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by

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This is a brief description of a computer program which was written by Oleh Weres to generate discrete grids for IFD* type computer programs.(1,2,3) The output of the program includes data which can be used directly for input to the program SHAFT78. The program is specifically intended for large-scale two or three-dimensional reservoir simulation. The program requires, as input, the x, y, z coordinates of the discrete element locations being used to specify a particular reservoir's geological system. From the list of element locations, the program finds the midpoints of lines joining adjacent elements. At each midpoint the program constructs a perpendicular plane. The intersections of the planes in the three-space defines an irregular (in general) n-sided polyhedron around each element center. In two-dimensions the program produces a unique "tiling" which has polygons with all faces perpendicular to the lines joining adjacent elements. The areas between adjoining elements and the volume of each element are calculated. The end result, in general, is a three-dimensional grid of n-sided polyhedra for which the element locations, the connecting (flow) areas, and the element volumes are all known. Since the grids are finite the program must have information about the boundary of the grid. This is supplied as a set of "dummy" elements which are used only to limit the extent of the grid and are not intended for use in the reservoir simulation.

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* Integrated Finite Difference, i.e., TRUMP, CCC, SHAFT, etc.

The program currently allows definition of up to 800 elements and 4000 interface areas. Each element can be assigned an arbitrary material identifier. The program uses only small core memory on the 7600.

Input for OGRE

Card 1 (8A10)

IPRINT	=	80 column title (label) card

Card 2 (6I5)

NNR	=	the number of elements in the grid
NNT	=	the total number of elements including dummy elements
MRANK	=	the total number of elements to be ranked
MRMAX	=	approximate number of neighbors to be tested for connection
MRMAXS	=	approximate number of neighbors to be tested for connection within a single material group.
NGIVEN	=	number of connections supplied as input

Default values for Card 2

MRANK	=	150
MRMAX	=	36
MRMAXS	=	11
NGIVEN	=	0

The program uses these values if the corresponding field is blank.

Card 3 (4E10.3)

EPSBC EPSYZ EPSIN EPSI	Parameters for various geometric tests. Set by default. Leave this card blank.

Card 4 (4E10.3)

THETA PHI PSI	Internal rotation angles. Set by default to nonzero values.
ANGC	If ANGC ≠ 0, the above variables may be set equal to zero.

For default leave this card blank.

Card 5 to NGIVEN + 5 (A5, 5X, A5)

Identifiers of pairs of elements whose connections are to be included in the calculation (above and beyond those which the program finds itself). Not present when NGIVEN = 0. These pairs of specified elements allow the user to insert connections as desired.

Card NGIVEN + 5 (A5, 5X, 3E20.12, 5X, A5)

⋮ NGIVEN + NNR + 5	Identifier, x, y and z location coordinates and material identifier
⋮ NGIVEN + NNT + 5	For each of NNR real elements, followed by same for each of NNT-NNR dummy elements.

The large number of significant figures is essential if input cards have been prepared by another program, but they are usually unnecessary otherwise.

The purpose for having a large number of significant digits is to keep I/O associated truncation from causing "exactly" (i.e., to within computational roundoff error) parallel planes to be "almost parallel" and thereby wreaking havoc with the calculation. Manually prepared input data is not subject to this and may be provided in any E20.n or F20.n format desired

<u>Discussion of OGRE Printed Output</u>

EPSBC, etc. are threshold values used to test whether or not various quantities are equal to zero. These quantities arise in tests to determine the identity of points, the parallelness of lines, the verticality of planes, etc. A threshold value is necessary because of roundoff error accumulation. The default values are appropriate for a problem with typical element separation on the order of 100 meters with all I/O and calculations in meters. Much smaller grid dimensions might require smaller test values and vice-versa.

The three angles THETA, PHI, PSI define an internal coordinate system which is actually employed in the calculation. The choice of default values is arbitrary, although the values employed probably shouldn't be much smaller than the default values. The default values are used when zeros or blank fields are inputted, and the value of ANGC is also zero. Setting ANGC not equal to zero will allow zero values as input for the three angles, should this be desired.

The conversion to the rotated internal coordinates is done at the time of input, and all coordinates are converted to the external coordinate system just prior to output. Thus, values in the internal coordinate system would only be seen in the context of an error message and source code controlled dump.

The purpose of this coordinate change is to eliminate exactly vertical planes and certain similar special elements from the mesh being calculated because exactly vertical planes would cause non-physical numerical divergences in certain of the algebraic manipulations.

The values of EPSBC, etc., and the rotation angles are best left alone unless trouble develops. Trouble is evidenced by the appearance of descriptive error messages ("TROUBLE - A THREE ENDED LINE", etc.) along with appropriate associated internal data values.

An oddball vertical plane or something similar caused by an unfortunate choice for the rotation angles will cause one or a few error-messages to be generated. A poor choice for one or more of the threshold test values will usually cause one hundred (the maximum number allowed) error messages to be generated. Either case can be dealt with by changing the appropriate values. In the former case, a completely arbitrary change should suffice.

There have been no program generated error messages since the code was debugged and the present default values adopted, but the possibility remains. The code is designed to "skip over" any difficulty that it recognizes during execution and complete the rest of the mesh the best it can. The list of inputted elements is self-explanatory.

The following page is generated during the actual calculation, which is performed element by element. K is the internal identifier of each element. It is simply the ordinal position within the input deck of elements. MMR is the total number of neighboring elements which the program identified as possibly connected neighbors. (Neighbors externally supplied under the NGIVEN option and not redundant to those identified by the program are included above and beyond MMR). NMAT is the number of material designation groups to which the MMR neighbors belong. NMS and IMS are the number of neighbors falling into the first material group identified, and the corresponding material identifier. In this example, all elements belong to the material (blank). If more than one material group is present, the (NMS, IMS) field is repeated as many times as necessary. In all cases, MMR $\leq$ MRMAX and NMS $\leq$ MRMAXS. This is the significance of these input parameters. When more than one material group is present, usually MMR $\geq$ NMS.

TOTAL NUMBER OF GEOMETRIC TROUBLE FLAGS is the number of times the program noted difficulties and acted upon them. Each instance results in the printing of an error message up to a maximum of 100 messages.

In OUTPUT NODE LIST, IMAT is the material identifier for each element. NC is the number of neighboring elements that it is connected to, and a list of the connected elements follows.

The TOTAL NUMBER OF CONNECTIONS (NCT within the program) is the total number of connections given or identified, including those between real elements and dummy elements. The NUMBER OF INTERELEMENT CONNECTIONS (NCF) does not include those between elements and dummy elements.

IFACE is the internal numerical identifier for each connection generated, and IA, IB are the numerical identifiers for the connected elements. NODEA and NODEB are the element names. DELT is the perpendicular (i.e., shortest) distance from either of the two element centers to the plane interface between them. (The two distances are always equal. Note that the line between the two nodes need not actually pass through the polygonal interface between them). The values A through D are the coefficients for the equation of the interface plane written in the form

$$Ax + By + Cz = D \tag{1}$$

User Defined File Outputs

There are three user defined output files required. TAPE4 is written on by the main program, OGRE, and TAPE5 and TAPE6 are written by the subroutine ISECT. TAPE4 is the SHAFT78 compatible output file. The first record gives the number of elements twice (NNR) followed by the total number of connections. The next NNR records give the name, material identifier, and volume for each of the elements. Note that OGRE uses the material identifier as a computation control input variable (more on this below). In general, this will not be the physical material identifier used by SHAFT78. Therefore, IMAT might have to be changed between running OGRE and running SHAFT78. The last NCT records describe the connections.

The values NA and NB are the elements which are connected. ISI is 1, 2 or 3 depending on which one of A, B and C has the greatest absolute value. ZR is C of the printed output. It is required by SHAFT78 to handle the effect of gravity upon flow. HTR is the interface heat transfer resistance used by SHAFT78. OGRE sets HTR = 0. If another value is desired, it must be supplied between OGRE and SHAFT78.

TAPE5 is the plotter output file which contains a list of all connections calculated. There is one record for each connection, for a total of NCT records. Each record contains the following:

NAMEA, NAMEB, N+1, (X, Y, Z) repeated N + 1 times

NAMEA and NAMEB are the names of the two connected nodes. N + 1 is the number of corners (edges) which the convex plane polygon which represents that connection has plus one. Each triplet (X, Y, Z) is the position in space of one of those corners. The coordinate triplets are arranged in proper order around the polygon, and the first one is repeated at the end, thereby closing the polygon.

TAPE5 is input for the program PLOTO which generates the actual plotter commands. It is <u>not</u> a plotter command file itself.

The records written on TAPE6 are a subset of these on TAPE5. That is, only those connections between two real elements are included. Those which connect a real element to a dummy element are <u>not</u> included. There are a total of NCF records in TAPE6, each of which is identical to one of the records in TAPE5.

TAPE5 contains the information needed to create a complete picture of the grid. Making such a picture after each run is essential when dealing with any but the simplest problem. This plot is done with half weight lines because all of the line segments are retraced two or three times as a consequence of representing shared edges.

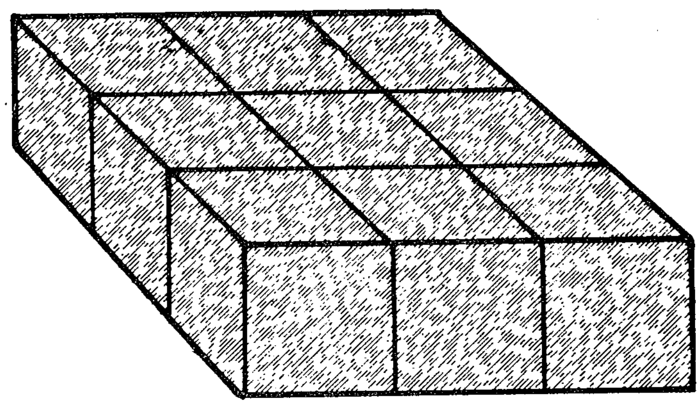
TAPE6 allows the internal flow connections within the grid to be visualized. This is also needed to properly check out a grid. These plots are even more useful as pairs of stereo plots rotated by a small angle relative to each other. Line them up in front of you, cross your eyes, and see the grid pop out in 3D.

Sample Problem 1

This test problem consists of a single layer of 9 squares with element centers at the x, y, z values given in the table below.

Figure 1

The Test Problem Grid of Nine Squares



XBL 786-1879

Table 1

The Locations of the Elements

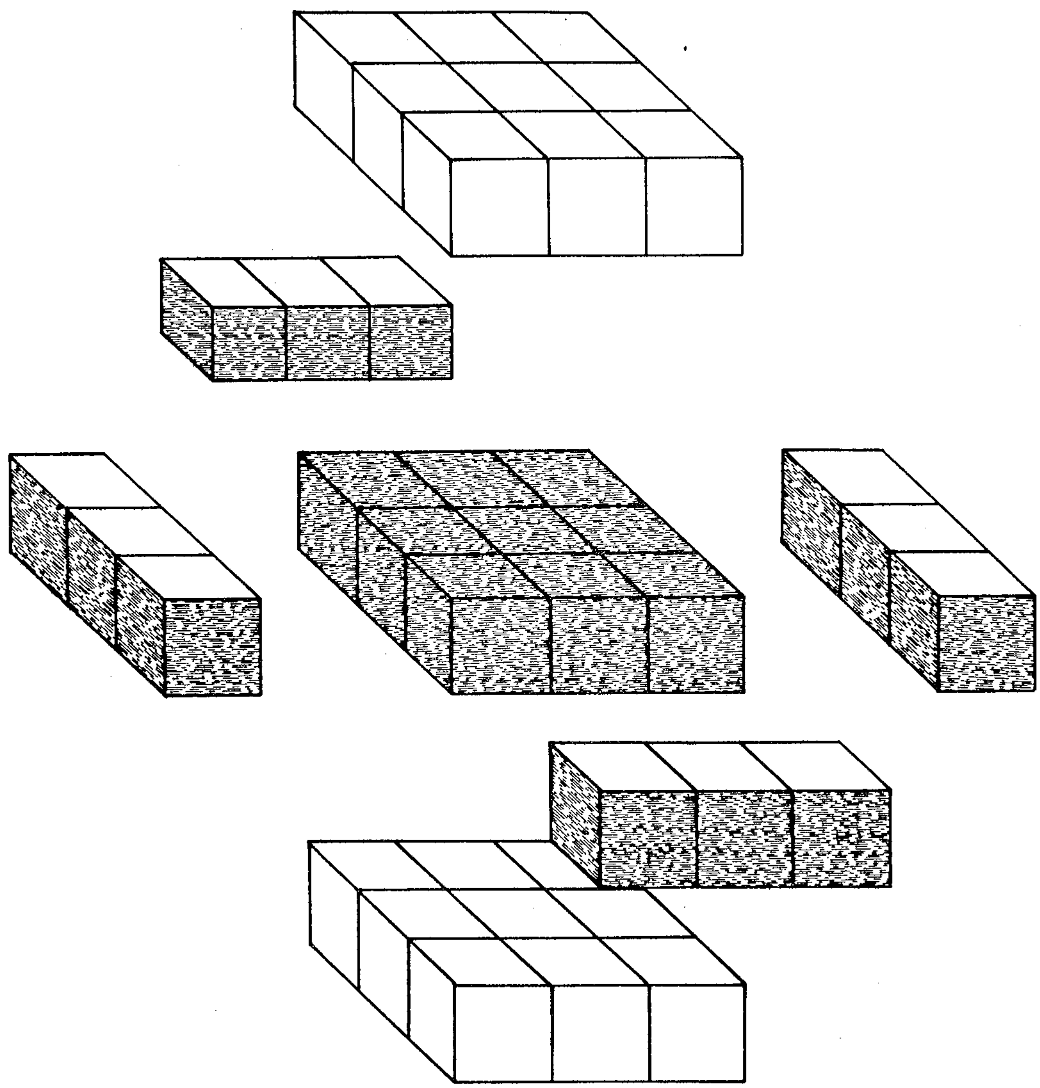
x	y	z
2	2	1
4	2	1
6	2	1
2	4	1
4	4	1
6	4	1
2	6	1
4	6	1
6	6	1

To generate this grid the boundary nodes are required as shown below.

The shaded elements are the real grid elements.

Figure 2

The Test Grid With Dummy Elements Exploded to Show
Their Relationship to the Real Grid



XBL 786-1878

Clearly, the smaller the number of real elements, NNR, the larger is the ratio of dummy to grid elements. For large, flat structures the ratio is about two to one, but may be smaller for more compact structures.

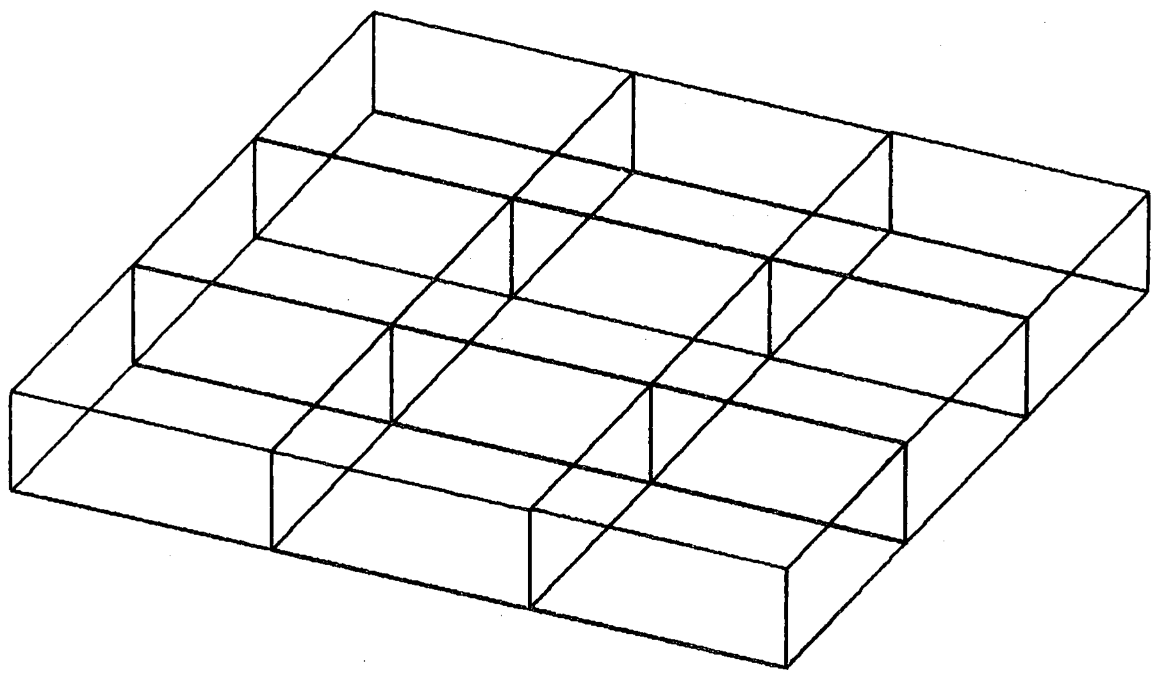
Usage

To use the program the compiled (MNF4) object deck (OGROB) can be accessed from the library RCS, owner SCHROEDER. The sample problem input from a terminal is shown below. In the example, the file SOGRE (use your own name for this file) contains the input file for subsequent input to the SHAFT78 program. The files TOGRE and FOGRE (use your own names for these files) contain data which is input to the plotting program, PLOTO. If you wish to print the contents of the SHAFT78 or PLOT files insert a card which copies TAPE4, TAPE5 and TAPE6 to the output file. Note that these are binary, not BCD, files. If there is no need to save the plot files for later use it is not necessary to catalog TAPE5 and TAPE6.

The test problem output is shown below. All defaults have been used in this sample problem, as seen on the previous page showing the test problem input file. The quantities A, B, and C are the coefficients in equation (1). In Figures 3 and 4 the computer generated plots of the complete grid (Figure 3), and the internal flow areas (Figure 4) is given.

User Terminal Input for Test Problem 1.

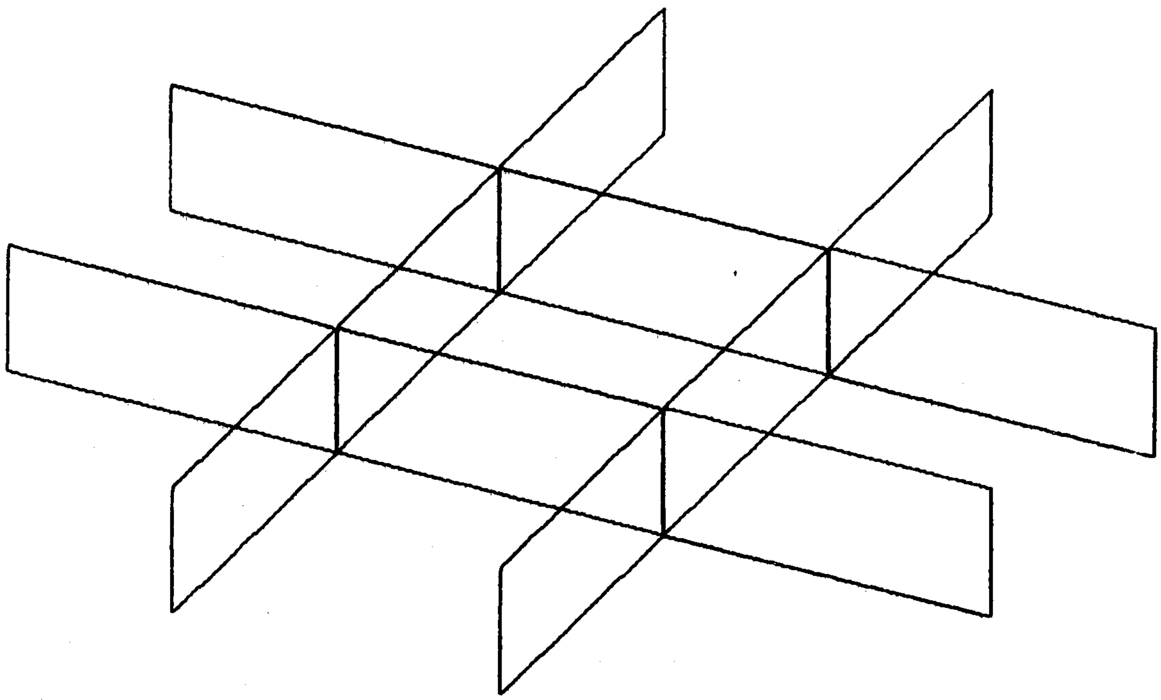
```
OGRE1,P12,T750,CM170000.471504,SCHROEDER
*HOLDOUT
LIBCOPY,RCS,LGO/RR,OGROB.
ATTSKIP,TAPE4,SOGRE.
CATALOG,TAPE4,SOGRE.
ENDSKIP.
ATTSKIP,TAPE5,TOGRE.
CATALOG,TAPE5,TOGRE.
ENDSKIP.
ATTSKIP,TAPE6,FOGRE.
CATALOG,TAPE6,FOGRE.
ENDSKIP.
LGO.
LIBCOPY,RCS,PLOTO/RR,PLOTO.
CALL,PLOTO.
EXIT.
DUMP.
FIN.
EOR
       OGRE TEST
    9   39

ABC22            2.0            2.0            1.0
ABC24            2.0            4.0            1.0
ABC26            2.0            6.0            1.0
ABC42            4.0            2.0            1.0
ABC44            4.0            4.0            1.0
ABC46            4.0            6.0            1.0
ABC62            6.0            2.0            1.0
ABC64            6.0            4.0            1.0
ABC66            6.0            6.0            1.0
DUM02            0.0            2.0            1.0
DUM04            0.0            4.0            1.0
DUM06            0.0            6.0            1.0
DUM20            2.0            0.0            1.0
DUM40            4.0            0.0            1.0
DUM60            6.0            0.0            1.0
DUM82            8.0            2.0            1.0
DUM84            8.0            4.0            1.0
DUM86            8.0            6.0            1.0
DUM28            2.0            8.0            1.0
DUM48            4.0            8.0            1.0
DUM68            6.0            8.0            1.0
LBC22            2.0            2.0            0.0
LBC24            2.0            4.0            0.0
LBC26            2.0            6.0            0.0
LBC42            4.0            2.0            0.0
LBC44            4.0            4.0            0.0
LBC46            4.0            6.0            0.0
LBC62            6.0            2.0            0.0
LBC64            6.0            4.0            0.0
LBC66            6.0            6.0            0.0
UBC22            2.0            2.0            2.0
UBC24            2.0            4.0            2.0
UBC26            2.0            6.0            2.0
UBC42            4.0            2.0            2.0
UBC44            4.0            4.0            2.0
UBC46            4.0            6.0            2.0
UBC62            6.0            2.0            2.0
UBC64            6.0            4.0            2.0
UBC66            6.0            6.0            2.0
EOR
EOF
<BOTTOM OF FILE>
```



XBL 787-9567

Figure 3

The Computer Generated Plot of the
Complete Grid for Test Problem 1



XBL 787-9568

Figure 4

The Computer Generated Plot of the Internal
Grid Interfaces for Test Problem 1

NNR,NNT,MRANK= 9 39 39 MRMAX,MRMAXS= 36 11 NGIVEN= 0

EPSBC,EPSYZ,EPSIN,EPSI= 1.0000E-07 1.0000E-07 1.0000E-06 1.0000E-07

THETA,FHI,PSI= .01700000 -.03700000 .07000000

THE ROTATION MATRIX IS

.99945518 .03298391 .00118897

-.03299934 .99931151 .01695755

-.00062883 -.01698755 .99985550

THE LIST OF NODES FOLLOWS

1	ABC22	2.000	2.000	1.000
2	ABC24	2.000	4.000	1.000
3	ABC26	2.000	6.000	1.000
4	ABC42	4.000	2.000	1.000
5	ABC44	4.000	4.000	1.000
6	ABC46	4.000	6.000	1.000
7	ABC62	6.000	2.000	1.000
8	ABC64	6.000	4.000	1.000
9	ABC66	6.000	6.000	1.000

THE FOLLOWING ARE DUMMY NODES

10	DUM02	0.000	2.000	1.000
11	DUM04	0.000	4.000	1.000
12	DUM06	0.000	6.000	1.000
13	DUM20	2.000	0.000	1.000
14	DUM40	4.000	0.000	1.000
15	DUM60	6.000	0.000	1.000
16	DUM82	8.000	2.000	1.000
17	DUM84	8.000	4.000	1.000
18	DUM86	8.000	6.000	1.000
19	DUM28	2.000	8.000	1.000
20	DUM48	4.000	8.000	1.000
21	DUM68	6.000	8.000	1.000
22	LBC22	2.000	2.000	0.000
23	LBC24	2.000	4.000	0.000
24	LBC26	2.000	6.000	0.000
25	LBC42	4.000	2.000	0.000
26	LBC44	4.000	4.000	0.000
27	LBC46	4.000	6.000	0.000
28	LBC62	6.000	2.000	0.000
29	LBC64	6.000	4.000	0.000
30	LBC66	6.000	6.000	0.000

Printed Output for Test Problem 1

31	UBC22	2.000	2.000	2.000
32	UBC24	2.000	4.000	2.000
33	UBC26	2.000	6.000	2.000
34	UBC42	4.000	2.000	2.000
35	UBC44	4.000	4.000	2.000
36	UBC46	4.000	6.000	2.000
37	UBC62	6.000	2.000	2.000
38	UBC64	6.000	4.000	2.000
39	UBC66	6.000	6.000	2.000

K	MMR	NMAT	NMS	IMS AND REPEAT
1	11	1	11	
2	11	1	11	
3	11	1	11	
4	11	1	11	
5	11	1	11	
6	11	1	11	
7	11	1	11	
8	11	1	11	
9	11	1	11	

OGRE TEST

TOTAL NUMBER OF GEOMETRIC TROUBLE FLAGS = 0

OUTPUT NODE LIST

NODE	X	Y	Z	VOLUME	IMAT	NC	CONNECTED NODES
ABC22	2.000	2.000	1.000	4.0000E+00		6	LBC22 UBC22 ABC42 ABC24 DUM20 DUM02
ABC24	2.000	4.000	1.000	4.0000E+00		6	ABC22 UBC24 LBC24 ABC26 DUM04 ABC44
ABC26	2.000	6.000	1.000	4.0000E+00		6	ABC24 UBC26 LBC26 DUM06 ABC46 DUM28
ABC42	4.000	2.000	1.000	4.0000E+00		6	ABC22 UBC42 LBC42 ABC44 DUM40 ABC62
ABC44	4.000	4.000	1.000	4.0000E+00		6	ABC24 ABC42 UBC44 LBC44 ABC46 ABC64
ABC46	4.000	6.000	1.000	4.0000E+00		6	ABC26 ABC44 UBC46 LBC46 DUM48 ABC66
ABC62	6.000	2.000	1.000	4.0000E+00		6	ABC42 UBC62 LBC62 DUM82 ABC64 DUM60
ABC64	6.000	4.000	1.000	4.0000E+00		6	ABC44 ABC62 UBC64 LBC64 DUM84 ABC66
ABC66	6.000	6.000	1.000	4.0000E+00		6	ABC46 ABC64 UBC66 LBC66 DUM86 DUM68

/ TOTAL CONNECTIONS = 42 INTERELEMENT CONNECTIONS = 12

IFACE	IA	IB	NODEA	NODEB	AREA	DELT	A	B	C	D
1	1	22	ABC22	LBC22	4.0000E+00	.500	.000000	.000000	-1.000000	-.500
2	1	31	ABC22	UBC22	4.0000E+00	.500	-.000000	.000000	1.000000	1.500
3	1	4	ABC22	ABC42	2.0000E+00	1.000	1.000000	.000000	.000000	3.000
4	1	2	ABC22	ABC24	2.0000E+00	1.000	-.000000	1.000000	.000000	3.000
5	1	13	ABC22	DUM20	2.0000E+00	1.000	.000000	-1.000000	.000000	-1.000
6	1	10	ABC22	DUM02	2.0000E+00	1.000	-1.000000	-.000000	-.000000	-1.000
7	2	32	ABC24	UBC24	4.0000E+00	.500	-.000000	-.000000	1.000000	1.500
8	2	23	ABC24	LBC24	4.0000E+00	.500	.000000	.000000	-1.000000	-.500
9	2	3	ABC24	ABC26	2.0000E+00	1.000	-.000000	1.000000	-.000000	5.000
10	2	11	ABC24	DUM04	2.0000E+00	1.000	-1.000000	-.000000	-.000000	-1.000
11	2	5	ABC24	ABC44	2.0000E+00	1.000	1.000000	.000000	-.000000	3.000
12	3	33	ABC26	UBC26	4.0000E+00	.500	-.000000	-.000000	1.000000	1.500
13	3	24	ABC26	LBC26	4.0000E+00	.500	.000000	.000000	-1.000000	-.500
14	3	12	ABC26	DUM06	2.0000E+00	1.000	-1.000000	.000000	-.000000	-1.000
15	3	5	ABC26	ABC46	2.0000E+00	1.000	1.000000	-.000000	.000000	3.000
16	3	19	ABC26	DUM28	2.0000E+00	1.000	-.000000	1.000000	-.000000	7.000
17	4	34	ABC42	UBC42	4.0000E+00	.500	-.000000	.000000	1.000000	1.500
18	4	25	ABC42	LBC42	4.0000E+00	.500	-.000000	.000000	-1.000000	-.500
19	4	5	ABC42	ABC44	2.0000E+00	1.000	.000000	1.000000	-.000000	3.000
20	4	14	ABC42	DUM40	2.0000E+00	1.000	.000000	-1.000000	.000000	-1.000
21	4	7	ABC42	ABC62	2.0000E+00	1.000	1.000000	.000000	.000000	5.000
22	5	35	ABC44	UBC44	4.0000E+00	.500	-.000000	-.000000	1.000000	1.500
23	5	26	ABC44	LBC44	4.0000E+00	.500	-.000000	.000000	-1.000000	-.500
24	5	6	ABC44	ABC46	2.0000E+00	1.000	-.000000	1.000000	.000000	5.000
25	5	8	ABC44	ABC64	2.0000E+00	1.000	1.000000	-.000000	.000000	5.000
26	6	36	ABC46	UBC46	4.0000E+00	.500	-.000000	-.000000	1.000000	1.500
27	6	27	ABC46	LBC46	4.0000E+00	.500	-.000000	.000000	-1.000000	-.500
28	6	20	ABC46	DUM48	2.0000E+00	1.000	.000000	1.000000	-.000000	7.000
29	6	9	ABC46	ABC66	2.0000E+00	1.000	1.000000	.000000	.000000	5.000
30	7	37	ABC62	UBC62	4.0000E+00	.500	-.000000	.000000	1.000000	1.500
31	7	28	ABC62	LBC62	4.0000E+00	.500	-.000000	.000000	-1.000000	-.500
32	7	16	ABC62	DUM82	2.0000E+00	1.000	1.000000	-.000000	.000000	7.000
33	7	8	ABC62	ABC64	2.0000E+00	1.000	-.000000	1.000000	-.000000	3.000

34	7	15	ABC62	DUM60	2.0000E+00	1.000	-.000000	-1.000000	-.000000	-1.000
35	8	38	ABC64	UBC64	4.0000E+00	.500	-.000000	-.000000	1.000000	1.500
36	8	29	ABC64	LBC64	4.0000E+00	.500	-.000000	.000000	-1.000000	-.500
37	8	17	ABC64	DUM84	2.0000E+00	1.000	1.000000	.000000	.000000	7.000
38	8	9	ABC64	ABC66	2.0000E+00	1.000	.000000	1.000000	.000000	5.000
39	9	39	ABC66	UBC66	4.0000E+00	.500	-.000000	-.000000	1.000000	1.500
40	9	30	ABC66	LBC66	4.0000E+00	.500	-.000000	.000000	-1.000000	-.500
41	9	18	ABC66	DUM86	2.0000E+00	1.000	1.000000	-.000000	-.000000	7.000
42	9	21	ABC66	DUM68	2.0000E+00	1.000	-.000000	1.000000	-.000000	7.000

Sample Problem 2

As a part of the current international agreement between the United States and Italy a simulation of the production history at the Serrazzano geothermal field in Larderello is being carried out at LBL. Figure 5 shows the aerial view of the contour map of the Serrazzano basement rock formation. The lines labeled A through S are the locations of reservoir cross-sections used to model the Serrázzano subsurface geology. Figure 6 shows one such cross-section with the crosses denoting real element locations. The center of the geothermal field is a horst structure bounded by graben in which it is believed there exists boiling water. Cross-sections for all of the lines A through S produce the grid shown in Figures 7 and 8. In subsequent pages the OGRE output for this major simulation problem is shown with the resulting calculated flow areas and element volumes.

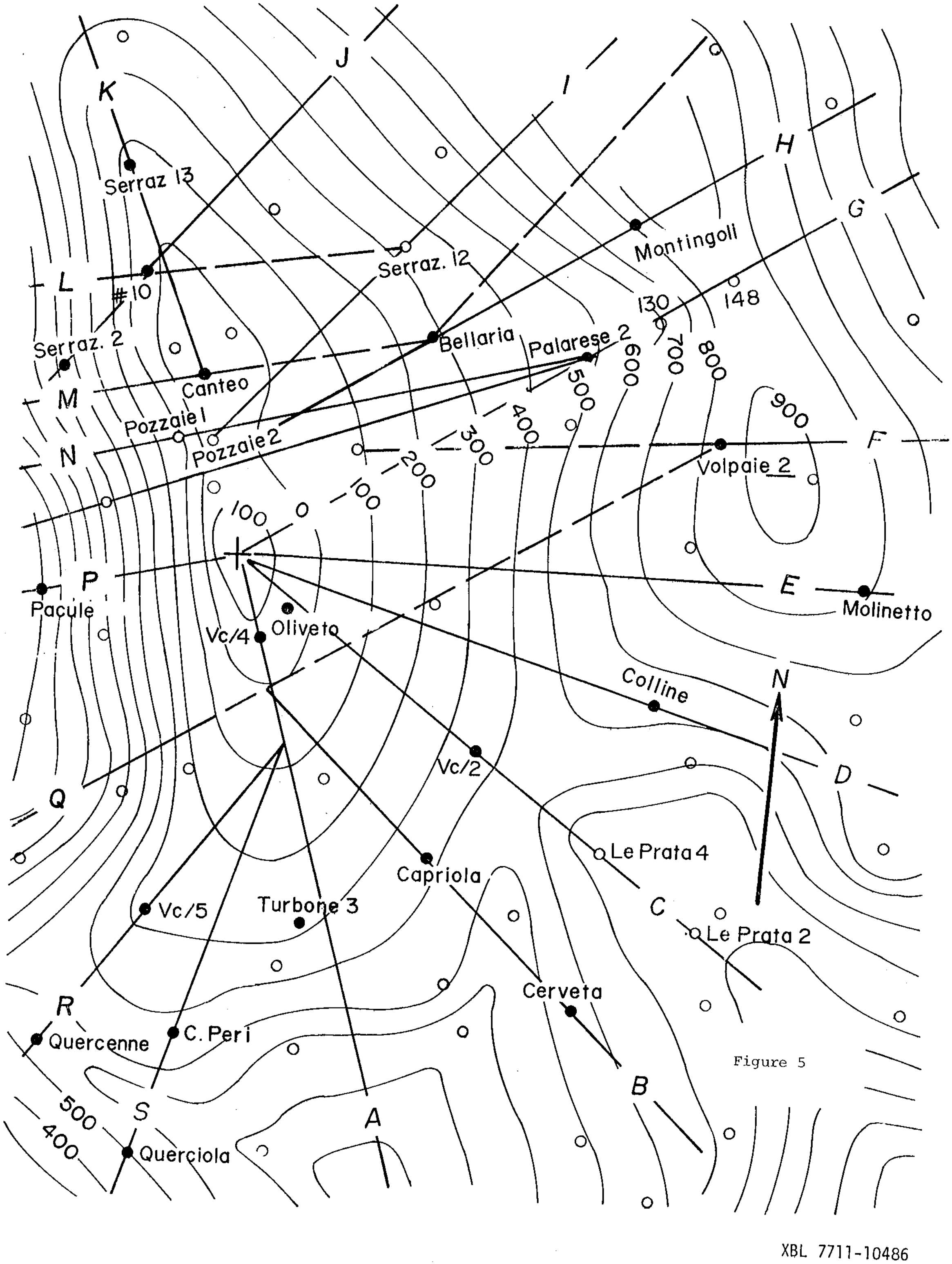


Figure 5

The Contour Map of the Top of the Basement for the Serrazzano Geothermal Field, Larderello, Italy

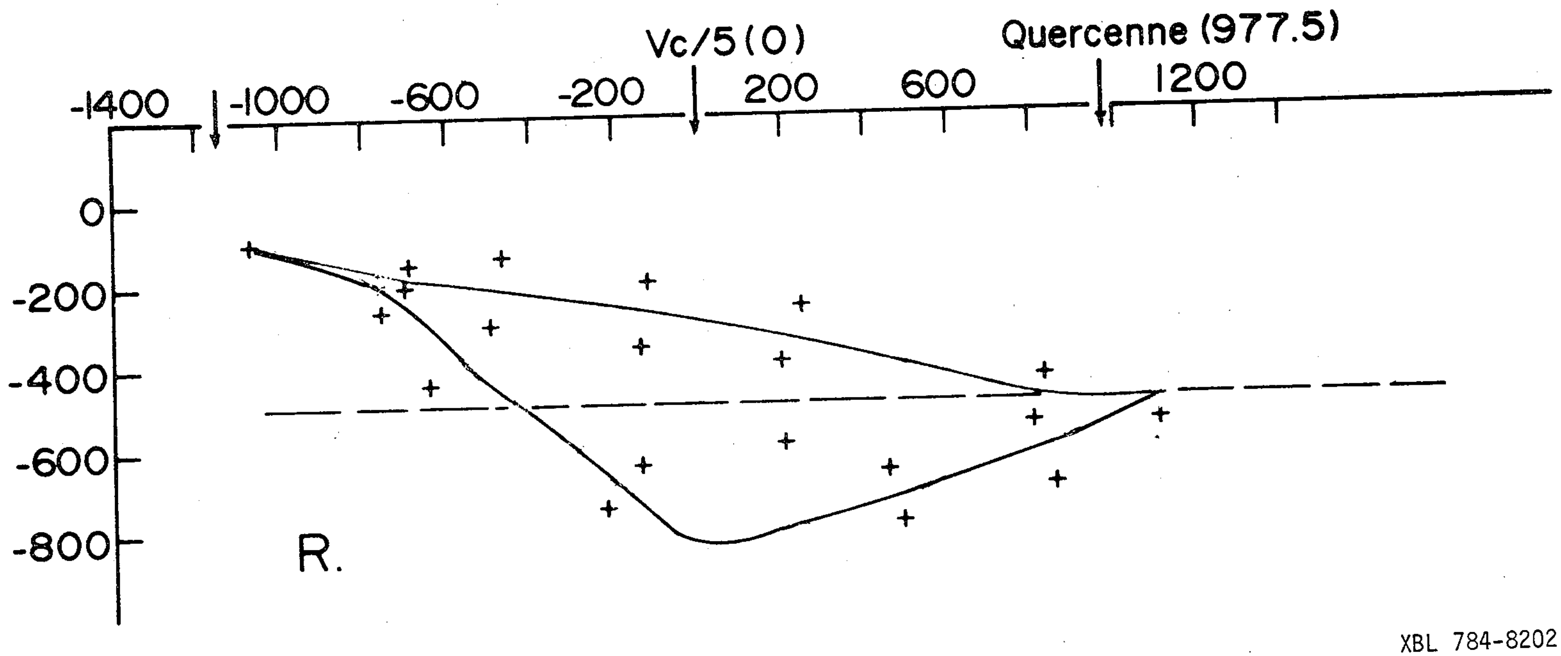
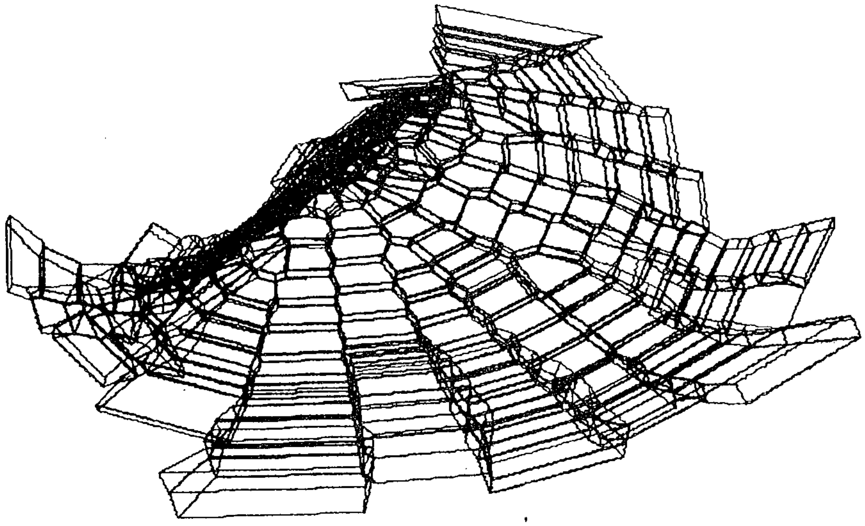
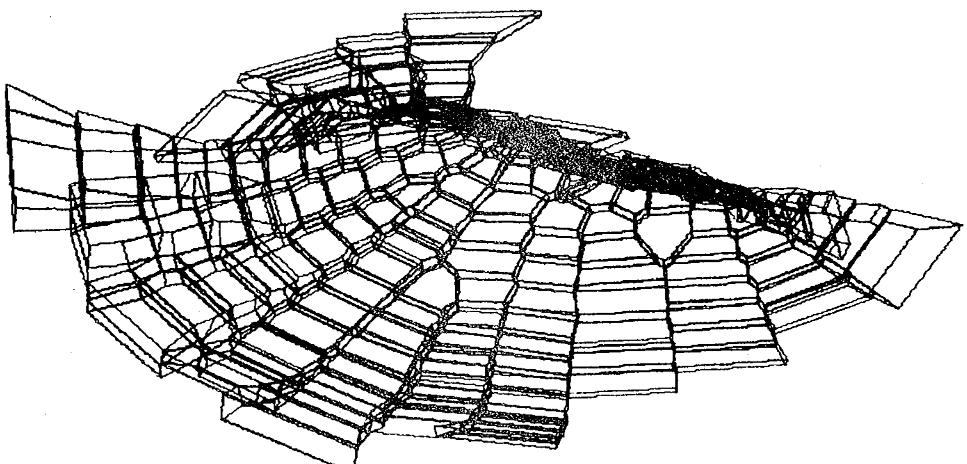


Figure 6

The R Contour used in the Serrazzano Reservoir Simulation Showing the Element Locations (+'s) and the Geological Boundaries (Solid Curves)



a

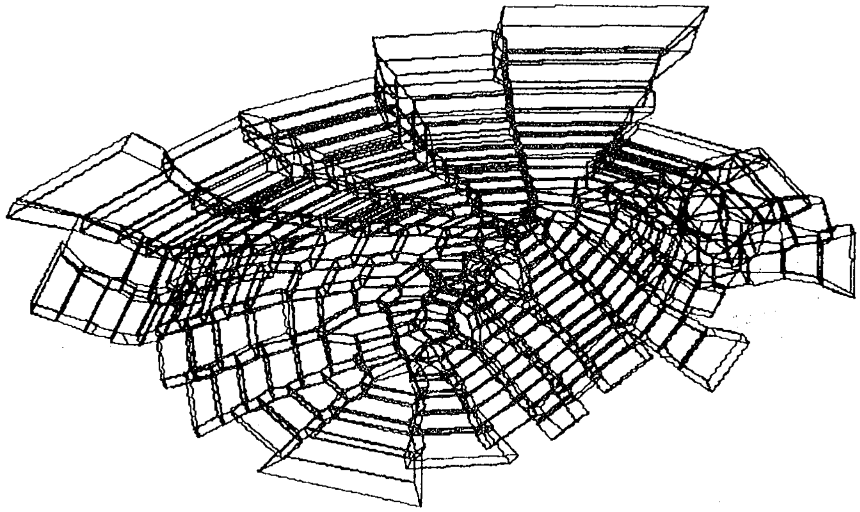


b

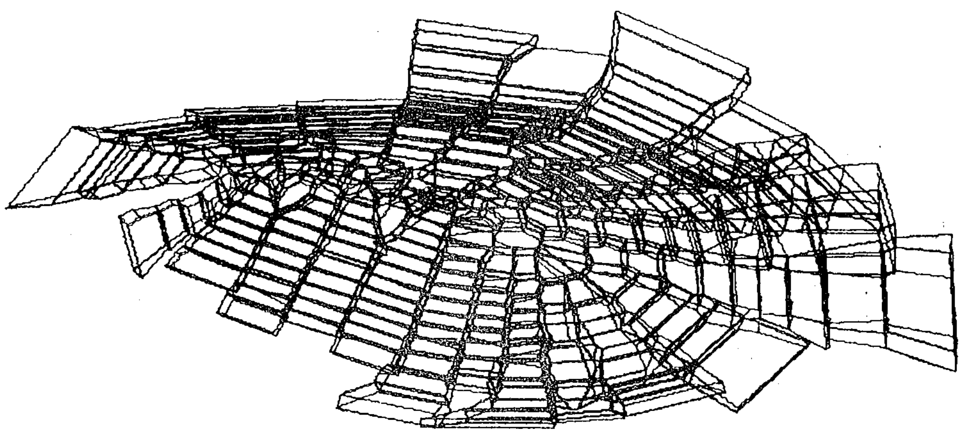
Figure 7

The OGRE Computed Grid for the Serrazzano Problem. Figures a Through d Have Been Rotated 90 Degrees in Each Frame to Allow Close Examination of the Elements. The Entire Grid is Shown.

XBL 787-9569



c



d

Figure 7 (cont'd)

XBL 787-9570

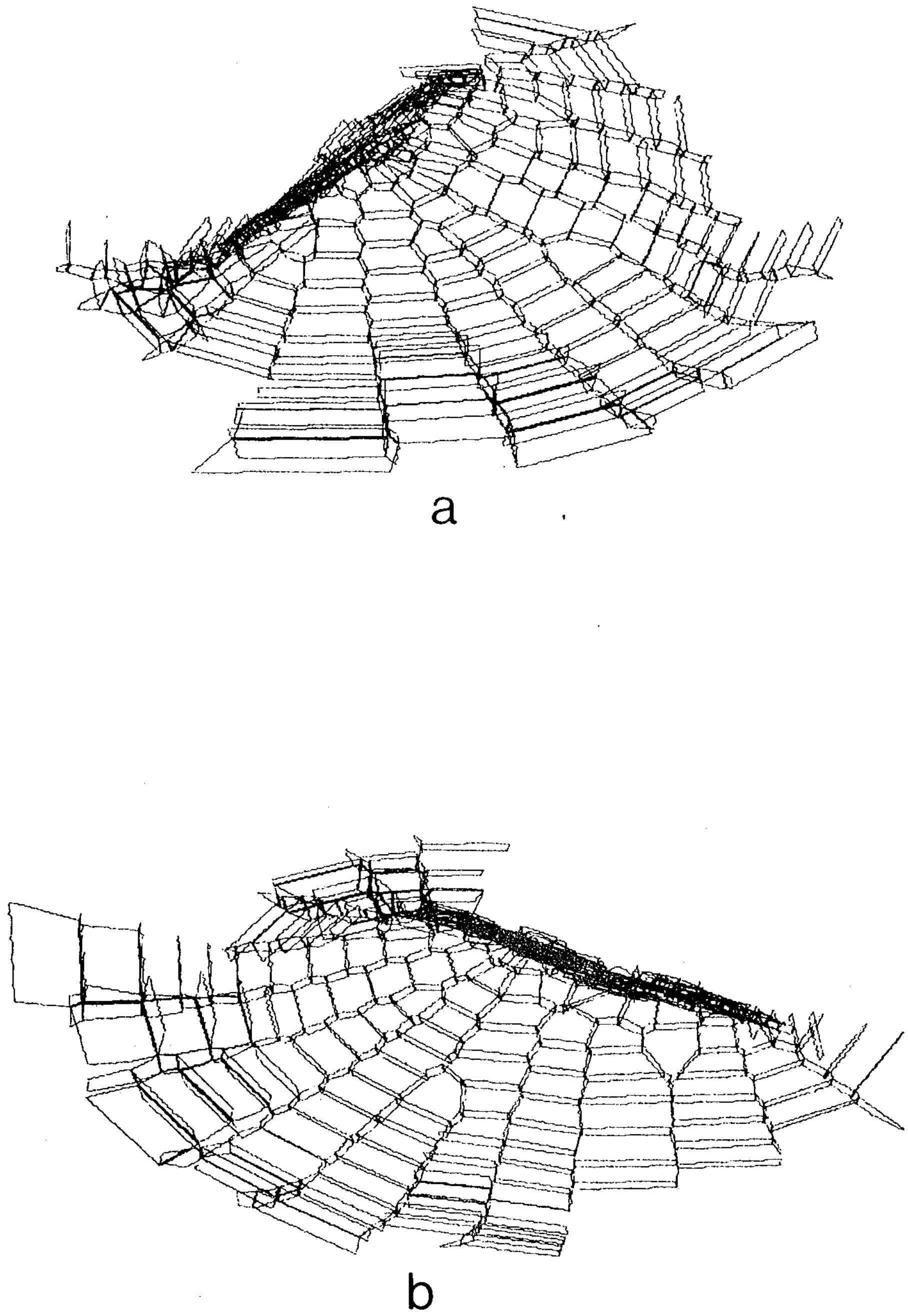
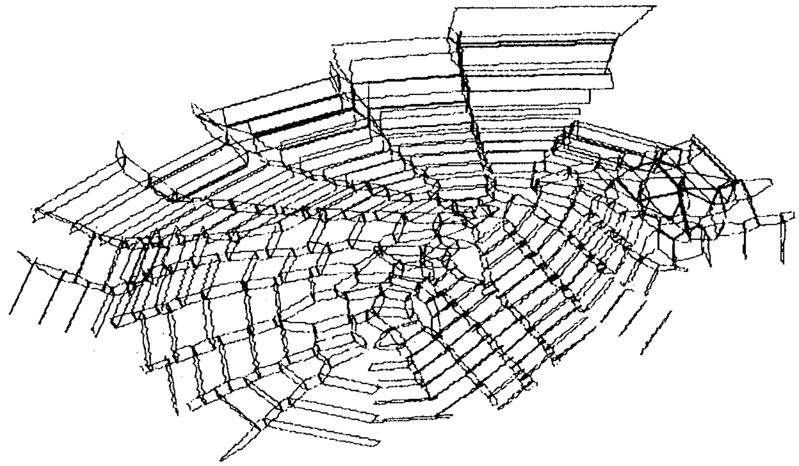


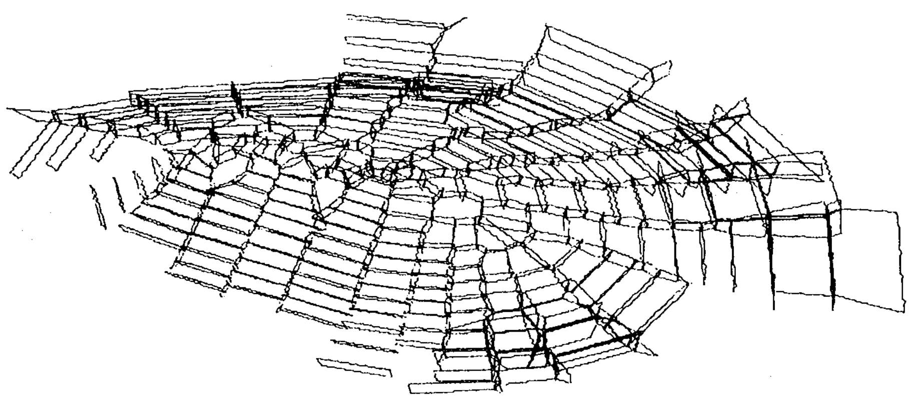
Figure 8

XBL 787-9571

The Plots of the Internal Interfaces for the Serrazzano Problem. The Succeeding Frames have been Rotated 90 Degrees to Allow Study of the Different Sides



c



d

Figure 8 (cont'd)

XBL 787-9572

```
CLEANED UP SERRAZZANO RUN WITH INPUT PREPARED BY PLUSN
NNR,NVT,MRANK=  233   693   150    MRMAX,MRMAXS=    36    11    NGIVEN=     2

EPSBC,EPSYZ,EPSIN,EPSI=      1.0000E-07      1.0000E-07      1.0000E-06      1.0000E-07

THETA,PHI,PSI=    .01700000   -.03700000    .07000000

THE ROTATION MATRIX IS

    .99945518    .03298391    .00118897

   -.03299934    .99931151    .01695755

   -.00062883   -.01698755    .99985550

THE LIST OF NODES FOLLOWS
```

1	FCA03	103.160	-355.328	100.000
2	FCA04	214.684	-739.467	0.000
3	FCA05	348.513	-1200.433	-100.000
4	FCA06	473.977	-1632.589	-200.000
5	FEA07	557.620	-1920.692	-300.000
6	FEA08	613.382	-2112.762	-400.000
7	FEA09	669.144	-2304.831	-500.000
8	FEA10	724.907	-2496.900	-600.000
9	FEA11	808.550	-2785.004	-700.000
10	FCB05	498.532	-1074.330	-100.000
11	FCB06	768.413	-1327.439	-200.000
12	FCB07	987.236	-1532.662	-300.000
13	FCB08	1227.941	-1758.408	-400.000
14	FCB09	1483.234	-1997.835	-500.000
15	FCB10	1650.998	-2155.173	-520.000
16	FEB11	1826.056	-2319.352	-560.000
17	FEB12	2022.996	-2504.053	-600.000
18	FEB13	2322.054	-2784.525	-600.000
19	FEB14	2759.699	-3194.972	-600.000
20	FEB33	2322.054	-2784.525	-460.000
21	FEB34	2759.699	-3194.972	-400.000
22	FCC03	201.264	-148.300	100.000
23	FCC04	442.781	-326.259	0.000
24	FCC05	732.601	-539.811	-100.000
25	FCC06	1006.320	-741.499	-200.000
26	FCC07	1288.089	-949.118	-300.000
27	FCC08	1553.758	-1144.874	-400.000
28	FEC09	1771.123	-1305.038	-460.000
29	FEC10	1916.033	-1411.814	-440.000
30	FEC11	2173.651	-1601.637	-560.000
31	FEC12	2495.673	-1838.917	-600.000
32	FEC13	2898.201	-2135.517	-680.000
33	FEC31	2173.651	-1601.637	-440.000
34	FEC32	2495.673	-1838.917	-400.000
35	FEC33	2898.201	-2135.517	-320.000

The next 3 pages from the interior of the Table have been deleted.

221	FEX11	-603.518	-1643.688	-780.000
222	FEX12	-786.144	-1828.750	-770.000
223	FEX13	-1003.890	-2049.400	-680.000
224	FEX14	-1235.684	-2284.286	-600.000
225	FCX15	-1453.430	-2504.937	-500.000
226	FEX41	-715.903	-1757.572	-640.000
227	FCY02	-512.525	1188.835	0.000
228	FCY03	-336.480	1226.362	80.000
229	FCY04	5.829	1299.330	0.000
230	FCZ02	-173.651	391.610	0.000
231	FCZ03	-16.916	423.767	20.000
232	FCZ04	198.595	467.983	0.000
233	FC101	0.000	210.000	100.000

THE FOLLOWING ARE DUMMY NODES

234	DEA12	1062.267	-3658.919	-920.000
235	DBA03	94.795	-326.518	-20.000
236	DBA04	209.108	-720.260	-110.000
237	DBA05	340.148	-1171.622	-220.000
238	DBA06	468.401	-1613.382	-320.000
239	DBA07	529.739	-1824.658	-440.000
240	DBA08	579.925	-1997.520	-540.000
241	DBA09	632.899	-2179.986	-670.000
242	DBA10	710.966	-2448.883	-830.000
243	DBA11	802.973	-2765.797	-800.000
244	DAA03	111.524	-384.138	220.000
245	DAA04	223.048	-768.277	120.000
246	DAA05	356.877	-1229.243	20.000
247	DAA06	479.554	-1651.796	-80.000
248	DAA07	571.561	-1968.710	-150.000
249	DAA08	630.111	-2170.382	-260.000
250	DAA09	694.237	-2391.262	-310.000
251	DAA10	755.576	-2602.538	-390.000
252	DAA11	822.490	-2833.021	-550.000
253	DEB15	3197.344	-3605.419	-600.000
254	DEB35	3197.344	-3605.419	-400.000
255	DBB05	483.944	-1060.648	-210.000
256	DBB06	739.237	-1300.075	-320.000
257	DBB07	965.354	-1512.140	-420.000
258	DBB08	1198.765	-1731.045	-510.000
259	DBB09	1461.352	-1977.313	-620.000
260	DBB10	1643.704	-2148.332	-650.000
261	DBB11	1811.468	-2305.670	-670.000
262	DBB12	1986.526	-2469.849	-790.000
263	DBB13	2307.466	-2770.844	-860.000
264	DBB14	2737.817	-3174.450	-960.000
265	DAB05	520.414	-1094.852	20.000
266	DAB06	790.296	-1347.961	-90.000
267	DAB07	1316.412	-1560.025	-180.000
268	DAB08	1264.411	-1792.612	-290.000
269	DAB09	1512.410	-2025.198	-380.000
270	DAB10	1665.586	-2168.855	-410.000
271	DAB11	1811.468	-2305.670	-440.000
272	DAB12	1993.820	-2476.690	-340.000
273	DAB13	2300.172	-2764.003	-340.000
274	DAB14	2737.817	-3174.450	-270.000
275	DEC14	3542.246	-2610.076	-680.000
276	DEC34	3542.246	-2610.076	-320.000
277	DBC03	197.587	-116.117	-117.014

The next 6 pages from the interior of the Table have been deleted.

650	DBW09	-474.881	-660.274	-560.834
651	DBW10	-556.629	-697.078	-660.985
652	DBW11	-638.105	-738.809	-771.643
653	DBW12	-752.014	-768.196	-880.000
654	DBW13	-916.017	-842.380	-980.000
655	DBW14	-1070.908	-912.443	-1110.000
656	DBW15	-1353.356	-1040.204	-1200.000
657	DCX16	-1643.080	-2697.117	-400.000
658	DAX05	-21.058	-1052.360	20.002
659	DAX06	-213.737	-1215.438	-97.959
660	DAX07	-323.194	-1308.361	-214.248
661	DAX08	-394.814	-1374.433	-304.922
662	DAX09	-451.887	-1442.684	-407.435
663	DAX10	-562.904	-1511.121	-415.182
664	DAX12	-722.927	-1764.690	-500.000
665	DAX13	-1003.890	-2049.400	-520.000
666	DAX14	-1221.636	-2270.051	-500.000
667	DAX15	-1432.358	-2483.584	-390.000
668	DBX05	29.197	-1303.655	-220.003
669	DBX06	-100.483	-1168.855	-302.663
670	DBX07	-181.027	-1269.902	-395.382
671	DBX08	-242.425	-1333.161	-476.893
672	DBX09	-310.829	-1412.939	-591.059
673	DBX10	-347.086	-1476.350	-729.528
674	DBX11	-554.350	-1593.863	-930.000
675	DBX12	-807.216	-1850.103	-900.000
676	DBX13	-1039.010	-2084.989	-820.000
677	DBX14	-1256.756	-2305.640	-700.000
678	DBX15	-1495.574	-2547.644	-620.000
679	DBX41	-624.591	-1665.041	-970.000
680	DAY02	-590.767	1172.156	90.000
681	DAY03	-336.480	1226.362	210.000
682	DAY04	35.170	1305.585	120.000
683	DBY02	-434.283	1205.513	-100.000
684	DBY03	-336.480	1226.362	-30.000
685	DBY04	-23.512	1293.076	-110.000
686	DAZ02	-252.019	375.531	90.000
687	DAZ03	2.676	427.786	140.000
688	DAZ04	218.187	472.003	120.000
689	DBZ02	-44.938	418.017	-168.935
690	DBZ03	-34.847	420.088	-199.655
691	DBZ04	179.003	463.963	-120.000
692	DB101	0.000	120.000	-100.000
693	DA101	0.000	250.000	210.000

2 CONNECTIONS GIVEN

FEN07	FCP07	143	155
FEA11	DEA12	9	234

K NMR NMAT NMS IMS AND REPEAT

1	37	7	5 AAAAA	8 WWWWW	6 CCCCC	3 EEEEE	11 PPPPP	3 GGGGG	1	
2	37	7	8 AAAAA	5 QQQQQ	3 XXXXX	9 WWWWW	3 BBBBB	5 CCCCC	3 RRRRR	
3	37	6	8 AAAAA	6 RRRRR	6 BBBBB	8 XXXXX	4 SSSSS	5 QQQQQ		
4	37	4	11 AAAAA	8 SSSSS	9 BBBBB	9 RRRRR				
5	37	4	11 AAAAA	10 SSSSS	9 BBBBB	7 RRRRR				
6	37	4	11 AAAAA	11 SSSSS	11 BBBBB	4 RRRRR				
7	37	4	11 AAAAA	11 SSSSS	11 BBBBB	4 RRRRR				
8	37	4	11 AAAAA	11 SSSSS	11 BBBBB	4 RRRRR				
9	37	4	11 AAAAA	11 SSSSS	11 BBBBB	4 RRRRR	4 QQQQQ	6 CCCCC	3 SSSSS	
10	37	7	5 BBBBB	9 AAAAA	5 RRRRR	5 XXXXX	4 SSSSS			
11	37	5	11 BBBBB	10 AAAAA	4 RRRRR	8 CCCCC	1 RRRRR			
12	37	5	11 BBBBB	11 AAAAA	11 CCCCC	3 SSSSS				
13	37	4	11 BBBBB	11 CCCCC	11 AAAAA	4 SSSSS				
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16	37	4	11 BBBBB	11 CCCCC	11 AAAAA	4 DDDDD				
17	37	4	11 BBBBB	11 CCCCC	11 AAAAA	4 DDDDD				
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19	37	4	11 BBBBB	11 CCCCC	9 AAAAA	6 DDDDD				
20	37	4	11 BBBBB	11 CCCCC	11 AAAAA	4 DDDDD				
21	37	4	11 BBBBB	11 CCCCC	9 AAAAA	6 DDDDD				
22	37	8	5 CCCCC	6 EEEEE	3 AAAAA	6 GGGGG	11 PPPPP	3 WWWWW	1	2 11111
23	37	6	8 CCCCC	9 EEEEE	6 AAAAA	4 WWWWW	6 GGGGG	4 PPPPP		
24	37	6	11 CCCCC	6 DDDDD	9 EEEEE	7 AAAAA	3 BBBBB	1 WWWWW		
25	37	5	11 CCCCC	9 DDDDD	8 BBBBB	6 EEEEE	3 AAAAA			
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30	37	4	11 CCCCC	11 BBBBB	11 DDDDD	4 EEEEE				
31	37	4	11 CCCCC	11 BBBBB	11 DDDDD	4 EEEEE				
32	37	4	11 CCCCC	11 BBBBB	11 DDDDD	4 EEEEE				
33	37	4	11 CCCCC	11 BBBBB	11 DDDDD	4 EEEEE				
34	37	4	11 CCCCC	11 BBBBB	11 DDDDD	4 EEEEE				
35	37	5	11 CCCCC	11 BBBBB	11 DDDDD	3 EEEEE	1 AAAAA			
36	37	4	11 DDDDD	11 EEEEE	11 CCCCC	4 GGGGG				
37	37	5	11 DDDDD	11 EEEEE	11 CCCCC	3 BBBBB	1 GGGGG			
38	37	4	11 DDDDD	11 EEEEE	11 CCCCC	4 BBBBB				
39	37	5	11 DDDDD	11 EEEEE	11 CCCCC	3 FFFFF	1 BBBBB			
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41	37	4	11 DDDDD	11 EEEEE	11 CCCCC	4 FFFFF				
42	37	4	11 DDDDD	11 EEEEE	11 CCCCC	4 FFFFF				
43	37	4	11 DDDDD	11 EEEEE	11 CCCCC	4 FFFFF				
44	37	4	11 DDDDD	11 EEEEE	11 CCCCC	4 FFFFF				
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46	37	4	11 DDDDD	11 EEEEE	11 CCCCC	4 FFFFF				
47	37	4	11 DDDDD	11 EEEEE	11 CCCCC	4 FFFFF				
48	37	8	5 GGGGG	5 EEEEE	6 CCCCC	10 PPPPP	2 11111	1	3 AAAAA	4 ZZZZZ
49	37	8	8 EEEEE	9 GGGGG	6 CCCCC	5 PPPPP	3 AAAAA	1	2 11111	3 ZZZZZ
50	37	4	11 EEEEE	6 DDDDD	11 GGGGG	9 CCCCC				
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56	37	4	11 EEEEE	11 DDDDD	11 FFFFF	4 GGGGG				
57	37	4	11 EEEEE	11 FFFFF	11 DDDDD	4 GGGGG				
58	37	4	11 EEEEE	11 FFFFF	11 DDDDD	4 GGGGG				

The next 2 pages from the interior of the Table have been deleted.

183	37	4	11 SSSSS	11 RRRRR	8 AAAAA	7 XXXXX						
184	37	4	11 SSSSS	11 RRRRR	11 AAAAA	4 XXXXX						
185	37	4	11 SSSSS	11 RRRRR	7 AAAAA	8 XXXXX						
186	37	4	11 SSSSS	11 RRRRR	9 AAAAA	6 XXXXX						
187	37	4	11 SSSSS	11 RRRRR	10 AAAAA	5 XXXXX						
188	37	4	11 SSSSS	11 RRRRR	9 AAAAA	6 XXXXX						
189	37	8	5 TTTTT	7 KKKKK	9 YYYYY	5 VVVVV	5 MMMMM	2 LLLLL	3 JJJJJ	1 IIIII		
190	37	8	5 TTTTT	6 JJJJJ	6 YYYYY	6 IIIII	6 KKKKK	4 VVVVV	3 UUJUU	1 LLLLL		
191	37	6	7 UUUUU	9 JJJJJ	6 KKKKK	11 VVVVV	3 LLLLL	1 TTTTT				
192	37	5	11 UUUUU	11 JJJJJ	10 KKKKK	4 VVVVV	1 TTTTT					
193	37	5	11 UUUUU	11 JJJJJ	11 KKKKK	3 TTTTT	1 VVVVV					
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195	37	5	11 UUUUU	11 JJJJJ	11 KKKKK	3 TTTTT	1 VVVVV					
196	37	7	9 VVVVV	9 LLLLL	6 KKKKK	3 TTTTT	6 YYYYY	3 JJJJJ	1 MMMMM			
197	37	7	11 LLLLL	11 VVVVV	6 KKKKK	2 UUUUU	2 JJJJJ	3 YYYYY	2 TTTTT			
198	37	5	11 VVVVV	11 LLLLL	9 KKKKK	3 UUUUU	3 JJJJJ					
199	37	5	11 VVVVV	11 LLLLL	8 KKKKK	4 UUUUU	3 JJJJJ					
200	37	5	11 VVVVV	11 LLLLL	9 KKKKK	4 UUUUU	2 JJJJJ					
201	37	4	11 VVVVV	11 KKKKK	11 LLLLL	4 UUUUU						
202	37	4	11 VVVVV	11 KKKKK	11 LLLLL	4 UUUUU						
203	37	6	11 WWWWW	6 AAAAA	5 CCCCC	11 PPPPP	3 QQQQQ	1 EEEEE				
204	37	6	11 WWWWW	6 AAAAA	6 QQQQQ	11 PPPPP	2 CCCCC	1 XXXXX				
205	37	5	11 WWWWW	9 QQQQQ	4 AAAAA	11 PPPPP	2 XXXXX					
206	37	5	11 WWWWW	11 QQQQQ	11 PPPPP	2 XXXXX	2 AAAAA					
207	37	4	11 WWWWW	11 QQQQQ	11 PPPPP	4 XXXXX						
208	37	4	11 WWWWW	11 QQQQQ	11 PPPPP	4 XXXXX						
209	37	4	11 WWWWW	11 QQQQQ	11 PPPPP	4 XXXXX						
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214	37	4	11 WWWWW	11 QQQQQ	10 PPPPP	5 XXXXX						
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223	37	4	11 XXXXX	11 RRRRR	11 QQQQQ	4 SSSSS						
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226	37	4	11 XXXXX	11 RRRRR	11 QQQQQ	4 SSSSS						
227	37	7	7 YYYYY	11 MMMMM	6 KKKKK	4 VVVVV	3 TTTTT	5 LLLLL	1 NNNNN			
228	37	8	8 YYYYY	6 KKKKK	11 MMMMM	3 TTTTT	3 VVVVV	3 IIIII	2 NNNNN	1 LLLLL		
229	37	8	8 YYYYY	6 TTTTT	6 IIIII	7 MMMMM	6 KKKKK	1 VVVVV	1 NNNNN	2 HHHHH		
230	37	8	8 ZZZZZ	3 KKKKK	2 11111	9 NNNNN	1	3 HHHHH	9 PPPPP	2 GGGGG	2 EEEEE	
231	37	9	8 ZZZZZ	3 KKKKK	2 11111	3 HHHHH	1	7 NNNNN	6 GGGGG	5 PPPPP		
232	37	10	8 ZZZZZ	3 HHHHH	8 GGGGG	3 KKKKK	2 11111	1	3 NNNNN	5 EEEEE	3 PPPPP	1 IIIII
233	37	8	1 11111	6 GGGGG	1	9 ZZZZZ	11 PPPPP	3 EEEEE	3 KKKKK	3 CCCCC		

CLEANED UP SERRAZZANO RUN WITH INPUT PREPARED BY PLUSN

TOTAL NUMBER OF GEOMETRIC TROUBLE FLAGS = 0

OUTPUT NODE LIST

NODE	X	Y	Z	VOLUME	IMAT	NC	CONNECTED NODES
FCA03	103.160	-355.328	100.000	1.0847E+07	AAAAA	14	DAA03 DBA03 FCW04 FCC03 DBW04 DAW04 DAC03 FCC04 DAC04 FCP02 DBP03 FCP03 FCA04 DAP03
FCA04	214.684	-739.467	.000	1.9618E+07	AAAAA	21	FCA03 DBA04 DAA04 FCQ05 FCX05 DBW04 DBX05 FCW04 DAX05 DAQ05 DAW04 DBA03 FCB05 FCW05 DAB05 FCC04 FCR05 DAC04 FCA05 FCC05
DAC05							
FCA05	348.513	-1200.433	-100.000	1.0473E+07	AAAAA	18	FCA04 DBA05 DAA05 FCR05 FCB05 DAR05 DBB05 DAB05 DBS06 FCB06 DBB06 FCA06 DAB05 DAA05 FES06 DAS06 DBA04 DAA04
FCA06	473.977	-1632.589	-200.000	1.7896E+07	AAAAA	16	FCA05 DBA06 DAA06 FEA07 FES05 DAA07 DAS06 DBS06 FCB06 DAB06 DBB06 FES07 DAS07 DAS05 FCB07 DAB07
FEA07	557.620	-1920.692	-300.000	2.4822E+07	AAAAA	17	FCA06 DAA07 DBA07 FEA08 DBA08 DAA08 DBA06 FES07 DAS07 FCB07 DBB07 DAB07 FES38 DAS08 FCB08 DBB08 DAB08
FEA08	613.382	-2112.762	-400.000	2.6650E+07	AAAAA	10	FEA07 DAA08 DBA08 FEA09 DBA09 FES38 FES08 DBB08 FCB08 DAB08
FEA09	669.144	-2304.831	-500.000	4.0817E+07	AAAAA	15	FEA08 DAA09 DBA09 FEA10 DAA08 FES38 FES08 DBB08 FCB08 DAB08 FES09 DBB09 FCB09 FES40 FES10
FEA10	724.907	-2496.900	-600.000	5.9183E+07	AAAAA	16	FEA09 DBA10 DAA10 DAA09 FEA11 DBA09 DBA11 DAA11 FES09 DBB09 FCB09 FES10 DBS09 FES40 DBB10 FCB10
FEA11	808.550	-2785.004	-700.000	8.0770E+07	AAAAA	10	FEA10 DBA11 DAA11 FES10 DBB10 FCB10 FES11 DBB11 DBS11 DEA12
FCB05	498.532	-1074.330	-100.000	1.8224E+07	BBBBB	13	FCA04 FCA05 DBB05 DAB05 DBA05 FCB05 DAB06 DBA04 DAA04 FCC05 DAC05 FCC05 DAC05
FCB06	768.413	-1327.439	-200.000	2.1449E+07	BBBBB	14	FCA05 FCA06 FCB05 DAB06 DBB06 FCB07 DAB07 DBB05 DBA06 DBA05 FCC06 DAC06 FCC07 DAC07
FCB07	987.236	-1532.662	-300.000	2.4923E+07	BBBBB	14	FCA06 FEA07 FCB06 DBB07 DAB07 DBB06 FCB08 DBB08 DBA06 DBA07 FCC07 DAC07 FCC08 DAC08
FCB08	1227.941	-1758.408	-400.000	2.9795E+07	BBBBB	13	FEA07 FEA08 FEA09 FCB07 DBB08 DAB08 DAB07 FCB09 DBB09 FCC08 DAC08 FEC09 DAC09
FCB09	1483.234	-1997.835	-500.000	3.1076E+07	BBBBB	17	FEA09 FEA10 FCB08 DBB09 DAB09 FCB10 DBB10 DAB08 FEC10 DBC10 FEC09 DAC10 FEC31 FEC11 DBC11 DAA09 DAA10
FCB10	1650.998	-2155.173	-520.000	2.5681E+07	BBBBB	15	FEA10 FEA11 FCB09 DAB10 DBB10 DAB11 DAB09 FEB11 DBB11 FEC11 FEC31 DBC11 FEC10 DAA10 DAA11
FEB11	1826.056	-2319.352	-560.000	3.1929E+07	BBBBB	10	FCB10 DBB11 DAB11 FEB12 DAB12 FEC11 FEC31 FEC12 FEC32 DAA11
FEB12	2022.996	-2504.053	-600.000	9.7216E+07	BBBBB	14	FEB11 DBB12 DAB12 DBB11 FEB13 FEB33 DAB13 DBB13 FEC12 DBC12 FEC32 FEC13 DBC13 DAA11
FEB13	2322.054	-2784.525	-600.000	1.3114E+08	BBBBB	7	FEB12 FEB33 DBB13 FEB14 FEC13 DBC13 DEA12
FEB14	2759.699	-3194.972	-600.000	2.6107E+08	BBBBB	9	FEB13 FEB34 DBB14 DEB15 FEB33 DBB13 DEC14 FEC13 DEA12
FEB33	2322.054	-2784.525	-460.000	9.7433E+07	BBBBB	11	FEB12 FEB13 FEB14 DAB13 DAB14 FEB34 FEC33 FEC13 FEC32 FEC12 DEA12
FEB34	2759.699	-3194.972	-400.000	1.6451E+08	BBBBB	7	FEB14 FEB33 DAB14 DEB35 DEC34 FEC33 DEA12
FCC03	201.264	-148.300	100.000	9.1291E+06	CCCCC	14	FCA03 DAC03 FCE03 DBE03 DAE03 DBC03 DBA03 FCP02 DBP03 FCC04 FCE04 DBC04 DBE04 DAE04
FCC04	442.781	-326.259	0.000	1.6293E+07	CCCCC	13	FCA03 FCA04 FCC03 DBC04 DAC04 FCE04 DBE04 DBA03 DAE04 FCC05 DBA04 FCE05 DAE05
FCC05	732.601	-539.811	-100.000	2.1938E+07	CCCCC	14	FCA04 FCB05 FCC04 DAC05 DBC05 FCC06 DAC04 DBC04 FCD06 DAD06 FCE05 DBA04 DAE05 DBB05
FCC06	1006.320	-741.499	-200.000	2.3065E+07	CCCCC	15	FCB05 FCB06 FCC05 DAC06 DBC06 FCC07 DAC05 DBC05 DBC07 FCD06 DAD06 FCD07 DAD07 DBB05 DBB06
FCC07	1288.089	-949.118	-300.000	2.5286E+07	CCCCC	14	FCB06 FCB07 FCC06 DBC07 DAC07 FCC08 DBC08 DAC06 FCD07 DAD07 FCD08 DAD08 DBB06 DBB07
FCC08	1553.758	-1144.874	-400.000	2.6357E+07	CCCCC	14	FCB07 FCB08 FCC07 DAC08 DBC08 FEC09 DBC09 DAC07 FCD08 DAD08

[The next 6 pages from the interior of the Table have been deleted.]

FCX08	-322.556	-1358.977	-400.000	5.2918E+06	XXXXX	14	FCQ08 FCQ09 FER06 FER07 FCX07 DBX08 DAX08 DAX09 FEX09 DBX07 DBX09 DBQ08 DBQ09 DAQ09
FEX09	-406.845	-1444.390	-500.000	6.7960E+06	XXXXX	11	FCQ09 FCQ10 FER07 FCX08 DAX09 DBX09 FEX10 DAX10 DBQ09 DAQ10 DAQ11
FEX10	-484.109	-1522.686	-600.000	1.6137E+07	XXXXX	17	FCQ10 FEQ11 FEQ12 FER07 FER08 FER38 FEX09 DBX10 DAX10 DBX09 FEX11 DAQ11 FEX41 DBX11 DBQ10 DAQ12 DBR08
FEX11	-603.518	-1643.688	-780.000	1.6705E+07	XXXXX	13	FEQ11 FEQ12 FEQ13 FER08 FEX10 DBX11 DBX41 FEX41 FEX12 DBX10 DAQ12 DBR08 DAQ13
FEX12	-786.144	-1828.750	-770.000	2.2481E+07	XXXXX	12	FEQ13 FER08 FER09 FEX11 DBX12 FEX41 DBX41 FEX13 DAX13 DAQ13 DCQ14 DBR08
FEX13	-1003.890	-2049.400	-680.000	2.5991E+07	XXXXX	10	FER09 FER10 FEX12 DBX13 DAX13 FEX14 DBX12 DBR10 DCQ15 DCQ14
FEX14	-1235.684	-2284.286	-600.000	2.1995E+07	XXXXX	9	FER10 FER11 FEX13 DAX14 DBX14 FCX15 DAX13 DBX13 DCQ15
FCX15	-1453.430	-2504.937	-500.000	3.7008E+07	XXXXX	11	FER11 FEX14 DAX15 DBX15 DCX16 DAX14 DBX14 DAR11 DER12 DBR11 DCQ15
FEX41	-715.903	-1757.572	-640.000	1.7635E+07	XXXXX	11	FER08 FER09 FEX10 FEX11 FEX12 DAX12 DAX10 DAQ13 DAX13 DAQ12 DCQ14
FCY02	-512.525	1188.835	0.000	1.0970E+07	YYYYY	19	FCK03 FCL05 FCL06 FCW04 FCM05 FEM06 FCV04 DAY02 DBY02 DBY03 FCY03 DBM06 DAM06 DAM05 DBK03 DAM06 DBV04 DAL05 DAL06
FCY03	-336.480	1226.362	80.000	6.8785E+06	YYYYY	14	FCK03 FCM03 FCM04 FCT04 FCY02 DBY03 DAY03 DAK03 DBM03 DAY02 DAM04 FCY04 DAT04 DAY04
FCY04	5.829	1299.330	.000	1.3858E+07	YYYYY	14	FCI04 FCI05 FCM03 FCT04 FCT05 FCY03 DBY04 DAY04 DAT04 DAI04 DBY03 DBM03 DAI05 DAT05
FCZ02	-173.651	391.610	.000	1.7099E+07	ZZZZZ	22	FCK01 FCN06 FEN05 FEN05 FEN07 FCP04 FCP05 FCP06 DAZ02 FCZ03 DBZ02 DAZ03 DBZ03 FCI01 DBK01 DAK01 DAI01 DBI01 DAN05 DBN05 DAN06 DBP05
FCZ03	-16.916	423.767	20.000	6.4868E+06	ZZZZZ	11	FCH06 FCK01 FCZ02 DAZ03 DBZ02 FCZ04 FCI01 DBZ04 DBK01 DBI01 DBG03
FCZ04	198.595	467.983	0.000	1.4370E+07	ZZZZZ	16	FCG03 FCG04 FCG05 FCH06 FCH05 FCK01 FCZ03 DAZ04 DBZ04 DAZ03 DBG04 DAH04 DAG05 FCI01 DBG03 DBG05
FCI01	.000	210.000	100.000	9.2544E+06	IIIII	17	FCG03 FCP02 FCP03 FCP04 FCZ02 FCZ03 FCZ04 DAI01 DBI01 DAZ03 DAG03 DBP03 DBG03 DAZ02 DAP03 DAZ04 DBZ04

/ TOTAL CONNECTIONS = 2581   INTERELEMENT CONNECTIONS = 678

IFACE	IA	IB	NODEA	NODEB	AREA	DELT	A	B	C	D
1	1	244	FCA03	DAA03	9.4293E+04	61.847	.067621	-.232918	.970143	248.599
2	1	235	FCA03	DBA03	7.0699E+04	61.847	-.067621	.232918	-.970143	-124.906
3	1	203	FCA03	FCW04	3.3287E+04	103.345	-.743185	-.462167	-.483816	142.517
4	1	22	FCA03	FCC03	2.9286E+04	114.548	.428222	.903573	-.000000	-162.377
5	1	645	FCA03	DBW04	2.6639E+03	114.581	-.391996	-.290956	-.872745	90.253
6	1	633	FCA03	DAW04	1.6263E+04	125.326	-.867289	-.496204	-.039896	208.182
7	1	288	FCA03	DAC03	8.3344E+03	127.455	.511187	.719081	.470756	-28.245
8	1	23	FCA03	FCC04	1.6190E+04	177.614	.956063	.081831	-.281509	219.014
9	1	289	FCA03	DAC04	8.7598E+03	186.199	.998454	.014341	.053706	289.474
10	1	150	FCA03	FCP02	5.3059E+03	189.275	-.272513	.938656	.211333	-151.235
11	1	546	FCA03	DBP03	2.5809E+02	190.197	-.322559	.922390	-.210308	-192.038
12	1	151	FCA03	FCP03	1.0459E+04	198.304	-.555708	.831378	.000000	-154.435
13	1	2	FCA03	FCA04	2.0414E+04	206.155	.270486	-.931673	-.242536	540.854
14	1	532	FCA03	DAP03	1.3195E+03	222.427	-.693095	.698053	.179834	-79.127
15	2	236	FCA04	DBA04	1.5767E+05	55.902	-.049875	.171792	-.983970	-81.840
16	2	245	FCA04	DAA04	1.6930E+05	61.847	.067621	-.232918	.970143	248.599
17	2	163	FCA04	FCQ05	1.4158E+04	185.105	-.832074	-.484449	-.270117	364.706
18	2	215	FCA04	FCX05	1.6931E+04	187.864	-.569914	-.777407	-.266150	640.379
19	2	645	FCA04	DBW04	2.4018E+03	194.503	-.517612	.815085	-.257065	-520.087
20	2	668	FCA04	DBX05	1.7462E+01	195.322	-.474825	-.675290	-.563181	593.478
21	2	203	FCA04	FCW04	2.0293E+04	195.955	-.676516	.736428	-.000000	-493.846
22	2	658	FCA04	DAX05	3.4233E+03	196.136	-.600966	-.797545	.052989	656.951
23	2	558	FCA04	DAQ05	9.6856E+03	197.138	-.876212	-.481925	.001082	365.397
24	2	633	FCA04	DAW04	5.8677E+03	214.336	-.767280	.605972	.209950	-398.483
25	2	235	FCA04	DBA03	6.8499E+02	215.232	-.278509	.959309	-.045461	-553.936

26	2	10	FCA04	FCB05	3.1304E+04	225.113	.630458	-.743767	-.222111	910.453
27	2	204	FCA04	FCW05	1.3590E+01	227.718	-.822218	.525115	-.219570	-337.105
28	2	265	FCA04	DAB05	2.2052E+03	234.611	.651568	-.757392	.042624	934.558
29	2	23	FCA04	FCC04	1.5494E+04	235.992	.483273	.875470	-.000000	-307.638
30	2	172	FCA04	FCR05	3.6116E+03	237.661	-.068610	-.975208	-.210336	944.066
31	2	289	FCA04	DAC04	1.2897E+04	241.790	.538275	.805408	.248149	-238.223
32	2	3	FCA04	FCA05	2.2194E+03	245.153	.272950	-.940150	-.203954	998.968
33	2	24	FCA04	FCC05	1.0028E+04	282.002	.918286	.353997	-.177304	217.374
34	2	290	FCA04	DAC05	8.8463E+03	288.826	.952337	.304556	.017311	268.068
35	3	237	FCA05	DBA05	7.8161E+04	61.847	-.067621	.232918	-.970143	-144.309
36	3	246	FCA05	DAA05	8.7174E+04	61.847	.067621	-.232918	.970143	268.002
37	3	172	FCA05	FCR05	5.5903E+04	83.230	-.999881	-.015451	.000000	-246.693
38	3	10	FCA05	FCB05	4.9648E+04	97.990	.765487	.643452	.000000	-407.649
39	3	578	FCA05	DAR05	3.0535E+01	110.665	-.831440	-.121449	.542178	-87.529
40	3	255	FCA05	DBB05	8.4874E+02	111.783	.605780	.625253	-.492026	-378.467
41	3	265	FCA05	DAB05	3.2887E+03	117.364	.732342	.449800	.511229	-218.482
42	3	596	FCA05	DBS06	4.5315E+03	219.766	-.417494	-.706128	-.571910	979.115
43	3	11	FCA05	FCB06	1.0810E+04	224.971	.933235	-.282272	-.222251	911.288
44	3	256	FCA05	DBB06	3.7757E+01	229.670	.850619	-.216925	-.478947	834.421
45	3	4	FCA05	FCA06	2.4055E+04	230.489	.272171	-.937478	-.216930	1472.415
46	3	266	FCA05	DAB06	1.4286E+03	232.936	.948293	-.316571	.021465	941.424
47	3	247	FCA05	DAA06	1.7240E+03	235.213	.278558	-.959478	.042515	1479.831
48	3	181	FCA05	FES06	2.9074E+03	238.737	-.456854	-.864535	-.209635	1138.278
49	3	591	FCA05	DAS06	2.6248E+02	244.141	-.459863	-.884203	-.081920	1153.491
50	3	236	FCA05	DBA04	3.7643E+01	250.050	-.278754	.960154	-.019996	-997.700
51	3	245	FCA05	DAA04	6.3802E+02	250.450	-.250479	.862760	.439210	-916.452
52	4	238	FCA06	DBA06	1.3700E+05	60.828	-.045836	.157380	-.986394	-21.372
53	4	247	FCA06	DAA06	1.4983E+05	60.828	.045836	-.157380	.986394	143.027
54	4	5	FCA06	FEA07	5.2828E+04	158.114	.264503	-.911364	-.316228	1834.121
55	4	181	FCA06	FES06	2.9897E+04	172.073	-.998416	.056262	-.000000	-393.006
56	4	248	FCA06	DAA07	3.5395E+03	176.777	.276008	-.950594	.141421	1831.407
57	4	591	FCA06	DAS06	8.3494E+03	177.556	-.985622	.001172	.168960	-325.311
58	4	596	FCA06	DBS06	6.0294E+03	182.488	-.846542	.333392	-.414749	-680.585
59	4	11	FCA06	FCB06	3.0879E+04	212.020	.694361	.719527	-.000000	-633.724
60	4	266	FCA06	DAB06	7.0087E+03	219.756	.719705	.647500	.250278	-546.441
61	4	256	FCA06	DBB06	1.6884E+02	220.979	.600191	.752352	-.271518	-668.538
62	4	182	FCA06	FES07	4.6657E+03	226.453	-.900107	-.375575	-.220797	457.141
63	4	592	FCA06	DAS07	2.6282E+03	235.404	-.893093	-.441777	.084960	516.346
64	4	237	FCA06	DBA05	8.8400E+02	240.208	-.278568	.959514	-.041631	-1449.992
65	4	12	FCA06	FCB07	8.8050E+03	266.186	.964098	.187701	-.187339	454.276
66	4	267	FCA06	DAB07	5.9663E+03	273.816	.990509	.132504	.036521	519.667
67	5	248	FEA07	DAA07	1.5443E+05	79.057	.088168	-.303688	.948683	426.907
68	5	239	FEA07	DBA07	1.2451E+05	86.023	-.162055	.558190	-.813733	-832.333
69	5	6	FEA07	FEA08	8.8217E+04	111.803	.249375	-.858950	-.447214	2034.822
70	5	240	FEA07	DBA08	2.8871E+04	126.491	.088168	-.303688	-.948683	1043.552
71	5	249	FEA07	DAA08	1.9157E+04	131.529	.275568	-.949179	.152057	2062.656
72	5	238	FEA07	DBA06	2.5803E+03	160.312	-.278267	.958475	-.062378	-1817.079
73	5	182	FEA07	FES07	2.4500E+04	252.640	-.972347	.233542	-.000000	-738.123
74	5	592	FEA07	DAS07	8.7952E+03	264.648	-.952434	.151355	.264502	-636.506
75	5	12	FEA07	FCB07	2.3846E+04	289.455	.742111	.670277	-.000000	-584.125
76	5	257	FEA07	DBB07	8.2227E+02	294.772	.691608	.692998	-.203547	-589.546
77	5	267	FEA07	DAB07	1.2445E+04	297.897	.770151	.605555	.201412	-495.832
78	5	184	FEA07	FES38	1.3464E+04	306.700	-.957616	-.270932	-.097816	322.435
79	5	593	FEA07	DAS08	1.3212E+02	321.716	-.932830	-.317177	.170958	359.463
80	5	13	FEA07	FCB08	6.9497E+03	348.449	.961864	.232357	-.143493	480.585
81	5	258	FEA07	DBB08	6.5573E+02	350.404	.914864	.270613	-.299654	430.683
82	5	268	FEA07	DAB08	1.5377E+03	359.186	.983879	.173293	.013920	561.195
83	6	249	FEA08	DAA08	1.6126E+05	76.158	.109829	-.378299	.919145	575.122
84	6	240	FEA08	DBA08	1.3259E+05	92.195	-.181447	.624985	-.759257	-1035.843
85	6	7	FEA08	FEA09	1.3023E+05	111.803	.249375	-.858950	-.447214	2258.429
86	6	241	FEA08	DBA09	2.9849E+04	139.463	.069971	-.241011	-.967997	1078.779
87	6	184	FEA08	FES38	3.7303E+04	322.462	-.997268	.040128	.062323	-398.835

[The next 40 pages from the interior of the Table have been deleted.]

2568	232	379	FCZ04	DAG04	1.0921E+02	160.546	.692463	-.617111	.373724	9.268
2569	232	233	FCZ04	FC101	5.1174E+03	170.290	-.583106	-.757483	.293616	-300.000
2570	232	365	FCZ04	DBG03	2.9176E+03	194.505	-.164248	-.981045	-.102825	-297.226
2571	232	367	FCZ04	DBG05	1.7851E+02	275.977	.916829	-.010481	-.399142	453.150
2572	233	693	FC101	DA101	5.6306E+04	58.523	-.000000	.341743	.939793	224.269
2573	233	692	FC101	DB101	3.4161E+04	109.659	-.000000	-.410365	-.911922	-67.710
2574	233	687	FC101	DAZ03	1.0205E+04	110.723	.012083	.983477	.180631	335.316
2575	233	378	FC101	DAG03	2.7303E+03	114.711	.807301	-.397839	.435876	74.753
2576	233	546	FC101	DBP03	1.1557E+04	114.774	-.085123	-.933431	-.348512	-116.098
2577	233	365	FC101	DBG03	1.1871E+04	115.146	.584912	-.536942	-.507924	-58.404
2578	233	686	FC101	DAZ02	1.4500E+04	150.843	-.835370	.548687	-.033147	262.752
2579	233	532	FC101	DAPG3	1.2401E+03	168.385	-.609218	-.756587	.237550	33.257
2580	233	688	FC101	DAZ04	2.1949E+03	170.771	.638828	.767118	.058558	337.721
2581	233	691	FC101	DBZ04	3.5267E+00	190.355	.470183	.667080	-.577869	272.654

Summary

The program OGRE is fully operational and allows construction of a grid made up of closed n-sided polygons in 3-space for use in reservoir simulation. The output of the grid construction from OGRE is input for the two-phase reservoir simulator SHAFT78. The output could be made compatible with any of the other related integrated finite difference programs which have evolved from the original TRUMP program. The input to OGRE is very simple, consisting basically of one card defining the number of real elements and dummy elements followed by the x, y, z coordinates of each of the elements. The output provides the interface distances and cross-sectional areas, and the element volumes. The plotting of the resulting calculation grid is automatic when the control cards are used as shown in the examples above.

This document will eventually be expanded to include a discussion of appropriate input preparation strategies and possible errors of input and computation.

OGRE PROGRAM LISTING

NOTE:

On the following pages, columns 73-80 of the comment cards have been cut off in order to enable full size reproduction of columns 1-72 of all cards.

PROGRAM OGRE(INPUT,OUTPUT,PUNCH,TAPE4,TAPE5,TAPE6)

```
      PROGRAM OGRE(INPUT,OUTPUT,PUNCH,TAPE4,TAPE5,TAPE6)
      COMMON /ARVC/ MRMAX,MRMAXS
      COMMON /CN/ ICPAV(4000),ICPBV(4000),ARCV(4000),DV(4000)
      COMMON /CNV/ ACV(4000),BCV(4000),CCV(4000),DCV(4000)
      COMMON /EPS/ EPSBC,EPSYZ,EPSIN,EPSI,EPSS
      COMMON /GIVE/ IAGIV(200),IBGIV(200),NGIVEN
      COMMON /ICV/ ICV(101),TV(100)
      COMMON /IMATV/ IMATV(800)
      COMMON /INAMEV/ INAMEV(800),IPLOT,IWRITE
      COMMON /INTEGER/ IA,IB,ID,KCT,KE,MRANK,NC,NCT,NIS,NNR,NNT
      COMMON /MATRIX/ THETA,PHI,PSI,A11,A12,A13,A21,A22,A23,A31,A32,A33
      COMMON /NCF/ NCF
      COMMON /NERR/ NERR
      COMMON /NP/ XV(800),YV(800),ZV(800)
      COMMON /VLM/ VLMV(800),NCV(800)
      DIMENSION IPRINT(8)
      READ 20,IPRINT
      PRINT 21,IPRINT
      READ 1,NNR,NNT,MRANK,MRMAX,MRMAXS,NGIVEN
      IF(MRANK.LE.0) MRANK=150
      IF(MRMAX.LE.0) MRMAX=36
      IF(MRMAXS.LE.0) MRMAXS=11
      IF(MRANK.GT.NNT) MRANK=NNT
      PRINT 7,NNR,NNT,MRANK,MRMAX,MRMAXS,NGIVEN
      READ 2,EPSBC,EPSYZ,EPSIN,EPSI
      IF(EPSBC.LE.0) EPSBC=1.0E-7
      IF(EPSYZ.LE.0) EPSYZ=1.0E-7
      IF(EPSIN.LE.0) EPSIN=1.0E-6
      IF(EPSI .LE.0) EPSI=1.0E-7
      PRINT 8,EPSBC,EPSYZ,EPSIN,EPSI
      READ 2,THETA,PHI,PSI,ANGC
      IF(ANGC.NE.0) GC TO 31
      IF(THETA.EQ.0) THETA=0.017
      IF(PHI.EQ.0) PHI=-0.037
      IF(PSI.EQ.0) PSI=0.07
   31 CONTINUE
      EPSS=10.*EPSYZ*EPSYZ
      IF(NGIVEN.EQ.0) GC TC 32
      READ 33,((IAGIV(K),IBGIV(K)),K=1,NGIVEN)
   32 CONTINUE
      CALL MATGEN
      IDIR=1
      NERR=0
      PRINT 11
      DO 4 K=1,NNT
      READ 5,INAMEV(K),XA,YA,ZA,IMATV(K)
      CALL TURN(IDIR,XA,YA,ZA,XR,YR,ZR)
      XV(K)=XR
      YV(K)=YR
      ZV(K)=ZR
      PRINT 9,K,INAMEV(K),XA,YA,ZA
      IF(K.EQ.NNR) PRINT 10
    4 CONTINUE
      IF(NGIVEN.EQ.0) GC TO 34
      PRINT 42,NGIVEN
      DO 35 K=1,NGIVEN
      ICPBV(K)=10000
```

```
**PROGRAM OGRE(INPUT,OUTPUT,PUNCH,TAPE4,TAPE5,TAPE6)**

      ICPAV(K)=10000
   35 CONTINUE
      DO 36 K=1,NNT
      NAMEK=INAMEV(K)
      DO 36 KA=1,NGIVEN
      IF(IAGIV(KA).EQ.NAMEK) ICPAV(KA)=K
      IF(IBGIV(KA).EQ.NAMEK) ICPBV(KA)=K
   36 CONTINUE
      DO 40 K=1,NGIVEN
      IAG=ICPAV(K)
      IBG=ICPBV(K)
      IF(IAG.GE.10000.OR.IBG.GE.10000.OR.IAG.EQ.IBG) GO TO 38
      IF(IAG.LT.IBG) GC TC 37
      ICPAV(K)=IBG
      ICPBV(K)=IAG
      ITS=IAGIV(K)
      IAGIV(K)=IBGIV(K)
      IBGIV(K)=ITS
      GO TO 37
   38 CCNTINUE
      PRINT 39,K,IAGIV(K),IBGIV(K)
   37 CONTINUE
      PRINT 41,IAGIV(K),IBGIV(K),ICPAV(K),ICPBV(K)
      IAGIV(K)=IAG
      IBGIV(K)=IBG
      ICPAV(K)=0
      ICPBV(K)=0
   40 CCNTINUE
   34 CONTINUE
      NCF=0
      CALL ARV
      IDIR=-1
      PRINT 21,IPRINT
      PRINT 27,NERR
      PRINT 22
      PRINT 25
      WRITE (4) NNR,NNR,NCT
      DO 23 K=1,NNR
      XA=XV(K)
      YA=YV(K)
      ZA=ZV(K)
      VL=VLMV(K)
      INAME=INAMEV(K)
      IMAT=IMATV(K)
      IPNT=K
      CALL FINDC(IPNT)
      NCC=NC
      IF(NCC.GT.10) NCC=10
      DO 30 KA=1,NC
      IC=ICV(KA)
      IA=ICPAV(IC)
      IB=ICPBV(IC)
      IF(IA.NE.K) ICV(KA)=INAMEV(IA)
      IF(IB.NE.K) ICV(KA)=INAMEV(IB)
   30 CONTINUE
      CALL TURN(IDIR,XA,YA,ZA,XR,YR,ZR)
      PRINT 24,INAME,XR,YR,ZR,VL,IMAT,NC,(ICV(KA),KA=1,NCC)
      IF(NC.GT.10) PRINT 29,(ICV(KA),KA=11,NC)
```

```
**PROGRAM OGRE(INPUT,OUTPUT,PUNCH,TAPE4,TAPE5,TAPE6)**

      WRITE (4) INAME,IMAT,VL
   23 CONTINUE
      PRINT 26,NCT,NCF
      PRINT 12
      HTR=0.
      DO 13 K=1,NCT
      XA=ACV(K)
      YA=BCV(K)
      ZA=CCV(K)
      CALL  TURN(IDIR,XA,YA,ZA,XR,YR,ZR)
      IA=ICPAV(K)
      IB=ICPBV(K)
      AREA=ARCV(K)
      DELT=DV(K)
      NA=INAMEV(IA)
      NB=INAMEV(IB)
      PRINT 14,K,IA,IB,NA,NB,AREA,DELT,XR,YR,ZR,DCV(K)
      AX=ABS(XR)
      AY=ABS(YR)
      AZ=ABS(ZR)
      ISI=1
      IF(AY.GT.AX) ISI=2
      IF(AZ.GT.AY) ISI=3
      WRITE (4) NA,NB,ISI,DELT,DELT,AREA,ZR,HTR
   13 CONTINUE
    1 FORMAT(6I5)
    2 FORMAT(4E10.3)
    3 FORMAT(3E10.3)
    5 FORMAT(A5,5X,3E2C.12,5X,A5)
    7 FORMAT(1X//1X,*NNR,NNT,MRANK=*,3I5,3X,*MRMAX,MRMAXS=*,2I5,3X,
     1*NGIVEN=*,I5//)
    8 FORMAT(1X,*EPSBC,EPSYZ,EPSIN,EPSI=*,1P4E15.4//)
    9 FORMAT(1X,I5,5X,A5,3X,3F12.3)
   1C FORMAT(1X//1X,*THE FCLLCWING ARE DUMMY NODES*//)
   11 FORMAT(1X,*THE LIST CF NODES FOLLOWS*//)
   12 FORMAT(1X,*IFACE*,3X,*IA*,3X,*IB*,2X,*NODEA*,2X,*NODEB*,10X,*AREA*
     1,10X,*DELT*,13X,*A*,13X,*B*,13X,*C*,13X,*D*//)
   14 FORMAT(1X,3I5,2X,A5,2X,A5,1PE14.4,0PF14.3,3F14.6,F14.3)
   20 FCRMAT(8A10)
   21 FORMAT(1H1,1X,8A1C)
   22 FORMAT(1X//1X,*CUTPUT NCDE LIST*//)
   24 FORMAT(1X,A5,2X,3F12.3,1PE14.4,3X,A5,I5,10(1X,A5))
   25 FORMAT(2X,*NODE*,13X,*X*,11X,*Y*,11X,*Z*,8X,*VOLUME*,4X,*IMAT*,3X,
     1*NC*,5X,*CONNECTED NCDES*//)
   26 FORMAT(1H/1X,*TOTAL CONNECTIONS =*,I5,5X,*INTERELEMENT CONNECTIONS
     1 =*,I5//)
   27 FORMAT(1X//1X,*TOTAL NUMBER OF GECMETRIC TROUBLE FLAGS =*,I7//)
   29 FORMAT(71X,10(1X,A5))
   33 FORMAT(A5,5X,A5)
   39 FORMAT(1X,*AN IMPCSSIBLE CCNNECTION GIVEN   K=*,I5,5X,A5,5X,A5)
   41 FCRMAT(6X,2(A5,5X),I5,5X,I5)
   42 FORMAT(1X///1X,I5,3X,*CCNNECTIONS GIVEN*//)
      END
```

SUBROUTINE ARV

```
      SUBROUTINE ARV
      COMMON /ARVC/ MRMAX,MRMAXS
      COMMON /CN/ ICPAV(4000),ICPBV(4000),ARCV(4000),DV(4000)
      COMMON /CNV/ ACV(4000),BCV(4000),CCV(4000),DCV(4000)
      COMMON /DIST/ DISTV(800),IRANKV(800),IELIMV(800)
      COMMON /GIVE/ IAGIV(200),IBGIV(200),NGIVEN
      COMMON /IMATV/ IMATV(800)
      COMMON /INTEGER/ IA,IB,ID,KCT,KE,MRANK,NC,NCT,NIS,NNR,NNT
      COMMON /LENGTH/ ALENGV(100)
      COMMON /NP/ XV(800),YV(800),ZV(800)
      COMMON /NPR/ XRV(800),YRV(800),ZRV(800)
      COMMON /VLM/ VLMV(800),NCV(800)
      DIMENSION IMSV(20),NMSV(20)
C
C     MRANK IS THE NUMBER OF NODES TO BE RANKED IN ORDER OF INCREASING
C     DISTANCE FROM THE GIVEN NODE K
C     NNR IS THE NUMBER OF REAL NODES
C     NNT IS THE TOTAL NUMBER OF NODES INCLUDING DUMMY NODES
C
      DO 6 K=1,NNR
      VLMV(K)=0.
    6 CONTINUE
      NCT=0
      NMAT=20
      PRINT 12
      DO 1 K=1,NNR
      KE=NCT+1
      IREF=K
      CALL DISTGEN(IREF)
      CALL RANK
      IA=K
      XA=XV(K)
      YA=YV(K)
      ZA=ZV(K)
      DO 9 KA=1,NMAT
      IMSV(KA)=0
      NMSV(KA)=0
    9 CONTINUE
      NMAT=0
      MMR=0
      DO 5 KA=2,MRANK
      IF(MMR.GT.MRMAX) GO TO 13
      IB=IRANKV(KA)
      IMATB=IMATV(IB)
      IF(NMAT.EQ.0) GO TO 7
      DO 8 KB=1,NMAT
      IF( IMATB.NE.IMSV(KB)) GO TO 8
      IF(NMSV(KB).GE.MRMAXS) GO TO 5
      NMSV(KB)=NMSV(KB)+1
      GO TO 10
    8 CONTINUE
    7 CONTINUE
      NMAT=NMAT+1
      IMSV(NMAT)=IMATB
      NMSV(NMAT)=1
   10 CONTINUE
      MMR=MMR+1
```

```
      **SUBROUTINE ARV**

      IF(IB.LE.IA) GO TO 5
      GC TC 14
   13 CONTINUE
      IF(NGIVEN.EQ.0) GC TO 17
      DO 15 KG=1,NGIVEN
      KGG=KG
      IF(IA.EQ.IAGIV(KG)) GC TO 16
   15 CONTINUE
      GO TO 17
   16 CONTINUE
      IB=IBGIV(KGG)
      IAGIV(KGG)=10000
      IBGIV(KGG)=10000
      DC 18 KG=KE,NCT
      IF(IB.EQ.ICPBV(KG)) GC TO 5
   18 CONTINUE
   14 CONTINUE
      NCT=NCT+1
      ICPAV(NCT)=IA
      ICPBV(NCT)=IB
      DIST=SQRT(DISTV(IB))
      DISI=1./DIST
      AC=XRV(IB)*DISI
      BC=YRV(IB)*DISI
      CC=ZRV(IB)*DISI
      ACV(NCT)=AC
      BCV(NCT)=BC
      CCV(NCT)=CC
      DCV(NCT)=DIST+AC*XA+BC*YA+CC*ZA
      DV(NCT)=DIST
    5 CONTINUE
   17 CONTINUE
      PRINT 11,K,MPR,NMAT,(NMSV(KA),IMSV(KA),KA=1,NMAT)
C
C     THE INTERFACIAL PLANES ARE IDENTIFIED IN TERMS OF THE NODES THEY
C     CONNECT IA ANC IB, AND THEIR EQUATIONS ARE STORED IN THE FORM OF
C    ARRAYS OF THE COEFFICIENTS IN THE EQUATION ACV*X+BCV*Y+CCV*Z-DCV=0
C     THEY ARE CLUMPED IN GROUPS OF THE SAME IA, WITH IB ALWAYS GREATER
C     DV IS THE DISTANCE CF EACH NODE FROM THE GIVEN INTERFACE PLANE
C      NCT IS THE TOTAL NUMBER OF INTERFACES IDENTIFIED.
C
      KK=K
      CALL FINDC(KK)
C
C     FINDC PULLS OUT ALL CF THE INTERFACES OF NODE IA, WHICH IS ONE OF
C     TWO NODES WHICH SHARE INTERFACE KCT.  THIS NEED NOT BE REPEATED FO
C     KCT BECAUSE THEY ARE CLUSTERD IN GROUPS OF COMMON IA.
C
      IF(NCT.LT.KE) GC TC 1
      ID=1
      DO 4 KCT=KE,NCT
      IB=ICPBV(KCT)
      ARCV(KCT)=0.
      IF(ID.EQ.-1) GO TO 4
      CALL LINES
      IF(ID.LT.1) GO TO 4
      CALL ISECT
C
```

```
      **SUBROUTINE ARV**
C     LINES CONSIDERS EACH INTERFACE WHICH IA HAS TO BE AN INFINITE PLAN
C     CALCULATES THE LINES CF INTERSECTION BETWEEN PLANE KCT AND THE PLA
C     ALL OTHER INTERFACES OF IA.  ISECT DETERMINES WHICH OF  THE LINES
C     GENERATED BY LINES ACTUALLY INCLUDE SEGMENTS WHICH ARE EDGES OF TH
C     CONVEX POLYGON WHICH IS THE ACTUAL INTERFACE KCT BETWEEN NODE VOLU
C     IA AND IB.  IT DETERMINES THE POSITIONS OF THE CORNERS, AND THE LE
C     OF THE PCLYGON EDGES BETWEEN THEM.
C
      IF(NIS.LT.3) GO TO 4
      A=0.
C
C    LOOP 3 CALCULATES THE AREA OF INTERFACE KCT AS A SUM OF TRIANGLES,
C     WHICH CORRESPCNDS TO AN EDGE OF THE POLYGON KCT.
C
      DC 3 KA=1,NC
      A=A+DISTV(KA)*ALENGV(KA)
    3 CONTINUE
      A=0.5*A
      ARCV(KCT)=A
      VI=0.3333333*DV(KCT)*A
      IF(IA.LE.NNR) VLMV(IA)=VLMV(IA)+VI
      IF(IB.LE.NNR) VLMV(IB)=VLMV(IB)+VI
C
C     THE VOLUME OF EACH NCDE VOLUME IS CALCULATED AS THE SUM OF THE VOL
C     OF POLYGONAL PYRAMIDS, THE BASE OF EACH OF WHICH IS AN INTERFACE P
C     EACH INTERFACE KCT CONTRIBUTES THE SAME VOLUME TO BOTH NODES IA AN
C
    4 CONTINUE
      CALL TAPP
    1 CONTINUE
C
C     VLMV(K) IS THE VCLUME OF CELL K
C      ARCV(K) IS THE AREA OF INTERFACE K
C
   11 FORMAT(1X,3I5,11(1X,I3,1X,A5))
   12 FORMAT(1H1/5X,*K   MMR NMAT   NMS   IMS   AND REPEAT*//)
      RETURN
      END
```

SUBROUTINE MATGEN

```
      SUBROUTINE MATGEN
      COMMON /MATRIX/ THETA,PHI,PSI,A11,A12,A13,A21,A22,A23,A31,A32,A33
      STHETA=SIN(THETA)
      CTHETA=COS(THETA)
      SPHI=SIN(PHI)
      CPHI=COS(PHI)
      SPSI=SIN(PSI)
      CPSI=COS(PSI)
      A11=CPSI*CPHI-CTHETA*SPHI*SPSI
      A12=CPSI*SPHI+CTHETA*CPHI*SPSI
      A13=SPSI*STHETA
      A21=-SPSI*CPHI-CTHETA*SPHI*CPSI
      A22=-SPSI*SPHI+CTHETA*CPHI*CPSI
      A23=CPSI*STHETA
      A31=STHETA*SPHI
      A32=-STHETA*CPHI
      A33=CTHETA
      PRINT 1,THETA,PHI,PSI
      PRINT 2
      PRINT 3,A11,A12,A13
      PRINT 3,A21,A22,A23
      PRINT 3,A31,A32,A33
    1 FORMAT(1X,*THETA,PHI,PSI=*,3F12.8//)
    2 FORMAT(1X,*THE RCTATION MATRIX IS*//)
    3 FORMAT(1X,3F12.8//)
      RETURN
      END
```

SUBROUTINE TURN(IDIR,XA,YA,ZA,XR,YR,ZR)

```
      SUBROUTINE TURN(IDIR,XA,YA,ZA,XR,YR,ZR)
      COMMON /MATRIX/ THETA,PHI,PSI,A11,A12,A13,A21,A22,A23,A31,A32,A33
      IF(IDIR.EG.0) RETURN
      IF(IDIR.LT.0) GC TO 1
      XR=A11*XA+A12*YA+A13*ZA
      YR=A21*XA+A22*YA+A23*ZA
      ZR=A31*XA+A32*YA+A33*ZA
      RETURN
    1 CONTINUE
      XR=A11*XA+A21*YA+A31*ZA
      YR=A12*XA+A22*YA+A32*ZA
      ZR=A13*XA+A23*YA+A33*ZA
      RETURN
      END
```

SUBROUTINE DISTGEN(IREF)

```
      SUBROUTINE DISTGEN(IREF)
      COMMON /DIST/ DISTV(800),IRANKV(800),IELIMV(800)
      COMMON /INTEGER/ IA,IB,ID,KCT,KE,MRANK,NC,NCT,NIS,NNR,NNT
      COMMON /NP/ XV(800),YV(800),ZV(800)
      COMMON /NPR/ XRV(800),YRV(800),ZRV(800)
C
C     XV,YV,ZV IS THE ABSOLUTE POSITION OF THE GIVEN NODE.
C
      XREF=XV(IREF)
      YREF=YV(IREF)
      ZREF=ZV(IREF)
      DO 1 K=1,NNT
      XD=0.5*(XV(K)-XREF)
      YD=0.5*(YV(K)-YREF)
      ZD=0.5*(ZV(K)-ZREF)
      XRV(K)=XD
      YRV(K)=YD
      ZRV(K)=ZD
      DISTV(K)=XD*XD+YD*YD+ZD*ZD
    1 CONTINUE
C
C     XRV,YRV,ZRV IS NOW THE VECTOR FROM NODE IREF TO THE MIDPOINT OF TH
C     LINE BETWEEN NODES IREF AND K.  AT THIS POINT, DISTV IS ITS LENGTH
C
      RETURN
      END
```

SUBROUTINE RANK

```
      SUBROUTINE RANK
C
C     THIS SUBROUTINE RANKS THE MRANK NODES NEAREST TO THE GIVEN NODE (I
C     ITSELF) IN  CRDER OF INCREASING DISTANCE SQUARED/4 DISTV.  THE USE
C     ARRAY IELIMV HERE IS DIFFERENT FROM THE USE IN SUBROUTINE IDC.
C     HERE IELIMV(K)=1 INDICATES THAT NODE K HAS NOT YET BEEN RANKED.
C
      COMMON /DIST/ DISTV(800),IRANKV(800),IELIMV(800)
      COMMON /INTEGER/ IA,IB,ID,KCT,KE,MRANK,NC,NCT,NIS,NNR,NNT
      DO 1 K=1,NNT
      IELIMV(K)=1
    1 CONTINUE
      CO 2 K=1,MRANK
C
C     FIND FIRST UNRANKED DISTANCE
C
      DO 3 KA=1,NNT
      IMIN=KA
      IF(IELIMV(IMIN).EC.1) GO TO 4
    3 CONTINUE
    4 CONTINUE
      DMIN=DISTV(IMIN)
C
C     COMPARE WITH OTHER UNRANKED DISTANCES.  REPLACE WITH ANOTHER ONE I
C     SMALLER.  CONTINUE UNTIL THE SMALLEST IS FOUND, AND RANK IT.
C
      DO 5 KA=1,NNT
      IF(IELIMV(KA).EC.0) GC TO 5
      CTEST=DISTV(KA)
      IF(DTEST.GT.DMIN) GO TO 5
      IMIN=KA
      DMIN=DTEST
    5 CONTINUE
C
C     NOW IMIN IS THE NUMBER OF THE NODE WHICH IS THE CLOSEST AMONG ALL
C     PREVIOUSLY UNRANKED NCDES TO THE GIVEN NODE.
C
      IRANKV(K)=IMIN
      IELIMV(IMIN)=0
    2 CONTINUE
C
C     IRANKV(K) IS THE NUMBER OF THE KTH NCDE AWAY FROM THE GIVEN NODE
C
      RETURN
      END
```

SUBROUTINE FINDC(IPNT)

```
      SUBROUTINE FINDC(IPNT)
C
C     THIS SUBROUTINE IDENTIFIES ALL INTERFACES WHICH NODE IPNT SHARES W
C     OTHER NODES, AND CALCULATES THE POSITION OF THE MIDPOINT BETWEEN T
C     GIVEN NODE AND EACH OF THE OTHER NODES CONNECTED TO IT.
C     THE ARRAY TV IS USED BY TESTS. THE SIGN OF TV(K) SERVES TO INDICAT
C     WHICH SIDE OF PLANE K NODE POINT IPNT LIES ON.
C
      COMMON /CN/ ICPAV(4000),ICPBV(4000),ARCV(4000),DV(4000)
      COMMON /CNV/ ACV(4000),BCV(4000),CCV(4000),DCV(4000)
      COMMON /ICV/ ICV(101),TV(100)
      COMMON /INTEGER/ IA,IB,ID,KCT,KE,MRANK,NC,NCT,NIS,NNR,NNT
      COMMON /NERR/ NERR
      COMMON /NP/ XV(800),YV(800),ZV(800)
      COMMON /VLM/ VLMV(800),NCV(800)
      NC=0
      ICV(101)=IPNT
      X=XV(IPNT)
      Y=YV(IPNT)
      Z=ZV(IPNT)
      NCV(IPNT)=100
      DO 1 K=1,NCT
      JA=ICPAV(K)
      JB=ICPBV(K)
      IF(IPNT.EQ.JA) GO TO 4
      IF(IPNT.EQ.JB) GO TO 4
      GO TO 1
    4 CONTINUE
      NC=NC+1
      IF(NC.GT.100) GO TO 2
      ICV(NC)=K
      TV(NC)=ACV(K)*X+BCV(K)*Y+CCV(K)*Z-DCV(K)
    1 CONTINUE
      NCV(IPNT)=NC
      RETURN
    2 CONTINUE
      NERR=NERR+1
      IF(NERR.GT.100) RETURN
      PRINT 3,IPNT
      RETURN
    3 FORMAT(1X,*WARNING NC EXCEEDS 100 FOR IPNT=*,I5)
      END
```

SUBROUTINE LINES

```
      SUBROUTINE LINES
C
C     THIS SUBROUTINE CALCULATES THE INTERSECTION LINES OF PLANE KCT WIT
C     OTHER INTERFACE PLANES OF NODE IA. (THEY ARE LISTED IN ICV.)  TWO
C     ALTERNATE ALGORITHMS ARE AVAILABLE.  THE ONE USUALLY EMPLOYED BEGI
C     REARRANGING THE DEFINING EQUATIONS OF PLANES KCT AND KA INTO THE F
C     Y=Y(X,Z).  SETTING THE TWO EXPRESSIONS THUS OBTAINED EQUAL TO EACH
C     GIVES AN EQUATION IN X AND Z WHICH IS THEN SOLVED FOR Z AS A FUNCT
C     X, Z=Z(X).  SUBSTITUTING THIS EXPRESSION BACK INTO ONE OF THE EXPR
C     FOR Y THEN GIVES AN EXPRESSION Y=Y(X).   THE LINE OF INTERSECTION
C     COMPLETELY DEFINED BY THESE TWO EXPRESSIONS WHICH ARE STORED AS TH
C     COEFFICIENTS IN THE FORMS Y(X)=YXV*X+YCV AND Z(X)=ZXV*X+ZCV.
C     FOR THIS METHOD TO BE USEABLE, THE NORMALS TO BOTH PLANES MUST HAV
C     NONZERO Y COMPONENTS.  IF THIS CONDITION IS NOT MET, THE CODE USES
C     AN ANALOGOUS ALGORITHM WHICH FIRST EQUATES TWO EXPRESSIONS FOR Z A
C     FUCTION OF X AND Y, AND THEN SOLVES THE RESULTING EQUATION FOR Y A
C     FUCTION OF X.  BACK SUBSTITUTION GIVES Z(X).  THIS OPTION REQUIRES
C     TH PLANE NORMALS HAVE NONZERO Z COMPONENTS.  IF NEITHER CONDITION
C     A WARNING IS PRINTED AND THE INTERFACE KCT IS DROPPED FROM FURTHER
C     CONSIDERATION. (THIS IS COMMUNICATED BY RETURNING ID=0 OR ID=-1.)
C
      LOGICAL LY1,LZ1,LY2,LZ2,LPAR
      COMMON /CN/ ICPAV(4000),ICPBV(4000),ARCV(4000),DV(4000)
      COMMON /CNV/ ACV(4000),BCV(4000),CCV(4000),DCV(4000)
      COMMON /EPS/ EPSBC,EPSYZ,EPSIN,EPSI,EPSS
      COMMON /ICV/ ICV(101),TV(100)
      COMMON /INTEGER/ IA,IB,ID,KCT,KE,MRANK,NC,NCT,NIS,NNR,NNT
      COMMON /LINES/ YXV(100),YCV(100),ZXV(100),ZCV(100),ISKIPV(100)
      COMMON /NERR/ NERR
      COMMON /NP/ XV(800),YV(800),ZV(800)
      ID=1
      A1=ACV(KCT)
      B1=BCV(KCT)
      C1=CCV(KCT)
      D1=DCV(KCT)
      LY1=ABS(B1).GT.EPSBC
      LZ1=ABS(C1).GT.EPSBC
C
C     WILL TRANSFER TO 11 IF NEITHER Y OR Z COMPONENT IS NONZERO.SETTING
C     WILL CAUSE THIS INTERFACE AND ALL OTHERS WITH THE SAME VALUE OF IA
C     HENCEFORTH BE IGNORED.
      IF(.NOT.(LY1.OR.LZ1)) GO TO 11
      IF(.NOT.LY1) GO TO 5
      AB=A1/B1
      CB=C1/B1
      DB=D1/B1
    5 CONTINUE
      IF(.NOT.LZ1) GO TO 6
      AC=A1/C1
      BC=B1/C1
      CC=D1/C1
    6 CONTINUE
      DO 1 KA=1,NC
      ISKIPV(KA)=1
      KC=ICV(KA)
      IA2=ICPAV(KC)
      IB2=ICPBV(KC)
```

SUBROUTINE LINES

```
      YXV(KA)=0.
      YCV(KA)=0.
      ZXV(KA)=0.
      ZCV(KA)=0.
      IF(.NOT.(IA.EQ.IA2.AND.IB.EQ.IB2)) GO TO 2
      ISKIPV(KA)=0
      GO TO 1
    2 CONTINUE
      A2=ACV(KC)
      B2=BCV(KC)
      C2=CCV(KC)
      D2=DCV(KC)
      LY2=ABS(B2).GT.EPSBC
      LZ2=ABS(C2).GT.EPSBC
C
C     SEE THE PRECEEDING COMMENT.
C
      IF(.NOT.(LY2.OR.LZ2)) GO TO 13
      IF(.NOT.(LY1.AND.LY2)) GO TO 9
      DNM=CB-C2/B2
      ABSDNM=ABS(DNM)
      IF(ABSDNM.GT.EPSYZ) GC TO 22
      CALL PTEST(LPAR,A1,B1,C1,A2,B2,C2)
      IF(.NOT.LPAR) GO TO 7
      ISKIPV(KA)=0
      GO TO 1
   22 CONTINUE
      DNMI=1./DNM
      ZX=(A2/B2-AB)*DNMI
      ZC=(CB-D2/B2)*DNMI
      YX=-AB-CB*ZX
      YC=-CB*ZC+DB
      GC TC 10
    9 CONTINUE
C
C     WILL TRANSFER TC 12 IF NEITHER OPTION MAY BE USED BECAUSE ONE PLAN
C     NORMAL HAS A ZERO Y COMPONENT AND THE OTHER A ZERO Z COMPONENT.
C     ID=0 WILL BE RETURNED IN THIS CASE.  THIS WILL DROP THE GIVEN INTE
C     FROM FURTHER CCNSIDERATICN, BUT WILL NOT EFFECT OTHER INTERFACES W
C     THE SAME IA.
C
      IF(.NOT.(LZ1.ANC.LZ2)) GC TO 12
      DNM=BC-B2/C2
      ABSDNM=ABS(DNM)
      IF(ABSDNM.GT.EPSYZ) GO TO 23
      CALL PTEST(LPAR,A1,B1,C1,A2,B2,C2)
      IF(.NOT.LPAR) GC TC 7
      ISKIPV(KA)=0
      GO TO 1
   23 CONTINUE
      DNMI=1./DNM
      YX=(A2/C2-AC)*DNMI
      YC=(DC-D2/C2)*DNMI
      ZX=-AC-BC*YX
      ZC=-BC*YC+DC
   10 CONTINUE
      YXV(KA)=YX
      YCV(KA)=YC
```

SUBROUTINE LINES

```
      ZXV(KA)=ZX
      ZCV(KA)=ZC
    1 CONTINUE
      RETURN
    7 CONTINUE
      ID=0
      NERR=NERR+1
      IF(NERR.GT.100) RETURN
      PRINT 15
      PRINT 20,DNM,EPSYZ
      PRINT 15,KCT,IA,IB,A1,B1,C1,D1,EPSBC
      PRINT 15,KC,IA2,IB2,A2,B2,C2,D2,EPSBC
      PRINT 21,LY1,LZ1,LY2,LZ2
      RETURN
   11 CONTINUE
      ID=-1
      NERR=NERR+1
      IF(NERR.GT.100) RETURN
      PRINT 8
      PRINT 14
      PRINT 15,KCT,IA,IB,A1,B1,C1,D1,EPSBC
      RETURN
   13 CONTINUE
      ID=-1
      NERR=NERR+1
      IF(NERR.GT.100) RETURN
      PRINT 8
      PRINT 15,KC,IA2,IB2,A2,B2,C2,D2,EPSBC
      PRINT 16
      PRINT 17
      PRINT 15,KCT,IA,IB,A1,B1,C1,D1,EPSBC
      RETURN
   12 CONTINUE
      ID=0
      NERR=NERR+1
      IF(NERR.GT.100) RETURN
      PRINT 18
      PRINT 15,KC,IA2,IB2,A2,B2,C2,D2,EPSBC
      PRINT 16
      PRINT 17
      PRINT 15,KCT,IA,IB,A1,B1,C1,D1,EPSBC
      PRINT 21,LY1,LZ1,LY2,LZ2
      RETURN
    8 FORMAT(1X,*HAVE FOUND AN INTERFACE WITH ZERO Y AND Z NORMAL COMPON
     1ENTS*)
   14 FORMAT(1X,*IT IS THE INTERFACE WHOSE INTERSECTIONS ARE BEING CALCU
     1LATED*)
   15 FORMAT(1X,*KC,IA,IB=*,3I5,3X,*A1,B1,C1,D1,EPSBC=*,1P5E15.4)
   16 FORMAT(1X,*THIS IS NOT THE INTERFACE WHOSE INTERSECTIONS ARE BEING
     1 CALCULATED*)
   17 FORMAT(1X,*THE FOLLOWING INTERFACES INTERSECTIONS ARE BEING CALCUL
     1ATED*)
   18 FORMAT(1X,*HAVE COME UPON TWO INTERFACES, ONE OF WHICH HAS A ZERO
     1Y NORMAL COMPONENT AND THE OTHER A ZERO Z COMPONENT*)
   19 FORMAT(1X,*HAVE COME UPON AN INTERSECTION LINE WHICH LIES IN THE Y
     1,Z PLANE.*)
   20 FORMAT(1X,*DNM,EPSYZ=*,1P2E15.4)
   21 FORMAT(1X,*LY1,LZ1,LY2,LZ2=*,4L5)
      END
```

```
      **SUBROUTINE ISECT**

      SUBROUTINE ISECT
C
C     THIS SUBROUTINE CALCULATES ALL CF THE PCINTS OF INTERSECTION BETWE
C     THE LINES IN PLANE KCT WHICH WERE CALCULATED BY LINES.  TESTS DETE
C     WHICH OF THESE PCINTS ARE ACTUALLY INTERFACE POLYGON CORNERS.
C
      LOGICAL LA
      COMMON /DIST/ DISTV(800),IRANKV(800),IELIMV(800)
      COMMON /EPS/ EPSBC,EPSYZ,EPSIN,EPSI,EPSS
      CCMMCN /ICV/ ICV(101),TV(100)
      COMMON /INAMEV/ INAMEV(800),IPLOT,IWRITE
      COMMCN /INTEGER/ IA,IB,ID,KCT,KE,MRANK,NC,NCT,NIS,NNR,NNT
      COMMON /LENGTH/ ALENGV(100)
      COMMON /LINES/ YXV(100),YCV(100),ZXV(100),ZCV(100),ISKIPV(100)
      COMMON /NCF/ NCF
      CCMMCN /NERR/ NERR
      COMMON /TESTS/ ISV(15),NLIS,XI,YI,ZI,LA
      DIMENSION XISV(30),YISV(30),ZISV(30),NLISV(30),ISM(15,30)
      DIMENSICN KIV(30),KIIV(30)
      CIMENSION XPV(30),YPV(30),ZPV(30)
      NLISV(1)=0
      ISM(1,1)=0
      NIS=0
      DO 1 K=1,NC
      CISTV(K)=0.
      IF(K.EQ.NC) GC TO 1
      IF(ISKIPV(K).EQ.0) GC TO 1
      KK=K+1
C
C
      DO 2 KA=KK,NC
      ISV(1)=K
      ISV(2)=KA
      IF(ISKIPV(KA).EG.0) GC TC 2
C
C     THERE ARE TWO POSSIBLE WAYS TO SOLVE FOR THE X COORDINATE OF THE
C     INTERSECTICN POINT.  CNE IS TO SET THE TWO EXPRESSIONS FOR Y(X) EQ
C     THIS REQUIRES THAT YD≠0.  IF YD=0, THE CODE ATTEMPTS TO SOLVE FOR
C     BY SETTING THE TWC Z(X) EQUAL.  THIS REQUIRES THAT ZD≠0.  IF BOTH
C     YD=0 AND ZD=0, THE TWC LINES ARE PARALLEL, AND THE CODE DOES NOT
C     ATTEMPT TO CALCULATE THEIR INTERSECTION.  RATHER, IT TRANSFERS TO
C
      YD=YXV(K)-YXV(KA)
      ABSYC=ABS(YD)
      IF(ABSYC.LT.EPSI) GC TC 18
      XI=(YCV(KA)-YCV(K))/YD
      GO TO 19
   18 CONTINUE
      ZD=ZXV(K)-ZXV(KA)
      ABSZC=ABS(ZD)
      IF(ABSZD.LT.EPSI) GO TO 2
      XI=(ZCV(KA)-ZCV(K))/ZD
   19 CONTINUE
      YI=YXV(K)*XI+YCV(K)
      ZI=ZXV(K)*XI+ZCV(K)
      CALL TESTS
      IF(.NOT.LA) GO TO 2
```

SUBROUTINE ISECT

```
      IF(NIS.EQ.0) GO TO 31
      DO 32 KC=1,NIS
      NLI=NLISV(KC)
      IF(NLI.NE.NLIS) GO TO 32
      DO 33 KB=1,NLIS
      IS=ISM(KB,KC)
      IF(IS.NE.ISV(KB)) GO TO 32
   33 CONTINUE
      GO TO 2
   32 CONTINUE
   31 CONTINUE
      NIS=NIS+1
      NLISV(NIS)=NLIS
      DO 25 KB=1,NLIS
      ISM(KB,NIS)=ISV(KB)
   25 CONTINUE
      XISV(NIS)=XI
      YISV(NIS)=YI
      ZISV(NIS)=ZI
    2 CONTINUE
    1 CONTINUE
C
C     NIS IS THE TOTAL NUMBER OF INTERSECTIONS WHICH HAVE BEEN ACCEPTED
C     TESTS AS CORNERS OF THE INTERFACE POLYGON KCT.  ISAV(K) AND ISBV(K
C     THE TWO LINES WHICH INTERSECTION K INVOLVES.  (THE ORDERING OF THE
C     HERE AND ELSEWHERE IN THE VARIOUS ARRAYS IS THE SAME AS THAT OF TH
C     CORRESPONDING PLANES IN ICV.)  XISV,YISV,ZISV ARE THE POSITIONS IN
C     OF THE INTERSECTION POINTS K.
C     LOOP 5 GOES THROUGH THE NC LINES AND DETERMINES WHICH RETAINED LIN
C     INTERSECTIONS INVOLVE EACH OF THE LINES, IF ANY.  LINES, PARTS OF
C     CONSTITUTE EDGES OF THE POLYGONAL FACES OF NODE VOLUME IA SHOULD T
C     PART IN TWO RETAINED INTERSECTIONS.  OTHER LINES SHOULD NOT TAKE P
C     ANY.
C     KI AND KII ARE THE TWO INTERSECTIONS (IF ANY) FOUND FOR LINE KB.
C     ALENGV(KB) IS THE DISTANCE BETWEEN THE TWO INTERSECTIONS WHICH INV
C     E KB AND, THEREFORE, IS EQUAL TO THE LENGTH OF THE EDGE OF THE INT
C     POLYGON  WHICH LIES ON KB.  IF KB DOES NOT INCLUDE AN EDGE, ALENGV
C     IS RETURNED AS ZERO.
C
      IF(NIS.LT.3) RETURN
      XCE=XISV(1)
      YCE=YISV(1)
      ZCE=ZISV(1)
      KD=1
      NEDGE=0
      KIV(1)=0
      KIIV(1)=0
      DO 5 KB=1,NC
      ALENGV(KB)=0.
      KI=0
      KII=0
      IF(ISKIPV(KB).EQ.0) GO TO 5
      DO 6 KA=1,NIS
      KAA=KA
      NLIS=NLISV(KA)
      DO 26 KC=1,NLIS
      IF(ISM(KC,KA).EQ.KB) GO TO 7
   26 CONTINUE
```

```
      **SUBROUTINE ISECT**

      GO TO 6
    7 CONTINUE
      IF(KI.NE.0) GC TO 9
      KI=KA
      GO TO 6
    9 CONTINUE
      IF(KII.NE.0) GO TO 27
      KII=KA
    6 CONTINUE
      IF(KII.EQ.0) GC TC 5
      IF(NEDGE.EQ.C) GO TO 13
      DO 30 K=1,NEDGE
      KIK=KIV(K)
      KIIK=KIIV(K)
      IF(KI.EQ.KIK.ANC.KII.EQ.KIIK) GO TO 5
      IF(KI.EQ.KIIK.AND.KII.EQ.KIK) GO TO 5
   30 CCNTINUE
   13 CCNTINUE
      NEDGE=NEDGE+1
      KIV(NEDGE)=KI
      KIIV(NEDGE)=KII
      XD=XISV(KI)-XISV(KII)
      YD=YISV(KI)-YISV(KII)
      ZD=ZISV(KI)-ZISV(KII)
      ALS=XD*XD+YD*YD+ZD*ZC
      ALENGV(KB)=SQRT(ALS)
      YX=YXV(KB)
      YC=YCV(KB)
      ZX=ZXV(KB)
      ZC=ZCV(KB)
      XM=XCE+YCE*YX+ZCE*ZX-YX*YC-ZX*ZC
      XM=XM/(1.+YX*YX+ZX*ZX)
      YM=YX*XM+YC
      ZM=ZX*XM+ZC
      XD=XM-XCE
      YD=YM-YCE
      ZD=ZM-ZCE
      DISS=XD*XD+YD*YD+ZD*ZD
      DISTV(KB)=SQRT(DISS)
      GO TO 5
   27 CONTINUE
      NERR=NERR+1
      IF(NERR.GT.100) RETURN
      KD=0
      PRINT 28,KB,KCT,KI,KII,KAA
    5 CONTINUE
      IDIR=-1
      DO 34 K=2,NEDGE
      IELIMV(K)=1
   34 CONTINUE
      KI=KIV(1)
      KIE=KIIV(1)
      XPV(1)=XISV(KI)
      YPV(1)=YISV(KI)
      ZPV(1)=ZISV(KI)
      NEDGP=NEDGE+1
      DO 35 K=2,NEDGP
      XPV(K)=XISV(KIE)
```

SUBROUTINE ISECT

```
      YPV(K)=YISV(KIE)
      ZPV(K)=ZISV(KIE)
      IF(K.EQ.NEDGP) GC TC 39
      DO 36 KA=2,NEDGE
      IF(IELIMV(KA).EC.0) GO TO 36
      KAA=KA
      IF(KIV(KA).EQ.KIE) GO TO 37
      IF(KIIV(KA).EC.KIE) GC TC 38
   36 CONTINUE
      GC TC 39
   37 CONTINUE
      KIE=KIIV(KAA)
      IELIMV(KAA)=0
      GO TO 35
   38 CONTINUE
      KIE=KIV(KAA)
      IELIMV(KAA)=0
   35 CCNTINUE
   39 CONTINUE
      DO 41 K=1,NEDGP
      XA=XPV(K)
      YA=YPV(K)
      ZA=ZPV(K)
      CALL TURN(IDIR,XA,YA,ZA,XR,YR,ZR)
      XPV(K)=XR
      YPV(K)=YR
      ZPV(K)=ZR
   41 CONTINUE
      WRITE (5) INAMEV(IA),INAMEV(IB),NEDGP,(XPV(K),YPV(K),ZPV(K),K=1,
     1NEDGP)
      IF(IB.GT.NNR) GC TO 40
      WRITE(6) INAMEV(IA),INAMEV(IB),NEDGP,(XPV(K),YPV(K),ZPV(K),K=1,
     1NEDGP)
      NCF=NCF+1
   40 CONTINUE
      IF(KD.GT.0) RETURN
      PRINT 23
      PRINT 20,IA,IB,ID,KCT,KE,MRANK,NC,NCT,NIS,NNR,NNT
      PRINT 23
      PRINT 20,NIS,NEDGE
      PRINT 23
      PRINT 11,(NLISV(K),K=1,NIS)
      PRINT 23
      DC 29 K=1,NIS
      NLIS=NLISV(K)
      PRINT 11,(ISM(KA,K),KA=1,NLIS)
   29 CCNTINUE
      PRINT 23
      PRINT 22,(XISV(K),K=1,NIS)
      PRINT 22,(YISV(K),K=1,NIS)
      PRINT 22,(ZISV(K),K=1,NIS)
      PRINT 23
      PRINT 20,(KIV(K),K=1,NEDGE)
      PRINT 20,(KIIV(K),K=1,NEDGE)
      PRINT 23
      PRINT 11,(ICV(K),K=1,NC)
      PRINT 23
      PRINT 22,(TV(K),K=1,NC)
```

SUBROUTINE ISECT

```
      PRINT 23
      PRINT 22,(YXV(K),K=1,NC)
      PRINT 23
      PRINT 22,(YCV(K),K=1,NC)
      PRINT 23
      PRINT 22,(ZXV(K),K=1,NC)
      PRINT 23
      PRINT 22,(ZCV(K),K=1,NC)
      PRINT 23
      PRINT 20,(ISKIPV(K),K=1,NC)
      PRINT 23
      PRINT 22,(ALENGV(K),K=1,NC)
      PRINT 22,(DISTV(K),K=1,NC)
      RETURN
   11 FORMAT(1X,10I13)
   12 FORMAT(1X,1P10E13.3)
   14 FORMAT(1X,*AN EDGE WHICH IS CONNECTED TC ONLY ONE VERTEX
     1*/1X,*KB=*,I5,3X,*KCT=*,I5/)
   16 FORMAT(1X,*TRCUBLE - NCNCOPLANAR LINES*)
   17 FORMAT(1X,*KCT,IA,IB,K,KA=*,5I5/1X,*YXV(K),YCV(K),YXV(KA),YCV(KA)=
     1*,1P4E15.4/1X,*ZXV(K),ZCV(K),ZXV(KA),ZCV(KA)=*,1P4E15.4)
   2C FORMAT(1X,2CI5)
   21 FORMAT(1H1)
   22 FORMAT(1X,1P6E20.10)
   23 FORMAT(1X//)
   28 FORMAT(1X,*TROUBLE - A THREE ENDED LINE*//1X,*KB,KCT=*,2I5,3X,*KI,
     1KII,KAA=*,3I5)
   42 FORMAT(1X,*KCT=*,I5,3X,*NEDGE=*,I5)
   43 FORMAT(1X,1P3E20.10)
      END
```

SUBROUTINE PTEST(LPAR,A1,B1,C1,A2,B2,C2)

```
      SUBROUTINE PTEST(LPAR,A1,B1,C1,A2,B2,C2)
      COMMON /EPS/ EPSBC,EPSYZ,EPSIN,EPSI,EPSS
      LOGICAL LPAR
      LPAR=.TRUE.
      AD=A2-A1
      BD=B2-B1
      CD=C2-C1
      TEST=AD*AD+BD*BD+CD*CD
      IF(TEST.LE.EPSS) RETURN
      AS=A2+A1
      BS=B2+B1
      CS=C2+C1
      TEST=AS*AS+BS*BS+CS*CS
      IF(TEST.LE.EPSS) RETURN
      LPAR=.FALSE.
      RETURN
      END
```

SUBROUTINE TESTS

```
      SUBRCUTINE TESTS
C
C     THIS SUBRCUTINE DETERMINES WHETHER OR NOT POINT XI,YI,ZI IS A VERT
C     NODE VOLUME IA.  LCOP 1 GOES THROUGH ALL NC INTERFACIAL PLANES WHI
C     NODE VOLUME IA.  THE POINT XI,YI,ZI IS ACCEPTED IF IT MEETS ONE OF
C     CCNDITICNS IN REGARD TO EACH OF THE PLANES.  ONE IS THAT IT LIE IN
C     PLANE.  THE OTHER IS THAT IT LIE ON THE SAME SIDE OF THE PLANE AS
C     NODE POINT IA.  THIS IS DETERMINED BY COMPARING THE SIGN OF TESTI
C     THAT OF TV(K).  (SEE FINDC.)
C
      LOGICAL LA
      COMMON /CNV/ ACV(4000),BCV(4000),CCV(4000),DCV(4000)
      COMMON /EPS/ EPSBC,EPSYZ,EPSIN,EPSI,EPSS
      COMMCN /ICV/ ICV(101),TV(100)
      COMMON /INTEGER/ IA,IB,ID,KCT,KE,MRANK,NC,NCT,NIS,NNR,NNT
      COMMON /TESTS/ ISV(15),NLIS,XI,YI,ZI,LA
      LA=.TRUE.
      IK=ISV(1)
      IKA=ISV(2)
      NLIS=2
      DO 1 K=1,NC
      IF(K.EQ.IK) GC TC 1
      IF(K.EQ.IKA) GO TO 1
      IC=ICV(K)
      IF(IC.EQ.KCT) GC TC 1
      AC=ACV(IC)
      BC=BCV(IC)
      CC=CCV(IC)
      DC=DCV(IC)
      TESTIN=AC*XI+BC*YI+CC*ZI-DC
      ABSIN=ABS(TESTIN)
      IF(ABSIN.GT.EPSIN) GO TO 3
      NLIS=NLIS+1
      ISV(NLIS)=K
      GO TC 1
    3 CONTINUE
      TESTP=TESTIN*TV(K)
      IF(TESTP.GT.0.) GO TC 1
      LA=.FALSE.
      RETURN
    1 CONTINUE
      IF(NLIS.EQ.2) RETURN
      IF(ISV(2).LT.ISV(3)) RETURN
      NLISP=NLIS+1
      ISV(NLISP)=1000
      DO 2 K=1,2
      KT=3-K
      IST=ISV(KT)
      KTP=KT+1
      DO 4 KA=KTP,NLISP
      KAA=KA
      IF(IST.LT.ISV(KA)) GC TC 5
    4 CONTINUE
    5 CONTINUE
      KAA=KAA-2
      DO 6 KA=KT,KAA
      ISV(KA)=ISV(KA+1)
```

SUBROUTINE TESTS

```
    6 CONTINUE
      ISV(KAA+1) =IST
      IF(ISV(1).LT.ISV(2)) RETURN
    2 CONTINUE
      RETURN
      END
```

SUBROUTINE TAMP

```
      SUBROUTINE TAMP
      COMMON /CN/ ICPAV(4000),ICPBV(4000),ARCV(4000),DV(4000)
      COMMON /CNV/ ACV(4000),BCV(4000),CCV(4000),DCV(4000)
      COMMON /EPS/ EPSBC,EPSYZ,EPSIN,EPSI,EPSS
      COMMON /INTEGER/ IA,IB,ID,KCT,KE,MRANK,NC,NCT,NIS,NNR,NNT
      COMMON /VLM/ VLMV(800),NCV(800)
      KEE=KE-1
      DO 1 K=KE,NCT
      IF(ARCV(K).LT.EPSS) GO TO 1
      KEE=KEE+1
      ICPAV(KEE)=ICPAV(K)
      ICPBV(KEE)=ICPBV(K)
      ARCV(KEE)=ARCV(K)
      DV(KEE)=DV(K)
      ACV(KEE)=ACV(K)
      BCV(KEE)=BCV(K)
      CCV(KEE)=CCV(K)
      DCV(KEE)=DCV(K)
    1 CONTINUE
      NDEC=NCT-KEE
      NCV(IA)=NCV(IA)-NDEC
      NCT=KEE
      RETURN
      END
```

REFERENCES

1. Edwards, A.L., 1972. TRUMP. UCRL-14754, rev. 3, (September 1, 1972).

2. Lippmann, M.J., C.F. Tsang and P.A. Witherspoon, 1977. Analysis of the Response of Geothermal Reservoirs Under Injection and Production Procedures. SPE 6537, presented at 47th Annual Meeting of Society of Petroleum Engineers, Bakersfield, California, (April 1977).

3. Lasseter, T.J., P.A. Witherspoon and M.J. Lippmann, 1975. Multiphase Multi-dimensional Simulation of Geothermal Reservoirs. Proceedings Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, (May 20-29, 1975).