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USER'S GUIDE - COMPUTER PROGRAM - COMBUSTOR RELIABILITY PREDICT--ETC(U)

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AFAPL-TR-77-8
Volume III

USER'S GUIDE - COMPUTER PROGRAM -
COMBUSTOR RELIABILITY PREDICTION

Vol II
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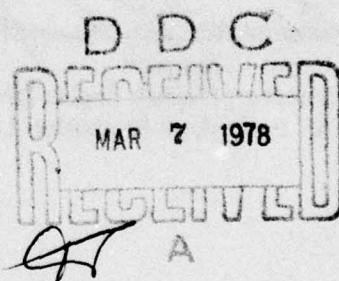
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WEST PALM BEACH, FLORIDA 33402

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Final Report for Period 15 June 1975 - 30 November 1976

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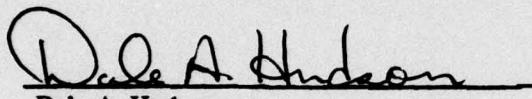
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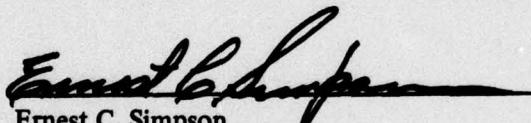
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This technical report has been reviewed and is approved for publication.


Dale A. Hudson
Project Engineer

FOR THE COMMANDER


Ernest C. Simpson
Director, Turbine Engine Division
Air Force Aero Propulsion Laboratory

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PREFACE

This final report was submitted by Pratt & Whitney Aircraft Group Government Products Division United Technologies Corporation, under Contract F33615-75-C-2057. The effort was sponsored by the Air Force Aero Propulsion Laboratory, Air Force Systems Command, Wright-Patterson AFB, Ohio with Dale Hudson/TBC as Project Engineer. Barry Schlein of Pratt & Whitney Aircraft was technically responsible for the work.

Technical assistance provided by W. H. Vogel and M. T. Loferski was essential to the completion of the project.

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SECTION I

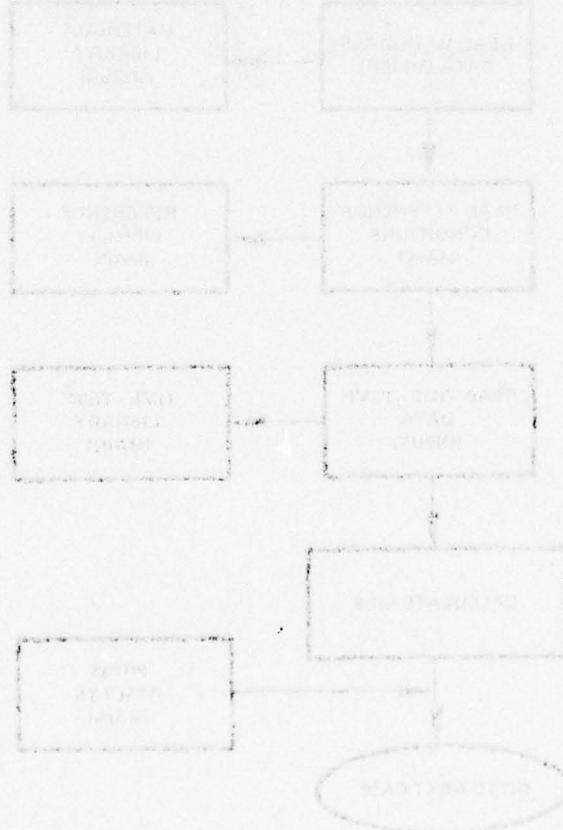
INTRODUCTION

This document is a user's guide to the Combustor Reliability Prediction Program.

The program relates burner crack initiation life and louver lip buckling life to the boundary conditions of compressor exit and turbine inlet temperature, expressed as a function of time. The user must provide a set of reference conditions; metal temperature and strain range for a particular set of compressor exit and turbine inlet gas temperatures. The program then integrates the damage for each failure mode over the flight and provides a predicted life.

Section 2 of the document provides a program flow map, an engineering description, and a definition of the function of each subroutine. A detailed engineering description, including failure model selection, model development and program sensitivity studies, are provided in the final report for this Contract (Volume I).

Section 3 contains the input instructions, a listing of input for a sample case and the corresponding program output.



SECTION II

PROGRAM DESCRIPTION

1. General Description

The Combustor Reliability Computer program described in this report is a FORTRAN program compiled on both an IBM 370/168 at P&WA and a CDC 2000 for use at Wright-Patterson AFB. An overview of the program is provided in schematic form in Figure 1. The figure traces the flow of the calculation from the input stages through the calculation of component environment and incremental damage at each portion of the flight to the final summation of the damage for the mission. The appropriate subroutines are indicated by name in parenthesis in each box.

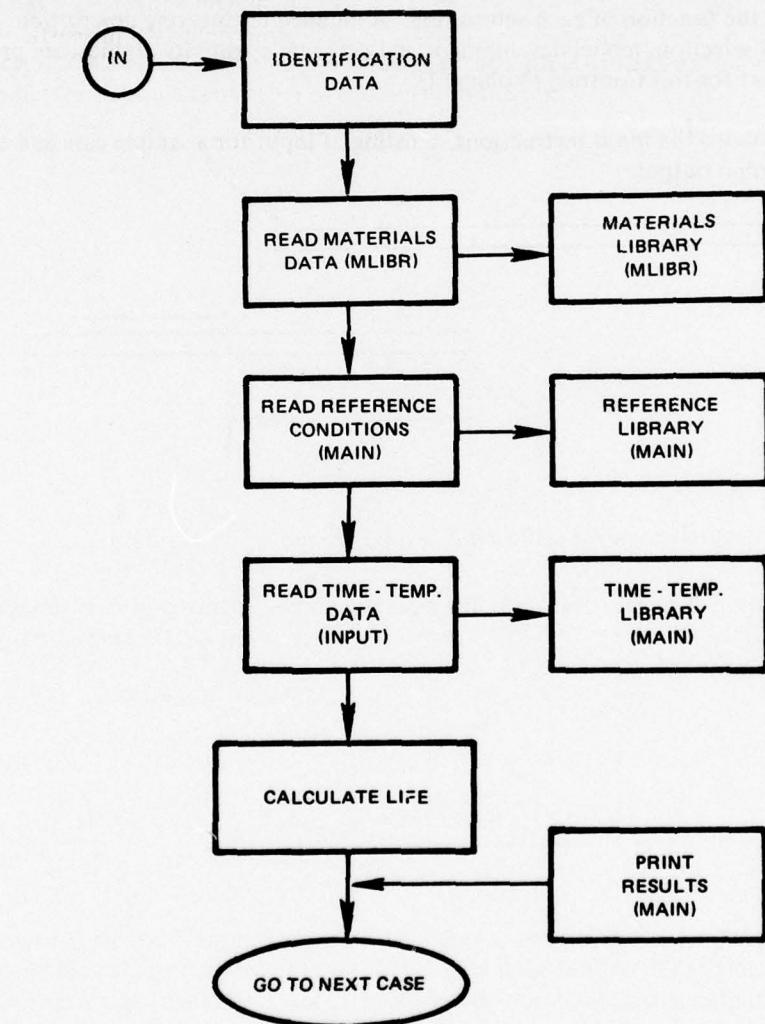


Figure 1. CRC Program Overview

TABLE 1
List Of Names, Routines, and Functions

<u>Name</u>	<u>Type</u>	<u>Purpose</u>
INPUT	Subroutine	reads in flight condition, temperature, and flight time
MAIN	Main Program	directs mission analysis program flow and calculates turbine metal temperature, stress, and strain range; reads in reference condition
MLIBR	Subroutine	reads and organizes materials' properties for turbine life analysis
UNBAR	Subroutine	interpolates two-dimensional tables

2. Life Calculation

a. Burner Creep-Low Cycle Fatigue (LCF) Cracking

This model, and the following one defining burner lip buckling life, are described in detail in the final report for this contract (Volume I).

The nomenclature for this section is described in Figure 2 and the following table.

- A, B = Influence coefficients for temperature referencing
- B_t = Time - temperature dependent plastic stress-strain relationship
- C = Strain-temperature proportionality constant, a function of material and radius.
- D_p = Material ductility
- E = Youngs modulus
- f = Flight increment
- K₁ = Temperature dependent plastic strain relationship
- L = Life
- m = Total number of increments
- n = Slope of the material LCF curve
- N_c = Damage fraction associated with creep
- N_f = Damage fraction associated with LCF
- T_K = Louver knuckle temperature

T_M	= Metal temperature
T_{MR}	= Reference condition metal temperature
T_1	= Combustor inlet temperature
T_{1R}	= Combustor inlet temperature under reference conditions
T_2	= Combustor exit temperature
T_{2R}	= Combustor exit temperature under reference conditions
$\Delta\epsilon_c$	= Endurance limit strain range
$\Delta\epsilon_{TR}$	= Total strain range

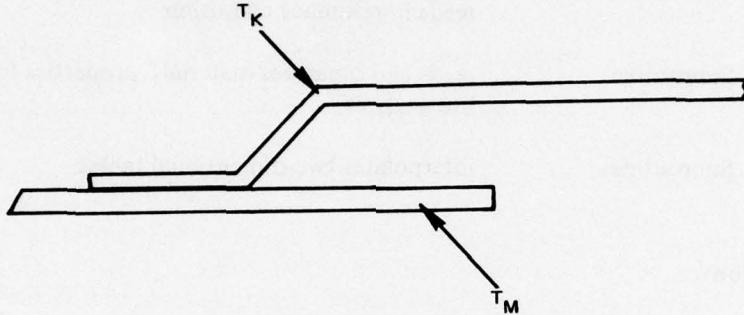


Figure 2. Burner Creep - LCF Nomenclature

At any flight condition, the metal temperature is related to temperatures at the reference conditions by:

$$T_M = T_{MR} + A(T_1 - T_{1R}) + B(T_2 - T_{2R}) \quad (1)$$

The cold knuckle of the louver (See Figure 2) is

$$T_K = T_1 + 20^{\circ}\text{F} \quad (2)$$

and the total strain range is calculated from

$$\Delta\epsilon_{TR} = C [T_M - T_K] \quad (3)$$

The program has built in curves of C as a function of radius for bending and hoop stress. The user selects the failure mode (axial or circumferential cracking). A fatigue damage fraction is calculated for take-off conditions (equation 4) and a creep damage factor is calculated over the entire flight spectrum (equation 5).

$$N_f = \left(\frac{\Delta\epsilon_{TR} - \Delta\epsilon_e}{D_p} \right)^{1.667} \quad (4)$$

$$N_c = \left[\frac{(\Delta\epsilon_{TR})^{1/n}}{1.25 D_p E} \right]^{1.25} \left\{ \left[K_1^{-1/n} - (B_t)_{i-1}^{-1/n} \right] + \sum_{i=2}^m \left[B_t_{i-1}^{-1/n} - B_t_i^{-1/n} \right] \right\}^{1.25} \quad (5)$$

The values of $\Delta\epsilon_e$, D_p , E , K_1 and B_t are functions of temperature (B_t is a function of time as well) and are obtained by interpolation of input data tables. The cracking life is then:

$$L = \frac{f}{N_c + N_f} \quad (6)$$

b. Burner Louver Lip Buckling

The burner louver lip buckling model is a dual mechanism failure model of thermal buckling and coating induced buckling. Failure is considered to occur when the lip is completely closed. Temperatures for this failure model are the same as those used in the creep - LCF model described in the preceding section (equations 1 and 2). Nomenclature for this section is described in Figure 3 and in the table below:

b	= Materials property parameter
C_{ri}	= Hoop restraint factor
C_{ro}	= Geometric hoop restraint factor
E	= Youngs modulus
i	= flight increment
k	= Lip buckling coefficient
L	= Lip length
m	= Material property parameter

n	= total number of flight increments
T_C	= Critical buckling temperature
T_K	= Louver knuckle temperature
T_M	= Louver lip temperature
t	= time
t_f	= time to failure
W	= Lip height
W_t	= Thermal buckling
δ	= Strip coating deflection
Δt	= Time increment

The subscript MAX refers to the largest value over the course of the mission while the superscript* indicates an equivalent value as explained in the text.

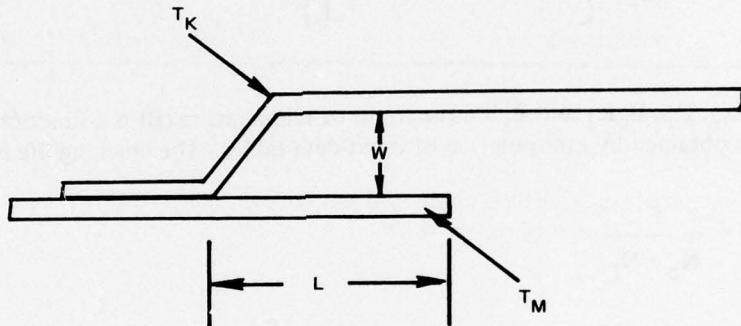


Figure 3. Burner Louver Lip Collapse Nomenclature

The temperature below which thermal buckling will not occur, called the critical buckling temperature, is determined from:

$$T_C = \Delta \epsilon_{ce} / k + T_K \quad (7)$$

where:

$$\Delta \epsilon_{ce} = \frac{\Delta \epsilon_{cp} E' + m \ln(\Delta \epsilon_{cp}) + b}{E + E'} \quad (8)$$

The values of E , m and b are functions of the material and hot metal temperature T_M while E' is Young's Modulus, evaluated at the cold knuckle temperature. The value of k is a function of the lip geometry and $\Delta \epsilon_{cp}$ is calculated from built in curves that relate the critical plastic strain to the lip temperature and buckling coefficient.

If the critical buckling temperature is exceeded, the lip buckles by an amount relative to the total strain. The curve, independent of material and radius, is built into the program. The program takes the maximum value of lip strain to calculate the thermal buckling.

Superimposed upon the thermal buckling is a coating induced buckling which forces the lip to close as a result of volumetric lip changes in the coating. The amount of closure is proportional to the geometry, temperature, and time at temperature. In any time increment, the amount of closure is:

$$W_{c_i} = C_{r_i} \left(\frac{L}{1.5} \right)^2 \delta_i \quad (9)$$

C_{r_i} is a geometric restraint factor that varies from C_{r_0} at or below the critical buckling temperature to 1 at 2000°F (1367°K). C_{r_i} is a function of lip geometry and is a part of the program. The coating strip deflection δ_i is a function of time at temperature and is computed from curves that are also a part of the program.

Since the lip temperature varies with each flight increment, an equivalent term is calculated to reach the deflection just prior to the start of the increment and at the new temperature. If δ_{i-1} represents the coating strip deflection up to the flight increment and T_{M_i} the new lip temperature:

$$t^*_{i-1} = f \left[\delta_{i-1}, T_{M_i} \right] \quad (10)$$

$$\delta_i = f \left[t^*_{i-1} + \Delta t_i, T_{M_i} \right] - \delta_{i-1} \quad (11)$$

At the conclusion of the flight, an equivalent temperature is calculated such that

$$T^* = f \left[\sum_{i=1}^n \delta_i \sum_{i=1}^n t_i \right] \quad (12)$$

Since failure is assumed to be the complete lip closure, the amount of strip coating closure for failure is

$$\delta_f = \frac{W - W_{t \max}}{C_{r \max}} \left(\frac{L}{1.5} \right)^2 \quad (13)$$

and the time to complete collapse

$$t_f = f \left[\delta_f, T^* \right] \quad (14)$$

SECTION III

PROGRAM OPERATION

This section describes both the input information and format required to run the mission analysis-failure model program, and the output from the program. A sample case (input and output) is also provided.

1. Program Input

a. Program Instructions

Details of the input for this deck, and the format of the input, are described in the following pages. Each page (or more than one page if required) illustrates and describes each data card or type of data card. Each card or type of card is divided into fields, or sequences of card columns, into which are entered the input parameter values.

Data will always be input in one of the three following forms:

- Floating point number (denoted by F. P.) – this form of input may consist of the characters “+”, “-” 0-9, and “.” (decimal point). If neither “+” nor “-” is input, then a positive number is assumed. The decimal point must be input unless otherwise specified. If the decimal point is input, then a number may be entered anywhere within its field. An additional character, “E”, may be used to input a floating point number with an exponent. For instance, the number 13,460,000.0 may be input as .1346 E8 or the number 0.0000001346 may be input as .1346 E-6. When a number is input with an exponent, then the exponent (E-6 for example) must be right adjusted within its field.
- Integer number (denoted by INT.) – this form of input may consist of the same characters as a floating point number except for the decimal point (a decimal point must not be input). An integer number must be right-adjusted within its field.
- Alphanumeric input (denoted by A/N) – this form of input may consist of any character available on the computer and may be entered anywhere within its field.

If the input field for a floating point number or an integer number is left blank, then a zero is assumed. Blanks in alphanumeric input will be blank characters.

b. Input Package

The input package is divided into three parts, as described below:

- Part 1 consists of the first card indicating the number of cases to be run and the number of burner material packages to be input.
- Part 2 (card types 2-7) defines the material properties. Up to five packages can be loaded.

- Part 3 is the reference condition package including eight data cards.

The case title card (card type 8) indicates the number of reference conditions, up to 5. The program will generate a life prediction for each reference condition input.

Card type 9 describes the flight duration and frequency used for averaging damage over a mixed set of missions.

Card type 10 identifies the material and the failure mode (cracking or buckling).

Card type 11 indicates the number of reference modes (louvers) to be analyzed plus the units of temperature input.

Card type 12 identifies the compressor exit and turbine inlet temperatures at the reference conditions.

A card type 13 is required for each louver to be analyzed to define parameters for either the cracking or buckling failure model.

Card type 14 identifies the flight condition and the time-gas temperature boundary condition.

The last card of each case (type 15) contains a minus 1.

NOTE

The input data cards, as described above, are illustrated on pages 10-24 following.

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Card Type: 1

Title: Indicator Card

General Instruction:

NCASES	IBRN	
0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 E9 70 71 72 73 74 75 76 77 78 79 80

Name	Type	Column(s)	Description
NCASES	INT	1-10	Total number of cases to be run (no limit). Each case is described by cards 8-14.
IBRN	INT	11-20	Number of Burner Material Packages input, up to a maximum of 5. Input described by card types 2-7.

Card Type: 2**Title:** Burner Material Package**General Instruction:**

Input package IBRN times if IBRN >0 on card Type 1, Columns 11-20.

NAME		BURNER MATERIAL PACKAGE																																																																													
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0																																													
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

Name	Type	Column(s)	Description
NAME	INT	1-4	Material name (1038, 5566, etc.)
TITLE	A/N	9-80	Descriptive title of material package.

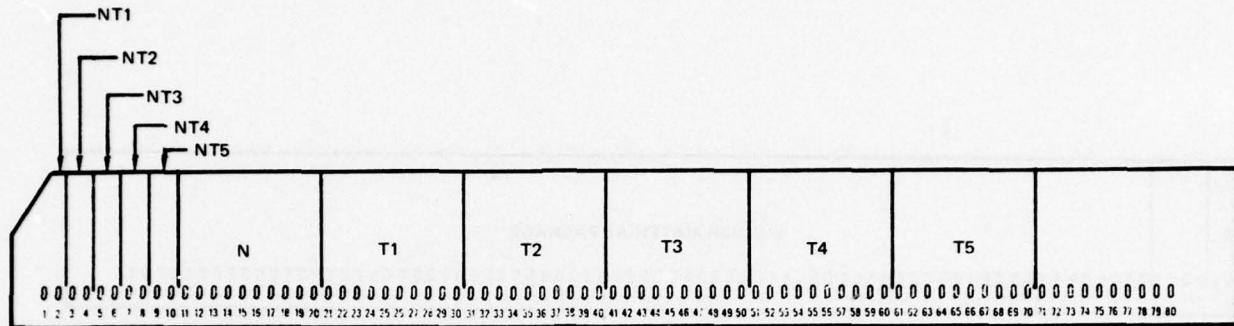
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Card Type: 3

Title: Burner Material Package

General Instruction:

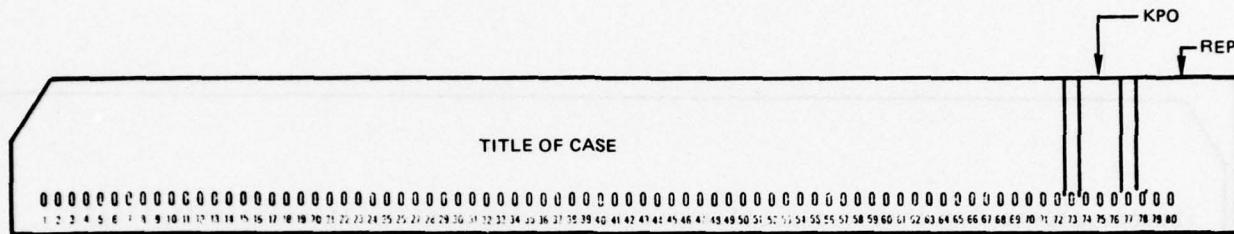


Name	Type	Column(s)	Description
NT1	INT.	1-2	Number of metal temperatures used to define parameters on card type 30 Max = 9
NT2	INT.	3-4	Number of metal temperatures used to define BT curve. Max = 9
NT3	INT.	5-6	Number of ϵ_{TR} and corresponding buckled deflection values input. Max = 15
NT4	INT.	7-8	No. of Tm for ϵ_{CP} curve
NT5	INT.	9-10	NT + NT5 ≤ 20 No. of buckling coeff. for ϵ_{CP} curve
N	F.P.	11-20	Material constant (N = 2.35 for 1038)
T1	F.P.	21-30	
T2	F.P.	31-40	
T3	F.P.	41-50	Time input for BT curve (input in ascending order)
T4	F.P.	51-60	
T5	F.P.	61-70	

Card Type: 8 (Required)

Title: Case Information

General Instruction:



Name	Type	Column(s)	Description
TITLE	A/N	1-72	Descriptive title describing case.
KPO	INT	74-76	Printout Option 0 – Standard 1 – Expanded
KREF	INT	78-80	Number of reference conditions up to a maximum of 5.

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Card Type: 9

Title: Case Information

General Instruction:

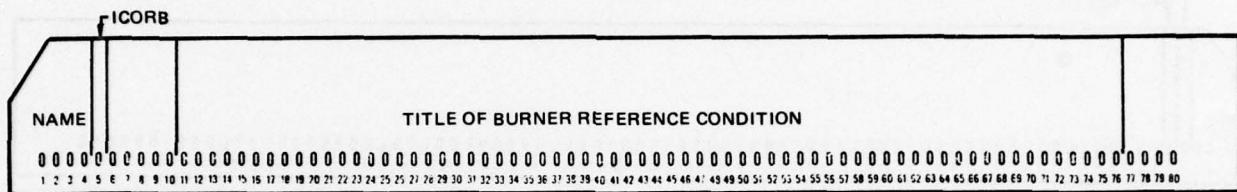
00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 10 11 12 13 14 15 16 17 18 19 80

Name	Type	Column(s)	Description
BT	F.P.	1-10	Block time - hours.
TT	F.P.	11-20	Taxi time - minutes.
FREQ	F.P.	21-30	Frequency of flights. When more than one case is run; the program will weight the damage for each case and print a summary life based upon each case and its frequency.

Card Type: 10

Title: Burner Cracking or Buckling Reference Condition

General Instruction:



Name	Type	Column(s)	Description
Name	INT.	1-4	Material name (1038, 5536, etc.)
ICORB	INT.	5	Indicator for cracking or buckling model (1 = cracking, 2 = buckling)
Title	A/N	11-76	Descriptive title or burner reference condition

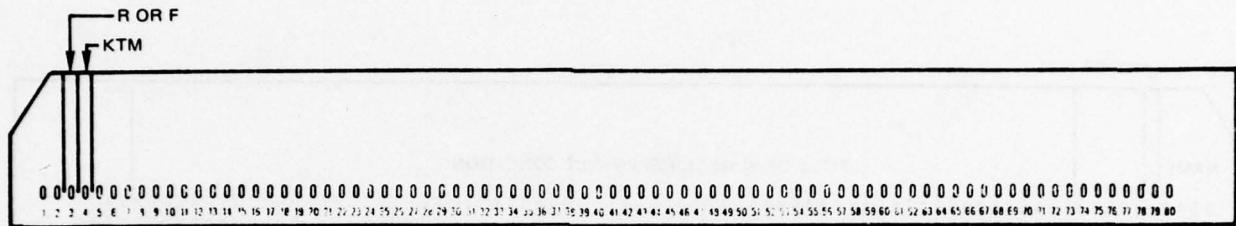
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Card Type: 11

Title: Burner Reference Condition

General Instruction:

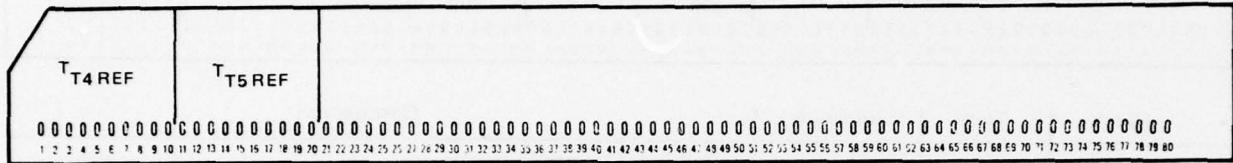


Name	Type	Column(s)	Description
NR	INT	1-2	Number of louvers, up to a maximum of 9, examined
RORF	INT	3	$^{\circ}\text{R}$ or $^{\circ}\text{F}$ ($0 = ^{\circ}\text{R}$, $1 = ^{\circ}\text{F}$)
KTM	INT	4	= 1 for burner

Card Type: 12

Title: Burner Reference Condition

General Instruction:



Name	Type	Column(s)	Description
TT4 Ref	F.P.	1-10	Reference T_{T4} ($^{\circ}$ R or $^{\circ}$ F)
TT5 Ref	F.P.	11-20	Reference T_{T5} ($^{\circ}$ R or $^{\circ}$ F)

Card Type: 13

Title: Burner Reference Condition

General Instruction:

Repeat NR Times

F8.5	F8.5	F8.5	F8.5	F8.5	F8.5	F8.5	F8.2	F8.2	F8.2
RAD	L	L ² /RH	W	CHB	A _{REF}	B _{REF}	BTMR	T ₄ (FI)	T ₅ (FI)
0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80									

Name	Type	Column(s)	Description		
RAD	F.P.	1-8	Radius of louver in inches		
L	F.P.	9-16	Louver lip length in inches – (not input if ICORB = 1)		
L2/RH	F.P.	17-24	Non-dimensional constant – (not input if ICORB = 1)		
W	F.P.	25-32	Non-deflected louver lip gap (See Fig. below)		
CHB	F.P.	33-40	Hoop or bending stress	1. = bending stress outer liner 2. = hoop stress - outer liner 3. = hoop stress - inner liner	
AREF	F.P.	41-48	Influence coefficient for T ₄	T _M = A _{REF} (T ₄ - T ₄ REF) + B _{REF} (T ₅ - T ₅ REF) + B _{TMR}	
BREF	F.P.	49-56	Influence coefficient for T ₅		
BTMR	F.P.	57-64	Reference Metal Temperature		
T4(FI)	F.P.	65-72	Flight idle T ₄		
T5(FI)	F.P.	73-80	Flight idle T ₅		

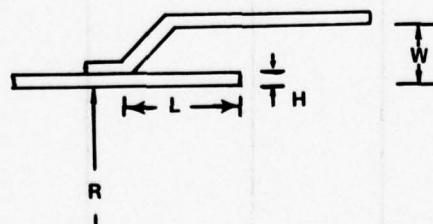


Figure 4 Louver Geometry

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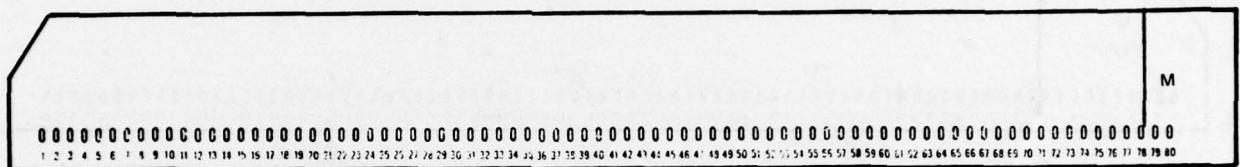
Volume III

Card Type: 15 (Required)

Title: Finalizing Card

General Instruction:

If M = 0 on this card, this card would then be the last card. If M = -1 then card type 1 must follow this card.



Name	Type	Column(s)	Description
M	INT	79-80	-1 indicates end of the data for the case.

c. Sample Case (Input and Output)

Table 2 consists of a listing of the input for a sample test case. The numbers to the right of the input listing on Table 2 indicate the card type corresponding to the preceding input instructions.

The test case predicts combustor creep low cycle fatigue (LCF), and lip buckling life, for two cases.

TABLE 2

Sample Case

FILE: W508AF DATA

	2	1								1
1038	JT9D	BRN	MAT'L PACKAGE	CRP-LCF, LOUVER BUCKLING RM	11/4/76 (BASE)					2
8 511 6	92.35		.01	.03	.1	.5	1.			3
1000.	.745	E 0.495	E 0.396	E-2.246	E 8.76	E-6.118	E 5.102	E 6		
-.35229E	1.00	E 0								
1400.	.805	E 0.535	E 0.291	E-2.22	E 8.14	E-5.1045	E 5.9	E 5		
-.23979E	1.00	E 0								
1500.	.720	E 0.485	E 0.265	E-2.21	E 8.157	E-5.94	E 4.82	E 5		
-.20458E	1.125	E 0								
1600.	.595	E 0.395	E 0.238	E-2.198	E 8.19	E-5.775	E 4.688	E 5		
-.16990E	1.23	E 0								
1700.	.480	E 0.315	E 0.21	E-2.184	E 8.277	E-5.56	E 4.51	E 5		
-.13768E	1.318	E 0								
1800.	.380	E 0.250	E 0.18	E-2.165	E 8.502	E-5.37	E 4.344	E 5		
-.10783E	1.38	E 0								
1900.	.31	E 0.200	E 0.149	E-2.136	E 8.770	E-5.213	E 4.213	E 5		
-.82390E	0.428	E 0								
2000.	.255	E 0.170	E 0.117	E-2.77	E 7.1063	E-4.99	E 3.1	E 5		
-.63830E	0.47	E 0								
1000.	.179	E-8.185	E-8.198	E-8.222	E-8.237	E-8				
1500.	.275	E-5.345	E-5.49	E-5.87	E-5.113	E-4				
1600.	.58	E-5.83	E-5.135	E-4.28	E-4.395	E-4				
1700.	.98	E-5.166	E-4.28	E-4.56	E-4.97	E-4				
1800.	.15	E-4.265	E-4.53	E-4.145	E-3.227	E-3				
0.	E 0.2	E-3.4	E-3.6	E-3.8	E-3.1	E-2.15	E-2.2	E-2		
.3	E-2.4	E-2.6	E-2.0	E 0.8	E-2.12	E-1.152	E-1.178	E-1		
.2	E-1.243	E-1.278	E-1.332	E-1.378	E-1.462	E-1				
.14	E 4.15	E 4.16	E 4.17	E 4.18	E 4.19	E 4.0	E 0.1	E-2		
.2	E-2.3	E-2.4	E-2.5	E-2.1	E-1.15	E-1.2	E-1.0	E 0		
.67	E-3.11	E-2.145	E-2.175	E-2.205	E-2.338	E-2.462	E-2.578	E-2		
.0	E-0.63	E-3.105	E-2.14	E-2.17	E-2.2	E-2.333	E-2.452	E-2		
.565	E-20.	E 0.55	E-3.98	E-3.134	E-2.163	E-2.191	E-2.320	E-2		
.438	E-2.552	E-2.0	E 0.54	E-3.93	E-3.126	E-2.152	E-2.179	E-2		
.302	E-2.412	E-2.517	E-2.0	E 0.4	E-3.82	E-3.113	E-2.14	E-2		
.165	E-2.28	E-2.385	E-2.485	E-2.0	E 0.38	E-3.72	E-3.1	E-2		
.126	E-2.15	E-2.257	E-2.354	E-2.447	E-2					
D7A LKAVGMISIION	10/11/76								1	2
4.0	10.0	1.0								9
10381	HAST-X	BRN CRACKING MODEL	RM	10/76						10

TABLE 2 (Cont'd)

111									11
1028.	2700.								12
15.	.4	.237	.11	2.	.6	.4	1870.	486.	1295.
10382	HAST-X BRN BUCKLING MODEL RM 8/3/76								13
111									10
1028.	2700.								11
15.	.4	.237	.11	3.	.6	.4	1870.	486.	1295.
	1	1480.	3024.	2.					12
	2	1354.	2782.	18.					13
	3	1260.	2660.	30.					
	3	1260.	2660.	30.					
	3	1260.	2660.	30.					
	3	1260.	2660.	30.					
	3	1260.	2660.	30.					
	3	1260.	2660.	30.					
	3	1260.	2660.	12.					

FILE: W508AF DATA A

4	1150.	2500.	18.0				14
5	1356.	2735.	.25				
D7A LKAVGMISISON 10/11/76						-1	15
4.0	10.0	1.0			1	0	8
							9
1	1410.	2960.	2.				
2	1335.	2680.	18.				
3	1160.	2360.	120.				
4	1110.	2260.	18.				
5	1360.	2660.	.25				
						-1	15

2. Program Output

This section notes the program output listing (Table 3) corresponding to the sample case in Table 2 above. The output has been labeled along the left margin with letters which correspond to the section in the description below:

Section	Description
A	Burner materials properties
B	Title and flight description
C1	Reference condition 1, cracking model
C2	Reference condition 2, buckling model
D	Flight condition - time - temperature relationship
E	Description of part life at the end of each increment of the flight profile. Note that the creep and fatigue fractions are all cumulative and are shown for each reference conditions.
E1	This portion of section E is only printed when KPO = 1, and represents the long form print out. Intermediate calculated quantities are printed.
F	Printout of mission life and breakdown of damage by flight portion.
G	Weighted average of the damage and damage breakdown for all the missions run.

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TABLE 3
PROGRAM OUTPUT LISTING

MATN= 0		IBRN= 1		1038 JT9D BRN MAT'L PACKAGE CRP-LCF, LOUVER BUCKLING RM 11/4/76 (BASE)	
--BURNER MATERIAL PROPERTIES--					
	ETR	WB			
0.0	0.0	0.0			
0.2000E-03	0.8000E-03	0.1200E-01			
0.4000E-03	0.1520E-01				
0.6000E-03	0.1780E-01				
0.8000E-03	0.2000E-01				
0.1000E-02	0.2430E-01				
0.1500E-02	0.2780E-01				
0.2000E-02	0.3320E-01				
0.3000E-02	0.3780E-01				
0.4000E-02	0.4620E-01				
0.6000E-02					
CRITICAL PLASTIC STRAIN					
TH-KB	0.0	0.00100	0.00200	0.00300	0.00400
1400.000	0.0	0.6700E-03	0.1100E-02	0.1450E-02	0.1750E-02
1500.000	0.0	0.6300E-03	0.1050E-02	0.1300E-02	0.1700E-02
1600.000	0.0	0.5500E-03	0.9800E-03	0.1340E-02	0.1630E-02
1700.000	0.0	0.5400E-03	0.9300E-03	0.1260E-02	0.1520E-02
1800.000	0.0	0.4000E-03	0.9200E-03	0.1130E-02	0.1400E-02
1900.000	0.0	0.3800E-03	0.7200E-03	0.1000E-02	0.1260E-02
THETAL					
1000.000	DP (SMOOTH)	DP (WELLED)	DETAILE	E	K1
1400.000	0.7450E+00	0.4950E+00	0.3960E-02	0.2460E+08	0.7600E-06
1500.000	0.8050E+00	0.5350E+00	0.3910E-02	0.2200E+08	0.1400E-05
1600.000	0.7200E+00	0.4850E+00	0.2650E-02	0.2100E+08	0.1570E-05
1700.000	0.4800E+00	0.3150E+00	0.2100E-02	0.1980E+08	0.1900E-05
1800.000	0.3800E+00	0.2500E+00	0.1800E-02	0.1840E+08	0.2770E-05
1900.000	0.3100E+00	0.2000E+00	0.1490E-02	0.1360E+08	0.5020E-05
2000.000	0.2550E+00	0.1700E+00	0.1170E-02	0.7700E+07	0.7700E-07
THETAL					
	T1= 0.010	T2= 0.030	BT	T3= 0.100	T4= 0.500
1000.000	0.1790E-08	0.1650E-08		0.1980E-08	0.2220E-08
1500.000	0.2750E-05	0.3450E-05		0.4900E-05	0.8700E-05
1600.000	0.5800E-05	0.8300E-05		0.1350E-04	0.3950E-04
1700.000	0.9800E-05	0.1660E-04		0.2800E-04	0.9700E-04
1800.000	0.1500E-04	0.2650E-04		0.5300E-04	0.1450E-03

A

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AFAPL-TR-77-8
Volume III

TABLE 3 (Cont'd)

W50607 MISSION ANALYSIS-- 6/14/77 VERSION	
D7A LKAVMISSION 10/11/76	
B	CASE INFORMATION KPO= 1 KREF= 2
	BLOCK TIME= 4.000 HRS TAXI TIME= 10.0 MIN FLIGHT FREQUENCY= 1.00
	***** REFERENCE CONDITION NC. 1 1038 HAST-X BRN CRACKING MODEL RM 10/76
	BURNER CRACKING MODEL
	METAL TEMPERATURE CALCULATED BY $T_M = T_{MR} + A * (T_4 - T_{RR}) + B * (T_5 - T_{SR})$
C1	REFERENCE POINT NO. 1 RADIUS= 15.000 IN. STRESS TYPE IS HOOP-CUTTER LINER A CONSTANT= 0.600 B CONSTANT= 0.400 TMR= 1870.000 LOUVER LIP LENGTH = 0.4000 $1^{**2}/RH = 0.2370$ NON-DEFLECTED LOUVER GAP--W=0.1100 BURNER KB=0.011470 REFERENCE DETH=0.003062 FLIGHT IDLE--T4= 486.00 T5= 1295.00 DETH=0.1776E-02
	***** REFERENCE CONDITION NC. 2 1038 HAST-X BRN BUCKLING MODEL RM 8/3/76
	LOUVER BUCKLING MODEL
	METAL TEMPERATURE CALCULATED BY $T_M = T_{MR} + A * (T_4 - T_{RR}) + B * (T_5 - T_{SR})$
C2	REFERENCE POINT NO. 1 RADIUS= 15.000 IN. STRESS TYPE IS HOOP-INNER LINER A CONSTANT= 0.600 B CONSTANT= 0.400 TMR= 1870.000 LOUVER LIP LENGTH = 0.4000 $1^{**2}/RH = 0.2370$ NON-DEFLECTED LOUVER GAP--W=0.1100 BURNER KB=0.011470 REFERENCE DETH=0.003062 FLIGHT IDLE--T4= 486.00 T5= 1295.00 DETH=0.1776E-02

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TABLE 3 (Cont'd)

--- INPUT FLIGHT CONDITIONS ---

FLIGHT COND	TT4	TT5	FLIGHT TIME
D	1 1480.	3024.	2.
	2 1354.	2782.	18.
	3 1260.	2660.	30.
	3 1260.	2660.	30.
	3 1260.	2660.	30.

***** LIFE CALCULATIONS *****

FLIGHT COND	TT4	TT5	FLIGHT TIME
E1	1 1480.	3024.	2.
	{ DETR=0.3873E-02 TH=0.1811E+04 TK=0.1040E+04 TC=0.1754E+04 CRMCR=0.2092E-03 TDAMFA=0.2896E-03		
REP COND	REP PT.	CREEP FRAC	FATIGUE FRAC
1	1	0.2092E-03	0.2896E-03
2	1	0.1250E-01	

FLIGHT COND	TT4	TT5	FLIGHT TIME
E1	2 1354.	2782.	18.
	{ DETR=0.3873E-02 TH=0.1639E+04 TK=0.9140E+03 TC=0.1733E+04 CRMCR=0.2505E-03 TDAMFA=0.2896E-03		
REP COND	REP PT.	CREEP FRAC	FATIGUE FRAC
1	1	0.2505E-03	0.2896E-03
2	1	0.1923E-01	

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TABLE 3 (Cont'd)

FLIGHT COND	TT4	TT5	FLIGHT TIME
E1	3 $\{ \begin{array}{l} DETR=0.3873E-02 \\ TH=0.1533E+04 \end{array} \}$	1260. $\{ \begin{array}{l} 2660. \\ DTB=0.1533E+04 \end{array} \}$	30. $\{ \begin{array}{l} 7132E+03 \\ TC=0.1687E+03 \end{array} \}$ TDAMCR=0.2607E-03 CRMAX=0.6874E+00 WBMAX=0.2959E-01 ECE=0.2622E-02 DT=0.2149E-01
REF COND	REF PT.	CREEP FRAC	FATIGUE FRAC
1	1	0.2607E-03	0.2896E-03
2	1	0.2149E-01	
FLIGHT COND	TT4	TT5	FLIGHT TIME
E1	3 $\{ \begin{array}{l} DETR=0.3873E-02 \\ TH=0.1533E+04 \end{array} \}$	1260. $\{ \begin{array}{l} 2660. \\ DTB=0.1533E+04 \end{array} \}$	30. $\{ \begin{array}{l} 7132E+03 \\ TC=0.1687E+04 \end{array} \}$ TDAMCR=0.2646E-03 CRMAX=0.6874E+00 WBMAX=0.2959E-01 ECE=0.2622E-02 DT=0.2359E-01
REF COND	REF PT.	CREEP FRAC	FATIGUE FRAC
1	1	0.2646E-03	0.2896E-03
2	1	0.2359E-01	
FLIGHT COND	TT4	TT5	FLIGHT TIME
E1	3 $\{ \begin{array}{l} DETR=0.3873E-02 \\ TH=0.1533E+04 \end{array} \}$	1260. $\{ \begin{array}{l} 2660. \\ DTB=0.1533E+04 \end{array} \}$	30. $\{ \begin{array}{l} 7132E+03 \\ TC=0.1687E+04 \end{array} \}$ TDAMCR=0.2668E-03 CRMAX=0.6874E+00 WBMAX=0.2959E-01 ECE=0.2622E-02 DT=0.2556E-01
REF COND	REF PT.	CREEP FRAC	FATIGUE FRAC
1	1	0.2668E-03	0.2896E-03
2	1	0.2556E-01	
FLIGHT COND	TT4	TT5	FLIGHT TIME
E1	3 $\{ \begin{array}{l} DETR=0.3873E-02 \\ TH=0.1533E+04 \end{array} \}$	1260. $\{ \begin{array}{l} 2660. \\ DTB=0.1533E+04 \end{array} \}$	30. $\{ \begin{array}{l} 7132E+03 \\ TC=0.1687E+04 \end{array} \}$ TDAMCR=0.2683E-03 CRMAX=0.6874E+00 WBMAX=0.2959E-01 ECE=0.2622E-02 DT=0.2742E-01
REF COND	REF PT.	CREEP FRAC	FATIGUE FRAC
1	1	0.2683E-03	0.2896E-03
2	1	0.2742E-01	
FLIGHT COND	TT4	TT5	FLIGHT TIME
E1	3 $\{ \begin{array}{l} DETR=0.3873E-02 \\ TH=0.1533E+04 \end{array} \}$	1260. $\{ \begin{array}{l} 2660. \\ DTB=0.1533E+04 \end{array} \}$	30. $\{ \begin{array}{l} 7132E+03 \\ TC=0.1687E+04 \end{array} \}$ TDAMCR=0.2694E-03 CRMAX=0.6874E+00 WBMAX=0.2959E-01 ECE=0.2622E-02 DT=0.2919E-01
REF COND	REF PT.	CREEP FRAC	FATIGUE FRAC
1	1	0.2694E-03	0.2896E-03
2	1	0.2919E-01	

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TABLE 3 (Cont'd)

	FLIGHT COND	TT4	TT5	FLIGHT TIME
E	E1 { DETR=0.3873E-02 TH=0.1533E+04 TK=0.8200E+03	3 1260.	2660.	30. DTB=0.7132E+04 TC=0.1687E+04 CRMCR=0.2702E-03 TDAMFA=0.2896E-03 CRMMAX=0.6874E+00 WBMAX=0.2959E-01 ECE=0.2622E-02 DT=0.3089E-01
REF COND	REF PT. CREEP FRAC FATIGUE FRAC	1 1	0.2702E-03 0.2896E-03	0.3089E-01

	FLIGHT COND	TT4	TT5	FLIGHT TIME
E	E1 { DETR=0.3873E-02 TH=0.1533E+04 TK=0.8200E+03	3 1260.	2660.	12. DTB=0.7132E+04 TC=0.1687E+04 CRMCR=0.2704E-03 TDAMFA=0.2896E-03 CRMMAX=0.6874E+00 WBMAX=0.2959E-01 ECE=0.2622E-02 DT=0.3155E-01
REF COND	REF PT. CREEP FRAC FATIGUE FRAC	1 1	0.2704E-03 0.2896E-03	0.3155E-01

	FLIGHT COND	TT4	TT5	FLIGHT TIME
E	E1 { DETR=0.3873E-02 TH=0.1403E+04 TK=0.7100E+03	4 1150.	2500.	18. DTB=0.6932E+04 TC=0.1601E+04 CRMCR=0.2710E-03 TDAMFA=0.2896E-03 CRMMAX=0.6874E+00 WBMAX=0.2959E-01 ECE=0.2697E-02 DT=0.3171E-01
REF COND	REF PT. CREEP FRAC FATIGUE FRAC	1 1	0.2710E-03 0.2896E-03	0.3171E-01

	FLIGHT COND	TT4	TT5	FLIGHT TIME
E	E1 { DETR=0.3542E-02 TH=0.1621E+04 TK=0.9160E+03	5 1356.	2735.	0. DTB=0.7048E+04 TC=0.1745E+04 CRMCR=0.3461E-03 TDAMFA=0.2896E-03 CRMMAX=0.6874E+00 WBMAX=0.2959E-01 ECE=0.2507E-02 DT=0.3176E-01
REF COND	REF PT. CREEP FRAC FATIGUE FRAC	1 1	0.3461E-03 0.2896E-03	0.3176E-01

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TABLE 3 (Cont'd)

REFERENCE CONDITION NO. 1 1038 HAST-X BRN CRACKING MCDEL RM 10/76					
PERCENT CREEP DAMAGE BREAKDOWN					
REFERENCE POINT NO.	1	CYCCLIC LIFE=	1573.10	LIFE BASED ON BLOCK TIME=	6292.41
CLIMB	6.50	CRUISE	3.14	DESCENT	0.09
DESCENT	0.09	FN REV	11.61		
REFERENCE CONDITION NO. 2 1038 HAST-X BRN BUCKLING MODEL RM 8/3/76					
PERCENT CREEP DAMAGE BREAKDOWN					
REFERENCE POINT NO.	1	CYCCLIC LIFE=	938.54	LIFE BASED ON BLOCK TIME=	3754.16
CLIMB	21.20	CRUISE	38.80	DESCENT	0.20
DESCENT	0.20	FN REV	0.14		
W50807 MISSION ANALYSIS-- 6/14/77 VERSION					
D7A LKAVMISSION 10/11/76					
CASE INFORMATION KREF= 0					
KPO= 1					
BLOCK TIME= 4.000 HRS					
TAXI TIME= 10.0 MIN					
FLIGHT FREQUENCY= 1.00					
--- INPUT FLIGHT CONDITIONS ---					
FLIGHT COND TT4 TT5 FLIGHT TIME					
D	1	1419.	2960.	2.	
	2	1335.	2680.	18.	
	3	1160.	2360.	120.	
	4	1110.	2260.	18.	
	5	1360.	2660.	0.	

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TABLE 3 (Cont'd)

***** LIFE CALCULATIONS *****					
	FLIGHT COND	TT4	TT5	FLIGHT TIME	
$E \left\{ \begin{array}{l} DETR=0.3885E-02 \\ TH=0.1743E+04 \end{array} \right.$	1	1410.	2360.	2.	
	2	DETRE=0.3885E-02 TH=0.1743E+04 DTB=0.7732E+03 TDAMCR=0.1887E-03 TDAMPA=0.1894E-03 CRMAX=0.6205E+00 WBMAX=0.2963E-01 ECE=0.2285E-02 DT=0.7941E-02			
$E \left\{ \begin{array}{l} DETR=0.3885E-02 \\ TH=0.1586E+04 \end{array} \right.$	1	1335.	2680.	18.	
	2	DETRE=0.3885E-02 TH=0.1586E+04 DTB=0.6912E+03 TDAMCR=0.2298E-03 TDAMPA=0.1894E-03 CRMAX=0.6205E+00 WBMAX=0.2963E-01 ECE=0.2559E-02 DT=0.1261E-01			
$E \left\{ \begin{array}{l} DETR=0.3885E-02 \\ TH=0.1353E+04 \end{array} \right.$	1	1160.	2360.	120.	
	2	DETRE=0.3885E-02 TH=0.1353E+04 DTB=0.6332E+03 TDAMCR=0.2827E-03 TDAMPA=0.1894E-03 CRMAX=0.6205E+00 WBMAX=0.2963E-01 ECE=0.2708E-02 DT=0.1261E-01			
$E \left\{ \begin{array}{l} DETR=0.3383E-02 \\ TH=0.1593E+04 \end{array} \right.$	1	1110.	2260.	18.	
	2	DETRE=0.3383E-02 TH=0.1593E+04 DTB=0.6132E+04 TDAMCR=0.2850E-03 TDAMPA=0.1894E-03 CRMAX=0.6205E+00 WBMAX=0.2963E-01 ECE=0.2733E-02 DT=0.1261E-01			
$E \left\{ \begin{array}{l} DETR=0.3383E-02 \\ TH=0.9200E+03 \end{array} \right.$	1	1	0.2850E-03	0.1894E-03	
	2	DETRE=0.3383E-02 TH=0.9200E+03 DTB=0.6732E+03 TDAMCR=0.5186E-03 TDAMPA=0.2258E-03 CRMAX=0.6205E+00 WBMAX=0.2963E-01 ECE=0.2548E-02 DT=0.1261E-01			
$E \left\{ \begin{array}{l} DETR=0.3383E-02 \\ TH=0.1593E+04 \end{array} \right.$	1	1	0.5186E-03	0.2258E-03	
	2	DETRE=0.3383E-02 TH=0.1593E+04 DTB=0.1762E+04 TDAMCR=0.6205E+00 CRMAX=0.6205E+00 WBMAX=0.2963E-01 ECE=0.2548E-02 DT=0.1261E-01			

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TABLE 3 (Cont'd)

REFERENCE CONDITION NO. 1 1038 HAST-X BRN CRACKING MODEL RM 10/76

REFERENCE POINT NO.	1
CYCLIC LIFE-	1343.43
LIFE BASED ON BLOCK TIME=	5373.71
LIFE BASED ON FLIGHT TIME=	5149.81

F

PERCENT CREEP DAMAGE BREAKDOWN

TAKE OFF	50.79
CLIMB	5.52
CRUISE	7.11
DESCENT	0.30
PN REV	36.28

REFERENCE CONDITION NO. 2 1038 HAST-X BRN BUCKLING MODEL RM 8/3/76

REFERENCE POINT NO.	1
CYCLIC LIFE-	5524.48
LIFE BASED ON BLOCK TIME=	22097.91
LIFE BASED ON FLIGHT TIME=	21177.17

F

PERCENT CREEP DAMAGE BREAKDOWN

TAKE OFF	62.67
CLIMB	36.84
CRUISE	0.0
DESCENT	0.0
PN REV	0.48

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TABLE 3 (Cont'd)

*****	REFERENCE CONDITION SUMMARY	*****
AVERAGE FLIGHT TIME =	3.83	
AVERAGE BLOCK TIME =	4.00	
TOTAL FREQUENCY =	2.00	
*****	*****	*****
REFERENCE CONDITION NO. 1	1038	HAST-X BRN CRACKING MODEL RM 10/76
REFERENCE POINT NO.	1	
CYCLED LIFE=	1449.22	
LIFE BASED ON BLOCK TIME=	5796.89	
LIFE BASED ON FLIGHT TIME=	5313.81	
*****	*****	*****
PERCENT CREEP DAMAGE BREAKDOWN		
TAKE OFF	63.54	
CLIMB	5.97	
CRUISE	5.28	
DESCENT	0.21	
PN REV	25.01	
*****	*****	*****
REFERENCE CONDITION NO. 2	1038	HAST-X BRN BUCKLING MODEL RM 8/3/76
REFERENCE POINT NO.	1	
CYCLED LIFE=	1604.50	
LIFE BASED ON BLOCK TIME=	6417.99	
LIFE BASED ON FLIGHT TIME=	5883.15	
*****	*****	*****
PERCENT CREEP DAMAGE BREAKDOWN		
TAKE OFF	46.01	
CLIMB	25.66	
CRUISE	27.73	
DESCENT	0.36	
PN REV	0.24	

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