CR135171

A Method to Estimate Weight and Dimensions of Aircraft Gas Turbine Engines

Final Report

Volume II: User's Manual

May 1977

Boeing Military Airplane Development

Seattle, Washington 98124

Prepared for

National Aeronautics and Space Administration

NASA-Lewis Research Center

Contract NAS3-19913

1. Report No. CR135171	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle A Method to Estimate Weight and Dimensions of Aircraft Gas Turbine Engines—Final Report Vol II - Users Manual		5. Report Date May 1977
		6. Performing Organization Code
7. Authors R. J. Pera, E. Onat, G. W. Klees, E. Tjonneland		8. Performing Organization Report No. D6-44258
9. Performing Organization Name and Address Boeing Military Airplane Development P. O. Box 3707 Seattle, Washington, 98124		10. Work Unit No.
		11. Contract or Grant No. NAS3-19913
12. Sponsoring Agency Name and Address *National Aeronautics & Space Administration* Washington, D.C. 20546		13. Type of Report and Period Covered Contractor Report
		14. Sponsoring Agency Code
15. Supplementary Notes Final Report (see also NASA CR135170 Method of Analysis and CR135172, Programmer's Manual) Program Manager, Laurence Fishbach, Wind Tunnel and Flight Division, Mission Analysis Branch, NASA Lewis Research Center, Cleveland, Ohio		

16. Abstract

A computerized method has been developed to estimate weight and envelope dimensions of aircraft gas turbine engines within ±5% to 10%. The method is based on correlations of component weight and design features of 29 data base engines. Rotating components are estimated by a preliminary design procedure where blade geometry, operating conditions, material properties, shaft speed, hub-tip ratio, etc., are the primary independent variables used. The development and justification of the method selected, the various methods of analysis, the use of the program, and a description of the input-output data are discussed in this report.

17. Key Words (Suggested by Author(s))		18. Distribution Statement
Engine Weight	Weight Analysis	Unclassified-Unlimited
Gas Turbines	Turbine Engines	
Aircraft Propulsion	Computerized Simulation	
Prediction Analysis Techniques		

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	42	

*For sale by the National Technical Information Service, Springfield, Virginia 22161

A METHOD TO ESTIMATE WEIGHT AND DIMENSIONS OF AIRCRAFT GAS TURBINE ENGINES

Vol. II – Users Manual

By R. J. Pera, E. Onat, G. W. Klees, E. Tjonneland

1.0 INTRODUCTION

This user's manual for the WATE-1 computer program contains a description of input-output data, values of typical inputs and sample cases. A description of the method and engineering analysis is given in CR135170; the Fortran Listings are contained in CR135172.

WATE-1 is designed to function around a component-type engine cycle analysis program NNEP[1]. The calculated thermodynamic output data of NNEP is a necessary input to WATE-1 for component sizing. Use of NNEP is not described here since it is unchanged from its normal mode of operation.

Normally, only the design point case of NNEP is used to generate the WATE-1 inputs. Additional NNEP off-design points may be desirable to define other WATE-1 inputs, such as maximum shaft overspeed, or maximum operating temperature for each component. In order to produce the most accurate weight estimate, the design case input data should encompass the maximum performance level required of each component, i.e., maximum flow, work, speed, temperature. All components that contribute weight must also be included in the NNEP engine model. WATE-1 will not calculate weight for components which are not included in the NNEP engine simulation.

WATE-1 has the ability to also accept an input weight scaler for each component so that selected components can be increased or decreased (or eliminated altogether) to determine sensitivities, etc. Both SI and English units of measure can be used.

LIST OF SYMBOLS

R	–	Radius
RPM	–	Speed
TLP	–	$U_t^2/2gJ\Delta h/N_{stage}$
U_t	–	Tip Speed
g	–	32.1415 ft-lb_f/sec^2-lb_m
J	–	778 BTU/lb_m
Δh	–	Enthalpy Change
N_{stage}	–	Number of Stages

2.0 PROGRAM STRUCTURE AND DECK STACKING

The overall program structure is shown in the flow chart, Figure 1. NNEP design point data is stored in the "thermodynamic data" for use in calculating weights and dimensions (W/D) in the WATE-1 part of the program. Computer execution time, core storage, and output print requirements have been increased slightly over the NNEP program.

The order of deck stacking of the Job Control cards and NNEP input data are unchanged from the normal operation of NNEP. Two new inputs have been added to the NNEP indicator set. The indicators, IWT = TRUE and IPLT = TRUE signals that the weight and dimensions calculations are to be performed, and the WATE-1 Data Set is required following the NNEP inputs. Figure 2 shows a typical card-stacking arrangement necessary to operate NNEP and WATE-1.

3.0 WATE-1 INPUTS

The WATE-1 inputs are free-field format (NAMELIST), and begin in Column 2. There is no specified order to the inputs; however, for the concurrence in the following discussion, they have been grouped into Plot-Print Indicators, Length Indicators, Mechanical Design Indicators, and Design Values. Figure 3 shows a complete input set for a typical case.

3.1 Plot-Print Indicators

IWT	=	TRUE	– do weight calculation	
		FALSE	– do not do weight calculation	must be located in NNEP Inputs and optional in WATE-1 Inputs
IPLT	=	T	– gas path layout	
		F	– no gas path layout	
&W			– placed at end of NNEP inputs to signal beginning of WATE-1 inputs	
ISII	=	T	– SI units input	
		F	– English units input	
ISIØ	=	T	– SI units output	
		F	– English units	
IØUTCD	=	0	– short form–engine weight, length, and maximum radius	
		1	– long form–component weights and dimensions and short form	
IØUTCD	=	2	– debug option and long and short form	

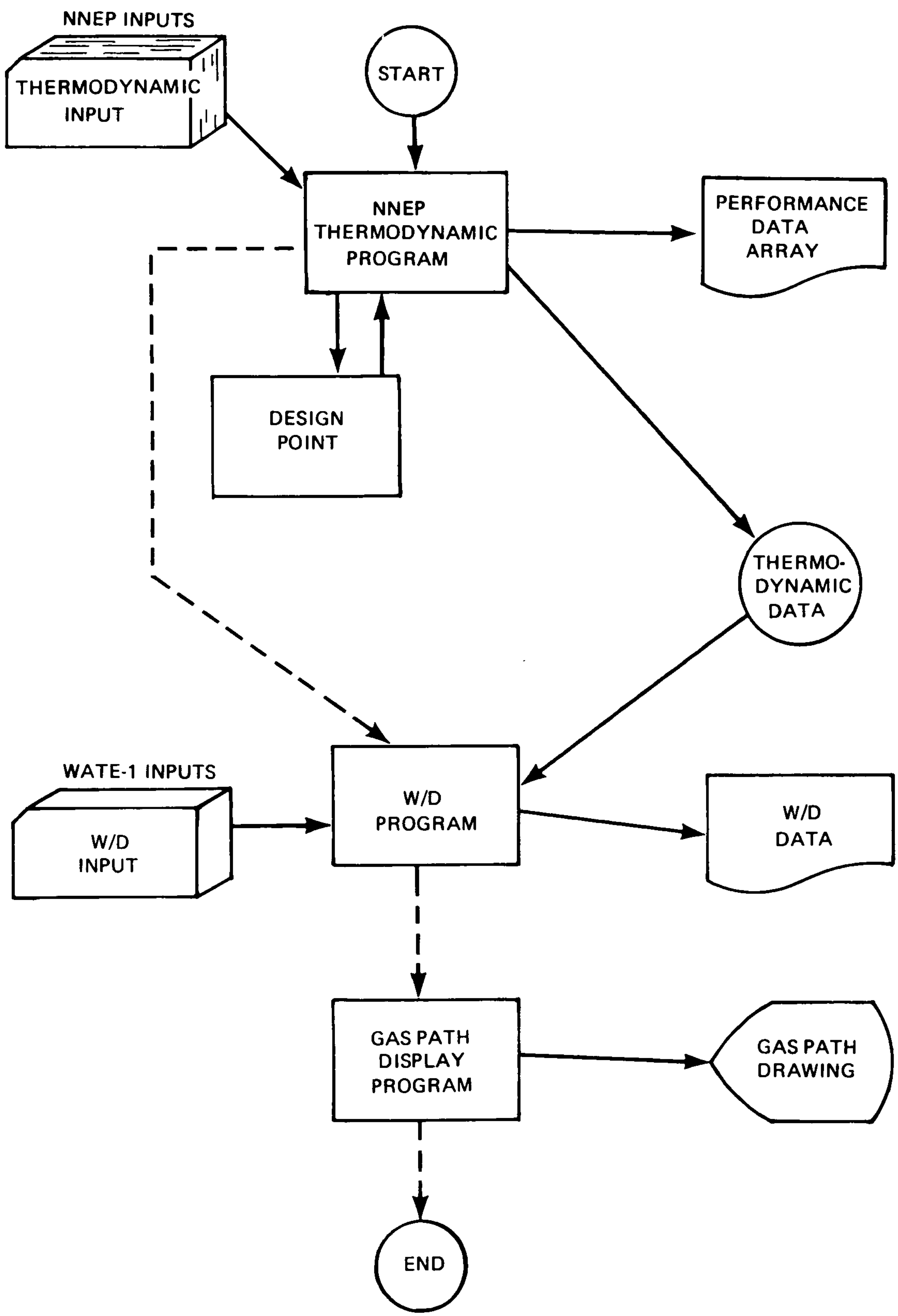


Figure 1 Overall Program Structure

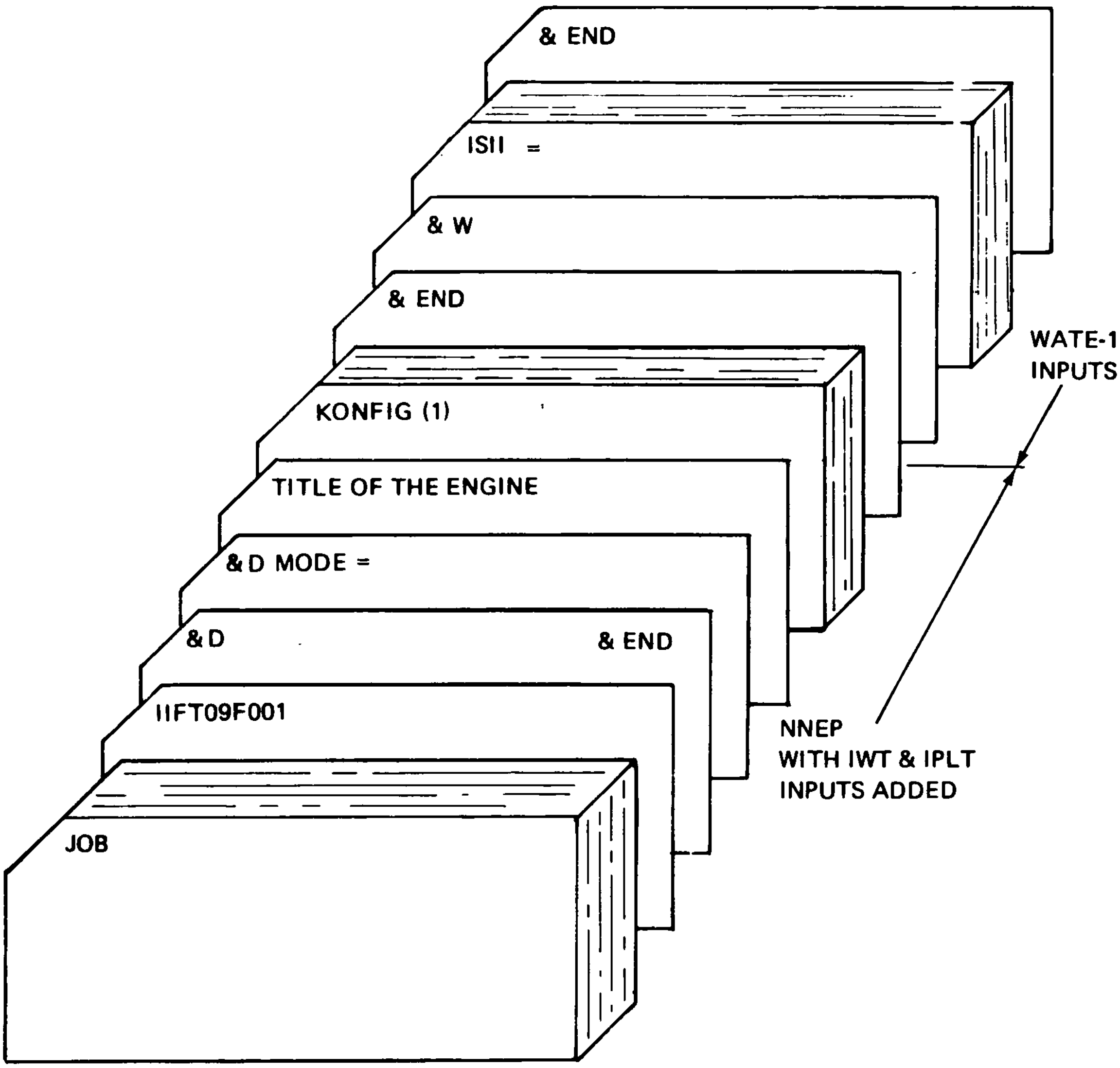


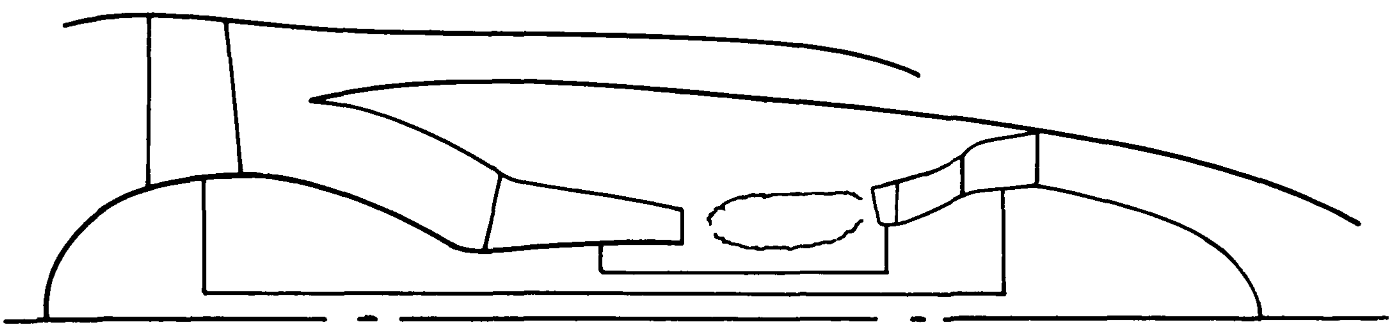
Figure 2 Deck Stacking

```
MODE      1 NOW BEING USED
&W
IPLT=T,
ISII=F,
ISIO=F,
IOUTCD=2,
ILENG(1)=2,3,5,6,7,8,9,10,11,
IWMEC(1,2)='FAN ',1,1,4,3*0,
IWMEC(1,3)='SPLT',6*0,
IWMEC(1,4)='DUCT',0,5*0,
IWMEC(1,5)='LPC ',1,2,4*0,
IWMEC(1,6)='PBUR',1,5*0,
IWMEC(1,7)='HPT ',0,5,-5,3*0,
IWMEC(1,8)='LPT ',1,2,7,3*0,
IWMEC(1,9)='MIX ',6*0,
IWMEC(1,10)='DUCT',2,4*0,
IWMEC(1,11)='NOZ ',1,10,4*0,
IWMEC(1,12)='SHAF',1,8,3*0,2,
IWMEC(1,13)='SHAF',2,7,3*0,5,
DESVAL(1,2)=.524,1.7,.45,1.5,3.5,2.5,.45,0.,0.,1.,0.,2.,1.,
DESVAL(1,3)=15*0.,
DESVAL(1,4)=.45,2*0.,11.,11*0.,
DESVAL(1,5)=.45,1.35,.70,1.2,2.,1.5,.3,0.,0.,1.,0.,2.,1.,
DESVAL(1,6)=100.,.015,
DESVAL(1,7)=.5,.28,1.5,1.5,1.5,.55,150000.,3.,1.,6*0.,
DESVAL(1,8)=.55,.243,1.5,2.,3.,.6,150000.,3.,1.,6*0.,
DESVAL(1,9)=15*0.,
DESVAL(1,10)=.1,2.,
DESVAL(1,11)=1.,14*0.,
DESVAL(1,12)=50000.,.3,.85,12*0.,
DESVAL(1,13)=50000.,.3,13*0.,
&END
```

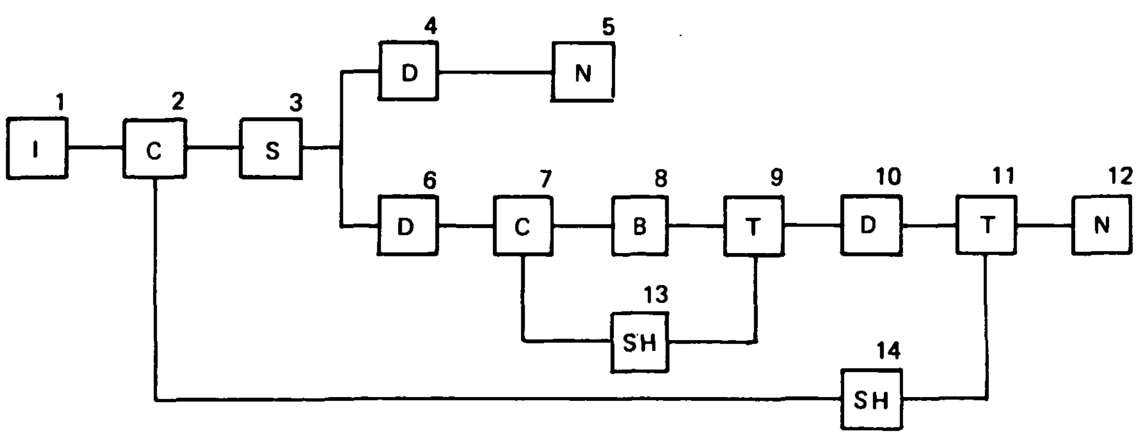

Figure 3 WATE-1 Input

3.2 Length Indicators

The ILENG input specifies only those components that contribute to the total additive engine length. The NNEP component number is specified in ILENG in the order that the components would add in length to achieve the total length. This must start with the first compressor and end with the furthest downstream nozzle. Figure 4 shows a typical engine and the ILENG inputs for that engine. The ILENG input does not include duct (4), nozzle (5) or shafts (13) and (14) because these components do not contribute to the total engine length.



ENGINE LAYOUT



ILENG (1) = 1,2,3,6,7,8,9,10,11,12,

FLOW PATH AND COMPONENT NUMBERS

Figure 4 Length Input

3.3 Mechanical Design Indicators

The mechanical design indicators (IWMEC) must be specified for each component of the NNEP simulation, with the exception of the NNEP Controls, Inlet, and Water Injection or any other component not represented in WATE-1.

A number of shaft components may be required to simulate an engine in NNEP, as shown in Figure 5. WATE-1 will determine the weight only for connecting shafts of major components, such as the typical HP or LP shaft. In the example of Figure 5, only shaft 15 and shaft 17 would be specified. The smaller component number must always be used on the inner shaft, with increasing component numbers as concentric shafts are added around the inner shaft.

IWMEC is a two-dimensional integer array that contains all of the mechanical design indicators. It is of the form IWMEC (N, M), where M is the component number used in NNEP, and N is the variable number as defined below for each component. Each variable in the IWMEC array for each component is identified as shown in Figure 3 in free-field NAMELIST format.

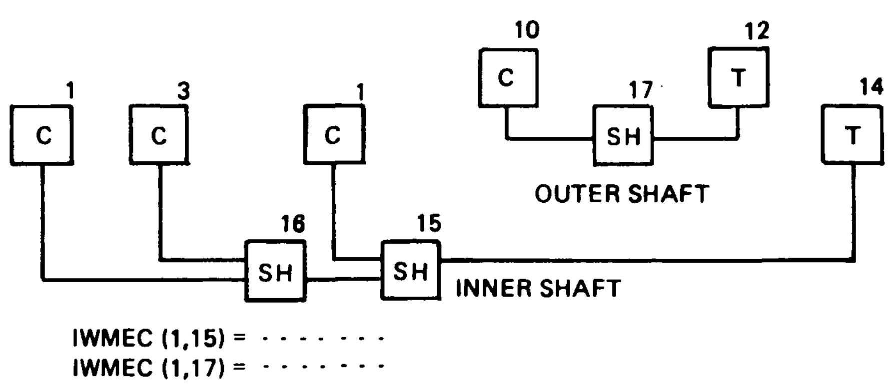


Figure 5 Shaft Input

3.1.1 Compressors

IWMEC Array Location	Description
1	Type of compressor being weighed. 'FAN' – Typical fan 'FØ' – Outer portion of non-rotating splitter fan 'FI' – Inner portion of non-rotating splitter fan 'RSFØ' – Outer portion of rotating splitter fan 'RSFI' – Inner portion of rotating splitter fan 'LPC' – Low pressure compressor 'HPC' – High pressure compressor
2	This indicates if the fan or compressor has stators. 1 – Stator weight is calculated 0 – Stator weight is not calculated
3	This is the indicator for 'front' frames in compressors. This input may be: 0 – No frame 1 – Single bearing frame for turbofans and turbojets without Power Takeoff (PTO) 2 – Single bearing frame with PTO 4 – Two bearing frame, such as the frame in front of the HPC in the JT8D or JT9D which extends outward to the fan outer case and holds two bearings with PTO
4	This is the indicator for the 'rear' frame in a compressor. 0 – No frame 1 – Single bearing frame for turbofans and turbojet without Power Takeoff (PTO) 2 – Single bearing frame with PTO 4 – Two bearing frame, such as the frame in front of the HPC in the JT8D or JT9D which extends outward to the fan outer case and holds two bearings with PTO
5	This is the component number connecting to this component for split flow compressors only. If this is the Fan Outer, the Fan Inner must be specified. If this is the Rotating Splitter Outer, the inner splitter must be specified, and vice versa.
6	Gear box indicator – 0 – No gear or component number of shaft
7	Number of stages

3.3.2 Turbines

Location	Description
1	This is the type of turbine. 'HPT' – High pressure turbine 'LPT' – Low pressure turbine
2	Indicator for turbine exit frame. 0 – No frame 1 – Frame
3	Compressor number from which the RPM is determined
4	Component number from which the outer radius limit for the turbine is determined. If the component number is positive, the outlet dimension is used. If negative, the inlet dimension is used. If 0, it will use the outlet of the feeding component.
5	Number of stages

3.3.3 Burners

Location	Description
1	This is the type of burner being weighed. The input is the burner name in four spaces. 'PBUR' – Primary burner (airframe will be included) 'DBUR' – Duct burner (a mean radius is specified) 'AUG' – Augmentor (no inner wall)
2	This is the indicator for frame weight, normally only for primary burners. This frame includes a bearing. 0 – No frame 1 – Frame

3.3.4 Ducts

Location	Description
1	Input 'DUCT'
2	Indicator as to type of duct 1 – Dummy – i.e., no weight or length 2 – Length input 3 – Length derived as in a duct connecting a splitter and a mixer

3.3.5 Shafts

Location	Description
1	'SHAF' – Standard shaft
2	Shaft number from inner to outer, i.e., 1, 2, 3, 4 or 5
3-6	Turbine numbers connected to this shaft. The last entry is the furthest downstream turbine. This is used for power summation.
7	First upstream compressor connected to the shaft

3.3.6 Mixers

Location	Description
1	Type of mixer
	'MIX' – The coannular emergence of two streams without mechanical mixer
	'FMIX' – Forced mixer, mechanical, i.e., Daisy lobed mixer
2	Indicator for primary input node
	0 – Primary is inner
	1 – Primary is outer

3.3.7 Nozzles

Location	Description
1	'NOZ' – Input
2	Nozzle type
	1 – Convergent
	2 – C-D variable area

Location	Description
3	Component number from which the nozzle inlet diameter can be determined. If this diameter is taken from the inlet of the component, the (–) component number must be entered. If (+), the exit node will be used. If the previous component determines the diameter, this location may be zero.
4	Thrust reverser type
	0 – None
	1 – Fan
	2 – Primary

3.3.8 Splitters

Location		Description
1	'SPLT'	– Input
2	1	– If inner stream is not primary

3.3.9 Annulus Inverting Valve

Location		Description
1	Input 'VALV'	
2	Location of Valve	
	1	– Inner
	2	– Outer
3	Component Number of Opposite Duct	
4	0 If Fixed, 1 If Movable	

3.3.10 Heat Exchangers

Location		Description
1	Input 'HTEX'	
2	Type	
	1	– Fixed Tube
	2	– Rotary
3	Flow Direction	
	1	– Parallel Flow
	2	– Counter Flow

3.4 Design Values

This section contains the mechanical and aerodynamic design data necessary to determine the weight and dimensions of each component. A summary of this array is shown in Table 1. If desired, the default values, Table 2, can be used for any component by not specifying the inputs for that component. The data required is in the floating-point two-dimensional array DESVAL (N, M), where M is the component number from NNEP and N is as defined below. A typical set of inputs is shown in Figure 3, and a typical range of values is shown in Table 3.

The calculated component weight can be adjusted by an input scaler, DESVAL (15, M), which is a factor applied to the calculated weight. A zero value, however, denotes that no scaling is used. If it is desired to zero-out the weight of a component, the scaler can be set to a trivial quantity such as .0001.

Table 1 DESVAL/DEFAUL Array

TYPE \ POSITION	1	2	3	4	5	6	7	8
COMP	MNI	PRM	H/T	SOLID	ARI	ARO	MNO	TMAXI
TURB	MNI	TLP*	SOLID	ARI	ARO	MNO	REFSTR .2% YIELD STRESS FOR DISK	MODE
BURN	VR	TR	DIA MEAN	REFLOC				
DUCTS	MACH	L/H	DIA MEAN	REFLOC				
TRAN/ SHAFTS	STRESS	RHO	H/T					
MIXERS	L/H	NO. PASS						
AIV	L/H	NO. PASS	MNI	MNØ	RH	WTIC	WTOC	WTW
HEATEX	#TUBE	MNIP	MNIS	BPR				
NOZ	L/D							
SPLT	MNI	H/T						

$$*TLP = \frac{\mu_T^2}{2gJ\Delta h/N_{STAGES}}$$

TYPE \ POSITION	9	10	11	12	13	14	15
COMP	TMAXO	RPMR	RHO BLADE	MODE	RPMSC	TMET	WEIGHT SCALER
TURB	RPMR						
BURN							
DUCTS							
SHAFTS							
MIXERS							
AIV							
HEATEX							
NOZ							

Table 2   DEFAUL Array

TYPE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FAN	.55	1.7	.45	1.5	4.	3.	.45	0.	0.	1.	2.	1.	0.	0.	0.
LPC	.5	1.5	.4	1.5	4.	3.	.45	0.	0.	1.	0.	2.	1.	0.	0.
HPC	.4	1.4	.7	1.5	3.	1.5	.3	0.	0.	1.0	0.	2.	1.	0.	0.
HPT	.3	.25	1.5	1.5	1.5	.45	125000.	2.	1.	6*0.					
LPT	.45	.25	1.5	2.	4.	.55	125000.	2.	1.	6*0.					
PBUR	100.	.015	13*0.												
DBUR	150.	.015	13*0.												
AUG	300.	.015	13*0.												
DUCT	.4	1.	0.	-1.	11*0.										
SHAFT	50000.	.286	13*0.												
MIXERS	1.	8.	13*0.												
NOZ	1.	14*0.													
AIV	1.	8.	.5	.5	1.1	1.1	1.1								
HTEX	5000.	.5	.5												

Table 3. Typical Range of Input Values for DESVAL/DEFAUL

TYPE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FAN	.5-.6	1.5-1.8	.4-.5	1.-1.5	3.-5.	2.-3.	.45-.55	0.	0.	1.	0.	*	1.	0.	*
LPC	.45-.6	1.5-1.8	.4-.5	1.-1.5	3.-5.	2.-3.	.45-.55	0.	0.	1.	0.	*	1.	0.	*
HPC	.4-.5	1.4-1.7	.6-.8	1.-1.5	2.-5.	1.-2.	.2-.3	0.	0.	1.	0.	*	1.	0.	*
HPT	.3-.4	.2-.3	1.-1.5	1.-2.	1.-2.	.45-.5	100 KSI 150 KSI	* *	1.	0.	0.	0.	0.	0.	
LPT	.4-.5	.1-.3	1.-1.5	2.-3.	4.-6.	.55-.6	100 KSI 150 KSI	*	1.						
PBUR	100-150	.01-.02	*	*											
DBUR	150-200	.01-.02	*	*											
AUG	200-300	.01-.02	0.	*											
DUCB	.4-.5	*	*	*											
SHAFB	40-50KSI	.28-.31	0.-.85												
MIXERS	1.-2.	7.-9.													
NOZ	1.-2.														
AIV	.8-1.2	6.-10.	.4-.6	.4-.6	*	*									
HTEX	5000.	.3-.5	.3-.5	*											

*NOT APPLICABLE – SEE TEXT

3.4.1 Compressor

Array Location	Description
1	Compressor face inlet Mach number
2	Maximum first stage pressure ratio
3	Compressor face hub-tip ratio – R_h/R_t
4	Blade solidity, ratio of blade cord to blade spacing
5	Blade aspect ratio at first stage
6	Blade aspect ratio at last stage
7	Compressor exit Mach number
8	Maximum compressor inlet temperature. ZERO If design point temperature is to be used for material selection °R, °K.
9	Maximum compressor outlet temperature. ZERO If design point temperature is to be used for material selection °R, °K.
10	Maximum speed ratio – RPM_{max}/RPM_{design}
11	Blade material density. ZERO If WATE-1 is to select material. lb/in^3, Kg/cc compressor design type
12	1. Constant hub radius design
	2. Constant mean radius design
	3. Constant tip radius design
13	RPM, scaler, normal input is 1. – use to match known RPM of engine
14	Temperature at which a change of material is required. If ZERO 1160°R will be used, °R, °K.
15	Compressor weight scaler, input ZERO If no scaling is desired.

3.4.2 Turbines

Location	Description
1	Turbine face inlet Mach number
2	Turbine loading parameter $U_T^2/2gJ\ h/N_{stages}$
3	Blade solidity blade cord/blade spacing
4	Blade aspect ratio of first stage
5	Blade aspect ratio of last stage
6	Turbine exit Mach number
7	Disk reference stress – .2% yield, this selects disk material. lb/in^2, Newton's/cm^2

Location	Description
8	Turbine design type 1. Constant tip radius design 2. Constant mean radius design 3. Constant hub radius design
9	Maximum speed ratio – RPM_{max}/RPM_{design}
10	Turbine control radius inches/cm – blank if transferred from a component
11	Density of material in turbine blades – $lb/in^3/_{KgKc}$
12-14	
15	Turbine weight scaler, input ZERO.–If no scaling is desired.

3.4.3 Burners

Location	Description
1	Burner through-flow velocity. ft/sec, m/sec.
2	Burner airflow residency time, sec.
3	Burner mean diameter, in. or cm. If zero, diameter is calculated to match connecting component.
4	Component number for calculating mean burner diameter. Enter zero if diameter is specified.
5-14	Not used.
15	Burner weight scaler, enter ZERO.–If no scaling is desired.

3.4.4 Ducts

Location	Description
1	Duct Mach number.
2	Length to height ratio of duct, required if mode 2 is used in IWMEC.
3	Duct mean diameter, in. or cm. If 0., duct diameter is calculated based on node specified below.
4	Node number to calculate mean diameter. Enter 0, if mean diameter is specified. Enter -1, if connecting component is to be used.
5-14	Not used.
15	Weight scaler, ZERO.–if no scaling is desired.

3.4.5 Shafts

Location	Description
1	Shaft allowable stress. lb/in^2, $Newton's/cm^2$
2	Shaft material density. lb/in^3, Kg/cc
3	Diameter ratio of shaft D_{inner}/D_{outer}.
4-14	Not used.
15	Shaft weight scaler. ZERO If no scaling desired.

3.4.6 Mixers

Location	Description
1	Effective length to diameter ratio of mechanical mixer, $L/\ 2A/\pi$, where L is the mixer length inlet to exit, A is the total flow area. Enter 0. if not a mechanical (forced) mixer.
2	Number of passages (or lobes) in mixer.
3-14	Not used.
15	Weight scaler. Enter ZERO. if no scaling is used.

3.4.7 Nozzles

1	Length to diameter ratio of nozzle
2	Bypass ratio for mixed flow nozzle for T/R weight.
3-14	Not used.
15	Weight scaler. ZERO. if no scaling desired.

3.4.8 Splitters

Location	Description
1	Only input if first calculated component in flow path. Mach number in.
2	H/T ratio in.
3-14	Blank.
15	Weight scaler.

3.4.9 Annulus Inverting Valve

Location	Description
1	Specific length – $L/\sqrt{4A/\pi}$
2	Number of passages.
3	Mach number of inner.
4	Mach number of outer.
5	Hub radius in inches/cm or – component number from which hub radius is taken or blank if feeding component determines the hub radius.
6	Inner cylinder weight – $lb/ft^2/Kg/m^2$.
7	Outer cylinder weight – $lb/ft^2/Kg/m^2$.
8	Wall weight - $lb/ft^3/Kg/m^2$.
9-14	Blank.
15	Weight scaler.

3.4.10 Heat Exchangers

Location	Description
1	Number of tubes if "Fixed" type.
2	Mach number in primary stream.
3	Mach number in secondary stream.
4	Engine Bypass ratio if "Rotary" type.

4.0 PROGRAM OUTPUT

The output from WATE-1 may be selected in any of three output formats. Either English or SI units can be selected. Examples of the output for the sample case, Figure 3, are shown for the short output in Figure 6, the long form, Figure 7, and the debug output, Figure 8. This output shows the mechanical design and weight breakdown within the individual component. The units in the output section are shown in Table 4 for English and SI units. The type of units used are noted in the units section of the output.

A flow path layout is also available for conventional type engines. A typical layout is shown in Figure 9. The layout is scaled such that it will fit on one page of the output.

TOTAL BARE ENGINE WEIGHT= 2915. ACCESSORIES= 262.02

ESTIMATED TOTAL LENGTH= 206. ESTIMATED MAXIMUM RADIUS= 29.

Figure 6 Short Output

WEIGHT INPUT DATA IN ENGL UNITS
WEIGHT OUTPUT DATA IN ENGL UNITS

COMP	WT	COMP	ACCU	UPSTREAM RADIUS				DOWNSTREAM RADIUS				
NO	EST	LEN	LEN	RI	RO	RI	RO	RI	RO	RI	RO	NSTAGE
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0
2	1029.	29.	29.	9.	20.	0.	0.	13.	18.	0.	0.	3
3	0.	0.	29.	0.	0.	0.	0.	13.	16.	16.	18.	0
4	29.	62.	91.	16.	18.	0.	0.	16.	18.	0.	0.	0
5	616.	25.	54.	9.	13.	0.	0.	11.	11.	0.	0.	10
6	250.	18.	72.	9.	13.	0.	0.	9.	13.	0.	0.	0
7	126.	5.	78.	10.	11.	0.	0.	10.	13.	0.	0.	2
8	469.	13.	91.	9.	12.	0.	0.	9.	14.	0.	0.	2
9	0.	0.	91.	4.	16.	16.	21.	4.	21.	0.	0.	0
10	46.	58.	149.	0.	29.	0.	0.	0.	29.	0.	0.	0
11	295.	58.	206.	0.	29.	0.	0.	0.	27.	0.	0.	0
12	40.	0.	0.	9.	20.	10.	11.	0.	0.	0.	0.	0
13	14.	0.	0.	9.	13.	0.	0.	0.	0.	0.	0.	0

TOTAL BARE ENGINE WEIGHT= 2915. ACCESSORIES= 262.02

ESTIMATED TOTAL LENGTH= 206. ESTIMATED MAXIMUM RADIUS= 29.

Figure 7 Long Output

```
*************
*           *
*  FAN    2 *
*           *
************2
DUCT
 M NO   VEL   T TOT    P TOT    P STAT   AREA     GAM
0.524  570.  519.    1905.    1579.     6.9517  1.4005

  U TIP  STRESS      DEN   W/AREA    TR      H/T
 1258.9 26757.6    0.168   2.339    1.800   0.450

 COMPRESSOR  2 MECHANICAL DESIGN

 LOADING    N STG   DIAM  U TIP C     RPM    C RPM
   0.874     3.00   39.98  1258.9   7216.9   7216.9

FRAME WT  =    95.67

STAGE     1
  WD    WB    WS    WN    WC    CL    RHOB  RHOD   AR
  65.   59.   59.    0.   26.   7.4 0.168 0.168  3.50
   PR   DEL H  MACH   AREA  R HUB   R TIP  NB U TIP     STR    WEIGHT TIN
 1.4789  16.7 0.524  6.952  8.99   19.99  59 1258.9 26758.   209.   519.

 STAGE     2
   WD    WB    WS    WN    WC    CL    RHOB  RHOD   AR
  91.   34.   34.   51.   21.    6.2 0.168 0.168  3.00
   PR   DEL H  MACH   AREA  R HUB   R TIP  NB U TIP     STR    WEIGHT TIN
 1.4155  16.7 0.499  5.180 11.02   18.95  67 1193.2 20191.   231.   588.

 STAGE     3
   WD    WB    WS    WN    WC    CL    RHOB  RHOD   AR
  97.   23.   23.   46.   19.    5.7 0.168 0.168  2.50
   PR   DEL H  MACH   AREA  R HUB   R TIP  NB U TIP     STR    WEIGHT TIN
 1.3671  16.7 0.475  4.017 12.17   18.23  70 1148.1 15768.   208.   658.

 FRAME WT  =  2[illegible]5.15


  N STG  WEIGHT  LENGTH
     3  1028.68   28.80

 DUCT
  M NO   VEL   T TOT    P TOT    P STAT   AREA     GAM
 0.450  582.  727.    5447.    4743.     3.2206  1.3951

   PR     AD EF     PO      TO      HP
  2.8600  0.8700  5447.2   726.9  16910.
   HI       HO      WI      CWI
  123.95  174.07  238.50  265.00

 ******************* TOTAL COMP WEIGHT IS  1028.680
```

Figure 8 Debug Output

```
*************
*           *
*  HPC   5  *
*           *
*************
DUCT
 M NO   VEL   T TOT    P TOT    P STAT   AREA     GAM
0.450  582.  727.     5447.    4743.      1.8196  1.3951

  U TIP  STRESS       DEN   W/AREA    TR       H/T
 1285.1 23331.5     0.168    0.687   1.200     0.700

 COMPRESSOR  5 MECHANICAL DESIGN

 LOADING    N STG    DIAM  U TIP C      RPM     C RPM
   0.651    10.00    25.58  1085.6 11515.5   9727.5

FRAME WT   =  118.22

STAGE     1
  WD    WB    WS    WN    WC     CL    RHOB   RHOD    AR
 24.   14.   14.   36.   10.    4.5 0.168 0.168  2.00
  PR   DEL H  MACH   AREA  R HUB   R TIP   NB U TIP     STR    WEIGHT TIN
1.3603  17.8 0.450  1.820  8.95   12.79   50 1285.1 23331.    99.   727.

STAGE     2
  WD    WB    WS    WN    WC     CL    RHOB   RHOD    AR
 20.    9.    9.   29.    8.    3.6 0.168 0.168  1.94
  PR   DEL H  MACH   AREA  R HUB   R TIP   NB U TIP     STR    WEIGHT TIN
1.3241  17.8 0.435  1.442  9.42   12.45   60 1250.7 18516.    75.   800.

STAGE     3
  WD    WB    WS    WN    WC     CL    RHOB   RHOD    AR
 16.    6.    6.   25.    7.    3.0 0.168 0.168  1.89
  PR   DEL H  MACH   AREA  R HUB   R TIP   NB U TIP     STR    WEIGHT TIN
1.2943  17.8 0.420  1.171  9.75   12.19   70 1225.3 15048.    59.   873.

STAGE     4
  WD    WB    WS    WN    WC     CL    RHOB   RHOD    AR
 13.    4.    4.   21.    6.    2.6 0.168 0.168  1.83
  PR   DEL H  MACH   AREA  R HUB   R TIP   NB U TIP     STR    WEIGHT TIN
1.2704  17.8 0.405  0.970  9.98   12.00   81 1206.2 12477.    49.   946.

STAGE     5
  WD    WB    WS    WN    WC     CL    RHOB   RHOD    AR
 11.    3.    3.   18.    5.    2.2 0.168 0.168  1.78
  PR   DEL H  MACH   AREA  R HUB   R TIP   NB U TIP     STR    WEIGHT TIN
1.2499  17.8 0.390  0.818 10.15   11.86   93 1191.5 10527.    41.  1017.

STAGE     6
  WD    WB    WS    WN    WC     CL    RHOB   RHOD    AR
 10.    3.    3.   16.    4.    2.0 0.168 0.168  1.72
  PR   DEL H  MACH   AREA  R HUB   R TIP   NB U TIP     STR    WEIGHT TIN
1.2324  17.8 0.375  0.701 10.28   11.74  104 1180.1  9018.    36.  1089.
```

Figure 8 Cont.

```
STAGE     7
  WD    WB    WS    WN    WC    CL    RHOB   RHOD    AR
  9.    2.    2.   14.    4.    1.8  0.168  0.168   1.67
  PR   DEL H  MACH   AREA  R HUB   R TIP  NB U TIP     STR    WEIGHT TIN
1.2173  17.8 0.360  0.608 10.39  11.65 115 1171.0  7829.    32. 1159.

STAGE     8
  WD    WB    WS    WN    WC    CL    RHOB   RHOD    AR
 12.    3.    3.   13.    3.    1.6  0.286  0.286   1.61
  PR   DEL H  MACH   AREA  R HUB   R TIP  NB U TIP     STR    WEIGHT TIN
1.2042  17.8 0.345  0.534 10.47  11.58 126 1163.6 11712.    39. 1229.

STAGE     9
  WD    WB    WS    WN    WC    CL    RHOB   RHOD    AR
 15.    3.    3.   12.    3.    1.5  0.286  0.286   1.56
  PR   DEL H  MACH   AREA  R HUB   R TIP  NB U TIP     STR    WEIGHT TIN
1.1926  17.8 0.330  0.475 10.53  11.52 136 1157.7 10407.    36. 1299.

STAGE    10
  WD    WB    WS    WN    WC    CL    RHOB   RHOD    AR
 15.    2.    2.   11.    3.    1.4  0.286  0.286   1.50
  PR   DEL H  MACH   AREA  R HUB   R TIP  NB U TIP     STR    WEIGHT TIN
1.1824  17.8 0.315  0.426 10.59  11.47 146 1152.8  9343.    33. 1367.

 N STG   WEIGHT   LENGTH

   10    616.43    25.43

DUCT
 M NO    VEL    T TOT    P TOT    P STAT    AREA     GAM
0.300   544.  1436.   51236.   48231.     0.3874  1.3539

  PR      AD EF       PO       TO       HP
 9.4060   0.8700 51235.9   1435.6   33965.
  HI       HO      W1      CW1
 174.07   352.23  134.75   61.97

******************/ TOTAL COMP WEIGHT IS   616.477

*************
*           *
*  PBUR  6  *
*           *
************2
BURNER NUMBER     6
  RIN      ROUT       LENGTH      MACH       WSPEC
   8.758    12.909    18.000     0.055      4.596
  CAS WT    LIN WT    NOZ WT    INC WT     FRAME      WTOT
    24.2      40.4      17.8      16.4     151.3      250.2
```

Figure 8   Cont.

```
*************
*           *
*  HPT   7  *
*           *
************2
DUCT
 M NO   VEL   T TOT    P TOT    P STAT   AREA     GAM
0.500 1186. 2621.  46112.  39327.    0.3977  1.2968

  U TIP  STRESS      DEN  W/AREA    TR      H/T
 1106.0  9819.5   0.286   0.246   1.000   0.922

 TURBINE  7  MECHANICAL DESIGN
    H/T    N STG LOADING     AREA
  0.922   2.000   0.280   0.398
     UT     RTIP     RHUB    DEL H      RPM     TORQ
 1106.0    11.0    10.1    174.5 11515.5 185913.

STAGE     1
 DISK    BLADE  VANE    HWD     CASE    AR
   6.4     2.3     8.4    21.7     4.0   1.50
  PR   DEL H   MACH   AREA  R HUB   R TIP   NB  U TIP    STR    WEIGHT  LENGTH
1.8453  87.3 0.500  0.398 10.14  11.01 180 1106.0  9820.   42.84    2.02

STAGE     2
 DISK    BLADE  VANE    HWD     CASE    AR
  10.8     6.4    23.7    35.5     6.8   1.50
  PR   DEL H   MACH   AREA  R HUB   R TIP   NB  U TIP    STR    WEIGHT  LENGTH
2.0063  87.3 0.525  0.666 10.14  11.55 116 1160.9 16456.   83.19    3.29

 N STG   LENGTH  WEIGHT
    2      5.31   126.03

DUCT
 M NO   VEL   T TOT    P TOT    P STAT   AREA     GAM
0.550 1149. 2028.  12436.  10243.    1.2074  1.3127

  PR       TR      AD EF     PO       TO      TO.1
 3.7081  1.2928  0.8600 12435.6  2027.7  2027.7
 H IN     H OUT     AREA    FLOW     HP
 699.28  524.74     5.17  137.56  33969.

******************** TOTAL TURB WEIGHT IS    126.028

*************
*           *
*  LPT   8  *
*           *
************2
DUCT
 M NO   VEL   T TOT    P TOT    P STAT   AREA     GAM
0.550 1149. 2028.  12438.  10245.    1.2072  1.3127
```

Figure 8 Cont.

```
  U TIP   STRESS      DEN   W/AREA    TR      H/T
  727.0 11708.5    0.286   0.777   1.000    0.765

 TURBINE  & MECHANICAL DESIGN
    H/T    N STG LOADING    AREA
  0.765    2.000   0.243   1.207
     UT     RTIP    RHUB   DEL H      RPM    TORQ
  727.0     11.5     8.8    86.9  7216.9 147693.

STAGE     1
 DISK    BLADE  VANE    HWD     CASE    AR
   5.0    22.4    66.0   38.9     9.9   2.00
  PR  DEL H  MACH   AREA  R HUB  R TIP  NB  U TIP    STR    WEIGHT  LENGTH
1.4669  43.4 0.550  1.207  8.83  11.54  80  727.0 11709.  142.18    4.77

STAGE     2
 DISK    BLADE  VANE    HWD     CASE    AR
   6.9    27.6    81.4   34.0     9.3   3.00
  PR  DEL H  MACH   AREA  R HUB  R TIP  NB  U TIP    STR    WEIGHT  LENGTH
1.5156  43.4 0.575  1.652  8.83  12.39  98  780.6 16019.  159.21    4.17

FRAME WT  =  167.79



 N STG   LENGTH  WEIGHT
    2     13.41  469.18

DUCT
 M NO   VEL   T TOT   P TOT    P STAT  AREA    GAM
0.600 1154. 1722.    5594.    4436.    2.3313  1.3249

  PR       TR      AD EF     PO       TO      TO.1
 2.2236  1.1779  0.8600  5593.7  1721.5  1721.5
 H IN    H OUT    AREA   FLOW     HP
 524.77  437.87   16.80  137.56  16912.

******************* TOTAL TURB WEIGHT IS   469.184


*************
*           *
*  AUG  10  *
*           *
************2
BURNER NUMBER    10
  RIN     ROUT      LENGTH      MACH      WSPEC
   0.0     24.120    48.000     0.143     11.899
  CAS WT   LIN WT   NOZ WT   INC WT    WTOT
    23.7    120.0    296.1      0.0     439.8
```

Figure 8 Cont.

```
*************
*           *
*  NOZ  11  *
*           *
************2
NOZZLE   11
WEIGHT=   568.95 LENGTH=   48.239 TR WT=    0.0


*************
*           *
*  DUCT  4  *
*           *
************2
DUCT ,   4
RH=   15.78 RT=   17.69 LENG=   62.16
AREA=   1.401 RHO=.168
      CAS WT        INC WT       WTOT
     15.5408        13.8556       29.3964


*************
*           *
*  SHAF 12  *
*           *
************2
SHAFT  12
   DO      DI    LENG      DN      WT
  3.54    3.01  48.74    0.65  40.03


*************
*           *
*  SHAF 13  *
*           *
************2
SHAFT  13
   DO      DI    LENG      DN      WT
  4.35    3.94  18.00    1.27  14.33


*************
*           *
*  ACCS WT  *
*           *
************2

  ACCS WT= 301.414
```

Figure 8 Cont.

WEIGHT INPUT DATA IN ENGL UNITS
WEIGHT OUTPUT DATA IN ENGL UNITS

COMP NO	WT EST	COMP LEN	ACCU LEN	UPSTREAM RADIUS RI	RO	RI	RO	DOWNSTREAM RADIUS RI	RO	RI	RO	NSTAGE
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0
2	1132.	29.	29.	9.	20.	0.	0.	13.	18.	0.	0.	3
3	0.	0.	29.	0.	0.	0.	0.	13.	16.	16.	18.	0
4	32.	62.	91.	16.	18.	0.	0.	16.	18.	0.	0.	0
5	678.	25.	54.	9.	13.	0.	0.	11.	11.	0.	0.	10
6	275.	18.	72.	9.	13.	0.	0.	9.	13.	0.	0.	0
7	139.	5.	78.	10.	11.	0.	0.	10.	13.	0.	0.	2
8	516.	13.	91.	9.	12.	0.	0.	9.	14.	0.	0.	2
9	0.	0.	91.	4.	16.	16.	21.	4.	21.	0.	0.	0
10	484.	48.	139.	0.	24.	0.	0.	0.	24.	0.	0.	0
11	626.	48.	187.	0.	24.	0.	0.	0.	22.	0.	0.	0
12	44.	0.	0.	9.	20.	10.	11.	0.	0.	0.	0.	0
13	16.	0.	0.	9.	13.	0.	0.	0.	0.	0.	0.	0

TOTAL BARE ENGINE WEIGHT= 3941. ACCESSORIES= 301.41

ESTIMATED TOTAL LENGTH= 187. ESTIMATED MAXIMUM RADIUS= 24.

Figure 8. Cont.

UPDATED INPUT DATA TO REFLECT CALCULATED INPUT

COMPONENT NO.	TYPE	DATINP1	DATINP2	DATINP3	DATINP4	DATINP5	DATINP6	DATINP7	DATINP8	DATINP9
1	INLET	0.23850D 03	0.0	0.14696D 02	0.0	0.0	0.90000D 00	0.0	0.0	0.0
2	COMPRESR	0.18000D 01	0.0	0.40000D 04	0.37610D 04	0.26590D 03	0.37620D 04	0.10113D 01	0.37630D 04	0.99222D 00
3	SPLITTER	0.77000D 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	DUCT B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	COMPRESR	0.13000D 01	0.26000D-01	0.51455D 04	0.37070D 04	0.61418D 02	0.37080D 04	0.90909D 00	0.37090D 04	0.13246D 01
6	DUCT B	0.10000D 00	0.0	0.0	0.26500D 04	0.94000D 00	0.18300D 05	0.0	0.0	0.0
7	TURBINE	0.40000D 01	0.10000D 01	0.46733D 00	0.38010D 04	0.70645D 00	0.38020D 04	0.96727D 00	0.90244D 00	0.10000D 01
8	TURBINE	0.25000D 01	0.0	0.38577D 00	0.38030D 04	0.72633D 00	0.38040D 04	0.94012D 00	0.81558D 00	0.10000D 01
9	MIXER	0.70773D 03	0.63925D 03	0.24000D 00	0.0	0.0	0.0	0.0	0.0	0.0
10	DUCT B	0.60000D-01	0.0	0.0	0.0	0.90000D 00	0.18300D 05	0.0	0.0	0.0
11	NOZZLE	0.47268D 03	0.10000D 01	0.0	0.0	0.98000D 00	0.10000D 01	0.0	0.0	0.10000D 01
12	SHAFT	0.40000D 04	0.10000D 01	0.15000D 01	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01
13	SHAFT	0.60000D 04	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01

CASE IDENTIFICATION SIMPLE MODEL

STATION PROPERTY OUTPUT DATA

FLOW STATION	WEIGHT FLOW STATP1	TOTAL PRESSURE STATP2	TOTAL TEMPERATURE STATP3	FUEL/AIR RATIO STATP4	REFERRED FLOW STATP5	MACH NUMBER STATP6	STATIC PRESSURE STATP7	INTERFACE CORRECTED FLOW ERROR STATP8
1	0.23850D 03	0.14696D 02	0.51867D 03	0.0	0.23850D 03	0.0	0.0	0.0
2	0.23850D 03	0.13226D 02	0.51867D 03	0.0	0.26499D 03	0.0	0.0	0.0
4	0.23850D 03	0.37628D 02	0.72687D 03	0.0	0.10969D 03	0.0	0.0	0.0
5	0.13475D 03	0.37628D 02	0.72687D 03	0.0	0.61970D 02	0.0	0.0	0.0
6	0.13124D 03	0.35581D 03	0.14356D 04	0.0	0.90183D 01	0.0	0.0	0.0
7	0.35034D 01	0.35581D 03	0.14356D 04	0.0	0.0	0.0	0.0	0.0
8	0.13405D 03	0.32022D 03	0.26500D 04	0.21425D-01	0.13906D 02	0.0	0.0	0.0
9	0.13756D 03	0.66376D 02	0.20276D 04	0.20868D-01	0.46276D 02	0.0	0.0	0.0
10	0.13756D 03	0.36649D 02	0.17216D 04	0.20868D-01	0.94801D 02	0.24000D 00	0.37401D 02	0.0
11	0.10375D 03	0.37628D 02	0.72687D 03	0.0	0.47717D 02	0.0	0.0	0.0
12	0.24131D 03	0.37401D 02	0.13157D 04	0.11790D-01	0.15101D 03	0.0	0.0	0.0
13	0.24131D 03	0.35157D 02	0.13157D 04	0.11790D-01	0.16065D 03	0.10000D 01	0.18780D 02	0.0
14	0.24131D 03	0.35157D 02	0.13157D 04	0.11790D-01	0.16065D 03	0.11729D 01	0.14696D 02	0.0
15	0.10375D 03	0.37628D 02	0.72687D 03	0.0	0.47717D 02	0.12734D 00	0.37401D 02	0.0

COMPONENT OUTPUT DATA

COMPONENT NO.	TYPE	DATOUT1	DATOUT2	DATOUT3	DATOUT4	DATOUT5	DATOUT6	DATOUT7	DATOUT8	DATOUT9
1	INLET	0.0	0.0	0.0	0.10000D 01	0.10000D 01	0.0	0.90000D 00	0.10000D 01	0.0
2	COMPRESR	-0.16912D 05	0.40000D 04	0.0	0.18000D 01	0.40000D 04	0.10000D 01	0.26590D 03	0.87000D 00	0.28600D 01
3	SPLITTER	0.77000D 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	DUCT B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	COMPRESR	-0.33969D 05	0.60000D 04	0.0	0.13000D 01	0.51455D 04	0.98500D 00	0.61418D 02	0.87000D 00	0.94060D 01
6	DUCT B	0.0	0.10000D 00	0.0	0.21425D-01	0.0	0.10123D 05	0.0	0.94000D 00	0.26500D 04
7	TURBINE	0.33969D 05	0.60000D 04	0.10000D 01	0.40000D 01	0.46733D 00	0.56800D 04	0.70645D 00	0.86000D 00	0.37073D 01
8	TURBINE	0.16912D 05	0.40000D 04	0.10000D 01	0.25000D 01	0.38577D 00	0.52440D 04	0.72633D 00	0.86000D 00	0.22234D 01
9	MIXER	0.70773D 03	0.63925D 03	0.16387D 01	0.10114D 01	0.47274D 03	0.16773D 03	0.0	0.94990D-16	0.10000D 01
10	DUCT B	0.0	0.60000D-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	NOZZLE	0.13785D 05	0.18379D 04	0.23923D 01	0.48393D 03	0.47288D 03	0.10000D 01	0.98000D 00	0.18721D 01	0.23923D 01
12	SHAFT	0.0	0.40000D 04	0.40000D 04	0.40000D 04	0.0	0.0	0.0	0.0	0.0
13	SHAFT	0.0	0.60000D 04	0.60000D 04	0.60000D 04	0.0	0.0	0.0	0.0	0.0

MACH= 0.0 ALTITUDE= 0. RECOVERY= 0.9000 0 ITERATIONS 2 PASSES

AIRFLOW (LB/SEC)	238.50	GROSS THRUST	13785.01	FUEL FLOW (LB/HR)	10122.81
NET THRUST	13785.01	TSFC	0.7343	NET THRUST/AIRFLOW	57.7988
TOTAL INLET DRAG	0.0	TOTAL BRAKE SHAFT HP	0.0	BOATTAIL DRAG	0.0
INSTALLED THRUST	13785.01	INSTALLED TSFC	0.7343	SPILLAGE + LIP DRAG	0.0

Figure 8 Cont.

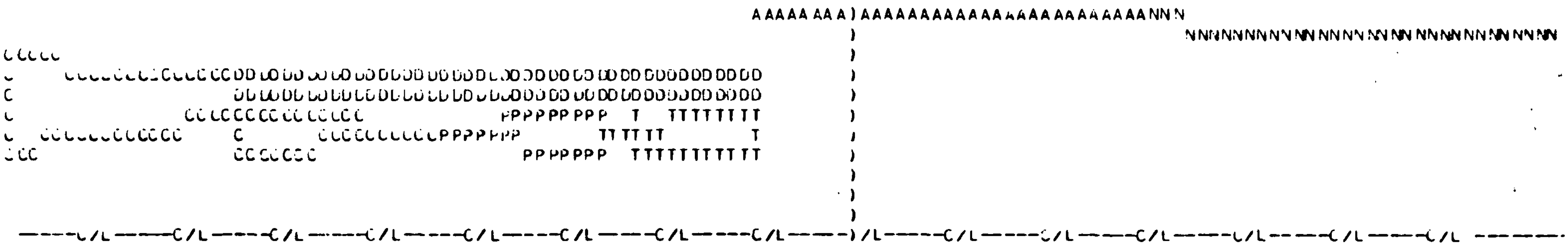


Figure 9 Flow Path

Table 4. Output Units

VARIABLE	SI UNITS	ENGLISH UNITS
Velocity	m/sec	ft/sec
Temperature	^oK	^oR
Pressure	n/m^2	lb/ft^2
Area	M^2	ft^2
Stress	N/cm^2	lb/in^2
Density	kg/cm^3	lb/in^3
Weight	kg	lb
Length	cm	in
Enthalpy	kwatts	btu/sec
Horsepower	kwatts	hp
Weight flow	kg/sec	lb/sec
Weight flow/unit area	kg/m^2sec	lb/ft^2 sec
Radius	cm	in

5.0 EXAMPLE CASE

A simple mixed flow augmented turbofan is used as an example for the WATE-1 input and execution. Figure 10 shows a schematic and a block diagram of the engine. From this block diagram, the component numbers are determined.

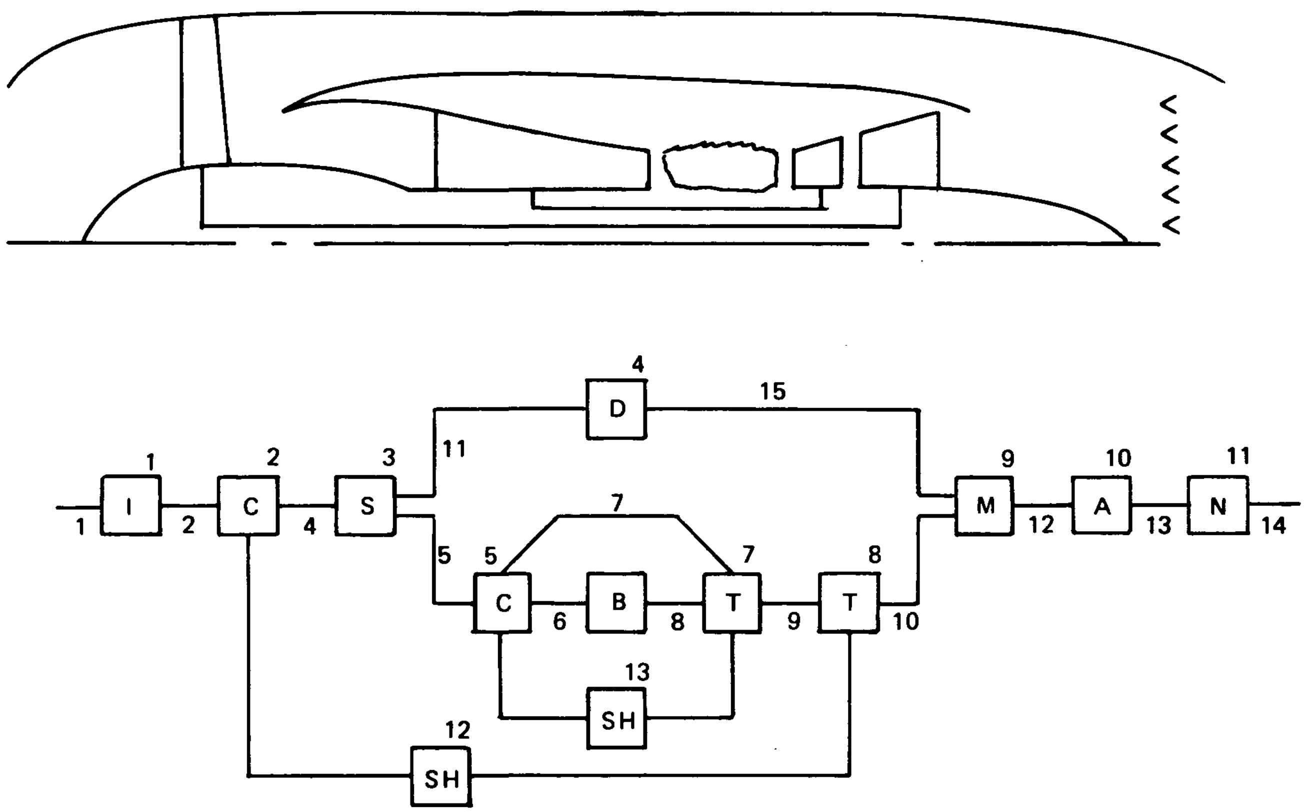


Figure 10   Engine Schematic

To construct the input deck the indicator section must first be set, Figure 11. In this example, the units in and out are English, so ISII and ISIO are set false. Since the weight and gas path layout are desired, IWT and IPLT are set true. The debug option is turned on with IOUTCD set equal to 2. The length inputs are then entered in ILENG. Since the duct (4) and shaft (12) and (13) do not contribute to the total length, they are not entered. Also, the components are entered as the flow would progress through the engine.

```
MODE      1 NOW BEING USED
&W
IPLT=T,
ISII=F,
ISIO=F,
IOUTCD=2,
ILENG(1)=2,3,5,6,7,8,9,10,11,
IWMEC(1,2)='FAN ',1,1,4,3*0,
IWMEC(1,3)='SPLT',6*0,
IWMEC(1,4)='DUCT',3,5*0,
IWMEC(1,5)='HPC ',1,2,4*0,
IWMEC(1,6)='PBUR',1,5*0,
IWMEC(1,7)='HPT ',0,5,-5,3*0,
IWMEC(1,8)='LPT ',1,2,7,3*0,
IWMEC(1,9)='MIX ',6*0,
IWMEC(1,10)='AUG ',6*0,
IWMEC(1,11)='NOZ ',2,-10,4*0,
IWMEC(1,12)='SHAF',1,8,3*0,2,
IWMEC(1,13)='SHAF',2,7,3*0,5,
DESVAL(1,2)=.524,1.7,.45,1.5,3.5,2.5,.45,0.,0.,1.,0.,2.,1.,0,1.1,
DESVAL(1,3)=14*0.,1.1,
DESVAL(1,4)=.45,2*0.,11.,10*0.,1.1,
DESVAL(1,5)=.45,1.35,.70,1.2,2.,1.5,.3,0.,0.,1.,0.,2.,1.,0,1.1,
DESVAL(1,6)=100.,.015,0.,5.,10*0.,1.1,
DESVAL(1,7)=.5,.28,1.5,1.5,1.5,.55,150000.,3.,1.,5*0.,1.1,
DESVAL(1,8)=.55,.243,1.5,2.,3.,.6,150000.,3.,1.,5*0.,1.1,
DESVAL(1,9)=14*0.,1.1,
DESVAL(1,10)=250.,.016,12*0.,1.1,
DESVAL(1,12)=50000.,.3,.65,11*0.,1.1,
DESVAL(1,11)=1.,13*0.,1.1,
DESVAL(1,13)=50000.,.3,12*0.,1.1,
&END
```

Figure 11 WATE-1 Input Example

The IWMEC values are now entered. Since no inlet weight calculations are done, the inlet is not entered. This is true with any component entered in the NNEP KONFIG section; it is not entered in IWMEC if no routine exists to weigh it. In the example, the IWMEC (1,2) card says a "fan" is being weighed. The weight will include stators, IWMEC (2,2) = 1, a front frame, IWMEC (3,2) = 1, and an intermediate frame, IWMEC (4,2) = 4. The IWMEC (1,8) card says a "LPT" is being weighed. It has a turbine exit frame, IWMEC (2,8) = 1, and it is connected to component 2, IWMEC (3,8) = 7. The nozzle has variable area capability, IWMEC (2,11) = 2, and its diameter will be taken from the inlet to the augmentor, IWMEC (3,11) = 10. Since the augmentor has constant diameter, the node position for taking the diameter is of no consequence.

The DESVAL inputs follow the IWMEC inputs. Component numbers used in DESVAL must agree with those used in IWMEC. Input of DESVAL data will override the default values. For the example case, the fan design card DESVAL (1,2) indicates that the compressor inlet Mach number is 0.524, the maximum first stage pressure ratio is 1.7 and the inlet hub/tip ratio is 0.45. The compressor has a blade solidity of 1.5 with a first blade aspect ratio of 3.5. The last stage has an aspect ratio of 2.5 and an exit Mach number of 0.45. The inlet and exit temperatures calculated in NNEP will be used for disk material determination, DESVAL (8,2) and DESVAL (9,2) are 0.; the RPM ratio between maximum and design is 1.0. The blade material will also be chosen by the code because DESVAL (11,2) is 0. The design of the fan is a constant mean line since the mode, DESVAL (12,2), equals 2. Also, no speed scaling or weight scaling will be done since DESVAL (13,2) is 1.0 and DESVAL (15,2) is 0. A material change temperature of 1160^{o}R will be used since DESVAL (14,2) is 0.

The HP turbine DESVAL (1,7) has an inlet Mach number of 0.5 and a turbine loading of 0.28. It has 1.5 solidity with inlet and exit blade aspect ratio equal to 1.5. The exit Mach number is 0.55. The disk material is a high strength super/alloy with a reference stress of 150,000 psi. A constant tip radius is used in the design, DESVAL (8,7) = 3., and a speed ratio of 1. is specified for stress calculations.

To end the inputs, a "&END" is entered. This will initiate execution of WATE-1. The output of WATE-1 is shown in Figure 12 for the example case.

```
*************
*           *
*  FAN   2  *
*           *
************2
DUCT
 M NO   VEL   T TOT    P TOT    P STAT   AREA    GAM
0.524  570.  519.    1905.    1579.     6.9517  1.4005

  U TIP  STRESS      DEN   W/AREA    TR      H/T
 1258.9 26757.6    0.168    2.339   1.800   0.450

 COMPRESSOR  2 MECHANICAL DESIGN

 LOADING   N STG   DIAM  U TIP C    RPM   C RPM
   0.874    3.00   39.98  1258.9  7216.9  7216.9

FRAME WT  =   95.67

STAGE     1
  WD   WB   WS   WN   WC    CL    RHOB  RHOD   AR
  65.  59.  59.   0.  26.    7.4 0.168 0.168  3.50
   PR  DEL H  MACH  AREA  R HUB  R TIP  NB U TIP    STR    WEIGHT TIN
 1.4789  16.7 0.524  6.952  8.99  19.99  59 1258.9 26758.  209.  519.

 STAGE     2
   WD   WB   WS   WN   WC    CL    RHOB  RHOD   AR
  91.  34.  34.  51.  21.    6.2 0.168 0.168  3.00
   PR  DEL H  MACH  AREA  R HUB  R TIP  NB U TIP    STR    WEIGHT TIN
 1.4155  16.7 0.499  5.180 11.02  18.95  67 1193.2 20191.  231.  588.

 STAGE     3
   WD   WB   WS   WN   WC    CL    RHOB  RHOD   AR
  97.  23.  23.  46.  19.    5.7 0.168 0.168  2.50
   PR  DEL H  MACH  AREA  R HUB  R TIP  NB U TIP    STR    WEIGHT TIN
 1.3671  16.7 0.475  4.017 12.17  18.23  70 1148.1 15768.  208.  658.

 FRAME WT  =  285.15



  N STG   WEIGHT  LENGTH
     3  1028.68   28.80

 DUCT
  M NO   VEL   T TOT    P TOT    P STAT   AREA    GAM
 0.450  582.  727.    5447.    4743.     3.2206  1.3951

   PR      AD EF      PO      TO      HP
  2.8600  0.8700  5447.2   726.9  16910.
   HI       HO       WI      CWI
  123.95  174.07  238.50  265.00

 ******************** TOTAL COMP WEIGHT IS  1028.680
```

Figure 12 WATE-1 Output Example

```
*************
*           *
*  HPC   5  *
*           *
************2
DUCT
 M NO   VEL   T TOT    P TOT    P STAT   AREA     GAM
0.450  582.  727.     5447.    4743.      1.8196  1.3951

  U TIP  STRESS       DEN   W/AREA    TR       H/T
 1285.1 23331.5    0.168    0.687    1.200    0.700

 COMPRESSOR  5 MECHANICAL DESIGN

 LOADING    N STG    DIAM  U TIP C      RPM    C RPM
   0.651    10.00    25.58  1085.6 11515.5   9727.5

FRAME WT  =  118.22

STAGE     1
  WD    WB    WS    WN    WC    CL    RHOB   RHOD    AR
 24.   14.   14.   36.   10.    4.5 0.168 0.168   2.00
  PR   DEL H  MACH   AREA  R HUB   R TIP   NB U TIP     STR    WEIGHT TIN
1.3603  17.8 0.450  1.820  8.95   12.79   50 1285.1 23331.    99.   727.

STAGE     2
  WD    WB    WS    WN    WC    CL    RHOB   RHOD    AR
 20.    9.    9.   29.    8.    3.6 0.168 0.168   1.94
  PR   DEL H  MACH   AREA  R HUB   R TIP   NB U TIP     STR    WEIGHT TIN
1.3241  17.8 0.435  1.442  9.42   12.45   60 1250.7 18516.    75.   800.

STAGE     3
  WD    WB    WS    WN    WC    CL    RHOB   RHOD    AR
 16.    6.    6.   25.    7.    3.0 0.168 0.168   1.89
  PR   DEL H  MACH   AREA  R HUB   R TIP   NB U TIP     STR    WEIGHT TIN
1.2948  17.8 0.420  1.171  9.75   12.19   70 1225.3 15048.    59.   873.

STAGE     4
  WD    WB    WS    WN    WC    CL    RHOB   RHOD    AR
 13.    4.    4.   21.    6.    2.6 0.168 0.168   1.83
  PR   DEL H  MACH   AREA  R HUB   R TIP   NB U TIP     STR    WEIGHT TIN
1.2704  17.8 0.405  0.970  9.98   12.00   81 1206.2 12477.    49.   946.

STAGE     5
  WD    WB    WS    WN    WC    CL    RHOB   RHOD    AR
 11.    3.    3.   18.    5.    2.2 0.168 0.168   1.78
  PR   DEL H  MACH   AREA  R HUB   R TIP   NB U TIP     STR    WEIGHT TIN
1.2499  17.8 0.390  0.818 10.15   11.86   93 1191.5 10527.    41.  1017.

STAGE     6
  WD    WB    WS    WN    WC    CL    RHOB   RHOD    AR
 10.    3.    3.   16.    4.    2.0 0.168 0.168   1.72
  PR   DEL H  MACH   AREA  R HUB   R TIP   NB U TIP     STR    WEIGHT TIN
1.2324  17.8 0.375  0.701 10.28   11.74  104 1180.1  9018.    36.  1089.
```

Figure 12 Cont.

```
STAGE      7
  WD    WB    WS    WN    WC    CL    RHOB   RHOD    AR
  9.    2.    2.   14.    4.    1.8 0.168 0.168  1.67
  PR   DEL H  MACH   AREA  R HUB   R TIP  NB U TIP     STR    WEIGHT TIN
1.2173  17.8 0.360  0.608 10.39  11.65 115 1171.0  7829.   32. 1159.

STAGE      8
  WD    WB    WS    WN    WC    CL    RHOB   RHOD    AR
 16.    3.    3.   13.    3.    1.6 0.286 0.286  1.61
  PR   DEL H  MACH   AREA  R HUB   R TIP  NB U TIP     STR    WEIGHT TIN
1.2042  17.8 0.345  0.534 10.47  11.58 126 1163.6 11712.   39. 1229.

STAGE      9
  WD    WB    WS    WN    WC    CL    RHOB   RHOD    AR
 15.    3.    3.   12.    3.    1.5 0.286 0.286  1.56
  PR   DEL H  MACH   AREA  R HUB   R TIP  NB U TIP     STR    WEIGHT TIN
1.1926  17.8 0.330  0.475 10.53  11.52 136 1157.7 10407.   36. 1299.

STAGE     10
  WD    WB    WS    WN    WC    CL    RHOB   RHOD    AR
 15.    2.    2.   11.    3.    1.4 0.286 0.286  1.50
  PR   DEL H  MACH   AREA  R HUB   R TIP  NB U TIP     STR    WEIGHT TIN
1.1824  17.8 0.315  0.426 10.59  11.47 146 1152.8  9343.   33. 1367.

 N STG   WEIGHT   LENGTH

   10    616.48    25.43

DUCT
 M NO   VEL   T TOT    P TOT    P STAT   AREA     GAM
0.300   544. 1436.   51236.   48231.     0.3874 1.3539

  PR     AD EF      PO      TO      HP
 9.4060  0.8700 51235.9  1435.6  33965.
  HI      HO      W1     CWI
 174.07  352.23  134.75   61.97

******************* TOTAL COMP WEIGHT IS   616.477

************
*          *
*  PBUR  6 *
*          *
***********2
BURNER NUMBER     6
  RIN     ROUT      LENGTH     MACH      WSPEC
   8.758    12.909    18.000     0.055     4.596
  CAS WT    LIN WT   NOZ WT   INC WT    FRAME      WTOT
    24.2      40.4      17.8      16.4    151.3     250.2
```

Figure 12 Cont.

```
*************
*           *
*  HPT   7  *
*           *
************2
DUCT
 M NO   VEL   T TOT    P TOT    P STAT   AREA     GAM
0.500 1186. 2621.  46112.  39327.    0.3977  1.2968

  U TIP   STRESS      DEN   W/AREA    TR       H/T
 1106.0   9819.5   0.286   0.246   1.000   0.922

 TURBINE  7  MECHANICAL DESIGN
    H/T    N STG LOADING     AREA
  0.922    2.000   0.280    0.398
     UT     RTIP     RHUB    DEL H      RPM     TORQ
 1106.0     11.0     10.1    174.5 11515.5 185913.

STAGE      1
 DISK    BLADE  VANE    HWD     CASE    AR
   6.4     2.3     8.4    21.7     4.0   1.50
  PR   DEL H   MACH   AREA  R HUB   R TIP  NB  U TIP    STR    WEIGHT  LENGTH
1.8453  87.3 0.500   0.398 10.14   11.01 180 1106.0  9820.    42.84     2.02

STAGE      2
 DISK    BLADE  VANE    HWD     CASE    AR
  10.8     6.4    23.7    35.5     6.8   1.50
  PR   DEL H   MACH   AREA  R HUB   R TIP  NB  U TIP    STR    WEIGHT  LENGTH
2.0063  87.3 0.525   0.666 10.14   11.55 116 1160.9 16456.    83.19     3.29

 N STG   LENGTH   WEIGHT
    2      5.31   126.03

DUCT
 M NO   VEL   T TOT    P TOT    P STAT   AREA     GAM
0.550 1149. 2028.  12436.  10243.    1.2074  1.3127

  PR        TR      AD EF     PO        TO       TO.1
 3.7081  1.2928  0.8600 12435.6  2027.7   2027.7
 H IN     H OUT     AREA   FLOW      HP
 699.28  524.74    5.17  137.56  33969.

****************** TOTAL TURB WEIGHT IS   126.028

*************
*           *
*  LPT   8  *
*           *
************2
DUCT
 M NO   VEL   T TOT    P TOT    P STAT   AREA     GAM
0.550 1149. 2028.  12438.  10245.    1.2072  1.3127
```

Figure 12 Cont.

```
  U TIP  STRESS     DEN  W/AREA   TR     H/T
  727.0 11708.5   0.286   0.777   1.000   0.765

 TURBINE  8  MECHANICAL DESIGN
    H/T    N STG LOADING     AREA
  0.765    2.000   0.243    1.207
     UT     RTIP    RHUB    DEL H      RPM    TORQ
  727.0     11.5     8.8     86.9  7216.9 147693.

STAGE     1
 DISK    BLADE  VANE    HWD    CASE    AR
   5.0    22.4    66.0   38.9    9.9  2.00
  PR   DEL H  MACH  AREA  R HUB  R TIP  NB  U TIP   STR   WEIGHT  LENGTH
1.4669  43.4 0.550  1.207  8.83  11.54  80  727.0 11709.  142.18    4.77

STAGE     2
 DISK    BLADE  VANE    HWD    CASE    AR
   6.9    27.6    81.4   34.0    9.3  3.00
  PR   DEL H  MACH  AREA  R HUB  R TIP  NB  U TIP   STR   WEIGHT  LENGTH
1.5156  43.4 0.575  1.652  8.83  12.39  98  780.6 16019.  159.21    4.17

FRAME WT  =  167.79


 N STG  LENGTH  WEIGHT
    2    13.41  469.18

DUCT
 M NO  VEL   T TOT    P TOT    P STAT   AREA    GAM
0.600 1154. 1722.    5594.    4436.    2.3313  1.3249

  PR       TR      AD EF     PO       TO      TO.1
 2.2236  1.1779  0.8600   5593.7  1721.5  1721.5
 H IN     H OUT    AREA    FLOW     HP
 524.77  437.87    16.80  137.56  16912.

******************** TOTAL TURB WEIGHT IS   469.184


*************
*           *
*  AUG  10  *
*           *
************2
BURNER NUMBER   10
  RIN     ROUT      LENGTH      MACH      WSPEC
   0.0     24.120   48.000     0.143     11.899
  CAS WT   LIN WT   NOZ WT    INC WT     WTOT
    23.7    120.0    296.1       0.0     439.8
```

Figure 12 Cont.

```
*************
*           *
*  NOZ  11  *
*           *
************2
NOZZLE    11
WEIGHT=   568.95 LENGTH=   48.239 TR WT=     0.0


*************
*           *
*  DUCT  4  *
*           *
************2
DUCT ,    4
RH=   15.78 RT=   17.69 LENG=   62.16
AREA=   1.401 RHO=.168
      CAS WT       INC WT       WTOT
     15.5408       13.8556       29.3964


*************
*           *
*  SHAF 12  *
*           *
************2
SHAFT  12
   DO      DI    LENG      DN      WT
  3.54    3.01  48.74    0.65  40.03


*************
*           *
*  SHAF 13  *
*           *
************2
SHAFT  13
   DO      DI    LENG      DN      WT
  4.35    3.94  18.00    1.27  14.33


*************
*           *
*  ACCS WT  *
*           *
************2

  ACCS WT= 301.414
```

Figure 12 Cont.

WEIGHT INPUT DATA IN ENGL UNITS
WEIGHT OUTPUT DATA IN ENGL UNITS

COMP	WT	COMP	ACCU	UPSTREAM RADIUS				DOWNSTREAM RADIUS				
NO	EST	LEN	LEN	RI	RO	RI	RO	RI	RO	RI	RO	NSTAGE
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0
2	1132.	29.	29.	9.	20.	0.	0.	13.	18.	0.	0.	3
3	0.	0.	29.	0.	0.	0.	0.	13.	16.	16.	18.	0
4	32.	62.	91.	16.	18.	0.	0.	16.	18.	0.	0.	0
5	678.	25.	54.	9.	13.	0.	0.	11.	11.	0.	0.	10
6	275.	18.	72.	9.	13.	0.	0.	9.	13.	0.	0.	0
7	139.	5.	78.	10.	11.	0.	0.	10.	13.	0.	0.	2
8	516.	13.	91.	9.	12.	0.	0.	9.	14.	0.	0.	2
9	0.	0.	91.	4.	16.	16.	21.	4.	21.	0.	0.	0
10	484.	48.	139.	0.	24.	0.	0.	0.	24.	0.	0.	0
11	626.	48.	187.	0.	24.	0.	0.	0.	22.	0.	0.	0
12	44.	0.	0.	9.	20.	10.	11.	0.	0.	0.	0.	0
13	16.	0.	0.	9.	13.	0.	0.	0.	0.	0.	0.	0

TOTAL BARE ENGINE WEIGHT= 3941. ACCESSORIES= 301.41

ESTIMATED TOTAL LENGTH= 187. ESTIMATED MAXIMUM RADIUS= 24.

Fig. 12 Cont.

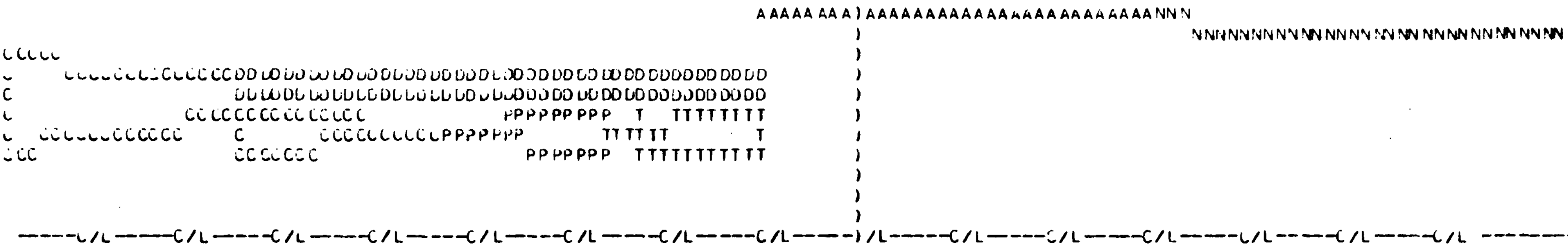


Figure 12. Cont.

UPDATED INPUT DATA TO REFLECT CALCULATED INPUT

COMPONENT NO.	TYPE	DATINP1	DATINP2	DATINP3	DATINP4	DATINP5	DATINP6	DATINP7	DATINP8	DATINP9
1	INLET	0.23850D 03	0.0	0.14696D 02	0.0	0.0	0.90000D 00	0.0	0.0	0.0
2	COMPRESR	0.18000D 01	0.0	0.40000D 04	0.37610D 04	0.26590D 03	0.37620D 04	0.10113D 01	0.37630D 04	0.99222D 00
3	SPLITTER	0.77000D 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	DUCT B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	COMPRESR	0.13000D 01	0.26000D-01	0.51455D 04	0.37070D 04	0.61418D 02	0.37080D 04	0.90909D 00	0.37090D 04	0.13246D 01
6	DUCT B	0.10000D 00	0.0	0.0	0.26500D 04	0.94000D 00	0.16300D 05	0.0	0.0	0.0
7	TURBINE	0.40000D 01	0.10000D 01	0.46733D 00	0.38010D 04	0.70645D 00	0.38020D 04	0.96727D 00	0.90244D 00	0.10000D 01
8	TURBINE	0.25000D 01	0.0	0.38577D 00	0.38030D 04	0.72633D 00	0.38040D 04	0.94012D 00	0.81558D 00	0.10000D 01
9	MIXER	0.70773D 03	0.63925D 03	0.24000D 00	0.0	0.0	0.0	0.0	0.0	0.0
10	DUCT B	0.60000D-01	0.0	0.0	0.0	0.90000D 00	0.18300D 05	0.0	0.0	0.0
11	NOZZLE	0.47288D 03	0.10000D 01	0.0	0.0	0.98000D 00	0.10000D 01	0.0	0.0	0.10000D 01
12	SHAFT	0.40000D 04	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01
13	SHAFT	0.60000D 04	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01	0.10000D 01

CASE IDENTIFICATION SIMPLE MODEL

STATION PROPERTY OUTPUT DATA

FLOW STATION	WEIGHT FLOW STATP1	TOTAL PRESSURE STATP2	TOTAL TEMPERATURE STATP3	FUEL/AIR RATIO STATP4	REFERRED FLOW STATP5	MACH NUMBER STATP6	STATIC PRESSURE STATP7	INTERFACE CORRECTED FLOW ERROR STATP8
1	0.23850D 03	0.14696D 02	0.51867D 03	0.0	0.23850D 03	0.0	0.0	0.0
2	0.23850D 03	0.13226D 02	0.51867D 03	0.0	0.26499D 03	0.0	0.0	0.0
4	0.23850D 03	0.37828D 02	0.72687D 03	0.0	0.10969D 03	0.0	0.0	0.0
5	0.13475D 03	0.37828D 02	0.72687D 03	0.0	0.61970D 02	0.0	0.0	0.0
6	0.13124D 03	0.35581D 03	0.14356D 04	0.0	0.90183D 01	0.0	0.0	0.0
7	0.35034D 01	0.35581D 03	0.14356D 04	0.0	0.0	0.0	0.0	0.0
8	0.13405D 03	0.32022D 03	0.26500D 04	0.21425D-01	0.13906D 02	0.0	0.0	0.0
9	0.13756D 03	0.86376D 02	0.20276D 04	0.20868D-01	0.46276D 02	0.0	0.0	0.0
10	0.13756D 03	0.36849D 02	0.17216D 04	0.20868D-01	0.94801D 02	0.24000D 00	0.37401D 02	0.0
11	0.10375D 03	0.37628D 02	0.72687D 03	0.0	0.47717D 02	0.0	0.0	0.0
12	0.24131D 03	0.37401D 02	0.13157D 04	0.11790D-01	0.15101D 03	0.0	0.0	0.0
13	0.24131D 03	0.35157D 02	0.13157D 04	0.11790D-01	0.16065D 03	0.10000D 01	0.18780D 02	0.0
14	0.24131D 03	0.35157D 02	0.13157D 04	0.11790D-01	0.16065D 03	0.11729D 01	0.14696D 02	0.0
15	0.10375D 03	0.37628D 02	0.72687D 03	0.0	0.47717D 02	0.12734D 00	0.37401D 02	0.0

COMPONENT OUTPUT DATA

COMPONENT NO.	TYPE	DATOUT1	DATOUT2	DATOUT3	DATOUT4	DATOUT5	DATOUT6	DATOUT7	DATOUT8	DATOUT9
1	INLET	0.0	0.0	0.0	0.10000D 01	0.10000D 01	0.0	0.90000D 00	0.10000D 01	0.0
2	COMPRESR	-0.16912D 05	0.40000D 04	0.0	0.18000D 01	0.40000D 04	0.10000D 01	0.26590D 03	0.87000D 00	0.28600D 01
3	SPLITTER	0.77000D 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	DUCT B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	COMPRESR	-0.33969D 05	0.60000D 04	0.0	0.13000D 01	0.51455D 04	0.98500D 00	0.61418D 02	0.87000D 00	0.94060D 01
6	DUCT B	0.0	0.10010D 00	0.0	0.21425D-01	0.0	0.10123D 05	0.0	0.94000D 00	0.26500D 04
7	TURBINE	0.33969D 05	0.60000D 04	0.10000D 01	0.40000D 01	0.46733D 00	0.56800D 04	0.70645D 00	0.86000D 00	0.37073D 01
8	TURBINE	0.16912D 05	0.40000D 04	0.10000D 01	0.25000D 01	0.38577D 00	0.52440D 04	0.72633D 00	0.86000D 00	0.22234D 01
9	MIXER	0.70773D 03	0.63925D 03	0.10387D 01	0.19114D 01	0.47274D 03	0.16773D 03	0.0	0.94990D-16	0.10000D 01
10	DUCT B	0.0	0.60000D-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	NOZZLE	0.13785D 05	0.18379D 04	0.23923D 01	0.48393D 03	0.47288D 03	0.10000D 01	0.98000D 00	0.18721D 01	0.23923D 01
12	SHAFT	0.0	0.40000D 04	0.40000D 04	0.40000D 04	0.0	0.0	0.0	0.0	0.0
13	SHAFT	0.0	0.60000D 04	0.60000D 04	0.60000D 04	0.0	0.0	0.0	0.0	0.0

MACH= 0.0 ALTITUDE= 0. RECOVERY= 0.9000 0 ITERATIONS 2 PASSES

AIRFLOW (LB/SEC)	238.50	GROSS THRUST	13785.01	FUEL FLOW (LB/HR)	10122.81
NET THRUST	13785.01	TSFC	0.7343	NET THRUST/AIRFLOW	57.7988
TOTAL INLET DRAG	0.0	TOTAL BRAKE SHAFT HP	0.0	BOATTAIL DRAG	0.0
INSTALLED THRUST	13785.01	INSTALLED TSFC	0.7343	SPILLAGE + LIP DRAG	0.0

Figure 12 Cont.

6.0 PROGRAM DIAGNOSTICS

The WATE-1 program contains error printout to aid the user in trouble shooting an input deck. A listing of the error messages and their meanings are shown in Table 5. None of these errors will cause termination of the program. The component routine in which the error occurred will be terminated and the program will continue its calculations. The components calculated after an error may or may not be in error.

Table 5. Error Messages

1.	"Compressor, I, pressure ratio is too high" - more than 20 compressor stages calculated. First stage maximum pressure ratio too small.
2.	"Compressor, I. stage and blade parameters, meaningless" - stage inlet Mach number less than or equal to zero, or hub radius of compressor equals zero.
3.	"Duct is not converging - error only called for rotating splitter fan component. Inlet or exit Mach numbers of fan may be input incorrectly.
4.	"Error in shaft" - iteration for shaft diameter not converging. Check shaft inputs.
5.	"Turbine, I, work or radius too high, RC = , X.XX" - more than 9 turbine stages calculated - turbine loading parameter too small or control radius improperly input.
6.	"Turbine, I, stage and blade parameters meaningless" - Mach number or hub radius less than or equal to zero.

REFERENCES

1. Fishbach, L. H. and Caddy, M. J., "NNEP - The Navy-NASA Engine Program," NASA TM X-71857, Dec. 1975.