SWALES AEROSPACE

Primer on A4EI:

Computer Code for Bonded Joint Analysis

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for

GSFC FEMCI

by

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Outline

- A4EI Description and Uses
- Theory
- Joint Failure Criteria
- Input Specification
- Example Problem
- Feed Horn Bonded Repair Case

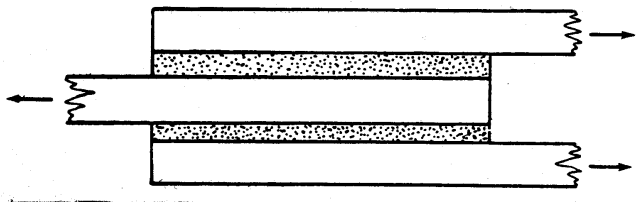
SWALES AEROSPACE

A4EI

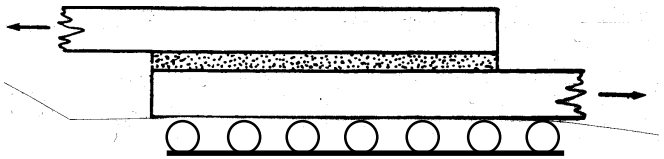
- Computer Code for Bonded Joint Design/Analysis from USAF
  - Originally Coded for CDC by Douglas Aircraft (John Hart-Smith)
  - Converted for IBM PC (less precision)
  - Interactive or File Inputs
- Semi-Empirical Methodology
  - Substantiation from Tests Needed for Confident Failure Prediction
- Limited Joint Configurations and Loading Types
  - Configurations on Next Slide
  - Loadings
    - Tension
    - Compression
    - Edgewise Shear
- One-Dimensional Adherend and Adhesive Response

Joint Configurations

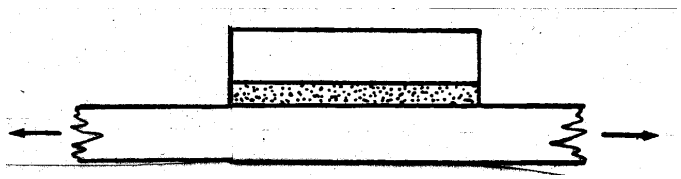
Double-Lap



Supported Single-Lap



Doubler



Theory

- One-Dimensional Extension of Adherends Under Direct (Axial) Load (No Bending)

$$\frac{d\delta_1}{dx} = \frac{T_1}{E_1 t_1} \; ; \; \frac{d\delta_2}{dx} = \frac{T_2}{E_2 t_2}$$

- Continuous Shear-Spring Approximation for Adhesive

$$\gamma_{ADH} = \frac{\delta_1 - \delta_2}{\eta} \quad and \quad \tau = G_{ADH} \; \gamma_{ADH}$$

Where Subscript 1 ≡ Properties of Adherend 1
Subscript 2 ≡ Properties of Adherend 2
δ ≡ Axial Extension
E ≡ Adherend Young's Modulus
t ≡ Adherend Thickness
T ≡ Axial Load (Lb/width)
G ≡ Adhesive Shear Modulus
η≡ Bondline Thickness

- Reference: NASA CR-112235: L.J. Hart-Smith, Adhesive-Bonded Double-Lap Joints, Jan. 1973

Adhesive Shear Stress-Strain Approximation

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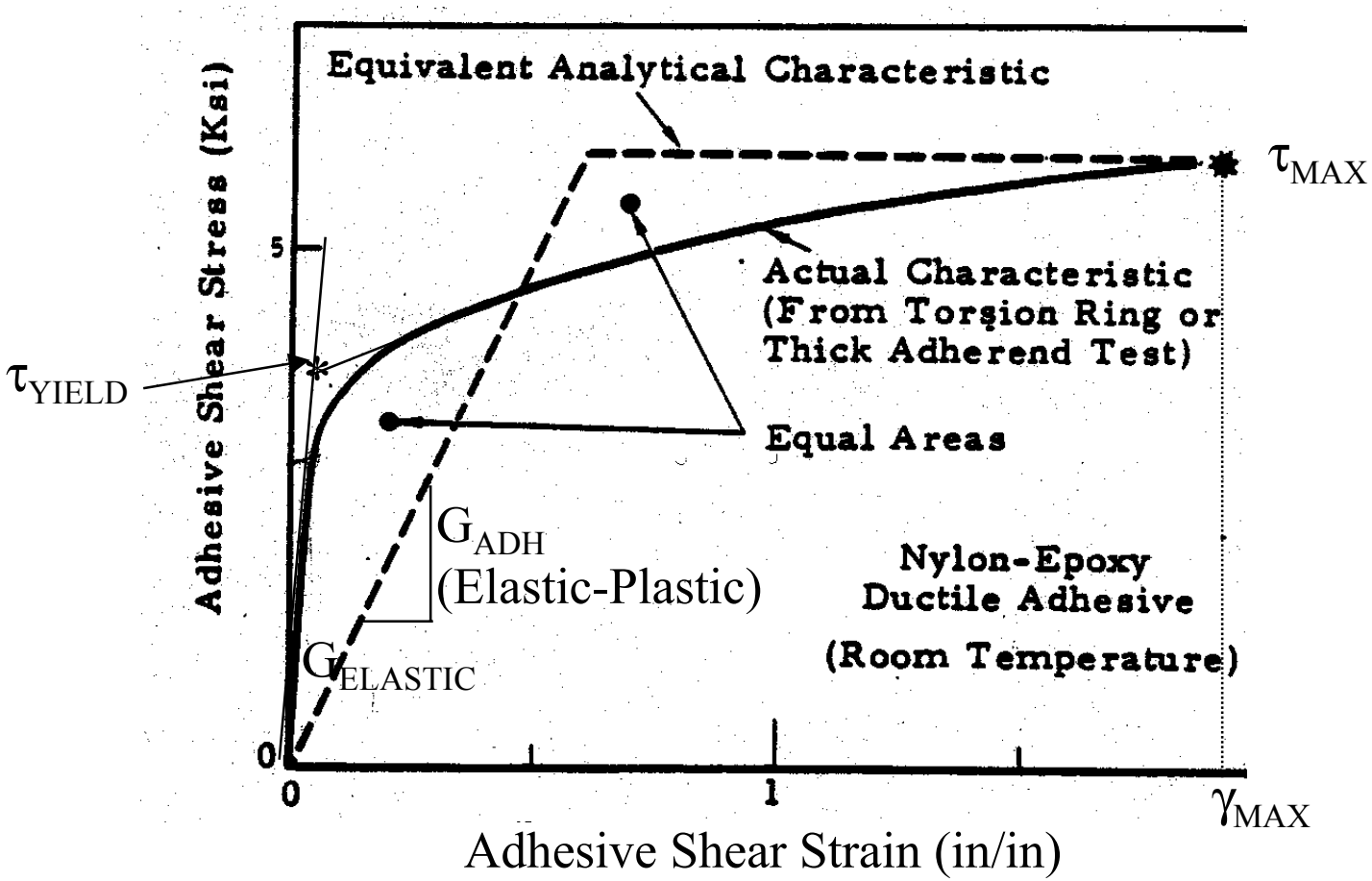

Joint Failure per A4EI

- Adhesive Reaches Maximum Shear Strain

$$\gamma_{ADH} \geq \gamma_{MAX}$$

  - Interpretations
    - Cohesive Failure in Adhesive
    - Max. Shear Strain in Adhesive When:
      - Metal or Composite Adherend Fail in Interlaminar Peel
      - Composite Adherend Fails in Interlaminar Shear
      - Adhesive Fails Adhesively to an Adherend (Poor Surface Prep)
- Adherend(s) Reach Strength Limit
- A4EI Does not Calculate Bond Peel Stress

A4EI Input Features

- Option of Input File or Interactive Input Definition
- Input Given at Stations along Joint Length
  - Up to 50 Stations Permitted
  - # Stations (NSTNS) = # Laps (ASTEPS) + 1
- Properties Below Can Vary @ Stations
  - Adherend Properties (either one or both)
    - Thickness
    - Stiffness (E×t)
    - Strength (Lb/in)
  - Adhesive Properties
    - Maximum Shear Stress
    - Shear Modulus
    - Maximum Shear Strain
    - Bond Thickness
    - Degree of Disbond (0 to 1, with 0 ≡ 100% properties & 1 ≡ 0% properties)
  - Geometry
    - Step Length

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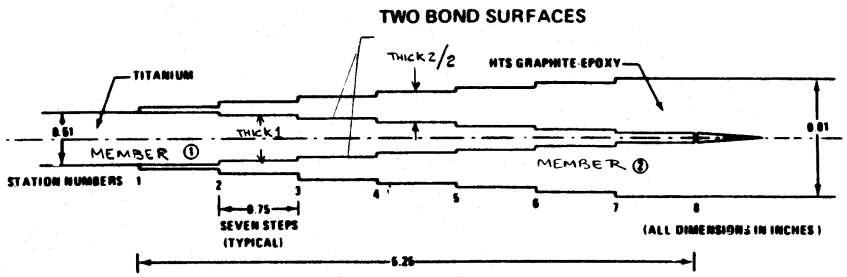
A4EI Input Conventions

- Station Numbering
  - Left to Right, Starting @ 1 & Ending @ NSTNS
- Adherend Position Convention
  - $\text{Adherend}_1 \equiv$ Inner Adherend
  - $\text{Adherend}_2 \equiv$ Outer Adherend
- Lap Joints
  - Full Load in Adherend_1 @ Station_1
  - Full Load in Adherend_2 @ Station_{NSTNS}
  - Thckns @ Stations
    - Double Lap: Thckns_2 = Total Thickns of Outer Adherends
    - Single & Double Lap: $\text{Thickns}_1 = 0$ @ NSTNS (Last Station)
- Doubler Joint
  - Full Load in Continuous Adherend (#1) @ Station_1
  - Shared Load in Both Adherends @ NSTNS
  - 1/2 Lap Length is Modeled
  - $\text{Thickns}_1 \neq 0$ @ NSTNS (Last Station)

A4EI Lap Conventions

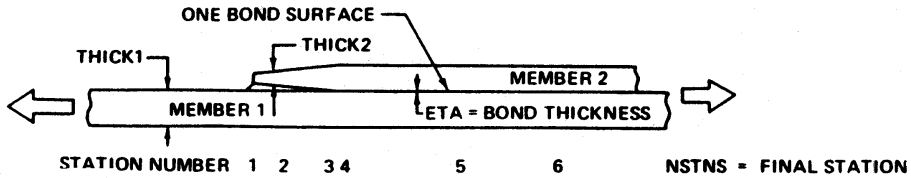
BONDED JOINT GEOMETRY AND IDENTIFICATION OF STATION NUMBERS FOR THE PROGRAM A4EI

BONDED JOINT



ASSIGN A STATION NUMBER TO EACH CHANGE IN ADHEREND OR ADHESIVE

BONDED DOUBLER



CONVENTION REQUIRES THAT ALL LOAD BE IN MEMBER 1 AT STATION 1 AND SHARED BETWEEN BOTH MEMBERS AT FINAL STATION

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Input File

- Define Input using Records
- Six Types of Records
  - Record Types: A, B, C, D, E, F
- Some Record Types are Mandatory
  - Mandatory Records: A, C, D, E, F
- One Record is Optional
  - Optional Record: B (Used To define a Title)
- Some Records are Required for Each Station
  - Station Data Records: D (Adhesive Props) and E (Adherend Props)
- Record A May be Repeated Depending on Loading and Geometry

SWALES AEROSPACE

Record A

- Purpose:
  - Initiation of a New Problem or Continuation of a Previous Problem with New Loading
  - Printout Control
- Variables: NCASE, ASF1, ASF2, ASF3

Variable	Value	Meaning
NCASE	0	New Problem; New Load Case
	1	Old Geometry; New Load Case
ASF1	0	Printout of Input Data
	1	No Input Data Printout
ASF2	0	Printout of Joint Capabilities; Elastic & Elastic/Plastic Distributions
	1	Printout of Joint Capabilities Only
ASF3	0	No Title
	1	User Defined Title

- Special Instructions:
  - Initial Record Required @ Beginning of Input
  - Subsequent Records Required for Either New Geometry or New Loading with Old Geometry. These are at the end of the Data file.

Record B

- Purpose:
  - Title Definition for Output
- Variables: User Defined Title Up to 72 Characters
- Special Instructions:
  - Include with Input when ASF3=1
  - Omit when ASF3=0

Record C

- Purpose:
  - Joint Description
- Variables: MNSTEP, DBLRJT, ANDLB, FACTOR, RVRSN

Variable	Value	Meaning
MNSTEP	1≤MNSTEP≤49	#STEPS in Joint (Adhesive or Adherend(s))
DBLRJT	0	Splice
	1	Doubler
ANDLB	0	Non-Symmetric Adhesive Stress & Strain Solution Algorithm (Doublers Must Have ANDLB=0)
	1	Symmetric Solution Algorithm
FACTOR	1	Single Bond (Enter Actual Adherend Thickness)
	2	Double Bond (Enter Thickness Sum of Outer Adherend)
RVRSND	0	Allows Reversal of Ends To Improve Accuracy (Analysis Begins @ Critical End)
	1	Automatic End Reversal is Overridden

- Special Instructions:
  - Mandatory Required Record

Record D

- Purpose:
  - Adhesive Property Definition per Station
  - Adherend CTE Definition per Station
- Variables: TAUMAX, G, GAMMAX, ETA, ALPHA1, ALPHA2, DISBND

Variable	Meaning
TAUMAX	Adhesive Max. Shear Strength
G	Adhesive Shear Modulus (Elastic Portion)
GAMMAX	Adhesive Max. Shear Strain (Sum of Elastic & Plastic Strains)
ETA	Adhesive Thickness (Must be >0; Default = 0.005”)
ALPHA1	CTE of ADHEREND1 (inner adherend)
ALPHA2	CTE of ADHEREND2 (outer adherend)
DISBND	Bond Effectivity (No Disbond Allowed in First Step)

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Record D: Special Instructions

- One Record Required for Each Station
- For Identical Properties @ Stations:
  - Input Properties Once @ $Station_1$
  - Enter Zeros on Successive Input Cards to Repeat Properties
- To "Zero-Out" ALPH1, ALPH2, or DISBOND:
  - Enter -1 for That Value
- Caution:
  - Cannot Set ETA_N=0, Even for DISBONDED STEP
  - Default is ETA_N=0.005 inches
  - No Disbond Allowed in First Step
- Minimum Input (Record D):
  - True Values for N=1 and N=NSTNS
  - Zero Values for All Variables @ Other Stations
    - Denotes Uniform Adherends with Equal Step Lengths

Record E

- Purpose
  - Adherend Property & Joint Geometry Definition per Station
- Variables: THICK1, THICK2, STEPL, ETONE, ETTWO, STRONE, STRTWO

Variable	Meaning
THICK1	Thickness of Inner Adherend
THICK2	Total Thickness of Outer Adherend(s)
STEPL	Station's Step Length
ETONE	E x T of Inner Adherend
ETTWO	E x T of Outer Adherend(s) (See THICK2)
STRONE	F^{ULT}x T of Inner Adherend
STRTWO	F^{ULT}xT of Outer Adherend(s) (See THICK2)

- Special Instructions
  - One Record Required per Station
  - Repeated Values @ Subsequent Stations Signified with Zeros after Initial Definition
  - Above Technique not Applicable for THICK1, THICK2, STRONE, and STRTWO at Last Station (NSTNS)

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Record F

- Purpose:
  - Applied Loading Definition
  - DELTA T Definition for Thermal Stresses
  - Diagnostic Parameter Definition for Convergence Failures
- Variables: PLOAD, SGNLD, DELTEMP, RESDUL, PLONE, PLTWO, DIAGNE, DIAGNP, DIAGNT

Variable	Value	Meaning
PLOAD	0	Keys A4EI to Calculate Elastic & Elastic/Plastic Joint Strengths (Lb/inch)
	Positive Number	Applied Load Magnitude per Joint Width
SGNLD	+1	Tensile Applied Load
	-1	Compressive Applied Load
	0	Inplane Shear Applied Load
DELTEMP	Usually a Negative Number	Temperature Difference: Operating – Stress Free
RESDUL	0	Used for Applied & ΔT Loading
	Non-Zero Number	Residual Stresses/Strains due to ΔT only
PLONE	Positive Number	Running Shear Load on Adherend1 (Same Sense as SGNLD)
PLTWO	Positive Number	Running Shear Load on Adherend2 (Same Sense as SGNLD)
DIAGNE DIAGNP DIAGNT	0	No Diagnostics in Printout
	1	Partial Diagnostics in Printout
	2	Full Diagnostics in Printout

Record F (Continued)

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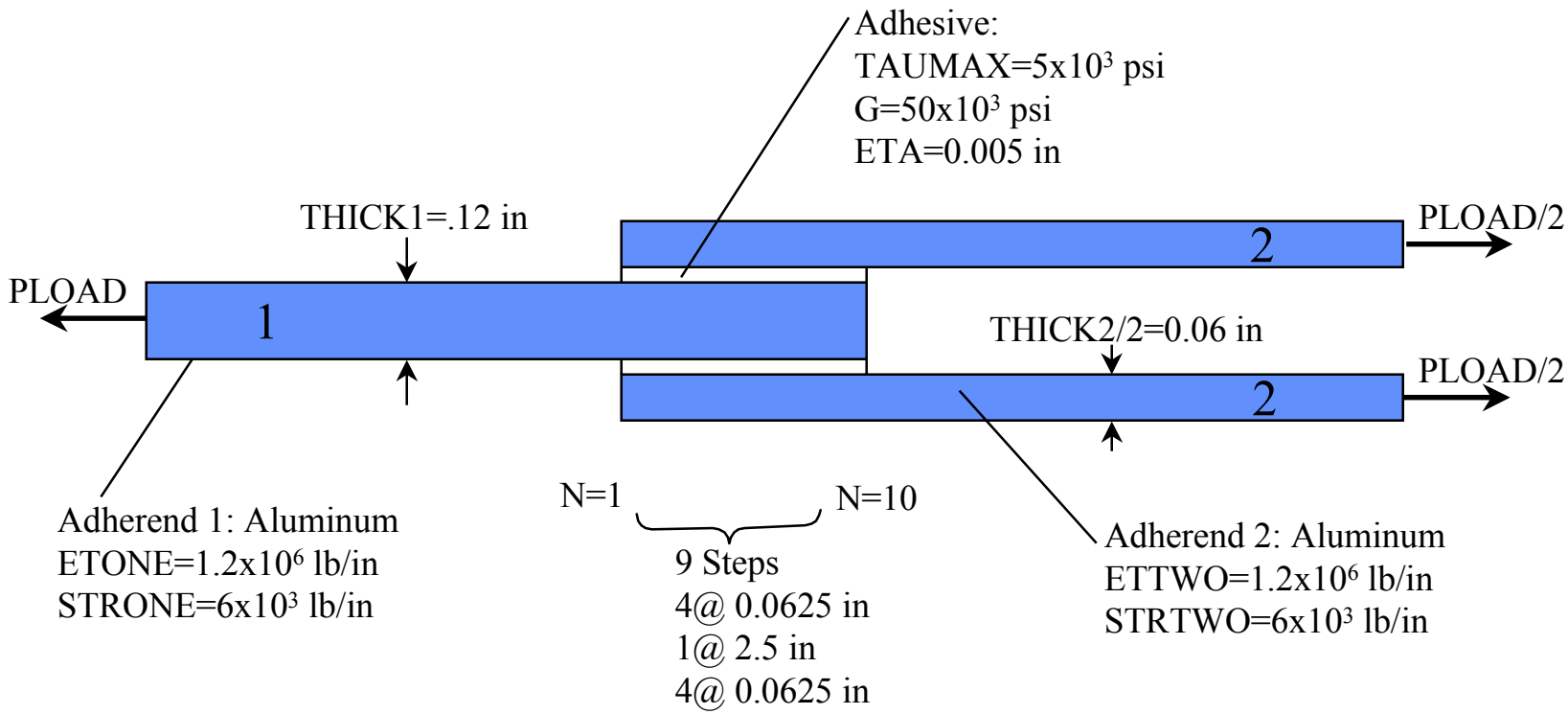
- Special Instructions:
  - Compressive Load can also be defined with PLOAD<1 and SGNLD=1
  - Edgewise Shear
    - SGNLD=0: G Calculated from Adherend E Assuming Nu=0.3 (isotropic)
    - Anisotropic Adherends:
      - Input Gxy in place of Ex
      - Treat Load as Tensile (SGNLD=1)
  - For Only Residual Stresses/Strains due to ΔT:
    - PLOAD=0, SGNLD=1, RESDUL=1, ΔT=Actual Value
  - For ΔT to Fail Joint in Absence of Applied Load:
    - PLOAD=0, SGNLD=1, RESDUL=0, ΔT=Various Values until Joint Strength=0 (Cumbersome Iterative Process)

Example Problem



CASE	Problem
1	Tensile Joint Strength Capability (Constant ETA)
2	Case 1 Geometry; +2400 lb/in Loading
3	Case 1 Geometry; +4800 lb/in Loading
4	Variable ETA; Joint Strength Capability

Example Problem Input File

Record

```
A   0  0  0  1                                                  CASE 1
B   DOUBLE LAP EXAMPLE
C   9  0  0  2  0
D   5000.  50000. 0.5000 0.0050 0.0 0.0 0.0
       0.      0.     0.     0.   0.  0.  0.
       0.      0.     0.     0.   0.  0.  0.
       0.      0.     0.     0.   0.  0.  0.
       0.      0.     0.     0.   0.  0.  0.   Uniform Adhesive Properties
       0.      0.     0.     0.   0.  0.  0.
       0.      0.     0.     0.   0.  0.  0.
       0.      0.     0.     0.   0.  0.  0.
       0.      0.     0.     0.   0.  0.  0.
       0.      0.     0.     0.   0.  0.  0.
E  0.120 0.120  0.0625 1200000. 1200000.   6000.   6000.
   0.120 0.120  0.0625 1200000. 1200000.   6000.   6000.
   0.120 0.120  0.0625 1200000. 1200000.   6000.   6000.
   0.120 0.120  0.0625 1200000. 1200000.   6000.   6000.
   0.120 0.120  2.5    1200000. 1200000.   6000.   6000.
   0.120 0.120  0.0625 1200000. 1200000.   6000.   6000.
   0.120 0.120  0.0625 1200000. 1200000.   6000.   6000.
   0.120 0.120  0.0625 1200000. 1200000.   6000.   6000.
   0.120 0.120  0.0625 1200000. 1200000.   6000.   6000.
   0.000 0.120  1.000  0.000    120000.    0.000   6000.
F      0.  1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
A      1   1    0    0                                          CASE 2
F   2400.  1.   0.0  0.0  0.0  0.0  0.0  0.0  0.0
A      1   1    0    0                                          CASE 3
F   4800.  1.   0.0  0.0  0.0  0.0  0.0  0.0  0.0
A      0   0    0    1                                          CASE 4
```

Example Problem Input File (cont.)

```
Record
B       DOUBLE LAP JOINT WITH VARYING BOND THICKNESS
C            9   0    0    2    0
D        5000. 50000. 0.5   .006    0.  0.  0.
            0.     0.   0.  .00575  0.  0.  0.
            0.     0.   0.  .0055   0.  0.  0.
            0.     0.   0.  .00525  0.  0.  0.
            0.     0.   0.  .005    0.  0.  0.
            0.     0.   0.  .00525  0.  0.  0.
            0.     0.   0.  .0055   0.  0.  0.
            0.     0.   0.  .00575  0.  0.  0.
            0.     0.   0.  .006    0.  0.  0.
            0.     0.   0.  .006    0.  0.  0.
E           .12   .12   .0625  1200000.  1200000.  6000.  6000.
            0.     0.    0.    0.        0.        0.     0.
            0.     0.    0.    0.        0.        0.     0.
            0.     0.    0.    0.        0.        0.     0.
            0.     0.   2.5    0.        0.        0.     0.
            0.     0.   .0625  0.        0.        0.     0.
            0.     0.    0.    0.        0.        0.     0.
            0.     0.    0.    0.        0.        0.     0.
            0.     0.    0.    0.        0.        0.     0.
            0.    .12    1.    0.        1200000.  0.     6000.
F           0.    1.0    0.    0.        0.        0.     0.   0.   0.
```

Example Problem Output File

```
1                  02/08/01
   DOUBLE LAP EXAMPLE
0
                    *** STEPPED-LAP ADHESIVE-BONDED JOINT ***
0
                                 *** INPUT DATA ***
  NCASE =  0, ASF1 = 0., ASF2 = 0., ASF3 = 1.
0
  MNSTEP =  9, DBLRJT = 0., ANDLB = 0., FACTOR = 2., RVRSND = 0.
0
                                 *** INPUT DATA ***
  N      STEPL     THICK1  THICK2      STRONE    STRTWO        ETONE      ETTWO
        (INCH)     (INCH)  (INCH)     (LBS/IN)  (LBS/IN)       (PSI)      (PSI)

  1     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  2     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  3     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  4     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  5     0.8333     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  6     0.8333     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  7     0.8333     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  8     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  9     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
 10     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
 11     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
 12     1.0000     0.0000  0.1200          0.      6000.            0.    120000.
0
  N   ETA      TAUMAX      G       GAMMAX  GAMMAE     ALPHA1      ALPHA2   PERCENT
     (INCH)    (PSI)     (PSI)    (IN/IN)  (IN/IN)   (/DEG.F)    (/DEG.F)  DISBOND

  1  0.0050     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  2  0.0050     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  3  0.0050     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  4  0.0050     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  5  0.0050     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  6  0.0050     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  7  0.0050     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  8  0.0050     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  9  0.0050     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
 10  0.0050     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
 11  0.0050     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
 12  0.0050     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
0
```

2.5 { 5, 6, 7

Example Problem Output File (cont.)

```
 *** DOUBLE BOND SURFACE ***
1                  02/08/01
   DOUBLE LAP EXAMPLE

 THE ELASTIC JOINT STRENGTH (POUNDS/INCH)                          =     3464.1
 THE TEMPERATURE DIFFERENTIAL (OPERATING - CURE) (DEGREES F)       =        0.0
 THE ADHESIVE IS MOST SEVERELY LOADED IN STEP NUMBER                       11
 THE ADHEREND(S) 'ONE'MOST SEVERELY LOADED IS IN STEP NUMBER                1
 THE ADHEREND(S) 'TWO' MOST SEVERELY LOADED IS IN STEP NUMBER              11
0
                              *** TENSILE LOADING ***
0
```

	N	STEPL (INCH)	THICK1 (INCH)	THICK2 (INCH)	TAU (PSI)	GAMMA (IN/IN)	DELTA1 (INCH)	DELTA2 (INCH)	TLDONE (LBS/IN)	STRONE (LBS/IN)	TLDTWO (LBS/IN)	STRTWO (LBS/IN)
	1	0.0313	0.1200	0.1200	5000.0	0.1000	0.0000	0.0005	3464.	6000.	0.	6000.
	1	0.0313	0.1200	0.1200	4174.6	0.0835	0.0001	0.0005	3178.	6000.	286.	6000.
	1	0.0000	0.1200	0.1200	3485.4	0.0697	0.0002	0.0005	2939.	6000.	525.	6000.
	2	0.0313	0.1200	0.1200	3485.4	0.0697	0.0002	0.0005	2939.	6000.	525.	6000.
	2	0.0313	0.1200	0.1200	2910.1	0.0582	0.0002	0.0005	2740.	6000.	724.	6000.
	2	0.0000	0.1200	0.1200	2429.7	0.0486	0.0003	0.0006	2574.	6000.	890.	6000.
LEFT	3	0.0313	0.1200	0.1200	2429.7	0.0486	0.0003	0.0006	2574.	6000.	890.	6000.
MIDDLE	3	0.0313	0.1200	0.1200	2028.6	0.0406	0.0004	0.0006	2435.	6000.	1029.	6000.
RIGHT	3	0.0000	0.1200	0.1200	1693.7	0.0339	0.0004	0.0006	2319.	6000.	1145.	6000.
	4	0.0313	0.1200	0.1200	1693.7	0.0339	0.0004	0.0006	2319.	6000.	1145.	6000.
	4	0.0313	0.1200	0.1200	1414.1	0.0283	0.0005	0.0006	2222.	6000.	1242.	6000.
	4	0.0000	0.1200	0.1200	1180.6	0.0236	0.0006	0.0007	2141.	6000.	1323.	6000.
	5	0.4167	0.1200	0.1200	1180.6	0.0236	0.0006	0.0007	2141.	6000.	1323.	6000.
	5	0.4167	0.1200	0.1200	106.5	0.0021	0.0012	0.0012	1769.	6000.	1695.	6000.
	5	0.0000	0.1200	0.1200	9.7	0.0002	0.0018	0.0018	1735.	6000.	1729.	6000.
	6	0.4167	0.1200	0.1200	9.7	0.0002	0.0018	0.0018	1735.	6000.	1729.	6000.
	6	0.4167	0.1200	0.1200	1.7	0..700	0.0024	0.0024	1732.	6000.	1732.	6000.
	6	0.0000	0.1200	0.1200	9.7	0.0002	0.0030	0.0030	1729.	6000.	1735.	6000.
	7	0.4167	0.1200	0.1200	9.7	0.0002	0.0030	0.0030	1729.	6000.	1735.	6000.
	7	0.4167	0.1200	0.1200	106.5	0.0021	0.0036	0.0036	1695.	6000.	1769.	6000.
	7	0.0000	0.1200	0.1200	1180.7	0.0236	0.0042	0.0043	1323.	6000.	2141.	6000.
	8	0.0313	0.1200	0.1200	1180.7	0.0236	0.0042	0.0043	1323.	6000.	2141.	6000.
	8	0.0313	0.1200	0.1200	1414.1	0.0283	0.0042	0.0043	1242.	6000.	2222.	6000.
	8	0.0000	0.1200	0.1200	1693.7	0.0339	0.0042	0.0044	1145.	6000.	2319.	6000.
	9	0.0313	0.1200	0.1200	1693.7	0.0339	0.0042	0.0044	1145.	6000.	2319.	6000.
	9	0.0313	0.1200	0.1200	2028.6	0.0406	0.0043	0.0045	1029.	6000.	2435.	6000.
	9	0.0000	0.1200	0.1200	2429.7	0.0486	0.0043	0.0045	890.	6000.	2574.	6000.
	10	0.0313	0.1200	0.1200	2429.7	0.0486	0.0043	0.0045	890.	6000.	2574.	6000.
	10	0.0313	0.1200	0.1200	2910.1	0.0582	0.0043	0.0046	724.	6000.	2740.	6000.
	10	0.0000	0.1200	0.1200	3485.5	0.0697	0.0043	0.0047	525.	6000.	2939.	6000.

Example Problem Output File (cont.)

```
 11  0.0312  0.1200  0.1200   3485.5  0.0697  0.0043  0.0047       525.    6000.    2939.    6000.
 11  0.0312  0.1200  0.1200   4174.6  0.0835  0.0043  0.0047       286.    6000.    3178.    6000.
 11  0.····  0.1200  0.1200   5000.0  0.1000  0.0043  0.0048         0.    6000.    3464.    6000.
 11  0.0000  0.1200  0.1200   5000.0  0.1000  0.0043  0.0048         0.    6000.    3464.    6000.
 12  0.0000  0.0000  0.1200   5000.0  0.1000  0.0043  0.0048         0.       0.    3464.    6000.
1                   02/08/01
   DOUBLE LAP EXAMPLE

 THE ELASTIC-PLASTIC JOINT STRENGTH (POUNDS/INCH)                    =     6000.0
 THE TEMPERATURE DIFFERENTIAL (OPERATING - CURE) (DEGREES F)         =        0.0
 THE ADHESIVE IS MOST SEVERELY LOADED IN STEP NUMBER                        11
 THE ADHEREND(S) 'ONE'MOST SEVERELY LOADED IS IN STEP NUMBER                 1
 THE ADHEREND(S) 'TWO' MOST SEVERELY LOADED IS IN STEP NUMBER               11
0
```

"X" "ΔX"

```
                          *** TENSILE LOADING ***
0
  N   STEPL  THICK1  THICK2   TAU     GAMMA   DELTA1  DELTA2     TLDONE   STRONE   TLDTWO   STRTWO
      (INCH)  (INCH)  (INCH)  (PSI)   (IN/IN)  (INCH)  (INCH)    (LBS/IN) (LBS/IN) (LBS/IN) (LBS/IN)
```

"0"

"X"	N	STEPL (INCH)	THICK1 (INCH)	THICK2 (INCH)	TAU (PSI)	GAMMA (IN/IN)	DELTA1 (INCH)	DELTA2 (INCH)	TLDONE (LBS/IN)	STRONE (LBS/IN)	TLDTWO (LBS/IN)	STRTWO (LBS/IN)
0	1	0.0625	0.1200	0.1200	5000.0	0.2000	0.0000	0.0010	6000.	6000.	0.	6000.
.0625	1	0.0000	0.1200	0.1200	5000.0	0.1440	0.0003	0.0010	5375.	6000.	625.	6000.
.0625	2	0.0625	0.1200	0.1200	5000.0	0.1440	0.0003	0.0010	5375.	6000.	625.	6000.
.125	2	0.0000	0.1200	0.1200	5000.0	0.1010	0.0006	0.0011	4750.	6000.	1250.	6000.
.125	3	0.0018	0.1200	0.1200	5000.0	0.1010	0.0006	0.0011	4750.	6000.	1250.	6000.
.1268	3	0.0304	0.1200	0.1200	5000.0	0.1000	0.0006	0.0011	4732.	6000.	1268.	6000.
.1572	3	0.0304	0.1200	0.1200	4196.3	0.0839	0.0007	0.0011	4454.	6000.	1546.	6000.
.1876	3	0.0000	0.1200	0.1200	3521.7	0.0704	0.0008	0.0011	4220.	6000.	1780.	6000.
.1876	4	0.0313	0.1200	0.1200	3521.7	0.0704	0.0008	0.0011	4220.	6000.	1780.	6000.
.2189	4	0.0313	0.1200	0.1200	2940.4	0.0588	0.0009	0.0012	4019.	6000.	1981.	6000.
.2502	4	0.0000	0.1200	0.1200	2455.0	0.0491	0.0010	0.0012	3850.	6000.	2150.	6000.
.2502	5	0.4167	0.1200	0.1200	2455.0	0.0491	0.0010	0.0012	3850.	6000.	2150.	6000.
.6669	5	0.4167	0.1200	0.1200	221.5	0.0044	0.0022	0.0022	3077.	6000.	2923.	6000.
1.0836	5	0.0000	0.1200	0.1200	20.1	0.0004	0.0032	0.0032	3007.	6000.	2993.	6000.
1.0836	6	0.4167	0.1200	0.1200	20.1	0.0004	0.0032	0.0032	3007.	6000.	2993.	6000.
1.5003	6	0.4167	0.1200	0.1200	3.6	0.0001	0.0042	0.0043	3000.	6000.	3000.	6000.
7.917	6	0.0000	0.1200	0.1200	20.1	0.0004	0.0053	0.0053	2993.	6000.	3007.	6000.
1.917	7	0.4167	0.1200	0.1200	20.1	0.0004	0.0053	0.0053	2993.	6000.	3007.	6000.
2.3337	7	0.4167	0.1200	0.1200	221.5	0.0044	0.0063	0.0063	2923.	6000.	3077.	6000.
2.7504	7	0.0000	0.1200	0.1200	2455.0	0.0491	0.0073	0.0075	2150.	6000.	3850.	6000.
2.7504	8	0.0313	0.1200	0.1200	2455.0	0.0491	0.0073	0.0075	2150.	6000.	3850.	6000.
2.7817	8	0.0313	0.1200	0.1200	2940.4	0.0588	0.0073	0.0076	1981.	6000.	4019.	6000.
2.813	8	0.0000	0.1200	0.1200	3521.8	0.0704	0.0074	0.0077	1780.	6000.	4220.	6000.
2.813	9	0.0304	0.1200	0.1200	3521.8	0.0704	0.0074	0.0077	1780.	6000.	4220.	6000.
2.8434	9	0.0304	0.1200	0.1200	4196.3	0.0839	0.0074	0.0078	1546.	6000.	4454.	6000.
2.8738												

Example Problem Output File (cont.)

```
                0.0304
2.8756    9  0.0018  0.1200  0.1200  5000.0  0.1000  0.0074  0.0079     1268.   6000.   4732.   6000.
2.8756    9  0.0000  0.1200  0.1200  5000.0  0.1010  0.0074  0.0079     1250.   6000.   4750.   6000.
2.9381   10  0.0625  0.1200  0.1200  5000.0  0.1010  0.0074  0.0079     1250.   6000.   4750.   6000.
2.9381   10  0.0000  0.1200  0.1200  5000.0  0.1440  0.0075  0.0082      625.   6000.   5375.   6000.
3.0006   11  0.0625  0.1200  0.1200  5000.0  0.1440  0.0075  0.0082      625.   6000.   5375.   6000.
3.0006   11  0.0000  0.1200  0.1200  5000.0  0.2000  0.0075  0.0085        0.   6000.   6000.   6000.
         12  0.0000  0.0000  0.1200  5000.0  0.2000  0.0075  0.0085        0.      0.   6000.   6000.
1                        02/08/01
   DOUBLE LAP EXAMPLE

 THE POTENTIAL BOND STRENGTH FOR THE ADHERENDS WITH REAL
      STIFFNESSES BUT UNLIMITED STRENGTHS (POUNDS/INCH)              =    10392.3
 THE TEMPERATURE DIFFERENTIAL (OPERATING - CURE) (DEGREES F)         =        0.0
 THE ADHESIVE IS MOST SEVERELY LOADED IN STEP NUMBER                        11
0
                                *** TENSILE LOADING ***
0
  N   STEPL  THICK1  THICK2   TAU     GAMMA   DELTA1  DELTA2     TLDONE   STRONE   TLDTWO   STRTWO
      (INCH)  (INCH)  (INCH)  (PSI)   (IN/IN)  (INCH)  (INCH)    (LBS/IN) (LBS/IN) (LBS/IN) (LBS/IN)

  1  0.0625  0.1200  0.1200   5000.0  0.5000  0.0000  0.0025     10392.   6000.      0.    6000.
  1  0.0000  0.1200  0.1200   5000.0  0.3983  0.0005  0.0025      9767.   6000.    625.    6000.
  2  0.0625  0.1200  0.1200   5000.0  0.3983  0.0005  0.0025      9767.   6000.    625.    6000.
  2  0.0000  0.1200  0.1200   5000.0  0.3095  0.0010  0.0026      9142.   6000.   1250.    6000.
  3  0.0625  0.1200  0.1200   5000.0  0.3095  0.0010  0.0026      9142.   6000.   1250.    6000.
  3  0.0000  0.1200  0.1200   5000.0  0.2338  0.0015  0.0026      8517.   6000.   1875.    6000.
  4  0.0625  0.1200  0.1200   5000.0  0.2338  0.0015  0.0026      8517.   6000.   1875.    6000.
  4  0.0000  0.1200  0.1200   5000.0  0.1712  0.0019  0.0028      7892.   6000.   2500.    6000.
  5  0.0964  0.1200  0.1200   5000.0  0.1712  0.0019  0.0028      7892.   6000.   2500.    6000.
  5  0.3685  0.1200  0.1200   5000.0  0.1000  0.0025  0.0030      6928.   6000.   3464.    6000.
  5  0.3685  0.1200  0.1200    595.9  0.0119  0.0043  0.0044      5403.   6000.   4990.    6000.
  5  0.0000  0.1200  0.1200     71.6  0.0014  0.0059  0.0059      5221.   6000.   5172.    6000.
  6  0.4167  0.1200  0.1200     71.6  0.0014  0.0059  0.0059      5221.   6000.   5172.    6000.
  6  0.4167  0.1200  0.1200     12.8  0.0003  0.0077  0.0077      5196.   6000.   5196.    6000.
  6  0.0000  0.1200  0.1200     71.6  0.0014  0.0095  0.0096      5172.   6000.   5221.    6000.
  7  0.3685  0.1200  0.1200     71.6  0.0014  0.0095  0.0096      5172.   6000.   5221.    6000.
  7  0.3685  0.1200  0.1200    595.9  0.0119  0.0111  0.0112      4990.   6000.   5403.    6000.
  7  0.0964  0.1200  0.1200   5000.0  0.1000  0.0125  0.0130      3464.   6000.   6928.    6000.
  7  0.0000  0.1200  0.1200   5000.0  0.1712  0.0127  0.0136      2500.   6000.   7892.    6000.
  8  0.0625  0.1200  0.1200   5000.0  0.1712  0.0127  0.0136      2500.   6000.   7892.    6000.
  8  0.0000  0.1200  0.1200   5000.0  0.2338  0.0128  0.0140      1875.   6000.   8517.    6000.
  9  0.0625  0.1200  0.1200   5000.0  0.2338  0.0128  0.0140      1875.   6000.   8517.    6000.
  9  0.0000  0.1200  0.1200   5000.0  0.3095  0.0129  0.0145      1250.   6000.   9142.    6000.
 10  0.0625  0.1200  0.1200   5000.0  0.3095  0.0129  0.0145      1250.   6000.   9142.    6000.
 10  0.0000  0.1200  0.1200   5000.0  0.3983  0.0130  0.0150       625.   6000.   9767.    6000.
 11  0.0625  0.1200  0.1200   5000.0  0.3983  0.0130  0.0150       625.   6000.   9767.    6000.
 11  0.0000  0.1200  0.1200   5000.0  0.5000  0.0130  0.0155         0.   6000.  10392.    6000.
 12  0.0000  0.0000  0.1200   5000.0  0.5000  0.0130  0.0155         0.      0.  10392.    6000.
0
```

Example Problem Output File (cont.)

```
 THE APPLIED LOAD, PLOAD (LBS/INCH)                                  =     2400.0
 THE TEMPERATURE DIFFERENTIAL (OPERATING - CURE) (DEGREES F)         =        0.0
 THE ADHESIVE IS MOST SEVERELY LOADED IN STEP NUMBER                    1
 THE ADHEREND(S) 'ONE'MOST SEVERELY LOADED IS IN STEP NUMBER            1
 THE ADHEREND(S) 'TWO' MOST SEVERELY LOADED IS IN STEP NUMBER          11
0
                              *** TENSILE LOADING ***
0
```

N	STEPL (INCH)	THICK1 (INCH)	THICK2 (INCH)	TAU (PSI)	GAMMA (IN/IN)	DELTA1 (INCH)	DELTA2 (INCH)	TLDONE (LBS/IN)	STRONE (LBS/IN)	TLDTWO (LBS/IN)	STRTWO (LBS/IN)
1	0.0313	0.1200	0.1200	3464.1	0.0693	0.0000	0.0003	2400.	6000.	0.	6000.
1	0.0313	0.1200	0.1200	2892.2	0.0578	0.0001	0.0003	2202.	6000.	198.	6000.
1	0.0000	0.1200	0.1200	2414.8	0.0483	0.0001	0.0004	2037.	6000.	363.	6000.
2	0.0313	0.1200	0.1200	2414.8	0.0483	0.0001	0.0004	2037.	6000.	363.	6000.
2	0.0313	0.1200	0.1200	2016.1	0.0403	0.0002	0.0004	1898.	6000.	502.	6000.
2	0.0000	0.1200	0.1200	1683.3	0.0337	0.0002	0.0004	1783.	6000.	617.	6000.
3	0.0313	0.1200	0.1200	1683.3	0.0337	0.0002	0.0004	1783.	6000.	617.	6000.
3	0.0313	0.1200	0.1200	1405.4	0.0281	0.0003	0.0004	1687.	6000.	713.	6000.
3	0.0000	0.1200	0.1200	1173.4	0.0235	0.0003	0.0004	1606.	6000.	794.	6000.
4	0.0313	0.1200	0.1200	1173.4	0.0235	0.0003	0.0004	1606.	6000.	794.	6000.
4	0.0313	0.1200	0.1200	979.7	0.0196	0.0003	0.0004	1539.	6000.	861.	6000.
4	0.0000	0.1200	0.1200	818.0	0.0164	0.0004	0.0005	1483.	6000.	917.	6000.
5	0.4167	0.1200	0.1200	818.0	0.0164	0.0004	0.0005	1483.	6000.	917.	6000.
5	0.4167	0.1200	0.1200	73.8	0.0015	0.0008	0.0008	1226.	6000.	1174.	6000.
5	0.0000	0.1200	0.1200	6.7	0.0001	0.0013	0.0013	1202.	6000.	1198.	6000.
6	0.4167	0.1200	0.1200	6.7	0.0001	0.0013	0.0013	1202.	6000.	1198.	6000.
6	0.4167	0.1200	0.1200	1.2	0..200	0.0017	0.0017	1200.	6000.	1200.	6000.
6	0.0000	0.1200	0.1200	6.7	0.0001	0.0021	0.0021	1198.	6000.	1202.	6000.
7	0.4167	0.1200	0.1200	6.7	0.0001	0.0021	0.0021	1198.	6000.	1202.	6000.
7	0.4167	0.1200	0.1200	73.8	0.0015	0.0025	0.0025	1174.	6000.	1226.	6000.
7	0.0000	0.1200	0.1200	818.0	0.0164	0.0029	0.0030	917.	6000.	1483.	6000.
8	0.0313	0.1200	0.1200	818.0	0.0164	0.0029	0.0030	917.	6000.	1483.	6000.
8	0.0313	0.1200	0.1200	979.7	0.0196	0.0029	0.0030	861.	6000.	1539.	6000.
8	0.0000	0.1200	0.1200	1173.4	0.0235	0.0029	0.0030	794.	6000.	1606.	6000.
9	0.0313	0.1200	0.1200	1173.4	0.0235	0.0029	0.0030	794.	6000.	1606.	6000.
9	0.0313	0.1200	0.1200	1405.4	0.0281	0.0029	0.0031	713.	6000.	1687.	6000.
9	0.0000	0.1200	0.1200	1683.3	0.0337	0.0030	0.0031	617.	6000.	1783.	6000.
10	0.0313	0.1200	0.1200	1683.3	0.0337	0.0030	0.0031	617.	6000.	1783.	6000.
10	0.0313	0.1200	0.1200	2016.1	0.0403	0.0030	0.0032	502.	6000.	1898.	6000.
10	0.0000	0.1200	0.1200	2414.8	0.0483	0.0030	0.0032	363.	6000.	2037.	6000.
11	0.0313	0.1200	0.1200	2414.8	0.0483	0.0030	0.0032	363.	6000.	2037.	6000.
11	0.0313	0.1200	0.1200	2892.2	0.0578	0.0030	0.0033	198.	6000.	2202.	6000.
11	0.0000	0.1200	0.1200	3464.1	0.0693	0.0030	0.0033	0.	6000.	2400.	6000.
12	0.0000	0.0000	0.1200	3464.1	0.0693	0.0030	0.0033	0.	0.	2400.	6000.

0

Example Problem Output File (cont.)

```
 THE APPLIED LOAD, PLOAD (LBS/INCH)                                  =     4800.0
 THE TEMPERATURE DIFFERENTIAL (OPERATING - CURE) (DEGREES F)         =        0.0
 THE ADHESIVE IS MOST SEVERELY LOADED IN STEP NUMBER                            1
 THE ADHEREND(S) 'ONE'MOST SEVERELY LOADED IS IN STEP NUMBER                    1
 THE ADHEREND(S) 'TWO' MOST SEVERELY LOADED IS IN STEP NUMBER                  11
0
                              *** TENSILE LOADING ***
0
```

N	STEPL (INCH)	THICK1 (INCH)	THICK2 (INCH)	TAU (PSI)	GAMMA (IN/IN)	DELTA1 (INCH)	DELTA2 (INCH)	TLDONE (LBS/IN)	STRONE (LBS/IN)	TLDTWO (LBS/IN)	STRTWO (LBS/IN)
1	0.0625	0.1200	0.1200	5000.0	0.1460	0.0000	0.0007	4800.	6000.	0.	6000.
1	0.0000	0.1200	0.1200	5000.0	0.1025	0.0002	0.0007	4175.	6000.	625.	6000.
2	0.0043	0.1200	0.1200	5000.0	0.1025	0.0002	0.0007	4175.	6000.	625.	6000.
2	0.0291	0.1200	0.1200	5000.0	0.1000	0.0002	0.0007	4132.	6000.	668.	6000.
2	0.0291	0.1200	0.1200	4226.7	0.0845	0.0003	0.0008	3864.	6000.	936.	6000.
2	0.0000	0.1200	0.1200	3572.9	0.0715	0.0004	0.0008	3638.	6000.	1162.	6000.
3	0.0313	0.1200	0.1200	3572.9	0.0715	0.0004	0.0008	3638.	6000.	1162.	6000.
3	0.0313	0.1200	0.1200	2983.1	0.0597	0.0005	0.0008	3433.	6000.	1367.	6000.
3	0.0000	0.1200	0.1200	2490.7	0.0498	0.0006	0.0009	3263.	6000.	1537.	6000.
4	0.0313	0.1200	0.1200	2490.7	0.0498	0.0006	0.0009	3263.	6000.	1537.	6000.
4	0.0313	0.1200	0.1200	2079.5	0.0416	0.0007	0.0009	3120.	6000.	1680.	6000.
4	0.0000	0.1200	0.1200	1736.2	0.0347	0.0008	0.0010	3001.	6000.	1799.	6000.
5	0.4167	0.1200	0.1200	1736.2	0.0347	0.0008	0.0010	3001.	6000.	1799.	6000.
5	0.4167	0.1200	0.1200	156.6	0.0031	0.0017	0.0017	2454.	6000.	2346.	6000.
5	0.0000	0.1200	0.1200	14.2	0.0003	0.0025	0.0025	2405.	6000.	2395.	6000.
6	0.4167	0.1200	0.1200	14.2	0.0003	0.0025	0.0025	2405.	6000.	2395.	6000.
6	0.4167	0.1200	0.1200	2.5	0.0001	0.0034	0.0034	2400.	6000.	2400.	6000.
6	0.0000	0.1200	0.1200	14.2	0.0003	0.0042	0.0042	2395.	6000.	2405.	6000.
7	0.4167	0.1200	0.1200	14.2	0.0003	0.0042	0.0042	2395.	6000.	2405.	6000.
7	0.4167	0.1200	0.1200	156.6	0.0031	0.0050	0.0050	2346.	6000.	2454.	6000.
7	0.0000	0.1200	0.1200	1736.2	0.0347	0.0058	0.0060	1799.	6000.	3001.	6000.
8	0.0313	0.1200	0.1200	1736.2	0.0347	0.0058	0.0060	1799.	6000.	3001.	6000.
8	0.0313	0.1200	0.1200	2079.5	0.0416	0.0058	0.0060	1680.	6000.	3120.	6000.
8	0.0000	0.1200	0.1200	2490.6	0.0498	0.0059	0.0061	1537.	6000.	3263.	6000.
9	0.0313	0.1200	0.1200	2490.6	0.0498	0.0059	0.0061	1537.	6000.	3263.	6000.
9	0.0313	0.1200	0.1200	2983.1	0.0597	0.0059	0.0062	1367.	6000.	3433.	6000.
9	0.0000	0.1200	0.1200	3572.9	0.0715	0.0059	0.0063	1162.	6000.	3638.	6000.
10	0.0291	0.1200	0.1200	3572.9	0.0715	0.0059	0.0063	1162.	6000.	3638.	6000.
10	0.0291	0.1200	0.1200	4226.7	0.0845	0.0060	0.0064	936.	6000.	3864.	6000.
10	0.0043	0.1200	0.1200	5000.0	0.1000	0.0060	0.0065	668.	6000.	4132.	6000.
10	0.0000	0.1200	0.1200	5000.0	0.1025	0.0060	0.0065	625.	6000.	4175.	6000.
11	0.0625	0.1200	0.1200	5000.0	0.1025	0.0060	0.0065	625.	6000.	4175.	6000.
11	0.0000	0.1200	0.1200	5000.0	0.1460	0.0060	0.0067	0.	6000.	4800.	6000.
12	0.0000	0.0000	0.1200	5000.0	0.1460	0.0060	0.0067	0.	0.	4800.	6000.

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1                  02/08/01
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Example Problem Output File (cont.)

```
 DOUBLE LAP JOINT WITH VARYING BOND THICKNESS
0
                    *** STEPPED-LAP ADHESIVE-BONDED JOINT ***
0
                                 *** INPUT DATA ***
  NCASE =  0, ASF1 = 0., ASF2 = 0., ASF3 = 1.
0
  MNSTEP =  9, DBLRJT = 0., ANDLB = 0., FACTOR = 2., RVRSND = 0.
0
                                 *** INPUT DATA ***
  N      STEPL     THICK1  THICK2      STRONE    STRTWO        ETONE      ETTWO
        (INCH)     (INCH)  (INCH)     (LBS/IN)  (LBS/IN)       (PSI)      (PSI)

  1     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  2     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  3     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  4     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  5     0.8333     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  6     0.8333     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  7     0.8333     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  8     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
  9     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
 10     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
 11     0.0625     0.1200  0.1200       6000.      6000.      1200000.   1200000.
 12     1.0000     0.0000  0.1200          0.      6000.            0.   1200000.
0
  N   ETA      TAUMAX      G       GAMMAX  GAMMAE     ALPHA1      ALPHA2   PERCENT
     (INCH)    (PSI)     (PSI)    (IN/IN)  (IN/IN)   (/DEG.F)    (/DEG.F)  DISBOND

  1  0.0060     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  2  0.0057     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  3  0.0055     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  4  0.0053     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  5  0.0050     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  6  0.0050     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  7  0.0050     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  8  0.0053     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
  9  0.0055     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
 10  0.0057     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
 11  0.0060     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
 12  0.0060     5000.    50000.   0.5000  0.1000   0.0000E+00  0.0000E+00    0.0
0
```

Example Problem Output File (cont.)

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 *** DOUBLE BOND SURFACE ***
1                  02/08/01
 DOUBLE LAP JOINT WITH VARYING BOND THICKNESS

 THE ELASTIC JOINT STRENGTH (POUNDS/INCH)                          =     3877.4
 THE TEMPERATURE DIFFERENTIAL (OPERATING - CURE) (DEGREES F)       =        0.0
 THE ADHESIVE IS MOST SEVERELY LOADED IN STEP NUMBER                         1
 THE ADHEREND(S) 'ONE'MOST SEVERELY LOADED IS IN STEP NUMBER                 1
 THE ADHEREND(S) 'TWO' MOST SEVERELY LOADED IS IN STEP NUMBER               11
0
                              *** TENSILE LOADING ***
0
```

N	STEPL (INCH)	THICK1 (INCH)	THICK2 (INCH)	TAU (PSI)	GAMMA (IN/IN)	DELTA1 (INCH)	DELTA2 (INCH)	TLDONE (LBS/IN)	STRONE (LBS/IN)	TLDTWO (LBS/IN)	STRTWO (LBS/IN)
1	0.0313	0.1200	0.1200	5000.0	0.1000	0.0000	0.0006	3877.	6000.	0.	6000.
1	0.0313	0.1200	0.1200	4222.7	0.0845	0.0001	0.0006	3590.	6000.	288.	6000.
1	0.0000	0.1200	0.1200	3560.2	0.0712	0.0002	0.0006	3347.	6000.	530.	6000.
2	0.0313	0.1200	0.1200	3715.0	0.0743	0.0002	0.0006	3347.	6000.	530.	6000.
2	0.0313	0.1200	0.1200	3126.8	0.0625	0.0003	0.0006	3134.	6000.	744.	6000.
2	0.0000	0.1200	0.1200	2627.3	0.0525	0.0004	0.0007	2955.	6000.	923.	6000.
3	0.0313	0.1200	0.1200	2746.7	0.0549	0.0004	0.0007	2955.	6000.	923.	6000.
3	0.0313	0.1200	0.1200	2304.1	0.0461	0.0004	0.0007	2797.	6000.	1080.	6000.
3	0.0000	0.1200	0.1200	1929.9	0.0386	0.0005	0.0007	2665.	6000.	1212.	6000.
4	0.0313	0.1200	0.1200	2021.8	0.0404	0.0005	0.0007	2665.	6000.	1212.	6000.
4	0.0313	0.1200	0.1200	1691.0	0.0338	0.0006	0.0007	2549.	6000.	1328.	6000.
4	0.0000	0.1200	0.1200	1412.8	0.0283	0.0006	0.0008	2453.	6000.	1425.	6000.
5	0.4167	0.1200	0.1200	1483.5	0.0297	0.0006	0.0008	2453.	6000.	1425.	6000.
5	0.4167	0.1200	0.1200	133.8	0.0027	0.0014	0.0014	1985.	6000.	1892.	6000.
5	0.0000	0.1200	0.1200	12.2	0.0002	0.0020	0.0021	1943.	6000.	1935.	6000.
6	0.4167	0.1200	0.1200	12.2	0.0002	0.0020	0.0021	1943.	6000.	1935.	6000.
6	0.4167	0.1200	0.1200	2.2	0..200	0.0027	0.0027	1939.	6000.	1939.	6000.
6	0.0000	0.1200	0.1200	12.2	0.0002	0.0034	0.0034	1935.	6000.	1943.	6000.
7	0.4167	0.1200	0.1200	12.2	0.0002	0.0034	0.0034	1935.	6000.	1943.	6000.
7	0.4167	0.1200	0.1200	133.8	0.0027	0.0041	0.0041	1892.	6000.	1985.	6000.
7	0.0000	0.1200	0.1200	1483.5	0.0297	0.0047	0.0048	1425.	6000.	2453.	6000.
8	0.0313	0.1200	0.1200	1412.8	0.0283	0.0047	0.0048	1425.	6000.	2453.	6000.
8	0.0313	0.1200	0.1200	1691.0	0.0338	0.0047	0.0049	1328.	6000.	2549.	6000.
8	0.0000	0.1200	0.1200	2021.7	0.0404	0.0047	0.0050	1212.	6000.	2665.	6000.
9	0.0313	0.1200	0.1200	1929.8	0.0386	0.0047	0.0050	1212.	6000.	2665.	6000.
9	0.0313	0.1200	0.1200	2304.1	0.0461	0.0048	0.0050	1080.	6000.	2797.	6000.
9	0.0000	0.1200	0.1200	2746.7	0.0549	0.0048	0.0051	923.	6000.	2955.	6000.
10	0.0313	0.1200	0.1200	2627.3	0.0525	0.0048	0.0051	923.	6000.	2955.	6000.
10	0.0313	0.1200	0.1200	3126.8	0.0625	0.0048	0.0052	744.	6000.	3134.	6000.
10	0.0000	0.1200	0.1200	3715.0	0.0743	0.0048	0.0053	530.	6000.	3347.	6000.
11	0.0313	0.1200	0.1200	3560.2	0.0712	0.0048	0.0053	530.	6000.	3347.	6000.
11	0.0313	0.1200	0.1200	4222.7	0.0845	0.0048	0.0053	288.	6000.	3590.	6000.
11	0.0000	0.1200	0.1200	5000.0	0.1000	0.0048	0.0054	0.	6000.	3877.	6000.
12	0.0000	0.0000	0.1200	5000.0	0.1000	0.0048	0.0054	0.	0.	3877.	6000.

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1                  02/08/01
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Example Problem Output File (cont.)

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 DOUBLE LAP JOINT WITH VARYING BOND THICKNESS

 THE ELASTIC-PLASTIC JOINT STRENGTH (POUNDS/INCH)                    =     6000.0
 THE TEMPERATURE DIFFERENTIAL (OPERATING - CURE) (DEGREES F)         =        0.0
 THE ADHESIVE IS MOST SEVERELY LOADED IN STEP NUMBER                        11
 THE ADHEREND(S) 'ONE'MOST SEVERELY LOADED IS IN STEP NUMBER                 1
 THE ADHEREND(S) 'TWO' MOST SEVERELY LOADED IS IN STEP NUMBER               11
0
                              *** TENSILE LOADING ***
0
```

N	STEPL (INCH)	THICK1 (INCH)	THICK2 (INCH)	TAU (PSI)	GAMMA (IN/IN)	DELTA1 (INCH)	DELTA2 (INCH)	TLDONE (LBS/IN)	STRONE (LBS/IN)	TLDTWO (LBS/IN)	STRTWO (LBS/IN)
1	0.0625	0.1200	0.1200	5000.0	0.1696	0.0000	0.0010	6000.	6000.	0.	6000.
1	0.0000	0.1200	0.1200	5000.0	0.1230	0.0003	0.0010	5375.	6000.	625.	6000.
2	0.0455	0.1200	0.1200	5000.0	0.1283	0.0003	0.0010	5375.	6000.	625.	6000.
2	0.0085	0.1200	0.1200	5000.0	0.1000	0.0005	0.0011	4920.	6000.	1080.	6000.
2	0.0085	0.1200	0.1200	4768.2	0.0954	0.0005	0.0011	4837.	6000.	1163.	6000.
2	0.0000	0.1200	0.1200	4546.5	0.0909	0.0006	0.0011	4758.	6000.	1242.	6000.
3	0.0313	0.1200	0.1200	4753.2	0.0951	0.0006	0.0011	4758.	6000.	1242.	6000.
3	0.0313	0.1200	0.1200	3987.3	0.0797	0.0007	0.0011	4485.	6000.	1515.	6000.
3	0.0000	0.1200	0.1200	3339.6	0.0668	0.0008	0.0012	4257.	6000.	1743.	6000.
4	0.0313	0.1200	0.1200	3498.6	0.0700	0.0008	0.0012	4257.	6000.	1743.	6000.
4	0.0313	0.1200	0.1200	2926.3	0.0585	0.0009	0.0012	4057.	6000.	1943.	6000.
4	0.0000	0.1200	0.1200	2444.9	0.0489	0.0010	0.0013	3889.	6000.	2111.	6000.
5	0.4167	0.1200	0.1200	2567.2	0.0513	0.0010	0.0013	3889.	6000.	2111.	6000.
5	0.4167	0.1200	0.1200	231.6	0.0046	0.0022	0.0022	3080.	6000.	2920.	6000.
5	0.0000	0.1200	0.1200	21.1	0.0004	0.0032	0.0032	3007.	6000.	2993.	6000.
6	0.4167	0.1200	0.1200	21.1	0.0004	0.0032	0.0032	3007.	6000.	2993.	6000.
6	0.4167	0.1200	0.1200	3.8	0.0001	0.0043	0.0043	3000.	6000.	3000.	6000.
6	0.0000	0.1200	0.1200	21.1	0.0004	0.0053	0.0053	2993.	6000.	3007.	6000.
7	0.4167	0.1200	0.1200	21.1	0.0004	0.0053	0.0053	2993.	6000.	3007.	6000.
7	0.4167	0.1200	0.1200	231.6	0.0046	0.0063	0.0064	2920.	6000.	3080.	6000.
7	0.0000	0.1200	0.1200	2567.2	0.0513	0.0073	0.0075	2111.	6000.	3889.	6000.
8	0.0313	0.1200	0.1200	2444.9	0.0489	0.0073	0.0075	2111.	6000.	3889.	6000.
8	0.0313	0.1200	0.1200	2926.3	0.0585	0.0073	0.0076	1943.	6000.	4057.	6000.
8	0.0000	0.1200	0.1200	3498.7	0.0700	0.0074	0.0077	1743.	6000.	4257.	6000.
9	0.0313	0.1200	0.1200	3339.6	0.0668	0.0074	0.0077	1743.	6000.	4257.	6000.
9	0.0313	0.1200	0.1200	3987.3	0.0797	0.0074	0.0078	1515.	6000.	4485.	6000.
9	0.0000	0.1200	0.1200	4753.2	0.0951	0.0074	0.0080	1242.	6000.	4758.	6000.
10	0.0085	0.1200	0.1200	4546.5	0.0909	0.0074	0.0080	1242.	6000.	4758.	6000.
10	0.0085	0.1200	0.1200	4768.3	0.0954	0.0074	0.0080	1163.	6000.	4837.	6000.
10	0.0455	0.1200	0.1200	5000.0	0.1000	0.0075	0.0080	1080.	6000.	4920.	6000.
10	0.0000	0.1200	0.1200	5000.0	0.1283	0.0075	0.0082	625.	6000.	5375.	6000.
11	0.0625	0.1200	0.1200	5000.0	0.1230	0.0075	0.0082	625.	6000.	5375.	6000.
11	0.0000	0.1200	0.1200	5000.0	0.1696	0.0075	0.0085	0.	6000.	6000.	6000.
12	0.0000	0.0000	0.1200	5000.0	0.1696	0.0075	0.0085	0.	0.	6000.	6000.

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1                  02/08/01
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Example Problem Output File (cont.)

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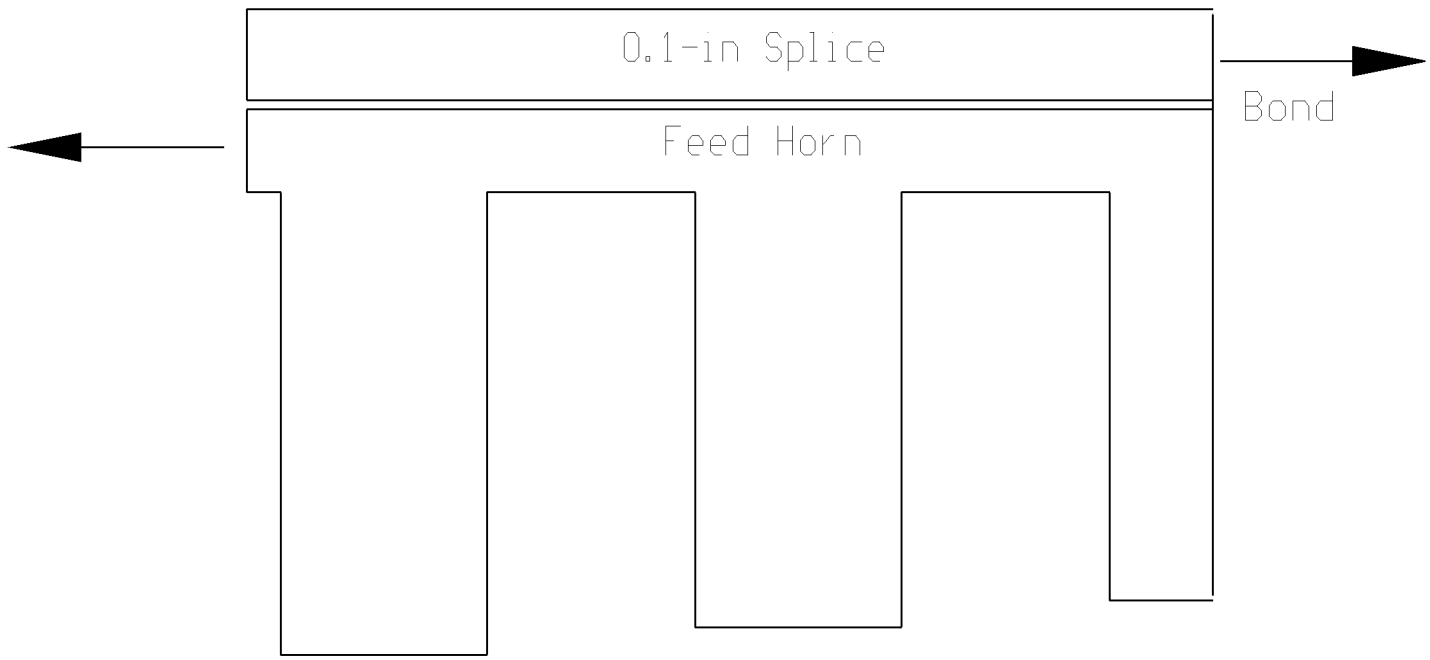
 DOUBLE LAP JOINT WITH VARYING BOND THICKNESS

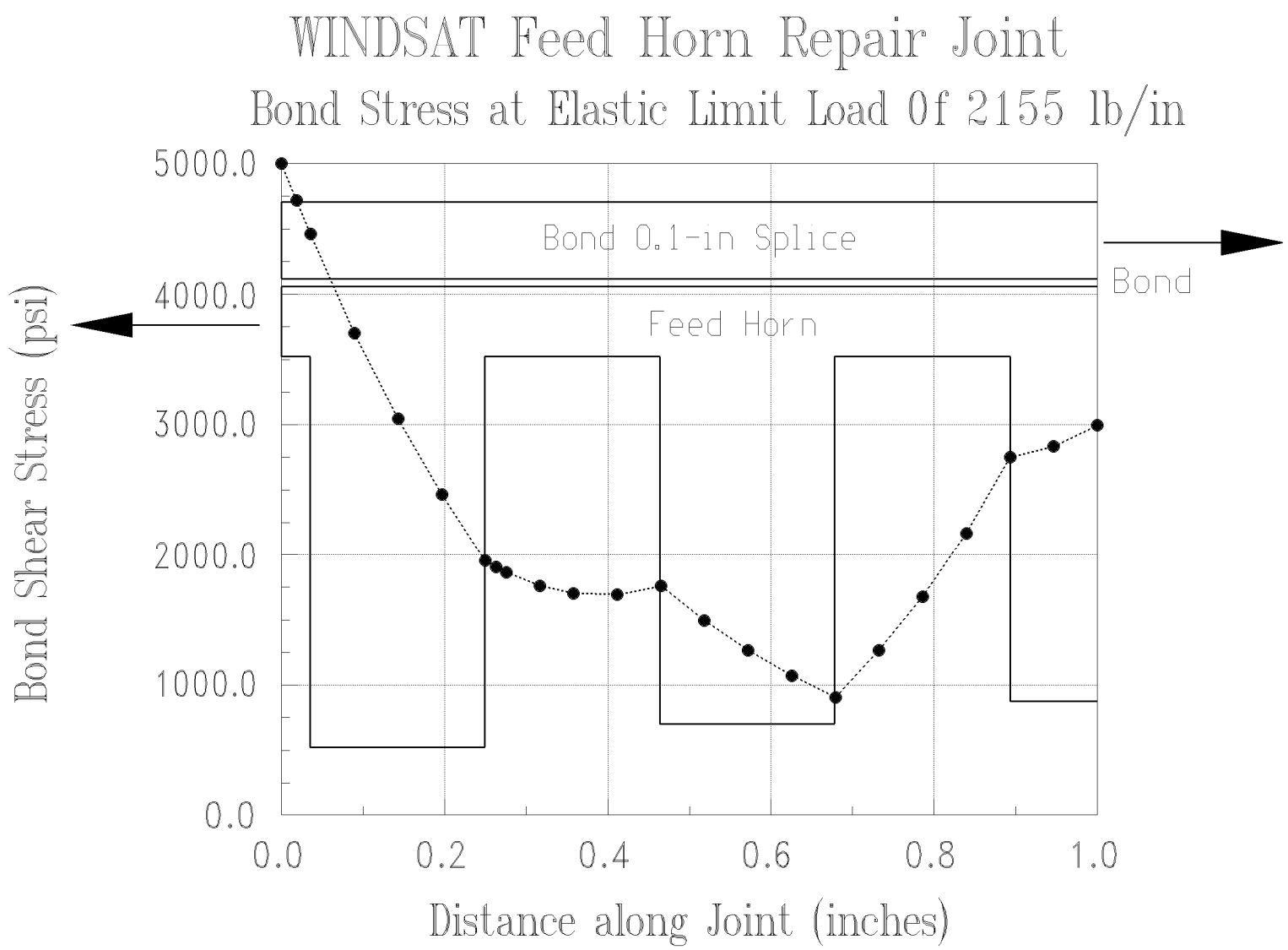
 THE POTENTIAL BOND STRENGTH FOR THE ADHERENDS WITH REAL
      STIFFNESSES BUT UNLIMITED STRENGTHS (POUNDS/INCH)              =    11489.1
 THE TEMPERATURE DIFFERENTIAL (OPERATING - CURE) (DEGREES F)         =        0.0
 THE ADHESIVE IS MOST SEVERELY LOADED IN STEP NUMBER                           11
0
                              *** TENSILE LOADING ***
0
```

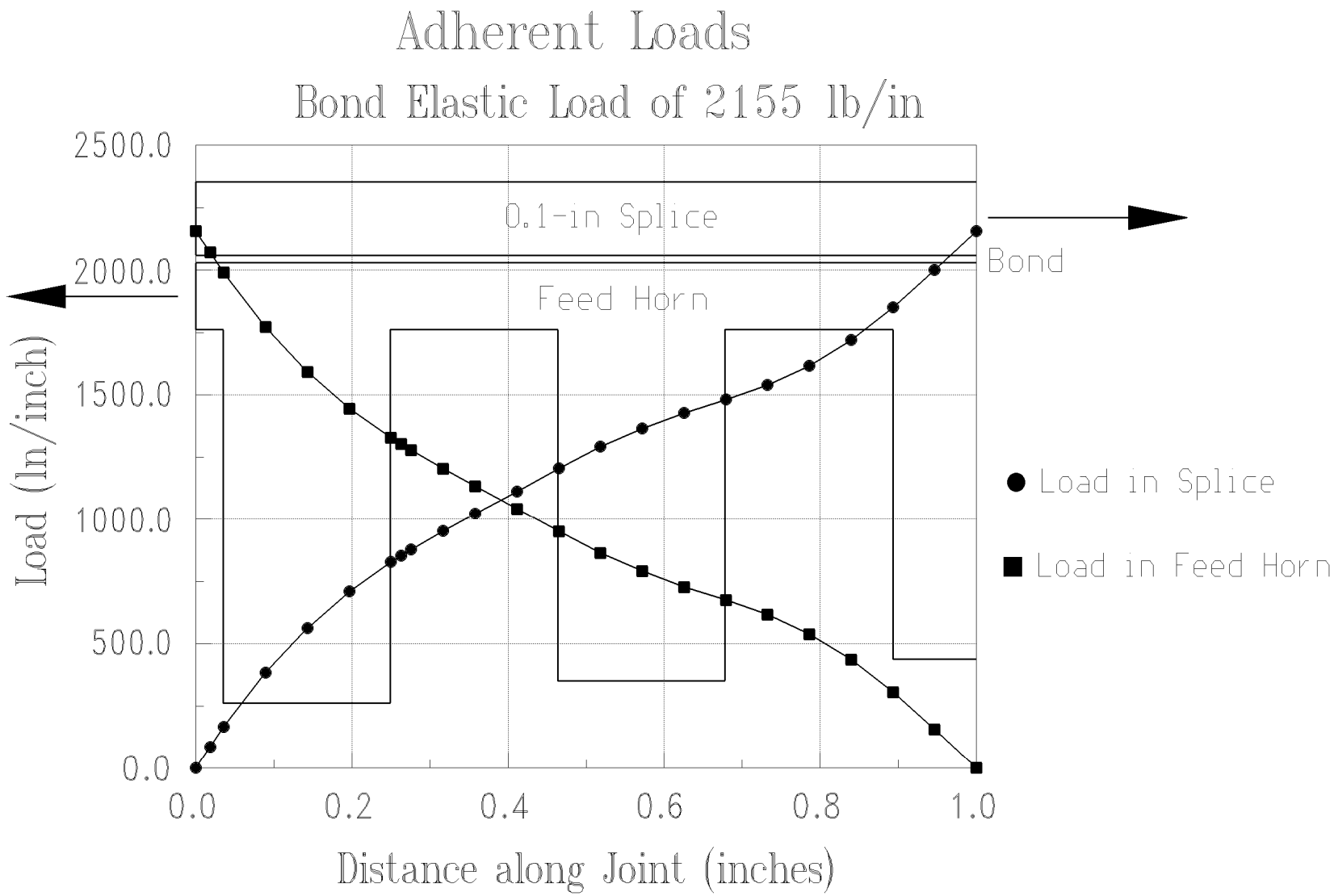
N	STEPL (INCH)	THICK1 (INCH)	THICK2 (INCH)	TAU (PSI)	GAMMA (IN/IN)	DELTA1 (INCH)	DELTA2 (INCH)	TLDONE (LBS/IN)	STRONE (LBS/IN)	TLDTWO (LBS/IN)	STRTWO (LBS/IN)
1	0.0625	0.1200	0.1200	5000.0	0.5000	0.0000	0.0030	11489.	6000.	0.	6000.
1	0.0000	0.1200	0.1200	5000.0	0.4057	0.0006	0.0030	10864.	6000.	625.	6000.
2	0.0625	0.1200	0.1200	5000.0	0.4233	0.0006	0.0030	10864.	6000.	625.	6000.
2	0.0000	0.1200	0.1200	5000.0	0.3362	0.0011	0.0031	10239.	6000.	1250.	6000.
3	0.0625	0.1200	0.1200	5000.0	0.3515	0.0011	0.0031	10239.	6000.	1250.	6000.
3	0.0000	0.1200	0.1200	5000.0	0.2723	0.0016	0.0031	9614.	6000.	1875.	6000.
4	0.0625	0.1200	0.1200	5000.0	0.2853	0.0016	0.0031	9614.	6000.	1875.	6000.
4	0.0000	0.1200	0.1200	5000.0	0.2147	0.0021	0.0033	8989.	6000.	2500.	6000.
5	0.1513	0.1200	0.1200	5000.0	0.2255	0.0021	0.0033	8989.	6000.	2500.	6000.
5	0.3410	0.1200	0.1200	5000.0	0.1000	0.0032	0.0037	7477.	6000.	4013.	6000.
5	0.3410	0.1200	0.1200	698.1	0.0140	0.0050	0.0051	5986.	6000.	5503.	6000.
5	0.0000	0.1200	0.1200	98.2	0.0020	0.0067	0.0067	5778.	6000.	5711.	6000.
6	0.4167	0.1200	0.1200	98.2	0.0020	0.0067	0.0067	5778.	6000.	5711.	6000.
6	0.4167	0.1200	0.1200	17.6	0.0004	0.0087	0.0087	5745.	6000.	5745.	6000.
6	0.0000	0.1200	0.1200	98.2	0.0020	0.0107	0.0107	5711.	6000.	5778.	6000.
7	0.3410	0.1200	0.1200	98.2	0.0020	0.0107	0.0107	5711.	6000.	5778.	6000.
7	0.3410	0.1200	0.1200	698.1	0.0140	0.0123	0.0123	5503.	6000.	5986.	6000.
7	0.1513	0.1200	0.1200	5000.0	0.1000	0.0137	0.0142	4013.	6000.	7477.	6000.
7	0.0000	0.1200	0.1200	5000.0	0.2255	0.0141	0.0152	2500.	6000.	8989.	6000.
8	0.0625	0.1200	0.1200	5000.0	0.2147	0.0141	0.0152	2500.	6000.	8989.	6000.
8	0.0000	0.1200	0.1200	5000.0	0.2853	0.0142	0.0157	1875.	6000.	9614.	6000.
9	0.0625	0.1200	0.1200	5000.0	0.2723	0.0142	0.0157	1875.	6000.	9614.	6000.
9	0.0000	0.1200	0.1200	5000.0	0.3515	0.0143	0.0162	1250.	6000.	10239.	6000.
10	0.0625	0.1200	0.1200	5000.0	0.3362	0.0143	0.0162	1250.	6000.	10239.	6000.
10	0.0000	0.1200	0.1200	5000.0	0.4233	0.0143	0.0168	625.	6000.	10864.	6000.
11	0.0625	0.1200	0.1200	5000.0	0.4057	0.0143	0.0168	625.	6000.	10864.	6000.
11	0.0000	0.1200	0.1200	5000.0	0.5000	0.0144	0.0174	0.	6000.	11489.	6000.
12	0.0000	0.0000	0.1200	5000.0	0.5000	0.0144	0.0174	0.	0.	11489.	6000.

0

Splice Joint Repair Idealization




WINDSAT Feed Horn Repair Joint
Bond Stress at Elastic Limit Load Of 2155 lb/in
Bond 0.1-in Splice
Feed Horn
Bond
Bond Shear Stress (psi)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Distance along Joint (inches)


Adherent Loads
Bond Elastic Load of 2155 lb/in
2500.0
2000.0
1500.0
1000.0
500.0
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Load (lb/inch)
Distance along Joint (inches)
0.1-in Splice
Feed Horn
Bond
Load in Splice
Load in Feed Horn

Conclusions for Repair Case

- A4EI Conservatively Calculated Bond Shear Stress and Splice Load
- Corrugations Result in Adhesive Shear Stress Peaking @ Left End
- Feed Horn will Fail Before Bond Due to Notch Stress Concentration
- First Design had Tapered Splice
  - Corrugations Delayed Off Loading in Splice At Taper
    - Result: Premature Failure of Splice
  - Taper Modified to Uniform Splice
    - Result: Sufficient Strength in Splice
- Repair was Successfully Proof Tested