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Thermal/Structural Tailoring of Engine Blades (T/STAEBL)

User's Manual

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1. T/STAEBL SYSTEM OVERVIEW

The T/STAEBL hollow blade optimizer is a series of programs, each designed to perform a specific task in the analysis and design of candidate turbine blade and vane configurations. The system of programs is controlled by a shell program, which executes the appropriate program module. The programs communicate with each other via a structure of data blocks. Some of these data blocks must be provided by the user, as program inputs. Most of the data blocks, however, are generated by the STAEBL system as a run executes.

Details on the workings of the individual T/STAEBL modules are provided in the STAEBL Theoretical Manual (Reference 1).

2. T/STAEBL DATA BLOCK STRUCTURE

The T/STAEBL cooled airfoil analysis system modules are all stand-alone programs, with no calling arguments. The analysis modules of the T/STAEBL system communicate among each other through a system of data blocks. The data blocks may contain basic input data, data produced by one program that will be required by another, or system outputs. To aid system development, increase flexibility, and speed new user learning, all data blocks are in ASCII format. Thus, any intermediate inputs and outputs may be edited and interpreted by the user.

The T/STAEBL data blocks are all numbered. A detailed list of the data blocks, their number designations, and their usage is provided in the STAEBL Theoretical Manual (Reference 1). This user's manual focuses on a subset of the STAEBL data blocks, i.e., those blocks required as input for a cooled blade or vane optimization. Blocks are stored as data files in the user's directory, named according to the following format: b0iii.j, where iii is the data block number, and j is the section number. For files where section is not relevant, such as Block 0, Control Information, the j index is a 0. The file for Block 0 is thus named: "b0000.0".

2.1 Required Input Data Blocks

To run a cooled airfoil optimization, a number of input data blocks are required. These blocks, listed in Table 1, include the necessary data for optimization control, as well as for thermal and structural analysis of a candidate cooled foil design. Inputs for Block 0503, Optimization Control, are detailed in Section 3, Optimization Control. Inputs for Blocks 0502, Finite Element Mesh, and 0516, Finite Element Control, are discussed in Section 5, Vibration Analysis Inputs. All other input data blocks are utilized by the cooled blade analysis modules and are discussed in Section 4, Thermal Analysis Inputs.

Table 1 T/STAEBL Input Data Blocks

Block Number	Airfoil Sections	Description
0000	0	Control Information
0001	1–5	Section Geometry
0012	0	Materials Data
0016	0	Cycle Definition
0017	1–5	Row & Column Breakup
0022	1–5	Creep
0023	1–5	Film Hole Geometry
0024	2–4	HGAS Film
0025	2–4	TGAS Film
0026	2–4	ETA Film
0027	2–4	HCOOLANT
0028	2–4	TCOOLANT
0029	2–4	HPEDESTAL
0030	2–4	TPEDESTAL
0031	2–4	HFILMHOLE
0032	2–4	TFILMHOLE
0037	1–5	Pedestal Geometry
0093	2–4	External PS/PT
0095	0	External P–Total
0096	0	Internal P–Total
0097	0	External T–Total
0099	0	1DHT Reference Data
0101	2–4	Pressure Side Boundary Layer Data
0102	2–4	Suction Side Boundary Layer Data
0104	2–4	Film Effectiveness
0400	2–4	Heat Transfer, Internal Cooling Base Input
0401	0	Internal Cooling Input Files
0501	0	Coating Thickness
0502	0	Finite Element Mesh Control
0503	0	Optimization Control
0504	0	Network Analysis Post–Processing
0505	0	Network Analysis Iteration Control
0506	0	Network Analysis Post–Processing
0507	0	1–D Heat Transfer Control
0512	1–5	Thermal Analysis Flag Points
0513	0	Global Section Radii
0514	0	Network Cross–Reference Table
0516	0	Finite Element Analysis Control
0520	0	Oxidation Life Parameters

3. OPTIMIZATION CONTROL (BLOCK 0503)

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Design Variation Procedure

In the Aero/Structural Tailoring of Engine Blades program (Reference 2), which allowed the optimization of fan and compressor blading, basic geometric and aerodynamic parameters were input via design curves. While T/STAEBL still utilizes the design curve principle, the design curves are now inferred from the input geometry and performance data blocks. As such, the optimization inputs of T/STAEBL are a subset of the inputs used in Aero/STAEBL. ABSCISSA and CURVE cards are not permitted. Instead, a blade is defined using five data sections, at 0%, 25%, 50%, 75%, and 100% spans. Thus, the allowable abscissa values are predefined. Additionally, the program automatically builds design curves for a generous number of parameters. Those parameters that may be altered as design variables are listed in Table 2.

Within T/STAEBL, those parameters that are to be treated as design variables or constraints for a particular optimization are defined in data Block 0503. The inputs for Block 0503 are discussed in this section. Block 0503 is called TSTAEBL INP and must reside on the end user's 191 disk.

T/STAEBL Design Variables

As previously mentioned, the T/STAEBL design curves are automatically constructed by the program to allow the set of variables listed in Table 2. Not all variables lead directly to design curves, however – the first five variables, as noted, are single valued. While tilts could be generalized into design curve formats, they are currently treated as tip tilt values. Tilts at intermediate sections are linearly interpolated from zero at the root to the indicated tip values.

Table 2 T/STAEBL Design Variables

Variable	Abbreviation
Single Valued Parameters	
Variable	Abbreviation
Supply Pressure	SUPPRS
Axial Tilt	AXTILT*
Tangential Tilt	TANTILT*
Secondary Material Angle	SMATANG
Coating Thickness	COATTHK
Design Curves	
Variable	Abbreviation
Rib 1 Thickness	RIB1THK
Rib 2 Thickness	RIB2THK
Rib 3 Thickness	RIB3THK
Cavity 1 Pressure Side Thickness	CV1PTHK
Cavity 1 Suction Side Thickness	CV1STHK
Cavity 2 Pressure Side Thickness	CV2PTHK
Cavity 2 Suction Side Thickness	CV2STHK
Cavity 3 Pressure Side Thickness	CV3PTHK
Cavity 3 Suction Side Thickness	CV3STHK
Cavity 4 Pressure Side Thickness	CV4PTHK
Cavity 4 Suction Side Thickness	CV4STHK
Cavity 1 Trip Strip Height	CAV1TSH
Cavity 1 Trip Strip Pitch	CAV1TSP
Cavity 1 Trip Strip Angle	CAV1TSA
Cavity 2 Trip Strip Height	CAV2TSH
Cavity 2 Trip Strip Pitch	CAV2TSP
Cavity 2 Trip Strip Angle	CAV2TSA
Cavity 3 Trip Strip Height	CAV3TSH
Cavity 3 Trip Strip Pitch	CAV3TSP
Cavity 3 Trip Strip Angle	CAV3TSA
Pedestal 1 Diameter	PED1DIA
Pedestal 2 Diameter	PED2DIA
Pedestal 3 Diameter	PED3DIA
Pedestal 4 Diameter	PED4DIA
Pedestal 5 Diameter	PED5DIA
Pedestal 6 Diameter	PED6DIA
Pedestal 7 Diameter	PED7DIA
Pedestal Spacing	PEDSPAC
Film Hole 1 Diameter	FLM1DIA
Film Hole 2 Diameter	FLM2DIA
Film Hole 3 Diameter	FLM3DIA
Film Hole 1 Spacing	FLM1SPC
Film Hole 2 Spacing	FLM2SPC

*Not a meaningful design variable for vanes.

To include a parameter as a design variable, it must be referenced on a VARIABLE card. Note that the radial section for the variable derives from the mnemonic in field 2 of the VARIABLE card, rather than from a LOC input in field 4, as in Aero/STAEBL. The radial section number is appended to the abbreviation for the design variable, falling in the eighth column of the second field (column 16 on the card image). Thus, to vary the cavity 2 pressure side wall thickness at the 50% span location (section 3), the user must declare CV1PTHK3 to be a design variable by including an appropriate VARIABLE card.

As the optimizer alters the value of a variable, the design curves are updated, and intermediate section value increments are determined from spline fits. Since the user may want to hold a value at a section constant, a CONSTANT card has been provided. Also, the user may vary one term in direct proportion with another through usage of a DEPEND card.

A notable deviation from Aero/STAEBL is the capability to alter a curve with only two values declared on that curve. Previously, three values were needed, so that a quintic spline could be employed. In T/STAEBL, this requirement has been relaxed. If only two parameters are defined on a particular curve, other parameter deltas are determined through a linear fit procedure. Both interpolation and extrapolation are permitted. If three or more parameters are defined for a curve, a full quintic spline procedure is used, comparable to the procedure of Aero/STAEBL.

Constraints

Two forms of constraints are permitted in T/STAEBL: side constraints, and constraints on calculated values. Side constraints define the upper and lower limits of values which a variable is allowed to take. Since their value relative to the parameter value is known at the start of any function call, gradient values are not required for these constraints.

Within the T/STAEBL analysis procedure, many values are calculated that give important information relating to the life or performance of an airfoil. These values are stored in a data Block 0515, with the values arranged as listed in Table 3. By referencing an appropriate address in this data block, the user may prescribe allowable limits for any of these values. This process is accomplished by using a CONSTRNT card. If only a single speed analysis is called for in the finite element control, fields 31 through 40 in this data block will be meaningless.

Objective Function

Due to the variability of cost/weight/performance trades depending on aircraft, fuel cost, cost of raw materials, etc., a general objective function has been included in the T/STAEBL system. By using the OBJECTIV card, the user is allowed to define the objective function as a linear combination of the items stored in fields 90 through 97 of the calculated values data block (Block 0515). The terms to be included in the objective function are identified via mnemonic abbreviations, as listed on Table 4, rather than by their address in the data block.

Using this procedure, the user is required to supply the cost sensitivities to the program. If no OBJECTIV card is provided, T/STAEBL will default to a minimum airfoil weight optimization.

Table 3 Calculated T/STAEBL Performance Parameters (Block 0515)

Location	Calculated Value Description
-1- thru -10-	Natural frequencies, first analysis speed, first ten modes of vibration
-31- thru -40-	Natural frequencies, second analysis speed, second ten modes of vibration
-90-	Single airfoil weight, lb
-91-	Root section P/A membrane stress, psi
-92-	Coolant flow rate, lb/sec
-93-	Average profile loss, Δ pt/pt
-94-	Average film mixing loss, Δ pt/pt
-95-	Maximum temperature, °F
-96-	Average blade temperature, °F
-97-	Percent of life used in 10 hours

Table 4 Objective Function Abbreviations

Abbreviation	Description	Block 0515 Address
WEIGHT	Single airfoil weight, lb	90
RSP/A	Root section P/A membrane stress, psi	91
CFLRATE	Coolant flow rate, %Wae	92
AVPRLOSS	Average profile loss, Δ pt/pt	93
AVFMLOSS	Average film mixing loss, Δ pt/pt	94
MAXTEMP	Maximum temperature, °F	95
AVBLTEMP	Average blade temperature, °F	96
PL1FEUSE	Percent of life used in 10 hours	97

INPUT DATA CARD FORMAT:

1. All continuation cards must follow the parent card. Continuation is designated via any alphanumeric input in field -10- of the previous card. All continuation cards must follow the parent card in proper order.

2. All input is currently inserted in free field format within the specified 8 column field, except where specifically stated otherwise.

3. A $ in column 1 indicates a comment card for any data input section. The card will be ignored. The only exception to this is the $$PARAM card used for analysis control in the bulk data section of the finite element inputs.

4. A comment card cannot precede a continuation card.

OPTIMIZATION CONTROL CARD CROSS REFERENCES:

Within the optimization control, only the OPTIMIZE and CONSTRNT cards are completely independent of other card sets. Card cross reference requirements are listed below.

MOST INDEPENDENT				MOST DEPENDENT
OPTIMIZE CONSTRNT	⟶	VARIABLE CONSTANT	⟶	DEPEND

To alter a curve, a variable may be defined with reference to a legal variable name. On that curve, other station locations may be VARIABLEs, may be held CONSTANT, or may vary in proportion to a defined variable according to a DEPEND relationship.

****

..CONSTANT..

The CONSTANT card defines points on the CURVE card which are held fixed during the optimization. The CONSTANT card references a CURVE card, to specify which value to hold constant. By having VARIABLE cards and also CONSTANT cards reference the same curve, it is possible to alter the design selected by that particular curve.

****

field locations..

1	2	3	4	5	6	7	8	9
CONSTANT	CONST_DESC			CONST_VAL				

example..

1	2	3	4	5	6	7	8	9
CONSTANT	RIB1THK1			.125				

Field	Format	Name	Description
-1-	alpha*8	CARD_TYPE	card type = CONSTANT
-2-	alpha*7	CONST_DESC	mnemonic name for CONSTANT type (see Table 2 for allowable names)
	alpha*1	CONST_SECT	airfoil section where parameter is to be held constant
-3-			- blank -
-4-			- blank -
-5-	real*8	CONST_VAL	value at which parameter is to be held constant

Note:

1. If a design curve is to be modified, a minimum of 2 VARIABLE, CONSTANT, and/or DEPEND locations must reference that curve.

****

..CONSTRNT..

The CONSTRNT cards define the constraints for the optimization program. A constraint compares a value calculated during a function call, such as stress, with an allowable value. This comparison is accomplished by using these values in a specified equation form. Each CONSTRNT card defines the form of the constraint equation, and the terms to be used in the equation. The function call generated terms are stored in an array (Block 0515) and referenced by array location (see Table 3). The permitted constraint equation forms are listed in Table 5. The CONSTRNT card must include a continuation card.

****

field locations (card 1)..

1	2	3	4	5	6	7	8	9
CONSTRNT	CON_DESC	CON_FACT	CON_FORM	CON_ADS	CON_TERM	CON_TERM	CON_TERM	CON_TERM

example..

1	2	3	4	5	6	7	8	9
CONSTRNT	FOILWT	1.0	2	0	90			

..card 1..

Field	Format	Name	Description
-1-	alpha*8	CARD_TYPE	card type = CONSTRNT
-2-	alpha*7	CON_DESC	mnemonic name of constraint
	alpha*1		One blank column
-3-	real*8	CON_FACT	multiplication factor applied to calculated performance parameter (Table 3) for analysis calibration (default = 1.0)
-4-	integer*8	CON_FORM	equation form of the constraint (see Table 5 for allowable forms)
-5-	integer*8	CON_ADS	0 = nonlinear inequality constraint 2 = linear inequality constraint -1 = nonlinear equality constraint
-6- thru -9-	integer*8	CON_TERM	location of calculated performance parameter in storage array (see Table 3)
-10-			- blank -

..CONSTRNT..
(continued)

field locations (card 2)..

1	2	3	4	5	6	7	8	9
CON_VAL1	CON_VAL2	CON_VAL3	CON_VAL4	CON_VAL5	CON_VAL6	CON_VAL7	CON_VAL8	

example..

1	2	3	4	5	6	7	8	9
	12.1							

.. card 2 ..

Field	Format	Name	Description
-1- thru -8-	real*8	CON_VAL1 -thru- CON_VAL8	values needed to calculate constraint equations listed in Table 5

Notes:

1. Card 2 is required.
2. Refer to Tables 3 and 5 to properly set up constraint equations.

Table 5 lists the available library of constraint equations in STAEBL. The catalog number is input on the CONSTRNT card field -4-, IFORM. Each equation compares one or more of the VAL1 through VAL8 input values to function(s) call generated TERM, located by ITERM1 through ITERM4 on the CONSTRNT card (see Table 3). Equations are interpreted as follows:

G.LT.0	—	inactive constraint
G.EQ.0	—	active constraint
G.GT.0	—	violated constraint

The ADS optimizer allows a tolerance band about zero for defining a constraint as active.

Table 5 Library of Constraint Equations

Catalog Number	Form of Equation	Description
-1-	G = (TERM - VAL1) / VAL1	upper bound constraint (TERM ≤ VAL)
-2-	G = (VAL1 - TERM) / VAL1	lower bound constraint (TERM ≥ VAL)
-3-	G = VAL2 - (TERM - VAL1) / VAL1	lower limit constraint w/margin (TERM ≥ V1 - V1*V2)
-4-	G = (TERM - VAL1) / VAL1 + VAL2	upper limit constraint w/margin (TERM ≤ V1 - V1*V2)
-5-	G = VAL2 - ABS (TERM - VAL1) / VAL1	dual sided constraint
-6-	EQ1 = VAL3 - (1. - TERM1 / VAL1) EQ2 = VAL3 - (TERM2 / VAL2 - 1.) G = smallest value between EQ1, EQ2	excitation crossing constraint between two speeds

Note: Catalog number 6 requires VAL2 be greater than or equal to VAL1

****

..DEPEND..

The DEPEND card defines points on the CURVE card which are dependent upon a specified VARIABLE. The DEPEND card allows the user to alter CURVE values without defining another independent design variable. A constant multiplier is permitted.

****

field locations..

1	2	3	4	5	6	7	8	9
DEPEND	DEP_DESC	DEP_LBL		DEP_CONST				

example..

1	2	3	4	5	6	7	8	9
DEPEND	RIB3THK3	4		.75				

Field	Format	Name	Description
-1-	alpha*8	CARD_TYPE	card type = DEPEND
-2-	alpha*7	DEP_DESC	mnemonic name for DEPENDent variable (see Table 2)
	alpha*1	DEP_SECT	airfoil section to be dependent
-3-	integer*8	DEP_LBL	variable card ID for independent design parameter
-4-			- blank -
-5-	integer*8	DEP_CONST	value assigned to VARIABLE value multiplier (default = 1.0)

Notes:

1. A total of 50 dependent variables is currently allowed.

2. If a design curve is to be modified, a minimum of 2 VARIABLE, CONSTANT, and/or DEPEND locations must reference that curve.

****

..NECKGEOM..

The NECKGEOM card defines the airfoil extended neck geometry. The extended neck is assumed to be of constant cross section, running radially from the attachment radius to the airfoil root. T/STAEBL uses the NECKGEOM card to build a finite element beam model of the root. This beam neck model is cantilevered at the attachment radius.

****

field locations..

1	2	3	4	5	6	7	8	9
NECKGEOM	Z_RADIUS	AREA	IMIN	IMAX	KTORS	THET_MIN		

example..

1	2	3	4	5	6	7	8	9
NECKGEOM	12.4378	.9892	.09193	.2977	.289	7.0		

Field	Format	Name	Description
-1-	alpha*8	CARD_TYPE	card type = NECKGEOM
-2-	real*8	Z_RADIUS	radius at blade attachment
-3-	real*8	AREA	area of extended neck section
-4-	real*8	IMIN	neck section minimum moment of inertia
-5-	real*8	IMAX	neck section maximum moment of inertia
-6-	real*8	KTORS	neck section torsional stiffness
-7-	real*8	THET_MIN	root broach angle, measured from engine axial direction

****

..OBJECTIV..

The OBJECTIV card defines the objective function for the desired optimization execution. The final value for the objective function is the sum of the values associated with the selected OBJ_VARs times their respective weighting coefficients. Acceptable OBJ_VAR names are listed in Table 4.

****

field locations..

1	2	3	4	5	6	7	8	9
OBJECTIV	OBJ_VAR	OBJ_COEFF	OBJ_VAR	OBJ_COEFF	OBJ_VAR	OBJ_COEFF	OBJ_VAR	OBJ_COEFF

example..

1	2	3	4	5	6	7	8	9
OBJECTIV	WEIGHT	1.0	MAXTEMP	.35				

Field	Format	Name	Description
-1-	alpha*8	CARD_TYPE	card type = OBJECTIV
-2-	alpha*8	OBJ_VAR	mnemonic of calculated performance parameter to include in objective function summation (permitted names are listed in Table 4)
-3-	real*8	OBJ_COEFF	weighting coefficient for previous performance parameter
-4-	alpha*8	OBJ_VAR	mnemonic of calculated performance parameter to include in objective function summation
-5-	real*8	OBJ_COEFF	weighting coefficient for previous performance parameter
-6-	alpha*8	OBJ_VAR	mnemonic of calculated performance parameter to include in objective function summation
-7-	real*8	OBJ_COEFF	weighting coefficient for previous performance parameter
-8-	alpha*8	OBJ_VAR	mnemonic of calculated performance parameter to include in objective function summation
-9-	real*8	OBJ_COEFF	weighting coefficient for previous performance parameter

Notes:

1. Allowable names for the OBJ_VAR objective function parameters are listed in Table 4.
2. A continuation card may be used if required for long objective function definitions. To flag a continuation, put a non-blank character in column 80 of the OBJECTIV card. Columns 1 thru 8 of the continuation card must be blank. Data field 2 of the continuation card lists the next OBJ_VAR item. A maximum of 8 OBJ_VAR and OBJ_COEFF sets is permitted.
3. Default is weight minimization.

****

..OPTIMIZE..

The OPTIMIZE card defines the optimization solution procedure, the optimization strategy, the search procedure and the ADS output requests. Refer to the STAEBL Theoretical Manual for an explanation of the input terms.

****

field locations..

1	2	3	4	5	6	7	8	9
OPTIMIZE	ISTRAT	IOPT	ISERCH	IPRINT			MAXITER	BV_TYPE

example..

1	2	3	4	5	6	7	8	9
OPTIMIZE	0	5	8	3552			50	BLADE

Field	Format	Name	Description
-1-	alpha*8	CARD_TYPE	card type = OPTIMIZE
-2-	integer*8	ISTRAT	ADS optimization strategy
-3-	integer*8	IOPT	ADS optimization procedure
-4-	integer*8	ISERCH	ADS 1-D search procedure
-5-	integer*8	IPRINT	ADS output request
-6-			- blank -
-7-			- blank -
-8-	integer*8	MAXITER	maximum number of function calls allowed for this run (default = 10,000)
-9-	alpha*8	BV_TYPE	blade or vane logical switch = "BLADE" or "VANE"

****

..VARIABLE..

Each VARIABLE card defines one optimization design variable. Those parameters, which are legal as design variables, are listed on Table 2. In STAEBL, note that each design variable represents the change of a given quantity, not the absolute value.

****

field locations..

1	2	3	4	5	6	7	8	9
VARIABLE	VAR_DESC	VAR_LBL			VMIN	VMAX	VSTART	

example..

1	2	3	4	5	6	7	8	9
VARIABLE	SUPPRS	1			-5.	5.0	0.123456	

card 1..

Field	Format	Name	Description
-1-	alpha*8	CARD_TYPE	card type = VARIABLE
-2-	alpha*7	VAR_DESC	mnemonic name for variable (must be an allowable name; see Table 2)
	alpha*1	VAR_SECT	airfoil section number to be varied
-3-	integer*8	VAR_LBL	variable label (identification) number
-4-			- blank -
-5-			- blank -
-6-	real*8	VMIN	minimum value for variable (side constraint)
-7-	real*8	VMAX	maximum value for variable (side constraint)
-8-	real*16	VSTART	initial value for design variable; default = 0. (length 16)

Notes:

1. The VARIABLE LABEL # will always be unique.
2. If a design curve is to be modified, a minimum of 2 VARIABLE, CONSTANT, and/or DEPEND locations must reference that curve.

4. THERMAL ANALYSIS INPUTS

To perform a thermal analysis in the T/STAEBL system, numerous input data blocks, listed in Table 6, are required. To put these input requirements into perspective, the user must recall that the T/STAEBL system includes many modules, performing many integrated tasks, including network, heat flow, stress, life, and vibration analyses. Unfortunately, a result of the complexity of the system is the requirement for a large amount of data, all relevant to the cooled blade design process.

For those data blocks that require data on a section by section basis, multiple input files will exist. Thus, for five input sections, the following block 001 input files will be required:

b0001.1 b0001.2 b0001.3 b0001.4 b0001.5

Table 6 T/STAEBL Thermal Analysis Input Data Blocks

Block Number	Airfoil Sections	Description	Page
0000	0	Control Information	19
0001	1–5	Section Geometry	19
0012	0	Materials Data	20
0016	0	Cycle Definition	22
0017	1–5	Row & Column Breakup	23
0022	1–5	Creep Inputs	24
0023	1–5	Film Hole Geometry	25
0024	1–5	HGAS Film	26
0025	1–5	TGAS Film	26
0026	1–5	ETA Film	26
0027	1–5	HCOOLANT	27
0028	1–5	TCOOLANT	27
0029	1–5	HPEDESTAL	27
0030	1–5	TPEDESTAL	27
0031	1–5	HFILMHOLE	28
0032	1–5	TFILMHOLE	28
0037	1–5	Pedestal Geometry	29
0093	1–5	External PS/PT	29
0095	0	External P–Total	30
0096	0	Internal P–Total	30
0097	0	External T–Total	31
0099	0	Internal Cooling 1DHT Reference Data	31
0101	1–5	Pressure Side Boundary Layer Data	32
0102	1–5	Suction Side Boundary Layer Data	32
0104	1–5	Film Effectiveness	33
0400	1–5	Base Inputs for Conduction and Network Analyses	34
0401	0	Network Analysis Input Files	38
0501	0	Coating Thickness	43
0504	0	Network Analysis Post–Processing	43
0505	0	Network Analysis Iteration Control	44
0506	0	Network Analysis Post–Processing Control	44
0507	0	1–D Heat Transfer Control	44
0512	1–5	Thermal Analysis Flag Point Definition	45
0513	0	Global Section Radii	47
0514	0	Network to Section/Cavity Cross–Reference Table	47
0520	0	Oxidation Life Parameters	50

4.1 Block Inputs

Input formats for those thermal analysis data blocks required to initiate a T/STAEBL optimization are listed in this section. Data item formats are alpha-numeric (A), integer (I), or floating point (F). Data items must be placed in appropriate columns of the card image.

4.1.1 Block 0000 - Control Information

This data block, while required, is not referenced for any data in T/STAEBL. Thus, just leave the sample Block 0 intact.

4.1.2 Block 0001 - Section Geometry

This data block describes the basic airfoil section to be optimized. For each cross-section (constant radius), exterior and cavity coordinates will be input. Each coordinate set is designated as a curve. Coordinate points are input in counterclockwise direction. One coordinate card is required for each point. Coordinate inputs begin with the external curve, and continue for each cavity in the order from nose to trailing edge. The first point on the external curve is the stagnation point. The first point for any cavity is the point with minimum X coordinate. The sections should be stacked (X axis is engine axis, Y is engine tangential).

Card Type 1:
BLOCK 1 5 E3 First Blade Tip Section
Format: A80
Data: A descriptive comment to aid file editing/viewing.

Card Type 2: Insert a blank card here.

Card Type 3:
NCURV NEXT NCAV1 NCAV2 NCAV3 ... NCAV11 RAD1
Format: 13I5,F10
Data:

NCURV	-	Total number of curves on the cross-section (external plus number of cores)
NEXT	-	Number of points on external curve
NCAV1	-	Number of points on cavity 1 curve
...		
NCAV11	-	Number of points on cavity 11 curve
RAD1	-	Radius of cross-section (in.).

Card Type 4: Insert a blank card here.

Card Type 5: (NEXT + NCAV1 + NCAV1 + NCAV3 + ... + NCAV11 cards required)
X Y
Format: 2F10
Data:

X	-	Point X coordinate (in.)
Y	-	Point Y coordinate (in.).

4.1.3 Block 0012 – Materials Data

This data block stores material properties. The material data consists of a set of nine properties:

1. Specific Heat – Typical
2. Thermal Conductivity
3. Mean Coefficient of Linear Expansion
4. Elastic Modulus – Dynamic
5. 0.2% Yield Strength
6. 0.02% Yield Strength
7. Density
8. 0.50%, 0.75% and 1.00% Creep, or
   0.50%, 1.00% and 2.00% Creep, or
   0.20%, 0.50% and 1.00% Creep
9. Stress Rupture.

There are 8 card types to describe the materials data. Card type 1 is the block title card. Card type 2 specifies the number of materials to be used. The properties data for a material to be stored is contained on a set of cards defined as card types 3 through 8. This set of cards is repeated for each material to be stored.

Card types 3 and 4 contain identifying information (names, property types, etc.) for a specific material and property. Card type 5 contains properties data for property types 2 through 7. This card type is repeated for each property type. Card type 6 contains density data. Card type 7 contains creep property data. Card type 8 contains the material stress rupture data.

Card Type 1:
```
   BLOCK  12   0   0  MATERIAL PROPERTIES
```
Format: A80
Data: A descriptive comment to aid file editing/viewing.

Card Type 2:
```
   NMAT
```
Format: I5
Data: NMAT - Number of materials (maximum of 3)

Card Type 3:

MATL	MLAB		
Format:	A12,A68		
Data:	MATL	-	Material identification (i.e., METAL1)
	MLAB	-	Descriptive material label (i.e., Anisotropic Material)

Card Type 4: (NMAT sets of card types 4 through 8)

MC PC PTITLE

Format: A10,A10,A40

Data:
- MC - Material code
- PC - Property code
- PTITLE - Title for this property. Allowable titles are:
  SPECIFIC HEAT
  THERMAL CONDUCTIVITY
  MEAN COEFFICIENT OF LINEAR EXPANSION
  ELASTIC MODULUS
  0.2% YIELD STRENGTH
  0.02% YIELD STRENGTH
  DENSITY
  0.50%, 0.75% AND 1.00% CREEP
  0.50%, 1.00% AND 2.00% CREEP
  0.20%, 0.50% AND 1.00% CREEP
  STRESS RUPTURE

Card Type 5A:

CON INTLIM

Format: F10,I5

Data:
- CON - Multiplier for subsequent data
- INTLIM - Material property interpolation limit, 1 to 25

Note: Properties are stored in an array of 25 values, corresponding to temperatures from 100 to 2500°F. INTLIM is used to truncate property values above a certain temperature. For temperatures above that corresponding to INTLIM, the property value is held to the value at INTLIM. For temperatures below INTLIM, properties are interpolated.

Card Type 5B: (5 cards present – total of 25 values)

DATA1 DATA2 DATA3 DATA4 DATA5

Format: 5F15

Data: DATA1 ... DATA5 - Material property data, for inputs of Specific Heat, Thermal Conductivity, Mean Coefficient of Linear Expansion, Elastic Modulus, 0.2% Yield Strength, or 0.02% Yield Strength. These DATA items are stored after being multiplied by CON. The interpolation range is 100 to 2500°F, in increments of 100. If INTLIM is less than 25, then the remaining values of DATA are set equal to the last value obtained.

Card Type 6:
DENS

Format: F15
Data: DENS - Density (lb/cu.in.).

Card Type 7A: Creep Constant Inputs
CON1 NSIGN NEPSN

Format: F15,I5,I5
Data: CON1 - Constant
NSIGN - Number of sigma values (max of 50)
NEPSN - Number of epsilon values (max of 50)

Card Type 7B: [1 + (NSIGN-1)/5 cards required]
SIGTB1 SIGTB2 SIGTB3 SIGTB4 SIGTB5

Format: 5F15
Data: SIGTBi - Sigma values (psi).

Card Type 7C: [1 + (NSIGN*NEPSN-1)/5 cards required]
PT(1,1) PT(2,1) PT(3,1) PT4(4,1) PT5(5,1)

Format: 5F15
Data: PTi - Creep parameter value, PT(i,j), i = 1,NEPSN, j = 1,NSIGN

Card Type 7D: [1 + (NEPSN-1)/5 cards required]
EPSTB1 EPSTB2 EPSTB3 EPSTB4 EPSTB5

Format: 5F15
Data: EPSTBi - Epsilon values (in./in.).

Card Type 8A: Stress Rupture Inputs
CON2 NRUPN

Format: F15,I5
Data: CON2 - Constant
NRUPN - Number of stress rupture values (max of 50).

Card Type 8B: [1 + (NRUPN-1)/5 cards required]
SRUPT1 SRUPT2 SRUPT3 SRUPT4 SRUPT5

Format: 5F15
Data: SRUPTi - Stress values (psi).

Card Type 8C: [1 + (NRUPN-1)/5 cards required]
PRUPT1 PRUPT2 PRUPT3 PRUPT4 PRUPT5

Format: 5F15
Data: PRUPTi - Stress rupture parameter values.

4.1.4 Block 0016 - Cycle Definition

Card Type 1:
BLOCK 16 STEADY STATE

Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2:
KARDS

Format: I5

Data: KARDS - Cycle type indicator. Use 0 for T/STAEBL. This will activate steady-state analysis based on boundary conditions at the power condition to be specified on the left boxes of card type 3.

Card Type 3: Intervals
HGAS_L HGAS_R TGAS_L TGAS_R ETA_FL ETA_FR HCPF_L HCPF_R TCPF_L TCPF_R
(All this data on one card image)

Format: 10X,10I5,F10

Data:
- HGAS_L - Hgas power condition for the left
- HGAS_R - Hgas power condition for the right
- TGAS_L - Tgas power condition for the left
- TGAS_R - Tgas power condition for the right
- ETA_FL - ETA film power condition for the left
- ETA_FR - ETA film power condition for the right
- HCPF_L - Hcool, Hped, Hfh power condition for the left
- HCPF_R - Hcool, Hped, Hfh power condition for the right
- TCPF_L - Tcool, Tped, Tfh power condition for the left
- TCPF_R - Tcool, Tped, Tfh power condition for the right

Note: Power conditions listed here should be 1 for both left and right.

4.1.5 Block 0017 – Row and Column Breakup

This data block is a subsequent instruction from the course breakup defined in Block 0512. The points identified in Block 0512 denote regions which are then divided further into smaller elements that are described by the number of rows and columns in each region. A region with 1 row and 1 column can exist.

Card Type 1:
BLOCK 17 BLADE BREAKUP

Format: A80

Data: A descriptive comment to aid file editing.

Card Type 2:
NROWCO

Format: I5

Data: NROWCO - The number of row and column pairs (max of 100).
Breakup pairs are listed in the following order:
Pressure side (leading edge to trailing edge)
Suction side (leading edge to trailing edge)
Leading edge
Ribs (leading edge to trailing edge)
Pedestals (leading edge to trailing edge).

Card Type 3:
ROW1 COL1 ROW2 COL2 ROW3 COL3 ROW4 COL4

Format: 16I5

Data:
- ROWi - Number of rows for pair i
- COLi - Number of columns for pair i.

4.1.6 Block 0022 - Creep Inputs

This data block transmits the creep inputs for the T/STAEBL analysis. A data block is required for each cross section. In order to reduce analysis time, the total creep time should be 10 hours. The optimization uses "% life used in 10 hours." These cards are not used for vanes, but the files must exist for the system to work. Files with blank cards can be used.

Card Type 1:
BLOCK 22 CREEP, SECTION 5

Format: A80

Data: A descriptive comment to aid file editing.

Card Type 2:
TCREEP NJPTS NUMFP NTDS NTDS2 NTMAX NPRINT DELTA DT CRTOL INDCYL

Format: F10,6I5,3F10,I5

Data:

TCREEP	-	Total creep time (hrs)
NJPTS	-	Number of elements whose stress/strain will be reviewed (max of 50)
NUMFP	-	Number of intermediate creep printout times during the total creep time (max of 50). Does include TCREEP.
NTDS	-	Number of temperature distributions for transient stress analysis (max of 50).
NTDS2	-	Number of temperature distributions for post–creep low cycle fatigue (LCF) analysis (max of 50). Input a –1 to reuse the same temperature blocks.
NTMAX	-	Maximum number of iterations (default of 40)
NPRINT	-	Extra printout request (set to 0)
DELTA	-	Convergence tolerance (default = 0.01)
DT	-	First time step for starting creep calculation (default = 0.01) (hrs)
CRTOL	-	Tolerance on creep step calculation (default = 0.0001)
INDCYL	-	Cycle indicator: 0 = Creep.

Card Type 3: (Required if NJPTS on previous card > 0).
JP1 JP2 JP3 JP4 ...

Format: 16I5

Data: JPi - Element numbers whose stress/strain results are to be reviewed.

Note: The elements listed on this card are those to be reviewed during both elastic/plastic and creep analyses.

Card Type 4: Creep Printout Times (Omit if NUMFP = 0).
PRINT1 PRINT2 PRINT3 ...

Format: 8F10

Data: PRINTi - Intermediate full printout creep times desired (hrs).

Card Type 5: Pull & Moments (NTDS cards required)
ANO AMX AMY

Format: 3F10

Data:

ANO	-	Net pull for temperature distribution (lbf)
AMX	-	X moment for temperature distribution (in–lbf)
AMY	-	Y moment for temperature distribution (in–lbf).

4.1.7 Block 0023 – Film Hole Geometry

This set of files describes the film hole geometries. A file is required for each blade section.

Card Type 1:
BLOCK 23 FILM HOLE GEOMETRY, SECTION 5
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2: Film Hole Limits
NFH ROTFH
Format: I5,F10
Data:
- NFH - Number of film holes (max of 100)
- ROTFH - Rotation angle for this set of film holes (°F)
  Positive: film holes were rotated clockwise
  Negative: film holes were rotated counterclockwise.

Card Type 3: Film Hole Geometry (NFH cards required)
X1 Y1 X2 Y2 DIAM HPERIN FANGLE
Format: 7F10
Data:
- X1 - X coordinate of a film hole end centerline
- Y1 - Y coordinate of same film hole end centerline
- X2 - X coordinate of other film hole end centerline
- Y2 - Y coordinate of other film hole end centerline
- DIAM - Diameter of the film hole (in.)
- HPERIN - Number of film holes per inch of depth
- FANGLE - Angle of the film hole (degrees).

Note: The order of these cards should be consistent with the order of the boundary condition cards in Blocks 0031 and 0032.

Card Type 4: Cut Element Limits (NFH sets of card types 4 and 5 required)
NHF
Format: I10
Data:
- NHF - Number of cut elements for this film hole.

Card Type 5: Cut Element Geometry (NHF cards required for each set of cards 4 and 5)
ICUT FHA FHL
Format: I10,2F10
Data:
- ICUT - Surface element number that has been cut
- FHA - Surface area of film hole in element
- FHL - Conduction length of film hole to element center (cannot be zero).

4.1.8 Blocks 0024 through 0026 – HGAS, TGAS, and ETA FILM

These blocks have identical formats. A file is required for each airfoil cross-section.

Card Type 1:
BLOCK 24 E3 36K FLT ENG BLADE 1/4 TIP TE

Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2:
IFOR IREF TBASE PBASE

Format: 2I5,2F10
Data:
- IFOR - Describe the type of format for all gas heat transfer coefficients (pressure side and suction side)
  1 - curve of S vs HGAS, TGAS, or ETA Film
- IREF - Element number for reference coolant temperature (use for Block 26 only)
- TBASE - Input relative total temperature (°F) (use for Blocks 24 and 25 only)
- PBASE - Inlet relative total pressure (psia) (Block 24 only).

Card Type 3: Curve Boundary Condition Limits (only for IFOR = 1)
NPS NSS

Format: 2I5
Data:
- NPS - Number of pressure side S vs HGAS, TGAS or ETA film entries (max of 125)
- NSS - Number of suction side S vs HGAS, TGAS or ETA film entries (max of 125).

Card Type 4: HGAS, TGAS, or ETA Film Curve (only for IFOR = 1)
S DATA

Format: 2F10
Data:
- S - Surface length (in.) along the external curve measured from the stagnation point (S = 0.)
- DATA - HGAS (btu/hr ft^2 °F), TGAS (°F) or ETA film.

Note: Input all pressure side values first followed by suction side values second.

4.1.9 Blocks 0027 and 0028 – HCOOLANT and TCOOLANT

These blocks have identical formats. A file is required for each airfoil cross–section.

Card Type 1:
BLOCK 27 SLTO H-COOL
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2:
NCAV IFOR1 IFOR2 IFOR3 IFOR4 ...
Format: 12I5
Data: NCAV – Number of coolant cavities (does not include film holes or pedestals)
IFORi – Format type for cavity i Hcoolant or Tcoolant input:
2 – element by element.

Card Type 3: Element by Element Limits (only for IFOR = 2)
NELE
Format: I5
Data: NELE – Number of elements for element by element input on the entire cavity surface including pressure side and suction side (max of 500).

Card Type 4: HCOOLANT or TCOOLANT Values by Element [(NELE–1)/8 + 1 cards required)
DATA1 DATA2 DATA3 ...
Format: 8F10
Data: DATAi – HCOOLANT (btu/hr ft^2 °F) or TCOOLANT (°F) for surface element number i.

Note: Values are input in order of surface numbering beginning with the first external surface element.

4.1.10 Blocks 0029 and 0030 – HPEDESTAL and TPEDESTAL

These blocks have identical formats. A file is required for each airfoil cross–section.

Card Type 1:
BLOCK 29 PEDESTALS H–PED
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2: HPEDESTAL or TPEDESTAL Format
NPED IFOR
Format: 2I5
Data: NPED – Number of pedestals with associated boundary conditions (max of 15)
IFOR – Format type for Hcoolant or Tcoolant
2 – element by element.

Note: NPED of the following card sets are required.

Card Type 3: Element by Element Limits (only for IFOR = 2)

NELE

Format: I5

Data: NELE – Number of elements for element by element input for this pedestal (max of 150).

Card Type 4: HPEDESTAL or TPEDESTAL Values by Element [(NELE–1)/8 + 1 cards required] (only for IFOR = 2)

DATA1 DATA2 DATA3 ...

Format: 8F10

Data: DATAi – HPEDESTAL (btu/hr ft^2 °F) or TPEDESTAL (°F) for surface element number i.

Note: Values are input in order of surface numbering beginning with the first pedestal element.

4.1.11 Blocks 0031 and 0032 – HFILMHOLE and TFILMHOLE

These blocks have identical formats. A file is required for each airfoil cross-section.

Card Type 1:

BLOCK 31 SLTO H-FILE HOLE

Format: A80

Data: A descriptive comment to aid file editing.

Card Type 2: HFILMHOLE or TFILMHOLE Format

NFILM IFOR

Format: 2I5

Data: NFILM – Number of film holes with associated boundary conditions (max of 100)

IFOR – Format type for HFILMHOLE or TFILMHOLE:
4 – linear fit.

Note: NFILM sets of the following cards must be included.

Card Type 3: Linear Fit Film Hole (only for IFOR = 4)

NVAL HFHVAL1 HFHVAL2 HFHVAL3 ...

Format: I5,5X,7F10

Data: NVAL – Number of values for the linear fit (max of 7). At least 2 points are required.
2 – linear from the first intersection to the last intersection point
3 – linear fit from the first intersection point to mid-point, mid-point to the last intersection point.

HFHVALi – HFILMHOLE (btu/hr ft^2 °F) or TFILMHOLE (°F), value i.

Note: Film hole order should be consistent with Block 23. Values should be input from the first intersection point with the airfoil surface to the last intersection point with the airfoil surface in the order that the (X,Y) defining points were input.

4.1.12 Block 0037 – Pedestal Geometry

A file is required for each airfoil cross-section.

Card Type 1:
BLOCK 37 PEDESTAL GEOMETRY
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2: Pedestal Limit
NPED
Format: I5
Data: NPED - Number of pedestals (max of 15).

Card Type 3: Pedestal Geometry (NPED cards required)
IP1LOC IP2LOC IP3LOC IP4LOC PEDCVF PEDCDF PEDCYA PEDNPI PEDDIA NTER
Format: 4I5,5F10,I10
Data:
- IP1LOC - Lower left point number of pedestal on a curve
- IP2LOC - Lower right point number of pedestal on a curve
- IP3LOC - Upper left point number of pedestal on a curve
- IP4LOC - Upper right point number of pedestal on a curve
- PEDCVF - Convection factor. PEDCVF = 1.0 – PEDCDF
- PEDCDF - Conduction factor
  PEDCDF = pedestal area / rectangular area
  PEDCDF = (n * pi/4 * d**2) / (w * d)
- PEDCYA - Cylindrical surface area of one pedestal
- PEDNPI - Number of pedestals per inch
- PEDDIA - Pedestal diameter
- NTER - Number of tiers.

Note: Use Block 0001 to reference curves.

4.1.13 Block 0093 – External PS/PT

A file is required for each airfoil cross-section. This information duplicates similar data in Blocks 0101 and 0102. The data here is used as boundary conditions for the three-dimensional finite analysis.

Card Type 1:
BLOCK 93 EXTERNAL PS/PT Q-TIP E3 1B
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2: Number of Entries
NPS NSS OFFSET
Format: 2I5,F10
Data:
- NPS - Number of pressure side S vs Ps/Pt entries (max of 50)
- NSS - Number of suction side S vs Ps/Pt entries (max of 50)
- OFFSET - Mean camber line offset from the stagnation point.

Card Type 3: Pressure Ratio (NPS + NSS cards required)
S PSPT

Format: 2F10

Data: S - Surface length (in.) measured from the leading edge reference point

PSPT - Ps/Pt at the value of S.

Note: Input pressure side values, then suction side values.

4.1.14 Block 0095 – External P-TOTAL

Card Type 1:
BLOCK 95 EXTERNAL INLET PT PROFILE

Format: A80

Data: A descriptive comment to aid file editing.

Card Type 2: Number of Points
NPTTOT

Format: I5

Data: NPTTOT - Number of points (max of 50).

Card Type 3: External Total Pressure (NPTTOT cards)
RADPT PTTOT

Format: 2F10

Data: RADPT - Radius (in.) of external total pressure data

PTTOT - External total pressure (lb./in. sq.).

Note: Input the external total pressure distribution as a function of radius.

4.1.15 Block 0096 – Internal P-TOTAL

Card Type 1:
BLOCK 96 INTERNAL PT - BASED ON CAVITY 3

Format: A80

Data: A descriptive comment to aid file editing.

Card Type 2: Number of Points
NPTTOT

Format: I5

Data: NPTTOT - Number of points (max of 50).

Card Type 3: Internal Total Pressure (NPTTOT cards)
RADPT PTTOT

Format: 2F10

Data: RADPT - Radius (in.) of internal total pressure

PTTOT - Internal total pressure (lb./in. sq.).

4.1.16 Block 0097 – External T-TOTAL

Card Type 1:
BLOCK 97 EXTERNAL INLET TT PROFILE
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2: Number of Points
NPTTOT
Format: I5
Data: NPTTOT - Number of points (max of 50).

Card Type 3: External Total Temperature (NPTTOT cards)
RADPT PTTOT
Format: 2F10
Data: RADPT - Radius (in.) of external temperature data
PTTOT - External total temperature (°F).

4.1.17 Block 0099 – Internal Cooling 1DHT Reference Data

Card Type 1:
BLOCK 99 1-D HT REF DATA (SPREAD OF FILM COOLING)
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2: Radius Data
RROOT RTIP
Format: 2F10
Data: RROOT - Root radius (in.)
RTIP - Tip radius (in.).

Card Type 3: Span Locations
ETAMIN ETAMAX
Format: 2F10
Data: ETAMIN - Minimum span fraction where ETA film is to be applied
ETAMAX - Maximum span fraction where ETA film is to be applied.

4.1.18 Blocks 0101 and 0102 – Pressure Side and Suction Side Boundary Layer Data

These blocks have identical formats. A file is required for each airfoil cross-section.

Card Type 1:
BLOCK 101 PRESSURE SIDE BOUNDARY LAYER DATA
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2: Control Items
TITLE IRC INPD
Format: A70,I2,I8
Data: TITLE - Case description
IRC - Radius of curvature control indicator:
1 – Program expects local radius of curvature
INPD - Transition point location indicator:
0 – Finds its own transition point
1 – Forces the transition point to be located at STR.

Card Type 3: Options
DIST LONI DELTS SANHT NGAS
Format: F10,I1,19X,F10,20X,F10,I1
Data: DIST - Turbulence level (normally 0.10)
LONI - Boundary layer laminar wall surface temperature:
0 – Temperature in °F
1 – Temperature in °R
DELTS - Stagnation point offset to be added to input values of S, STR, and SHF
SANHT - Roughness height (micro in.). If left blank, a smooth surface is assumed.
NGAS - Type of gas:
0 – Products of combustion (default)
3 – Air.

Card Type 4: Inlet Variables
VREL RLE PTOTAL TTOTAL STR
Format: 4F10,20X,F10
Data: VREL - Approach velocity relative to airfoil (ft/sec)
RLE - Airfoil leading edge radius (in.)
PTOTAL - Free stream total pressure relative to airfoil (psia)
TTOTAL - Free stream total temperature relative to airfoil (°F)
STR - Distance along surface from stagnation point to desired transition point (in.); for INPD = 1 only (card 2).

Card Type 5: Leading Edge and Unsteady Variables
MTRAN IUSTDY SS PPSPT
Format: I3,I7,2F10
Data: MTRAN - Transition flow option (usually 3)
IUSTDY - Unsteady effects option (always 0)
SS - Second point opposite side S distance
PPSPT - Second point opposite side Ps/Pt.

Card Type 6:
S PSPTOR TWALL RAD RADJ

Format: 3F10,20X,2F10

Data:
- S - Distance along surface (in.)
- PSPTOR - Ratio of static to total pressure
- TWALL - Wall surface temperature (°F). If the first input temperature is nonzero but the second and third are zero, then a constant wall temperature calculation will be performed. If the first input temperature is less than -500, an adiabatic wall calculation will be performed.
- RAD - Radius of axisymmetric body in arbitrary units. May be left blank for a two-dimensional case.
- RADJ - Longitudinal radius of curvature, positive for suction side. May be left blank for negligible curvature.

Note: A maximum of 200 cards of this type may be input. The input stream is terminated by inserting a blank card.

Card Type 6A: End of File Indicator
A blank card is required to signal the end of the Type 6 inputs.

4.1.19 Block 0104 – Film Effectiveness

A file is required for each airfoil cross-section.

Card Type 1:
BLOCK 104 FILM EFFECTIVNESS INPUTS

Format: A80

Data: A descriptive comment to aid file editing.

Card Type 2: General Information
FOIL I2FOIL WAE ISHD ISHR

Format: A1,5X,I5,F10,2I5

Data:
- FOIL - Type of airfoil:
  B = blade
  V = vane
- I2FOIL - Number of airfoils
- WAE - Engine flow rate (lb/sec)
- ISHD - Showerhead area indicator:
  0 - S/H over entire airfoil
- ISHR - Showerhead option:
  0 – No showerhead
  1 – Showerhead.

Card Type 2A: Aero Information

XMACH WMAIN CAERO GAERO GAMMA TCREF TCAERO TGAERO

Format: 8F10

Data:
- XMACH - Free stream inlet relative Mach number
- WMAIN - Mainstream flow rate (lb/sec)
- CAERO - Specific heat ratio of coolant
- GAERO - Specific heat ratio of primary air
- GAMMA - Specific heat ratio of gas
- TCREF - Reference coolant temperature
- TCAERO - Coolant source total temperature (°F)
- TGAERO - Relative gas total temperature (°F).

Card Type 3: Film Groups

NPS NSS

Format: 2I5

Data:
- NPS - Number of pressure side film groups
- NSS - Number of suction side film groups.

Card Type 4: Film Group Description

SURF NROW ICURVE IHEAT

Format: A1,4X,3I5

Data:
- SURF - Airfoil surface ("P" or "S") of film group
- NROW - Number of rows in film group
- ICURVE - Film correlation curve number (all options lead to the same result)
- IHEAT - HG augmentation: a 0, indicating full coverage, is recommended.

Card Type 5: Hole Description

SLOC WC TCA DIA ANGL XPITCH ANG2 SPAN

Format: 8F10

Data:
- SLOC - S location of film row (in.)
- WC - Cooling air flow (lb/s)
- TCA - Cooling air temperature (°F)
- DIA - Film hole diameter (in.)
- ANGL - In-plane hole angle (degrees)
- XPITCH - Hole to hole pitch (in.)
- ANG2 - Spanwise hole angle (degrees)
- SPAN - Span associated with WC (in.).

4.1.20 Block 0400 - Base Inputs for Conduction and Network Analyses

A file is required for each airfoil cross-section.

Card Type 1:

BLOCK 400 QUARTER-TIP HEAT TRANSFER INFO

Format: A80

Data: A descriptive comment to aid file editing.

Card Type 2A: Paths (see Figure 1)
PATH1 PATH2 PATH3 ...

Format: 14I5

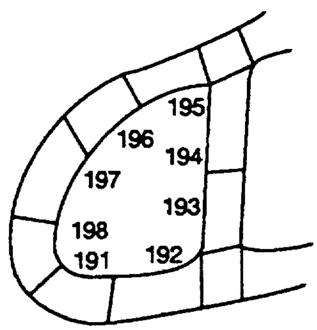
Data: PATHi - Paths which require revision of 1D information.

Note: Card types 2A and 2B are used together. 2A identifies the paths (max = 14/card), followed by 2B which identifies the segment and elements (max = 12/card, 60/section). Twenty repetitions of 2B may occur per path card 2A. The sequence ends with a blank card.

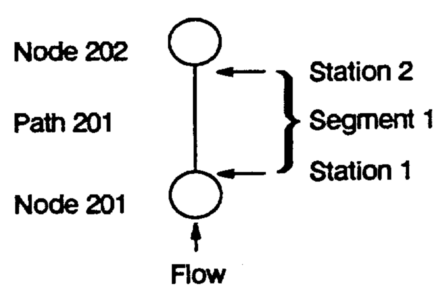
Cards 2A and 2B are instructions for updating 1-D heat transfer cards in Network Analysis (Block 401).

- Updating information is to come from Section 2 of a completed thermal analysis.
  Thus, instructions are in Block b0400.2

- Break-up model for Section 2 shows surface elements.



- Network model of Path 201



- Corresponding Block 400 cards.

b0400.2			(Filename)
Block 400	Section 2	Title Card	(Title card)
201			(Path number)
1	191-198		(Segment, then elements)

Figure 1. Interpretation of Block 400, Cards 2A and 2B

Card Type 2B: Segment/Elements (see Figure 1)

NSEC NODEID1 NODEID2 NODEID3 . . .

Format: 5X,13I5

Data:
- NSEC - Path segment number
- NODEIDi - Internal surface element (max = 12/card, 60/section). A negative element number will include all elements between element (i-1) and ABS (element (i)).

Note: This card identifies the path segment number(s) (max = 20/card type 2A) and the elements which bound path and section. List all element surfaces so that total Q can be calculated. Input only as many cards as required.

Card Type 2C: Insert a blank card here.

Card Type 3A: Node Information (see Figure 2)

NODE PTH1 X1 SC1 PTH2 X2 SC2 XHF1 XHR1 XTR1 XHF2 XHR2 XTR2

Format: 2I5,A1,I4,I5,A1,I4,6F5

Data:
- NODE - Internal surface element number
- PTH1 - Path number for network analysis output to be applied to element
- X1 - Heat transfer coefficient indicator (TRP and CFI only):
  - R - Use rough (or stagnation)
  - S - Use smooth (or channel)
  - blank - Use average Hcoolant output supplied by network analysis
- SC1 - Network analysis segment number
- PTH2 - Segment path number (optional)
- X2 - Segment H. T. coefficient indicator (optional)
- SC2 - Second segment number (optional)
- XHF1 - H. T. coefficient option
- XHR1 - H. T. coefficient option
- XTR1 - H. T. coefficient option
- XHF2 - H. T. coefficient option
- XHR2 - H. T. coefficient option
- XTR2 - H. T. coefficient option.

Notes: 1) Follow this group of cards with a blank card.

2) The options for inputs on this card give the following:

1) IF: (XHF1 = 0. AND XHR1 = 0.)
   THEN: HOUT1 = H
2) IF: (XHF1 > 0. AND XHR1 = 0.)
   THEN: HOUT1 = XHF1 * H
3) IF: (XHF1 < 0. AND XHR1 = 0.)
   THEN: HOUT1 = ABS(XHF1) * H / (HT factor)
4) IF: (XHF1 = 0. AND XHR1 > 0.)
   THEN: HOUT1 = XHR1 * (H rough - H smooth) + H smooth
5) IF: (XHF1 > 0. AND XHR1 > 0.)
   THEN: HOUT1 = XHR1 * (H rough - XHF1 * H smooth) + XHF1 * H smooth
6) IF: (XHF1 < 0. AND XHR1 > 0.)
   THEN: HOUT1 = (XHR1 * (Hrough - ABS(XHF1) * Hsmooth)
   + ABS(XHF1) * Hsmooth) / (HT factor)

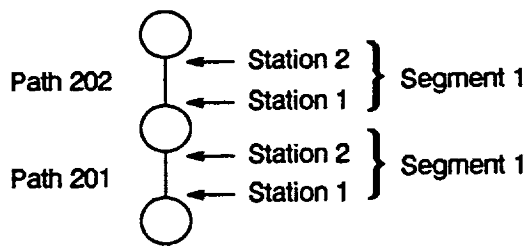
Card Type 3A (continued):

Notes:

7) IF: (XTR1 > 0.)
   THEN: TOUT1 = XTR1 * (Tcout - Tcin) + Tcin
8) If path #1 and path #2 are input, THEN:
   HOUT = (HOUT1 + HOUT2) / 2 and
   TOUT = (TOUT1 + TOUT2) /2

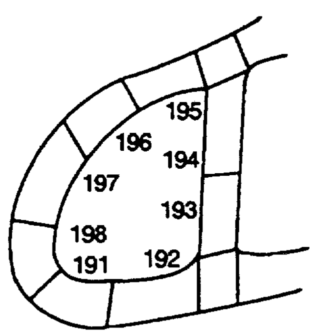
Card type 3 provides instructions for updating internal boundary conditions in Blocks 27 through 30.

- Updating information goes to Section 2. Thus, instructions are in Block b0400.2
- Network model



Note: Trip strip paths include smooth and rough wall info.

- Break-up model for Section 2



- Corresponding Card Type 3A

191 201S 1 2025 1 0.0 0.0 0.0 0.0 0.0 0.0

- 191 — Element number
- 201 — First path
- S — Smooth wall h
- 1 — Segment 1
- 0.0 0.0 0.0 0.0 0.0 0.0 — These instruct the processor to use average values from Path 201 - Segment 1 and Path 202 - Segment 1

Figure 2. Interpretation of Block 400, Card Type 3A

Card Type 3B: Insert a blank card here.

Card Type 4A: Internal and External Nodes
NID NOD
Format: 2I5
Data: NID - Internal surface element number
NOD - External surface element number.

Notes: 1) These surface element numbers are used as the source for Tgas, ETA film and Hgas values.
2) Use as many cards as needed. End with a blank card.
3) A value of -1 for NID will direct the program to determine NOD for each NID by calculating the direction of maximum Q flux from each internal surface element.

Card Type 4B: Insert a blank card here.

Card Type 5A: Film Hole Path
NHOLE NODF NPTHH
Format: 3I5
Data: NHOLE - Film hole number (must agree with Block 23 data)
NODF - External surface element for 1-D heat transfer calculation
NPTHH - Internal cooling path number.

Card Type 5B: Future Data
NPTHH
Format: 10X,14I5
Data: NPTHH - Internal cooling path number.

Note: One set of cards 5A and 5B is required for each cooling hole.

4.1.21 Block 0401 - Network Analysis Input File

Card Type 1:
BLOCK 401 E3 FIRST BLADE MODEL
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2: Global Indicators
RPM
Format: F10
Data: RPM - Rotational speed (rpm).

Card Type 3: Material Code Indicator

MATL	MATCOD		
Format:	A4,6X,A8		
Data:	MATL	-	Card title, must be "MATL"
	MATCOD	-	Material code, must be consistent with Block 12 data (i.e., METAL1).

Note: Materials properties are accessed from data Block 12 which supplies the conductivity for paths using the 1DHT flow option.

Card Type 4: Reference Indicators

REFE	NFOILS PT4 WAE		
Format:	A4,6X,I5,5X,2F10		
Data:	REFE	-	Card title, must be "REFE"
	NFOILS	-	Number of airfoils
	PT4	-	Compressor discharge pressure
	WAE	-	Engine air flow.

Note: This card type is used to calculate non–dimensional flows and pressures relative to engine air flow compressor exit pressure.

Card Type 5: Debug

Note: Use of this option is not recommended – insert a blank card here.

Card Type 6: Source Node Description

NAMEN	PTN TTN RAD		
Format:	I10,3F10		
Data:	NAMEN	-	Source node number (arbitrary)
	PTN	-	Total absolute pressure at node (lb/sq.in.)
	TTN	-	Total temperature at this node (°F)
	RAD	-	Distance from axis of rotation (in.).

Note: Input one card for each source node. End with a blank card.

Card Type 7: Sink Node Description

NAMES	PSN TSN RSD		
Format:	I10,3F10		
Data:	NAMES	-	Sink node number (arbitrary)
	PSN	-	Exit static absolute pressure (lb/sq.in.)
	TSN	-	Total temperature (°F). Used only if the path reverses and this sink becomes a source.
	RSD	-	Distance from axis of rotation (in.).

Note: Input one card for each sink node. End with a blank card.

Card Type 8: Internal Node Description

NAMEI RID IBAL

Format: I10,20X,F10,I10

Data:
- NAMEI - Internal node number
- RID - Radial coordinate (in.)
- IBAL - Type of flow balance:
  0 – Program chooses.

Card Type 9: Path Header

NAMEP ITYPE NODEP1 NODEP2 IHF

Format: I5,A5,2I5,45X,I5

Data:
- NAMEP - Path number
- ITYPE - Path type:
  - CHN – Channel
  - ARL – Arbitrary loss
  - TRP – Trip strips
  - PED – Pedestals
  - BLD – Bleed
- NODEP1 - Node number at upstream end of path
- NODEP2 - Node number at downstream end of path
- IHF - One-dimensional heat flow indicator: The value of "IHF" specifies the number of cards containing 1D information that are to follow card type 10A. IHF must equal one less than the number of 10A cards.

Card Type 10A: Channel Detail

S TEMPR ARA PERIM HT WDTH DIM WPF HTF

Format: 7F10,2F5

Data:
- S - Streamline distance along path (in.). Successive values must be increasing.
- TEMPR - Wall temperature (°F). Ignore if IHF > 0.

Note: Enter only one of the following field combinations:
ARA-PERIM, HT-WDTH, OR DIM.
- ARA - Cross section area (sq.in.)
- PERIM - Perimeter (in.)
- HT - Height (in.)
- WDTH - Width (in.)
- DIM - Diameter (in.)
- WPF - Wetted perimeter factor (default = 1.0)
- HTF - Heat transfer factor (default = 1.0).

Note: Place two or more cards after card type 9 if the path type is CHN. There must be a finite S between two stations of a path.

Card Type 10C: Arbitrary Loss Detail

NSCS AKF1 AKL1 AKH1 AKAW1 AKF2 AKL2 AKH2 AKAW2 AKF3 AKL3 AKH3 AKAW3 (all this data on one card)

Format: I5,15X,12F5

Data:
- NSCS - Number of sections on this ARL path. NSCS = number of CHN cards for the path - 1.
- AKFi - Friction multiplying factor - section i
- AKLi - Velocity head loss multiplying factor - section i
  P = 1/2 Klp V*V
- AKHi - Heat transfer coefficient multiplying factor section i
- AKAWi - Wetted area multiplying factor - section i.

Note: Insert 10C-ARL card(s) followed by two or more 10A-CHN cards. Use as many cards as required for input of all path sections (blank fields are set to 1 for AKF, AKH, and AKAW, to 0 for AKL). The second card contains data for sections 4 through 7, the third for sections 8 through 11, etc.

Card Type 10D1: Trip Strip Detail

IT NSCS

Format: 2I10

Data:
- IT - Type of trip strip:
  5 - Han, Park, Ibraham correlation
- NSCS - Number of sections on this TRP path.

Note: Insert 10D1 and 10D2 type cards followed by two or more 10A-CHN cards.

Card Type 10D2: Trip Strip Detail

HITRP STTRP HCHN1 EPS HCHN2 ANGL SEG

Format: 7F10

Data:
- HITRP - Trip strip height (in.)
- STTRP - Streamline distance between consecutive strips (in.)
- HCHN1 - Channel height 1 (in.)
- EPS - Smooth/rough wall surface area ratio
- HCHN2 - Channel height 2 (in.)
- ANGL - Skewing angle (degrees)
- SEG - % of trip strip removed / 100.

Card Type 10E: Pedestal Detail

IHTSEL IFFSEL IPETYP NRWS PEDRO1 PEDDIA1 PEDRO2 PEDDIA2 ...

Format: I1,2I2,I5,14F5

Data:

IHTSEL - Heat transfer correlation selection indicator:
2 - Metzger pedestal correlation

IFFSEL - Friction factor correlation selection indicator:
0 - Metzger pedestal correlation

IPETYP - Pedestal type indicator:
0 - Staggered

NRWS - Number of rows (max = 20)

PEDROi - Number of pedestals in row i

PEDDIAi - Pedestal diameter for row i.

Notes: 1) Insert 10E-PED card(s) followed by two or more 10A-CHN cards. The 10A-CHN cards must use the height-width option and the number of 10A-CHN cards must equal NRWS + 1.

2) The first station is assumed to go through the center of the first pedestal and the last station is assumed to be unblocked.

Card Type 10F: Bleed Detail

KBTYP BLDARA DISCOF

Format: I10,2F10

Data:

KBTYP - Type of bleed:
0 - Arbitrary discharge bleed

BLDARA - Bleed area (sq. in.)

DISCOF - Discharge coefficient.

Note: This card type precedes all other bleed type inputs.

Card Type 10M: One-Dimensional Heat Flow Detail

HGASFL TGASFL THKFL AKFL AGFL AMFL FLO1 FLO2

Format: 8F10

Data:

HGASFL - External heat transfer coefficient (btu/ft^2 hr F)

TGASFL - External gas temperature (°F)

THKFL - Thickness (in.)

AKFL - Conductivity (btu-in/ft^2/hr/F). Overridden by selecting a material from Block 12.

AGFL - Gas area flag (sq. in.):
AGFL = 0, AGFL = DAW
AGFL > 0, AGFL = AGFL
AGFL < 0, AGFL = ABS(AGFL) * DAW

AMFL - Metal area flag (sq. in.):
AMFL = 0, AMFL = (AGFL + ACOOL) / 2.
AMFL > 0, AMFL = AMFL
AMFL < 0, AMFL = ABS(AMFL) * AGFL

Card Type 10M (continued):

Note: HGASFL, TGASFL, THKFL and AKFL require a nonzero value input on the first card. Subsequent zeros will assume the value on the last nonzero card.

FLO1	-	Flow information
FLO2	-	Flow information.

Note: Follow the last 10A–CHN card with N–1 (N = number of channel cards) 10M–1DHT cards. The valid path types are: CHN, ARL, TRP, PED, LEI, and CFI.

Card Type C: Comment Card
C COMMENT
Format: A1,79A1
Data: C - Comment flag, "C"
COMMENT - Any comment desired by the user.

Note: Comment cards are allowed anywhere in Block 401, except that after a path header card has been encountered, the associated card set may not have comment cards included.

4.1.22 Block 0501 – Coating Thickness

Card Type 1:
BLOCK 501 COATING THICKNESS
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2: Thickness Input
THICK
Format: F10
Data: THICK - Thickness of protective coating.

4.1.23 Block 0504 – Network Analysis Post–Processing

This file reflects a dialog required for interactive network analysis usage. As such, it is recommended that the sample provided be unchanged.

Card Type 1:
BLOCK 504 PARAMETERS FOR NETWORK POST PROCESSING
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2
1

Card Type 3: Data Block Pointer
401

Card Type 4
0 0

4.1.24 Block 0505 – Network Analysis Iteration Control

This file reflects a dialog required for interactive network analysis usage. As such, it is recommended that the sample provided be unchanged.

4.1.25 Block 0506 – Network Analysis Post-Processing Control

This file reflects a dialog required for interactive network analysis post-processing, including generation of Block 410. As such, it is recommended that the sample provided be unchanged.

4.1.26 Block 0507 – 1-D Heat Transfer Control

This file reflects a dialog required for interactive cooled blade analysis. As such, it is recommended that the sample provided be unchanged.

Card Type 1:
BLOCK 507   0   0   Heat Transfer Control
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2:   Network File Count
NNET
Format: I5
Data: NNET   –   Number of network files for heat transfer analysis.

Card Type 3:   Network Solution Files
FILE1 FILE2 FILE3 ...
Format: 9I5
Data: FILEi   –   File of network solution. Up to 9 network models are allowed.

Card Type 4:   Analysis Sections
NSEC
Format: I5
Data: NSEC   –   Number of cross-sections to be analyzed.

Card Type 5:   Sections Used
NS1 NS2 NS3 ...
Format: 9I5
Data: NSi   –   Sections used in heat transfer analysis.

4.1.27 Block 0512 – Flag Point Definition

A file is required for each airfoil cross-section.

Card Type 1:
BLOCK 512 FLAG POINT DEFINITION
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2: Flag Point Count
NFLAG
Format: I5
Data: NFLAG – Number of flag points per set on cross-section.

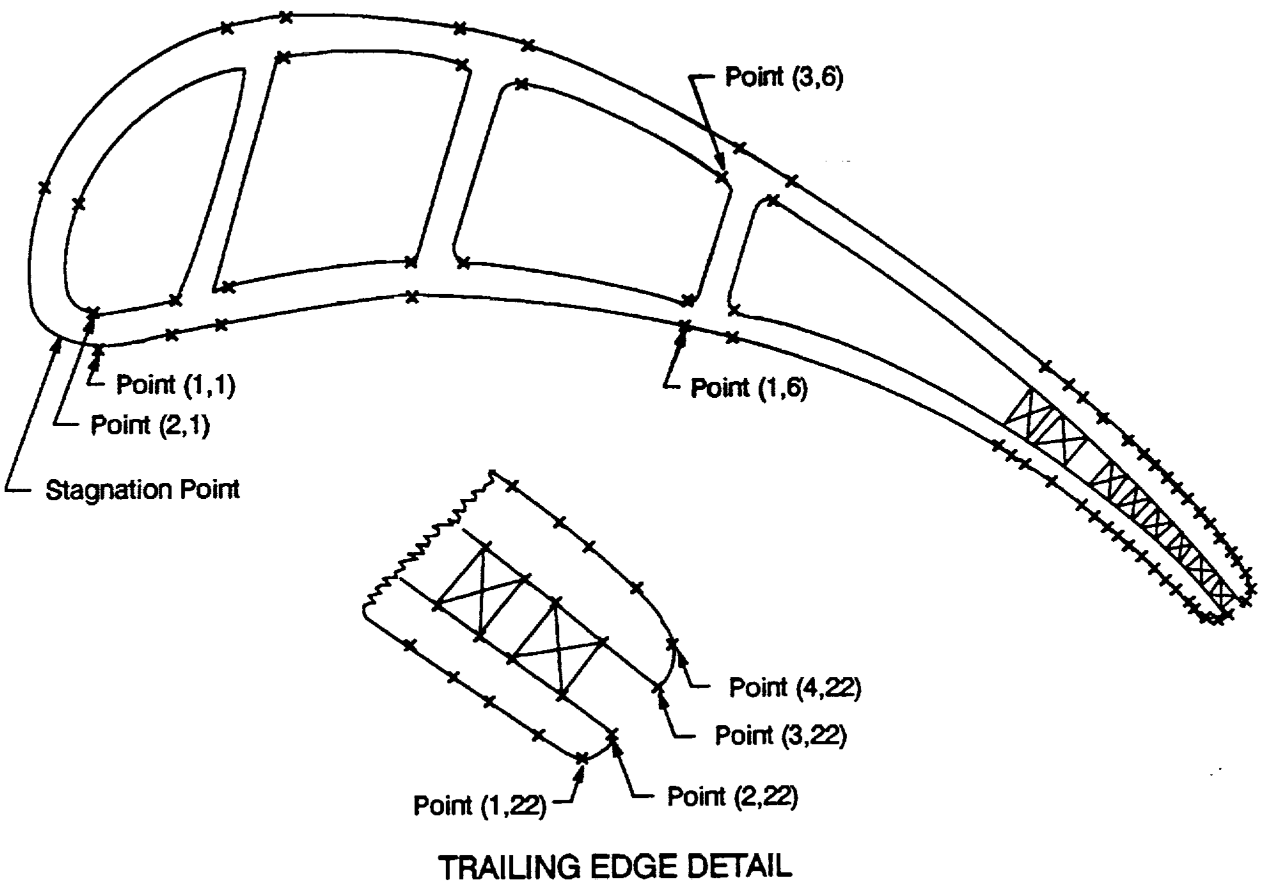
Card Type 3: Flag Point Coordinates
XFLAG YFLAG SFLAG
Format: 3F10
Data: XFLAG – X coordinate of flag point, in.
YFLAG – Y coordinate of flag point, in.
SFLAG – Arc length, S, leading edge to flag point, in.

Note: Flag points define the corners of mesh sections, or "Superblocks." Four sets of coordinates are required:

1 – Pressure side exterior flag points
2 – Pressure side core flag points
3 – Suction side core flag points
4 – Suction side exterior flag points.

Thus, 4 * NFLAG card 3's are required. The flag points are a subset of the coordinates of Block 1, and are selected for their locations, as shown in Figure 3. Generally, each cavity will be described by four corner flag points. Similarly, four flag points define each pedestal. The trailing edge, due to its open geometry, is defined with four flag points.

SFLAG can be approximate when starting.



- User selects flag points for Block 512
- Block 512 s distances can be approximate
- Four sets in the sequence:
  - Pressure side external
  - Pressure side internal
  - Suction side internal
  - Suction side external
- Flag points must exist as Block 1 coordinates

Figure 3. Flag Point Selection

4.1.28 Block 0513 – Global Section Radii

Card Type 1:
BLOCK 513 GLOBAL SECTION RADII
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2: Section Count
NSECT
Format: I5
Data: NSECT – Number of cross-sections used for blade representation. "5" is recommended.

Card Type 3: Root Radius
RROOT
Format: F10
Data: RROOT – Radius of airfoil root section, in.

Card Type 4: Tip Radius
RTIP TCAP
Format: F10,20X,F10
Data: RTIP – Radius of airfoil tip section, in.
TCAP – Thickness of airfoil tip cap, in.

Card Type 5: Section Radii – NSECT cards required, from root to tip.
RSECT NSEC AMASS
Format: F10,I5,15X,F10
Data: RSECT – Radius of airfoil section, in.
NSEC – Section number
AMASS – Mass multiplying factor to give correct pull for creep analysis. This factor accounts for the otherwise neglected added masses of pedestals and trip strips.

4.1.29 Block 0514 – Network to Section/Cavity Cross–Section Reference Table

This data block provides the necessary cross–reference between the planar orientation of the network analysis (Block 401), and the cross–section representation of the film analysis (Block 104).

Card Type 1:
BLOCK 514 NETWORK TO SECTION/CAVITY CROSS SECTION REFERENCE TABLE
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2: Column Header
This card is not read; it serves as an aid to file construction. Please leave as given in the examples.

Card Type 3: Cross-Reference Table - One card needed for each path detailed in Block 401 (see Figures 4 and 5).

PATH TYPE SECI CAVI SELO CAVO FHR NHLS

Format: I5,A5,2I5,5X,4I5

Data:

	PATH	-	Path number (see card type 9, Block 401)
	TYPE	-	Path type (see card type 9, Block 401)
	SECI	-	Cross-section associated with path first station
	CAVI	-	Cavity associated with path first station
	SELO	-	Cross-section associated with path last station
	CAVO	-	Cavity associated with path last station
	FHR	-	Film hole row number as in Block 104
	NHLS	-	Number of holes associated with this path.

Note: All film holes are assumed to be applied at one section which is indicated by SECT1.

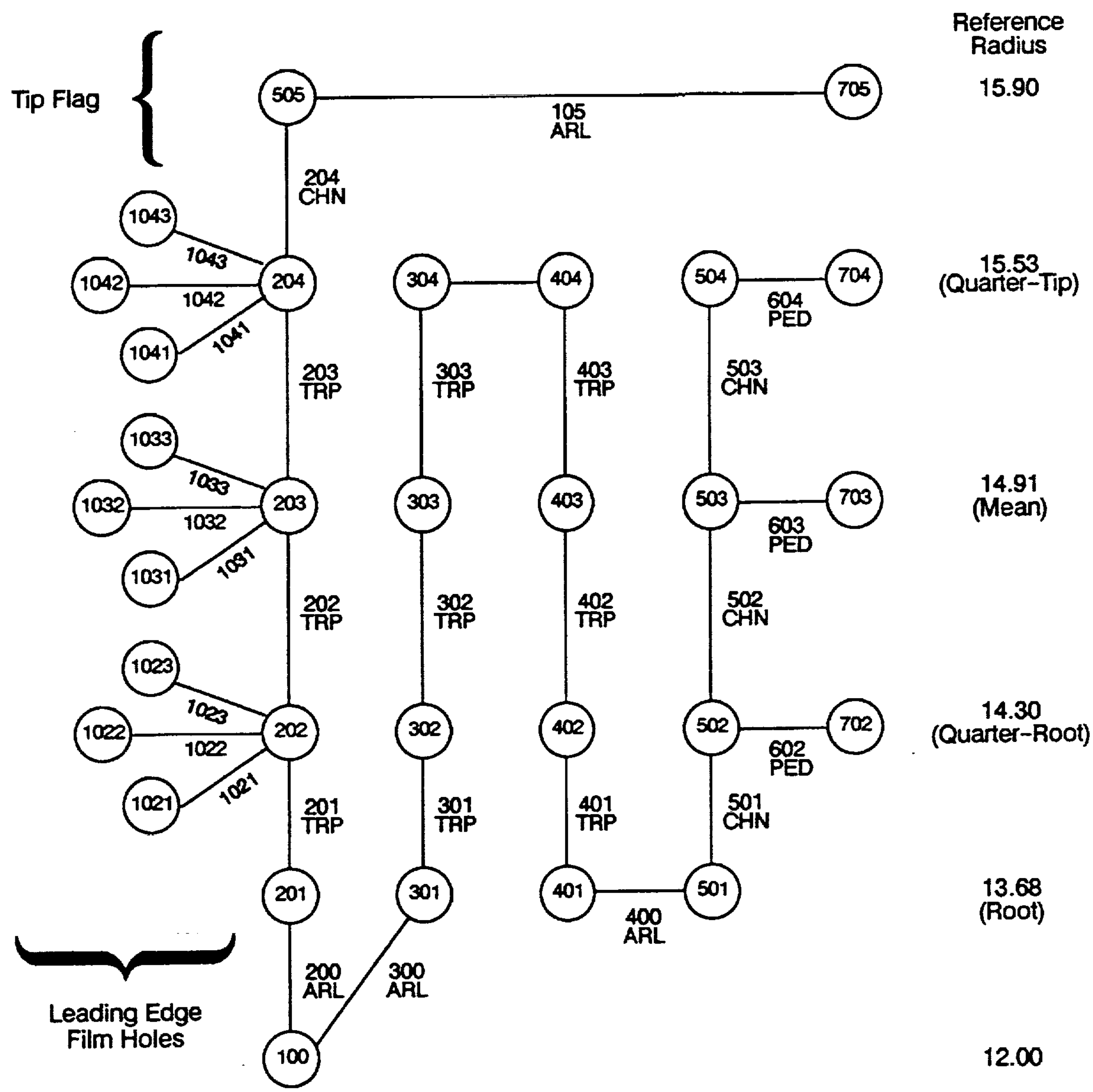
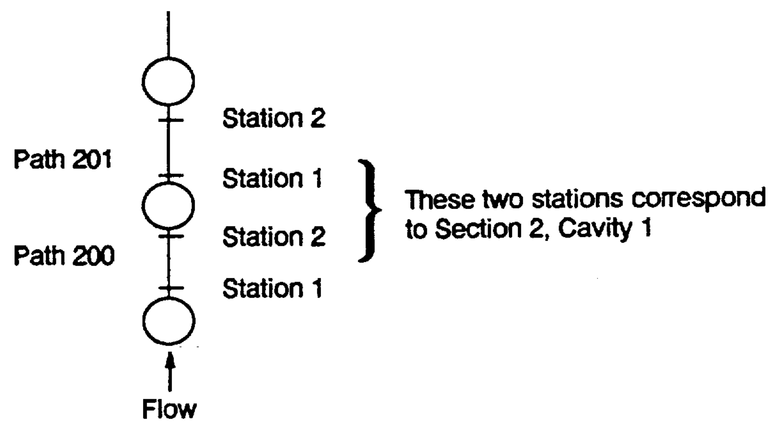


Figure 4. Network Node-Path Map

This block is used by v541b to build areas and perimeters for the network.

- Network model



- Corresponding Block 514

BLOCK 514								(Title Card)
PATH	TYPE	SECI	CAVI	SELO	CAVO	FHR	NHLS	(Label Card)
200	ARL	0	0	1	1			
201	TRP	1	1	2	1			
. . .								
1021	ARL	2				1	4	

(Film hole 1021 corresponds to Block 23 film hole details, but there are four holes modeled by this path.)

Figure 5. Interpretation of Block 514

4.1.30 Block 0520 – Oxidation Life Parameters

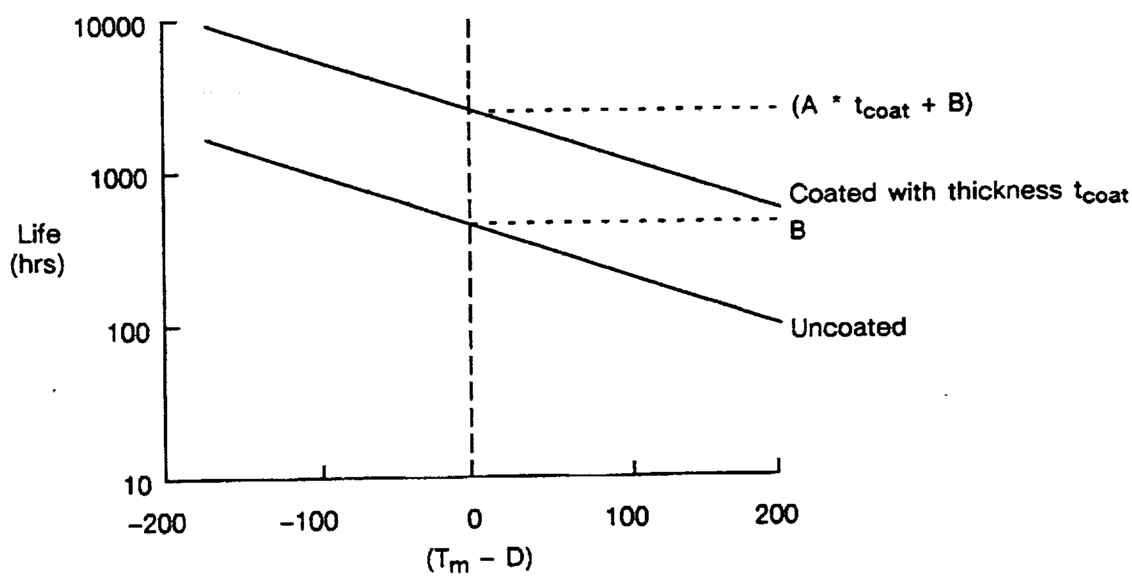
This data block is required for vanes. A blank card set may be used for blades.

Card Type 1:
BLOCK 520 OXIDATION LIFE PARAMETERS
Format: A80
Data: A descriptive comment to aid file editing.

Card Type 2: Parameters
A B C D
Format: 4F10
Data: A, B, C, and D are parameters used in the prediction of oxidation life. The equation form for oxidation life is:

$$Life(hrs) = [A * t_{coat} + B]\ e^{-c(T_m - D)}$$

where T_m is the maximum metal temperature, and t_{coat} is the coating thickness.
D represents a reference temperature associated with the empirical data.
C represents the slope of the life versus temperature curve.
B represents the life of the uncoated vane when T_m = D.
A is used to determine the life of the coated vane.



5. VIBRATION ANALYSIS INPUTS

T/STAEBL includes a finite element analysis that has both static and modal analysis capabilities to perform the vibrations analysis of a rotating airfoil. The finite element code has an element library that includes spring, beam, and shell (both triangular and quadrilateral) elements. To model the hollow cooled airfoils applicable to T/STAEBL, beam elements are utilized in the airfoil neck. Quadrilateral plate elements are used to model both walls of the cooled airfoil, as well as modelling the ribs that tie the walls together. Trailing edge pedestals are modelled using links to tie the offset airfoil walls.

The T/STAEBL finite element analysis is similar to the one utilized by the STAT propfan optimization package (Reference 3). As such, it has extensive capabilities, including nonlinear static analysis, as well as rotating blade eigenvalue analysis. For the present application, however, only linear, prestressed eigenvalue analysis is relevant. Thus, only that capability is discussed in this manual. If a nonlinear application is desired, the control cards detailed in Reference 4 may be employed.

To perform the T/STAEBL finite element frequency analysis, three separate inputs are required:

1. Block 0502, finite element mesh control, to interface between the cooled blade coordinate descriptions and the finite element mesh generation
2. Extended neck geometry definition, already discussed in Block 0503 inputs (Section 3)
3. Block 0516, finite element analysis control.

5.1 Block 0502 – Finite Element Mesh Control

This data block tells the T/STAEBL system how to build its finite element model from the airfoil coordinates of the cooled airfoil analysis system. To build this block for a new blade, the analyst will first have to build the thermal analysis data blocks, and make a partial T/STAEBL run. Blocks 0517 and 0091 are required to properly assemble this data block.

Data Block 0517 contains just one data item, on the second card, in I5 format. This data item, NUNC, the number of uncooled elements, tells the user how many of the Block 0091 coordinates are relevant to the finite element mesh.

Data Block 0091 contains the thermal analysis breakup element centers, on a section by section basis. The breakup for each section is consistent, so the user need investigate in detail only one section. Section 3 is suggested as representative of the entire blade. Starting with the third card, cross-section center coordinates are listed, as: Xi Yi Xj Yj Xk Yk. Each card contains coordinates (at constant radius) for three points. The format is F11.5. The user must plot the coordinates of the first NUNC points, for selection of those points which are desired to use in the finite element mesh.

Once the user has plotted these points, he/she should be easily able to mesh the blade. Points will be selected to serve as nodal points for a plate mesh of the airfoil. T/STAEBL will automatically determine the correct element thickness from the current geometry. The user should select intersections of airfoil walls and ribs as points for the mesh. For CPU efficiency, we suggest using only one element through the ribs. For minimal bandwidth, we suggest starting the mesh numbering at 1 at the leading edge, then alternating sides, until the trailing edge is reached. In modelling the pedestal area near the trailing edge, we suggest using two or three ribs, and assigning to their thickness the local pedestal diameter.

The thermal to structural mesh data block (Block 0502) then may be constructed, as detailed below.

Card 1:
BLOCK 502
Format: A5,I4

Card 2:
NGRDS NELS
Format: 2I4
Data: NGRDS - Number of structural GRIDS on cross-section mesh
NELS - Number of elements in cross-section mesh.

Card 3: (NGRDS cards required)
IGRD ICS
Format: 6I4
Data: IGRD - Structural mesh number, coincides with point number
ICS - on cooled airfoil analysis mesh.

Card 4: (NELS cards required)
IG1 IG2 PID
Format: 2I4, A7
Data: IG1 - IG1 and IG2 describe element connectivity, for side of structural
IG2 - element in the cross-section. Input the appropriate structural mesh node number.
PID - Element section (for thickness) identifier. Permitted names include internally generated design curves listed in Table 2 in Section 3. Additionally, LEADEDG is permitted to identify the airfoil leading edge.

5.2 Block 0503 – Optimization Control

This data block, discussed in Section 3 of this manual, includes the NECKGEOM card, which describes the properties of an extended neck, if one is present. If no neck model is desired, this card may be omitted. If the user wishes to include a neck model, he/she need only add an appropriate NECKGEOM card to the Block 0503 inputs.

5.3 Block 0516 – Finite Element Analysis Control

This section describes the control cards needed by the finite element program, and also lists those NASTRAN bulk data cards which are required to supplement the automatically created airfoil and neck models.

Please note that there is currently no user control over the master degrees of freedom selected for the Guyan reduction performed during the eigenvalue analysis. The points to be included in the ASET are currently automatically generated as:

	Master DOF	Master GRIDS
No Neck:	123	33, 38, 42, 59, 64, 68
Neck:	123	30, 35, 39, 56, 61, 65

Analysis Control Cards

These analysis control cards ($$PARAM cards) define analysis type, procedure and output. The control cards appear in the finite element program bulk data, instead of in a case control structure, as in NASTRAN, because no case control capability is available in the T/STAEBL finite element code. Those familiar with the NASTRAN case control will recognize that these $$PARAM cards perform the same function. Each $$PARAM card has an assigned mnemonic name. This section describes the following $$PARAM cards:

Note: All $$PARAM cards have been assigned default values, as explained within the respective card definitions.

Bulk Data Cards

Supplementary bulk data cards are required to define the loadings, boundary conditions, Guyan reduction parameters, and, in the case of conventional, extended neck airfoils, the platform model and airfoil to neck connectivities.

Those bulk data cards that are recognized by the T/STAEBL finite element code are classified according to function as shown below.

Note: Only single field (8 column) data input is available. Input is free field within the specified 8 column field.

****

..CONVERGE..

The CONVERGE parameter card defines the convergence criterion value and type. The current choices for type are:

1. STRAIN - Change in strain energy between iterations
2. DEFLEC - Maximum change in any deflection component between iteration (not currently functional). If this card is omitted, the program will use STRAIN at a value of .001.

****

field locations..

1	2	3	4	5	6	7	8	9
$$PARAM	CONVERGE	CTYPE	VALUE					

example..

1	2	3	4	5	6	7	8	9
$$PARAM	CONVERGE	STRAIN	.002					

Field	Format	Name	Description
-1-	alpha	$$PARAM	defines this card as a $$PARAM type
-2-	alpha	CONVERGE	defines $$PARAM card type
-3-	alpha	CTYPE	convergence test type: STRAIN - strain energy DEFLEC - deflection (not functional) (default - STRAIN)
-4-	real	VALUE	convergence criterion value (default for STRAIN = .001)

****

..K6ROT..

The K6ROT parameter card is used to eliminate the plate element in-plane rotation singularity. The input value is a multiplication factor used to couple all three in-plane rotation degrees of freedom for the triangular element using the method of Chapter 13.4 of the reference below. If this card is omitted, no coupling occurs.

****

field locations..

1	2	3	4	5	6	7	8	9
$$PARAM	K6ROT	ROTK6						

example..

1	2	3	4	5	6	7	8	9
$$PARAM	K6ROT	1.E-6						

Field	Format	Name	Description
-1-	alpha	$$PARAM	defines this card as a $$PARAM type
-2-	alpha	K6ROT	defines $$PARAM card type
-3-	alpha	ROTK6	value of multiplication factor. 1.E-6 is recommended.

Reference:

Zienkiewicz, O. C., The Finite Element Method, McGraw-Hill, 1977, Third Edition.

****

..LOADID..

The LOADID parameter card controls the order of load application. The program currently allows up to 8 load cases to be sequentially analyzed. The LOADID card references RFORCE identification numbers only. This is a required card and has no defaults. End of input is signaled by a blank field.

****

field locations..

1	2	3	4	5	6	7	8	9	10
$$PARAM	LOADID	LD(1)	LD(2)	LD(3)	LD(4)	LD(5)	LD(6)	LD(7)	LD(8)

example..

1	2	3	4	5	6	7	8	9	10
$$PARAM	LOADID	1							

Field	Format	Name	Description
-1-	alpha	$$PARAM	defines this card as a $$PARAM type
-2-	alpha	LOADID	defines $$PARAM card type
-3- thru -10-	integer	LD(1) -thru- LD(8)	RFORCE load identification number

Note:

1. An RFORCE card is required for each indicated LD load identification.

****

..MAXITER..

The MAXITER parameter card defines the maximum number of iterations per load case allowed in order to achieve a converged solution. If this card is omitted, then MAXITER is defaulted to 20.

****

field locations..

1	2	3	4	5	6	7	8	9
$$PARAM	MAXITER	MAX						

example..

1	2	3	4	5	6	7	8	9
$$PARAM	MAXITER	10						

Field	Format	Name	Description
-1-	alpha	$$PARAM	defines this card as a $$PARAM type
-2-	alpha	MAXITER	defines $$PARAM card type
-3-	integer	MAX	maximum number of iterations/load to achieve a converged solution (default = 20)

****

..NONLIN..

The NONLIN parameter card selects either a linear, prestressed stress and frequency analysis or a full nonlinear static analysis followed by a frequency analysis.

****

field locations..

1	2	3	4	5	6	7	8	9
$$PARAM	NONLIN	TYPE						

example..

1	2	3	4	5	6	7	8	9
$$PARAM	NONLIN	YES						

Field	Format	Name	Description
-1-	alpha	$$PARAM	defines this card as a $$PARAM type
-2-	alpha	NONLIN	defines $$PARAM card type
-3-	alpha	TYPE	NO - linear, prestressed analysis YES - full nonlinear analysis (default = YES)

****

..STRESS..

The STRESS parameter card allows the user to ensure efficient execution time in the finite element module by controlling modal stress calculations.

****

field locations..

1	2	3	4	5	6	7	8	9
$$PARAM	STRESS	TYPE						

example..

1	2	3	4	5	6	7	8	9
$$PARAM	STRESS	NO						

Field	Format	Name	Description
-1-	alpha	$$PARAM	defines this card as a $$PARAM type
-2-	alpha	STRESS	defines $$PARAM card type
-3-	alpha	TYPE	NO - no modal stress calculation YES - modal stresses are calculated (default = YES)

****

BULK DATA DECK

The bulk data deck contains the necessary $$PARAM control cards, as well as that supplementary data required to define the loadings, eigenvalue extraction procedures, and neck materials. The cards utilize NASTRAN bulk data input format. The cards listed are required, with the exception of the MAT1 (or MAT2) card, which may be omitted if no extended neck is present, and the RFORCE card, which may be omitted for analysis of a non-rotating component.

The following bulk data cards are available:

MAT1 - Materials Property Definition
MAT2 - Materials Property Definition
EIGR - Eigenvalue Extraction Control
RFORCE - RPM Control.

****

****

MATERIAL PROPERTIES DEFINITION

Both isotropic and anisotropic materials are available in T/STAEBL. In each case, only elastic, temperature independent properties are currently available.

****

LINEAR ISOTROPIC MATERIALS

field locations..

1	2	3	4	5	6	7	8	9
MAT1	MID	E	G	NU	RHO			

example..

1	2	3	4	5	6	7	8	9
MAT1	1	16.1E6		.33	.41E-3			

Field	Format	Name	Description
-1-	alpha	MAT1	defines linear, isotropic material properties
-2-	integer	MID	material identification number
-3-	real	E	Young's modulus
-4-	real	G	shear modulus
-5-	real	NU	Poissons' ratio
-6-	real	RHO	mass density

Note:

1. If any one of the E, G, or NU fields is blank, the missing item will be calculated based upon the relation $E = 2*(1+NU)*G$.

LINEAR ANISOTROPIC MATERIALS

field locations..

1	2	3	4	5	6	7	8	9
MAT2	MID	G11	G12	G13	G22	G23	G33	RHO

example..

1	2	3	4	5	6	7	8	9
MAT2	101	19.E6	4.E6	0.	10.E6	0.	11.E6	.31E-3

Field	Format	Name	Description
-1-	alpha	MAT2	defines linear, anisotropic material properties
-2-	integer	MID	material identification number
-3-	real	G11	G11 term of material property array property card (see note below)
-4-	real	G12	(see note below)
-5-	real	G13	(see note below)
-6-	real	G22	(see note below)
-7-	real	G23	(see note below)
-8-	real	G33	(see note below)
-9-	real	RHO	mass density

Notes:

1. The convention for the Gij on fields 3 through 8 is represented by the matrix relationship:

$$\begin{matrix} \sigma 1 \\ \sigma 2 \\ \sigma 12 \end{matrix} = \left| \begin{matrix} G11 & G12 & G13 \\ G12 & G22 & G23 \\ G13 & G23 & G33 \end{matrix} \right| \begin{matrix} \epsilon 1 \\ \epsilon 2 \\ \epsilon 12 \end{matrix}$$

2. 2x2 matrices (transverse shear properties) use elements G11, G12, and G22. In this case, G33 must be blank.

****

EIGENVALUE EXTRACTION CONTROL

The T/STAEBL finite element code uses an upper Hessenberg extraction procedure similar to the Givens' (GIV) method of the NASTRAN program. An eigenvalue extraction control card is required to indicate the number of eigenvectors and the frequency range that the analyst is considering for later analysis.

****

REAL EIGENVALUE EXTRACTION DATA

field locations..

1	2	3	4	5	6	7	8	9
EIGR			F1	F2		ND		

example..

1	2	3	4	5	6	7	8	9
EIGR			50.	3000.		10		

Field	Format	Name	Description
-1-	alpha	EIGR	eigenvalue extraction control
-4-	real	F1	lower frequency of range of interest
-5-	real	F2	upper frequency of range of interest
-7-	integer	ND	desired number of eigenvectors

****

LOAD DEFINITION

To determine the natural frequencies of a rotating blade at a speed condition, include an RFORCE card. For a static structure, such as a vane, this card may be omitted.

****

STATIC LOAD DUE TO CENTRIFUGAL FORCE FIELD

field locations..

1	2	3	4	5	6	7	8	9
RFORCE	SID			A	N1	N2	N3	

example..

1	2	3	4	5	6	7	8	9
RFORCE	SID			100.	0.	0.	1.	

Field	Format	Name	Description
-1-	alpha	RFORCE	defines a static load due to a centrifugal force field
-2-	integer	SID	load set identification number
-5-	real	A	scale factor for rotational velocity, revolutions per unit time
-6- thru -8-	real	N1, N2, N3	components of rotation direction vector, global coordinate system, rotation about system origin

Note:

1. RFORCE card load sets must be selected by the $$PARAM LOADID card.

6. PROGRAM EXECUTION AT NASA-LEWIS RESEARCH CENTER

Background Files Needed Before Executing the System:

- All data input blocks mentioned in Table 1 must be created.
- All files must be in appropriate directories (see Sections 4 and 7).

Running the System:

TSTAEBL has been designed to run on a CRAY via CMS. To execute the system, type in V549. The system will then indicate the maximum number of iterations (MAXITER) specified by the user; an option will also appear to quit if this number is incorrect. Upon continuing the program, a job will be submitted to execute the shells which will run the system on the CRAY. All necessary input will be accessed and all desired output will be disposed back to CMS.

Expected Output:

- Each program creates a diagnostics file if there are program errors.
- The following output files will be disposed to the end user's CMS reader:
    1. ADS output file which describes the optimizer's function call evaluations
    2. TSTAEBL final report which describes all scaled and unscaled variables, constraints, objective function, frequencies, and thermal analysis results for each function call
    3. Finite element mesh output file
    4. Finite element frequency output file.

Restarting an Optimization:

In the event that a job does not finish successfully, a file, TSTAEBL OUTPUT, will be sent to your reader. Receive this file onto your 191 disk, together with the Block 515 files, and execute V549REPT which will generate a report. Take the design variable and objective function values from the last successful design move and place them accordingly into the TSTAEBL INP file (Block 503); then rerun the system.

7. SAMPLE INPUT

The model used to develop the code was the Energy Efficient Engine (EEE) first blade. This section contains a complete listing of the input data.

Although the list is continuous, each block of data is indicated by the work BLOCK, followed by the block number, the section number, a zero, and a descriptive name associated with the block.

This file set will be delivered with the code, and should be available from archival tapes at NASA-Lewis Research Center.

Block 0 is required to set some general parameters in V545.

```
(tof)
FGNAME       2   1
FGTITLE     15   3
SECTION      1  18
V546TWC1     5  19
V546TWC2     5  24
(eof)
```

Block 1 is used to describe the external and core contours. The system requires five files, one for each section. This data is for section 1 only, portions have been removed.

```
(tof)
BLOCK    1    1    0 E3 FIRST BLADE ROOT
                                                              (Blank Card)
   5   53   27   30   29   59    0    0    0    0    0    0    0 13.67800
                                                              (Blank Card)
-0.55950  -0.13050          (Card 1 Start of External Contour)
---
 0.03929  -0.16021          (Middle point on Pressure Side)
---
 0.67844  -1.14648          (Max x)
---
 0.03929   0.50515          (Middle point on Suction  Side)
---
-0.66715  -0.05064          (Min x)
---
-0.58641  -0.13950          (Card 53 End of External Contour)
-0.57910  -0.08100          (Card 53 + 1 Start of First Cavity)
---
-0.40000   0.01000          (Middle point on Pressure Side)
---
-0.31000   0.31000          (Max X)
---
-0.41512   0.26609          (Middle point on Suction Side)
---
-0.59264  -0.08194          (Card 53+27 End of First Cavity)
-0.27153   0.06443          (Card 80+1  Start of Second Cavity)
---
```

```
-0.15274  -0.00324          (Middle point on Pressure Side)
—
 0.03100   0.39000          (Max X)
—
-0.25086   0.16186          (Card 80+30  End of Second Cavity)
 0.01653  -0.05958          (Card 110+1  Start of Third Cavity)
—
 0.17922  -0.21139          (Middle point on Pressure Side)
—
 0.28047   0.02308          (Max X)
—
 0.01653  -0.04315          (Card 110+29  End of Third Cavity)
—
 0.24500  -0.29100          (Card 139+1   Start of Fourth Cavity)
—
 0.54466  -0.87326          (Middle point on Pressure Side)
—
 0.69819  -1.27338          (Max X)
—
 0.54279  -0.76363          (Middle point on Suction Side)
—
 0.25681  -0.26343          (Card 139+59 End of Fourth Cavity)
(eof)
```

Block 12 describes material properties. Values represent array values for 100 degree increments in temperature from 100°F.

```
(tof)
BLOCK    12     0     0 MATERIAL PROPERTIES
    2
METAL1       REPRESENTATIVE ANISOTROPIC MATERIAL
METAL1    CPT     P  SPECIFIC HEAT
   1.000000       25
  0.1010000      0.1010000      0.1033906      0.1056875      0.1078906
  0.1100000      0.1119058      0.1134687      0.1151723      0.1175000
  0.1202734      0.1233333      0.1268515      0.1310000      0.1356770
  0.1410000      0.1468123      0.1540000      0.1636050      0.1750000
  0.1881364      0.2018889      0.2018889      0.2018889      0.2018889
METAL1       REPRESENTATIVE ANISOTROPIC MATERIAL
METAL1    TCT     P  THERMAL CONDUCTIVITY
   1.000000       25
   56.00000       57.60394       62.96135       68.33553       73.72647
   79.13420       84.55872       90.00000       95.46631       100.9791
   106.5248       112.0649       117.5612       123.0000       128.4028
   133.7780       139.1255       144.4451       149.7366       155.0000
   160.7712       167.4444       167.4444       167.4444       167.4444
METAL1       REPRESENTATIVE ANISOTROPIC MATERIAL
METAL1    CET     P  MEAN COEFFICIENT OF MCPCAR EXPANSION
  0.1000000E-05   25
  0.6770002E-05  0.6770002E-05  0.6770002E-05  0.6770002E-05  0.6770002E-05
```

```
 0.6770002E-05  0.6868775E-05  0.6970253E-05  0.7076153E-05  0.7189580E-05
 0.7302592E-05  0.7418438E-05  0.7544960E-05  0.7690423E-05  0.7855614E-05
 0.8031245E-05  0.8233371E-05  0.8488739E-05  0.8807575E-05  0.9149982E-05
 0.9528673E-05  0.9996672E-05  0.9996672E-05  0.9996672E-05  0.9996672E-05
METAL1      REPRESENTATIVE ANISOTROPIC MATERIAL
METAL1    EDTQ    P  ELASTIC MODULUS - DYNAMIC
   1000000.     25
 0.1817210E+08  0.1796691E+08  0.1774286E+08  0.1750000E+08  0.1723720E+08
 0.1695322E+08  0.1665260E+08  0.1634000E+08  0.1601596E+08  0.1568187E+08
 0.1532934E+08  0.1495000E+08  0.1454391E+08  0.1411000E+08  0.1365859E+08
 0.1320000E+08  0.1273000E+08  0.1225000E+08  0.1178687E+08  0.1127000E+08
 0.1063000E+08   9800000.       9800000.       9800000.       9800000.
METAL1      REPRESENTATIVE ANISOTROPIC MATERIAL
METAL1    YBTQ    P  0.2% YIELD STRENGTH
   1000.000       25
   122761.9       122049.6       121462.3       121000.0       120621.5
   120275.0       120141.0       120399.9       120999.9       121899.9
   123100.0       125199.9       124300.0       115600.0       98500.00
   83000.00       68000.00       49972.89       37573.05       24814.34
   14920.78       7342.609       7342.609       7342.609       7342.609
METAL1      REPRESENTATIVE ANISOTROPIC MATERIAL
METAL1    YATQ    P  0.02% YIELD STRENGTH
   1000.000       25
   45570.42       45328.89       45276.42       45415.41       45766.36
   46353.67       47105.45       47954.32       48887.82       50044.26
   51569.14       52046.52       57489.98       63520.91       61972.72
   52791.68       43392.00       33570.30       24632.03       16665.04
   10647.39       4977.414       4977.414       4977.414       4977.414
METAL1      REPRESENTATIVE ANISOTROPIC MATERIAL
METAL1    ROT     P  DENSITY
  0.3120000
METAL1      REPRESENTATIVE ANISOTROPIC MATERIAL
METAL1    PBTQ1   P  0.50% , 1.00% AND 2.00%  CREEP
   18.00000        9    3
   5.000000       9.000000       15.00000       20.00000       30.00000
   40.00000       60.00000       80.00000       100.0000
   52400.00       53300.00       53800.00       49850.00       50550.00
   51200.00       47250.00       48030.00       48740.00       45700.00
   46600.00       47290.00       43250.00       44420.00       45170.00
   41400.00       42800.00       43570.00       38500.00       40250.00
   40910.00       36200.00       38070.00       38950.00       34000.00
   35950.00       37200.00
  0.5000000       1.000000       2.000000
METAL1      REPRESENTATIVE ANISOTROPIC MATERIAL
METAL1    PRTQ1   P  STRESS RUPTURE
   18.00000        9
   5.000000       9.000000       15.00000       20.00000       30.00000
   40.00000       60.00000       80.00000       110.0000
   54300.00       51700.00       49250.00       47850.00       45780.00
```

```
  44250.00       41900.00       40150.00       38070.00
COAT1       REPRESENTATIVE THERMAL BARRIER COATING
COAT1     CPT    P  SPECIFIC HEAT
  1.000000       25
 0.1180000      0.1240000      0.1300000      0.1350000      0.1400000
 0.1430000      0.1470000      0.1500000      0.1520000      0.1530000
 0.1550000      0.1570000      0.1580000      0.1585000      0.1590000
 0.1595000      0.1598000      0.1600000      0.1600000      0.1600000
 0.1600000      0.1600000      0.1600000      0.1600000      0.1600000
COAT1       REPRESENTATIVE THERMAL BARRIER COATING
COAT1     TCT    P  THERMAL CONDUCTIVITY
  1.000000       25
  5.950800       6.261600       6.572400       6.883200       7.194000
  7.506000       7.816800       8.127600       8.463600       8.749200
  9.060000       9.370800       9.681600       9.992400       10.30320
  10.61400       10.92600       11.23600       11.61840       11.85840
  12.16920       12.40000       12.40000       12.40000       12.40000
COAT1       REPRESENTATIVE THERMAL BARRIER COATING
COAT1     CET    P  MEAN COEFFICIENT OF MCPCAR EXPANSION
 0.1000000E-05   25
 0.4100002E-05  0.4247600E-05  0.4395200E-05  0.4542900E-05  0.4690500E-05
 0.4838100E-05  0.4985700E-05  0.5133300E-05  0.5281000E-05  0.5428600E-05
 0.5576200E-05  0.5723800E-05  0.5871400E-05  0.6019000E-05  0.6166700E-05
 0.6314300E-05  0.6461900E-05  0.6609500E-05  0.6757100E-05  0.6904800E-05
 0.7052400E-05  0.7200000E-05  0.7200000E-05  0.7200000E-05  0.7200000E-05
COAT1       REPRESENTATIVE THERMAL BARRIER COATING
COAT1     EDTQ   P  ELASTIC MODULUS - DYNAMIC
  1000000.       25
  6400000.       6204800.       6009500.       5814300.       5619000.
  5423800.       5228600.       5033300.       4838100.       4642900.
  4447600.       4252400.       4057100.       3861900.       3666700.
  3471400.       3276200.       3081000.       2885700.       2690500.
  2495200.       2300000.       2300000.       2300000.       2300000.
COAT1       REPRESENTATIVE THERMAL BARRIER COATING
COAT1     YBTQ   P  0.2% YIELD STRENGTH
  1000.000       25
  122761.9       122049.6       121462.3       121000.0       120621.5
  120275.0       120141.0       120399.9       120999.9       121899.9
  123100.0       125199.9       124300.0       115600.0       98500.00
  83000.00       68000.00       49972.89       37573.05       24814.34
  14920.78       7342.609       7342.609       7342.609       7342.609
COAT1       REPRESENTATIVE THERMAL BARRIER COATING
COAT1     YATQ   P  0.02% YIELD STRENGTH
  1000.000       25
  45570.42       45328.89       45276.42       45415.41       45766.36
  46353.67       47105.45       47954.32       48887.82       50044.26
  51569.14       52046.52       57489.98       63520.91       61972.72
  52791.68       43392.00       33570.30       24632.03       16665.04
```

```
  10647.39     4977.414     4977.414     4977.414     4977.414
COAT1     REPRESENTATIVE THERMAL BARRIER COATING
COAT1     ROT   P  DENSITY
 0.2050000
COAT1     REPRESENTATIVE THERMAL BARRIER COATING
COAT1     PBTQ1  P  0.50% , 1.00% AND 2.00%  CREEP
  18.00000      9   3
  5.000000     9.000000     15.00000     20.00000     30.00000
  40.00000     60.00000     80.00000     100.0000
  52400.00     53300.00     53800.00     49850.00     50550.00
  51200.00     47250.00     48030.00     48740.00     45700.00
  46600.00     47290.00     43250.00     44420.00     45170.00
  41400.00     42800.00     43570.00     38500.00     40250.00
  40910.00     36200.00     38070.00     38950.00     34000.00
  35950.00     37200.00
 0.5000000     1.000000     2.000000
COAT1     REPRESENTATIVE THERMAL BARRIER COATING
COAT1     PRTQ1  P  STRESS RUPTURE
  18.00000      9
  5.000000     9.000000     15.00000     20.00000     30.00000
  40.00000     60.00000     80.00000     110.0000
  54300.00     51700.00     49250.00     47850.00     45780.00
  44250.00     41900.00     40150.00     38070.00
(eof)
```

Block 16 is used to hold steady-state configuration. The system is not capable of modeling transients.

```
(tof)
BLOCK   16    0    0 STEADY STATE CONFIG OF CYCLE DEFINITION BLOCK
   0
           1    1    1    1    1    1    1    1    1    1    0.0000
   0   0.0000    0.0000    0
(eof)
```

Block 17 is used to break up superblocks described by the flag points. The system requires five blocks, one for each section. Section 1 data is shown.

```
(tof)
BLOCK   17    1    0 ROW & COLUMN BREAKUP
  53
   1    1    1    1    1    2    1    1    1    3    1    1    1    4    1    1
   1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
   1    1    1    1    1    1    1    1    1    1    1    2    1    1    1    2
   1    1    1    3    1    1    1    4    1    1    1    1    1    1    1    1
   1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
   1    1    1    1    1    3    2    1    2    1    1    1    1    1    1    1
   1    1    1    1    1    1    1    1    1    1
(eof)
```

Block 22 controls the creep calculation. The system requires five files, one for each section. Section 1 data is shown.

```
(tof)
BLOCK   22    1    0 CREEP
   10.000    5    5    1   -1    0    0   0.00000   0.00000   0.00000    0
    7   27   35   55   57
    2.0000    4.0000    6.0000    8.0000    10.0000
 15466.000     0.000     0.000
(eof)
```

Block 23 details film hole geometry. The system requires five files, one for each section. Section 2 is shown.

```
(tof)
BLOCK   23    2    0 FILM HOLE GEOMETRY
    3   0.00000
  -0.48600   0.10000  -0.42000   0.01000   0.01500   6.50000  90.00000
  -0.51600   0.07000  -0.62300   0.01000   0.01500   6.50000  90.00000
  -0.48500   0.15000  -0.59500   0.20000   0.01500   6.50000  90.00000
         2
       162   0.00245   0.05500
       163   0.00012   0.05800
         2
       164   0.00259   0.00800
       165   0.00012   0.01000
         2
       166   0.00259   0.05900
       167   0.00012   0.05900
(eof)
```

Block 24 is used to describe Hgas on the external surface. The system requires three files, one for each of the analysis sections. This data is for section 2 only. Starting values can be approximate.

```
(tof)
BLOCK   24    2    0 E3 36K FLT ENG BLADE 1/4 ROOT
    1    0    1850.0  256.6001
    3    4
   0.00000 2000.0000
   1.00000  500.0000
   2.00000  500.0000
   0.00000 2000.0000
   1.00000  500.0000
   2.00000  500.0000
   3.00000  500.0000
(eof)
```

Block 25 is used to describe Tgas on the external surface. The system requires three files, one for each of the analysis sections. This data is for section 2 only. Starting values can be approximate.

```
(tof)
BLOCK   25    2    0 E3 36K FLT ENG BLADE 1/4 ROOT
   1    0     1850.0
   3    4
  0.00000 1850.0000
  1.00000 1850.0000
  2.00000 1850.0000
  0.00000 1850.0000
  1.00000 1850.0000
  2.00000 1850.0000
  3.00000 1850.0000
(eof)
```

Block 26 is used to describe ETA gas on the external surface. The system requires three files, one for each of the analysis sections. This data is for section 2 only. Starting values can be approximate.

```
(tof)
BLOCK   26     2     1   Film effectiveness
   1  195
   3    4
  0.00000   0.10000
  1.00000   0.10000
  2.00000   0.10000
  0.00000   0.10000
  1.00000   0.10000
  2.00000   0.10000
  3.00000   0.10000
(eof)
```

Block 27 is used to describe h-cool on the internal surface. The system requires three files, one for each of the analysis sections. This data is for section 2 only. Starting values can be approximate.

```
(tof)
BLOCK   27    2    1  SLTO H-COOL
   4    2    2    2    2    0    0    0    0    0    0    0
   8
 400.00000 800.00000 800.00000 400.00000 400.00000 800.00000 800.00000 800.00000
   8
 400.00000 400.00000 800.00000 800.00000 400.00000 400.00000 800.00000 800.00000
   9
 400.00000 400.00000 800.00000 800.00000 800.00000 400.00000 800.00000 800.00000
 800.00000
  39
 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000
 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000
 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000
 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000
```

```
800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000
(eof)
```

Block 28 is used to describe T–cool on the internal surface. The system requires three files, one for each of the analysis sections. This data is for section 2 only. Starting values can be approximate.

```
(tof)
BLOCK   28    2    1     SLTO T-COOL
   4    2    2    2    2    0    0    0    0    0    0    0
   8
 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000
   8
 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000
   9
 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000
 800.00000
  39
 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000
 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000
 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000
 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000
 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000 800.00000
(eof)
```

Block 29 is used to describe h–ped on the internal surface. The system requires three files, one for each of the analysis sections. This data is for section 2 only. Starting values can be approximate.

```
(tof)
BLOCK   29    2    1   PEDESTALS H-PED
   7    2
   1
1000.00000
   1
1000.00000
   1
1000.00000
   1
1000.00000
   1
1000.00000
   1
1000.00000
   1
1000.00000
(eof)
```

Block 30 is used to describe T-ped on the internal surface. The system requires three files, one for each of the analysis sections. This data is for section 2 only. Starting values can be approximate. Initial distributions can be approximate.

```
(tof)
BLOCK   30    2    1    SLTO T- PED
   7    2
   1
 800.00000
   1
 800.00000
   1
 800.00000
   1
 800.00000
   1
 800.00000
   1
 800.00000
   1
 800.00000
(eof)
```

Block 31 is used to describe H in the film holes. The system requires three files, one for each of the analysis sections. This data is for section 2 only. Starting values can be approximate.

```
(tof)
BLOCK   31    2    1    SLTO H-FILM HOLE
   3    4    3    3    2    0    0    0    0    0    0    0
   5      1000.0000 1000.0000 1000.0000 1000.0000 1000.0000
   5      1000.0000 1000.0000 1000.0000 1000.0000 1000.0000
   5      1000.0000 1000.0000 1000.0000 1000.0000 1000.0000
(eof)
```

Block 32 is used to describe T in the film holes. The system requires three files, one for each of the analysis sections. This data is for section 2 only. Starting values can be approximate.

```
(tof)
BLOCK   32    2    1    SLTO T-FILM HOLE
   3    4    3    3    2    0    0    0    0    0    0    0
   2       800.0000  800.0000
   2       800.0000  800.0000
   2       800.0000  800.0000
(eof)
```

Block 37 is used to describe the pedestal geometry. The system requires five files, one for each section. This data is for section 1 only.

```
(tof)
BLOCK   37    1    0 PEDESTAL GEOMETRY
    7
    9   10   47   46   0.82000   0.18000   0.00200   8.70000   0.06000        1
   11   12   45   44   0.82000   0.18000   0.00200   8.70000   0.06000        1
   13   14   43   42   0.40900   0.59100   0.00200   8.70000   0.03000        1
   15   16   41   40   0.40900   0.59100   0.00200   8.70000   0.03000        1
   17   18   39   38   0.40900   0.59100   0.00200   8.70000   0.03000        1
   20   21   36   35   0.40900   0.59100   0.00200   8.70000   0.03000        1
   22   23   33   32   0.40900   0.59100   0.00200   8.70000   0.03000        1
(eof)
```

Block 93 is used to describe external pressure distribution. See also Blocks 101 and 102 which have pressure distribution. The system requires three files, one for each analysis section. This data is for section 2 only, portions have been removed.

```
(tof)
BLOCK   93    2    0 EXTERNAL PS/PT Q-ROOT E3 1B
   24   40    0.0000
    0.0000    1.0000          (Card 1  Start of pressure side)
    ---
    0.6025    0.9956          (Card 12 Middle of pressure side)
    ---
    1.9075    0.4756          (Card 24 End of pressure side)
    ---
    0.0000    1.0000          (Card 24+1  Start of suction side)
    ---
    0.7652    0.7147          (Card 20+20 Middle of suction side)
    ---
    2.8996    0.3732          (Card 40+40 End of suction side)
(eof)
```

Block 95 is used to describe the external total pressure profile.

```
(tof)
BLOCK   95    0    0 EXTERNAL INLET PT PROFILE
    5
   13.6780  249.8000
   14.2960  256.6001
   14.9135  263.3000
   15.5310  270.0000
   16.1490  276.8000
(eof)
```

Block 96 is used to describe the internal total pressure profile. Used for vibration analysis.

```
(tof)
BLOCK   96     0     0 INTERNAL PT - BASED ON CAVITY 3
    5
   13.6780  260.8999
   14.2960  271.3000
   14.9135  281.1001
   15.5310  292.5000
   16.1490  294.0000
(eof)
```

Block 97 is used to describe the external total temperature profile.

```
(tof)
BLOCK   97     0     0 EXTERNAL INLET TT PROFILE
    5
   13.6780 1630.0000
   14.2960 2250.0000
   14.9135 2650.0000
   15.5310 2720.0000
   16.1490 1860.0000
(eof)
```

Block 99 is used to detail limits of film cooling spread.

```
(tof)
BLOCK   99     0     0 1-D HT REF DATA (SPREAD OF FILM COOLING)
   13.6780   16.1490
       0.0        0.9
(eof)
```

Block 101 is used to calculate the pressure side external boundary layer. See also Block 93 which has pressure distribution data. The system requires three files, one for each analysis section. This data is for section 2 only, portions have been removed.

```
(tof)
BLOCK  101    2    0 PRESSURE SIDE BOUNDARY LAYER DATA
E3 36K FLT ENG BLADE 1/4 ROOT                                            1 0 00001
   0.100000          F   0.00000 0.0000000          0   0.00000    0.00000      0.0
 719.90015   0.08000.25660D+031850.00000   0.00000   0.00000   0.0010000 0.00000
  3     0    0.02178    0.96049    1.66341   0.00000   0.00000    0.0000      0.00
  0.000000  1.0000001586.33081  0.000000  0.000000  0.000000  0.072000
  — (Cards 2-9 removed)
  0.473208  0.9969401280.26904  0.000000  0.000000  0.000000 -0.445500
  — (Cards 11-19 removed)
  1.407867  0.8934301421.48071  0.000000  0.000000  0.000000 -4.527800
  — (Cards 21-23 removed)
  1.907519  0.4756001378.70508  0.000000  0.000000  0.000000  0.395200
(eof)
```

Block 102 is used to calculate the suction side external boundary layer. See also Block 93 which has pressure distribution data. The system requires three files, one for each analysis section. This data is for section 2 only, portions have been removed.

```
(tof)
BLOCK  102    2    0 SUCTION  SIDE BOUNDARY LAYER DATA
E3 36K FLT ENG BLADE 1/4 ROOT                                            1 0 00001
   0.100000          F   0.00000 0.0000000          0   0.00000    0.00000      0.0
 719.89990   0.08000.25660D+031850.00000   0.00000   0.00000   0.0010000 0.00000
  3     0    0.02542    0.99897    1.66341   0.00000   0.00000    0.0000      0.00
  0.000000  1.0000001536.28955  0.000000  0.000000  0.000000  0.072000
  — (Cards 2-9 removed)
  0.204647  0.8696501486.82275  0.000000  0.000000  0.000000  2.266700
  — (Cards 11-19 removed)
  0.820931  0.6757901479.85986  0.000000  0.000000  0.000000  0.311700
  — (Cards 21-29 removed)
  1.627730  0.3061901406.44043  0.000000  0.000000  0.000000 11.692700
  — (Cards 31-37 removed)
8 2.899580  0.3731701399.99976  0.000000  0.000000  0.000000 23.436493
(eof)
```

Block 104 is used to calculate external film effectiveness. The system requires three files, one for each analysis section. This data is for section 2 only.

```
(tof)
BLOCK  104    2    0 FILM DECK INPUT
B       54     147.   0    0    0   1
   0.30500   2.59400   1.35000   1.30000   1.30000 624.00000 624.000001850.00000
    1   2
P        1    8    1    0
   0.09000   0.00105 768.00000   0.01500  90.00000   0.16670  45.00000   0.60000
S        1    9    1    0
   0.09000   0.00121 768.00000   0.01500  90.00000   0.16670  45.00000   0.60000
S        1    9    1    0
   0.25000   0.00140 768.00000   0.01500  90.00000   0.16670  45.00000   0.60000
(eof)
```

Block 400 is used to interface between network and section by section analysis. The system requires three files, one for each analysis section. This data is for section 2 only.

```
(tof)
BLOCK  400    2    0 QUARTER ROOT M571/P783 TRANSFER INFO
  201   0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  191 -198
  301   0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  199 -206
  401   0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  207 -215
  501   0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  216 -220  251 -254
  602   0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  221 -250
  202   0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  191 -198
  302   0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  199 -206
  402   0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  207 -215
  502   0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  216 -220  251 -254
  603   0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  221 -250
  203   0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  191 -198
  303   0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  199 -206
  403   0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  207 -215
  503   0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
```

```
        1  216 -220  251 -254
 604    0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  221 -250
1021    0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  262 -263
1022    0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  264 -265
1023    0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  266 -267
1031    0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  262 -263
1032    0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  264 -265
1033    0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  266 -267
1041    0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  262 -263
1042    0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  264 -265
1043    0    0    0    0    0    0    0    0    0    0    0    0    0    0.0000
        1  266 -267
                                                      (Blank Card)
 191  201S   1  202S   1    0.00 0.00 0.00     0.00 0.00 0.00
 192  201R   1  202R   1    0.00 0.00 0.00     0.00 0.00 0.00
 193  201R   1  202R   1    0.00 0.00 0.00     0.00 0.00 0.00
 194  201S   1  202S   1    0.00 0.00 0.00     0.00 0.00 0.00
 195  201S   1  202S   1    0.00 0.00 0.00     0.00 0.00 0.00
 196  201R   1  202R   1    0.00 0.00 0.00     0.00 0.00 0.00
 197  201R   1  202R   1    0.00 0.00 0.00     0.00 0.00 0.00
 198  201R   1  202R   1    0.00 0.00 0.00     0.00 0.00 0.00
 199  301S   1  302S   1    0.00 0.00 0.00     0.00 0.00 0.00
 200  301S   1  302S   1    0.00 0.00 0.00     0.00 0.00 0.00
 201  301R   1  302R   1    0.00 0.00 0.00     0.00 0.00 0.00
 202  301R   1  302R   1    0.00 0.00 0.00     0.00 0.00 0.00
 203  301S   1  302S   1    0.00 0.00 0.00     0.00 0.00 0.00
 204  301S   1  302S   1    0.00 0.00 0.00     0.00 0.00 0.00
 205  301R   1  302R   1    0.00 0.00 0.00     0.00 0.00 0.00
 206  301R   1  302R   1    0.00 0.00 0.00     0.00 0.00 0.00
 207  401S   1  402S   1    0.00 0.00 0.00     0.00 0.00 0.00
 208  401S   1  402S   1    0.00 0.00 0.00     0.00 0.00 0.00
 209  401R   1  402R   1    0.00 0.00 0.00     0.00 0.00 0.00
 210  401R   1  402R   1    0.00 0.00 0.00     0.00 0.00 0.00
 211  401R   1  402R   1    0.00 0.00 0.00     0.00 0.00 0.00
 212  401S   1  402S   1    0.00 0.00 0.00     0.00 0.00 0.00
 213  401R   1  402R   1    0.00 0.00 0.00     0.00 0.00 0.00
 214  401R   1  402R   1    0.00 0.00 0.00     0.00 0.00 0.00
 215  401R   1  402R   1    0.00 0.00 0.00     0.00 0.00 0.00
 216  501S   1  502S   1    0.00 0.00 0.00     0.00 0.00 0.00
 217  501    1  502    1    0.00 0.00 0.00     0.00 0.00 0.00
 218  501    1  502    1    0.00 0.00 0.00     0.00 0.00 0.00
```

219	501	1	502	1	0.00	0.00	0.00	0.00	0.00	0.00
220	501	1	502	1	0.00	0.00	0.00	0.00	0.00	0.00
221	602	1	0	0	0.00	0.00	0.00	0.00	0.00	0.00
222	602	1	0	0	0.00	0.00	0.00	0.00	0.00	0.00
223	602	2	0	0	0.00	0.00	0.00	0.00	0.00	0.00
224	602	2	0	0	0.00	0.00	0.00	0.00	0.00	0.00
225	602	3	0	0	0.00	0.00	0.00	0.00	0.00	0.00
226	602	3	0	0	0.00	0.00	0.00	0.00	0.00	0.00
227	602	4	0	0	0.00	0.00	0.00	0.00	0.00	0.00
228	602	4	0	0	0.00	0.00	0.00	0.00	0.00	0.00
229	602	5	0	0	0.00	0.00	0.00	0.00	0.00	0.00
230	602	5	0	0	0.00	0.00	0.00	0.00	0.00	0.00
231	602	6	0	0	0.00	0.00	0.00	0.00	0.00	0.00
232	602	6	0	0	0.00	0.00	0.00	0.00	0.00	0.00
233	602	7	0	0	0.00	0.00	0.00	0.00	0.00	0.00
234	602	7	0	0	0.00	0.00	0.00	0.00	0.00	0.00
235	602	7	0	0	0.00	0.00	0.00	0.00	0.00	0.00
236	602	7	0	0	0.00	0.00	0.00	0.00	0.00	0.00
237	602	7	0	0	0.00	0.00	0.00	0.00	0.00	0.00
238	602	7	0	0	0.00	0.00	0.00	0.00	0.00	0.00
239	602	6	0	0	0.00	0.00	0.00	0.00	0.00	0.00
240	602	6	0	0	0.00	0.00	0.00	0.00	0.00	0.00
241	602	5	0	0	0.00	0.00	0.00	0.00	0.00	0.00
242	602	5	0	0	0.00	0.00	0.00	0.00	0.00	0.00
243	602	4	0	0	0.00	0.00	0.00	0.00	0.00	0.00
244	602	4	0	0	0.00	0.00	0.00	0.00	0.00	0.00
245	602	3	0	0	0.00	0.00	0.00	0.00	0.00	0.00
246	602	3	0	0	0.00	0.00	0.00	0.00	0.00	0.00
247	602	2	0	0	0.00	0.00	0.00	0.00	0.00	0.00
248	602	2	0	0	0.00	0.00	0.00	0.00	0.00	0.00
249	602	1	0	0	0.00	0.00	0.00	0.00	0.00	0.00
250	602	1	0	0	0.00	0.00	0.00	0.00	0.00	0.00
251	501	1	502	1	0.00	0.00	0.00	0.00	0.00	0.00
252	501	1	502	1	0.00	0.00	0.00	0.00	0.00	0.00
253	501	1	502	1	0.00	0.00	0.00	0.00	0.00	0.00
254	501	1	502	1	0.00	0.00	0.00	0.00	0.00	0.00
255	602	1	0	0	0.00	0.00	0.00	0.00	0.00	0.00
256	602	2	0	0	0.00	0.00	0.00	0.00	0.00	0.00
257	602	3	0	0	0.00	0.00	0.00	0.00	0.00	0.00
258	602	4	0	0	0.00	0.00	0.00	0.00	0.00	0.00
259	602	5	0	0	0.00	0.00	0.00	0.00	0.00	0.00
260	602	6	0	0	0.00	0.00	0.00	0.00	0.00	0.00
261	602	7	0	0	0.00	0.00	0.00	0.00	0.00	0.00

(Blank Card)

-1 0

(Blank Card)

1	131	1021												
		1021	0	0	0	0	0	0	0	0	0	0	0	0	0
3	188	1023												
		1023	0	0	0	0	0	0	0	0	0	0	0	0	0

```
    2  190 1022
           1022    0    0    0    0    0    0    0    0    0    0    0    0    0
(eof)
```

Block 401 is the network for modeling internal flows.

```
(tof)
BLOCK  401    0    0 E3 FIRST BLADE MODEL FOR BENCHMARKING STAEBL
 13936.000    0    0   0.00000   0.00000                               0   0.00000
MATL      METAL1
REFE          54         449.000   146.900
000000000000000000000000000000000000000000000000000000000000
       100 233.00000 624.00000  12.00000            0.00000
                                                       (Blank Card)
      1021 255.800002000.00000  14.30000
      1022 243.800002000.00000  14.30000
      1023 224.000002000.00000  14.30000
      1031 262.300052000.00000  14.91000
      1032 253.100012000.00000  14.91000
      1033 234.700002000.00000  14.91000
      1041 269.500002000.00000  15.53000
      1042 259.500002000.00000  15.53000
      1043 235.800002000.00000  15.53000
       702  96.200002000.00000  14.30000
       703  97.300002000.00000  14.91000
       704  98.200002000.00000  15.53000
       705 269.000002000.00000  15.90000
                                                       (Blank Card)
       201                      13.68000         0         0
       202                      14.30000         0         0
       203                      14.91000         0         0
       204                      15.53000         0         0
       301                      13.68000         0         0
       302                      14.30000         0         0
       303                      14.91000         0         0
       304                      15.53000         0         0
       404                      15.53000         0         0
       403                      14.91000         0         0
       402                      14.30000         0         0
       401                      13.68000         0         0
       501                      13.68000         0         0
       502                      14.30000         0         0
       503                      14.91000         0         0
       504                      15.53000         0         0
       505                      15.90000         0         0
                                                       (Blank Card)
```

```
200  ARL  100  201   0.00000   0.00000   0.00000   0    0    0    0
  10.0000.000      1.0001.0001.0001.000
 0.000001000.00000   0.10700   1.26000   0.00000   0.00000   0.000001.0001.000
 1.680001200.00000   0.03940   1.05000   0.00000   0.00000   0.000001.0001.000
201  TRP  201  202   0.00000   0.00000   0.00000   0    0    0    1
       5         1
 0.01260   0.10000   0.21600   0.53600   0.00000   0.00000
 0.000001200.00000   0.03940   1.05400   0.00000   0.00000   0.000001.0001.000
 0.620001590.00000   0.03340   1.02400   0.00000   0.00000   0.000001.0001.000
916.2603 1581.6104 0.1197348  100.0000  -0.69351   0.00000   0.00000   0.00000
202  TRP  202  203   0.00000   0.00000   0.00000   0    0    0    1
       5         1
 0.01260   0.10000   0.21600   0.53600   0.00000   0.00000
 0.000001590.00000   0.03340   1.02400   0.00000   0.00000   0.000001.0001.000
 0.620001702.00000   0.02230   0.69600   0.00000   0.00000   0.000001.0001.000
889.1030 2041.0295 0.1335959  100.0000  -0.62726   0.00000   0.00000   0.00000
203  TRP  203  204   0.00000   0.00000   0.00000   0    0    0    1
       5         1
 0.01100   0.11000   0.17300   0.62200   0.00000   0.00000
 0.000001702.00000   0.02230   0.69600   0.00000   0.00000   0.000001.0001.000
 0.620001735.00000   0.02360   0.67900   0.00000   0.00000   0.000001.0001.000
944.5808 2277.0115 0.1106763  100.0000  -0.84356   0.00000   0.00000   0.00000
204  CHN  204  505   0.00000   0.00000   0.00000   0    0    0    0
 0.000001735.00000   0.02360   0.67900   0.00000   0.00000   0.000001.0001.000
 2.800001790.00000   0.00940   0.15200   0.00000   0.00000   0.000001.0001.000
1021  ARL  202 1021   0.00000   0.00000   0.00000   0    0    0    1
  10.0000.000      1.0003.0001.0001.000
 0.000001590.00000   0.00071   0.18800   0.00000   0.00000   0.000001.0001.000
 0.050001590.00000   0.00071   0.18800   0.00000   0.00000   0.000001.0001.000
  5.7988   12.770311.9231367  100.0000  -0.00634   0.00000   0.00000   0.00000
1022  ARL  202 1022   0.00000   0.00000   0.00000   0    0    0    1
  10.0000.000      1.0003.0001.0001.000
 0.000001590.00000   0.00071   0.18800   0.00000   0.00000   0.000001.0001.000
 0.050001590.00000   0.00071   0.18800   0.00000   0.00000   0.000001.0001.000
  9.7318   12.756311.9224262  100.0000  -0.00849   0.00000   0.00000   0.00000
1023  ARL  202 1023   0.00000   0.00000   0.00000   0    0    0    1
  10.0000.000      1.0003.0001.0001.000
 0.000001590.00000   0.00071   0.18800   0.00000   0.00000   0.000001.0001.000
 0.050001590.00000   0.00071   0.18800   0.00000   0.00000   0.000001.0001.000
  8.1211   12.729511.9228106  100.0000  -0.00656   0.00000   0.00000   0.00000
1031  ARL  203 1031   0.00000   0.00000   0.00000   0    0    0    1
  10.0000.000      1.0003.0001.0001.000
 0.000001702.00000   0.00126   0.25100   0.00000   0.00000   0.000001.0001.000
 0.050001702.00000   0.00126   0.25100   0.00000   0.00000   0.000001.0001.000
846.6521 2235.5967 0.2034760  100.0000  -0.82100   0.00000   0.00000   0.00000
1032  ARL  203 1032   0.00000   0.00000   0.00000   0    0    0    1
  10.0000.000      1.0003.0001.0001.000
 0.000001702.00000   0.00094   0.18800   0.00000   0.00000   0.000001.0001.000
 0.050001702.00000   0.00094   0.18800   0.00000   0.00000   0.000001.0001.000
```

```
1411.0005 2233.1838 0.0944595  100.0000  -1.15086   0.00000   0.00000   0.00000
1033  ARL  203 1033   0.00000   0.00000   0.00000   0    0    0    1
  10.0000.000      1.0003.0001.0001.000
 0.000001702.00000   0.00126   0.25100   0.00000   0.00000   0.000001.0001.000
 0.050001702.00000   0.00126   0.25100   0.00000   0.00000   0.000001.0001.000
1178.9180 2228.4338 0.1534510  100.0000  -0.85375   0.00000   0.00000   0.00000
1041  ARL  204 1041   0.00000   0.00000   0.00000   0    0    0    1
  10.0000.000      1.0003.0001.0001.000
 0.000001735.00000   0.00088   0.23600   0.00000   0.00000   0.000001.0001.000
 0.050001735.00000   0.00088   0.23600   0.00000   0.00000   0.000001.0001.000
  1.4090     3.727311.9807777  100.0000  -0.00234   0.00000   0.00000   0.00000
1042  ARL  204 1042   0.00000   0.00000   0.00000   0    0    0    1
  10.0000.000      1.0003.0001.0001.000
 0.000001735.00000   0.00088   0.23600   0.00000   0.00000   0.000001.0001.000
 0.050001735.00000   0.00088   0.23600   0.00000   0.00000   0.000001.0001.000
  2.3647     3.723111.9806004  100.0000  -0.00287   0.00000   0.00000   0.00000
1043  ARL  204 1043   0.00000   0.00000   0.00000   0    0    0    1
  10.0000.000      1.0003.0001.0001.000
 0.000001735.00000   0.00088   0.23600   0.00000   0.00000   0.000001.0001.000
 0.050001735.00000   0.00088   0.23600   0.00000   0.00000   0.000001.0001.000
  1.9733     3.715311.9806967  100.0000  -0.00239   0.00000   0.00000   0.00000
 105  ARL  505  705   0.00000   0.00000   0.00000   0    0    0    0
  10.0000.000      1.0003.0001.0001.000
 0.000001735.00000   0.00628   1.25700   0.00000   0.00000   0.000001.0001.000
 0.050001735.00000   0.00628   1.25700   0.00000   0.00000   0.000001.0001.000
 300  ARL  100  301   0.00000   0.00000   0.00000   0    0    0    0
  10.0000.000      1.0001.0001.0001.000
 0.000001000.00000   0.09700   0.80000   0.00000   0.00000   0.000001.0001.000
 1.680001200.00000   0.07110   1.18900   0.00000   0.00000   0.000001.0001.000
 301  TRP  301  302   0.00000   0.00000   0.00000   0    0    0    1
       5         1
 0.02000   0.10000   0.29000   0.49000   0.00000   0.00000
 0.000001552.00000   0.07110   1.18900   0.00000   0.00000   0.000001.0001.000
 0.620001552.00000   0.05320   1.02400   0.00000   0.00000   0.000001.0001.000
672.8770 1570.3069 0.1657013  100.0000  -0.74492   0.00000   0.00000   0.00000
 302  TRP  302  303   0.00000   0.00000   0.00000   0    0    0    1
       5         1
 0.02000   0.10000   0.29000   0.49000   0.00000   0.00000
 0.000001552.00000   0.05320   1.02400   0.00000   0.00000   0.000001.0001.000
 0.620001657.00000   0.05080   0.95100   0.00000   0.00000   0.000001.0001.000
621.5142 2028.9402 0.1677787  100.0000  -0.70905   0.00000   0.00000   0.00000
 303  TRP  303  304   0.00000   0.00000   0.00000   0    0    0    1
       5         1
 0.01500   0.15000   0.24000   0.42000   0.00000   0.00000
 0.000001657.00000   0.05080   0.95100   0.00000   0.00000   0.000001.0001.000
 0.620001678.00000   0.05360   1.07400   0.00000   0.00000   0.000001.0001.000
580.6677 2264.2681 0.1176063  100.0000  -1.16079   0.00000   0.00000   0.00000
 304  ARL  304  404   0.00000   0.00000   0.00000   0    0    0    0
  10.0000.000      1.0005.3001.0001.000
 0.000001678.00000   0.05360   1.07400   0.00000   0.00000   0.000001.0001.000
```

```
 0.300001664.00000   0.03730   1.12500   0.00000   0.00000   0.000001.0001.000
403  TRP  404  403   0.00000   0.00000   0.00000    0    0    0    1
      5         1
 0.01000   0.13000   0.19000   0.45000   0.00000   0.00000
 0.000001664.00000   0.03730   1.12500   0.00000   0.00000   0.000001.0001.000
 0.620001664.00000   0.04160   1.00000   0.00000   0.00000   0.000001.0001.000
560.8953 2261.8845 0.0817858 100.0000  -1.16171   0.00000   0.00000   0.00000
402  TRP  403  402   0.00000   0.00000   0.00000    0    0    0    1
      5         1
 0.01300   0.14500   0.23000   0.45000   0.00000   0.00000
 0.000001664.00000   0.04160   1.00000   0.00000   0.00000   0.000001.0001.000
 0.620001460.00000   0.03360   0.85100   0.00000   0.00000   0.000001.0001.000
564.2048 2024.0959 0.1229764 100.0000  -0.57247   0.00000   0.00000   0.00000
401  TRP  402  401   0.00000   0.00000   0.00000    0    0    0    1
      5         1
 0.01300   0.14500   0.23000   0.45000   0.00000   0.00000
 0.000001664.00000   0.03360   0.85100   0.00000   0.00000   0.000001.0001.000
 0.620001460.00000   0.14640   1.11100   0.00000   0.00000   0.000001.0001.000
599.1956 1562.0459 0.1220146 100.0000  -0.54009   0.00000   0.00000   0.00000
400  ARL  401  501   0.00000   0.00000   0.00000    0    0    0    0
  10.0000.000     1.0005.3001.0001.000
 0.000001460.00000   0.14640   1.11100   0.00000   0.00000   0.000001.0001.000
 0.300001481.00000   0.03430   0.98700   0.00000   0.00000   0.000001.0001.000
501  CHN  501  502   0.00000   0.00000   0.00000    0    0    0    1
 0.000001481.00000   0.03430   0.98700   0.00000   0.00000   0.000001.0001.000
 0.620001670.00000   0.02420   0.97300   0.00000   0.00000   0.000001.0001.000
715.0618 1567.5701 0.0655294 100.0000  -0.62907   0.00000   0.00000   0.00000
502  CHN  502  503   0.00000   0.00000   0.00000    0    0    0    1
 0.000001670.00000   0.02420   0.97300   0.00000   0.00000   0.000001.0001.000
 0.620001670.00000   0.01970   1.04500   0.00000   0.00000   0.000001.0001.000
599.6843 2026.2722 0.0711355 100.0000  -0.64388   0.00000   0.00000   0.00000
503  CHN  503  504   0.00000   0.00000   0.00000    0    0    0    1
 0.000001670.00000   0.01970   1.04500   0.00000   0.00000   0.000001.0001.000
 0.620001850.00000   0.01190   0.66100   0.00000   0.00000   0.000001.0001.000
619.8171 2265.9846 0.0518479 100.0000  -0.92953   0.00000   0.00000   0.00000
602  PED  502  702   0.00000   0.00000   0.00000    0    0    0    0
2 0 0     7  8.50.060  8.50.060  8.50.030  8.50.030  8.50.030  8.50.030  8.50.030
 0.0     1563.0                            0.045     0.927          1.   1.
 0.072001563.00000   0.00000   0.00000   0.04000   0.92700   0.000001.0001.000
 0.182001578.00000   0.00000   0.00000   0.03500   0.92700   0.000001.0001.000
 0.280001586.00000   0.00000   0.00000   0.03000   0.92700   0.000001.0001.000
 0.380001584.00000   0.00000   0.00000   0.02800   0.92700   0.000001.0001.000
 0.479001568.00000   0.00000   0.00000   0.02200   0.92700   0.000001.0001.000
 0.575001541.00000   0.00000   0.00000   0.02000   0.92700   0.000001.0001.000
 0.622001520.00000   0.00000   0.00000   0.02000   0.92700   0.000001.0001.000
603  PED  503  703   0.00000   0.00000   0.00000    0    0    0    0
2 0 0     7  5.70.060  5.70.060  5.70.030  5.70.030  5.70.030  5.70.030  5.70.030
 0.0     1693.0                            0.037     0.617          1.   1.
 0.072001693.00000   0.00000   0.00000   0.03200   0.61700   0.000001.0001.000
 0.178001702.00000   0.00000   0.00000   0.02500   0.61700   0.000001.0001.000
```

```
   0.273001720.00000  0.00000  0.00000  0.02400  0.61700  0.000001.0001.000
   0.368001732.00000  0.00000  0.00000  0.02300  0.61700  0.000001.0001.000
   0.468001722.00000  0.00000  0.00000  0.02200  0.61700  0.000001.0001.000
   0.558001682.00000  0.00000  0.00000  0.02100  0.61700  0.000001.0001.000
   0.610001684.00000  0.00000  0.00000  0.02000  0.61700  0.000001.0001.000
  604  PED  504  704  0.00000  0.00000  0.00000  0    0    0    0
2 0 0    7  6.20.060 6.20.060 6.20.030 6.20.030 6.20.030 6.20.030 6.20.030
   0.0    1746.0                        0.042    0.678           1.   1.
   0.085001746.00000  0.00000  0.00000  0.03900  0.67800  0.000001.0001.000
   0.184001760.00000  0.00000  0.00000  0.03200  0.67800  0.000001.0001.000
   0.275001780.00000  0.00000  0.00000  0.03000  0.67800  0.000001.0001.000
   0.368001800.00000  0.00000  0.00000  0.02700  0.67800  0.000001.0001.000
   0.474001792.00000  0.00000  0.00000  0.02200  0.67800  0.000001.0001.000
   0.576001768.00000  0.00000  0.00000  0.02000  0.67800  0.000001.0001.000
   0.620001760.00000  0.00000  0.00000  0.02000  0.67800  0.000001.0001.000
(eof)
```

Block 501 is the starting coating thickness.

```
(tof)
BLOCK  501    0    0 COATING THICKNESS
  0.002500
(eof)
```

Block 502 contains control parameters for finite element analysis. This file should also be given the name C0502.0 because it is fetched into the CRAY.

```
(tof)
BLOCK  FE
  13  17
2    58
4    2
7    5
9    9
11   14
13   27
1    56
3    30
5    31
6    33
8    37
10   42
12   55
1   2   LEADEDG
2   4   CV1PTHK
4   7   CV2PTHK
7   9   CV3PTHK
```

```
9   11  CV4PTHK
11  13  CV4PTHK
1   3   CV1STHK
3   5   CV2STHK
5   6   CV2STHK
6   8   CV3STHK
8   10  CV4STHK
10  12  CV4STHK
3   4   RIB1THK
6   7   RIB2THK
8   9   RIB3THK
10  11  PED1DIA
12  13  PED7DIA
```

Block 503 is used to control the optimization. This block should also be given the name C0503.0 and is fetched from the CRAY processor.

```
(tof)
$  E3 TEST CASE - 1ST TURBINE BLADE, FULL OPTIMIZATION   Block 503
$
$   RECALIBRATED, STARTING FROM BASELINE GEOMETRY
$
$  NECK GEOMETRY DATA
$
NECKGEOM 12.4378 .9892   .09193  .2977   .289    7.0
$
$   DESIGN VARIABLES FOR COOLING OPTIMIZATION
$
$VARIABLESUPPRS                          -30.     30.
$VARIABLECOATTHK                         -.0001   .02
$VARIABLEAXTILT                          -1.      1.
$VARIABLETANTILT                         -1.      1.
VARIABLERIB1THK1      1                  -.01     .01      0.000
VARIABLERIB1THK5      2                  -.01     .01      0.000
VARIABLERIB2THK1      3                  -.01     .01      0.000
VARIABLERIB2THK5      4                  -.01     .01      0.000
VARIABLERIB3THK1      5                  -.01     .01      0.000
VARIABLERIB3THK5      6                  -.01     .01      0.000
VARIABLECV1PTHK5      7                  -.01     .01      0.000
VARIABLECV1STHK5      8                  -.01     .01      0.000
VARIABLECV2PTHK5      9                  -.01     .01      0.000
VARIABLECV2STHK5      10                 -.01     .01      0.000
VARIABLECV3PTHK5      11                 -.01     .01      0.000
VARIABLECV3STHK5      12                 -.01     .01      0.000
VARIABLECV4PTHK5      13                 -.01     .01      0.000
VARIABLECV4STHK5      14                 -.01     .01      0.000
DEPEND   CV1PTHK1     7        0.8000
DEPEND   CV1STHK1     8        0.8000
DEPEND   CV2PTHK1     9        0.8000
```

```
DEPEND   CV2STHK1      10        0.8000
DEPEND   CV3PTHK1      11        0.8000
DEPEND   CV3STHK1      12        0.8000
DEPEND   CV4PTHK1      13        0.8000
DEPEND   CV4STHK1      14        0.8000
$VARIABLECAV1TSH        7                  -.01    .01
$VARIABLECAV2TSH        7                  -.01    .01
$VARIABLECAV3TSH        7                  -.01    .01
$VARIABLECAV1TSP        8                  -.01    .01
$VARIABLECAV2TSP        8                  -.01    .01
$VARIABLECAV3TSP        8                  -.01    .01
$VARIABLEPED1DIA        9                  -.01    .01
$VARIABLEPED2DIA        9                  -.01    .01
$VARIABLEPED3DIA        9                  -.01    .01
$VARIABLEPED4DIA        9                  -.01    .01
$VARIABLEPED5DIA        9                  -.01    .01
$VARIABLEPED6DIA        9                  -.01    .01
$VARIABLEPED7DIA        9                  -.01    .01
$VARIABLEPEDSPAC       10                  -.08    .5
$VARIABLEFLM1DIA       11                  -.005   .01
$VARIABLEFLM2DIA       11                  -.005   .01
$VARIABLEFLM3DIA       11                  -.005   .01
$VARIABLEFLM1SPC       12                  -.08    .5
$VARIABLEFLM2SPC       12                  -.08    .5
$VARIABLEFLM3SPC       12                  -.08    .5
$
$   CONSTRAINTS
$
$  F1 >= 1850
CONSTRNTFREQ1              2      0       1
         1850.0
$
$  F2 <= 2700
CONSTRNTFREQ2              1      0       2
         2700.0
$
OPTIMIZE 0      4       8       3552     15
(eof)
```

Block 504 contains parameters used by the processor for selecting network models. (Users should use the values indicated.)

```
(tof)
BLOCK  504    0    0 PARAMETERS FOR V544 POST PROCESSING
1
401
0 0
(eof)
```

Block 505 contains parameters used by the processor for conduction analysis. (Users should use the values indicated.)

```
(tof)
                                                          (Blank Card)
                 **  PRINT / PLOT  CONTROL  **

           0 <= GEOMETRY PRINT  ( 0-SHORT , 1-LONG )
           0 <= MATERIAL PRINT  ( 0-SHORT , 1-LONG )
           0 <= TRANSIENT PRINT ( 0-SHORT , 1-LONG )
           0 <= PLOTTER PAPER TYPE  ( 1 - VERSATEC
                                      2 - CALCOMP SMALL GRID
                                      3 - CALCOMP LARGE WHITE
                                      5 - CALCOMP LARGE GRID
                                     10 - CALCOMP SMALL WHITE  )
                                                          (Blank Card)
                  ** INTERNAL INDICATORS **

          50 <= NRLIM  - max outer loop iterations
           0 <= ISTBL  - check for stable time step (0-No , 1-Yes)
      0.0010 <= CLNGTH - minimum conducton length
      0.0010 <= ESOR   - inner loop convergence criterion
      0.0010 <= ENR    - outer loop convergence criterion
(eof)
```

Block 506 contains parameters used by the processor for network analysis post processing. (Users should use the values indicated.)

```
(tof)
BLOCK  506    0    0 NETWORK ANALYSIS POST-PROCESSING
   40    1
1480              V545 MAT1
 647              V545 COAT1
1480              V544 MAT1
YES               Use Coating
647              V544 COAT1
(eof)
```

Block 507 contains parameters used by the processor for 1-D Heat Transfer. (Users should use the values indicated.)

```
(tof)
BLOCK  507    0    0 1-D HEAT TRANSFER CONTROL
    1
  401
    3
    2    3    4
(eof)
```

Block 510 contains the optimization parameters. The system requires a zero file in order to create a base condition and start working toward the optimum. Block 510–0 contains general parameters.

```
(tof)
BLOCK  510    0    0 INSTRUCTIONS FROM ADS - GENERAL PARAMETERS
SUPPLY PRESSURE              0.00000
SECONDARY MATL ANGLE         0.00000
COATING THICKNESS            0.00000
AXIAL TILT                   0.00000
TANGENTIAL TILT              0.00000
(eof)
```

Block 510 contains the optimization parameters. The system requires a zero file in order to create a base condition and start working toward the optimum. Block 510–1 contains section parameters. The system requires five files, one for each section. Section 1 file is shown.

```
(tof)
BLOCK  510    1    0 INSTRUCTIONS FROM ADS - SECTION 1 PARAMETERS
RIB 1 THICKNESS              0.00000
RIB 2 THICKNESS              0.00000
RIB 3 THICKNESS              0.00000
CAV 1 PS THICKNESS           0.00000
CAV 1 SS THICKNESS           0.00000
CAV 2 PS THICKNESS           0.00000
CAV 2 SS THICKNESS           0.00000
CAV 3 PS THICKNESS           0.00000
CAV 3 SS THICKNESS           0.00000
CAV 4 PS THICKNESS           0.00000
CAV 4 SS THICKNESS           0.00000
CAV 1 TRIP HEIGHT            0.00000
CAV 1 TRIP PITCH             0.00000
CAV 1 TRIP ANGLE             0.00000
CAV 2 TRIP HEIGHT            0.00000
CAV 2 TRIP PITCH             0.00000
CAV 2 TRIP ANGLE             0.00000
CAV 3 TRIP HEIGHT            0.00000
CAV 3 TRIP PITCH             0.00000
CAV 3 TRIP ANGLE             0.00000
PED 1 DIA                    0.00000
PED 2 DIA                    0.00000
PED 3 DIA                    0.00000
PED 4 DIA                    0.00000
PED 5 DIA                    0.00000
PED 6 DIA                    0.00000
PED 7 DIA                    0.00000
PED SPACING                  0.00000
FH  1 DIAMETER               0.00000
FH  2 DIAMETER               0.00000
FH  3 DIAMETER               0.00000
FH  1 SPACING                0.00000
```

```
FH  2 SPACING                  0.00000
FH  3 SPACING                  0.00000
(eof)
```

Block 512 contains the flag points used to start the airfoil breakup into elements. The system requires five files, one for each section. Section 1 file is shown.

```
(tof)
BLOCK  512    1    0 FLAG POINTS FOR STAEBL
   22
 -0.518891 -0.105276  0.047639
 -0.386147 -0.046811  0.193324
 -0.274959 -0.034837  0.305396
 -0.141319 -0.060230  0.441815
 -0.020209 -0.118956  0.576608
  0.140521 -0.249907  0.784316
  0.207056 -0.323062  0.883202
  0.388269 -0.589085  1.205483
  0.415217 -0.638585  1.261834
  0.427353 -0.661883  1.288099
  0.454297 -0.716007  1.348556
  0.475306 -0.760652  1.397895
  0.487512 -0.787632  1.427504
  0.515839 -0.853387  1.499078
  0.526940 -0.880429  1.528299
  0.551050 -0.942031  1.594492
  0.560814 -0.968182  1.622446
  0.584699 -1.034822  1.693162
  0.595122 -1.065041  1.724972
  0.616980 -1.133801  1.797563
  0.625407 -1.159965  1.824673
  0.633910 -1.174540  0.000000
 -0.546310 -0.063300  0.037260
 -0.400000  0.010000  0.201490
 -0.273020  0.036360  0.029050
 -0.121000 -0.001000  0.191590
  0.016530 -0.059580  0.000000
  0.179220 -0.211390  0.232980
  0.245000 -0.291000  0.000000
  0.414330 -0.574460  0.332878
  0.440560 -0.625210  0.390006
  0.451540 -0.649450  0.416617
  0.476220 -0.705430  0.477796
  0.494710 -0.751750  0.527670
  0.506510 -0.779170  0.557521
  0.534070 -0.845800  0.629626
  0.544660 -0.873260  0.659057
  0.567000 -0.936000  0.725656
  0.576700 -0.962330  0.753715
  0.599110 -1.029790  0.824800
```

0.610000	-1.060000	0.856914
0.633110	-1.127020	0.927806
0.642000	-1.155000	0.957164
0.649530	-1.179850	0.000000
-0.579100	0.011910	0.966740
-0.323400	0.332510	0.542090
-0.176490	0.420240	0.862970
0.031000	0.390000	0.612980
0.123980	0.258890	0.806720
0.279390	0.007910	0.478880
0.340800	-0.157150	2.294390
0.473370	-0.548040	1.880693
0.491970	-0.606970	1.818898
0.499430	-0.628680	1.795942
0.518210	-0.686190	1.735444
0.534430	-0.737480	1.681651
0.542790	-0.763630	1.654198
0.564650	-0.833330	1.581151
0.572760	-0.860160	1.553123
0.593290	-0.927610	1.482617
0.601700	-0.955680	1.453315
0.622520	-1.021620	1.384167
0.631040	-1.051360	1.353230
0.652800	-1.118740	1.282402
0.661630	-1.149320	1.250573
0.668800	-1.173560	0.000000
-0.628680	0.035130	4.604794
-0.380465	0.393999	4.166534
-0.211113	0.509934	3.960953
0.083094	0.477296	3.652478
0.213269	0.311785	3.440909
0.322854	0.022714	3.131751
0.378523	-0.144890	2.955095
0.502444	-0.539193	2.541840
0.520392	-0.598369	2.480020
0.527035	-0.620336	2.457064
0.544524	-0.678242	2.396507
0.560058	-0.729783	2.342556
0.567941	-0.756135	2.314998
0.588557	-0.826454	2.241745
0.596265	-0.853535	2.213710
0.615088	-0.921629	2.143625
0.622853	-0.949819	2.114583
0.641722	-1.015903	2.045722
0.650660	-1.045202	2.014574
0.670719	-1.111206	1.944290
0.678102	-1.144553	1.911309
0.677870	-1.164780	0.000000

(eof)

Block 513 contains nominal radii of section information and factors related to pull calculations.

```
(tof)
BLOCK  513    0     0 GLOBAL SECTION RADII
    5       NSECT
  13.67800 ROOT
  16.14900 TIP                 0.1900
  13.67800     1 GEOMETRY      1.0130
  14.29600     2 ANALYSIS      1.0130
  14.91350     3 ANALYSIS      1.0130
  15.53100     4 ANALYSIS      1.0130
  16.14900     5 GEOMETRY      1.0500
(eof)
```

Block 514 contains information used to translate areas and perimeters of optimizer created geometry into network models.

```
(tof)
BLOCK  514    0     0 NETWORK TO SECTION/CAVITY CROSS REFERENCE TABLE
 PATH TYPE SECT  CAV       SECT  CAV  FHR NHLS
  200  ARL    0    0          1    1
  201  TRP    1    1          2    1
  202  TRP    2    1          3    1
  203  TRP    3    1          4    1
  204  CHN    4    1          0    0
 1021  ARL    2                         1    4
 1022  ARL    2                         2    4
 1023  ARL    2                         3    4
 1031  ARL    3                         1    4
 1032  ARL    3                         2    3
 1033  ARL    3                         3    4
 1041  ARL    4                         1    5
 1042  ARL    4                         2    5
 1043  ARL    4                         3    5
  105  ARL    5                         0
  300  ARL    0    0          2    1
  301  TRP    2    1          2    2
  302  TRP    2    2          3    2
  303  TRP    3    2          4    2
  304  ARL    4    2          4    3
  403  TRP    4    3          3    3
  402  TRP    3    3          2    3
  401  TRP    2    3          1    3
  400  ARL    1    3          1    4
  501  CHN    1    4          2    4
  502  CHN    2    4          3    4
  503  CHN    3    4          4    4
  602  PED    2    4          2    4
  603  PED    3    4          3    4
  604  PED    4    4          4    4
(eof)
```

Block 516 is used to control the finite element mesh This file should also be given the name C0516.0 because it is fetched into the CRAY.

```
(tof)
$$PARAM   NONLIN       NO
$$PARAM   STRESS       NO
$$PARAM   LOADID        1
$$PARAM    K6ROT  1.0E-4
$$PARAM  MAXITER       25
$$PARAM  CONVERG  STRAIN  .00005
MAT1           1 15.3+6              0.3 .000815
RFORCE         1                  237.83 0.        0.       1.
EIGR           1     GIV     50.  30000.       10       10       0        +EIGR2
+EIGR2    MAX
(eof)
```

8. REFERENCES

1. T/STAEBL Theoretical Manual (to be published).

2. Brown, K. W., "Aero/Structural Tailoring of Engine Blades (Aero/STAEBL)," NASA Contractor Report CR-180805, March 1988.

3. STAT Final Report (to be published).

4. STAT User's Manual (to be published).

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13. ABSTRACT ***(Maximum 200 words)***

The Thermal/Structural Tailoring of Engine Blades (T/STAEBL) system is a family of computer programs executed by a control program. The T/STAEBL system performs design optimizations of cooled, hollow turbine blades and vanes. This manual contains an overview of the system, fundamentals of the data block structure, and detailed descriptions of the inputs required by the optimizer. Additionally, the thermal analysis input requirements are described as well as the inputs required to perform a finite element blade vibrations analysis.

14. SUBJECT TERMS

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