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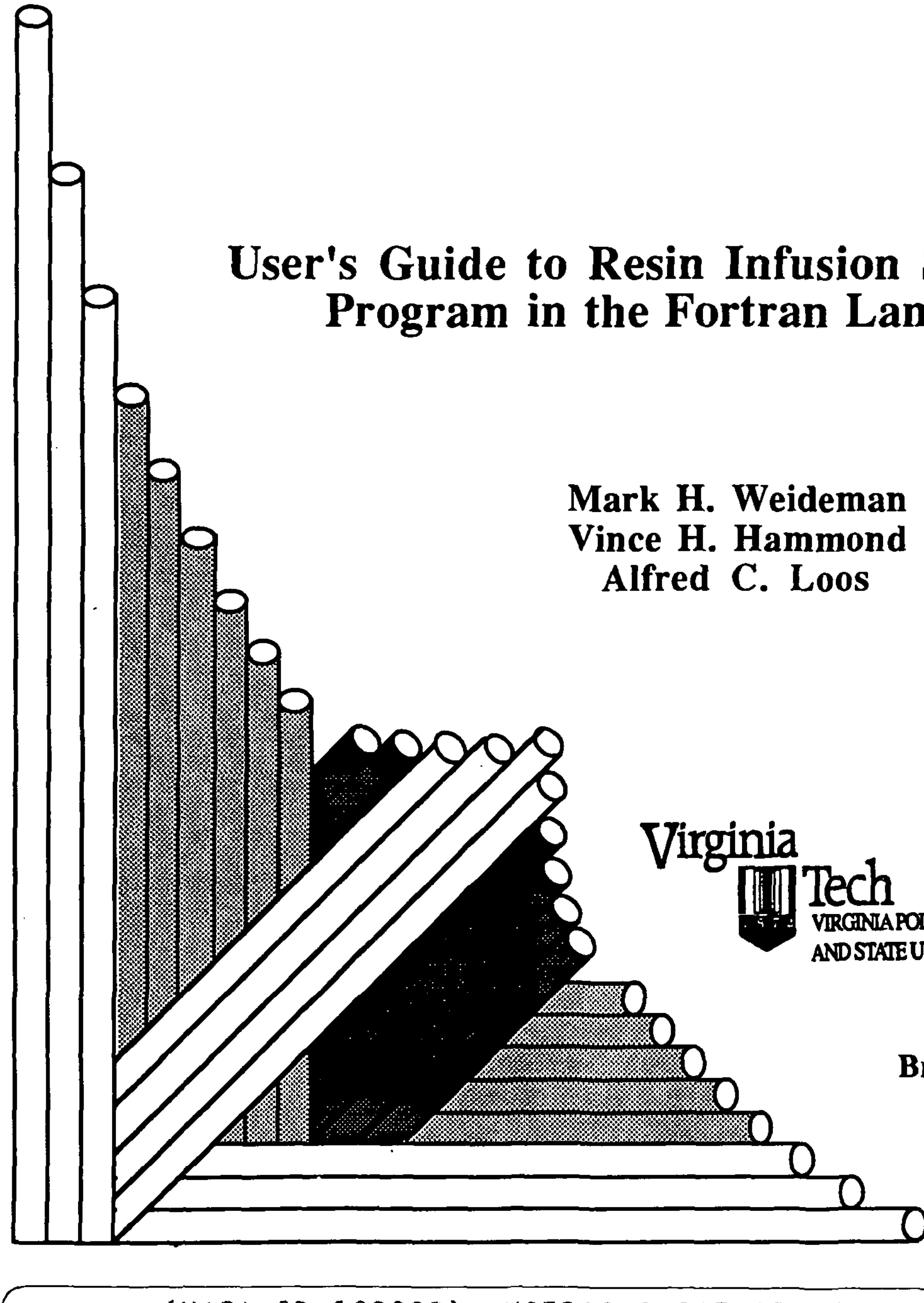
CENTER FOR COMPOSITE MATERIALS AND STRUCTURES



User's Guide to Resin Infusion Simulation Program in the Fortran Language

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User's Guide to Resin Infusion Simulation Program in the Fortran Language

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1.0 Introduction

The resin infusion technique is a simple and cost effective process for the manufacture of advanced textile composite panels. A typical layup incorporates the placement of a dry textile preform onto a predegassed (B-staged) epoxy resin film. The layup is inserted into a metal mold, enclosed in a vacuum bag, and placed into a hot press. Heat is applied to reduce the viscosity of the resin and pressure is applied to force the resin to permeate and saturate the fabric preform. Additional thermal energy is applied to fully cure the composite panel after full saturation.

Knowledge of the heat transfer within the layup and the rate of infiltration is required to insure that panels can be efficiently and successfully fabricated using this technique. The fabricator should be able to generate the proper temperature and pressure cycles for a particular fabric preform/resin film composite panel.

In order for the resin film infusion process to be fully understood, a nonisothermal infiltration/cure model was created to simulate the through-the-thickness infiltration of a porous fabric preform with an epoxy resin. The model utilizes an one-dimensional transient heat transfer finite element model to determine the through- the-thickness temperature distribution within the layup as a function of time during infiltration and cure. A one-dimensional porous flow finite element model is utilized to determine the pressure distribution within the saturated fabric preform during infiltration. D'arcy's law was utilized to predict the movement of the infiltration flow front as a function of time during infiltration. A full description of the theory behind the simulation model is presented in [1].

The model presently incorporates the compaction and permeability characteristics of 11 different fabric preforms and the kinetics and rheology characteristics of two different epoxy resin systems. To execute the program, the user must supply the following information:

1) Simulation title
2) Fabric preform type/compaction model

3) Resin type

4) Resin prestage history

5) Panel planar dimensions

6) Number of fabric preform layers

7) Layup materials/material layer heights/layup profile

8) Temperature boundary conditions/profile

9) Pressure boundary conditions/profile

10) Temperature survey profile

11) Time step for calculations/data

12) Density of finite element mesh in composite materials

The Program outputs the following information:

1) Input data/parameters

2) Fabric preform thickness/fiber volume fraction and resin film thickness as a function of compaction pressure

3) Flow front position as a function of time

4) Total infiltration time

5) Temperature and resin degree of cure/viscosity as a function of time at resin flow front

6) Temperature and resin degree of cure/viscosity as a function of time at the bottom of the saturated fabric preform

7) Temperature and resin degree of cure/viscosity (if relevant) as a function of time at selected locations within the layup

Included in the user's guide is a detailed step-by-step description of the program operator commands and a listing of the input and output data file contents. Sample input and output data files are also presented. Finally, a complete listing of the program is provided.

1.1 Steps for Running the Resin Infusion Simulation Program

A) Preliminary steps

1) In order to run the program, you need an IBMpc or an IBM compatible computer.

2) Insert disk into the proper disk drive. Make sure that the computer is in MS/DOS and that the CAPS LOCK is on.

3) If you would like to see a list of previous input data files, type "DIR *.DAT" at the command prompt. This should list on the screen all of the previous input data files.

4) Type RTMCL at the command prompt in order to start the program. To halt the program at any time, press and hold the CONTROL key and then press the PAUSE key. Release both keys simultaneously. This should stop the program and return you to the command prompt.

5) When inputting data, make sure that there are no spaces between value entries.

B) Data Input and Modification

1) At the command prompt, type in the name of an input data file. The default data file is "DATA.DAT".

   Example: DATA.DAT.

2) After the file is created/opened, the main menu will appear. To modify or list input data, enter the number beside the item which is to be listed or modified. Enter '0' to accept the file as shown.

   Example: Enter '2' to change the fabric preform type.

3) The following input data can be directly modified by the user.

   Code #.: 1

   Item: Title of Simulation.

   Notes: The title of the simulation model can be customized to describe the simulation. The description can contain both letters and numbers but is limited to a total of 70 characters.

Example: RTM SIMULATION NUMBER 1

Code #.: 2

Item: Fabric Preform Compaction Model:

Notes: A list of available fabric preform compaction models will appear on the screen. Enter the number beside the fabric compaction model that you wish to use in the simulation. The dry compaction models should be used if only one compaction pressure is to be applied during the simulation. The wet compaction models should be used if multiple compaction pressures are applied during the simulation.

Example: Enter '1' to change to the TTI IM7/8HS DRY COMPACTION model.

Code #.: 3

Item: Resin Model

Notes: A list of available resin types will appear on the screen. Enter the number corresponding to the resin that you wish to use. The Hercules 3501-6 is a hot melt high viscosity resin system and the Shell 1282/878 resin is a low viscosity resin system.

Example: Enter '2' to change to the Shell 1282/878 resin.

Additional Notes: When choosing the Shell 1282/878 resin system, care should be taken to ensure that a temperature exceeding 120 °C is not used for the degassing simulation.

Code #.: 4

Item: Initial Resin Degree of Cure

Notes: Enter a '4' to change the initial resin. After entering a '4', a prompt will appear asking for the new number of time/ temperature steps for the resin prestaging history profile. (Enter a '0' to keep the same resin prestaging history profile.) Resin prestaging may result from extensive room temperature storage or from the removal of entrapped gases from the resin during degassing at elevated temperatures. After entering the new number of time/temp steps (minimum of 2), a prompt will appear asking you to input the new values of time and temperature. The time and temperature and the beginning and end of a temperature hold or a linear temperature heating/cooling ramp should be entered. The time should be in minutes and the temperature should be in degrees Celsius. The values should be separated by a comma and each value should contain a decimal point.

Example: 0.0,27.0

Additional Notes: After all the values are inputted, the program determines the initial degree of cure and the corresponding viscosity for the resin. The data is automatically displayed in the menu under the title of "Degree of cure".

Code #.: 5

Item: Composite Panel Planar Dimensions

Notes: The data input should be in meters and contain a decimal point. First the length and then the width of the panel are entered. The values are entered consecutively and are separated by a comma.

Example: 2.5,3.0

Code #.: 6

Item: Number of Individual Fabric Preform Layers

Notes: For the TTI IM7/8HS, a layer is defined as an individual planar ply of interwoven 0/90 fiber tows. The typical entry for a 6.35 mm panel processed at 695 kPa is 16 layers. Each layer of the Hexcel 12k knitted and knitted/stitched preforms contains 16 individual plies of 12k uniweave, and the preform thickness ranges from 6 to 8mm. The thickness of the 3-D preforms ranges between 6 to

8 mm, and the thickness of the 2-D braided and braided/stitched preforms range between 5 and 7mm. The Hexcel 3k, 6k, and 12k Kevlar knit preforms have thickness of 1.25 mm, 1.0 mm, and 0.75 mm, respectively at 695 kPa. The input should range from 1 to 100 and should also be an integer.

Example: 16

Code #.: 7

Item: Layup Assembly for RTM simulation

Notes: To alter the simulation layup profile and materials (including fabric preform and resin panel), input the number of desired material layers. (By entering a '0', the profile shown on the screen will be accepted for use.) The simulation model is used to solve for the temperature distribution through-the-thickness of the layup as a function of time. The height and material for each layer is entered. The height should be separated from the material type by a comma.

Example (4 Layer Layup):

5.0,STEEL
0.0,RESIN PANEL
0.0,FIBER PREFORM
5.0,STEEL

Additional Notes: The fiber preform should always be layered next to the resin panel. The height of both the fiber preform and the resin panel are determined by the model and not be entered. After entering the last layer, the program automatically returns to the main menu. To view the new layup, enter a '7' and then a '0' to return to the menu.

Code #.: 8

Item: Time Versus Temperature Profile:

Notes: After entering an '8', a screen will appear asking for the new number of temperature/time steps. (Enter a '0' to keep the temperature/time profile shown on the screen.) A temperature/time step is defined as the temperature/time point at either the beginning or end of a temperature hold or linear temperature ramp. (The model assumes a linear temperature ramp rate or hold between each time step. After entering the new number of temp/time steps, a prompt will appear asking you to input the time and temperatures at the upper and lower surfaces of the layup. Identical or separate temperatures may be applied at the upper and lower surfaces of the layup at each time step. The time should be in minutes and the temperature should be in degrees Celsius. The values should include a decimal point and should be separated by a comma.

Example: 4.5,100.0,100.0

Code #.: 9

Item: Time Versus Pressure Profile:

Notes: A prompt will appear asking for the number of time/pressure points for the applied compaction pressure/profile. (By entering a '0', the currently displayed profile will be retained.) A point is defined as the time at which a particular compaction pressure is initially applied to the layup. The pressure will remain constant until altered by another time/pressure point. After entering the new number of points, a prompt will appear asking for the time and total compaction pressure at each time/pressure point. The total compaction pressure is equal to the sum of the applied mechanical pressure and vacuum bag pressure (if a vacuum bag is utilized to enclose the layup). If a vacuum chamber is used, enter only the applied mechanical pressure from the platens. The model assumes a step function between each time/pressure value. The time should be in minutes with pressure values in Pascals absolute.

Example: 1.0,1500.0

Additional Notes: The compaction pressure should remain constant during the infiltration phase, since the model is currently configured to simulate infiltration and not consolidation.

Code #.: 10

Item: Temperature Survey

Notes: A prompt will appear asking if a temperature survey is desired if no temperature survey was previously chosen. If a temperature survey was entered from the input data file the location and material of each survey point will be displayed. If a survey is desired enter 'Y' and hit return. (If no survey is desired the program will return to the main screen prompt.) A prompt will appear asking if the old survey is acceptable. If changes are desired, enter 'N'. Prompts will then appear asking for the number of survey points in each material layer and the percent depth location from the top of each layer. When all of the required data has been entered, the program will return to the main screen prompt.

Example (number of points in fabric preform layer): 1

Example (% depth location from top of fabric preform layer for pt. #.1): .5

Additional Notes: During the simulation, the program will record the temperature and resin degree of cure/viscosity (if applicable) as a function of time for each survey point in a individual data file.

Code #.: 11

Item: Program Time Step

Notes: A prompt will appear presenting the upper and lower limits for the program time step (sec). The upper time step limit is set at 180 sec. The lower limit is a function of the total length of the cure cycle entered into the program and the maximum number of input data points (currently set at 400). For an accurate simulation, the time step should be near the lower time limit. For a rapid simulation, a large time step should be utilized.

Example: 45.

Code #.: 12

Item: Mesh density for Composite Materials

Notes: A prompt will appear presenting the upper and lower limits for the number of one-dimensional, quadratic finite elements per meter of composite materials (fabric preform, saturated fabric preform, resin panel). The lower limit represents the minimum density required for an accurate solution. The upper limit is a function of the program memory capacity, and the total height of the layup (including the number of fabric preform layers). Enter a low number if a rapid simulation is desired, or the upper limit if an accurate simulation is desired.

Example: 7500

4) After modifying or creating the new file, you will be asked if you would like to save these changes in a new data file. Type a capital 'Y' to save the changes. The new filename should contain the delimiter '.DAT'.
Example: FILENAME.DAT

5) If a temperature survey was desired, a prompt will appear asking for a four character prefix to represent the first half of the temperature survey data file names. The program will create a file from the four character name which will contain a listing of the temperature survey locations and material layers.
Example: DATA

6) You will be asked to input a name for the newly created results file. The name should describe the simulation so that the file can be easily identified in the future.

C) Calculation of Results

1) The program will present the total time (min) and normalized infiltration front position during each time step. The layup sequence at the start and end of

the infiltration phase will also be presented.

2) Once the preform has been fully saturated, only the total time (min) at each time step will be presented on the screen.

D) Data Output

1) In order to view the data stored in the results file, the following guidelines should be followed: At the command prompt, type the output filename
Example: TYPE DATA.OUT

2) To stop the screen from scrolling, press the PAUSE button located on the upper right-hand side of the keyboard.

3) To start the screen scrolling again, press the CONTROL button first and then, while holding the CONTROL button down, press the PAUSE button.

4) The above process can be repeated as often as desired in viewing the results. NOTE: If, in an attempt to stop the screen, the CONTROL and PAUSE buttons are hit, then the file will be stopped and the command prompt will appear in the lower left hand side of the screen. To view the file again, return to step 1 of the above instructions.

5) In order to print out a hard copy of the results generated by the simulation, the following command should be used to generate a printout which can be retained for further study. An explanation of the printout is given in the following section.
Example: PRINT DATA.OUT

1.3 Explanation of Results

The top half of the page (through the applied pressure cycle), is a printout of the data inputted by the user during the creation of the data file used in the simulation. Starting with the Resin Panel Characteristics, the remainder of the data is generated by the simulation. The following list explains the contents of the output data files.

Item: Input Data

Description: The data obtained from the input data file is presented at the beginning of the output data file. For a full description refer to section 1.2 and/or 2.0.

Item: Resin volume

Description: Expressed in cubic meters, this is the initial volume of the resin panel at the corresponding pressure value.

Item: Resin Panel/Fabric Panel Thickness

Description: Expressed in meters, this is the thickness of the resin panel and/or fabric preform at that pressure.

Item: Resin Mass

Description: This is the mass of the resin panel, expressed in grams, at the given pressure.

Item: Fiber Volume Fraction

Description: This is the volume fraction of fibers in the preform at the corresponding applied compaction pressure.

Item: Porosity

Description: This is equal to the resin volume fraction. It is equal to 1 minus the fiber volume fraction.

The output table entitled "INFILTRATION FRONT SIMULATION DATA" details the resin behavior and various parameters during resin infiltration of the preform. The temperature, resin viscosity, and resin degree of cure at the infiltration front are listed in the table. The normalized position represents the fraction of fiber preform that the resin has penetrated. A value of 0 indicates that none of the fiber preform has been penetrated while a 1 indicates that the resin has completely infiltrated through the fiber preform.

In the output table entitled "RESIN CURE DATA FOR ENTIRE SIMULATION," the temperature, viscosity, and degree of cure are monitored at a position near the bottom of the saturated fabric preform.

1.3 Sample Data Output

```
MAIN DATA OUTPUT FILE: DATA.OUT
INPUT DATA FILE: DATA.DAT
***********************************************************************
RTM SIMULATION TITLE:    RTM SIMULATION FILE # 1.
***********************************************************************

FABRIC PREFORM:      TTI IM7/8HS D/W COMPACTION
        #. OF PLIES  16

RESIN PANEL:     HERCULES 3501 INT. DEG. of CURE .02077

RESIN PRESTAGE HISTORY
 #.      TIME(min)      TEMP(C)   DEGREE of CURE    VISCOSITY(Pa.s)
 1          .00         27.00       .00000003     122144.70
 2        10.00        100.00       .00302429          1.22
 3        20.00        100.00       .02077149          1.76
SPECIMEN LENGTH (m)   .15240 SPECIMEN HEIGHT (m)   .15240

LAYUP PROFILE:
LAYER #. MATERIAL        HEIGHT (meters)
  1  STEEL                .020
  2  FIBER PREFORM    (height det. by RTM model)
  3  RESIN PANEL      (height det. by RTM model)
  4  STEEL                .010
  5  ALUMINUM               .002

APPLIED TEMPERATURE CYCLE:
              TIME (min)   UPPER/LOWER TEMP(C)
                .0000          27.2220
              50.0000         177.0000
             150.0000         177.0000
```

152.0000 177.0000

APPLIED PRESSURE CYCLE:

TIME(min)	PLATEN PRESSURE (Pa)	VAC.+CAPILLARY PRESSURE (Pa)
.00	300000.00	-17046.18
152.00	300000.00	-17046.18

RESIN PANEL DATA:

COMP. PRES. (Pa)	RESIN VOL. (m^3)	RESIN PANEL THICKNESS (m)	RESIN MASS
300000.0000	.000055	.002379	69.6093
300000.0000	.000055	.002379	69.6093

FABRIC PREFORM DATA:

COMP. PRES. (Pa)	FABRIC PANEL THICKNESS (m)	POROSITY	FIBER VOL F
300000.0000	.006240	.381178	.618822
300000.0000	.006240	.381178	.618822

INFILTRATION FRONT SIMULATION DATA:

#.	TIME	TEMP	VISC	DEG. of CURE	POS.
1	1.50	30.29	170703.30	.020775	.000000
2	3.00	33.78	48988.86	.020780	.000795
3	4.50	37.27	16300.71	.020787	.003038
4	6.00	40.93	5842.69	.020797	.003691
5	7.50	44.55	2359.75	.020813	.005034
6	9.00	48.39	1000.93	.020835	.008115
7	10.50	51.98	485.35	.020868	.013255
8	12.00	55.70	246.24	.020914	.021995
9	13.50	59.26	136.25	.020979	.033363
10	15.00	62.88	78.58	.021070	.050899
11	16.50	66.55	47.12	.021198	.072929
12	18.00	70.30	29.18	.021377	.101510
13	19.50	74.01	18.87	.021626	.137061
14	21.00	77.70	12.65	.021970	.180280
15	22.50	81.44	8.71	.022446	.230654
16	24.00	85.40	6.05	.023114	.290208
17	25.50	89.52	4.29	.024064	.359662
18	27.00	93.45	3.18	.025393	.438389
19	28.50	97.61	2.39	.027288	.538630
20	30.00	101.68	1.87	.029972	.632993
21	31.50	105.94	1.50	.033832	.752905
22	33.00	110.24	1.24	.039358	.887020

FINAL TIME, min = 35.16 FINAL POS. =1.00000000

RESIN CURE DATA FOR ENTIRE SIMULATION

#.	TIME (min)	TEMP (Deg C)	VISC (Pa.s)	DEG. of CURE
1	1.50	30.30	.00	.000000
2	3.00	33.81	.00	.000000
3	4.50	37.30	.00	.000000
4	6.00	40.98	.00	.000000
5	7.50	44.62	.00	.000000
6	9.00	48.47	.00	.000000
7	10.50	52.07	.00	.000000
8	12.00	55.70	246.24	.020914
9	13.50	59.26	136.25	.020979
10	15.00	62.78	79.81	.021069
11	16.50	66.37	48.29	.021195
12	18.00	70.01	30.25	.021370
13	19.50	73.56	19.86	.021609
14	21.00	77.12	13.46	.021936
15	22.50	80.73	9.33	.022383
16	24.00	84.44	6.60	.022998
17	25.50	88.41	4.70	.023869
18	27.00	92.19	3.50	.025072
19	28.50	96.35	2.60	.026771
20	30.00	100.96	1.94	.029297
21	31.50	106.45	1.43	.033376
22	33.00	113.81	1.03	.041197
23	34.50	126.10	.73	.064082
24	36.00	130.92	.75	.084732
25	37.50	135.72	.76	.104618
26	39.00	140.32	.77	.123796
27	40.50	144.86	.79	.142193
28	42.00	149.38	.80	.159715
29	43.50	153.88	.82	.176673
30	45.00	158.37	.86	.193994
31	46.50	162.86	.94	.213100
32	48.00	167.36	1.10	.235574
33	49.50	171.86	1.45	.262887
34	51.00	174.22	2.25	.292461
35	52.50	175.09	3.97	.322035
36	54.00	175.64	7.53	.351114

37	55.50	176.05	15.24	.379475
38	57.00	176.36	32.75	.406969
39	58.50	176.59	74.13	.433502
40	60.00	176.77	175.47	.459018
41	61.50	176.90	430.86	.483490
42	63.00	177.00	806.06	.506915
43	64.50	177.08	1024.41	.529303
44	66.00	177.13	1295.32	.550678
45	67.50	177.17	1626.10	.571067
46	69.00	177.20	2023.65	.590506
47	70.50	177.22	2494.51	.609032
48	72.00	177.24	3045.15	.626683
49	73.50	177.25	3682.19	.643497
50	75.00	177.25	4413.44	.659513
51	76.50	177.26	5248.88	.674769
52	78.00	177.26	6201.71	.689302
53	79.50	177.26	7289.73	.703145
54	81.00	177.26	8536.51	.716334
55	82.50	177.25	9973.60	.728900
56	84.00	177.25	11642.20	.740874
57	85.50	177.25	13596.33	.752285
58	87.00	177.25	15905.72	.763162
59	88.50	177.24	18660.48	.773531
60	90.00	177.24	21977.85	.783417
61	91.50	177.24	26010.56	.792843
62	93.00	177.23	30958.01	.801833
63	94.50	177.23	37085.04	.810407
64	96.00	177.23	44738.61	.818587
65	97.50	177.23	54384.71	.826391
66	99.00	177.22	66652.62	.833838
67	100.50	177.22	82390.31	.840945
68	102.00	177.22	102759.40	.847728
69	103.50	177.21	129357.80	.854204
70	105.00	177.21	164400.00	.860386
71	106.50	177.21	211003.00	.866290
72	108.00	177.21	273533.80	.871928
73	109.50	177.21	358220.70	.877313
74	111.00	177.20	473991.00	.882458
75	112.50	177.20	633761.00	.887372
76	114.00	177.20	856361.90	.892068
77	115.50	177.20	1169550.00	.896556
78	117.00	177.20	1614346.00	.900845
79	118.50	177.20	2252302.00	.904945
80	120.00	177.20	3176219.00	.908865
81	121.50	177.19	4527620.00	.912612
82	123.00	177.19	6523122.00	.916196

83	124.50	177.19	9499523.00	.919623
84	126.00	177.19	**********	.922901
85	127.50	177.19	**********	.926037
86	129.00	177.19	**********	.929036
87	130.50	177.19	**********	.931907
88	132.00	177.19	**********	.934654
89	133.50	177.18	**********	.937282
90	135.00	177.18	**********	.939798
91	136.50	177.18	**********	.942207
92	138.00	177.18	**********	.944513
93	139.50	177.18	**********	.946721
94	141.00	177.18	**********	.948835
95	142.50	177.18	**********	.950860
96	144.00	177.18	**********	.952799
97	145.50	177.18	**********	.954657
98	147.00	177.18	**********	.956437
99	148.50	177.18	**********	.958142

1.4 Temperature Survey Data Output

If a temperature survey is desired, a data file containing information pertaining to all of the individual temperature files will be created. The file will list the individual data file names and the corresponding material layer and position of the survey point. The following listing is provided as an example.

```
#######################################################
FILES FOR TEMP SURVEY:
#######################################################
FILE   LAYER#.  MATERIAL    PT#.  LOCATION(% DEPTH)
-------------------------------------------------
DATA0201.ASC      2   FIBER PREFORM        1      .500
```

The individual temperature survey files will contain the file name, the material layer, the position of the survey point, and a listing of the temperature and resin degree of cure and viscosity (if applicable) as a function of time at the survey point. The following abbreviated listing is provided as an example. All of the data files created from the temperature survey routine will have the suffix: ASC.

```
#######################################################
 FILE NAME:DATA0201.ASC LAYER #.:  2 MATERIAL:FIBER PREFORM
 Pt. #.   1% POSITION:  .500

#######################################################
 TIME(min)  TEMP(C)        VISC(Pa.s)  D.O.C.     POS(m)
--------------------------------------------------
     1.50     30.41          .00   .00000000   .00318677
     3.00     33.97          .00   .00000000   .00318429
     4.50     37.51          .00   .00000000   .00317729
     6.00     41.22          .00   .00000000   .00317525
     7.50     44.90          .00   .00000000   .00317106
     9.00     48.78          .00   .00000000   .00316145
    10.50     52.41          .00   .00000000   .00314541
    12.00     56.11          .00   .00000000   .00325343
    13.50     59.73          .00   .00000000   .00325343
    15.00     63.33          .00   .00000000   .00325343
    16.50     67.02          .00   .00000000   .00325343
    18.00     70.77          .00   .00000000   .00325343
    19.50     74.46          .00   .00000000   .00325343
    21.00     78.12          .00   .00000000   .00325343
    22.50     81.82          .00   .00000000   .00325343
    24.00     85.73          .00   .00000000   .00325343
    25.50     89.76          .00   .00000000   .00325343
    27.00     93.49          .00   .01627451   .00325343
    28.50     96.91          .00   .02717371   .00325343
    30.00    100.05          .00   .02946873   .00325343
    31.50    103.45          .00   .03259517   .00325343
    33.00    107.24          .00   .03677734   .00325343
```

2.0 Direct Editing of an Input Data File

If a standard line editor is available, the input data file may be easily modified. The following list explains the contents of an input data file.

Line #.: 1
Item: A70
Description: Input Data File Name
Format: A70

Line #.: 2
Item: ANAME
Description: Title of simulation.
Format: A52

Line #.: 3
First Item: IFAB
Description: Code number referring to a particular fabric preform compaction model.
Definition: 1 - TTI IM7/8HS Dry Compaction
2 - TTI IM7/8HS Wet Compaction
3 - TTI IM7/8HS w TACTIFIER DRY COMPACTION
4 - TTI IM7/8HS w TACTIFIER WET COMPACTION
5 - HEXCEL AS4 12k K $(45/0/-45/90)_{2S}$ DRY COMPACTION
6 - KEXCEL AS4 12k K $(45/0/-45/90)_{2S}$ WET COMPACTION
7 - HEXCEL AS4 12k K/S $(45/0/-45/90)_{2S}$ DRY COMPACTION
8 - HEXCEL AS4 12k K/S $(45/0/-45/90)_{2S}$ WET COMPACTION
9 - HEXCEL AS4 12k (45/0/-45/90) KEVLAR KNIT DRY COMPACTION
10 - HEXCEL AS4 12k (45/0/-45/90) KEVLAR KNIT WET COMPACTION
11 - HEXCEL AS4 6k (45/0/-45/90) KEVLAR KNIT DRY COMPACTION
12 - HEXCEL AS4 6k (45/0/-45/90) KEVLAR KNIT WET COMPACTION

13 - HEXCEL AS4 3k (45/0/-45/90) KEVLAR KNIT DRY COMPACTION
14 - HEXCEL AS4 3k (45/0/-45/90) KEVLAR KNIT WET COMPACTION
15 - JAPANESE T300 3-D WEAVE QUASI-ISO. DRY COMPACTION
16 - JAPANESE T300 3-D WEAVE QUASI-ISO. WET COMPACTION
17 - FIBER INNOVATIONS AS4 3-D BRAID +/-30/0 DRY COMPACTION
18 - FIBER INNOVATIONS AS4 3-D BRAID +/-30/0 WET COMPACTION
19 - FIBER INNOVATIONS AS4 2-D BRAID +/-30/0 DRY COMPACTION
20 - FIBER INNOVATIONS AS4 2-D BRAID +/-30/0 WET COMPACTION
21 - FIBER INNOVATIONS AS4 2-D BRAID STITCHED +/-30/0 DRY COMPACTION
22 - FIBER INNOVATIONS AS4 2-D BRAID STITCHED +/-30/0 WET COMPACTION

Second Item: IRES

Description: Code number referring to resin model/type.

Definition: 1 - Hercules 3501-6
2 - Shell 1282/878

Format: 2I4

Line #.: 4

Item: AFABRIC(IFAB)

Description: Title of the fabric preform compaction model (see line #2).

Format: 2I4

Line #.: 5

Item: ARESIN(IRES)

Description: Title of resin type/model (see line #2).

Format: A52

Line #.: 6

Item: NUMDGS

Description: Number of time/temperature steps for resin precure/degassing procedure.

Format: I4

Line #.: 7 + (I-1)*1, I=1,NUMDGS

First Item: TIMEPCR(I)

Description: Time (min) of resin precure/degassing step.

Second Item: TEMPPCR(I)

Description: Temperature (°C) of resin precure/degassing step.

Format: 2E16.8

Line #.: 8 + NUMDGS - 1

Item: ALPHA(1,1), ALPHA(2,1), ALPHA(3,1)

Description: Initial resin degree(s) of cure.

Format: 3E16.8

Line #.: 9 + NUMDGS - 1

First Item: RLGTH

Description: Length (m) of composite panel.

Second Item: WIDTH

Description: Width (m) of composite preform.

Format: 2E16.8

Line #.: 10 + NUMDGS - 1

Item: NPLIES

Description: Number of distinct material layers in the fabric preform.

Format: I4

Line #.: 11 + NUMDGS - 1

Item: NUMLAYR

Description: Number of distinct material layers in the simulation layup.

Format: I4

Line #.: 11 + NUMDGS - 1 +(J - 1)*1, J=1,NUMLAYR

First Item: AMATL(J)

Description: Title of material layer in the simulation layup.

Second Item: HEIGHT(J)

Description: Height (m) of the material layer.

Format: A16,E16.8

Line #.: 12 + NUMDGS + NUMLAYR - 2

First Item: NTEMPS

Description: Number of time/temperature steps for the simulation (temperature boundary conditions).

Second Item: ICHKBC

Description: Number of distinct applied temperature boundary conditions.

Definition: 1 - Identical temperature boundary conditions applied at the upper and lower external surfaces of the RTM layup.

2 - Separate temperature boundary conditions applied at the upper and lower external surfaces of the RTM layup.

Format: 2I4

Line #.: 13 + NUMDGS + NUMLAYR - 2 + (K-1)*1, K=1,NTEMPS

First Item: TIMEIN(K)

Description: Time (min) of temperature boundary condition step.

If ICHKBC = 1

Second Item: TAUTO(1,K)

Description: Temperature (°C) boundary conditions at the upper and lower external surfaces of the RTM layup.

Format: 2E16.8

If ICHKBC = 2

Second Item: TAUTO(1,K)

Description: Temperature (°C) boundary conditions at the upper external surface of the RTM layup.

Third Item: TAUTO(2,K)

Description: Temperature (°C) boundary conditions at the lower external surface of the RTM Layup.

Format:3E16.8

Line #.: 14 + NUMDGS + NUMLAYR + NTEMPS - 3

First Item: NPRES

Description: Number of time/pressure steps for the simulation (pressure boundary conditions).

Second Item: NRMS

Description: Program flag no longer used in program.

Format: 2I4

Line #.: 15 + NUMDGS + NUMLAYR + NTEMPS - 3 + (L-1)*1, L=1,NPRES

First Item: TIMEPR(L)

Description: Start time (min) of pressure application step and hold.

Second Item: TPRESS(L)

Description: Applied mechanical pressure (kPa), absolute.

Format: 2E16.8

Line #.: 16+ NUMDGS + NUMLAYR + NTEMPS + NPRES - 4

Item: Ques(17)

Description: Answer to question regarding the desire for a temperature survey.

Definition: Y - Temperature survey

N - No temperature survey

Format: A1

If a temperature survey is desired

Line #.: 17 + NUMDGS + NUMLAYR + NTEMPS + NPRES - 4 + (1-M)*1, M=1,NUMLAYR

Item: NUMSRVY(M)

Description: Number of points to survey in a particular material layer. There must be at least one input for each material layer. If no points in a particular material layer are to be surveyed, enter 0. When NUMSRVY(M)=0, no input is required for PERSRVY(M,N) in the next line.

Format: I4

Line #.: 18 + NUMDGS + NUMLAYR + NTEMPS + NPRES - 4 +
(1-M)*1 + (1-N)*1, M=1,NUMLAYR, N=1,NUMSRVY(M)

Item: PERSRVY(M,N)

Description: Position (%) of the temperature survey location from top of the material layer. See page 8 and section 1.4.

Format: E16.8

If no temperature survey is desired

Line #.: 17 + NUMDGS + NUMLAYR + NTEMPS + NPRES - 4

If a temperature survey is desired

Line #.: 19 + NUMDGS + NUMLAYR + NTEMPS + NPRES - 4 +
(1-M)*1 + (1-N)*1, M=1,NUMLAYR, N=1,NUMSRVY(M)

First Item: DELTAT

Description: Program Time Step in seconds.

Second Item: NMIXNDS

Description: Number of one-dimensional, quadratic finite elements per meter of composite material.

Format: E16.8,I5

2.1 Sample input Data File

```
 INPUT DATA FILE: DATA.DAT
 RTM SIMULATION FILE # 1.
   1   1
   TTI IM7/8HS D/W COMPACTION
   HERCULES 3501-6
   3
   .00000000E+00  .27000000E+02
   .10000000E+02  .10000000E+03
   .20000000E+02  .10000000E+03
   .20968120E-02  .15548540E+00  .76692400E-01
   .15240000E+00  .15240000E+00
  16
   5
STEEL           .20000000E-01
FIBER PREFORM   .00000000E+00
RESIN PANEL     .00000000E+00
STEEL           .10000000E-01
ALUMINUM        .25000000E-02
   4   1
   .00000000E+00  .27222000E+02
   .50000000E+02  .17700000E+03
   .15000000E+03  .17700000E+03
   .15200000E+03  .17700000E+03
   2   1
   .00000000E+00  .30000000E+06  .00000000E+00
   .15200000E+03  .30000000E+06  .00000000E+00
Y
   0
   1
   .50000000E+00
   0
   0
   0
   .90000000E+02  7500
```

3.0 RTM.DAT Description/Contents

The RTM.DAT data file contains the fabric preform and resin film characteristics along with the physical properties of the layup materials (other than the fabric preform or resin panel) and support data for the finite element model. The RTM.DAT data file is accessed directly by the RTMCL program during the start of the simulation model. Items in this file can only be modified with a line editor. If modifications are made, the RTMCL program may have to be modified also and recompiled. The following list contains all of the items in the RTM.DAT data file.

Line #.: 1-7
Item: Title(1-7)
Description: Title of the data file and other relevant information.
Format: A70

Line #.: 8
Item: Title(8)
Description: Title of fabric preform information section.
Format: A70

Line #.: 9
Item: IFABNUM
Description: Number of different fabric preform types
Definition: 11 - TTI IM7/8HS, Hexcel Fabric Preforms, etc.
Format: I4

Line #.: 10 + (I-1)*10, I=1,IFABNUM
Item: FABTITLE(I)
Description: Title of an individual fabric preform type.
Format: A70

Line #.: 11 + (I-1)*10, I=1,IFABNUM
Item: IP(I)
Description: Code number to refer to fabric preform permeability versus porosity

characterization model.

Definition: 1 - Kozeny-Carman model

2 - Modified Gebart model

Format: I4

Line #.: 12 + (I-1)*10, I=1,IFABNUM

First Item: AREALZ(I)

Description: Dry areal weight (Kg/m^2) of fabric preform.

Second Item: DF(I)

Description: Cross-sectional diameter (m) of a individual fiber (primary fibers of fabric preform).

Third Item: FROE(I)

Description: Density (Kg/m^3) of individual fibers (Primary fibers of fabric preform).

Format: 3E16.8

Line #.: 13 + (I-1)*10, I=1,IFABNUM

First Item: FTHICK(I)

Description: Uncompacted thickness (m) of an individual layer of a fabric preform material.

Second Item: COEFA(I)

Description: Coefficient for permeability versus porosity model.

Definition: If IP(I) = 1 then COEFA(I) - Kozeny-Carman constant.

If IP(I) = 2 then COEFA(I) - modified Gebart constant S.

Third Item: COEFB(I)

Description: Coefficient for permeability versus porosity model.

Definition: If IP(I) = 1 then COEFB(I) - 0.

If IP(I) = 2 then COEFB(I) - modified Gebart minimum porosity.

Format: 3E16.8

Line #.: 14 + (I-1)*10, I=1,IFABNUM

First Item: SPCF(I)

Description: Specific heat (J/g C) of individual fibers (primary fibers of fabric preform).

Second Item: TCONDF(I)

Description: Longitudinal thermal conductivity (J/m sec) of individual fibers (primary fibers of fabric preform).

Third Item: TCZF(I)

Description: Transverse thermal conductivity (J/m sec) of individual fibers (primary fibers of fabric preform).

Format: 3E16.8

Line #.: 15 + (I-1)*10, I=1,IFABNUM

Item: AFABRIC((I-1)*2+1)

Description: Title of a dry fabric preform/compaction model.

Format: 3E16.8

Line #.: 16-17 + (I-1)*10, I=1,IFABNUM

Item: COEFF((I-1)*2+1,J), J=1,5

Description: Five constants for a 4th order least squares equation representing the dry compaction of a single layer of a fabric preform with respect to an applied compressive pressure.

Format: 3E16.8

Line #.: 18 + (I-1)*10, I=1,IFABNUM

Item: AFABRIC((I-1)*2+2)

Description: Title of a wet fabric preform/compaction model.

Format: A70

Line #.: 19-20 + (I-1)*10, I=1,IFABNUM

Item: COEFF((I-1)*2+2,J), J=1,5

Description: Five constants for a 4th order least squares fit representing the wet compaction of a single layer of a fabric preform with respect to an applied compressive pressure.

Format: 3E16.8

Line #.: 21 + (I-1)*10, I=1,IFABNUM

Item: Title(9)

Description: Title of resin film information section.

Format: A70

Line #.: 22 + (I-1)*10, I=1,IFABNUM

Item: IRESNUM

Description: Number of different resin film systems/models

Definition: 2 - Hercules 3501-6 and Shell 1282/878.

Format: I4

Line #.: 23 + (I-1)*10, I=1,IFABNUM

Item: Title(10)

Description: Title of first resin film system information section.

Format: A70

Line #.: 24 + (I-1)*10, I=1,IFABNUM

Item: ARESIN(1)

Description: Title of first resin system/model (Hercules 3501-6).

Format: A70

Line #.: 25 + (I-1)*10, I=1,IFABNUM

First Item: ROE(1)

Description: Density (Kg/m^3) of first resin system.

Second Item: SPCF(1)

Description: Specific heat (J/g C) of first resin system.

Third Item: TCONDR(1)

Description: Thermal conductivity (J/m sec) of first resin system.

Format: E16.8

Line #.: 26 + (I-1)*10, I=1,IFABNUM

First Item: HRR(1)

Description: Heat of reaction (J/g) of first resin system.

Second Item: ST(1)

Description: Surface Tension (dynes/cm) of first resin system.

Third Item: CANGLE(1)

Description: Contact angle (deg.) of first resin system.

Format: E16.8

Line #.: 27 + (I-1)*10, I=1,IFABNUM

Item: C(L), L=1,3

Description: Constants for the Hercules 3501-6 kinetics sub-model.

Format: 3E16.8

Line #.: 28 + (I-1)*10, I=1,IFABNUM

Item: ARES(L), L=1,3

Description: Arrhenius constants (1/sec) for the Hercules 3501-6 kinetics sub-model.

Format: 3E16.8

Line #.: 29 + (I-1)*10, I=1,IFABNUM

Item: ER(L), L=1,3

Description: Constants (J/mol) for Hercules 3501-6 kinetics sub-model.

Format: 3E16.8

Line #.: 30 + (I-1)*10, I=1,IFABNUM

Item: AN(L), L=1,3

Description: Constants for Hercules 3501-6 kinetics sub-model.

Format: 3E16.8

Line #.: 31 + (I-1)*10, I=1,IFABNUM

Item: CONE,CTWO

Description: WLF parameter constants

Format: 2E16.8

Line #.: 32 + (I-1)*10, I=1,IFABNUM

Item: Title(11)

Description: Title of second resin film system information section.

Format: A70

Line #.: 33 + (I-1)*10, I=1,IFABNUM

Item: ARESIN(2)

Description: Title of first resin system/model (Shell 1282/878).

Format: A70

Line #.: 34 + (I-1)*10, I=1,IFABNUM

First Item: ROE(2)

Description: Density (Kg/m^3) of second resin system.

Second Item: SPCF(2)

Description: Specific heat (J/g C) of second resin system.

Third Item: TCONDR(2)

Description: Thermal conductivity (J/m sec) of second resin system.

Format: 3E16.8

Line #.: 35 + (I-1)*10, I=1,IFABNUM

First Item: HRR(2)

Description: Heat of reaction (J/g) of second resin system.

Second Item: ST(2)

Description: Surface Tension (dynes/cm) of second resin system.

Third Item: CANGLE(2)

Description: Contact angle (deg.) of second resin system.

Format: 3E16.8

Line #.: 36-46 + (I-1)*10, I=1,IFABNUM

Item: AA(1-8),R,CAPU,RMUINF,AMU,EMU,A1(1-4),A2(1-4), E1(1-4), and E2(1-4)

Description: Constants for the Shell 1282/878 kinetic and viscosity sub-models.

Format: 3E16.8

Line #.: 47 + (I-1)*10, I=1,IFABNUM

Item: TITLE(12)

Description: Title of layup material information section.

Format: A70

Line #.: 48 + (I-1)*10, I=1,IFABNUM

Item: NUMATRLS

Description: Number of different layup materials in database.

Format: I4

Line #.: 49 + (I-1)*10 + (J-1)*2, I=1,INUMFAB, J=1,NUMATRLS

Item: AMATLIB(J)

Description: Title of layup material.

Format: A70

Line #.: 50 + (I-1)*10 + (J-1)*2, I=1,INUMFAB, J=1,NUMATRLS

First Item: ROEM(J)

Description: Density (Kg/m^3) of layup material.

Second Item: SPCM(J)

Description: Specific heat (J/g C) of layup material.

Third Item: TKM(J)

Description: Thermal Conductivity (J/m sec) of layup material.

Fourth Item: NMATNDS(J)

Description: Number of FEM quadratic elements per meter of layup material thickness.

Format: 3E16.8,2X,I5

Line #.: 51 + (I-1)*10 + (J-1)*2, I=1,IFABNUM, J=1,NUMATRLS

Item: TITLE(14)

Description: Title of supplemental data.

Format: A70

Line #.: 52 + (I-1)*10 + (J-1)*2, I=1,IFABNUM, J=1,NUMATRLS

First Item: FRAC

Description: Constant

Second Item: GAS

Description: Universal gas constant.

Format: 2E16.8

Line #.: 53 + (I-1)*10 + (J-1)*2, I=1,IFABNUM, J=1,NUMATRLS

Item: TITLE(15)

Description: Title of data used in the one-dimensional, FEM analysis.

Format: A70

Line #.: 54 - 55 + (I-1)*10 + (J-1)*2, I=1,IFABNUM, J=1,NUMATRLS

Item: TKCOEF(1,1)-TKCOEF(3,1)

Description: Coefficients for one-dimensional FEM quadratic thermal conductivity matrix (utilizing half-bandwith storage).

Format: 3E16.8

Line #.: 56 - 57 + (I-1)*10 + (J-1)*2, I=1,IFABNUM, J=1,NUMATRLS

Item: CNCOEF(1,1)-CNCOEF(3,1)

Description: Coefficients for one-dimensional FEM quadratic specific heat matrix (utilizing half-bandwith storage).

Format: 3E16.8

Line #.: 58 + (I-1)*10 + (J-1)*2, I=1,IFABNUM, J=1,NUMATRLS

Item: PHETA

Description: Constant for time iteration method for the FEM heat transfer model.

Format: 1E16.8

Line #.: 59 + (I-1)*10 + (J-1)*2, I=1,IFABNUM, J=1,NUMATRLS

Item: IVISCTME

Description: Number of time segments between thermal time steps, for the infiltration model.

Format: I4

Line #.: 60 + (I-1)*10 + (J-1)*2, I=1,IFABNUM, J=1,NUMATRLS

Item: IJUMPA, IJUMPB, IJUMPC, IJUMPD, and IJUMPE

Description: Flag statements for the main program.

Format: 8I2

Line #.: 61 + (I-1)*10 + (J-1)*2, I=1,IFABNUM, J=1,NUMATRLS

Item: NMAX

Description: The maximum number of data sets to be sent to an output device.

Format: I4

Line #.: 62 + (I-1)*10 + (J-1)*2, I=1,IFABNUM, J=1,NUMATRLS

First Item: XMAX

Description: Number used to determine maximums of output data.

Second Item: XMIN

Description: Number used to determine minimums of output data.

Format: 2E16.8

3.1 Listing of RTM.DAT

```
##########################################################################
#                    RTM Primary Input Data File                         #
#      Date of Rev. 12/26/89-1/04/90-4/26/90-10/15/91   M.H.W.           #
#            (file contains resin, fabric, tool plate,                   #
#               pressure plate, and FEM data.) H20                       #
##########################################################################

********************  Fabric Characteristics  **********************
 11
--------------- TTI IM7/8HS Fabric Characteristics (0/90) -----------
  2
  .42960000E+00  .50000000E-05  .17800000E+04
  .74809522E-03  .94400000E+01  .28300000E+00
  .71176000E+03  .25977000E+02  .83652182E+01
  TTI IM7/8HS DRY COMPACTION
 -.60719000E-04 -.43330000E-04  .67554000E-04
 -.12162000E-04  .68500000E-06
  TTI IM7/8HS WET COMPACTION
  .85922615E-03 -.87092899E-03  .30597814E-03
 -.40621174E-04  .19002950E-05
---------------- TTI IM7/8HS Fabric with Tactifier ------------------
  2
  .44170000E+00  .50000000E-05  .17600000E+04
  .43074114E-03  .58507600E+01  .24108390E+00
  .71176000E+03  .25977000E+02  .83652182E+01
  TTI IM7/8HS w TACTIFIER DRY COMPACTION
 -.36038138E-04  .45193725E-04 -.20510230E-04
  .38443973E-05 -.22180753E-06
  TTI IM7/8HS w TACTIFIER WET COMPACTION
  .49613615E-02 -.37940583E-02  .10649985E-02
 -.13004909E-03  .58705171E-05
---------------- HEXCEL AS4 12K K (+45/0/-45/90)2S -----------------
  2
  .69577910E+01  .80000000E-05  .18000000E+04
  .10414000E-01  .23700000E+01  .23652000E+00
  .71176000E+03  .25977000E+02  .83652182E+01
  HEXCEL AS4 12k K (45/0/-45/90)2S S DRY COMPACTION
 -.28340760E-02  .14710500E-03  .70998530E-03
 -.13881580E-03  .79234780E-05
  HEXCEL AS4 12k K (45/0/-45/90)2S S WET COMPACTION
 -.72484860E-05  .61972680E-03  .32786510E-04
 -.60353150E-05  .18241060E-06
---------------- HEXCEL AS4 12k K/S (+45/0/-45/90)2S ---------------
```

1
.73265370E+01 .80000000E-05 .18000000E+04
.76936600E-02 .13887500E+02 -.14398000E-03
.71176000E+03 .25977000E+02 .11252600E+02
HEXCEL AS4 12k K/S (45/0/-45/90)2S DRY COMPACTION
.11988160E-03 -.74673410E-04 -.65645520E-04
.28464280E-04 -.19545520E-05
HEXCEL AS4 12k K/S (45/0/-45/90)2S WET COMPACTION
.67917910E-04 -.12211490E-04 -.31407200E-04
.14571480E-04 -.96069600E-06
--------------- Hexcel AS4 12k (+45/0/-45/90) Kevlar Knit -----------
2
.17033750E+01 .80000000E-05 .18000000E+04
.24994000E-02 .11040570E+01 .14497000E+00
.71176000E+03 .25977000E+02 .83652182E+01
HEXCEL AS4 12k (+45/0/-45/90) KEVLAR KNIT DRY COMPACTION
-.30002431E-02 .21079722E-02 -.46827945E-03
.50345913E-04 -.20845245E-05
HEXCEL AS4 12k (+45/0/-45/90) KEVLAR KNIT WET COMPACTION
-.30600790E-03 .61498537E-03 -.14193586E-03
.16769658E-04 -.72141931E-06
--------------- Hexcel AS4 6k (+45/0/-45/90) Kevlar Knit ------------
2
.11112400E+01 .80000000E-05 .18000000E+04
.14208125E-02 .26627430E+01 .22385100E+00
.71176000E+03 .25977000E+02 .83652182E+01
HEXCEL AS4 6k (+45/0/-45/90) KEVLAR KNIT DRY COMPACTION
.77974717E-04 -.14619249E-03 .58728595E-04
-.57777815E-05 .18799009E-06
HEXCEL AS4 6k (+45/0/-45/90) KEVLAR KNIT WET COMPACTION
.34225010E-04 -.76689909E-04 .29420449E-04
-.73745933E-06 -.10454594E-06
--------------- Hexcel AS4 3k (+45/0/-45/90) Kevlar Knit -----------
2
.83516750E+00 .80000000E-05 .18000000E+04
.10941844E-02 .10748310E+01 .13809700E+00
.71176000E+03 .25977000E+02 .83652182E+01
HEXCEL AS4 3k (+45/0/-45/90) KEVLAR KNIT DRY COMPACTION
-.45464737E-03 .25357677E-03 -.33825767E-04
.31679070E-05 -.14583339E-06
HEXCEL AS4 3k (+45/0/-45/90) KEVLAR KNIT WET COMPACTION
-.16099150E-03 .35519647E-03 -.13668357E-03
.23835617E-04 -.14147906E-05
--------------- Japanese T300 3-D Weave Quasi-Iso. -------------------
2
.54144100E+01 .70000000E-05 .18000000E+04

.66230000E-02 .73161510E+01 .32637300E+00
.71176000E+03 .25977000E+02 .83652182E+01
JAPANESE T300 3-D WEAVE QUASI-ISO. DRY COMPACTION
-.36430166E-02 .27981673E-02 -.81307251E-03
.10852335E-03 -.50541134E-05
JAPANESE T300 3-D WEAVE QUASI-ISO. WET COMPACTION
.14633973E-03 -.31382025E-03 .98778613E-04
-.28254859E-05 -.13980702E-06
---------- FIBER INNOVATIONS AS4 3-D BRAID +/-30/0 --------------------
2
.60505280E+01 .80000000E-05 .18000000E+04
.91694000E-02 .56259420E+01 .29938300E+00
.71176000E+03 .25977000E+02 .83652182E+01
FIBER INNOVATIONS AS4 3-D BRAID +/-30/0 DRY COMPACTION
-.15158055E-02 -.23556783E-03 .52164210E-03
-.86793932E-04 .45747225E-05
FIBER INNOVATIONS AS4 3-D BRAID +/-30/0 WET COMPACTION
.10702587E-01 -.10618139E-01 .34625778E-02
-.42150390E-03 .17965354E-04
---------- FIBER INNOVATIONS AS4 2-D BRAID +/-30/0 -------------------
2
.55206000E+01 .80000000E-05 .18000000E+04
.77258000E-02 .31586590E+01 .26251300E+00
.71176000E+03 .25977000E+02 .83652182E+01
FIBER INNOVATIONS AS4 2-D BRAID +/-30/0 DRY COMPACTION
.12168266E-03 -.99752288E-03 .55351603E-03
-.75346161E-04 .34399119E-05
FIBER INNOVATIONS AS4 2-D BRAID +/-30/0 WET COMPACTION
.27863957E-03 -.63926488E-03 .28037335E-03
-.17187783E-04 -.32032072E-06
------- FIBER INNOVATIONS AS4 2-D BRAID STITCHED +/-30/0 --------------
1
.73080000E+01 .80000000E-05 .18000000E+04
.77540000E-02 .45464168E+02 .42509838E-04
.71176000E+03 .25977000E+02 .11252600E+02
FIBER INNOVATIONS AS4 2-D BRAID STITCHED +/-30/0 DRY COMPACTION
-.28422881E-02 .23721671E-02 -.69789542E-03
.94624760E-04 -.44479070E-05
FIBER INNOVATIONS AS4 2-D BRAID STITCHED +/-30/0 WET COMPACTION
-.81732593E-02 .62683412E-02 -.17291672E-02
.21314647E-03 -.94517735E-05
********************** Resin Characteristics ************************
2
--------------- Hercules 3501-6 Charateristics --------------------
HERCULES 3501-6
.12600000E+04 .12560000E+04 .16740000E+00

```
  .50520000E+06  .01312500E+00  .00000000E+00
  .85000000E+00  .95000000E-01  .55000000E-01
  .34969961E+08  .20945092E+09  .11832893E+21
  .11220000E+05  .10250000E+05  .20570000E+05
  .10600000E+01  .11700000E+01  .30500000E+01
  .29067000E+02  .36926000E+02
---------------- Shell 1282/878 Chracteristics --------------------
  SHELL 1282/878
  .11580000E+04  .20934000E+04  .20770000E+00
  .28800000E+06  .40000000E-01  .00000000E+00
 -.13119000E-04  .16357000E-01 -.67848000E+01
  .93680000E+03 -.20306000E-04  .25619000E-01
 -.10764600E+02  .15076940E+04  .83140000E+01
  .44786587E+05  .75652500E-08  .10766816E+04
  .16702909E+05
  .50663000E+02  .50663000E+02  .50663000E+02
  .49876000E+22  .29203700E+03  .29203700E+03
  .76908482E+14  .90382000E+01
  .35305600E+05  .35305600E+05  .35305600E+05
  .19682300E+06  .30485075E+05  .30485076E+05
  .11968662E+06  .15230702E+05
------------------- LAYUP MATERIAL DATA ---------------------------
  7
STEEL
  .78010000E+04  .47300000E+03  .52000000E+02   500
ALUMINUM
  .27074000E+04  .87090000E+03  .20250000E+03  1000
VACUUM BAG
  .22000000E+04  .15480000E+04  .40000000E+01  1000
RELEASE FILM
  .22000000E+04  .15480000E+04  .33540000E+00  1000
TEFLON FIBERGLS
  .23800000E+04  .10955100E+04  .70680000E+00  1000
E GLASS
  .26000000E+04  .80332800E+03  .80332800E+00  1000
S GLASS
  .24000000E+04  .71128000E+03  .30287800E+01  1000
-------------------- Supplemental Data -----------------------------
  .87500000E+01  .83140000E-02
------------- 1-D HEAT QUADRATIC HEAT TRANSFER -----------------------
  .23333333E+01 -.26666666E+01  .33333333E+00
  .53333333E+01 -.26666666E+01  .23333333E+01
  .13333333E+00  .66666666E-01 -.33333333E-01
  .40000000E+00  .66666666E-01  .13333333E+00
  .87800000E+00
 30
```

0 0 0 0 0
199
-.10000000E+16 .10000000E+16

4.0 Listing of RTMCL.FOR

```
C###########################################################################
C############################## MAIN PROGRAM ############################
C COPYRIGHT, 1992. MARK H. WEIDEMAN, VINCENT H. HAMMOND, AND
C  DR. ALFRED C. LOOS
C  DEPARTMENT OF ENGINEERING SCIENCE AND MECHANICS
C  NORRIS HALL
C  VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
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C  THIS PROGRAM WAS DEVELOPED FOR NASA LANGLEY RESEARCH
C  CENTER UNDER GRANT NAG-1-343. MR. H.BENSON DEXTER WAS PROJECT
C  MONITOR.
C###########################################################################
C###########################################################################
C ******************* DATAFILE ACCESS PRIMARY **********************
      CHARACTER*1 QUES(30)
      CHARACTER*4 PREFX,SUFX
      CHARACTER*12 FNTEMP(12,12)
      CHARACTER*17 AMATLIB(12),AMATL(12)
      CHARACTER*70 ANPRT
      CHARACTER*70 FN(4),ANAME,AFABRIC(48),ARESIN(12),ATEMPWRT(4)
      CHARACTER*10 FD(1)
      COMMON/BCS/ TIMEIN(200),TAUTO(2,200),
     1      TIMEPR(7),TPRESS(7),TVAC(7),NTEMPS,NPRES,ICHCKBC
      COMMON RPERM(7)
      COMMON/FABSIN/ A(5),COMPP(7),RLGTH,WIDTH,RVOL(7),RTHK(7),
     1      TUNCPT,ZETA,DIAFI,RHOFI,RKCC,PORO(7),FTHK(7),NPLIES,
     2     TCONF,TZF,SPF,NFABNDS,TCONR,SPR,RROE,NRESNDS,HR,RMASS(7),
     3      SPMIX(7),ROEMIX(7),TKTZMIX(7),FABINFIL(7),NMIXNDS,VF(7),
     4      IPERM,ERR,RMIN,PMIN,SURFTEN,CONTANG,
     5      TCONFAB(7),SPFAB(7),RHOFAB(7)
      COMMON/RESIN/ TEMP(799),ALPHA(3,799),FRATE(3,799),FVISC(799),
     1      IRES,ARES(3),C(3),ER(3),AN(3),CONE,CTWO,
     2      AA(8),A1(4),E1(4),A2(4),E2(4),R,RMUINF,CAPU
      COMMON/VISCPDT/ IVISCTME,TVTIME(3),VD(799,3),VISC(799,3)
      COMMON/FLOWFRNT/ NFLBCNDS,FLP(799),PRES(799),PL(3,3),
     1      PG(799,3),DELJMP(799),QG(799,1),HRESIDUE(40)
      COMMON/LAYUP/ NUMATRLS,HEIGHT(12),THICK(12),
     1      ROEM(12),SPCM(12),TKM(12),NMATNDS(12),NUMSRVY(12),
     2      PERSRVY(12,12),POSRVY(12,12)
      COMMON/HEATCOEF/ TKCOEF(3,3),CNCOEF(3,3),NUMNDS(12),NUMLAYR,
     1      DELZ(12,400),TKTZ(12,400),CP(12,400),RHO(12,400),
     2      TKG(799,3),CG(799,3),PHETA,DELTAT,
```

```
     3      TKBTPT(799,3),TKBT(799,3)
      COMMON/TEMPDET/ NI(12),NJ(12),NBCS,GFM(799,1),TKFM(799,1),
     1      VFR(799),DZS(799)
      COMMON/SIGNALS/ IJUMPA,IJUMPB,IJUMPC,IJUMPD,IJUMPE,NMAX,
     1      XMAX,XMIN
      COMMON/PREDGS/ NUMDGS,TIMEDGS(21),TEMPDGS(21),ALPPRT(21),
     1      VISCPRT(21)
C**********************************************************************
      DIMENSION RESDEFL(7),POS(7),TIMEWR(400),TMIN(400),
     1          VMIN(400),AMAX(400),TEMPBC(2),POSW(400),
     2          ITWRITE(12,12,4),IJUNIT(12,12),ICMSRVY(12),
     3          TMPU(700),TMPV(700)
      IFCMPT=1
      ICLEAR=1
      IFLSRT=0
      HRESIDUE(1)=0.000000010D0
C>>>> READ-IN AND DETERMINATION OF INITIAL DATA <<<<
c     print*,'initial call to reads'
      CALL READS(ANAME,IFAB,AFABRIC,ARESIN,AMATLIB,AMATL,QUES,
     +ANPRT)
c     print*,'rperm(ifcmpt)=',rperm(ifcmpt)
      ICL=0
      ICLLAYR=NUMLAYR
      DO 7 I=1,ICLLAYR
        IF(AMATL(I).EQ.'RESIN PANEL') THEN
          ICL=-1
          GOTO 7
        ELSE
        ENDIF
        ICMSRVY(I+ICL)=NUMSRVY(I)
    7 CONTINUE
c     print*,'initial call to getz'
      CALL GETZ(AMATLIB,AMATL,IFCMPT,ISRT,IRESRT,IEND,IADFAB,IADR)
c     print*,'initial call to getkcrk'
      CALL GETKCRK(ICLEAR,IR,IC)
      DO 9 I=1,IR
        TEMP(I)=(TAUTO(1,1)+TAUTO(2,1))/2.0D0+273.15D0
    9 CONTINUE
      ALPHAINT=((C(1)*ALPHA(1,1))+(C(2)*ALPHA(2,1))+
     +(C(3)*ALPHA(3,1)))
      DO 12 J=1,3
        DO 10 I=IRESRT,IEND
          ALPHA(J,I)=ALPHA(J,1)
   10   CONTINUE
        DO 11 I=1,ISRT-1
        ALPHA(J,I)=0.0D0
```

```
   11    CONTINUE
   12 CONTINUE
c     print*,'initial call to resdata'
      CALL RESDATA(IRESRT,IEND)
c     print*,'............... initial data ..................'
c     print*,' #.         temp(K)         Deg. of Cure'
C(((((((((((((((   ROUTINE TO DET. HEAT TRANSFER   )))))))))))))))
      FTHKCHK=1.0D0/(2000.0D0*NFABNDS)
      RTHKCHK=1.0D0/(2000.0D0*NRESNDS)
      STHKCHK=1.0D0/(2.0D0*NMIXNDS)
      ITMAX=INT((TIMEPR(NPRES)-TIMEPR(1))/(DELTAT/60.0D0))
c     print*,'itmax=',itmax
      NFREQ=ITMAX/NMAX+1
C------------------ OPEN OF MAIN FILE DATADUMP PRG. -----------------
      WRITE(6,902)
  902 FORMAT(' ','ENTER A NEW FILE NAME FOR THE DATA OUTPUT',//)
      READ(5,903) FN(3)
  903 FORMAT(A52)
      OPEN(7,FILE=FN(3),STATUS='NEW')
      WRITE(7,707) FN(3)
      WRITE(7,708) ANPRT
      WRITE(7,702)
      WRITE(7,672) ANAME
      WRITE(7,702)
      WRITE(7,673) AFABRIC(IFAB),NPLIES
      WRITE(7,674) ARESIN(IRES),ALPHAINT
      WRITE(7,3000)
      WRITE(7,3010) (I,TIMEDGS(I),TEMPDGS(I),ALPPRT(I),VISCPRT(I),
     +I=1,NUMDGS)
      WRITE(7,675) RLGTH,WIDTH
      WRITE(7,4000)
      DO 4030 I=1,NUMLAYR
        IF(AMATL(I).EQ.'FIBER PREFORM' .OR. AMATL(I).EQ.
     +  'RESIN PANEL') THEN
        WRITE(7,4015) I,AMATL(I)
4015    FORMAT(' ',' ',I3,'   ',A16,'(height det. by RTM model)')
        ELSE
        WRITE(7,4017) I,AMATL(I),HEIGHT(I)
4017    FORMAT(' ',' ',I3,'   ',A16,'     ',F6.3,'   ')
        ENDIF
4030  CONTINUE
      WRITE(7,676)
      IF(ICHCKBC.EQ.1) THEN
        WRITE(7,677)
        WRITE(7,678) (TIMEIN(I),TAUTO(1,I),I=1,NTEMPS)
      ELSEIF(ICHCKBC.EQ.2) THEN
```

```
      WRITE(7,711)
      WRITE(7,712) (TIMEIN(I),TAUTO(1,I),TAUTO(2,I),I=1,NTEMPS)
     ELSE
     ENDIF
     WRITE(7,679)
     WRITE(7,680)
     WRITE(7,681) (TIMEPR(I),TPRESS(I),TVAC(I),I=1,NPRES)
     WRITE(7,682)
     WRITE(7,683)
     WRITE(7,684) (COMPP(I),RVOL(I),RTHK(I),RMASS(I),I=1,NPRES)
     WRITE(7,685)
     WRITE(7,686)
     WRITE(7,687) (COMPP(I),FTHK(I),PORO(I),VF(I),I=1,NPRES)
     WRITE(7,690)
     WRITE(7,709)
     WRITE(7,703)
     WRITE(7,705)
C---------------------- INPUT OF TEMP SURVEY DATAFILE NAME ------------
     IF(QUES(17).NE.'Y') GOTO 47
      WRITE(6,15)
 15   FORMAT(' ','ENTER A NEW NAME (4 CHARACTERS LONG)',/,
   1        ' ','FOR THE TEMPERATURE SURVEY DATA FILES',//)
      READ(5,16) PREFX
 16   FORMAT(1A4)
      SUFX='.ASC'
      ATEMPWRT(1)='##########################################################'
      ATEMPWRT(2)='FILES FOR TEMP SURVEY:'
      ATEMPWRT(3)='FILE    LAYER#.   MATERIAL    PT#.   LOCATION(%
DEPTH)'
      ATEMPWRT(4)='--------------------------------------------------'
      OPEN(9,FILE=PREFX,STATUS='NEW')
      WRITE(9,21) ATEMPWRT(1),ATEMPWRT(2),ATEMPWRT(1),ATEMPWRT(3),
    +          ATEMPWRT(4)
      DO 29 I=1,NUMLAYR
        DO 27 J=1,NUMSRVY(I)
          IF(I.LT.10) THEN
            ITWRITE(I,J,1)=0
            ITWRITE(I,J,2)=I
          ELSE
            ITWRITE(I,J,1)=INT(I/10.0D0)
            ITWRITE(I,J,2)=I-INT(ITWRITE(I,J,1)*10.0D0)
          ENDIF
          IF(J.LT.10) THEN
            ITWRITE(I,J,3)=0
            ITWRITE(I,J,4)=J
          ELSE
```

```
          ITWRITE(I,J,3)=INT(J/10.0D0)
          ITWRITE(I,J,4)=J-INT(ITWRITE(I,J,3)*10.0D0)
        ENDIF
        WRITE(9,25) PREFX,ITWRITE(I,J,1),ITWRITE(I,J,2),
     +   ITWRITE(I,J,3),ITWRITE(I,J,4),SUFX,I,AMATL(I),J,
     +   PERSRVY(I,J)
27      CONTINUE
29    CONTINUE
21    FORMAT(1A52)
25    FORMAT(1A4,4I1,1A4,3X,1I4,3X,1A17,4X,1I4,4X,F6.3)
      CLOSE(9)
      OPEN(9,FILE=PREFX,STATUS='OLD')
      READ(9,21)ATEMPWRT(1),ATEMPWRT(2),ATEMPWRT(1),ATEMPWRT(3),
     +       ATEMPWRT(4)
      DO 37 I=1,NUMLAYR
        IF(NUMSRVY(I).EQ.0) GOTO 37
        DO 36 J=1,NUMSRVY(I)
          READ(9,34) FNTEMP(I,J)
36      CONTINUE
37    CONTINUE
      CLOSE(9)
      ATEMPWRT(3)=' TIME(min)  TEMP(C)  VISC(Pa.s)  D.O.C.  POS(m)'
      DO 40 I=1,NUMLAYR
        IF(NUMSRVY(I).EQ.0) GOTO 40
        DO 39 J=1,NUMSRVY(I)
          IJUNIT(I,J)=(10*I)+J
          OPEN(UNIT=IJUNIT(I,J),FILE=FNTEMP(I,J),STATUS='NEW')
          WRITE(IJUNIT(I,J),21) ATEMPWRT(1)
          WRITE(IJUNIT(I,J),45) FNTEMP(I,J),I,AMATL(I)
          WRITE(IJUNIT(I,J),46) J,PERSRVY(I,J)
          WRITE(IJUNIT(I,J),21) ATEMPWRT(1),ATEMPWRT(3),ATEMPWRT(4)
39      CONTINUE
40    CONTINUE
34    FORMAT(1A12)
45    FORMAT(' ','FILE NAME:',1A12,'LAYER #.:',I4,'MATERIAL:',1A17)
46    FORMAT(' ','Pt. #.',I4,'% POSITION:',F6.3,' ',/)
c---------- START OF TIME LOOP ----------
     IJUMPOVR=0
47   DO 660 ITME=1,ITMAX
     print*,'itme=',itme
       NBCS=2
       IACHK=0
       IBCHK=0
       TIME=TIME+(DELTAT/60.0D0)
       print*,'time=',time
       IF(TIME.GE.TIMEIN(NTEMPS-1)) GOTO 691
```

```
      DO 48 I=1,NPRES-1
        IF(TIME.GE.TIMEPR(I) .AND. TIME.LT.TIMEPR(I+1)) IFCMPT=I
        IF(IJUMPC.EQ.1) FABINFIL(IFCMPT)=FTHK(IFCMPT)
  48  CONTINUE
C<<<<<<<<<<<<<<<<<<< START OF INFILTRATION PHASE
>>>>>>>>>>>>>>>>>>>
      IF(IJUMPPVR.EQ.1) GOTO 50
      IF(POS(IFCMPT).GE.1.0D0) THEN
        IJUMPPVR=1
        IJUMPOVR=1
        TINFILF=TIME
        PINFILF=POS(IFCMPT)
c       print*,'tinfilf=',tinfilf,'pinfilf=',pinfilf
        POS(IFCMPT)=1.0D0
      ELSE
      ENDIF
  50 IF(IJUMPOVR.EQ.1) GOTO 559
C:::::::::::: SUBSTITUTE ROUTINE FOR RESIN DEFLECTION ::::::::::::
      FTHK(IFCMPT)=FTHK(IFCMPT)-FABINFIL(IFCMPT)
      RTHK(IFCMPT)=RTHK(IFCMPT)-(FABINFIL(IFCMPT)*PORO(IFCMPT))
C     print*,'fthk(',ifcmpt,') =',fthk(ifcmpt)
C     print*,'rthk(',ifcmpt,') =',rthk(ifcmpt)
C<<<<<<<<<<<<<< GENERATION OF SATURATED LAYER >>>>>>>>>>>>>>>
C     print*,'fabinfil(',ifcmpt,') =',fabinfil(ifcmpt)
C     print*,'sthkchk=',sthkchk,'ijumpa=',ijumpa
      IF(FABINFIL(IFCMPT).GE.STHKCHK .AND. IJUMPA.NE.1) THEN
        NUMLAYR=NUMLAYR+1
        print*,'numlayr=',numlayr
        DO 400 J=1,NUMLAYR
          IF(AMATL(J).EQ.'FIBER PREFORM') THEN
            DO 390 K=NUMLAYR,J+2,-1
              AMATL(K)=AMATL(K-1)
              HEIGHT(K)=HEIGHT(K-1)
              THICK(K)=THICK(K-1)
              NUMSRVY(K)=NUMSRVY(K-1)
              IF(NUMSRVY(K).EQ.0) GOTO 390
              DO 389 L=1,NUMSRVY(K)
                PERSRVY(K,L)=PERSRVY(K-1,L)
 389          CONTINUE
 390        CONTINUE
            AMATL(J+1)='SATURATED PREFORM'
          ELSE
          ENDIF
 400  CONTINUE
       do 403 ijk=1,numlayr
         print*,'amatl(',ijk,') =',amatl(ijk)
```

```
 403  continue
      IJUMPA=1
    ELSE
    ENDIF
C<<<<<<<<<<<<<< ELIMINATION OF RESIN PANEL >>>>>>>>>>>>>>>>>>>
    IF(RTHK(IFCMPT).LT.RTHKCHK .AND. IJUMPB.NE.1) THEN
      NUMLAYR=NUMLAYR-1
      DO 450 J=1,NUMLAYR
        IF(AMATL(J).EQ.'RESIN PANEL') THEN
          DO 440 K=J,NUMLAYR
            AMATL(K)=AMATL(K+1)
            HEIGHT(K)=HEIGHT(K+1)
            THICK(K)=THICK(K+1)
            DO 439 L=1,NUMSRVY(K+1)
              PERSRVY(K,L)=PERSRVY(K+1,L)
 439        CONTINUE
            NUMSRVY(K)=NUMSRVY(K+1)
 440      CONTINUE
        ELSE
        ENDIF
 450  CONTINUE
      IADR=-1
      do 453 ijk=1,numlayr
        print*,'amatl(',ijk,') =',amatl(ijk)
 453  continue
      IJUMPB=1
    ELSE
    ENDIF
C<<<<<<<<<<<<<<<<<< ELIMINATION OF FIBER PREFORM >>>>>>>>>>>>>>>>
    IF(FTHK(IFCMPT).LE.FTHKCHK .AND. IJUMPC.NE.1) THEN
      NUMLAYR=NUMLAYR-1
      DO 550 J=1,NUMLAYR
        IF(AMATL(J).EQ.'FIBER PREFORM') THEN
          DO 540 K=J,NUMLAYR
            AMATL(K)=AMATL(K+1)
            HEIGHT(K)=HEIGHT(K+1)
            THICK(K)=THICK(K+1)
            DO 539 L=1,NUMSRVY(K+1)
              PERSRVY(K,L)=PERSRVY(K+1,L)
 539        CONTINUE
          NUMSRVY(K)=NUMSRVY(K+1)
 540        CONTINUE
        ELSE
        ENDIF
 550  CONTINUE
      IADFAB=-1
```

```
        do 554 ijk=1,numlayr
           print*,'amatl(',ijk,') =',amatl(ijk)
  554   continue
        IJUMPC=1
        POS(IFCMPT)=1.0D0
        IPRINT=1
      ELSE
      ENDIF
      IF(FTHK(IFCMPT).LE. 0.0D0)  THEN
        print*,'fully infiltrated'
        FABINFIL(IFCMPT)=FTHK(IFCMPT)+FABINFIL(IFCMPT)
        POS(IFCMPT)=1.0D0
C       print*,'fabinfil(ifcmpt)=',fabinfil(ifcmpt)
      ELSE
      ENDIF
C<<<<<<<<<<<< CALL TO GETZ TO GET NEW DELZ'S >>>>>>>>>>>>>>>>>>
c     print*,'time step call to getz'
      CALL GETZ(AMATLIB,AMATL,IFCMPT,ISRT,IRESRT,IEND,IADFAB,IADR)
      IF(ISRT.EQ.0) ISRT=1
      ICLEAR=1
c     print*,'time step call to getkcrh'
      CALL GETKCRK(ICLEAR,IR,IC)
C     Routines To Restore Temperatures
      IF(IRESRV.EQ.1) THEN
        DO 470 IPREV=IEND+1,IR
          TEMP(IPREV)=TMPU(IPREV-IEND)
C          print*,'tempnc(',iprev,') =',temp(iprev)
  470   CONTINUE
        DO 475 IPREV=IRESRT,IEND
          TEMP(IPREV)=TMPV(IPREV-IRESRT+1)
C          print*,'tempr(',iprev,') =',temp(iprev)
  475   CONTINUE
      ELSE
      ENDIF
      DO 480 IRESTORE=IR-1,2,-1
        IF(TEMP(IRESTORE+1).EQ.0.0D0) TEMP(IRESTORE+1)=TEMP(IRESTORE)
  480 CONTINUE
C     print*,'ir=',ir
C<<<<< DET. OF FLOWFRNT POS. AND THICKNESS RESTORATION >>>>>>>>>
      FTHK(IFCMPT)=FTHK(IFCMPT)+FABINFIL(IFCMPT)
      RTHK(IFCMPT)=RTHK(IFCMPT)+(FABINFIL(IFCMPT)*PORO(IFCMPT))
c     print*,'itme=',itme
      POS(IFCMPT)=FABINFIL(IFCMPT)/FTHK(IFCMPT)
      print*,'pos(',ifcmpt,') =',pos(ifcmpt)
C<<<<<<<<<<< PREDICTION OF INTERMEDIATE VISC. FOR INFIL >>>>>>>>>>>
      ICLRNEW=ICLRNEW+1
```

```
      IF(POS(IFCMPT).LE.1.0D0) THEN
C       print*,'iresrt=',iresrt
C       print*,'isrt=',isrt
        DO 350 I=1,3
          IF((ITME-I).Lt.0 .OR. I.EQ.3) THEN
            TVTIME(I)=TIME
            DO 347 J=1,IFLSRT
              JSET=2
              VM=FVISC(IRESRT-(1+(J-1)*2))
c             print*,'vm=',vm
c             saftey check of viscosities
 346          IF(VM.LE.0) THEN
                VM=FVISC(IRESRT-(1+(J-1)*2-JSET))
                JSET=JSET+2
                GOTO 346
              ELSE
              ENDIF
              VD(J,I)=VM
c             print*,'fvisc(',isrt,') =',fvisc(isrt)
c             print*,'vd(',j,',',i,') =',vd(j,i)
 347        CONTINUE
            VD(IFLSRT+1,I)=FVISC(IRESRT)
c           print*,'vd(',iflsrt+1,',',i,') =',vd(iflsrt+1,i)
          ELSEIF((ITME-I).Ge.0 .AND. I.NE.3) THEN
            TVTIME(I)=TVTIME(I+1)
            DO 348 J=1,1+IFLSRT
              VD(J,I)=VD(J,I+1)
              IF(ICLRNEW.GT.2 .AND. VD(J,I).EQ.0.0D0) THEN
                VD(J,I)=VD(J-1,I)
              ELSE
              ENDIF
c             print*,'vd(',j,',',i,') =',vd(j,i)
 348        CONTINUE
          ELSE
          ENDIF
 350    CONTINUE
C<<<< CAL TO VISC. DET. AND FLOWFRNT. DET. >>>>
c       print*,'time step call to viscoef'
        CALL VISCOEF(ITME,IFLSRT)
c       print*,'time step call to infil'
c       print*,'time=',time
        CALL INFIL(TIME,DELTAT,IFCMPT,NMIXNDS,RPERM,TKCOEF,
     +  NUMSMPT,COMPP,TVAC,FABINFIL,IFLSRT,PORO)
c       print*,'time=',time
      ELSE
      ENDIF
```

```
C<<<<<<<<<<<<<<<<<<<< DET. OF DELZ'S AND VFR'S >>>>>>>>>>>>>>>>>>>>>
  559 DO 570 I=1,NUMLAYR
        IF(AMATL(I).EQ.'SATURATED PREFORM'.AND. ISRT.NE.IRESRT) THEN
          DO 565 J=ISRT,IEND
            DZS(J)=DELZ(I,J+1-ISRT)
            VFR(J)=PORO(IFCMPT)
  565     CONTINUE
          IACHK=1
        ELSEIF(AMATL(I).EQ.'RESIN PANEL') THEN
          DO 568 J=IRESRT,IEND
            DZS(J)=DELZ(I,J+1-IRESRT)
            VFR(J)=1.0D0
  568     CONTINUE
          IBCHK=1
        ELSE
        ENDIF
  570 CONTINUE
C<<<< SETING OF ALPHA'S FOR SYSTEM (check is .15) >>>>
c     print*,'alpha(',k,',',iresrt+1,') =',alpha(k,iresrt+1)
c     print*,'first check !'
      DO 573 K=1,3
        DO 571 J=IRESRT+1,ISRT,-1
        IF(ALPHA(K,J).EQ.0.0D0 .OR. ALPHA(K,J).LT.(ALPHA(K,J+1)*
     +  .150D0)) ALPHA(K,J)=ALPHA(K,J+1)
        IF(FRATE(K,J).EQ.0.0D0 .OR. FRATE(K,J).LT.(FRATE(K,J+1)*
     +  .150D0)) FRATE(K,J)=FRATE(K,J+1)
c       print*,'alpha(',k,',',j,') =',alpha(k,j)
c       print*,'frate(',k,',',j,') =',frate(k,j)
  571   CONTINUE
c       print*,'second check !'
        DO 572 J=IRESRT,IEND-1
        IF(ALPHA(K,J+1).LT.(ALPHA(K,J)*.150D0)) ALPHA(K,J+1)=
     +  ALPHA(K,J)
        IF(FRATE(K,J+1).LT.(FRATE(K,J)*.150D0)) FRATE(K,J+1)=
     +  FRATE(K,J)
c       print*,'alpha(',k,',',j+1,') =',alpha(k,j+1)
c       print*,'frate(',k,',',j+1,') =',frate(k,j+1)
  572   CONTINUE
  573 CONTINUE
C<<<<<<<<<<<< CLEAR OUT OF OTHER BOUNDARY ALPHA'S >>>>>>>>>
      DO 577 K=1,3
        DO 575 I=IEND+1,IR
          ALPHA(K,I)=0.0D0
  575   CONTINUE
  577 CONTINUE
      IF(IACHK.EQ.1 .AND. IBCHK.EQ.1) THEN
```

```
      DZS(IRESRT)=(DZS(IRESRT)+DZS(IRESRT-1))/2.0D0
      VFR(IRESRT)=(VFR(IRESRT)+VFR(IRESRT-1))/2.0D0
     ELSE
     ENDIF
C<<<<<<<<<<<<<<<<<<<<<< DETERMINATION OF TEMP BCS
>>>>>>>>>>>>>>>>>>>>
     DO 590 I=1,NTEMPS-1
       IF(TIME.GE.TIMEIN(I) .AND. TIME.LT.TIMEIN(I+1)) GOTO 593
  590 CONTINUE
  593 JK=0
c    print*,'temp bcs'
c    print*,'ir=',ir,'i=',i
     DO 595 J=1,IR,IR-1
       JK=JK+1
       TEMP(J)=((TAUTO(JK,I+1)-TAUTO(JK,I))*(TIME-TIMEIN(I))/
    +  (TIMEIN(I+1)-TIMEIN(I)))+TAUTO(JK,I)+273.15D0
c      print*,'temp(',j,') =',temp(j)
       NI(JK)=J
       NJ(JK)=NI(JK)
  595  CONTINUE
c    print*,'time step call to ttime'
     TR=TEMP(1)
     TS=TEMP(IR)
     CALL TTIME(iprint,IR,IC,ISRT,IEND,TR,TS)
C    Setting of Previous Temperatures
     IRESRV=1
     DO 601 IPREV=1,IR-IEND
       TMPU(IPREV)=TEMP(IPREV+IEND)
c      print*,'tempprevnc(',iprev,') =',tmpu(iprev)
  601 CONTINUE
     DO 602 IPREV=1,IEND-IRESRT+1
       TMPV(IPREV)=TEMP(IPREV+IRESRT-1)
c      print*,'tempprevr(',iprev,') =',tmpv(iprev)
  602 CONTINUE
C------------------------ WRITE OUT TO DATA FILES ----------------------
C------------------------ INFILTRATION FRONT DATA ----------------------
     IF(POS(IFCMPT).GE.1.0D0) GOTO 596
     TRED=TEMP(ISRT)-273.0D0
     ALPHAISR=((C(1)*ALPHA(1,ISRT))+(C(2)*ALPHA(2,ISRT))+
    +(C(3)*ALPHA(3,ISRT)))
     IPOWRT=IPOSWRT+1
     TPOSWRT=TIME
     PPOSWRT=POS(IFCMPT)
     WRITE(7,705) ITME,TIME,TRED,FVISC(ISRT),ALPHAISR,POS(IFCMPT)
C------------------------ TEMPERATURE HISTORY DATA ---------------------
 596    ICOUNT=ICOUNT+1
```

```
          IF(ICOUNT.EQ.NFREQ) THEN
             IWRITE=IWRITE+1
             IF(QUES(17).NE.'Y') GOTO 111
             IF(IJUMPC.EQ.1) GOTO 244
             DO 243 I=1,NUMLAYR
                IF(AMATL(I+1).EQ.'SATURATED PREFORM' .AND. POS(IFCMPT)
     +            .LT.1.0D0) THEN
                 DO 237 K=2,NUMNDS(I+1)-1,2
                    DELZ(I,K+NUMNDS(I)-1)=DELZ(I+1,K)
C                    print*,'delz(',i,',',k+numnds(i)-1,') =',delz(i+1,k)
 237              CONTINUE
                 ISUB=I
                 NUMNDS(I)=NUMNDS(I)+NUMNDS(I+1)-1
C                 print*,'numnds(',i,') =',numnds(i)
                 THICK(I)=THICK(I)+THICK(I+1)
C                 print*,'thick(',i,') =',thick(i)
                ELSE
                ENDIF
 243         CONTINUE
C---- DET. OF PARTICULAR TEMP AND VISCOSITY/DEGREE OF CURE (IF
C------------------------- APPLICIABLE) ---------------------
 244 JK=0
       IADDWRT=0
       DO 100 I=1,NUMLAYR
          IF(IJUMPC.NE.1 .AND. AMATL(I).EQ.
     +    'SATURATED PREFORM') GOTO 100
C         WRITE(4,300) I,THICK(I),NUMSRVY(I),AMATL(I)
          DO 70 J=1,NUMSRVY(I)
             SUMSRVY=0.0D0
             IF(NUMSRVY(I).EQ.0.0D0) GOTO 70
             POSRVY(I,J)=(PERSRVY(I,J)*THICK(I))
c            print*,'persrvy(',i,',',j,') =',persrvy(i,j)
c            print*,'posrvy(',i,',',j,') =',posrvy(i,j)
C             WRITE(4,301) PERSRVY(I,J),POSRVY(I,J)
            DO 55 K=2+JK,NUMNDS(I)+JK-1,2
c               print*,'delz(',i,',',k-jk,') =',delz(i,k-jk)
c               print*,'sumsrvy=',sumsrvy
               IF(SUMSRVY.GE.POSRVY(I,J)) THEN
                ZETA=(DELZ(I,K-JK)-(SUMSRVY-POSRVY(I,J)))/DELZ(I,K-JK)
c               print*,'zeta=',zeta
                TEMPWRT=(((-1.0D0)/2.0D0)*ZETA*(1.0D0-ZETA)*TEMP(K-1))+
     +                 ((1.0D0+ZETA)*(1.0D0-ZETA)*TEMP(K))+
     +                 ((1.0D0/2.0D0)*ZETA*(1.0D0+ZETA)*TEMP(K+1))-
     +                 273.0D0
c               print*,'tempwrt=',tempwrt
                FVISCWT=(((-1.0D0)/2.0D0)*ZETA*(1.0D0-ZETA)*FVISC(K-1))+
```

```
     +                  ((1.0D0+ZETA)*(1.0D0-ZETA)*FVISC(K))+
     +                  ((1.0D0/2.0D0)*ZETA*(1.0D0+ZETA)*FVISC(K+1))
c              print*,'fviscwt=',fviscwt
               ALPHAWT=0.0D0
               DO 51 L=1,3
                 ALPHAWT=ALPHAWT+C(L)*((((-1.0D0)/2.0D0)*ZETA*
     +            (1.0D0-ZETA)*ALPHA(L,K-1))+((1.0D0+ZETA)*
     +            (1.0D0-ZETA)*ALPHA(L,K))+((1.0D0/2.0D0)*ZETA*
     +            (1.0D0+ZETA)*ALPHA(L,K+1)))
  51           CONTINUE
c              print*,'alphawt=',alphawt
               ISUBJK=K-JK
c              print*,'isubjk =',isubjk
C-------------- ROUTINE TO RESET FILE WRITE DATA -------------------
C              PRINT*,'IJUMPA=',IJUMPA,'IJUMPC=',IJUMPC,
C    +          'IJUMPB=',IJUMPB
               IF(I.LE.1) GOTO 52
               IF(IJUMPA.EQ.1 .AND. IJUMPC.NE.1) THEN
                 IF(AMATL(I-1).EQ.'SATURATED PREFORM')
     +             IADDWRT=1*(IJUMPB-1)
               ELSEIF(IJUMPA.EQ.1 .AND. IJUMPC.EQ.1) THEN
                 IF(AMATL(I-1).EQ.'SATURATED PREFORM') IADDWRT=1
               ELSE
               ENDIF
c              print*,'iaddwrt=',iaddwrt
c              print*,'amatl(',i,')=',amatl(i)
c              print*,'ijunit(',i+iaddwrt,',',j,') =',
c    +          ijunit(i+iaddwrt,j)
 52            WRITE(IJUNIT(I+IADDWRT,J),302) TIME,TEMPWRT,FVISCWRT,
     +                                ALPHAWT,POSRVY(I,J)
               GOTO 70
              ELSE
              ENDIF
              SUMSRVY=SUMSRVY+DELZ(I,K-JK)
 55         CONTINUE
 70       CONTINUE
        JK=JK+NUMNDS(I)
c       print*,'jk =',jk
 100  CONTINUE
      IF(IJUMPC.NE.1) THICK(ISUB)=THICK(ISUB)-THICK(ISUB+1)
 111        ICOUNT=0
         TIMEWR(IWRITE)=TIME
         POSW(IWRITE)=POS(IFCMPT)
         TMIN(IWRITE)=TEMP(IRESRT-2)-273.0D0
         AMAX(IWRITE)=((C(1)*ALPHA(1,IRESRT-2))+
     +   (C(2)*ALPHA(2,IRESRT-2))+(C(3)*ALPHA(3,IRESRT-2)))
```

```
          VMIN(IWRITE)=FVISC(IRESRT-2)
        ELSE
        ENDIF
  300 FORMAT(I4,E16.8,I4,A16)
  301 FORMAT(2E16.8)
  302 FORMAT(F10.2,2X,F8.2,2X,F12.2,2X,F10.8,2X,F10.8)
  660 CONTINUE
      IF(QUES(17).EQ.'Y') THEN
       IADDWRT=0
       DO 665 I=1,ICLLAYR
         DO 662 J=1,ICMSRVY(I)
           CLOSE(UNIT=IJUNIT(I,J))
  662      CONTINUE
  665    CONTINUE
      ELSE
      ENDIF
  691 TINFILF=((TINFILF-TPOSWRT)*(1-PPOSWRT)/(PINFILF-PPOSWRT))+
     +        TPOSWRT
      PINFILF=1.0D0
      WRITE(7,701) TINFILF,PINFILF
      WRITE(7,710)
      WRITE(7,720)
      WRITE(7,723)
      WRITE(7,730) (I,TIMEWR(I),TMIN(I),VMIN(I),AMAX(I),I=1,IWRITE)
      CLOSE(7)
  701 FORMAT(///,' ','FINAL TIME, min = ',F10.2,' FINAL POS. =',F10.8)
  702 FORMAT(' ','*****************************************************
     +*****************')
  690 FORMAT(/,'-----------------------------------------------------
     +-----------------')
  707 FORMAT(' MAIN DATA OUTPUT FILE: ',A30)
  708 FORMAT(' INPUT DATA FILE: ',A30)
  672 FORMAT(' ','RTM SIMULATION TITLE: ',1A60)
  673 FORMAT(/,' ','FABRIC PREFORM:  ',1A70,' #. OF PLIES',1I4,/)
  674 FORMAT(' ','RESIN PANEL:  ',1A16,' INT. DEG. of CURE',
     +1F6.5,/)
 3000 FORMAT(' ','RESIN PRESTAGE HISTORY',/,
     1' ',' #.        TIME(min)       TEMP(C)   DEGREE of CURE   ',
     2'  VISCOSITY(Pa.s)')
 3010 FORMAT(2X,I3,4X,F10.2,4X,F10.2,5X,F10.8,5X,F10.2)
 4000 FORMAT(/,' ','LAYUP PROFILE:',/,
     1' ','LAYER #. MATERIAL        HEIGHT (meters)')
  675 FORMAT(' ','SPECIMEN LENGTH (m)  ',1F7.5,' SPECIMEN HEIGHT (m)  ',
     +1F7.5)
  676 FORMAT(/,' ','APPLIED TEMPERATURE CYCLE:')
  677 FORMAT(' ','                    TIME (min)   UPPER/LOWER TEMP(C)  ')
```

```
 678 FORMAT(18X,1F10.4,7X,1F10.4)
 711 FORMAT(' ','    TIME(min)     UPPER TEMP(C)    LOWER TEMP(C)')
 712 FORMAT(7X,1F10.4,5X,1F10.4,5X,1F10.4)
 679 FORMAT(/,' ','APPLIED PRESSURE CYCLE:')
 680 FORMAT(' ','    TIME(min)  PLATTEN PRESSURE (Pa)  VAC.+CAPILLARY
    +PRESSURE (Pa)')
 681 FORMAT(4X,1F10.2,3X,1F14.2,10X,1F14.2)
 682 FORMAT(/,' ','RESIN PANEL DATA:')
 683 FORMAT(' ','COMP. PRES. (Pa)  RESIN VOL. (m^3)  RESIN PANEL THICKN
    +ESS (m)  RESIN MASS (grams)')
 684 FORMAT(2X,1F14.4,7X,1F7.6,15X,1F7.6,11X,1F10.4)
 685 FORMAT(/,' ','FABRIC PREFORM DATA:')
 686 FORMAT(' ','COMP. PRES. (Pa)   FABRIC PANEL THICKNESS (m)
POROSITY
    + FIBER VOLUME FRACTION')
 687 FORMAT(2X,1F14.4,8X,1F7.6,17X,F7.6,12X,F7.6)
 709 FORMAT(///,' ',' INFILTRATION FRONT SIMULATION DATA: ')
 703 FORMAT(' ','   #.     TIME       TEMP       VISC       DEG.',
    1' of CURE        POS.')
 704 FORMAT(' ','          (min)     (Deg C)    (Pa.s.)         ')
 705 FORMAT(2X,I4,4X,F6.2,6X,F6.2,4X,F10.2,8X,F8.6,9X,F8.6)
 710 FORMAT(////,' ',' RESIN CURE DATA FOR ENTIRE SIMULATION')
 720 FORMAT(' ','   #.     TIME       TEMP       VISC       DEG.',
    1' of CURE ')
 723 FORMAT(' ','          (min)     (Deg C)    (Pa.s)          ')
 730 FORMAT(2X,I4,4X,F6.2,6X,F6.2,4X,F10.2,9X,F8.6)
     close(9)
     STOP
     END
C-------------------------------------------------------------------
                              S U B R O U T I N E
READS(ANAME,IFAB,AFABRIC,ARESIN,AMATLIB,AMATL,QUES,
    +ANPRT)
C-------------------------------------------------------------------
     CHARACTER*1 QUES(30)
     CHARACTER*70 ANPRT,ANAME,FN(4),AFABRIC(48),ARESIN(12)
     CHARACTER*80 TITLE(15),FABTITLE(5),MISLN(10)
     CHARACTER*17 AMATLIB(12),AMATL(12)
     COMMON/BCS/ TIMEIN(200),TAUTO(2,200),
    1       TIMEPR(7),TPRESS(7),TVAC(7),NTEMPS,NPRES,ICHCKBC
     COMMON RPERM(7)
     COMMON/FABSIN/ A(5),COMPP(7),RLGTH,WIDTH,RVOL(7),RTHK(7),
    1       TUNCPT,ZETA,DIAFI,RHOFI,RKCC,PORO(7),FTHK(7),NPLIES,
    2     TCONF,TZF,SPF,NFABNDS,TCONR,SPR,RROE,NRESNDS,HR,RMASS(7),
    3       SPMIX(7),ROEMIX(7),TKTZMIX(7),FABINFIL(7),NMIXNDS,VF(7),
    4       IPERM,ERR,RMIN,PMIN,SURFTEN,CONTANG,
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     5      TCONFAB(7),SPFAB(7),RHOFAB(7)
      COMMON/RESIN/ TEMP(799),ALPHA(3,799),FRATE(3,799),FVISC(799),
     1      IRES,ARES(3),C(3),ER(3),AN(3),CONE,CTWO,
     2      AA(8),A1(4),E1(4),A2(4),E2(4),R,RMUINF,CAPU
      COMMON/VISCPDT/ IVISCTME,TVTIME(3),VD(799,3),VISC(799,3)
      COMMON/LAYUP/ NUMATRLS,HEIGHT(12),THICK(12),
     1      ROEM(12),SPCM(12),TKM(12),NMATNDS(12),NUMSRVY(12),
     2      PERSRVY(12,12),POSRVY(12,12)
      COMMON/HEATCOEF/ TKCOEF(3,3),CNCOEF(3,3),NUMNDS(12),NUMLAYR,
     1      DELZ(12,400),TKTZ(12,400),CP(12,400),RHO(12,400),
     2      TKG(799,3),CG(799,3),PHETA,DELTAT,
     3      TKBTPT(799,3),TKBT(799,3)
      COMMON/SIGNALS/ IJUMPA,IJUMPB,IJUMPC,IJUMPD,IJUMPE,NMAX,
     1      XMAX,XMIN
      COMMON/PREDGS/ NUMDGS,TIMEDGS(21),TEMPDGS(21),ALPPRT(21),
     1      VISCPRT(21)
      DIMENSION AREALZ(24),DF(24),FROE(24),FTHCK(24),IP(24),
     +CA(24),CB(24),SPCF(24),TCONDF(24),TCZF(24),
     +zxy(48,5),ROE(3),SPCR(3),TCONDR(3),HRR(3),ST(3),
     +CANGLE(3),TIVAC(7)
      INTREDO=1
C     OPEN FILE PRIMARY TO RECIEVE DATA (PROJECT)
      OPEN(1,FILE='RTM.DAT',STATUS='OLD')
C     READ-IN OF INITIAL TITLES
      READ(1,3000) (TITLE(I),I=1,7)
C     READ-IN OF FABRIC CHARACTERISTICS
      READ(1,3000) TITLE(8)
      READ(1,3010) IFABNUM
      DO 2970 I=1,IFABNUM
        READ(1,3000) FABTITLE(I)
        READ(1,3010) IP(I)
        READ(1,3020) AREALZ(I),DF(I),FROE(I),FTHCK(I),
     +   CA(I),CB(I),SPCF(I),TCONDF(I),TCZF(I)
c       print*,'ca(',i,') =',ca(i)
c       print*,'cb(',i,') =',cb(i)
        READ(1,3001) AFABRIC((I-1)*2+1)
        READ(1,3020) (zxy((I-1)*2+1,K),K=1,5)
c       print*,'zxy(1)=',zxy((i-1)*2+1,1)
        READ(1,3001) AFABRIC((I-1)*2+2)
        READ(1,3020) (zxy((I-1)*2+2,K),K=1,5)
 2970 CONTINUE
C     READ-IN OF RESIN CHARCATERISTICS
      READ(1,3000) TITLE(9)
      READ(1,3012) IRESNUM
C     READ-IN OF 3501-6 CHARCTERISTICS
      READ(1,3000) TITLE(10)
```

```
      READ(1,3001) ARESIN(1)
      READ(1,3020) ROE(1),SPCR(1),TCONDR(1),HRR(1),ST(1),CANGLE(1)
      READ(1,3020) (C(I),I=1,3),(ARES(I),I=1,3),(ER(I),I=1,3),
     +(AN(I),I=1,3),CONE,CTWO
C     READ-IN OF SHELL 1282 CHARCTERISTICS
      READ(1,3000) TITLE(11)
      READ(1,3001) ARESIN(2)
      READ(1,3020) ROE(2),SPCR(2),TCONDR(2),HRR(2),ST(2),CANGLE(2)
      READ(1,3020) (AA(I),I=1,8),R,CAPU,RMUINF,AMU,EMU
      READ(1,3020) (A1(I),I=1,4),(A2(I),I=1,4)
      READ(1,3020) (E1(I),I=1,4),(E2(I),I=1,4)
C     READ-IN OF THERMAL CHARACTERISTICS OF LAYUP MATERIALS
      READ(1,3000) TITLE(12)
      READ(1,3010) NUMATRLS
      DO 2980 I=1,NUMATRLS
        READ(1,3002) AMATLIB(I)
        READ(1,3021) ROEM(I),SPCM(I),TKM(I),NMATNDS(I)
 2980 CONTINUE
C     READ-IN OF MISL. INITIAL DATA
      READ(1,3000) TITLE(14)
      READ(1,3020) FRAC,GAS
C     READ-IN OF SUPPORT DATA FOR 1-D HEAT TRANSFER (QUADRATIC)
      READ(1,3000) TITLE(15)
      READ(1,3020) (TKCOEF(1,I),I=1,3),
     +TKCOEF(2,1),TKCOEF(2,2),TKCOEF(3,1)
      READ(1,3020) (CNCOEF(1,I),I=1,3),
     +CNCOEF(2,1),CNCOEF(2,2),CNCOEF(3,1)
      READ(1,3020) PHETA
      READ(1,3010) IVISCTME
      READ(1,3040) IJUMPA,IJUMPB,IJUMPC,IJUMPD,IJUMPE
      READ(1,3010) NMAX
      READ(1,3020) XMAX,XMIN
      CLOSE(1)
 3000 FORMAT(A90)
 3001 FORMAT(A70)
 3002 FORMAT(A16)
 3010 FORMAT(I4)
 3012 FORMAT(I4,3X,I5)
 3020 FORMAT(3E16.8)
 3021 FORMAT(3E16.8,2X,I5)
 3030 FORMAT(8I2)
 3040 FORMAT(5I4)
C- USER ACCESS/CREATION OF DATAFILES (MODIFICATION OF INPUT DATA)
--
C----------------------- ACCESS OF NON-PERMANENT DATA -----------------
      WRITE(6,46)
```

```
 46  FORMAT(/,' ','**********************************************',/,
    1' ','* RTM SIMULATION PROGRAM FOR 1-D INFIL/CURE *',/,
    2' ','*          OF GRAPHITE EPOXY PANELS           *',/,
    3' ','**********************************************',//)
     WRITE(6,47)
 47  FORMAT(/,' ','ENTER THE NAME OF THE RTM INPUT DATA FILE',/,
    1' ',' (ENTER DATA.DAT TO CREATE A NEW DATA SET)',//)
     READ(5,30) FN(1)
     ANPRT=FN(1)
C------------- DATAFILE ACCESS OF USER MODIFIED DATA ------------------
     OPEN(2,FILE=FN(1),STATUS='OLD')
     READ(2,30) MISLN(1)
     READ(2,30) ANAME
     READ(2,45) IFAB,IRES
     READ(2,30) AFABRIC(IFAB)
     READ(2,30) ARESIN(IRES)
     READ(2,40) NUMDGS
     READ(2,43) (TIMEDGS(I),TEMPDGS(I),I=1,NUMDGS)
     READ(2,44) ALPHA(1,1),ALPHA(2,1),ALPHA(3,1)
     READ(2,43) RLGTH,WIDTH
     READ(2,40) NPLIES
     READ(2,40) NUMLAYR
     READ(2,41) (AMATL(I),HEIGHT(I),I=1,NUMLAYR)
     READ(2,45) NTEMPS,ICHCKBC
     IF(ICHCKBC.EQ.1) THEN
       READ(2,43) (TIMEIN(I),TAUTO(1,I),I=1,NTEMPS)
       DO 48 I=1,NTEMPS
         TAUTO(2,I)=TAUTO(1,I)
 48    CONTINUE
     ELSEIF(ICHCKBC.EQ.2) THEN
       READ(2,44) (TIMEIN(I),TAUTO(1,I),TAUTO(2,I),I=1,NTEMPS)
     ELSE
     ENDIF
     READ(2,45) NPRES,NRMS
     READ(2,44) (TIMEPR(I),TPRESS(I),TIVAC(I),I=1,NPRES)
     READ(2,33) QUES(17)
     IF(QUES(17).EQ.'Y') THEN
     DO 80 I=1,NUMLAYR
       READ(2,40) NUMSRVY(I)
       IF(NUMSRVY(I).EQ.0) GOTO 80
       READ(2,36) (PERSRVY(I,J),J=1,NUMSRVY(I))
 80  CONTINUE
     ELSE
     ENDIF
     READ(2,32) DELTAT,NMIXNDS
     CLOSE(2)
```

```
      WRITE(6,49)
   49 FORMAT(' ',' ',///)
C---------------- RESIN PRESTAGE/DEGAS ROUTINE -----------------
   50 IF(INTREDO.EQ.1) THEN
        ALPHA(1,1)=0.0D0
        ALPHA(2,1)=0.0D0
        ALPHA(3,1)=0.0D0
        TEMPSTEP=1.0D0
        TPRE=0.0D0
        INTCNT=INT((TIMEDGS(NUMDGS)-TIMEDGS(1))*60.0D0)
        DO 57 IDOC=1,INTCNT
          DO 52 I=1,NUMDGS-1
            IF(TPRE.GE.TIMEDGS(I) .AND.
     +       TPRE.LT.TIMEDGS(I+1)) GOTO 53
   52     CONTINUE
   53     TEMP(1)=((TEMPDGS(I+1)-TEMPDGS(I))*(TPRE-TIMEDGS(I))/
     +    (TIMEDGS(I+1)-TIMEDGS(I)))+273.0D0+TEMPDGS(I)
          CALL RESDATA(1,1)
          DO 54 J=1,3
            ALPHA(J,1)=ALPHA(J,1)+(TEMPSTEP*FRATE(J,1))
   54     CONTINUE
          DO 56 I=1,NUMDGS-1
            IF(TPRE.LT.TIMEDGS(I)+.01 .AND.
     +       TPRE.GT.TIMEDGS(I)-.01) THEN
              ALPPRT(I)=(ALPHA(1,1)*C(1))+(ALPHA(2,1)*C(2))+
     +         (ALPHA(3,1)*C(3))
              VISCPRT(I)=FVISC(1)
            ELSE
            ENDIF
   56     CONTINUE
          TPRE=TPRE+TEMPSTEP/60.0D0
   57   CONTINUE
        ALPHASUM=(ALPHA(1,1)*C(1))+(ALPHA(2,1)*C(2))+(ALPHA(3,1)*
     + C(3))
        ALPPRT(NUMDGS)=ALPHASUM
        VISCPRT(NUMDGS)=FVISC(1)
        ALPHAINT=ALPHASUM
        INTREDO=0
      ELSE
      ENDIF
C--------------- DETERMINATION OF PERMEABILITY DATA -------------------
      IDESIGN=INT((IFAB*1.0D0)/2.0D0+.50D0)
c     print*,'idesign=',idesign
      DO 58 I=1,5
        A(I)=zxy(IFAB,I)
c       print*,'a(',i,') =',a(i)
```

```
  58 CONTINUE
     ZETA=AREALZ(IDESIGN)
     DIAFI=DF(IDESIGN)
     RHOFI=FROE(IDESIGN)
     TUNCPT=FTHCK(IDESIGN)
     IF(IP(IDESIGN).EQ.1) THEN
       IPERM=IP(IDESIGN)
       RKCC=CA(IDESIGN)
       ERR=CB(IDESIGN)
c      print*,'1perm=',iperm,'rkcc=',rkcc,'err=',err
     ELSE
       IPERM=IP(IDESIGN)
c      PRINT*,'CA(',IDESIGN,') =',CA(IDESIGN)
       RMIN=CA(IDESIGN)
       PMIN=CB(IDESIGN)
c     print*,'2perm=',iperm,'Rmin=',Rmin,'pmin=',pmin
     ENDIF
     SPF=SPCF(IDESIGN)
     TCONF=TCONDF(IDESIGN)
     TZF=TCZF(IDESIGN)
     RROE=ROE(IRES)
     SPR=SPCR(IRES)
     TCONR=TCONDR(IRES)
     HR=HRR(IRES)
     SURFTEN=ST(IRES)
     CONTANG=CANGLE(IRES)
C     print*,'surften=',surften,'contang=',contang
     CALL PERMS(TIVAC)
C     print*,'nmixnds=',nmixnds,'nresnds=',nresnds,'nfabnds=',nfabnds
c    FAIL-SAFE COMMANDS FOR PROGRAM (DELTAT AND NMIXNDS)
     TMIN=INT(60.0D0*(TIMEPR(NPRES)-TIMEPR(1))/399.0D0)+1
     TMAX=180.0D0
1000 IF(DELTAT.LT.TMIN .OR. DELTAT.GT.TMAX) THEN
     WRITE(6,1010) TMIN,TMAX
1010 FORMAT(' ','WARNING: FOR PROPER EXECUTION OF THE PROGRAM',/,
    1' ','ENTER A TIME STEP BETWEEN ',/,
    2' ',F6.2,' SECS. AND ',F6.2,' SECS.',/)
     READ(5,1011) DELTAT
1011 FORMAT(E16.8)
     GOTO 1000
     ELSE
     ENDIF
     NODESTM=1
     DO 1020 IJK=1,NUMLAYR
       DO 1015 IJ=1,NUMATRLS
       IF(AMATL(IJK).EQ.AMATLIB(IJ)) THEN
```

```
         NODESTM=NODESTM+INT(HEIGHT(IJK)*NMATNDS(IJ)*2.0D0)
         ELSE
         ENDIF
1015    CONTINUE
1020 CONTINUE
      NODEDENS=(799/2)-NODESTM
      NODEOVR=INT(NODEDENS/(FTHK(NPRES)+RTHK(NPRES))/2)
      IF(NODEOVR.GT.7500) NODEOVR=7500
      NODEUNDR=100
1024 IF(NMIXNDS.LT.NODEUNDR .OR. NMIXNDS.GT.NODEOVR) THEN
      WRITE(6,1027) NODEUNDR,NODEOVR
1027 FORMAT(' ','WARNING: FOR PROPER EXECUTION OF THE PROGRAM',/,
     1' ','ENTER A COMPOSITE MATERIALS FINITE ELEMENT MESH ',/,
     2' ','DENSITY (integer) WHICH IS BETWEEN ',I5,' AND ',I5,/,
     3' ','ELEMENTS PER METER',/)
      READ(6,1028) NMIXNDS
1028 format(i5)
      GOTO 1024
      ELSE
      ENDIF
      NFABNDS=NMIXNDS
      NRESNDS=NMIXNDS
C------------ PRESENTATION OF PROGRAM INPUT VARIABLES --------------
      WRITE(6,60) FN(1)
 60  FORMAT(' ','************** PROGRAM DATA FILE:',A12,
     1' ','****************************')
      WRITE(6,61) ANAME
 61  FORMAT(' ','1) TITLE: --- ',A50)
      WRITE(6,62) AFABRIC(IFAB)
 62  FORMAT(' ','2) FABRIC MODEL: --- ',A70)
      WRITE(6,63) ARESIN(IRES)
 63  FORMAT(' ','3) RESIN MODEL: --- ',A50)
      IF(IRES.EQ.2) C(1)=1.0D0
      ALPHASUM=((C(1)*ALPHA(1,1))+(C(2)*ALPHA(2,1))+
     +(C(3)*ALPHA(3,1)))
      WRITE(6,70) ALPHASUM
 70  FORMAT(' ','4) INITIAL RESIN DEGREE OF CURE: ---  ',E16.8)
      WRITE(6,92) RLGTH,WIDTH
 92  FORMAT(' ','5) LAMINATE DIMENSIONS: ---',/,
     1' ','   LENGTH = ',E16.8,' METERS',/,
     2' ','   WIDTH  = ',E16.8,' METERS')
      WRITE(6,130) NPLIES
130  FORMAT(' ','6) #. OF PLIES IN LAMINATE: ---   ',I3)
      WRITE(6,180)
180  FORMAT(' ','7) RTM LAYUP PROFILE')
      WRITE(6,190)
```

```
 190 FORMAT(' ','8) INFIL/CURE B.C. TEMPERATURE vs. TIME PROFILE')
     WRITE(6,200)
 200 FORMAT(' ','9) INFIL/CURE B.C. PRESSURE vs. TIME PROFILE')
     WRITE(6,205)
 205 FORMAT(' ','10) TEMPERATURE SURVEY PROFILE')
     WRITE(6,206) DELTAT
 206 FORMAT(' ','11) PROGRAM TIME STEP: ---    ',F6.2,' SECS.')
     WRITE(6,207) NMIXNDS
 207 FORMAT(' ','12) COMPOSITE MATERIALS FINITE ELEMENT MESH',/,
    1' ','    DENSITY: --- ',I5,' QUADRATIC ELEMENTS PER METER')
     WRITE(6,210)
 210 FORMAT(' ','*****************************************'
    1'***************************',//)
C------------------ MODIFICATION OF USER INPUT DATA ------------------
     WRITE(6,212)
 212 FORMAT(' ','PLEASE ENTER THE #. OF THE ITEM WHICH IS TO BE',/,
    1' ','MODIFIED (ENTER 0 FOR NONE)')
     READ(5,40) IMOD
     WRITE(6,49)
     IF(IMOD.EQ.0) THEN
       GOTO 399
     ELSEIF(IMOD.EQ.1) THEN
       WRITE(6,215)
 215   FORMAT(' ','ENTER NEW DESIGNATING TITLE FOR PROBLEM',/)
       READ(5,30) ANAME
     ELSEIF(IMOD.EQ.2) THEN
       WRITE(6,217)
 217   FORMAT(' ','ENTER THE #. (integer) FOR THE NEW FABRIC MODEL',/)
       WRITE(6,218) (IFP,AFABRIC(IFP),IFP=1,2*IFABNUM)
 218   FORMAT(' ',I2,') ',A70)
       READ(5,40) IFAB
     ELSEIF(IMOD.EQ.3) THEN
       WRITE(6,220)
 220   FORMAT(' ','ENTER THE #. (integer) FOR THE NEW RESIN MODEL',/,
    1  ' ','1) HERCULES 3501-6',/,
    2  ' ','2) SHELL 1282/878',/)
       READ(5,40) IRES
     ELSEIF(IMOD.EQ.4) THEN
        WRITE(6,230)
 230    FORMAT(' ','RESIN PRESTAGE HISTORY',/,
    1  ' ',' #.      TIME(min)     TEMP(C)    DEGREE of CURE   ',
    2  '  VISCOSITY(Pa.s)',/)
        WRITE(6,231) (I,TIMEDGS(I),TEMPDGS(I),ALPPRT(I),VISCPRT(I),
    +  I=1,NUMDGS)
 231    FORMAT(2X,I3,4X,F10.2,4X,F10.2,4X,F10.8,4X,F10.2)
        WRITE(6,232)
```

```
232     FORMAT(/,' ','ENTER THE #. OF TEMP/TIME STEPS',/,
   1    ' ','(integer) FOR THE RESIN PRESTAGE HISTORY PROFILE',/,
   2    ' ','(ENTER 0 TO KEEP SAME PROFILE)',/)
        READ(5,40) ITEES
        IF(ITEES.EQ.0) GOTO 291
        NUMDGS=ITEES
        DO 237 I=1,NUMDGS
          WRITE(6,236) I,I
236        FORMAT(' ','ENTER TIME(min) (',I3,'), AND TEMP(C)
   +       (',I3,')',/,
   1       ' ','(EXAMPLE: 0.,27.)',/)
          READ(5,43) TIMEDGS(I),TEMPDGS(I)
237     CONTINUE
        INTREDO=1
      ELSEIF(IMOD.EQ.5) THEN
        WRITE(6,240)
240     FORMAT(' ','ENTER THE LENGTH (meters) AND WIDTH (meters) ',/,
   1    ' ','OF THE LAMINATE',/)
        READ(5,43) RLGTH,WIDTH
      ELSEIF(IMOD.EQ.6) THEN
        WRITE(6,250)
250     FORMAT(' ','ENTER THE #. OF PLIES IN THE LAMINATE',/,
   1    ' ','(integer)',/)
        READ(5,40) NPLIES
      ELSEIF(IMOD.EQ.7) THEN
        WRITE(6,252)
252     FORMAT(' ','CURRENT LAYUP PROFILE:',/,
   1    ' ','LAYER #. MATERIAL        HEIGHT (meters)',/)
        DO 259 I=1,NUMLAYR
          IF(AMATL(I).EQ.'FIBER PREFORM' .OR. AMATL(I).EQ.
   +      'RESIN PANEL') THEN
            WRITE(6,253) I,AMATL(I)
253         FORMAT(' ',' ',I3,'    ',A16,'(height det. by RTM model)')
          ELSE
            WRITE(6,254) I,AMATL(I),HEIGHT(I)
254         FORMAT(' ',' ',I3,'    ',A16,'     ',F6.3,'    ')
          ENDIF
259     CONTINUE
        WRITE(6,260)
260     FORMAT(/,' ','ENTER THE #. OF MATERIAL LAYERS (integer)',/,
   1    ' ',' IN THE LAYUP PROFILE (ENTER 0 TO KEEP SAME PROFILE)',/)
        READ(5,40) NTEES
        IF(NTEES.EQ.0) GOTO 291
        NUMLAYR=NTEES
        DO 264 I=1,NUMLAYR
          WRITE(6,262) I
```

```
262       FORMAT(' ','ENTER THE HEIGHT (meters) AND THE  ',/,
   1      ' ','MATERIAL (STEEL, ALUMINUM, FIBER PREFORM,'
   +      ' S GLASS, E GLASS, VACUUM BAG, OR RESIN PANEL FOR LAYER',/,
   2      ' ',' #.',I3,' (ENTER 0. FOR COMPOSITE MATERIAL HEIGHTS)',/)
          READ(5,42) HEIGHT(I),AMATL(I)
264     CONTINUE
       ELSEIF(IMOD.EQ.8) THEN
        IF(ICHCKBC.EQ.1) THEN
         WRITE(6,265)
265       FORMAT(' ','INFIL/CURE TEMPERATURE vs. TIME B.C. PROFILE',/,
   1      ' ',' #.          TIME(min)     UPPER/LOWER TEMP.(Deg.C)',/)
         WRITE(6,266) (I,TIMEIN(I),TAUTO(1,I),I=1,NTEMPS)
266       FORMAT(2X,I3,9X,F10.2,9X,F10.2)
        ELSEIF(ICHCKBC.EQ.2) THEN
         WRITE(6,267)
267       FORMAT(' ','INFIL/CURE TEMPERATURE vs. TIME B.C. PROFILE',/,
   1      ' ',' #.        TIME(min)     UPPER TEMP (Deg. C)     LOWER',
   2      ' TEMP (Deg. C)',/)
         WRITE(6,268) (I,TIMEIN(I),TAUTO(1,I),TAUTO(2,I),I=1,NTEMPS)
268       FORMAT(2X,I3,9X,F10.2,9X,F10.2,9X,F10.2)
        ELSE
        ENDIF
        WRITE(6,269)
269     FORMAT(/,' ','ENTER THE #. OF TEMP/TIMES STEPS (integer)',/,
   1    ' ','FOR THE INFIL/CURE PROFILE (ENTER 0 FOR TO KEEP SAME',/,
   2    ' ','PROFILE)',/)
        READ(5,40) ITEES
        IF(ITEES.EQ.0) GOTO 291
        NTEMPS=ITEES
        WRITE(6,270)
270        FORMAT(' ','ARE BOTH UPPER AND LOWER TEMPERATURE
BOUNDARY ',
   +    'CONDITIONS IDENTICAL (Y/N) ?',/)
        READ(5,33) QUES(16)
        ICHCKBC=1
        IF(QUES(16).EQ.'N') ICHCKBC=2
        IF(ICHCKBC.EQ.1) THEN
          DO 275 I=1,NTEMPS
            WRITE(6,273) I,I
273          FORMAT(' ','ENTER TIME(min) (',I3,') AND UPPER/LOWER B.',
   +         'C. TEMP(Deg. C)  (',I3,')',/)
            READ(5,43) TIMEIN(I),TAUTO(1,I)
            TAUTO(2,I)=TAUTO(1,I)
275       CONTINUE
        ELSEIF(ICHCKBC.EQ.2) THEN
          DO 278 I=1,NTEMPS
```

```
          WRITE(6,276) I,I,I
276        FORMAT(' ','ENTER TIME(min) (',I3,'), UPPER B.C. TEMP ',
   +       'B.C. (Deg. C) (',I3,'), AND LOWER B.C. TEMP (Deg. C)',
   +       ' (',I3,') ',/)
          READ(5,44) TIMEIN(I),TAUTO(1,I),TAUTO(2,I)
278      CONTINUE
      ELSE
      ENDIF
    ELSEIF(IMOD.EQ.9) THEN
      WRITE(6,280)
280   FORMAT(' ','INFIL/CURE PRESSURE vs. TIME PROFILE',/,
   1  ' ',' #.        TIME(min)       COMP. PRES.(Pa)    VAC.'
   2  ' PRES.(Pa)',/)
      WRITE(6,281) (I,TIMEPR(I),TPRESS(I),TIVAC(I),I=1,NPRES)
281   FORMAT(2X,I3,9X,F10.2,9X,F10.2,9X,F10.2)
      WRITE(6,282)
282   FORMAT(/,' ','ENTER THE #. OF TEMP/TIMES STEPS',/,
   1  ' ','  (integer) FOR THE INFIL/CURE PROFILE (ENTER ',/,
   2  ' ','0 FOR TO KEEP SAME PROFILE)',/)
      READ(5,40) ITEES
      IF(ITEES.EQ.0) GOTO 291
      NPRES=ITEES
      DO 285 I=1,NPRES
        WRITE(6,283) I,I,I
283      FORMAT(' ','ENTER TIME(min) (',I3,'), COMP. PRES. (kPa) ',
   1     ' ','(',I3,'), AND VAC. PRES.(kPa) (',I3,')',/)
        READ(5,44) TIMEPR(I),TPRESS(I),TIVAC(I)
285   CONTINUE
    ELSEIF(IMOD.EQ.10) THEN
      IF(QUES(17).EQ.'N') THEN
        WRITE(6,300)
300          FORMAT(' ','NO TEMPERATURE SURVEY IS CURRENTLY
SELECTED.',/,
   1    ' ','DO YOU WISH TO HAVE A RECORD OF TEMPERATURES AS A ',/,
   2    ' ','FUNCTION OF TIME FOR PARTICULAR DEPTH LOCATIONS',
   +    ' (Y/N)?.',/)
        READ(5,33) QUES(17)
      ELSEIF(QUES(17).EQ.'Y') THEN
        WRITE(6,307)
307     FORMAT(' ','TEMPERATURE SURVEY :',//)
        DO 340 I=1,NUMLAYR
          WRITE(6,310) I,AMATL(I),NUMSRVY(I)
310        FORMAT(' ','LAYER #.: ',I2,' MATERIAL:',A16,'#. OF TEMP',
   +       ' SURVEY POINTS:',I2,/)
          IF(NUMSRVY(I).EQ.0) GOTO 340
          WRITE(6,320) (I,J,PERSRVY(I,J),J=1,NUMSRVY(I))
```

```
320        FORMAT(' ','POSITION OF CHECK POINT (',I2,',',I2,') ',/,
  1       ' ','(% OF DEPTH FROM TOP OF LAYER): ',F6.3' ',/)
340     CONTINUE
      WRITE(6,343)
343    FORMAT(' ','DO YOU WISH TO HAVE A TEMP. SURVEY FOR THE ',
  +    ' SIMULATION (Y/N)?',/)
      READ(5,33) QUES(17)
      WRITE(6,347)
347    FORMAT(' ','DO YOU WANT TO KEEP THE SAME TEMPERATURE ',/,
  +    ' ','SURVEY (Y/N) ?',/)
      READ(5,33) QUES(18)
      ELSE
      ENDIF
      IF(QUES(17).EQ.'N') THEN
       WRITE(6,351)
351      FORMAT(' ','NO TEMPERATURE SURVEY HAS BEEN SELECTED',/)
      ELSEIF(QUES(17).EQ.'Y') THEN
       IF(QUES(18).EQ.'Y') GOTO 291
       DO 380 I=1,NUMLAYR
          WRITE(6,360) I,AMATL(I)
360         FORMAT(' ','ENTER THE #. OF SURVEY PTS. (integer)',/,
  1         ' ','FOR LAYER #. ',I2,' (',A16,') (DEFAULT=0)',//)
          READ(6,40) NUMSRVY(I)
          IF(NUMSRVY(I).EQ.0) GOTO 380
          DO 370 J=1,NUMSRVY(I)
             WRITE(6,366) J,I,AMATL(I)
366            FORMAT(' ','ENTER LOCATION OF TEMP SURVEY PT.'
  +            ' #.:',I2,/,
  1            ' ','IN TERMS OF % DEPTH FROM TOP OF LAYER #.:',I2,/,
  2            ' ','(',A16,') ',/)
             READ(5,36) PERSRVY(I,J)
370         CONTINUE
380      CONTINUE
      ELSE
      ENDIF
    ELSEIF(IMOD.EQ.11) THEN
       WRITE(6,382) TMIN,TMAX
382     FORMAT(' ','FOR PROPER EXECUTION OF THE PROGRAM',/,
  1    ' ','ENTER A TIME STEP BETWEEN ',/,
  2    ' ',F6.2,' SECS. AND ',F6.2,' SECS.',/)
       READ(5,385) DELTAT
385     FORMAT(E16.8)
    ELSEIF(IMOD.EQ.12) THEN
       WRITE(6,394) NODEUNDR,NODEOVR
394     FORMAT(' ','FOR PROPER EXECUTION OF THE PROGRAM',/,
  1    ' ','ENTER A COMPOSITE MATERIALS FINITE ELEMENT MESH ',/,
```

```
  2   ' ','DENSITY (integer) WHICH IS BETWEEN ',I5,' AND ',I5,/,
  3   ' ','ELEMENTS PER METER',/)
      READ(6,395) NMIXNDS
 395   format(i5)
    ELSE
    ENDIF
 291 WRITE(6,49)
    GOTO 50
C----------------------- FORMAT READ STATEMENTS ----------------------
 30  FORMAT(A70)
 31  FORMAT(' ','INPUT DATA FILE: ',A30)
 33  FORMAT(A1)
 36  FORMAT(E16.8)
 39  FORMAT(4I4)
 40  FORMAT(I4)
 41  FORMAT(A16,E16.8)
 42  FORMAT(E16.8,A16)
 43  FORMAT(2E16.8)
 45  FORMAT(2I4)
 44  FORMAT(3E16.8)
 32  FORMAT(E16.8,I4)
C--------------------- WRITE OUT TO NEW DATA FILE -------------------
 399 WRITE(6,400)
 400 FORMAT(' ','DO YOU WISH TO STORE THE CHANGES IN A NEW',
   1' ','DATA FILE (Y/N)',/)
    READ(5,33) QUES(2)
    IF(QUES(2).NE.'Y') GOTO 500
    WRITE(6,430)
 430 FORMAT(' ','ENTER THE NAME OF A NEW INPUT DATA FILE',//)
    READ(5,30) FN(2)
    OPEN(3,FILE=FN(2),STATUS='NEW')
    WRITE(3,31) FN(2)
    WRITE(3,30) ANAME
    WRITE(3,45) IFAB,IRES
    WRITE(3,30) AFABRIC(IFAB)
    WRITE(3,30) ARESIN(IRES)
    WRITE(3,40) NUMDGS
    WRITE(3,43) (TIMEDGS(I),TEMPDGS(I),I=1,NUMDGS)
    WRITE(3,44) ALPHA(1,1),ALPHA(2,1),ALPHA(3,1)
    WRITE(3,43) RLGTH,WIDTH
    WRITE(3,40) NPLIES
    WRITE(3,40) NUMLAYR
    WRITE(3,41) (AMATL(I),HEIGHT(I),I=1,NUMLAYR)
    WRITE(3,45) NTEMPS,ICHCKBC
    IF(ICHCKBC.EQ.1) THEN
      WRITE(3,43) (TIMEIN(I),TAUTO(1,I),I=1,NTEMPS)
```

```
      ELSEIF(ICHCKBC.EQ.2) THEN
        WRITE(3,44) (TIMEIN(I),TAUTO(1,I),TAUTO(2,I),I=1,NTEMPS)
      ELSE
      ENDIF
      WRITE(3,45) NPRES,NRMS
      WRITE(3,44) (TIMEPR(I),TPRESS(I),TIVAC(I),I=1,NPRES)
      WRITE(3,33) QUES(17)
      IF(QUES(17).EQ.'Y') THEN
      DO 460 I=1,NUMLAYR
        WRITE(3,40) NUMSRVY(I)
        IF(NUMSRVY(I).EQ.0) GOTO 460
        WRITE(3,36) (PERSRVY(I,J),J=1,NUMSRVY(I))
 460  CONTINUE
      ELSE
      ENDIF
      WRITE(3,32) DELTAT,NMIXNDS
      CLOSE(3)
 500  RETURN
      END
C-----------------------------------------------------------------
C ** CALCULATES THE MATERIAL PERMEABILITY TENSOR                  **
C-----------------------------------------------------------------
      SUBROUTINE PERMS(TIVAC)
      COMMON/BCS/ TIMEIN(200),TAUTO(2,200),
     1     TIMEPR(7),TPRESS(7),TVAC(7),NTEMPS,NPRES,ICHCKBC
      COMMON RPERM(7)
      COMMON/FABSIN/ A(5),COMPP(7),RLGTH,WIDTH,RVOL(7),RTHK(7),
     1     TUNCPT,ZETA,DIAFI,RHOFI,RKCC,PORO(7),FTHK(7),NPLIES,
     2    TCONF,TZF,SPF,NFABNDS,TCONR,SPR,RROE,NRESNDS,HR,RMASS(7),
     3     SPMIX(7),ROEMIX(7),TKTZMIX(7),FABINFIL(7),NMIXNDS,VF(7),
     4     IPERM,ERR,RMIN,PMIN,SURFTEN,CONTANG,
     5     TCONFAB(7),SPFAB(7),RHOFAB(7)
      DIMENSION RLNP(7),DEFL(7),TIVAC(7)
C **  CALCULATES THE DEFORMED THICKNESS  **
      DO 100 I=1,NPRES
        COMPP(I)=TPRESS(I)
        RLNP(I)=DLOG(COMPP(I)/1000.0D0)
c       print*,'a(1)=',a(1),'a(2)=',a(2),'a(3)=',a(3),
c    +  'a(4)=',a(4),'a(5)=',a(5)
        DEFL(I)=A(1)+(A(2)*RLNP(I))+(A(3)*(RLNP(I)**2.0D0))+
     1  (A(4)*(RLNP(I)**3.0D0))+(A(5)*(RLNP(I)**4.0D0))
        FTHK(I)=NPLIES*(TUNCPT-DEFL(I))
c       print*,'fthk(',i,') =',fthk(i)
C **  CALCULATES POROSITY AND PERMEABILITY  **
c       print*,'zeta=',zeta
c       print*,'tuncpt=',tuncpt
```

```
C        print*,'rhofi=',rhofi
         PORO(I)=1.D0-NPLIES*ZETA/FTHK(I)/RHOFI
c        print*,'contang=',contang,'surften=',surften
         TVAC(I)=TIVAC(I)-((4.0d0*SURFTEN/DIAFI)*((1.0D0-PORO(I))/
     +   PORO(I))*DCOS(CONTANG))
c        print*,'tvac(',i,') =',tvac(i)
         VF(I)=1.0D0-PORO(I)
c        print*,'poro(',i,') =',poro(i)
c        print*,'diafi=',diafi
c        print*,'rkcc=',rkcc
c        print*,'Rmin=',Rmin
         IF(IPERM.EQ.1) THEN
           RPERM(I)=(DIAFI**2.0D0)*((1.0D0/RKCC)*((PORO(I)**3.0D0)/
     +     ((1.0D0-PORO(I))**2.0D0))+ERR)
         ELSE
c          print*,'diafi=',diafi,'poro(',i,') =',poro(i)
           RPERM(I)=(DIAFI**2.0D0)*(RMIN*.25D0*(((((1.0D0-PMIN)/
     +     (1.0D0-PORO(I)))**.50D0)-1.0D0)**2.50D0))
c          print*,'Rmin=',Rmin,'pmin=',pmin
         ENDIF
c        print*,'rperm(',i,') =',rperm(i)
         RVOL(I)=FTHK(I)*RLGTH*WIDTH*PORO(I)
         RTHK(I)=FTHK(I)*PORO(I)
         RMASS(I)=RROE*RVOL(I)*1000.0D0
C ** CALULATION OF MIXED PROPERTIES **
         C1=(1.0D0-PORO(I))/3.1415926D0
         B=2.0D0*(TCONR/TCONF-1.0D0)
         C2=SQRT(1.0D0-(B*B*C1))
         C3=C2/(1.0D0+B*SQRT(C1))
         TKTZMIX(I)=(1.0D0-2.0D0*SQRT(C1))*TCONR+TCONR/B*
     +             (3.1415926D0-4.0D0/C2*ATAN(C3))
         SPMIX(I)=(PORO(I)*SPR)+((1.0D0-PORO(I))*SPF)
         ROEMIX(I)=(PORO(I)*RROE)+((1.0D0-PORO(I))*RHOFI)
C ** CALCULATION OF DRY FABRIC PREFORM PROPERTIES **
         TCONFAB(I)=TZF*VF(I)
c        print*,'tconfab(',i,') =',tconfab(i)
         SPFAB(I)=SPF
c        print*,'spfab(',i,') =',spfab(i)
         RHOFAB(I)=RHOFI*VF(I)
c        print*,'rhofab(',i,') =',rhofab(i)
 100  CONTINUE
C     CORRECTIONS FOR INITIAL THERMAL CONSTANTS OF DRY PREFORM
      RETURN
      END
     SUBROUTINE GETZ(AMATLIB,AMATL,IFCMPT,ISRT,IRESRT,IEND,
     + IADFAB,IADR)
```

```
C---------------------------------------------------------------
C    SUBROUTINE TO GET THERMAL CNTS. AND DITRIBUTIONS
C---------------------------------------------------------------
      CHARACTER*17 AMATLIB(12),AMATL(12)
      COMMON/FABSIN/ A(5),COMPP(7),RLGTH,WIDTH,RVOL(7),RTHK(7),
     1     TUNCPT,ZETA,DIAFI,RHOFI,RKCC,PORO(7),FTHK(7),NPLIES,
     2   TCONF,TZF,SPF,NFABNDS,TCONR,SPR,RROE,NRESNDS,HR,RMASS(7),
     3     SPMIX(7),ROEMIX(7),TKTZMIX(7),FABINFIL(7),NMIXNDS,VF(7),
     4     IPERM,ERR,RMIN,PMIN,SURFTEN,CONTANG,
     5     TCONFAB(7),SPFAB(7),RHOFAB(7)
      COMMON/LAYUP/ NUMATRLS,HEIGHT(12),THICK(12),
     1     ROEM(12),SPCM(12),TKM(12),NMATNDS(12),NUMSRVY(12),
     2     PERSRVY(12,12),POSRVY(12,12)
      COMMON/HEATCOEF/ TKCOEF(3,3),CNCOEF(3,3),NUMNDS(12),NUMLAYR,
     1     DELZ(12,400),TKTZ(12,400),CP(12,400),RHO(12,400),
     2     TKG(799,3),CG(799,3),PHETA,DELTAT,
     3     TKBTPT(799,3),TKBT(799,3)
C------------ DETERMINATION OF THERMAL CNTS.  --------------------
      IJ=0
      IADFAB=0
      IADMIX=0
      IADR=0
      IDA=0
      DO 1100 I=1,NUMLAYR
c       print*,'I=',I
        THICK(I)=0.0D0
        DO 1070 J=1,NUMATRLS
        IF(AMATL(I).EQ. AMATLIB(J)) THEN
          NUMNDS(I)=(INT(HEIGHT(I)*NMATNDS(J)))*2+1
          ichka=int(height(i)*nmatnds(j))
C          print*,'ichka=',ichka,'numnds(',i,') = ichka+3 =',numnds(i)
          IF(IDA.EQ.0) IJ=IJ+NUMNDS(I)+(1-i)
          DO 1010 K=1,NUMNDS(I)
            IF(K.GT.NUMNDS(I)-2) THEN
              DELZ(I,K)=HEIGHT(I)-THICK(I)+1.0d0/nmatnds(j)
            ELSE
              DELZ(I,K)=1.0D0/NMATNDS(J)
            endif
            IOVR=2*(K/2)
            IF(K.EQ.IOVR) THICK(I)=THICK(I)+DELZ(I,K)
            TKTZ(I,K)=TKM(J)
c           print*,'tktz(',i,',',k,') =',tktz(i,k)
            CP(I,K)=SPCM(J)
            RHO(I,K)=ROEM(J)
 1010     CONTINUE
          GOTO 1100
```

```
      ELSEIF(AMATL(I).EQ.'FIBER PREFORM') THEN
        IDA=1
        NUMNDS(I)=INT(FTHK(IFCMPT)*NFABNDS)*2+1
        ichkb=int(fthk(ifcmpt)*nfabnds)
C        print*,'ichkb=',ichkb,'numnds(',i,') =',numnds(i)
        IADFAB=NUMNDS(I)
        DO 1020 K=1,NUMNDS(I)
          IF(K.GT.NUMNDS(I)-2) THEN
            DELZ(I,K)=FTHK(IFCMPT)-THICK(I)+1.0d0/nfabnds
          ELSE
            DELZ(I,K)=1.0D0/NFABNDS
          endif
          IOVR=2*(K/2)
          IF(K.EQ.IOVR) THICK(I)=THICK(I)+DELZ(I,K)
          TKTZ(I,K)=TCONFAB(IFCMPT)
c         print*,'tktz(',i,',',k,')=',tktz(i,k)
          CP(I,K)=SPFAB(IFCMPT)
          RHO(I,K)=RHOFAB(IFCMPT)
 1020    CONTINUE
        GOTO 1100
      ELSEIF(AMATL(I).EQ.'SATURATED PREFORM') THEN
        IDA=1
        NUMNDS(I)=INT(FABINFIL(IFCMPT)*NMIXNDS)*2+1
        ichkc=int(fabinfil(ifcmpt)*nmixnds)
C        print*,'ichkc=',ichkc,'numnds(i)=',numnds(i)
        IADMIX=NUMNDS(I)-1
        DO 1025 K=1,NUMNDS(I)
          IF(K.GT.NUMNDS(I)-2) THEN
            DELZ(I,K)=FABINFIL(IFCMPT)-THICK(I)+1.0d0/nmixnds
          ELSE
            DELZ(I,K)=1.0D0/NMIXNDS
          endif
          IOVR=2*(K/2)
          IF(K.EQ.IOVR) THICK(I)=THICK(I)+DELZ(I,K)
          TKTZ(I,K)=TKTZMIX(IFCMPT)
c         print*,'tktz(',i,',',k,') =',tktz(i,k)
          CP(I,K)=SPMIX(IFCMPT)
          RHO(I,K)=ROEMIX(IFCMPT)
 1025    CONTINUE
        GOTO 1100
      ELSEIF(AMATL(I).EQ.'RESIN PANEL') THEN
        IDA=1
        NUMNDS(I)=(INT(RTHK(IFCMPT)*NRESNDS))*2+1
        ichkd=int(rthk(ifcmpt)*nresnds)
C        print*,'ichkd=',ichkd,'numnds(i)=',numnds(i)
        IADR=NUMNDS(I)
```

```
        DO 1030 K=1,NUMNDS(I)
          IF(K.GT.NUMNDS(I)-2) THEN
            DELZ(I,K)=RTHK(IFCMPT)-THICK(I)+1.0d0/nresnds
          ELSE
            DELZ(I,K)=1.0D0/NRESNDS
          endif
          IOVR=2*(K/2)
          IF(K.EQ.IOVR) THICK(I)=THICK(I)+DELZ(I,K)
          TKTZ(I,K)=TCONR
c         print*,'tktz(',i,',',k,') =',tktz(i,k)
          CP(I,K)=SPR
          RHO(I,K)=RROE
 1030    CONTINUE
        GOTO 1100
      ELSE
      ENDIF
 1070  CONTINUE
 1100 CONTINUE
C     print*,'IJ =',IJ
      ISRT=IJ+IADFAB
C     print*,'isrt=',isrt
      IRESRT=ISRT+IADMIX
C     print*,'iresrt=',iresrt
      IEND=IRESRT+IADR-1
C     print*,'iend=',iend
      RETURN
      END
      SUBROUTINE GETKCRK(ICLEAR,IR,IC)
      COMMON/HEATCOEF/ TKCOEF(3,3),CNCOEF(3,3),NUMNDS(12),NUMLAYR,
     1      DELZ(12,400),TKTZ(12,400),CP(12,400),RHO(12,400),
     2      TKG(799,3),CG(799,3),PHETA,DELTAT,
     3      TKBTPT(799,3),TKBT(799,3)
      DIMENSION TKT(3,3),CNL(3,3)
C-----------------------------------------------------------------
C     SUBROUTINE FOR DET. OF [K] AND [C] GLOBAL
C-----------------------------------------------------------------
C     GENERATION OF LOCAL [K]'S AND [C]'S
      ITP=0
      DO 80 I=1,NUMLAYR
       DO 75 ILP=2,NUMNDS(I)-1,2
       ITP=ITP+2
        DO 70 JLP=1,3
         DO 65 KLP=1,4-JLP
          TKT(JLP,KLP)=TKCOEF(JLP,KLP)*(TKTZ(I,ILP)/DELZ(I,ILP))
          CNL(JLP,KLP)=(CP(I,ILP)*RHO(I,ILP)*DELZ(I,ILP))*
     +             (CNCOEF(JLP,KLP))
```

```
  65    CONTINUE
  70   CONTINUE
C     SEND OFF TO LOCAL ASSEMBLER
      CALL ASSEMBLY(ICLEAR,ITP,TKT,TKG)
      CALL ASSEMBLY(ICLEAR,ITP,CNL,CG)
  75  CONTINUE
  80 CONTINUE
     IR=ITP+1
     IC=3
c--------------    det. of individual W-pheta parts     -----------
     DO 120 I=1,IR
       DO 115 J=1,IC
       TKBTPT(I,J)=((PHETA*TKG(I,J))+(CG(I,J)/DELTAT))
       TKBT(I,J)=((CG(I,J)/DELTAT)-((1-PHETA)*TKG(I,J)))
 115    CONTINUE
 120 CONTINUE
C------------------------------------------------------------------
     RETURN
     END
     SUBROUTINE ASSEMBLY(ICLEAR,ILP,AL,AG)
     DIMENSION AL(3,3),AG(799,3)
C------------------------------------------------------------------
C     ASSEMBLY ROUTINE (QUADRATIC 1-D ELEMENT)
C------------------------------------------------------------------
     IF(ICLEAR.EQ.1) THEN
       DO 172 IERASE=1,400
         DO 171 J=1,3
         AG(IERASE,J)=0.0D0
 171      CONTINUE
 172    CONTINUE
       ICLEAR=0
     ELSE
     ENDIF
     IF(ILP.EQ.2) THEN
       DO 180 I=1,3
         DO 175 J=1,4-I
         AG(I,J)=AL(I,J)
 175      CONTINUE
 180    CONTINUE
     ELSE
       DO 190 I=1,3
         DO 185 J=1,3
         AG((ILP-2)+I,J)=AG((ILP-2)+I,J)+AL(I,J)
 185      CONTINUE
 190    CONTINUE
     ENDIF
```

```
C-----------------------------------------------------------------
      RETURN
      END
C-----------------------------------------------------------------
C ** CALCULATES THE DEGREE OF CURE AND VISCOSITY OF THE RESIN
  **
C-----------------------------------------------------------------
      SUBROUTINE RESDATA(ISRT,IEND)
      COMMON/RESIN/ TEMP(799),ALPHA(3,799),FRATE(3,799),FVISC(799),
     1       IRES,ARES(3),C(3),ER(3),AN(3),CONE,CTWO,
     2       AA(8),A1(4),E1(4),A2(4),E2(4),R,RMUINF,CAPU
      DIMENSION RM(4),RN(4)
c     print*,'resin - in'
      DO 700 I=ISRT,IEND,1
C *****************  RESIN ROUTINES  *********************
      IF(IRES.EQ.1) THEN
C--------- HERCULES 3501-6 ROUTINE C/L--------------------------
c     print*,'temp(',i,') =',temp(i)
        DO 100 J=1,3
c          print*,'alpha(',j,',',i,') =',alpha(j,i)
           if(alpha(j,i).ge.1.0d0) alpha(j,i)=0.99999990d0
           FRATE(J,I)=(ARES(J)*DEXP((-ER(J))/
     +      TEMP(I)))*((1-ALPHA(J,I))**AN(J))
  100   CONTINUE
C     Determination of Viscosity
      ALPHASUM=((C(1)*ALPHA(1,I))+(C(2)*ALPHA(2,I))+
     +(C(3)*ALPHA(3,I)))
C     print*,'alphasum=',alphasum
      TG=(283.420D0+(196.50D0*ALPHASUM)-(925.40D0*
     +(ALPHASUM**2.0D0))+(3435.0D0*(ALPHASUM**3.0D0))-
     +(4715.0D0*(ALPHASUM**4.0D0))+(2197.0D0*(ALPHASUM**5.0D0)))
c     print*,'alphasum(',i,') =',alphasum
      IF(ALPHASUM.GE.0.50D0) THEN
        VTG=(1.0D+12)
      ELSE
        VTG=DEXP(20.720D0+(8.560D0*ALPHASUM)-
     +  (9.690D0*(ALPHASUM**2.0D0))+(41.170D0*(ALPHASUM**3.0D0)))
c       print*,'vtg(',i,') =',vtg
      ENDIF
      IF(TEMP(I).LT.TG) THEN
        FVISC(I)=VTG
      ELSE
        FVISC(I)=VTG*DEXP((CONE*(TG-TEMP(I)))/(CTWO+(TEMP(I)-TG)))
c       print*,'fvisc(',i,') =',fvisc(i)
      ENDIF
      ELSEIF(IRES.EQ.2) THEN
```

```
C--------- SHELL 1282/878 ROUTINE -------------------------------
       IF(TEMP(I).LE.383.0D0) THEN
         ICH=1
       ELSEIF(TEMP(I).LE.408.0D0 .AND. TEMP(I).GT.383.0D0) THEN
         ICH=2
       ELSEIF(TEMP(I).LE.422.0D0 .AND. TEMP(I).GT.408.0D0) THEN
         ICH=3
       ELSE
         ICH=4
       ENDIF
       IF(ICH.EQ.1) THEN
         RM(ICH)=0.57760D0
         RN(ICH)=2.0340D0
       ELSE
         RM(ICH)=AA(4)+TEMP(I)*(AA(3)+TEMP(I)*(AA(2)+TEMP(I)*AA(1)))
         RN(ICH)=AA(8)+TEMP(I)*(AA(7)+TEMP(I)*(AA(6)+TEMP(I)*AA(5)))
       ENDIF
       RKMU=AMU*DEXP(-EMU/R/TEMP(I))
       RK1=A1(ICH)*DEXP(-E1(ICH)/R/TEMP(I))
       RK2=A2(ICH)*DEXP(-E2(ICH)/R/TEMP(I))
       FRATE(1,I)=(RK1+(RK2*ALPHA(1,I)**RM(ICH)))*
     +  ((1.0D0-ALPHA(1,I))**RN(ICH))/60.0D0
       FVISC(I)=RMUINF*EXP(CAPU/R/TEMP(I)+RKMU*ALPHA(1,I))
      ELSE
      ENDIF
C     print*,'fvisc(',i,') =',fvisc(i)
 700  CONTINUE
C------------------------------------------------------------------
c     print*,'resin - out'
      RETURN
      END
      SUBROUTINE VISCOEF(ITME,IFLSRT)
C------------------ VISCOSITY PREDICTOR SUBROUTINE -----------------
      COMMON/VISCPDT/ IVISCTME,TVTIME(3),VD(799,3),VISC(799,3)
C      < SEPARATION INTO CNST., LINEAR, OR, QUADRATIC VISC.
FORMULATIONS >
C     print*,'iflsrt=',iflsrt
      DO 702 I=1,1+IFLSRT
      IF(ITME.EQ.1) THEN
        VISC(I,1)=0.0D0
        VISC(I,2)=0.0D0
        VISC(I,3)=VD(I,3)
      ELSEIF(ITME.EQ.2) THEN
        VISC(I,1)=0.0D0
        VISC(I,2)=(VD(I,3)-VD(I,2))/(TVTIME(3)-TVTIME(2))
        VISC(I,3)=((VD(I,3)*TVTIME(2))-(VD(I,2)*TVTIME(3)))/
```

```
     +         (TVTIME(2)-TVTIME(3))
      ELSE
        A=VD(I,1)/((TVTIME(1)-TVTIME(2))*(TVTIME(1)-TVTIME(3)))
        B=VD(I,2)/((TVTIME(2)-TVTIME(1))*(TVTIME(2)-TVTIME(3)))
        C=VD(I,3)/((TVTIME(3)-TVTIME(1))*(TVTIME(3)-TVTIME(2)))
        VISC(I,1)=A+B+C
        VISC(I,2)=(-A)*(TVTIME(2)+TVTIME(3))+(-B)*(TVTIME(1)+
     +         TVTIME(3))+(-C)*(TVTIME(1)+TVTIME(2))
        VISC(I,3)=(A*TVTIME(2)*TVTIME(3))+(B*TVTIME(1)*TVTIME(3))+
     +         (C*TVTIME(1)*TVTIME(2))
      ENDIF
  702 CONTINUE
C-------------------------------------------------------------------
      RETURN
      END
C-------------------------------------------------------------------
      SUBROUTINE INFIL(TIME,DELTAT,IFCMPT,NMIXNDS,RPERM,TKCOEF,
     1NUMSMPT,COMPP,TVAC,FABINFIL,IFLSRT,PORO)
C-------------------------------------------------------------------
      COMMON/VISCPDT/ IVISCTME,TVTIME(3),VD(799,3),VISC(799,3)
      COMMON/FLOWFRNT/ NFBCNDS,FLP(799),PRES(799),PL(3,3),PG(799,3),
     1      DELJMP(799),QG(799,1),HRESIDUE(40)
      DIMENSION RPERM(7),TKCOEF(3,3),COMPP(7),VISCFL(799),TVAC(7),
     1VISP(799),NIP(2),NJP(2),FABINFIL(7),PORO(7)
      NFLBCNDS=2
      NUMSMPT=1
      ICHK=1
      TMOD=TIME
      DELTAINF=DELTAT/IVISCTME
C<<<< DET. OF VISC(min) FOR INTERMEDIATE THERMAL TIME STEP >>>>
      DO 799 IVTSC=1,IVISCTME
        IREDO=0
        TMOD=TMOD+(DELTAINF/60.0D0)
C        print*,'ivtsc =',ivtsc,'tmod=',tmod
        IFLCLR=1
        DO 703 IVISC=1,1+IFLSRT
          VISCFL(IVISC)=(VISC(IVISC,1)*(TMOD**2.0D0))+
     +                (VISC(IVISC,2)*TMOD)+VISC(IVISC,3)
C          print*,'viscfl(',ivisc,') =',viscfl(ivisc)
  703   CONTINUE
C<<<< DET. OF CNTS. FOR SATURATED LAYERS (based on therm and res.) >>>>
  705   IFLCLR=1
        DO 707 I=1,IFLSRT
          DELJMP(I)=1.0D0/NMIXNDS
          VISP(I)=VISCFL(I)
  707   CONTINUE
```

```
      DO 709 I=1+IFLSRT,IRESIDUE+IFLSRT+1
        DELJMP(I)=HRESIDUE(I-IFLSRT)
        IF(DELJMP(I).LE.0.0D0) DELJMP(I)=0.1D-10
        VISP(I)=VISCFL(1+IFLSRT)
 709  CONTINUE
C     print*,'infiltration phase initial cnsts.'
C     print*,' #.      deljmp        visp'
      do 710 i=1,iresidue+iflsrt+1
C       print*,'  ',i,'  ',deljmp(i),'    ',visp(i)
 710  continue
C<<<< GENERATION OF LOCAL PRES. DISTRIBUTION MATRIX >>>>
      DO 723 I=1,IFLSRT+IRESIDUE+1
        DO 717 J=1,3
          DO 711 K=1,4-J
          PL(J,K)=((-RPERM(IFCMPT))/(DELJMP(I)*
     +          VISP(I)))*TKCOEF(J,K)
 711        CONTINUE
 717      CONTINUE
        IPFLOW=I*2
C       print*,'ipflow=',ipflow
        CALL ASSEMBLY(IFLCLR,IPFLOW,PL,PG)
        IFLCLR=0
 723  CONTINUE
      IRFLOW=IPFLOW+1
      ICFL=3
      DO 727 I=1,IRFLOW
        QG(I,1)=0.0D0
 727  CONTINUE
C<<<< IMPOSITION OF FLOW BCNDS >>>>
      NIP(1)=1
      NJP(1)=1
      NIP(2)=IRFLOW
      NJP(2)=NIP(2)
      PRES(1)=COMPP(IFCMPT)
      PRES(IRFLOW)=TVAC(IFCMPT)
C<<<< DET. OF DISTRIBUTED PRESSURES (BASED ON CONTINUITY EQ.) >>>>
C     print*,'call to infil reducer'
      CALL REDUCER(IRFLOW,ICFL,NIP,NFLBCNDS,PG,QG,PRES,NROWFL)
C     print*,'nfowfl =',nrowfl
C     print*,'call to infil gausjord'
      CALL GAUSJORD(ICFL,ICHK,NFLBCNDS,NJP,NROWFL,PG,QG,PRES)
C<<<<<< RE-ESTABLISHMENT OF PRESSURE BC'S >>>>>>>>>
      PRES(1)=COMPP(IFCMPT)
C     print*,'distributed pressures'
      do 732 i=1,irflow
C       print*,'pres(',i,') =',pres(i)
```

```
 732    continue
C<<<< DET. OF FLOW FRONT ADVANCEMENT (BASED UPON MIDDLE OF
NODE) >>>>
       ZETA=0.0d0
       ZSUM=((-.50D0)*(1.0D0-ZETA)*PRES(IRFLOW-2))+((-2.0D0)*
   +       ZETA*PRES(IRFLOW-1))+(.50D0*(1.0D0+ZETA)*PRES(IRFLOW))
C       print*,'zsum=',zsum
C       print*,'VISP(',IFLSRT+1,')=',visp(iflsrt+1)
       HADD=(abs((-DELTAINF)*(2.0D0/VISP(IFLSRT+1))*
   +       (RPERM(IFCMPT)/PORO(IFCMPT))*ZSUM))**0.50D0
C       print*,'hadd',hadd
C<<<< REINTERATION SCHEME >>>>
       IREDO=IREDO+1
C       print*,'reinteration step #.',iredo
       IF(IREDO.GT.4) THEN
         IRESIDUE=1
         HRESIDUE(IRESIDUE+1)=HADD
         HRESIDUE(IRESIDUE)=HRESIDUE(IRESIDUE)+(HADD*RESET)
         RESET=1.0D0
         GOTO 799
       ELSE
         HRESIDUE(IRESIDUE+1)=HADD
         GOTO 705
       ENDIF
 799 CONTINUE
C<<<< REDUCTION OF OVERALL MESH DENSITY >>>>
 801    HTCHK=(1.0D0/NMIXNDS)
       HTADD=HRESIDUE(IRESIDUE)
C       print*,'htadd =',htadd
       IF(HTADD.GE.HTCHK) THEN
         IFLSRT=IFLSRT+1
C         print*,'iflsrt=',iflsrt
         HTADD=(HTADD-HTCHK)
       ELSE
       ENDIF
      HRESIDUE(1)=HTADD
C      print*,'hresidue(1)=',hresidue(1)
      FABINFIL(IFCMPT)=HTADD+((1.0D0/NMIXNDS)*IFLSRT)
C      print*,'fabinfil(',ifcmpt,') =',fabinfil(ifcmpt)
C-----------------------------------------------------------------
      RETURN
      END
C-----------------------------------------------------------------
      SUBROUTINE TTIME(iprint,IR,IC,ISRT,IEND,TR,TS)
C-----------------------------------------------------------------
      COMMON/FABSIN/ A(5),COMPP(7),RLGTH,WIDTH,RVOL(7),RTHK(7),
```

```
     1     TUNCPT,ZETA,DIAFI,RHOFI,RKCC,PORO(7),FTHK(7),NPLIES,
     2    TCONF,TZF,SPF,NFABNDS,TCONR,SPR,RROE,NRESNDS,HR,RMASS(7),
     3     SPMIX(7),ROEMIX(7),TKTZMIX(7),FABINFIL(7),NMIXNDS,VF(7),
     4     IPERM,ERR,RMIN,PMIN,SURFTEN,CONTANG,
     5     TCONFAB(7),SPFAB(7),RHOFAB(7)
      COMMON/RESIN/ TEMP(799),ALPHA(3,799),FRATE(3,799),FVISC(799),
     1     IRES,ARES(3),C(3),ER(3),AN(3),CONE,CTWO,
     2     AA(8),A1(4),E1(4),A2(4),E2(4),R,RMUINF,CAPU
      COMMON/TEMPDET/ NI(12),NJ(12),NBCS,GFM(799,1),TKFM(799,1),
     1     VFR(799),DZS(799)
      COMMON/HEATCOEF/ TKCOEF(3,3),CNCOEF(3,3),NUMNDS(12),NUMLAYR,
     1     DELZ(12,400),TKTZ(12,400),CP(12,400),RHO(12,400),
     2     TKG(799,3),CG(799,3),PHETA,DELTAT,
     3     TKBTPT(799,3),TKBT(799,3)
      DIMENSION GOV(799,1),UR(799,1),RTT(799,1)
c --------------    multiplication of load vector    ----------------
C     print*,'ttime'
      ICHK=2
      DO 145 I=1,IR
        DO 143 J=I-IC,I+IC
        IF(J.GT.I) THEN
          K=I
          L=J
          IF(L.LT.1) GOTO 143
          IF((L-K+1).GT.IC) GOTO 143
        ELSEIF(J.LT.I .OR. J.EQ.I) THEN
          K=J
          L=I
          IF(K.LT.1) GOTO 143
          IF((L-K+1).GT.IC) GOTO 143
        ELSEIF(J.GT.IR) THEN
          GOTO 143
        ELSE
        ENDIF
        GOV(I,1)=GOV(I,1)+(TKBT(K,(L-K+1))*TEMP(J))
  143   CONTINUE
  145 CONTINUE
C------------------------- INITIAL HEAT VECTOR ---------------------
      DO 146 I=ISRT,IEND
        FRATESUM=((C(1)*FRATE(1,I))+(C(2)*FRATE(2,I))+
     +  (C(3)*FRATE(3,I)))
        UR(I,1)=((FRATESUM*HR*VFR(I)*RROE)*(1.-PHETA)*
     +  (DZS(I)/480.0D0)+(FRATESUM*HR*VFR(I)*RROE)*PHETA*
     +  (DZS(I)/480.0D0))
C       print*,'ur(',i,',1) =',ur(i,1)
  146 CONTINUE
```

```
      RTT(1,1)=(64.0D0*UR(1,1))+(32.0D0*UR(2,1))-(16.0D0*UR(3,1))
      RTT(2,1)=(32.0D0*UR(1,1))+(256.0D0*UR(2,1))+(32.0D0*UR(3,1))
      RTT(3,1)=((-16.0D0)*UR(1,1))+(32.0D0*UR(2,1))+(64.0D0*UR(3,1))
      DO 150 I=3,IR-2,2
        RTT(I,1)=RTT(I,1)+(64.*UR(I,1))+(32.*UR(I+1,1))-(16.*UR(I+2,1))
        RTT(I+1,1)=(32.*UR(I,1))+(256.*UR(I+1,1))+(32.*UR(I+2,1))
        RTT(I+2,1)=((-16.)*UR(I,1))+(32.*UR(I+1,1))+(64.*UR(I+2,1))
  150 CONTINUE
C---------------------- LOOP TO DET. LOAD VECTOR -------------------
      NROW=IR
      DO 154 I=1,NBCS
        NI(I)=NJ(I)
  154 CONTINUE
      DO 156 I=1,IR
        DO 155 J=1,IC
          TKFM(I,J)=TKBTPT(I,J)
  155   CONTINUE
        GFM(I,1)=GOV(I,1)+RTT(I,1)
  156 CONTINUE
      CALL REDUCER(IR,IC,NI,NBCS,TKFM,GFM,TEMP,NROW)
      CALL GAUSJORD(IC,ICHK,NBCS,NJ,NROW,TKFM,GFM,TEMP)
      TEMP(1)=TR
      TEMP(IR)=TS
      CALL RESDATA(ISRT,IEND)
C     print*,'intermediate FEM temp data'
C     print*,' #.      temp(K)        visc          alpha'
      DO 192 J=1,3
        DO 191 I=ISRT,IEND
          ALPHA(J,I)=ALPHA(J,I)+(DELTAT*FRATE(J,I))
  191   CONTINUE
  192 CONTINUE
      CALL RESDATA(ISRT,IEND)
      DO 196 I=IEND+1,IR+1
        FVISC(I)=0.0D0
        ALPHA(1,I)=0.0D0
        ALPHA(2,I)=0.0D0
        ALPHA(3,I)=0.0D0
  196 CONTINUE
      if(iprint.gt.1) goto 198
C     do 197 i=1,ir
C       alphasum=((c(1)*alpha(1,i))+(c(2)*alpha(2,i))+
C    +  (c(3)*alpha(3,i)))
C       print*,' ',i,'    ',temp(i),'    ',fvisc(i),'    ',alphasum
C 197 continue
  198 DO 199 I=1,IR
        GOV(I,1)=0.0D0
```

```
      RTT(I,1)=0.0D0
  199 CONTINUE
c-------------------------------------------------------
      RETURN
      END
      SUBROUTINE REDUCER(IROW,ICOL,NIJ,NBCNDS,GK,GQ,U,NRBCNDS)
      DIMENSION NIJ(12),GK(799,3),GQ(799,1),U(799)
C***********************************************************
C     REDUCTION OF MATRICES FOR KNOWN TEMPERATURES
C***********************************************************
c     print*,'reducer'
      LIM=ICOL-1
      NRBCNDS=IROW
      DO 810 IH=1,NBCNDS
        DO 809 I=NIJ(IH)-LIM,NIJ(IH)+LIM
        IF(I.GT.NIJ(IH)) THEN
          J=NIJ(IH)
          K=I
          IF(K.LT.1) GOTO 809
        ELSEIF(I.LT.NIJ(IH) .OR. I.EQ.NIJ(IH)) THEN
          K=NIJ(IH)
          J=I
          IF(J.LT.1) GOTO 809
        ELSEIF(I.GT.NRBCNDS .OR. (K-J+1).GT.ICOL) THEN
          GOTO 809
        ELSE
        ENDIF
        GQ(I,1)=GQ(I,1)-(U(NIJ(IH))*GK(J,(K-J+1)))
  809   CONTINUE
  810 CONTINUE
      DO 830 I=1,NRBCNDS
        DO 820 J=NBCNDS,1,-1
        K=NIJ(J)-I+1
        IF(K.GT.ICOL .OR. K.LT.1) GOTO 820
          DO 815 L=K,LIM
          GK(I,l)=GK(I,L+1)
  815     CONTINUE
        GK(I,l)=0.0D0
  820   CONTINUE
  830 CONTINUE
      DO 880 J=1,NBCNDS
      IF(NIJ(J).LT.NRBCNDS) THEN
        DO 850 K=NIJ(J),NRBCNDS-1
        GQ(K,1)=GQ(K+1,1)
          DO 845 L=1,ICOL
          GK(K,L)=GK(K+1,L)
```

```
 845       CONTINUE
 850    CONTINUE
        DO 860 L=1,NBCNDS
        IF(NIJ(L).EQ.NIJ(J)) GOTO 865
 860    CONTINUE
 865    DO 870 M=L,NBCNDS
        NIJ(M+1)=NIJ(M+1)-1
 870    CONTINUE
        NRBCNDS=NRBCNDS-1
      ELSE
        NRBCNDS=NRBCNDS-1
      ENDIF
 880 CONTINUE
C**********************************************************
      RETURN
      END
      SUBROUTINE GAUSJORD(ICOL,ICHK,NBCNDS,NJI,NRBCNDS,GK,GQ,U)
      DIMENSION NJI(12),GK(799,3),GQ(799,1),U(799)
C**********************************************************
C    GAUSS-JORDAN HALF-BANDWITH ROUTINE FOR MATRICES
C**********************************************************
C    SOLVER ROUTINE TO DET. NEW TEMPS.
c    print*,'gaussjord'
      DO 940 J=1,NRBCNDS-1
        DO 900 K=2,ICOL
        GQ(K+(J-1),1)=GQ(K+(J-1),1)-
     +              ((GK(J,K)*GQ(J,1))/GK(J,1))
          DO 890 L=1,ICOL-1
          IF((K+J-1).GT.NRBCNDS .OR. (L+K-1).GT.ICOL) GOTO 900
          GK(K+(J-1),L)=GK(K+(J-1),L)-
     +                ((GK(J,K)*GK(J,L+K-1))/GK(J,1))
 890       CONTINUE
 900    CONTINUE
 940 CONTINUE
      DO 990 J=NRBCNDS,1,-1
        DO 970 K=2,ICOL
        GQ(J,1)=GQ(J,1)-(U(J+K-1)*GK(J,K))
 970    CONTINUE
      U(J)=GQ(J,1)/GK(J,1)
 990 CONTINUE
C       RE-ESTABLISHMENT OF U'S
      IF(ICHK.EQ.1) THEN
        DO 1010 I=NRBCNDS,1,-1
        U(I+1)=U(I)
 1010   CONTINUE
      ELSE
```

```
      DO 1040 I=1,NBCNDS
        DO 1020 J=NRBCNDS,NJI(I),-1
        U(J+1)=U(J)
1020      CONTINUE
      NRBCNDS=NRBCNDS+1
1040   CONTINUE
    ENDIF
    DO 2000 I=1,400
      GQ(I,1)=0.0D0
      DO 1999 J=1,3
        GK(I,J)=0.0D0
1999   CONTINUE
2000 CONTINUE
C***********************************************************
    RETURN
    END
```

Reference

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9. Performing Organization Name and Address Virginia Polytechnic Institute and State University Department of Engineering Science and Mechanics Blacksburg, VA 24061-0219			10. Project/Task/Work Unit No.
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			14.
15. Supplementary Notes			

16. Abstract

RTMCL is a user friendly computer code which simulates the manufacture of fabric composites by the resin infusion process. The computer code is based on the process simulation model described in reference 1 of the report. Included in the user's guide is a detailed step-by-step description of how to run the program and enter and modify the input data set. Sample input and output data files are included along with an explanation of the results. Finally, a complete listing of the program is provided.

17. Key Words and Document Analysis. 17a. Descriptors

Resin transfer molding (RTM), resin film infusion, composite, textile preform, manufacturing, process modeling

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

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- contact point for other organizations and individuals,
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