 | 4.00 | .20 |
| 20 | 5.87963 | .05880 | 0.00000 | 0 | 4.00 | 4.00 | .20 |
| 21 | 7.40787 | .07408 | 0.00000 | 0 | 4.00 | 4.00 | .20 |
| 22 | 9.33333 | .09333 | 0.00000 | 0 | 4.00 | 4.00 | .20 |
| 23 | 11.75926 | .11759 | 0.00000 | 0 | 4.00 | 4.00 | .20 |
| 24 | 14.81574 | .14816 | 0.00000 | 0 | 4.00 | 4.00 | .20 |

XE( 2)= 0.00 ALPO( 2)= 5.9614 LEAV( 2)= 1 NUM( 2)= 24 KN( 2)= 1

DALP( 1, 2)= .0336 RA( 1, 2)= .1239 DALP( 2, 2)= .0456 RA( 2, 2)= .1315

DALP( 3, 2)= .0541 RA( 3, 2)= .1376 DALP( 4, 2)= .0599 RA( 4, 2)= .1421

DALP( 5, 2)= .0635 RA( 5, 2)= .1449 DALP( 6, 2)= .0652 RA( 6, 2)= .1458

DALP( 7, 2)= .0652 RA( 7, 2)= .1449 DALP( 8, 2)= .0635 RA( 8, 2)= .1421

DALP( 9, 2)= .0599 RA( 9, 2)= .1376 DALP(10, 2)= .0541 RA(10, 2)= .1315

DALP(11, 2)= .0456 RA(11, 2)= .1239 DALP(12, 2)= .0336 RA(12, 2)= .1153

DALP(13, 2)= .0170 RA(13, 2)= .1060 DALP(14, 2)= -.0053 RA(14, 2)= .0965

DALP(15, 2)= -.0343 RA(15, 2)= .0875 DALP(16, 2)= -.0690 RA(16, 2)= .0799

DALP(17, 2)= -.1036 RA(17, 2)= .0748 DALP(18, 2)= -.1266 RA(18, 2)= .0729

DALP(19, 2)= -.1266 RA(19, 2)= .0748 DALP(20, 2)= -.1036 RA(20, 2)= .0799

DALP(21, 2)= -.0690 RA(21, 2)= .0875 DALP(22, 2)= -.0343 RA(22, 2)= .0965

DALP(23, 2)= -.0053 RA(23, 2)= .1060 DALP(24, 2)= .0170 RA(24, 2)= .1153

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COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO.   1          CRD 7-TUBE AR=2.3 NOZZLE  -  VJ=2200 FPS - TTJ=1600 DEG-R

XE( 3)=    0.00  ALPO( 3)=  .7254  LEAV( 3)=  1    NUM( 3)= 24    KN( 3)=  1
       DALP( 1, 3)=  .0336    RA( 1, 3)=  .1239  DALP( 2, 3)=  .0456    RA( 2, 3)=  .1315
       DALP( 3, 3)=  .0541    RA( 3, 3)=  .1376  DALP( 4, 3)=  .0599    RA( 4, 3)=  .1421
       DALP( 5, 3)=  .0635    RA( 5, 3)=  .1449  DALP( 6, 3)=  .0652    RA( 6, 3)=  .1458
       DALP( 7, 3)=  .0652    RA( 7, 3)=  .1449  DALP( 8, 3)=  .0635    RA( 8, 3)=  .1421
       DALP( 9, 3)=  .0599    RA( 9, 3)=  .1376  DALP(10, 3)=  .0541    RA(10, 3)=  .1315
       DALP(11, 3)=  .0456    RA(11, 3)=  .1239  DALP(12, 3)=  .0336    RA(12, 3)=  .1153
       DALP(13, 3)=  .0170    RA(13, 3)=  .1060  DALP(14, 3)= -.0053    RA(14, 3)=  .0965
       DALP(15, 3)= -.0343    RA(15, 3)=  .0875  DALP(16, 3)= -.0690    RA(16, 3)=  .0799
       DALP(17, 3)= -.1036    RA(17, 3)=  .0748  DALP(18, 3)= -.1266    RA(18, 3)=  .0729
       DALP(19, 3)= -.1266    RA(19, 3)=  .0748  DALP(20, 3)= -.1036    RA(20, 3)=  .0799
       DALP(21, 3)= -.0690    RA(21, 3)=  .0875  DALP(22, 3)= -.0343    RA(22, 3)=  .0965
       DALP(23, 3)= -.0053    RA(23, 3)=  .1060  DALP(24, 3)=  .0170    RA(24, 3)=  .1153
XE( 4)=    0.00  ALPO( 4)= 1.7726  LEAV( 4)=  1    NUM( 4)= 24    KN( 4)=  1
       DALP( 1, 4)=  .0336    RA( 1, 4)=  .1239  DALP( 2, 4)=  .0456    RA( 2, 4)=  .1315
       DALP( 3, 4)=  .0541    RA( 3, 4)=  .1376  DALP( 4, 4)=  .0599    RA( 4, 4)=  .1421
       DALP( 5, 4)=  .0635    RA( 5, 4)=  .1449  DALP( 6, 4)=  .0652    RA( 6, 4)=  .1458
       DALP( 7, 4)=  .0652    RA( 7, 4)=  .1449  DALP( 8, 4)=  .0635    RA( 8, 4)=  .1421
       DALP( 9, 4)=  .0599    RA( 9, 4)=  .1376  DALP(10, 4)=  .0541    RA(10, 4)=  .1315
       DALP(11, 4)=  .0456    RA(11, 4)=  .1239  DALP(12, 4)=  .0336    RA(12, 4)=  .1153
       DALP(13, 4)=  .0170    RA(13, 4)=  .1060  DALP(14, 4)= -.0053    RA(14, 4)=  .0965
       DALP(15, 4)= -.0343    RA(15, 4)=  .0875  DALP(16, 4)= -.0690    RA(16, 4)=  .0799
       DALP(17, 4)= -.1036    RA(17, 4)=  .0748  DALP(18, 4)= -.1266    RA(18, 4)=  .0729
       DALP(19, 4)= -.1266    RA(19, 4)=  .0748  DALP(20, 4)= -.1036    RA(20, 4)=  .0799
       DALP(21, 4)= -.0690    RA(21, 4)=  .0875  DALP(22, 4)= -.0343    RA(22, 4)=  .0965
       DALP(23, 4)= -.0053    RA(23, 4)=  .1060  DALP(24, 4)=  .0170    RA(24, 4)=  .1153
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COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO.   1              CRD 7-TUBE AR=2.3 NOZZLE  -  VJ=2200 FPS - TTJ=1600 DEG-R

     XE( 5)=    0.00  ALPO( 5)= 2.8198  LEAV( 5)=  1   NUM( 5)= 24    KN( 5)=  1
          DALP( 1, 5)=  .0336    RA( 1, 5)=  .1239  DALP( 2, 5)=  .0456    RA( 2, 5)=  .1315
          DALP( 3, 5)=  .0541    RA( 3, 5)=  .1376  DALP( 4, 5)=  .0599    RA( 4, 5)=  .1421
          DALP( 5, 5)=  .0635    RA( 5, 5)=  .1449  DALP( 6, 5)=  .0652    RA( 6, 5)=  .1458
          DALP( 7, 5)=  .0652    RA( 7, 5)=  .1449  DALP( 8, 5)=  .0635    RA( 8, 5)=  .1421
          DALP( 9, 5)=  .0599    RA( 9, 5)=  .1376  DALP(10, 5)=  .0541    RA(10, 5)=  .1315
          DALP(11, 5)=  .0456    RA(11, 5)=  .1239  DALP(12, 5)=  .0336    RA(12, 5)=  .1153
          DALP(13, 5)=  .0170    RA(13, 5)=  .1060  DALP(14, 5)= -.0053    RA(14, 5)=  .0965
          DALP(15, 5)= -.0343    RA(15, 5)=  .0875  DALP(16, 5)= -.0690    RA(16, 5)=  .0799
          DALP(17, 5)= -.1036    RA(17, 5)=  .0748  DALP(18, 5)= -.1266    RA(18, 5)=  .0729
          DALP(19, 5)= -.1266    RA(19, 5)=  .0748  DALP(20, 5)= -.1036    RA(20, 5)=  .0799
          DALP(21, 5)= -.0690    RA(21, 5)=  .0875  DALP(22, 5)= -.0343    RA(22, 5)=  .0965
          DALP(23, 5)= -.0053    RA(23, 5)=  .1060  DALP(24, 5)=  .0170    RA(24, 5)=  .1153
     XE( 6)=    0.00  ALPO( 6)= 3.8670  LEAV( 6)=  1   NUM( 6)= 24    KN( 6)=  1
          DALP( 1, 6)=  .0336    RA( 1, 6)=  .1239  DALP( 2, 6)=  .0456    RA( 2, 6)=  .1315
          DALP( 3, 6)=  .0541    RA( 3, 6)=  .1376  DALP( 4, 6)=  .0599    RA( 4, 6)=  .1421
          DALP( 5, 6)=  .0635    RA( 5, 6)=  .1449  DALP( 6, 6)=  .0652    RA( 6, 6)=  .1458
          DALP( 7, 6)=  .0652    RA( 7, 6)=  .1449  DALP( 8, 6)=  .0635    RA( 8, 6)=  .1421
          DALP( 9, 6)=  .0599    RA( 9, 6)=  .1376  DALP(10, 6)=  .0541    RA(10, 6)=  .1315
          DALP(11, 6)=  .0456    RA(11, 6)=  .1239  DALP(12, 6)=  .0336    RA(12, 6)=  .1153
          DALP(13, 6)=  .0170    RA(13, 6)=  .1060  DALP(14, 6)= -.0053    RA(14, 6)=  .0965
          DALP(15, 6)= -.0343    RA(15, 6)=  .0875  DALP(16, 6)= -.0690    RA(16, 6)=  .0799
          DALP(17, 6)= -.1036    RA(17, 6)=  .0748  DALP(18, 6)= -.1266    RA(18, 6)=  .0729
          DALP(19, 6)= -.1266    RA(19, 6)=  .0748  DALP(20, 6)= -.1036    RA(20, 6)=  .0799
          DALP(21, 6)= -.0690    RA(21, 6)=  .0875  DALP(22, 6)= -.0343    RA(22, 6)=  .0965
          DALP(23, 6)= -.0053    RA(23, 6)=  .1060  DALP(24, 6)=  .0170    RA(24, 6)=  .1153
```

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO.   1            CFD 7-TUBE AR=2.3 NOZZLE  -  VJ=2200 FPS - TTJ=1600 DEG-R

```
XF( 7)=     0.00  ALPO( 7)= 4.9142  LEAV( 7)=  1   NUM( 7)= 24    KN( 7)=  1
      DALP( 1, 7)=  .0336    RA( 1, 7)=  .1239  DALP( 2, 7)=  .0456    RA( 2, 7)=  .1315
      DALP( 3, 7)=  .0541    RA( 3, 7)=  .1376  DALP( 4, 7)=  .0599    RA( 4, 7)=  .1421
      DALP( 5, 7)=  .0635    RA( 5, 7)=  .1449  DALP( 6, 7)=  .0652    RA( 6, 7)=  .1458
      DALP( 7, 7)=  .0652    RA( 7, 7)=  .1449  DALP( 8, 7)=  .0635    RA( 8, 7)=  .1421
      DALP( 9, 7)=  .0599    RA( 9, 7)=  .1376  DALP(10, 7)=  .0541    RA(10, 7)=  .1315
      DALP(11, 7)=  .0456    RA(11, 7)=  .1239  DALP(12, 7)=  .0336    RA(12, 7)=  .1153
      DALP(13, 7)=  .0170    RA(13, 7)=  .1060  DALP(14, 7)= -.0653    RA(14, 7)=  .0965
      DALP(15, 7)= -.0343    RA(15, 7)=  .0875  DALP(16, 7)= -.0690    RA(16, 7)=  .0799
      DALP(17, 7)= -.1036    RA(17, 7)=  .0748  DALP(18, 7)= -.1266    RA(18, 7)=  .0729
      DALP(19, 7)= -.1266    RA(19, 7)=  .0748  DALP(20, 7)= -.1036    RA(20, 7)=  .0799
      DALP(21, 7)= -.0690    RA(21, 7)=  .0875  DALP(22, 7)= -.0343    RA(22, 7)=  .0965
      DALP(23, 7)= -.0653    RA(23, 7)=  .1060  DALP(24, 7)=  .0170    RA(24, 7)=  .1153
XE( 8)=     0.00  ALPO( 8)= 0.0000  LEAV( 8)= 24   NUM( 8)=  1    KN( 8)=  1
      DALP( 1, 8)=  .2618    RA( 1, 8)=  .0365  DALP(
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* * * M G R * * *  PAGE 5

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1  CPD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

EXIT CONDITIONS

| CON-TOUR | TOTAL PRESS. (PSF) | TOTAL TEMP. (DEG R) | STATIC TEMP. (DEG R) | VELOCITY (FPS) | MACH NUMBER | MOMENTUM FLUX (LB/SQ-FT) | ENTHALPY FLUX (LB/SQ-FT) |
|---|---|---|---|---|---|---|---|
| 1 | 2116.00 | 540.00 | 540.00 | .30 | .0003 | .20000E-03 | 0. |
| 2 | 5732.00 | 1665.00 | 1239.57 | 2199.45 | 1.2979 | .48123E+04 | .15423E+08 |
| 3 | 5732.00 | 1665.00 | 1239.57 | 2199.45 | 1.2979 | .48123E+04 | .15423E+08 |
| 4 | 5732.00 | 1665.00 | 1239.57 | 2199.45 | 1.2979 | .48123E+04 | .15423E+08 |
| 5 | 5732.00 | 1665.00 | 1239.57 | 2199.45 | 1.2979 | .48123E+04 | .15423E+08 |
| 6 | 5732.00 | 1665.00 | 1239.57 | 2199.45 | 1.2979 | .48123E+04 | .15423E+08 |
| 7 | 5732.00 | 1665.00 | 1239.57 | 2199.45 | 1.2979 | .48123E+04 | .15423E+08 |
| 8 | 5732.00 | 1665.00 | 1239.57 | 2199.45 | 1.2979 | .48123E+04 | .15423E+08 |

OUNDARY NO. 2 HAS BEEN DESIGNATED AS THE REFERENCE

AL = .20886E+08  ALFA = 1.00000  AK = .80000E-01  BK = 0.

ATOTAL= .32923  DEQ = .07292  IOUIT= 100  NN = 0  UREF = 2199.45

STREX= 1.25992  STREP= .01000

ALPHMC= .5000  BETAMC= .2500

CMMC= .080000  CMVP= .250000

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1　　　CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .07292 (X/DEQ = 1.00000)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/[illegible] |
|---|---|---|---|---|---|---|---|---|
| 1 | .00001 | 0.00 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00037 | .00010 |
| 1 | .00001 | 10.00 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .000[illegible] | .00010 |
| 1 | .00001 | 20.00 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00140 | .00010 |
| 1 | .00001 | 30.00 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00143 | .00010 |
| 2 | .00729 | 0.00 | 2199.46 | .0009948 | 1239.57 | 1.00000 | .0015[illegible] | .10000 |
| 2 | .00729 | 10.00 | 2199.46 | .0009948 | 1239.57 | 1.00000 | .00189 | .10000 |
| 2 | .00729 | 20.00 | 2199.46 | .0009948 | 1239.57 | 1.00000 | .00186 | .10000 |
| 2 | .00729 | 30.00 | 2199.46 | .0009948 | 1239.57 | 1.00000 | .0018[illegible] | .10000 |
| 3 | .01458 | 0.00 | 2199.46 | .0009948 | 1239.57 | 1.00000 | .00044 | .20000 |
| 3 | .01458 | 7.50 | 2199.46 | .0009948 | 1239.57 | 1.00000 | .00079 | .20000 |
| 3 | .01458 | 15.00 | 2199.46 | .0009948 | 1239.57 | 1.00000 | .00122 | .20000 |
| 3 | .01458 | 22.50 | 2199.46 | .0009948 | 1239.57 | 1.00000 | .00090 | .20000 |
| 3 | .01458 | 30.00 | 2199.46 | .0009948 | 1239.57 | 1.00000 | .00099 | .20000 |
| 4 | .02188 | 0.00 | 2199.20 | .0009950 | 1239.31 | .99988 | .00289 | .30000 |
| 4 | .02188 | 7.50 | 2199.20 | .0009950 | 1239.31 | .99988 | .00303 | .30000 |
| 4 | .02188 | 15.00 | 2199.20 | .0009950 | 1239.31 | .99988 | .00288 | .30000 |
| 4 | .02188 | 22.50 | 2199.20 | .0009950 | 1239.31 | .99988 | .00298 | .30000 |
| 4 | .02188 | 30.00 | 2199.19 | .0009950 | 1239.31 | .99988 | .00293 | .30000 |
| 5 | .02917 | 0.00 | 2145.44 | .0010195 | 1209.46 | .97562 | .05247 | .40000 |
| 5 | .02917 | 6.00 | 2145.76 | .0010195 | 1209.52 | .97559 | .05261 | .40000 |
| 5 | .02917 | 12.00 | 2145.80 | .0010196 | 1209.48 | .97561 | .05253 | .40000 |
| 5 | .02917 | 18.00 | 2145.90 | .0010195 | 1209.48 | .97566 | .05253 | .40000 |
| 5 | .02917 | 24.00 | 2145.75 | .0010195 | 1209.52 | .97558 | .05261 | .40000 |
| 5 | .02917 | 30.00 | 2145.83 | .0010195 | 1209.46 | .97562 | .05247 | .40000 |
| 6 | .03646 | 0.00 | 1378.61 | .0011597 | 1063.24 | .62680 | .13781 | .50000 |
| 6 | .03646 | 6.00 | 1371.48 | .0011595 | 1063.44 | .62355 | .13785 | .50000 |
| 6 | .03646 | 12.00 | 1373.[illegible]7 | .0011622 | 1062.79 | .62428 | .13785 | .50000 |
| 6 | .03646 | 18.00 | 1373.57 | .0011622 | 1062.79 | .62428 | .13785 | .50000 |
| 6 | .03646 | 24.00 | 1371.48 | .0011595 | 1063.44 | .62355 | .13785 | .50000 |
| 6 | .03646 | 30.00 | 1378.61 | .0011597 | 1063.24 | .62680 | .13781 | .50000 |
| 7 | .04375 | 0.00 | 203.54 | .0016983 | 726.07 | .09254 | .04225 | .60000 |
| 7 | .04375 | 5.00 | 202.12 | .0016972 | 726.54 | .09189 | .04202 | .60000 |
| 7 | .04375 | 10.00 | 202.14 | .0016972 | 726.54 | .09190 | .04202 | .60000 |
| 7 | .04375 | 15.00 | 203.59 | .0016983 | 726.06 | .09257 | .04224 | .60000 |
| 7 | .04375 | 20.00 | 202.17 | .0016972 | 726.53 | .09192 | .04200 | .60000 |
| 7 | .04375 | 25.00 | 202.17 | .0016972 | 726.53 | .09192 | .04200 | .60000 |
| 7 | .04375 | 30.00 | 203.61 | .0016983 | 726.06 | .09257 | .04223 | .60000 |
| 8 | .05104 | 0.00 | 2.52 | .0021214 | 591.26 | .00114 | .00253 | .70000 |
| 8 | .05104 | 5.00 | 2.53 | .0021241 | 58[illegible].51 | .00115 | .00292 | .70000 |
| 8 | .05104 | 10.00 | 2.94 | .0021451 | 574.83 | .00134 | .00294 | .70000 |
| 8 | .05104 | 15.00 | 3.47 | .0021627 | 57[illegible].17 | .00158 | .00284 | .70000 |
| 8 | .05104 | 20.00 | 3.64 | .0021692 | 566.44 | .00166 | .00287 | .70000 |
| 8 | .05104 | 25.00 | 3.96 | .0021748 | 566.98 | .00175 | .00287 | .70000 |
| 8 | .05104 | 30.00 | 4.12 | .0021794 | 565.79 | .00187 | .00278 | .70000 |
| 9 | .05833 | .00 | 3.24 | .0021555 | 572.96 | .00147 | .00145 | .80000 |
| 9 | .05833 | 4.29 | 1.35 | .0020752 | 594.21 | .00062 | .00191 | .80000 |
| 9 | .05833 | 8.57 | 0.60 | .0022835 | [illegible] | 0.00100 | 0.00000 | .80000 |
| 9 | .05833 | 12.86 | 0.66 | .0022835 | [illegible] | 0.00000 | 0.00000 | .80000 |

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1          CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .07292 (X/DEQ = 1.00000)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 9 | .05833 | 17.14 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | .80000 |
| 9 | .05833 | 21.43 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | .80000 |
| 9 | .05833 | 25.71 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | .80000 |
| 9 | .05833 | 30.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | .80000 |
| 10 | .06563 | 0.00 | 203.37 | .0016986 | 725.94 | .09246 | .04216 | .90000 |
| 10 | .06563 | 4.29 | 168.30 | .0017420 | 707.84 | .07638 | .03710 | .90000 |
| 10 | .06563 | 8.57 | 95.34 | .0018676 | 660.25 | .04335 | .02447 | .90000 |
| 10 | .06563 | 12.86 | 33.49 | .0020323 | 606.73 | .01523 | .01067 | .90000 |
| 10 | .06563 | 17.14 | 5.84 | .0021636 | 569.91 | .00266 | .00325 | .90000 |
| 10 | .06563 | 21.43 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | .90000 |
| 10 | .06563 | 25.71 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | .90000 |
| 10 | .06563 | 30.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | .90000 |
| 11 | .07292 | 0.00 | 1378.45 | .0011598 | 1063.19 | .62672 | .13779 | 1.00000 |
| 11 | .07292 | 3.75 | 1282.33 | .0011754 | 1049.07 | .58302 | .13990 | 1.00000 |
| 11 | .07292 | 7.50 | 1015.37 | .0012396 | 994.75 | .46165 | .13664 | 1.00000 |
| 11 | .07292 | 11.25 | 608.69 | .0013846 | 899.58 | .27674 | .10947 | 1.00000 |
| 11 | .07292 | 15.00 | 242.76 | .0016504 | 747.13 | .11037 | .05941 | 1.00000 |
| 11 | .07292 | 18.75 | 57.20 | .0019585 | 629.60 | .02600 | .01884 | 1.00000 |
| 11 | .07292 | 22.50 | 6.44 | .0021637 | 569.90 | .00293 | .00379 | 1.00000 |
| 11 | .07292 | 26.25 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.00000 |
| 11 | .07292 | 30.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.00000 |
| 12 | .08021 | 0.00 | 2145.74 | .0010196 | 1209.42 | .97558 | .05248 | 1.10000 |
| 12 | .08021 | 3.75 | 2124.54 | .0010266 | 1201.14 | .96594 | .06481 | 1.10000 |
| 12 | .08021 | 7.50 | 2025.14 | .0010525 | 1171.60 | .92075 | .10460 | 1.10000 |
| 12 | .08021 | 11.25 | 1717.49 | .0011052 | 1115.68 | .78087 | .15852 | 1.10000 |
| 12 | .08021 | 15.00 | 1059.87 | .0012270 | 1004.97 | .48188 | .16340 | 1.10000 |
| 12 | .08021 | 18.75 | 353.54 | .0015447 | 798.27 | .16074 | .08533 | 1.10000 |
| 12 | .08021 | 22.50 | 53.70 | .0019665 | 627.03 | .02441 | .01880 | 1.10000 |
| 12 | .08021 | 26.25 | 2.21 | .0021721 | 567.69 | .00100 | .00334 | 1.10000 |
| 12 | .08021 | 30.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.10000 |
| 13 | .08750 | 0.00 | 2199.19 | .0009950 | 1239.30 | .99988 | .00213 | 1.20000 |
| 13 | .08750 | 3.33 | 2198.94 | .0009952 | 1239.07 | .99977 | .00350 | 1.20000 |
| 13 | .08750 | 6.67 | 2196.64 | .0009967 | 1237.12 | .99872 | .01146 | 1.20000 |
| 13 | .08750 | 10.00 | 2175.80 | .0010076 | 1223.80 | .98925 | .04213 | 1.20000 |
| 13 | .08750 | 13.33 | 2032.46 | .0010508 | 1173.47 | .92408 | .11890 | 1.20000 |
| 13 | .08750 | 16.67 | 1500.16 | .0011379 | 1083.61 | .68206 | .18610 | 1.20000 |
| 13 | .08750 | 20.00 | 616.35 | .0013828 | 891.74 | .28023 | .13029 | 1.20000 |
| 13 | .08750 | 23.33 | 110.21 | .0018367 | 671.34 | .05011 | .03566 | 1.20000 |
| 13 | .08750 | 26.67 | 7.85 | .0021552 | 572.14 | .00357 | .00463 | 1.20000 |
| 13 | .08750 | 30.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.20000 |
| 14 | .09479 | 0.00 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00140 | 1.30000 |
| 14 | .09479 | 3.33 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00161 | 1.30000 |
| 14 | .09479 | 6.67 | 2199.44 | .0009948 | 1239.55 | .99999 | .00087 | 1.30000 |
| 14 | .09479 | 10.00 | 2198.75 | .0009953 | 1238.90 | .99968 | .00583 | 1.30000 |
| 14 | .09479 | 13.33 | 2175.18 | .0010078 | 1223.48 | .98897 | .04684 | 1.30000 |
| 14 | .09479 | 16.67 | 1911.43 | .0010745 | 1147.62 | .86905 | .15684 | 1.30000 |
| 14 | .09479 | 20.00 | 1022.06 | .0012373 | 996.57 | .46469 | .17621 | 1.30000 |
| 14 | .09479 | 23.33 | 208.70 | .0016920 | 728.79 | .09489 | .06070 | 1.30000 |

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1    CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .07292 (X/DEQ = 1.00000)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 14 | .09479 | 26.67 | 14.75 | .0021165 | 582.59 | .00671 | .00707 | 1.30000 |
| 14 | .09479 | 30.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.30000 |
| 15 | .10208 | 0.00 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00031 | 1.40000 |
| 15 | .10208 | 3.00 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00186 | 1.40000 |
| 15 | .10208 | 6.00 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00140 | 1.40000 |
| 15 | .10208 | 9.00 | 2199.45 | .0009948 | 1239.56 | 1.00000 | .00159 | 1.40000 |
| 15 | .10208 | 12.00 | 2198.55 | .0009954 | 1238.72 | .99959 | .00723 | 1.40000 |
| 15 | .10208 | 15.00 | 2161.63 | .0010135 | 1216.62 | .98280 | .06160 | 1.40000 |
| 15 | .10208 | 18.00 | 1801.51 | .0010921 | 1129.12 | .81907 | .17685 | 1.40000 |
| 15 | .10208 | 21.00 | 834.46 | .0012917 | 954.61 | .37939 | .16055 | 1.40000 |
| 15 | .10208 | 24.00 | 146.71 | .0017738 | 695.16 | .06670 | .04583 | 1.40000 |
| 15 | .10208 | 27.00 | 9.45 | .0021459 | 574.63 | .00430 | .00516 | 1.40000 |
| 15 | .10208 | 30.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.40000 |
| 16 | .10938 | 0.00 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00104 | 1.50000 |
| 16 | .10938 | 3.00 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00222 | 1.50000 |
| 16 | .10938 | 6.00 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00272 | 1.50000 |
| 16 | .10938 | 9.00 | 2199.45 | .0009948 | 1239.56 | 1.00000 | .00182 | 1.50000 |
| 16 | .10938 | 12.00 | 2198.81 | .0009953 | 1238.95 | .99971 | .00629 | 1.50000 |
| 16 | .10938 | 15.00 | 2161.18 | .0010137 | 1216.41 | .98260 | .06199 | 1.50000 |
| 16 | .10938 | 18.00 | 1752.09 | .0010996 | 1121.40 | .79660 | .18152 | 1.50000 |
| 16 | .10938 | 21.00 | 710.45 | .0013394 | 920.63 | .32301 | .14531 | 1.50000 |
| 16 | .10938 | 24.00 | 98.26 | .0018615 | 662.41 | .04468 | .03259 | 1.50000 |
| 16 | .10938 | 27.00 | 4.21 | .0021836 | 564.70 | .00192 | .00363 | 1.50000 |
| 16 | .10938 | 30.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.50000 |
| 17 | .11667 | 0.00 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00206 | 1.60000 |
| 17 | .11667 | 2.73 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00239 | 1.60000 |
| 17 | .11667 | 5.45 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00178 | 1.60000 |
| 17 | .11667 | 8.18 | 2199.45 | .0009948 | 1239.56 | 1.00000 | .00157 | 1.60000 |
| 17 | .11667 | 10.91 | 2198.91 | .0009952 | 1239.04 | .99975 | .00557 | 1.60000 |
| 17 | .11667 | 13.64 | 2174.93 | .0010080 | 1223.34 | .98885 | .04751 | 1.60000 |
| 17 | .11667 | 16.36 | 1906.35 | .0010753 | 1146.70 | .86674 | .15670 | 1.60000 |
| 17 | .11667 | 19.09 | 1039.03 | .0012332 | 999.94 | .47241 | .17474 | 1.60000 |
| 17 | .11667 | 21.82 | 235.07 | .0016608 | 742.44 | .10687 | .06531 | 1.60000 |
| 17 | .11667 | 24.55 | 20.71 | .0020856 | 591.22 | .00942 | .00875 | 1.60000 |
| 17 | .11667 | 27.27 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.60000 |
| 17 | .11667 | 30.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.60000 |
| 18 | .12396 | 0.00 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00154 | 1.70000 |
| 18 | .12396 | 2.73 | 2199.45 | .0009948 | 1239.57 | 1.00000 | .00141 | 1.70000 |
| 18 | .12396 | 5.45 | 2199.45 | .0009948 | 1239.56 | 1.00000 | .00162 | 1.70000 |
| 18 | .12396 | 8.18 | 2199.13 | .0009950 | 1239.25 | .99985 | .00436 | 1.70000 |
| 18 | .12396 | 10.91 | 2188.71 | .0010013 | 1231.46 | .99512 | .02817 | 1.70000 |
| 18 | .12396 | 13.64 | 2051.20 | .0010465 | 1178.33 | .93259 | .11403 | 1.70000 |
| 18 | .12396 | 16.36 | 1433.87 | .0011478 | 1074.26 | .65192 | .18468 | 1.70000 |
| 18 | .12396 | 19.09 | 478.50 | .0014574 | 846.09 | .21756 | .10756 | 1.70000 |
| 18 | .12396 | 21.82 | 62.84 | .0019401 | 635.56 | .02857 | .02146 | 1.70000 |
| 18 | .12396 | 24.55 | 2.80 | .0021965 | 561.37 | .00127 | .00342 | 1.70000 |
| 18 | .12396 | 27.27 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.70000 |
| 18 | .12396 | 30.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.70000 |

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1  CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .07292 (X/DEQ = 1.00000)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 19 | .13125 | 0.00 | 2199.19 | .0009950 | 1239.32 | .99988 | .00325 | 1.80000 |
| 19 | .13125 | 2.50 | 2198.99 | .0009951 | 1239.12 | .99979 | .00412 | 1.80000 |
| 19 | .13125 | 5.00 | 2197.42 | .0009962 | 1237.75 | .99908 | .00926 | 1.80000 |
| 19 | .13125 | 7.50 | 2185.40 | .0010030 | 1229.37 | .99361 | .02954 | 1.80000 |
| 19 | .13125 | 10.00 | 2106.46 | .0010321 | 1194.73 | .95772 | .08446 | 1.80000 |
| 19 | .13125 | 12.50 | 1776.53 | .0010963 | 1124.82 | .80771 | .15885 | 1.80000 |
| 19 | .13125 | 15.00 | 1038.20 | .0012327 | 1000.33 | .47203 | .16182 | 1.80000 |
| 19 | .13125 | 17.50 | 318.73 | .0015743 | 783.25 | .14491 | .07710 | 1.80000 |
| 19 | .13125 | 20.00 | 47.64 | .0019859 | 620.91 | .02166 | .01638 | 1.80000 |
| 19 | .13125 | 22.50 | 2.88 | .0021988 | 560.79 | .00131 | .00320 | 1.80000 |
| 19 | .13125 | 25.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.80000 |
| 19 | .13125 | 27.50 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.80000 |
| 19 | .13125 | 30.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.80000 |
| 20 | .13854 | 0.00 | 2145.68 | .0010196 | 1209.39 | .97555 | .05255 | 1.90000 |
| 20 | .13854 | 2.50 | 2129.85 | .0010249 | 1203.09 | .96835 | .06116 | 1.90000 |
| 20 | .13854 | 5.00 | 2061.96 | .0010438 | 1181.30 | .93749 | .08886 | 1.90000 |
| 20 | .13854 | 7.50 | 1867.77 | .0010820 | 1139.60 | .84920 | .13235 | 1.90000 |
| 20 | .13854 | 10.00 | 1436.12 | .0011483 | 1073.86 | .65295 | .16129 | 1.90000 |
| 20 | .13854 | 12.50 | 756.51 | .0013212 | 933.33 | .34395 | .12913 | 1.90000 |
| 20 | .13854 | 15.00 | 231.75 | .0016626 | 741.66 | .10537 | .05730 | 1.90000 |
| 20 | .13854 | 17.50 | 37.77 | .0020185 | 610.90 | .01717 | .01295 | 1.90000 |
| 20 | .13854 | 20.00 | 2.50 | .0022007 | 560.32 | .00114 | .00315 | 1.90000 |
| 20 | .13854 | 22.50 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.90000 |
| 20 | .13854 | 25.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.90000 |
| 20 | .13854 | 27.50 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.90000 |
| 20 | .13854 | 30.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 1.90000 |
| 21 | .14583 | 0.00 | 1378.11 | .0011599 | 1063.10 | .62657 | .13781 | 2.00000 |
| 21 | .14583 | 2.31 | 1303.87 | .0011715 | 1052.52 | .59281 | .13796 | 2.00000 |
| 21 | .14583 | 4.62 | 1100.68 | .0012170 | 1013.17 | .50043 | .13495 | 2.00000 |
| 21 | .14583 | 6.92 | 773.97 | .0013145 | 938.05 | .35189 | .11671 | 2.00000 |
| 21 | .14583 | 9.23 | 414.00 | .0015002 | 821.91 | .18823 | .08055 | 2.00000 |
| 21 | .14583 | 11.54 | 154.16 | .0017639 | 699.08 | .07009 | .03861 | 2.00000 |
| 21 | .14583 | 13.85 | 37.12 | .0020204 | 610.32 | .01688 | .01201 | 2.00000 |
| 21 | .14583 | 16.15 | 4.97 | .0021826 | 564.95 | .00226 | .00328 | 2.00000 |
| 21 | .14583 | 18.46 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.00000 |
| 21 | .14583 | 20.77 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.00000 |
| 21 | .14583 | 23.08 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.00000 |
| 21 | .14583 | 25.38 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.00000 |
| 21 | .14583 | 27.69 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.00000 |
| 21 | .14583 | 30.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.00000 |
| 22 | .15313 | 0.00 | 203.27 | .0016988 | 725.85 | .09242 | .04220 | 2.10000 |
| 22 | .15313 | 2.14 | 181.15 | .0017236 | 715.40 | .08236 | .03875 | 2.10000 |
| 22 | .15313 | 4.29 | 131.99 | .0018010 | 684.65 | .06001 | .03049 | 2.10000 |
| 22 | .15313 | 6.43 | 73.29 | .0019140 | 644.25 | .03332 | .01912 | 2.10000 |
| 22 | .15313 | 8.57 | 31.17 | .0020427 | 603.66 | .01417 | .00955 | 2.10000 |
| 22 | .15313 | 10.71 | 9.03 | .0021524 | 572.88 | .00410 | .00396 | 2.10000 |
| 22 | .15313 | 12.86 | 1.10 | .0021963 | 561.44 | .00050 | .00274 | 2.10000 |
| 22 | .15313 | 15.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.10000 |

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1        CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .07292 (X/DEQ = 1.00000)

| M | P | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 22 | .15313 | 17.14 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.10000 |
| 22 | .15313 | 19.29 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.10000 |
| 22 | .15313 | 21.43 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.10000 |
| 22 | .15313 | 23.57 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.10000 |
| 22 | .15313 | 25.71 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.10000 |
| 22 | .15313 | 27.86 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.10000 |
| 22 | .15313 | 30.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.10000 |
| 23 | .16042 | 0.00 | 4.61 | .0021890 | 563.29 | .00210 | .00280 | 2.20000 |
| 23 | .16042 | 2.14 | 3.77 | .0021944 | 561.93 | .00172 | .00285 | 2.20000 |
| 23 | .16042 | 4.29 | 2.16 | .0022076 | 558.56 | .00098 | .00276 | 2.20000 |
| 23 | .16042 | 6.43 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.20000 |
| 23 | .16042 | 8.57 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.20000 |
| 23 | .16042 | 10.71 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.20000 |
| 23 | .16042 | 12.86 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.20000 |
| 23 | .16042 | 15.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.20000 |
| 23 | .16042 | 17.14 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.20000 |
| 23 | .16042 | 19.29 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.20000 |
| 23 | .16042 | 21.43 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.20000 |
| 23 | .16042 | 23.57 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.20000 |
| 23 | .16042 | 25.71 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.20000 |
| 23 | .16042 | 27.86 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.20000 |
| 23 | .16042 | 30.00 | 0.00 | .0022835 | 540.00 | 0.00000 | 0.00000 | 2.20000 |

CIRCUMFERENTIALLY-AVERAGED PARAMETERS

| NR | RADIUS | MACH NO. | TEMP. | INTENSITY | FREQUENCY |
|---|---|---|---|---|---|
| 1 | .0001 | 1.9662 | 2.2955 | .66006E-12 | 0. |
| 2 | .1000 | 1.9662 | 2.2955 | .24773E-06 | 3. |
| 3 | .2000 | 1.9662 | 2.2955 | .95416E-08 | 0. |
| 4 | .3000 | 1.9666 | 2.2951 | .21384E-04 | 7. |
| 5 | .4000 | 1.9182 | 2.2398 | .16103E+05 | 2416. |
| 6 | .5000 | 1.2278 | 1.9688 | .17198E+08 | 25958. |
| 7 | .6000 | .1809 | 1.3452 | .51043E+04 | 16407. |
| 8 | .7000 | .0028 | 1.0583 | .39885E-04 | 4377. |
| 9 | .8000 | .0019 | 1.0777 | .41234E-06 | 524. |
| 10 | .9000 | .1277 | 1.2755 | .10304E+04 | 5139. |
| 11 | 1.0000 | .8929 | 1.8257 | .11824E+08 | 12312. |
| 12 | 1.1000 | 1.5573 | 2.1133 | .29016E+08 | 5707. |
| 13 | 1.2000 | 1.7232 | 2.2014 | .42213E+08 | 2595. |
| 14 | 1.3000 | 1.7745 | 2.2247 | .40008E+08 | 1676. |
| 15 | 1.4000 | 1.7964 | 2.2343 | .41582E+08 | 1326. |
| 16 | 1.5000 | 1.8024 | 2.2367 | .42918E+08 | 1313. |
| 17 | 1.6000 | 1.7963 | 2.2339 | .38624E+08 | 1513. |
| 18 | 1.7000 | 1.7761 | 2.2255 | .43543E+08 | 1888. |
| 19 | 1.8000 | 1.7236 | 2.2014 | .30032E+08 | 2593. |
| 20 | 1.9000 | 1.5589 | 2.1139 | .24184E+08 | 4755. |
| 21 | 2.0000 | .8929 | 1.8257 | .14303E+08 | 8933. |
| 22 | 2.1000 | .1275 | 1.2750 | .15046E+04 | 3436. |
| 23 | 2.2000 | .0029 | 1.0397 | .19514E-04 | 733. |

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA= 1 X= .07292 ITH= 10 THETA= 110.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA= 1 X= .07292 ITH= 11 THETA= 120.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA= 1 X= .07292 ITH= 12 THETA= 130.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA= 1 X= .07292 ITH= 13 THETA= 140.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA= 1 X= .07292 ITH= 14 THETA= 150.00 NTP= 3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA= 1 X= .07292 ITH= 15 THETA= 160.00 NTP= 3

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X( 1)=    .0729  UBI( 1)= .25899E+21  FM( 1)= .2419E+01  UAVG( 1)= 1847.59  UMAX( 1)= 2199.46

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  2      X=     .09187      ITH= 10      THETA=  110.00      NTP=  3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  2      X=     .09187      ITH= 11      THETA=  120.00      NTP=  3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  2      X=     .09187      ITH= 12      THETA=  130.00      NTP=  3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  2      X=     .09187      ITH= 13      THETA=  140.00      NTP=  3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  2      X=     .09187      ITH= 14      THETA=  150.00      NTP=  3

X( 2)=    .0919  UBI( 2)= .26385E+21  FM( 2)= .2529E+01  UAVG( 2)= 1767.58  UMAX( 2)= 2199.46
WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  3      X=     .11575      ITH= 10      THETA=  110.00      NTP=  3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  3      X=     .11575      ITH= 11      THETA=  120.00      NTP=  3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  3      X=     .11575      ITH= 12      THETA=  130.00      NTP=  3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  3      X=     .11575      ITH= 13      THETA=  140.00      NTP=  3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  3      X=     .11575      ITH= 14      THETA=  150.00      NTP=  3

X( 3)=    .1157  UBI( 3)= .26192E+21  FM( 3)= .2664E+01  UAVG( 3)= 1674.56  UMAX( 3)= 2199.45
WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  4      X=     .14583      ITH= 10      THETA=  110.00      NTP=  3

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  4      X=     .14583      ITH= 11      THETA=  120.00      NTP=  3
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WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  4      X=    .14583     ITH= 12     THETA=  130.00     NTP=  3


WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  4      X=    .14583     ITH= 13     THETA=  140.00     NTP=  3


X( 4)=     .1458  UBI( 4)= .25722E+21  FM( 4)= .2843E+01  UAVG( 4)= 1572.60  UMAX( 4)= 2199.41

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  5      X=    .18374     ITH= 10     THETA=  110.00     NTP=  3


WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  5      X=    .18374     ITH= 11     THETA=  120.00     NTP=  3


WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  5      X=    .18374     ITH= 12     THETA=  130.00     NTP=  3


X( 5)=     .1837  UBI( 5)= .24966E+21  FM( 5)= .3047E+01  UAVG( 5)= 1467.27  UMAX( 5)= 2197.57

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  6      X=    .23150     ITH= 10     THETA=  110.00     NTP=  3


WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA=  6      X=    .23150     ITH= 11     THETA=  120.00     NTP=  3


X( 6)=     .2315  UBI( 6)= .23294E+21  FM( 6)= .3277E+01  UAVG( 6)= 1364.33  UMAX( 6)= 2179.00
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COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1                CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .29167 (X/DEQ = 4.00000)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 1 | .00001 | 0.00 | 2106.11 | .0010468 | 1177.90 | .95756 | .00168 | .00010 |
| 1 | .00001 | 10.00 | 2106.11 | .0010468 | 1177.90 | .95756 | .00168 | .00010 |
| 1 | .00001 | 20.00 | 2106.11 | .0010468 | 1177.90 | .95756 | .00168 | .00010 |
| 1 | .00001 | 30.00 | 2106.11 | .0010468 | 1177.90 | .95756 | .00168 | .00010 |
| 2 | .00729 | 0.00 | 2079.70 | .0010551 | 1168.73 | .94555 | .05657 | .10000 |
| 2 | .00729 | 10.00 | 2079.72 | .0010550 | 1168.73 | .94556 | .05658 | .10000 |
| 2 | .00729 | 20.00 | 2079.72 | .0010550 | 1168.73 | .94556 | .05658 | .10000 |
| 2 | .00729 | 30.00 | 2079.70 | .0010551 | 1168.73 | .94555 | .05658 | .10000 |
| 3 | .01458 | 0.00 | 1994.78 | .0010776 | 1144.29 | .90694 | .08729 | .20000 |
| 3 | .01458 | 7.50 | 1994.74 | .0010776 | 1144.27 | .90692 | .08729 | .20000 |
| 3 | .01458 | 15.00 | 1994.77 | .0010776 | 1144.28 | .90694 | .08730 | .20000 |
| 3 | .01458 | 22.50 | 1994.73 | .0010776 | 1144.27 | .90692 | .08730 | .20000 |
| 3 | .01458 | 30.00 | 1994.77 | .0010776 | 1144.28 | .90694 | .08730 | .20000 |
| 4 | .02188 | 0.00 | 1838.10 | .0011099 | 1111.01 | .83571 | .11429 | .30000 |
| 4 | .02188 | 7.50 | 1838.13 | .0011099 | 1111.02 | .83572 | .11430 | .30000 |
| 4 | .02188 | 15.00 | 1838.04 | .0011099 | 1110.97 | .83568 | .11431 | .30000 |
| 4 | .02188 | 22.50 | 1838.06 | .0011099 | 1110.95 | .83569 | .11432 | .30000 |
| 4 | .02188 | 30.00 | 1837.99 | .0011100 | 1110.92 | .83566 | .11432 | .30000 |
| 5 | .02917 | 0.00 | 1601.57 | .0011489 | 1073.31 | .72817 | .13158 | .40000 |
| 5 | .02917 | 6.00 | 1601.44 | .0011489 | 1073.23 | .72811 | .13160 | .40000 |
| 5 | .02917 | 12.00 | 1601.30 | .0011491 | 1073.07 | .72804 | .13166 | .40000 |
| 5 | .02917 | 18.00 | 1601.02 | .0011493 | 1072.85 | .72792 | .13172 | .40000 |
| 5 | .02917 | 24.00 | 1600.72 | .0011496 | 1072.64 | .72778 | .13176 | .40000 |
| 5 | .02917 | 30.00 | 1600.68 | .0011496 | 1072.58 | .72776 | .13178 | .40000 |
| 6 | .03646 | 0.00 | 1298.70 | .0011959 | 1031.04 | .59046 | .13255 | .50000 |
| 6 | .03646 | 6.00 | 1298.61 | .0011963 | 1030.74 | .59043 | .13268 | .50000 |
| 6 | .03646 | 12.00 | 1296.97 | .0011975 | 1029.74 | .58968 | .13295 | .50000 |
| 6 | .03646 | 18.00 | 1295.36 | .0011988 | 1028.56 | .58895 | .13329 | .50000 |
| 6 | .03646 | 24.00 | 1294.41 | .0011999 | 1027.64 | .58851 | .13355 | .50000 |
| 6 | .03646 | 30.00 | 1293.49 | .0012004 | 1027.20 | .58810 | .13363 | .50000 |
| 7 | .04375 | 0.00 | 980.18 | .0012487 | 987.46 | .44565 | .11324 | .60000 |
| 7 | .04375 | 5.00 | 978.21 | .0012502 | 986.28 | .44475 | .11362 | .60000 |
| 7 | .04375 | 10.00 | 973.63 | .0012537 | 983.54 | .44267 | .11462 | .60000 |
| 7 | .04375 | 15.00 | 967.62 | .0012584 | 979.85 | .43994 | .11590 | .60000 |
| 7 | .04375 | 20.00 | 961.38 | .0012636 | 975.87 | .43710 | .11703 | .60000 |
| 7 | .04375 | 25.00 | 956.95 | .0012673 | 972.99 | .43508 | .11782 | .60000 |
| 7 | .04375 | 30.00 | 955.55 | .0012685 | 972.08 | .43445 | .11812 | .60000 |
| 8 | .05104 | 0.00 | 758.09 | .0012799 | 963.41 | .34467 | .06822 | .70000 |
| 8 | .05104 | 5.00 | 751.56 | .0012834 | 960.81 | .34170 | .07114 | .70000 |
| 8 | .05104 | 10.00 | 733.93 | .0012928 | 953.80 | .33369 | .07705 | .70000 |
| 8 | .05104 | 15.00 | 710.08 | .0013064 | 943.84 | .32285 | .08252 | .70000 |
| 8 | .05104 | 20.00 | 686.08 | .0013216 | 933.04 | .31193 | .08631 | .70000 |
| 8 | .05104 | 25.00 | 668.47 | .0013335 | 924.72 | .30393 | .08843 | .70000 |
| 8 | .05104 | 30.00 | 662.07 | .0013379 | 921.68 | .30101 | .08911 | .70000 |
| 9 | .05833 | 0.00 | 758.05 | .0012799 | 963.41 | .34465 | .06817 | .80000 |
| 9 | .05833 | 4.29 | 745.61 | .0012839 | 960.44 | .33900 | .07124 | .80000 |
| 9 | .05833 | 8.57 | 710.47 | .0012950 | 952.16 | .32302 | .07635 | .80000 |
| 9 | .05833 | 12.86 | 658.39 | .0013121 | 939.74 | .29934 | .07855 | .80000 |

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1     CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .29167 (X/DEQ = 4.00000)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 9 | .05833 | 17.14 | 597.88 | .0013330 | 925.00 | .27183 | .07582 | .80000 |
| 9 | .05833 | 21.43 | 540.35 | .0013531 | 911.29 | .24567 | .06819 | .80000 |
| 9 | .05833 | 25.71 | 498.87 | .0013676 | 901.61 | .22682 | .05719 | .80000 |
| 9 | .05833 | 30.00 | 483.69 | .0013728 | 898.19 | .21991 | .05027 | .80000 |
| 10 | .06563 | 0.00 | 980.09 | .0012487 | 987.45 | .44561 | .11321 | .90000 |
| 10 | .06563 | 4.29 | 958.94 | .0012541 | 983.25 | .43599 | .11533 | .90000 |
| 10 | .06563 | 8.57 | 898.45 | .0012692 | 971.57 | .40849 | .11892 | .90000 |
| 10 | .06563 | 12.86 | 805.40 | .0012938 | 953.09 | .36618 | .11906 | .90000 |
| 10 | .06563 | 17.14 | 692.79 | .0013244 | 931.01 | .31498 | .11248 | .90000 |
| 10 | .06563 | 21.43 | 579.98 | .0013541 | 916.63 | .26369 | .09745 | .90000 |
| 10 | .06563 | 25.71 | 492.43 | .0013716 | 899.03 | .22389 | .07158 | .90000 |
| 10 | .06563 | 30.00 | 458.84 | .0013756 | 896.38 | .20861 | .03069 | .90000 |
| 11 | .07292 | 0.00 | 1298.64 | .0011960 | 1031.04 | .59044 | .13253 | 1.00000 |
| 11 | .07292 | 3.75 | 1278.97 | .0011997 | 1027.81 | .58150 | .13588 | 1.00000 |
| 11 | .07292 | 7.50 | 1213.17 | .0012120 | 1017.42 | .55158 | .14287 | 1.00000 |
| 11 | .07292 | 11.25 | 1109.82 | .0012334 | 999.73 | .50459 | .14800 | 1.00000 |
| 11 | .07292 | 15.00 | 977.73 | .0012630 | 976.32 | .44453 | .14727 | 1.00000 |
| 11 | .07292 | 18.75 | 829.45 | .0012980 | 950.00 | .37712 | .13834 | 1.00000 |
| 11 | .07292 | 22.50 | 686.00 | .0013309 | 926.50 | .31190 | .11965 | 1.00000 |
| 11 | .07292 | 26.25 | 576.02 | .0013506 | 912.95 | .26189 | .08882 | 1.00000 |
| 11 | .07292 | 30.00 | 533.54 | .0013553 | 909.80 | .24258 | .04985 | 1.00000 |
| 12 | .08021 | 0.00 | 1601.50 | .0011489 | 1073.30 | .72813 | .13157 | 1.10000 |
| 12 | .08021 | 3.75 | 1577.02 | .0011528 | 1069.60 | .71701 | .13788 | 1.10000 |
| 12 | .08021 | 7.50 | 1503.70 | .0011648 | 1058.63 | .68367 | .15133 | 1.10000 |
| 12 | .08021 | 11.25 | 1383.35 | .0011848 | 1040.71 | .62895 | .16335 | 1.10000 |
| 12 | .08021 | 15.00 | 1219.62 | .0012135 | 1016.11 | .55451 | .16798 | 1.10000 |
| 12 | .08021 | 18.75 | 1028.14 | .0012507 | 985.89 | .46745 | .16135 | 1.10000 |
| 12 | .08021 | 22.50 | 838.03 | .0012885 | 956.97 | .38102 | .14139 | 1.10000 |
| 12 | .08021 | 26.25 | 688.35 | .0013137 | 938.60 | .31296 | .10494 | 1.10000 |
| 12 | .08021 | 30.00 | 629.41 | .0013201 | 934.09 | .28617 | .05050 | 1.10000 |
| 13 | .08750 | 0.00 | 1838.04 | .0011099 | 1111.01 | .83568 | .11428 | 1.20000 |
| 13 | .08750 | 3.33 | 1817.98 | .0011135 | 1107.37 | .82656 | .12296 | 1.20000 |
| 13 | .08750 | 6.67 | 1756.96 | .0011241 | 1096.90 | .79882 | .14180 | 1.20000 |
| 13 | .08750 | 10.00 | 1653.43 | .0011412 | 1080.52 | .75174 | .16119 | 1.20000 |
| 13 | .08750 | 13.33 | 1507.73 | .0011642 | 1059.16 | .68550 | .17533 | 1.20000 |
| 13 | .08750 | 16.67 | 1326.82 | .0011932 | 1033.45 | .60325 | .18014 | 1.20000 |
| 13 | .08750 | 20.00 | 1116.83 | .0012287 | 1003.54 | .50778 | .17240 | 1.20000 |
| 13 | .08750 | 23.33 | 915.38 | .0012641 | 975.46 | .41619 | .15031 | 1.20000 |
| 13 | .08750 | 26.67 | 760.19 | .0012869 | 958.20 | .34563 | .11059 | 1.20000 |
| 13 | .08750 | 30.00 | 699.78 | .0012926 | 953.93 | .31816 | .03942 | 1.20000 |
| 14 | .09479 | 0.00 | 1994.74 | .0010776 | 1144.28 | .90693 | .08729 | 1.30000 |
| 14 | .09479 | 3.33 | 1974.99 | .0010822 | 1139.49 | .89795 | .10155 | 1.30000 |
| 14 | .09479 | 6.67 | 1914.02 | .0010953 | 1125.76 | .87023 | .12855 | 1.30000 |
| 14 | .09479 | 10.00 | 1807.55 | .0011154 | 1105.52 | .82182 | .15554 | 1.30000 |
| 14 | .09479 | 13.33 | 1652.47 | .0011410 | 1080.71 | .75131 | .17663 | 1.30000 |
| 14 | .09479 | 16.67 | 1451.76 | .0011721 | 1052.06 | .66005 | .18673 | 1.30000 |
| 14 | .09479 | 20.00 | 1218.12 | .0012089 | 1019.96 | .55383 | .18205 | 1.30000 |
| 14 | .09479 | 23.33 | 982.56 | .0012485 | 987.61 | .44673 | .15998 | 1.30000 |

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1                CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .29167 (X/DEQ = 4.00000)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 14 | .09479 | 26.67 | 798.20 | .0012757 | 966.58 | .36291 | .11775 | 1.30000 |
| 14 | .09479 | 30.00 | 725.24 | .0012831 | 960.98 | .32973 | .00455 | 1.30000 |
| 15 | .10208 | 0.00 | 2079.68 | .0010551 | 1168.72 | .94554 | .05655 | 1.40000 |
| 15 | .10208 | 3.00 | 2064.03 | .0010596 | 1163.69 | .93843 | .07855 | 1.40000 |
| 15 | .10208 | 6.00 | 2015.26 | .0010726 | 1149.60 | .91626 | .10976 | 1.40000 |
| 15 | .10208 | 9.00 | 1928.64 | .0010923 | 1128.86 | .87687 | .14000 | 1.40000 |
| 15 | .10208 | 12.00 | 1799.20 | .0011168 | 1104.08 | .81802 | .16525 | 1.40000 |
| 15 | .10208 | 15.00 | 1624.99 | .0011454 | 1076.54 | .73881 | .18425 | 1.40000 |
| 15 | .10208 | 18.00 | 1411.64 | .0011788 | 1046.01 | .64181 | .19010 | 1.40000 |
| 15 | .10208 | 21.00 | 1172.55 | .0012181 | 1012.27 | .53311 | .18135 | 1.40000 |
| 15 | .10208 | 24.00 | 942.79 | .0012592 | 979.23 | .42865 | .15690 | 1.40000 |
| 15 | .10208 | 27.00 | 766.69 | .0012872 | 957.97 | .34858 | .11462 | 1.40000 |
| 15 | .10208 | 30.00 | 698.15 | .0012947 | 952.41 | .31742 | .04002 | 1.40000 |
| 16 | .10938 | 0.00 | 2106.08 | .0010469 | 1177.88 | .95755 | .00131 | 1.50000 |
| 16 | .10938 | 3.00 | 2089.92 | .0010520 | 1172.16 | .95020 | .06982 | 1.50000 |
| 16 | .10938 | 6.00 | 2039.21 | .0010665 | 1156.23 | .92714 | .10518 | 1.50000 |
| 16 | .10938 | 9.00 | 1948.12 | .0010882 | 1133.09 | .88573 | .13772 | 1.50000 |
| 16 | .10938 | 12.00 | 1810.36 | .0011151 | 1105.80 | .82310 | .16571 | 1.50000 |
| 16 | .10938 | 15.00 | 1623.35 | .0011464 | 1075.63 | .73807 | .18444 | 1.50000 |
| 16 | .10938 | 18.00 | 1393.64 | .0011837 | 1041.70 | .63363 | .18980 | 1.50000 |
| 16 | .10938 | 21.00 | 1135.88 | .0012300 | 1002.50 | .51644 | .17962 | 1.50000 |
| 16 | .10938 | 24.00 | 888.64 | .0012808 | 962.75 | .40403 | .15401 | 1.50000 |
| 16 | .10938 | 27.00 | 698.70 | .0013180 | 935.53 | .31767 | .11212 | 1.50000 |
| 16 | .10938 | 30.00 | 624.17 | .0013288 | 927.94 | .28378 | .05158 | 1.50000 |
| 17 | .11667 | 0.00 | 2079.64 | .0010551 | 1168.69 | .94553 | .05661 | 1.60000 |
| 17 | .11667 | 2.73 | 2064.86 | .0010594 | 1163.93 | .93881 | .07639 | 1.60000 |
| 17 | .11667 | 5.45 | 2018.88 | .0010717 | 1150.53 | .91790 | .10564 | 1.60000 |
| 17 | .11667 | 8.18 | 1937.32 | .0010906 | 1130.61 | .88082 | .13436 | 1.60000 |
| 17 | .11667 | 10.91 | 1815.35 | .0011144 | 1106.47 | .82536 | .15985 | 1.60000 |
| 17 | .11667 | 13.64 | 1650.35 | .0011426 | 1079.16 | .75034 | .17834 | 1.60000 |
| 17 | .11667 | 16.36 | 1445.39 | .0011768 | 1047.82 | .65716 | .18636 | 1.60000 |
| 17 | .11667 | 19.09 | 1210.33 | .0012201 | 1010.61 | .55029 | .18208 | 1.60000 |
| 17 | .11667 | 21.82 | 965.46 | .0012752 | 966.93 | .43895 | .16525 | 1.60000 |
| 17 | .11667 | 24.55 | 743.54 | .0013331 | 924.94 | .33806 | .13778 | 1.60000 |
| 17 | .11667 | 27.27 | 578.88 | .0013749 | 896.83 | .26319 | .09931 | 1.60000 |
| 17 | .11667 | 30.00 | 515.41 | .0013875 | 888.71 | .23434 | .05403 | 1.60000 |
| 18 | .12396 | 0.00 | 1994.58 | .0010777 | 1144.15 | .90685 | .08734 | 1.70000 |
| 18 | .12396 | 2.73 | 1977.29 | .0010818 | 1139.85 | .89899 | .09823 | 1.70000 |
| 18 | .12396 | 5.45 | 1924.61 | .0010935 | 1127.67 | .87477 | .12066 | 1.70000 |
| 18 | .12396 | 8.18 | 1831.25 | .0011116 | 1109.29 | .83259 | .14455 | 1.70000 |
| 18 | .12396 | 10.91 | 1695.34 | .0011354 | 1086.06 | .77080 | .16479 | 1.70000 |
| 18 | .12396 | 13.64 | 1516.33 | .0011654 | 1058.07 | .68941 | .17735 | 1.70000 |
| 18 | .12396 | 16.36 | 1302.89 | .0012043 | 1023.87 | .59237 | .17931 | 1.70000 |
| 18 | .12396 | 19.09 | 1057.75 | .0012582 | 979.99 | .48091 | .16939 | 1.70000 |
| 18 | .12396 | 21.82 | 818.59 | .0013262 | 929.78 | .37218 | .14918 | 1.70000 |
| 18 | .12396 | 24.55 | 606.74 | .0013991 | 881.32 | .27586 | .12107 | 1.70000 |
| 18 | .12396 | 27.27 | 452.02 | .0014540 | 848.04 | .20551 | .08595 | 1.70000 |
| 18 | .12396 | 30.00 | 392.42 | .0014709 | 838.30 | .17842 | .04972 | 1.70000 |

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1                    CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .29167 (X/DEQ = 4.00000)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 19 | .13125 | 0.00 | 1837.39 | .0011165 | 1110.42 | .83539 | .11439 | 1.80000 |
| 19 | .13125 | 2.50 | 1820.44 | .0011136 | 1107.30 | .82768 | .12007 | 1.80000 |
| 19 | .13125 | 5.00 | 1768.89 | .0011228 | 1098.22 | .80424 | .13359 | 1.80000 |
| 19 | .13125 | 7.50 | 1681.42 | .0011378 | 1083.77 | .76447 | .14907 | 1.80000 |
| 19 | .13125 | 10.00 | 1556.92 | .0011587 | 1064.21 | .70787 | .16204 | 1.80000 |
| 19 | .13125 | 12.50 | 1397.48 | .0011866 | 1039.14 | .63537 | .16931 | 1.80000 |
| 19 | .13125 | 15.00 | 1206.70 | .0012245 | 1006.97 | .54864 | .16868 | 1.80000 |
| 19 | .13125 | 17.50 | 997.54 | .0012764 | 966.03 | .45354 | .15935 | 1.80000 |
| 19 | .13125 | 20.00 | 787.82 | .0013429 | 918.24 | .35819 | .14249 | 1.80000 |
| 19 | .13125 | 22.50 | 593.76 | .0014217 | 867.30 | .26996 | .12005 | 1.80000 |
| 19 | .13125 | 25.00 | 431.22 | .0015017 | 821.12 | .19606 | .09427 | 1.80000 |
| 19 | .13125 | 27.50 | 316.89 | .0015595 | 790.68 | .14408 | .06595 | 1.80000 |
| 19 | .13125 | 30.00 | 273.46 | .0015771 | 781.86 | .12433 | .04087 | 1.80000 |
| 20 | .13854 | 0.00 | 1598.74 | .0011516 | 1070.72 | .72688 | .13194 | 1.90000 |
| 20 | .13854 | 2.50 | 1579.89 | .0011548 | 1067.79 | .71831 | .13512 | 1.90000 |
| 20 | .13854 | 5.00 | 1523.25 | .0011644 | 1058.99 | .69256 | .14277 | 1.90000 |
| 20 | .13854 | 7.50 | 1429.27 | .0011868 | 1044.23 | .64983 | .15099 | 1.90000 |
| 20 | .13854 | 10.00 | 1301.85 | .0012052 | 1023.13 | .59190 | .15622 | 1.90000 |
| 20 | .13854 | 12.50 | 1136.77 | .0012407 | 993.84 | .51684 | .15577 | 1.90000 |
| 20 | .13854 | 15.00 | 954.54 | .0012896 | 956.17 | .43399 | .14844 | 1.90000 |
| 20 | .13854 | 17.50 | 766.15 | .0013530 | 911.36 | .34834 | .13455 | 1.90000 |
| 20 | .13854 | 20.00 | 585.08 | .0014320 | 861.07 | .26601 | .11549 | 1.90000 |
| 20 | .13854 | 22.50 | 425.42 | .0015230 | 809.65 | .19342 | .09352 | 1.90000 |
| 20 | .13854 | 25.00 | 296.85 | .0016132 | 764.39 | .13496 | .07079 | 1.90000 |
| 20 | .13854 | 27.50 | 208.01 | .0016788 | 734.48 | .09457 | .04826 | 1.90000 |
| 20 | .13854 | 30.00 | 174.26 | .0016987 | 725.87 | .07923 | .03019 | 1.90000 |
| 21 | .14583 | 0.00 | 1287.46 | .0012079 | 1020.84 | .58535 | .13417 | 2.00000 |
| 21 | .14583 | 2.31 | 1273.23 | .0012109 | 1018.35 | .57888 | .13532 | 2.00000 |
| 21 | .14583 | 4.62 | 1221.46 | .0012216 | 1009.39 | .55535 | .13771 | 2.00000 |
| 21 | .14583 | 6.92 | 1140.20 | .0012400 | 994.44 | .51840 | .13956 | 2.00000 |
| 21 | .14583 | 9.23 | 1033.56 | .0012672 | 973.08 | .46989 | .13924 | 2.00000 |
| 21 | .14583 | 11.54 | 905.48 | .0013048 | 944.99 | .41169 | .13506 | 2.00000 |
| 21 | .14583 | 13.85 | 764.63 | .0013539 | 910.74 | .34764 | .12645 | 2.00000 |
| 21 | .14583 | 16.15 | 619.74 | .0014161 | 870.74 | .28177 | .11370 | 2.00000 |
| 21 | .14583 | 18.46 | 481.43 | .0014913 | 826.87 | .21889 | .09777 | 2.00000 |
| 21 | .14583 | 20.77 | 357.91 | .0015764 | 782.20 | .16273 | .08012 | 2.00000 |
| 21 | .14583 | 23.08 | 254.57 | .0016664 | 739.96 | .11574 | .06236 | 2.00000 |
| 21 | .14583 | 25.38 | 175.01 | .0017501 | 704.58 | .07957 | .04584 | 2.00000 |
| 21 | .14583 | 27.69 | 121.64 | .0018079 | 682.03 | .05530 | .03092 | 2.00000 |
| 21 | .14583 | 30.00 | 101.49 | .0018249 | 675.70 | .04614 | .02011 | 2.00000 |
| 22 | .15313 | 0.00 | 937.77 | .0012946 | 952.48 | .42637 | .11983 | 2.10000 |
| 22 | .15313 | 2.14 | 924.95 | .0012987 | 949.49 | .42053 | .11979 | 2.10000 |
| 22 | .15313 | 4.29 | 887.81 | .0013163 | 941.04 | .40365 | .11943 | 2.10000 |
| 22 | .15313 | 6.43 | 828.08 | .0013308 | 926.59 | .37649 | .11795 | 2.10000 |
| 22 | .15313 | 8.57 | 749.54 | .0013598 | 906.80 | .34079 | .11460 | 2.10000 |
| 22 | .15313 | 10.71 | 656.99 | .0013990 | 881.41 | .29870 | .10870 | 2.10000 |
| 22 | .15313 | 12.86 | 556.37 | .0014486 | 851.20 | .25296 | .10008 | 2.10000 |
| 22 | .15313 | 15.00 | 454.56 | .0015083 | 817.51 | .20667 | .08910 | 2.10000 |

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1        CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .29167 (X/DEQ = 4.00000)

| M | P | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 22 | .15313 | 17.14 | 357.45 | .0015777 | 781.57 | .16252 | .07634 | 2.10000 |
| 22 | .15313 | 19.29 | 270.54 | .0016543 | 745.39 | .12301 | .06280 | 2.10000 |
| 22 | .15313 | 21.43 | 197.22 | .0017346 | 710.86 | .08967 | .04961 | 2.10000 |
| 22 | .15313 | 23.57 | 137.95 | .0018142 | 679.67 | .06272 | .03736 | 2.10000 |
| 22 | .15313 | 25.71 | 93.76 | .0018844 | 654.37 | .04260 | .02675 | 2.10000 |
| 22 | .15313 | 27.86 | 64.47 | .0019313 | 638.46 | .02931 | .01780 | 2.10000 |
| 22 | .15313 | 30.00 | 53.60 | .0019445 | 634.12 | .02437 | .01197 | 2.10000 |
| 23 | .16042 | 0.00 | 613.13 | .0014195 | 868.70 | .27876 | .09412 | 2.20000 |
| 23 | .16042 | 2.14 | 603.28 | .0014242 | 865.80 | .27429 | .09360 | 2.20000 |
| 23 | .16042 | 4.29 | 575.04 | .0014387 | 857.06 | .26145 | .09196 | 2.20000 |
| 23 | .16042 | 6.43 | 530.39 | .0014629 | 842.91 | .24114 | .08886 | 2.20000 |
| 23 | .16042 | 8.57 | 472.73 | .0014970 | 823.72 | .21493 | .08401 | 2.20000 |
| 23 | .16042 | 10.71 | 406.78 | .0015409 | 800.25 | .18495 | .07730 | 2.20000 |
| 23 | .16042 | 12.86 | 337.15 | .0015942 | 773.46 | .15329 | .06887 | 2.20000 |
| 23 | .16042 | 15.00 | 269.33 | .0016558 | 744.68 | .12246 | .05929 | 2.20000 |
| 23 | .16042 | 17.14 | 206.72 | .0017239 | 715.30 | .09399 | .04904 | 2.20000 |
| 23 | .16042 | 19.29 | 152.21 | .0017958 | 686.64 | .06920 | .03887 | 2.20000 |
| 23 | .16042 | 21.43 | 107.77 | .0018681 | 660.08 | .04900 | .02951 | 2.20000 |
| 23 | .16042 | 23.57 | 73.44 | .0019367 | 636.70 | .03339 | .02149 | 2.20000 |
| 23 | .16042 | 25.71 | 48.22 | .0019964 | 617.66 | .02193 | .01484 | 2.20000 |
| 23 | .16042 | 27.86 | 31.74 | .0020367 | 605.42 | .01443 | .00958 | 2.20000 |
| 23 | .16042 | 30.00 | 25.54 | .0020484 | 601.96 | .01161 | .00650 | 2.20000 |
| 24 | .16771 | 0.00 | 357.30 | .0015779 | 781.48 | .16245 | .06487 | 2.30000 |
| 24 | .16771 | 2.00 | 351.61 | .0015824 | 779.25 | .15986 | .06431 | 2.30000 |
| 24 | .16771 | 4.00 | 335.59 | .0015957 | 772.74 | .15258 | .06270 | 2.30000 |
| 24 | .16771 | 6.00 | 310.08 | .0016176 | 762.26 | .14098 | .05991 | 2.30000 |
| 24 | .16771 | 8.00 | 277.07 | .0016481 | 748.17 | .12597 | .05592 | 2.30000 |
| 24 | .16771 | 10.00 | 240.00 | .0016861 | 731.32 | .10912 | .05096 | 2.30000 |
| 24 | .16771 | 12.00 | 200.67 | .0017312 | 712.27 | .09123 | .04505 | 2.30000 |
| 24 | .16771 | 14.00 | 161.87 | .0017820 | 691.95 | .07360 | .03854 | 2.30000 |
| 24 | .16771 | 16.00 | 126.11 | .0018367 | 671.37 | .05734 | .03189 | 2.30000 |
| 24 | .16771 | 18.00 | 94.96 | .0018929 | 651.41 | .04318 | .02550 | 2.30000 |
| 24 | .16771 | 20.00 | 68.67 | .0019496 | 632.46 | .03122 | .01954 | 2.30000 |
| 24 | .16771 | 22.00 | 47.91 | .0020039 | 615.35 | .02178 | .01446 | 2.30000 |
| 24 | .16771 | 24.00 | 32.27 | .0020531 | 600.60 | .01467 | .01031 | 2.30000 |
| 24 | .16771 | 26.00 | 20.97 | .0020947 | 588.65 | .00954 | .00709 | 2.30000 |
| 24 | .16771 | 28.00 | 13.73 | .0021219 | 581.12 | .00624 | .00464 | 2.30000 |
| 24 | .16771 | 30.00 | 10.98 | .0021299 | 578.95 | .00499 | .00327 | 2.30000 |
| 25 | .17500 | 0.00 | 186.12 | .0017495 | 704.80 | .08462 | .03924 | 2.40000 |
| 25 | .17500 | 2.00 | 182.65 | .0017538 | 703.08 | .08304 | .03873 | 2.40000 |
| 25 | .17500 | 4.00 | 173.41 | .0017661 | 698.20 | [illegible] | .03741 | 2.40000 |
| 25 | .17500 | 6.00 | 159.16 | .0017860 | 690.39 | [illegible] | .03532 | 2.40000 |
| 25 | .17500 | 8.00 | 140.63 | .0018134 | 679.99 | [illegible] | .03232 | 2.40000 |
| 25 | .17500 | 10.00 | 120.08 | .0018468 | 667.68 | [illegible] | .02878 | 2.40000 |
| 25 | .17500 | 12.00 | 99.05 | .0018850 | 654.15 | [illegible] | .02488 | 2.40000 |
| 25 | .17500 | 14.00 | 78.44 | .0019274 | 639.77 | .03566 | .02070 | 2.40000 |
| 25 | .17500 | 16.00 | 59.91 | .0019714 | 625.49 | .02724 | .01663 | 2.40000 |
| 25 | .17500 | 18.00 | 44.13 | .0020153 | 611.86 | .02006 | .01290 | 2.40000 |

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = .29167 (X/DEQ = 4.00000)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 25 | .17500 | 20.00 | 31.18 | .0020583 | 599.09 | .01418 | .00964 | 2.40000 |
| 25 | .17500 | 22.00 | 21.12 | .0020987 | 587.55 | .00960 | .00694 | 2.40000 |
| 25 | .17500 | 24.00 | 13.77 | .0021344 | 577.71 | .00626 | .00481 | 2.40000 |
| 25 | .17500 | 26.00 | 8.66 | .0021636 | 569.92 | .00394 | .00334 | 2.40000 |
| 25 | .17500 | 28.00 | 5.41 | .0021826 | 564.96 | .00246 | .00232 | 2.40000 |
| 25 | .17500 | 30.00 | 4.18 | .0021877 | 563.64 | .00190 | .00192 | 2.40000 |
| 26 | .18229 | 0.00 | 86.65 | .0019098 | 645.67 | .03940 | .02081 | 2.50000 |
| 26 | .18229 | 1.87 | 85.59 | .0019131 | 644.56 | .03869 | .02052 | 2.50000 |
| 26 | .18229 | 3.75 | 80.94 | .0019217 | 641.64 | .03680 | .01974 | 2.50000 |
| 26 | .18229 | 5.62 | 74.69 | .0019357 | 637.02 | .03396 | .01860 | 2.50000 |
| 26 | .18229 | 7.50 | 66.40 | .0019552 | 630.67 | .03019 | .01697 | 2.50000 |
| 26 | .18229 | 9.37 | 57.15 | .0019786 | 623.19 | .02598 | .01510 | 2.50000 |
| 26 | .18229 | 11.25 | 47.65 | .0020048 | 615.05 | .02166 | .01303 | 2.50000 |
| 26 | .18229 | 13.12 | 38.29 | .0020337 | 606.33 | .01741 | .01087 | 2.50000 |
| 26 | .18229 | 15.00 | 29.65 | .0020641 | 597.40 | .01348 | .00879 | 2.50000 |
| 26 | .18229 | 16.87 | 22.17 | .0020942 | 588.81 | .01008 | .00693 | 2.50000 |
| 26 | .18229 | 18.75 | 16.03 | .0021229 | 580.84 | .00729 | .00534 | 2.50000 |
| 26 | .18229 | 20.62 | 11.14 | .0021501 | 573.50 | .00507 | .00396 | 2.50000 |
| 26 | .18229 | 22.50 | 7.44 | .0021746 | 567.05 | .00338 | .00293 | 2.50000 |
| 26 | .18229 | 24.37 | 4.76 | .0021955 | 561.63 | .00216 | .00224 | 2.50000 |
| 26 | .18229 | 26.25 | 2.88 | .0022116 | 557.56 | .00131 | .00172 | 2.50000 |
| 26 | .18229 | 28.12 | 1.66 | .0022189 | 555.72 | .00076 | .00151 | 2.50000 |
| 26 | .18229 | 30.00 | 1.19 | .0022174 | 556.08 | .00054 | .00132 | 2.50000 |
| 27 | .18958 | 0.00 | 36.06 | .0020411 | 604.12 | .01640 | .00971 | 2.60000 |
| 27 | .18958 | 1.87 | 35.36 | .0020436 | 603.37 | .01608 | .00957 | 2.60000 |
| 27 | .18958 | 3.75 | 33.52 | .0020500 | 601.50 | .01524 | .00917 | 2.60000 |
| 27 | .18958 | 5.62 | 30.72 | .0020600 | 598.59 | .01397 | .00858 | 2.60000 |
| 27 | .18958 | 7.50 | 27.12 | .0020736 | 594.64 | .01233 | .00776 | 2.60000 |
| 27 | .18958 | 9.37 | 23.02 | .0020905 | 589.84 | .01046 | .00681 | 2.60000 |
| 27 | .18958 | 11.25 | 18.93 | .0021087 | 584.75 | .00861 | .00587 | 2.60000 |
| 27 | .18958 | 13.12 | 14.96 | .0021285 | 579.32 | .00680 | .00485 | 2.60000 |
| 27 | .18958 | 15.00 | 11.39 | .0021486 | 573.90 | .00518 | .00392 | 2.60000 |
| 27 | .18958 | 16.87 | 8.30 | .0021685 | 568.62 | .00379 | .00304 | 2.60000 |
| 27 | .18958 | 18.75 | 5.84 | .0021868 | 563.87 | .00265 | .00246 | 2.60000 |
| 27 | .18958 | 20.62 | 3.89 | .0022033 | 559.65 | .00177 | .00192 | 2.60000 |
| 27 | .18958 | 22.50 | 2.43 | .0022167 | 556.26 | .00111 | .00165 | 2.60000 |
| 27 | .18958 | 24.37 | 1.34 | .0022241 | 554.42 | .00061 | .00160 | 2.60000 |
| 27 | .18958 | 26.25 | .34 | .0021745 | 567.06 | .00015 | .00148 | 2.60000 |
| 27 | .18958 | 28.12 | 0.00 | .0022835 | 546.00 | 0.00000 | 0.00000 | 2.60000 |
| 27 | .18958 | 30.00 | 0.00 | .0022835 | 546.00 | 0.00000 | 0.00000 | 2.60000 |

AD-A094 292 GENERAL ELECTRIC CO CINCINNATI OH AIRCRAFT ENGINE GROUP F/G 20/1
HIGH VELOCITY JET NOISE SOURCE LOCATION AND REDUCTION. TASK 2 S--ETC(U)
MAY 78 P R GLIEBE DOT-OS-30034
UNCLASSIFIED R78AEG324 FAA-RD-76-79-2A NL

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CIRCUMFERENTIALLY-AVERAGED PARAMETERS

| NR | RADIUS | MACH NO. | TEMP. | INTENSITY | FREQUENCY |
|---|---|---|---|---|---|
| 1 | .0001 | 1.8828 | 2.1813 | .68664E-07 | 1. |
| 2 | .1000 | 1.8592 | 2.1644 | .26994E+05 | 722. |
| 3 | .2000 | 1.7832 | 2.1191 | .11244E+07 | 1793. |
| 4 | .3000 | 1.6431 | 2.0574 | .11132E+08 | 3336. |
| 5 | .4000 | 1.4313 | 1.9870 | .39960E+08 | 5082. |
| 6 | .5000 | 1.1587 | 1.9059 | .53881E+08 | 6414. |
| 7 | .6000 | .8649 | 1.8144 | .24459E+08 | 6497. |
| 8 | .7000 | .6355 | 1.7476 | .26335E+07 | 4183. |
| 9 | .8000 | .5695 | 1.7321 | .11638E+07 | 1968. |
| 10 | .9000 | .6926 | 1.7611 | .25946E+08 | 4375. |
| 11 | 1.0000 | .9058 | 1.8300 | .12463E+09 | 5019. |
| 12 | 1.1000 | 1.1205 | 1.9054 | .28211E+09 | 4338. |
| 13 | 1.2000 | 1.2928 | 1.9686 | .43157E+09 | 3225. |
| 14 | 1.3000 | 1.4069 | 2.0138 | .54259E+09 | 2189. |
| 15 | 1.4000 | 1.4638 | 2.0402 | .61131E+09 | 1565. |
| 16 | 1.5000 | 1.4704 | 2.0443 | .63218E+09 | 1422. |
| 17 | 1.6000 | 1.4314 | 2.0251 | .59685E+09 | 1913. |
| 18 | 1.7000 | 1.3472 | 1.9843 | .50905E+09 | 2664. |
| 19 | 1.8000 | 1.2142 | 1.9246 | .39118E+09 | 3517. |
| 20 | 1.9000 | 1.0335 | 1.8461 | .26257E+09 | 4260. |
| 21 | 2.0000 | .8152 | 1.7450 | .13209E+09 | 4643. |
| 22 | 2.1000 | .5862 | 1.6208 | .39271E+08 | 4499. |
| 23 | 2.2000 | .3809 | 1.4848 | .57567E+07 | 3848. |
| 24 | 2.3000 | .2220 | 1.3533 | .37244E+06 | 2885. |
| 25 | 2.4000 | .1158 | 1.2414 | .10119E+05 | 1887. |
| 26 | 2.5000 | .0541 | 1.1557 | .11334E+03 | 1078. |
| 27 | 2.6000 | .0226 | 1.0958 | .54414E+00 | 556. |

WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT
KA= 7 X= .29167 ITH= 11 THETA= 120.00 NTP= 3

| | | | | | |
|---|---|---|---|---|---|
| X( 7)= | .2917 | UBI( 7)= .19492E+21 | FM( 7)= .3531E+01 | UAVG( 7)= 1266.03 | UMAX( 7)= 2106.11 |
| X( 8)= | .3675 | UBI( 8)= .13113E+21 | FM( 8)= .3820E+01 | UAVG( 8)= 1170.16 | UMAX( 8)= 1951.26 |
| X( 9)= | .4630 | UBI( 9)= .60935E+20 | FM( 9)= .4151E+01 | UAVG( 9)= 1077.16 | UMAX( 9)= 1731.67 |
| X(10)= | .5833 | UBI(10)= .17529E+20 | FM(10)= .4530E+01 | UAVG(10)= 986.98 | UMAX(10)= 1506.85 |
| X(11)= | .7350 | UBI(11)= .38719E+19 | FM(11)= .4972E+01 | UAVG(11)= 899.31 | UMAX(11)= 1347.75 |
| X(12)= | .9260 | UBI(12)= .12720E+19 | FM(12)= .5529E+01 | UAVG(12)= 808.47 | UMAX(12)= 1276.87 |

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1     CPD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = 1.16667 (X/DEQ = 15.99999)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 1 | .00001 | 0.00 | 1238.43 | .0012299 | 1002.62 | .56306 | .00079 | .00016 |
| 1 | .00001 | 10.00 | 1238.43 | .0012299 | 1002.62 | .56306 | .00079 | .00016 |
| 1 | .00001 | 20.00 | 1238.43 | .0012299 | 1002.62 | .56306 | .00079 | .00016 |
| 1 | .00001 | 30.00 | 1238.43 | .0012299 | 1002.62 | .56306 | .00079 | .00016 |
| 2 | .01167 | 0.00 | 1236.43 | .0012310 | 1001.65 | .56215 | .01959 | .16000 |
| 2 | .01167 | 10.00 | 1236.43 | .0012310 | 1001.65 | .56215 | .01960 | .16000 |
| 2 | .01167 | 20.00 | 1236.44 | .0012310 | 1001.66 | .56216 | .01961 | .16000 |
| 2 | .01167 | 30.00 | 1236.44 | .0012310 | 1001.66 | .56216 | .01960 | .16000 |
| 3 | .02333 | 0.00 | 1230.90 | .0012345 | 998.88 | .55964 | .02794 | .32000 |
| 3 | .02333 | 7.50 | 1230.89 | .0012345 | 998.87 | .55963 | .02794 | .32000 |
| 3 | .02333 | 15.00 | 1230.90 | .0012345 | 998.88 | .55964 | .02797 | .32000 |
| 3 | .02333 | 22.50 | 1230.92 | .0012345 | 998.88 | .55965 | .02797 | .32000 |
| 3 | .02333 | 30.00 | 1230.98 | .0012344 | 998.9[illegible] | .55967 | .02798 | .32000 |
| 4 | .03500 | 0.00 | 1221.34 | .0012405 | 994.04 | .55529 | .03476 | .32000 |
| 4 | .03500 | 7.50 | 1221.47 | .0012404 | 994.07 | .55535 | .03477 | .48000 |
| 4 | .03500 | 15.00 | 1221.39 | .0012404 | 994.07 | .55532 | .03482 | .48000 |
| 4 | .03500 | 22.50 | 1221.41 | .0012404 | 994.08 | .55532 | .03489 | .48000 |
| 4 | .03500 | 30.00 | 1221.32 | .0012404 | 994.07 | .55528 | .03491 | .48000 |
| 5 | .04667 | 0.00 | 1206.88 | .0012493 | 986.99 | .54872 | .04115 | .64000 |
| 5 | .04667 | 6.00 | 1206.94 | .0012493 | 987.02 | .54875 | .04119 | .64000 |
| 5 | .04667 | 12.00 | 1206.98 | .0012493 | 987.05 | .54876 | .04135 | .64000 |
| 5 | .04667 | 18.00 | 1206.86 | .0012492 | 987.07 | .54871 | .04154 | .64000 |
| 5 | .04667 | 24.00 | 1206.74 | .0012492 | 987.10 | .54865 | .04169 | .64000 |
| 5 | .04667 | 30.00 | 1206.84 | .0012492 | 987.12 | .54870 | .04170 | .64000 |
| 6 | .05833 | 0.00 | 1187.62 | .0012613 | 977.66 | .53996 | .04768 | .80000 |
| 6 | .05833 | 6.00 | 1187.62 | .0012612 | 977.69 | .53996 | .04783 | .80000 |
| 6 | .05833 | 12.00 | 1187.26 | .0012611 | 977.75 | .53980 | .04814 | .80000 |
| 6 | .05833 | 18.00 | 1187.[illegible]6 | .0012610 | 977.86 | .53971 | .04850 | .80000 |
| 6 | .05833 | 24.00 | 1187.09 | .0012608 | 977.98 | .53972 | .04878 | .80000 |
| 6 | .05833 | 30.00 | 1187.07 | .0012608 | 978.03 | .53971 | .04888 | .80000 |
| 7 | .07000 | 0.00 | 1162.27 | .0012765 | 966.01 | .52843 | .05460 | .96000 |
| 7 | .07000 | 5.00 | 1162.31 | .0012764 | 966.08 | .52845 | .05478 | .96000 |
| 7 | .07000 | 10.00 | 1161.97 | .0012762 | 966.24 | .52830 | .05520 | .96000 |
| 7 | .07000 | 15.00 | 1161.48 | .0012759 | 966.44 | .52808 | .05571 | .96000 |
| 7 | .07000 | 20.00 | 1161.28 | .0012755 | 966.70 | .52799 | .05618 | .96000 |
| 7 | .07000 | 25.00 | 1160.97 | .0012753 | 966.86 | .52784 | .05648 | .96000 |
| 7 | .07000 | 30.00 | 1160.92 | .0012752 | 966.94 | .52782 | .05655 | .96000 |
| 8 | .08167 | 0.00 | 1130.21 | .0012946 | 952.48 | .51386 | .06181 | 1.12000 |
| 8 | .08167 | 5.00 | 1130.05 | .0012944 | 952.61 | .51378 | .06208 | 1.12000 |
| 8 | .08167 | 10.00 | 1129.59 | .0012940 | 952.92 | .51358 | .06272 | 1.12000 |
| 8 | .08167 | 15.00 | 1128.75 | .0012935 | 953.32 | .51320 | .06347 | 1.12000 |
| 8 | .08167 | 20.00 | 1128.07 | .0012928 | 953.79 | .51289 | .06411 | 1.12000 |
| 8 | .08167 | 25.00 | 1127.39 | .0012924 | 954.10 | .51258 | .06453 | 1.12000 |
| 8 | .08167 | 30.00 | 1127.07 | .0012923 | 954.20 | .51243 | .06465 | 1.12000 |
| 9 | .09333 | 0.00 | 1090.28 | .0013155 | 937.34 | .49570 | .06894 | 1.28000 |
| 9 | .09333 | 4.29 | 1090.08 | .0013153 | 937.50 | .49561 | .06919 | 1.28000 |
| 9 | .09333 | 8.57 | 1089.36 | .0013147 | 937.91 | .49529 | .06987 | 1.28000 |
| 9 | .09333 | 12.86 | 1088.33 | .0013139 | 938.49 | .49482 | .07072 | 1.28000 |

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1    CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = 1.16667 (X/DEQ = 15.99999)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 9 | .09333 | 17.14 | 1087.31 | .0013129 | 939.17 | .49436 | .07151 | 1.28000 |
| 9 | .09333 | 21.43 | 1086.04 | .0013122 | 939.73 | .49378 | .07208 | 1.28000 |
| 9 | .09333 | 25.71 | 1085.25 | .0013115 | 940.17 | .49342 | .07242 | 1.28000 |
| 9 | .09333 | 30.00 | 1084.88 | .0013113 | 940.31 | .49325 | .07253 | 1.28000 |
| 10 | .10500 | 0.00 | 1042.41 | .0013387 | 921.08 | .47394 | .07553 | 1.44000 |
| 10 | .10500 | 4.29 | 1041.87 | .0013385 | 921.26 | .47369 | .07585 | 1.44000 |
| 10 | .10500 | 8.57 | 1040.72 | .0013376 | 921.88 | .47317 | .07667 | 1.44000 |
| 10 | .10500 | 12.86 | 1038.96 | .0013363 | 922.76 | .47237 | .07767 | 1.44000 |
| 10 | .10500 | 17.14 | 1037.13 | .0013348 | 923.78 | .47154 | .07854 | 1.44000 |
| 10 | .10500 | 21.43 | 1035.17 | .0013336 | 924.64 | .47065 | .07914 | 1.44000 |
| 10 | .10500 | 25.71 | 1033.91 | .0013326 | 925.30 | .47007 | .07946 | 1.44000 |
| 10 | .10500 | 30.00 | 1033.26 | .0013323 | 925.51 | .46978 | .07954 | 1.44000 |
| 11 | .11667 | 0.00 | 985.99 | .0013642 | 903.86 | .44829 | .08105 | 1.60000 |
| 11 | .11667 | 3.75 | 985.47 | .0013639 | 904.08 | .44805 | .08133 | 1.60000 |
| 11 | .11667 | 7.50 | 984.09 | .0013629 | 904.73 | .44742 | .08206 | 1.60000 |
| 11 | .11667 | 11.25 | 981.92 | .0013615 | 905.70 | .44644 | .08298 | 1.60000 |
| 11 | .11667 | 15.00 | 979.34 | .0013598 | 906.84 | .44526 | .08384 | 1.60000 |
| 11 | .11667 | 18.75 | 976.76 | .0013580 | 908.00 | .44409 | .08448 | 1.60000 |
| 11 | .11667 | 22.50 | 974.34 | .0013565 | 908.99 | .44299 | .08488 | 1.60000 |
| 11 | .11667 | 26.25 | 972.70 | .0013555 | 909.66 | .44225 | .08504 | 1.60000 |
| 11 | .11667 | 30.00 | 972.31 | .0013551 | 909.95 | .44207 | .08510 | 1.60000 |
| 12 | .12833 | 0.00 | 921.76 | .0013917 | 885.99 | .41909 | .08510 | 1.76000 |
| 12 | .12833 | 3.75 | 920.97 | .0013914 | 886.24 | .41873 | .08538 | 1.76000 |
| 12 | .12833 | 7.50 | 918.91 | .0013901 | 887.02 | .41779 | .08610 | 1.76000 |
| 12 | .12833 | 11.25 | 915.85 | .0013883 | 888.21 | .41640 | .08701 | 1.76000 |
| 12 | .12833 | 15.00 | 912.22 | .0013861 | 889.63 | .41475 | .08781 | 1.76000 |
| 12 | .12833 | 18.75 | 908.30 | .0013838 | 891.05 | .41297 | .08835 | 1.76000 |
| 12 | .12833 | 22.50 | 904.86 | .0013820 | 892.27 | .41140 | .08861 | 1.76000 |
| 12 | .12833 | 26.25 | 902.56 | .0013807 | 893.09 | .41036 | .08866 | 1.76000 |
| 12 | .12833 | 30.00 | 901.71 | .0013802 | 893.38 | .40997 | .08866 | 1.76000 |
| 13 | .14000 | 0.00 | 850.11 | .0014216 | 867.36 | .38651 | .08730 | 1.92000 |
| 13 | .14000 | 3.33 | 849.37 | .0014212 | 867.60 | .38617 | .08750 | 1.92000 |
| 13 | .14000 | 6.67 | 847.30 | .0014201 | 868.33 | .38523 | .08805 | 1.92000 |
| 13 | .14000 | 10.00 | 843.77 | .0014183 | 869.38 | .38363 | .08876 | 1.92000 |
| 13 | .14000 | 13.33 | 839.44 | .0014161 | 870.72 | .38166 | .08943 | 1.92000 |
| 13 | .14000 | 16.67 | 834.79 | .0014138 | 872.18 | .37954 | .08988 | 1.92000 |
| 13 | .14000 | 20.00 | 830.35 | .0014115 | 873.58 | .37753 | .09009 | 1.92000 |
| 13 | .14000 | 23.33 | 826.85 | .0014096 | 874.76 | .37593 | .09009 | 1.92000 |
| 13 | .14000 | 26.67 | 824.45 | .0014084 | 875.51 | .37484 | .09001 | 1.92000 |
| 13 | .14000 | 30.00 | 823.73 | .0014079 | 875.80 | .37452 | .08998 | 1.92000 |
| 14 | .15167 | 0.00 | 772.49 | .0014541 | 847.97 | .35122 | .08750 | 2.08000 |
| 14 | .15167 | 3.33 | 771.38 | .0014538 | 848.19 | .35072 | .08767 | 2.08000 |
| 14 | .15167 | 6.67 | 768.55 | .0014525 | 848.91 | .34943 | .08813 | 2.08000 |
| 14 | .15167 | 10.00 | 764.35 | .0014506 | 850.06 | .34752 | .08871 | 2.08000 |
| 14 | .15167 | 13.33 | 759.01 | .0014482 | 851.47 | .34509 | .08918 | 2.08000 |
| 14 | .15167 | 16.67 | 753.47 | .0014455 | 853.05 | .34257 | .08943 | 2.08000 |
| 14 | .15167 | 20.00 | 747.99 | .0014430 | 854.52 | .34008 | .08941 | 2.08000 |
| 14 | .15167 | 23.33 | 743.72 | .0014409 | 855.79 | .33814 | .08923 | 2.08000 |

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = 1.16667 (X/DEQ = 15.99999)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 14 | .15167 | 26.67 | 740.75 | .0014395 | 856.58 | .33679 | .08902 | 2.08000 |
| 14 | .15167 | 30.00 | 739.65 | .0014391 | 856.84 | .33629 | .08893 | 2.08000 |
| 15 | .16333 | 0.00 | 690.42 | .0014898 | 827.68 | .31391 | .08564 | 2.24000 |
| 15 | .16333 | 3.00 | 689.59 | .0014894 | 827.88 | .31353 | .08575 | 2.24000 |
| 15 | .16333 | 6.00 | 686.80 | .0014885 | 828.43 | .31226 | .08603 | 2.24000 |
| 15 | .16333 | 9.00 | 682.73 | .0014868 | 829.35 | .31041 | .08638 | 2.24000 |
| 15 | .16333 | 12.00 | 677.69 | .0014846 | 830.56 | .30812 | .08667 | 2.24000 |
| 15 | .16333 | 15.00 | 671.85 | .0014822 | 831.90 | .30546 | .08677 | 2.24000 |
| 15 | .16333 | 18.00 | 665.83 | .0014799 | 833.24 | .30272 | .08666 | 2.24000 |
| 15 | .16333 | 21.00 | 660.62 | .0014775 | 834.56 | .30035 | .08640 | 2.24000 |
| 15 | .16333 | 24.00 | 656.27 | .0014757 | 835.59 | .29838 | .08605 | 2.24000 |
| 15 | .16333 | 27.00 | 653.51 | .0014745 | 836.28 | .29712 | .08578 | 2.24000 |
| 15 | .16333 | 30.00 | 652.68 | .0014740 | 836.57 | .29675 | .08568 | 2.24000 |
| 16 | .17500 | 0.00 | 606.81 | .0015289 | 806.53 | .27589 | .08184 | 2.40000 |
| 16 | .17500 | 3.00 | 605.99 | .0015285 | 806.75 | .27552 | .08193 | 2.40000 |
| 16 | .17500 | 6.00 | 602.90 | .0015276 | 807.20 | .27411 | .08208 | 2.40000 |
| 16 | .17500 | 9.00 | 598.56 | .0015260 | 808.06 | .27214 | .08227 | 2.40000 |
| 16 | .17500 | 12.00 | 592.66 | .0015240 | 809.09 | .26946 | .08234 | 2.40000 |
| 16 | .17500 | 15.00 | 586.40 | .0015216 | 810.36 | .26661 | .08225 | 2.40000 |
| 16 | .17500 | 18.00 | 579.83 | .0015192 | 811.65 | .26362 | .08193 | 2.40000 |
| 16 | .17500 | 21.00 | 574.00 | .0015169 | 812.90 | .26097 | .08149 | 2.40000 |
| 16 | .17500 | 24.00 | 569.29 | .0015150 | 813.93 | .25883 | .08101 | 2.40000 |
| 16 | .17500 | 27.00 | 566.13 | .0015138 | 814.56 | .25740 | .08062 | 2.40000 |
| 16 | .17500 | 30.00 | 565.13 | .0015133 | 814.81 | .25694 | .08049 | 2.40000 |
| 17 | .18667 | 0.00 | 524.23 | .0015714 | 784.69 | .23834 | .07644 | 2.56000 |
| 17 | .18667 | 2.73 | 523.45 | .0015711 | 784.83 | .23799 | .07647 | 2.56000 |
| 17 | .18667 | 5.45 | 520.84 | .0015705 | 785.15 | .23680 | .07651 | 2.56000 |
| 17 | .18667 | 8.18 | 516.92 | .0015693 | 785.74 | .23502 | .07655 | 2.56000 |
| 17 | .18667 | 10.91 | 511.73 | .0015678 | 786.50 | .23266 | .07649 | 2.56000 |
| 17 | .18667 | 13.64 | 505.65 | .0015661 | 787.38 | .22990 | .07627 | 2.56000 |
| 17 | .18667 | 16.36 | 499.45 | .0015640 | 788.42 | .22708 | .07592 | 2.56000 |
| 17 | .18667 | 19.09 | 493.33 | .0015619 | 789.45 | .22430 | .07540 | 2.56000 |
| 17 | .18667 | 21.82 | 487.93 | .0015600 | 790.42 | .22184 | .07483 | 2.56000 |
| 17 | .18667 | 24.55 | 483.66 | .0015585 | 791.20 | .21990 | .07429 | 2.56000 |
| 17 | .18667 | 27.27 | 481.02 | .0015574 | 791.74 | .21870 | .07392 | 2.56000 |
| 17 | .18667 | 30.00 | 480.13 | .0015570 | 791.94 | .21829 | .07378 | 2.56000 |
| 18 | .19833 | 0.00 | 444.85 | .0016173 | 762.41 | .20226 | .06978 | 2.72000 |
| 18 | .19833 | 2.73 | 444.06 | .0016171 | 762.53 | .20190 | .06978 | 2.72000 |
| 18 | .19833 | 5.45 | 441.44 | .0016166 | 762.75 | .20070 | .06974 | 2.72000 |
| 18 | .19833 | 8.18 | 437.39 | .0016157 | 763.17 | .19886 | .06964 | 2.72000 |
| 18 | .19833 | 10.91 | 432.15 | .0016145 | 763.74 | .19648 | .06942 | 2.72000 |
| 18 | .19833 | 13.64 | 426.10 | .0016130 | 764.46 | .19373 | .06906 | 2.72000 |
| 18 | .19833 | 16.36 | 419.72 | .0016113 | 765.27 | .19083 | .06854 | 2.72000 |
| 18 | .19833 | 19.09 | 413.45 | .0016095 | 766.10 | .18798 | .06790 | 2.72000 |
| 18 | .19833 | 21.82 | 407.99 | .0016078 | 766.94 | .18550 | .06722 | 2.72000 |
| 18 | .19833 | 24.55 | 403.63 | .0016064 | 767.62 | .18352 | .06660 | 2.72000 |
| 18 | .19833 | 27.27 | 400.90 | .0016054 | 768.08 | .18227 | .06616 | 2.72000 |
| 18 | .19833 | 30.00 | 399.90 | .0016051 | 768.23 | .18182 | .06600 | 2.72000 |

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = 1.16667 (X/DEQ = 15.99999)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 19 | .21000 | 0.00 | 370.73 | .0016662 | 740.06 | .16855 | .06228 | 2.88000 |
| 19 | .21000 | 2.50 | 370.01 | .0016661 | 740.10 | .16823 | .06225 | 2.88000 |
| 19 | .21000 | 5.00 | 367.92 | .0016658 | 740.23 | .16728 | .06217 | 2.88000 |
| 19 | .21000 | 7.50 | 364.58 | .0016653 | 740.45 | .16576 | .06200 | 2.88000 |
| 19 | .21000 | 10.00 | 360.11 | .0016647 | 740.74 | .16373 | .06172 | 2.88000 |
| 19 | .21000 | 12.50 | 354.93 | .0016637 | 741.15 | .16137 | .06133 | 2.88000 |
| 19 | .21000 | 15.00 | 349.35 | .0016625 | 741.68 | .15883 | .06081 | 2.88000 |
| 19 | .21000 | 17.50 | 343.58 | .0016613 | 742.23 | .15621 | .06017 | 2.88000 |
| 19 | .21000 | 20.00 | 338.18 | .0016599 | 742.84 | .15376 | .05948 | 2.88000 |
| 19 | .21000 | 22.50 | 333.44 | .0016587 | 743.40 | .15160 | .05879 | 2.88000 |
| 19 | .21000 | 25.00 | 329.79 | .0016576 | 743.89 | .14994 | .05821 | 2.88000 |
| 19 | .21000 | 27.50 | 327.48 | .0016569 | 744.21 | .14889 | .05781 | 2.88000 |
| 19 | .21000 | 30.00 | 326.69 | .0016566 | 744.32 | .14853 | .05767 | 2.88000 |
| 20 | .22167 | 0.00 | 303.31 | .0017173 | 718.03 | .13790 | .05436 | 3.04000 |
| 20 | .22167 | 2.50 | 302.60 | .0017173 | 718.02 | .13758 | .05431 | 3.04000 |
| 20 | .22167 | 5.00 | 300.64 | .0017172 | 718.06 | .13669 | .05418 | 3.04000 |
| 20 | .22167 | 7.50 | 297.45 | .0017171 | 718.13 | .13524 | .05394 | 3.04000 |
| 20 | .22167 | 10.00 | 293.36 | .0017167 | 718.30 | .13338 | .05359 | 3.04000 |
| 20 | .22167 | 12.50 | 288.49 | .0017161 | 718.52 | .13116 | .05312 | 3.04000 |
| 20 | .22167 | 15.00 | 283.14 | .0017155 | 718.80 | .12873 | .05252 | 3.04000 |
| 20 | .22167 | 17.50 | 277.74 | .0017145 | 719.18 | .12628 | .05183 | 3.04000 |
| 20 | .22167 | 20.00 | 272.60 | .0017136 | 719.60 | .12394 | .05109 | 3.04000 |
| 20 | .22167 | 22.50 | 268.15 | .0017125 | 720.03 | .12192 | .05038 | 3.04000 |
| 20 | .22167 | 25.00 | 264.66 | .0017117 | 720.40 | .12033 | .04977 | 3.04000 |
| 20 | .22167 | 27.50 | 262.47 | .0017110 | 720.66 | .11933 | .04937 | 3.04000 |
| 20 | .22167 | 30.00 | 261.72 | .0017108 | 720.75 | .11899 | .04922 | 3.04000 |
| 21 | .23333 | 0.00 | 243.54 | .0017699 | 696.68 | .11073 | .04640 | 3.20000 |
| 21 | .23333 | 2.31 | 243.02 | .0017700 | 696.67 | .11049 | .04635 | 3.20000 |
| 21 | .23333 | 4.62 | 241.46 | .0017701 | 696.63 | .10978 | .04621 | 3.20000 |
| 21 | .23333 | 6.92 | 239.06 | .0017701 | 696.62 | .10869 | .04598 | 3.20000 |
| 21 | .23333 | 9.23 | 235.80 | .0017701 | 696.61 | .10721 | .04564 | 3.20000 |
| 21 | .23333 | 11.54 | 231.86 | .0017701 | 696.62 | .10542 | .04520 | 3.20000 |
| 21 | .23333 | 13.85 | 227.52 | .0017699 | 696.70 | .10344 | .04466 | 3.20000 |
| 21 | .23333 | 16.15 | 222.94 | .0017695 | 696.83 | .10136 | .04404 | 3.20000 |
| 21 | .23333 | 18.46 | 218.46 | .0017690 | 697.04 | .09932 | .04336 | 3.20000 |
| 21 | .23333 | 20.77 | 214.31 | .0017683 | 697.31 | .09744 | .04268 | 3.20000 |
| 21 | .23333 | 23.08 | 210.74 | .0017676 | 697.58 | .09582 | .04204 | 3.20000 |
| 21 | .23333 | 25.38 | 208.00 | .0017670 | 697.83 | .09457 | .04152 | 3.20000 |
| 21 | .23333 | 27.69 | 206.28 | .0017666 | 698.00 | .09379 | .04118 | 3.20000 |
| 21 | .23333 | 30.00 | 205.69 | .0017664 | 698.07 | .09352 | .04106 | 3.20000 |
| 22 | .24500 | 0.00 | 191.94 | .0018229 | 676.44 | .08727 | .03874 | 3.36000 |
| 22 | .24500 | 2.14 | 191.56 | .0018230 | 676.41 | .08709 | .03869 | 3.36000 |
| 22 | .24500 | 4.29 | 190.41 | .0018231 | 676.35 | .08657 | .03857 | 3.36000 |
| 22 | .24500 | 6.43 | 188.54 | .0018234 | 676.25 | .08572 | .03835 | 3.36000 |
| 22 | .24500 | 8.57 | 186.04 | .0018237 | 676.15 | .08458 | .03804 | 3.36000 |
| 22 | .24500 | 10.71 | 183.00 | .0018240 | 676.04 | .08320 | .03765 | 3.36000 |
| 22 | .24500 | 12.86 | 179.58 | .0018242 | 675.97 | .08165 | .03718 | 3.36000 |
| 22 | .24500 | 15.00 | 175.91 | .0018242 | 675.94 | .07998 | .03664 | 3.36000 |

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = 1.16667 (X/DEQ = 15.99999)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 22 | .24500 | 17.14 | 172.18 | .0018241 | 675.97 | .07828 | .03605 | 3.36000 |
| 22 | .24500 | 19.29 | 168.57 | .0018239 | 676.07 | .07664 | .03544 | 3.36000 |
| 22 | .24500 | 21.43 | 165.28 | .0018235 | 676.21 | .07515 | .03484 | 3.36000 |
| 22 | .24500 | 23.57 | 162.49 | .0018231 | 676.37 | .07388 | .03430 | 3.36000 |
| 22 | .24500 | 25.71 | 160.36 | .0018226 | 676.53 | .07291 | .03386 | 3.36000 |
| 22 | .24500 | 27.86 | 159.03 | .0018223 | 676.64 | .07231 | .03358 | 3.36000 |
| 22 | .24500 | 30.00 | 158.58 | .0018222 | 676.68 | .07210 | .03348 | 3.36000 |
| 23 | .25667 | 0.00 | 148.57 | .0018751 | 657.61 | .06755 | .03165 | 3.52000 |
| 23 | .25667 | 2.14 | 148.24 | .0018752 | 657.58 | .06740 | .03160 | 3.52000 |
| 23 | .25667 | 4.29 | 147.26 | .0018754 | 657.48 | .06695 | .03147 | 3.52000 |
| 23 | .25667 | 6.43 | 145.67 | .0018759 | 657.34 | .06623 | .03126 | 3.52000 |
| 23 | .25667 | 8.57 | 143.53 | .0018764 | 657.16 | .06526 | .03096 | 3.52000 |
| 23 | .25667 | 10.71 | 140.94 | .0018769 | 656.97 | .06408 | .03058 | 3.52000 |
| 23 | .25667 | 12.86 | 138.01 | .0018774 | 656.79 | .06275 | .03013 | 3.52000 |
| 23 | .25667 | 15.00 | 134.87 | .0018778 | 656.66 | .06132 | .02962 | 3.52000 |
| 23 | .25667 | 17.14 | 131.67 | .0018780 | 656.58 | .05987 | .02906 | 3.52000 |
| 23 | .25667 | 19.29 | 128.57 | .0018780 | 656.57 | .05846 | .02849 | 3.52000 |
| 23 | .25667 | 21.43 | 125.74 | .0018779 | 656.62 | .05717 | .02794 | 3.52000 |
| 23 | .25667 | 23.57 | 123.33 | .0018776 | 656.71 | .05607 | .02744 | 3.52000 |
| 23 | .25667 | 25.71 | 121.49 | .0018774 | 656.81 | .05524 | .02704 | 3.52000 |
| 23 | .25667 | 27.86 | 120.34 | .0018771 | 656.89 | .05471 | .02678 | 3.52000 |
| 23 | .25667 | 30.00 | 119.95 | .0018771 | 656.92 | .05453 | .02669 | 3.52000 |
| 24 | .26833 | 0.00 | 112.88 | .0019255 | 640.38 | .05132 | .02529 | 3.68000 |
| 24 | .26833 | 2.00 | 112.64 | .0019256 | 640.34 | .05121 | .02526 | 3.68000 |
| 24 | .26833 | 4.00 | 111.93 | .0019260 | 640.24 | .05089 | .02515 | 3.68000 |
| 24 | .26833 | 6.00 | 110.78 | .0019264 | 640.08 | .05037 | .02497 | 3.68000 |
| 24 | .26833 | 8.00 | 109.22 | .0019271 | 639.87 | .04966 | .02473 | 3.68000 |
| 24 | .26833 | 10.00 | 107.32 | .0019278 | 639.64 | .04879 | .02442 | 3.68000 |
| 24 | .26833 | 12.00 | 105.13 | .0019285 | 639.41 | .04780 | .02406 | 3.68000 |
| 24 | .26833 | 14.00 | 102.75 | .0019291 | 639.19 | .04672 | .02364 | 3.68000 |
| 24 | .26833 | 16.00 | 100.27 | .0019296 | 639.02 | .04559 | .02319 | 3.68000 |
| 24 | .26833 | 18.00 | 97.79 | .0019300 | 638.90 | .04446 | .02272 | 3.68000 |
| 24 | .26833 | 20.00 | 95.44 | .0019302 | 638.84 | .04339 | .02224 | 3.68000 |
| 24 | .26833 | 22.00 | 93.31 | .0019302 | 638.83 | .04242 | .02179 | 3.68000 |
| 24 | .26833 | 24.00 | 91.51 | .0019301 | 638.87 | .04161 | .02139 | 3.68000 |
| 24 | .26833 | 26.00 | 90.16 | .0019299 | 638.92 | .04099 | .02108 | 3.68000 |
| 24 | .26833 | 28.00 | 89.31 | .0019298 | 638.97 | .04060 | .02088 | 3.68000 |
| 24 | .26833 | 30.00 | 89.02 | .0019297 | 638.99 | .04047 | .02081 | 3.68000 |
| 25 | .28000 | 0.00 | 84.19 | .0019734 | 624.84 | .03828 | .01978 | 3.84000 |
| 25 | .28000 | 2.00 | 84.00 | .0019735 | 624.80 | .03819 | .01975 | 3.84000 |
| 25 | .28000 | 4.00 | 83.43 | .0019739 | 624.69 | .03793 | .01966 | 3.84000 |
| 25 | .28000 | 6.00 | 82.50 | .0019745 | 624.51 | .03751 | .01950 | 3.84000 |
| 25 | .28000 | 8.00 | 81.24 | .0019752 | 624.28 | .03694 | .01928 | 3.84000 |
| 25 | .28000 | 10.00 | 79.70 | .0019760 | 624.01 | .03624 | .01901 | 3.84000 |
| 25 | .28000 | 12.00 | 77.94 | .0019769 | 623.74 | .03544 | .01868 | 3.84000 |
| 25 | .28000 | 14.00 | 76.01 | .0019777 | 623.48 | .03456 | .01832 | 3.84000 |
| 25 | .28000 | 16.00 | 74.00 | .0019785 | 623.25 | .03365 | .01792 | 3.84000 |
| 25 | .28000 | 18.00 | 71.99 | .0019790 | 623.08 | .03273 | .01751 | 3.84000 |

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1  CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = 1.16667 (X/DEQ = 15.99999)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 25 | .28000 | 20.00 | 70.07 | .0019794 | 622.97 | .03186 | .01710 | 3.84000 |
| 25 | .28000 | 22.00 | 68.33 | .0019795 | 622.91 | .03107 | .01671 | 3.84000 |
| 25 | .28000 | 24.00 | 66.87 | .0019795 | 622.91 | .03040 | .01637 | 3.84000 |
| 25 | .28000 | 26.00 | 65.76 | .0019795 | 622.93 | .02990 | .01611 | 3.84000 |
| 25 | .28000 | 28.00 | 65.06 | .0019794 | 622.96 | .02958 | .01593 | 3.84000 |
| 25 | .28000 | 30.00 | 64.63 | .0019793 | 622.97 | .02947 | .01587 | 3.84000 |
| 26 | .29167 | 0.00 | 61.63 | .0020180 | 611.04 | .02802 | .01514 | 4.00000 |
| 26 | .29167 | 1.87 | 61.50 | .0020181 | 611.00 | .02796 | .01512 | 4.00000 |
| 26 | .29167 | 3.75 | 61.11 | .0020185 | 610.96 | .02778 | .01505 | 4.00000 |
| 26 | .29167 | 5.62 | 60.46 | .0020190 | 610.73 | .02749 | .01493 | 4.00000 |
| 26 | .29167 | 7.50 | 59.59 | .0020197 | 610.52 | .02709 | .01476 | 4.00000 |
| 26 | .29167 | 9.37 | 58.51 | .0020206 | 610.26 | .02660 | .01455 | 4.00000 |
| 26 | .29167 | 11.25 | 57.26 | .0020215 | 609.99 | .02603 | .01431 | 4.00000 |
| 26 | .29167 | 13.12 | 55.88 | .0020224 | 609.71 | .02540 | .01403 | 4.00000 |
| 26 | .29167 | 15.00 | 54.41 | .0020232 | 609.46 | .02474 | .01373 | 4.00000 |
| 26 | .29167 | 16.87 | 52.91 | .0020240 | 609.24 | .02406 | .01341 | 4.00000 |
| 26 | .29167 | 18.75 | 51.44 | .0020245 | 609.06 | .02339 | .01308 | 4.00000 |
| 26 | .29167 | 20.62 | 50.05 | .0020249 | 608.95 | .02276 | .01277 | 4.00000 |
| 26 | .29167 | 22.50 | 48.81 | .0020252 | 608.88 | .02219 | .01247 | 4.00000 |
| 26 | .29167 | 24.37 | 47.76 | .0020252 | 608.86 | .02172 | .01222 | 4.00000 |
| 26 | .29167 | 26.25 | 46.98 | .0020252 | 608.86 | .02136 | .01202 | 4.00000 |
| 26 | .29167 | 28.12 | 46.49 | .0020252 | 608.87 | .02114 | .01189 | 4.00000 |
| 26 | .29167 | 30.00 | 46.32 | .0020252 | 608.88 | .02106 | .01185 | 4.00000 |
| 27 | .30333 | 0.00 | 44.28 | .0020588 | 598.94 | .02013 | .01135 | 4.16000 |
| 27 | .30333 | 1.87 | 44.18 | .0020589 | 598.90 | .02009 | .01133 | 4.16000 |
| 27 | .30333 | 3.75 | 43.88 | .0020592 | 598.80 | .01995 | .01127 | 4.16000 |
| 27 | .30333 | 5.62 | 43.39 | .0020598 | 598.63 | .01973 | .01117 | 4.16000 |
| 27 | .30333 | 7.50 | 42.72 | .0020606 | 598.42 | .01942 | .01103 | 4.16000 |
| 27 | .30333 | 9.37 | 41.89 | .0020614 | 598.16 | .01904 | .01086 | 4.16000 |
| 27 | .30333 | 11.25 | 40.93 | .0020624 | 597.88 | .01861 | .01066 | 4.16000 |
| 27 | .30333 | 13.12 | 39.87 | .0020634 | 597.60 | .01813 | .01043 | 4.16000 |
| 27 | .30333 | 15.00 | 38.74 | .0020643 | 597.34 | .01761 | .01018 | 4.16000 |
| 27 | .30333 | 16.87 | 37.58 | .0020651 | 597.10 | .01709 | .00992 | 4.16000 |
| 27 | .30333 | 18.75 | 36.45 | .0020658 | 596.91 | .01657 | .00966 | 4.16000 |
| 27 | .30333 | 20.62 | 35.37 | .0020662 | 596.77 | .01608 | .00940 | 4.16000 |
| 27 | .30333 | 22.50 | 34.41 | .0020665 | 596.69 | .01564 | .00916 | 4.16000 |
| 27 | .30333 | 24.37 | 33.60 | .0020667 | 596.65 | .01528 | .00895 | 4.16000 |
| 27 | .30333 | 26.25 | 32.99 | .0020667 | 596.63 | .01500 | .00879 | 4.16000 |
| 27 | .30333 | 28.12 | 32.61 | .0020667 | 596.64 | .01482 | .00869 | 4.16000 |
| 27 | .30333 | 30.00 | 32.48 | .0020667 | 596.64 | .01477 | .00865 | 4.16000 |
| 28 | .31500 | 0.00 | 31.22 | .0020955 | 588.45 | .01419 | .00832 | 4.32000 |
| 28 | .31500 | 1.76 | 31.15 | .0020956 | 588.42 | .01416 | .00831 | 4.32000 |
| 28 | .31500 | 3.53 | 30.95 | .0020959 | 588.34 | .01407 | .00827 | 4.32000 |
| 28 | .31500 | 5.29 | 30.63 | .0020964 | 588.19 | .01392 | .00819 | 4.32000 |
| 28 | .31500 | 7.06 | 30.18 | .0020970 | 588.01 | .01372 | .00810 | 4.32000 |
| 28 | .31500 | 8.82 | 29.62 | .0020978 | 587.78 | .01347 | .00798 | 4.32000 |
| 28 | .31500 | 10.59 | 28.97 | .0020987 | 587.54 | .01317 | .00783 | 4.32000 |
| 28 | .31500 | 12.35 | 28.25 | .0020996 | 587.28 | .01284 | .00767 | 4.32000 |

* * * M G R * * *



COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1 CRD 7-TUBE AR=2.3 NOZZLE - VJ=2200 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = 1.16667 (X/DEQ = 15.99999)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 28 | .31500 | 14.12 | 27.47 | .0021056 | 587.02 | .01249 | .00749 | 4.32000 |
| 28 | .31500 | 15.88 | 26.66 | .0021014 | 586.78 | .01212 | .00730 | 4.32000 |
| 28 | .31500 | 17.65 | 25.84 | .0021022 | 586.57 | .01175 | .00710 | 4.32000 |
| 28 | .31500 | 19.41 | 25.05 | .0021028 | 586.41 | .01139 | .00691 | 4.32000 |
| 28 | .31500 | 21.18 | 24.31 | .0021032 | 586.28 | .01105 | .00672 | 4.32000 |
| 28 | .31500 | 22.94 | 23.64 | .0021035 | 586.20 | .01075 | .00655 | 4.32000 |
| 28 | .31500 | 24.71 | 23.09 | .0021036 | 586.16 | .01050 | .00640 | 4.32000 |
| 28 | .31500 | 26.47 | 22.68 | .0021037 | 586.15 | .01031 | .00629 | 4.32000 |
| 28 | .31500 | 28.24 | 22.42 | .0021037 | 586.14 | .01020 | .00622 | 4.32000 |
| 28 | .31500 | 30.00 | 22.34 | .0021037 | 586.14 | .01016 | .00619 | 4.32000 |

## CIRCUMFERENTIALLY-AVERAGED PARAMETERS

| NR | RADIUS | MACH NO. | TEMP. | INTENSITY | FREQUENCY |
|---|---|---|---|---|---|
| 1 | .0002 | 1.1070 | 1.8567 | .36859E-08 | 0. |
| 2 | .1600 | 1.1052 | 1.8550 | .16573E+03 | 36. |
| 3 | .3200 | 1.1003 | 1.8498 | .39818E+04 | 75. |
| 4 | .4800 | 1.0918 | 1.8409 | .27782E+05 | 117. |
| 5 | .6400 | 1.0788 | 1.8279 | .12514E+06 | 167. |
| 6 | .8000 | 1.0613 | 1.8108 | .45802E+06 | 230. |
| 7 | .9600 | 1.0383 | 1.7898 | .14834E+07 | 312. |
| 8 | 1.1200 | 1.0089 | 1.7655 | .42972E+07 | 416. |
| 9 | 1.2800 | .9722 | 1.7386 | .10842E+08 | 540. |
| 10 | 1.4400 | .9278 | 1.7098 | .23371E+08 | 680. |
| 11 | 1.6000 | .8753 | 1.6794 | .42290E+08 | 828. |
| 12 | 1.7600 | .8151 | 1.6475 | .63877E+08 | 972. |
| 13 | 1.9200 | .7482 | 1.6139 | .80312E+08 | 1102. |
| 14 | 2.0800 | .6760 | 1.5783 | .84269E+08 | 1208. |
| 15 | 2.2400 | .6005 | 1.5406 | .73889E+08 | 1282. |
| 16 | 2.4000 | .5242 | 1.5009 | .54403E+08 | 1319. |
| 17 | 2.5600 | .4494 | 1.4594 | .33814E+08 | 1317. |
| 18 | 2.7200 | .3782 | 1.4167 | .17811E+08 | 1279. |
| 19 | 2.8800 | .3124 | 1.3739 | .79784E+07 | 1209. |
| 20 | 3.0400 | .2533 | 1.3316 | .30469E+07 | 1113. |
| 21 | 3.2000 | .2016 | 1.2909 | .99454E+06 | 998. |
| 22 | 3.3600 | .1574 | 1.2523 | .27804E+06 | 872. |
| 23 | 3.5200 | .1207 | 1.2167 | .66704E+05 | 743. |
| 24 | 3.6800 | .0909 | 1.1842 | .13745E+05 | 618. |
| 25 | 3.8400 | .0671 | 1.1550 | .24359E+04 | 501. |
| 26 | 4.0000 | .0487 | 1.1293 | .37173E+03 | 396. |
| 27 | 4.1600 | .0346 | 1.1068 | .48923E+02 | 306. |
| 28 | 4.3200 | .0241 | 1.0874 | .55651E+01 | 231. |

X(13)= 1.1667 UBI(13)= .76410E+18 FM(13)= .6247E+01 UAVG(13)= 715.30 UMAX(13)= 1238.43

X(14)= 1.4699 UBI(14)= .56088E+18 FM(14)= .7156E+01 UAVG(14)= 623.99 UMAX(14)= 1165.93

X(15)= 1.8520 UBI(15)= .35723E+18 FM(15)= .8293E+01 UAVG(15)= 537.77 UMAX(15)= 1043.83

X(16)= 2.3333 UBI(16)= .90889E+18 FM(16)= .9976E+01 UAVG(16)= 446.90 UMAX(16)= 892.50

X(17)= 2.9398 UBI(17)= .42769E+18 FM(17)= .1217E+02 UAVG(17)= 366.21 UMAX(17)= 737.45

X(18)= 3.7039 UBI(18)= .14890E+18 FM(18)= .1471E+02 UAVG(18)= 302.27 UMAX(18)= 595.63

COMPUTATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES

CASE NO. 1    CRD 7-TUBE AR=2.3 NOZZLE - VJ=2290 FPS - TTJ=1600 DEG-R

AXIAL LOCATION = 4.66667 (X/DEQ = 63.99995)

| M | R | ANGLE | U | DENSITY | TEMP. | U/UREF | TURB.INT. | R/DEQ |
|---|---|---|---|---|---|---|---|---|
| 1 | .00005 | 0.00 | 474.50 | .0017583 | 701.27 | .21573 | .08242 | .00064 |
| 2 | .04667 | 0.00 | 469.72 | .00176[illegible]1 | 700.58 | .21356 | .08109 | .64000 |
| 3 | .09333 | 0.00 | 455.47 | .0017655 | 698.44 | .20708 | .07720 | 1.28000 |
| 4 | .14000 | 0.00 | 432.79 | .0017745 | 694.9[illegible] | .19677 | .07119 | 1.92000 |
| 5 | .18667 | 0.00 | 402.88 | .0017872 | 689.95 | .18317 | .06377 | 2.56000 |
| 6 | .23333 | 0.00 | 367.44 | .0018037 | 683.64 | .16736 | .05599 | 3.20000 |
| 7 | .28000 | 0.00 | 328.34 | .0018239 | 676.66 | .14928 | .04928 | 3.84000 |
| 8 | .32667 | 0.00 | 287.48 | .0018476 | 667.39 | .13071 | .04473 | 4.48000 |
| 9 | .37333 | 0.00 | 246.62 | .0018745 | 657.82 | .11213 | .04208 | 5.12000 |
| 10 | .42000 | 0.00 | 207.33 | .0019039 | 647.65 | .09426 | .04001 | 5.76000 |
| 11 | .46667 | 0.00 | 170.82 | .0019353 | 637.15 | .07766 | .03750 | 6.40000 |
| 12 | .51333 | 0.00 | 137.95 | .0019678 | 626.63 | .06272 | .03426 | 7.03999 |
| 13 | .56000 | 0.00 | 109.22 | .0020007 | 616.34 | .04966 | .03041 | 7.67999 |
| 14 | .60667 | 0.00 | 84.77 | .0020331 | 606.5[illegible] | .03854 | .02621 | 8.31999 |
| 15 | .65333 | 0.00 | 64.52 | .0020645 | 597.29 | .02933 | .02197 | 8.95999 |
| 16 | .70000 | 0.00 | 48.15 | .0020941 | 588.82 | .02189 | .01791 | 9.59999 |
| 17 | .74667 | 0.00 | 35.23 | .0021217 | 581.17 | .01602 | .01423 | 10.23999 |

CIRCUMFERENTIALLY-AVERAGED PARAMETERS

| NR | RADIUS | MACH NO. | TEMP. | INTENSITY | FREQUENCY |
|---|---|---|---|---|---|
| 1 | .0006 | .4240 | 1.2987 | .30796E+08 | 0. |
| 2 | .6400 | .4197 | 1.2974 | .21987E+09 | 45. |
| 3 | 1.2800 | .4070 | 1.2934 | .31172E+09 | 88. |
| 4 | 1.9200 | .3867 | 1.2869 | .26523E+09 | 126. |
| 5 | 2.5600 | .3599 | 1.2777 | .16353E+09 | 157. |
| 6 | 3.2000 | .3283 | 1.2660 | .82295E+08 | 181. |
| 7 | 3.8400 | .2933 | 1.2520 | .40375E+08 | 197. |
| 8 | 4.4800 | .2568 | 1.2359 | .23900E+08 | 204. |
| 9 | 5.1200 | .2202 | 1.2182 | .17821E+08 | 203. |
| 10 | 5.7600 | .1851 | 1.1994 | .14079E+08 | 195. |
| 11 | 6.4000 | .1525 | 1.1799 | .99452E+07 | 182. |
| 12 | 7.0400 | .1231 | 1.1604 | .58110E+07 | 164. |
| 13 | 7.6800 | .0974 | 1.1414 | .27496E+07 | 145. |
| 14 | 8.3200 | .0755 | 1.1232 | .10540E+07 | 124. |
| 15 | 8.9600 | .0574 | 1.1061 | .32955E+06 | 103. |
| 16 | 9.6000 | .0428 | 1.0904 | .84690E+05 | 84. |
| 17 | 10.2400 | .0312 | 1.0763 | .18014E+05 | 66. |

X(19)= 4.6667 UBI(19)= .42108E+17 FM(19)= .1815E+02 UAVG(19)= 244.56 UMAX(19)= 474.50

X(20)= 5.8796 UBI(20)= .19407E+17 FM(20)= .2238E+02 UAVG(20)= 197.74 UMAX(20)= 375.14

X(21)= 7.4079 UBI(21)= .23617E+16 FM(21)= .2746E+02 UAVG(21)= 160.31 UMAX(21)= 295.51

X(22)= 9.3333 UBI(22)= .59788E+15 FM(22)= .3491E+02 UAVG(22)= 126.19 UMAX(22)= 232.49

X(23)= 11.7593 UBI(23)= .10568E+15 FM(23)= .4246E+02 UAVG(23)= 102.85 UMAX(23)= 182.92

X(24)= 14.8157 UBI(24)= .21549E+14 FM(24)= .5098E+02 UAVG(24)= 84.39 UMAX(24)= 144.02

### *** SOUND PRESSURE LEVEL DIRECTIVITY ***

JET MACH NO. = 1.9662 JET DENSITY RATIO = .4356

JET VELOCITY = 2199.16 JET EQUIV. DIAM. = .0729

9.0 FT. ARC

| ANGLE = FREQ. | 20.0 | 30.0 | 40.0 | 50.0 | 60.0 | 70.0 | 80.0 | 90.0 | 100.0 | 110.0 | 120.0 | 130.0 | 140.0 | 150.0 | 160.0 | PWL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 73.4 | 73.7 | 74.1 | 74.7 | 75.5 | 76.4 | 77.6 | 79.1 | 80.9 | 83.1 | 85.6 | 88.6 | 92.7 | 97.6 | 102.1 | 119.6 |
| 125 | 76.0 | 76.3 | 76.8 | 77.4 | 78.2 | 79.1 | 80.3 | 81.8 | 83.6 | 85.8 | 88.3 | 91.4 | 95.7 | 100.6 | 104.9 | 122.5 |
| 160 | 78.5 | 78.8 | 79.4 | 80.0 | 80.9 | 81.9 | 83.2 | 84.7 | 86.5 | 88.6 | 91.2 | 94.4 | 99.0 | 103.7 | 107.8 | 125.4 |
| 200 | 80.4 | 80.8 | 81.4 | 82.1 | 83.1 | 84.2 | 85.5 | 87.0 | 88.9 | 91.1 | 93.6 | 97.0 | 101.7 | 106.3 | 110.1 | 127.9 |
| 250 | 82.1 | 82.5 | 83.1 | 83.9 | 85.0 | 86.2 | 87.6 | 89.2 | 91.1 | 93.3 | 95.9 | 99.5 | 104.4 | 108.8 | 112.2 | 130.2 |
| 315 | 83.7 | 84.2 | 84.8 | 85.6 | 86.7 | 87.9 | 89.4 | 91.2 | 93.2 | 95.5 | 98.2 | 102.0 | 107.0 | 111.1 | 114.1 | 132.4 |
| 400 | 85.4 | 85.9 | 86.5 | 87.3 | 88.3 | 89.6 | 91.1 | 93.0 | 95.1 | 97.5 | 100.3 | 104.4 | 109.4 | 113.3 | 115.9 | 134.5 |
| 500 | 86.7 | 87.2 | 87.9 | 88.8 | 89.8 | 91.1 | 92.6 | 94.5 | 96.7 | 99.2 | 102.1 | 106.5 | 111.4 | 115.1 | 117.4 | 136.2 |
| 630 | 87.8 | 88.3 | 89.0 | 90.0 | 91.1 | 92.5 | 94.1 | 96.0 | 98.2 | 100.7 | 103.7 | 108.4 | 113.2 | 116.6 | 118.5 | 137.7 |
| 800 | 88.9 | 89.4 | 90.0 | 91.0 | 92.1 | 93.6 | 95.3 | 97.3 | 99.6 | 102.2 | 105.2 | 110.0 | 114.7 | 117.7 | 119.3 | 138.8 |
| 1000 | 90.0 | 90.4 | 91.0 | 91.8 | 93.0 | 94.4 | 96.2 | 98.3 | 100.7 | 103.4 | 106.5 | 111.3 | 115.6 | 118.3 | 119.5 | 139.5 |
| 1250 | 91.6 | 91.9 | 92.3 | 92.9 | 93.9 | 95.2 | 96.9 | 99.0 | 101.6 | 104.4 | 107.6 | 112.4 | 116.1 | 118.3 | 119.2 | 139.7 |
| 1600 | 93.9 | 94.1 | 94.3 | 94.7 | 95.2 | 96.2 | 97.6 | 99.7 | 102.2 | 105.2 | 108.7 | 113.4 | 116.4 | 117.9 | 118.2 | 139.7 |
| 2000 | 96.1 | 96.3 | 96.4 | 96.7 | 97.0 | 97.6 | 98.6 | 100.2 | 102.6 | 105.7 | 109.3 | 114.1 | 116.6 | 117.4 | 117.4 | 139.6 |
| 2500 | 98.1 | 98.3 | 98.5 | 98.8 | 99.1 | 99.5 | 100.0 | 101.1 | 103.0 | 105.9 | 109.8 | 114.5 | 116.8 | 117.3 | 117.3 | 139.9 |
| 3150 | 99.6 | 99.9 | 100.2 | 100.7 | 101.1 | 101.6 | 102.0 | 102.6 | 103.8 | 106.1 | 110.3 | 115.1 | 117.4 | 118.0 | 117.8 | 140.5 |
| 4000 | 100.5 | 100.9 | 101.4 | 102.0 | 102.8 | 103.5 | 104.1 | 104.6 | 105.2 | 106.6 | 111.0 | 116.0 | 118.6 | 119.2 | 118.4 | 141.6 |
| 5000 | 101.4 | 101.6 | 102.1 | 102.8 | 103.7 | 104.7 | 105.7 | 106.4 | 106.9 | 107.7 | 112.2 | 117.3 | 120.2 | 120.3 | 118.6 | 142.8 |
| 6300 | 103.6 | 103.3 | 103.2 | 103.5 | 104.3 | 105.4 | 106.7 | 107.9 | 108.7 | 109.3 | 113.9 | 119.0 | 121.8 | 121.1 | 118.4 | 144.1 |
| 8000 | 108.4 | 107.4 | 106.2 | 105.3 | 105.1 | 105.9 | 107.3 | 108.9 | 110.3 | 111.0 | 115.8 | 120.7 | 123.2 | 121.4 | 117.7 | 145.3 |
| 10000 | 114.5 | 113.2 | 111.4 | 109.3 | 107.5 | 106.8 | 107.6 | 109.3 | 111.2 | 112.4 | 117.2 | 122.0 | 124.1 | 121.2 | 116.7 | 146.4 |
| 12500 | 113.8 | 114.0 | 114.3 | 114.7 | 112.2 | 109.4 | 108.3 | 109.4 | 111.5 | 113.4 | 118.1 | 122.8 | 124.4 | 120.5 | 115.4 | 147.2 |
| 16000 | 112.5 | 112.7 | 113.0 | 113.4 | 114.0 | 114.7 | 111.2 | 109.7 | 111.5 | 113.8 | 118.3 | 123.0 | 124.1 | 119.2 | 113.8 | 147.3 |
| 20000 | 111.3 | 111.5 | 111.8 | 112.2 | 112.7 | 113.4 | 114.3 | 111.7 | 111.1 | 113.5 | 117.9 | 122.5 | 123.3 | 117.8 | 112.4 | 147.0 |
| 25000 | 110.0 | 110.2 | 110.5 | 110.9 | 111.4 | 112.1 | 113.0 | 114.2 | 111.6 | 112.7 | 117.0 | 121.5 | 122.0 | 116.3 | 111.2 | 146.4 |
| 31500 | 108.5 | 108.7 | 109.0 | 109.3 | 109.9 | 110.5 | 111.4 | 112.5 | 114.2 | 111.4 | 115.5 | 119.9 | 120.4 | 114.7 | 110.1 | 145.5 |
| 40000 | 106.7 | 106.9 | 107.2 | 107.6 | 108.1 | 108.7 | 109.5 | 110.6 | 112.2 | 111.8 | 113.0 | 117.7 | 118.4 | 112.9 | 108.9 | 144.3 |
| 50000 | 104.8 | 105.0 | 105.2 | 105.6 | 106.1 | 106.8 | 107.6 | 108.6 | 110.0 | 111.7 | 110.0 | 115.2 | 116.3 | 110.9 | 107.3 | 143.3 |
| 63000 | 102.3 | 102.5 | 102.8 | 103.2 | 103.7 | 104.3 | 105.1 | 106.1 | 107.5 | 108.9 | 107.9 | 112.0 | 113.6 | 108.0 | 105.0 | 142.0 |
| 80000 | 99.2 | 99.4 | 99.7 | 100.1 | 100.6 | 101.2 | 102.0 | 103.0 | 104.3 | 105.6 | 108.2 | 107.6 | 109.9 | 104.0 | 101.1 | 141.0 |
| OVERALL | 121.0 | 120.8 | 120.7 | 120.9 | 120.7 | 121.0 | 121.1 | 121.5 | 122.3 | 123.3 | 127.2 | 131.9 | 133.6 | 131.8 | 130.6 | 157.2 |
| PNL | 126.2 | 125.6 | 124.8 | 124.3 | 124.9 | 125.7 | 126.7 | 128.0 | 129.3 | 130.6 | 134.8 | 139.7 | 142.6 | 143.0 | 142.6 | |
| PNLT | 129.6 | 128.9 | 128.1 | 127.7 | 128.2 | 129.0 | 130.1 | 131.3 | 132.6 | 134.0 | 138.2 | 143.0 | 146.0 | 146.3 | 145.9 | |

## APPENDIX D

## PROGRAM SOURCE CODE LISTING

This appendix contains the FORTRAN IV source code listing for the aeroacoustic prediction model, suitable for running on the CDC 7600 computer. The listing of subroutines is in alphabetical order, as follows:

1. MAIN Program (MGB)
2. ARRCCOS
3. ATMOS
4. CRD
5. ERF
6. LSPFIT
7. OUTPUT
9. PNLC
9. SHOCK
10. SLICE
11. TPNLC

```
      PROGRAM MGB(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)              MGB      2
CM*G*B      MANI*GLIEBE*BALSA JET NOISE PREDICTION                    MGB      3
C           HIGH VELOCITY SUPPRESSOR NOZZLE JET NOISE                 MGB      4
C                                                                     MGB      5
C     GENERAL ELECTRIC COMPANY - AIRCRAFT ENGINE GROUP                MGB      6
C     PROGRAM NO. J2851M    --   SEPTEMBER 1977                       MGB      7
C                                                                     MGB      8
C        BASED ON JET NOISE THEORY DUE TO R. MANI(C.R.+D.C.)          MGB      9
C        AERODYNAMIC FLOW FIELD PREDICTION  DUE TO R. KENDALL         MGB     10
C        ACOUSTIC SOURCE INTENSITY SPECTRUM MODEL DUE TO P. GLIEBE    MGB     11
C        ACOUSTIC  PROPAGATION MODEL DUE TO T. BALSA (C.R.+D.C.)      MGB     12
C        PROGRAM WRITTEN BY P. GLIEBE                                 MGB     13
C                                                                     MGB     14
C     ** PROGRAM REVISED 10/20/76 TO REFLECT MODIFICATIONS DEVELOPED  MGB     15
C        ON CDC VERSION AT C.R.+D.C. AUG.-OCT.,1976 **                MGB     16
C                                                                     MGB     17
C                                                                     MGB     18
      COMMON/NOIS/ALFA,BETA,AK,BK,DIA,ASR,AL,NUMANG,DIST              MGB     19
      COMMON/AERO/SUE,FIRSTU,KX,KA,CM,CO,RHOE,ATOTAL,RJET,NPRINT,NPR  MGB     20
     1,UM,RHOM,ALPHMC,BETAMC,NN                                       MGB     21
      COMMON/PROFL/ UR(200),TAUR(200),RHOR(200),SIGR(200)             MGB     22
     1,DRDR(200),D2RDR2(200),DUDR(200)                                MGB     23
      COMMON/FARFLD/ SSTN(34),OBSTN(34),FO(34),SPLO(34),RADIUS(19),   MGB     24
     1THETA(19),THETD(19),DSPL(19,34),SPL(19,34),PWL(34),OASPL(19)    MGB     25
     2,FMIN,FMAX                                                      MGB     26
      COMMON/SHLD/ G2(200),RIN(200),MACH(200),TEMP(200),RSIG(19,5),   MGB     27
     1TERM(200),SHIFLD(200),MCIN(200),THE,CT,NTP,NR,ALPHT(19),ITH     MGB     28
      COMMON/AREA/X(24),UMAX(24),UAVG(24),FM(24),UBI(24)              MGB     29
      COMMON/SHKDTA/PT,PS,UE,AC,DEQ,DS,NEST,GAM,NCELL                 MGB     30
C                                                                     MGB     31
      DIMENSION       DSIG(24),XE(110),ALPO(110),LEAV(110),NUM(110),  MGB     32
     1KN(110),DALP(40,110),PA(40,110),PT(110),TT(110),TE(110),PU2E(110),  MGB     33
     2UE(110),EF(110),ACH(110),IDENT(10),RMIN(24),NOV(24)             MGB     34
     3,RCBDY(40),XCBDY(40),AAA(200),BETAIN(24),DELTIN(24)             MGB     35
     4,AMUIN(24),DS(110),DEQ(110),NCELL(110)                          MGB     36
      INTEGER FO,FMIN,FMAX                                            MGB     37
C                                                                     MGB     38
      DATA FO/50,63,80,100,125,160,200,250,315,400,500,630,800,1000,  MGB     39
     11250,1600,2000,2500,3150,4000,5000,6300,8000,10000,12500,16000, MGB     40
     220000,25000,31500,40000,50000,63000,80000,100000/               MGB     41
      DATA ALPHT/19*0.5/, BETAIN/24*4.0/, DELTIN/24*4.0/, AMUIN/24*0.2/  MGB     42
C                                                                     MGB     43
C                                                                     MGB     44
```

```
      NAMELIST/INPUT/        KX,NEST,LPHI,ISYM,NOV,CM,CH,GAM,CP,DTHM,RU2M,
     1PS,X,DSIG,XE,ALPO,LFAV,NUM,KN,DALP,RA,PT,
     2TT,IQUIT,ALFA,AK,BK,ATOTAL,DEQ,NN,NUMANG,DIST,
     3NCASE,UF,NBREF,CMMC,CMVR,RMIN,NPRINT,STRFX,
     4STRFR,NCBDY,RCBDY,XCBDY,ALPHT,BETAIN,DELTIN,
     5AMUIN,FMIN,FMAX,ALPHMC,BETAMC,DS,NCELL
C
C     INITIALIZE
C
      NN=0
      KX=15
      IQUIT=50
      NPRINT=1
      LPHI=9999
      NCASE=1
      KNCAS=0
      NPAGE=0
      NBREF=2
      FMIN=50
      FMAX=100000
      PI=3.1415927
      PI2=6.2831853
      ROOT2=SQRT(2.)
      DTHM=0.1
      RU2M=3.0
      CM=0.075
      CH=1.150
      CMVR=0.25
      CMMC=0.08
      STRFX=1.259921
      STRFR=.01
      ALPHMC=0.5
      BETAMC=0.325
      ALFA=1.0
      AK  =0.08
      BK  =0.0
C
    1 KNCAS=KNCAS+1
      READ(5,554)  (IDENT(K),K=1,8)
      READ(5,INPUT)
      NPAGE=NPAGE +1
      IT=1
      WRITE(6,500) NPAGE,KNCAS,(IDENT(K),K=1,8 )
C
C     WRITE  INPUT DATA
C
```

```
      IF(CP.LE.0.) CP=1716.0*GAM/(GAM-1.)                               MGB   91
      WRITE(6,502)                                                      MGB   92
      WRITE(6,504)KX,NEST,LPHI,ISYM,NPRINT,CM,CH,GAM,CP,                MGB   93
     1DTHW,RU2M,PS                                                      MGB   94
      IF(X(1).LE.0.0) X(1)=DEQ(1)                                       MGB   95
      IF(DSIG(1).LE.0.0) DSIG(1)=STRFR*X(1)                             MGB   96
      DO 20 KA=2,KX                                                     MGB   97
      IF(X(KA).LE.0.) X(KA)=STRFX*X(KA-1)                               MGB   98
      IF(DSIG(KA).LE.0.) DSIG(KA)=STRFR*X(KA)                           MGB   99
   20 CONTINUE                                                          MGB  100
      IF(NCBDY.LE.0) GO TO 15                                           MGB  101
      CALL LSPFIT(XCBDY,RCBDY,NCBDY,X,RMIN,KX,0, AAA)                   MGB  102
   15 CONTINUE                                                          MGB  103
      WRITE(6,506)                                                      MGB  104
      WRITE(6,508)(I,X(I),DSIG(I),RMIN(I),NOV(I),RETAIN(I),DELTIN(I),   MGB  105
     1AMUIN(I),I=1,KX)                                                  MGB  106
C                                                                       MGB  107
      GAMA=GAM-1.0                                                      MGB  108
      PGC=CP*GAMA/GAM                                                   MGB  109
C                                                                       MGB  110
      LINE=30+KX                                                        MGB  111
      M=1                                                               MGB  112
      DO 100 K=2,NEST                                                   MGB  113
      WRITE(6,510)K,XE(K),K,ALPO(K),K,LEAV(K),                          MGB  114
     1K,NUM(K),K,KN(K)                                                  MGB  115
      NUMK=NUM(K)                                                       MGB  116
      WRITE(6,512)(N,K,DALP(N,K),N,K,RA(N,K),N=1,NUMK)                  MGB  117
      LINE=LINE+NUMK                                                    MGB  118
      IF(LINE.LT.50) GO TO 100                                          MGB  119
      IF(K.GE.NEST) GO TO 100                                           MGB  120
      NPAGE=NPAGE +1                                                    MGB  121
      WRITE(6,500) NPAGE,KNCAS,(IDENT(N),N=1,8 )                        MGB  122
      LINE=4                                                            MGB  123
  100 CONTINUE                                                          MGB  124
C                                                                       MGB  125
      DO 200 K=1,NEST                                                   MGB  126
      ACH2=2.0*((PT(K    )/PS)**(1.0-1.0/GAM)-1.0)/GAMA                 MGB  127
      TE(K)=TT(K)/(1.0+.5*GAMA*ACH2)                                    MGB  128
      SV2  =GAM*PGC*TE(K)                                               MGB  129
      PU2E(K)=ACH2*GAM*PS                                               MGB  130
      UE(K)=0.0                                                         MGB  131
      FF(K)=0.0                                                         MGB  132
      IF(ACH2.EQ.0.0) GO TO 200                                         MGB  133
      UE(K)=SQRT(ACH2*SV2)                                              MGB  134
      FF(K)=PU2E(K)*CP*(TT(K)-TT(1))/UE(K)                              MGB  135
```

```
      IF(ACH2.GT.0.0) GO TO 200
      WRITE(6,516)   ACH2
      STOP
  200 ACH(K)=SORT(ACH2)
      UREF=UE(NBREF)
      RU2REF=RU2E(NBREF)
      FIRSTU=UE(1)
      SUF=UREF
      TAA=TE(1)
      PAA=PS
      RHOE=PAA/(1716.0*TAA)
      CO=SORT(1716.0*GAM*TAA)
      A0=CO
      AL=RHOE*(SUF/CO)**5*SUF**3*ATOTAL
      ASP=PS*GAM*GAM*PGC*SORT(GAM*PGC*TE(1))*TE(1)
      RJET=TAA/TE(NBREF)
      DIA=DEQ(1)
      DJET=DIA
      UJET=SUE-FIPSTU
      EMACH=UJET/CO
      UNITS=478.8*478.8*.25E8*RHOE*CO
C
C     WRITE  EXIT CONDITIONS
C
      NPAGE=NPAGE +1
      WRITE(6,500) NPAGE,KNCAS,(IDENT(K),K=1,8 )
      WRITE(6,518)
      WRITE(6,520)(K,PT(K),TT(K),TE(K),UE(K),ACH(K),RU2E(K),EF(K),
     1K=1,NEST)
      WRITE(6,540) NBREF
C
C     WRITE ADDITIONAL INPUT
C
      BETA=BETAIN(1)
      AMULT=AMUIN(1)
      WRITE(6,522) AL,ALFA,AK,PK,ATOTAL,DIA,IQUIT,NN,UREF
      WRITE(6,548) STREX,STPER
      WRITE(6,550) ALPHMC,BETAMC
      WRITE(6,542) CMMC,CMVR
C
C
C     BEGINNING OF X LOOP ( KA = INDEX ON X )
C
      NPR=NPRINT
      IF(NPRINT.LE.0) WRITE(6,552)
```

```
      DO 2002 KA=1,KX                                              MGR  181
      NPR=NPR+1                                                    MGR  182
      LINE = 60                                                    MGR  183
      SIG=.001*DSIG(KA)                                            MGR  184
      RUG=SIG                                                      MGR  185
      SIG=SIG+RMIN(KA)                                             MGR  186
      SRU2M=0.0                                                    MGR  187
      SRUM=0.0                                                     MGR  188
      SUMX=0.0                                                     MGR  189
      TSTO=0.0                                                     MGR  190
      UMAX(KA)=0.0                                                 MGR  191
      XND=X(KA)/DIA                                                MGR  192
      DX=X(KA)*(STREX-1.0)/(STREX+1.0)                             MGR  193
      BETA=BETAIN(KA)                                              MGR  194
      DELTA=DELTIN(KA)                                             MGR  195
      AMULT=AMUIN(KA)                                              MGR  196
C                                                                  MGR  197
C                                                                  MGR  198
C     INTEGRATION WITH RESPECT TO RADIUS ( M=INDEX ON R)           MGR  199
C                                                                  MGR  200
      DO 1500 M=1,IGRIT                                            MGR  201
      TSTHL=0.0                                                    MGR  202
      SRU2 =0.0                                                    MGR  203
      SRU =0.0                                                     MGR  204
      SUR =0.0                                                     MGR  205
      SDU=0.0                                                      MGR  206
      SEFE=0.0                                                     MGR  207
C                                                                  MGR  208
      GO TO(104,106),IT                                            MGR  209
  104 IS=(44*(M-1))/(7*LPHI)+3                                     MGR  210
      IF(LPHI.GT.590) IS=1                                         MGR  211
  106 DPHI=LPHI*IS                                                 MGR  212
      DPHI=PI2/DPHI                                                MGR  213
      ISSY=IS+1-ISYM                                               MGR  214
      PHI=0.0                                                      MGR  215
C                                                                  MGR  216
C                                                                  MGR  217
C     INTEGRATION WITH RESPECT TO ANGLE ( I = INDEX ON PHI )       MGR  218
C                                                                  MGR  219
      DO 1200 I=1,ISSY                                             MGR  220
      PHID=180.*PHI/PI                                             MGR  221
      RU2 =RU2F(I)                                                 MGR  222
      FFF =0.0                                                     MGR  223
      STP =0.0                                                     MGR  224
      STC =0.0                                                     MGR  225
      STX=0.0                                                      MGR  226
      TAU =0.0                                                     MGR  227
      UM  =0.0                                                     MGR  228
      RU=0.0                                                       MGR  229
```

```
      DU=0.0                                                            MGB
C                                                                       MGB
C                                                                       MGB
C     INITIALIZATION AND BOUNDARY INTEGRATION ( K = INDEX ON BOUNDARY ) MGB
C                                                                       MGB
      DO 1100 K=2,NEST                                                  MGB
      NODE=2                                                            MGB
      SIC=0.0                                                           MGB
      SIR=0.0                                                           MGB
      SIX=0.0                                                           MGB
      VI=0.0                                                            MGB
      TI=0.0                                                            MGB
      NUMK=NUM(K)                                                       MGB
      LEAF=LEAV(K)                                                      MGB
      KNK=KN(K)                                                         MGB
      IMH=1                                                             MGB
      IF(X(KA).LE.XE(K)) GO TO 1100                                     MGB
      IF((UE(K).EQ.0.0).AND.(UE(KNK).EQ.0.0)) GO TO 1100                MGB
      VMAX=AMAX1(UE(K),UE(KNK))                                         MGB
      VMIN=AMIN1(UE(K),UE(KNK))                                         MGB
      VR=VMIN/VMAX                                                      MGB
      CVR=1./(1.+CMVR*VR)                                               MGB
      CMC=1.+CMMC*ACH(K)                                                MGB
      DBDX=CM*CVR/CMC                                                   MGB
      DHDX=CH*DBDX                                                      MGB
      IF(DHDX.EQ.DBDX) IMH=2                                            MGB
      CMX=DBDX*(X(KA)-XE(K))                                            MGB
      CHX=DHDX*(X(KA)-XE(K))                                            MGB
      PHAL=PHI-ALPO(K)                                                  MGB
  560 ARPA=ABS(PHAL)                                                    MGB
      IF(ARPA.LE.PI)GO TO 575                                           MGB
      PHAL=PHAL-SIGN(PI2,PHAL)                                          MGB
      GO TO 560                                                         MGB
C                                                                       MGB
  575 COSPA=COS(ARPA)                                                   MGB
      DELSIG=SIG                                                        MGB
      DELRA=RA(NUMK,K)                                                  MGB
      IF(NCBDY.LE.0) GO TO 605                                          MGB
      CALL LSPFIT(XCBDY,RCBDY,NCBDY,XE(K),RMINEX,1,0,AAA)               MGB
      RMNSQE=RMINEX*RMINEX                                              MGB
      SIGSQ=SIG*SIG                                                     MGB
      RMINSQ=RMIN(KA)*RMIN(KA)                                          MGB
      RASQ=RA(NUMK,K)*RA(NUMK,K)                                        MGB
      DELSIG=SQRT(SIGSQ-RMINSQ)                                         MGB
      DELRA=SQRT(RASQ-RMNSQE)                                           MGB
  605 CONTINUE                                                          MGB
```

```
      RADO=SQRT((DELRA-DELSIG)*(DELRA-DELSIG)
     1+2.0*DELRA*DELSIG*(1.0-COSPA))
C
      IF(RADO.GT.(.0005*DELSIG)) GO TO 600
      NODE=1
      GO TO 650
  600 COSTO=(DELSIG-DELRA*COSPA)/RADO
C
      IF(ABS(COSTO).LT.1.0)GO TO 610
      THO=(PI-SIGN(PI,COSTO))/2.0
      SINTO=0.0
      GO TO 620
C
  610 SINTO=SIGN(SQRT(1.0-COSTO*COSTO),PHAL)
      THO=PI-SIGN(PI-ARCCOS(COSTO),PHAL)
C
  620 RADX=RADO/CMX
      POWER=RADX*RADX
      IF(POWER.GT.25.0) GO TO 625
      VAO=1.0-EXP(-POWER)
      GO TO(630,640),IMH
  630 TAO=1.0-EXP(-(RADO/CHX)*(RADO/CHX))
  640 SA=DRDX*(0.88623*ERF(RADX)+RADX*(VAO-1.0))
      SAPO=SA*COSTO
      SACO=SA*SINTO
      SAXO=((DRDX*RADX)**2)*(1.-VAO)
      GO TO 635
  625 CONTINUE
      VAO=1.0
      TAO=1.0
      SA =0.88623*DRDX
      SAPO=SA*COSTO
      SACO=SA*SINTO
      SAXO=0.0
  635 CONTINUE
C
C     LEAF INTEGRATION
C     J = LEAF NUMBER OF BOUNDARY K
C     N = POINT NUMBER OF BOUNDARY K
C
  650 DO 1000 J=1,LEAF
      DO 1000 N=1,NUMK
      PHAL=PHAL-DALP(N,K)
  660 ABPA=ABS(PHAL)
      IF(ABPA.LE.PI)GO TO 670
      PHAL=PHAL-SIGN(PI2,PHAL)
      GO TO 660
C
  670 COSPA=COS(ABPA)
      DELRA=RA(N,K)
```

```
      IF(NCBDY.GT.0) DELPA=SQRT(RA(N,K)*RA(N,K)-RMNSQE)               MGB  326
      RAD =SQRT((DELRA-DELSIG)*(DELRA-DELSIG)                         MGB  327
     1+2.0*DELRA*DELSIG*(1.0-COSPA))                                  MGB  328
      IF(RAD.GT.(.0005*DELSIG)) GO TO 680                             MGB  329
      NODE=1                                                          MGB  330
      GO TO 900                                                       MGB  331
C                                                                     MGB  332
  680 COST=(DELSIG-DELRA*COSPA)/RAD                                   MGB  333
      IF(ABS(COST).LT.1.0)GO TO 690                                   MGB  334
      TH=(PI-SIGN(PI,COST))/2.0                                       MGB  335
      SINT=0.0                                                        MGB  336
      GO TO 710                                                       MGB  337
C                                                                     MGB  338
  690 SINT=SIGN(SQRT(1.0-COST*COST),PHAL)                             MGB  339
      TH=PI-SIGN(PI-ARCCOS(COST),PHAL)                                MGB  340
      GO TO(700,710),NODE                                             MGB  341
  700 NODE=2                                                          MGB  342
      DTH=0.0                                                         MGB  343
      GO TO 800                                                       MGB  344
C                                                                     MGB  345
  710 DTH=TH-THO                                                      MGB  346
      ABDTH=ABS(DTH)                                                  MGB  347
      IF(ABDTH.LE.DTHM) GO TO 800                                     MGB  348
      IF(ABDTH.LE.PI)GO TO 730                                        MGB  349
C                                                                     MGB  350
C     CORRECTION--0-360                                               MGB  351
C                                                                     MGB  352
  720 THO=THO+SIGN(PI2,DTH)                                           MGB  353
      GO TO 710                                                       MGB  354
C                                                                     MGB  355
C     INITIATION OF AUXILIARY INTEGRATION                             MGB  356
C                                                                     MGB  357
  730 LQ=ABDTH/DTHM+1.0                                               MGB  358
      Q=LQ                                                            MGB  359
      DTH=DTH/Q                                                       MGB  360
      RCRC=RADO*COSTO-RAD*COST                                        MGB  361
      RCRC=RCRC+SIGN(.00000001,RCRC)                                  MGB  362
      ABLE=(RADO*SINTO-RAD*SINT)/RCRC                                 MGB  363
      BKR=RADO*SINTO-ABLE*RADO*COSTO                                  MGB  364
C                                                                     MGB  365
C     AUXILIARY INTEGRATION                                           MGB  366
C                                                                     MGB  367
      DO 790 L=1,LQ                                                   MGB  368
      TH=THO+DTH                                                      MGB  369
      COST=COS(TH)                                                    MGB  370
```

```
      SINT=SIN(TH)                                                      MGB  371
      RAD=BKR/(SINT-ABLE*COST)                                          MGB  372
      RADX=RAD/CMX                                                      MGB  373
      POWER=RADX*RADX                                                   MGB  374
      IF(POWER.GT.25.0) GO TO 725                                       MGB  375
      VA =1.0-EXP(-POWER)                                               MGB  376
      SA=DBDX*(0.88623*ERF(RADX)+RADX*(VA-1.0))                         MGB  377
      SAR=SA*COST                                                       MGB  378
      SAC=SA*SINT                                                       MGB  379
      SAX=((DBDX*RADX)**2)*(1.-VA)                                      MGB  380
      GO TO 735                                                         MGB  381
  725 CONTINUE                                                          MGB  382
      VA=1.0                                                            MGB  383
      TA=1.0                                                            MGB  384
      SA=0.88623*DBDX                                                   MGB  385
      SAR=SA*COST                                                       MGB  386
      SAC=SA*SINT                                                       MGB  387
      SAX=0.C                                                           MGB  388
  735 CONTINUE                                                          MGB  389
      VI=VI+(VA+VAO)*DTH                                                MGB  390
      SIR=SIR+(SAR+SARO)*DTH                                            MGB  391
      SIC=SIC+(SAC+SACO)*DTH                                            MGB  392
      SIX=SIX+(SAX+SAXO)*DTH                                            MGB  393
      GO TO(740,750),IMH                                                MGB  394
C                                                                       MGB  395
  740 CONTINUE                                                          MGB  396
      IF(POWER.GT.25.0) GO TO 745                                       MGB  397
      TA=-EXP(-(RAD/CHX)*(RAD/CHX))+1.0                                 MGB  398
  745 CONTINUE                                                          MGB  399
      TI=TI+(TA+TAO)*DTH                                                MGB  400
      TAO=TA                                                            MGB  401
C                                                                       MGB  402
  750 VAO=VA                                                            MGB  403
      SACO=SAC                                                          MGB  404
      SARO=SAR                                                          MGB  405
      SAXO=SAX                                                          MGB  406
      THO=TH                                                            MGB  407
  790 CONTINUE                                                          MGB  408
      GO TO 900                                                         MGB  409
C                                                                       MGB  410
C     MAIN LINE INTEGRATION                                             MGB  411
C                                                                       MGB  412
  800 RADX=RAD/CMX                                                      MGB  413
      POWER=RADX*RADX                                                   MGB  414
      IF(POWER.GT.25.0) GO TO 825                                       MGB  415
```

```
      VA =1.0-EXP(-POWER)                                         MGB
      SA=DRDX*(0.88623*ERF(RADX)+RADX*(VA-1.0))                   MGB
      SAR=SA*COST                                                 MGB
      SAC=SA*SINT                                                 MGB
      SAX=((DRDX*RADX)**2)*(1.-VA)                                MGB
      GO TO 835                                                   MGB
  825 CONTINUE                                                    MGB
      VA=1.0                                                      MGB
      TA=1.0                                                      MGB
      SA=0.88623*DRDX                                             MGB
      SAR=SA*COST                                                 MGB
      SAC=SA*SINT                                                 MGB
      SAX=0.0                                                     MGB
  835 CONTINUE                                                    MGB
      VI=VI+(VA+VAO)*DTH                                          MGB
      SIR=SIR+(SAR+SARO)*DTH                                      MGB
      SIC=SIC+(SAC+SACO)*DTH                                      MGB
      SIX=SIX+(SAX+SAXO)*DTH                                      MGB
      GO TO(810,820),IMH                                          MGB
C                                                                 MGB
  810 CONTINUE                                                    MGB
      IF(POWER.GT.25.0) GO TO 845                                 MGB
      TA=-EXP(-(RAD/CHX)*(RAD/CHX))+1.0                           MGB
  845 CONTINUE                                                    MGB
      TI=TI+(TA+TAO)*DTH                                          MGB
      TAO=TA                                                      MGB
C                                                                 MGB
  820 VAO=VA                                                      MGB
      SACO=SAC                                                    MGB
      SARO=SAR                                                    MGB
      SAXO=SAX                                                    MGB
      THO=TH                                                      MGB
  900 RADO=RAD                                                    MGB
      COSTO=COST                                                  MGB
      SINTO=SINT                                                  MGB
 1000 CONTINUE                                                    MGB
C                                                                 MGB
C     NEST SUMMATIONS                                             MGB
C                                                                 MGB
      GO TO(1020,1010),IMH                                        MGB
 1010 TI=VI                                                       MGB
 1020 CONTINUE                                                    MGB
C                                                                 MGB
 1050 UGLY=.07957747*(RU2E(K)-RU2E(KNK))                          MGB
      EFE =.07957747*(EF(K)-EF(KNK))*TI+EFE                       MGB
 1060 RU2=UGLY*VI+RU2                                             MGB
      UGLY=.07957747*(UE(K)**2-UE(KNK)**2)                        MGB
```

```
      STC=UGLY*SIC+STC
      STR=UGLY*SIR+STR
      STX=10.0*UGLY*SIX+STX
 1100 CONTINUE
C
C     FINAL CALCULATIONS
C
      IF(RU2.GT.0.0) GO TO 1110
C
      U=0.0
      RHO=RHOE
      T=TT(1   )
      UND=0.0
      TURBIN=0.0
      RU2=0.0
      RU =0.0
      TAU=0.0
      DU =0.0
      UR =0.0
      EFE=0.0
      IF(NPRINT.LE.0) GO TO 1116
      IF(NPR.LT.NPRINT) GO TO 1116
      GO TO 1117
C
 1110 RMP=RU2*PGC/PS
      UAP=SQRT(RMP* TT(    1))
      RM=RMP/(2.0*CP)
      HM=EFF*RM/(UAP*RU2)
      PSI=RU2/2.0+CP*PS/PGC
      HPSI=EFE/(2.0*PSI)
      U=HPSI+SQRT(HPSI**2+RU2*CP*TT(1)/PSI)
      IF(U.GT.UMAX(KA)) UMAX(KA)=U
C
 1113 T=U*U/RMP
      TAU=SQRT(STR*STR + DELTA*STC*STC + BETA*STX*STX)
      ACHM=U/SQRT(GAM*PGC*T)
      RU=RU2/U
      RHO=RU/U
C
      UR=TAU**3.5
      DU=SQRT(STR*STR+AMULT*STC*STC)
C
      IF(NPRINT.LE.0) GO TO 1116
      IF(NPR.LT.NPRINT) GO TO 1116
      UND=U/UREF
      TURBIN=SQRT( TAU )/UREF
 1117 CONTINUE
      RND=SIG/DIA
 1115 LINE=LINE+1
      IF(LINE.LE.55) GO TO 1120
      NPAGE=NPAGE +1
      WRITE(6,500) NPAGE,KNCAS,(IDENT(K),K=1,8 )
```

```
      WRITE(6,534) X(KA),XND
      LINF=8
 1120 CONTINUE
      WRITE(6,536) M,SIG,PHID,U,RHO,T,UND,TURBIN,RND
 1116 CONTINUE
      IF(I.GT.1)GO TO 1130
C
      TSTH=RU2-RU2E(1)
      TSTL=TSTH
      GO TO 1140
 1130 TSTH=MAX1(TSTH,(RU2-RU2E(1)))
      TSTL=MIN1(TSTL,(RU2-RU2E(1)))
      IF(I.NE.ISSY)GO TO1145
 1140 IF(ISYM.EQ.1)GO TO1145
C
      SUB=SUB+UB/2.0
      SRU=SRU+RU/2.0
      SRU2=SRU2+RU2/2.0
      SDU=SDU+DU/2.0
      SEFE=SEFE+EFE/2.0
      GO TO 1150
C
 1145 CONTINUE
      SRU=SRU+RU
      SUB=SUB+UB
      SRU2=SRU2+RU2
      SDU=SDU+DU
      SEFE=SEFE+EFE
 1150 CONTINUE
C
      PHI=PHI+DPHI
 1200 CONTINUE
      FIS=IS
      TSTD=MAX1(TSTD,ABS(TSTH-TSTL))
      SUBM=SUB/FIS*SIG+SUBM
      SRUM=SRU/FIS*SIG+SRUM
      SRU2M=SRU2/FIS*SIG+SRU2M
      TAUR(M)=(SUB/FIS)**0.2857143
      DUDR(M)=SDU/FIS
      IF(SRU.LE.0.0) GO TO 1210
      IF(SRU2.LE.0.0) GO TO 1210
      UR(M)=SRU2/SRU
      HTR=SEFE/SRU
      TTR=HTR/CP+TT(1)
      TSR=TTR-0.5*UR(M)*UR(M)/CP
      RHOR(M)=PS/(PGC*TSR)
```

```
      GO TO 1220                                                        MGB  561
 1210 CONTINUE                                                          MGB  562
      UR(M)=0.0                                                         MGB  563
      RHOR(M)=RHOE                                                      MGB  564
      TAUR(M)=0.0                                                       MGB  565
      DUDR(M)=0.0                                                       MGB  566
 1220 CONTINUE                                                          MGB  567
      SIGR(M)=SIG                                                       MGB  568
      TSTHL=AMAX1(TSTHL,ABS(TSTH),ABS(TSTL))                            MGB  569
      IF(M.LE.NOV(KA)) GO TO 1260                                       MGB  570
      IF(TSTHL.LE.RU2M)GO TO 1510                                       MGB  571
 1260 SIG=SIG+DSIG(KA)-BUG                                              MGB  572
      BUG=0.0                                                           MGB  573
 1500 CONTINUE                                                          MGB  574
 1510 IF(TSTD.GT.2.0*RU2M)GO TO 1600                                    MGB  575
      IT=2                                                              MGB  576
      IS=1                                                              MGB  577
      IF(TSTD.GT.RU2M)GO TO 1600                                        MGB  578
      ISYM=1                                                            MGB  579
 1600 CONTINUE                                                          MGB  580
C                                                                       MGB  581
C                                                                       MGB  582
      CALL LSPFIT(SIGR,RHOR,M,SIGR,DRDP,M,1,D2RDR2)                     MGB  583
      CMX=CM*X(KA)                                                      MGB  584
      DO 1605 IR=1,M                                                    MGB  585
      IF(UP(IR).LE.0.0) GO TO 1605                                      MGB  586
      DUDR(IR)=DUDR(IR)/(UR(IR)*CM*CMX)                                 MGB  587
 1605 CONTINUE                                                          MGB  588
      FM  (KA)=PI2*SRUM*DSIG(KA)*32.17405                               MGB  589
      UAVG(KA)=SRU2M/SRUM                                               MGB  590
      URI (KA)=PI2*SU8M*DSIG(KA)*UMAX(KA)/X(KA)                         MGB  591
      IF(NN.EQ.4) GO TO 1800                                            MGB  592
      CALL SLICE(X(KA),DSIG(KA),DX,M)                                   MGB  593
 1800 CONTINUE                                                          MGB  594
      WRITE(6,524)                                                      MGB  595
      WRITE(6,526) KA,X(KA),KA,URI(KA),KA,FM(KA),KA,UAVG(KA),KA,UMAX(KA) MGB  596
      IF(NPR.GE.NPRINT) NPR=0                                           MGB  597
 2000 CONTINUE                                                          MGB  598
C                                                                       MGB  599
      IF(NN.EQ.4) GO TO 4000                                            MGB  600
      CALL OUTPUT(FMACH,DJET,RJET,UJET,UNITS)                           MGB  601
 4000 CONTINUE                                                          MGB  602
      IF(KNCAS.LT.NCASE) GO TO 1                                        MGB  603
      STOP                                                              MGB  604
C                                                                       MGB  605
C     FORMAT SECTION                                                    MGB  606
C                                                                       MGB  607
```

```
  500 FORMAT(1H1,10X,21H* * *  M  G  R  * * *,20X,4HPAGEI4///5X,61HCOMPU MGB   608
     1TATION OF AERO-ACOUSTIC PROPERTIES OF SUPPRESSOR NOZZLES///2X,      MGB   609
     28HCASE NO.I5,5X,8A10//)                                             MGB   610
  502 FORMAT(1H0,40X,10HINPUT DATA//)                                     MGB   611
  504 FORMAT(          9H0      KX=I3,13H          NEST=I3,12H       LPHI= MGB   612
     1I5,12H        ISYM=I2,14H         NPRINT=I3,  11H         CM=F6.3// MGB   613
     2          9H       CH=F6.3,9H      GAM=F6.3,8H      CP=F7.1,10H     DTH MGB   614
     3M=F7.4,10H      RU2M=F7.4,8H      PS=F7.1/)                         MGB   615
  506 FORMAT(1H0,//15X,82HCOMPUTATION MESH CONTROL PARAMETERS........... MGB   616
     1............./  TURBULENCE CONSTANTS//15X,9HSLICE NO.,5X,1HX,14X,   MGB   617
     24HDSIG,11X,4HRMIN,09X,3HNOV,6X,4HBETA,5X,5HDELTA,6X,2HMU//)         MGB   618
  508 FORMAT(I20,3F15.5,I10,3F10.2)                                       MGB   619
  510 FORMAT(13H0            XE(I2,2H)=F8.2,                     7H  ALPO MGB   620
     1(I2,2H)=F7.4,     7H  LEAV(I2,2H)=I3, 7H    NUM(I2,2H)=I3,7H    KN(I MGB   621
     22,2H)=I3)                                                           MGB   622
  512 FORMAT(23H0                    DALP(I2,1H,I2,2H)=F7.4,7H    RA(I2,1H, MGB   623
     1I2,2H)=F7.4,7H  DALP(I2,1H,I2,2H)=F7.4,7H    RA(I2,1H,I2,2H)=F7.4) MGB   624
  516 FORMAT(//80H**** ERROR - MACH NO. SQUARE IS NOT GREATER THAN ZERO  MGB   625
     1- CASE WILL TERMINATE ****)                                         MGB   626
  518 FORMAT(1H0,35X,15HEXIT CONDITIONS//3X,4HCON-,2X,5HTOTAL,6X,5HTOTAL MGB   627
     1,5X,6HSTATIC,2X,8HVELOCITY,5X,4HMACH,5X,8HMOMENTUM,6X,8HENTHALPY/   MGB   628
     23X,4HTOUR,2X,6HPRESS.,5X,5HTEMP.,5X,5HTEMP.,4X,5H(FPS),6X,6HNUMBER MGB   629
     3,6X,4HFLUX,10X,4HFLUX/9X,5H(PSF),5X,7H(DEG R),3X,7H(DEG R),23X,    MGB   630
     410H(LB/SQ-FT),4X,10H(LB/SQ-FT)//)                                   MGB   631
  520 FORMAT(I6,4F10.2,F10.4,2E14.5)                                      MGB   632
  522 FORMAT(1H0, 5X,5H AL =E11.5,  5X,6HALFA =F10.5,                     MGB   633
     15X,4HAK =E12.5,5X,4HRK =E12.5// 6X,7HATOTAL=F 9.5,5X,6HDEQ  =F10.5 MGB   634
     2,  5X,6HIQUIT=I5, 5X,4HNN =I3,    5X,6HUREF =F10.2)                 MGB   635
  524 FORMAT(1H )                                                         MGB   636
  526 FORMAT(3H X(I2,2H)=F9.4,6H  UBI(I2,2H)=E11.5,5H  FM(I2,2H)=E10.4,   MGB   637
     17H  UAVG(I2,2H)=F8.2,7H  UMAX(I2,2H)=F8.2)                          MGB   638
  528 FORMAT(6E12.5)                                                      MGB   639
  534 FORMAT(17H AXIAL LOCATION =F10.5,11H  (X/DEQ = F10.5,1H)//          MGB   640
     13X,1HM,5X,1HR,7X,5HANGLE,5X,1HU,7X,7HDENSITY,6X,5HTEMP.,3X6HU/UREF MGB   641
     2,2X,9HTURB.INT,2X,5HR/DEQ//)                                        MGB   642
  536 FORMAT(I4,F10.5,F8.2,F9.2,F12.7,F10.2,3F9.5)                        MGB   643
  540 FORMAT(1H0,//12HBOUNDARY NO. I05,38H  HAS BEEN DESIGNATED AS THE R MGB   644
     1EFERENCE//)                                                         MGB   645
  542 FORMAT(1H0, 5X,5HCMMC=F11.6,05X,5HCMVR=F11.6//)                     MGB   646
  548 FORMAT(1H0, 5X,6HSTRFX=F10.5,5X,6HSTRFR=F10.5  )                    MGB   647
  550 FORMAT(1H0,5X,7HALPHMC=F9.4,5X,7HBETAMC=F9.4)                       MGB   648
  552 FORMAT(1H1)                                                         MGB   649
  554 FORMAT(8A10)                                                        MGB   650
      END                                                                 MGB   651
```

```
FUNCTION ARCCOS      76/76    OPT=1                              FTN 4.5+410         10/10/77  14.30.05$

      CARCCOS     ARC COSINE  (PRINCIPAL VALUE)
            FUNCTION ARCCOS(X)
            IF(X.GT.0.0) GO TO 5
            IF(X.LT.0.0) GO TO 10
            ARCCOS = 1.5707963
            GO TO 15
          5 ARCCOS = ATAN(SQRT(1.-X**2)/X)
            GO TO 15
         10 ARCCOS = ATAN(SQRT(1.-X**2)/X)+3.1415927
         15 RETURN
            END
```

```
SUBROUTINE ATMOS      76/76    OPT=1                             FTN 4.5+410         10/10/77  14.30.05$

      C              ATMOSPHERIC ATTENUATION SUBROUTINE
      C
      C
      C     ATMOSPHERIC AIR ATTENUATION CORRECTIONS FOR STANDARD DAY
      C     (59 DEG. F AND 70 PCT. REL. HUM.)  FROM SAE ARP 866 (1964)
      C     ARE ADDED TO LOSSLESS SPECTRA
      C
      C
            SUBROUTINE ATMOS(SPL,RADIUS)
      C
      C
            DIMENSION SPL(19,34),RADIUS(19),AA(34)
            DATA AA/.07,.09,.11,.14,.18,.23,.29,.36,.45,.58,.72,.92,
           11.17,1.47,1.85,2.39,3.03,3.97,5.47,7.73,9.03,12.87,18.76,26.97,
           238.98,58.67,84.58,121.56,175.77,256.39,363.19,519.95,752.16,
           31015.82/
      C
      C
            DO 1 I=1,19
            DO 1 J=1,34
            IF(SPL(I,J).LE.0.0 ) GO TO 1
            SPL(I,J)=SPL(I,J)-RADIUS(I)*AA(J)/1000.0
          1 CONTINUE
            RETURN
            END
```

```
      SUBROUTINE CRD                                                      CRD
*                                                                         CRD
*                                                                         CRD
      COMMON/SHLD/ G2(200),RIN(200),MACH(200),TEMP(200),RSIG(19,5),      CRD
     1TERM(200),SHIELD(200),MCIN(200),THE,CT,NTP,NR,ALPHT(19),ITH         CRD
      REAL MACH,MCIN,MC,KIN,K,M0                                          CRD
*                                                                         CRD
*     CALCULATION OF DIRECTIVITY                                          CRD
*                                                                         CRD
*                                                                         CRD
      PI=3.1415926                                                        CRD
      PI02=PI/2.                                                          CRD
      DO 11 IR=1,NR                                                       CRD
      R0=RIN(IR)                                                          CRD
      MC=MCIN(IR)                                                         CRD
      SHIELD(IR)=0.0                                                      CRD
**********                                                                CRD
      IF(THE.GT.PI02 ) GO TO 260                                          CRD
**********                                                                CRD
*                                                                         CRD
*     FINDING RELATIONSHIP BETWEEN R0 AND TURNING PTS.                    CRD
*                                                                         CRD
      IF(NTP.EQ.0) GO TO 260                                              CRD
      IF(NTP.EQ.1) GO TO 230                                              CRD
      IF(NTP.EQ.2) GO TO 250                                              CRD
      RSIG(ITH,1)=RSIG(ITH,NTP-1)                                         CRD
      RSIG(ITH,2)=RSIG(ITH,NTP)                                           CRD
      NTP=2                                                               CRD
      GO TO 250                                                           CRD
230   CONTINUE                                                            CRD
*                                                                         CRD
*     ONE TURNING POINT                                                   CRD
*                                                                         CRD
      RSIG1=RSIG(ITH,1)                                                   CRD
      IF(R0.GE.RSIG1) GO TO 260                                           CRD
      R1=R0                                                               CRD
      R2=RSIG1                                                            CRD
      GO TO 261                                                           CRD
250   CONTINUE                                                            CRD
*                                                                         CRD
*     TWO TURNING POINTS                                                  CRD
*                                                                         CRD
      RSIG1=RSIG(ITH,1)                                                   CRD
      RSIG2=RSIG(ITH,2)                                                   CRD
```

```
      IF(RO.GE.RSIG2) GO TO 260                                          CRD  46
      IF(RO.LE.RSIG1) GO TO 262                                          CRD  47
      R1=RO                                                              CRD  48
      R2=RSIG2                                                           CRD  49
      GO TO 261                                                          CRD  50
  262 CONTINUE                                                           CRD  51
      R1=RSIG1                                                           CRD  52
      R2=RSIG2                                                           CRD  53
  261 CONTINUE                                                           CRD  54
*                                                                        CRD  55
*     CALCULATION OF EXP. SHIELDING                                      CRD  56
*                                                                        CRD  57
*     FINDING INTERVAL INTO WHICH R1 AND R2 FALL                         CRD  58
*                                                                        CRD  59
      DO 265 J=1,NR                                                      CRD  60
      IF(RIN(J).GT.R1) GO TO 266                                         CRD  61
  265 CONTINUE                                                           CRD  62
  266 CONTINUE                                                           CRD  63
      J1=J                                                               CRD  64
      J11=J1-1                                                           CRD  65
      DO 267 J=1,NR                                                      CRD  66
      IF(RIN(J).GT.R2) GO TO 268                                         CRD  67
  267 CONTINUE                                                           CRD  68
  268 CONTINUE                                                           CRD  69
      J2=J                                                               CRD  70
      J21=J2-1                                                           CRD  71
*                                                                        CRD  72
*     EVALUATION OF INTEGRAL OF G                                        CRD  73
*                                                                        CRD  74
      IF(J1.EQ.J2) GO TO 269                                             CRD  75
      IF(J1.EQ.J21) GO TO 270                                            CRD  76
      J211=J21-1                                                         CRD  77
      SUM=0.                                                             CRD  78
      DO 281 J=J1,J211                                                   CRD  79
      GM=.5*(SQRT(ABS(G2(J)))+SQRT(ABS(G2(J+1))))                        CRD  80
      SUM=SUM+GM*(RIN(J+1)-RIN(J))                                       CRD  81
  281 CONTINUE                                                           CRD  82
      GO TO 284                                                          CRD  83
  269 CONTINUE                                                           CRD  84
*                                                                        CRD  85
*     J1=J2                                                              CRD  86
*                                                                        CRD  87
      SGN1=1.                                                            CRD  88
      SGN2=1.                                                            CRD  89
      IF(G2(J11).LT.0.) SGN1=-1.                                         CRD  90
      IF(G2(J1).LT.0.) SGN2=-1.                                          CRD  91
      SG1=SQRT(ABS(G2(J11)))*SGN1                                        CRD  92
      SG2=SQRT(ABS(G2(J1)))*SGN2                                         CRD  93
```

```
      SLOPE=(SG2-SG1)/(RIN(J1)-RIN(J11))                                CRD  94
      SUM=SG1*R2+SLOPE*(.5*R2**2-RIN(J11)*R2)                           CRD  95
     A-SG1*R1-SLOPE*(.5*R1**2-RIN(J11)*R1)                              CRD  96
      SUM=-SUM                                                          CRD  97
      GO TO 280                                                         CRD  98
  279 CONTINUE                                                          CRD  99
      SUM=0.                                                            CRD 100
  284 CONTINUE                                                          CRD 101
*                                                                       CRD 102
*     CALCULATION OF END CONTRIBUTIONS                                  CRD 103
*                                                                       CRD 104
      SGN1=1.                                                           CRD 105
      SGN2=1.                                                           CRD 106
      IF(G2(J11).LT.0.) SGN1=-1.                                        CRD 107
      IF(G2(J1).LT.0.) SGN2=-1.                                         CRD 108
      SG1=SQRT(ABS(G2(J11)))*SGN1                                       CRD 109
      SG2=SQRT(ABS(G2(J1)))*SGN2                                        CRD 110
      SLOPE=(SG2-SG1)/(RIN(J1)-RIN(J11))                                CRD 111
      SUM1=SG1*RIN(J1)+SLOPE*(.5*RIN(J1)**2                             CRD 112
     A-RIN(J11)*RIN(J1))-SG1*R1                                         CRD 113
     B-SLOPE*(.5*R1**2-RIN(J11)*R1)                                     CRD 114
      SUM1=-SUM1                                                        CRD 115
      SGN1=1.                                                           CRD 116
      SGN2=1.                                                           CRD 117
      IF(G2(J21).LT.0.) SGN1=-1.                                        CRD 118
      IF(G2(J2).LT.0.) SGN2=-1.                                         CRD 119
      SG1=SQRT(ABS(G2(J21)))*SGN1                                       CRD 120
      SG2=SQRT(ABS(G2(J2)))*SGN2                                        CRD 121
      SLOPE=(SG2-SG1)/(RIN(J2)-RIN(J21))                                CRD 122
      SUM2=SG1*R2+SLOPE*(.5*R2**2                                       CRD 123
     A-RIN(J21)*R2)-SG1*RIN(J21)                                        CRD 124
     B-SLOPE*(.5*RIN(J21)**2-RIN(J21)*RIN(J21))                         CRD 125
      SUM2=-SUM2                                                        CRD 126
      SUM=SUM1+SUM2+SUM                                                 CRD 127
  280 CONTINUE                                                          CRD 128
      SHIELD(IR)=SUM                                                    CRD 129
  260 CONTINUE                                                          CRD 130
*                                                                       CRD 131
*     CALCULATION OF UNSHIELDED SOLUTION                                CRD 132
*                                                                       CRD 133
      G0SQ=ABS(G2(IR))                                                  CRD 134
      IF(G2(IR).LT.0.0) G0SQ=0.0                                        CRD 135
      T0=TEMP(IR)                                                       CRD 136
      TERM(IR)=(CT*CT+G0SQ)**2/T0                                       CRD 137
   79 CONTINUE                                                          CRD 138
   11 CONTINUE                                                          CRD 139
      RETURN                                                            CRD 140
      END                                                               CRD 141
```

```
FUNCTION ERF         76/76    OPT=1                          FTN 4.5+410        10/10/77  14.30.05$

      CERF          ERROR FUNCTION APPROXIMATION                                ERF        2
            FUNCTION ERF(X)                                                     ERF        3
            SIGN=1.0                                                            ERF        4
            IF(X.LT.0.0) SIGN=-1.0                                              ERF        5
            IF(ABS(X).GT.5.0) GO TO 50                                          ERF        6
            T=1.0/(1.0+0.47047*ABS(X))                                          ERF        7
            ERF=1.0-(0.3480242*T-0.0958798*T*T+0.7478556*T*T*T)*EXP(-X*X)       ERF        8
            ERF=ERF*SIGN                                                        ERF        9
        100 RETURN                                                              ERF       10
         50 ERF=SIGN                                                            ERF       11
            GO TO 100                                                           ERF       12
            END                                                                 ERF       13
```

```
SUBROUTINE LSPFIT     76/76    OPT=1                         FTN 4.5+410        10/10/77  14.30.05$

      *LSPFIT     INTEGRATE OR INTERPOLATE                                      LSPFIT     2
      C                                                                         LSPFIT     3
      C     INTEGRATE OR INTERPOLATE USING A PARABOLA WHICH PASSED THROUGH THE LSPFIT     4
      C     AND (I+1) POINTS BUT MISSES THE (I-1) AND (I+2) POINTS (IF THEY BO LSPFIT     5
      C     EXIST) SUCH THAT THE SQUARE OF THE DEVIATION IS A MINIMUM.  NOTE   LSPFIT     6
      C     THAT  I  IS GENERALLY SELECTED SUCH THAT                           LSPFIT     7
      C              X(I).LE.XC.LT.X(I+1)                                      LSPFIT     8
      C     THE EQUATION FOR THE PARABOLA IS                                   LSPFIT     9
      C              Y-Y(I) = B*(X-X(I)) + C*(X-X(I))**2                       LSPFIT    10
                                                                               LSPFIT    11
            SUBROUTINE LSPFIT(X,Y,NPTS,XC,YC,NXC,ND,AAA)                       LSPFIT    12
            DIMENSION AAA(100)                                                 LSPFIT    13
            DIMENSION X(10),Y(10), XC(10),YC(10)                               LSPFIT    14
      C      NOTE. THE DIMENSION *10* DOES NOT NEED TO AGREE WITH THE CALLING  LSPFIT    15
                                                                               LSPFIT    16
      C    INPUT-                                                              LSPFIT    17
      C     X, Y      PTS. ON CURVE                                            LSPFIT    18
      C     NPTS      NO. OF X                                                 LSPFIT    19
      C     XC        LIST OF X AT WHICH CALC TO BE DONE                       LSPFIT    20
      C     YC(1)     INTEGRATION CONSTANT IF  ND=-1                           LSPFIT    21
      C     NXC       NO. OF XC                                                LSPFIT    22
      C     ND        =0 TO GET COORD.  =1 TO GET 1ST DERIVATIVE.              LSPFIT    23
      C               =-1 FOR INTEGRATION                                      LSPFIT    24
                                                                               LSPFIT    25
```

```
C     OUTPUT
C      YC        COORDINATE OR DERIVATIVE AT XC     OR
C                YC(IC)= INTEGRAL(Y*DX) FROM XC(1) TO XC(IC) WHERE IC=2,NXC

C     NOTES-
C      *X* MAY BE IN EITHER ASCENDING OR DESCENDING ORDER.
C      FOR INTEGRATION *XC* MUST BE IN THE SAME ORDER AS *X*.  FOR INTERP
C         NO SPECIAL ORDER IS REQUIRED.

       COMMON /CLSPF / I

       LOGICAL WITHIN

       N      = NPTS-1
       I      = MAX0(1,MIN0(I,N))
       IF(ND.EQ.(-1)) I=1
       ISAVE = 0
       SGN    = SIGN(1.,X(N+1)-X(1))

C     BEGIN INTERPOLATION LOOP FOR XC(IC)   IC=1,NXC
       IC     = 1

C     LOCATE APPROPRIATE INTERVAL
  100 WITHIN= .FALSE.
      NCOUNT= N
  102 IF(NCOUNT) 119,103,103
  103 NCOUNT= NCOUNT-1

      XI     = X(I)
      XD     = XC(IC)-XI
      IF(N) 104,120,104
  104 IF(SGN*XD) 105,107,110

C      F.LT.0. (F IS THE FRACTIONAL POSITION IN THE INTERVAL)
  105 IF(I.EQ.1)      GO TO 120
      IF(ND.EQ.(-1)) GO TO 119
      I     = I-1
      GO TO 102

C      F.EQ.0
  107 IF(X(I+1).NE.XI) GO TO 120
      GO TO 116

C      F.GT.0.
  110 IF(SGN*(XC(IC)-X(I+1))) 120,112,114

C      F.EQ.1.0.  CHECK FOR INTEGRATION AND DOUBLE POINT BEFORE INCREMEN
  112 IF((ND.EQ.(-1)) .OR. (I.NE.N .AND. X(I+1).EQ.X(I+2))) GO TO 120
```

```
C       F.GT.1.0
  114 IF(I.EQ.N) GO TO 120
      IF(ND.EQ.(-1)) GO TO 122
  116 I     = I+1
      GO TO 102

  119 CONTINUE

C     PRELIMINARY CALCULATIONS FOR INTERPOLATION OR INTEGRATION
  120 WITHIN=.TRUE.
  122 IF(I-ISAVE) 124,129,124
  124 ISAVE = I
      YI    = Y(I)
      X3    = X(I+1)-XI
      Y3    = Y(I+1)-YI
      C     = 0.
      TOP   = 0.
      BOT   = 0.
      IF(I.LE.1) GO TO 127
      X1    = X(I-1)-XI
      X13   = X(I-1)-X(I+1)
      TOP   = X1*(Y3*X1-(Y(I-1)-YI)*X3)*X13
      BOT   = X1*X1*X13*X13*X3
  127 IF(I.GE.N .OR. (XD.EQ.0. .AND. BOT.NE.0.)) GO TO 128
      X4    = X(I+2)-XI
      X43   = X(I+2)-X(I+1)
      TOP   = TOP + X4*(Y3*X4-(Y(I+2)-YI)*X3)*X43
      BOT   = BOT + X4*X4*X43*X43*X3
  128 IF(BOT.NE.0.) C = -TOP/BOT
      B     = 0.
      IF(N.GT.0 .AND. X3.NE.0.) B = (Y(I+1)-YI)/X3 - C*X3
  129 IF(ND) 130,140,141

C     ND=-1. INTEGRATE
  130 IF(.NOT.WITHIN) XD=X3
      S1    = (YI + (B/2. + C/3.*XD)*XD)*XD
      IF(WITHIN) GO TO 135
C     *I* IS BEING INCREMENTED TO FIND APPROPRIATE INTERVAL.  HENCE.
C       CUMULATE THE INTEGRAL OF THE ITH INTERVAL.
      SA    = SA + S1
      GO TO 116
C     APPROPRIATE INTERVAL FOUND.   X(I)-XC(IC)-X(I+1)
  135 IF(IC.EQ.1) SA=YC(IC)-S1
      IF(IC.NE.1) YC(IC)=SA+S1
      GO TO 150
```

```
      C     ND=0.  INTERPOLATE FOR COORDINATES                              LSPFIT     121
        140 YC(IC)= YI + (B + C*XD)*XD                                      LSPFIT     122
            GO TO 150                                                       LSPFIT     123
                                                                            LSPFIT     124
      C     ND=1.  FIRST DERIVATIVE                                         LSPFIT     125
        141 YC(IC)= B + 2.*C*XD                                             LSPFIT     126
            GO TO 150                                                       LSPFIT     127
                                                                            LSPFIT     128
        150 IC     = IC+1                                                   LSPFIT     129
            AAA(IC-1)=2.*C                                                  LSPFIT     130
            IF(NXC-IC) 900,160,160                                          LSPFIT     131
        160 IF(ND.NE.(-1).AND.XC(IC).EQ.XC(IC-1)) I=I+1                     LSPFIT     132
            GO TO 100                                                       LSPFIT     133
                                                                            LSPFIT     134
        900 RETURN                                                          LSPFIT     135
            END                                                             LSPFIT     136
```

```
SUBROUTINE OUTPUT      76/76    OPT=1                FTN 4.5+410          10/10/77  14.30.05$

            SUBROUTINE OUTPUT(EMACH,DJET,RJET,UJET,UNITS)                   OUTPUT       2
            COMMON/NOIS/ALFA,BETA,AK,BK,DIA,ASR,AL,NUMANG,DIST              OUTPUT       3
            COMMON/FARFLD/ SSTN(34),OBSTN(34),FO(34),SPLO(34),RADIUS(19),   OUTPUT       4
           1THETA(19),THETD(19),DSPL(19,34),SPL(19,34),PWL(34),OASPL(19)    OUTPUT       5
           2,FMIN,FMAX                                                      OUTPUT       6
            DIMENSION AAA(19)                                               OUTPUT       7
            DIMENSION TSPL(33,19),PNL(19),PNLT(19)                          OUTPUT       8
            INTEGER FO,FMIN,FMAX                                            OUTPUT       9
      C                                                                     OUTPUT      10
      C                                                                     OUTPUT      11
            PI=3.1415926                                                    OUTPUT      12
            DELTH=PI/18.                                                    OUTPUT      13
            DO 34 J=1,34                                                    OUTPUT      14
            IF(FO(J).LE.FMIN) JMIN=J                                        OUTPUT      15
            IF(FO(J).LE.FMAX) JMAX=J                                        OUTPUT      16
            OBSTN(J)=FLOAT(FO(J))*DJET/UJET                                 OUTPUT      17
         34 CONTINUE                                                        OUTPUT      18
      C                                                                     OUTPUT      19
      C                                                                     OUTPUT      20
      C       CONVERSION FROM NARROW-BAND TO 1/3-OCTAVE                     OUTPUT      21
      C                                                                     OUTPUT      22
            DO 5 I=1,15                                                     OUTPUT      23
            COFF=UNITS*AK/(2.0*PI*ASR*RADIUS(I )**2)                        OUTPUT      24
            DO 5 J=JMIN,JMAX                                                OUTPUT      25
```

```
      IF(DSPL(I,J).LE.0.0) GO TO 7                                      OUTPUT  26
      IF(OBSTN(J).GT.30.0) GO TO 7                                      OUTPUT  27
      SPL(I,J)=10.*ALOG10(COFF*DSPL(I,J))                               OUTPUT  28
      RFO=FLOAT(FO(J))                                                  OUTPUT  29
      SPL(I,J)=SPL(I,J)+10.*ALOG10(RFO)-6.3536                          OUTPUT  30
      GO TO 5                                                           OUTPUT  31
    7 CONTINUE                                                          OUTPUT  32
      SPL(I,J)=0.0                                                      OUTPUT  33
    5 CONTINUE                                                          OUTPUT  34
C                                                                       OUTPUT  35
      CALL SHOCK                                                        OUTPUT  36
C                                                                       OUTPUT  37
C     OVERALL POWER LEVEL CALCULATION                                   OUTPUT  38
C                                                                       OUTPUT  39
      SUM=0.0                                                           OUTPUT  40
      DO 70 J=JMIN,JMAX                                                 OUTPUT  41
      IF(OBSTN(J).GT.30.0) GO TO 70                                     OUTPUT  42
      PWR=0.0                                                           OUTPUT  43
      DO 60 I=1,15                                                      OUTPUT  44
      PSQ=10.**(SPL(I,J)/10.)                                           OUTPUT  45
      PWR=PWR+PSQ*(RADIUS(I)**2)*SIN(THETA(I))                          OUTPUT  46
   60 CONTINUE                                                          OUTPUT  47
      PWR=2.0*PI/UNITS*DELTH*PWR                                        OUTPUT  48
      PWL(J)=130.+10.*ALOG10(1.3558*PWR)                                OUTPUT  49
      SUM=SUM+PWR                                                       OUTPUT  50
   70 CONTINUE                                                          OUTPUT  51
      OAPWL=130.0+10.*ALOG10(1.3558*SUM)                                OUTPUT  52
      CALL ATMOS(SPL,RADIUS)                                            OUTPUT  53
C                                                                       OUTPUT  54
C     COMPUTE PNL AND PNLT                                              OUTPUT  55
C                                                                       OUTPUT  56
      DO 55 I=1,19                                                      OUTPUT  57
      DO 54 J=1,33                                                      OUTPUT  58
      TSPL(J,I)=SPL(I,J)                                                OUTPUT  59
   54 CONTINUE                                                          OUTPUT  60
      CALL PNLC(TSPL(1,I),.15,PNL(I),OASPL(I))                          OUTPUT  61
      CALL TPNLC(TSPL(1,I),PNLT(I))                                     OUTPUT  62
      PNLT(I)=PNLT(I)+PNL(I)                                            OUTPUT  63
   55 CONTINUE                                                          OUTPUT  64
C                                                                       OUTPUT  65
C     OVERALL SOUND PRESSURE LEVEL CALCULATION                          OUTPUT  66
C                                                                       OUTPUT  67
      DO 80 I=1,15                                                      OUTPUT  68
      SUM=0.0                                                           OUTPUT  69
      DO 90 J=JMIN,JMAX                                                 OUTPUT  70
      IF(OBSTN(J).GT.30.0) GO TO 90                                     OUTPUT  71
      SUM=SUM+10.**(SPL(I,J)/10.)                                       OUTPUT  72
   90 CONTINUE                                                          OUTPUT  73
      OASPL(I)=10.*ALOG10(SUM)                                          OUTPUT  74
   80 CONTINUE                                                          OUTPUT  75
```

```
C                                                                       OUTPUT  76
C     PRINT OBSERVED SOUND PRESSURE LEVEL SPECTRA                       OUTPUT  77
C                                                                       OUTPUT  78
      WRITE(6,100) FMACH,RJET,UJET,DJET                                 OUTPUT  79
      IF(NUMANG.LE.1) WRITE(6,114) RADIUS(8)                            OUTPUT  80
      IF(NUMANG.GE.2) WRITE(6,116) RADIUS(8)                            OUTPUT  81
      WRITE(6,106)(THETD(I),I=1,15)                                     OUTPUT  82
      DO 40 J=JMIN,JMAX                                                 OUTPUT  83
      IF(OBSTN(J).GT.30.0) GO TO 40                                     OUTPUT  84
      WRITE(6,110) FO(J),(SPL(I,J),I=1,15),PWL(J)                       OUTPUT  85
   40 CONTINUE                                                          OUTPUT  86
      WRITE(6,112)(OASPL(I),I=1,15),OAPWL                               OUTPUT  87
      WRITE(6,128) (PNL(I),I=1,15)                                      OUTPUT  88
      WRITE(6,130) (PNLT(I),I=1,15)                                     OUTPUT  89
      RETURN                                                            OUTPUT  90
C                                                                       OUTPUT  91
C     FORMAT SECTION                                                    OUTPUT  92
C                                                                       OUTPUT  93
  100 FORMAT(1H1//20X,40H*** SOUND PRESSURE LEVEL DIRECTIVITY ***//     OUTPUT  94
     110X,15HJET MACH NO. = F10.4,5X,20HJET DENSITY RATIO = F10.4//     OUTPUT  95
     210X,15HJET VELOCITY = F10.2,5X,20HJET EQUIV. DIAM.  = F10.4//)    OUTPUT  96
  106 FORMAT(1H0,7HANGLE =15F7.1,3X,3HPWL/8H   FREQ.)                   OUTPUT  97
  110 FORMAT(I8,16F7.1)                                                 OUTPUT  98
  112 FORMAT(8HOOVERALL,16F7.1)                                         OUTPUT  99
  114 FORMAT(1H0,30X,F10.1,2X,7HFT. ARC//)                              OUTPUT 100
  116 FORMAT(1H0,27X,F10.1,2X,12HFT. SIDELINE//)                        OUTPUT 101
  128 FORMAT (8H0  PNL  ,15F7.1)                                        OUTPUT 102
  130 FORMAT (8H0  PNLT ,15F7.1)                                        OUTPUT 103
      END                                                               OUTPUT 104
```

SUBROUTINE PNLC 76/76 OPT=1 FTN 4.5+410 10/10/77 14.30.05

```
      *PNLC     CALCULATION OF PNDB,OASPL,PT. CORR.,TPNL                PNLC   2
          SUBROUTINE PNLC(SS,FAC,PNDB,OASPL)                            PNLC   3
          REAL MAXNOY,NOY                                               PNLC   4
          DIMENSION PC(9,24),SS(24)                                     PNLC   5
                                                                        PNLC   6
      *   DATA FROM SAE ARP 865A (1969 REVISION)                        PNLC   7
                                                                        PNLC   8
          DATA  ((PC(I,J),I=1,9),J=1,12)/                               PNLC   9
         149.,0.079520,55.,0.058098,64.,0.043478,91.01,0.030103,52.,    PNLC  10
         144.,0.068160,51.,0.058098,60.,0.040570,85.88,0.030103,51.,    PNLC  11
         139.,0.068160,46.,0.052288,56.,0.036831,87.32,0.030103,49.,    PNLC  12
         134.,0.059640,42.,0.047534,53.,0.036831,79.85,0.030103,47.,    PNLC  13
         130.,0.053013,39.,0.043573,51.,0.035336,79.76,0.030103,46.,    PNLC  14
         127.,0.053013,36.,0.043573,48.,0.033333,75.96,0.030103,45.,    PNLC  15
         124.,0.053013,33.,0.040221,46.,0.033333,73.96,0.030103,43.,    PNLC  16
         121.,0.053013,30.,0.037349,44.,0.032051,74.91,0.030103,42.,    PNLC  17
         118.,0.053013,27.,0.034859,42.,0.030675,94.63,0.030103,41.,    PNLC  18
         116.,0.053013,25.,0.034859,40.,0.030103,100.00,0.030103,40.,   PNLC  19
         116.,0.053013,25.,0.034859,40.,0.030103,100.00,0.030103,40.,   PNLC  20
         116.,0.053013,25.,0.034859,40.,0.030103,100.00,0.030103,40./   PNLC  21
          DATA  ((PC(I,J),I=1,9),J=13,24)/                              PNLC  22
         116.,0.053013,25.,0.034859,40.,0.030103,100.00,0.030103,40.,   PNLC  23
         116.,0.053013,25.,0.034859,40.,0.030103,100.00,0.030103,40.,   PNLC  24
         115.,0.059640,23.,0.034859,38.,0.030103,100.00,0.030103,38.,   PNLC  25
         112.,0.053013,21.,0.040221,34.,0.029960,100.00,0.029960,34.,   PNLC  26
         19.,0.053013,18.,0.037349,32.,0.029960,100.00,0.029960,32.,    PNLC  27
         15.,0.047712,15.,0.034859,30.,0.029960,100.00,0.029960,30.,    PNLC  28
         14.,0.047712,14.,0.034859,29.,0.029960,100.00,0.029960,29.,    PNLC  29
         15.,0.053013,14.,0.034859,29.,0.029960,100.00,0.029960,29.,    PNLC  30
         16.,0.053013,15.,0.034859,30.,0.029960,100.00,0.029960,30.,    PNLC  31
         110.,0.068160,17.,0.037349,31.,0.029960,100.00,0.029960,31.,   PNLC  32
         117.,0.079520,23.,0.037349,37.,0.042285,44.29,0.029960,34.,    PNLC  33
         121.,0.059640,29.,0.043573,41.,0.042285,50.72,0.029960,37./    PNLC  34
                                                                        PNLC  35
          SUMSPL=0.                                                     PNLC  36
          SUMNOY=0.                                                     PNLC  37
          MAXNOY=0.                                                     PNLC  38
                                                                        PNLC  39
      * FIND MAXIMUM NOY VALUE AND SUM OF NOY VALUES AND SUMSPL         PNLC  40
                                                                        PNLC  41
          DO 50 K=1,24                                                  PNLC  42
          I=K                                                           PNLC  43
          IF(FAC.LT..2) GO TO 10                                        PNLC  44
          I=3*K-1                                                       PNLC  45
```

```
      IF(I.GT.23) GO TO 55                                        PNLC      46
   10 EXPSPL=10.**(.1*SS(I))                                      PNLC      47
      SUMSPL=SUMSPL+EXPSPL                                        PNLC      48
      IF(SS(I).GE.PC(7,I)) GO TO 300                              PNLC      49
      IF(SS(I).GE.PC(5,I)) GO TO 280                              PNLC      50
      IF(SS(I).GE.PC(3,I)) GO TO 260                              PNLC      51
      IF(SS(I).GE.PC(1,I)) GO TO 240                              PNLC      52
      NOY=0.                                                      PNLC      53
      GO TO 30                                                    PNLC      54
  240 NOY=.1*10.**(PC(2,I)*(SS(I)-PC(1,I)))                       PNLC      55
      GO TO 30                                                    PNLC      56
  260 NOY=10.**(PC(4,I)*(SS(I)-PC(5,I)))                          PNLC      57
      GO TO 30                                                    PNLC      58
  280 NOY=10.**(PC(6,I)*(SS(I)-PC(5,I)))                          PNLC      59
      GO TO 30                                                    PNLC      60
  300 NOY=10.**(PC(8,I)*(SS(I)-PC(9,I)))                          PNLC      61
   30 SUMNOY=SUMNOY+NOY                                           PNLC      62
      IF(MAXNOY.GT.NOY) GO TO 50                                  PNLC      63
      MAXNOY=NOY                                                  PNLC      64
   50 CONTINUE                                                    PNLC      65
                                                                  PNLC      66
*  CALCULATE OASPL,PNDB,TPNL                                      PNLC      67
                                                                  PNLC      68
   55 OASPL=10.*ALOG10(SUMSPL)                                    PNLC      69
      PNL=MAXNOY+FAC*(SUMNOY-MAXNOY)                              PNLC      70
      IF(PNL.GT..0625) GO TO 60                                   PNLC      71
      PNDB=0.                                                     PNLC      72
      RETURN                                                      PNLC      73
   60 PNDB=40.+33.22*ALOG10(PNL)                                  PNLC      74
      RETURN                                                      PNLC      75
      END                                                         PNLC      76
```

SUBROUTINE SHOCK    76/76    OPT=1    FTN 4.5+410    10/10/77  14.30.05$

```
CSHOCK        EMPIRICAL SHOCK-CELL NOISE CORRELATION              SHOCK      2
C                                                                 SHOCK      3
C                                                                 SHOCK      4
C     EMPIRICAL SHOCK CELL NOISE PREDICTION BASED ON SNECMA CORRELATION SHOCK 5
C     AND MODIFICATIONS BY GLIEBE (GE TM 76-673)                  SHOCK      6
C                                                                 SHOCK      7
C                                                                 SHOCK      8
      SUBROUTINE SHOCK                                            SHOCK      9
C                                                                 SHOCK     10
```

```
      COMMON/FARFLD/ SSTN(34),OBSTN(34),FO(34),SPLO(34),RADIUS(19),      SHOCK
     1THETA(19),THETD(19),DSPL(19,34),SPL(19,34),PWL(34),OASPL(19)       SHOCK
     2,FMIN,FMAX                                                         SHOCK
      COMMON/SHKDTA/PT,PS,UE,CO,DEQ,DS,NEST,GAM,NCELL                    SHOCK
      DIMENSION SSPL(19,34),PT(110),UE(110),DEQ(110),NCELL(110),DS(110)  SHOCK
      REAL MJ,MC,LAVG,L1                                                 SHOCK
      INTEGER FO,FMIN,FMAX                                               SHOCK
C                                                                        SHOCK
C                                                                        SHOCK
      IF(NCELL(1).LE.0) RETURN                                           SHOCK
      DO 2 J=1,34                                                        SHOCK
      IF(FO(J).LE.FMIN) JMIN=J                                           SHOCK
      IF(FO(J).LE.FMAX) JMAX=J                                           SHOCK
    2 CONTINUE                                                           SHOCK
C                                                                        SHOCK
C     INDEX OVER BOUNDARY NUMBER - NB                                    SHOCK
C                                                                        SHOCK
      GEXP=(GAM-1.0)/GAM                                                 SHOCK
      PRCRIT=(0.5*(GAM+1.0))**(GAM/(GAM-1.0))                            SHOCK
C                                                                        SHOCK
      DO 1 NB=2,NEST                                                     SHOCK
      N=NCELL(NB)                                                        SHOCK
      IF(N.LE.0) GO TO 1                                                 SHOCK
      PR=PT(NB)/PS                                                       SHOCK
      IF(PR.LE.PRCRIT) GO TO 1                                           SHOCK
      MJ=SQRT((2.0/(GAM-1.0))*(PR**GEXP-1.0))                            SHOCK
      BETA=SQRT(MJ**2-1.0)                                               SHOCK
      DSPL1=40.0*ALOG10(BETA)                                            SHOCK
     1  + 10.0*ALOG10(FLOAT(N)/8.0)                                      SHOCK
     3  + 10.0*ALOG10(DS(NB)/DEQ(NB))                                    SHOCK
      LAVG=1.1*BETA*DEQ(NB)                                              SHOCK
      UC=0.7*(UE(NB)-UE(1))                                              SHOCK
      MC=UC/CO                                                           SHOCK
      VO=UE(1)                                                           SHOCK
C                                                                        SHOCK
C     INDEX OVER EACH OBSERVER ANGLE                                     SHOCK
C                                                                        SHOCK
      DO 10 I=1,15                                                       SHOCK
      DO 14 J=JMIN,JMAX                                                  SHOCK
      SSPL(I,J)=0.0                                                      SHOCK
   14 CONTINUE                                                           SHOCK
      THT=0.01745329*THETD(I)                                            SHOCK
      CTH=COS(THT)                                                       SHOCK
      THCR=3.1415926                                                     SHOCK
      IF(MC.LE.1.0) GO TO 12                                             SHOCK
      THCR=THCR-ATAN(SQRT(MC**2-1.0))                                    SHOCK
   12 CONTINUE                                                           SHOCK
      IF(THT.GE.THCR) GO TO 10                                           SHOCK
```

```
C                                                             SHOCK   59
C     COMPUTE PEAK FREQUENCY AND MAXIMUM SPL                  SHOCK   60
C                                                             SHOCK   61
      CONV=1.0+MC*CTH                                         SHOCK   62
      FP  =UC/LAVG/CONV/(1.0-VO*CTH/CO)                       SHOCK   63
      DSPL2=20.0*ALOG10(DEQ(NH)/RADIUS(I))                    SHOCK   64
      SPLMAX=151.6+DSPL1+DSPL2                                SHOCK   65
     2  - 40.0*ALOG10(1.0-VO*CTH/CO)                          SHOCK   66
C                                                             SHOCK   67
C     COMPUTE SPECTRA                                         SHOCK   68
C                                                             SHOCK   69
      DO 16 J=JMIN,JMAX                                       SHOCK   70
      FR=FLOAT(FO(J))/FP                                      SHOCK   71
      IF(FR.GT.1.0) GO TO 18                                  SHOCK   72
      SSPL(I,J)=SPLMAX+ 70.0*ALOG10(FR)                       SHOCK   73
      GO TO 19                                                SHOCK   74
   18 CONTINUE                                                SHOCK   75
      SSPL(I,J)=SPLMAX-10.0*ALOG10(FR)                        SHOCK   76
   19 CONTINUE                                                SHOCK   77
   16 CONTINUE                                                SHOCK   78
   10 CONTINUE                                                SHOCK   79
C                                                             SHOCK   80
C     ADD SHOCK NOISE TO TOTAL NOISE                          SHOCK   81
C                                                             SHOCK   82
      DO 40 I=1,15                                            SHOCK   83
      DO 40 J=JMIN,JMAX                                       SHOCK   84
      IF(SSPL(I,J).LT.0.0) GO TO 40                           SHOCK   85
      PSOM=10.0**(SPL(I,J)/10.0)                              SHOCK   86
      PSOS=10.0**(SSPL(I,J)/10.0)                             SHOCK   87
      PSOT=PSOM+PSOS                                          SHOCK   88
      SPL(I,J)=10.0*ALOG10(PSOT)                              SHOCK   89
   40 CONTINUE                                                SHOCK   90
    1 CONTINUE                                                SHOCK   91
      RETURN                                                  SHOCK   92
      END                                                     SHOCK   93
```

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CSLICE      RADIAL PROFILE PARAMETER CALCULATION                            SLICE    2
C                                                                           SLICE    3
      SUBROUTINE SLICE(X,DSIG,DX,M)                                         SLICE    4
C                                                                           SLICE    5
      COMMON/NOIS/ALFA,BETA,AK,BK,DEQ,ASR,AL,NUMANG,DIST                    SLICE    6
      COMMON/AERO/SUE,FIRSTU,KX,KA,CM,CO,RHOE,ATOTAL,RJET,NPRINT,NPR        SLICE    7
     1,UM,RHOM,ALPHMC,RETAMC,NN                                             SLICE    8
      COMMON/PROFL/ UR(200),TAUR(200),RHOR(200),SIGR(200)                   SLICE    9
     1,DRDR(200),D2RDR2(200),DUDR(200)                                      SLICE   10
      COMMON/FARFLD/ SSTN(34),ORSTN(34),FO(34),SPLO(34),RADIUS(19),         SLICE   11
     1THETA(19),THETD(19),DSPL(19,34),SPL(19,34),PWL(34),OASPL(19)          SLICE   12
     2,FMIN,FMAX                                                            SLICE   13
      COMMON/SHLD/ G2(200),RIN(200),MACH(200),TEMP(200),RSIG(19,5),         SLICE   14
     1TERM(200),SHIFLD(200),MCIN(200),THE,CT,NTP,NR,ALPHT(19),ITH           SLICE   15
      DIMENSION DS(200),FS(200),AAA(200)                                    SLICE   16
      REAL MACH,MCIN,MC,KIN,K,MO                                            SLICE   17
      INTEGER FO,FMIN,FMAX                                                  SLICE   18
C                                                                           SLICE   19
C                                                                           SLICE   20
C     INITIALIZE CONSTANTS AND ARENA GEOMETRY                               SLICE   21
C                                                                           SLICE   22
      IF(KA.GT.1) GO TO 10                                                  SLICE   23
      PI=3.1415926                                                          SLICE   24
      RAD=PI/180.                                                           SLICE   25
      CON1=SQRT(PI/2.0)                                                     SLICE   26
      CON2=SQRT(PI)                                                         SLICE   27
      CNST=6.2831853                                                        SLICE   28
      RHOESQ=RHOE**2                                                        SLICE   29
      UJET= SUE-FIRSTU                                                      SLICE   30
      EMACH=UJET/CO                                                         SLICE   31
      DDTHED=.01                                                            SLICE   32
      DTHED=10.0                                                            SLICE   33
      DDTHE=DDTHED*RAD                                                      SLICE   34
      THETD(1)=20.0                                                         SLICE   35
      THETA(1)=160.0*RAD                                                    SLICE   36
      DO 11 I=1,15                                                          SLICE   37
      IF(I.EQ.1) GO TO 12                                                   SLICE   38
      THETD(I)=THETD(I-1)+DTHED                                             SLICE   39
      THETA(I)=RAD*(180.0-THETD(I))                                         SLICE   40
   12 CONTINUE                                                              SLICE   41
      DO 11 J=1,34                                                          SLICE   42
      DSPL(I,J)=0.0                                                         SLICE   43
      SPL(I,J)=0.0                                                          SLICE   44
   11 CONTINUE                                                              SLICE   45
      IF(NUMANG.LE.1) GO TO 7                                               SLICE   46
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```
      DO 8 I=1,15                                                       SLICE  47
      RADIUS(I)=DIST/SIN(RAD*THETD(I))                                  SLICE  48
    8 CONTINUE                                                          SLICE  49
      GO TO 2                                                           SLICE  50
    7 CONTINUE                                                          SLICE  51
      IF(NUMANG.GT.0) GO TO 4                                           SLICE  52
      WRITE(6,110)                                                      SLICE  53
  110 FORMAT(49H0*** ARC RADIUS OMITTED - 100 FT. ARC ASSUMED ***)      SLICE  54
      DIST=100.0                                                        SLICE  55
    4 CONTINUE                                                          SLICE  56
      DO 3 I=1,15                                                       SLICE  57
      RADIUS(I)=DIST                                                    SLICE  58
    3 CONTINUE                                                          SLICE  59
    2 CONTINUE                                                          SLICE  60
   10 CONTINUE                                                          SLICE  61
C                                                                       SLICE  62
C                                                                       SLICE  63
C     CALCULATION OF DIMENSIONLESS RADIAL PROFILES                      SLICE  64
C                                                                       SLICE  65
      DO 1 NR=1,M                                                       SLICE  66
      PIN(NR)=SIGR(NR)/DEQ                                              SLICE  67
      MACH(NR)=(UR(NR)-FIRSTU)/CO                                       SLICE  68
      MCIN(NR)=ALPHMC*MACH(NR)+BETAMC*EMACH                             SLICE  69
      TEMP(NR)=RHOE/RHOR(NR)                                            SLICE  70
    1 CONTINUE                                                          SLICE  71
C                                                                       SLICE  72
C                                                                       SLICE  73
C     SOURCE STRENGTH EVALUATION                                        SLICE  74
C                                                                       SLICE  75
      DV=.25*PI*(DSIG**2)*DX                                            SLICE  76
      DRMIN=DSIG/2.0                                                    SLICE  77
      DO 5 NR=1,M                                                       SLICE  78
      IF(NR.EQ.1.AND.SIGR(1).LE.DRMIN) GO TO 6                          SLICE  79
      DV=2.*PI*SIGR(NR)*DSIG*DX                                         SLICE  80
    6 CONTINUE                                                          SLICE  81
      DS(NR)=0.0                                                        SLICE  82
      OMEGR=ABS(DUDR(NR))                                               SLICE  83
      IF(OMEGR.LE.0.0) GO TO 5                                          SLICE  84
      UPR=SQRT(TAUP(NR))                                                SLICE  85
      DS(NR)=RHOESQ*DV*UPR**7                                           SLICE  86
      FS(NR)=0.5*ALFA*OMEGR/PI                                          SLICE  87
    5 CONTINUE                                                          SLICE  88
      IF(NPRINT.LE.0) GO TO 135                                         SLICE  89
      IF(NPR.GE.NPRINT) WRITE(6,120)                                    SLICE  90
  120 FORMAT(1H1///20X,37HCIRCUMFERENTIALLY-AVERAGED PARAMETERS//4X,2HNR SLICE  91
     16X,6HRADIUS,5X,8HMACH NO.,5X,5HTEMP.,5X,9HINTENSITY,5X,9HFREQUENCY SLICE  92
     2//)                                                               SLICE  93
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      IF(NPR.GE.NPRINT) WRITE(6,125)(NR,RIN(NR),MACH(NR),TEMP(NR),DS(NR) SLICE   94
     1,FS(NR),NR=1,M)                                                  SLICE   95
  125 FORMAT(I6,3F12.4,E14.5,F10.0)                                    SLICE   96
  135 CONTINUE                                                         SLICE   97
C                                                                      SLICE   98
C                                                                      SLICE   99
C     INDEX OF THETA FOR SHIELDING/DIRECTIVITY                         SLICE  100
C                                                                      SLICE  101
      NR=M                                                             SLICE  102
      NR1=NR-1                                                         SLICE  103
      DO 15 ITH=1,15                                                   SLICE  104
*                                                                      SLICE  105
*     CALCULATION OF G AND ITS ZEROS                                   SLICE  106
*                                                                      SLICE  107
      THE=THETA(ITH)                                                   SLICE  108
43    CONTINUE                                                         SLICE  109
      CT=COS(THE)                                                      SLICE  110
      CTSQ=CT*CT                                                       SLICE  111
*                                                                      SLICE  112
*     CALCULATION OF G-SQUARE                                          SLICE  113
*                                                                      SLICE  114
      DO 20 J=1,NR                                                     SLICE  115
      G2(J)=(1.0-MACH(J)*CT)**2/TEMP(J)-CTSQ                           SLICE  116
      IF(G2(J).EQ.0.) GO TO 42                                         SLICE  117
20    CONTINUE                                                         SLICE  118
      GO TO 44                                                         SLICE  119
42    CONTINUE                                                         SLICE  120
      THE=THE+DDTHE                                                    SLICE  121
      GO TO 43                                                         SLICE  122
44    CONTINUE                                                         SLICE  123
*                                                                      SLICE  124
*     CALCULATION OF ZEROS OF G                                        SLICE  125
*                                                                      SLICE  126
      RSIG(ITH,1)=0.                                                   SLICE  127
      RSIG(ITH,2)=0.                                                   SLICE  128
      RSIG(ITH,3)=0.                                                   SLICE  129
      RSIG(ITH,4)=0.                                                   SLICE  130
      RSIG(ITH,5)=0.                                                   SLICE  131
      NTP=0                                                            SLICE  132
      DO 21 J=1,NR1                                                    SLICE  133
      SLOPE=(G2(J+1)-G2(J))/(RIN(J+1)-RIN(J))                          SLICE  134
      IF(SLOPE.EQ.0.) GO TO 21                                         SLICE  135
      ROOT=RIN(J+1)-G2(J+1)/SLOPE                                      SLICE  136
      IF(ROOT.GE.RIN(J).AND.ROOT.LE.RIN(J+1)) GO TO 40                 SLICE  137
      GO TO 21                                                         SLICE  138
40    CONTINUE                                                         SLICE  139
      NTP=NTP+1                                                        SLICE  140
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      RSIG(ITH,NTP)=ROOT                                                SLICE     141
   21 CONTINUE                                                          SLICE     142
      IF(NTP.GT.0) GO TO 41                                             SLICE     143
      IF(G2(NR1).GT.0.0) GO TO 41                                       SLICE     144
      NTP=1                                                             SLICE     145
      RSIG(ITH,1)=RIN(NR)                                               SLICE     146
   41 CONTINUE                                                          SLICE     147
      IF(NTP.GT.2) WRITE(6,150)KA,X,ITH,THETD(ITH),NTP                  SLICE     148
  150 FORMAT(53H0WARNING - NO. OF TURNING POINTS IS GREATER THAN 2 AT / SLICE     149
     14H KA=I3,5X,2HX=F10.5,5X,4HITH=I3,5X,6HTHETA=F8.2,5X,4HNTP=I3//)  SLICE     150
C                                                                       SLICE     151
C                                                                       SLICE     152
C     CALCULATION OF DIRECTIVITY                                        SLICE     153
C                                                                       SLICE     154
      XOR=X/RADIUS(ITH)                                                 SLICE     155
      RSORSQ=1.0-2.0*XOR*CT+XOR**2                                      SLICE     156
      RSTAR=RADIUS(ITH)*SQRT(RSORSQ)                                    SLICE     157
      CONVF=ABS(1.0+FIRSTU*CT/CO)                                       SLICE     158
      CALL CRD                                                          SLICE     159
      DO 30 IR=1,M                                                      SLICE     160
      IF(FS(IR).LE.0.0) GO TO 30                                        SLICE     161
      MC=MCIN(IR)                                                       SLICE     162
      CONVO=1.0-MC*CT                                                   SLICE     163
      CONV2=CONVO**2+TAUR(IR)*(ALPHT(ITH)/CO)**2                        SLICE     164
      IF(NN.GT.1) CONV2=1.0                                             SLICE     165
      IF(NN.GT.0.AND.NN.LT.3) SHIELD(IR)=0.0                            SLICE     166
      DO 45 J=1,34                                                      SLICE     167
      FC=FLOAT(FO(J))                                                   SLICE     168
      K=CNST*FC*DEQ/CO                                                  SLICE     169
      FR=FC/FS(IR)                                                      SLICE     170
      FRSQ=FR*FR                                                        SLICE     171
      POWER=0.125*FRSQ*CONV2                                            SLICE     172
      IF(POWER.GT.20.0) GO TO 45                                        SLICE     173
      EXPON=EXP(-POWER)                                                 SLICE     174
      HF=FRSQ*FRSQ*EXPON                                                SLICE     175
      DIRECT=TERM(IR)                                                   SLICE     176
      IF(SHIELD(IR).GT.0.) GO TO 46                                     SLICE     177
      GO TO 47                                                          SLICE     178
   46 CONTINUE                                                          SLICE     179
      POWER=2.0*K*SHIELD(IR)                                            SLICE     180
      IF(POWER.GT.20.0) GO TO 45                                        SLICE     181
      DIRECT=DIRECT*EXP(-POWER)                                         SLICE     182
   47 CONTINUE                                                          SLICE     183
      DSPL(ITH,J)=DSPL(ITH,J)+HF*DS(IR)*DIRECT/RSORSQ/CONV2             SLICE     184
     1/CONVF                                                            SLICE     185
   45 CONTINUE                                                          SLICE     186
   30 CONTINUE                                                          SLICE     187
   15 CONTINUE                                                          SLICE     188
      RETURN                                                            SLICE     189
      END                                                               SLICE     190
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      *TPNLC       THIS SECTION CALCULATES TONE CORRECTED PNL                  TPNLC     2
      C            SPECTRAL IRREGULARITY CORRECTION                            TPNLC     3
      C                                                                        TPNLC     4
      C            THIS PROCEDURE DETERMINES A SPECTRAL IRREGULARITY           TPNLC     5
      C            (E.G.,PURE TONE) CORRECTION FACTOR =C= VIA SECTION B36.3    TPNLC     6
      C            OF THE FAA NOISE CERTIFICATION DOCUMENT (NOV 17,1969) AS    TPNLC     7
      C            A FUNCTION OF THE UNCORRECTED 1/3 OCTAVE SPECTRUM,SPL.      TPNLC     8
      C                                                                        TPNLC     9
            SUBROUTINE TPNLC(SPL,PTCOR)                                        TPNLC    10
            DIMENSION SPL(24),ISPLF(24),S(24),SPLP(24),SPLPP(24),SP(25),       TPNLC    11
           1 SBAR(24),F(24)                                                    TPNLC    12
      C                                                                        TPNLC    13
      C     *INITIALIZE SPL FLAG*                                              TPNLC    14
            DO 1 I=1,24                                                        TPNLC    15
          1 ISPLF(I) = 0                                                       TPNLC    16
      C                                                                        TPNLC    17
      C     *STEP 1*                                                           TPNLC    18
            DO 5 I=4,24                                                        TPNLC    19
          5 S(I)=SPL(I) - SPL(I-1)                                             TPNLC    20
      C                                                                        TPNLC    21
      C     *STEP 2 AND 3*                                                     TPNLC    22
            DO 10 I=5,24                                                       TPNLC    23
            IF(ABS(S(I)-S(I-1)).LE.5.0) GO TO 10                               TPNLC    24
            IF(S(I).GT.0.0.AND.S(I).GT.S(I-1)) ISPLF(I)=1                      TPNLC    25
            IF(S(I).LE.0.0.AND.S(I-1).GT.0.0) ISPLF(I-1)=1                     TPNLC    26
         10 CONTINUE                                                           TPNLC    27
      C                                                                        TPNLC    28
      C     *STEP 4*                                                           TPNLC    29
            DO 25 I=1,24                                                       TPNLC    30
            IF(ISPLF(I).EQ.0) GO TO 20                                         TPNLC    31
            IF(I.EQ.24) GO TO 15                                               TPNLC    32
      C           STEP 4B MODIFIED SUCH THAT PRECEDING AND FOLLOWING           TPNLC    33
      C           NON-FLAGGED SOUND PRESSURE LEVELS EMPLOYED IN AVERAGE.       TPNLC    34
            II = I                                                             TPNLC    35
            DO 11 J=1,20                                                       TPNLC    36
            II = II-1                                                          TPNLC    37
            IF(ISPLF(II).EQ.0) GO TO 12                                        TPNLC    38
         11 CONTINUE                                                           TPNLC    39
         12 SPLL = SPL(II)                                                     TPNLC    40
            IP1 = I+1                                                          TPNLC    41
            DO 13 J=IP1,24                                                     TPNLC    42
            IF(ISPLF(J).EQ.0) GO TO 14                                         TPNLC    43
         13 CONTINUE                                                           TPNLC    44
            J = 24                                                             TPNLC    45
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   14 SPLU = SPL(J)                                    TPNLC
      SPLP(I) = (SPLL+SPLU)/2.                         TPNLC
      GO TO 25                                         TPNLC
   15 SPLP(24) = SPL(23)+S(23)                         TPNLC
      GO TO 25                                         TPNLC
   20 SPLP(I) = SPL(I)                                 TPNLC
   25 CONTINUE                                         TPNLC
C                                                      TPNLC
C    *STEP 5*                                          TPNLC
      DO 30 I=4,24                                     TPNLC
   30 SP(I) = SPLP(I)-SPLP(I-1)                        TPNLC
      SP(3) = SP(4)                                    TPNLC
      SP(25) = SP(24)                                  TPNLC
C                                                      TPNLC
C    *STEP 6*                                          TPNLC
      DO 35 I=3,23                                     TPNLC
   35 SBAR(I) = (SP(I)+SP(I+1)+SP(I+2))/3.             TPNLC
C                                                      TPNLC
C    *STEP 7*                                          TPNLC
      SPLPP(1) = SPL(1)                                TPNLC
      SPLPP(2) = SPL(2)                                TPNLC
      SPLPP(3) = SPL(3)                                TPNLC
      DO 40 I=4,24                                     TPNLC
   40 SPLPP(I) = SPLPP(I-1)+SBAR(I-1)                  TPNLC
C                                                      TPNLC
C    *STEP 8*                                          TPNLC
      DO 45 I=1,24                                     TPNLC
   45 F(I) = SPL(I)-SPLPP(I)                           TPNLC
C                                                      TPNLC
C    *STEP 9 AND 10*                                   TPNLC
      CMAX = 0.0                                       TPNLC
      DO 65 I=1,24                                     TPNLC
      IF(I.GE.11.AND.I.LE.21) GO TO 50                 TPNLC
C     *FREQ 500HZ OR FREO%5u00HZ*                      TPNLC
      TC2 = F(I)/6.                                    TPNLC
      TC3 = 3.333                                      TPNLC
      GO TO 55                                         TPNLC
C     *500 =FREQ =5000HZ*                              TPNLC
   50 TC2 = F(I)/3.                                    TPNLC
      TC3 = 6.666                                      TPNLC
   55 IF(F(I).LT.3.0) GO TO 65                         TPNLC
      IF(F(I).GE.20.0) GO TO 60                        TPNLC
      CMAX = AMAX1(CMAX,TC2)                           TPNLC
      GO TO 65                                         TPNLC
   60 CMAX = AMAX1(CMAX,TC3)                           TPNLC
   65 CONTINUE                                         TPNLC
      PTCOR=CMAX                                       TPNLC
  500 RETURN                                           TPNLC
      END                                              TPNLC
```

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