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ORION: An interactive color post-processor for two dimensional finite element codes

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JoAnne L. Levatin

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ORION an interactive color post-processor for two dimensional finite element codes. For more information consult the user's manual or contact:

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Mechanical Engineering Department

August, 1985

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ABSTRACT

This report is a user's manual for the post-processor, ORION. ORION reads the binary plot files generated by the two-dimensional finite element codes currently used at LLNL. Contour and color fringe plots of a large number of quantities may be displayed on meshes consisting of triangular and quadrilateral elements. ORION can compute strain measures, interface pressures along slide lines, reaction forces along constrained boundaries, and momentum. ORION runs on the CRAY-1 and VAX computers.

INTRODUCTION

BACKGROUND

ORION [1] is the interactive post-processor for NIKE2D [2], DYNA2D [3], TACO2D [4], TOPAZ [5], and GEM2D [6]. ORION remains under continuous development by the authors, and frequent users, therefore, are encouraged to make suggestions concerning new features they would like implemented.

CAPABILITIES

ORION has the capability to plot:

- o color fringes,
- o contour lines,
- o vector plots,
- o principal stress lines,
- o deformed meshes and material outlines,
- o time histories,
- o reaction forces along constrained boundaries,
- o interface pressures along slidelines,
- o user specified labels.

Most strain measures are computed internally in ORION for display.

EXECUTION

ORION is in public on all CRAY machines in Livermore and may be executed by typing

ORION C=**cfile** G=**pfile** S=**sfile**

where

cfile = input file containing commands
pfile = first binary plot file
sfile = all commands are saved in **sfile**

After exhausting the commands in **cfile**, ORION returns control to the terminal for interactive input. The **sfile**, whose default name is ORNSAV, may be used as the **cfile** in subsequent runs. When used interactively, the execution line is

ORION G=**pfile** S=**sfile**

or

ORION G=**pfile**

On VAX/VMS computers ORION will prompt for the input line. File names should be kept to under 8 characters and the file type designation should not be typed, i.e., the user should enter:

G = pfile

even though the file name is **pfile.DAT;1.** Instead of the monitor number, the user enters the number for the device desired. A list of terminals and associated numbers is printed to the terminal before the "TMDS:" prompt. TMDS is an acronym for Television Monitor Display System.

DATABASE

Presently, THOR [7] and POSTACO [8] binary databases are read by ORION. Others are also implemented and read. New databases can be trivally added by anyone who has a complete understanding of ORION's undocumented organizational structure. We will not attempt to describe the structure here since it is too complicated, but for those who do not have an understanding but wish to add a new database, we have included comment cards in the source.

COMMAND DEFINITIONS

Commands common to phases I and II

HELP	Enter HELP and display all available commands. Description of each command is available in the HELP package.
TV n	Use TMDS with monitor number n. If n is the red channel of a color TMDS, ORION will automatically grab the green and blue channel. (The authors must be aware of the TMDS channel numbers for this to occur, however.)
TV $-n_1$ n_2 n_3	Use color TMDS with monitor numbers n_1, n_2, and n_3 for the red, green, and blue channels, respectively.
T or END	Terminate.
Z r z $\Delta\ell$	Zoom in at point (r,z) with window $\Delta\ell$.
UZ a b $\Delta\ell$	Zoom in at point (a,b) with window $\Delta\ell$ where a, b, and $\Delta\ell$ are numbers between 0 and 1. The picture is assumed to lie in a unit square.
UZG	Cover currently displayed picture with a 10 by 10 square grid to aid in zooming with the unity zoom, "UZ", command.

FIX	Set TMDS picture to its current window. This window is set until it is reset by the "GSET, "FSET," or "SETF" commands or released by the "UNFIX" command.
UNFIX	Release current TMDS window set by the "FIX," "GSET," "FSET" or "SETF" commands.
GSET r z $\Delta\ell$	Center TMDS pictures at point (r,z) with square window of width $\Delta\ell$. This window is set until it is reset or the "UNFIX" command is typed.
FSET n Δr Δz	Center TMDS pictures at node n with a rectangular Δr x Δz window. This window is set until it is reset with or the "UNFIX" command is typed.
SETF r z Δr Δz	Center TMDS pictures at point (r,z) with a rectangular Δr x Δz window. This window is set until it is reset or the "UNFIX" command is typed.
FR80 filmtype	Select FR80 camera. FR80 default filmtype is FICHE48. Other options include: FICH48D, FICHE24, FICH24D, 35mm, COLOR35, DICO35, P16mm, COLOR16, DICO16, CSLIDE35, HARDCOPY, REPORT, VUGRAPH, and VUGRAF11. This command, if used, must precede the "PLOTS" command.

CLASS level	Set classification level of FR80 output. The default is UNCLASS. Other levels include: PROGLEV, PARD, ADP, CONFIDNT, SRD, and SYSTEM. This command, if used, must precede the "PLOTS" command.
GIVE	Give the FR80 file to the system for plotting upon termination. This command, if used, must precede the "PLOTS" command.
PLOTS	Create FR8Ø plotfile containing a record of the TMDS display.
LTS	List each state number and time word contained in the database on the computer terminal.
DTS n ℓ_1 $m_1 \ldots \ell_n$ m_n	Delete states ℓ_i to m_i for i=1,2,...,n from the database. These states are recovered when ORION is terminated.
C	Comment - proceed to next card.
TTY	Return control to the terminal. This command may be placed anywhere in an ORION command file.
CFILE	Return control to the command file specified on the execute line. This command is used from the terminal.
GRID	Overlay TMDS displays with a grid of orthogonal lines.

NOGRID	Do not overlay TMDS displays with a grid of orthogonal lines (default).
TIME t	Read state corresponding to time t into memory. If t does not correspond to a particular state in the database, ORION will interpolate between two states to time t. If t exceeds the maximum time in the database, ORION will extrapolate to time t using the last two states.
STATE n	Read state n into memory.
G	View mesh.
UDG	Display nodal points of the undeformed mesh as dots on the mesh plots. Retyping "UDG" turns this option off.
RPVA	Reflect mesh, contour, fringe, etc., plots about vertical axis. Retyping "RPVA" turns this option off.
RPHA	Reflect mesh, contour, fringe, etc., plots about horizontal axis. Retyping "RPHA" turns this option off.
M n	Plot material n with any of the next three commands.
V	View mesh of material n.
NDPLT	Plot node numbers on mesh of material n.

ELPLT	Plot element number on mesh of material n.
HEAD	Define heading to appear on all plots. Desired heading is expected on the next line in the input deck. If typed interactively, ORION will prompt for the heading.
HDSZ m	The heading is plotted m characters to a line.
TSCL tscl	Scale time by tscl.
GSCL gscl	Scale length by gscl.
SSCL sscl	Scale stress by sscl.
TMOD scl shf	Modify TOPAZ (TACO) temperature state by scaling it by scl and shifting it by shf.
FRAME	Frame plots with a reference grid (default).
NOFRAME	Do not plot a reference grid.
RJET n i	Send a copy of the FR8Ø file to rjet n using plot format i where i=1 gives a 5" plot i=2 gives a 8" plot i=3 gives a 10.5" plot i=4 gives the largest possible plot. If i is negative, the plot is sideways, rotated 90 degrees clockwise on the paper. Plots may be sent to either the 11 or 22 inch plotters.

PHSØ **filename** — Return to initialization phase and use the plotfile sequence beginning with file, filename.

RESO n_x n_y — Set the x and y resolutions of ORION plots to n_x and n_y, respectively. We default both n_x and n_y to 1024.

TEXT n s t m a — Define text line n at location (s,t). Characters are plotted m to a line at an angle a. Coordinates s and t lie between 0 and 1 inclusive and refer to the area within the frame. The "UZG" command may be used as an aid in setting s and t. The desired text is expected on the next line in the input deck. If typed interactively, ORION will prompt for the text. Text will not be plotted until the "USETXT" command is typed.

USETXT — Display all text defined with the TEXT command.

DELTXT — Do not display text defined with the TEXT command.

DTXT m n — Delete text lines m to n.

The following commands apply to time history plots, interface plots, etc.

ASET amin amax — Set minimum and maximum values on abscissa to amin and amax, respectively. If amin=amax=0.0 (default) ORION determines the minimum and maximum values.

ATXT	Replace default label on abscissa. The desired text is expected on the next line of the input deck. If typed interactively, ORION will prompt for the text.
OTXT	Replace default label on ordinate. The desired text is expected on the next line of the input deck. If typed interactively, ORION will prompt for the text.
DATXT	Restore default label on abscissa.
DOTXT	Restore default label on ordinate.
OSET omin omax	Set minimum and maximum values on ordinate to omin and omax, respectively. If omin=omax=0.0 (default) ORION determines the minimum and maximum values.
ASCL f_a	Scale all abscissa data by f_a. The default is $f_a = 1$.
OSCL f_o	Scale all ordinate data by f_o. The default is $f_o = 1$.
SMOOTH n	Smooth a data curve by replacing each data point by the average of the 2n adjacent points. The default is n=0.
LOGO	Put LLNL logo on all plots (default). Retyping this command removes the logo.

Addendum:

ORION Commands Implemented Since August 1985

Commands Common to Phase I and Phase II

dmo	dmo { on | off }	Enable/disable drawing of material outlines
file	file *file_name*	Specify *file_name* for associated commands "print", "etime" (and related commands)
lamina	lamina *file_name*	Specify material data *file_name* containing lamination information
lcnn	lcnn	Enable/disable assignment of side numbers from lowest numbered node of an element; command "lcnn" toggles between each setting
norefresh	norefresh	Disable graphics refreshing
npdata	npdata	Output nodal coordinates to "ornout"
nplp	nplp *n*	Adjust number *n* of points in a line
pale	palette n c_1 ... c_n	Set user-defined color palette of *n* colors using color indices c_1 through c_n
ply	ply n p_1 ... p_n	Set lamina plies of *n* plies using ply indices p_1 through p_n

		NOTE: lamina must be called before ply
plys	plys p_1 p_n *stride*	Set lamina ply indices p_1 through p_n using *stride* NOTE: lamina must be called before plys
refresh	refresh	Enable graphics refreshing
speckles	speckles *level*	Enable correction procedure for "speckled" fringe plots wherein elements whose nodal values fluctuate about 0.0 will be correctly plotted
thick	thick *frame* thick *head* thick *mesh*	Set line and stroked character text for "thicker" plot headings, frames (axes and legends), and mesh grids
thin	thin *frame* thin *head* thin *mesh*	Set line and stroked character text for "thinner" plot headings, frames (axes and legends), and mesh grids
traction	traction *n* m_1 ... m_n	Compute traction force(s) and moment(s) of *n* materials m_1 through m_n
ztol	ztol tolerance	Obtain z-tolerance value for fringe, contour, et cetera, interval levels

PHASE I COMMANDS

DE e_1 e_2	Delete elements e_1 to e_2.
DM n m_1 m_2 ... m_n	Delete n materials including m_1, m_2,..., and m_n.
CMN e_1 e_2 m	Change material number of elements e_1 to e_2 to m.
O	Plot outlines of all material.
UDO	Display nodal points of the undeformed outline as dots on the outline plots. Retyping "UDO" turns this command off.
MO	Plot material outline of material n where n is defined with the "M" command.
B	Determine boundary nodes of material n and display boundary with nodes on TMDS. The material number, n, is defined with the "M" command.
FSON	Plot only free surfaces and slideline interfaces with "O" command. [Must be used before "O" command.]
FSOFF	Turn off the "FSON" command.
GO	View mesh right of centerline and outline left of centerline.

HEMP	Switch geometry plots to a left-handed coordinate system with the radial coordinate along the positive vertical axis, and the axial coordinates plotted along the horizontal axis. To turn this command off, simply retype it. If this option is active, interface pressures are not computed correctly.
MNOFF	Do not plot material numbers with the "O", "G", and "GO" commands (default).
MNON	Plot material numbers with "O", "G", and "GO" commands.
DSF s	Displacements are scaled by s. The default is 1.
CONTOUR c n m_1 m_2 ... m_n	Contour component number c on n materials including materials m_1, m_2, ..., m_n. If n is zero, only the outline of material m_1 with contours is plotted. Component numbers are given in Table 1.
PRIN c n m_1 m_2...m_n	Plot lines of principal stress and strain in the yz plane on n materials including materials m_1, m_2,...,m_n. If n is zero, only the outline of material m_1 is plotted. The lines are plotted in the principal stress and strain directions. Permissible component numbers in Table 1 include 0, 5, 6, 100, 105, 106,...,etc. Orthogonal lines of both maximum and minimum stress are plotted if components 0, 100, 200, etc. are specified.

FRINGE c n m_1 $m_2 \ldots m_n$	Fringe component number c on n materials including m_1, $m_2, \ldots, m_n$. If n is zero, only the outline of material m_1 with contours is plotted. Component numbers are given in Table 1.
NCOL n	Number of colors in fringe plots is n. The default value for n is 6 which includes colors white, blue, cyan, green, yellow, and red. An alternative value for n is 5 which eliminates the minimum value white.
PROFILE c n m_1 $m_2 \ldots m_n$	Plot component c versus element number for n materials including materials m_1, $m_2, \ldots, m_n$. If n is Ø, then component c is plotted for all elements. Component numbers are given in Table 1.
VECTOR c n m_1 $m_2 \ldots m_n$	Make a vector plot of component c on n materials including materials m_1, $m_2, \ldots, m_n$. If n is zero, only the outline of material m_1 with vectors is plotted. Component c may be set to "D" "V" or "F" for vector plots of displacement velocity, or heat flux respectively.
LINE c n m_1 $m_2 \ldots m_n$	Plot variation of component c along line defined with the "NLDF", "PLDF", "NSDF", or the "NSSDF" commands given below. In determining variation, consider n materials including material number m_1, $m_2, \ldots m_n$.

NLDF n n_1 $n_2 \ldots n_3$	Define line for "LINE" command using n nodes including node numbers n_1, $n_2, \ldots n_n$. This line moves with the nodes.
PLDF n r_1 $z_1 \ldots r_n$ z_n	Define line for "LINE" command using n coordinate pairs (r_1,z_1), $(r_2,z_2),\ldots(r_n,z_n)$. This line is fixed in space.
NSDF m	Define line for "LINE" command as side m. Side m is defined for material n by the "B" command.
NSSDF ℓ m	Define line for "LINE" command and that includes boundary nodes ℓ to m (counterclockwise) in the interface definitions. This command must follow the "B" command.
RANGE r_1 r_2.	Set the range of levels to be between r_1 and r_2 instead of in the range chosen automatically by ORION. To deactivate this command, type RANGE 0. 0.
MOLP	Overlay the mesh on the contour, fringe, principal stress, and principal strain plots. Retyping "MOLP" turns this option off.
NUMCON n	Plot n contour levels. The default is 9.
PLOC	Plot letters on contour lines to identify their levels (default).

NLOC	Do not plot letters on contour lines.
IFD n	Begin definition of interface n. If interface n has been previously defined, this command has the effect of destroying the old definition.
IFS m	Include side m in the interface definition. Side m is defined for material n by the "B" command.
IFN ℓ m	Include boundary nodes ℓ to m (counterclockwise) in the interface definition. This command must follow the "B" command.
IFP c m	Plot component c of interface m. Component numbers are given in Table 2.
IFMS c m n i_1 i_2 ... i_n	Plot multiple states. Component c of interface m is plotted for n states including states $i_1, i_2, \ldots,$ and i_n.
IFVA r_c z_c	Plot the angular location of the interface based on the center point (r_c, z_c) along the abcissa. Positive angles are measured counterclockwise from the y axis.
IFVS	Plot the distance along the interface from the first interface node along the abcissa (default).
LOSER i	Write a LOSER file for interface i.

No.	Component	No.	Component
1	y	21*	ln (V/Vo) (volumetric strain)
2	z	22*	y-displacement
3	hoop	23*	z-displacement
4	yz	24*	maximum displacement
5	maximum principal	25*	y-velocity, y-heat flux
6	minimum principal	26*	z-velocity, z-heat flux
7	von Mises (Appendix A)	27*	maximum velocity, max. heat flu
8	pressure or average strain	28	ij normal
9	maximum principal-minimum principal	29	jk normal
10	y minus hoop	30	kl normal
11	maximum shear	31	li normal
12	ij and kl normal (Appendix B)	32	ij shear
13	jk and li normal	33	jk shear
14	ij and kl shear	34	kl shear
15	jk and li shear	35	li shear
16	y-deviatoric	36*	relative volume V/Vo
17	z-deviatoric	37*	Vo/V-1
18	hoop-deviatoric	38*	bulk viscosity, Q
19*	effective plastic strain	39*	P + Q
20*	temperature	40*	density

Table 1. Component numbers for element variables. By adding 100, 200 300, 400, and 500 to the component numbers not superscripted by an asterisk, components numbers for infinitesimal strains, Green-St. Venant strains, Almansi strains, strain rates, and extensions are obtained, respectively. Maximum and minimum principal stresses and strains are in the yz plane. The corresponding hoop quantities must be examined to determine the overall extremum. Strain calculations are described in Appendix C.

No.	Component
1	pressure
2	shear stress
3	normal force
4	tangential force
5	y-force
6	z-force

Table 2. Component numbers for interface variables. In axisymmetric geometries the force is per unit radian.

R n m k	Repeat command. ORION will repeat the command that immediately follows for states n to m incrementing by k. This command applies to the "G", "GO", "O", "MO", "CONTOUR", "IFP", and "IFMS" commands.
RMC n m k ℓ	Repeat multiple commands. ORION will repeat the commands that immediately follow, including the next ℓ lines of input for states n to m incrementing by k. This command is generally preferred over repetitious use of the I/O intensive "R" command.
MOVIE $t_{\emptyset}$ t_k k ℓ	Repeat multiple commands. ORION will repeat the commands that immediately follow, including the next ℓ lines of input, starting at time $t_{\emptyset}$ and ending at time t_k in k equal increments.
PHS2	Proceed to Phase II.

PHASE II COMMANDS

PHS1	Return to Phase I.
ELEMENTS n e_1 e_2 ... e_n	Select the n elements for time history plots with element numbers $e_1, e_2, \ldots, e_n$.
COMP n c_1 c_2 ... c_n	Select the n stress and strain components for element time history plots with numbers $c_1, c_2, \ldots, c_n$. Components are listed in Table 1.
NODES n n_1 n_2 ... n_n	Select for time history plots the n nodes with numbers $n_1, n_2, \ldots, n_n$.
MATLS n m_1 m_2 ... m_n	Select the n materials for time history plots with material numbers $m_1, m_2, \ldots, m_n$.
IFNDS n n_1 n_2 ... n_n	Select the n interface nodes with node numbers $n_1, n_2, \ldots, n_n$ for time history plots.
IFFP	Pack total interface forces for all interfaces.
GATHER	Read through the plot files and store the time histories for all the variables specified in the "ELEMENTS", "COMP", "NODES", "MATLS", and "IFNDS" commands. This command must be typed before any time histories can be plotted.

EXPDATA **filename**	Plot experimental data in file **filename** on next plot generated by any of the commands "NTIME", "ETIME",..., etc. which follow. The data structure of **filename** is described in Appendix D.
CENTER r_c z_c	Set center for radial time history plots at (r_c,z_c) [Must then use NTIME command.]
ETIME c n e_1 e_2 ... e_n	Plot component c for n elements with numbers $e_1,e_2,\ldots,e_n$ over time. The component and element numbers must be defined with the "COMP" and "ELEMENTS" commands, respectively.
NTIME c n n_1 n_2 ... n_n	Plot component c for n nodes with numbers $n_1,n_2,\ldots,n_n$ over time. Component numbers are defined in Table 3. The node numbers must be defined in the "NODES" command.
MTIME c n m_1 m_2 ... m_n	Plot component c for n materials with numbers $m_1,m_2,\ldots m_n$ over time. Component numbers are defined in Table 4. The material numbers must be defined in the "MATLS" command.
NRTIME c n_1 n_2	Plot over time the difference in component c by subtracting the value of c at node n_2 from the value at node n_1. Component numbers are defined in Table 3. The node numbers must be defined in the "NODES" command.

ITIME $c\ n\ n_1\ n_2 \ldots n_n$	Plot over time component c for n interface nodes with numbers $n_1, n_2, \ldots, n_n$. Component numbers are defined in Table 2. The interface node numbers must be defined in the "IFNDS" command.
FTIME $c\ n\ i_1\ i_2 \ldots i_n$	Plot over time component c for n interfaces with numbers $i_1, i_2, \ldots, i_n$. Component numbers are defined in Table 5.
GTIME c	Plot over time global variable c. Component numbers are defined in Table 6.
SSPLT $e\ c_1\ c_2$	Plot component c_1 versus c_2 for element e. The component and element numbers must be defined with the "COMP" and "ELEMENTS" commands, respectively.
PALL	Plot all data packed by the GATHER command.
PRINT	Print plotted time history data in file ORNOUT. Only data plotted after this command is printed.
COLUMN	Printed data is written with the format 2E20.11.

No.	Component
1	y-displacement
2	z-displacement
3	y-velocity, y-heat flux
4	z-velocity, z-heat flux
5	y-acceleration
6	z-acceleration
7	temperature
8	r-coordinate
9	z-coordinate
10	radius

Table 3. Component numbers for nodal time history plots. The radius is relative to point (r_c, z_c) defined in the "CENTER" command.

No.	Component	No.	Component
1	y-momentum	10	y-negative velocity
2	y-positive momentum	11	z-rigid body velocity
3	y-negative momentum	12	z-positive velocity
4	z-momentum	13	z-negative velocity
5	z-positive momentum	14	kinetic energy per unit mass
6	z-negative momentum	15	internal energy
7	kinetic energy	16	y rigid body acceleration
8	y-rigid body velocity	17	z rigid body acceleration
9	y-positive velocity		

Table 4. Component numbers for material time history plots.

No.	Component
1	total y-force
2	total z-force

Table 5. Component numbers for total interface force time history plots.

No.	Component
1	total kinetic energy
2	total internal energy
3	kinetic + internal energy
4	y-momentum
5	z-momentum
6	y-rigid body velocity
7	z-rigid body velocity

Table 6. Component numbers for global variable time history plots.

EXAMPLE

Use of ORION is demonstrated in the example which follows. The input file which correlates the command and figure number is shown below.

COMMAND	TMDS FIGURE
BOX S14	
1625 PLOTS	C FIGURE 1
GO	C FIGURE 2
STATE 51 GO	C FIGURE 3
STATE 6 CONTOUR 8 1 2	C FIGURE 4
IFD 1 M 1 B	
IFS 1	
IFD 2 M 2 B	C FIGURE 5
IFS 2	
IFVA 0 0	
IFMS 1 1 5 7 8 9 10 11	C FIGURE 6
IFMS 1 2 5 7 8 9 10 11	C FIGURE 7
PHS2 IFFP IFNDS 2 5 106 GATHER	
ASET 0 50.	
ITIME 1 1 106	C FIGURE 8
FTIME 2 2 1 2	C FIGURE 9
PHS1 DE 77 600	
MOVIE 0 200 5 0 GO	C FIGURE 10-15
RJET 10 -1	
END	

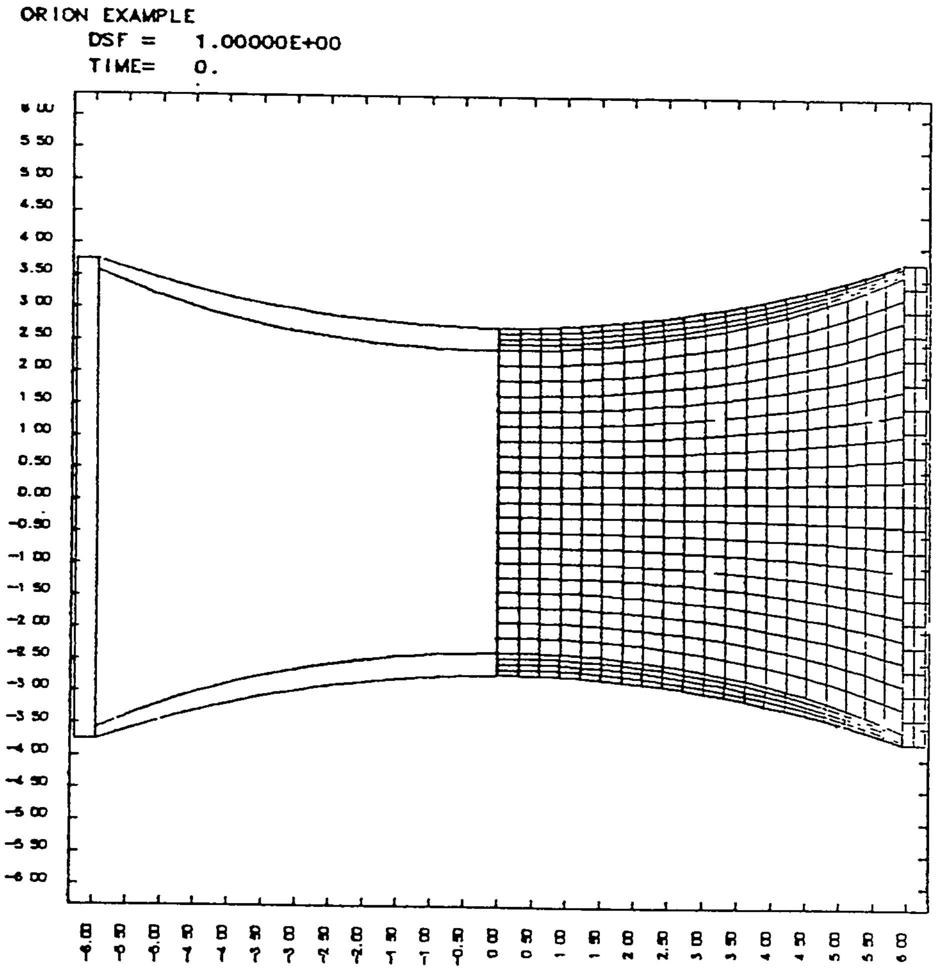


Fig. 1.

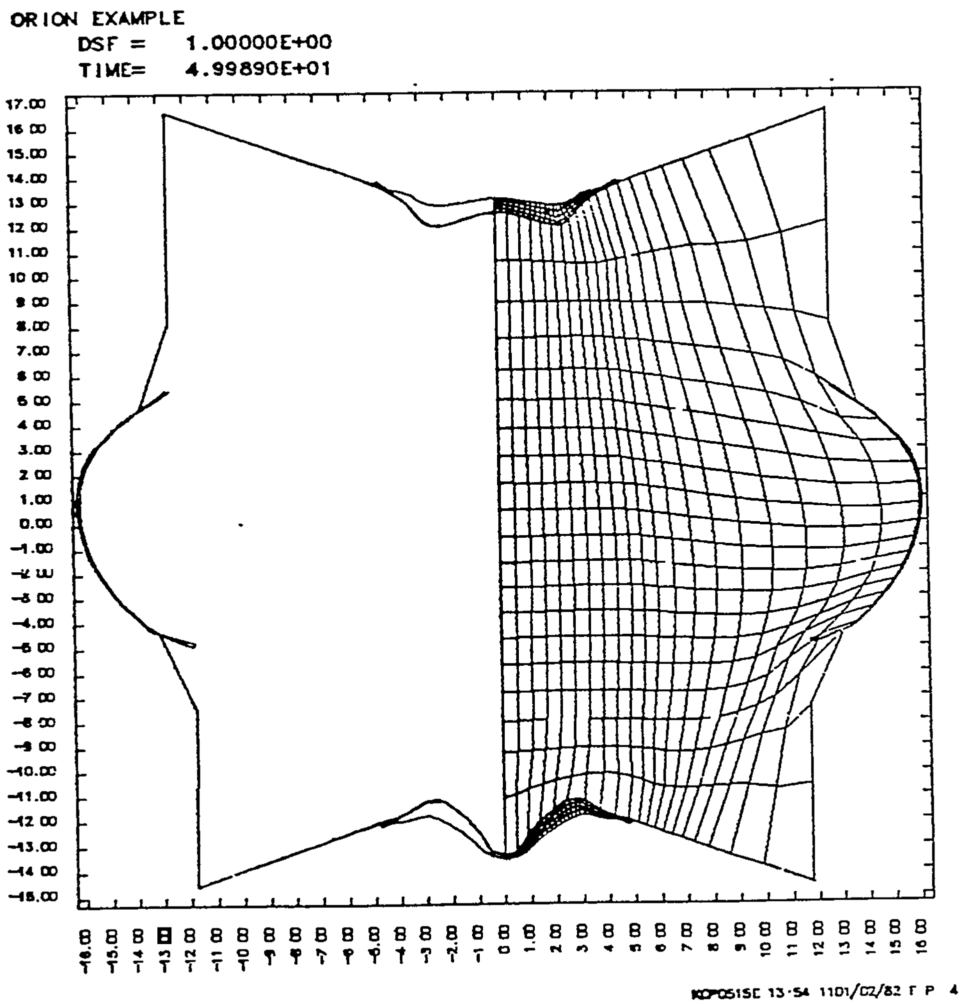


Fig. 2.

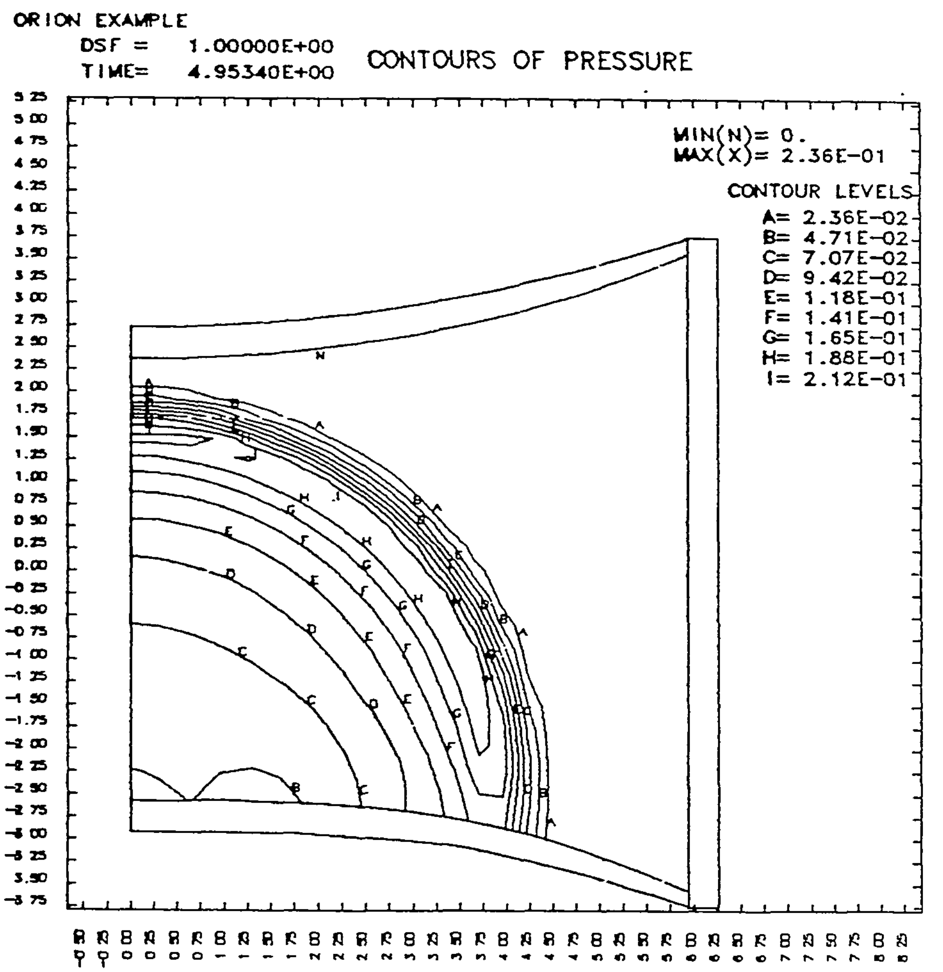

ORION EXAMPLE
DSF = 1.00000E+00
TIME= 4.95340E+00
CONTOURS OF PRESSURE
MIN(N)= 0.
MAX(X)= 2.36E-01
CONTOUR LEVELS
A= 2.36E-02
B= 4.71E-02
C= 7.07E-02
D= 9.42E-02
E= 1.18E-01
F= 1.41E-01
G= 1.65E-01
H= 1.88E-01
I= 2.12E-01

Fig. 3.

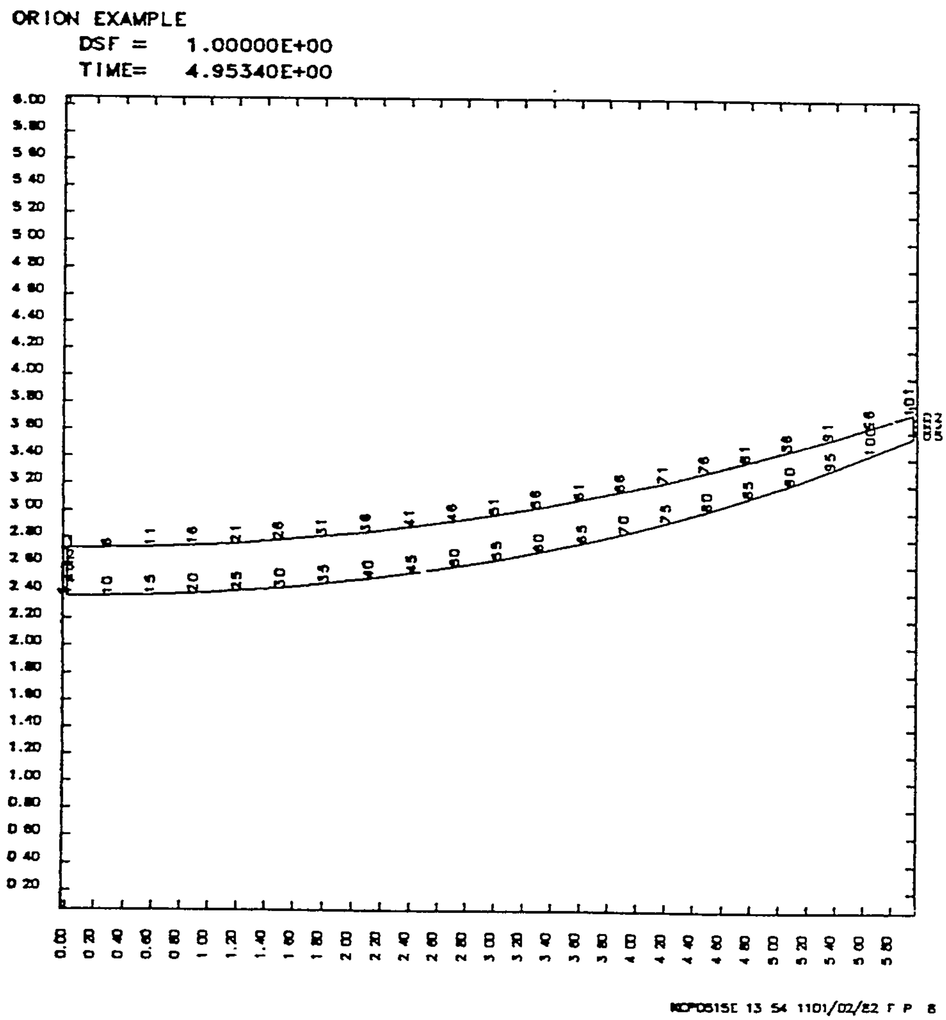


Fig. 4.

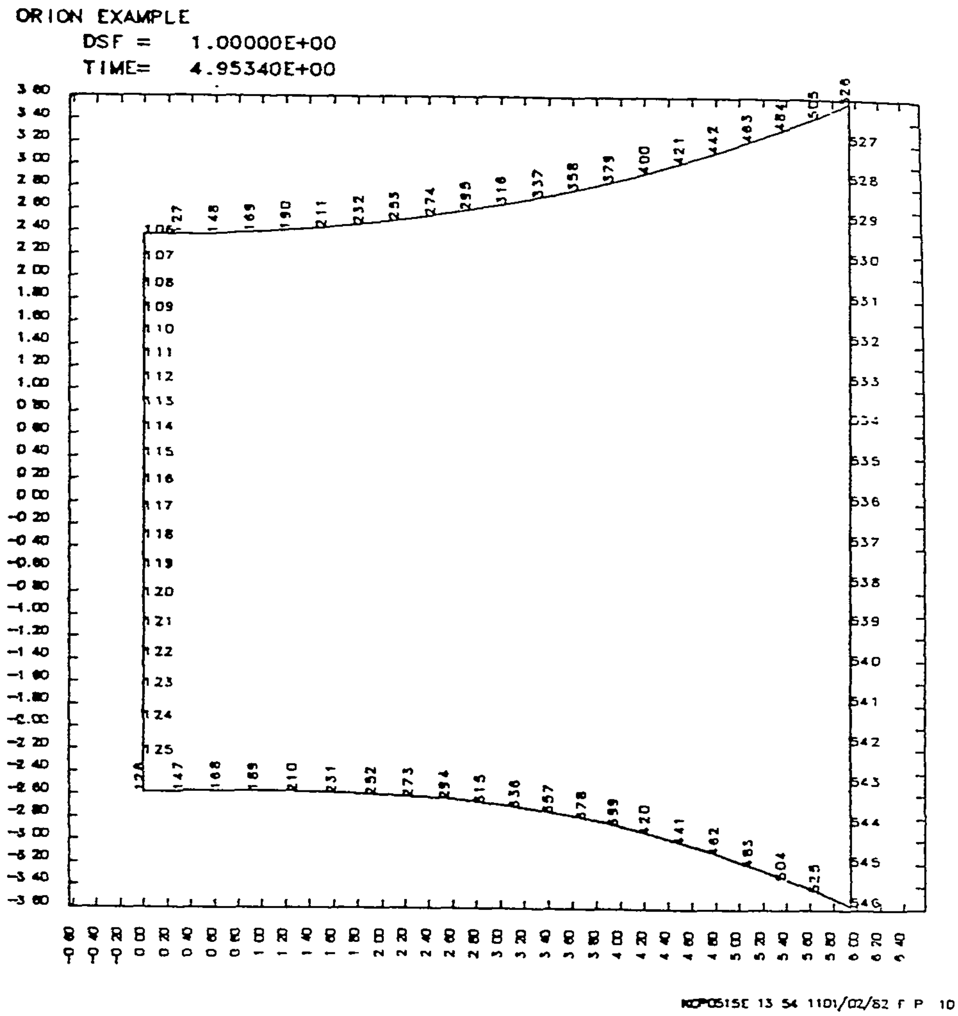


Fig. 5.

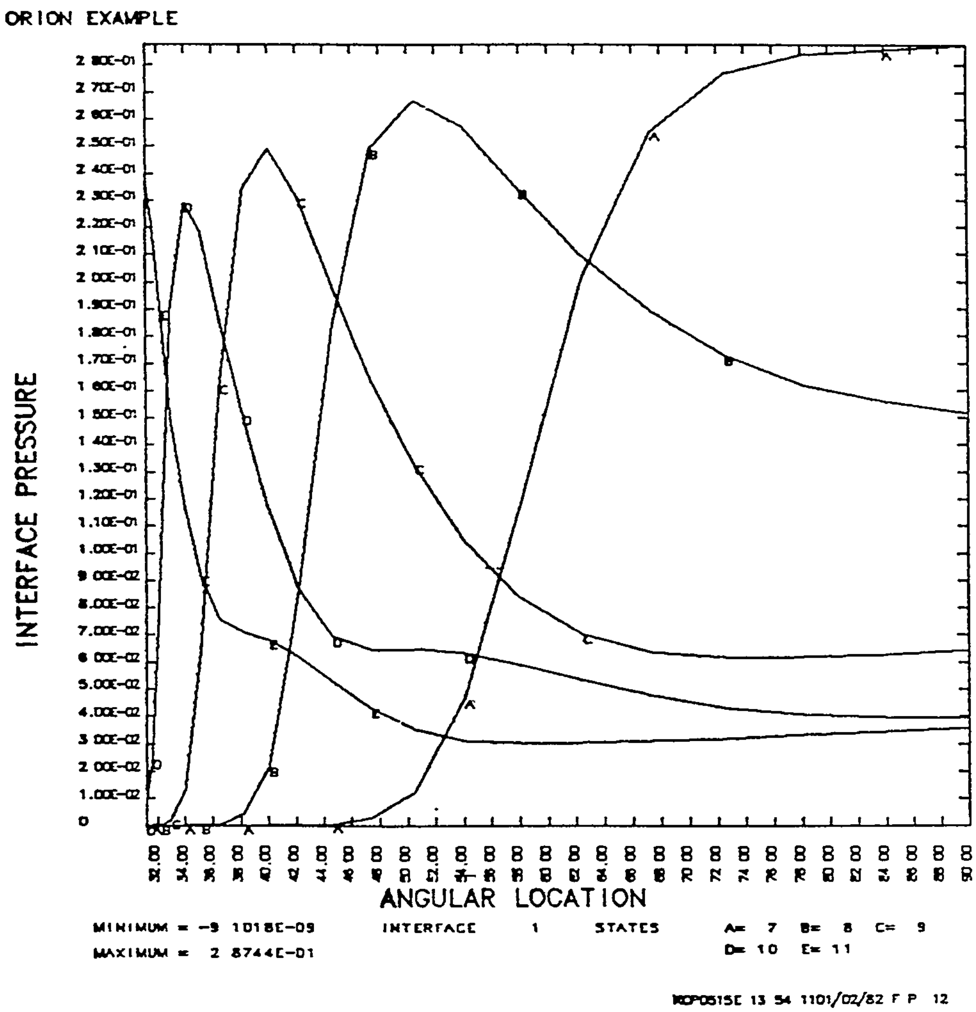

ORION EXAMPLE
INTERFACE PRESSURE
ANGULAR LOCATION
MINIMUM = -9 1018E-09
MAXIMUM = 2 8744E-01
INTERFACE 1
STATES
A= 7 B= 8 C= 9
D= 10 E= 11
NOPO515E 13 54 1101/02/82 F P 12

Fig. 6.

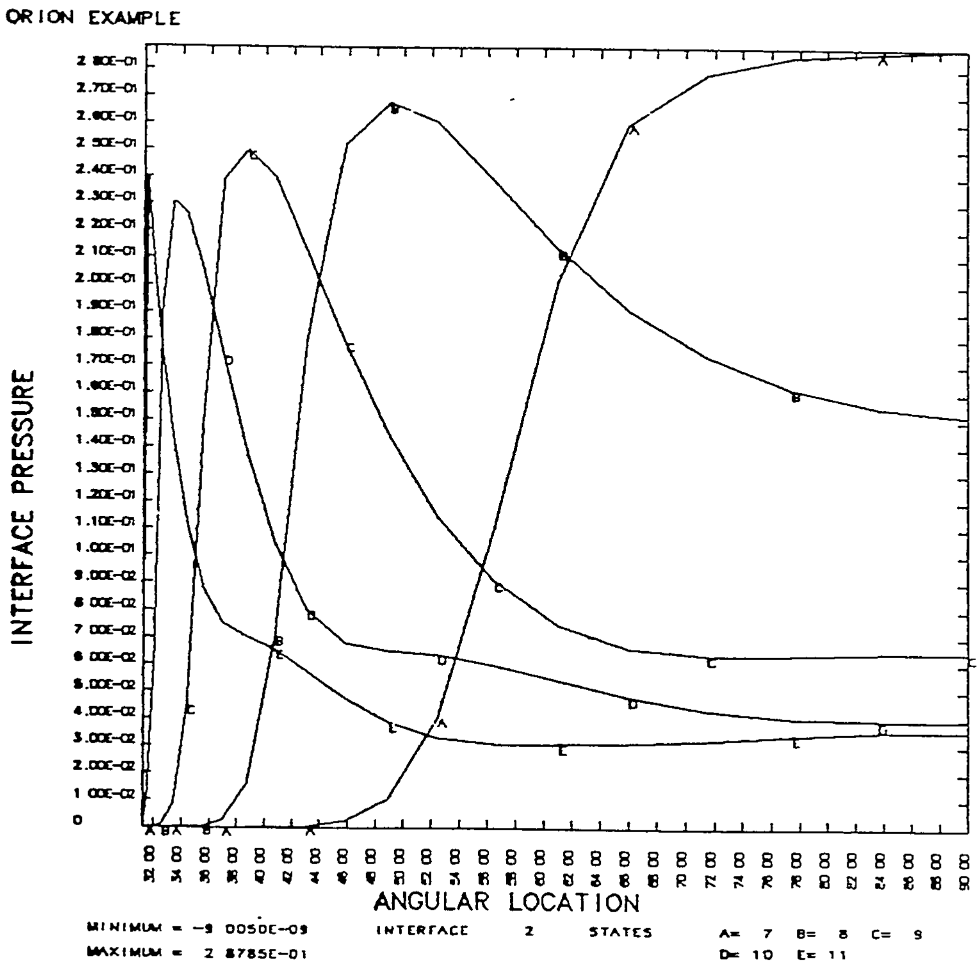
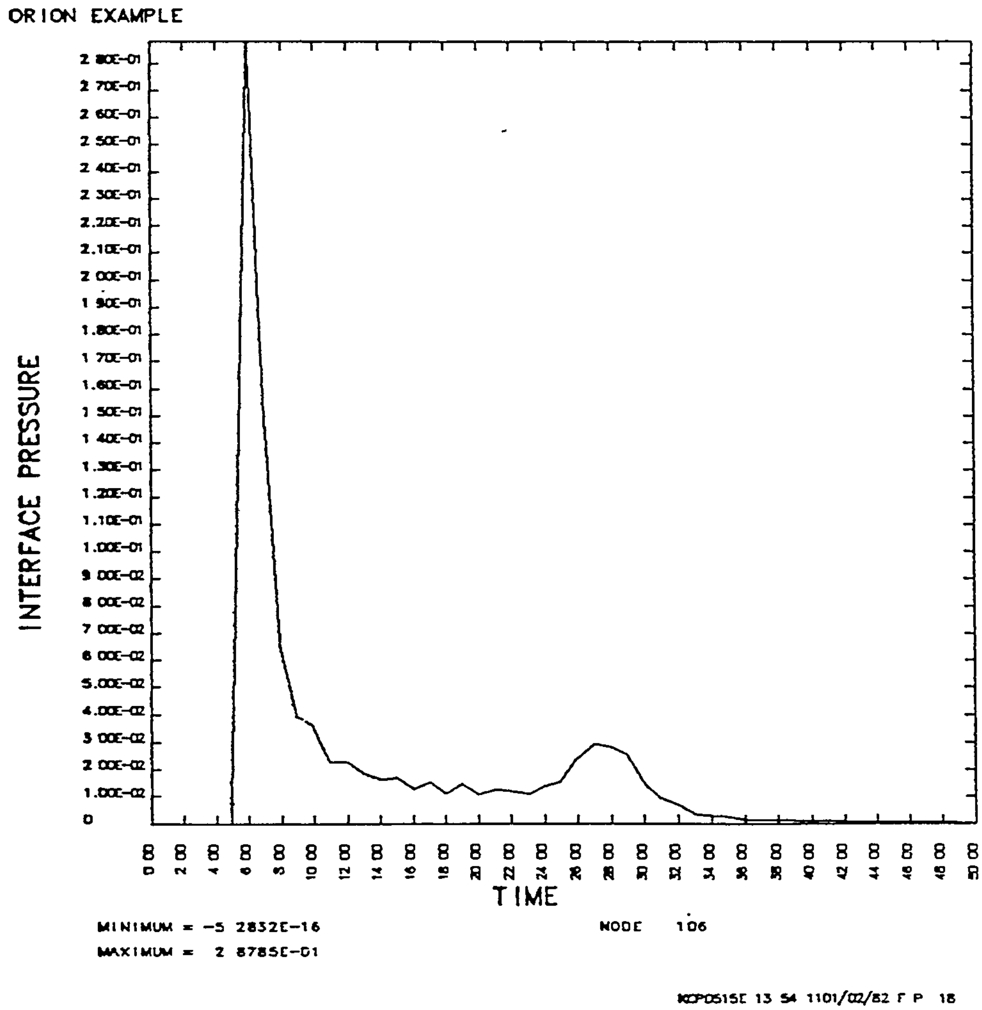

ORION EXAMPLE
INTERFACE PRESSURE
ANGULAR LOCATION
MINIMUM = -9 0050E-09
MAXIMUM = 2 8785E-01
INTERFACE 2
STATES
A= 7 B= 8 C= 9
D= 10 E= 11

Fig. 7.



ORION EXAMPLE
INTERFACE PRESSURE
TIME
MINIMUM = -5 2832E-16
MAXIMUM = 2 8785E-01
NODE 106

Fig. 8.

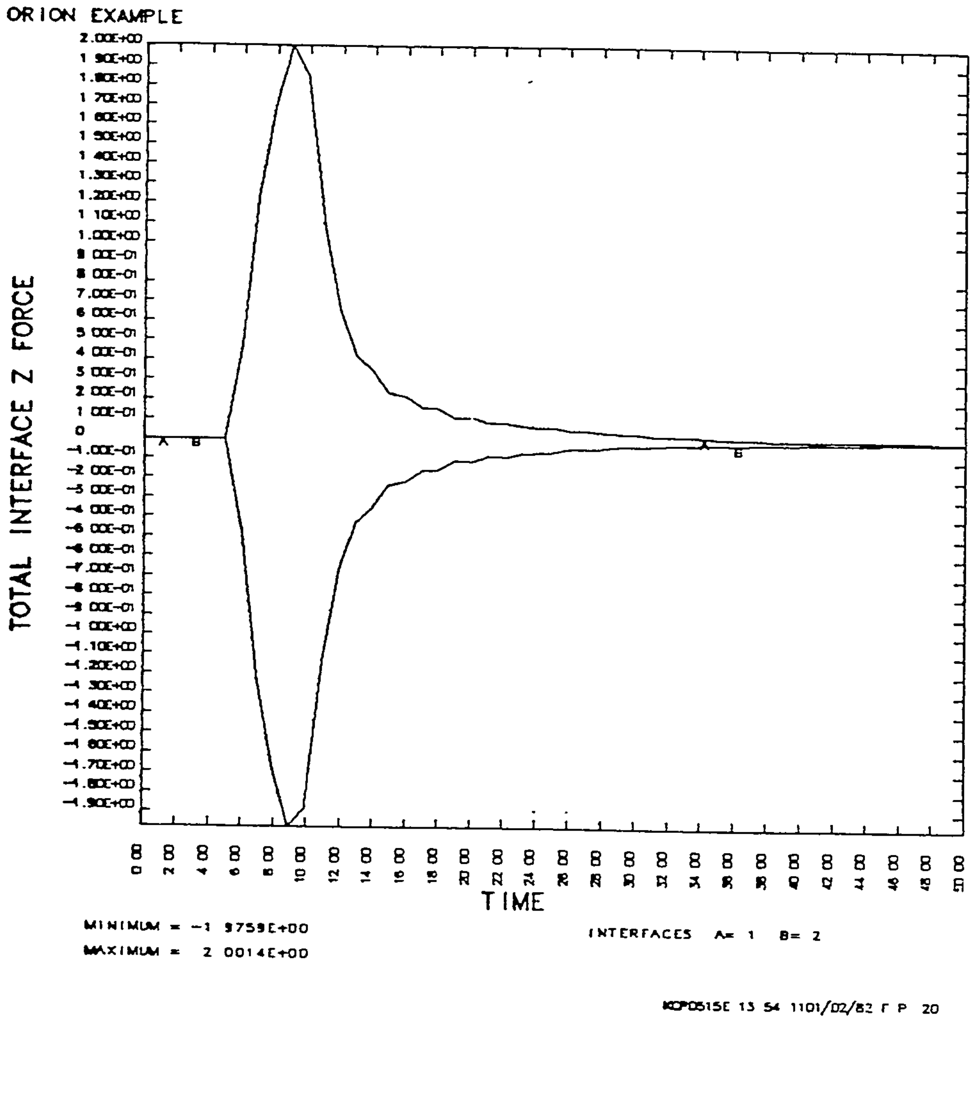

ORION EXAMPLE
TOTAL INTERFACE Z FORCE
TIME
MINIMUM = -1 9759E+00
MAXIMUM = 2 0014E+00
INTERFACES A= 1 B= 2

Fig. 9.

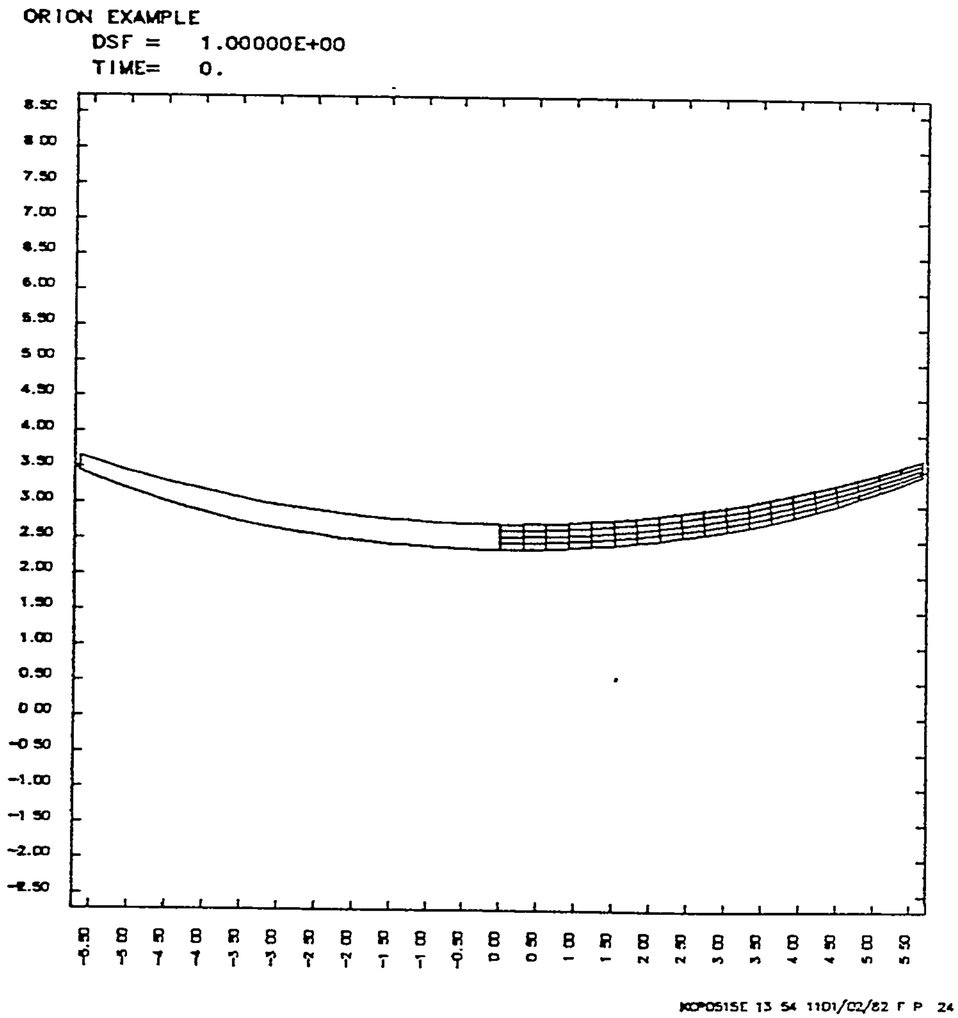

ORION EXAMPLE
DSF = 1.00000E+00
TIME= 0.
KCPOSISE 13 54 11D1/02/82 F P 24

Fig. 10.

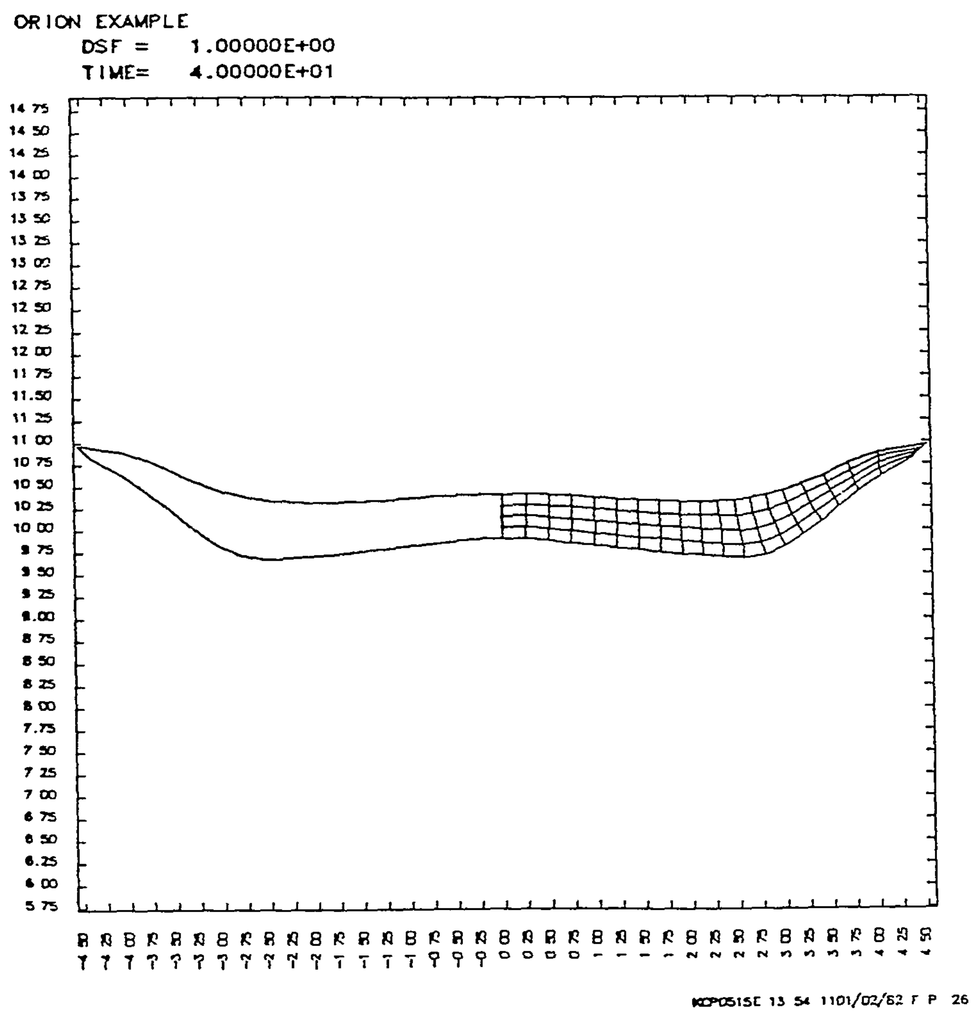

ORION EXAMPLE
DSF = 1.00000E+00
TIME= 4.00000E+01
14 75
14 50
14 25
14 00
13 75
13 50
13 25
13 00
12 75
12 50
12 25
12 00
11 75
11.50
11 25
11 00
10 75
10 50
10 25
10 00
9 75
9 50
9 25
9.00
8 75
8 50
8 25
8 00
7.75
7 50
7 25
7 00
6 75
6 50
6.25
6 00
5 75

Fig. 11.

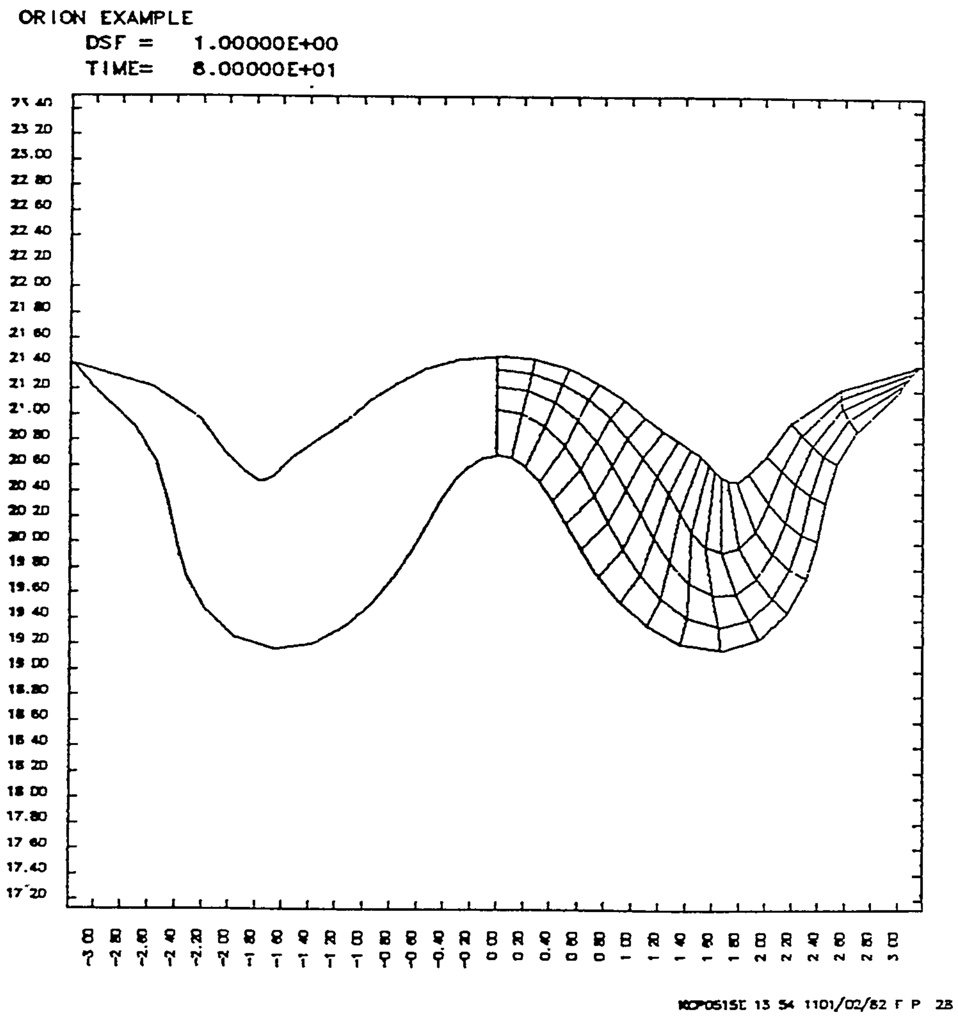


Fig. 12.

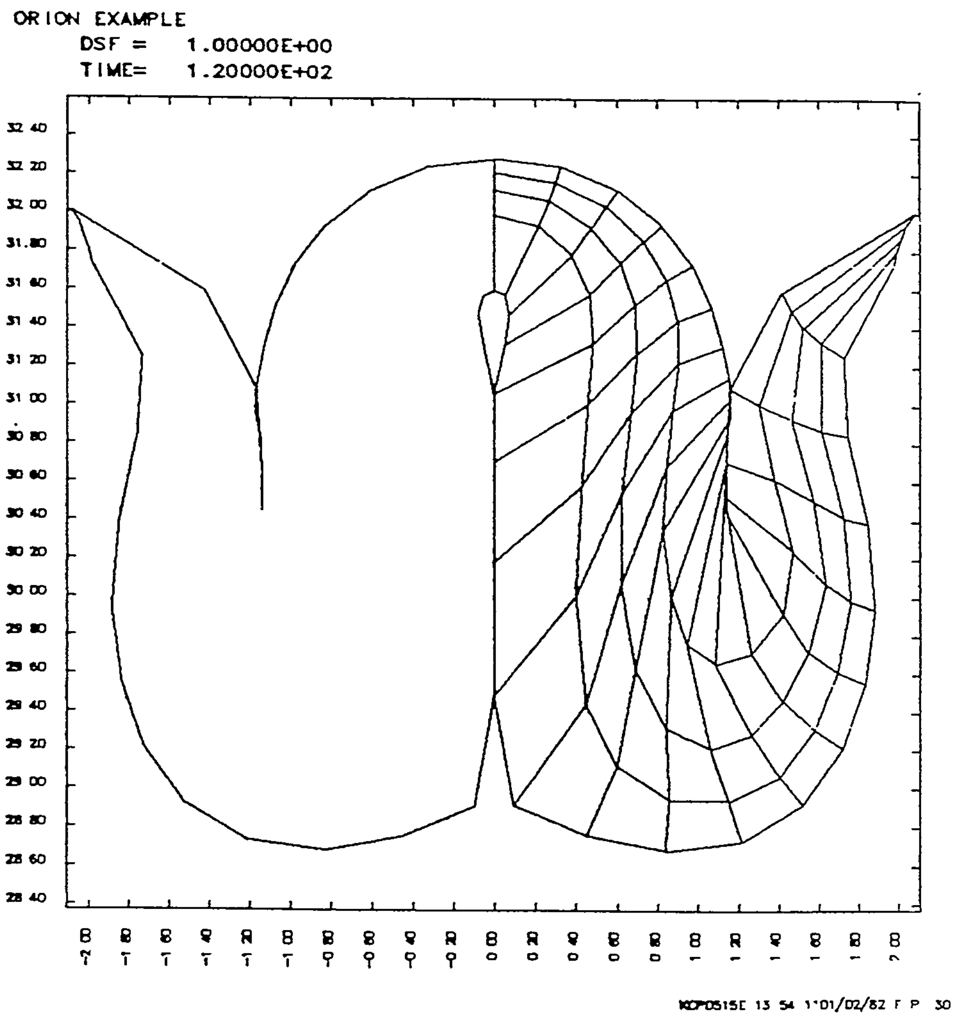


Fig. 13.

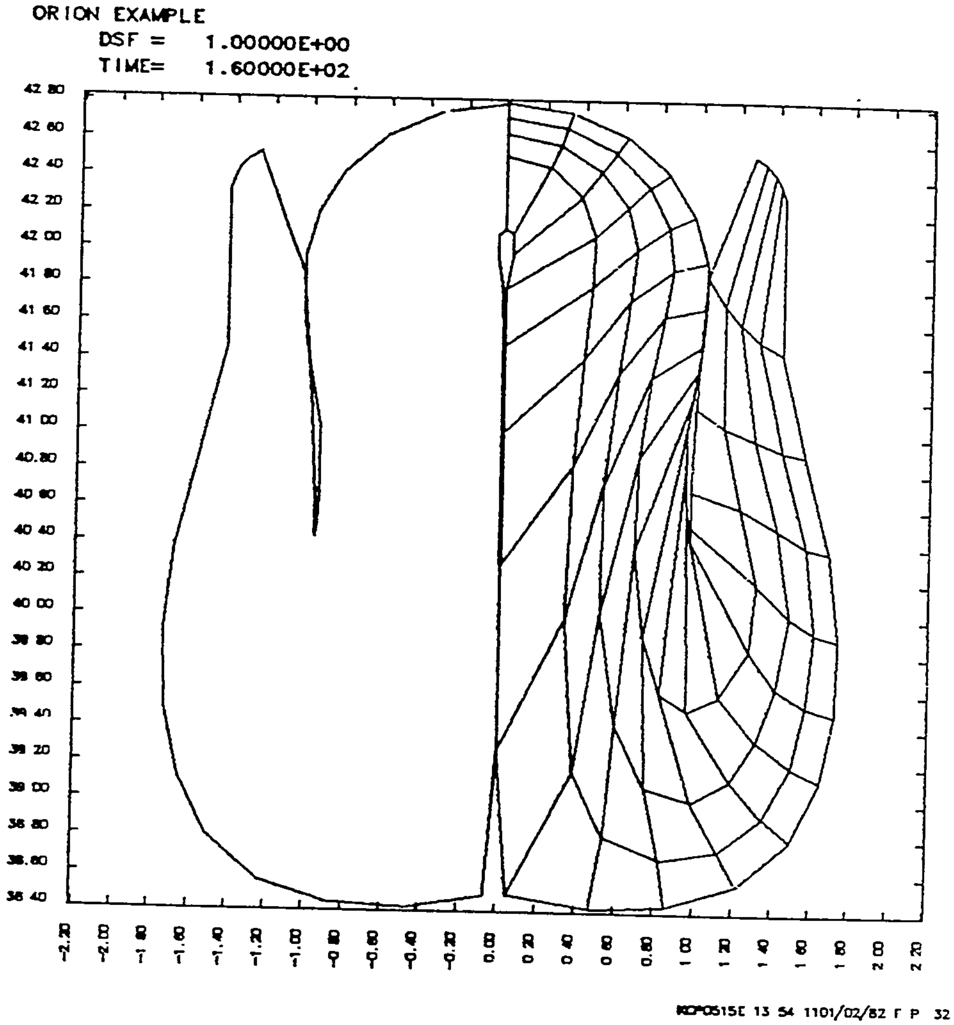


Fig. 14.

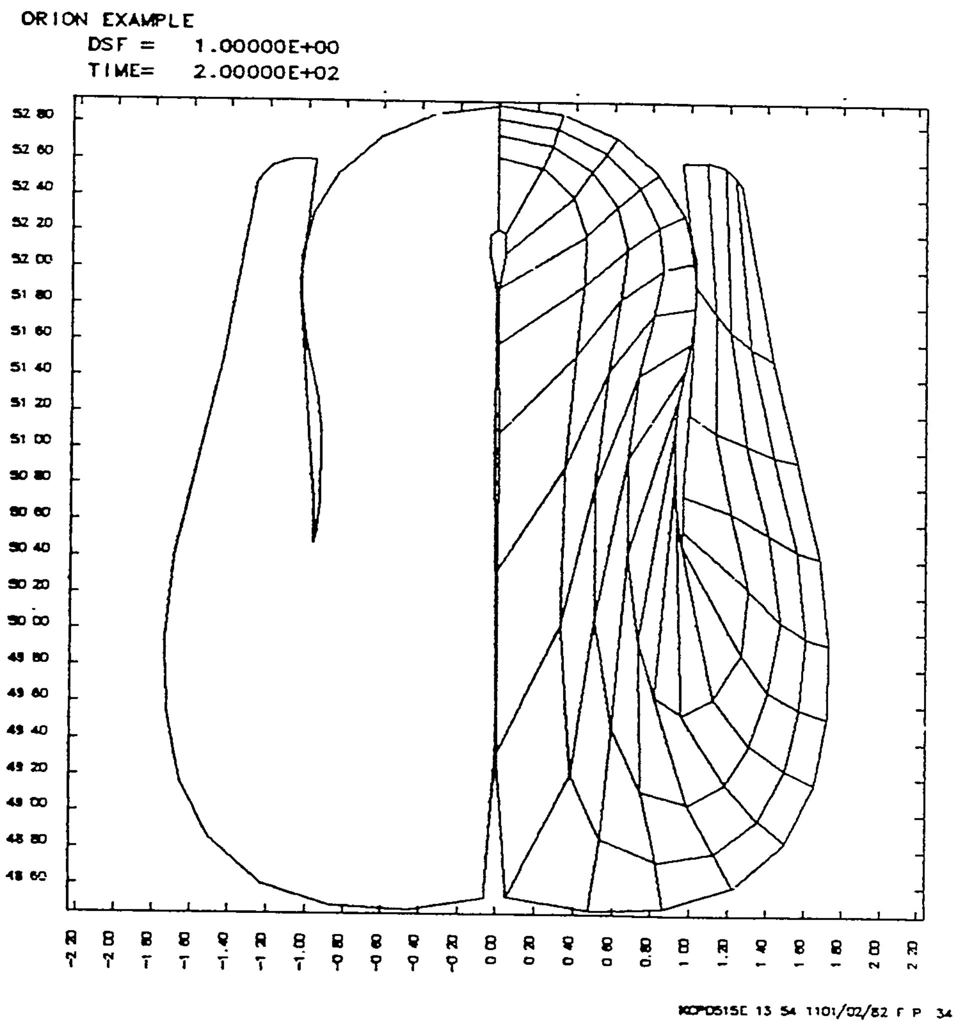


Fig. 15.

ACKNOWLEDGEMENTS

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APPENDIX A

EFFECTIVE STRESS AND STRAIN

The effective stress and strain, component 7, and the effective plastic strain, component 19, are defined here to avoid confusion:

effective stress σ

$$\sigma = \left(\frac{3}{2} s_{ij} s_{ij} \right)^{1/2}$$

effective strain ε, E, ...

$$\bar{\varepsilon} = \left(\frac{2}{3} \varepsilon^d_{ij} \varepsilon^d_{ij} \right)^{1/2}$$

$$\vdots \quad ,$$

effective plastic strain ε_p

$$\bar{\varepsilon}_p = \int_0^t \left(\frac{2}{3} D^p_{ij} D^p_{ij} \right)^{1/2} dt .$$

The terms s_{ij} and ε^d_{ij} are the deviatoric components of the stress and strain tensors

$$s_{ij} = \sigma_{ij} - \frac{1}{3} \sigma_{kk} \delta_{ij} ,$$

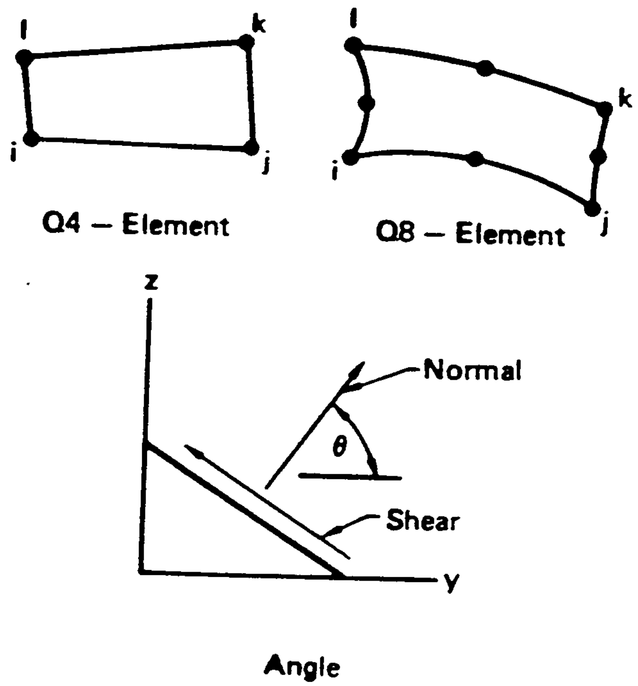
$$\varepsilon^d_{ij} = \varepsilon_{ij} - \frac{1}{3} \varepsilon_{kk} \delta_{ij} ,$$

and D^p_{ij} is the plastic component of the rate of deformation tensor. The effective plastic strain is written into the plot file with the stress state.

APPENDIX B

NORMAL AND SHEAR COMPONENTS

The normal and shear stress and strain components can be readily defined as shown in Figure F.1 below.



ij & kl

jk & li

$$\theta = \tan^{-1} \frac{z_j+z_k-z_i-z_l}{y_j+y_k-y_i-y_l} \qquad \theta = \tan^{-1} \frac{z_k+z_l-z_i-z_j}{y_k+y_l-y_i-y_j}$$

Figure F.1. Definition of normal and shear components for Q4 and Q8 elements.

APPENDIX C

STRAIN CALCULATIONS

Assume that particles in a body have coordinates y and z that map to positions Y and Z at time zero. These coordinates are related through the displacements v and w by

$$y = Y + v(Y,Z,t),$$

$$z = Z + w(Y,Z,t).$$

Velocities are given by the time derivatives of the displacements

$$\overset{\circ}{v} = \overset{\circ}{y} = \frac{\partial y}{\partial t} = \frac{\partial v}{\partial t} \quad ,$$

$$\overset{\circ}{w} = \overset{\circ}{z} = \frac{\partial z}{\partial t} = \frac{\partial w}{\partial t} \quad .$$

The deformation gradient matrix

$$\underset{\sim}{F} = \begin{matrix} \frac{\partial y}{\partial Y} & \frac{\partial y}{\partial Z} & 0 \\ \frac{\partial z}{\partial Y} & \frac{\partial z}{\partial Z} & 0 \\ 0 & 0 & \frac{y}{Y} \end{matrix} \quad ,$$

and the velocity gradient matrix

$$\underset{\sim}{L} = \begin{matrix} \frac{\partial \overset{\circ}{v}}{\partial y} & \frac{\partial \overset{\circ}{v}}{\partial z} & 0 \\ \frac{\partial \overset{\circ}{w}}{\partial y} & \frac{\partial \overset{\circ}{w}}{\partial z} & 0 \\ 0 & 0 & \frac{\overset{\circ}{y}}{y} \end{matrix} \quad ,$$

are useful for defining the strain measures:

infinitesimal strain matrix

$$\underset{\sim}{\varepsilon} = \frac{1}{2} (\underset{\sim}{F} + \underset{\sim}{F}^t) - I \quad ,$$

Green-St. Venant strain matrix

$$\underset{\sim}{E} = \frac{1}{2} (\underset{\sim}{F}^t \underset{\sim}{F} - \underset{\sim}{I}) \quad ,$$

Almansi strain matrix

$$\underset{\sim}{e} = \frac{1}{2} (\underset{\sim}{I} - \underset{\sim}{f}^t \underset{\sim}{f}) \quad ,$$

rate of deformation matrix

$$\underset{\sim}{D} = \frac{1}{2} (\underset{\sim}{L} + \underset{\sim}{L}^t) \quad ,$$

extensions

$$E_{(\underset{\sim}{N})} = [\underset{\sim}{N}^t \, (\underset{\sim}{F}^t \underset{\sim}{F}) \, \underset{\sim}{N}]^{1/2} - I \quad ,$$

where I is the identity matrix and $f = F^{-1}$. The extensions correspond to strain gage data in that they measure the extension of a line of unit length whose direction before deformation is N. In plane strain problems, $F_{33} = 1$ and $L_{33} = 0$.

APPENDIX D

EXPERIMENTAL DATA FILE

The time history options of ORION allows experimental data to be plotted. The data is contained in the data file named with the "EXPDATA" command.

More than one data record may be contained in the file. Points of each record will be plotted with a different character. The first number of the data record gives the number of points, N, in the record and is specified as an integer in columns 1-5; i.e., a I5 field. The N lines that follow define the data points such that in columns 1-20 a time value is specified and in columns 21-40, the corresponding function value is defined. Here 2E20.0 field is assumed. ORION ceases to plot data points when the end-of-file is detected, that is, after all data records contained in the file are plotted.

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