NASA CONTRACTOR REPORT

NASA CR-143923

(NASA-CR-143923) USERS MANUAL: MSFC CRACK GROWTH ANALYSIS COMPUTER PROGRAM (Del West Associates, Inc.) 69 p HC $4.25 CSCL 20K

N75-32506

Unclas

G3/39 41181

USERS MANUAL

MSFC CRACK GROWTH ANALYSIS COMPUTER PROGRAM

By Matthew Creager
Del West Associates, Inc.
Woodland Hills, California

September 1975

Prepared for

N A S A - GEORGE C. MARSHALL SPACE FLIGHT CENTER
Marshall Space Flight Center, Alabama 35812

FORWARD

The computer program described in this manual was developed under Contract Number NAS8-31101. The Contract was monitored by C. Bianca of The George C. Marshall Space Flight Center. The author would like to acknowledge the informative technical discussions held with J. E. Collipriest, Jr. and R. M. Ehret during the course of this work.

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. NASA CR-143923	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE USERS MANUAL MSFC CRACK GROWTH ANALYSIS COMPUTER PROGRAM		5. REPORT DATE September 1975
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Matthew Creager		8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS Del West Associates, Inc. Woodland Hills, California		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO. NAS8-31101
		13. TYPE OF REPORT & PERIOD COVERED
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D. C. 20546		Contractor Report
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Described in this report is the crack growth analysis program developed for the George C. Marshall Space Flight Center by Del West Associates, Inc.. Also described are the input and output formats and options.

The technical approaches used within the computer program are presented. Included are example data and problems.

17. KEY WORDS	18. DISTRIBUTION STATEMENT Unclassified - Unlimited

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	69	NTIS

MSFC - Form 3292 (Rev December 1972)

For sale by National Technical Information Service, Springfield, Virginia 22151

TABLE OF CONTENTS

SUMMARY

The crack growth analysis program developed for the George C. Marshall Space Flight Center by Del West Associates, Inc. is described. The technical approaches used within the computer program are presented and the input and output formats and options are described. Example data and example problems are included.

INTRODUCTION

In order to include the important consideration of structural failure due to the presence of flaws and crack-like defects in aerospace hardware; it is necessary to have a computer program capable of performing crack growth analysis that is easy to use and generally applicable. The need for a computer program (as opposed to simple hand calculations) arises from the complexity of growth descriptions required for crack growth analysis of real materials in complex structure under a variety of loading and environmental conditions. The MSFC crack growth computer program developed by Del West was designed to meet this need.

The MSFC crack growth computer program calculates crack growth for part through cracks, through the thickness cracks and cracks which are transitioning from part through cracks to through the thickness cracks. The computer program has been written to be flexible in its operation and to be easily adapted and changed as fracture mechanics technology changes and/or the design usage of the program changes.

The computer program is essentially an integration routine which calculates crack growth from an in initial defect size and terminates calculation when the crack is sufficiently large for a critical condition (instability or rapid growth) to be reached. In addition, if a design life is not met for a particular structure, the program has the capability of varying the thickness of the structure so as to establish the thickness which will meet the design requirements.

During the period when a crack is a part through crack, crack growth in the depth and surface directions may be different due to variations in stress intensity factors and/or directional dependence of material properties. The MSFC computer program considers both of these effects and hence incorporates realistic crack shape changes. During the period when a crack is transitioning from a part through crack to a through the thickness crack, the crack lengths on the backside and the frontside are different. The MSFC computer program tracks the growth of these two dimensions separately; evaluating the stress intensity factors at each surface until these dimensions are the same and the crack has completed its transition to a through the thickness crack.

The computer program allows two different methods of load input. For each step in the loading block, the user specifies either: (1) Maximum Stress, Minimum Stress, Number of Cycles or (2) Maximum Stress, Stress Ratio, Number of Cycles. It should be noted that if crack growth mechanisms other than fatigue are being considered (e.g., static stress corrosion) the appropriate rate variable can be used instead of cycles (e.g., time at load) in conjunction with appropriate material constants as described below to perform a wide range of phenomenological studies.

The use of a limit load (a load which may be higher than any load in the actual spectrum) to determine the end of design life is a common practice. The MSFC computer program has therefore been written to consider a separate limit load (apart from those in the spectrum) and to determine when it causes failure. However, after failure due to limit load occurs, the crack growth calculation continues. The limit load failure information is included in the output.

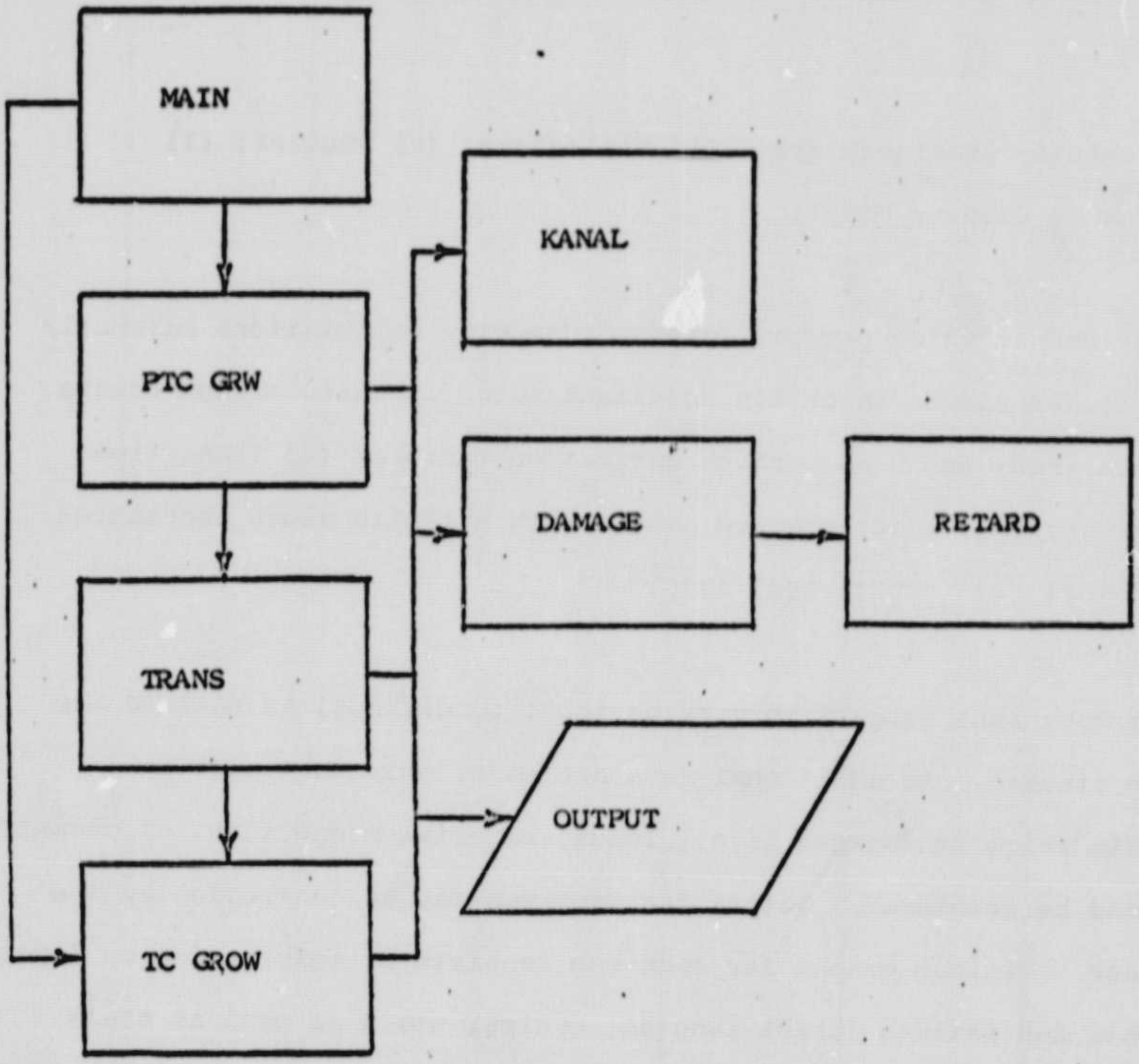
The crack growth rate material properties may presently be input into the program in any of three formats: (1) Paris equation with upper and lower cutoffs in stress intensity factor; (2) Forman equation with upper and lower cutoffs in stress intensity factor; (3) Collipriest-Ehret equation with additional upper and lower cutoffs in stress intensity factor. An important feature of the material property description is that different materials properties (crack growth equations, fracture properties, yield stress, etc.) may be designated for each step in the loading spectrum. Thus varying temperatures and environments may be considered.

The MSFC crack growth computer program has the capability of utilizing any one of three crack growth retardation models. Of course, the effects of retardation on crack growth will not be considered if the user does not request it. The three models presently available are: (1) Willenborg; (2) Wheeler; (3) Grumman Closure Model.

The module which performs stress intensity calculations currently includes stress intensity equations for: (1) Part through cracks with front and back surface correction factors; (2) Transition cracks; (3) Center cracked panels with a finite width correction factor; (4) Compact test specimens.

As many runs (each with varying input conditions) as desired may be stacked. As additional runs are made, only that section of data which is changed (i.e., loads, material properties, or geometry) need be reentered. Output for each run may be controlled by the user. Minimum output for each run consists of information on input data and failure (crack lengths, cycles, etc.) as well as crack lengths, stress intensity factors, and crack growth rates for the first and last cycle of each stress level in the first load block applied as a part through crack, transitional crack or through crack. Additional information (crack lengths, stress intensity factors, and crack growth rates) for particular blocks and loading steps may be requested by the user.

A flow chart showing all subroutines is presented in Figure 1.



Subroutine	Function
MAIN	Reads Input, Sequences Runs, Performs Iteration on Thickness, Calls Appropriate Crack Growth Module.
PTC GRW	Calculates Crack Growth for a Part Through Crack
TRANS	Calculates Crack Growth for a Transitional Crack
TC GROW	Calculates Crack Growth for a Through the Thickness Crack
KANAL	Evaluates all Stress Intensity Factors.
DAMAGE	Calculates Crack Growth Rates
RETARD	Modifies Input to DAMAGE to Account for Retardation Effects.

Figure 1. Overall Flow Diagram
MSFC Crack Growth Analysis Program

TECHNICAL APPROACH

The essence of the crack growth analysis procedures consists of:

1) Considering each loading step in a load block in turn.
2) Evaluating stress intensity factors, using the stresses from the step under consideration.
3) Using these stress intensity factors (and previous loading history if retardation is considered) to calculate crack growth rate.
4) Consider a small amount of growth ($\sim$1% of current crack size) and calculate the number of cycles it takes to grow that amount. If that amount exceeds the number of cycles not yet consumed in the step then only those remaining cycles are used and a corresponding crack growth increment is calculated.
5) Crack lengths are incremented, cycle count is incremented.
6) This process is continued until all cycles in the step are considered. The next step is then called. At the end of a block the first step is called again.
7) The calculation ends when:
   a) The critical stress intensity (either at the surface or at the depth of a crack) is exceeded.
   b) There is no crack growth ($< 10^{-8}$ in.) for an entire block.
   c) The crack growth rate goes to infinity (when using the Forman equation for crack growth rate).
   d) The maximum number of blocks is exceeded.
8) All input and all output data are in units compatible with Kips and inches. (e.g., Ksi, Ksi $\sqrt{in.}$ and in/cycle.)

The subroutines PTCGRW, TRANS, and TCGROW calculate the crack growth increments, return to main for information on the next loading step, consider when to end the calculation and transfer to each other (PTCGRW → TRANS ↔ TCGROW) as required. For a part through crack PTCGRW performs these functions until TRANS is called. TRANS is called when the crack depth equals the plate thickness. TRANS performs these functions while the crack is transitioning to a through crack and calls TCGROW when the back surface length exceeds 95% of the front surface length. TCGROW performs these functions when the crack is a through crack and may be called by TRANS or in those cases when a through crack is considered initially it is called from MAIN initially.

The equations in KANAL, DAMAGE AND RETARD are, of course, the heart of the crack growth analysis program. These are described below.

KANAL

KANAL is a subroutine which returns factors, which when multipied by the appropriate loading term yields stress intensity factors. Thus the loading input must be compatable with the crack configuration considered. For the configuration currently in the program the corresponding name (KTYPO) and required load description are as follows:

KTYPO	Configuration	Load Description
1	Center Cracked Tension Panel	Gross Stress (Ksi)

KTYPO	Configuration	Load Description
2	ASTM E-399 Compact Specimen	Pin Force (Kips)
3	Part Through Crack	Gross Stress (Ksi)
4	Transition Crack	Gross Stress (Ksi)

The equation used for the center cracked panel is taken from Fedderson (Ref. 1) and is:

$$K = \sigma\sqrt{\pi C \operatorname{Sec} \frac{\pi C}{W}}$$

where the dimensions are given in Figure 2.

The equation used for the compact specimen is taken from Ref. 2

$$K = \frac{P}{t\sqrt{W}} \left[29.6 \left(\frac{C}{W}\right)^{1/2} - 185.5 \left(\frac{C}{W}\right)^{3/2} + 655.7 \left(\frac{C}{W}\right)^{5/2} - 1017.0 \left(\frac{C}{W}\right)^{7/2} + 638.9 \left(\frac{C}{W}\right)^{9/2} \right]$$

For the part through crack the stress intensity is evaluated at the surface and at the depth. In both computations a term "Q" is used. "Q" is composed of an elliptical integral, $\phi\,(a/2C)$ which accounts for some effects of crack shape and Ω also contains a plasticity correction factor. An approximation developed by Rawe (Ref. 3) for the pertinent elliptic integral is used in the computer program.

$$\phi^2 = 1. + 4.593\ (a/2C)^{1.65}$$

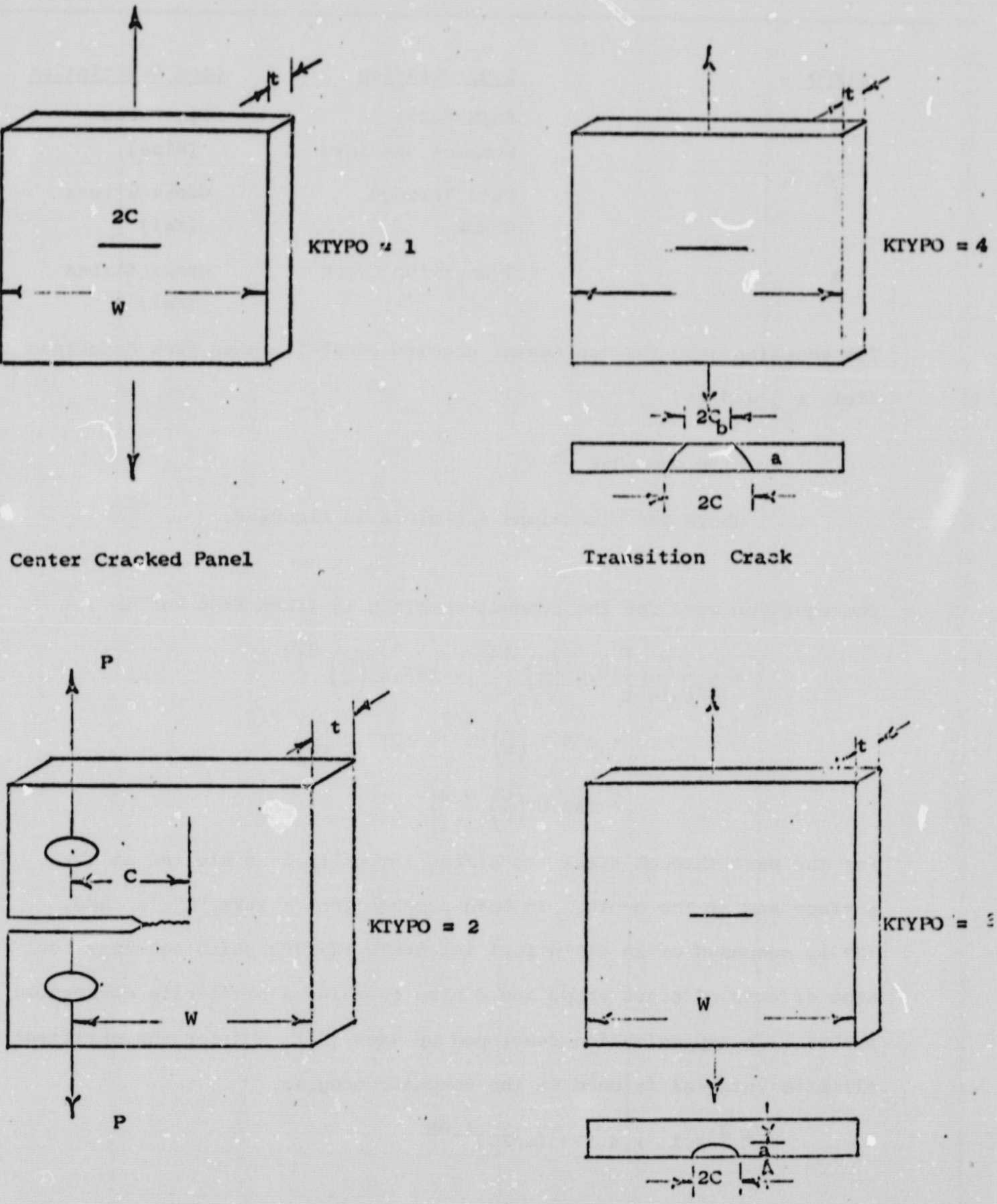


Figure 2 - Crack Configuration

The plasticity correction factor is that proposed by Irwin(Ref. 4) except that the range in stress is used since the stress range and the reversed plastic zone it produces is significant in fatigue. The equation for Q is

$$Q = \phi^2 = .212 \frac{\Delta\sigma^2}{\sigma_{ys}}$$

Where $\Delta\sigma$ is the gross stress range and σ_{ys} is the .2% offset yield stress. For the stress intensity at the front surface the equation used is

$$K\ (\text{Surface}) = (1.12 + .11\ a/C)\sigma\sqrt{\frac{\pi a}{Q}\ \frac{a}{C}}$$

Where the expression in parenthesis is a "front surface correction factor." This factor is simply a linear variarion with shape between the two available solutions (e.g., 1.12 for a/c = 0 and 1.23 for a/2 = 1, Ref.5 and 6 respectively.) The expression for the stress intensity at the depth is taken from the work of Shah and Kobayashi (Ref. 7) with $K\ (\text{depth}) = \sigma M_{back} M_{front} \sqrt{\pi a/Q}$

Their expréssion for M_{front} is:

$$M_{front} = 1 + .2\ (1 = a/2C)^2$$

Their backface correction factor has been put in an equation form by Collipriest and Ehret (Ref. 8) and is:

$$M_{back} = 1 + \frac{1}{0.502}\left[0.089\left(\frac{a}{t}\right) - 0.2315\left(\frac{a}{t}\right)^2 - 0.3873\left(\frac{a}{t}\right)^3 + 5.28\left(\frac{a}{t}\right)^4 - 9.11\left(\frac{a}{t}\right)^5 + 5.233\left(\frac{a}{t}\right)^6\right]$$
$$\times\left[1.109 - 9.142\left(\frac{a}{2c}\right) + 41.56\left(\frac{a}{2c}\right)^2 - 86.55\left(\frac{a}{2c}\right)^3 + 65.5\left(\frac{a}{2c}\right)^4\right]$$

The stress intensity equations used for a crack during transition are approximate expressions developed by R. M. Ehret which predict observed crack growth behavior. The stress intensity for the front surface if taken to be: (See Figure 2)

$$K_{front} = \sqrt{\pi C \quad Sec \frac{\pi (C+CB)}{2W}}$$

and the stress intensity for the back surface is taken to be

$$K_{back} = \sqrt{\frac{CB/C}{1-\sqrt{1-(CB/C)^2}}} \quad K_{front}$$

DAMAGE

The subroutine DAMAGE currently contains three equations for calculating crack growth rate. In all cases the independent variables are the effective stress intensity factor, KE, and the effective stress ratio, RE. When retardation is not used KE is simply the stress intensity range (KMAX - KMIN) and RE is simply the stress ratio. When retardation is used, KE and RE are calculated in RETARD.

The following equations all contain material property constants designated by D(NC,1,J). NC indicates whether the surface (NC = 1) or depth(NC = 2) is being considered. 1 is the constant number in that equation and indicates the order of the constant on input type 10 cards. J is the material type number. In order to call out the proper equation the corresponding equation name (NEQ) must be called out on card type 9 columns 11 - 14. Note that each material type could use a different NEQ.

NEQ	EQUATION
1	Collipriest-Ehret
2	Paris
3	Forman

The Collipriest-Ehret equation is

$$\frac{da}{dn} = C_1 \ \mathrm{EXP} \left[C_2 \quad \mathrm{TANH}^{-1} \left(\frac{\ln(KE^2/(1-RE)\ D\ (NC,3,J)\ D\ (NC,4,J)}{\ln\ (1-RE)\ D\ (NC,4,J)/D\ \ (NC,3,J)} \right) \right]$$

$$C_1 = D(NC,1,J) \left[D(NC,3,J) \quad D(NC,4,J) \right] \frac{D(NC,2,J)}{2}$$

$$C_2 = \ln \left[\left(\frac{D(NC,3,J)}{D(NC,4,J)} \right) \frac{D(NC,2,J)}{2} \right]$$

where

D(NC,1,J)	Crack growth rate coefficient
D(NC,2,J)	Dimensionless Coefficient relating to midrange slope
D(NC,3,J)	Critical stress intensity (upper asymptote)
D(NC,4,J)	Threshold stress intensity range (lower asymptote)

The Paris equation is

$$\frac{da}{dn} = D(NC,1,J) \quad DE^{D(NC,2,J)}$$

The Forman equation is

$$\frac{da}{dn} = \frac{D(NC,1,J) \quad KE^{D(NC,2,J)}}{(1-RE) \quad D(NC,3,J)-KE}$$

where

D(NC,1,J)	Crack growth rate coefficient
D(NC,2,J)	Crack growth rate exponent
D(NC,3,J)	Critical stress intensity (upper asymptote)

RETARD

The subroutine RETARD currently contains three retardation models. In each of these a crack tip plastic zone r_y is calculated according to the equation

$$r_y = \frac{1}{(2\pi)Pz} \times \frac{K^2_{max}}{\sigma_{ys}^{\ 2}}$$

where Pz is a constant depending on the degree of plane stress versus plane strain For plane stress Pz = 1. For plane strain Pz = 3.

The following is the retardation equation number for each retardation model. (Input for Columns 15 - 18, Card Type 9)

NRET		
1	Willenborg Model	(Ref. 9)
2	Wheeler Model	(Ref. 10)
3	Grumman Closure Model	(Ref. 11)

The Willenborg retardation model calls for no constants other than Pz. The only material property input for this model is therefore

CR(NC,1,J) = Pz

The "Wheeler" model in this computer program is actually a variation of the model originally presented by Wheeler. Wheeler used a modification to the crack growth rate to produce a retardation effect and we have used a modification to the dependent variable KE. If the

Paris equation is used for crack growth rate the "Wheeler" model in this computer program is identical to the model presented in Ref. 10. The input material properties for this model are

CR(NC,1,J) = Pz

CR(NC,2,J) = m/n

where m is identical to the "m" used in Ref. 10 and n is the exponent in the Paris equation (i,e., if the "Wheeler m" were 5 and the Paris "n" 4, the input value for CR(NC,2,J) is 1.25)

The details of the Grumman Closure model are too complex to be described here. The input is described below

Input Quantity	Name in Reference
CR(NC,1.J)	Pz
CR(NC,2,J)	$C_{f_{-1}}$
CR(NC,3,J)	C_{f_o}
CR(NC,4,J)	p
CR(NC,5,J)	NSAT
CR(NC,6,J)	γ_1
CR(NC,7,J)	B

INPUT

There are 13 distinct data input card formats. These are described below:

CARD TYPE	FIELD	NOMENCLATURE	DESCRIPTION
1	1-40	TITL	Any alphanumeric description of group of runs
2	1-4	NRUNS	Total number of runs (one run corresponds to a unique set of input data.)
2	5-10	NBLOCK	Maximum number of blocks to be considered. Crack growth calculation ceases when the number of blocks exceeds this number.
2	11-14	NBLOCK	Block interval for which additional data will be printed (e.g., 3 would imply that blocks 3, 6, 9, 12....etc. would have data printed out).
2	15-18	MSTEP	Step interval for which additional data will be printed (in the blocks called out above).
3	1-10	CSTRS	Constant multiplier for stress inputs. Allows stress spectrum to be varied by changing one number only. (e.g., one run with this constant 1 and one run with this constant 1.1, will show the effect of varying the stress 10%).
3	10-14	NSUP	Constant for suppression of retardation in crack growth analysis. If zero, retardation is not considered. If retardation is to be considered, constant must be 1.

CARD TYPE	FIELD	NOMENCLATURE	DESCRIPTION
3	15-18	NLOAD	Constant to indicate whether new load data is to be input. If zero, (or any number not equal to 1) load data will not be read in and load data from previous run will be used. If it is 1, card types 4 and 5 must follow.
3	18-22	NGEOM	Constant to indicate whether new geometry data is to be input. If zero (or any number other than 1) geometry data will not be read in and geometry data from previous run will be used. If it is 1, card types 6 and 7 must be read in.
3	22-26	NMAT	Constant to indicate whether new material data is to be input. If zero (or any number other than 1) material data will not be read in and material data from previous run will be used. If it is 1, card types 8, 9, 10, and 11, 12, 13, if needed must be read in.
3	27-30	ITER	Maximum number of iterations to find thickness that produces the desired life. May not exceed 10, may be left blank. Remaining items on card three are left blank, if iter equals zero (or blank).
3	31-40	PIT	Parameter to control rate of convergence on iteration to find thickness. Usually set to exponential power in Paris crack growth equation for crack growth data. When other crack growth equation is used, approximate value of a "Paris exponent" will be sufficient. Must always be greater than 1.
3	40-50	BLIFE	Desired life in blocks.

CARD TYPE	FIELD	NOMENCLATURE	DESCRIPTION
4	1-4	NSTEP	Number of steps in load blocks.
4	4-8	IR	Zero if input format includes minimum stress, 1 if input format includes stress ratio.
4	8-18	SIGLM	Limit stress for additional end of life determinational. Failure due to limit load does not terminate crack growth calculation.
5	1-10	SMAX	Maximum stress.
5	11-20	SMIN	Minimum stress if 1R = 0, stress ratio of 1R = 1.
5	21-30	UNIT	Number of cycles or alternate rate variable.
5	31-34	TYPE	Material property data type to be used.
6	1-4	KTYPO	Initial stress intensity type.
7	1-10	W	Plate width.
7	11-20	TH	Plate thickness
7	21-30	CO	Initial half surface length for part through crack or center crack. Corresponds to "a" in E 399-72 description of compact specimen.
7	30-40	AO	Crack depth for a part through crack. May be left zero for through cracks.
8	1-4	NJ	Number of material property types.
9	1-10	SIGYS	Yield stress.
9	11-14	NEQ	Equation to be used for crack growth. 1 = Collipriest=Ehret, 2 = Paris, 3 = Forman.

CARD TYPE	FIELD	NOMENCLATURE	DESCRIPTION
9	15-18	NRET	Model to be used for retardation 0 = none, 1 = Willenberg, 2 = Wheeler, 3 = Grumman Closure (not debugged).
9	18-22	NDUP	Constant to indicate whether crack growth properties are the same in depth and surface directions. If constant = 1, they are not and two sets of D's and CR's (see cards 10-13) must be input.
9	23-32	KCRC	Critical stress intensity in surface direction (upper cutoff).
9	33-42	KOC	Threshold stress intensity in surface direction (lower cutoff).
9	43-52	KCRA	Critical stress intensity in depth direction. Need not be input if crack is a through crack.
9	53-62	KOA	Threshold stress intensity in depth direction. Need not be input if crack is a through crack.
10	1-10	D(1,I,J)	Constants in crack growth equations - surface direction. Data is read in until a zero is reached. See text for description of constants.
11	1-10	D(2,I,J)	Constants in crack growth equation - depth direction. Data is read in until a zero is reached. If NDUP $\neq$ 1, card is not used. See text for description of constants.
12	1-10	CR(1,I,J)	Constants in retardation equation - surface direction. Data is read in until a zero is reached. See text for description of constants.
13	1-10	CR(2,I,J)	Constants in retardation equation - depth direction. Data is read in until a zero is reached. If NDUP $\neq$ 1, card is not used. See text for description of constants.

CARD TYPE	FIELD	WHEN INPUT DATA REQUIRED
1	1-40	Once for each session.
2	1-16	Once for each session.
3	1-22	Once for each run.
3	22-50	Whenever an iteration on thickness to meet design life is desired.
4	1-18	Whenever NLOAD = 1.
5	1-34	NSTEP times when NLOAD = 1.
6	1-4	Whenever NGEOM = 1.
7	1-40	Whenever NGEOM = 1.
8	1-4	Whenever NMAT = 1.
9	1-62	NJ times, when NMAT = 1.
10	1-10	NJ times, when NMAT = 1.
11	1-10	NJ times, when NDUP = 1 and NMAT = 1.
12	1-10	NJ times, when NMAT = 1 and NRET ≠ 0.
13	1-10	NJ times, when NMAT = 1 and NRET ≠ 0 and NDUP = 1.

Card	Fields								
1	← TITLE →								
2	NRUNS	NBLOCK	MBLOCK	NSTEP					
3	NSTRS	NSUP	NLOAD	NGEOM	NMAT	ITER	PIT	BLIFE	
4	NSTEP	IR	SIGLM						
5	SMAX	SMIN	UNIT	TYPE	NSTEP Card 5's are input				
6	KTYPQ								
7	W	TH	CO	AO					
8	NJ								
9	SIGYS	NEQ	NREI	NDUP	KCRC	KDC	KCPA	KDA	
10	D(1, x, J)	Until D = 0							
11	D(2,x,J)	Until D=0 if NDUP = 1	NJ Sets of Card 9-13 are input						
12	CR(1,x,J)	Until CR = 0							
13	CR(2,x,J)	Until CR = 0 if NDUP = 1							

CONTROL OF OUTPUT

In addition to information describing the input data and on fracture, the computer program output consists of crack lenghts, stress intensity factors, crack growth rates, and cycle counts. These are printed out for the first and last cycle in the step. This data is always printed for each step of the first block encountered in any of the growth modules (PTCGRW, TRANS or TCGROW) This data may also be printed out for additional blocks and steps as desired by the user. These additional blocks and steps are controlled by specifying the increment for blocks and steps for which print out will be made MBLOCK AND MSTEP respectively. Thus if every step in every other block is wanted, MBLOCK is set equal to 2 and MSTEP is set equal to 1.

INPUT FOR ADDITIONAL RUNS

A full set of input data is not necessary for each additional run. The use of a stress multiplier constant (CSTRS) allows all the stress to be varied by a constant percentage without inputting any additional input cards other than card type 3. If the stresses are to be used directly as they are on card type 5, CSTRS is input as 1.

The input constant NSUP allows retardation to be suppressed on subsequent runs. That is if a run is made that considers retardation, the following run will perform the same analysis without retardation if NSUP = 0. When retardation is considered NSUP must be set equal to 1. Obviously the order of running the cases must be retarded, followed by unretarded.

In order to control whether loading data, geometry data, or material properties are to be read in for a particular run, the constants NLOAD, NGEOM, NMAT must be input. If data is to be read in, the appropriate constant must be 1, it it is not to be read in, the appropriate constant is 1. If data is not read in, data from the previous run is used. Obviously, for the first run NLOAD, NGEOM AND NMAT must all be 1.

ITERATION ON THICKNESS

For a given design life (in blocks) the computer program will search for the thickness which will meet that life requirement. The number of iterations attempted is input by the user. The maximum that this may be is ten. This computer program ceases its search when the allowed number of iterations is exceeded or the computed life lies between 100% and 105% of the design life. Life is arbitrarily defined as the number of blocks completed plus the number of steps completed/total number of steps.

In addition to inputting the number of iterations and the design life, an exponent which will control the rate of convergence to the correct thickness must be inserted. When the Paris equation is used with zero threshold for a through the thickness crack, the use of the exponent of the Paris equation for the convergence parameter should result in a convergence to the correct solution in a single cycle. Any constant equal to or greater than the "Paris coefficient" should insure convergence.

CRACK GROWTH RATE DATA

The following data for use in the Collipriest/Ehret equation (NEQ = 1) is typical data for the materials listed. The data is included for example purposes only and caution is advised with regard to design implications of the data presented. The crack growth rate is in in/cycle and the stress intensity factor is in Ksi $\sqrt{\text{in.}}$

Material	D(NC,1,J) Coefficient	D(NC,2,J) Relates to Midrange Slope	D(NC,3,J) Upper Asymptote	D(NC,4,J) Lower Asymptote
2024-T851	1.6×10^{-9}	3.45	38.0	3.4
2124-T851	3.3×10^{-10}	4.0	31.0	3.5
2219-T87 (70°F)	2.2×10^{-9}	3.3	40.0	5.5
2219-T87 (-320°F)	8.9×10^{-12}	4.82	50.0	5.5
7075-T6	4.4×10^{-8}	2.53	33.0	3.0
7075-T76	6.3×10^{-9}	3.0	30.0	3.0
7075-T73	1.07×10^{-8}	2.67	40.0	3.5
Ti-6Al-4VSTA	6.8×10^{-10}	3.3	50.0	7.0
Ti-6AL-4V Annealed	5.7×10^{-10}	3.18	84.0	6.0
Inconnel 718 (STA)	4.0×10^{-10}	2.7	115.0	15.0
D6AC	7.5×10^{-10}	2.74	90.0	6.0

CRACK GROWTH ANALYSIS EXAMPLE

Sample input data for a series of two runs is given on page 29. The first run is a part through crack subjected to a series of two loads of 1000 cycles each. The material properties associated with each load level are different so as to model the effect of temperature variations. The second run is the same except that the initial crack configuration is a through the thickness center cracked panel. No ouput beyond the normally supplied out is requested for these runs. The output is shown on pages 30 through 33.

A second example consisting of a series of three runs is presented on pages34 through 45 . Page 34 is the input for these three runs. For these runs data on every other block was requested. The output was therefore rather extensive. All the information was not needed here and therefore only the first and last page of output of those runs discussed are reproduced.

The first run has two loading steps, calls for a retardation model (Willenborg) and requests a maximum of three iterations to find a thickness compatable with the design life. A rather low (compared to the "Paris exponent") convergence exponent of 2 was used. The output for the first iteration is shown on pages 36 through 38 and

The report on the iteration is shown on page 39 . Due to the use of the excessively low value of the convergence exponent, the thickness has not converged to the appropriate value. Note, however, that the information is still quite useful and that a simple hand plot of the result will show that the correct thickness is about .52 inches.

In the second run retardation was suppressed and no iteration was requested. Note that the life for a thickness of .5 inches goes from 137 blocks with retardation to 81 blocks without retardation.

In the third run a step which simulated a 480 second hold at a constant load with a resulting sustained load crack growth was included. The crack growth model was assumed to follow a "Paris" format (NEQ = 2) with an exponent of 1 and an appropriate constant was assumed. As can be seen by the results, the life was reduced further under these assumptions.

```
 2219-70   AND 320   PEC/CCI
   2 100 100      1
1.            0   1   1   1
   .2   0 30.
   30.        0.0      1000.      1
   30.        0.0      1000.      2
   3
99.          1.        .2         3
   2
  50.         1   0   0  40.      3.5       40.         3.5
  2.2E-9
  3.3                                                          Run 1
  4.0
  3.5
  0.
  70.         1   0   0  50.      5.5       50.         5.5
  8.9E-12
  4.82
  50.
  5.5
  0.
   1.0        0   0   1   0
   1                                                           Run 2
   6.         .5       .25
```

RUN 1 OF 2 RUNS 2219 - 70 AND 320 - PEC/CCT

LOAD INPUT DATA

STRESS FACTOR	1.000+00
LIMIT STRESS	3.000+01

STEP	MAX STRESS	MIN STRESS	UNITS(CYCLES)	MATERIAL TYPE
1	3.000+01	0.000	1.000+03	1
2	3.000+01	0.000	1.000+03	2

GEOMETRY INPUT DATA

CRACK TYPE	3
WIDTH	9.900+01
THICKNESS	1.000+00
CRACK DEPTH	1.000-01
HALF CRACK LENGTH	2.000-01

MATERIAL INPUT DATA

MATERIAL TYPE	YIELD STRENGTH	GROWTH EQUATION	RETARDATION MODEL	CRITICAL STRESS INTENSITY (SURFACE)	THRESHOLD STRESS INTENSITY (SURFACE)	CRITICAL STRESS INTENSITY (DEPTH)	THRESHOLD STRESS INTENSITY (DEPTH)
1	5.000+01	1	0	4.000+01	3.500+00	4.000+01	3.500+00
2	7.000+01	1	0	5.000+01	5.500+00	5.000+01	5.500+00

CONSTANT NUMBER	MATERIAL TYPE	EQUATION CONSTANTS: CRACK GROWTH RATE SURFACE	CRACK GROWTH RATE DEPTH	RETARDATION MODEL SURFACE	RETARDATION MODEL DEPTH
1	1	2.200-09	2.200-09	0.000	0.000
2	1	3.300+00	3.300+00	0.000	0.000
3	1	4.000+01	4.000+01	0.000	0.000
4	1	3.500+00	3.500+00	0.000	0.000
1	2	8.900-12	8.900-12	0.000	0.000
2	2	4.820+00	4.820+00	0.000	0.000
3	2	5.000+01	5.000+01	0.000	0.000
4	2	5.500+00	5.500+00	0.000	0.000

RUN 1 2219 - 70 AND 320 - PEC/CCT

CRACK IS A PART THRU CRACK

BLOCK	STEP	CYCLES	HALF SURFACE CRACK LENGTH (IN)	CRACK DEPTH (IN)	KMAX-SURFACE (KSI ROOT-IN)	KMAX-DEPTH (KSI ROOT-IN)	SURFACE GROWTH RATE (IN/CYCLE)	DEPTH GROWTH RATE (IN/CYCLE
1	1	0.000	2,000-01	1.000-01	1.190+01	1,330+01	7,783-06	1,811-05
1	1	1.000+03	2,095-01	1.195-01	1,336+01	1,596+01	1,144-05	2,096-05
1	2	0.000	2,095-01	1.195-01	1,328+01	1,580+01	2,271-06	5,334-06
1	2	1.000+03	2,119-01	1.249-01	1,364+01	1,595+01	2,599-06	5,576-06

FRACTURE OCCURS DURING BREAKTHROUGH IN THE 6 BLOCK AND THE 2 STEP AFTER 7,845+02 CYCLES

RUN 2 OF 2 RUNS 2219 - 70 AND 320 - PEC/CCT

LOAD INPUT DATA

STRESS FACTOR	1.000+00
LIMIT STRESS	3.000+01

STEP	MAX STRESS	MIN STRESS	UNITS(CYCLES)	MATERIAL TYPE
1	3.000+01	0.000	1.000+03	1
2	3.000+01	0.000	1.000+03	2

GEOMETRY INPUT DATA

CRACK TYPE	1
WIDTH	6.000+00
THICKNESS	5.000-01
HALF CRACK LENGTH	2.500-01

MATERIAL INPUT DATA

MATERIAL TYPE	YIELD STRENGTH	GROWTH EQUATION	RETARDATION MODEL	CRITICAL STRESS INTENSITY (SURFACE)	THRESHOLD STRESS INTENSITY (SURFACE)	CRITICAL STRESS INTENSITY (DEPTH)	THRESHOLD STRESS INTENSIT (DEPTH)
1	5.000+01	1	0	4.000+01	3.500+00	4.000+01	3.500+00
2	7.000+01	1	0	5.000+01	5.500+00	5.000+01	5.500+00

--------------EQUATION CONSTANTS--------------

CONSTANT NUMBER	MATERIAL TYPE	CRACK GROWTH RATE SURFACE	CRACK GROWTH RATE DEPTH	RETARDATION MODEL SURFACE	RETARDATION MODEL DEPTH
1	1	2.200-09	2.200-09	0.000	0.000
2	1	3.300+00	3.300+00	0.000	0.000
3	1	4.000+01	4.000+01	0.000	0.000
4	1	3.500+00	3.500+00	0.000	0.000
1	2	8.900-12	8.900-12	0.000	0.000
2	2	4.820+00	4.820+00	0.000	0.000
3	2	5.000+01	5.000+01	0.000	0.000
4	2	5.500+00	5.500+00	0.000	0.000

RUN 2 2219 - 70 AND 320 - PEC/CCT

CRACK IS A THROUGH CRACK

BLOCK	STEP	CYCLES	HALF CRACK LENGTH (IN)	KMAX (KSI ROOT-IN)	CRACK GROWTH RATE (IN/CYCLE)
1	1	0.000	2.500-01	2.677+01	1.994-04

LIMIT LOAD FRACTURE OCCURS IN THE 1 BLOCK 1 STEP AFTER 3.691+02 CYCLES

CRITICAL K AT SURFACE HAS BEEN EXCEEDED IN THE 1 BLOCK AND THE 1 STEP AFTER 3.691+02 CYCLES

```
D6AC-RETARD/NO RETARD/WITH DADT
   3    500    2    1
        1.        1     1     1     1     3     2.        200.
   2    0       180.
  150.      0.          4.          1
  100.         0.        20.
   3
   99.          .5        .075        .05
   1
  190.          1     1     0    90.          6.          90.     6.
  7.5E-10
  2.74
  90.
  6.
  0.
  1.
  0.
        1           0     0     0     0     0
        1           0     1     0     1     0
   3    0       130.
  150.      0.          4.          1
  100.      0.         20.          1
  100.      0.        480.          2
  190.          1     0     0    90.          6.          90.     6.
  7.5E-10
  2.74
```

RUN 1

RUN 2

RUN 3

Continued on next page

```
 90.
 6.
 0.                                                              RUN 3 Cont.
 190.         2    0     0   90.      0.           90.      0.
 4.E-9
 1.
 0.
```

RUN 1 OF 2 RUNS D6AC - RETARD/NO RETARD/WITH DADT

LOAD INPUT DATA

STRESS FACTOR 1.000E+00
LIMIT STRESS 1.800E+02

STEP	MAX STRESS	MIN STRESS	UNITS(CYCLES)	MATERIAL TYPE
1	1.500E+02	0.0	4.000E+00	1
2	1.600E+02	0.0	7.000E+01	1

GEOMETRY INPUT DATA

CRACK TYPE	3
WIDTH	9.900E+01
THICKNESS	5.000E-01
CRACK DEPTH	7.500E-02
HALF CRACK LENGTH	5.000E-02

MATERIAL INPUT DATA

MATERIAL TYPE	YIELD STRENGTH	GROWTH EQUATION	RETARDATION MODEL	CRITICAL STRESS INTENSITY (SURFACE)	THRESHOLD STRESS INTENSITY (SURFACE)	CRITICAL STRESS INTENSITY (DEPTH)	THRESHOLD STRESS INTENSITY (DEPTH)
1	1.900E+02	1	1	9.000E+01	6.000E+00	9.000E+01	6.000E+00

CONSTANT NUMBER	MATERIAL TYPE	EQUATION CONSTANTS: CRACK GROWTH RATE SURFACE	CRACK GROWTH RATE DEPTH	RETARDATION MODEL SURFACE	RETARDATION MODEL DEPTH
1	1	7.500E-10	7.500E-10	1.000E+00	1.000E+00
2	1	2.740E+00	2.740E+00	0.0	0.0
3	1	9.000E+01	9.000E+01	0.0	0.0
4	1	6.000E+00	6.000E+00	0.0	0.0

ITERATION PARAMETERS

DESIGN LIFE	2.000E+02
CONVERGENCE EXPONENT	2.000E+00
ITERATION NUMBER	1

CRACK IS A PART THRU CRACK

BLOCK	STEP	CYCLES	HALF SURFACE CRACK LENGTH (IN)	CRACK DEPTH (IN)	KMAX-SURFACE (KSI ROOT-IN)	KMAX-DEPTH (KSI ROOT-IN)	SURFACE GROWTH RATE (IN/CYCLE)	DEPTH GROWTH RATE (IN/CYCLE)
1	1	0.0	5.000E-02	7.500E-02	5.952E+01	3.926E+01	9.975E-05	1.892E-05
1	1	4.000E+00	5.040E-02	7.508E-02	5.952E+01	3.926E+01	9.975E-05	1.892E-05
1	2	0.0	5.040E-02	7.508E-02	3.930E+01	2.601E+01	2.694E-06	7.543E-07
1	2	2.000E+01	5.045E-02	7.509E-02	3.930E+01	2.601E+01	2.694E-06	7.543E-07
2	1	0.0	5.045E-02	7.509E-02	5.954E+01	3.942E+01	9.996E-05	1.917E-05
2	1	4.000E+00	5.085E-02	7.517E-02	5.954E+01	3.942E+01	9.996E-05	1.917E-05
2	2	0.0	5.085E-02	7.517E-02	3.933E+01	2.612E+01	2.702E-06	7.648E-07
2	2	2.000E+01	5.091E-02	7.518E-02	3.933E+01	2.612E+01	2.702E-06	7.648E-07
4	1	0.0	5.136E-02	7.526E-02	5.962E+01	3.975E+01	1.007E-04	1.976E-05
4	1	4.000E+00	5.176E-02	7.534E-02	5.962E+01	3.975E+01	1.007E-04	1.976E-05
4	2	0.0	5.176E-02	7.535E-02	3.937E+01	2.634E+01	2.707E-06	7.860E-07
4	2	2.000E+01	5.182E-02	7.537E-02	3.937E+01	2.634E+01	2.707E-06	7.860E-07
6	1	0.0	5.228E-02	7.546E-02	5.970E+01	4.010E+01	1.014E-04	2.026E-05
6	1	4.000E+00	5.268E-02	7.555E-02	5.970E+01	4.010E+01	1.014E-04	2.026E-05
6	2	0.0	5.269E-02	7.555E-02	3.941E+01	2.656E+01	2.713E-06	8.079E-07
6	2	2.000E+01	5.274E-02	7.556E-02	3.941E+01	2.656E+01	2.713E-06	8.079E-07
8	1	0.0	5.320E-02	7.566E-02	5.978E+01	4.045E+01	1.021E-04	2.085E-05
8	1	4.000E+00	5.361E-02	7.574E-02	5.978E+01	4.045E+01	1.021E-04	2.085E-05
8	2	0.0	5.361E-02	7.574E-02	3.946E+01	2.679E+01	2.718E-06	8.307E-07
8	2	2.000E+01	5.366E-02	7.576E-02	3.946E+01	2.679E+01	2.718E-06	8.307E-07
10	1	0.0	5.412E-02	7.586E-02	5.985E+01	4.081E+01	1.028E-04	2.146E-05
10	1	4.000E+00	5.454E-02	7.595E-02	5.985E+01	4.081E+01	1.028E-04	2.146E-05
10	2	0.0	5.454E-02	7.595E-02	3.950E+01	2.702E+01	2.724E-06	8.540E-07
10	2	2.000E+01	5.459E-02	7.596E-02	3.950E+01	2.702E+01	2.724E-06	8.540E-07
12	1	0.0	5.506E-02	7.607E-02	5.993E+01	4.117E+01	1.035E-04	2.211E-05
12	1	4.000E+00	5.547E-02	7.616E-02	5.993E+01	4.117E+01	1.035E-04	2.211E-05
12	2	0.0	5.547E-02	7.616E-02	3.955E+01	2.726E+01	2.730E-06	8.780E-07
12	2	2.000E+01	5.553E-02	7.617E-02	3.955E+01	2.726E+01	2.730E-06	8.780E-07
14	1	0.0	5.600E-02	7.628E-02	6.001E+01	4.154E+01	1.043E-04	2.278E-05
14	1	4.000E+00	5.641E-02	7.637E-02	6.001E+01	4.154E+01	1.043E-04	2.278E-05
14	2	0.0	5.641E-02	7.637E-02	3.959E+01	2.750E+01	2.736E-06	9.025E-07
14	2	2.000E+01	5.647E-02	7.639E-02	3.959E+01	2.750E+01	2.736E-06	9.025E-07
16	1	0.0	5.694E-02	7.650E-02	6.009E+01	4.192E+01	1.050E-04	2.348E-05
16	1	4.000E+00	5.736E-02	7.659E-02	6.009E+01	4.192E+01	1.050E-04	2.348E-05
16	2	0.0	5.736E-02	7.659E-02	3.964E+01	2.775E+01	2.742E-06	9.277E-07
16	2	2.000E+01	5.742E-02	7.661E-02	3.964E+01	2.775E+01	2.742E-06	9.277E-07
18	1	0.0	5.789E-02	7.672E-02	6.017E+01	4.230E+01	1.058E-04	2.421E-05
18	1	4.000E+00	5.832E-02	7.682E-02	6.017E+01	4.230E+01	1.058E-04	2.421E-05
18	2	0.0	5.832E-02	7.682E-02	3.968E+01	2.799E+01	2.748E-06	9.534E-07
18	2	2.000E+01	5.837E-02	7.684E-02	3.968E+01	2.799E+01	2.748E-06	9.534E-07
20	1	0.0	5.885E-02	7.696E-02	6.025E+01	4.268E+01	1.065E-04	2.497E-05
20	1	4.000E+00	5.928E-02	7.706E-02	6.025E+01	4.268E+01	1.065E-04	2.497E-05
20	2	0.0	5.928E-02	7.706E-02	3.973E+01	2.824E+01	2.754E-06	9.797E-07
20	2	2.000E+01	5.933E-02	7.708E-02	3.973E+01	2.824E+01	2.754E-06	9.797E-07
22	1	0.0	5.981E-02	7.720E-02	6.033E+01	4.307E+01	1.073E-04	2.576E-05
22	1	4.000E+00	6.024E-02	7.730E-02	6.033E+01	4.307E+01	1.073E-04	2.576E-05
22	2	0.0	6.024E-02	7.730E-02	3.977E+01	2.849E+01	2.760E-06	1.006E-06
22	2	2.000E+01	6.030E-02	7.732E-02	3.977E+01	2.849E+01	2.760E-06	1.006E-06
24	1	0.0	6.078E-02	7.745E-02	6.041E+01	4.346E+01	1.081E-04	2.657E-05
24	1	4.000E+00	6.122E-02	7.755E-02	6.041E+01	4.346E+01	1.081E-04	2.657E-05
24	2	0.0	6.122E-02	7.755E-02	3.982E+01	2.874E+01	2.767E-06	1.034E-06
24	2	2.000E+01	6.127E-02	7.758E-02	3.982E+01	2.874E+01	2.767E-06	1.034E-06
26	1	0.0	6.176E-02	7.770E-02	6.050E+01	4.386E+01	1.089E-04	2.742E-05

150	1	4.000E+00	1.934E-01	1.525E-01	8.190E+01	8.033E+01	1.972E-03	1.374E-03
150	2	0.0	1.934E-01	1.525E-01	5.357E+01	5.254E+01	5.288E-06	4.995E-06
150	2	7.000E+01	1.935E-01	1.526E-01	5.357E+01	5.254E+01	5.288E-06	4.995E-06
152	1	0.0	2.031E-01	1.593E-01	8.366E+01	8.240E+01	3.714E-03	2.241E-03
152	1	4.000E+00	2.272E-01	1.762E-01	8.779E+01	8.733E+01	2.458E-02	1.718E-02
152	2	0.0	2.272E-01	1.762E-01	5.742E+01	5.713E+01	6.557E-06	6.400E-06
152	2	2.000E+01	2.273E-01	1.763E-01	5.742E+01	5.713E+01	6.557E-06	6.400E-06

LIMIT LOAD FRACTURE OCCURS IN THE 137 BLOCK 2 STEP AFTER 0.0 CYCLES

CRITICAL K AT DEPTH HAS BEEN EXCEEDED IN THE 153 BLOCK AND THE 1 STEP AFTER 2.199E-01 CYCLES

THICKNESS	LIFE	PERCENT OF REQUIRED LIFE
5.000E-01	1.535E+02	76.75
5.707E-01	3.325E+02	166.25
4.426E-01	6.250E+01	31.25

RUN 2 OF 3 RUNS D6AC - RETARD/NO RETARD/WITH DADT

LOAD INPUT DATA

STRESS FACTOR	1.000E+00
LIMIT STRESS	1.800E+02

STEP	MAX STRESS	MIN STRESS	UNITS(CYCLES)	MATERIAL TYPE
1	1.500E+02	0.0	4.000E+00	1
2	1.000E+02	0.0	2.000E+01	1

GEOMETRY INPUT DATA

CRACK TYPE	3
WIDTH	9.900E+01
THICKNESS	5.000E-01
CRACK DEPTH	7.500E-02
HALF CRACK LENGTH	5.000E-02

MATERIAL INPUT DATA

MATERIAL TYPE	YIELD STRENGTH	GROWTH EQUATION	RETARDATION MODEL	CRITICAL STRESS INTENSITY (SURFACE)	THRESHOLD STRESS INTENSITY (SURFACE)	CRITICAL STRESS INTENSITY (DEPTH)	THRESHOLD STRESS INTENSITY (DEPTH)
1	1.900E+02	1	0	9.000E+01	6.000E+00	9.000E+01	6.000E+00

		---------------EQUATION CONSTANTS---------------			
		CRACK GROWTH RATE		RETARDATION MODEL	
CONSTANT NUMBER	MATERIAL TYPE	SURFACE	DEPTH	SURFACE	DEPTH
1	1	7.500E-10	7.500E-10	1.000E+00	1.000E+00
2	1	2.740E+00	2.740E+00	0.0	0.0
3	1	9.000E+01	9.000E+01	0.0	0.0
4	1	6.000E+00	6.000E+00	0.0	0.0

CRACK IS A PART THRU CRACK

BLOCK	STEP	CYCLES	HALF SURFACE CRACK LENGTH (IN)	CRACK DEPTH (IN)	KMAX-SURFACE (KSI ROOT-IN)	KMAX-DEPTH (KSI ROOT-IN)	SURFACE GROWTH RATE (IN/CYCLE)	DEPTH GROWTH RATE (IN/CYCLE)
1	1	0.0	5.000E-02	7.500E-02	5.952E+01	3.926E+01	9.975E-05	1.892E-05
1	1	4.000E+00	5.040E-02	7.508E-02	5.952E+01	3.926E+01	9.975E-05	1.892E-05
1	2	0.0	5.040E-02	7.508E-02	3.931E+01	2.601E+01	1.900E-05	5.662E-06
1	2	2.000E+01	5.078E-02	7.519E-02	3.931E+01	2.601E+01	1.900E-05	5.662E-06
2	1	0.0	5.078E-02	7.519E-02	5.960E+01	3.954E+01	1.004E-04	1.936E-05
2	1	4.000E+00	5.118E-02	7.527E-02	5.960E+01	3.954E+01	1.004E-04	1.936E-05
2	2	0.0	5.118E-02	7.527E-02	3.936E+01	2.620E+01	1.907E-05	5.774E-06
2	2	2.000E+01	5.156E-02	7.538E-02	3.936E+01	2.620E+01	1.907E-05	5.774E-06
4	1	0.0	5.235E-02	7.558E-02	5.975E+01	4.013E+01	1.019E-04	2.031E-05
4	1	4.000E+00	5.276E-02	7.566E-02	5.975E+01	4.013E+01	1.019E-04	2.031E-05
4	2	0.0	5.276E-02	7.566E-02	3.945E+01	2.658E+01	1.921E-05	6.010E-06
4	2	2.000E+01	5.314E-02	7.578E-02	3.945E+01	2.658E+01	1.921E-05	6.010E-06
6	1	0.0	5.394E-02	7.599E-02	5.991E+01	4.074E+01	1.033E-04	2.134E-05
6	1	4.000E+00	5.435E-02	7.607E-02	5.991E+01	4.074E+01	1.033E-04	2.134E-05
6	2	0.0	5.435E-02	7.607E-02	3.954E+01	2.698E+01	1.936E-05	6.262E-06
6	2	2.000E+01	5.474E-02	7.620E-02	3.954E+01	2.698E+01	1.936E-05	6.262E-06
8	1	0.0	5.554E-02	7.641E-02	6.007E+01	4.136E+01	1.048E-04	2.245E-05
8	1	4.000E+00	5.596E-02	7.650E-02	6.007E+01	4.136E+01	1.048E-04	2.245E-05
8	2	0.0	5.596E-02	7.650E-02	3.964E+01	2.739E+01	1.951E-05	6.529E-06
8	2	2.000E+01	5.635E-02	7.663E-02	3.964E+01	2.739E+01	1.951E-05	6.529E-06
10	1	0.0	5.717E-02	7.686E-02	6.023E+01	4.200E+01	1.063E-04	2.364E-05
10	1	4.000E+00	5.759E-02	7.695E-02	6.023E+01	4.200E+01	1.063E-04	2.364E-05
10	2	0.0	5.759E-02	7.695E-02	3.973E+01	2.780E+01	1.966E-05	6.809E-06
10	2	2.000E+01	5.798E-02	7.709E-02	3.973E+01	2.780E+01	1.966E-05	6.809E-06
12	1	0.0	5.881E-02	7.732E-02	6.040E+01	4.265E+01	1.079E-04	2.492E-05
12	1	4.000E+00	5.924E-02	7.742E-02	6.040E+01	4.265E+01	1.079E-04	2.492E-05
12	2	0.0	5.924E-02	7.742E-02	3.983E+01	2.823E+01	1.982E-05	7.103E-06
12	2	2.000E+01	5.964E-02	7.756E-02	3.983E+01	2.823E+01	1.982E-05	7.103E-06
14	1	0.0	6.047E-02	7.781E-02	6.057E+01	4.331E+01	1.096E-04	2.627E-05
14	1	4.000E+00	6.091E-02	7.792E-02	6.057E+01	4.331E+01	1.096E-04	2.627E-05
14	2	0.0	6.091E-02	7.792E-02	3.993E+01	2.865E+01	1.998E-05	7.409E-06
14	2	2.000E+01	6.131E-02	7.806E-02	3.993E+01	2.865E+01	1.998E-05	7.409E-06
16	1	0.0	6.215E-02	7.832E-02	6.074E+01	4.398E+01	1.113E-04	2.771E-05
16	1	4.000E+00	6.259E-02	7.843E-02	6.074E+01	4.398E+01	1.113E-04	2.771E-05
16	2	0.0	6.259E-02	7.843E-02	4.003E+01	2.909E+01	2.015E-05	7.728E-06
16	2	2.000E+01	6.300E-02	7.859E-02	4.003E+01	2.909E+01	2.015E-05	7.728E-06
18	1	0.0	6.385E-02	7.886E-02	6.092E+01	4.465E+01	1.132E-04	2.924E-05
18	1	4.000E+00	6.430E-02	7.898E-02	6.092E+01	4.465E+01	1.132E-04	2.924E-05
18	2	0.0	6.430E-02	7.898E-02	4.014E+01	2.952E+01	2.033E-05	8.058E-06
18	2	2.000E+01	6.471E-02	7.914E-02	4.014E+01	2.952E+01	2.033E-05	8.058E-06
20	1	0.0	6.558E-02	7.942E-02	6.110E+01	4.533E+01	1.151E-04	3.086E-05
20	1	4.000E+00	6.604E-02	7.955E-02	6.110E+01	4.533E+01	1.151E-04	3.086E-05
20	2	0.0	6.604E-02	7.955E-02	4.025E+01	2.996E+01	2.051E-05	8.401E-06
20	2	2.000E+01	6.645E-02	7.971E-02	4.025E+01	2.996E+01	2.051E-05	8.401E-06
22	1	0.0	6.732E-02	8.001E-02	6.129E+01	4.600E+01	1.171E-04	3.258E-05
22	1	4.000E+00	6.779E-02	8.014E-02	6.129E+01	4.600E+01	1.171E-04	3.258E-05
22	2	0.0	6.779E-02	8.014E-02	4.036E+01	3.040E+01	2.070E-05	8.755E-06
22	2	2.000E+01	6.820E-02	8.032E-02	4.036E+01	3.040E+01	2.070E-05	8.755E-06
24	1	0.0	6.905E-02	8.063E-02	6.149E+01	4.668E+01	1.192E-04	3.439E-05
24	1	4.000E+00	6.957E-02	8.077E-02	6.149E+01	4.668E+01	1.192E-04	3.439E-05
24	2	0.0	6.957E-02	8.077E-02	4.048E+01	3.083E+01	2.091E-05	9.121E-06
24	2	2.000E+01	6.995E-02	8.095E-02	4.048E+01	3.083E+01	2.091E-05	9.121E-06
26	1	0.0	7.084E-02	[illegible]	6.169E+01	4.726E+01	1.215E-04	3.631E-05

88	1	4.000E+00	1.711E-01	1.386E-01	7.314E+01	7.516E+01	8.999E-04	5.576E-04
88	2	0.0	1.711E-01	1.386E-01	5.125E+01	4.935E+01	4.964E-05	4.260E-05
88	2	2.000E+01	1.721E-01	1.394E-01	5.125E+01	4.935E+01	4.964E-05	4.260E-05
90	1	0.0	1.772E-01	1.428E-01	7.945E+01	7.680E+01	1.156E-03	7.176E-04
90	1	4.000E+00	1.820E-01	1.458E-01	8.022E+01	7.782E+01	1.243E-03	8.512E-04
90	2	0.0	1.820E-01	1.458E-01	5.249E+01	5.093E+01	5.494E-05	4.839E-05
90	2	2.000E+01	1.831E-01	1.468E-01	5.249E+01	5.093E+01	5.494E-05	4.839E-05
92	1	0.0	1.904E-01	1.517E-01	8.180E+01	7.971E+01	1.424E-03	1.211E-03
92	1	4.000E+00	1.992E-01	1.573E-01	8.295E+01	8.126E+01	7.605E-03	1.690E-03
92	2	0.0	1.992E-01	1.573E-01	5.441E+01	5.335E+01	6.433E-05	5.894E-05
92	2	2.000E+01	2.004E-01	1.585E-01	5.441E+01	5.335E+01	6.433E-05	5.894E-05
94	1	0.0	2.204E-01	1.720E-01	8.687E+01	8.601E+01	1.263E-02	7.947E-03

LIMIT LOAD FRACTURE OCCURS IN THE 81 BLOCK 1 STEP AFTER 0.0 CYCLES

CRITICAL K AT DEPTH HAS BEEN EXCEEDED IN THE 94 BLOCK AND THE 1 STEP AFTER 6.666E-01 CYCLES

ORIGINAL PAGE IS
OF POOR QUALITY

RUN 3 OF 3 RUNS D6AC - RETARD/NO RETARD/WITH DAPT

LOAD INPUT DATA

STRESS FACTOR	1.000E+00
LIMIT STRESS	1.800E+02

STEP	MAX STRESS	MIN STRESS	UNITS(CYCLES)	MATERIAL TYPE
1	1.500E+02	0.0	4.000E+00	1
2	1.000E+02	0.0	2.000E+01	1
3	1.000E+02	0.0	4.800E+02	2

GEOMETRY INPUT DATA

CRACK TYPE	3
WIDTH	9.400E+01
THICKNESS	5.000E-01
CRACK DEPTH	7.500E-02
HALF CRACK LENGTH	5.000E-02

MATERIAL INPUT DATA

MATERIAL TYPE	YIELD STRENGTH	GROWTH EQUATION	RETARDATION MODEL	CRITICAL STRESS INTENSITY (SURFACE)	THRESHOLD STRESS INTENSITY (SURFACE)	CRITICAL STRESS INTENSITY (DEPTH)	THRESHOLD STRESS INTENSITY (DEPTH)
1	1.900E+02	1	0	9.000E+01	6.000E+00	9.000E+01	6.000E+00
2	1.900E+02	2	0	9.000E+01	0.0	9.000E+01	0.0

CONSTANT NUMBER	MATERIAL TYPE	--------------EQUATION CONSTANTS-------------- CRACK GROWTH RATE SURFACE	DEPTH	RETARDATION MODEL SURFACE	DEPTH
1	1	7.500E-10	7.500E-10	1.000E+00	1.000E+00
2	1	2.740E+00	2.740E+00	0.0	0.0
3	1	9.000E+01	9.000E+01	0.0	0.0
4	1	6.000E+00	6.000E+00	0.0	0.0
1	2	4.000E-09	4.000E-09	0.0	0.0
2	2	1.000E+00	1.000E+00	0.0	0.0

ORIGINAL PAGE IS
OF POOR QUALITY

RUN 3 D6AC -- RETARD/NO RETARD/WITH DADT

CRACK IS A PART THRU CRACK

BLOCK	STEP	CYCLES	HALF SURFACE CRACK LENGTH (IN)	CRACK DEPTH (IN)	KMAX-SURFACE (KSI ROOT-IN)	KMAX-DEPTH (KSI ROOT-IN)	SURFACE GROWTH RATE (IN/CYCLE)	DEPTH GROWTH RATE (IN/CYCLE)
1	1	0.0	5.000E-02	7.500E-02	5.952E+01	3.926E+01	9.975E-05	1.892E-05
1	1	4.000E+00	5.040E-02	7.508E-02	5.952E+01	3.926E+01	9.975E-05	1.892E-05
1	2	0.0	5.040E-02	7.508E-02	3.931E+01	2.601E+01	1.900E-05	5.662E-06
1	2	2.000E+01	5.078E-02	7.519E-02	3.931E+01	2.601E+01	1.900E-05	5.662E-06
1	3	0.0	5.078E-02	7.519E-02	3.934E+01	2.610E+01	1.574E-07	1.044E-07
1	3	4.800E+02	5.085E-02	7.524E-02	3.934E+01	2.610E+01	1.574E-07	1.044E-07
2	1	0.0	5.085E-02	7.524E-02	5.962E+01	3.957E+01	1.006E-04	1.940E-05
2	1	4.000E+00	5.126E-02	7.532E-02	5.962E+01	3.957E+01	1.006E-04	1.940E-05
2	2	0.0	5.126E-02	7.532E-02	3.937E+01	2.622E+01	1.909E-05	5.766E-06
2	2	2.000E+01	5.164E-02	7.543E-02	3.937E+01	2.622E+01	1.909E-05	5.766E-06
2	3	0.0	5.164E-02	7.543E-02	3.940E+01	2.631E+01	1.576E-07	1.052E-07
2	3	4.800E+02	5.171E-02	7.548E-02	3.940E+01	2.631E+01	1.576E-07	1.052E-07
4	1	0.0	5.258E-02	7.573E-02	5.981E+01	4.022E+01	1.024E-04	2.045E-05
4	1	4.000E+00	5.299E-02	7.581E-02	5.981E+01	4.022E+01	1.024E-04	2.045E-05
4	2	0.0	5.299E-02	7.581E-02	3.949E+01	2.664E+01	1.927E-05	6.047E-06
4	2	2.000E+01	5.337E-02	7.593E-02	3.949E+01	2.664E+01	1.927E-05	6.047E-06
4	3	0.0	5.337E-02	7.593E-02	3.952E+01	2.673E+01	1.581E-07	1.069E-07
4	3	4.800E+02	5.345E-02	7.598E-02	3.952E+01	2.673E+01	1.581E-07	1.069E-07
6	1	0.0	5.433E-02	7.624E-02	6.001E+01	4.059E+01	1.042E-04	2.160E-05
6	1	4.000E+00	5.474E-02	7.633E-02	6.001E+01	4.059E+01	1.042E-04	2.160E-05
6	2	0.0	5.474E-02	7.633E-02	3.961E+01	2.708E+01	1.946E-05	6.327E-06
6	2	2.000E+01	5.513E-02	7.646E-02	3.961E+01	2.708E+01	1.946E-05	6.327E-06
6	3	0.0	5.513E-02	7.646E-02	3.964E+01	2.718E+01	1.585E-07	1.087E-07
6	3	4.800E+02	5.521E-02	7.651E-02	3.964E+01	2.718E+01	1.585E-07	1.087E-07
8	1	0.0	5.610E-02	7.678E-02	6.021E+01	4.158E+01	1.061E-04	2.285E-05
8	1	4.000E+00	5.652E-02	7.687E-02	6.021E+01	4.158E+01	1.061E-04	2.285E-05
8	2	0.0	5.652E-02	7.687E-02	3.973E+01	2.753E+01	1.965E-05	6.623E-06
8	2	2.000E+01	5.692E-02	7.700E-02	3.973E+01	2.753E+01	1.965E-05	6.623E-06
8	3	0.0	5.692E-02	7.700E-02	3.976E+01	2.763E+01	1.590E-07	1.105E-07
8	3	4.800E+02	5.699E-02	7.706E-02	3.976E+01	2.763E+01	1.590E-07	1.105E-07
10	1	0.0	5.789E-02	7.734E-02	6.042E+01	4.228E+01	1.081E-04	2.419E-05
10	1	4.000E+00	5.832E-02	7.744E-02	6.042E+01	4.228E+01	1.081E-04	2.419E-05
10	2	0.0	5.832E-02	7.744E-02	3.985E+01	2.799E+01	1.985E-05	6.937E-06
10	2	2.000E+01	5.872E-02	7.757E-02	3.985E+01	2.799E+01	1.985E-05	6.937E-06
10	3	0.0	5.872E-02	7.757E-02	3.988E+01	2.809E+01	1.595E-07	1.124E-07
10	3	4.800E+02	5.880E-02	7.763E-02	3.988E+01	2.809E+01	1.595E-07	1.124E-07
12	1	0.0	5.971E-02	7.792E-02	6.062E+01	4.300E+01	1.102E-04	2.562E-05
12	1	4.000E+00	6.015E-02	7.803E-02	6.062E+01	4.300E+01	1.102E-04	2.562E-05
12	2	0.0	6.015E-02	7.803E-02	3.997E+01	2.845E+01	2.005E-05	7.265E-06
12	2	2.000E+01	6.055E-02	7.817E-02	3.997E+01	2.845E+01	2.005E-05	7.265E-06
12	3	0.0	6.055E-02	7.817E-02	4.001E+01	2.856E+01	1.600E-07	1.142E-07
12	3	4.800E+02	6.063E-02	7.823E-02	4.001E+01	2.856E+01	1.600E-07	1.142E-07
14	1	0.0	6.155E-02	7.853E-02	6.084E+01	4.373E+01	1.123E-04	2.716E-05
14	1	4.000E+00	6.200E-02	7.864E-02	6.084E+01	4.373E+01	1.123E-04	2.716E-05
14	2	0.0	6.200E-02	7.864E-02	4.010E+01	2.893E+01	2.027E-05	7.609E-06
14	2	2.000E+01	6.241E-02	7.880E-02	4.010E+01	2.893E+01	2.027E-05	7.609E-06
14	3	0.0	6.241E-02	7.880E-02	4.013E+01	2.903E+01	1.605E-07	1.161E-07
14	3	4.800E+02	6.249E-02	7.885E-02	4.013E+01	2.903E+01	1.605E-07	1.161E-07
16	1	0.0	6.342E-02	7.917E-02	6.106E+01	4.447E+01	1.146E-04	2.881E-05
16	1	4.000E+00	6.388E-02	7.929E-02	6.106E+01	4.447E+01	1.146E-04	2.881E-05
16	2	0.0	6.388E-02	7.929E-02	4.023E+01	2.940E+01	2.049E-05	7.968E-06
16	2	2.000E+01	6.429E-02	7.945E-02	4.023E+01	2.940E+01	2.049E-05	7.968E-06
16	3	0.0	6.429E-02	7.945E-02	4.027E+01	2.951E+01	1.611E-07	1.180E-07

78	3	4.800E+02	1.618E-01	1.331E-01	5.032E+01	4.794E+01	2.013E-07	1.918E-07
80	1	0.0	1.658E-01	1.357E-01	7.763E+01	7.422E+01	5.242E-04	4.871E-04
80	1	4.000E+00	1.691E-01	1.377E-01	7.799E+01	7.474E+01	8.759E-04	5.248E-04
80	2	0.0	1.691E-01	1.377E-01	5.113E+01	4.906E+01	4.917E-05	4.161E-05
80	2	2.000E+01	1.701E-01	1.385E-01	5.113E+01	4.906E+01	4.917E-05	4.161E-05
80	3	0.0	1.701E-01	1.385E-01	5.129E+01	4.921E+01	2.051E-07	1.968E-07
80	3	4.800E+02	1.702E-01	1.386E-01	5.129E+01	4.921E+01	2.051E-07	1.968E-07
82	1	0.0	1.752E-01	1.419E-01	7.929E+01	7.636E+01	1.114E-03	6.692E-04
82	1	4.000E+00	1.798E-01	1.447E-01	7.965E+01	7.689E+01	1.196E-03	7.182E-04
82	2	0.0	1.798E-01	1.447E-01	5.233E+01	5.062E+01	5.422E-05	4.726E-05
82	2	2.000E+01	1.804E-01	1.457E-01	5.233E+01	5.062E+01	5.422E-05	4.726E-05
82	3	0.0	1.804E-01	1.457E-01	5.251E+01	5.078E+01	2.100E-07	2.031E-07
82	3	4.800E+02	1.810E-01	1.459E-01	5.251E+01	5.078E+01	2.100E-07	2.021E-07
84	1	0.0	1.881E-01	1.504E-01	8.150E+01	7.920E+01	1.788E-03	1.094E-03
84	1	4.000E+00	1.960E-01	1.554E-01	8.264E+01	8.078E+01	2.386E-03	1.517E-03
84	2	0.0	1.960E-01	1.554E-01	5.410E+01	5.291E+01	6.273E-05	5.636E-05
84	2	2.000E+01	1.973E-01	1.565E-01	5.410E+01	5.291E+01	6.273E-05	5.636E-05
84	3	0.0	1.973E-01	1.565E-01	5.431E+01	5.309E+01	7.172E-07	2.124E-07
84	3	4.800E+02	1.974E-01	1.566E-01	5.431E+01	5.309E+01	2.172E-07	2.124E-07
86	1	0.0	2.129E-01	1.679E-01	8.565E+01	8.447E+01	6.717E-03	4.206E-03

LIMIT LOAD FRACTURE OCCURS IN THE 72 BLOCK 2 STEP AFTER 0.0 CYCLES

CRITICAL K AT DEPTH HAS BEEN EXCEEDED IN THE 86 BLOCK AND THE 1 STEP AFTER 1.632E+00 CYCLES

ORIGINAL PAGE IS
OF POOR QUALITY

REFERENCES

1) Feddersen, C. E., Discussion to: Plane Strain Crack Toughness Testing, ASTM STP No. 410, pg 77, 1966.

2) Anonymous "Standard Method of Test for Plane Strain Fracture Toughness of Metallic Material," E399-72, 1974 Annual Book of ASTM Standards.

3) Rawe, R. A. & D. E. Schwab, "Safe Life Design Practices: Practical Applications of Fracture Mechanics." Printed Lecture Notes for Course Presented at UCLA, Mar., 1970.

4) ASTM Special Committee on Fracture Testing of High-Strength Metallic Materials,"Progress in the Measurement of Fracture Toughness and the Application of Fracture Mechanics to Engineering Problems," Materials Research & Standards Vol. 4, No. 3, March, 1964, p. 107

5) Isida, M., "Stress Intensity Factors for the Tension of an Eccentrically Cracked Strip," Trans. ASME Series E, J. of Applied Mechanics, Vol. 33, p 674, 1965.

6) Smith, F. W., Emery, A. F. and Kobayashi, A. S., "Stress Intensity Factors for Semicircular Cracks" (Part II - Semi-Infinite Solid) Transactions of ASME, Series E., J of Applied Mechanics (Dec., 1967)

7) Shah, R. C. and Kobayashi, A. S., "On the Surface Flaw Problem," presented at the ASME 93rd Annual (Winter) Meeting, N. Y., N. Y., Nov. 1972.

8) Collipriest, J. E. and Ehret, R. M;"Computer Modeling of Part Through Crack Growth," Report SD 72-Ce-0015B, Space Division, Rockwell International Corp., Downey, Ca. (July, 1972.)

9) Willenborg, R. M., Engle, R. M., and Wood, H. A.,"A Crack Growth Retardation Model Using an Effective Stress Concept," AFFDL Technical Memorandum 71-1-FBN

10) Wheeler, D. E. "Crack Growth Under Spectrum Loading," General Dynamics, Fort Worth Division, FZM 5602 (June, 1970).

11) Bell, P. D., and Creager, M. " Crack Growth Analysis for Arbitrary Spectrum Loading," AFFDL-TR-74-129, Vol. 1, Final Report: June, 1972 - Oct., 1974.

APPENDIX

COMPUTER PROGRAM LISTING

APPENDIX

COMPUTER PROGRAM LISTING

```
      COMMON A,AP(2),ALIM,AOL(2),C,CB,CLIM,CH(2,10,10),CD,CUME,
     1 CUMELM,D(2,10,10),DK,DKE,DXMX,FA,FC,INC,KCL,KCI,KOL,
     2 KOA,KOC,KCRA,KCRC,KMAX,OA,OC,PI,R,RE,RVOL(2),ROL(2),
     3 SIG,SIGLM,SIGY,SIGYS(10),SMIN(422),SMAX(422),TH,
     4 UNIT(422),W,DCTMP,DELTMP,DXTMP,
     5 ALOWN,BLOCK,FLAG1,I,ICD(2),ICK(2),ICR(2),IBLOCK,IFIRST,IPRN(4),
     6 ISTEP,ITRANS,J,KTYPE,NC,NEQ(10),NR,NRET(10),TYPE,TITL
      DIMENSION THICK(10),PCTLF(10)
      INTEGER ALOWN,BLOCK,FLAG1,TYPE(422),ONSTEP,TITL(20)
      REAL KCL,KCI,KOL,KOA(10),KOC(10),KCRA(10),KCRC(10),KMAX,INC
      REAL LIFE(10)
      DO 5 I=1,2
      DO 5 J=1,10
      DO 5 K=1,10
      D(I,J,K)=0
    5 CH(I,J,K)=0
      PI=3.1415927
      DCTMP=0.
      DELTMP=0.
      DXTMP=0.
      ONSTEP=-1
      NR=0
      READ (5,5001) (TITL(I), I=1,20)
      READ (5,5002) NRUNS,NBLOCK,MBLOCK,MSTEP
      IF (MBLOCK) 7,6,7
    6 MBLOCK=NBLOCK+1
    7 CONTINUE
   10 READ (5,5003) CSTRS,NSUP,NLOAD,NGEOM,NMAT,ITER,PIT,BLIFE
      DO 9 K=1,10
    9 NRET(K)=NSUP*NRET(K)
      ITCNT=0
      IF (ITER-10) 12,12,11
   11 ITER=10
   12 IF (NLOAD-1) 90,20,90
   20 READ (5,5004) NSTEP,IR,SIGLM
      IF (MSTEP-(ONSTEP+1)) 23,21,23
   23 IF (MSTEP)  22,21,22
   21 MSTEP=NSTEP+1
   22 CONTINUE
      DO 30  I=1,NSTEP
   30 READ (5,5005) SMAX(I),SMIN(I),UNIT(I),TYPE(I)
   40 DO 50 I=1,NSTEP
   50 SMIN(I)=SMIN(I)*SMAX(I)
   60 IF (CSTRS) 70,90,70
   70 SIGLM = CSTRS*SIGLM
      DO 80 I=1,NSTEP
      SMIN(I)=CSTRS*SMIN(I)
   80 SMAX(I)=CSTRS*SMAX(I)
   90 IF (NGEOM-1) 110,100,110
  100 READ (5,5002) KTYPO
      READ (5,5006) W,TH,CO,AO
      OTH=TH
  110 IF (NMAT-1) 401,115,401
  115 READ (5,5002) NJ
      DO 400 J=1,NJ
      READ (5,5007) SIGYS(J),NEQ(J),NRET(J),NDUP,
     1 KCRC(J),KOC(J),KCRA(J),KOA(J)
      NRET(J)=NSUP*NRET(J)
      I=0
  120 I=I+1
      READ (5,5006) D(1,I,J)
      IF (D(1,I,J)) 120,130,120
  130 DO 135 JI=1,10
  135 D(1,JI,J)=0
      IF (NDUP-1) 140,160,140
  140 DO 150 I=1,10
  150 D(2,I,J)=D(1,I,J)
      GO TO 190
  160 I=0
```

```
00344          170 I=I+1
00345              READ (5,5006) D(2,I,J)
00350              IF (D(2,I,J)) 170,180,170
00353          180 DO 185 J1=1,10
00356          185 D(2,J1,J)=0
00360          190 IF (NRET(J)) 200,400,200
00363          200 I=0
00364          210 I=I+1
00365              READ (5,5006) CR(1,I,J)
00370              IF (CR(1,I,J)) 210,220,210
00373          220 DO 225 J1=1,10
00376          225 CR(1,J1,J)=0
00400              IF (NDUP-1) 230,250,230
00403          230 DO 240 I=1,10
00406          240 CR(2,I,J)=CR(1,I,J)
00410              GO TO 400
00411          250 I=0
00412          260 I=I+1
00413              READ (5,5006) CR(2,I,J)
00416              IF (CR(2,I,J)) 260,270,260
00421          270 DO 275 J1=1,10
00424          275 CR(2,J1,J)=0
00426          400 CONTINUE
00430          401 NR=NR+1
00431              IF (NR-1) 410,410,440
00434          410 I=NLOAD+NGEOM+NMAT
00435              IF (I-3) 420,430,420
00440          420 WRITE(6,6001)
00442              STOP
00443          430 OCSTRS=CSTRS
00444              ONSTEP=NSTEP
00445              GO TO 530
00446          440 IF (NLOAD-1) 450,430,450
00451          450 IF (OCSTRS-CSTRS) 460,530,460
00454          460 IF (OCSTRS) 490,470,490
00457          470 DO 480 I=1,ONSTEP
00462              SMIN(I)=SMIN(I)*CSTRS
00463          480 SMAX(I)=SMAX(I)*CSTRS
00465              SIGLM = CSTRS*SIGLM
00466              OCSTRS=CSTRS
00467              GO TO 530
00470          490 DO 500 I=1,ONSTEP
00473              SMIN(I)=SMIN(I)/OCSTRS
00474          500 SMAX(I)=SMAX(I)/OCSTRS
00476              SIGLM = SIGLM/OCSTRS
00477              OCSTRS=CSTRS
00500              IF (CSTRS) 510,530,510
00503          510 DO 520 I=1,ONSTEP
00506              SMIN(I)=SMIN(I)*CSTRS
00507          520 SMAX(I)=SMAX(I)*CSTRS
00511              SIGLM = CSTRS*SIGLM
00512          530 WRITE(6,8002) NR,NRUNS,TITL
00517              WRITE(6,8003) CSTRS,SIGLM
00523              DO 540 J1=1,NSTEP
00526          540 WRITE(6,8004) J1,SMAX(J1),SMIN(J1),UNIT(J1),TYPE(J1)
00536              WRITE(6,8005) KTYPO,A,TH
00543              IF (KTYPO-1) 542,541,542
00546          541 WRITE(6,8007) CO
00551              GO TO 543
00552          542 WRITE(6,8006) AO
00555              WRITE(6,8007) CO
00560          543 WRITE(6,8008)
00562              DO 550 J1=1,NJ
00565              WRITE(6,8009) J1,SIGYS(J1),NEQ(J1),NRET(J1),KCRC(J1),KOC(J1),
00565             1 KCRA(J1),KOA(J1)
00577          550 CONTINUE
00601              WRITE(6,8010)
00603              DO 580 J1=1,NJ
00606              DO 580 J2=1,10
00611              IF (D(1,J2,J1)) 570,561,570
00614          561 IF (D(2,J2,J1)) 570,562,570
00617          562 IF (CR(1,J2,J1)) 570,563,570
00622          563 IF (CR(2,J2,J1)) 570,580,570
```

```
00625       570 WRITE(6,80[illegible]) J2,J1,D(1,J2,J1),D(2,J2,J1),
00625          1 CR(1,J2,J1),CR(2,J2,J1)
00635       580 CONTINUE
00640           IF (ITER) 582,582,581
00643       581 K=ITCNT+1
00644           WRITE(6,8012) BLIFE,PIT,K
00651       582 CONTINUE
00652           ICK(1)=0
00653           ICK(2)=20
00654           ICD(1)=0
00655           ICD(2)=20
00656           ICR(1)=0
00657           ICR(2)=20
00660           INC=.01
00661           ING=0
00662           BLOCK=1
00663           I=1
00664           ITRANS=0
00665           IPRN(1)=-1
00666           IPRN(2)=-1
00667           IPRN(3)=-1
00670           IPRN(4)=2*NSTEP
00671           FLAG1=0
00672           CUME=0
00673           KTYPE=KTYPO
00674           C=CO
00675           A=AO
00676           OA=A
00677           OC=C
00700           AP(1)=CO
00701           AP(2)=AO
00702           RVOL(1)=0
00703           ALOWN=0
00704           RVOL(2)=0
00705           KOL=0
00706           KCL=0
00707           KC1=0
00710       590 CONTINUE
00711           IF (MOD(BLOCK,MBLOCK)) 595,591,595
00714       591 IF (MOD(I,MSTEP)) 595,592,595
00717       592 DO 594 K=1,3
00722           IF (IPRN(K)-IPRN(4)) 594,593,594
00725       593 IPRN(K)=IPRN(K)-2
00726       594 CONTINUE
00730       595 CONTINUE
00731           IF (ITRANS-1) 597,596,597
00734       596 CALL TRANS
00735           GO TO 620
00736       597 IF (KTYPE-3) 600,610,600
00741       600 CALL TCGROW
00742           GO TO 620
00743       610 CALL PTCGRW
00744       620 CONTINUE
00745           IF (ICR(1)+1) 710,710,630
00750       630 CUME = 0
00751           I=I+1
00752           IF (I-NSTEP) 590,590,660
00755       660 BLOCK=BLOCK+1
00756           IF (KTYPE-3) 680,670,680
00761       670 IF (A-OA)700,680,700
00764       680 IF (C-OC) 700,681,700
00767       681 IF (DELTMP-1.E-8) 682,700,700
00772       682 IF (DXTMP-1.E-8) 683,700,700
00775       683 IF (ITRANS-1) 684,685,684
01000       684 IF (KTYPE-3) 690,685,690
01003       685 IF (DCTMP-1.E-8) 690,700,700
01006       690 WRITE(6,6020)
01010           ING=1
01011           GO TO 710
01012       700 OA=A
01013           OC=C
01014           I=1
```

```
01015                 IF (BLOCK-NBLOCK) 590,590,710
01020             710 IF (ITER) 800,800,720
01023             720 ITCNT=ITCNT+1
01024                 THICK(ITCNT)=TH
01025                 LIFE(ITCNT)=FLOAT(BLOCK)+FLOAT(I)/FLOAT(NSTEP)
01026                 PCTLF(ITCNT)=LIFE(ITCNT)*100./BLIFE
01027                 DIF=PCTLF(ITCNT)/100.
01030                 IF (DIF-1.) 740,740,730
01033             730 IF (DIF-1.05) 760,740,740
01036             740 IF (ITCNT-ITER) 750,760,760
01041             750 DIF=(BLIFE/LIFE(ITCNT))**(1./PIT)
01042                 TH=TH*DIF
01043                 IF(CSTRS) 753,751,753
01046             751 CSTRS=1./DIF
01047                 DO 752 K=1,ONSTEP
01052                 SMIN(K)=SMIN(K)*CSTRS
01053             752 SMAX(K)=SMAX(K)*CSTRS
01055                 SIGLM=SIGLM*CSTRS
01056                 OCSTRS=CSTRS
01057                 GO TO 530
01060             753 CSTRS=CSTRS/DIF
01061                 DO 754 K=1,ONSTEP
01064                 SMIN(K)=SMIN(K)/OCSTRS*CSTRS
01065             754 SMAX(K)=SMAX(K)/OCSTRS*CSTRS
01067                 SIGLM=SIGLM/OCSTRS*CSTRS
01070                 OCSTRS=CSTRS
01071                 GO TO 530
01072             760 WRITE(6,6021)
01074                 DO 770 K=1,ITCNT
01077             770 WRITE(6,6022) THICK(K),LIFE(K),PCTLF(K)
01105                 TH=OTH
01106                 IF (ING-1) 800,780,800
01111             780 WRITE(6,8013)
01113             800 IF (NR-NRUNS) 820,810,810
01116             810 CONTINUE
01117                 STOP
01120             820 IF (ICR(1)+1) 830,10,830
01123             830 IF(FLAG1) 10,10,840
01126             840 WRITE(6,6019) IBLOCK,ISTEP,CUMELM
01133                 GO TO 10
01134            5001 FORMAT(20A4)
01135            5002 FORMAT(I4,I6,2I4)
01136            5003 FORMAT(E10.3,5I4,2E10.3)
01137            5004 FORMAT(2I4,E10.3)
01140            5005 FORMAT(3E10.3,I4)
01141            5006 FORMAT(4E10.3)
01142            5007 FORMAT(E10.3,3I4,4E10.3)
01143            6001 FORMAT(34H1INCOMPLETE INPUT SET, JOB ABENDED)
01144            6019 FORMAT(35H0LIMIT LOAD FRACTURE OCCURS IN THE ,I6,7H BLOCK ,
01144               1 I4,12H STEP AFTER ,1PE12.3,7H CYCLES)
01145            6020 FORMAT(10H0NO GROWTH )
01146            6021 FORMAT(28H1                ITERATION RESULTS ,//25X,
01146               1 11HPERCENT  OF,/37H   THICKNESS      LIFE   REQUIRED LIFE,//)
01147            6022 FORMAT(1P2E12.3,0PF8.2)
01150            8002 FORMAT(4H1RUN,I4,3H OF,I4,5H RUNS,10X,20A4,/16H0LOAD INPUT DATA)
01151            8003 FORMAT(1H0,5X,15HSTRESS FACTOR  ,1PE12.3,/1H ,5X,
01151               115HLIMIT STRESS   ,E12.3,/1H0,5X,
01151               262HSTEP   MAX STRESS   MIN STRESS   UNITS(CYCLES)   MATERIAL TYPE,
01151               3//)
01152            8004 FORMAT(1H ,4X,I4,2X,1PE12.3,E13.3,2X,E12.3,8X,I4)
01153            8005 FORMAT(1H-,19HGEOMETRY INPUT DATA,/1H0,5X,17HCRACK TYPE      ,
01153               18X,I4,/1H ,5X,17HWIDTH            ,1PE12.3,
01153               2/1H ,5X,17HTHICKNESS         ,E12.3)
01154            8006 FORMAT(1H ,5X,17HCRACK DEPTH      ,1PE12.3)
01155            8007 FORMAT(1H ,5X,17HHALF CRACK LENGTH,1PE12.3)
01156            8008 FORMAT(1H-,19HMATERIAL INPUT DATA,/1H0,58X,8HCRITICAL,10X,
01156               1 9HTHRESHOLD,9X,8HCRITICAL,10X,9HTHRESHOLD,/1H ,5X,
01156               256HMATERIAL      YIELD        GROWTH    RETARDATION  STRESS ,
01156               363HINTENSITY  STRESS INTENSITY  STRESS INTENSITY  STRESS INTENSITY
01156               4,/1H ,7X,42HTYPE       STRENGTH       EQUATION       MODEL ,7X,
01156               59H(SURFACE),9X,9H(SURFACE),10X,7H(DEPTH),11X,7H(DEPTH),/)
01157            8009 FORMAT(1H ,8X,I4,4X,1PE12.3,5X,I4,8X,I4,8X,E12.3,3(8X,E12.3))
```

```
01160          8010 FORMAT(1H0,21X,14H--------------&,18HEQUATION CONSTANTS,
01160             114H--------------,/1H ,37H CONSTANT  MATERIAL      CRACK GROWTH ,
01160             228HRATE         RETARDATION MODEL,/1H ,17H  NUMBER      TYPE,6X,
01160             342HSURFACE       DEPTH       SURFACE       DEPTH)
01161          8011 FORMAT(1H ,2X,I4,6X,I4,3X,1P4E12.3)
01162          8012 FORMAT(1H-,20HITERATION PARAMETERS,/1H0,5X,
01162             1 20HDESIGN LIFE          ,1PE12.3,/1H ,5X,
01162             2 20HCONVERGENCE EXPONENT,E12.3,/1H ,5X,
01162             3 20HITERATION NUMBER    ,8X,I4)
01163          8013 FORMAT(1H-,18HITERATIONS STOPPED,/1H ,
01163             1 33HLAST PERCENTAGE LIFE IS INCORRECT,
01163             2 /1H ,22HNO GROWTH HAS OCCURRED)
01164              END

      END OF COMPILATION:        NO  DIAGNOSTICS.

@HDG,P      PTCGRA
```

```
00101                SUBROUTINE PTCGRW
00103                COMMON A,AP(2),ALIM,AOL(2),C,CB,CLIM,CR(2,10,10),CD,CUME,
00103               1 CUMELM,D(2,10,10),DK,DKE,DXDX,FA,FC,INC,KCL,KCI,KOL,
00103               2 KOA,KOC,KCRA,KCRC,KMAX,OA,OC,PI,R,RE,RYOL(2),ROL(2),
00103               3 SIG,SIGLM,SIGY,SIGYS(10),SMIN(422),SMAX(422),TH,
00103               4 UNIT(422),W,DCTMP,DELTMP,DXTMP,
00103               5 ALOWN,BLOCK,FLAGI,I,ICD(2),ICK(2),ICR(2),IBLOCK,IFIRST,IPRN(4),
00103               6 ISTEP,ITRANS,J,KTYPE,NC,NEQ(10),NR,NRET(10),TYPE,TITL
00104                INTEGER ALOWN,BLOCK,FLAGI,TYPE(422),TITL(20)
00105                REAL KCL,KCI,KOL,KOA(10),KOC(10),KCRA(10),KCRC(10),KMAX
00106                REAL INC,KA,KC
00107                K=0
00110                IFIRST=1
00111                J=TYPE(I)
00112          1025 DEL=INC*A
00113                IF (NRET(J)) 1050,1050,1030
00116          1030 IF (ABS(RYOL(2))-.0001) 1050,1050,1038
00121          1038 IF (DEL-.1*RYOL(2)) 1050,1050,1040
00124          1040 DEL=.1*RYOL(2)
00125          1050 A=A+DEL
00126                IF (ABS(A-DEL-TH)-1.E-6) 1060,1060,1070
00131          1060 CALL TRANS
00132                RETURN
00133          1070 IF (A-TH) 1090,1090,1080
00136          1080 DEL=TH-A+DEL
00137                A=TH
00140          1090 SIGY=SIGYS(J)
00141                IF (FLAGI) 1130,1100,1130
00144          1100 R=0
00145                SIG=SIGLM
00146                CALL KANAL
00147                IF (SIGLM*FA-KCRA(J)) 1110,1110,1120
00152          1110 IF (SIGLM*FC-KCRC(J)) 1130,1130,1120
00155          1120 FLAGI=1
00156                ALIM=A
00157                CLIM=C
00160                IBLOCK=BLOCK
00161                ISTEP=I
00162                CUMELM=CUME
00163          1130 A=A-DEL/2
00164                SIG=SMAX(I)
00165                R=SMIN(I)/SMAX(I)
00166                KTYPE=3
00167                CALL KANAL
00170                A=A-DEL/2
00171                KA=FA*SIG
00172                KC=FC*SIG
00173                DKA=(1-R)*KA
00174                DKC=(1-R)*KC
00175                IF (KA-KCRA(J)) 1140,1140,1150
00200          1140 IF (KC-KCRC(J)) 1160,1160,1153
00203          1150 IF (FLAGI) 1152,1152,1151
00206          1151 WRITE(6,6019) IBLOCK,ISTEP,CUMELM
00213          1152 WRITE (6,6002) BLOCK,I,CUME
00220                ICR(I)=-1
00221                RETURN
00222          1153 IF (FLAGI) 1155,1155,1154
00225          1154 WRITE(6,6019) IBLOCK,ISTEP,CUMELM
00232          1155 WRITE (6,6003) BLOCK,I,CUME
00237                ICR(I)=-1
00240                RETURN
00241          1160 IF (KOA(J)-DKA) 1180,1170,1170
00244          1170 DADX=0
00245                IF (KOC(J)-DKC) 1190,1172,1172
00250          1172 K=1
00251                DCDX=0
00252                GO TO 1211
00253          1180 KMAX=KA
00254                DK=DKA
00255                NC=2
00256                CALL DAMAGE
```

```
00257          IF (DXDX) 1181,1182,1182
00262     1181 ICR(I)=-1
00263          RETURN
00264     1182 CONTINUE
00265          DADX=DXDX
00266          IF (KDC(J)-DKC) 1190,1200,1200
00271     1190 KMAX=KC
00272          DK=DKC
00273          NC=1
00274          CALL DAMAGE
00275          IF (DXDX) 1191,1192,1192
00300     1191 ICR(I)=-1
00301          RETURN
00302     1192 CONTINUE
00303          DCDX=DXDX
00304          GO TO 1210
00305     1200 DCDX=0
00306     1210 AVAIL=UNIT(I)-CUME
00307     1211 IF (IPRN(1)-IPRN(4)) 1201,1205,1205
00312     1201 IF (IPRN(1)) 1202,1203,1203
00315     1202 WRITE(6,8002) NR,TITL
00321          WRITE(6,8003)
00323          IPRN(1)=0
00324          DELTMP=0.
00325          DCTMP=0.
00326          DXTMP=0.
00327     1203 IF (IFIRST-1) 1205,1204,1205
00332     1204 IFIRST=0
00333          IPRN(1)=IPRN(1)+1
00334          WRITE(6,8004) BLOCK,I,CUME,C,A,KC,KA,DCDX,DADX
00347          IF (K) 5000,1205,5000
00352     1205 CONTINUE
00353          IF (ALOWN-1) 1230,1220,1230
00356     1220 DX=1
00357          DEL=DADX
00360          DC=DCDX
00361          GO TO 1260
00362     1230 IF (DADX) 1235,1265,1235
00365     1235 IF (DEL/DADX-AVAIL) 1250,1250,1240
00370     1240 DELTMP=DELTMP+AVAIL*DADX
00371          IF (A) 1241,1242,1241
00374     1241 IF (DELTMP/A-1.E-4) 1244,1244,1242
00377     1242 A=A+DELTMP
00400          DELTMP=0.
00401     1244 DCTMP=DCTMP+AVAIL*DCDX
00402          IF (C) 1245,1246,1245
00405     1245 IF (DCTMP/C-1.E-4) 5000,5000,1246
00410     1246 C=C+DCTMP
00411          DCTMP=0.
00412          GO TO 5000
00413     1250 DX=DEL/DADX
00414          DC=DX*DCDX
00415          GO TO 1260
00416     1265 DC=INC*C
00417          IF (RYOL(I)-1.E-4) 1258,1258,1256
00422     1256 IF (NRET(J)) 1257,1258,1257
00425     1257 DC=AMIN1(.1*RYOL(I),DC)
00426     1258 IF (DCDX) 5000,5000,1259
00431     1259 DX=DC/DCDX
00432          DEL=DX*DADX
00433     1260 IF (DX-AVAIL) 1280,1280,1270
00436     1270 DELTMP=DELTMP+AVAIL*DADX
00437          IF (A) 1271,1272,1271
00442     1271 IF (DELTMP/A-1.E-4) 1274,1274,1272
00445     1272 A=A+DELTMP
00446          DELTMP=0.
00447     1274 DCTMP=DCTMP+AVAIL*DCDX
00450          IF (C) 1275,1276,1275
00453     1275 IF (DCTMP/C-1.E-4) 5000,5000,1276
00456     1276 C=C+DCTMP
00457          DCTMP=0.
00460          GO TO 5000
```

```
00461     1280 DELTMP=DELTMP+DEL
00462          IF (A) 1281,1282,1281
00465     1281 IF (DELTMP/A-1.E-4) 1284,1284,1282
00470     1282 A=A+DELTMP
00471          DELTMP=0.
00472     1284 DCTMP=DCTMP+DC
00473          IF (C) 1285,1286,1285
00476     1285 IF (DCTMP/C-1.E-4) 1288,1288,1286
00501     1286 C=C+DCTMP
00502          DCTMP=0.
00503     1288 DXTMP=DXTMP+DX
00504          IF (CUME) 1289,1290,1289
00507     1289 IF (DXTMP/CUME-1.E-4) 1025,1025,1290
00512     1290 CUME=CUME+DXTMP
00513          DXTMP=0.
00514          GO TO 1025
00515     5000 CONTINUE
00516          CUME=UNIT(I)
00517          IF (IPRN(1)-IPRN(4)) 5010,5020,5020
00522     5010 IPRN(1) = IPRN(1)+1
00523          WRITE(6,8005) BLOCK,I,CUME,C,A,KC,KA,DCDX,DADX
00536     5020 CONTINUE
00537          RETURN
00540     6002 FORMAT(45H0CRITICAL K AT DEPTH HAS BEEN EXCEEDED IN THE,I6,
00540         1 14H BLOCK AND THE,I4,11H STEP AFTER,1PE12.3,7H CYCLES )
00541     6003 FORMAT(47H0CRITICAL K AT SURFACE HAS BEEN EXCEEDED IN THE,I6,
00541         1 14H BLOCK AND THE,I4,11H STEP AFTER,1PE12.3,7H CYCLES )
00542     6019 FORMAT(35H0LIMIT LOAD FRACTURE OCCURS IN THE ,I6,7H BLOCK ,
00542         1 I4,12H STEP AFTER ,1PE12.3,7H CYCLES)
00543     8002 FORMAT(5H1RUN ,I4,5X,20A4,/1H0,50X,26HCRACK IS A PART THRU CRACK,
00543         1 /1H0,42X,12HHALF SURFACE,50X,7HSURFACE,9X,5HDEPTH)
00544     8003 FORMAT(1H ,12X,45HBLOCK  STEP          CYCLES        CRACK LENGTH   ,
00544         156HCRACK DEPTH    KMAX-SURFACE    KMAX-DEPTH    GROWTH RATE,4X,
00544         211HGROWTH RATE,/1H ,46X,4H(IN),11X,4H(IN),6X,13H(KSI ROOT-IN),2X,
00544         313H(KSI ROOT-IN),4X,10H(IN/CYCLE),5X,10H(IN/CYCLE),//)
00545     8004 FORMAT(10H                 ,I6,3X,I4,7(3X,1PE12.3))
00546     8005 FORMAT(10H                 ,I6,3X,I4,7(3X,1PE12.3))
00547          END

END OF COMPILATION:        NO  DIAGNOSTICS.

@HDG,P      RETAND
```

```
00101          SUBROUTINE RETARD
00103          COMMON A,AP(2),ALIM,AOL(2),C,CB,CLIM,CR(2,10,10),CO,CUME,
00103         1 CUMELM,D(2,10,10),DK,DKE,DXDX,FA,FC,INC,KCL,KCI,KOL,
00103         2 KOA,KOC,KCRA,KCRC,KMAX,OA,OC,PI,R,RE,RYOL(2),ROL(2),
00103         3 SIG,SIGLM,SIGY,SIGYS(10),SMIN(422),SMAX(422),TH,
00103         4 UNIT(422),W,OCTMP,DELTMP,DXTMP,
00103         6 ISTEP,ITRANS,J,KTYPE,NC,NEQ(10),NR,NRET(10),TYPE,TITL
00104          INTEGER ALOWN,BLOCK,FLAGI,TYPE(422),TITL(20)
00105          REAL KCL,KCI,KOL,KOA(10),KOC(10),KCRA(10),KCRC(10),KMAX,INC
00106          REAL KAP,KMINE,KC2,KMAXE
00107          PZ = CR(NC,1,J)
00110          IF (NRET(J)) 500,500,10
00113       10 IF (NRET(J)-3) 20,20,500
00116       20 J1=NRET(J)
00117          IF (NC-1) 22,21,22
00122       21 X=C
00123          GO TO 23
00124       22 X=A
00125       23 CONTINUE
00126          GO TO (30,200,300), J1
00126    C
00126    C     WILLENBORG MODEL
00126    C
00127       30 RY=(KMAX/SIGY)**2
00130          RI=CR(NC,1,J)*2.*PI
00131          RI=1./RI
00132          RY=RY*RI
00133          IF (RY-AP(NC)+X) 50,40,40
00136       40 AP(NC)=X+RY
00137          RYOL(NC)=RY
00140       50 KAP=2*PI*(AP(NC)-X)
00141          KAP=SQRT(KAP)*SIGY
00142          KMAXE=2*KMAX-KAP
00143          KMINE=(1+R)*KMAX - KAP
00144          IF (KMINE) 60,60,70
00147       60 KMINE=0
00150       70 IF (KMAXE) 80,80,90
00153       80 KMAXE=0
00154       90 DKE=KMAXE-KMINE
00155          RE=KMINE/KMAXE
00156          GO TO 430
00156    C
00156    C     WHEELER MODEL
00156    C
00157      200 RY=(KMAX/SIGY)**2
00160          RI=CR(NC,1,J)*2.*PI
00161          RI=1./RI
00162          RY=RY*RI
00163          IF (RY-AP(NC)+X) 220,210,210
00166      210 AP(NC)=X+RY
00167          RYOL(NC)=RY
00170      220 DKE=RY/(AP(NC)-X)
00171          DKE=DKE**CR(NC,2,J)
00172          DKE=DKE*(1.-R)*KMAX
00173          RE=R
00174          GO TO 430
00174    C
00174    C     GRUMMAN CLOSURE MODEL
00174    C
```

```
00175      300 ALOWN=0
00176          PZ=CR(NC,1,J)
00177          CFM1 = CR(NC,2,J)
00200          CFO = CR(NC,3,J)
00201          P = CR(NC,4,J)
00202          NSAT = CR(NC,5,J)
00203          GAM1 = CR(NC,6,J)
00204          BG = CR(NC,7,J)
00205          RY=(KMAX/SIGY)**2
00206          R1=PZ*2*PI
00207          R1=1./R1
00210          RY=R1*RY
00211          CF2=CFM1+(CFO-CFM1)*(1+R)**P
00212          KC2=CF2*KMAX
00213          IF (R*KMAX-ROL(NC)*KOL) 310,320,320
00216      310 ROL(NC)=(R*KMAX)/KOL
00217          CF1=CFM1+(CFO-CFM1)*(1+ROL(NC))**P
00220          KC1=CF1*KOL
00221          AOL(NC)=X
00222      320 IF (KMAX-KCL) 330,330,340
00225      330 DKE=0
00226          RE=0
00227          GO TO 430
00230      340 IF (KC2-KCL) 350,350,380
00233      350 IF (AP(NC)-X-RY) 360,370,370
00236      360 KCL=KC1-(KC1-KC2)*((X-AOL(NC))/RYOL(NC))**BG
00237          GO TO 400
00240      370 KCL=KC2
00241          GO TO 400
00242      380 IF (CUME+1-NSAT) 390,370,370
00245      390 GAM=GAM1+(1-GAM1)*CUME/(NSAT-1)
00246          KCL=GAM*KMAX
00247          ALOWN=1
00250      400 DKE=KMAX-KCL
00251          RE=KCL/KMAX
00252          IF (AP(NC)-X-RY) 410,420,420
00255      410 IF (KMAX-KOL) 430,430,420
00260      420 KC1=KC2
00261          KOL=KMAX
00262          ROL(NC)=R
00263          AOL(NC)=X
00264          RYOL(NC)=RY
00265          AP(NC)=AOL(NC)+RYOL(NC)
00266      430 RETURN
00267      500 WRITE(6,1000) NRET(J)
00272     1000 FORMAT(11HONRET(J) = ,I3,13H OUT OF RANGE)
00273          STOP
00274          END

     END OF COMPILATION:        NO  DIAGNOSTICS.
```

```
            SUBROUTINE TCGROW
            COMMON A,AP(2),ALIM,AOL(2),C,CB,CLIM,CR(2,10,10),CO,CUME,
           1 CUMELM,D(2,10,10),DK,DKE,DXDX,FA,FC,INC,KCL,KCI,KOL,
           2 KOA,KOC,KCRA,KCRC,KMAX,OA,OC,PI,R,RE,RVOL(2),ROL(2),
           3 SIG,SIGLM,SIGY,SIGYS(10),SMIN(422),SMAX(422),TH,
           4 UNIT(422),W,DCTMP,DELTMP,DXTMP,
           5 ALOWN,BLOCK,FLAGI,I,ICD(2),ICK(2),ICR(2),IBLOCK,IFIRST,IPRN(4),
           6 ISTEP,ITRANS,J,KTYPE,NC,NEQ(10),NR,NRET(10),TYPE,TITL
            INTEGER ALOWN,BLOCK,FLAGI,TYPE(422),TITL(20)
            REAL KCL,KCI,KOL,KOA(10),KOC(10),KCRA(10),KCRC(10),KMAX
            REAL INC,KC
            IFIRST=1
       1000 J=TYPE(I)
       1025 DEL=INC*C
            IF (NRET(J)) 1050,1050,1030
       1030 IF (ABS(RYOL(1))-.0001) 1050,1050,1038
       1038 IF (DEL-.1*RYOL(1)) 1050,1050,1040
       1040 DEL=.1*RYOL(1)
       1050 C=C+DEL
            SIGY=SIGYS(J)
            IF (FLAGI) 1130,1100,1130
       1100 R=0
            SIG=SIGLM
            CALL KANAL
            IF (SIGLM*FC-KCRC(J)) 1130,1130,1120
       1120 FLAGI=1
            CLIM=C
            IBLOCK=BLOCK
            ISTEP=I
            CUMELM=CUME
       1130 C=C-DEL/2
            SIG=SMAX(I)
            R=SMIN(I)/SMAX(I)
            CALL KANAL
            C=C-DEL/2
            KC=FC*SIG
            DKC=(1-R)*KC
            IF (KC-KCRC(J)) 1160,1160,1153
       1153 IF (FLAGI) 1155,1155,1154
       1154 WRITE(6,6019) IBLOCK,ISTEP,CUMELM
       1155 WRITE (6,6003) BLOCK,I,CUME
            ICR(1)=-1
            RETURN
       1160 IF (KOC(J)-DKC) 1190,1170,1170
       1170 DCDX=0
            GO TO 1180
       1190 KMAX=KC
            DK=DKC
            NC=1
            CALL DAMAGE
            DCDX=DXDX
       1180 IF (IPRN(2)-IPRN(4)) 1191,1195,1195
       1191 IF (IPRN(2)) 1192,1193,1193
       1192 WRITE(6,8002) NR,TITL
            WRITE(6,8003)
            IPRN(2)=0
            DELTMP=0.
            DXTMP=0.
       1193 IF (IFIRST-1) 1195,1194,1195
       1194 IFIRST=0
            IPRN(2)=IPRN(2)+1
            WRITE(6,8004) BLOCK,I,CUME,C,KC,DCDX
```

```
00243      1195 CONTINUE
00244           IF (DCDX) 1200,5000,1210
00247      1200 ICR(I)=-1
00250           RETURN
00251      1210 AVAIL=UNIT(I)-CUME
00252           IF (ALOWN-1) 1230,1220,1230
00255      1220 DX=1
00256           DEL=DCDX
00257           GO TO 1280
00260      1230 DX=DEL/DCDX
00261           IF (DX-AVAIL) 1280,1280,1270
00264      1270 DELTMP=DELTMP+AVAIL*DCDX
00265           IF (C) 1271,1272,1271
00270      1271 IF (DELTMP/C-1.E-4) 5000,5000,1272
00273      1272 C=C+DELTMP
00274           DELTMP=0.
00275           GO TO 5000
00276      1280 DELTMP=DELTMP+DEL
00277           IF (C) 1281,1282,1281
00302      1281 IF (DELTMP/C-1.E-4) 1284,1284,1282
00305      1282 C=C+DELTMP
00306           DELTMP=0.
00307      1284 DXTMP=DXTMP+DX
00310           IF (CUME) 1285,1286,1285
00313      1285 IF (DXTMP/CUME-1.E-4) 1025,1025,1286
00316      1286 CUME=CUME+DXTMP
00317           DXTMP=0.
00320           GO TO 1025
00321      5000 CONTINUE
00322           CUME=UNIT(I)
00323           IF (IPRN(2)-IPRN(4)) 5010,5020,5020
00326      5010 IPRN(2)=IPRN(2)+1
00327           WRITE(6,8005) BLOCK,I,CUME,C,KC,DCDX
00337      5020 CONTINUE
00340           RETURN
00341      6003 FORMAT(47H0CRITICAL K AT SURFACE HAS BEEN EXCEEDED IN THE,I6,
00341          1 14H BLOCK AND THE,I4,11H STEP AFTER,1PE12.3,7H CYCLES )
00342      6019 FORMAT(35H0LIMIT LOAD FRACTURE OCCURS IN THE ,I6,7H BLOCK ,
00342          1 I4,12H STEP AFTER ,1PE12.3,7H CYCLES)
00343      8002 FORMAT(5H1RUN ,I4,5X,20A4,/1H0,50X,24HCRACK IS A THROUGH CRACK,
00343          1/1H0,46X,4HHALF,25X,5HCRACK)
00344      8003 FORMAT(1H ,12X,45HBLOCK  STEP        CYCLES       CRACK LENGTH    ,
00344           14X,4HKMAX,7X,11HGROWTH RATE,/1H ,46X,4H(IN),6X,13H(KSI ROOT-IN),
00344           24X,10H(IN/CYCLE),//)
00345      8004 FORMAT(10H                   ,I6,3X,I4,7(3X,1PE12.3))
00346      8005 FORMAT(10H                   ,I6,3X,I4,7(3X,1PE12.3))
00347           END

      END OF COMPILATION:         NO  DIAGNOSTICS.
```

```
00101         SUBROUTINE TRANS
00103         COMMON A,AP(2),ALIM,AGL(2),C,CB,CLIM,CR(2,10,10),CD,CUME,
00103        1 CUMELM,D(2,10,10),D.,DKE,DXDX,FA,FC,INC,KCL,KCI,KOL,
00103        2 KOA,KOC,KCRA,KCRC,KMAX,OA,OC,PI,R,RE,RYOL(2),ROL(2),
00103        3 SIG,SIGLM,SIGY,SIGYS(10),SMIN(422),SMAX(422),TH,
00103        4 UNIT(422),W,DCTMP,DELTMP,DXTMP,
00103        5 ALOWN,BLOCK,FLAG1,I,ICD(2),ICK(2),ICR(2),IBLOCK,IFIRST,IPRN(4),
00103        6 ISTEP,ITRANS,J,KTYPE,NC,NEQ(10),NR,NRET(10),TYPE,TITL
00104         INTEGER ALOWN,BLOCK,FLAG1,TYPE(422),ONSTEP,TITL(20)
00105         REAL KCL,KCI,KOL,KOA(10),KOC(10),KCRA(10),KCRC(10),KMAX,INC
00106         REAL KA,KC
00107         K=0
00110         IFIRST=1
00111         IF (ITRANS-1) 10,180,10
00114      10 CONTINUE
00115         ITRANS=1
00116         KTYPE=1
00117         FLAG2=0
00120         CALL KANAL
00121         IF (FC*SMAX(I)-KCRC(J)) 110,110,100
00124     100 WRITE(6,6021) BLOCK,I,C ME
00131         ICR(I)=-1
00132         RETURN
00133     110 IF (FLAG1) 140,120,140
00136     120 IF (FC*SIGLM-KCRC(J)) 140,140,130
00141     130 FLAG1=1
00142         ALIM=A
00143         CLIM=C
00144         IBLOCK=BLOCK
00145         ISTEP=1
00146         CUMELM=CUME
00147     140 CB=.01
00150         KTYPE=4
00151         SIGY=SIGYS(J)
00152         SIG=SMAX(I)
00153         R=SMIN(I)/SIG
00154     150 CALL KANAL
00155         IF (FA*SIG-KCRC(J)) 180,180,160
00160     160 CB=CB+.02*C
00161         FLAG2=1
00162         IF (CB-C) 150,170,170
00165     170 WRITE(6,6022) BLOCK,I,CUME
00172         WRITE(6,6023) CB,C
00176         ICR(I)=-1
00177         RETURN
00200     180 DEL=INC*CB
00201         IF (NRET(J)) 209,209,201
00204     201 IF (ABS(RYOL(I))-.0001) 209,209,202
00207     202 IF (DEL-.1*RYOL(I)) 209,209,203
00212     203 DEL=.1*RYOL(I)
00213     209 CB=CB+DEL
00214         IF (CB-.95*C) 220,220,210
00217     210 ITRANS=0
00220         CALL TCGROW
00221         RETURN
00222     220 CONTINUE
00223         SIG=SIGLM
00224         CALL KANAL
00225         IF (SIGLM*FA-KCRC(J)) 1110,1110,1120
00230    1110 IF (SIGLM*FC-KCRC(J)) 1130,1130,1120
00233    1120 FLAG1=1
00234         CBLIM=CB
00235         CLIM=C
00236         IBLOCK=BLOCK
00237         ISTEP=1
00240         CUMELM=CUME
00241    1130 CB=CB-DEL/2
00242         SIG=SMAX(I)
00243         R=SMIN(I)/SMAX(I)
00244         CALL KANAL
00245         CB=CB-DEL/2
00246         KA=FA*SIG
```

```
00247              KC=FC*SIG
00250              DKA=(1-R)*KA
00251              DKC=(1-R)*KC
00252              IF (KA-KCRC(J)) 1140,1140,1150
00255         1140 IF (KC-KCRC(J)) 1160,1160,1153
00260         1150 IF (FLAG1) 1152,1152,1151
00263         1151 WRITE(6,6019) IBLOCK,ISTEP,CUMELM
00270         1152 WRITE (6,6002) BLOCK,I,CUME
00275              ICR(1)=-1
00276              RETURN
00277         1153 IF (FLAG1) 1155,1155,1154
00302         1154 WRITE(6,6019) IBLOCK,ISTEP,CUMELM
00307         1155 WRITE (6,6003) BLOCK,I,CUME
00314              ICR(1)=-1
00315              RETURN
00316         1160 IF (KDC(J)-DKA) 1180,1170,1170
00321         1170 DADX=0
00322              IF (KDC(J)-DKC) 1190,1172,1172
00325         1172 K=1
00326              GO TO 1209
00327         1180 KMAX=KA
00330              DK=DKA
00331              NC=1
00332              CALL DAMAGE
00333              IF (DADX) 1182,1184,1184
00336         1182 ICR(1)=-1
00337              RETURN
00340         1184 DADX=DXDX
00341              IF (KDC(J)-DKC) 1190,1200,1200
00344         1190 KMAX=KC
00345              DK=DKC
00346              NC=1
00347              CALL DAMAGE
00350              IF (DXDX) 1192,1194,1194
00353         1192 ICR(1)=-1
00354              RETURN
00355         1194 DCDX=DXDX
00356              GO TO 1210
00357         1200 DCDX=0
00360         1210 AVAIL=UNIT(I)-CUME
00361         1209 IF (IPRN(3)-IPRN(4)) 1211,1215,1215
00364         1211 IF (IPRN(3)) 1212,1213,1213
00367         1212 WRITE(6,8002) NR,TITL
00373              WRITE(6,8003)
00375              IPRN(3)=0
00376              DELTMP=0.
00377              DCTMP=0.
00400              DXTMP=0.
00401         1213 IF (IFIRST-1) 1215,1214,1215
00404         1214 IFIRST=0
00405              IPRN(3)=IPRN(3)+1
00406              WRITE(6,8004) BLOCK,I,CUME,C,CB,KC,KA,DCDX,DADX
00421              IF (K) 5000,1215,5000
00424         1215 CONTINUE
00425              IF (ALOWN-1) 1230,1220,1230
00430         1220 DX=1
00431              DEL=DADX
00432              DC=DCDX
00433              GO TO 1260
00434         1230 IF (DADX) 1235,1259,1235
00437         1235 IF (DEL/DADX-AVAIL) 1250,1250,1240
00442         1240 DELTMP=DELTMP+AVAIL*DADX
00443              IF (CB) 1241,1242,1241
00446         1241 IF (DELTMP/CB-1.E-4) 1244,1244,1242
00451         1242 CB=CB+DELTMP
00452              DELTMP=0.
00453         1244 DCTMP=DCTMP+AVAIL*DCDX
00454              IF (C) 1245,1246,1245
00457         1245 IF (DCTMP/C-1.E-4) 5000,5000,1246
00462         1246 C=C+DCTMP
00463              DCTMP=0.
```

```
00464          GO TO 5000
00465     1250 DX=DEL/DADX
00466          DC=DX*DCDX
00467          GO TO 1260
00470     1255 DC=INC*C
00471          IF (RYOL(I)-1.E-4) 1258,1258,1256
00474     1256 IF (NRET(J)) 1257,1258,1257
00477     1257 DC=AMIN1(.1*RYOL(I),DC)
00500     1258 IF (DCDX) 5000,5000,1259
00503     1259 DX=DC/DCDX
00504          DEL=DX*DADX
00505     1260 IF (DX-AVAIL) 1280,1280,1270
00510     1270 DELTMP=DELTMP+AVAIL*DADX
00511          IF (CB) 1271,1272,1271
00514     1271 IF (DELTMP/CB-1.E-4) 1274,1274,1272
00517     1272 CB=CB+DELTMP
00520          DELTMP=0.
00521     1274 DCTMP=DCTMP+AVAIL*DCDX
00522          IF (C) 1275,1276,1275
00525     1275 IF (DCTMP/C-1.E-4) 5000,5000,1276
00530     1276 C=C+DCTMP
00531          DCTMP=0.
00532          GO TO 5000
00533     1280 DELTMP=DELTMP+DEL
00534          IF (CB) 1281,1282,1281
00537     1281 IF (DELTMP/CB-1.E-4) 1284,1284,1282
00542     1282 CB=CB+DELTMP
00543          DELTMP=0.
00544     1284 DCTMP=DCTMP+DC
00545          IF (C) 1285,1286,1285
00550     1285 IF (DCTMP/C-1.E-4) 1288,1288,1286
00553     1286 C=C+DCTMP
00554          DCTMP=0.
00555     1288 DXTMP=DXTMP+DX
00556          IF (CUME) 1289,1290,1289
00561     1289 IF (DXTMP/CUME-1.E-4) 180,180,1290
00564     1290 CUME=CUME+DXTMP
00565          DXTMP=0.
00566          GO TO 180
00567     5000 CONTINUE
00570          CUME=UNIT(I)
00571          IF (IPRN(3)-IPRN(4)) 5010,5020,5020
00574     5010 IPRN(3)=IPRN(3)+1
00575          WRITE(6,8005) BLOCK,I,CUME,C,CB,KC,KA,DCDX,DADX
00610     5020 CONTINUE
00611          RETURN
00612     6002 FORMAT(45H0CRITICAL K AT DEPTH HAS BEEN EXCEEDED IN THE,I6,
00612         1 14H BLOCK AND THE,I4,11H STEP AFTER,1PE12.3,7H CYCLES )
00613     6003 FORMAT(47H0CRITICAL K AT SURFACE HAS BEEN EXCEEDED IN THE,I6,
00613         1 14H BLOCK AND THE,I4,11H STEP AFTER,1PE12.3,7H CYCLES )
00614     6019 FORMAT(35H0LIMIT LOAD FRACTURE OCCURS IN THE ,I6,7H BLOCK ,
00614         1 I4,12H STEP AFTER ,1PE12.3,7H CYCLES)
00615     6021 FORMAT(43H0FRACTURE OCCURS DURING BREAKTHROUGH IN THE,
00615         1 I6,14H BLOCK AND THE,I4,11H STEP AFTER,1PE12.3,7H CYCLES)
00616     6022 FORMAT(41H0FRACTURE OCCURS DURING TRANSITION IN THE,
00616         1 I6,14H BLOCK AND THE,I4,11H STEP AFTER,1PE12.3,7H CYCLES)
00617     6023 FORMAT(6H0CB = ,1PE12.3,7H    C = ,E12.3)
00620     8002 FORMAT(5H1RUN ,I4,5X,20A4,/1H0,50X,
00620         130HCRACK IS A CRACK IN TRANSITION,/1H0,43X,
00620         225HHALF FRONT      HALF BACK,38X,5HFRONT,9X,4HBACK)
00621     8003 FORMAT(1H ,12X,49HBLOCK  STEP          CYCLES       CRACK LENGTH    ,
00621         160HCRACK LENGTH     KMAX-FRONT      KMAX-BACK      GROWTH RATE    ,
00621         211HGROWTH RATE,/1H ,46X,4H(IN),11X,4H(IN),6X,13H(KSI ROOT-IN),
00621         32X,13H(KSI ROOT-IN),4X,10H(IN/CYCLE),5X,10H(IN/CYCLE),//)
00622     8004 FORMAT(1OH                 ,I6,3X,I4,7(3X,1PE12.3))
00623     8005 FORMAT(1OH                 ,I6,3X,I4,7(3X,1PE12.3))
00624          END

     END OF COMPILATION:          1 DIAGNOSTICS.
```

```
00101                SUBROUTINE DAMAGE
00103                COMMON A,AP(2),ALIM,AOL(2),C,CB,CLIM,CR(2,10,10),CD,CUME,
00103               1 CUMELM,D(2,10,10),DK,DKE,DXDX,FA,FC,INC,KCL,KCI,KOL,
00103               2 KOA,KOC,KCRA,KCRC,KMAX,OA,OC,PT,R,RE,RYOL(2),ROL(2),
00103               3 SIG,SIGLM,SIGY,SIGYS(10),SMIN(422),SMAX(422),TH,
00103               4 UNIT(422),W,DCTMP,DELTMP,DXTMP,
00103               5 ALOWN,BLOCK,FLAGI,I,ICD(2),ICK(2),ICR(2),IBLOCK,IFIRST,IPRN(4),
00103               6 ISTEP,ITRANS,J,KTYPE,NC,NEQ(10),NR,NRET(10),TYPE,TITL
00104                INTEGER ALOWN,BLOCK,FLAGI,TYPE(422),TITL(20)
00105                REAL KCL,KCI,KOL,KOA(10),KOC(10),KCRA(10),KCRC(10),KMAX,INC
00106                REAL KO,KCR
00107                RE=R
00110                DKE=(1.-RE)*KMAX
00111                IF (NEQ(J)) 500,500,10
00114             10  IF (NEQ(J)-3) 20,20,500
00117             20 J1=NEQ(J)
00120                GO TO (30,200,300), J1
00120      C
00120      C         COLLIPRIEST-EHRET EQUATION
00120      C
00121             30 CD=D(NC,1,J)
00122                PN=D(NC,2,J)
00123                KO=D(NC,4,J)
00124                KCR=D(NC,3,J)
00125                IF (NRET(J)) 80,90,80
00130             80 CALL RETARD
00131             90 CC1=ALOG(KCR/KO)
00132                CC2=CC1*PN/2.
00133                CC1=PN/2.
00134                CC1=(KCR*KO)**CC1
00135                CC1=CD*CC1
00136                T1=(1.-RE)*KCR*KO
00137                T1=(DKE**2)/T1
00140                T1=ALOG(T1)
00141                T2=(1.-R)*KCR/KO
00142                T2=ALOG(T2)
00143                T1=T1/T2
00144                T3=(1.+T1)/(1.-T1)
00145                T2=.5*ALOG(T3)
00146                T1=CC2*T2
00147                T2=EXP(T1)
00150                DXDX=CC1*T2
00151                GO TO 600
00151      C
00151      C         PARIS EQUATION
00151      C
00152            200 IF (NC-2) 220,210,220
00155            210 CD=D(2,1,J)
00156                PN=D(2,2,J)
00157                GO TO 250
00160            220 CD=D(1,1,J)
00161                PN=D(1,2,J)
00162            250 IF (NRET(J)) 260,270,260
00165            260 CALL RETARD
00166            270 DXDX=-1
00167                IF (DKE-KOC(J)) 271,275,275
00172            271 IF (NC-1) 275,272,275
00175            272 DXDX=0
00176                GO TO 600
00177            275 IF (DKE-KOA(J)) 276,278,278
00202            276 IF (NC-2) 278,277,278
00205            277 DXDX=C
00206                GO TO 600
00207            278 DXDX=CD*DKE**PN
00210                GO TO 600
00210      C
00210      C         FORMAN EQUATION
00210      C
00211            300 DXDX=-1
00212                IF (DKE-KOC(J)) 310,330,330
00215            310 IF (NC-1) 330,320,330
```

```
00220        320 DXDX=0
00221            GO TO 600
00222        330 IF (DKE-KDA(J)) 340,360,360
00225        340 IF (NC-2) 360,350,360
00230        350 DXDX=0
00231            GO TO 600
00232        360 IF ((1.-RE)*D(NC,3,J)-DKE) 370,370,380
00235        370 WRITE(6,6001)
00237            GO TO 600
00240        380 DXDX = D(NC,1,J)*DKE**D(NC,2,J)
00241            DXDX=DXDX/((1.-RE)*D(NC,3,J)-DKE)
00242            GO TO 600
00243        500 WRITE (6,1000) NEW(J)
00246            STOP
00247        600 RETURN
00250       1000 FORMAT (10H0NEW(J) = ,I3,13H OUT OF RANGE)
00251       6001 FORMAT(39H0CRACK GROWTH RATE HAS GONE TO INFINITY)
00252            END

     END OF COMPILATION:        NO DIAGNOSTICS.

@HDG,P     DEL

@PRT,S     DEL
FURPUR 25R1-08/06-17:59
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      SUBROUTINE KANAL
      COMMON A,AP(2),ALIM,AOL(2),C,CB,CLIM,CR(2,10,10),CO,CUME,
     1 CUMELM,D(2,10,10),DK,DKE,DXDX,FA,FC,INC,KCL,KCI,KOL,
     2 KOA,KOC,KCRA,KCRC,KMAX,OA,OC,PI,R,RE,RYOL(2),ROL(2),
     3 SIG,SIGLM,SIGY,SIGYS(10),SMIN(422),SMAX(422),TH,
     4 UNIT(422),W,DCTMP,DELTMP,DXTMP,
     5 ALOWN,BLOCK,FLAG1,I,ICD(2),ICK(2),ICR(2),IBLOCK,IFIRST,IPRN(4),
     6 ISTEP,ITRANS,J,KTYPE,NC,NEQ(10),NR,NRET(10),TYPE,TITL
      INTEGER ALOWN,BLOCK,FLAG1,TYPE(422),TITL(20)
      REAL KCL,KCI,KOL,KOA(10),KOC(10),KCRA(10),KCRC(10),KMAX,INC
      IF (KTYPE) 500,500,10
   10 IF (KTYPE-4) 20,20,500
   20 GO TO (30,50,70,100), KTYPE
C
C     CENTER CRACKED PANEL
C
   30 Z = PI*C
      Q= SQRT(Z)
      Z = COS(Z/W)
      Z = 1./Z
      Z = SQRT(Z)
      FC = Q*Z
      FA = 0
      GO TO 600
C
C     COMPACT SPECIMEN
C
   50 W1 = A/W
      W2 = SQRT(W1)
      FC = 29.6*W2 - 185.5*W1*W2
      W2 = W2*W1*W1
      FC = FC + 655.7*W2 - 1017.0*W2*W1
      W2 = W2*W1*W1
      FC = FC + 638.9 * W2
      FC = FC/TH
      FC = FC/SQRT(W)
      FA = 0
      GO TO 600
C
C     PART THROUGH CRACK
C
   70 PHI2=1. + 4.593*(A/(2.*C))**1.65
      Q=((1.-R)*SIG/SIGY)**2.
      Q=PHI2-.212*Q
      FC=SQRT(PI*A/Q*A/C)
      FC=FC*(1.12+.11*A/C)
      W1=A/TH
      W2=.089*W1-.2315*W1**2-.3873*W1**3+5.26*W1**4
      W2=W2-9.11*W1**5+5.233*W1**6
      W1=A/(2.*C)
      FA=1.109-9.142*W1+41.56*W1**2-86.55*W1**3+65.5*W1**4
      PHI2=(W2*FA/.502) + 1.
      PHI2=PHI2*(1. + .12*(1.-W1)**2)
      FA=SQRT(PI*A/Q)
      FA=FA*PHI2
      GO TO 600
C
C     TRANSITION CRACK
C
  100 FC=PI*(C+CB)/(2.*W)
      FC=1./COS(FC)
      FC=SQRT(FC*PI*C)
      FA=1.-SQRT(1.-(CB/C)**2)
      FA=CB/(C*FA)
      FA=SQRT(FA)*FC
  600 RETURN
  500 WRITE (6,1000) KTYPE
 1000 FORMAT (10HOKTYPE =  ,I3,13H OUT OF RANGE)
      STOP
      END

END OF COMPILATION:        NO  DIAGNOSTICS.
```


☆U.S. GOVERNMENT PRINTING OFFICE 1978-641-255/56 REGION NO. 4