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# ASDIR-II
## VOLUME I
## USERS MANUAL

December 1975

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DEPUTY FOR DEVELOPMENT PLANNING
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This technical report has been reviewed and is approved for publication.

JAMES H. HALL
Colonel, USAF
Deputy for Development Planning

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Aeronautical Systems Division Infrared Signature Prediction Program (ASDIR) is a state-of-the-art functionally modularized computer code. Volume I is the ASDIR User Manual which describes the program input and provides the user with example applications.

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# PREFACE

The Aeronautical Systems Division's Infra-Red Signature Prediction Model (ASDIR) is an integrated system of computer programs.

The ASDIR-II computer program has been developed for computing, by analytical model, the infrared signature produced by the hot parts and the exhaust plume of aircraft. The program development was accomplished in two steps. The first step consisted of collecting, evaluating, and isolating those major sections of existing and available computer programs which analytically modelled the various major areas of the overall objective in a superior manner. The second step consisted of compiling the above selected program sections, creating an overall control program, and writing new program elements to complete the required analytical model.

The documentation for ASDIR-II has been written in three volumes: Volume I - USER Manual - describes the program input and provides the user with example applications, Volume II - PROGRAM DESCRIPTION - describes the program and its various functions, and Volume III - REFERENCE DOCUMENTATION - provides the user with essential background material.

The work reported herein was conducted by Capt C. W. Stone and Mr. S. E. Tate of the Propulsion and Energy Division, Directorate of Advanced Systems Design. Assistance in program shakedown and improvement of programming efficiency was provided by Mr. W. C. Lichtenberg of the same Division. Sample preparation assistance was provided by Lt. T. E. Dayton of ASD/ENYW. This effort was conducted during the period 1 July 1973 to 1 July 1975.

TABLE OF CONTENTS

## INTRODUCTION

Infrared (IR) energy is emitted by hot parts and hot gases. A number of emitting sources exist in the field of view of IR seeking missiles and IR detection systems which are observing an aerospace system (aircraft) in flight. Important emitters include:

- . Background (earth objects, sky, clouds, etc)
- . Hot parts of engine exhaust systems.
- . Hot gases of engine exhaust (plume).
- . Heat exchangers (oil coolers).
- . Scintillated sunlight reflections.
- . Aircraft lights (internal & external).
- . Aerodynamically heated leading edges and surfaces.

The radiated energy will contain both gray-body Lambertion spectra and also molecular species spectra. Emitted energy rays which pass through the mixed and cooled exhaust gases will experience spectral attenuation prior to being exposed to atmospheric attenuation. An infrared signature of an energy emitting source is defined as the frequency spectra and distribution in azimuth and elevation of infrared energy emitted by a radiating source as the energy enters the transmission media (the atmosphere in case of aircraft). ASDIR-II calculates the infrared signature of aerospace systems.

ASDIR-II was developed to be a suitably accurate but timewise and computer-resources-wise practical computer analysis or model of the infrared signature. The details of the computer program are presented and described in volumes II and III of this report. The purpose and intent of this volume is to instruct the ASDIR-II user in the use and application of the computer model. Example problems will be found in the Appendix.

## APPLICATION OF ASDIR-II

### Program Operation

Program accuracy, simplicity, and rapidity of execution were optimized by maximizing reliance on geometric symmetry in the development of the plume structure and the irradiance rays. It follows that, ASDIR-II is an axisymmetric analysis and the resulting IR signature is a surface of revolution about the aircraft line-of-flight. Points of IR observance are located in space relative to the signature emitter by slant range and aspect, where aspect is the included angle measured from the aftward aircraft line-of-flight. Aspect angles of azimuth and elevation must first be converted to the axisymmetric included angle during input data preparation. Infrared signatures of aircraft configurations which are not surfaces of revolution must be composed of output data of several axisymmetric IR signatures using the principles of superposition.

While the step-by-step directions below will cover the following points, it is appropriate to emphasize a few program features here:

1. Input data are grouped into several categories. Input data sets are coded with IDS numbers and Input blocks are coded with IB numbers. Input data sets make use of namelist "reads" with the exception of IDS1 which uses formatted "reads". All IB data are formatted.

2. When engine hot parts are analyzed in the SIGNIR portion of ASDIR-II (IHOT≠0) the aspect angle selections are read in at IB54 and 55. These angles are sequentially selected by a counter, ICHECK. The sequential selection requires that program control return to a point near the beginning of the program for each aspect angle selection and, thereby, repeating read instruction for IDS-2, namelist CASE. For this reason a b$CASEb$ card must be provided for each repeat cycle until all angles have been selected. The angle list can be intentionally cut short by simply omitting the appropriate number of b$CASEb$ cards or by inserting a b$CASEbTERM=TRUE.b$ card after the desired number of b$CASEb$ cards. If too many b$CASEb$ cards are input, a program stop will occur when the angle list is exhausted. Each b$CASEb$ card represents an opportunity to develop a special output for a single angle such as a plotting deck, a plume characteristic plot, a spectrum analysis, or some other output selection. An appropriate designation (i.e., ISPAT=2 to request a plotting deck) is simply entered on selected input cards as, for example:

b$CASEbISPAT=2b$

then neutralized on the next card as:

b$CASEbISPAT=0b$

where the b designates a blank card column.

3. Certain input data items are redundant in that they are "read in" by more than one "read". Certain other data fall in essentially the same category in that more than one quantity represents the same input. Input data which involve redundancy or compatibility and their input location are summarized in Table I.

4. A final data compatibility requirement exists when an "input" states the number of items to be entered. It is important to enter the appropriate number of values so stated. These interactions are summarized in Table II.

5. Radiance from the engine exhaust nozzle cavity is normally the most significant part of the overall aircraft IR signature. The radiance is directly dependent upon the geometric view factors, a set of values which is extremely tedious to generate for each engine to be analyzed. Provisions are included in ASDIR-II for generating these view factors as punched card output in a view factor computer run. For the view factor computer run IB49 through 53 and all IDS input from IDS-2 to IDS-6 may be excluded from the input string if the program execution is requested to stop after punching the view factors. Inputs required for punching view factors and requesting STOP include all "IB" data up to IB48 and specifically:

| | | | |
|---|---|---|---|
| IDS1 | bb03 | | |
| IB7 | bb0x-1 | Note: | Surface node temperatures are usually not known, so x will usually be zero. |

When the view factor cards have been punched, they must be included in the input as IB10 and IB11. In addition IDS1 and IB7 require revision to:

| | |
|---|---|
| IDS1 | bb01 |
| IB7 | bb0x01 |

for resumption of IR signature program execution.

## TABLE I INPUT COMPATABILITY REQUIREMENTS

| INPUT QUANTITY | NAME | INPUT LOCATION |
|---|---|---|
| Stream total temperatures (of primary and secondary flow) | TEMPO, TW<br>TTP, TTS<br>TTPN, TTSN | IB5, IB9<br>IB43, 44<br>IDS5 |
| Overall nozzle length | X2, X10, X20, TPL, XF<br>ANL | IB4, 5, 6, 12<br>IDS2 |
| Nozzle exit dimensions | Y2, Y10, Y20, AACT<br>RPN, RSN, RP | IB4, 5, 17<br>IDS2 |
| Stream total pressures | PTP, PTS<br>EPR, FPR | IB43, 44<br>IDS5 |
| Stream flow rates | WP, WS<br>WAPAC, WASAC | IB43, 44<br>IDS5 |
| Ambient pressure | PAMB<br>ALTPLM | IB45<br>IDS2 |
| IR wavelengths | BAND1, BAND2<br>AMI, AMF, IFILTER | IB57<br>IDS2 |
| Scenerio | ALTPLM, ALTOBS, RANGE | IDS2 |

TABLE II INTERACTIVE INPUT

| INPUT QUANTITY | LOCATION OF INPUT: NUMBER OF ENTRIES | DATA |
|---|---|---|
| Nozzle geometry | IB3 | IB4,5,8,10,11,13,14,15 16,20,24,27,33,41,43, 44,47,49,53 |
| Fluid nodes | IB8 | IB9 |
| Transpiration cooled nodes | IB24 | IB25, 26 |
| Film cooled nodes | IB27 | IB28, 29, 30, 31, 32 |
| Convection-film nodes | IB33 | IB34, 35, 36, 37 |
| Cooling Data table | IB38 | IB39 |
| Multiple fluid node surfaces | IB41 | IB42 |
| Objects protruding into streams | IB47 | IB48 |
| Conduction paths | IB49 | IB50 |
| Special fluid nodes | IB51 | IB52 |
| Aspect angles | IB54 | IB55 |
| The following input are in IDS-2: | | |
| Observation points | NRANG | ALTOBS(i) RANGE(i) |
| External radiating areas | NEXT | EAREA(i), ETEMP(i) |
| External nozzle plug coordinates | NP | XP, RP |

## BASIC ASDIR-II AIRCRAFT CONFIGURATION

The aircraft configuration most simply represented by ASDIR-II is axisymmetric, single-engined, and gas turbine powered with no external parts shielding or blocking the view of the hot exhaust nozzle opening or the plume. The IR signature of this basic configuration is completely developed by simply preparing the input data in accordance with the input data instructions below. The output can include listings of spectrally and spatially resolved radiance, plume gas parameters and species, equivalent black body area and temperatures of the nozzle exit plane, etc., or line printer plots or Calcomp Plotter punched decks as directed by output control parameters selected and given in the input. A Calcomp plot of a spatially resolved IR signature is included with example problem 1, Appendix A. (Calcomp plotting routines are not included as part of ASDIR-II).

Included in the program initialization are appropriate input quantities which describe a generic basic configuration plume-only sample case. The sample IR signature covers the band from 2.0 to 2.1 micrometers (μM) wavelengths. The short version output of the sample case is provided in the Appendix and at the end of the program listing for those users who have obtained their own copy of the program. The sample case can be exercized by the following five input cards:

1. bb0000
2. b$CASEb$
3. b$PLUMINb$
4. b$POWERb$
5. b$CASEbTERM=.TRUE.b$

where the first b is in column one. The $ represents the CDC 6600 namelist syntax. When executing ASDIR-II on another computer system, the namelist format and syntax of that system should be used. The sample case is executed in 4.5 seconds on the USAF/ASD computer center's CDC 6600 computer using SCOPE 3.4.3.

## PRACTICAL AIRCRAFT CONFIGURATIONS

Since aircraft configuration of practical interest are considerably more complex than the basic configuration considered in the ASDIR-II model, more effort in preparing input data and combining output data will be required for their representation. Common additional input data preparation will require:

- hand prepared external surface emissivity weighted areas (ABE), and temperatures (TBB) representing aircraft components for each aspect angle (ASPDEG, resolved from azimuth and elevation) to be considered.

- hand prepared shielded hot part areas (ABB) of engine internal hot parts for each aspect angle to be considered. Shielded hot part areas are exposed engine part areas as output by SIGNIR but are partly or wholly shielded by aircraft components such as the empennage.

- (Plume radiance cannot be partially shielded conveniently. Complete shielding of plume radiation, and its attenuation influence, can be achieved by setting IRADCK=2 in IDS 2).

Additional output data preparation which will be commonly required is the summing of results of several computer runs. A twin engine configuration signature can be developed, for example, by doubling the results from a single engine computer case. Suppose, further, that each engine is shielded differently by aircraft components. In this case, each engine with its particular shielding pattern would be put on the computer separately and the results added to form the composite whole signature. For a multi-engine (i.e., four, six, eight, etc.) configuration more single engine cases will be required. The development of an engine less aircraft (IRADCK=2) signature to be added to the several shielded engine-only signatures is a practicable approach and reduces the probability of inadvertantly including a component more than once.

The prescribed technique of superposition of signatures does involve small but unknown error in the composite signature in that some aircraft components, engines, or plumes may be seen through plumes of near engines at some viewing aspects. This error can be considered, in certain instances, as causing the results to be conservative. Also, this error will tend to "washout" as a function of range as atmospheric attenuation spectrally absorbs progressively more energy.

## PROGRAM CONTROL SCHEME

Program control parameters are included in the input data for selecting the various program functions as well as the I/O functions. The program (and input requirements) control logic flow diagram is given in Figure 1. The six control codes are:

| | | |
|---|---|---|
| . IHOT | . ICHECK | . IRADCK |
| . NFLW | . IFILTER | . KDATA |

The details of IHOT are discussed in the Preparation of Input Data Deck section.

NFLW is an automatic control which alerts the program to the fact that it is processing the first of many sequential calculations.

When the program begins its second sequence, the NFLW control is changed from 0 to 1 to indicate to the program that preliminary calculations have been made and that most read directives need not be repeated. NFLW is included in the input (IDS-2) but it serves no purpose for the program user and should, therefore, be omitted and ignored.

ICHECK is an automatic counter which selects the sequential calculation quantities ASPDEG, ABB, and TBB. In addition, when ICHECK is <0, namelist CASE is written in the output, ALTOBS and RANGE inputs are converted to units of kilometers, and AMI and AMF are admitted to operational computer registers. These functions make ICHECK convenient to rebegin the ASPDEG sequence with or without a new set of ranges, observer altitudes, or IR band wavelengths.

IFILTER designates to the computer that a filter is used in conjunction with the IR sensor. Either preloaded filter characteristics shown in figs 2 through 6, can be designated or filter characteristics can be input in IDS-4.

When a filter is designated, the IR band designators in IDS-2 are over-written by the filter band wavelengths. The namelist FILT in IDS-4 is read when IFILTER<0.

KDATA is normally not used for input control, although it possesses the potential to affect a read of plume structure data from tape or punched cards which had been produced by a previous computer run. The normal utility of KDATA is to select output options as explained in the Preparation of Input Data Deck section.

Several output options are available in the program such as spatial and plotting punched card output, etc. Each is explained under its control

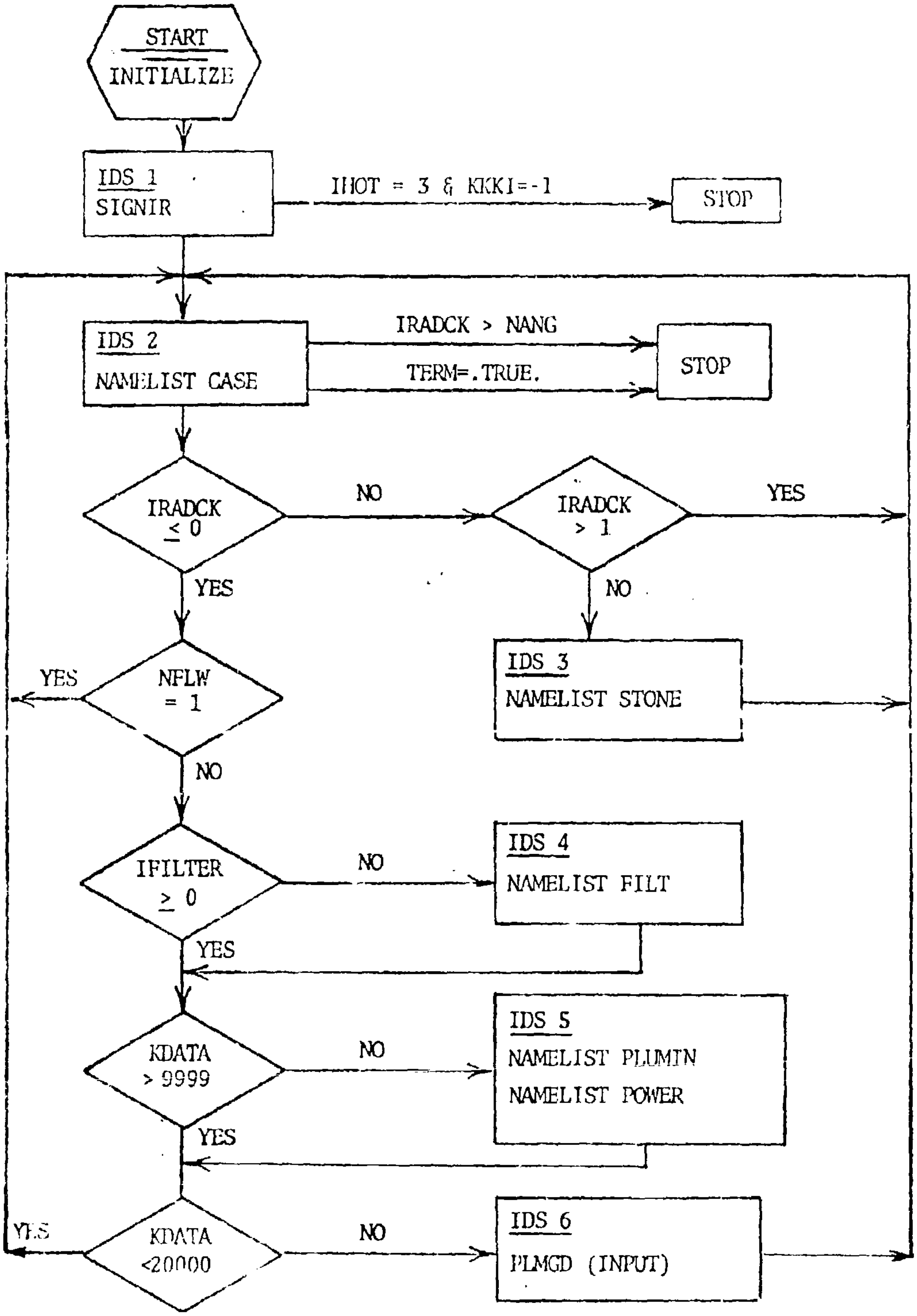
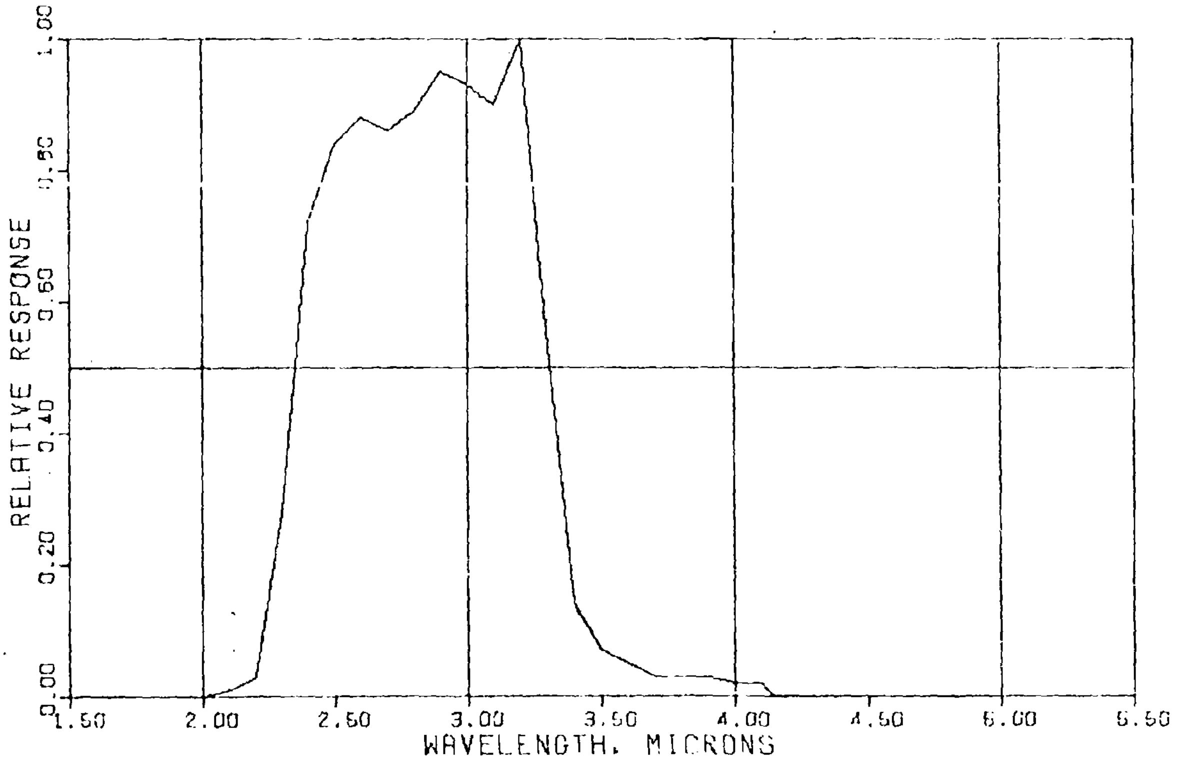
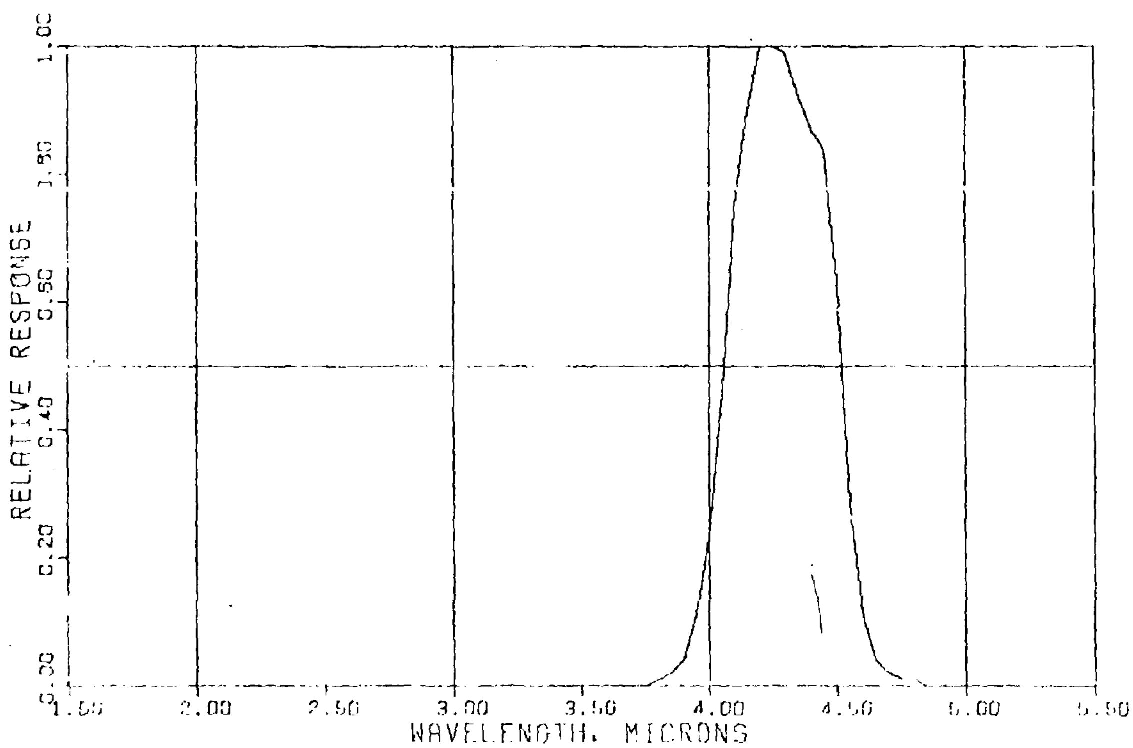



Figure 1. Input Data Set Logic Tree




BAND 1

Figure 2: Filter characteristics designated by IFILTER=1.




BAND 2

Figure 3: Filter characteristics designated by IFILTER=2.

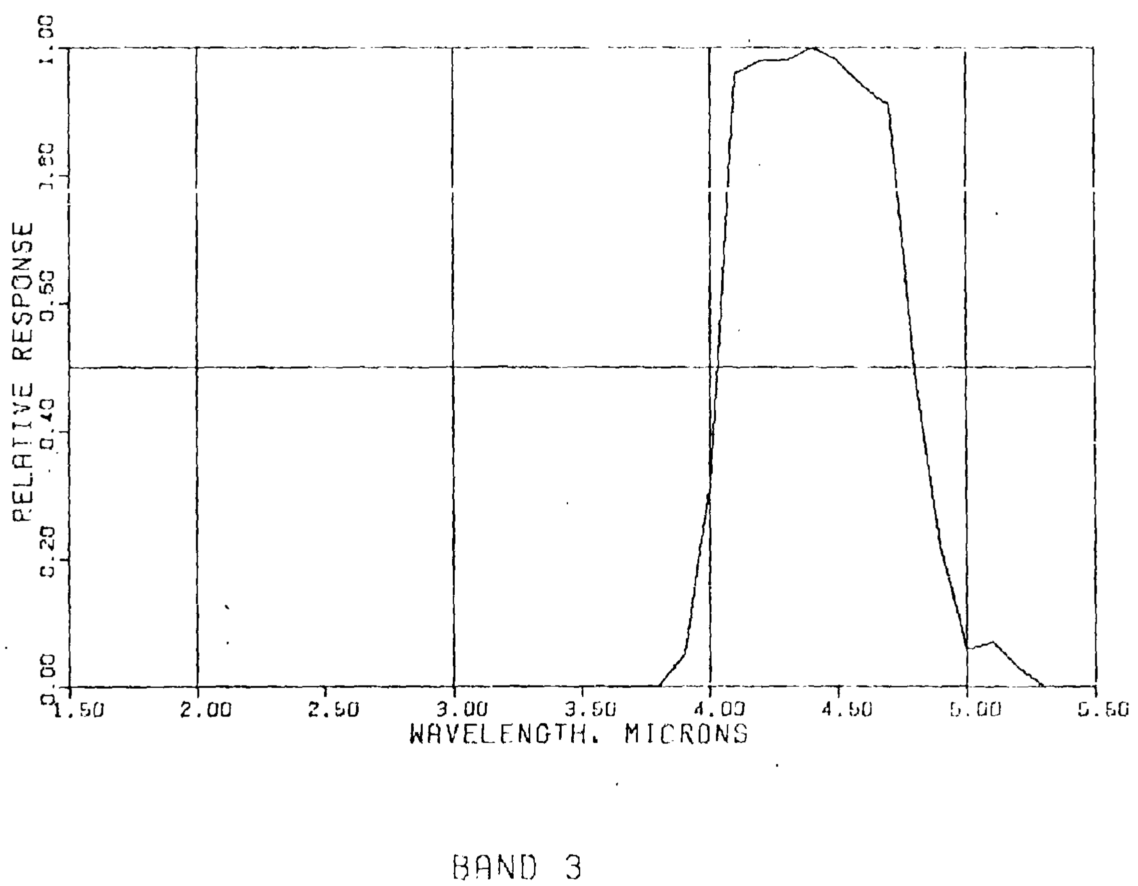



Figure 4: Filter characteristics designated by IFILTER =3.

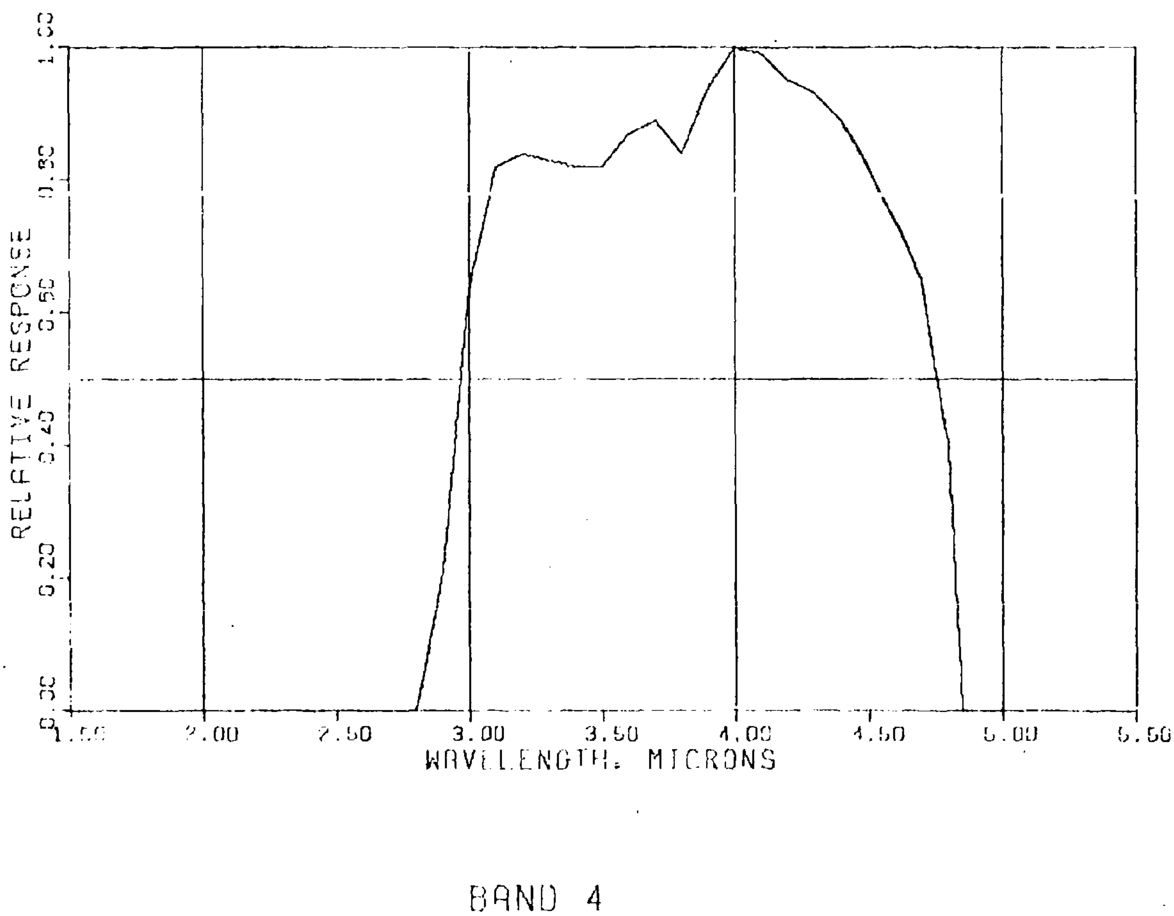



Figure 5: Filter characteristics designated by IFILTER =4.

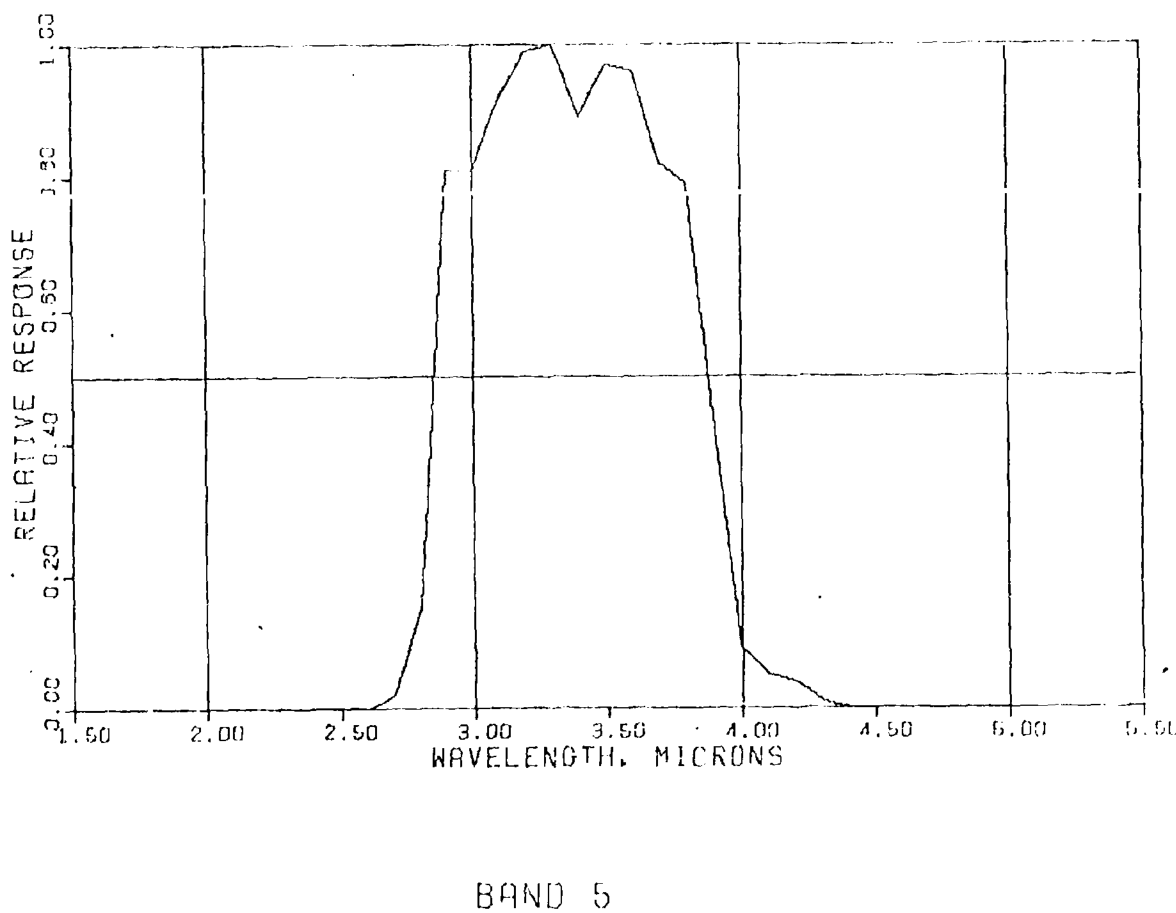



Figure 6: Filter characteristics designated by IFILTER =5.

code in the Preparation of Input Data Deck section. The output options control codes are:

| | |
|---|---|
| Print Control Card | (IB-2) |
| KKKI | (IB-7) |
| K50, NPLOT | (IB-56) |
| IL | (IDS-2) |
| ISPAT | (IDS-2) |
| ITAU | (IDS-2) |
| KDATA | (IDS-2) |

## PREPARATION OF INPUT DATA DECK

The description of the aircraft and background must be detailed, arranged, and punched into an Input Data Deck. The Input Data Deck is organized in two categories; Input Data Sets (IDS) which are predominately in namelist format, and Input Blocks (IB) which are formatted for computer read. The IB's are prepared exclusively to satisfy the internal hot parts (SIGNIR) input requirements. In preparing the IB input cards, it is particularly important to provide every card requested even if a given card is blank.

The instructions for the preparation of each input card are given below in the sequence required for input "read" by the program. For input Data Decks which involve logical branching, as depicted in Figure 1, instructions are provided below at the branching points to indicate the next required input. Cross reference to relevant input are also provided to assist in compatibility of input data and avoid anomalies such as an engine operating at 40000 ft altitude in an aircraft flying at 10000 ft.

Every Input Data Deck will begin with IDS-1.

IDS-1

IHOT (2X,I2) Initial program control directive declaring the exclusion or inclusion (and mode) of engine internal hot part analysis. For proper directives, enter:

bb00 - To bypass internal hot parts calculations. Provide ASPDEG, ABB, TBB, ALTPLM, and engine operation data in IDS-2 and IDS-5 from previous ASDIR runs or other information sources (if required data is not available, see next directive). Skip directly to IDS-2.

bb01 - To enter internal hot parts calculations. Omit ASPDEG, ABB, and TBB in IDS-2. Insure compatibility among IB4, 5, 6, 9, 12, 17, 43, 44, 45, 57 and IDS-2, 5. Skip directly to SIGNIR.

bb02 - To bypass internal hot parts calculation and enter SIGSUB. Omit ABB, ASPDEG, and TBB in IDS-2. As for the bb01 code instructions, insure compatibility. This code is preferred over bb00 for rerunning previously run flight conditions. Proceed directly to SIGSUB.

bb03 - To acquire geometric view factors. It is usually desirable to punch the view factors by use of bb00-1 in IB7. Inclusion of IDS-2 through 5 is not required. (See IB7 for alternatives). The IHOT-bb03 code together with KKKI= -1(IB7) are required to STOP operation after punching view factors. Skip directly to SIGNIR.

## SIGSUB

This portion of IDS-1 provides the output of SIGNIR but does not invoke the calculation of SIGNIR. SIGSUB is a convenient way of entering data which had been computed and printed in the output in a previous run. SIGSUB is accessed by IHOT=bb02. Enter up to twenty (20) combinations of aspect angle, equivalent radiating area, and effective black body temperature in the following substitute IB formats:

SIB1

| | | |
|---|---|---|
| NANG | = | Number of combinations of axisymmetric included aspect angle, radiating area, and radiating temperature. (up to 20) |
| | | Input format 2X, I2 |

SIB2

| | | |
|---|---|---|
| AX | = | Equivalent radiating area representing a discrete portion of the observer's field of view. (Sq. Cm.) |
| ATX | = | Effective black body temperature of area AX (Deg. K) |
| AA8 | = | Axisymmetric included aspect angle of observer relative to the aircraft aft line of flight. (Degrees) |
| | | Input format 3F10.5 |

Repeat SIB2 for each value entered in SIB1.

Bypass SIGNIR and proceed to IDS-2.

## SIGNIR

The inputs to SIGNIR are to be prepared under fifty-seven IB formats of which many are repeated in input data loops as necessary to read in similar data. These data constitute the geometric and flow details of the hot aft end of engines from the turbine discharge to the nozzle exit. Several modes of nozzle cooling are offered for analysis by the program as well as paths of conductive, radiative, and convective heat transfer. The geometric view factors are generated by SIGNIR. In the instructional steps below, each element of data required is described and certain repeat loop notations are made.

IB1

TITLE = Title cards. User is allowed 80 spaces per each of 5 cards to write this literal information. 5 cards are required. If less than 5 cards are needed, supply the remainder with blank cards.

Input format 20A4

A

A

IB2

Print control card. For radiation results only, input a blank card. For additional print-out, input a 1 for each of the following parameters to be printed.

| | | |
|---|---|---|
| PRINT1 | = | Print control for stream compressible flow information. |
| PRINT2 | = | Print control for surface boundary layer information. |
| PRINT3 | = | Print control for surface node average heat transfer coefficients. |
| PRINT4 | = | Print control for fluid node temperatures. |
| PRINT5 | = | Print control for surface cooling results. |
| PRINT6 | = | Print control for internal geometric view factors. |
| PRINT7 | = | Print control for temperatures of all configuration nodes. |
| PRINT8 | = | Print control for the configurations external view factors. |
| PRINT9 | = | Print control for radiation results unattenuated by atmosphere. Also see K50 in IB56. |
| PRINT0 | = | Print control for force factor information. |

Input format 2X, 10I2

IB3

| | | |
|---|---|---|
| NN | = | Total number of fluid streams. (up to 5) |
| NNN | = | Total number of surfaces. (up to 5) |
| N | = | Total number of surface nodes. (up to 44) |
| NO | = | Total number of entrance-exit nodes. (up to 5) |
| NNNN | = | Axis node indicator (input 1 if node exists; if not, input zero). |

Input format 2X, 5I2

B

B

IB4

Physical data necessary to describe the surface nodes and axis node. Each card represents information for one node.

X1 = Node upstream axial coordinate. (in.)
Y1 = Node upstream radial coordinate. (in.)
X2 = Node downstream axial coordinate. (in.)
Y2 = Node downstream radial coordinate. (in.)
VECT = Node surface orientation parameter. (If node represents outside surface of the frustum of a cone, input +1.; if it represents inside surface, input a -1.; axis node has value of +1.)
NODE = Node number.*
ISURF = Surface number on which node is located.

Input format 5F10.5, 2I2

Repeat IB4 for each surface node (up to 44) & axis node if one exists.

* Assign axis node number to be one greater than final fluid node number.

IB5

Entrance exit node. Each card represents information for one node. For a disk node the upstream coordinate correspond to the coordinate of the disk inner ring.

X10 = Node upstream axial coordinate. (in.)
Y10 = Node upstream radial coordinate. (in.)
X20 = Node downstream axial coordinate. (in.)
Y20 = Node downstream radial coordinate. (in.)
VECTO = Node surface orientation parameter. If node is an exit disk node, input +1.; if it is an entrance disk node, input -1. If node is not a disk, follow the convention of VECT provided in IB4.
TEMPO = Node temperature. (°R)
NODEO = Node number.

Input format 6F10.5, I2

C

(C)

Repeat IB5 for each entrance-exit node.

IB6

TPL = Total axial length of the system. (in.)

Input format F10.5

IB7

KKI = Surface node temperature indicator; (input 1 if surface node temperatures are input; if not, input zero).

KKKI = Internal geometric view factors and surface node areas indicator (input 1 if they are input; if not, input zero, input -1 if they are to be punched).

NOTE: The calculation of geometric view factors is lengthy and minimization of repeat calculations should be applied whenever possible. The early use of -1 in KKKI is recommended. bb03 is required in IDS-1 and IDS-2 through 5 can be omitted for this run. KKKI = -1 calls for a computer STOP after punching the view factors.

If surface node temperatures are not input, bypass IB8 and IB9.

Input format 2X, 2I2

IB8

NNAT = Total number of fluid nodes and special fluid nodes if any (up to 30).

Input format 2X, I2

IB9

TW = Surface node temperatures ($^{o}$R)
Each card will contain a maximum of 8 temperatures. Temperatures must be input according to the numerical order of the nodes; i.e., the first will be the temperature of node 1, the eighth the temperature of node 8. This is a very sensitive parameter; see Table I.

Input format 8F10.5

(D)

D

IB9 is repeated until all surface node temperatures, entrance-exit nodes, fluid nodes and special fluid nodes have been input, 8 to a card, up to 79 values.

If internal geometric view factors are not input, bypass IB10 and IB11.

Begin loop 1 on IB10 and IB11. The number of times this loop will be operated is equal to the total number of surface and entrance-exit nodes.

IB10

F = Internal geometric view factors.
Input node view factors (node corresponding to the number of times through loop 1) to all numerically higher surface and entrance-exit nodes in a numerical order; i.e., if third time through loop 1, view factors would be input as from node 3 to 4, 3 to 5, 3 to 6, etc. Repeat this card for the given node to the other nodes, 8 values to a card.

Input format 8F10.5

IB11

AREA = Surface area of the surface node or the entrance-exit node that corresponds to the number of times through loop 1. (Sq. in.)

Input format 1F10.5

END of LOOP 1; Return to IB10 or proceed.

If surface node temperatures are not input, go to IB14.

E

E

IB12

| | |
|---|---|
| XF | = Axial distance representing end of fluid stream, NN. (Begin with the first fluid stream). (in.) |
| | Input format 1F10.5 |

IB13

| | |
|---|---|
| JSURF | = Upper surface number and then lower surface number corresponding to the fluid stream of IB12 |
| | Input format 2X, 2I2 |

Repeat IB12 and IB13 for each flow stream.

Go to IB53

IB14

| | |
|---|---|
| KSURF | = A surface number. |
| NZ | = Total number of surface and axis nodes along that surface. |
| KOOL | = Counter to define cooling along surface. Input one of the following:<br>0, for no cooling.<br>1, for transpiration cooling.<br>2, for film cooling.<br>3, for convection-film cooling, counter flow configuration.<br>4, for convection-film cooling, parallel flow configuration. |
| | Input format 2X, 3I2 |

F

F

IB15

NODEN = All surface nodes along the surface (KSURF) above.

Input format 2X, 20I2

Repeat IB14 and IB15 for each surface, NNN.

Begin loop 2 which incorporates IB16 through IB40. This loop will identify fully the fluid streams, their surfaces and surface cooling if any. Loop 2 will be operated once for each fluid stream, NN.

IB16

ISTREM = Fluid stream number.

K = Type of fluid stream. Input one of the following:
- 0, for secondary stream.
- 1, for primary stream.
- 2, for mixed stream.

KK = Fluid stream exit indicator. Input one if the fluid stream does exit to ambient surroundings or 0 if the stream does not.

XI = Axial location representing start of fluid stream. (in.)

XF = Axial location representing end of fluid stream. (in.)

If the exit node is not a disc and KK=1, set XF to the smaller of X10 and X20(IB5) and AACT(IB17) to the related fluid stream cross section area.

Input format 2X, 3I2, 2X, 2F10.5

If the above fluid stream does not exit to the ambient surroundings, go to IB18.

G

G

IB17

AACT = Cross sectional area of the fluid stream exit. This is the end of the tailpipe for the fluid flow stream in IB16. (Sq. in.)

Input format 1F10.5

IB18

NNA = Total number of fluid nodes within this fluid stream.

Input format 2X, I2

IB19

NODEN2 = Fluid node number. *

KIK = Type of fluid node. Input one of the following:
0, for secondary fluid node,
1, for primary or fully mixed fluid node.

XX2 = Approximate axial coordinate which represents the mid-point of the fluid node. (in.)

Input format 2X, 2I2, 4X, F10.5

Repeat IB19 until all the fluid nodes for the fluid stream of IB16 have been entered.

* Numbered consecutively after surface node numbers.

Begin loop 3, an internal loop to be executed 2 times for each time through loop 2. Once for each of the surfaces that border the fluid flow stream in IB16. This loop incorporates IB20 through IB40.

H

H

IB20

JSURF = Upper surface number then lower surface number boardering the fluid stream in IB16.

KA = Type of fluid stream immediately adjacent to the surface. Input one of the following:
0, for secondary stream.
1, for primary or fully mixed stream.

THETA = Initial momentum thickness of the surface boundary layer. Input a value of -1 if the surface did not begin with the fluid stream of IB16. If the surface does begin with this fluid stream, input a known initial value or a best estimate. A value of approximately .001 inches might be expected for these surfaces. (in.)

HIA = Initial flat plate shape factor for the surface boundary layer. Use the same criteria for this parameter as for THETA; a -1. if the surface does not begin with the fluid flow stream. An approximate value of about 1.3 might be expected for this parameter. (nondimensional)

Input format 2X, 2I2, 4X, 2F10.5

If there is no surface cooling on the entire surface of IB20, bypass IB21 through IB40.

If the surface cooling information for the surface of IB20 has been input earlier in loops 2 or 3, bypass IB21 through IB40.

I

I

IB21

| | |
|---|---|
| TTSC | = Total temperature of the coolant supply fluid for the surface in IB20. (°R) |
| RSC | = Coolant supply fluid gas constant (ft. lb./lb. °R) |
| GAMASC | = Coolant supply fluid specific heat ratio. |
| CPSC | = Coolant supply fluid specific heat (BTU/lb. °R) |
| WSET | = Coolant supply fluid flow rate. (lb./sec.) If this parameter is to be computed, input 0.0. |
| TS | = Temperature of the heat source adding heat to the coolant supply fluid in the coolant delivery system, (°R). If no source exists, enter 0.0. |
| UA | = Overall heat transfer coefficient between heat source and coolant supply fluid, (BTU/hr. °R). If no heat is transferred enter 0.0. |

Input format 7F10.5

If coolant supply fluid flow rate is not to be calculated, bypass IB22.

IB22

| | |
|---|---|
| PTSC | = Total pressure of coolant supply fluid source. (lb./sq. in.) |
| K12 | = Pressure loss parameter for the coolant delivery system. $K_{12} = \sigma \Delta P / W^{n_{12}}$ lb./sq. in./(lb./sec.)$^n$ |
| N12 | = Pressure loss exponent for the coolant delivery system. $n_{12} = L_n(\sigma \Delta P / K_{12}) / L_n W$ (nondimensional) |

Input format 3F10.5

If surface is convection-film cooled, go to IB33. If surface is film cooled, go to IB27. If surface is transpiration cooled, go to IB23.

J

(J)

IB23

K23 = Pressure loss parameter for the coolant discharge.
$K23 = \sigma\Delta P/W^{n23}$ lb./sq. in./(lb./sec.)$^{n}$.

N23 = Pressure loss exponent for coolant discharge.
$n23 = \mathrm{Ln}(\sigma\Delta P/K23)/\mathrm{Ln}W$ (nondimensional)

PORS = Ratio of the surface cooling material. (Percent of open surface area to the total surface area).

Input format 3F10.5

IB24

MA = Number of surface nodes that make up the transpiration cooled portion of the surface. (The transpiration cooled surface is that portion of the surface that extends from the upstream coordinate of the transpiration material to the downstream end of the surface.) (up to 20)

Input format 2X, I2

IB25

LX = Surface node numbers of the nodes that make up the transpiration cooled surface. Nodes are input in the increasing axial direction. (up to 20 values)

Input format 2X, 10I2

IB26

XN = Axial coordinate of the surface node representing part or all of the transpiration material (in.).

YN = Radial coordinate corresponding to XN, (in.)
For XN and YN, input upstream coordinates of each of the nodes and in the order listed in IB25. Then input the downstream end surface coordinates. Repeat this card for these coordinates, 4 sets of data to a card.

Input format 8F10.5

(K)

K

Bypass IB27 through IB40.

IB27

| | |
|---|---|
| NUM | = Number of film cooling slots (up to 20) |
| MA | = Number of surface nodes that makeup the film cooled portion of the surface (The film cooled portion of the surface is that portion of the surface that extends from the start of the cooling through the downstream end of the surface.) (up to 20) |

Input format 2X, 2I2

IB28

| | |
|---|---|
| NODEN1 | = Surface node numbers of the nodes that makeup the film cooling surface (up to 20 values) (The nodes are input in the increasing axial direction.) |

Input format 2X, 10I2

IB29

| | |
|---|---|
| LX | = Number of cooling slots for each node. (The amount of data entered on this card will be equal to the number of nodes, MA, of IB27.) |

Input format 2X, 10I2

IB30

| | |
|---|---|
| S | = Slot height of film cooling slots. (in.). The order of input shall be in an increasing axial direction. The total amount of data entered will be equal to the number of slots, NUM, in IB27. Each card will contain a maximum of 8 values. |

Input format 8F10.5

L

(L)

IB31

XN = Axial coordinate of a cooling slot, (in.)
YN = Radial coordinate corresponding to XN, (in.)
For XN and YN, input the coordinates of each of the cooling slots and then the coordinates of the end of the surface. Each card will hold 4 sets of data.

Input format 8F10.5

IB32

CDX = Film cooling, slot discharge coefficient for each surface (up to 2)

Input format 1F10.5

Bypass IB33 through IB40.

IB33

NUM = Number of convection-film cooling slots (up to 20).
NB = Number of convection-film cooled shingles with heat exchangers plus 1 for any surface that extends beyond the last heat exchanger (up to 20).
MA = Number of surface nodes making up the convection-film surface (up to 20).
(The convection-film surface is that portion of the surface that extends from the start of the surface cooling through the downstream end of the surface.)

Input format 2X, 3I2

If convection-film cooling has a parallel flow configuration, go to IB35.

(M)

M

IB34

| | |
|---|---|
| XN | = Axial coordinate for cooling. (in.) |
| YN | = Radial coordinate corresponding to XN. (in.) |
| S | = Height of the cooling slot. (in.) |
| K5 | = Combined turning and exit pressure loss parameter (lb.sq. in./(lb./sec.)$^2$ |

Input format 4F10.5

Repeat IB34 for each (up to 20) of the cooling slot coordinates; for the end coordinate of the last heat exchanger, and the coordinate for the downstream end of the surface if they do not coincide with those of the end of the last heat exchanger. Use S = 0.0 and K5 = 0.0 where coordinates do not represent a cooling slot.

Go to IB36

IB35

| | |
|---|---|
| XY | = Axial coordinate for cooling. (in.) |
| YN | = Radial coordinate corresponding to XN. (in.) |
| S | = Height of the cooling slot. (in.) |
| K5 | = Combined turning and exit pressure loss parameter. (lb./sq. in./lb./sec.$^2$) (Uses S = 0.0 and K5 = 0.0 where coordinates do not represent cooling slots.) |

Input format 4F10.5

Repeat IB35 for the upstream coordinates of the first heat exchanger, for each (up to 20) of the cooling slot coordinates, and the coordinate for the downstream end of the surface.

N

N

IB36

NODEN1 = Surface node numbers that makeup the convection-film cooled surface. (The nodes are input in the increasing axial direction, up to 20 for each of up to 2 surfaces)

Input format 2X, 10I2

IB37

LX = Number of cooling slots for each node. (The amount of data entered on this card will be equal to the number of nodes, MA, in IB33, up to 20 for each of up to 2 surfaces). Input format 2X, 10I2

If this is not the first set of convection-film data entered into this program, bypass IB38 through IB40.

IB38

NN1 = The number of sets of points making up the convection-film cooling heat exchanger parameters table. (up to 21)

Input format 2X, I2

IB39

REN1 = Reynolds number for the flow through the heat exchanger.

HXP1 = Heat exchanger parameter, $h\,N_{pn}^{2/5}/G\,C_p$ corresponding to REN1 above.

F1 = Heat exchanger friction factor corresponding to REN1 above. (up to 21 values each parameter)

Input format 3F10.5

O

O

Repeat IB39 equal to the number of sets of points, NN1 given in IB38.

IB40

| | |
|---|---|
| HXT | = Plate-fin heat exchanger thickness. (in.) |
| AR | = Plate-fin heat exchanger flow to frontal area ratio. |
| SVHX | = Plate-fin heat exchanger heat transfer area to volume between plates ($ft.^{-1}$). |
| HD | = Plate-fin heat exchanger hydraulic diameter (ft.) |

Input format 4F10.5

End of loop 3; Return to IB20 or proceed.

End of loop 2; Return to IB16 or proceed.

IB41

| | |
|---|---|
| ICS | = Number of surfaces that are associated with more than one fluid stream (up to 5) |

Input format 2X, I2

If there are not surfaces that are associated with more than one fluid stream, go to IB43.

IB42

| | |
|---|---|
| ICSURF | = Surface numbers of those surfaces that are associated with more than one fluid stream. The amount of data entered on this card will be equal to ICS entered on IB41 (up to 5 values) |

Input format 2X, 10I2

P

P

IB43

| | |
|---|---|
| PTP | = Total pressure of the hot fluid stream. (lb./sq. in.) |
| TTP | = Total temperature of the hot fluid stream. (°R) |
| RP | = Gas constant of the hot fluid stream. (ft. lb./lb. °R) |
| GAMMAP | = Specific heat ratio of the hot fluid stream. |
| WP | = Fluid flow rate of the hot fluid stream. (lb./sec.) (Enter 0.0 for each of these parameters if the configuration contains no primary fluid stream.) (See Table I) |

Input format 5F10.5

IB44

| | |
|---|---|
| PTS | = Total pressure of the cool fluid stream. (lb./Sq. in) |
| TTS | = Total temperature of the cool fluid stream. (°R) |
| RS | = Gas constant of the cool fluid stream. (ft. lb./lb. °R) |
| GAMMAS | = Specific heat ratio of the cool fluid stream. |
| WS | = Fluid flow rate of the cool fluid stream. (lb./sec.) (Enter 0.0 for each of these parameters if the configuration contains no secondary fluid stream.) (See Table I) |

Input format 5F10.5

IB45

| | |
|---|---|
| PAMB | = Ambient pressure. (lb./sq. in.) |

Input format F10.5

IB46

| | |
|---|---|
| NODIM | = Surface or entrance-exit node. |
| NODEF | = The fluid node that is next to NODIM. Repeat the information above for all (up to 50) surface and entrance-exit nodes. Each card contains a maximum of 19 sets of data. Make N+NO(IB3) entries. |

Input format 2X, 38I2

Q

Q

Begin loop 4 on IB47 and IB48. This loop will be executed the same number of times as there are fluid streams in the configuration.

IB47

| | |
|---|---|
| IA | = Number of sets of points (up to 50) to describe any nonaxisymmetric area lumps existing within each (up to 5) fluid stream, taken in sequence. |

Input format 2X, I2

If there are no nonaxisymmetric area lumps within the fluid stream, bypass IB48.

IB48

| | |
|---|---|
| XA | = Axial coordinate for a nonaxisymmetric area lump. (in.) |
| AREAM | = Corresponding amount of cross-sectional area within the fluid stream that a nonaxisymmetric area lump takes up at location XA. Input XA and AREAM for the number of points, IA, entered in IB47. Each card holds 4 sets of data. |

Input format 8F10.5

End of loop 4; Return to IB47 or proceed
If IHOT=03 (IDS1) and KKK1=-1 (IB7), terminate the Input Data Deck here. Program execution will stop for insertion of view factors in IB10 and 11.

If surface node temperatures are input, go to IB53.

IB49

| | |
|---|---|
| NCK | = Number of conduction paths that do not involve a fluid stream. (up to 79-N(IB3)) |

Input format 2X, I2

R

R

If no conduction paths
go to IB53.

IB50

NODE1 = Surface node involved in conduction.
NODE2 = Surface node or special fluid node which completes the conduction path from NODE1.
HTARY = The overall heat transfer coefficient between NODE1 and NODE2. (BTU/hr. °F)

Input format 2X, 2I2, 4X, F10.5

Repeat IB50 for the number of conduction paths
entered in IB49.

IB51

NN = Number of special fluid nodes (up to 79-N (IB3))

Input format 2X, I2

If no special fluid nodes, go to IB53.

IB52

NODE1 = Special fluid node number.
T = Temperature of special fluid node number NODE1 (Deg. R)

Input format 2X, I2, 6X, F10.5

S

(S)

Repeat IB52 for the number of special fluid nodes entered in IB51.

IB53

EMM = Emissivity of surface and entrance-exit nodes. Use a value of 1.0 for open entrance-exit nodes. Enter data corresponding to the numerical order of nodes these represent. Each card will contain 8 values (up to 50 values).

Input format 8F10.5

IB54

NAS = Number of off-axis angles (up to 20) to be evaluated.

Input format 2X, I2

IB55

THA = Engine off-axis angles (degrees) (up to 20 values) (List in increasing order. Each card holds 8 values.)

Input format 8F10.5

IB56

K50 = Second print control for hot metal radiation. Enter 0 if hot metal spectra is to be printed; enter 1 to bypass spectra print output.

NPLOT = Line printer plot control. Enter 1 to plot intensity vs wavelength. Enter 0 to bypass plot.

WL = Max. wavelength computed. Input 0.0 for default WL of 14μM. If *** check appears in the output, increase WL.

2X, 2I2, F10.3

(T)

T

IB57

BAND1 = Wavelength of lowest end of IR spectrum to be considered for this aircraft, but greater than 1.0 micron.

BAND 2 = Wavelength of highest end of IR spectrum to be considered for this aircraft, but less than 14.0 micron.

See also note comment for WL in IB56.

NOTE: Specific IR detection bands will be selected below in IDS2.

Input format 2F10.5

IDS2

## IDS 2 INPUT FOR CASE DEFINITION

This input data set consists of input-output control code, program path control code, and case defining parameters. The compilation of these quantities constitutes the input data package referred to as CASE. Because of the beneficial interaction with existing values in the computer registers, the namelist format has been selected as the input mode. Quantities omitted in the namelist do not disturb values already in storage.

In the order shown for namelist CASE in program INPUT program listing, the input quantities are as follows:

| | |
|---|---|
| ABB | - Effective black body area of the nozzle exit in square centimeters. |
| AL | - Effective axial length of the plume in feet. DATINT presets AL to 1000 ft and AL is subsequently calculated in PLMDM. Except in very special cases, AL should be omitted here. |
| ALTOBS(i) | - Up to 5 observing sensor altitudes in feet. |
| ALTPLM | - Altitude of target in feet. |
| AMF | - Upper frequency of desired spectral band in micrometers (microns, µM). This value must be within the range of .9 through 200. µM. Omit if IFILTER is designated greater than zero. |
| AMI | - Lower frequency of desired spectral band in micrometers. This value must also be within the range of .9 through 200. µM. Omit if IFILTER is designated greater than zero. |
| ASPDEG | - Aspect angle in degrees. This is the semivertex cone angle between the line of view and the aftward plume centerline. The plume centerline is assumed within the program to coincide with the line of flight. |
| DDS | - Number of segments which represent the observed ray of radiated energy. DATINT presets DDS to 16. This value is adequate for most applications and, therefore, DDS should normally be omitted. |

(NOTE: Omit ABB, ASPDEG, and TBB if IHOT (IDS1) = 0).

EAREA(i) - Up to 20 external effective black body radiating areas such as external hot engine surfaces, other hot surfaces on the target aircraft, etc. Like ABB, this area must be provided in square centimeters. Provide also, ETEMP and NEXT.

ETEMP(i) - Up to 20 external radiating area's temperatures in degrees Kelvin.

IFILTER - Filter input control integer. DATINT presets IFILTER to zero. Five filter band characteristics are preloaded in program FILTER. If it is desired to invoke one of these filters, so designate by setting IFILTER = n ($1 \leq n \leq 5$) in namelist CASE. If another filter is desired, designate IFILTER =-1 and prepare its characteristics for namelist FILT (See Figure 1 and IDS 4). Ensure that the band AMI to AMF defines the filter if IFILTER <0 .

IL - Intermediate calculation output control integer preset in DATINT to -1 for normal program operation. This special output call prints the geometry, spectra, and spectral integration of each ray in PLUSIG as they are calculated. This output call consumes a lot of paper and, therefore, should normally be omitted. Although IL should be omitted for normal program execution, it must be reset to -1 for repeated IRADCK ≠ 0 analyses per program execution.

IRADCK - Program control integer. DATINT presets IRADCK to zero for normal cases and plumes. Special analyses may require the IR signature of simple hot targets attenuated through the atmosphere. For such cases, simply designate IRADCK = 2 and provide EAREA, ETEMP, NEXT, etc. Other special analyses require the IR signature of gas emissions attenuated through the atmosphere. For these cases, designate IRADCK = 1 and provide input as required in IDS 3. For normal program operation, omit IRADCK.

ISPAT - A spatial output control integer which has been preset to zero in DATINT for normal program operation. Designate ISPAT=0 to write spatial plume radiance on a scratch tape. Designate ISPAT =1 for listing output or ISPAT = 2 for listing and punch card output of spatial plume radiance data. When ISPAT ≠ 0, NEXIT and NANGSEG are each set to 7. The punch card output is suitable for plotting. See Appendix A for Calcomp plot example.

ITAU - A second spectral output control integer which has been preset to -1 in DATINT for normal program operation. When ITAU is designated greater than or equal to zero, the spectral radiance of the entire ray is printed in ALPLUM. ITAU should be omitted for normal operation.

ITYPE - A spectral line lapping parameter control integer preset to 1 in DATINT for normal program operation. ITYPE selects the line lapping function in subroutine TAUCAL. Except for very special spectroscopic analyses, ITYPE should be omitted.

KDATA - Program output control integer preset to 1 in DATINT for minimum output operation. KDATA is a five digit integer represented by KDATA = ABCDE. KDATA is decoded in program PLMDM and the designator A is utilized in program ASDIR 2. The KDATA code breakdown is as follows:

A is redefined IREAD:

= 0, the plume will be computed.

= 1, the plume gas data array will be read from a data tape 8.

= 2, the plume gas data array will be read from input (cards punched in a previous program execution, see IDS 6).

B is redefined IFILE:

= 0, bypass file function.

= 1, record plume gas data array on data tape 8.

C is redefined IPNCH:

= 0, bypass punch function.

= 1, punch plume gas data array on input/output cards.

D is redefined IPRNT:

= 0, bypass print function.

= 1, print plume gas data array on output line printer.

KDATA (Cont'd) — E is redefined IPLOT:

- = 0, plot plume static temperature, $CO_2$ concentration, $H_2O$ concentration, and velocity on the line printer.
- =1, bypass line printer plots.
- =2, plot static temperature.
- =3, plot $CO_2$ concentration.
- =4, plot $H_2O$ concentration.
- =5, plot velocity.

NA - Atmospheric ray segmentation control integer preset to 5 in DATINT for normal program operation. This value is normally adequate and, therefore, can be omitted.

NANGSEG - Ray angular segmentation control integer preset to 3 in DATINT for normal program operation. For finer spatial analyses of plume structure, NANGSEG = 7 is suggested. Usually, NANGSEG = 3 is adequate and NANGSEG may be omitted.

NATMO - Atmospheric relative humidity control integer preset to 2 in DATINT for normal program operation. Input NATMO = 1 for low humidity or = 3 for high humidity. The atmosphere model excludes particulates, aerosols, and abnormal gas content. For normal (mid range) humidity, NATMO may be omitted.

NEXIT - Ray height segmentation control integer preset to 5 in DATINT for normal program operation. For finer spatial analyses of plume structure, NEXIT = 7 is suggested. Usually, NEXIT = 5 is adequate and NEXIT may be omitted.

NEXT - Number of external radiating areas designator integer preset to zero in DATINT for normal program operation.

NFLW - Program control integer preset to zero in DATINT for normal program operation. NFLW should be omitted.

NP - Number of external nozzle plug coordinates integer preset to zero in DATINT. If the nozzle of the subject engine has an external plug, designate NP = 2 and provide values for XP and RP. If no external plug, omit NP, XP, and RP.

NRANG - Number of slant ranges integer preset to 1 in DATINT. If different than 1, designate the number of ranges to be analyzed (maximum of 5).

NUINC - Spectral wave number stepping size (real) preset to 50. in DATINT for rapid program operation. Finer steps are available within the program as follows:

| NUINC = | increment (wave no.) | band (wave no.) |
|---|---|---|
| n | n | 50 - 11000 |
| 0 | ( 25 | 50 - 2000 |
| | 10 | 2000 - 2400 |
| | 25 | 2400 - 3080 |
| | 10 | 3080 - 3770 |
| | 25 | 3770 - 11000 ) |

Values of 25., 10., or zero are suggested as spectroscopically reasonable values of n. Small values, such as 1, will use a lot of computer time.

RANGE(i) - Up to 5 slant ranges, from the observing sensor to the target aircraft, in feet preset to zero in DATINT. The zero range is equivalent to no atmospheric attenuation.

RAYPNT - Intermediate calculati , output control preset in DATINT to zero for noi. al program operation. Similarly to IL, this special output call prints ray geometry and average properties in PLURAY as they are calculated. This call also uses a lot of paper and, therefore, should normally be omitted.

TBACK - Background black body radiating temperature in degrees Kelvin preset to zero in DATINT.

TBB - Effective black body temperature of the nozzle exit in degrees Kelvin.

**TERM** Logical program stop command preset to TERM = .FALSE. immediate prior to read namelist CASE in program INPUT. After completion of desired program execution, provide a TERM = .TRUE. namelist CASE input.

**NUFRST** Spectral integation initiator index integer preset to zero in DATINT. Once the spectral integration structure has been organized in PLUSIG, NUFRST is reset to 1 for the remainder of the program execution.

**ICHECK** A program and input cycle control integer preset to zero in Input. ICHECK is incremented for each executive cycle of ASDIR-II. When IHOT = 0, ASPDEG, ABB, and TBB must be provided in every CASE input when a value change is desired. ICHECK= -2 must be used to request the output listing of the $CASE . . . $ namelist input.

When IHOT≠0, ICHECK sequentially selects the next aspect angle (ASPDEG) data to be processed. When ASPDEG data is exhausted, program operation will terminate. The selection process can be repeated if in the last (or any) CASE input, ICHECK is reset. A simple change of IR band can be made by giving ICHECK =0 and new values for AMI, and AMF. Changes can include new values for DDS, EAREA, ETEMP, IL, IRADCK, ISPAT, ITAM, ITYPE, KDATA, NA, NANGSEG, NATMO, NEXIT, NEXT, NRANG, RAYPNT, and TBACK. New values for ALTOBS, and RANGE can be included in any CASE input. Examples are given in the appendices.

**RPN** The radius in inches of the primary nozzle.

**RTE** The radius in inches of the turbine exit stage.

**ANL** The axial nozzle length in inches from the turbine exit plane to the nozzle exit plane.

**RSN** The radius in inches of the secondary nozzle at the nozzle exit plane. If the subject engine has no secondary nozzle, designate RSN = 0 or RSN = RPN.

**XP** The external length in inches of the nozzle plug. If the subject engine has no plug, omit XP since it has been preset to zero in DATINT. If the subject engine has an external plug, designate also RP and NP = 2.

**RP** The radius in inches of the external nozzle plug in the plane of the nozzle exit.

## IDS 3 SPECIAL GAS CHEMISTRY INPUT

This input data set consists of gas temperature and species partial pressure combinations for the special calculation of energy radiated from a simple gas target. A control value is required in namelist CASE (IDS2) for IRADCK (IRADCK = 1).

In the order shown for namelist STONE in subroutine PLURAY program listing, the input quantities are as follows:

- P1(i) - Partial pressure in atmospheres of the H2O species in the target gas. The array will accept from 1 to 50 values.
- P2(i) - Partial pressure in atmospheres of the CO2 species in the target gas. The array will accept from 1 to 50 values.
- P3(i) - Partial pressure in atmospheres of the diluent in the target gas. The array will accept from 1 to 50 values.
- XT(i) - Temperature in degrees Kelvin of the target gas mixture. The array will accept from 1 to 50 values.

## IDS 4 FILTER DEFINITION

This input data set provides the opportunity to designate one of the five filter characteristics preloaded in program FILTER or to input specific characteristics of some other filter. A control value is required in namelist CASE (IDS 2) for IFILTER.

For the selection of a preloaded filter, designate IFILTER = n where n is the filter selected 1 through 5. Having designated IFILTER > 0, the AMI and AMF quantities of IDS 1 are redefined to suit the designated filter band. These bands are shown in the program listing in data statements for AB to AC in program INPUT and for AST to AFN in program FILTER. The five filter transmission coefficient sets are shown in data statements in program FILTER.

For the election to provide specific filter transmission coefficients, designate IFILTER = -1. In this analysis, AMI and AMF define the filter band within a 5 μM limit.

In the order shown for namelist FILT in program FILTER, the input quantities are as follows:

ASTART - The lower wavelength of the filter band characteristics in micrometers. The value of ASTART must agree with the value of AMI entered in IDS 2.

FR(i) - Up to 100 specific filter transmission coefficients which describe the filter over the band AMI to AMF. The transmission coefficients must describe the filter at .05 μM intervals.

## IDS 5 ENGINE OPERATION DEFINITION

This input data set provides several modes which ultimately define the plume gas data at the nozzle exit plane. The use of two separate namelist input modes is available for providing the plume input data. The first, namelist PLUMIN, will accept plume description data directly and will be discussed first. The second, namelist POWER, will accept engine operating parameters from which the plume gas data at the nozzle exit plane can be calculated. A feature of the engine operation calculation is the calculation of flight conditions in accordance with the Military Standard 210 day type based on the ICAO 1962 Standard Atmosphere. A second feature is the simple combustion chemistry calculation to provide the CO2 and H2O species concentrations for an N-Tane fuel for those input situations when CO2 is not provided in namelist PLUMIN.

Namelist PLUMIN is devoted exclusively to the definition of the plume by specifying the gas flow parameters at the nozzle exit plane. If the ambient properites are known for the subject flight condition of the target aircraft, as well as the nozzle exit gas properties, then the plume calculations are completely defined by namelist PLUMIN. Three parameters of PLUMIN (PA, U8, and XCO2) are utilized to key the program function. If XCO2 is omitted, the subroutine CHEM will be called to compute XCO2 and XH2O as a function of EQR and TANE.

If U8, the primary nozzle exit velocity is omitted, the engine operation input namelist POWER will be read and the engine will be considered to be operating at the provided values of PA, UA, and TA in air. This input mode is appropriate for analyzing engines for test cell operations. For such an application, FLTM can be omitted in POWER making use of UA or UA can be overwritten by designating FLTM in POWER depending on the availability of test cell data.

If in addition to the omission of U8, PA is also omitted, the quantity ALTPLM (IDS 2) will be utilized in subroutine THRUST to calculate the MIL STD 210, hot, standard, or cold atmospheric conditions as well as calculating the engine operation after reading namelist POWER.

In the order shown for namelist PLUMIN in program FLINP (or PLUME) in the program listing, the input quantities are as follows:

| | |
|---|---|
| RPN | - Repeated from IDS 2 and should be omitted. |
| RSN | - Repeated from IDS 2 and should be omitted. |
| XR | - Repeated from IDS 2 and should be omitted. |
| RP | - Repeated from IDS 2 and should be omitted. |
| KDATA | - Repeated from IDS 2 and should be omitted. |

TANE - Effective link number of simple fuel chain molecules. The fuel assumed is represented by an HCH chain molecule with atomic hydrogen ends:

```
    H   H         H
    |   |         |
H - C - C - . . . - C - H
    |   |         |
    H   H         H
```

I.e., $C_nH_{2n+2}$ with n links. A light ker sene such as JP-4 is represented by n = 9.0. TANE is preset to 9.0 in program FLINP.

EQR - The effective stoichiometric equivalence rat o preset to 0.25 in FLINP. This input is utilized only if U8 is provided and XC02 is omitted.

XC02(i) - The mole fraction concentration of carbon dioxide in the primary nozzle exhaust. If XC02 is to be provided here, designate XC02 = 11 * .n where .n represents the mole fraction. If desired, and the data is known, the eleven required values can be entered individually to reflect a known distribution. The eleven values represent ten equal radius increments from centerline (or plug) to the edge of the primary nozzle. (See text).

XH20(i) - The mole fraction concentration of water vapor in the primary nozzle exhaust. Entry of H20 data is similar to entry of C02 data and is required if XC02 data is provided.

XC02A - The mole fraction concentration of carbon dioxide in the ambient atmosphere, preset to .00033 in FLINP.

XH20A - The mole fraction concentration of water vapor (humidity) in the ambient atmosphere, preset to .00033 in FLINP.

U8(i) - The exhaust nozzle gas velocity in feet per second relative to the nozzle. If a flat velocity profile across the nozzle exit is to be entered, designate U8(1) = 11 * n, m where n is primary nozzle exit velocity and m is the secondary flow exit velocity. If actual profile data is to be entered, provide the individual profile values in radial increments of (RPN-RP)/10. to fill out the primary and secondary nozzles. If U8 is to be calculated, omit U8, and a flat profile will be assumed.

T8T(i) - The exhaust nozzle total temperature in degrees Rankine. Data input is similar to the input of U8, and is required if U8 is provided.

P8 - The primary nozzle exit static pressure in atmospheres preset to zero in DATINT. The pressure is considered constant over the exit of the nozzle.

PQ - The secondary nozzle static pressure in atmospheres, preset to P8 (i.e., zero) in FLINP, and is constant over the exit of the secondary nozzle.

UA - Flight velocity in feet per second. Must be input here if U8 is entered. (See text).

TA - Ambient temperature in degrees Rankine. Must be input here if U8 and PA are entered. (See text).

PA - Ambient pressure in atmospheres. If the ambient pressure, temperature, and velocity are to be calculated, omit PA. (See text and notes in program FLINP listing).

Namelist POWER is devoted to the definition of the engine operation from which the plume may ultimately be defined. The input data consists of ambient atmosphere, flight condition, and engine operating parameter. The engine operating parameters can be provided in either absolute or normalized form.

As discussed above, the ambient conditions are calculated by the use of a standard atmosphere model on a function of altitude, and a meteorological code, METEC. The flight and engine ram parameters are derived from the ambient conditions and the flight Mach number, FLTM.

In the order shown for namelist POWER in program THRUST program listing, the input quantities are as follows:

METEC - Meteorological code integer preset to zero in THRUST. The zero value represents an ICAO 1962 standard day. A Mil Std 210 cold day is represented by designating, METEC = -1, and a hot day is represented by, METEC = +1.

NORM - An engine data normalization code integer. If the engine data is in absolute form, it is not normalized so designate NORM = 0. NORM is preset to 1 in THRUST because the engine data default case is normalized. (Omission of NORM is not recommended since it is difficult to distinguish prepared data cards in its absence.)

JET - Number of co-annular jets integer preset to 1 in THRUST. If a mixed exhaust fanjet engine is being analyzed, designate JET = 1. Designate JET = 2 only when the secondary fan exhaust is separate but coplanar with the primary exhaust. A non-coplanar fanjet engine can be synthesized by expanding the secondary to ambient pressure and considering it to be coplanar which requires some pre-input manual calculation of a ficticious secondary nozzle.

FLTM - Flight Mach number. This value will overwrite previously entered values of velocity.

TSFCC - Corrected thrust specific fuel consumption in pounds of fuel per pound thrust per hour ($W_F/T$) if NORM = 0; or $W_F/(T^* \sqrt{\Theta_{T2}})$ if NORM = 1 where $\Theta_{T2} = T_{T2}/518.688$ and $T_{T2}$ is the flight ram temperature in degrees Rankine.

RREC - Inlet ram recovery factor in decimal form of the ratio of the engine face total pressure to flight ram pressure.

FN - Engine output thrust (T) in pounds if NORM = 0; or ($T/\delta_{T2}$) if NORM = 1 where $\delta_{T2} = P_{T2}/14.696$ and $P_{T2}$ is engine face total pressure in pounds per square inch.

FNRT - Engine rated thrust (RT) at the 100% or intermediate power lever setting in pounds if NORM = 0; or ($RT/\delta_{T2}$) if NORM = 1.

EPR - Engine pressure ratio ($P_{T7}/P_{T2}$) as the ratio of the nozzle exit total pressure to the engine face total pressure. If NORM = 0, EPR = $P_{T7}$ in psia.

FPR - Secondary pressure ratio ($P_{T2.5}/P_{T2}$) as the ratio of the secondary nozzle exit total pressure to the engine face total pressure. If NORM = 0, FPR = $P_{T2.5}$ in psia.

## IDS 6 INPUT OF PREVIOUSLY COMPUTED PLUME

This input data set provides an input mode whereby a previously computed plume can be reinserted into the program for further, different, or repeated analysis. A control value is required in namelist CASE for KDATA: i.e., KDATA = 2XXXX. When KDATA is greater than 20000, the entire plume gas data array will be read by the program from input cards in program PLMDM.

Inasmuch as the input cards for this input data set should have been produced by the program in a previous operation, no attempt should be made to prepare these 7544 input quantities manually. The following is a brief summary of the contents of the plume gas data array (PLMGD):

| | | | |
|---|---|---|---|
| PLMGD (1) | = | DELAM | $\delta$AMB - PAMB/14.696 |
| (2) | = | THEAM | $\theta$AMB = TA/518.688 |
| (3) | = | METEC+2 | Meteorological code |
| (4) | = | TA | Degrees Rankine |
| (5) | = | ALTPLM | IR target altitude |
| (7) | = | PNRT | % normal rated thrust |
| (8) | = | JET | Number of co-annular jets |
| (9) | = | WP | Primary gas flow rate (lb/sec) |
| (10) | = | WS | Secondary air flow rate (lb/sec) |
| (11) | = | WF | Fuel flow rate (lb/hour) |
| (12) | = | FARW | Overall fuel to air ratio |

TTPN - The effective total temperature in the primary nozzle (TT7) in degrees Rankine if NORM = 0; or ($TT7/\theta_{T2}$) if NORM = 1.

TTSN - The effective total temperature in the secondary nozzle ($TT2.5/\theta_{T2}$) if NORM = 1.

WAPAC - The primary nozzle gas flow rate (WP) in pounds per second if NORM = 0; or ($WP * \sqrt{\theta_{T2}}/\delta_{T2}$) if NORM = 1.

WASAC - The secondary nozzle gas flow rate (WS) in pounds per second if NORM = 0; or ($WS * \sqrt{\theta_{T2}}/\delta_{T2}$) if NORM = 1.

| | |
|---|---|
| PLMGD (13) = PNPR (Cont'd) | Primary nozzle total to static pressure ratio at the nozzle exit. |
| (14) = SNPR | Secondary nozzle total to static pressure ratio aft the nozzle exit. |
| (15) = PTP | Primary nozzle exit total pressure (PT7) in psia. |
| (16) = PTS | Secondary nozzle exit total pressure (PT 2.5) in psia. |
| (17) = TTP | Primary nozzle exit total temperature (TT7) in degrees Rankine. |
| (18) = TTS | Secondary nozzle exit total temperature (TT 2.5) in degrees Rankine. |
| (19) = FN | Engine nozzle force or thrust in pounds. |
| (20) = PNMACH | Primary nozzle exit Mach number. |
| (21) = SNMACH | Secondary nozzle exit Mach number. |
| (22) = PNVEL | Primary nozzle exit velocity in feet per second. |
| (23) = SNVEL | Secondary nozzle exit velocity in feet per second. |
| (24) = P8 | Primary nozzle exit static pressure in atmospheres. |
| (25) = PQ | Secondary nozzle exit statis pressure in atmospheres. |
| (26) = RP | Primary nozzle gas constant in feet per degree Rankine. |
| (27) = RS | Secondary nozzle and ambient gas constant in feet per degree Rankine. |
| (28) = | A primary nozzle gas parameter. |
| (29) = | A secondary nozzle gas parameter. |
| (31) = XEN(1) | A primary nozzle interior station in negative inches measured from the nozzle exit plane. |

| | | |
|---|---|---|
| PLMGD (Cont'd) | (32) = REN(1) | A primary nozzle interior radius in inches at station PLMGD (31). |
| | (33) = XEN(3) | The primary nozzle exit station of the secondary nozzle exit plane fixed at zero. |
| | (34) = REN(3) | The secondary nozzle exit radius in inches preset to primary nozzle exit radius in DATINT. |
| | (35) = NEN | Number of primary nozzle coordinates in PLMGD array. |
| | (42) = RF | Nozzle plug radius in inches at nozzle exit plane, preset to zero in DATINT. |
| | (43) = XF | Nozzle plug external length in inches from the nozzle exit plane preset to zero in DATINT. |
| | (44) = RPN | Primary nozzle radius in inches. |
| | (45 - 94) | A table of plume stations in feet from nozzle exit plane. |
| | (95 - 144) | A table of number of plume radii at each plume station in integers. |
| | (145-7644) | The plume gas data table containing the plume radius ordinate in feet, the plume velocity in feet per second, the plume pressure in atmospheres, the plume temperature in degrees Rankine, carbon dioxide concentration in mole fraction, and water vapor concentration in mole fraction. |

## APPENDIX A

### ORIENTATION AND DEFAULT SAMPLE

ASDIR-II geometric orientation and a program default sample are presented in this appendix. Three example or demonstration IR signatures are developed in the following appendices. All Samples and demonstrations therein presented are purely generic in that all dimensions and engine performance data were arbitrarily assumed. Consequently, these cases relate not to a single aerosystem, but directly to all aerosystems.

Figure A1 shows the general scenerio representing the domain of the ASDIR-II program. Distinctive features of the scenerio as interpreted by the program are indicated. The aspect angle of the observer relative to the targetted aerosystem, (indicated in Figure 1 as ASPDEG), is the included angle measured from the aerosystem's flight path. This angle, ASPDEG, is derivable from elevation and azimuth angles relative to the aerosystem as shown in Figure A2 and A3. These angles are each derivable from absolute (relative to earth) elevation and azimuth angles from the pitch, yaw, and roll angles of the aerosystem. This resolution is not shown. It is to be noted that ASPDEG and elevation and azimuth are the only angular measures relevant to the IR signature.

The line joining the aerosystem target and the IR observer is designated in the figures as R which indicates "slant" range. In Figure A4, the axis of the plane which contains both the R vector and included angle ASPDEG, the DZ axis, is the major axis of an apparent projection plane. The DD axis, othogonal to DZ and R, is the lateral axis of the apparent projection plan. The establishment of the DZ, DD plane provides a reference plane onto which the nozzle exit area and plume radiant intensities are projected in preparation for the spatial integration of the radiated IR energy into an IR signature. External radiating surface intensities are taken by ASDIR-II to be in the DX, DD apparent projection plane whose physical location, conceptionally, represents an image screen normal to the R vector between the observer and the target aerosystem at the "near" edge of the target geometry. Distances of various parts of the target to the apparent projection plane are ignored as is atmospheric absorption of IR energy along these distances. The process of defining elemental ray areas, subsequent integration of radiant energy emission and absorption in a ray element, and the ultimate projection of elemental ray energy onto the apparent projection plane is depicted in Figure A5. Circular section area elements (RAR) are defined on the apparent projection plan (DZ, DD). Intensity integration along any ray parallel to "R" is initiated at the projection of RAR either on the nozzle exit plane (designated "O" in Figure A5) or at the far edge of the target, and progresses through the target "P" to the apparent projection plane at "Q". Integration of the radiant intensity over all ray's to the geometric limits of the target represents the source radiation of the target in the direction of the observer.

For assistance in the installation of the ASDIR-II program on various computer systems, the program has been initialized with appropriate quantities representing input data of a simple plume-only problem for which the IR signature is computed over a very narrow IR band. These initialized input quantities are referenced as the default sample case. The primary objective for the default sample is the exercise of ASDIR-II in its new installation.

The default sample case is executed with a "blank" Input Data Deck as discussed on page 7 on the report text. The output to be expected is shown in Figures A6, A7, and A8. This output represents a minimum output. Additional output for the default sample case may be requested by including appropriate control codes in the input as discussed in the guide text, and demonstrated in the following appendices. Figure A6 shows a typical output header consisting of program output which describes the case under study. The output listing of the input in Figure A7 is a complete listing of all data registers addressed in inputs utilizing the namelist format. The namelists to be found in the output encompass only IDS2 and IDS5.

As may be expected, the default case is ultrashort, consisting of a single set of values and a very narrow (.1 μM) IR band. The entire IR signature output is shown in Figure A8.

## APPENDIX A FIGURES

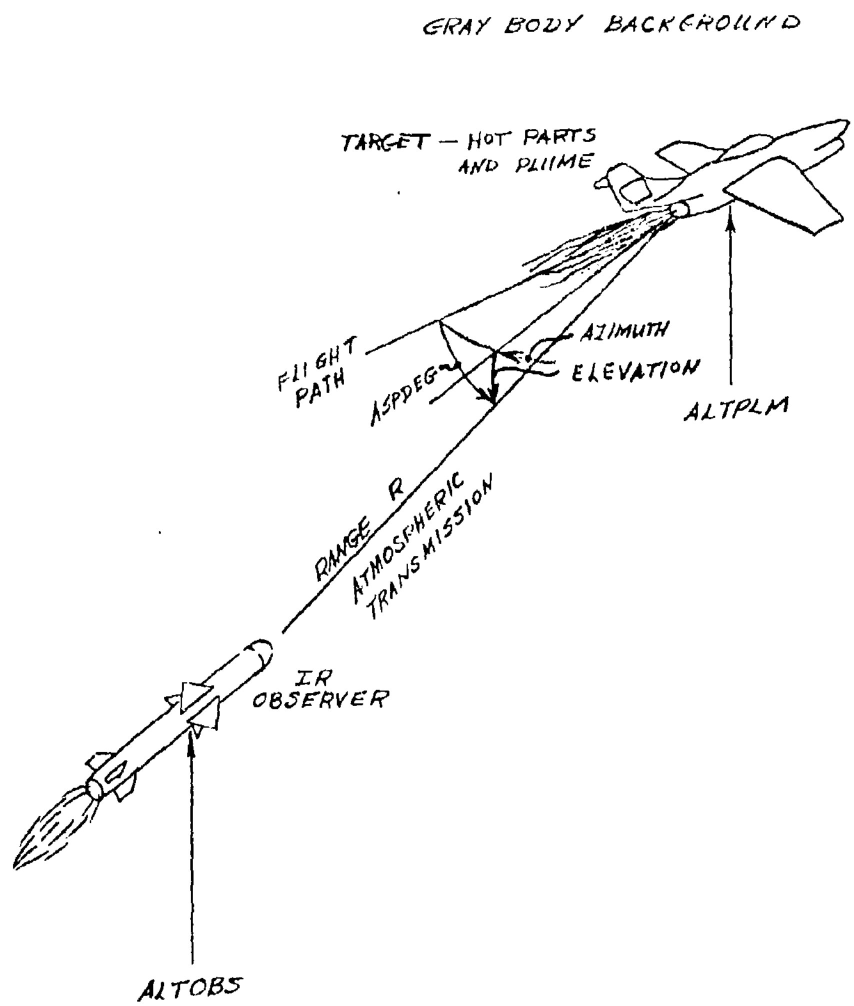
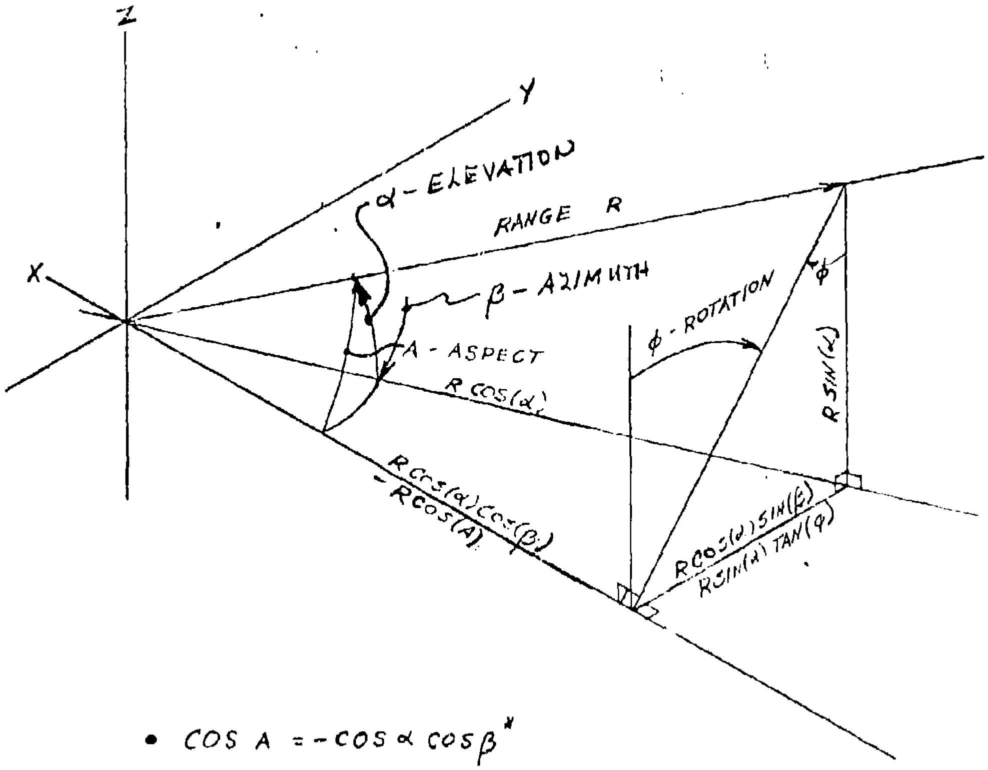



FIGURE A1 GEOMETRIC ORIENTATION - SCENERIO




- $COS\ A = -COS\ \alpha\ COS\ \beta^{*}$
- $TAN\ \phi = SIN\ \beta^{*} / TAN\ \alpha$

* β ALWAYS OCCURS FIRST, THEN α up or down from horizontal.

FIGURE A2 GEOMETRIC ORIENTATION - OBSERVER ASPECT

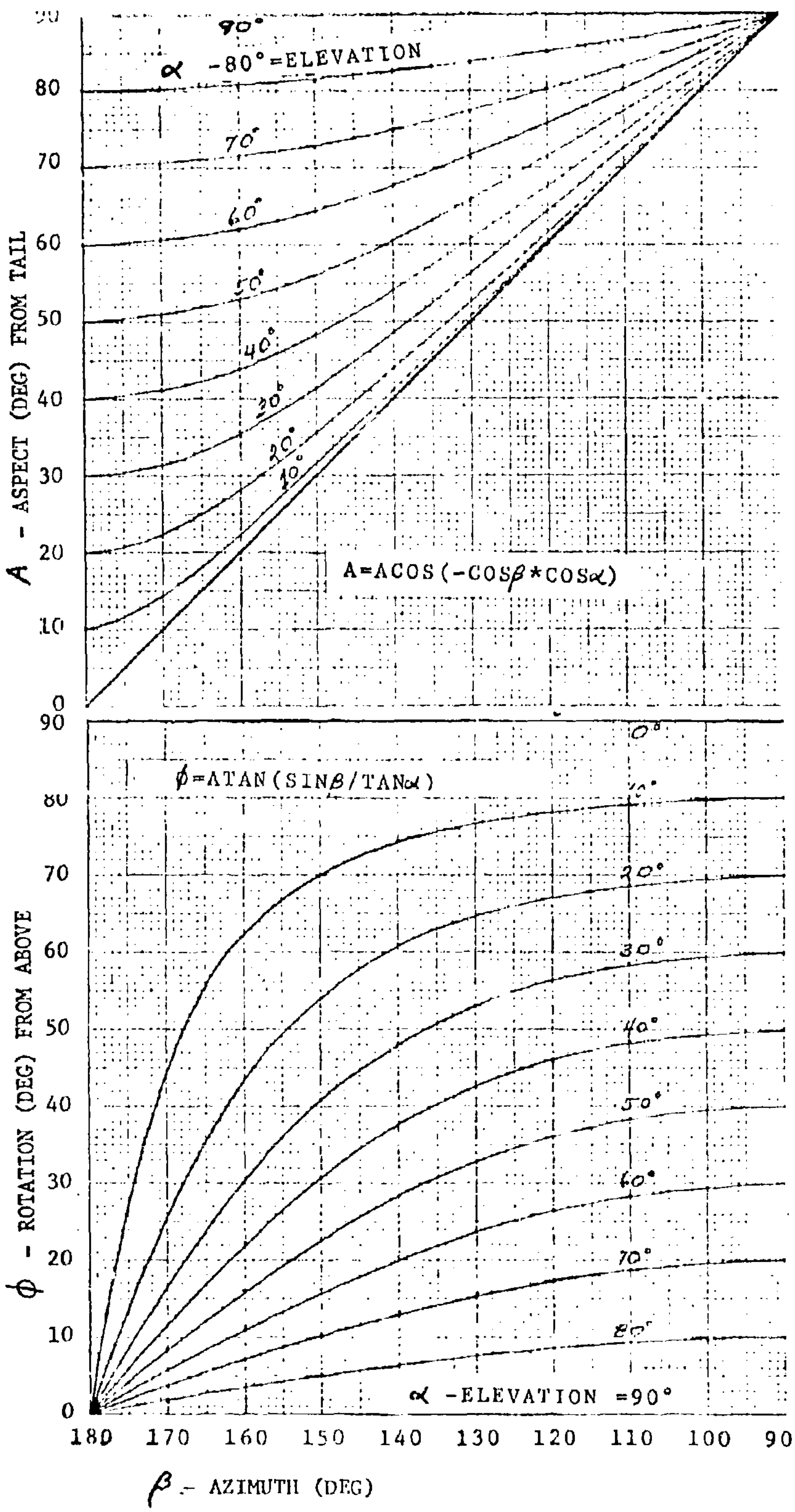
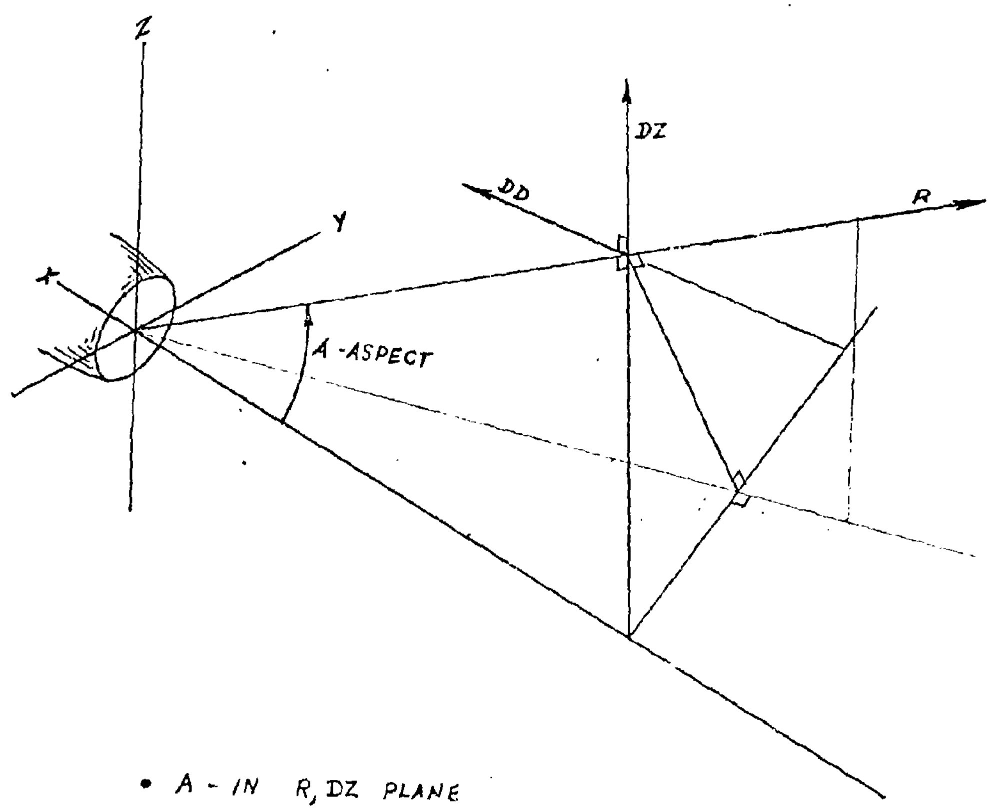



FIGURE A3 GEOMETRIC RESOLUTION




• A - IN R, DZ PLANE
• DZ, DD - PLANE OF APPARENT PROJECTION
• DD - ORTHOGONAL TO DZ AND R

FIGURE A4 GEOMETRIC ORIENTATION - APPARENT PROJECTION

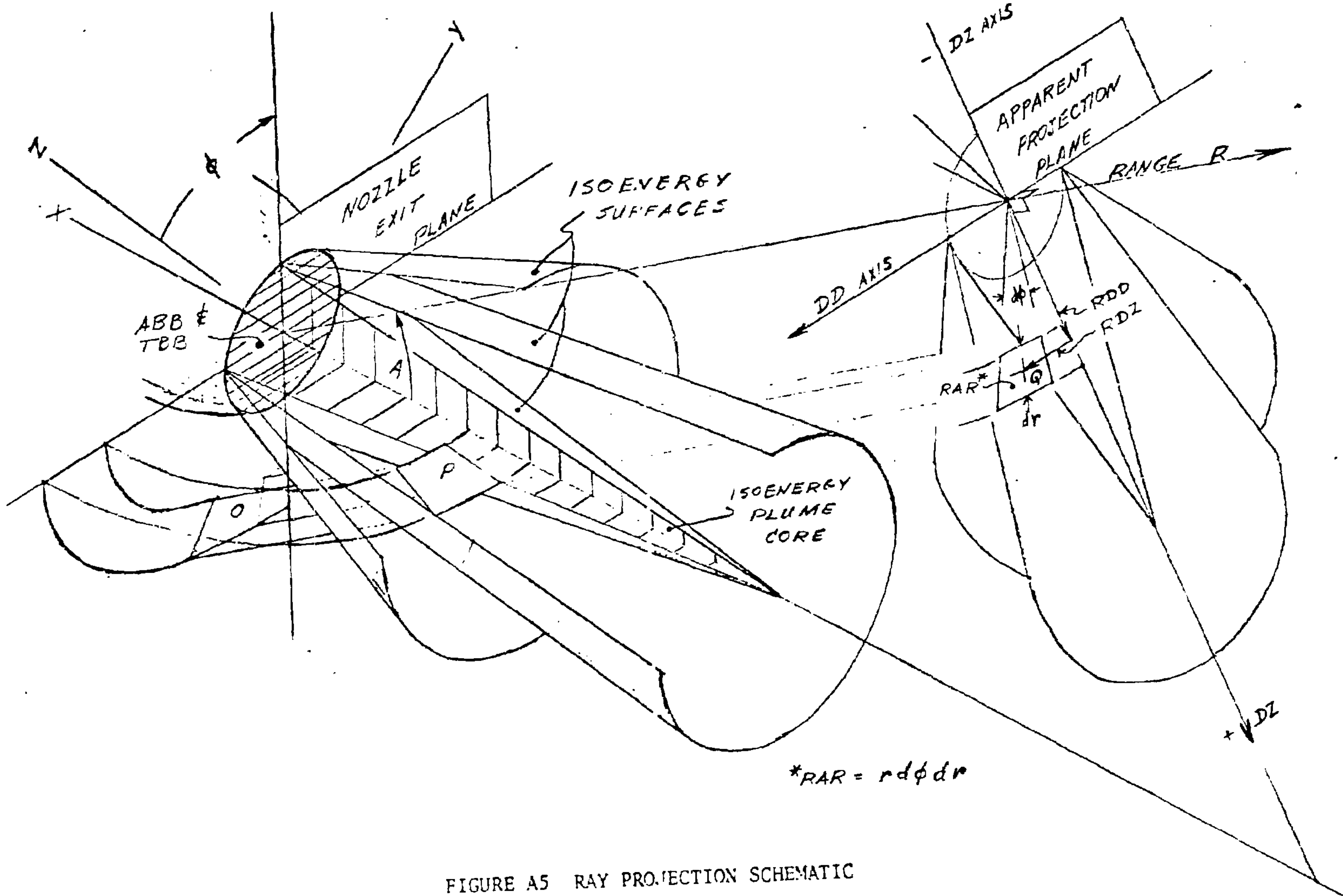



FIGURE A5 RAY PROJECTION SCHEMATIC

* * * A S D I R * * *

PLUME ANALYSIS



* FLIGHT CONDITIONS **

ALTITUDE IS 0. FEET.
WEATHER IS ICAO MIL STD 210 STANDARD DAY
WITH .000330 WATER CONTENT.
VISIBLE CONTRAIL IS NOT EXPECTED
CASE MACH NUMBER IS .22 AT AMBIENT:
PRESSURE OF 14.70 PSIA.
TEMPERATURE OF 519. DEGR.
VELOCITY OF 244. FT/SEC.

ENGINE IS RUNNING WITH A FUEL EQUIVALENCE RATIO (FOR) OF .248

** FLOW FIELD INPUT

| RADIUS (FEET) | VELOCITY (FT/SEC) | TEMPERATURE (DEG R) | XCO2 | XH2O |
|---|---|---|---|---|
| 0.0000 | 1856.08 | 1769.02 | .033149 | .036796 |
| .0500 | 1856.08 | 1769.02 | .033149 | .036796 |
| .1000 | 1856.08 | 1769.02 | .033149 | .036796 |
| .1500 | 1856.08 | 1769.02 | .033149 | .036796 |
| .2000 | 1856.08 | 1769.02 | .033149 | .036796 |
| .2500 | 1856.08 | 1769.02 | .033149 | .036796 |
| .3000 | 1856.08 | 1769.02 | .033149 | .036796 |
| .3500 | 1856.08 | 1769.02 | .033149 | .036796 |
| .4000 | 1856.08 | 1769.02 | .033149 | .036796 |
| .4500 | 1856.08 | 1769.02 | .033149 | .036796 |
| .5000 | 1856.08 | 1769.02 | .033149 | .036796 |
| ** AMBIENT CONDITIONS | | | | |
| .5500 | 243.82 | 518.67 | .000330 | .000330 |

** INPUT PARAMETERS

| | | PLUME | AMBIENT |
|---|---|---|---|
| PRESSURE, | P | 1.303 | 1.000 ATMOS. |
| SPECIFIC HEAT, | CP | .294 BTU/LB-F | |
| GAS CONSTANT, | R | 53.456 FT/F | |
| SP. HT. RATIO | | 1.305 | |
| MACH NUMBER | | 1.000 | |

DPDX = 0.000000
R8= .500 XC= 2.536 REND= 43.65 XL= 147.933

FIGURE A6 DEFAULT OUTPUT HEADER

```
$CASE
ABB      = 0.0,
AL       = .1E+04,
ALTOBS   = 0.0, 0.0, 0.0, 0.0, 0.0,
ALTPLM   = 0.0,
AMF      = .21E+01,
AMI      = .2E+01,
ASPDEG   = .9E+02,
DDS      = .16E+02,
EAREA    = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
ETEMP    = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
IFILTER  = 0,
IL       = -1,
IRADCK   = 0,
ISPAT    = 0,
ITAU     = -1,
ITYPE    = 1,
KDATA    = 1,
NA       = 5,
NANGSEG  = 3,
NATMO    = 2,
NEXIT    = 5,
NEXT     = 0,
NFLW     = 0,
NP       = 0,
NRANG    = 1,
NUINC    = .5E+02,
RANGE    = 0.0, 0.0, 0.0, 0.0, 0.0,
RAYPNT   = 0.0,
TBACK    = 0.0,
TBB      = 0.0,
TERM     = F,
NUFRST   = 0,
ICHECK   = -2,
RPN      = 0.0,
RTE      = 0.0,
ANL      = 0.0,
RSN      = 0.0,
XP       = 0.0,
RP       = 0.0,
AR       = 0.0,
$END
```

FIGURE A7 DEFAULT OUTPUT LISTING OF NAMELIST INPUT

```
$PLUMIN
RPN    = .5E+00,
RSN    = .5E+00,
XP     = 0.0,
RP     = 0.0,
KDATA  = 1,
TANE   = .9E+01,
EQR    = .25E+00,
XCO2   = .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,
         .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,
         .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,
XH2O   = .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,
         .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,
XCO2A  = .33E-03,
XH2OA  = .33E-03,
U8     = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
T8T    = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0
P8     = 0.0,
PQ     = 0.0,
UA     = .1E+02,
TA     = .519E+03,
PA     = 0.0,
$END
```

FIGURE A7 DEFAULT OUTPUT LISTING OF NAMELIST INPUT (cont'd)

```
$POWER
METEC  = 0,
NORM   = 1,
JET    = 1,
FLTM   = .2E+00,
TSFCC  = .996E+00,
RREC   = .1E+01,
FN     = .2593E+04,
FNRT   = .2593E+04,
EPR    = .23298E+01,
FPR    = 0.0,
TTPN   = .1758E+04,
TTSN   = 0.0,
WAPAC  = .439E+02,
WASAC  = 0.0,
$END
```

FIGURE A7 DEFAULT OUTPUT LISTING OF NAMELIST INPUT(cont'd)

```
*** POINT SOURCE IR INTENSITY ***

    SPECTRAL BAND     - 2.00 TO 2.10 MICRONS
    VEHICLE ALTITUDE  -  0.00 KM OR  0.00 KFT
    ASPECT ANGLE      -  90.0 DEGREES IN A NOR. ATMOSPHERE.
    EFFECTIVE BLACK BODY AREA -   ABB =   0.0000 CMSQ
    EFFECTIVE BB TEMPERATURE  -   TBB =   0.0000 DEGK
    EFFECTIVE BACKGROUND TEMP - TBACK =   0.0000 DEGK

    SLT RNG (KM/NM)     0./   0.
    OB ALT (KM/KFT)     0./   0.

    BCKGRND (W/STR)     0.0000
    METALS  (W/STR)     0.0000
    ATT MET (W/STR)     0.0000
    PLM GAS (W/STR)      .0092
    EXT EMS (W/STR)     0.0000
    APP RAD (W/STR)      .0092
```

FIGURE A8  DEFAULT IR SIGNATURE OUTPUT

APPENDIX B

## GENERIC NOZZLE I DEMONSTRATION

A typical turbofan engine-only case has been developed for the purpose of demonstrating the basic operation of ASDIR-II. Various basic output modes are also demonstrated. This initial demonstration involves only the IR energy radiated from the internal hot parts and plume of a separate-flow, coplanar, axisymmetrice turbofan engine exhaust nozzle. The nozzle diagram for Generic Nozzle I (GN-1) is shown in Figure B1. This rather short exhaust system is sectioned into two streams and each stream is sectioned into several fluid nodes. The stream fluid nodes are defined by the containing surface nodes as indicated in the figure. The surface node length is selected such that the geometric curvature is negligible, the surface temperature along the node may be considered constant and (or) the length does not appreciably exceed about 20 inches. The entrance and exit nodes are numbered (last) as if they were a surface node and are assigned a temperature and emissivity as if they were a solid surface. Of course an exit node appears, in radiance, as if it were a cold surface represented by the background temperature. Since radiant energy passes freely through an entrance or exit (surface) node, the assigned emissivity is unity (1.0) as if the physical mechanism were 100% absorption or emission, which it is. GN-1 also employs the special fluid nodes representing thermal sinks (or sources), and conduction nodes of heat transfer.

The internal and external radiant view factors are to be generated by ASDIR-II by use of the 03 code in IDS-1 and the -1 code in IB-7. The last card of the view factor Input Data Deck is, appropriately, IB-48. A computer listing of this Input Data Deck with instruction steps annotated for the view factors of GN-1 is shown in Figure B2. The view factor run also provides a summary of the internal flow parameters, calculated wall temperatures, etc. in its output if these quantities were requested in IB-2. The full output (print codes 1 through 10 requested) is provided in Figure B3. In addition to the printed output, this program execution also provides the punched (view factor and area) cards. The punched deck "header" card and "end" card are removed and the deck is inserted into the Input Data Deck as IB-10 and IB-11 as punched. The controls of IDS-1, IB-2, and IB-7 are changed, in this case, to 01 code, Zero's, and 01 code respectively. The remaining input cards are provided (IB-49 etc.) as required and the Input Data Deck is ready of generate the IR signature of GN-1 of Figure B1 and its plume as shown in Figure B4. Figure B4 is also annotated along the left margin with instruction steps.

A summary of the internal hot parts emission eminating from the nozzle is provided in the output which shows equivalent black body area (ABB) and temperature (TBB) as a function of aspect angle (ASPDEG). This summary, shown in Figure B5, is developed in ASDIR-II by expressing the peak radiant energy of the hot parts emission in terms of area and temperature. Further along in the program, the emission from the engine interior is determined from these areas and temperatures by using the black body spectra over the specific IR band of interest. For this reason, the band stated in Figure B5 must exceed the specific IR band of interest and must extend to a sufficiently long wavelength so that the " *** CHECK" notation is not printed. This upper band limit is controlled by WL in IB-56. The IR signature "output header", shown in Figure B6, provides, primarily, case description summary information. The contrail comment is preemptive and is (at reporting time) inoperative.

The input data of IDS-2 and IDS-5 are printed in the output to show the input data actually controlling the program. The output listing shown in Figure B-7, are quite helpful in diagnosing a troublesome run if the input data was actually different than intended. These namelist writes occur soon after the namelist read only when ICHECK=-2.

A gas data description of the plume is printed in the output when the second digit (D) of KDATA is set to 1, as shown in Figure B8. A total of 49 stations are generated and printed, but only a few printer pages are included in the figure. When the first digit (E) of KDATA is non-unity, selected quantities of the plume gas data are plotted on the line printer. A value of five (5) will plot the velocity values in the plume as shown in Figure B9. The output format for the IR signature is shown in Figure B10. Again, because of the many pages of printer output, only a few aspect angles are shown. It should be noted that altitudes and ranges are printed-out in kilometers. The spatially resolved IR emission can be plotted by use of an auxilliary CALCOMP program and plotter. ASDIR-II will produce data cards suitable for such spatial plot by designating ISPAT=2. The resulting plot will appear as Figure B11 for a broadside aspect of 90 degrees. When ISPAT is specified 1 or 2, the spatial data is printed as shown in Figure B12. In this data listing, the columns are headed by quantities described in Figure A3 and A4 of appendix A. Intensity values are listed as watts per steradian per $cm^2$ under headings of range and designation of filter. The IR signature is plotted in polar form in Figure B13 in which is shown the effects of range and observer altitude.

## APPENDIX B FIGURES

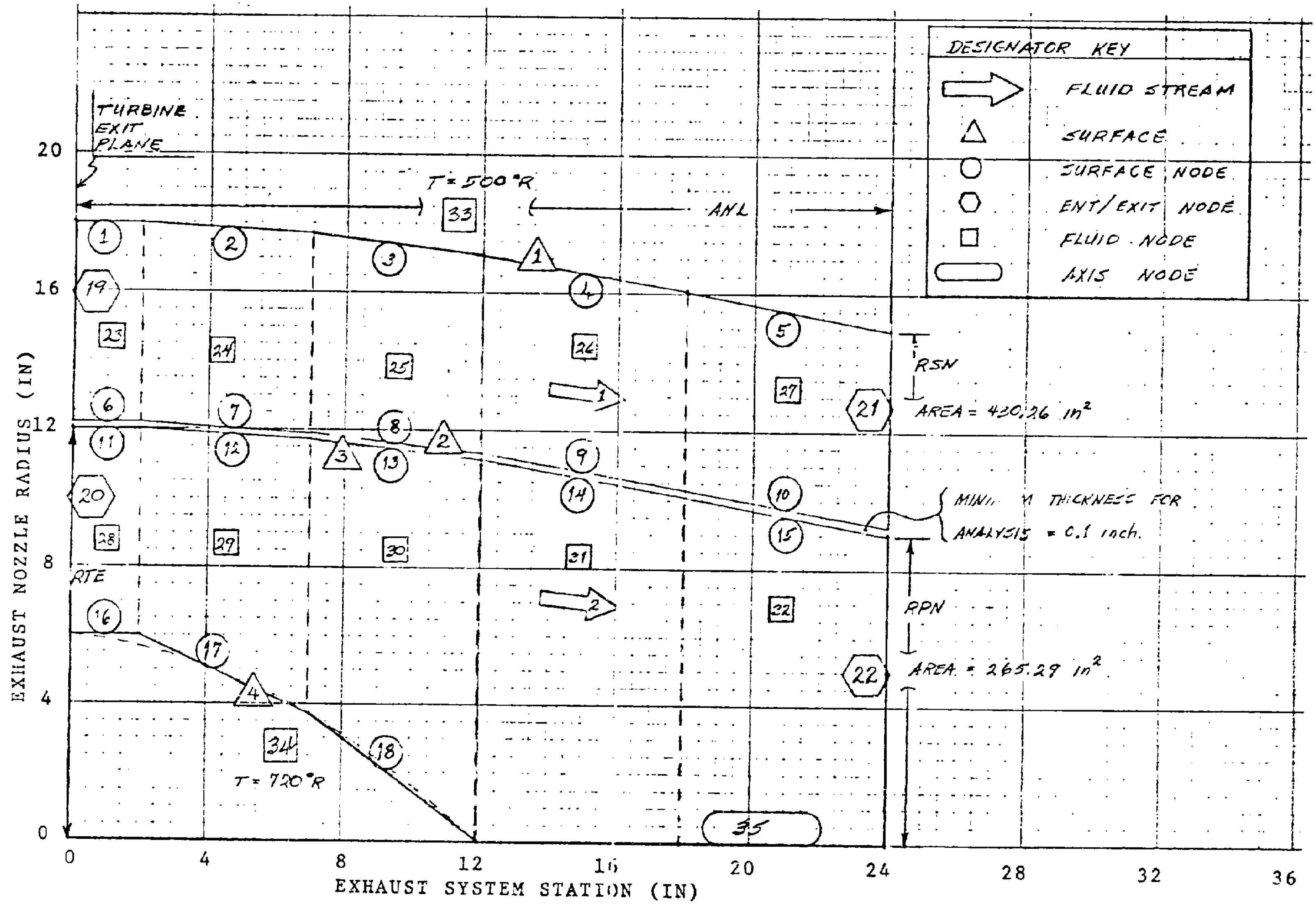



FIGURE B1 GN-1 NOZZLE DIAGRAM

```
IDS 1   03
IB1                 <<-***************->>
1           THIS IS THE FIRST ASDIR II SAMPLE INPUT SET
1                               <-->
1           <<-         GENERIC NOZZLE I            ->>
1                   <<-***************->>
2
3        0204180401
4      0.0      18.0      2.0      18.0      -1.0      0101
4      2.0      18.0      7.0      17.7      -1.0      0201
4      7.00     17.7      12.0     17.1      -1.0      0301
4      12.0     17.1      18.0     16.1      -1.0      0401
4      18.0     16.1      24.0     15.0      -1.0      0501
4      0.0      12.2      2.0      12.2      +1.0      0602
4      2.0      12.2      7.0      11.9      +1.0      0702
4      7.0      11.9      12.0     11.3      +1.0      0802
4      12.0     11.3      18.0     10.3      +1.0      0902
4      18.0     10.3      24.0     9.38318   +1.0      1002
4      0.0      12.0      2.0      12.0      -1.0      1103
4      2.0      12.0      7.0      11.7      -1.0      1203
4      7.0      11.7      12.0     11.1      -1.0      1303
4      12.0     11.1      18.0     10.1      -1.0      1403
4      18.0     10.1      24.0     9.18936   -1.0      1503
4      0.0      6.0       2.0      6.0       +1.0      1604
4      2.0      6.0       7.0      3.7       +1.0      1704
4      7.0      3.7       12.0     0.0       +1.0      1804
4      12.0     00.0      24.0     00.0      +1.0      3504
5      0.00     12.2      0.00     18.0      -1.0      0600.0    19
5      0.00     6.00      0.00     12.0      -1.0      1330.0    20
5      24.0     9.38318   24.0     15.0      +1.0      0450.0    21
5      24.0     00.0      24.0     9.18936   +1.0      0460.0    22
6      24.0
7        00-1
14       010500
15       0102030405
14       0205
15       0607080910
14       0305
15       1112131415
14       040400
15       16171835
16       010001   00.0      24.0
17     430.26
18       05
19       2300     01.0
19       2400     04.5
19       2500     09.5
19       2600     15.0
19       2700     21.
20       0100     0.1       1.3
20       0200     0.1       1.3
16       020101   0.0       24.0
17     265.29
18       0500
19       2801     1.0
19       2901     4.5
19       3001     9.5
19       3101     15.0
19       3201     21.0
20       0301     0.001     1.3
20       0401     0.001     1.3
41       00
43     22.636     1400.0    53.38     1.33      [illegible]402
44     23.154     605.0     53.3      1.40      215.56
45     12.232
46       0123022403250426052706230724082509261027112812291[illegible]0143115[illegible]17291830
         1923202821272232
47       00
47       00
```

FIGURE B2   GN-1 VIEW FACTOR INPUT DATA DECK

A I R C R A F T   S I G N A T U R E

P R E D I C T I O N   P R O G R A M

THESE RESULTS CONTAIN THE FOLLOWING INFORMATION,

1. COMPOUND COMPRESSIBLE FLOW INFORMATION.
2. SURFACE HEAT TRANSFER INFORMATION.
3. AVERAGE SURFACE HEAT TRANSFER COEFFICIENTS.
4. AVERAGE SYSTEM GAS TEMPERATURES.
5. SURFACE COOLING INFORMATION.
6. SYSTEM SURFACE FORCE FACTOR CALCULATIONS.
7. SYSTEM INTERNAL VIEW FACTORS.
8. SYSTEM WALL TEMPERATURES.
9. SYSTEM EXTERNAL VIEW FACTORS.
10. SYSTEM RADIATION PATTERNS.
11. SYSTEM RADIATION LEVEL BANDWIDTHS.

FIGURE B3 GN-1 OUTPUT OF NOZZLE INTERNAL ANALYSIS

FLOW STREAM NO. 1 FLOW INFORMATION

| AXIAL DISTANCE (INCHES) | OUTER SURF DIS (INCHES) | INNER SURF DIS (INCHES) | FLOW AREA (SQIN) | STATIC PRESS (LB/SQIN) | PRIMARY MACH NO | PRIMARY REC TEMP (DEG R.) | PRIMARY VELOCITY (FT/SEC) | PRIMARY DENSITY (LB/CUFT) |
|---|---|---|---|---|---|---|---|---|
| 0.00 | 12.00 | 6.00 | 339.29 | 18.76 | .5375 | 1292.23 | 905.32 | .0408 |
| 1.00 | 12.00 | 6.00 | 339.29 | 18.76 | .5375 | 1292.23 | 905.32 | .0408 |
| 2.00 | 12.00 | 6.00 | 339.29 | 18.76 | .5375 | 1292.23 | 905.32 | .0408 |
| 3.00 | 11.94 | 5.54 | 351.46 | 19.10 | .5109 | 1292.95 | 862.41 | .0413 |
| 4.00 | 11.88 | 5.08 | 362.31 | 19.36 | .4898 | 1293.49 | 828.11 | .0418 |
| 5.00 | 11.82 | 4.62 | 371.80 | 19.56 | .4729 | 1293.92 | 800.53 | .0421 |
| 6.00 | 11.76 | 4.16 | 380.11 | 19.72 | .4593 | 1294.25 | 778.42 | .0423 |
| 7.00 | 11.70 | 3.70 | 387.04 | 19.84 | .4480 | 1294.50 | 760.89 | .0425 |
| 8.00 | 11.58 | 2.96 | 393.75 | 19.95 | .4388 | 1294.73 | 744.79 | .0427 |
| 9.00 | 11.46 | 2.22 | 397.11 | 20.01 | .4341 | 1294.84 | 737.02 | .0428 |
| 10.00 | 11.34 | 1.48 | 397.11 | 20.01 | .4341 | 1294.84 | 737.00 | .0428 |
| 11.00 | 11.22 | .74 | 393.77 | 19.96 | .4388 | 1294.73 | 744.74 | .0427 |
| 12.00 | 11.10 | .00 | 387.08 | 19.84 | .4486 | 1294.50 | 760.81 | .0425 |
| 13.00 | 10.93 | 0.00 | 375.54 | 19.63 | .4667 | 1294.07 | [illegible] | .0422 |
| 14.00 | 10.77 | 0.00 | 364.18 | 19.40 | .4864 | 1293.58 | 822.55 | .0418 |
| 15.00 | 10.60 | 0.00 | 352.99 | 19.14 | .5078 | 1293.03 | 857.35 | .0414 |
| 16.00 | 10.43 | 0.00 | 341.98 | 18.84 | .5314 | 1292.40 | 895.39 | .0409 |
| 17.00 | 10.27 | 0.00 | 331.14 | 18.50 | .5575 | 1291.68 | 937.33 | .0404 |
| 18.00 | 10.10 | 0.00 | 320.47 | 18.12 | .5868 | 1290.84 | 984.06 | .0397 |
| 19.00 | 9.95 | 0.00 | 310.91 | 17.71 | .6171 | 1289.94 | 1031.92 | .0391 |
| 20.00 | 9.80 | 0.00 | 301.50 | 17.23 | .6519 | 1288.86 | 1086.41 | .0383 |
| 21.00 | 9.64 | 0.00 | 292.23 | 16.65 | .6931 | 1287.53 | 1150.13 | .0373 |
| 22.00 | 9.49 | 0.00 | 283.11 | 15.91 | .7442 | 1285.81 | 1228.07 | .0360 |
| 23.00 | 9.34 | 0.00 | 274.13 | 14.89 | .8145 | 1283.32 | 1332.99 | .0343 |
| 24.00 | 9.19 | 0.00 | 265.29 | 12.29 | .9961 | 1276.39 | 1591.89 | .0297 |

FIGURE B3 GN-1 OUTPUT OF NOZZLE INTERNAL ANALYSIS(cont'd)

FLOW STREAM NO. 1 HEAT TRANSFER INFORMATION
SURFACE NO. 1

| X (IN.) | Y (IN.) | MACH NO | DEL (IN.) | SKIN FRICTION | HT (BTU/SQFT,HR,DEGF) |
|---|---|---|---|---|---|
| 0.000 | 6.000 | .538 | .010988 | .008347 | 133.728 |
| 1.000 | 6.000 | .538 | .037868 | .005282 | 91.495 |
| 2.000 | 6.000 | .538 | .059988 | .004622 | 80.700 |
| 3.000 | 5.540 | .511 | .089297 | .003992 | 71.189 |
| 4.000 | 5.080 | .490 | .122156 | .003296 | 63.783 |
| 5.000 | 4.620 | .473 | .157255 | .002790 | 58.351 |
| 6.000 | 4.160 | .459 | .196524 | .002401 | 54.019 |
| 7.000 | 3.700 | .449 | .242001 | .002097 | 50.385 |
| 8.000 | 2.960 | .439 | .324722 | .001805 | 45.991 |
| 9.000 | 2.220 | .434 | .448969 | .001570 | 41.908 |
| 10.000 | 1.480 | .434 | .654383 | .001427 | 37.943 |
| 11.000 | .740 | .439 | 1.061136 | .001331 | 33.54[illegible] |
| 12.000 | [illegible] | .449 | [illegible] | .001237 | 28.7[illegible] |



FIGURE B3 GN-1 OUTPUT OF NOZZLE INTERNAL ANALYSIS (cont'd)

FLOW STREAM NO. 1 HEAT TRANSFER INFORMATION
SURFACE NO. 2

| X (IN.) | Y (IN.) | MACH NO | DEL (IN.) | SKIN FRICTION | HT (BTU/SQFT,HR,DEGF) |
|---|---|---|---|---|---|
| 0.000 | 12.[illegible] | .539 | .010088 | .008347 | 133.728 |
| 1.000 | 12.030 | .538 | .037868 | .005282 | 91.495 |
| 2.000 | 12.010 | .538 | .059988 | .004622 | 80.700 |
| 3.000 | 11.940 | .511 | .081868 | .004078 | 72.848 |
| 4.000 | 11.880 | .490 | .103988 | .003428 | 66.553 |
| 5.000 | 11.820 | .473 | .124452 | .002961 | 62.101 |
| 6.000 | 11.760 | .459 | .143829 | .002617 | 58.748 |
| 7.000 | 11.700 | .449 | .162399 | .002367 | 56.147 |
| 8.000 | 11.580 | .439 | .181493 | .002170 | 53.884 |
| 9.000 | 11.460 | .434 | .199096 | .002058 | 52.296 |
| 10.000 | 11.340 | .434 | .215296 | .002087 | 51.465 |
| 11.000 | 11.220 | .439 | .228257 | .002231 | 51.292 |
| 12.000 | 11.100 | .449 | .239119 | .002472 | 51.719 |
| 13.000 | 10.933 | .467 | .249159 | .002809 | 52.834 |
| 14.000 | 10.767 | .486 | .258879 | .003162 | 54.087 |
| 15.000 | 10.600 | .508 | .27[illegible]882 | .003457 | 55.165 |
| 16.000 | 10.433 | .531 | .285411 | .003707 | 56.050 |
| 17.000 | 10.267 | .557 | .302026 | .003918 | 56.727 |
| 18.000 | 10.100 | .587 | .321524 | .004102 | 57.161 |
| 19.000 | 9.948 | .617 | .343907 | .004255 | 57.260 |
| 20.000 | 9.796 | .652 | .370629 | .004379 | 56.964 |
| 21.000 | 9.645 | .693 | .401572 | .004494 | 56.243 |
| 22.000 | 9.493 | .744 | .438099 | .004604 | 54.872 |
| 23.000 | 9.341 | .814 | .483148 | .004720 | 52.281 |
| 24.000 | 9.189 | .996 | .566934 | .004913 | 42.943 |

FIGURE B3 GN-1 OUTPUT OF NOZZLE INTERNAL ANALYSIS (cont'd)

FLOW STREAM NO. 2 FLOW INFORMATION

| AXIAL DISTANCE (INCHES) | OUTER SURF DIS (INCHES) | INNER SURF DIS (INCHES) | FLOW AREA (SQIN) | STATIC PRESS (LB/SQIN) | SECOND. MACH NO | SECOND. REC TEMP (DEG R.) | SECOND. VELOCITY (FT/SEC) | SECOND. DENSITY (LB/CUFT) |
|---|---|---|---|---|---|---|---|---|
| 0.00 | 18.0[illegible] | 12.29 | 550.28 | 19.06 | .5346 | 601.37 | 626.88 | .0900 |
| 1.00 | 18.0[illegible] | 12.2[illegible] | 550.28 | 19.06 | .5346 | 601.37 | 626.88 | .0900 |
| 2.00 | 18.[illegible] | 12.2[illegible] | 550.28 | 19.06 | .5346 | 601.37 | 626.88 | .0900 |
| 3.00 | 17.94 | 12.14 | 548.09 | 19.02 | .5378 | 601.33 | 630.39 | .0898 |
| 4.00 | 17.88 | 12.09 | 545.91 | 18.97 | .5410 | 601.29 | 633.96 | .0897 |
| 5.00 | 17.82 | 12.[illegible] | 543.72 | 18.93 | .5442 | 601.25 | 637.57 | .0895 |
| 6.00 | 17.76 | 11.95 | 541.53 | 18.88 | .5476 | 601.21 | 641.24 | .0894 |
| 7.00 | 17.7[illegible] | 11.9[illegible] | 539.35 | 18.84 | .5509 | 601.17 | 644.97 | .0892 |
| 8.00 | 17.58 | 11.7[illegible] | 534.98 | 18.74 | .5579 | 601.08 | 652.6[illegible] | .0889 |
| 9.00 | 17.46 | 11.65 | 530.60 | 18.54 | .565[illegible] | 600.98 | 66[illegible].46 | .0886 |
| 10.00 | 17.34 | 11.54 | 526.23 | 18.54 | .5724 | 600.88 | 668.50 | [illegible] |
| 11.00 | 17.22 | 11.42 | 521.86 | 18.43 | .5801 | 600.78 | 677.0[illegible] | .0879 |
| 12.00 | 17.1[illegible] | 11.3[illegible] | 517.48 | 18.32 | .5881 | 600.67 | 685.70 | .0875 |
| 13.00 | 16.93 | 11.13 | 511.41 | 18.16 | .5997 | 600.52 | 699.32 | .0869 |
| 14.00 | 16.77 | 10.97 | 505.34 | 1[illegible].98 | .6119 | 600.35 | 711.63 | .0863 |
| 15.00 | 16.6[illegible] | 10.83 | 499.26 | 17.79 | .625[illegible] | 600.16 | 725.70 | .0857 |
| 16.00 | 16.43 | 10.63 | 493.19 | 17.59 | .6389 | 599.96 | 740.64 | .0850 |
| 17.00 | 16.27 | 10.47 | 487.11 | 17.38 | .6538 | 599.75 | 756.57 | .0842 |
| 18.00 | 16.1[illegible] | 10.31 | 481.04 | 17.14 | .6698 | 599.51 | 773.65 | .0834 |
| 19.00 | 15.92 | 10.15 | 472.42 | 16.77 | .6951 | 599.14 | 8[illegible].29 | .0821 |
| 20.00 | 15.73 | 9.99 | 463.86 | 16.34 | .7238 | 598.70 | 830.3[illegible] | .0806 |
| 21.00 | 15.55 | 9.84 | 455.36 | 15.83 | .7575 | 598.18 | 855.00 | .0788 |
| 22.00 | 15.37 | 9.69 | 446.93 | 15.21 | .7988 | 597.52 | 9[illegible].94 | .0766 |
| 23.00 | 15.18 | 9.54 | 438.56 | 14.36 | .8548 | 596.60 | 952.68 | .073[illegible] |
| 24.00 | 15.0[illegible] | 9.38 | 430.26 | 12.27 | .9973 | 594.16 | 10[illegible]8.18 | .0657 |

FIGURE B3 [illegible] OUTPUT OF NOZZLE INTERNAL ANALYSIS (cont'd)

FLOW STREAM NO. 2 HEAT TRANSFER INFORMATION
SURFACE NO. 3

| X (IN.) | Y (IN.) | MACH NO | DEL (IN.) | SKIN FRICTION | HT (BTU/SQFT,HR,DEGF) |
|---|---|---|---|---|---|
| 0.000 | 12.260 | .535 | 1.009799 | .001884 | 40.032 |
| 1.000 | 12.230 | .535 | 1.021922 | .001853 | 39.931 |
| 2.000 | 12.200 | .535 | 1.034055 | .001832 | 39.842 |
| 3.000 | 12.140 | .538 | 1.049769 | .001839 | 39.793 |
| 4.000 | 12.080 | .541 | 1.062048 | .001909 | 39.829 |
| 5.000 | 12.020 | .544 | 1.074518 | .001928 | 39.862 |
| 6.000 | 11.960 | .545 | 1.087183 | .001946 | 39.893 |
| 7.000 | 11.900 | .551 | 1.100385 | .001964 | 39.921 |
| 8.000 | 11.780 | .558 | 1.117578 | .001989 | 39.993 |
| 9.000 | 11.650 | .565 | 1.131519 | .002025 | 40.135 |
| 10.000 | 11.540 | .572 | 1.145943 | .002060 | 40.266 |
| 11.000 | 11.420 | .580 | 1.160870 | .002094 | 40.387 |
| 12.000 | 11.300 | .588 | 1.176320 | .002128 | 40.495 |
| 13.000 | 11.133 | .600 | 1.196109 | .002165 | 40.635 |
| 14.000 | 10.967 | .612 | 1.213631 | .002212 | 40.755 |
| 15.000 | 10.800 | .625 | 1.232009 | .002257 | 40.875 |
| 16.000 | 10.633 | .639 | 1.251411 | .002301 | 40.959 |
| 17.000 | 10.467 | .654 | 1.271932 | .002345 | 41.000 |
| 18.000 | 10.300 | .670 | 1.293684 | .002398 | 40.991 |
| 19.000 | 10.147 | .695 | 1.315274 | .002444 | 40.892 |
| 20.000 | 9.994 | .724 | 1.332175 | .002515 | 40.755 |
| 21.000 | 9.842 | .757 | 1.352184 | .002588 | 40.379 |
| 22.000 | 9.689 | .799 | 1.376560 | .002665 | 39.627 |
| 23.000 | 9.536 | .855 | 1.408813 | .002750 | 38.153 |
| 24.000 | 9.383 | .997 | 1.489334 | .002872 | 32.509 |

FIGURE B3 GN-1 OUTPUT OF NOZZLE THERMAL ANALYSIS(cont'd)

FLOW STREAM NO. 2 HEAT TRANSFER INFORMATION
SURFACE NO. 4

| X (IN.) | Y (IN.) | MACH NO | DEL (IN.) | SKIN FRICTION | HT (BTU/SQFT,HR,DEGF) |
|---|---|---|---|---|---|
| 0.000 | 18.000 | .535 | 1.009799 | .001834 | 40.032 |
| 1.000 | 18.000 | .535 | 1.021922 | .001883 | 39.931 |
| 2.000 | 18.000 | .535 | 1.034555 | .001882 | 39.872 |
| 3.000 | 17.940 | .538 | 1.048296 | .001890 | 39.818 |
| 4.000 | 17.880 | .541 | 1.059153 | .001910 | 39.858 |
| 5.000 | 17.820 | .544 | 1.070177 | .001930 | 39.906 |
| 6.000 | 17.750 | .548 | 1.081373 | .001949 | 39.950 |
| 7.000 | 17.700 | .551 | 1.092962 | .001967 | 39.994 |
| 8.000 | 17.580 | .558 | 1.106856 | .001994 | 40.097 |
| 9.000 | 17.460 | .565 | 1.117449 | .002032 | 40.270 |
| 10.000 | 17.340 | .572 | 1.128455 | .002069 | 40.433 |
| 11.000 | 17.220 | .58 | 1.139874 | .002105 | 40.585 |
| 12.000 | 17.100 | .588 | 1.151739 | .00214 | 40.726 |
| 13.000 | 16.933 | .600 | 1.166396 | .002185 | 40.881 |
| 14.000 | 16.767 | .612 | 1.178516 | .002229 | 41.078 |
| 15.000 | 16.600 | .625 | 1.191417 | .002277 | 41.245 |
| 16.000 | 16.433 | .639 | 1.205 69 | .002325 | 41.375 |
| 17.000 | 16.267 | .654 | 1.2198 | .002371 | 41.463 |
| 18.000 | 16.100 | .670 | 1.235576 | .002418 | 41.490 |
| 19.000 | 15.917 | .695 | 1.253857 | .002475 | 41.419 |
| 20.000 | 15.733 | .724 | 1.267745 | .002549 | 41.300 |
| 21.000 | 15.550 | .757 | 1.284596 | .002624 | 40.936 |
| 22.000 | 15.367 | .799 | 1.305666 | .002703 | 40.190 |
| 23.000 | 15.183 | .855 | 1.334319 | .002795 | 39.708 |
| 24.000 | 15.000 | .997 | 1.408892 | .002914 | 32.991 |

FIGURE B3 GN-1 OUTPUT OF NOZZLE INTERNAL ANALYSIS(cont'd)

AVERAGE HEAT TRANSFER COEFFICIENTS
(BTU/SQFT,HR,DEGF)

NODE NO. 1
HT COEFFICIENT 99.354
SURFACE AREA 75.398 (SQIN)

NODE NO. 2
HT COEFFICIENT 67.8[illegible]4
SURFACE AREA 2[illegible]5.414 (SQIN)

NODE NO. 3
HT COEFFICIENT 57.513
SURFACE AREA 24[illegible].[illegible]17 (SQIN)

NODE NO. 4
HT COEFFICIENT [illegible]9.354
SURFACE AREA 15[illegible].796 (SQIN)

NODE NO. 5
HT COEFFICIENT 69.199
SURFACE AREA [illegible]48.346 (SQIN)

NODE NO. 6
HT COEFFICIENT [illegible]9.298
SURFACE AREA 733.659 (SQIN)

NODE NO. 7
HT COEFFICIENT 56.362
SURFACE AREA 1[illegible]53.436 (SQIN)

NODE NO. 8
HT COEFFICIENT 55.171
SURFACE AREA 1356.228 (SQIN)

NODE NO. 9
HT COEFFICIENT 39.932
SURFACE AREA 153.34[illegible] (SQIN)

NODE NO. 10
HT COEFFICIENT 39.856
SURFACE AREA 455.[illegible]97 (SQIN)

NODE NO. 11
HT COEFFICIENT 40.020
SURFACE AREA 746.291 (SQIN)

NODE NO. 12
HT COEFFICIENT 40.339
SURFACE AREA 1082.444 (SQIN)

NODE NO. 13
HT COEFFICIENT 40.132
SURFACE AREA 1781.543 (SQIN)

NODE NO. 14
HT COEFFICIENT 39.932
SURFACE AREA 226.194 (SQIN)

NODE NO. 15
HT COEFFICIENT 39.856
SURFACE AREA 674.830 (SQIN)

NODE NO. 16
HT COEFFICIENT 40.114
SURFACE AREA 1112.[illegible]41 (SQIN)

NODE NO. 17
HT COEFFICIENT 40.55[illegible]
SURFACE AREA 1633.666 (SQIN)

NODE NO. 18
HT COEFFICIENT 40.435
SURFACE AREA 2116.923 (SQIN)



FIGURE B5 GN-1 OUTPUT OF NOZZLE INTERNAL ANAL[illegible]

FLUID LUMP TEMPERATURES

NODE NO. 23
TEMPERATURE=1292.23 DEG. R.

NODE NO. 24
TEMPERATURE=1293.72 DEG. R.

NODE NO. 25
TEMPERATURE=1294.85 DEG. R.

NODE NO. 26
TEMPERATURE=1293.[illegible]3 DEG. R.

NODE NO. 27
TEMPERATURE=1287.53 DEG. R.

NODE NO. 28
TEMPERATURE= 6[illegible]1.37 DEG. R.

NODE NO. 29
TEMPERATURE= 601.27 DEG. R.

NODE NO. 30
TEMPERATURE= 6[illegible].93 DEG. R.

NODE NO. 31
TEMPERATURE= 6[illegible].15 DEG. R.

NODE NO. 32
TEMPERATURE= 598.18 DEG. R.



SYSTEM SURFACE FORCE FACTORS

| NODE NO. | FORCE FACTOR (LB.) |
|---|---|
| 1 | 1.623 |
| 2 | -1653.8[illegible] |
| 3 | -2788.713 |
| 4 | 3.246 |
| 5 | 523.433 |
| 6 | 1725.746 |
| 7 | 3419.728 |
| 8 | 3813.784 |
| 9 | 1.101 |
| 10 | -514.581 |
| 11 | -1663.360 |
| 12 | -3260.343 |
| 13 | -3652.797 |
| 14 | 1.624 |
| 15 | 7[illegible]1.776 |
| 16 | 2496.840 |
| 17 | 4948.141 |
| 18 | 6721.361 |
| TOTAL NET SURFACE FORCE FACTOR | 10597.747 |

FIGURE B3 GN-1 OUTPUT OF NOZZLE INTERNAL ANALYSIS(cont'd)

```
SYSTEM INTERNAL VIEW FACTORS

F( 1, 1)=  .02777          F( 1, 1)=  .02777
F( 1, 2)=  .05910          F( 2, 1)=  .02380
F( 1, 3)=  .04071          F( 3, 1)=  .01672
F( 1, 4)=  .03051          F( 4, 1)=  .01083
F( 1, 5)=  .01696          F( 5, 1)=  .00644
F( 1, 6)=  .12469          F( 6, 1)=  .18397
F( 1, 7)=  .18935          F( 7, 1)=  .11293
F( 1, 8)=  .04536          F( 8, 1)=  .02795
F( 1, 9)=  .01197          F( 9, 1)=  .00655
F( 1,10)=  .00383          F(10, 1)=  .00231
F( 1,11)= 0.00000          F(11, 1)= 0.00000
F( 1,12)= 0.00000          F(12, 1)= 0.00000
F( 1,13)= 0.00000          F(13, 1)= 0.00000
F( 1,14)= 0.00000          F(14, 1)= 0.00000
F( 1,15)= 0.00000          F(15, 1)= 0.00000
F( 1,16)= 0.00000          F(16, 1)= 0.00000
F( 1,17)= 0.00000          F(17, 1)= 0.00000
F( 1,18)= 0.00000          F(18, 1)= 0.00000
F( 1,19)=  .42323          F(19, 1)=  .17397
F( 1,20)= 0.00000          F(20, 1)= 0.00000
F( 1,21)=  .02643          F(21, 1)=  .01393
F( 1,22)= 0.00000          F(22, 1)= 0.00000
            AREA( 1)=  226.19 SQ. IN.

F( 2, 2)=  .06488          F( 2, 2)=  .06488
F( 2, 3)=  .05240          F( 3, 2)=  .05347
F( 2, 4)=  .03984          F( 4, 2)=  .03528
F( 2, 5)=  .02205          F( 5, 2)=  .02078
F( 2, 6)=  .08216          F( 6, 2)=  .33198
F( 2, 7)=  .27333          F( 7, 2)=  .49489
F( 2, 8)=  .12333          F( 8, 2)=  .13876
F( 2, 9)=  .03023          F( 9, 2)=  .04115
F( 2,10)=  .00742          F(10, 2)=  .01110
F( 2,11)= 0.00000          F(11, 2)= 0.00000
F( 2,12)= 0.00000          F(12, 2)= 0.00000
F( 2,13)= 0.00000          F(13, 2)= 0.00000
F( 2,14)= 0.00000          F(14, 2)= 0.00000
F( 2,15)= 0.00000          F(15, 2)= 0.00000
F( 2,16)= 0.00000          F(16, 2)= 0.00000
F( 2,17)= 0.00000          F(17, 2)= 0.00000
F( 2,18)= 0.00000          F(18, 2)= 0.00000
F( 2,19)=  .24924          F(19, 2)=  .25445
F( 2,20)= 0.00000          F(20, 2)= 0.00000
F( 2,21)=  .03209          F(21, 2)=  .04190
F( 2,22)= 0.00000          F(22, 2)= 0.00000
            AREA( 2)=  561.78 SQ. IN.

F( 3, 3)=  .06695          F( 3, 3)=  .06695
F( 3, 4)=  .06083          F( 4, 3)=  .05279
F( 3, 5)=  .03438          F( 5, 3)=  .03176
F( 3, 6)=  .02256          F( 6, 3)=  .09100
F( 3, 7)=  .16296          F( 7, 3)=  .23658
F( 3, 8)=  .27019          F( 8, 3)=  .40528
F( 3, 9)=  .11945          F( 9, 3)=  .15933
F( 3,10)=  .02219          F(10, 3)=  .03255
F( 3,11)= 0.00000          F(11, 3)= 0.00000
F( 3,12)= 0.00000          F(12, 3)= 0.00000
F( 3,13)= 0.00000          F(13, 3)= 0.00000
F( 3,14)= 0.00000          F(14, 3)= 0.00000
F( 3,15)= 0.00000          F(15, 3)= 0.00000
F( 3,16)= 0.00000          F(16, 3)= 0.00000
F( 3,17)= 0.00000          F(17, 3)= 0.00000
F( 3,18)= 0.00000          F(18,    = 0.00000
F( 3,19)=  .12404          F(19, 3)=  .12418
F( 3,20)= 0.00000          F(20, 3)= 0.00000
F( 3,21)=  .04717          F(21, 3)=  .06035
F( 3,22)= 0.00000          F(22, 3)= 0.00000
            AREA( 3)=  550.56 SQ. IN.
```

FIGURE B3 GN-1 OUTPUT OF NOZZLE INTERNAL ANALYSIS (cont'd)

## SYSTEM INTERNAL VIEW FACTORS

| | |
|---|---|
| F( 4, 4)= .08315 | F( 4, 4)= .08315 |
| F( 4, 5)= .05913 | F( 5, 4)= .05294 |
| F( 4, 6)= .00506 | F( 6, 4)= .02093 |
| F( 4, 7)= .03938 | F( 7, 4)= .06588 |
| F( 4, 8)= .15733 | F( 8, 4)= .27292 |
| F( 4, 9)= .30139 | F( 9, 4)= .46325 |
| F( 4,10)= .10063 | F(10, 4)= .17010 |
| F( 4,11)= 0.00000 | F(11, 4)= 0.00000 |
| F( 4,12)= 0.00000 | F(12, 4)= 0.00000 |
| F( 4,13)= 0.00000 | F(13, 4)= 0.00000 |
| F( 4,14)= 0.00000 | F(14, 4)= 0.00000 |
| F( 4,15)= 0.00000 | F(15, 4)= 0.00000 |
| F( 4,16)= 0.00000 | F(16, 4)= 0.00000 |
| F( 4,17)= 0.00000 | F(17, 4)= 0.00000 |
| F( 4,18)= 0.00000 | F(18, 4)= 0.00000 |
| F( 4,19)= .06922 | F(19, 4)= .07981 |
| F( 4,20)= 0.00000 | F(20, 4)= 0.00000 |
| F( 4,21)= .08632 | F(21, 4)= .12729 |
| F( 4,22)= 0.00000 | F(22, 4)= 0.00000 |
| AREA( 4)= 634.44 SQ. IN. | |
| F( 5, 5)= .09024 | F( 5, 5)= .09024 |
| F( 5, 6)= .00105 | F( 6, 5)= .00407 |
| F( 5, 7)= .00797 | F( 7, 5)= .01237 |
| F( 5, 8)= .03167 | F( 8, 5)= .05143 |
| F( 5, 9)= .17653 | F( 9, 5)= .25490 |
| F( 5,10)= .29649 | F(10, 5)= .47081 |
| F( 5,11)= 0.00000 | F(11, 5)= 0.00000 |
| F( 5,12)= 0.00000 | F(12, 5)= 0.00000 |
| F( 5,13)= 0.00000 | F(13, 5)= 0.00000 |
| F( 5,14)= 0.00000 | F(14, 5)= 0.00000 |
| F( 5,15)= 0.00000 | F(15, 5)= 0.00000 |
| F( 5,16)= 0.00000 | F(16, 5)= 0.00000 |
| F( 5,17)= 0.00000 | F(17, 5)= 0.00000 |
| F( 5,18)= 0.00000 | F(18, 5)= 0.00000 |
| F( 5,19)= .03854 | F(19, 5)= .04174 |
| F( 5,20)= 0.00000 | F(20, 5)= 0.00000 |
| F( 5,21)= .23773 | F(21, 5)= .32931 |
| F( 5,22)= 0.00000 | F(22, 5)= 0.00000 |
| AREA( 5)= 595.99 SQ. IN. | |
| F( 6, 6)= 0.00000 | F( 6, 6)= 0.00000 |
| F( 6, 7)= 0.00000 | F( 7, 6)= 0.00000 |
| F( 6, 8)= 0.00000 | F( 8, 6)= 0.00000 |
| F( 6, 9)= 0.00000 | F( 9, 6)= 0.00000 |
| F( 6,10)= 0.00000 | F(10, 6)= 0.00000 |
| F( 6,11)= 0.00000 | F(11, 6)= 0.00000 |
| F( 6,12)= 0.00000 | F(12, 6)= 0.00000 |
| F( 6,13)= 0.00000 | F(13, 6)= 0.00000 |
| F( 6,14)= 0.00000 | F(14, 6)= 0.00000 |
| F( 6,15)= 0.00000 | F(15, 6)= 0.00000 |
| F( 6,16)= 0.00000 | F(16, 6)= 0.00000 |
| F( 6,17)= 0.00000 | F(17, 6)= 0.00000 |
| F( 6,18)= 0.00000 | F(18, 6)= 0.00000 |
| F( 6,19)= .40721 | F(19, 6)= .11345 |
| F( 6,20)= 0.00000 | F(20, 6)= 0.00000 |
| F( 6,21)= .00094 | F(21, 6)= .00033 |
| F( 6,22)= 0.00000 | F(22, 6)= 0.00000 |
| AREA( 6)= 153.31 SQ. IN. | |

FIGURE B3 GN-1 OUTPUT OF NOZZLE INTERNAL ANALYSIS(cont'd)

## SYSTEM INTERNAL VIEW FACTORS

| | |
|---|---|
| F( 7, 7)= -.00000 | F( 7, 7)= -.00000 |
| F( 7, 8)= 0.00000 | F( 8, 7)= 0.00000 |
| F( 7, 9)= 0.00000 | F( 9, 7)= 0.00000 |
| F( 7,10)= 0.00000 | F(10, 7)= 0.00000 |
| F( 7,11)= 0.00000 | F(11, 7)= 0.00000 |
| F( 7,12)= 0.00000 | F(12, 7)= 0.00000 |
| F( 7,13)= 0.00000 | F(13, 7)= 0.00000 |
| F( 7,14)= 0.00000 | F(14, 7)= 0.00000 |
| F( 7,15)= 0.00000 | F(15, 7)= 0.00000 |
| F( 7,16)= 0.00000 | F(16, 7)= 0.00000 |
| F( 7,17)= 0.00000 | F(17, 7)= 0.00000 |
| F( 7,18)= 0.00000 | F(18, 7)= 0.00000 |
| F( 7,19)= .16330 | F(19, 7)= .11255 |
| F( 7,20)= 0.00000 | F(20, 7)= 0.00000 |
| F( 7,21)= .00393 | F(21, 7)= .00346 |
| F( 7,22)= 0.00000 | F(22, 7)= 0.00000 |

AREA( 7)= 379.24 SQ. IN.

| | |
|---|---|
| F( 8, 8)= -.00000 | F( 8, 8)= -.00000 |
| F( 8, 9)= 0.00000 | F( 9, 8)= 0.00000 |
| F( 8,10)= 0.00000 | F(10, 8)= 0.00000 |
| F( 8,11)= 0.00000 | F(11, 8)= 0.00000 |
| F( 8,12)= 0.00000 | F(12, 8)= 0.00000 |
| F( 8,13)= 0.00000 | F(13, 8)= 0.00000 |
| F( 8,14)= 0.00000 | F(14, 8)= 0.00000 |
| F( 8,15)= 0.00000 | F(15, 8)= 0.00000 |
| F( 8,16)= 0.00000 | F(16, 8)= 0.00000 |
| F( 8,17)= 0.00000 | F(17, 8)= 0.00000 |
| F( 8,18)= 0.00000 | F(18, 8)= 0.00000 |
| F( 8,19)= .03870 | F(19, 8)= .02581 |
| F( 8,20)= 0.00000 | F(20, 8)= 0.00000 |
| F( 8,21)= .01516 | F(21, 8)= .01290 |
| F( 8,22)= 0.00000 | F(22, 8)= 0.00000 |

AREA( 8)= 367.04 SQ. IN.

| | |
|---|---|
| F( 9, 9)= -.00000 | F( 9, 9)= -.00000 |
| F( 9,10)= .00000 | F(10, 9)= .00000 |
| F( 9,11)= 0.00000 | F(11, 9)= 0.00000 |
| F( 9,12)= 0.00000 | F(12, 9)= 0.00000 |
| F( 9,13)= 0.00000 | F(13, 9)= 0.00000 |
| F( 9,14)= 0.00000 | F(14, 9)= 0.00000 |
| F( 9,15)= 0.00000 | F(15, 9)= 0.00000 |
| F( 9,16)= 0.00000 | F(16, 9)= 0.00000 |
| F( 9,17)= 0.00000 | F(17, 9)= 0.00000 |
| F( 9,18)= 0.00000 | F(18, 9)= 0.00000 |
| F( 9,19)= .01080 | F(19, 9)= .00750 |
| F( 9,20)= 0.00000 | F(20, 9)= 0.00000 |
| F( 9,21)= .06479 | F(21, 9)= .06215 |
| F( 9,22)= 0.00000 | F(22, 9)= 0.00000 |

AREA( 9)= 412.77 SQ. IN.

| | |
|---|---|
| F(10,10)= -.00000 | F(10,10)= -.00000 |
| F(10,11)= 0.00000 | F(11,10)= 0.00000 |
| F(10,12)= 0.00000 | F(12,10)= 0.00000 |
| F(10,13)= 0.00000 | F(13,10)= 0.00000 |
| F(10,14)= 0.00000 | F(14,10)= 0.00000 |
| F(10,15)= 0.00000 | F(15,10)= 0.00000 |
| F(10,16)= 0.00000 | F(16,10)= 0.00000 |
| F(10,17)= 0.00000 | F(17,10)= 0.00000 |
| F(10,18)= 0.00000 | F(18,10)= 0.00000 |
| F(10,19)= .00464 | F(19,10)= .00316 |
| F(10,20)= 0.00000 | F(20,10)= 0.00000 |
| F(10,21)= .31067 | F(21,10)= .27100 |
| F(10,22)= 0.00000 | F(22,10)= 0.00000 |

AREA(10)= 375.33 SQ. IN.

FIGURE B3 GN-1 OUTPUT OF NOZZLE INTERNAL ANALYSIS(cont'd)

SYSTEM INTERNAL VIEW FACTORS

| | |
|---|---|
| F(11,11)= .05229 | F(11,11)= .05229 |
| F(11,12)= .10798 | F(12,11)= .04365 |
| F(11,13)= .07545 | F(13,11)= .03154 |
| F(11,14)= .06154 | F(14,11)= .02291 |
| F(11,15)= .04051 | F(15,11)= .01665 |
| F(11,16)= .09264 | F(16,11)= .18528 |
| F(11,17)= .09344 | F(17,11)= .08401 |
| F(11,18)= .00563 | F(18,11)= .01173 |
| F(11,19)= 0.00000 | F(19,11)= 0.00000 |
| F(11,20)= .42691 | F(20,11)= .13974 |
| F(11,21)= 0.00000 | F(21,11)= 0.00000 |
| F(11,22)= .04347 | F(22,11)= .02471 |

AREA(11)= 150.80 SQ. IN.

| | |
|---|---|
| F(12,12)= .13315 | F(12,12)= .13315 |
| F(12,13)= .11408 | F(13,12)= .11795 |
| F(12,14)= .09801 | F(14,12)= .09023 |
| F(12,15)= .05683 | F(15,12)= .05763 |
| F(12,16)= .06135 | F(16,12)= .30344 |
| F(12,17)= .15753 | F(17,12)= .35033 |
| F(12,18)= .02234 | F(18,12)= .11523 |
| F(12,19)= 0.00000 | F(19,12)= 0.00000 |
| F(12,20)= .26114 | F(20,12)= .28705 |
| F(12,21)= 0.00000 | F(21,12)= 0.00000 |
| F(12,22)= .05272 | F(22,12)= .07412 |

AREA(12)= 372.95 SQ. IN.

| | |
|---|---|
| F(13,13)= .17209 | F(13,13)= .17209 |
| F(13,14)= .17169 | F(14,13)= .15287 |
| F(13,15)= .09152 | F(15,13)= .05977 |
| F(13,16)= .01667 | F(16,13)= .07974 |
| F(13,17)= .12854 | F(17,13)= .27645 |
| F(13,18)= .05685 | F(18,13)= .28361 |
| F(13,19)= 0.00000 | F(19,13)= 0.00000 |
| F(13,20)= .13689 | F(20,13)= .14553 |
| F(13,21)= 0.00000 | F(21,13)= 0.00000 |
| F(13,22)= .07711 | F(22,13)= .10485 |

AREA(13)= 360.71 SQ. IN.

| | |
|---|---|
| F(14,14)= .24006 | F(14,14)= .24006 |
| F(14,15)= .16355 | F(15,14)= .18017 |
| F(14,16)= .00365 | F(16,14)= .01963 |
| F(14,17)= .05463 | F(17,14)= .13195 |
| F(14,18)= .05565 | F(18,14)= .31125 |
| F(14,19)= 0.00000 | F(19,14)= 0.00000 |
| F(14,20)= .08231 | F(20,14)= .09930 |
| F(14,21)= 0.00000 | F(21,14)= 0.00000 |
| F(14,22)= .13429 | F(22,14)= .20508 |

AREA(14)= 405.12 SQ. IN.

| | |
|---|---|
| F(15,15)= .26047 | F(15,15)= .26047 |
| F(15,16)= .00073 | F(16,15)= .00354 |
| F(15,17)= .01935 | F(17,15)= .04244 |
| F(15,18)= .02810 | F(18,15)= .14291 |
| F(15,19)= 0.00000 | F(19,15)= 0.00000 |
| F(15,20)= .05259 | F(20,15)= .05711 |
| F(15,21)= 0.00000 | F(21,15)= 0.00000 |
| F(15,22)= .29585 | F(22,15)= .41014 |

AREA(15)= 367.76 SQ. IN.

FIGURE B3 GN-1 OUTPUT OF NOZZLE INTERNAL ANALYSIS(cont'd)

```
SYSTEM INTERNAL VIEW FACTORS

F(16,16)= 0.00000          F(16,16)= 0.00000
F(16,17)= 0.00000          F(17,16)= 0.00000
F(16,18)= 0.00000          F(18,16)= 0.00000
F(16,19)= 0.00000          F(19,16)= 0.00003
F(16,20)=  .40598          F(20,16)=  .09002
F(16,21)= 0.00000          F(21,16)= 0.00000
F(16,22)=  .00101          F(22,16)=  .00029
          AREA(16)=   75.40 SQ. IN.

F(17,17)= 0.00000          F(17,17)= 0.00000
F(17,18)= 0.00000          F(18,17)= 0.00000
F(17,19)= 0.00000          F(19,17)= 0.00000
F(17,20)=  .07450          F(20,17)=  .03683
F(17,21)= 0.00000          F(21,17)= 0.00000
F(17,22)=  .04109          F(22,17)=  .02598
          AREA(17)=  157.71 SQ. IN.

F(18,18)= 0.00000          F(18,18)= 0.00000
F(18,19)= 0.00004          F(19,18)= 0.00000
F(18,20)=  .00450          F(20,18)=  .00096
F(18,21)= 0.00000          F(21,18)= 0.00000
F(18,22)=  .13076          F(22,18)=  .03564
          AREA(18)=   72.70 SQ. IN.

F(19,19)= 0.00000          F(19,19)= 0.00000
F(19,20)= 0.00000          F(20,19)= 0.00000
F(19,21)=  .06405          F(21,19)=  .08192
F(19,22)= 0.00000          F(22,19)= 0.00000
          AREA(19)=  550.28 SQ. IN.

F(20,20)= 0.00000          F(20,20)= 0.00000
F(20,21)= 0.00000          F(21,20)= 0.00000
F(20,22)=  .09395          F(22,20)=  .12016
          AREA(20)=  339.29 SQ. IN.

F(21,21)= 0.00000          F(21,21)= 0.00000
F(21,22)= 0.00000          F(22,21)= 0.00000
          AREA(21)=  430.76 SQ. IN.

F(22,22)= 0.00000          F(22,22)= 0.00000
          AREA(22)=  265.29 SQ. IN.
```

FIGURE B3 CN-1 OUTPUT OF NOZZLE INTERNAL ANALYSIS(cont'd)

```
           input item number
           card column 1
IDS1 01
IB1               <<-**************->>
1        THIS IS THE FIRST ASDIR II SAMPLE INPUT SET
1                        <-->
1        <<-         GENERIC NOZZLE I           ->>
1                 <<-**************->>
2
3    0204180401
4  0.0      18.0      2.0      18.0      -1.0      0101
4  2.0      18.0      7.0      17.7      -1.0      0201
4  7.00     17.7      12.0     17.1      -1.0      0301
4  12.0     17.1      18.0     16.1      -1.0      0401
4  18.0     16.1      24.0     15.0      -1.0      0501
4  0.0      12.2      2.0      12.2      +1.0      0602
4  2.0      12.2      7.0      11.9      +1.0      0702
4  7.0      11.9      12.0     11.3      +1.0      0802
4  12.0     11.3      18.0     10.3      +1.0      0902
4  18.0     10.3      24.0     9.38318   +1.0      1002
4  0.0      12.0      2.0      12.0      -1.0      1103
4  2.0      12.0      7.0      11.7      -1.0      1203
4  7.0      11.7      12.0     11.1      -1.0      1303
4  12.0     11.1      18.0     10.1      -1.0      1403
4  18.0     10.1      24.0     9.18936   -1.0      1503
4  0.0      6.0       2.0      6.0       +1.0      1604
4  2.0      6.0       7.0      3.7       +1.0      1704
4  7.0      3.7       12.0     0.0       +1.0      1804
4  12.0     00.0      24.0     00.0      +1.0      3514
5  0.00     12.2      0.00     18.0      -1.0      0600.0    19
5  0.00     6.00      0.00     12.0      -1.0      1300.0    20
5  24.0     9.38318   24.0     15.0      +1.0      0450.0    21
5  24.0     00.0      24.0     9.18936   +1.0      0460.0    22
6  24.0
7    0001
10     .02777    .05910    .04071    .03051    .01695    .12469    .18335    .04536
10     .01197    .00393    0.00000   0.00000   0.00000   0.00000   [illegible] 0.00000
10    0.00000   0.00000    .42323   0.00000    .02643   0.00000
11  226.19467
10     .06488    .05247    .03984    .02205    .08216    .27333    .12333    .03023
10     .00742   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
10    0.00000    .24924   0.00000    .03209   0.00000
11  561.78278
10     .05695    .06083    .03438    .02256    .16296    .27013    .11345    .12219
10    0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   [illegible] 0.00000
10     .12464   0.00000    .04717   0.00000
11  550.55884
10     .08315    .05913    .00506    .03938    .15783    .30139    .10063   0.00000
10    0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000    .06022
10    0.00000    .08632   0.00000
11  634.43746
10     .09024    .00105    .00787    .03167    .17653    .29649   0.00000   0.00000
10    0.00000   0.00000   0.00000   0.00000   0.00000   0.00000    .03954   0.00000
10     .23773   0.00000
11  [illegible]
10    0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
10    0.00000   0.00000   0.00000   0.00000   0.00000    .40721   0.00000    .03094
10    0.00000
11  153.30972
10    -.00000   0.00000   0.00000   0.00000   0.00000   0.0000[illegible] [illegible] 0.00000
10    0.00000   0.00000   0.00000   0.00000    .16330   0.00000   [illegible] [illegible]
11  379.24271
10    -.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
10    0.00000   0.00000   0.00000    .03870   0.00000    .01516   0.00000
11  367.03923
10    -.00000    .00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
10    0.00000   0.00000    .01000   0.00000    .06479   0.00000
11  412.76654
10    -.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
10    0.00000    .00464   0.00000    .31067   0.00000
11  375.32565
10     .05229    .10795    .07545    .06154    .04061    .09764    .09344    .00563
10    0.00000    .42691   0.00000    .04347
```

FIGURE B4 GN-1 IR SIGNATURE INPUT DATA DECK

```
11  150.79645
10     .13315    .11408    .09801    .05683    .06135    .15753    .02234   0.00000
10     .26114   0.00000    .05272
11  372.94823
10     .17209    .17169    .09152    .01667    .12854    .05685   0.00000    .13589
10    0.00000    .07711
11  360.71096
10     .24006    .16355    .00365    .05463    .05555   0.00000    .08291   0.00000
10     .13429
11  405.12272
10     .26047    .00073    .01935    .02810   0.00000    .05269   0.00000    .29586
11  367.75977
10    0.00000   0.00000   0.00000   0.00000    .40508   0.00000    .00131
11   75.39822
10    0.00000   0.00000   0.00000    .07450   0.00000    .04109
11  167.71474
10    0.00000   0.00000    .00450   0.00000    .13076
11   72.30211
10    0.00000   0.00000    .06405   0.00000
11  550.28137
10    0.00000   0.00000    .09395
11  339.29201
10    0.00000   0.00000
11  430.25975
10    0.00000
11  265.28971
14    010500
15    0102030405
14    0205
15    0607080910
14    0305
15    1112131415
14    040400
15    15171835
16    010001   00.0       24.0
17 430.26
18    05
19    2300     01.0
19    2400     04.5
19    2500     09.5
19    2600     15.0
19    2700     21.
20    0100     0.1        1.3
20    0200     0.1        1.3
16    020101   0.0        24.0
17 265.29
18    0500
19    2801     1.0
19    2901     4.5
19    3001     9.5
19    3101     15.0
19    3201     21.0
20    0301     0.001      1.3
20    0401     0.001      1.3
41    00
43 22.636      1400.0     53.38     1.33      87.102
44 23.154      605.0      53.3      1.40      215.58
45 12.232
46    012302240325042605270623072408250926102711281229133014311532162917291830
      19232028212 72232
47    00
47    00
49    13
```

FIGURE B4 GN-1 IR SIGNATURE INPUT DATA DECK (cont'd)

```
50   0133    1.0
50   0233    1.0
50   0333    1.0
50   0433    1.0
50   0533    1.0
50   0611    1.0
50   0712    1.0
50   0813    1.0
50   0914    1.0
50   1015    1.0
50   1634    1.0
50   1734    1.0
50   1834    1.0
51   02
52   33      500.0
52   34      720.0
53  .4       .4       .4       .4       .4       .8       .8       .8
53  .8       .8       .8       .8       .8       .8       .8       .8
53  .8       .8       1.0      1.0      1.0      1.0
54   08
55  0.0      5.0      10.0     20.0     45.0     60.0     75.0     90.0
56   0100    5.5
57  1.7      5.5
IDS2 $CASE ALTOBS(1)= 5[illegible].,[illegible].,ALTPLM=5000.,NRANG=3,
     NDATA=[illegible],A[illegible]=[illegible],A[illegible]=[illegible],
     RANGE(1)=1[illegible].,1[illegible].,5[illegible].,
     RPN=9.18936,RSN=15.0,RTE=12.0,ANL=24.0 $
IDS5 $PLUMIN $
IDS5 $POWER NORM=0,JET=2,FLTM=[illegible],TSFC0=[illegible].9,RRED=[illegible] 98,FN=[illegible]365.,FNRT=6555.,
     EPR=22.636,FPR=23.154,TTPN=1400.,TTSN=605.,WAPAC=87.102,WASAC=215.58,$
IDS2 $CASE $
   2 $CASE $
   2 $CASE $
   2 $CASE $
   2 $CASE $
   2 $CASE $
   2 $CASE ISPAT=1,$
   2 $CASE TERM=.TRUE. $
```

FIGURE B4 [illegible] IR [illegible]GNATURE INPUT DATA DECK(cont'd)

HOT METALS
BANDWIDTH SUMMATION
1.70 - 5.50 MICRONS

| OFF AXIS ANGLE (DEG.) | BANDWIDTH RADIATION (W/ST.) | EQUIVALENT BLACK BODY TEMPERATURE (K) | EQUIVALENT BLACK BODY AREA (CM2) | EQUIVALENT BLACK BODY RADIATION (W/ST.) |
|---|---|---|---|---|
| 0.0 | 441.847 | 743.05 | 1629.15 | 441.847 |
| 5.0 | 460.356 | 739.26 | 1745.07 | 460.356 |
| 10.0 | 459.720 | 743.05 | 1731.36 | 459.720 |
| 20.0 | 449.234 | 746.88 | 1611.10 | 449.234 |
| 45.0 | 374.090 | 762.61 | 1199.91 | 374.090 |
| 60.0 | 259.545 | 762.61 | 832.50 | 259.545 |
| 75.0 | 131.911 | 762.61 | 423.11 | 131.911 |
| 90.0 | .000 | 526.69 | .00 | .000 |

ABB
TBB
ASPDEG

FIGURE B5 GN-1 INTERNAL HOT PARTS SUMMARY

* * * A S D I R * * *

PLUME ANALYSIS

** ENGINE DEFINITION

| | AXIAL | RADIAL (FEET) |
|---|---|---|
| | -2.0000 | 1.0000 |
| | 0.0000 | .7658 |

** CASE DEFINITION

WAVELENGTH 3.7500 4.8500 MICRONS
ASP ANGLE 0.0000 DEGREES

* PLUME DATA IS CALCULATED. **
* FLIGHT CONDITIONS **

ALTITUDE IS 5000. FEET.
WEATHER IS ICAO MIL STD 210 STANDARD DAY
WITH .000330 WATER CONTENT.
VISIBLE CONTRAIL IS NOT EXPECTED
CASE MACH NUMBER IS .50 AT AMBIENT
PRESSURE OF 12.23 PSIA.
TEMPERATURE OF 501. DEGR.
VELOCITY OF 599. FT/SEC.
ENGINE IS RUNNING WITH A FUEL EQUIVALENCE RATIO (EQR) OF .285

** FLOW FIELD INPUT

| RADIUS (FEET) | VELOCITY (FT/SEC) | TEMPERATURE (DEG R) | XCO2 | XH2O | |
|---|---|---|---|---|---|
| 0.0000 | 1651.06 | 1400.00 | .037842 | .042.11 | |
| .0766 | 1651.06 | 1400.00 | .037842 | .042.11 | |
| .1532 | 1651.06 | 1400.00 | .037842 | .042011 | |
| .2297 | 1651.06 | 1400.00 | .037842 | .042011 | |
| .3063 | 1651.06 | 1400.00 | .037842 | .042011 | |
| .3829 | 1651.06 | 1400.00 | .037842 | .042011 | Core Nozzle |
| .4595 | 1651.06 | 1400.00 | .037842 | .042011 | |
| .5360 | 1651.06 | 1400.00 | .037842 | .042.11 | |
| .6126 | 1651.06 | 1400.00 | .037842 | .042011 | |
| .6892 | 1651.06 | 1400.00 | .037842 | .042011 | |
| .7658 | 1651.06 | 1400.00 | .037842 | .042011 | |
| .8424 | 1088.01 | 607.19 | .000330 | .000330 | |
| .9189 | 1088.01 | 607.19 | .000330 | .000330 | |
| .9955 | 1088.01 | 607.19 | .000330 | .000330 | |
| 1.0721 | 1088.01 | 607.19 | .000330 | .000330 | Secondary Nozzle |
| 1.1487 | 1088.01 | 607.19 | .000330 | .000330 | |
| 1.2252 | 1088.01 | 607.19 | .000330 | .000330 | |

** AMBIENT CONDITIONS

| | | | | |
|---|---|---|---|---|
| 1.3018 | 598.97 | 500.84 | .000330 | .000330 |

** INPUT PARAMETERS

| | | PLUME | AMBIENT |
|---|---|---|---|
| PRESSURE, | P | .839 | .832 ATMOS. |
| SPECIFIC HEAT, | CP | .295 BTU/LB-F | |
| GAS CONSTANT, | R | 53.472 FT/F | |
| SP. HT. RATIO | | 1.394 | |
| MACH NUMBER | | 1.000 | |
| SECONDARY PRESS.= | | .856 ATMOS. | |

R8= .766 XC= 6.702 REND= 28.408 AL= 225.162

R8 = RPN
XC = Plume core length
REND = Radius at the end of the plume.
AL = Effective plume length.

FIGURE B6 GN-1 OUTPUT HEADER

```
$CASE
ABB      = 0.0,
AL       = .1E+04,
ALTOBS   = .5E+04, 0.0, 0.0, 0.0, 0.0,
ALTPLM   = .5E+04,
AMF      = .485E+01,
AMI      = .375E+01,
ASPDEG   = .9E+02,
DOS      = .16E+02,
EAREA    = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
ETEMP    = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
IFILTER  = 0,
IL       = -1,
IRADCK   = 0,
ISPAT    = 0,
ITAU     = -1,
ITYPE    = 1,
KDATA    = 14,
NA       = 5.
NANGSEG  = 3,
NATMO    = 2,
NEXIT    = 5,
NEXT     = 0,
NFLW     = 0,
NP       = 0,
NRANG    = 3,
NUINC    = .5E+02,
RANGE    = .1E+05, .1E+05, .5E+05, 0.0, 0.0,        RPN      = .918936E+01,
RAYPNT   = 0.0,                                      RTE      = .12E+02,
TBACK    = 0.0,                                      ANL      = .24E+02,
TBB      = 0.0,                                      RSN      = .15E+02,
TERM     = F,                                        XP       = 0.0,
NUFRST   = 0,                                        RP       = 0.0,
ICHECK   = 0,
```

FIGURE B7 GN-1 OUTPUT LISTING OF NAMELIST INPUT

```
$PLUHIN

RPN     = .765788E+00,

RSN     = .125E+01,

XP      = 0.0,

RP      = 0.0,

KDATA   = 14,

TANE    = .9E+01,

EQR     = .25E+00,

XCO2    = .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03,

XH2O    = .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03, .33E-03,     .33E-03,
          .33E-03,

XCO2A   = .33E-03,

XH2OA   = .33E-03,

U8      = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
          0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
          0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
          0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
          0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,

T8T     = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
          0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
          0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
          0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
          0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,

P8      = 0.0,

PQ      = 0.0,

UA      = .1E+02,

TA      = .519E+03,

PA      = 0.0,

$END
```

FIGURE B7 GN-1 OUTPUT LISTING OF NAMELIST INPUT(cont'd)

```
$POWER
METEC   = 0,
NORM    = 0,
JET     = 2,
FLTM    = .5E+00,
TSFCC   = .9E+00,
RREC    = .98E+00,
FN      = .6566E+04,
FNRT    = .6566E+04,
EPR     = .22636E+02,
FPR     = .23154E+02,
TTPN    = .14E+04,
TTSN    = .605E+03,
WAPAC   = .87102E+02,
WASAC   = .21558E+03,
$END
```

FIGURE B7 GN-1 OUTPUT LISTING OF NAMELIST INPUT(cont'd)

@*** PLUME GAS DATA ***>

STATION # = 1 STATION = 0.00 CENTERLINE MACH = 1.000 EDGE MACH = .969

| RADIUS (FEET) | VELOCITY (FT/SEC) | PRESSURE (ATM) | STAT TEMP (DEG R) | XCO2 (MOL FRAC) | XH2O (MOL FRAC) |
|---|---|---|---|---|---|
| 0.00 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .06 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .12 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .18 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .24 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .29 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .35 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .41 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .47 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .53 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .59 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .65 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .71 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .77 | 1651. | .83205 | 1215. | .037842 | .042011 |
| .81 | 1088. | .83205 | 525. | .000330 | .000330 |
| .85 | 1088. | .83205 | 525. | .000330 | .000330 |
| .89 | 1088. | .83205 | 525. | .000330 | .000330 |
| .93 | 1088. | .83205 | 525. | .000330 | .000330 |
| .97 | 1088. | .83205 | 525. | .000330 | .000330 |
| 1.02 | 1088. | .83205 | 525. | .000330 | .000330 |
| 1.06 | 1088. | .83205 | 525. | .000330 | .000330 |
| 1.11 | 1088. | .83205 | 525. | .000330 | .000330 |
| 1.15 | 1088. | .83205 | 525. | .000330 | .000330 |
| 1.19 | 1088. | .83205 | 525. | .000330 | .000330 |
| 1.24 | 599. | .83205 | 501. | .000330 | .000330 |
| 1.25 | 598. | .83205 | 501. | .000330 | .000330 |
| 34.43 | 538. | .83205 | 501. | .000330 | .000330 |

FIGURE B8 GN-1 PLUME GAS DATA (OUTPUT SAMPLE)

*** PLUME GAS DATA ***

| RADIUS (FEET) | VELOCITY (FT/SEC) | PRESSURE (ATM) | STAT TEMP (DEG R) | XCO2 (MOL FRAC) | XH2O (MOL FRAC) |
|---|---|---|---|---|---|
| STATION # = 2 | STATION = .44 | CENTERLINE MACH = 1.000 | EDGE MACH = .969 | | |
| 0.00 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .06 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .12 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .18 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .24 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .29 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .35 | 1651. | .83947 | 1215. | .037842 | .042011 |
| [illegible] | 1651. | .83947 | 1215. | .037842 | .042011 |
| [illegible] | 1651. | .83947 | 1215. | .037842 | .042011 |
| .53 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .59 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .65 | 1650. | .83947 | 1215. | .037842 | .042011 |
| .71 | 1649. | .83947 | 1211. | .037772 | .041933 |
| .76 | 1600. | .83947 | 1115. | .034497 | .038250 |
| .81 | 1136. | .83947 | 538. | .003589 | .003952 |
| .85 | 1090. | .83947 | 538. | .000522 | .000543 |
| .90 | 1088. | .83947 | 525. | .000336 | .000335 |
| .94 | 1088. | .83947 | 525. | .000330 | .000330 |
| .95 | 1088. | .83947 | 525. | .000330 | .000330 |
| 1.02 | 1088. | .83947 | 525. | .000330 | .000330 |
| 1.05 | 1087. | .83947 | 524. | .000330 | .000330 |
| 1.11 | 1084. | .83947 | 524. | .000330 | .000330 |
| 1.15 | 1057. | .83947 | 523. | .000330 | .000330 |
| 1.20 | 955. | .83947 | 521. | .000330 | .000330 |
| 1.25 | 741. | .83947 | 514. | .000330 | .000330 |
| 1.32 | 619. | .83947 | 515. | .000330 | .000330 |
| 1.34 | 598. | .83205 | 501. | .000330 | .000330 |
| 4.43 | 598. | .83205 | 501. | .000330 | .000330 |
| STATION # = 3 | STATION = .99 | CENTERLINE MACH = 1.000 | EDGE MACH = .632 | | |
| 0.00 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .12 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .24 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .35 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .47 | 1651. | .83947 | 1215. | .037842 | .042011 |
| .59 | 1650. | .83947 | 1214. | .037338 | .042007 |
| .71 | 1637. | .83947 | 1153. | .036531 | .040555 |
| .81 | 1217. | .83947 | 745. | .009034 | .010001 |
| .90 | 1093. | .83947 | 555. | .000720 | .000764 |
| .99 | 1086. | .83947 | 525. | .000336 | .000337 |
| 1.07 | 1064. | .83947 | 524. | .000330 | .000330 |
| 1.16 | 983. | .83947 | 523. | .000330 | .000330 |
| 1.27 | 8[illegible]2. | .83947 | 518. | .000330 | .000330 |
| 1.39 | 641. | .83947 | 508. | .000330 | .000330 |
| 1.41 | 598. | .83205 | 501. | .000330 | .000330 |

FIGURE B8 GN-1 PLUME GAS DATA (OUTPUT SAMPLE) (cont'd)

===* PLUME GAS DATA *==>

STATION # = 48 STATION = 225.16 CENTERLINE MACH = .591 EDGE MACH = .540

| RADIUS (FEET) | VELOCITY (FT/SEC) | PRESSURE (ATM) | STAT TEMP (DEG R) | XCO2 (MOL FRAC) | XH2O (MOL FRAC) |
|---|---|---|---|---|---|
| 0.00 | 650. | .83947 | 539. | .002397 | .002627 |
| 2.00 | 649. | .83947 | 539. | .002369 | .002596 |
| 4.00 | 648. | .83947 | 538. | .002287 | .002505 |
| 6.01 | 645. | .83947 | 537. | .002165 | .002363 |
| 8.02 | 640. | .83947 | 536. | .001997 | .002182 |
| 10.04 | 635. | .83947 | 534. | .001810 | .001974 |
| 12.06 | 629. | .83947 | 532. | .001611 | .001753 |
| 14.09 | 623. | .83947 | 530. | .001412 | .001533 |
| 16.13 | 617. | .83947 | 528. | .001225 | .001324 |
| 18.18 | 613. | .83947 | 525. | .001056 | .001137 |
| 20.23 | 608. | .83947 | 523. | .000913 | .000978 |
| 22.28 | 605. | .83947 | 521. | .000798 | .000850 |
| 24.33 | 603. | .83947 | 520. | .000713 | .000756 |
| 26.35 | 602. | .83947 | 518. | .000541 | .000675 |
| 28.41 | 598. | .83947 | 508. | .000411 | .000420 |
| 28.69 | 598. | .83215 | 501. | .000330 | .000330 |
| 34.43 | 598. | .83215 | 501. | .000330 | .000330 |

STATION # = 49 STATION = 247.56 CENTERLINE MACH = 0.000 EDGE MACH = 0.000

| RADIUS (FEET) | VELOCITY (FT/SEC) | PRESSURE (ATM) | STAT TEMP (DEG R) | XCO2 (MOL FRAC) | XH2O (MOL FRAC) |
|---|---|---|---|---|---|
| 0.00 | 598. | .83215 | 501. | .000330 | .000330 |
| 2.00 | 598. | .83215 | 501. | .000330 | .000330 |
| 4.00 | 598. | .83215 | 501. | .000330 | .000330 |
| 6.01 | 598. | .83215 | 501. | .000330 | .000330 |
| 8.02 | 598. | .83215 | 501. | .000330 | .000330 |
| 10.04 | 598. | .83215 | 501. | .000330 | .000330 |
| 12.06 | 598. | .83215 | 501. | .000330 | .000330 |
| 14.09 | 598. | .83215 | 501. | .000330 | .000330 |
| 16.13 | 598. | .83215 | 501. | .000330 | .000330 |
| 18.18 | 598. | .83215 | 501. | .000330 | .000330 |
| 20.23 | 598. | .83215 | 501. | .000330 | .000330 |
| 22.28 | 598. | .83215 | 501. | .000330 | .000330 |
| 24.33 | 598. | .83215 | 501. | .000330 | .000330 |
| 26.38 | 598. | .83215 | 501. | .000330 | .000330 |
| 28.41 | 598. | .83215 | 501. | .000330 | .000330 |
| 28.69 | 598. | .83215 | 501. | .000330 | .000330 |
| 34.43 | 598. | .83215 | 501. | .000330 | .000330 |

FIGURE B8 GN-1 PLUME GAS DATA (OUTPUT SAMPLE) (cont'd)

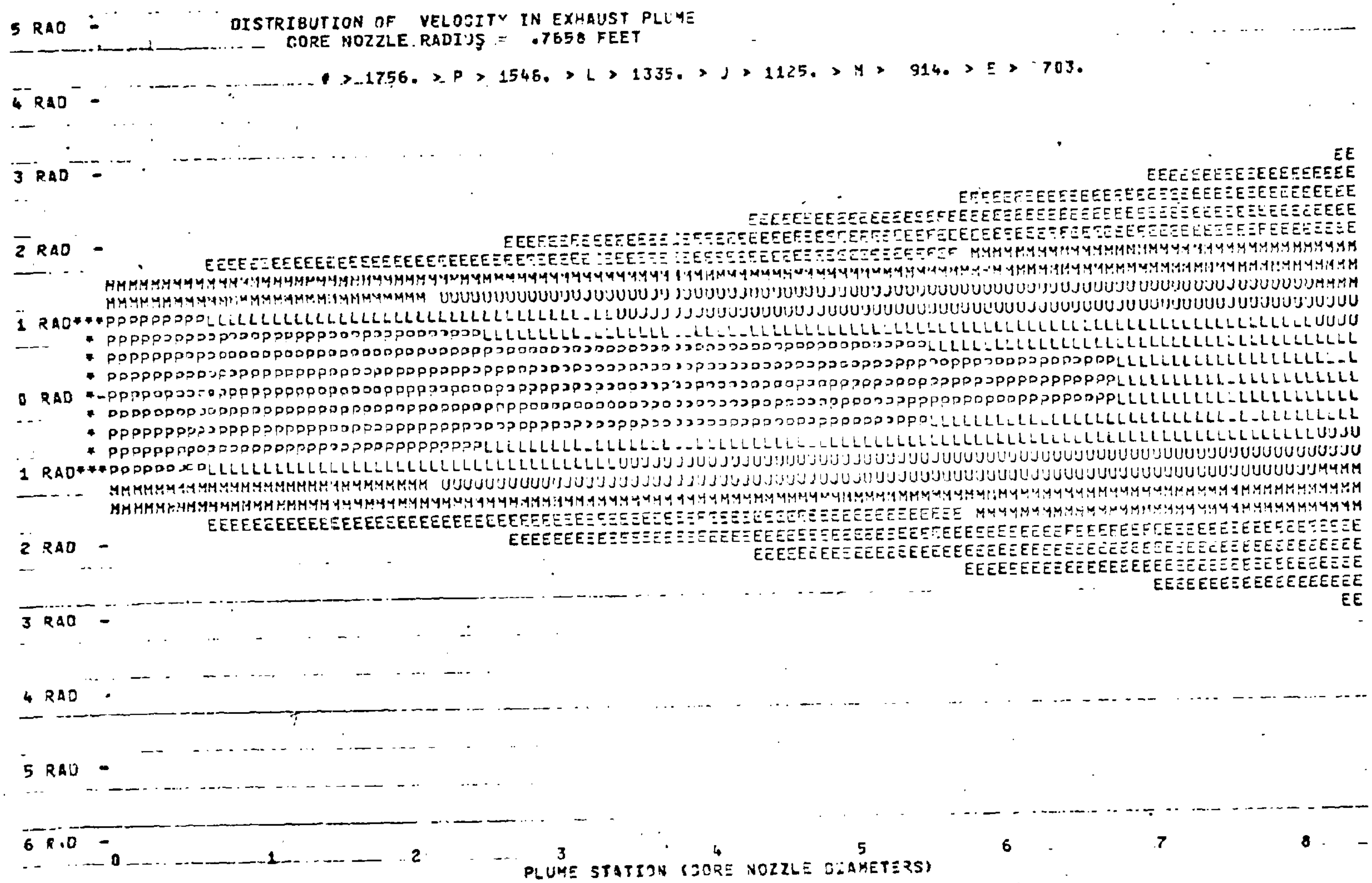



FIGURE B9 GN-1 PLUME GAS DATA PLOT

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***TOTAL SIGNATURE OVER THE SPECTRAL BAND 3.75 TO 4.85 MICRONS AT A RANGE OF      3.048 KM
FOR AN ASPECT ANGLE OF    0.0 DEGREES IN A NOR. ATMOSPHERE***

*VEHICLE ALTITUDE =   1.52 KM AND OBSERVER ALTITUDE =   1.52 KM

.UME POINT-SOURCE SIGNATURE
                  EFFECTIVE BLACK BODY AREA - ABB =  1623.1900  CMSQ
                  EFFECTIVE BB TEMPERATURE -  TBB =   743.0513  DEGK
                  EFFECTIVE BACKGROUND TEMP.-TBACK=     0.0000  DEGK
                  APPARENT RADIANCE =     84.6718  WATTS/STERADIAN
                  ATTENUATED METALS =     84.2437  WATTS/STERADIAN
                  METALS            =    160.9029  WATTS/STERADIAN
                  PLUME GAS SPECIES =       .4280  WATTS/STERADIAN
                  BACKGROUND        =      0.0000  WATTS/STERADIAN

***TOTAL SIGNATURE OVER THE SPECTRAL BAND 3.75 TO 4.85 MICRONS AT A RANGE OF      3.048 KM
FOR AN ASPECT ANGLE OF    0.0 DEGREES IN A NOR. ATMOSPHERE***

*VEHICLE ALTITUDE =   1.52 KM AND OBSERVER ALTITUDE =   0.00 KM

.UME POINT-SOURCE SIGNATURE
                  EFFECTIVE BLACK BODY AREA - ABB =  1623.1900  CMSQ
                  EFFECTIVE BB TEMPERATURE -  TBB =   743.0513  DEGK
                  EFFECTIVE BACKGROUND TEMP.-TBACK=     0.0000  DEGK
                  APPARENT RADIANCE =     79.9132  WATTS/STERADIAN
                  ATTENUATED METALS =     79.5761  WATTS/STERADIAN
                  METALS            =    160.9029  WATTS/STERADIAN
                  PLUME GAS SPECIES =       .3371  WATTS/STERADIAN
                  BACKGROUND        =      0.0000  WATTS/STERADIAN

***TOTAL SIGNATURE OVER THE SPECTRAL BAND 3.75 TO 4.85 MICRONS AT A RANGE OF     15.240 KM
FOR AN ASPECT ANGLE OF    0.0 DEGREES IN A NOR. ATMOSPHERE***

*VEHICLE ALTITUDE =   1.52 KM AND OBSERVER ALTITUDE =   0.00 KM

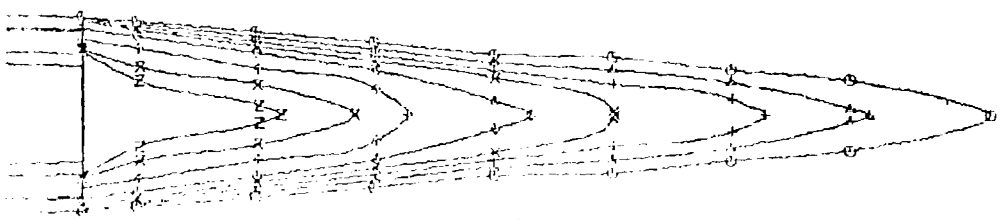
.UME POINT-SOURCE SIGNATURE
                  EFFECTIVE BLACK BODY AREA - ABB =  1623.1900  CMSQ
                  EFFECTIVE BB TEMPERATURE -  TBB =   743.0513  DEGK
                  EFFECTIVE BACKGROUND TEMP.-TBACK=     0.0000  DEGK
                  APPARENT RADIANCE =     56.5551  WATTS/STERADIAN
                  ATTENUATED METALS =     56.5246  WATTS/STERADIAN
                  METALS            =    160.9029  WATTS/STERADIAN
                  PLUME GAS SPECIES =       .0305  WATTS/STERADIAN
                  BACKGROUND        =      0.0000  WATTS/STERADIAN
```

FIGURE B10 GN-1 IR SIGNAUTRE OUTPUT (SAMPLE)

ASDIR

EXHAUST PLUME SPATIAL RADIANCE

ASPECT ANGLE 90 DEGREES



| | | |
|---|---|---|
| ⊕ | 0.20 E -4 | WATTS/ST./CM² |
| △ | 0.50 E -4 | WATTS/ST./CM² |
| + | 1.00 E -4 | WATTS/ST./CM² |
| × | 0.15 E -3 | WATTS/ST./CM² |
| ◇ | 0.20 E -3 | WATTS/ST./CM² |
| ↑ | 0.25 E -3 | WATTS/ST./CM² |
| X | 0.30 E -3 | WATTS/ST./CM² |
| Z | 0.32 E -3 | WATTS/ST./CM² |

FIGURE B11 GN-1 PLUME RADIANCE SPATIAL PLOT

NRANG IFILTER R8 SENO XC AL [illegible]

3 0 .7555 31.1721 6.7[illegible] [illegible]783 6.[illegible]379 [illegible]

RANGE 1 RANGE 2 RANGE 3 RANGE 4 RANGE 5

3.048 3.048 15.240

| RAR | ROD | RDZ | SIG(R1) | SIG(R2) | SIG(R3) |
|---|---|---|---|---|---|
| .1122724E+03 | .478713[illegible]E+00 | 0. | .36[illegible] | .3[illegible] | .335[illegible]E-04 |
| .2245448E+03 | .4775296E+00 | .1262148E+00 | .35[illegible]E-03 | .2926519[illegible]-03 | .391[illegible]-04 |
| .2245448E+03 | .4739721E+00 | .2523350E+00 | .35[illegible]-03 | .2975[illegible]-03 | .305[illegible]-04 |
| .2245448E+03 | .4684442E+00 | .37[illegible]E+00 | .3[illegible] | .25[illegible] | .3375[illegible]-04 |
| .2245448E+03 | .45374[illegible] | [illegible] | [illegible] | [illegible] | .23[illegible]-04 |
| .2245448E+03 | .44[illegible]E+00 | .5301378E+00 | .2[illegible] | .1820747E-03 | .2195995E-04 |
| .2024450E+03 | .4366534E+00 | .7[illegible]E+00 | .19[illegible]-04 | .1[illegible]-04 | .1452594E-5 |
| .2024450E+03 | .4230[illegible]+00 | .9812762E+00 | 0. | 0. | 0. |
| .1282768E+03 | .1435147E+01 | 0. | .3448487[illegible]-03 | .2[illegible]-03 | .36820[illegible]-04 |
| .2565536E+03 | .1434792E+01 | .144[illegible]E+00 | .37[illegible]-03 | [illegible] | .3575[illegible]-04 |
| .2565536E+03 | .1430[illegible]+01 | .298[illegible]+00 | .3[illegible]78854-03 | .2572[illegible]-03 | .3[illegible]-04 |
| .2565536E+03 | .1423[illegible]+01 | .4324164E+00 | [illegible]-03 | .2[illegible]-03 | .2[illegible]-04 |
| .2565536E+03 | .1414[illegible]+01 | .5763176E+00 | .13[illegible]E-03 | .11[illegible]-03 | .1[illegible]47[illegible] |
| .2565536E+03 | .1402294E+01 | .720015[illegible] | .5339[illegible] | .34[illegible]-05 | .1[illegible] |
| .2565536E+03 | .1387415E+01 | .8634[illegible]+00 | .8655574E-09 | .631467[illegible]-09 | .7[illegible] |
| .2565536E+03 | .1372535E+01 | .1008[illegible] | 0. | 0. | 0. |
| .1442812E+03 | .2393579E+01 | 0. | .2919534E-03 | .2437516E-03 | .3[illegible]-04 |
| .2885625E+03 | .2392055E+01 | .1621[illegible]+00 | .2802366E-03 | .2338367E-03 | .28[illegible]E-04 |
| .2885625E+03 | .2387493E+01 | .324[illegible]+00 | .2326335E-03 | .19358[illegible]E-03 | .2244889E-04 |
| .2885625E+03 | .2379855E+01 | .486[illegible]+00 | .1059[illegible]E-03 | .8658162E-04 | .[illegible]E-05 |
| .2885625E+03 | .2359203E+01 | .6482[illegible]+00 | .7624320E-05 | .5502794E-05 | .2573311E-06 |
| .2885625E+03 | .2355502E+01 | .8099[illegible]E+00 | .3275543E-05 | .2364237E-05 | .1157188E-07 |
| .2885625E+03 | .2339756E+01 | .9711478E+00 | .2194317E-08 | .1692312E-08 | .879[illegible]-10 |
| .2885625E+03 | .2322030E+01 | .1132528E+01 | 0. | 0. | 0. |
| .1602856E+03 | .3351010E+01 | 0. | .2354547E-03 | .1958186E-03 | .237[illegible]E-04 |
| .3205713E+03 | .3349317E+01 | .1801[illegible]+00 | .2030315E-03 | .1734134E-03 | .2[illegible]E-04 |
| .3205713E+03 | .3344238E+01 | .3603173E+00 | .1154514E-03 | .9514617E-04 | .1[illegible]E-04 |
| .3205713E+03 | .3335775E+01 | .5403169E+00 | .1273[illegible]-04 | .9395291[illegible]-05 | .4[illegible] |
| .3205713E+03 | .3323931E+01 | .7201257E+00 | .21[illegible]-05 | .15[illegible]E-05 | .74[illegible]-07 |
| .3205713E+03 | .3303710E+01 | .8976802E+00 | .90[illegible]-07 | .66[illegible]E-07 | .3[illegible]-08 |
| .3205713[illegible] | .3[illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| .3205713E+03 | .3271525[illegible]+01 | .1268154E+01 | 0. | 0. | 0. |
| .1762901E+03 | .4308442[illegible]+01 | 0. | .1674503[illegible]-03 | .1393772E-03 | .158[illegible]-04 |
| .3525801E+03 | .4306581E+01 | .1981374E+00 | .1753547E-03 | .1119[illegible]-03 | .12[illegible]-04 |
| .3525801E+03 | .4300993E+01 | .3962948E+00 | .44[illegible]-04 | .3548836E-04 | .337[illegible]-05 |
| .3525801E+03 | .4291685E+01 | .5942672E+00 | .54[illegible]E-05 | .4712528E-05 | .2[illegible]-06 |
| .3525801E+03 | .4278659E+01 | .7920298E+00 | .583555[illegible]-05 | .5401742E-05 | .31[illegible]-07 |
| .3525801E+03 | .4261918E+01 | .9895127E+00 | .5133324E-07 | .3776113E-07 | .195[illegible]-08 |
| .3525801E+03 | .4241459E+01 | .1186646E+01 | .1460251E-09 | .1073734E-09 | .539[illegible]E-10 |
| .3525801E+03 | .4201322E+01 | [illegible] | 0. | 0. | 0. |
| .1922945E+03 | .5265873E+01 | 0. | .1[illegible]303E-03 | .1212366E-03 | .1131816E-04 |
| .3845890E+03 | .5263842E+01 | .2161743[illegible] | .77[illegible]E-04 | .6471[illegible]-04 | .68[illegible]-05 |
| .3845890E+03 | .5257749E+01 | .4322772[illegible] | .1[illegible]-04 | .95[illegible]791 | .45[illegible]-05 |
| .3845890E+03 | .5247596E+01 | .6482[illegible]E+00 | .3[illegible]-05 | .27[illegible] | .1[illegible]387[illegible]-06 |
| .3845890E+03 | .5233386E+01 | .8639339E+00 | .5[illegible]551-05 | .3955[illegible]-05 | .1964944-07 |
| .3845890E+03 | .5215126E+01 | .1079345E+01 | .41[illegible]1491E-07 | .3[illegible]3946E-07 | .158[illegible]-08 |
| .3845890E+03 | .5192821E+01 | .1294375E+01 | .1947352E-09 | .1137546E-09 | .6355505E-10 |
| .3845890E+03 | .5170515E+01 | .1509405[illegible]+01 | 0. | 0. | 0. |
| .2082989E+03 | .5223365E+01 | 0. | .6742553E-04 | .5417418E-04 | .55[illegible]E-05 |
| .4165978E+03 | .6221155E+01 | .2241662E+00 | .2863682E-04 | .21[illegible]399E-04 | .1[illegible]E-05 |
| .4165978E+03 | .6214530E+01 | .4482497E+00 | .3280[illegible]E-05 | .6753[illegible]E-05 | .3[illegible]617E-06 |
| .4165978E+03 | .6203596E+01 | .7021578E+00 | .2518543E-05 | .1874395E-05 | .8[illegible]751E-07 |
| .4165978E+03 | .6188114E+01 | .9358839E+00 | .382942[illegible]-05 | .2777337E-05 | .1[illegible]51735-07 |
| .4165978E+03 | .6165334E+01 | .1169178E+01 | .3531330E-07 | .2643470E-07 | .133[illegible]-08 |
| .4165978E+03 | .6144172E+01 | .1402134E+01 | .1597[illegible]-08 | .1245359E-08 | .6[illegible]017-10 |
| .4165978E+03 | .6120010E+01 | .1635031E+01 | 0. | 0. | 0. |

FIGURE B12 GN-1 PLUME RADIANCE PARTIAL DATA

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

| RAR | R0D | RDZ | SIG(R1) | SIG(R2) | SIG(R3) |
|---|---|---|---|---|---|
| .1812266E+05 | .2391461E+02 | 0. | .7726339E-05 | .5696352E-05 | .3017959E-07 |
| .3624532E+05 | .2390929E+02 | .5656104E+01 | .5921557E-05 | .5027512E-05 | .2560927E-07 |
| .3624532E+05 | .2389331E+02 | .1133337E+02 | .4656525E-05 | .3434968E-05 | .1824527E-07 |
| .3624532E+05 | .2386676E+02 | .1699055E+01 | .2538437E-06 | .1438829E-05 | .3863903E-08 |
| .3624532E+05 | .2382946E+02 | .2264473E+01 | .1026513E-05 | .7525236E-07 | .4085525E-08 |
| .3624532E+05 | .2378159E+02 | .2829391E+01 | .2996179E-07 | .2223926E-07 | .1215357E-08 |
| .3624532E+05 | .2372313E+02 | .3392710E+01 | .4290572E-08 | .3153271E-08 | .1790448E-09 |
| .3624532E+05 | .2366467E+02 | .3956330E+01 | 0. | 0. | 0. |
| .3881343E+05 | .5833979E+02 | 0. | .1228374E-05 | .9057232E-07 | .5243316E-08 |
| .7762687E+05 | .5832839E+02 | .1213531E+01 | .1123546E-05 | .8261457E-07 | .4789964E-08 |
| .7762687E+05 | .5829418E+02 | .2426533E+01 | .8688369E-07 | .6425795E-07 | .3721432E-08 |
| .7762687E+05 | .5823718E+02 | .3638878E+01 | .5647170E-07 | .4154638E-07 | .2423354E-08 |
| .7762687E+05 | .5815742E+02 | .4849839E+01 | .2935469E-07 | .2192543E-07 | .1287294E-08 |
| .7762687E+05 | .5805491E+02 | .6059086E+01 | .1183122E-07 | .8878575E-08 | .5211883E-09 |
| .7762687E+05 | .5792970E+02 | .7266193E+01 | .2327339E-08 | .1764393E-08 | .1853406E-09 |
| .7762687E+05 | .5780448E+02 | .8473301E+01 | 0. | 0. | 0. |
| .5950421E+05 | .9276497E+02 | 0. | .7055538E-07 | .5265417E-07 | .3132641E-08 |
| .1190084E+06 | .9274749E+02 | .1860443E+01 | .6490545E-07 | .4854458E-07 | .2895110E-08 |
| .1190084E+06 | .9269595E+02 | .3720230E+01 | .5134491E-07 | .3850801E-07 | .2293419E-08 |
| .1190084E+06 | .9260767E+02 | .5578702E+01 | .3454313E-07 | .2625545E-07 | .1559247E-08 |
| .1190084E+06 | .9248538E+02 | .7435244E+01 | .1941254E-07 | .1453412E-07 | .8735477E-09 |
| .1190084E+06 | .9232922E+02 | .9289081E+01 | .8435535E-08 | .6325596E-08 | .3825373E-09 |
| .1190084E+06 | .9213626E+02 | .1113958E+02 | .1949315E-08 | .1441282E-08 | .8772369E-10 |
| .1190084E+06 | .9194430E+02 | .1299027E+02 | 0. | 0. | 0. |
| .8019499E+05 | .1271901E+03 | 0. | .5454345E-07 | .4127527E-07 | .2478381E-08 |
| .1603900E+06 | .1271666E+03 | .2537356E+01 | .5012505E-07 | .3747954E-07 | .2262915E-08 |
| .1603900E+06 | .1270959E+03 | .5013526E+01 | .3951550E-07 | .2972582E-07 | .1793101E-08 |
| .1603900E+06 | .1269781E+03 | .7518526E+01 | .2729546E-07 | .2032571E-07 | .1233442E-08 |
| .1603900E+06 | .1268133E+03 | .1002057E+02 | .1502130E-07 | .1185304E-07 | .7217726E-09 |
| .1603900E+06 | .1266015E+03 | .1251908E+02 | .7547531E-08 | .5591583E-08 | .3402022E-09 |
| .1603900E+06 | .1263428E+03 | .1501316E+02 | .1856437E-08 | .1372357E-08 | .3391903E-10 |
| .1603900E+06 | .1260841E+03 | .1750724E+02 | 0. | 0. | 0. |
| .1008858E+06 | .1616153E+03 | 0. | .4745743E-07 | .3540430E-07 | .2155402E-08 |
| .2017715E+06 | .1615097E+03 | .3154206E+01 | [illegible] | [illegible] | [illegible] |
| .2017715E+06 | .1614969E+03 | .6307423E+01 | .3517735E-07 | .2610500E-07 | .1592568E-08 |
| .2017715E+06 | .1613486E+03 | .9458349E+01 | .2492333E-07 | .1845850E-07 | .1125477E-08 |
| .2017715E+06 | .1611413E+03 | .1260594E+02 | .1542745E-07 | .1141326E-07 | .6959622E-09 |
| .2017715E+06 | .1608749E+03 | .1574967E+02 | .7582513E-08 | .5681188E-08 | .3475383E-09 |
| .2017715E+06 | .1605494E+03 | .1888564E+02 | .2085315E-08 | .1541584E-08 | .9463113E-10 |
| .2017715E+06 | .1602239E+03 | .2202421E+02 | 0. | 0. | 0. |
| .1215765E+06 | .1963465E+03 | 0. | .4472423E-07 | .3317391E-07 | .2031057E-08 |
| .2431531E+06 | .1960048E+03 | .3801181E+01 | .4144335E-07 | .3071439E-07 | .1880375E-08 |
| .2431531E+06 | .1958976E+03 | .7601019E+01 | .3381382E-07 | .2503520E-07 | .1532514E-08 |
| .2431531E+06 | .1957191E+03 | .1139817E+02 | .2445433E-07 | .1809917E-07 | .1107741E-08 |
| .2431531E+06 | .1954693E+03 | .1519130E+02 | .1552290E-07 | .1155726E-07 | .7053116E-09 |
| .2431531E+06 | .1951482E+03 | .1897306E+02 | .8401105E-08 | .6212348E-08 | .3814506E-09 |
| .2431531E+06 | .1947560E+03 | .2276013E+02 | .2535418E-08 | .1951351E-08 | .1202615E-09 |
| .2431531E+06 | .1943637E+03 | .2654119E+02 | 0. | 0. | 0. |
| .1422673E+06 | .2304657E+03 | 0. | .3134239E-07 | .2320858E-07 | .1424282E-08 |
| .2845346E+06 | .2304239E+03 | .4448093E+01 | .2943453E-07 | .2179450E-07 | .1337484E-08 |
| .2845346E+06 | .2302985E+03 | .8894615E+01 | .2458351E-07 | .1827148E-07 | .1121596E-08 |
| .2845346E+06 | .2300896E+03 | .1333500E+02 | .1871287E-07 | .1389311E-07 | .8513260E-09 |
| .2845346E+06 | .2297972E+03 | .1777667E+02 | .1304933E-07 | .9558530E-08 | .5943559E-09 |
| .2845346E+06 | .2294215E+03 | .2220906E+02 | .8158321E-08 | .6045727E-08 | .3734480E-09 |
| .2845346E+06 | .2289625E+03 | .2663361E+02 | .2959732E-08 | .2183652E-08 | .1353531E-09 |
| .2845346E+06 | .2285036E+03 | .3105816E+02 | 0. | 0. | 0. |
| | | | .1503357E+01 | .1223324E+01 | .1351353E+00 |

FIGURE B12 GN-1 PLUME RADIANCE SPATIAL DATA (cont'd)

*** GN-1 is a single engine (Figure 1) isolated in space with no external surface radiance, ie. engine-internal-hot-parts-with-plume only. ***

GN-1 Altitude: 5000 FT (1.524 KM)
Speed: 599 FT/SEC (0.5 Mach)
IR Band: 3.75 to 4.85 $\mu$M

| Key | Observer | |
|---|---|---|
| Sym. | Altitude-FT | Slant Range-FT |
| ○ | 5000 | 10000 |
| □ | 0 | 10000 |
| △ | 0 | 50000 |

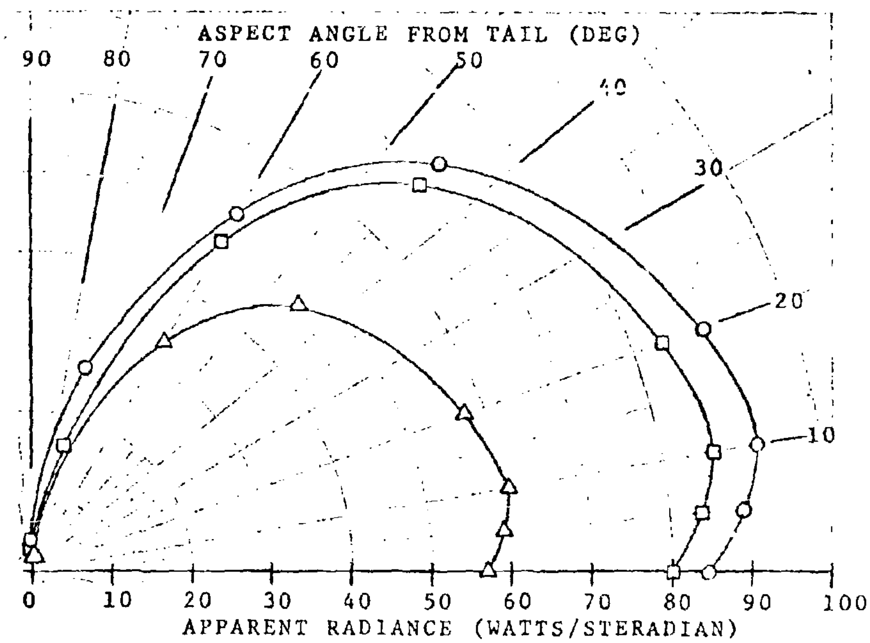



FIGURE B13 GN-1 IR SIGNATURE POLAR

## APPENDIX C

### GENERIC NOZZLE II (GN-2) DEMONSTRATION

A second typical single turbofan engine case has been developed for the purpose of demonstrating the operation of ASDIR-II for a practical configuration. Various alternative I/O modes are also demonstrated. This second demonstration involves not only the engine internal hot parts and exhaust gas plume emission, but also the IR emission from external surfaces of the entire aircraft. An IR missile from one mile will have a field of view diameter greater than 100 feet which is sufficiently large to encompass even a large aircraft. The demonstrator aircraft is shown in Figure C1 with temperature and emissivity data given in Table C1. The separated flow, axisymmetric engine exhaust nozzle (GN-2) has an external plug as shown in Figure C2. The view factors for GN-2 were obtained as demonstrated for GN-1, and this demonstration begins with the SIGSUB summary of which were already established in a "previous run."

A zero elevation analysis of GN-2 will include, in addition to external radiating surfaces, the IR signature resolved in two IR bands (2.5 to 3. and 4.5 to 5.), from two ranges (6076 feet and 12152 feet), and each range from two observer altitudes. In addition to these points of primary interest, the zero range reference point source will be included as will some aspect angle (0, 10, 30, 60, 90) coverage. Note that the ICHECK control will be exercised in this demonstration. Also note that this entire analysis was performed with a single Input Data Deck in a single computer run.

The Input Data Deck is shown in Figure C3 for the IR signature in which the SIGSUB engine representation has been determined in a preliminary run (not shown). The external radiating surfaces for zero elevation are included in IDS-2 (EAREA, ETEMP, NEXT). Note that the target aircraft is characterized by a single set of values for altitude, Mach number, engine operation, and plume. The aspect angles can be verified in S1B2 of Figure C3, and the ranges and observer altitudes can be verified in Figure C5. Observe the use of ICHECK, in Figure C3, to control the recycling of the programmed sequence. Also note the repeat use of IDS2 in Figures B4 and C3. In Figure C3, the EAREA's correspond to aspect angles shown in S1B2.

The signature output begins as shown in Figure C4. Figure C5 is an improved output format which requires less paper than the old format of Figure B10. Finally, the IR signatures are plotted in two bands, three ranges, and two observer altitudes in Figure C6. In passing, it is to be acknowledged that provisions are not included in ASDIR-II for automatic plotting of the IR signature polar which makes hand plotting of the output a necessary part of data reporting.

## APPENDIX C FIGURES

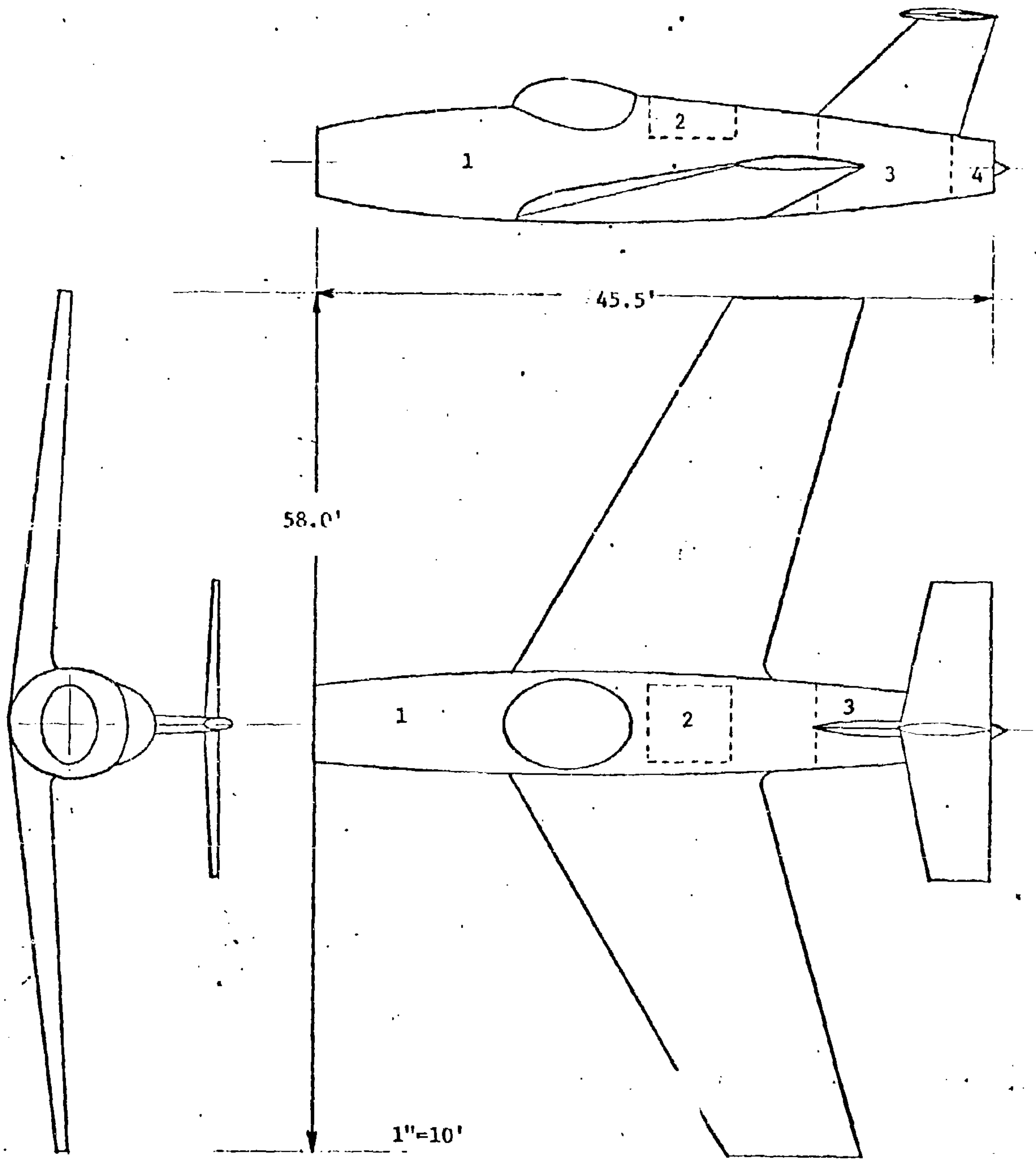



FIGURE C1 GN-2 IN A SINGLE ENGINE GENERIC AIRCRAFT

TABLE C1 EXTERNAL EMISSION DATA

| COMPONENT | NO. | EMISS. | TEMP. °K | AREA* $CM^2$ | | |
|---|---|---|---|---|---|---|
| | i | $\epsilon(i)$ | ETEMP(i) | ATOP(i) | ASIDE(i) | AEND(i) |
| BASIC A/C | 1 | .60 | 278. | 827767. | 283818. | 122632. |
| AVIO COOLER | 2 | .80 | 306. | 26942. | 13472. | 1433. |
| ENGINE BAY | 3 | .85 | 333. | 44745. | 44745. | 17953. |
| ENG SHROUD | 4** | .90 | 361. | 10363. | 10363. | 3932. |

NOTES:

* ASDIR2 accepts aspect angles measured from the tail. The aspect angle is the resultant of the azimuth ($\beta$) and the elevation ($\alpha$) as measured from the nose. Azimuth is positive toward the starboard wing and the elevation is positive up. The aspect is determined as described in Appendix A. The external radiating areas are prepared for input by the following;

$$EAREA(i)=(\epsilon(i))*(ATOP(i)*]SIN\alpha[+ASIDE(i)*]SIN\beta*COS\alpha[+ AEND(i)*]COS\beta*COS\alpha[)$$

where ] [ denotes absolute values and azimuth always occurs first, then elevation occur in the azimuthal plane.

** NEXT is given the largest value under NO. i.

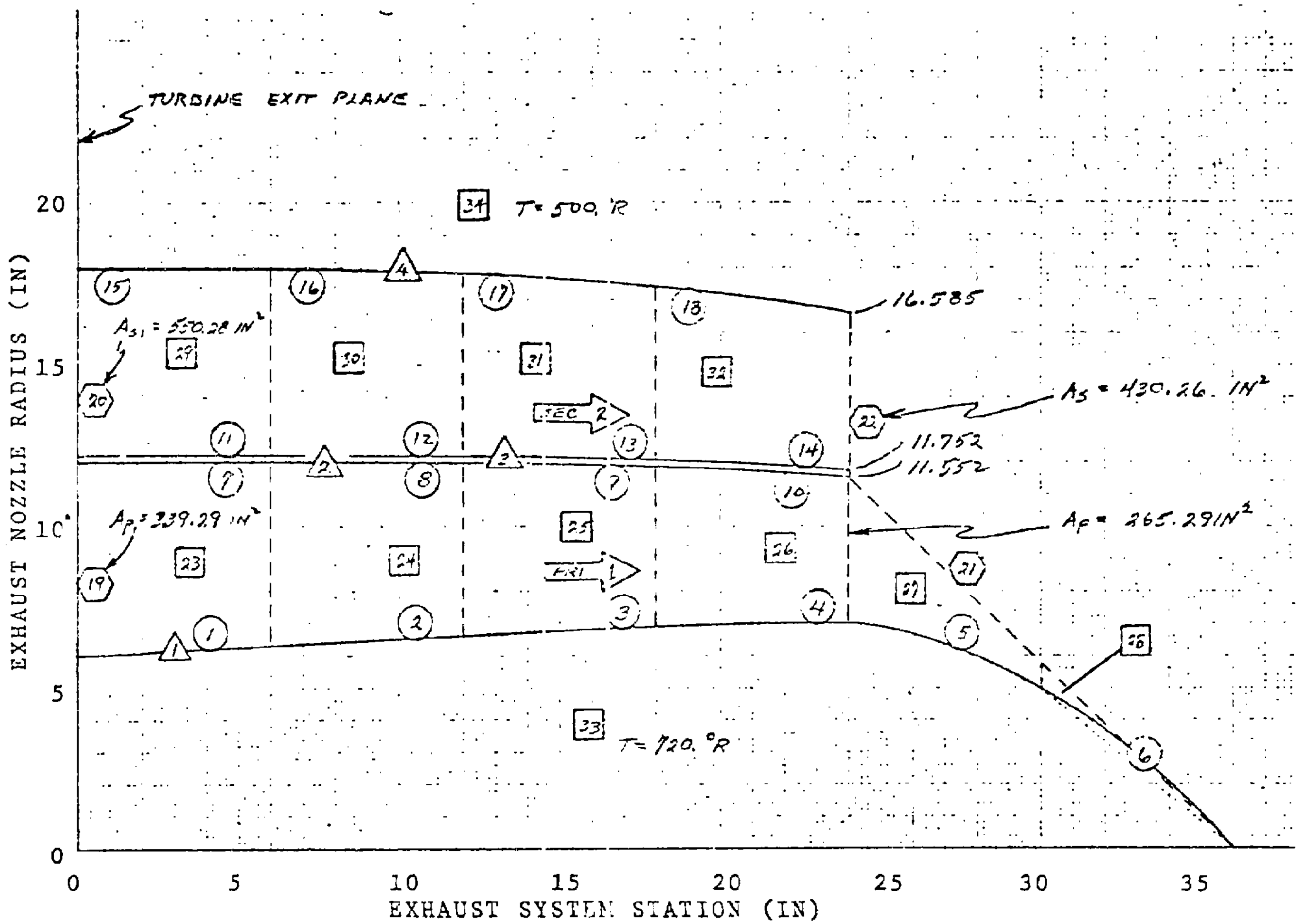



FIGURE C2 GN-2 NOZZLE DIAGRAM

```
IDS 1   02
SIB 1   05
    2  2318.34    762.61     0.0
    2  2185.78    724.48     10.0
    2  2094.74    68[illegible].25     3[illegible]
    2  1267.16    667.72     60.0
    2   435.49    649.75     90.0
IDS 2   $CASE ALTOBS(1)=3*5[illegible].,[illegible].,ALTPLM=3000.,AMI=2.5,AMF=3.0,
        NRANG=5,
        NEXT=4,ETEMP(1)=278.,3[illegible]6.,333.,361.,
        EAREA(1)=73579.,1146.,1526[illegible].,3539.,
        RANGE(1)=0.,6076.,12152.,6076.,12152.,
        NP=2,XP=12.0,[illegible]=7.[illegible],
        RPN=11.552,RSN=16.535,PTE=12.0,ANL=24. $
IDS 5   $PLUMIN $
IDS 5   $POWER NORM= ,JET=2,FLTM=[illegible].5,TSFCC=0.9,PRSC=0.98,FN=6555.,
        EPR=22.635,FPR=23.154,TTPN=1400.,TTSN=605.,WAPAC=8[illegible].112,
        FNRT=6566.,WASAC=215.58,$
IDS 2   $CASE
        EAREA(1)=102832.,3[illegible].,21633.,51[illegible]6.,
        $
    2   $CASE
        EAREA(1)=148865.,6381.,32232.,7728.,
        $
    2   $CASE
        EAREA(1)=184262.,99[illegible]7.,40567.,9847.,
        $
    2   $CASE
        EAREA(1)=170291.,10778.,38033.,9327.,
        $
    2   $CASE ICHECK=0,AMI=[illegible],AMF=F
        EAREA(1)=73579.,1146.,1526[illegible].,3539.,
        $
    2   $CASE
        EAREA(1)=102832.,30[illegible].,21633.,5186.,
        $
    2   $CASE
        EAREA(1)=148865.,6381.,32232.,7728.,
        $
    2   $CASE
        EAREA(1)=184262.,9907.,40567.,9847.,
        $
    2   $CASE
        EAREA(1)=17[illegible]291.,10778.,38[illegible]33.,9327.,
        $
    2   $CASE TERM=.TRUE. $
```

FIGURE C3 GN-2 IR SIGNATURE INPUT DATA DECK

```
* * * A S D I R * * *

PLUME ANALYSIS

** ENGINE DEFINITION

              AXIAL                   RADIAL      (FEET)

            -2.0000                  1.0000
             0.0000                   .9627

** PLUG DEFINITION

              AXIAL                   RADIAL      (FEET)

             1.0000                   .5833

 ** CASE DEFINITION

 WAVELENGTH          2.5              3.      MICRONS
 ASP ANGLE             0.              DEGREES

** PLUME DATA IS CALCULATED.    **

 ** FLIGHT CONDITIONS **

     ALTITUDE IS  5000. FEET.
     WEATHER IS ICAO MIL STD 210 STANDARD DAY
            WITH    .000333 WATER CONTENT.
                VISIBLE CONTRAIL IS NOT EXPECTED
     CASE MACH NUMBER IS  .53 AT AMBIENT
          PRESSURE OF      12.23 PSIA.
          TEMPERATURE OF  501. DEGR.
          VELOCITY OF      593. FT/SEC.

     ENGINE IS RUNNING WITH A FUEL EQUIVALENCE RATIO (FER) OF    .295
```

FIGURE C4   GN-2 IR SIGNATURE OUTPUT HEADER

** FLOW FIELD INPUT

| RADIUS (FEET) | VELOCITY (FT/SEC) | TEMPERATURE (DEG R) | XCO2 | XH2O |
|---|---|---|---|---|
| .5833 | 1651.05 | 1400.00 | .037842 | .042011 |
| .6213 | 1651.06 | 1400.00 | .037842 | .042011 |
| .6592 | 1651.06 | 1400.00 | .037842 | .042011 |
| .6971 | 1651.06 | 1400.00 | .037842 | .042011 |
| .7351 | 1651.06 | 1400.00 | .037842 | .042011 |
| .7730 | 1651.05 | 1400.00 | .037842 | .042011 |
| .8109 | 1651.06 | 1400.00 | .037842 | .042011 |
| .8489 | 1651.06 | 1400.00 | .037842 | .042011 |
| .8868 | 1651.06 | 1400.00 | .037842 | .042011 |
| .9247 | 1651.05 | 1400.00 | .037842 | .042011 |
| .9627 | 1651.05 | 1400.00 | .037842 | .042011 |
| 1.0006 | 1088.01 | 607.10 | .000330 | .000330 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 1.0765 | 1088.01 | 607.10 | .000330 | .000330 |
| 1.1144 | 1088.01 | 607.10 | .000330 | .000330 |

** AMBIENT CONDITIONS

| | | | | |
|---|---|---|---|---|
| 1.1523 | 598.97 | 500.84 | .000330 | .000330 |

** INPUT PARAMETERS

| | | PLUME | AMBIENT |
|---|---|---|---|
| PRESSURE, | P | .839 | .832 ATMOS. |
| SPECIFIC HEAT, | CP | .285 BTU/LB-F | |
| GAS CONSTANT, | R | 53.472 FT/F | |
| SP. HT. RATIO | | 1.334 | |
| MACH NUMBER | | 1.000 | |
| SECONDARY PRESS.= | | .856 ATMOS. | |

DPDX = .1000

R8= .953 XC= 5.170 REND= 10.015 AL= 111.445

FIGURE C4 GN-2 IR SIGNATURE OUTPUT HEADER (cont'd)

* POINT SOURCE IR INTENSITY ***

SPECTRAL BAND - 2.50 TO 3.00 MICRONS
VEHICLE ALTITUDE - 1.52 KM OR 5.00 KFT
ASPECT ANGLE - 0.0 DEGREES IN A NOR. ATMOSPHERE.
EFFECTIVE BLACK BODY AREA - ABB = 2318.3400 CMSQ
EFFECTIVE BB TEMPERATURE - TBB = 732.5100 DEGK
EFFECTIVE BACKGROUND TEMP - TBACK = 0.0000 DEGK

| | | | | | |
|---|---|---|---|---|---|
| SLT RNG (KM/NM) | 0./ 0. | 2./ 1. | 4./ 2. | 2./ 1. | 4./ 2. |
| OB ALT (KM/KFT) | 2./ 5. | 2./ 5. | 2./ 5. | 0./ 0. | [illegible] |
| BCKGRND (W/STR) | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| METALS (W/STR) | 91.41[illegible]4 | 91.4134 | 91.4134 | 91.4134 | 91.4134 |
| ATT MET (W/STR) | 46.7589 | 2[illegible].[illegible]959 | 15.8247 | 15.6397 | 1[illegible].4433 |
| PLM GAS (W/STR) | .8397 | .0812 | .0455 | .0531 | .0282 |
| EXT EMS (W/STR) | .195[illegible] | .[illegible]644 | .0515 | .0540 | .0411 |
| APP RAD (W/STR) | 47.7936 | 20.24[illegible]7 | 15.9229 | 15.7468 | 12.5126 |

* POINT SOURCE IR INTENSITY ***

SPECTRAL BAND - 2.5[illegible] TO 3.[illegible] MICRONS
VEHICLE ALTITUDE - 1.52 KM OR 5.[illegible] KFT
ASPECT ANGLE - 1[illegible].[illegible] DEGREES IN A NOR. ATMOSPHERE.
EFFECTIVE BLACK BODY AREA - ABB = 2135.78[illegible] CMSQ
EFFECTIVE BB TEMPERATURE - TBB = 724.4800 DEGK
EFFECTIVE BACKGROUND TEMP - TBACK = 0.0000 DEGK

| | | | | | |
|---|---|---|---|---|---|
| SLT RNG (KM/NM) | 0./ 0. | 2./ 1. | 4./ 2. | 2./ 1. | 4./ 2. |
| OB ALT (KM/KFT) | 2./ 5. | 2./ 5. | 2./ 5. | 0./ 0. | 0./ [illegible]. |
| BCKGRND (W/STR) | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| METALS (W/STR) | 60.1060 | 50.1050 | 60.1050 | 6[illegible].1[illegible] | 6[illegible].1[illegible] |
| ATT MET (W/STR) | 44.7565 | 13.8690 | 11.8126 | 11.3978 | 8.4643 |
| PLM GAS (W/STR) | 1.7957 | .0827 | .0455 | .0575 | .0284 |
| EXT EMS (W/STR) | .2812 | .0925 | .0739 | .[illegible]775 | .[illegible]59[illegible] |
| APP RAD (W/STR) | 46.9344 | 14.[illegible]442 | 1[illegible].9331 | 11.5289 | 8.5517 |

FIGURE C5 GN-2 IR SIGNATURE OUTPUT

* POINT SOURCE IR INTENSITY ***

SPECTRAL BAND - 2.50 TO 3.[illegible] MICRONS
VEHICLE ALTITUDE - 1.[illegible] KM OR [illegible] KFT
ASPECT ANGLE - 30.0 DEGREES IN A NOR. ATMOSPHERE.
EFFECTIVE BLACK BODY AREA - ABB = 2,[illegible] CMSQ
EFFECTIVE BB TEMPERATURE - TBB = 58[illegible].26[illegible] DEGK
EFFECTIVE BACKGROUND TEMP - TBACK = [illegible] DEGK

| | | | | | |
|---|---|---|---|---|---|
| SLT RNG (KM/NM) | 1./ [illegible]. | 2./ 1. | 4./ 2. | 3./ 1. | 4./ [illegible]. |
| OB ALT (KM/KFT) | 2./ 5. | 2./ 5. | 2./ 5. | 1./ 3. | 0./ 0. |
| BCKGRND (W/STR) | [illegible] | [illegible] | [illegible].0000 | 0.0000 | 0.0000 |
| METALS (W/STR) | 35.[illegible]775 | 35.0775 | 36.0775 | 35.0775 | 35.0775 |
| ATT MET (W/STR) | 32.3433 | 8.5816 | 5.6829 | 7.0480 | 5.2316 |
| PLM GAS (W/STR) | 5.8365 | .1178 | .0550 | .0759 | .0403 |
| EXT EMS (W/STR) | .4237 | .1333 | .1113 | .1158 | .0883 |
| APP RAD (W/STR) | 38.5035 | 8.8327 | 6.8602 | [illegible] | 5.3503 |

* POINT SOURCE IR INTENSITY ***

SPECTRAL BAND - 2.50 TO 3.00 MICRONS
VEHICLE ALTITUDE - 1.72 KM OR 3.00 KFT
ASPECT ANGLE - 60.0 DEGREES IN A NOR. ATMOSPHERE.
EFFECTIVE BLACK BODY AREA - ABB = 1,257.1600 CMSQ
EFFECTIVE BB TEMPERATURE - TBB = 557.7200 DEGK
EFFECTIVE BACKGROUND TEMP - TBACK = [illegible] DEGK

| | | | | | |
|---|---|---|---|---|---|
| SLT RNG (KM/NM) | [illegible]./ [illegible]. | 2./ 1. | [illegible]/ 2. | 3./ 1. | 4./ 2. |
| OB ALT (KM/KFT) | 2./ 5. | 2./ 5. | 2./ 5. | 1./ 3. | [illegible]/ [illegible]. |
| BCKGRND (W/STR) | [illegible] | [illegible] | [illegible] | [illegible] | 0.0000 |
| METALS (W/STR) | 17.6893 | 17.5893 | 17.5893 | 17.5893 | 17.5893 |
| ATT MET (W/STR) | 15.5157 | 4.2691 | [illegible] | 3.4897 | 2.5897 |
| PLM GAS (W/STR) | 6.6648 | .1044 | .0585 | .0577 | .0353 |
| EXT EMS (W/STR) | .5379 | .1768 | .1413 | .1483 | .1128 |
| APP RAD (W/STR) | 27.8186 | 4.57[illegible] | 3.2080 | 3.7043 | 2.7784 |



FIGURE C5 GN-2 IR SIGNATURE OUTPUT (cont'd)

* POINT SOURCE IR INTENSITY ***

SPECTRAL BAND - 2.50 TO 3.[illegible] MICRONS
VEHICLE ALTITUDE - 1.52 KM OR 5.[illegible] KFT
ASPECT ANGLE - 9[illegible] DEGREES IN A HOR. ATMOSPHERE.
EFFECTIVE BLACK BODY AREA - TB3 = 475.4900 CMSQ
EFFECTIVE BB TEMPERATURE - TB3 = 549.7500 DEGK
EFFECTIVE BACKGROUND TEMP - TRACK = 0.0000 DEGK

| SLT RNG (KM/NM) | 0./ 0. | 2./ 1. | 4./ 2. | 2./ 1. | 4./ 2. |
|---|---|---|---|---|---|
| OB ALT (KM/KFT) | 2./ 5. | 2./ 5. | 2./ 5. | 0./ 0. | 0./ 0. |
| BCKGRND (W/STR) | 0.0000 | 0.0000 | 0.0000 | 0.[illegible] | [illegible] |
| METALS (W/STR) | 3.9263 | 3.9263 | 3.9263 | 3.9263 | 3.9263 |
| ATT MET (W/STR) | 3.6010 | .9280 | .7232 | .7527 | .5565 |
| PLM GAS (W/STR) | 6.9659 | .1009 | .0555 | .0557 | .0346 |
| EXT EMS (W/STR) | .5080 | .1670 | .1334 | .1409 | .1965 |
| APP RAD (W/STR) | 1[illegible].9751 | 1.1957 | .9131 | .9377 | .7[illegible]77 |

FIGURE C5 GN-2 IR SIGNATURE OUTPUT (cont'd)

WAVELENGTH [illegible] ,1000 MI[illegible]
A[illegible] ANGL[illegible]

** POINT SOURCE IR INTENSITY ***

SPECTRAL BAND - 4.5[illegible] TO 5.00 MICRONS
VEHICLE ALTITUDE - 1.5[illegible] KM O[illegible] [illegible].00 KFT
ASPECT ANGLE - 0.0 DEGREES IN A [illegible] ATMOSPHERE.
EFFECTIVE BLACK BODY AREA - ABB = [illegible]319.[illegible] [illegible]
EFFECTIVE BB TEMPERATURE - TBB = 75[illegible].[illegible] DEGK
EFFECTIVE BACKGROUND TEMP - TBACK = 0.0000 DEGK

| | | | | | |
|---|---|---|---|---|---|
| SLT RNG (KM/NM) | 0./ [illegible]. | 2./ 1. | 4./ 2. | 2./ 1. | 4./ 2. |
| OB ALT (KM/KFT) | 2./ 5. | 2./ 5. | 2./ 5. | 0./ 0. | 0./ 0. |
| BCKGRND (W/STR) | [illegible] | [illegible] | [illegible] | [illegible] | 0.0000 |
| METALS (W/STR) | 109.4279 | 119.4279 | 1[illegible]9.4279 | 119.4279 | 109.4279 |
| ATT MET (W/STR) | 10[illegible].7675 | 7[illegible].9822 | 59.8753 | 53.8107 | 51.5473 |
| PLM GAS (W/STR) | 2.1917 | .5525 | .3594 | .4750 | .[illegible] |
| EXT EMS (W/STR) | 9.6871 | 6.4550 | 5.4[illegible] | [illegible].7743 | 4.6407 |
| APP RAD (W/STR) | 112.5[illegible] | 77.8899 | 65.5[illegible] | 70.0[illegible] | [illegible] |

** POINT SOURCE IR INTENSITY ***

SPECTRAL BAND - 4.5 TO 5.[illegible] MICRONS
VEHICLE ALTITUDE - 1.52 KM OR [illegible] KFT
ASPECT ANGLE - 1[illegible] DEG [illegible] IN [illegible] ATMOSPHERE.
EFFECTIVE BLACK BODY AREA - ABB = [illegible]133.[illegible] [illegible]
EFFECTIVE BB TEMPERATURE - TBB = [illegible]4.4[illegible] DEGK
EFFECTIVE BACKGROUND TEMP - TBACK = 0.0000 DEGK

| | | | | | |
|---|---|---|---|---|---|
| SLT RNG (KM/NM) | 0./ 0. | 2./ 1. | 4./ 2. | 2./ 1. | 4./ 2. |
| OB ALT (KM/KFT) | 2./ 5. | 2./ 5. | 2./ 5. | 3./ 0. | 0./ 0. |
| BCKGRND (W/STR) | 0.0000 | 0.0000 | 0.0000 | [illegible] | [illegible] |
| METALS (W/STR) | 83.3665 | 83.7665 | 83.[illegible] | 8[illegible] | [illegible] |
| ATT MET (W/STR) | 80.1921 | 54.5123 | 45.[illegible] | [illegible] | [illegible] |
| PLM GAS (W/STR) | 2.4997 | .5120 | .4[illegible]7 | .5[illegible] | [illegible] |
| EXT EMS (W/STR) | 13.[illegible] | [illegible] | 7.7[illegible] | [illegible] | [illegible] |
| APP RAD (W/STR) | 95.5401 | [illegible] | 54.[illegible]775 | [illegible] | [illegible] |

FIGURE C5 CH-2 IR SIGNATURE OUTPUT (cont'd)

* POINT SOURCE IR INTENSITY ***

SPECTRAL BAND - 4.50 TO 5.00 MICRONS
VEHICLE ALTITUDE - 1.52 KM OR 5.00 KFT
ASPECT ANGLE - 30.0 DEGREES IN A NOR. ATMOSPHERE.
EFFECTIVE BLACK BODY AREA - ABB = 2194.7400 CMSQ
EFFECTIVE BB TEMPERATURE - TBB = 69[illegible].2600 DEGK
EFFECTIVE BACKGROUND TEMP - TBACK = 0.0000 DEGK

| SLT RNG (KM/NM) | [illegible]./ [illegible]. | 2./ 1. | 4./ 2. | 2./ 1. | 4./ 2. |
|---|---|---|---|---|---|
| OB ALT (KM/KFT) | 2./ 5. | 2./ 5. | 2./ 5. | 0./ 0. | 0./ 0. |
| BCKGRND (W/STR) | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| METALS (W/STR) | 50.5224 | 50.5224 | 50.5224 | 50.5224 | 50.5224 |
| ATT MET (W/STR) | 59.2431 | 39.7945 | 33.4917 | 35.7475 | 28.7819 |
| PLM GAS (W/STR) | 4.1850 | 1.0072 | .5485 | .8870 | .5483 |
| EXT EMS (W/STR) | 20.7920 | 13.8499 | 11.6525 | 12.3305 | 9.9595 |
| APP RAD (W/STR) | 84.2201 | 54.6515 | 45.7928 | 43.0251 | 39.2897 |

* POINT SOURCE IR INTENSITY ***

SPECTRAL BAND - 4.50 TO 5.00 MICRONS
VEHICLE ALTITUDE - 1.52 KM OR 5.00 KFT
ASPECT ANGLE - 60.0 DEGREES IN A NOR. ATMOSPHERE.
EFFECTIVE BLACK BODY AREA - ABB = 1267.1600 CMSQ
EFFECTIVE BB TEMPERATURE - TBB = 667.7200 DEGK
EFFECTIVE BACKGROUND TEMP - TBACK = 0.0000 DEGK

| SLT RNG (KM/NM) | [illegible]./ [illegible]. | 2./ 1. | 4./ 2. | 2./ 1. | 4./ 2. |
|---|---|---|---|---|---|
| OB ALT (KM/KFT) | 2./ 5. | 2./ 5. | 2./ 5. | 0./ 0. | 0./ 0. |
| BCKGRND (W/STR) | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| METALS (W/STR) | 31.5334 | 31.5334 | 31.5334 | 31.5334 | 31.5334 |
| ATT MET (W/STR) | 31.1575 | 20.8153 | 17.4991 | 18.5970 | 15.0372 |
| PLM GAS (W/STR) | 4.1923 | .9570 | .5123 | .8442 | .5181 |
| EXT EMS (W/STR) | 26.3265 | 17.5364 | 14.7550 | 15.5398 | 12.6114 |
| APP RAD (W/STR) | 61.5737 | 39.3097 | 32.9570 | 35.2301 | 29.1567 |

FIGURE C5 GN-2 IR SIGNATURE OUTPUT (Cont'd)

* POINT SOURCE IR INTENSITY ***

SPECTRAL BAND - 4.50 TO 5.00 MICRONS
VEHICLE ALTITUDE - 1.52 KM OR 5.00 KFT
ASPECT ANGLE - 90.0 DEGREES IN A NOR. ATMOSPHERE.
EFFECTIVE BLACK BODY AREA - ABB = 435.4900 CMSQ
EFFECTIVE BB TEMPERATURE - TBB = 549.75[illegible] DEGK
EFFECTIVE BACKGROUND TEMP - TBACK = [illegible] DEGK

| SLT RNG (KM/NM) | [illegible]./ [illegible]. | 2./ 1. | 4./ 2. | 2./ 1. | 4./ 2. |
|---|---|---|---|---|---|
| OB ALT (KM/KFT) | 2./ 5. | 2./ 5. | 2./ 5. | 1./ 3. | ./ 0. |
| BCKGRND (W/STR) | [illegible] | 0.[illegible] | [illegible].0000 | 0.0000 | 0.0000 |
| METALS (W/STR) | 7.4534 | 7.4534 | 7.4534 | 7.4534 | 7.4534 |
| ATT MET (W/STR) | 7.3647 | 4.9202 | 4.1365 | 4.4190 | 3.5542 |
| PLM GAS (W/STR) | 4.0278 | .9295 | .5931 | .8188 | .5014 |
| EXT EMS (W/STR) | 24.8061 | 16.5238 | 13.9027 | 14.7830 | 11.8829 |
| APP RAD (W/STR) | 36.1985 | 22.3734 | 18.6325 | 20.0208 | 15.9385 |

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

FIGURE C5 GN-2 IR SIGNATURE OUTPUT (cont'd)

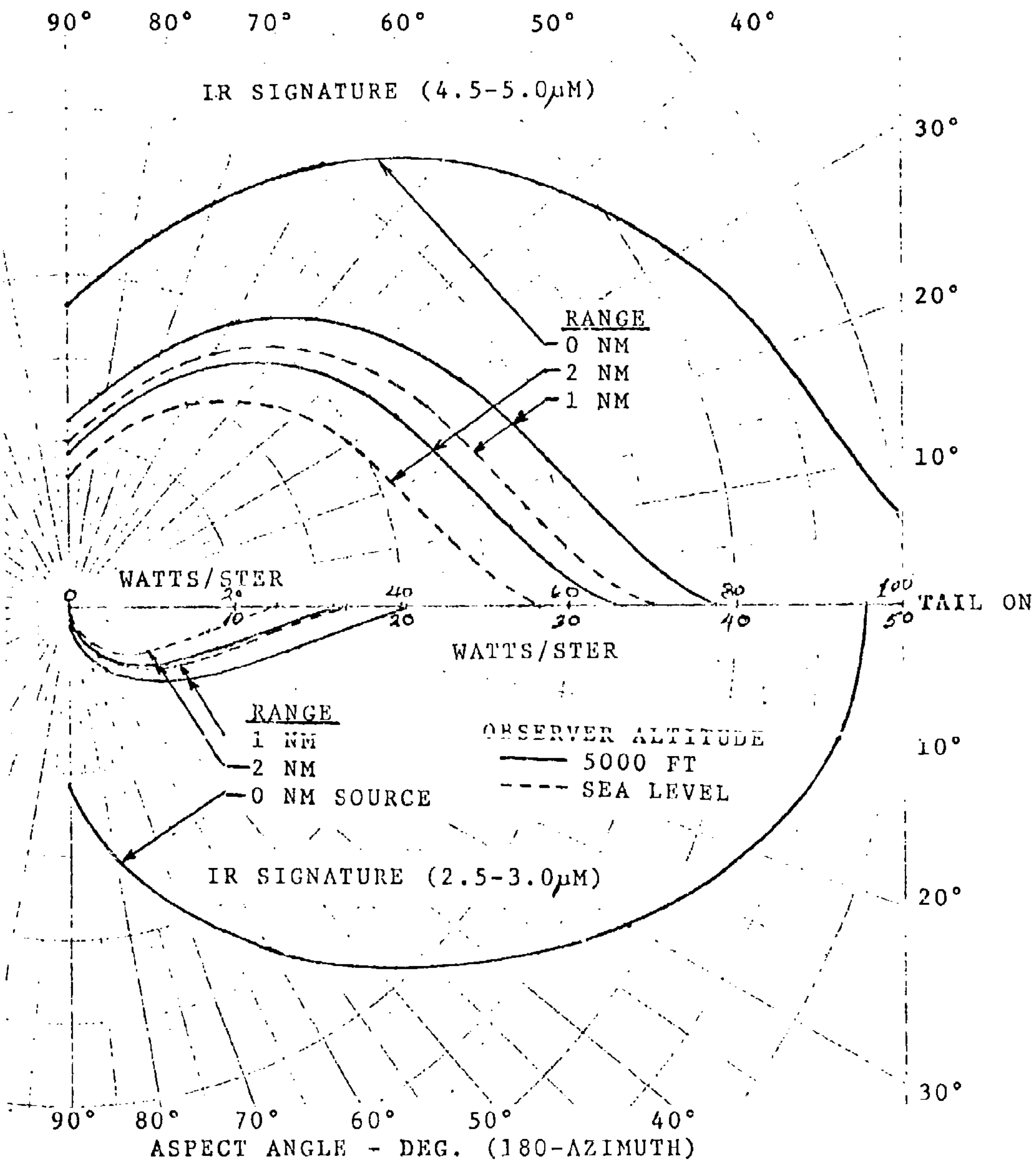



FIGURE C6 GN-2 IR SIGNATURE IN TWO B. DS AT ZERO ELEVATION

APPENDIX D

## GENERIC NOZZLE III (GN-3) DEMONSTRATION

The final typical turbofan engine case represents a twin engine aircraft shown in Figure D1. The engines are mounted together in the tail and have a partially mixed flow axisymmetric exhaust nozzle with no external plug. The plume interaction which may occur in the real exhaust nozzle with plumes has not been treated in ASDIR so, therefore must be neglected.

This case will demonstrate output superposition required for the IR analysis of multi-engine aircraft and engine shielding by aircraft parts. The second entry feature affected by SIGSUB will again be demonstrated as it was in Appendix C. The signature will be developed by first analyzing one engine by itself and then adding the external emitting surfaces of the aircraft to the Input Data Deck for the analysis of the second engine. The two outputs will be added to form the final IR signature. Figure D2 shows those aspects angles for which low temperature external parts block to some degree the view of the higher temperature radiating parts. The exhaust nozzle diagram is shown in Figure D3. The several input data decks, output samples, and a final IR signature plot in the plane of symmetry (zero azimuth) are also shown.

The IR Hot Part Summary Input Data Deck for the GN-3 demonstration is shown in Figure D4. The preliminary analysis to acquire the view factors was conducted but is not shown. Figure D5 shows the SIGSUB input format to represent the results obtained from the input of Figure D4. The output list of the input is omitted in these figures. Note in Figure D5 that the external radiating areas of the aircraft are fully described by input data (ETEMP, EAREA) but their analysis is excluded by the input, NEXT=0. The IR signature input data deck for one engine plus airframe is shown in Figure D6 wherein the NEXT = 4 input on the first IDS2 card is not rescinded by NEXT = 0 on the second IDS2 card. The other data of Figure D6 is identical to the engine only data in Figure D5. A sample of the engine only IR signature is shown in Figure D7 and engine plus airframe IR signature data is shown in Figure D8. The composite zero azimuth IR signature (sum of Figures D7 and D8) is shown in Figure D9. Since the tail shielding occurs only in the look-down scenerio, the observer altitude is above the target. In this case, a non-zero earth background is required for which a 290°K (62°F) blackbody has been assumed to be appropriate as indicated by texts on backgrounds.

## APPENDIX D FIGURES

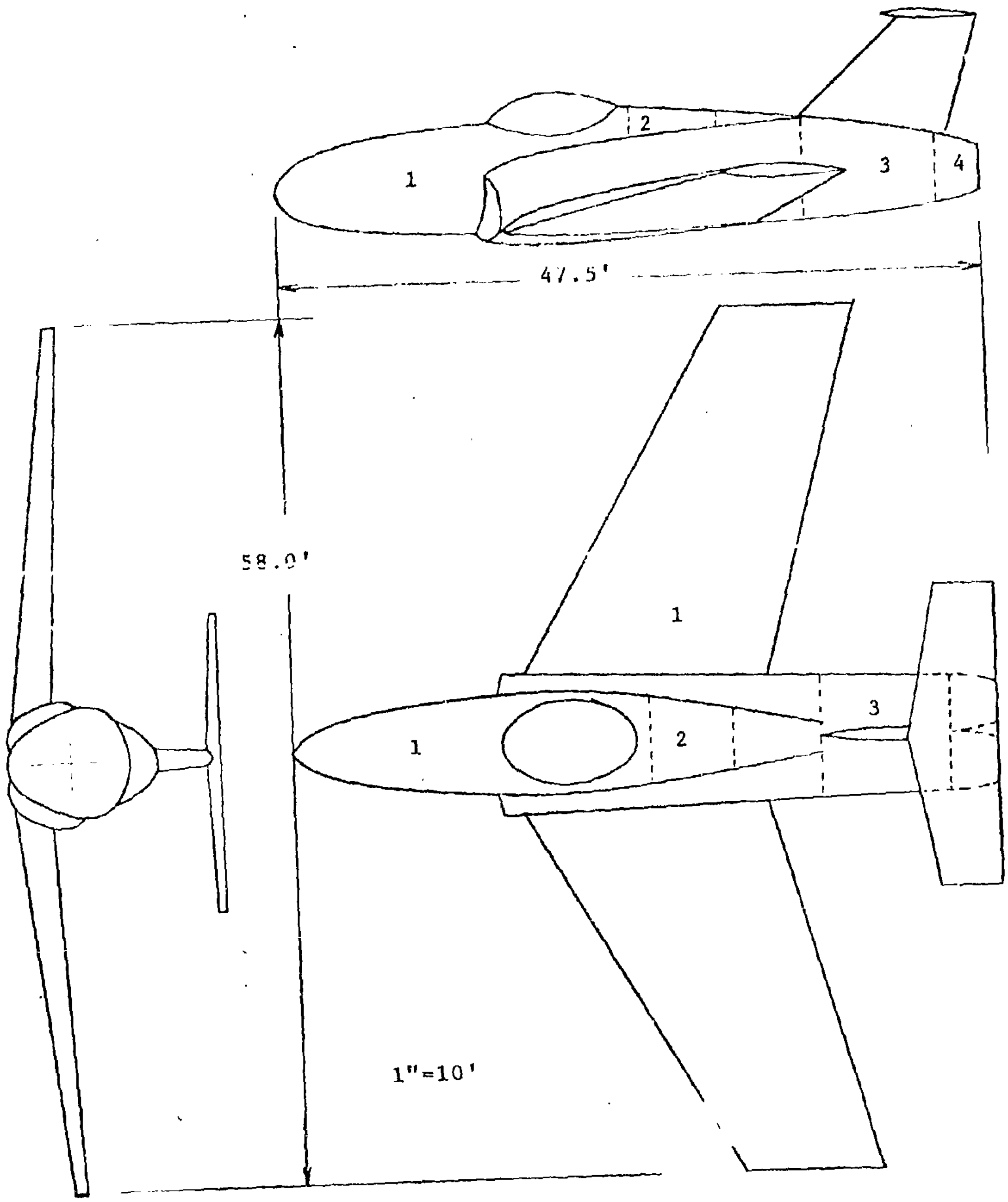



FIGURE D1 GN-3 IN A TWIN ENGINE GENERIC AIRCRAFT

TABLE D1 EXTERNAL EMISSION DATA

| COMPONENT | NO. | EMISS. | TEMP. °K | AREA* $CM^2$ | | |
|---|---|---|---|---|---|---|
| | i | (i) | ETEMP(i) | ATOP(i)** | ASIDE(i) | AEND(i) |
| BASIC A/C | 1 | .60 | 278. | 885273. | 299111. | 160304. |
| AVIO COOLER | 2 | .80 | 306. | 20067. | 9104. | 5261. |
| ENGINE BAY | 3 | .85 | 333. | 67076. | 49183. | 19045. |
| ENG SHROUD | 4 | .90 | 361. | 21832. | 13843. | 18711. |

NOTES:

* See Table C1 for the resolution of EAREA(i).

** The areas of radiating surfaces must be proportionately reduced to adjust for shielding by tail surfaces, wing tips, and other similar obstructions. For example, ATOP(i) must be considered as zero for elevations from below.

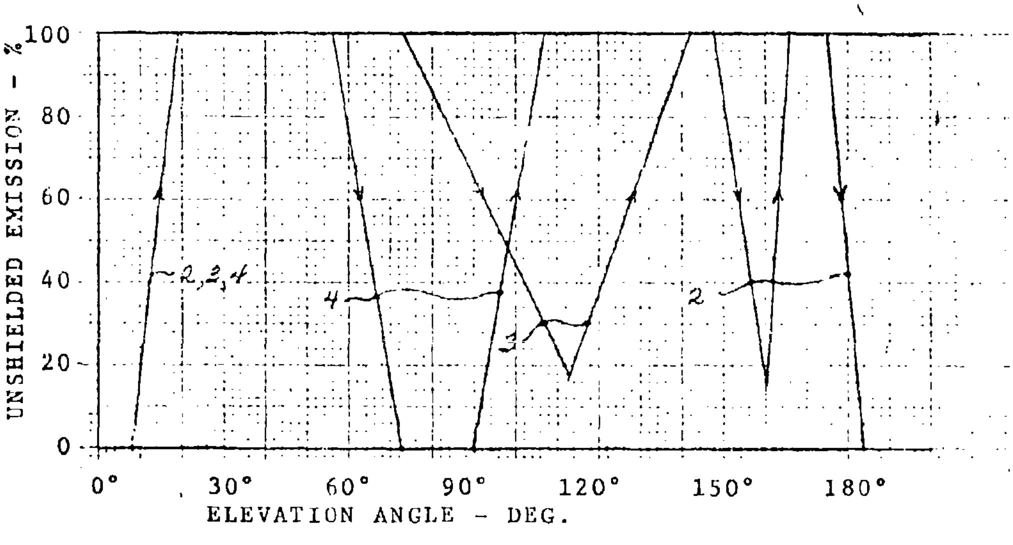



FIGURE D2 EMISSION SHIELDING BY PARTS OF A GENERIC TWIN ENGINE AIRCRAFT

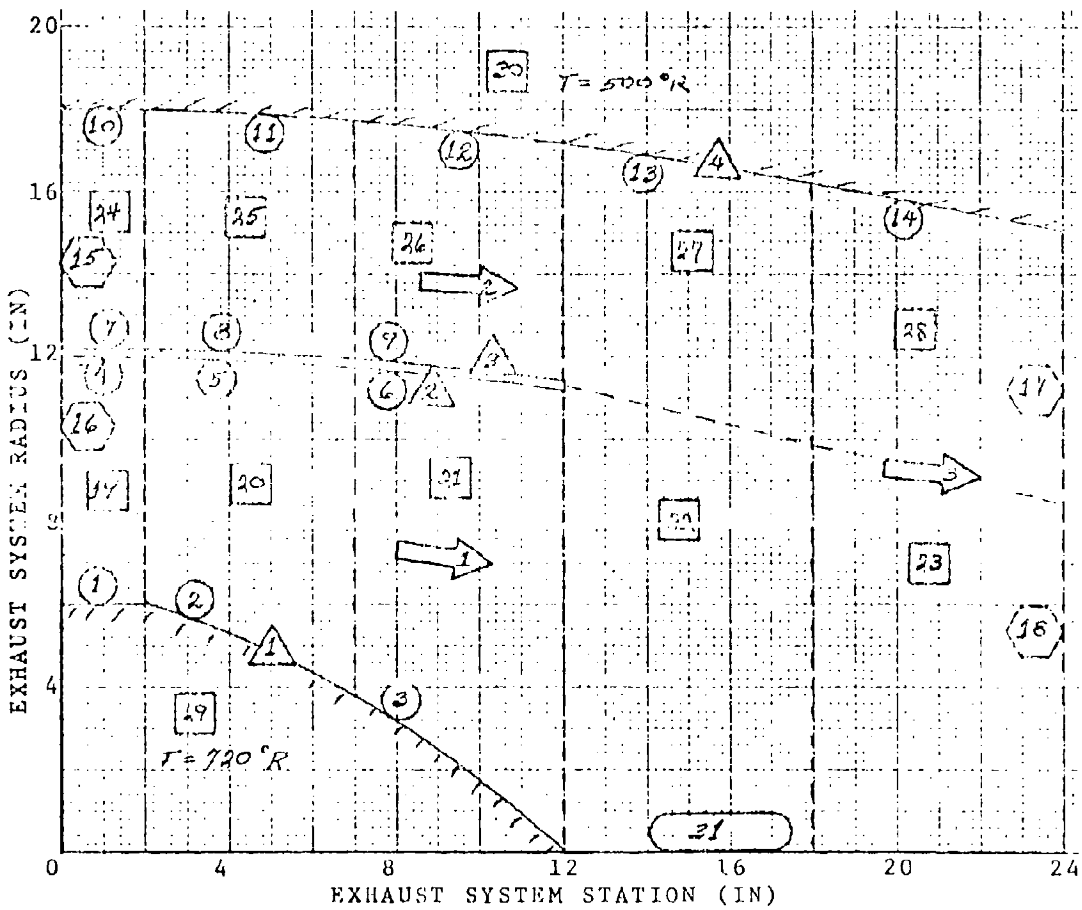



FIGURE D3 GN-3 NOZZLE DIAGRAM

```
IDS1  01
IB 1              <<-*****************->>
          THIS IS THE THIRD ASDIP II SAMPLE INPUT SET
      <<-     GENERIC NOZZLE III IN A TWIN  ENG A/C        ->>
                  <<-*****************->>
                            *

   2
   3  0304140401
   4 0.0        6.0        2.0        6.0        +1.        0101
     2.0        6.0        7.0        3.7        +1.        0201
     7.0        3.7        12.0       0.0        +1.        0301
     0.0        12.0       2.0        12.0       -1.0       0402
     2.0        12.0       7.0        11.7       -1.0       0502
     7.0        11.7       12.0       11.1       -1.0       0602
     0.0        12.2       2.00       12.2       +1.0       0703
     2.0        12.2       7.00       11.9       +1.0       0803
     7.0        11.9       12.0       11.3       +1.0       0903
     0.0        18.0       2.00       18.0       -1.0       1004
     2.0        18.0       7.00       17.7       -1.0       1104
     7.0        17.7       12.0       17.1       -1.0       1204
     12.0       17.1       18.0       16.1       -1.0       1304
     18.0       16.1       24.0       15.0       -1.0       1404
     12.0       0.0        24.0       0.0        +1.0       3101
   5 0.0        12.2       0.0        18.0       -1.0       500.       15
     0.0        6.0        0.0        12.0       -1.0       1400.      16
     24.0       8.4        24.0       15.0       +1.0       180.       17
     24.0       0.0        24.0       8.40       +1.0       190.       18
   6 24.0
   7  0001
  10  0.00000    0.00000    0.00000    .18528     .30344     .37974     [illegible]
      0.00000    0.00000    0.00000    0.00000    0.00000    .31137     [illegible]
      .01350     .00047
  11  75.39822
  10  0.00000    0.00000    .08401     .35030     .27545     0.00000    0.00000
      0.00000    0.00000    0.00000    .02120     .08527     0.00000    .17450
      .03398
  11 167.71474
  10  0.00000    .01173     .11523     .29361     0.00000    0.00000    [illegible]
      0.00000    0.00000    .14879     .17522     0.00000    .10451     .14783
  11  72.30211
  10  .05229     .10798     .07545     0.00000    0.00000    0.00000    0.00000
      0.00000    .01571     .04416     0.00000    .42691     .04873     .03775
  11 150.79645
  10  .13315     .11408     0.00000    0.00000    0.00000    0.00000    0.00000
      .04016     .06733     0.00000    .25114     .05459     .14559
  11 372.94823
  10  .17209     0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
      .10113     0.00000    .13689     .06606     .05783
  11 360.71096
  10  0.00000    0.00000    0.00000    .18397     .30108     .0810      .02097
      .40721     0.00000    .00094     0.00000
  11 153.30972
  10  -.00000    0.00000    .11293     .40489     .23658     .05988     .01237
      0.00000    .00394     0.00000
  11 379.24271
  10  -.00000    .02796     .18876     .41528     .27282     .25143     .03871
      .01509     0.00000
```

FIGURE D4  GN-3 HOT PARTS SUMMARY INPUT DATA DECK

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 11 | 367.03923 | | | | | | |
| 10 | .02777 | .05910 | .04071 | .03051 | .01697 | .42323 | 0.0000 |
| | .01009 | | | | | | |
| 11 | 226.19467 | | | | | | |
| 10 | .06488 | .05240 | .03984 | .02317 | .24924 | 0.0000 | .0439 |
| 11 | 561.78278 | | | | | | |
| 10 | .06695 | .07508 | .06902 | .12404 | 0.00040 | .03378 | .0563 |
| 11 | 550.55884 | | | | | | |
| 10 | .16234 | .13108 | .06922 | .00327 | .13069 | .07500 | |
| 11 | 634.43746 | | | | | | |
| 10 | .17164 | .23854 | .12718 | .25846 | .05687 | | |
| 11 | 595.99154 | | | | | | |
| 10 | 0.00000 | 0.00000 | .06929 | .00511 | | | |
| 11 | 550.28137 | | | | | | |
| 10 | 0.00000 | .11730 | .07946 | | | | |
| 11 | 339.29201 | | | | | | |
| 10 | 0.00000 | 0.00000 | | | | | |
| 11 | 485.18757 | | | | | | |
| 10 | 0.00000 | | | | | | |
| 11 | 221.67078 | | | | | | |
| 14 | 0104 | | | | | | |
| 15 | 01020331 | | | | | | |
| 14 | 0203 | | | | | | |
| 15 | 040506 | | | | | | |
| 14 | 0303 | | | | | | |
| 15 | 070809 | | | | | | |
| 14 | 0405 | | | | | | |
| 15 | 1011121314 | | | | | | |
| 16 | 0101 | 0.0 | 12.0 | | | | |
| 18 | 03 | | | | | | |
| 19 | 1901 | 1.0 | | | | | |
| | 2001 | 4.5 | | | | | |
| | 2101 | 9.5 | | | | | |
| 20 | 0201 | .001 | 1.3 | | | | |
| | 0101 | .001 | 1.3 | | | | |
| 16 | 02 | 0.0 | 12.0 | | | | |
| 18 | 03 | | | | | | |
| 19 | 24 | 1.0 | | | | | |
| | 25 | 4.5 | | | | | |
| | 26 | 9.5 | | | | | |
| 20 | 04 | 0.001 | 1.3 | | | | |
| | 03 | .001 | 1.3 | | | | |
| 16 | 030201 | 12.0 | 24.0 | | | | |
| 17 | 706.86 | | | | | | |
| 18 | 04 | | | | | | |
| 19 | 2201 | 15.0 | | | | | |
| | 2301 | 21.0 | | | | | |
| | 2701 | 15.0 | | | | | |
| | 2801 | 21.0 | | | | | |
| 20 | 0401 | -1. | -1. | | | | |
| | 0101 | -1. | -1. | | | | |
| 41 | 02 | | | | | | |
| 42 | 0104 | | | | | | |
| 43 | 22.636 | 1400. | 53.38 | 1.33 | 87.1 | | |
| 44 | 23.154 | 605. | 53.3 | 1.4 | 215.56 | | |
| 45 | 12.232 | | | | | | |
| 46 | 0119022003210419052006210724082509261024112512261327142815241519172281 | | | | | | |
| 47 | 00 | | | | | | |

FIGURE D4 GN-3 HOT PARTS SUMMARY INPUT DATA DECK cont'd.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 47 | 00 | | | | | | | |
| | 00 | | | | | | | |
| 49 | 11 | | | | | | | |
| 50 | 0129 | 1.0 | | | | | | |
| | 0229 | 1.0 | | | | | | |
| | 0329 | 1.0 | | | | | | |
| | 0407 | 1.0 | | | | | | |
| | 0508 | 1.0 | | | | | | |
| | 0609 | 1.0 | | | | | | |
| | 1030 | 1.0 | | | | | | |
| | 1130 | 1.0 | | | | | | |
| | 1230 | 1.0 | | | | | | |
| | 1330 | 1.0 | | | | | | |
| | 1430 | 1.0 | | | | | | |
| 51 | 02 | | | | | | | |
| 52 | 29 | 720. | | | | | | |
| | 30 | 500. | | | | | | |
| 53 | .95 | .95 | .95 | .95 | .95 | .95 | .85 | .85 |
| | .85 | .6 | .6 | .6 | .6 | .60 | 1.0 | 1.0 |
| | 1.0 | 1.0 | | | | | | |
| 54 | 16 | | | | | | | |
| 55 | 180. | 172. | 161. | 124. | 107. | 93. | 82. | 73. |
| | 67. | 38. | 32. | 20. | 14. | 5. | 4. | 90. |
| 56 | 01 | 0. | | | | | | |
| 57 | 2.0 | 10. | | | | | | |
| IDS2 | $CASE TERM=.TRUE. $ | | | | | | | |

FIGURE D4 GN-3 HOT PARTS SUMMARY INPUT DATA DECK cont'd.

```
IDS1   2
SIB1  16
   2      -0.        -0.        180.
   2      -0.        -0.        172.
   2      -0.        -0.        161.
   2      -0.        -0.        124.
   2      -0.        -0.        107.
   2      -0.        -0.         90.
   2     485.       759.         82.
   2    1038.       746.         73.
   2    1300.       746.         67.
   2    2285.       763.         38.
   2    2507.       763.         32.
   2    2666.       767.         20.
   2    2602.       771.         14.
   2    2537.       775.          5.
   2    2524.       775.          4.
   2      -0.        -0.         90.
IDS2$CASE NEXT=4,NRANG=2,ALTPLM=5[illegible].,AMI=2.5,AMF=3.[illegible],
     NEXT=0.,  <---Excludes external area radiance.
     ICHECK=-2,<---Requests namelist output of $CASE ... $.
     TBACK=290.,<---Typical "Earth" background temperature.
     ALTOBS(1)=3*5000.,RANGE(1)=0.,6076.,12152.,
     ETEMP(1)=  278.,   306.,   333.,   361.,
     EAREA(1)=     95182.,          0.,          0.,          0.,
     RPN=11.73,RSN=15.0,RTE=12.0,ANL=24.,
     $
IDS5$PLUMIN $
     $POWER NORM=0,JET=2,FLTM=0.5,TSFCC=0.9,RREC=0.98,FN=7130.,
     CPR-22.656,FPR-23.134,TTPN-1400.,TTSN-605.,WAPAC-137.72,
     FNRT=8000.,WASAC=137.51,$
IDS2$CASE
     ALTOBS(2)=5846.,6692.,
     EAREA(1)=     73924.,         0.,         0.,         0.,
     $
   2$CASE
     ALTOBS(2)=6978.,8956.,
     EAREA(1)=    172930.,      5227.,     18562.,      6397.,
     $
   2$CASE
     ALTOBS(2)=10037.,15074.,
     EAREA(1)=    440355.,     13369.,     47267.,     15290.,
     $
     $CASE
     ALTOBS(2)=10811.,16622.,
     EAREA(1)=    507954.,     15352.,     54523.,         0.,
     $
     $CASE
     ALTOBS(2)=11076.,17152.,
     EAREA(1)=    531164.,     16054.,     37059.,         0.,
     $
     $CASE
     ALTOBS(2)=11[illegible]17.,17[illegible]34.,
     EAREA(1)=    535788.,     16483.,     287[illegible].,     10583.,
     $
     $CASE
     ALTOBS(2)=10810.,16620.,
```

FIGURE D5 GN-3 IR SIGNATURE ENGINE ONLY INPUT DATA DECK

```
EAREA(1)=    528529.,     16583.,     17777.,     23714.,
$
$CASE
ALTOBS(2)=10593.,16186.,
EAREA(1)=    516435.,     16422.,     16585.,     24557.,
$
$CASE
ALTOBS(2)=8741.,12482.,
EAREA(1)=    363348.,     13200.,     47858.,     25357.,
$
$CASE
ALTOBS(2)=8220.,11440.,
EAREA(1)=    324095.,     12[illegible]76.,     43942.,     24593.,
$
$CASE
ALTOBS(2)=7078.,9156.,
EAREA(1)=    247797.,      1417.,     34712.,     22545.,
$
$CASE
ALTOBS(2)=6470.,7940.,
EAREA(1)=    196782.,      7968.,     29501.,     21[illegible]93.,
$
$CASE
ALTOBS(2)=5530.,6060.,
EAREA(1)=    116399.,      5[illegible]2.,     21[illegible]96.,     18488.,
$
$CASE
ALTOBS(2)=5424.,5848.,
EAREA(1)=    107253.,         0.,     20126.,     1817[illegible].,
$
$CASE
ALTOBS(2)=11076.,17152.,
EAREA(1)=    531164.,     16[illegible]54.,     57015.,     19349.,
$
$CASE TERM=.TRUE. $
```

FIGURE D5  GN-3 IR SIGNATURE ENGINE ONLY INPUT DATA DECK cont'd.

```
      2
     16
           -0.         -0.        180.
           -0.         -0.        172.
           -0.         -0.        161.
           -0.         -0.        124.
           -0.         -0.        107.
           -0.         -0.         90.
          485.        759.         82.
         1038.        746.         73.
         1300.        746.         67.
         2285.        763.         38.
         2507.        763.         32.
         2666.        767.         20.
         2602.        771.         14.
         2537.        775.          5.
         2524.        775.          4.
           -0.         -0.         90.
 $CASE NEXT=4,NRANG=2,ALTPLM=5010.,AMT=2.5,AMF=3.0,
 ICHECK=-2,
 TBACK=290.,
 ALTOBS(1)=3*5000.,RANGE(1)=0.,6076.,12152.,
 ETEMP(1)=  278.,  306.,  333.,  361.,
 EAREA(1)=     95182.,          0.,          0.,          0.,
 RPN=11.73,RSN=15.0,RTE=12.,,ANL=24.,
 $
 $PLUMIN $
 $POWER NORM=1,JET=2,FLTM=0.5,TSFCC=0.9,RREC=0.98,FN=7130.,
 CPR=22.636,FPR=23.154,TTPN=1404.,TTSN=615.,WAPAC=137.72,
 FNRT=8000.,WASAC=137.51,$
 $CASE
 ALTOBS(2)=5846.,5692.,
 EAREA(1)=     73924.,          0.,          0.,          0.,
 $
 $CASE
 ALTOBS(2)=6978.,8956.,
 EAREA(1)=    172930.,       5227.,      18562.,       6397.,
 $
 $CASE
 ALTOBS(2)=10037.,15174.,
 EAREA(1)=    440355.,      13309.,      47267.,      16290.,
 $
 $CASE
 ALTOBS(2)=10811.,16622.,
 EAREA(1)=    507954.,      15352.,      54523.,          0.,
 $
 $CASE
 ALTOBS(2)=11076.,17152.,
 EAREA(1)=    531164.,      16054.,      37059.,          0.,
 $
 $CASE
 ALTOBS(2)=11017.,17234.,
 EAREA(1)=    535798.,      16483.,      28[illegible].,      10583.,
 $
 $CASE
 ALTOBS(2)=10810.,16620.,
 EAREA(1)=    528529.,      16583.,      17777.,      23714.,
```

FIGURE D6  GN-3 IR SIGNATURE INPUT DATA DECK FOR ONE ENGINE PLUS AIRFRAME

```
$
$CASE
ALTOBS(2)=10593.,16186.,
EAREA(1)=   516435.,    16422.,    10585.,    24557.,
$
$CASE
ALTOBS(2)=8741.,12482.,
EAREA(1)=   363348.,    13200.,    47853.,    25357.,
$
$CASE
ALTOBS(2)=8226.,11440.,
EAREA(1)=   324095.,    12076.,    43942.,    24693.,
$
$CASE
ALTOBS(2, [illegible]078.,9156.,
EAREA(1)=   247797.,     1417.,    34712.,    22545.,
$
$CASE
ALTOBS(2)=5470.,7940.,
EAREA(1)=   196782.,     7968.,    29501.,    21093.,
$
$CASE
ALTOBS(2)=5530.,6250.,
EAREA(1)=   116399.,     5592.,    21096.,    18488.,
$
$CASE
ALTOBS(2)=5424.,5848.,
EAREA(1)=   107253.,        0.,    20126.,    18170.,
$
$CASE
ALTOBS(2)=11076.,17152.,
EAREA(1)=   531164.,    16054.,    57015.,    19649.,
$
$CASE TERM=.TRUE. $
```

FIGURE D 6 GN-3 IR SIGNATURE INPUT DATA DECK FOR ONE ENGINE PLUS AIRFRAME cont'd.

* * * A S D I R * * *

PLUME ANALYSIS

* FLIGHT CONDITIONS **

ALTITUDE IS 5000. FEET.
WEATHER IS ICAO MIL STD 210 STANDARD DAY
WITH .000330 WATER CONTENT.
VISIBLE CONTRAIL IS NOT EXPECTED
CASE MACH NUMBER IS .50 AT AMBIENT:
PRESSURE OF 12.23 PSIA.
TEMPERATURE OF 501. DEGR.
VELOCITY OF 599. FT/SEC.

ENGINE IS RUNNING WITH A FUEL EQUIVALENCE RATIO (FQR) OF .195

** INPUT PARAMETERS

| | PLUME | AMBIENT |
|---|---|---|
| PRESSURE, P | .839 | .832 ATMOS. |
| SPECIFIC HEAT, CP | .292 BTU/LB-F | |
| GAS CONSTANT, R | 53.432 FT/F | |
| SP. HT. RATIO | 1.307 | |
| MACH NUMBER | 1.000 | |
| SECONDARY PRESS.- | .855 ATMOS. | |
| PPDX = | 0.000000 | |

RB= .978 XC= 6.620 RENO= 36.405 AL= 287.866

** FLOW FIELD INPUT

| RADIUS (FEET) | VELOCITY (FT/SEC) | TEMPERATURE (DEG R) | XCO2 | XH2O |
|---|---|---|---|---|
| 0.0000 | 1651.36 | 1400.00 | .026262 | .023144 |
| .0973 | 1651.36 | 1400.00 | .026262 | .023144 |
| .1955 | 1651.36 | 1400.00 | .026262 | .023144 |
| .2933 | 1651.36 | 1400.00 | .026262 | .023144 |
| .3910 | 1651.36 | 1400.00 | .026262 | .023144 |
| .4888 | 1651.36 | 1400.00 | .026262 | .023144 |
| .5865 | 1651.36 | 1400.00 | .026262 | .023144 |
| .6843 | 1651.36 | 1400.00 | .026262 | .023144 |
| .7820 | 1651.36 | 1400.00 | .026262 | .023144 |
| .8798 | 1651.36 | 1400.00 | .026262 | .023144 |
| .9775 | 1651.36 | 1400.00 | .026262 | .023144 |
| 1.0753 | 1089.01 | 507.19 | .000330 | .000330 |
| 1.1730 | 1089.01 | 507.19 | .000330 | .000330 |
| ** AMBIENT CONDITIONS | | | | |
| 1.2708 | 598.97 | 500.64 | .000330 | .000330 |

FIGURE D7 GN-3 ENGINE ONLY IR SIGNATURE (SAMPLE).

```
*** POINT SOURCE IR INTENSITY ***

    SPECTRAL BAND          - 2.50 TO 3.00 MICRONS
    VEHICLE ALTITUDE -     1.52 KM OR    5.00 KFT
    ASPECT ANGLE           - 67.0 DEGREES IN A NOR. ATMOSPHERE.
    EFFECTIVE BLACK BODY AREA -     ABB = 1300.0000 CMSQ
    EFFECTIVE BB TEMPERATURE  -     TBB =  746.0000 DEGK
    EFFECTIVE BACKGROUND TEMP - TRACK =   290.0000 DEGK

    SLT RNG (KM/NM)       0./   0.    2./   1.
    OB ALT  (KM/KFT)      2./   5.    3./  11.

    BCKGRND (W/STR)      6.0373       6.0373
    METALS  (W/STR)     44.0083      44.0083
    ATT MET (W/STR)     39.0442      11.9405
    PLM GAS (W/STR)     16.8573       6.2686
    EXT EMS (W/STR)      0.0000       0.0000
    APP RAD (W/STR)     49.8642      12.1718


*** POINT SOURCE IR INTENSITY ***

    SPECTRAL BAND          - 2.50 TO 3.00 MICRONS
    VEHICLE ALTITUDE -     1.52 KM OR    5.00 KFT
    ASPECT ANGLE           - [illegible] DEGREES IN A NOR. ATMOSPHERE.
    EFFECTIVE BLACK BODY AREA -     ABB = 2285.0000 CMSQ
    EFFECTIVE BB TEMPERATURE        TBB =  753.0000 DEGK
    EFFECTIVE BACKGROUND TEMP - TRACK -   290.0000 DEGK

    SLT RNG (KM/NM)       0./   0.    2./   1.
    OB ALT  (KM/KFT)      2./   5.    3./   9.

    BGKGRND (W/STR)      4.0382       4.0382
    METALS  (W/STR)     90.4150      90.4150
    ATT MET (W/STR)     76.3706      23.1242
    PLM GAS (W/STR)     14.3674       4.2829
    EXT EMS (W/STR)      0.0000       0.0000
    APP RAD (W/STR)     87.2958      23.3689
```



FIGURE D7  GN-3 ENGINE ONLY IR SIGNATURE (SAMPLE) cont'd.

* * * A S O I R

PLUME ANALYSIS

** FLIGHT CONDITIONS **

ALTITUDE IS 5000. FEET.
WEATHER IS ICAO MIL STD 210 STANDARD DAY
WITH .000330 WATER CONTENT.
VISIBLE CONTRAIL IS NOT EXPECTED
CASE MACH NUMBER IS .50 AT AMBIENT
PRESSURE OF 12.23 PSIA.
TEMPERATURE OF 501. DEGR.
VELOCITY OF 599. FT/SEC.

ENGINE IS RUNNING WITH A FUEL EQUIVALENCE RATIO (EQR) OF .195

** INPUT PARAMETERS

| | | PLUME | AMBIENT |
|---|---|---|---|
| PRESSURE, | P | .839 | .832 ATMOS. |
| SPECIFIC HEAT, | CP | .292 BTU/LB-F | |
| GAS CONSTANT, | R | 53.432 FT/F | |
| SP. HT. RATIO | | 1.3?7 | |
| MACH NUMBER | | 1.000 | |
| SECONDARY PRESS.= | | .856 ATMOS. | |
| DPDX = | | .[illegible] | |

R8= .978 XC= 6.62? RENO= 36.465 AL= 287.865

** FLOW FIELD INPUT

| RADIUS (FEET) | VELOCITY (FT/SEC) | TEMPERATURE (DEG R) | XCO2 | XH2O |
|---|---|---|---|---|
| 0.0000 | 1651.36 | 1400.00 | .026262 | .029144 |
| .0978 | 1651.36 | 1400.00 | .026262 | .029144 |
| .1955 | 1651.36 | 1400.00 | .026262 | .029144 |
| .2933 | 1651.36 | 1400.00 | .026262 | .029144 |
| .3910 | 1651.36 | 1400.00 | .026262 | .029144 |
| .4888 | 1651.36 | 1400.00 | .026262 | .029144 |
| .5865 | 1651.36 | 14[illegible] | .026262 | .029144 |
| .6843 | 1651.36 | 1400.00 | .026262 | .029144 |
| .7820 | 1651.36 | 1400.00 | .026262 | .029144 |
| .8798 | 1651.36 | 1400.00 | .026262 | .029144 |
| .9775 | 1651.36 | 1400.00 | .026262 | .029144 |
| 1.0753 | 1088.01 | 607.19 | .000330 | .000330 |
| 1.1730 | 1088.01 | 607.19 | .000330 | .000330 |

** AMBIENT CONDITIONS

| | | | | |
|---|---|---|---|---|
| 1.2708 | 598.97 | 500.84 | .000330 | .000330 |

FIGURE D8 GN-3 ONE ENGINE PLUS AIRFRAME IR SIGNATURE (SAMPLE)

**COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION**

```
*** POINT SOURCE IR INTENSITY ***

    SPECTRAL BAND      - 2.50 TO 3.00 MICRONS
    VEHICLE ALTITUDE -   1.52 KM OR   5.00 KFT
    ASPECT ANGLE      -   67.0 DEGREES IN A NOR. ATMOSPHERE.
    EFFECTIVE BLACK BODY AREA -    ABB = 1300.0000 CMSQ
    EFFECTIVE BB TEMPERATURE  -    TBB =  746.0000 DEGK
    EFFECTIVE BACKGROUND TEMP - TBACK =  290.0000 DEGK

    SLT RNG (KM/NM)       0./    0.    2./    1.
    OB ALT (KM/KFT)       2./    5.    3./   11.

    BCKGRND (W/STR)       6.0373       6.0373
    METALS   (W/STR)     44.0083      44.0083
    ATT MET (W/STR)      39.6442      11.9415
    PLM GAS (W/STR)      15.8573       5.2685
    EXT EMS (W/STR)        .3965       -.0836
    APP RAD (W/STR)      50.2607      12.[illegible]882


*** POINT SOURCE IR INTENSITY ***

    SPECTRAL BAND      - 2.50 TO 3.00 MICRONS
    VEHICLE ALTITUDE -   1.52 KM OR   5.00 KFT
    ASPECT ANGLE      -   38.0 DEGREES IN A NOR. ATMOSPHERE.
    EFFECTIVE BLACK BODY AREA -    ABB = 2295.[illegible] CMSQ
    EFFECTIVE BB TEMPERATURE  -    TBB =  763.[illegible] DEGK
    EFFECTIVE BACKGROUND TEMP - TBACK =  290.0000 DEGK

    SLT RNG (KM/NM)       0./    0.    2./    1.
    OB ALT (KM/KFT)       2./    5.    3./    9.

    BCKGRND (W/STR)       4.0382       4.0382
    METALS   (W/STR)     90.4150      90.4150
    ATT MET (W/STR)      76.9706      23.1242
    PLM GAS (W/STR)      14.3634       4.2829
    EXT EMS (W/STR)        .6737        .0532
    APP RAD (W/STR)      87.9696      23.4221
```

FIGURE D8 GN-3 ONE ENGINE PLUS AIRFRAME IR SIGNATURE (SAMPLE) cont'd.

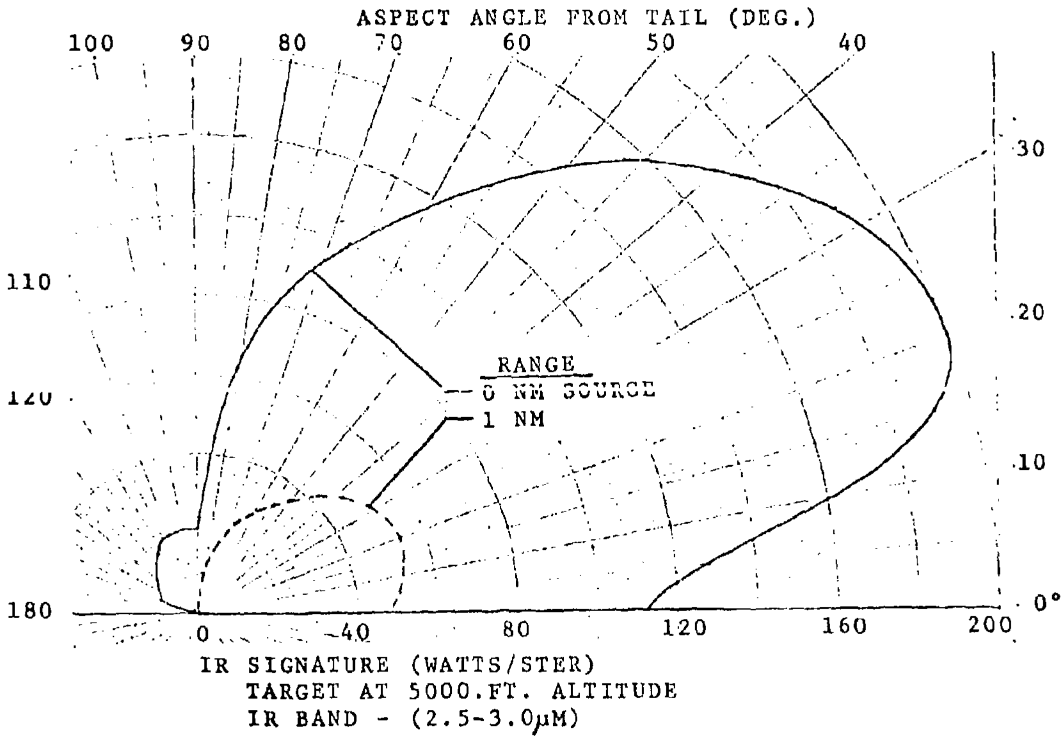



FIGURE D9 GN-3 COMPOSITE AIRCRAFT IR SIGNATURE
AT ZERO AZIMUTH.