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COMMISSION OF THE EUROPEAN COMMUNITIES

EURCYL - A PROGRAM TO GENERATE FINITE ELEMENT MESHES FOR PRESSURE VESSEL NOZZLES

E. S. M. I. S.

by

P. DE WINDT and J. REYNEN

1974

Joint Nuclear Research Centre
Ispra Establishment - Italy

Technology Division

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ABSTRACT

EURCYL is a program dealing with the automatic generation of finite element meshes for pressure vessel nozzles, using isoparametric elements with 8, 20 or 32 nodes.
Options exist to generate BWR nozzles as well as PWR nozzles.

1. INTRODUCTION

EURCYL is a program which generates automatically isoparametric finite element meshes of nozzles of current light water pressure vessels. The present report gives a description and a "How to Use" of EURCYL level 2. The difference with EURCYL level 1[(1)], lies in the option to generate also PWR nozzles.

Due to their larger diameter as compared to BWR nozzles, the PWR nozzles are usually embedded in the flange of the vessel (compare Fig. 1-a and Fig. 1-b).

The present report repeats to a great extent the description of EURCYL level 1[(1)], and as a result the potential user of EURCYL level 2 can consider (1) as obsolete.

2. TOPOLOGY

EURCYL starts to generate a quarter of a cylinder-cylinder intersection with local reinforcements and fillet radii, as represented in Fig. 2 and Fig. 3, including the necessary dimensions and various coordinate systems. Such geometry is typical for BWR nozzles (see Fig. 1-a).

2.1 BWR Nozzle:

Three regions are recognized

- nozzle zone: A to D
- transition zone: D, B, C to E
- vessel zone: E to F.

The topology of the elements corresponds to the topology of a wall (Fig. 4) with the three dimensions and corresponding number of elements as indicated in Table 1 and Fig. 5.

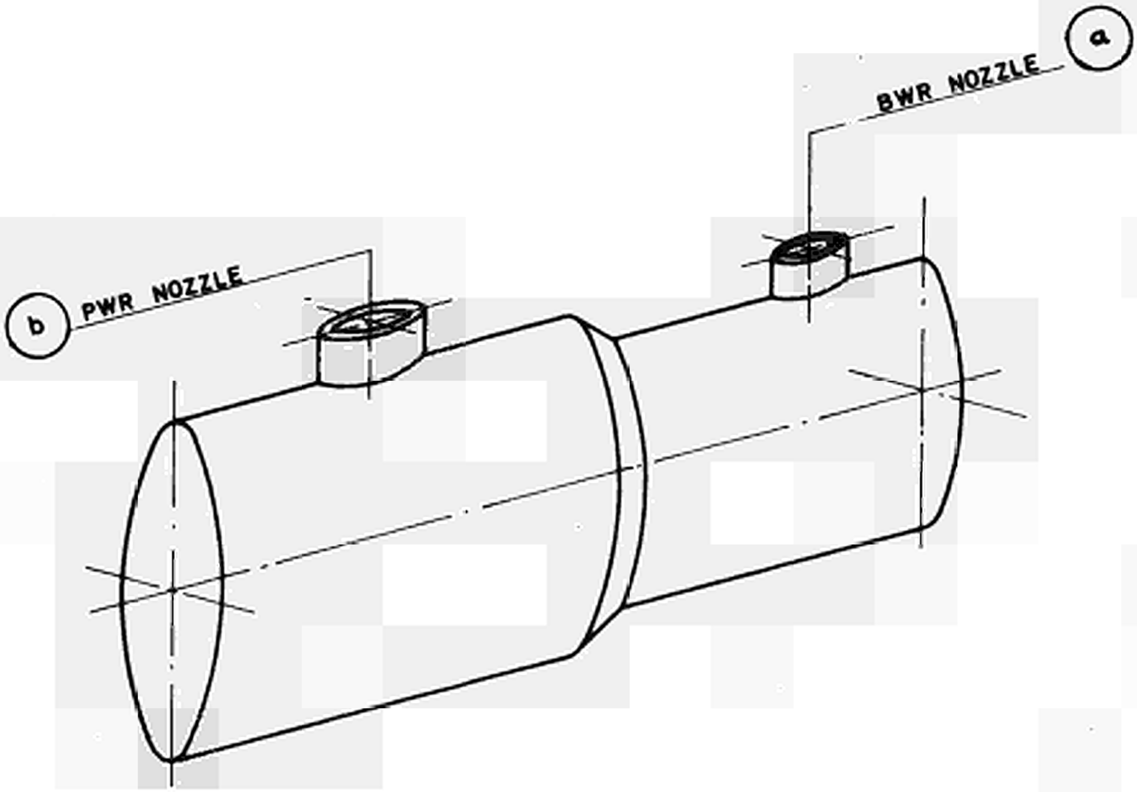
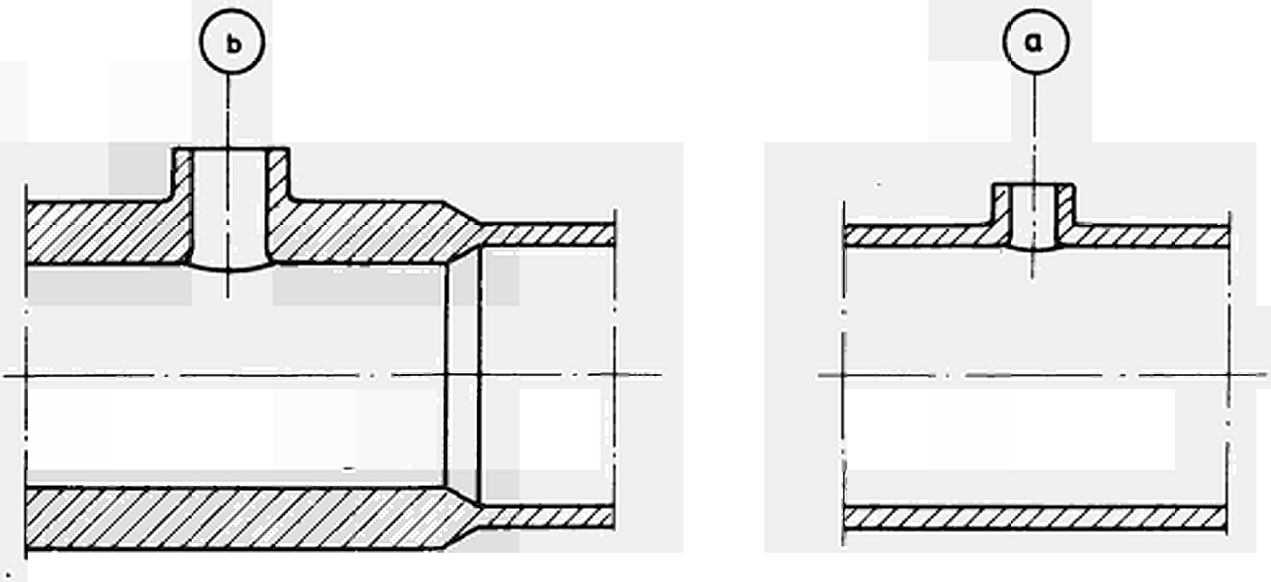


FIG. 1 – NOZZLE TYPES



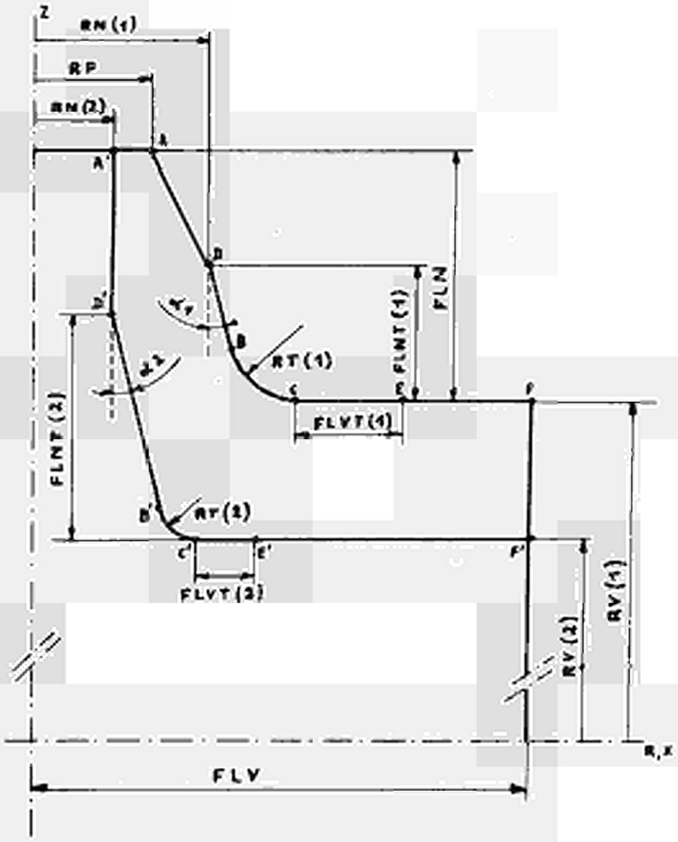


Fig. 2 : General Dimensions – 2-D Section

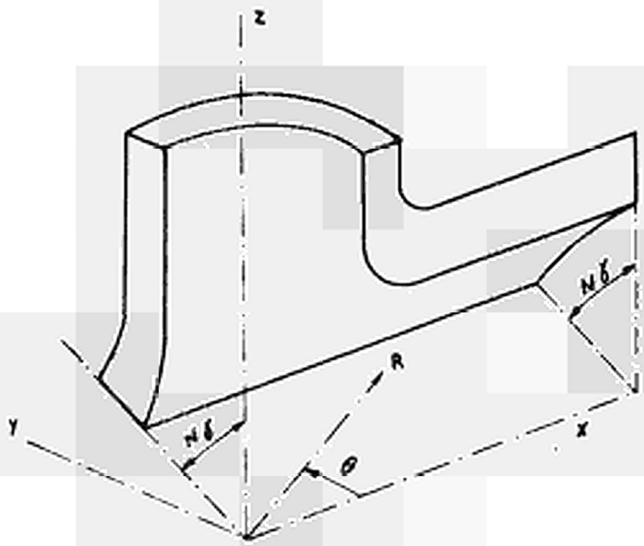


Fig. 3 : 3-D View with Coord. System
(x-y-z and R - θ - Z)

TABLE 1

Direction	Number of Elements
Length	NELL
Angular	NELA
Thickness	NELTH

The number of elements in angular direction corresponds to a quarter of the BWR nozzle ($0 \leqslant \theta \leqslant 90$, first quadrant). The number of elements in length direction is subdivided into the three zones mentioned before, as indicated in Table 2.

TABLE 2

Zone	Number of Elements
Nozzle	NELN
Transition	NELT
Vessel	NELV
Total Length	NELL=NELN+NELT+NELV

The numbering of elements is as indicated in Fig. 4, in thickness, angular and length direction respectively. Since for most applications NELTH < NELA < NELL, this numbering gives the smallest bandwidth for a front solution[5].

An option NELEM is introduced in order to be able to continue a mesh with NELEM-1 elements already generated.

Three types of elements can be used corresponding to the isoparametric elements used in BERSAFE[2] and FLHE[3]. They are given in Table 3 and Fig. 6.

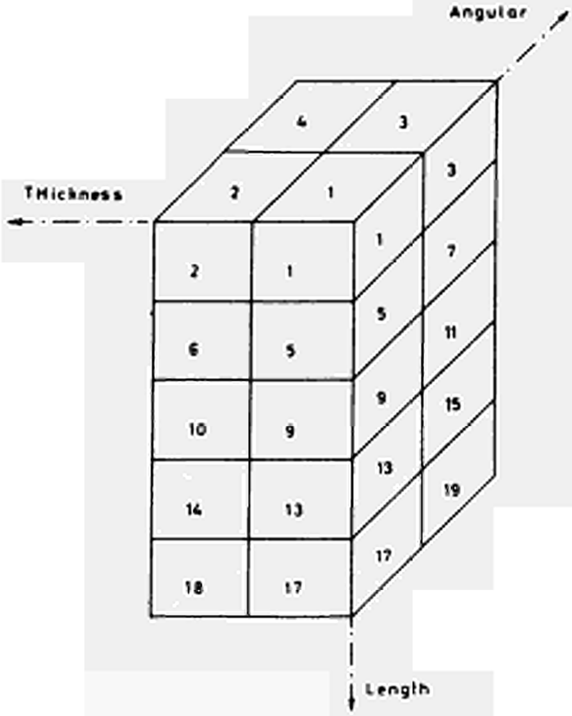


Fig. 4 : Element indexation

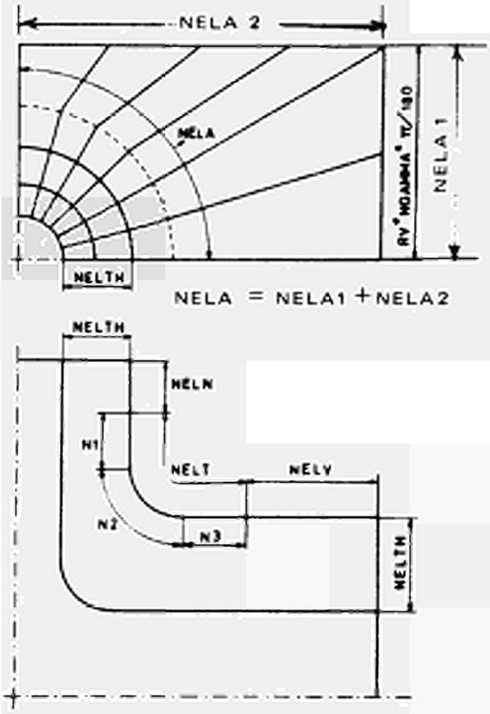


Fig. 5 : Element distribution

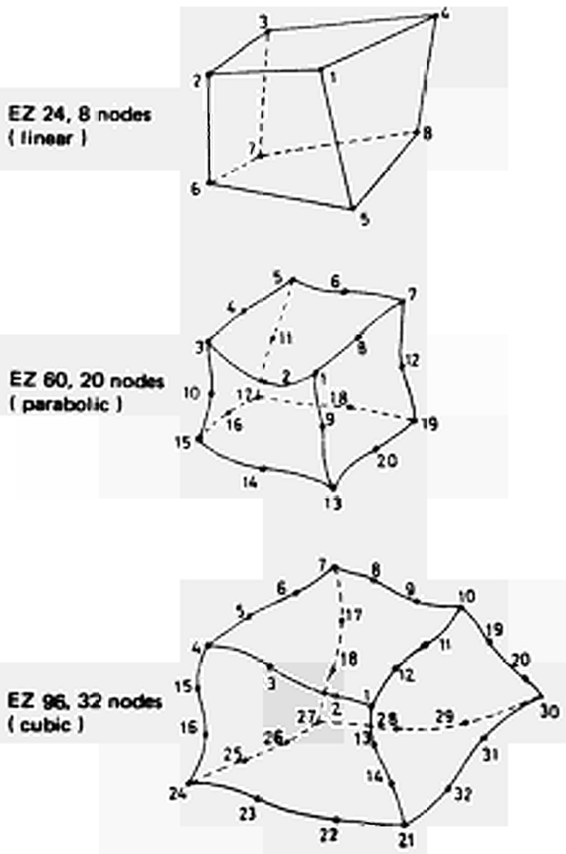


Fig. 6 : Element types

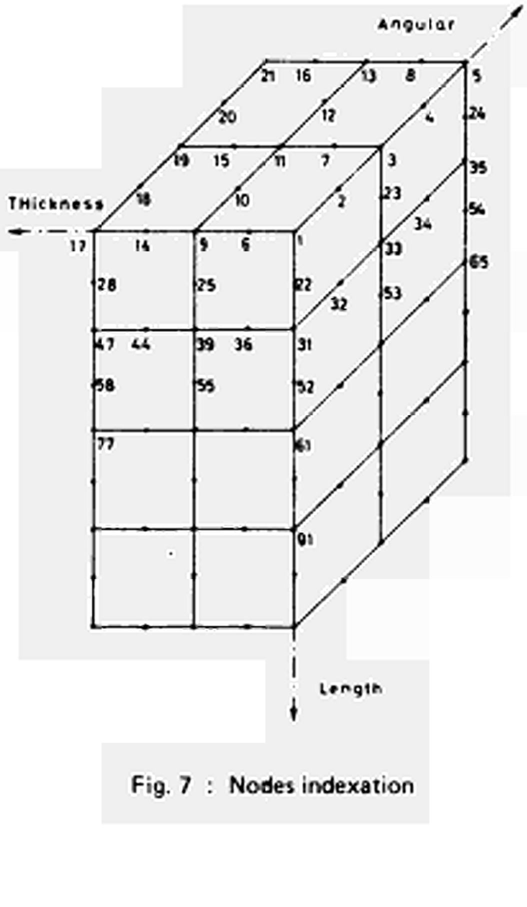


Fig. 7 : Nodes indexation

TABLE 3

EURCYL el. type	BERSAFE el. type	Number of nodes	Description
1	EZ24	8	linear
2	EZ60	20	parabolic
3	EZ96	32	cubic

The node numbering is straightforward and proceeds in the angular, thickness and length direction respectively (Fig. 7). The option NPOIN is introduced in order to be able to continue a mesh with NPOIN-1 nodes already generated.

EURCYL defines the bandwidth of the generated topology and the job is abandoned if the bandwidth exceeds a preset value defined by input (NBTOT).

EURCYL has options to generate 1/4, 1/2 or the complete intersection to be specified by input data NTHETA (Table 4). The node numbering starts at the angular plane θ-start. For option NTHETA=4 the nodes of the first angular plane (θ-start) coincide with those of the last angular plane (θ-end). In the topology definition, the former are retained. A similar situation occurs for NGAMMA=180^o (Fig. 3) and NTHETA=2 or 4, and also here the lower node numbers are retained.

TABLE 4

NTHETA	quadrants	θ-start	θ-end
1	1	0^o	90^o
2	1, 4	-90^o	90^o
3	1, 2	0^o	180^o
4	1, 2, 3, 4	-180^o	180^o

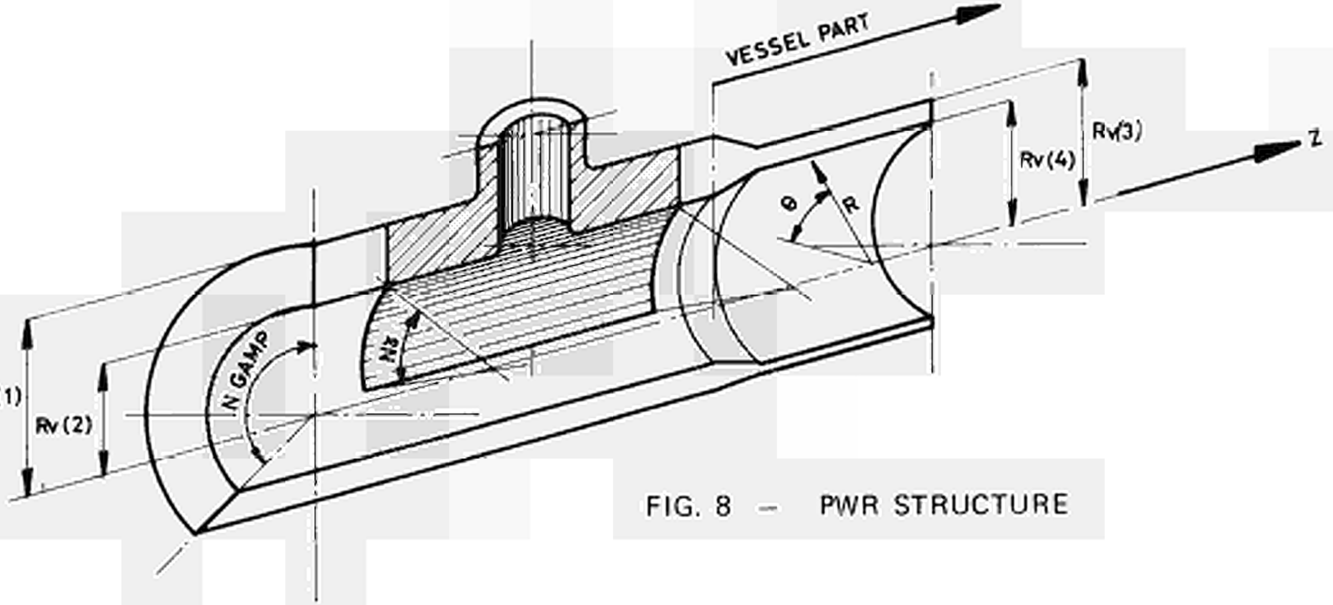


FIG. 8 – PWR STRUCTURE

An option (ITWOD) gives the possibility to generate 2-D topology corresponding to planes Z-X and Z-Y. They represent the approach of the 3-D nozzle by nozzle-on-plane respectively nozzle-on-sphere, i.e. 2D-axisymmetric approaches.

The elements are the isoparametric 2-D elements with 4, 8 or 12 nodes depending on NELTYP.

The output consists of a listing of the elements with corresponding nodes. Moreover, punched cards are produced with the output format of BERSAFE and FLHE.

2.2 PWR Nozzle

PWR pressure vessel nozzles are embedded in the flange providing additional strength to account for their larger diameter as compared to BWR nozzles (Fig. 1).

For the analysis of such nozzles it is not sufficient anymore to study a quarter of the nozzle; only the longitudinal plane is a symmetry plane and a half of the nozzle has to be analyzed.
EURCYL has an option (NPWR=1) to generate automatically a mesh of the geometry depicted in Figure 8. Only half of the structure can be generated by default, and automatically NTHETA will be equal to 3.

The mesh is generated by first considering it as a BWR nozzle mesh with vessel wall thickness equal to flange thickness, and next adding elements according to Figure 9. The element distribution is summarized in Table 5. The numbering of elements is as before i.e. in thickness, angular and length direction respectively. Those elements which do not exist, e.g. for angular planes beyond NELA1 outside the flange, are ignored.

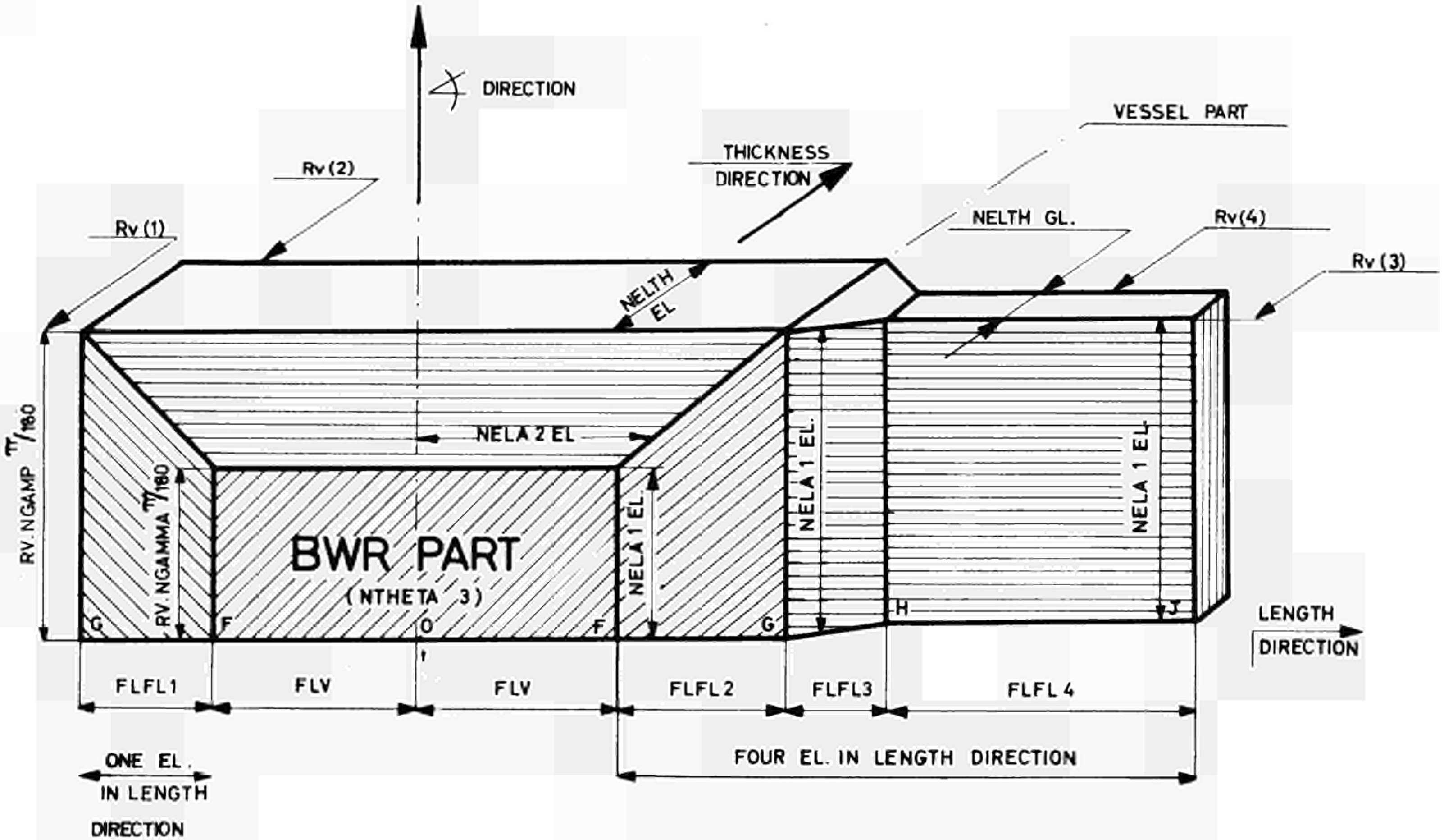


FIG. 9 – PWR STRUCTURE IN A DEVELOPED PLANE

TABLE 5

(compared with Fig. 7 and Fig. 8)

Directions	BWR Part	Extension	BWR Part + Extension
Angular	2* NELA	2* NELA	2* NELA
Thickness	NELTH	NELTH	NELTH
Length	NELL	1	NELL + 1 in Z < 0
		3	NELL + 1 + 3 in Z > 0

3. GEOMETRY

In a similar way as for the generation of the topology of the mesh, also the generation of the coordinates of the nodal points is carried out firstly for a BWR type nozzle, followed by an extension to PWR type nozzles, depending on the option NPWR.

3.1 BWR Nozzle

The coordinates of the nodal points depend on the distribution and on the type of the elements. The distribution and the type of elements depend on their turn on the structure and the expected stress distribution. For the nozzle structure the type of element should preferably be the parabolic or cubic isoparametric ones, in order to represent accurately the geometry of the curved surfaces (the linear element EZ24 with straight edges has only been included for completeness). The distribution of elements should be fine in regions of steep stress gradients and can be coarser elsewhere.

In EURCYL the distribution of elements is controlled by input. As far as the angular direction is concerned, the distribution is homogeneous for the nozzle zone (A-D) and transition zone (D-B-C-E) and nearly homogeneous for the vessel zone (E-F), see Fig. 5.

In the thickness direction the distribution is governed by a crowding factor CROWTH, according to a geometrical series with the smaller elements at the inside for CROWTH >1 (see appendix 1).

In the length direction the distribution is defined by NELN, NELT, NELV (see chapter 1) with corresponding crowding factors CROWN, CROWTR, CROWV according to geometrical series with increasing elements in the direction away from the intersection.

For the determination of the coordinates of the nodal points, first the coordinates of the points A, D, B, C, E and F (Fig. 2) for inside and outside surfaces and for the various angular planes have to be defined. For A and D the procedure is straight forward because they are on a cylindrical surface with axis Z. The coordinates of B and C follow from a transcendental equation, which is solved by iteration (appendix 3). Points C, E and F lie on a cylindrical surface with axis X. This surface is developed in a Z-X plane in which the coordinates are defined. Once the points A, D, B, C, E and F are defined, the summit nodes are found by geometrical interpolation using the crowding factors. Next the mid-side nodes are defined.

For the structural options NTHETA $\neq 1$ the additional coordinates are found by symmetry.

The output of the geometry consists of a list of cartesian (X-Y-Z) or cylindrical (r, θ, Z) coordinates depending on the option NCOORD. Punched cards are produced to be used in subsequent runs with finite element programs.

As for the topology, the option ITW0D allows the generation of the geometry in plane Z-X and/or Z-Y.

3.2 PWR Nozzle

The coordinates of the extension are generated in a developed plane and then converted to the real situation. It is noted that for a PWR nozzle NTHETA is equal to 3 by default.

The coordinate system is a rθz system with the z axis coinciding with the axial axis of the vessel. In this way the so-called R-elements of BERSAFE can be used which as unknowns have the displacements in a cylindrical coordinate system, rather than the usual unknowns in cartesian coordinates.

Input data follow from Fig. 8 and 9 and are specified in chapter 4.

4. HOW-TO-USE

Card No. 1: job title card

ccs 1-4	AJOB	A4	job name for BERSAFE program
ccs 5-80	TITLE	19A4	title of the job

Card No. 2: dimension card (see Fig. 2 and 3)

ccs 1-6	RV(1)	F6.2	external vessel radius
ccs 7-12	RV(2)	F6.2	internal vessel radius
ccs 12-18	FLV	F6.2	vessel length
ccs 19-24	RN(1)	F6.2	external nozzle radius
ccs 25-30	RN(2)	F6.2	internal nozzle radius
ccs 31-36	FLN	F6.2	nozzle length
ccs 37-42	RT(1)	F6.2	outside transition radius = 0 if transition not curved
ccs 43-48	RT(2)	F6.2	inside transition radius (= 0 if transition not curved)
ccs 49-54	FLVT(1)	F6.2	length of transition zone, outside vessel

ccs 55-60	FLVT(2)	F6.2	length of transition zone, inside vessel
ccs 61-66	FLNT(1)	F6.2	length of transition zone, outside nozzle
ccs 67-72	FLNT(2)	F6.2	length of transition zone, inside nozzle
ccs 73-78	RP	F6.2	external radius of nozzle entry, in case of conical form if = 0, RP=RN(1) (cylindrical form)

Card No. 3

ccs 1-6	ALFAC1	F6.2	angle in degrees of transition nozzle part, if conical (= 0 cylindrical)
ccs 7-12	ALFAC2	F6.2	angle in degrees of transition nozzle part, if conical (= 0 cylindrical)

Card No. 4: Element and structure option card

Reference: BWR type, quarter of a structure.

ccs 1-6	NELN	I6	number of elements in nozzle length
ccs 7-12	NELT	I6	number of elements in transition length
ccs 13-18	NELV	I6	number of elements in vessel length
ccs 19-24	NELA	I6	number of elements in angular direction
ccs 25-30	NELTH	I6	number of elements in the thickness
ccs 31-36	NELTYP	I6	element option: = 1 type EZ24 (linear, 8 nodes) = 2 type EZ60 (parabolic, 20 nodes) = 3 type EZ96 (cubic, 32 nodes)
ccs 37-42	NTHETA	I6	structure option: = 1 quadrant 1 = 2 quadrant 1 + 4 = 3 quadrant 1 + 2 = 4 quadrant 1 + 2 + 3 + 4

For PWR nozzle NTHETA = 3 by default.

ccs 43-48	NGAMMA	I6	angle in degrees of vessel sector (up to maximum 180^{o})
ccs 49-54	NCOORD	I6	coordinates option = 0 x-y-z = 1 r-θ-z (Fig. 3)

For PWR nozzle coordinate system r-θ-z (Fig. 3) according to Fig. 7 by default.

ccs 55-60	ITWOD	I6	= 0 3D data required = 1 2D data required: z-x plane = 2 2D data required: z-y plane = 3 3D and 2D (z-x and z-y) data required

For PWR nozzle ITWOD = 0 by default.

Card No. 5: crowding factor card

ccs 1-6	CROWN	F6.2	crowding factor along the nozzle if > 1 elements increasing away from the transition
ccs 7-12	CROWV	F6.2	crowding factor along the vessel if > 1 elements increasing away from the transition
ccs 13-18	CROWTH	F6.2	crowding factor along the thickness if > 1 elements increasing away from the inside surface
ccs 19-24	CROWTR	F6.2	crowding factor along the transition nozzle and vessel zones if > 1 elements increasing away from the junction, if = 1, automatically = 1.1

Card No. 6:

ccs 1-6	NPOIN	I6	index of first nodal point (3-D mesh)
ccs 7-12	NELEM	I6	index of first element (3-D mesh)
ccs 13-18	NBTOT	I6	maximum number of nodes allowed in the semi-bandwidth if = 0, NBTOT = 99
ccs 19-24	NPOIN1	I6	index of first nodal point (2-D mesh)
ccs 25-30	NELEM1	I6	index of first element (2-D mesh)
ccs 31-36	NPWR	I6	= 0 BWR nozzle = 1 PWR nozzle

The cards 7 and 8 are by-passed if NPWR = 0.

Card No. 7: PWR part card (Fig. 8)

ccs 1-6	FLFL1	F6.2	extension length in z negative with radii RV(1) and RV(2)
ccs 7-12	FLFL2	F6.2	extension length in z positive with radii RV(1) and RV(2)
ccs 13-18	FLFL3	F6.2	extension length in z positive conical zone of the vessel part
ccs 19-24	FLFL4	F6.2	vessel length with radii RV(3) and RV(4)
ccs 25-30	RV(3)	F6.2	vessel outer radius if = 0 RV(3) = RV(1)
ccs 31-36	RV(4)	F6.2	vessel inner radius if = 0 RV(4) = RV(2)

Card No. 8: PWR part card

ccs 1-6	NGAMP	I6	- PWR vessel sector (in degrees) N.B. 180 > NGAMP > NGAMMA

5. RESULTS

The output of EURCYL consists of listings of:

- the input data,

- the total number of nodes and elements (1),
- the maximum semi-bandwidth (1),
- the 3-D topology (2),
- the 2-D topology and geometry (2),
- the 3-D geometry (2).

(1) the job is immediately abandoned if these parameters do not agree with the BERSAFE and FLHE limitations,

(2) printed if required, this sequence is imposed due to program dimensions conveniences.

Further punched cards are produced for the topology and the geometry with the required formats for BERSAFE[2] and FLHE[3] use.

Topology cards - card type 11 BERSAFE

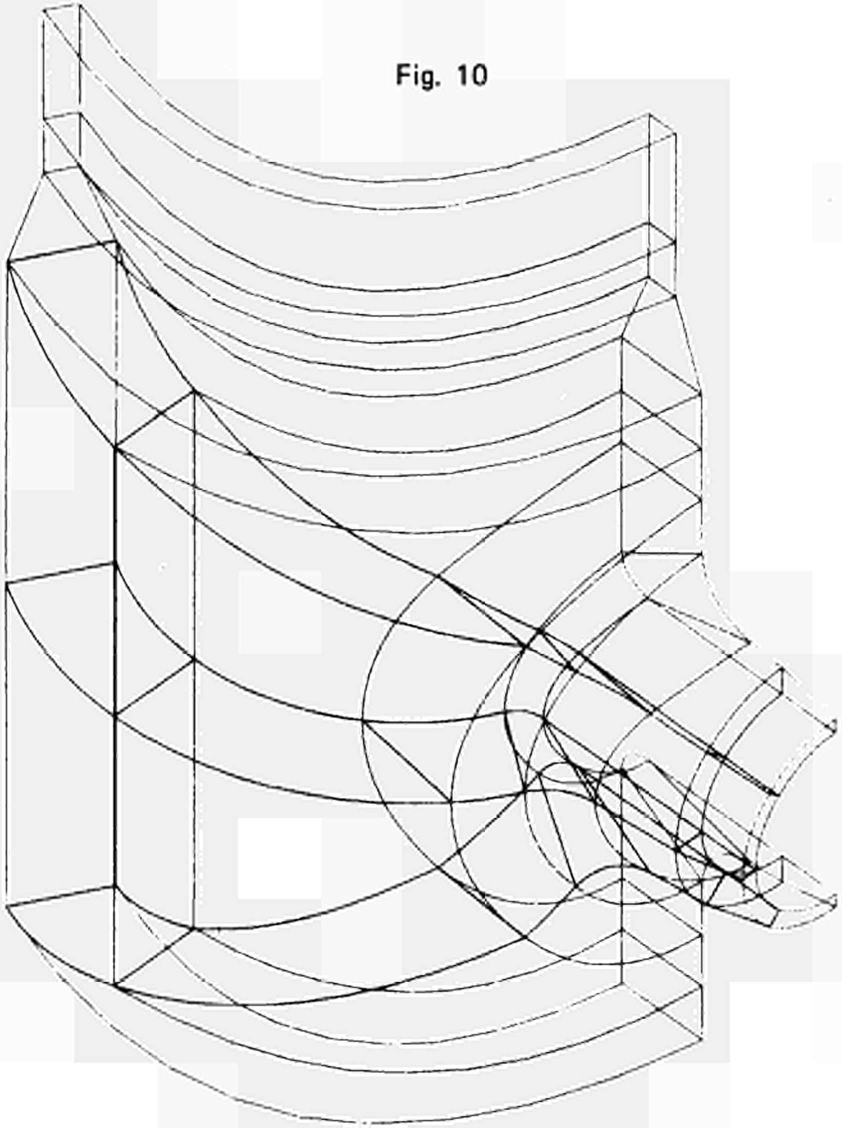
ccs 1-4	AJOB	A4	job name
ccs 5-6	11	I2	card type number (BERSAFE)
ccs 7-12			blank
ccs 13-16	NOEL	I4	element number
ccs 17-18	NNODES	I2	number of nodes
ccs 19-22 ccs 75-78	NODES	15I4	nodes series

N.B. if NNODES > 15, a continuation card is used with I4 formats (ccs 19-22, etc.) and NNODES = NNODES +1.

Geometry cards - card type 21 BERSAFE

ccs 1-4	AJOB	A4	job name
ccs 5-6	21	I2	card type number (BERSAFE)
ccs 7-10	NODE	I4	node number
ccs 11-18	GNODE	F8.3	X or R coordinate
ccs 19-26	GNODE	F8.3	Y or θ coordinate (θ in degrees)
ccs 27-34	GNODE	F8.3	Z coordinate

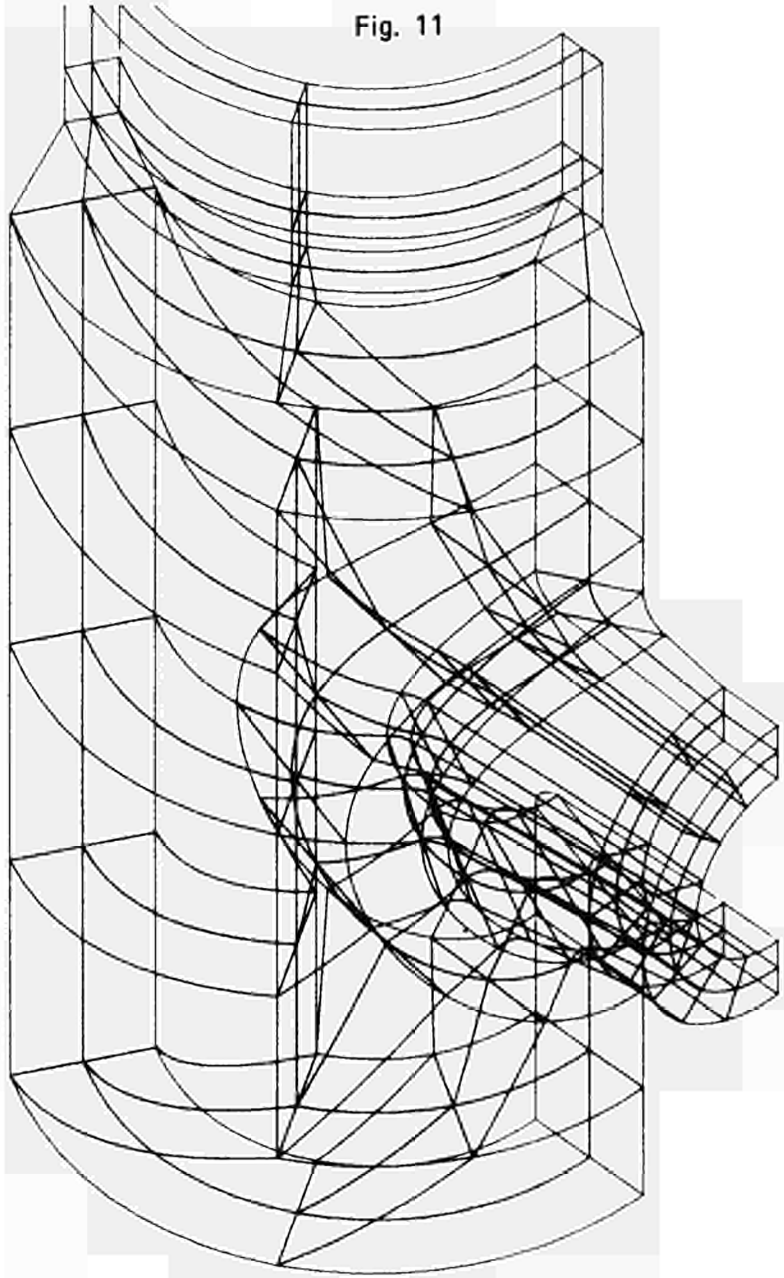
Fig. 10



TEST EURCYL LEVEL 2, TEST SAMPLE PWR NOZZLE TYPE

0.0 45.0 45.0 GLOB 0.0 0.0 0.0 CART

Fig. 11



TEST PWR SAMPLE TEST

Appendix 4 gives an example of the printed results of a structure represented by the Calcomp plot of Fig. 10. Fig. 11 gives another example.

6. CONCLUSIONS

EURCYL covers the automatic mesh generation of a broad field of cylinder-cylinder intersections. In particular the program is suited to generate meshes for both BWR and PWR nozzles, including local reinforcement and fillet radii. Punched cards are produced to serve as input for the finite element program systems BERSAFE and FLHE.

REFERENCES

(1) DE WINDT-REYNEN; "EURCYL - A Computer Program to Generate Finite Element Meshes for Cylinder-Cylinder Intersections", EUR-5030 e.

(2) HELLEN, T.K.; "BERSAFE (Phase 1), A Computer System for Stress Analysis - Part 1: User's Guide", October 1970, CEGB Report RD/B/N1761

(3) FULLARD, K.; "FLHE, A Finite Element Program for the Calculation of Temperatures in Arbitrary Structures. Part 1: User's Guide" - CEGB Report RD/B/N1849

(4) HELLEN, T.K.; "A Front Solution for Finite Element Techniques", CEGB Report RD/B/N1459, October 1969.

APPENDIX 1

Crowding Factors

If N is the number of nodes to be generated on a straight or curved line defined by the parameters x_1 and x_N with crowding factor R, the coordinates of the intermediate nodes are defined from:

$$x_j = x_1 + (x_N - x_1)\, CN$$

$$CN = (R^{j-1} - 1)/(R^{N-1} - 1)$$

$$CN = (j - 1)/(N - 1) \qquad \text{for } R = 1.$$

These formulae are used to define the coordinates of the summit nodes in the thickness direction, and for the nozzle zone A - D and the vessel zone E - F in length direction (Fig. 2).

APPENDIX 2

The distribution of the elements in the transition zone is defined by the number of elements NELT and the crowding factor R.

The program has to define the number of elements to be attributed to the distances DB, BC and CE, respectively N1, N2 and N3 (Fig. 5). An iterative procedure is applied.

As initial guess for the length of the elements in distance BC is taken

$$A = (DB + BC + CE)/NELT \qquad (1)$$

The number of elements in DB, BC and CE become respectively

$$N1 = \log(1 + (R-1)\,DB/A)/\log R \qquad (2)$$

$$N2 = BC/A \qquad (3)$$

$$N3 = \log(1 + (R-1)CE/A)/\log R \qquad (4)$$

These equations express that for BC the distribution is homogeneous (3) and for DB and CE the distribution is according to a geometrical series with first term A and ratio R.

The sum of the calculated elements is compared to the prescribed number NELT.

$$N1 + N2 + N3 = SUM \overset{?}{=} NELT \qquad (5)$$

A correction is applied to A according to

$$A = A\,(SUM/NELT)^{1/2} \qquad (6)$$

and the iteration loop returns to eq. (1) until (5) is satisfied.

Equations (2) and (4) follow from the sum S of a geometrical series with N terms:

$$S = A(R^N - 1)/(R - 1) \qquad (7)$$

Once N1, N2 and N3 are known, the summit nodes in BC are distributed homogeneously, and the summit nodes in DB and CE according to a geometrical series with ratio R (appendix 1).

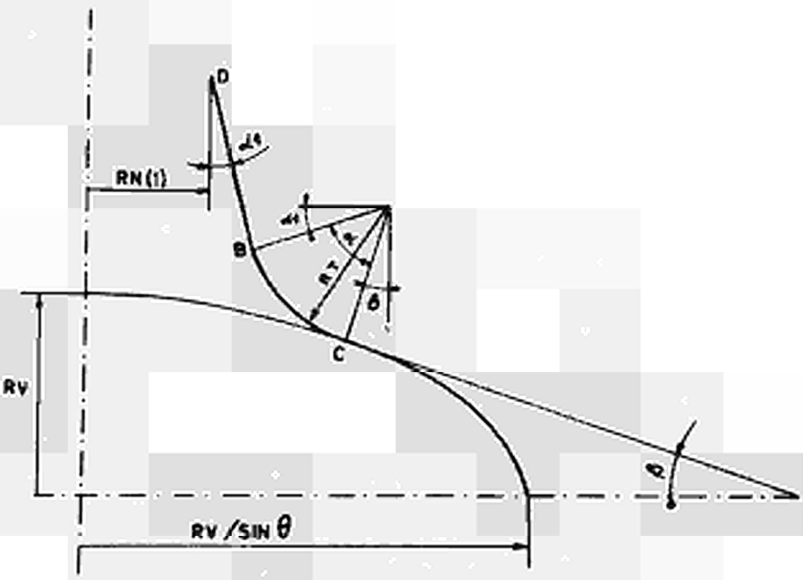


Fig. 12 : Transition profile in an angular plane θ

APPENDIX 3

The coordinates of points B and C in an angular plane θ are defined by transcendental equations which are solved by iteration.

The intersection of an angular plane θ with the vessel (radius RV) is an ellipse with half axis.

$RV/\sin\theta$ and RV (Fig. 12)

The iteration starts with a first guess for the radius RC of point C in the plane of intersection. The vertical position of C is then defined by:

$$ZC = (RV^2 - RC^2 \sin^2\theta)^{1/2} \qquad (1)$$

The angle β is defined by:

$$= \text{arctg}\,(RC \sin^2\beta / ZC) \qquad (2)$$

The angle α and the coordinates of points B become:

$$\alpha = \pi/2 - \alpha_1 - \beta \qquad (3)$$

$$RB = RC + RT \sin\beta - RT \cos\alpha_1 \qquad (4)$$

$$ZB = ZC + RT \cos\beta - RT \sin\alpha_1 \qquad (5)$$

The radius of point D becomes:

$$RD = RB - (ZD - ZB)\,\text{tg}\,\alpha_1 \qquad (6)$$

The value of RD is compared to the nozzle radius RN. The difference is subtracted from RC and the iteration continues with equation (1).

Equation (3) gives the value of α and the intermediate nodes between BC are defined by linear interpolation of the variable α.

APPENDIX 4

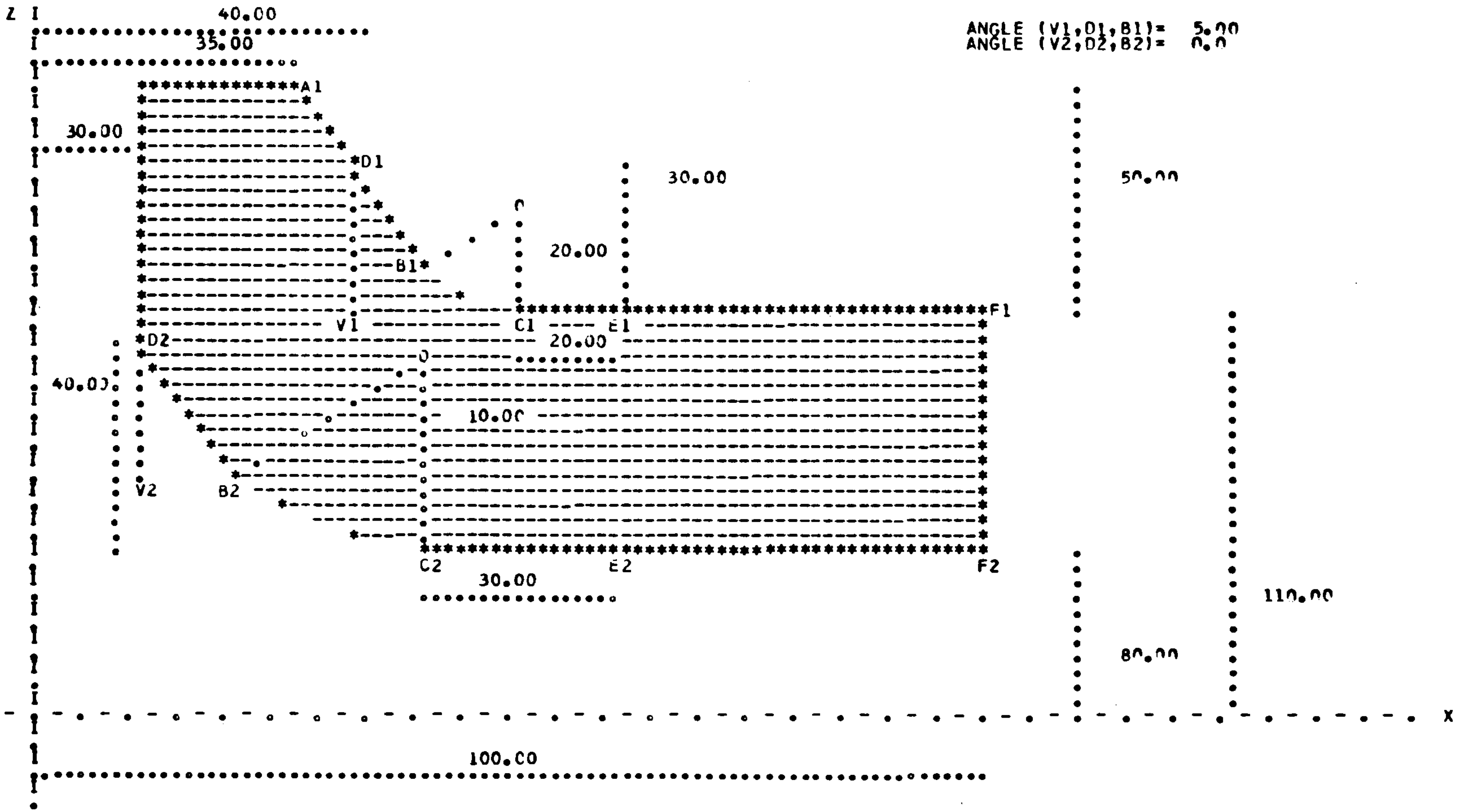
TEST SAMPLE

```
**************************************************************
*                                                            *
* PROGRAM EURCYL       THREE DIMENSIONAL  MESH GENERATION    *
*                                                            *
**************************************************************
```

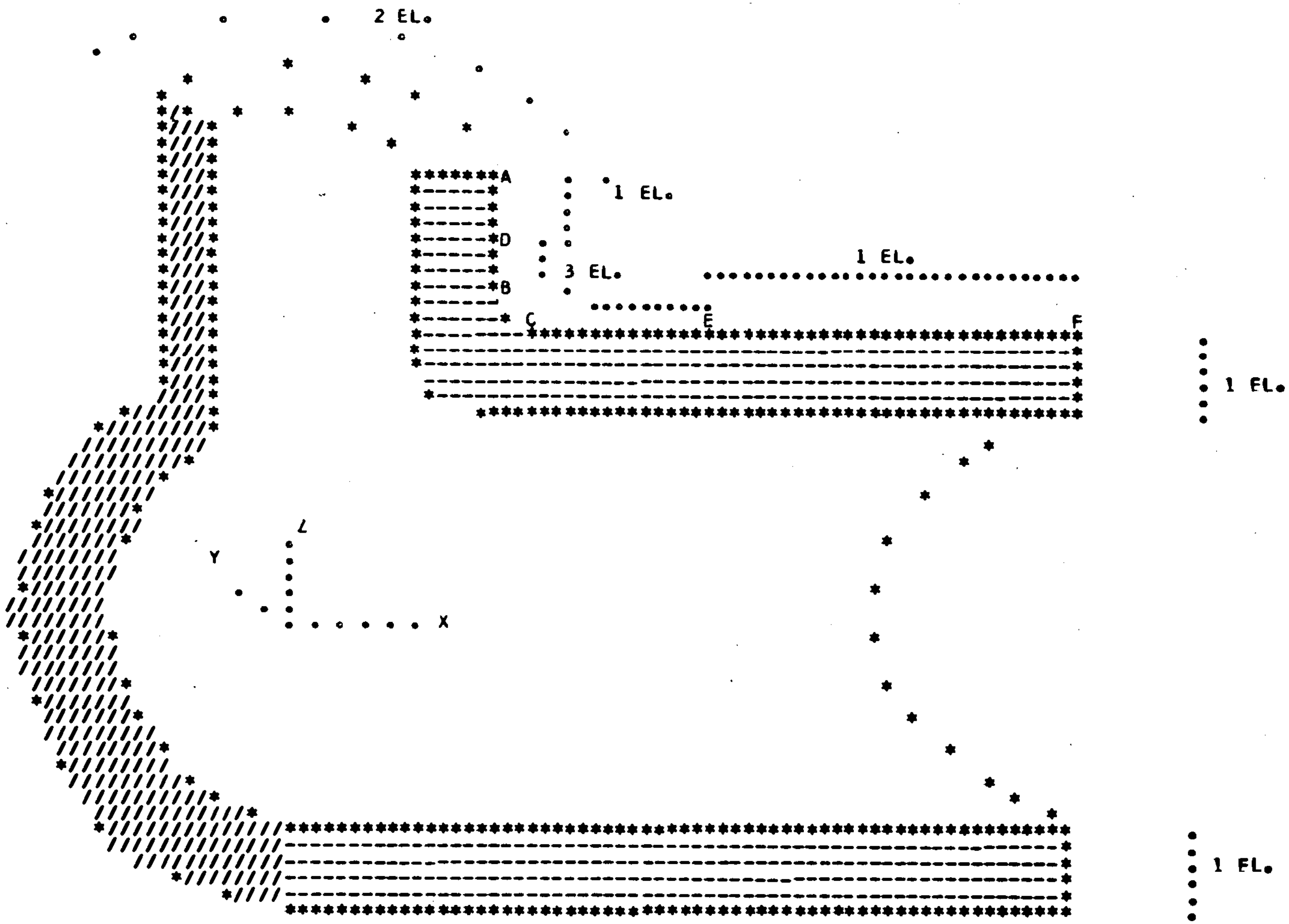
```
************************************************************************************
*  3-D  P W R  TYPE NOZZLE                                                         *
************************************************************************************
```

```
JOB NAME FOR BERSAFE ( OR FLHE ) . . TEST
                                     ******
```

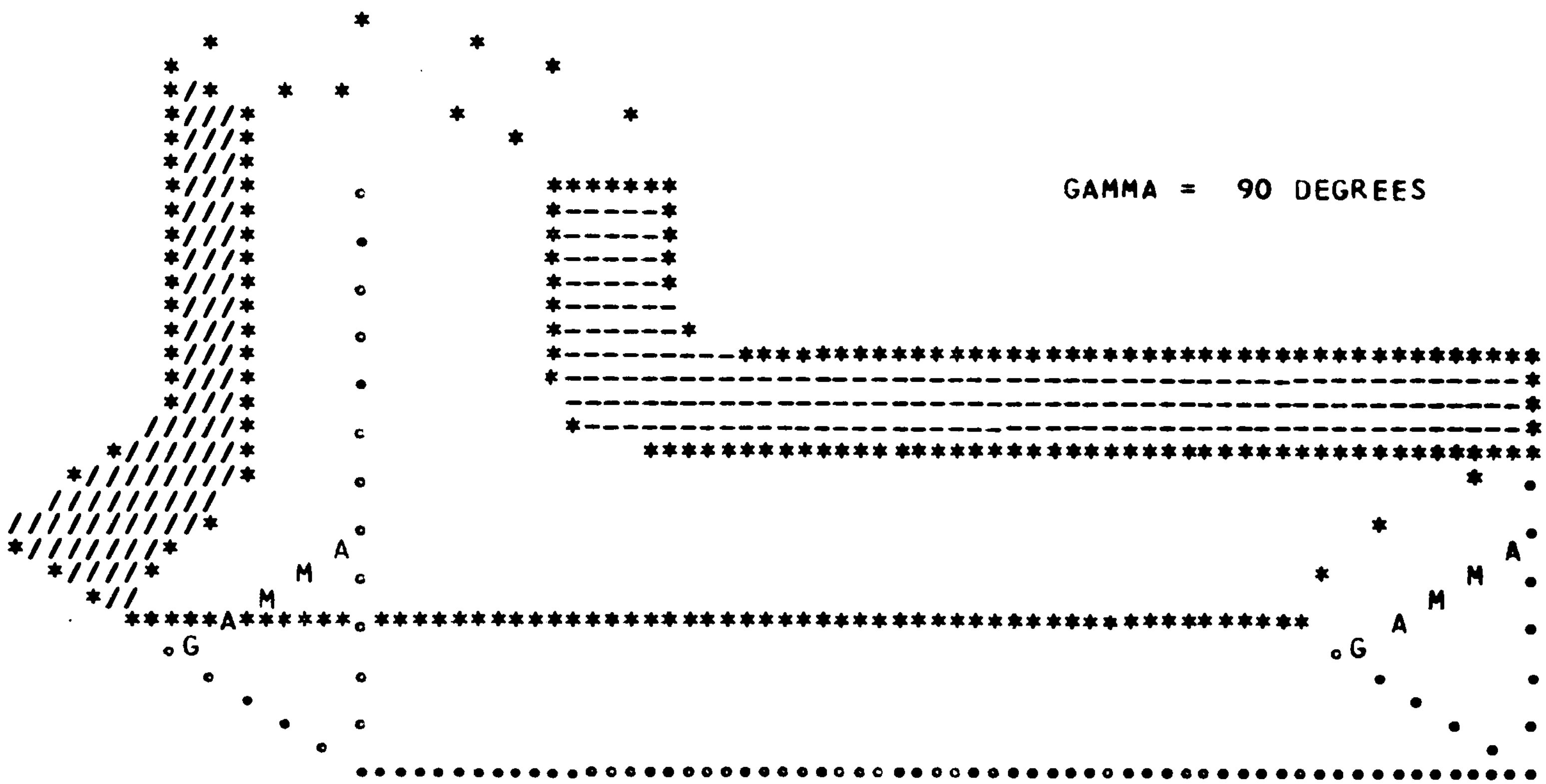
GENERAL 2-DIMENSIONAL VIEW WITH DIMENSIONS



GENERAL 3-DIMENSIONAL VIEW WITH ELEMENT INFORMATION



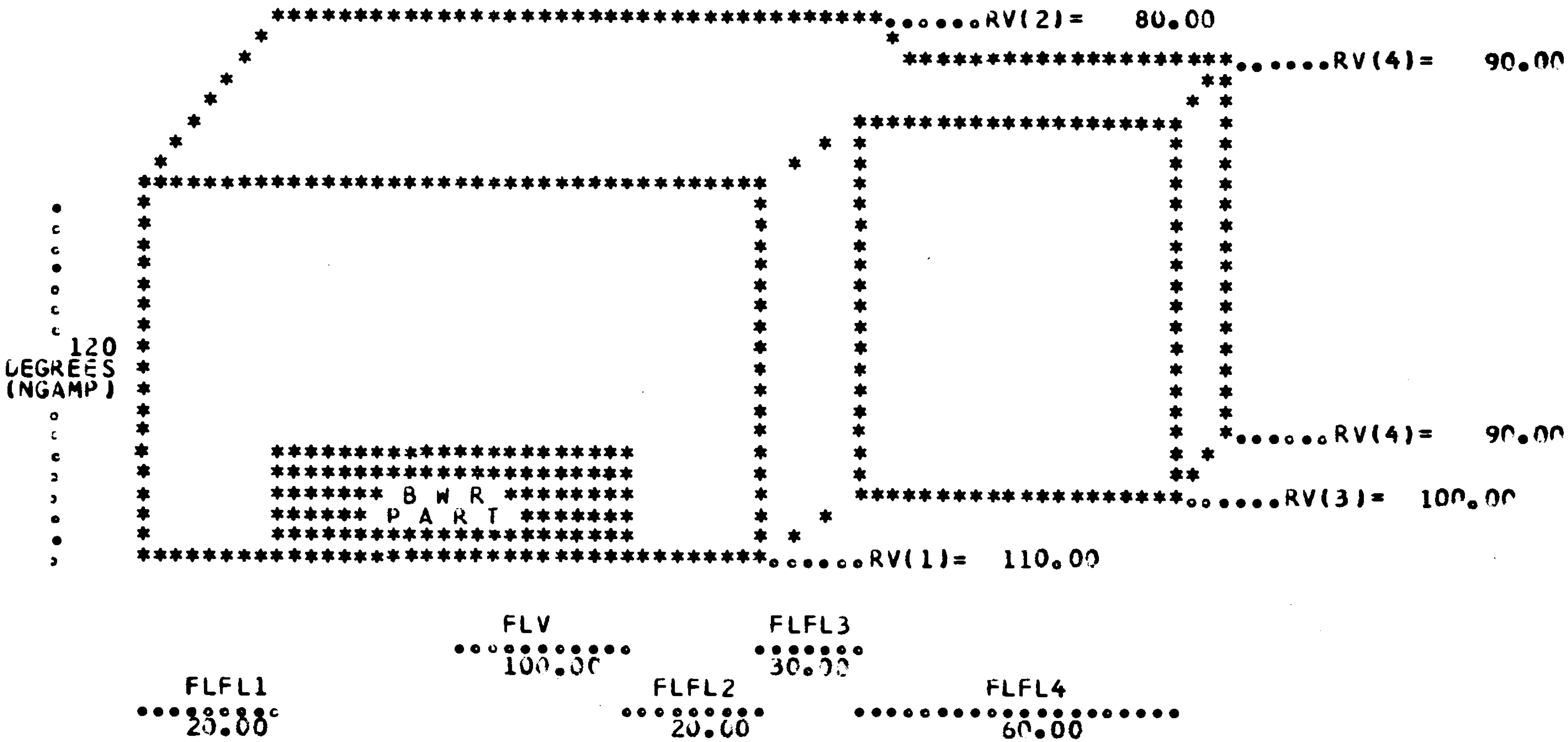
STRUCTURE TAKEN INTO CONSIDERATION



THE STRUCTURE IS DEFINED AROUND THE X-AXIS BY A SECTOR OF 90 DEGREES

HALF A STRUCTURE IS CONSIDERED WITH POSITIVE Y-COORD. AND POSITIVE + NEGATIVE X-COORD.

FWR OPTION PERSPECTIVE VIEW OF THE DEVELOPED STRUCTURE



EZ60 IS THE ELEMENT TYPE
****

THERE ARE 1 ELEMENTS ALONG THE NOZZLE (FROM A TO D)

THERE ARE 3 ELEMENTS ALONG THE TRANSITION (FROM D TO E)

THERE ARE 2 ELEMENTS IN THE 90 DEGREES NUZZLF SECTOR (BEWARE THE STRUCTURE CHOICE)

THERE ARE 1 ELEMENTS ALONG THE VESSEL(FRCM E TO F)

THERE ARE 1 ELEMENTS ALONG THE THICKNESS

THE OUTER PART OF THE NOZZLE IS CONICAL OR CYLINDRICAL,ANGLE = 5.000 DEGREES

THE INNER PART OF THE NOZZLE IS CONICAL OR CYLINDRICAL,ANGLE = 0.0 DEGREES

THERE ARE 0 POINTS AND 0 ELEMENTS BEFORE THIS MESH

FOR THIS 3-D STRUCTURE,THE HIGHEST NODE INDEX IS 33 AND THE HIGHEST ELEMENT INDEX IS 314
ATTENTION SOME NODE AND ELEMENT INDEXES ARE NOT USED IF PWR OPTION

NUMBER OF ELEMENTS ALONG THE TRANSITICN FROM NOZZLE TO VESSEL

```
         EXTERNAL PART      1 FROM D TO B
                            1 FROM B TO C
                            1 FROM C TO E

         INTERNAL PART      1 FROM D TO B
                            1 FROM B TO C
                            1 FROM C TO E
```

```
CROWDING FACTOR ALONG      THE NOZZLE(CROWN)         1.00
                           THE VESSEL(CROWV)         1.00
                           THE THICKNESS(CROWTH)     1.00
                           THE TRANSITION(CROWTR)    1.10
```

SEMI-BANDWIDTH = 35 NODES

LIST OF EL. WITH THEIR N.P.(CARDS PUNCHED ALSO FOR BERSAFE)

NUMBER OF EL. GENERATED 36

1	1	10	15	16	17	11	3	2	24	29	30	25	34	43	48	49	50	44	36	35
2	3	11	17	18	19	12	5	4	25	30	31	26	36	44	50	51	52	45	38	37
3	5	12	19	20	21	13	7	6	26	31	32	27	38	45	52	53	54	46	40	39
4	7	13	21	22	23	14	9	8	27	32	33	28	40	46	54	55	56	47	42	41
5	34	43	48	49	50	44	36	35	57	62	63	58	67	76	81	82	83	77	69	68
6	36	44	50	51	52	45	38	37	58	63	64	59	69	77	83	84	85	78	71	70
7	38	45	52	53	54	46	40	39	59	64	65	60	71	78	85	86	87	79	73	72
8	40	46	54	55	56	47	42	41	60	65	66	61	73	79	87	88	89	80	75	74
9	67	76	81	82	83	77	69	68	90	95	96	91	100	109	114	115	116	110	102	101
10	69	77	83	84	85	78	71	70	91	96	97	92	102	110	116	117	118	111	104	103
11	71	78	85	86	87	79	73	72	92	97	98	93	104	111	118	119	120	112	106	105
12	73	79	87	88	89	80	75	74	93	98	99	94	106	112	120	121	122	113	108	107
13	100	109	114	115	116	110	102	101	123	128	129	124	133	142	147	148	149	143	135	134
14	102	110	116	117	118	111	104	103	124	129	130	125	135	143	149	150	151	144	137	136
15	104	111	118	119	120	112	106	105	125	130	131	126	137	144	151	152	153	145	139	138
16	106	112	120	121	122	113	108	107	126	131	132	127	139	145	153	154	155	146	141	140
17	133	142	147	148	149	143	135	134	156	161	162	157	166	175	180	181	182	176	168	167
18	135	143	149	150	151	144	137	136	157	162	163	158	168	176	182	183	184	177	170	169
19	137	144	151	152	153	145	139	138	158	163	164	159	170	177	184	185	186	178	172	171
20	139	145	153	154	155	146	141	140	159	164	165	160	172	178	186	187	188	179	174	173
21	166	175	180	181	182	176	168	167	189	194	195	190	199	208	213	214	215	209	201	200
22	168	176	182	183	184	177	170	169	190	195	196	191	201	209	215	216	217	210	203	202
23	170	177	184	185	186	178	172	171	191	196	197	192	203	210	217	218	219	211	205	204
24	172	178	186	187	188	179	174	173	192	197	198	193	205	211	219	220	221	212	207	206
25	199	208	213	214	215	209	201	200	222	227	228	223	232	241	246	247	248	242	234	233
26	232	241	246	247	248	242	234	233	255	260	261	256	265	274	279	280	281	275	267	266

33	265	274	279	280	281	275	267	266	288	293	294	289	298	307	312	313	314	308	300	299

FURTHER INFORMATION FOR EURCY-51 AND EURCY-72

NELA1 = 1
NELA2 = 1

COORD. SYSTEM R - THETA - Z
****

LIST OF N.P. WITH COORD. (PUNCH ON CARDS WITH BERSAFE FORMAT)

1	160.000	90.000	35.000
2	160.560	85.215	32.336
3	161.903	81.207	24.749
4	163.235	78.574	13.394
5	163.783	77.661	-0.000
6	163.235	78.574	-13.394
7	161.903	81.207	-24.749
8	160.560	85.215	-32.336
9	160.000	90.000	-35.000
10	160.000	90.000	32.500
11	161.642	81.826	22.981
12	163.267	78.518	-0.000
13	161.642	81.826	-22.981
14	160.000	90.000	-32.500
15	160.000	90.000	30.000
16	160.411	85.896	27.716
17	161.400	82.448	21.213
18	162.383	80.172	11.481
19	162.788	79.380	-0.000
20	162.383	80.172	-11.481
21	161.400	82.448	-21.213
22	160.411	85.896	-27.716
23	160.000	90.000	-30.000
24	150.000	90.000	37.500
25	152.326	79.975	26.516
26	154.616	75.964	-0.000
27	152.326	79.975	-26.516
28	150.000	90.000	-37.500
29	150.000	90.000	30.000
30	151.493	81.950	21.213
31	152.971	78.690	-0.000
32	151.493	81.950	-21.213
33	150.000	90.000	-30.000
34	140.000	90.000	40.000
35	140.834	83.760	36.955
36	142.829	78.578	28.284
37	144.795	75.213	15.307
38	145.602	74.055	-0.000
39	144.795	75.213	-15.307
40	142.829	78.578	-28.284
41	140.834	83.760	-36.955
42	140.000	90.000	-40.000
43	140.000	90.000	35.000
44	142.171	79.975	24.749
45	144.309	75.964	-0.000
46	142.171	79.975	-24.749
47	140.000	90.000	-35.000
48	140.000	90.000	30.000
49	140.470	85.312	27.716
50	141.598	81.384	21.213
51	142.717	78.802	11.481
52	143.178	77.905	-0.000
53	142.717	78.802	-11.481

54	141.598	81.384	-21.213
55	140.470	85.312	-27.716
56	140.000	90.000	-30.000
57	134.128	90.000	40.511
58	133.205	77.465	28.911
59	132.730	71.919	-0.000
60	133.205	77.465	-28.911
61	134.128	90.000	-40.511
62	115.000	90.000	30.000
63	114.561	79.327	21.217
64	114.319	74.789	-0.000
65	114.561	79.327	-21.217
66	115.000	90.000	-30.000
67	128.257	90.000	41.022
68	126.791	82.850	38.098
69	123.639	76.178	29.538
70	121.025	71.208	16.149
71	120.080	69.330	-0.000
72	121.025	71.208	-16.149
73	123.639	76.178	-29.538
74	126.791	82.850	-38.098
75	128.257	90.000	-41.022
76	109.128	90.000	35.511
77	105.700	76.107	25.380
78	103.052	69.442	-0.000
79	105.700	76.107	-25.380
80	109.128	90.000	-35.511
81	90.000	90.000	30.000
82	89.291	82.616	27.703
83	87.762	76.007	21.222
84	86.486	71.312	11.478
85	86.024	69.597	-0.000
86	86.486	71.312	-11.478
87	87.762	76.007	-21.222
88	89.291	82.616	-27.703
89	90.000	90.000	-30.000
90	115.254	90.000	47.434
91	113.814	73.270	32.763
92	112.767	66.164	-0.000
93	113.814	73.270	-32.763
94	115.254	90.000	-47.434
95	82.929	90.000	32.929
96	82.203	73.954	22.721
97	81.672	67.319	-0.000
98	82.203	73.954	-22.721
99	82.929	90.000	-32.929
100	110.000	90.000	60.946
101	110.000	78.044	55.013
102	110.000	68.746	39.876
103	110.000	63.209	20.537
104	110.000	61.360	-0.000
105	110.000	63.209	-20.537
106	110.000	68.746	-39.876
107	110.000	78.044	-55.013
108	110.000	90.000	-60.946
109	95.000	90.000	50.473
110	94.988	69.523	33.230
111	94.982	62.311	-0.000
112	94.988	69.523	-33.230
113	95.000	90.000	-50.473
114	80.000	90.000	40.000

115	80.000	79.177	36.268
116	80.000	70.592	26.583
117	80.000	65.366	13.812
118	80.000	63.619	-0.000
119	80.000	65.366	-13.812
120	80.000	70.592	-26.583
121	80.000	79.177	-36.268
122	80.000	90.000	-40.000
123	110.000	90.000	70.946
124	110.000	65.063	46.947
125	110.000	56.151	-0.000
126	110.000	65.063	-46.947
127	110.000	90.000	-70.946
128	80.000	90.000	60.473
129	80.000	60.619	40.301
130	80.000	49.958	-0.000
131	80.000	60.619	-40.301
132	80.000	90.000	-60.473
133	110.000	90.000	80.946
134	110.000	74.058	73.490
135	110.000	61.380	54.018
136	110.000	53.584	28.191
137	110.000	50.943	-0.000
138	110.000	53.584	-28.191
139	110.000	61.380	-54.018
140	110.000	74.058	-73.490
141	110.000	90.000	-80.946
142	95.000	90.000	80.946
143	94.594	56.863	54.018
144	94.244	44.782	-0.000
145	94.594	56.863	-54.018
146	95.000	90.000	-80.946
147	80.000	90.000	80.946
148	80.000	68.079	73.490
149	80.000	50.647	54.018
150	80.000	39.928	28.191
151	80.000	36.296	-0.000
152	80.000	39.928	-28.191
153	80.000	50.647	-54.018
154	80.000	68.079	-73.490
155	80.000	90.000	-80.946
156	110.000	90.000	90.473
157	110.000	30.690	77.009
158	110.000	25.471	-0.000
159	110.000	30.690	-77.009
160	110.000	90.000	-90.473
161	80.000	90.000	90.473
162	80.000	25.324	77.009
163	80.000	18.148	-0.000
164	80.000	25.324	-77.009
165	80.000	90.000	-90.473
166	110.000	90.000	100.000
167	110.000	45.000	100.000
168	110.000	0.000	100.000
169	110.000	0.000	50.000
170	110.000	0.000	0.0
171	110.000	0.000	-50.000
172	110.000	0.000	-100.000
173	110.000	45.000	-100.000
174	110.000	90.000	-100.000
175	95.000	90.000	100.000

176	95.000	0.000	100.000
177	95.000	0.000	0.0
178	95.000	0.000	-100.000
179	95.000	90.000	-100.000
180	80.000	90.000	100.000
181	80.000	45.000	100.000
182	80.000	0.000	100.000
183	80.000	0.000	50.000
184	80.000	0.000	0.0
185	80.000	0.000	-50.000
186	80.000	0.000	-100.000
187	80.000	45.000	-100.000
188	80.000	90.000	-100.000
189	110.000	90.000	110.000
190	110.000	-15.000	110.000
191	110.000	-15.000	0.0
192	110.000	-15.000	-110.000
193	110.000	90.000	-110.000
194	80.000	90.000	110.000
195	80.000	-15.000	110.000
196	80.000	-15.000	0.0
197	80.000	-15.000	-110.000
198	80.000	90.000	-110.000
199	110.000	90.000	120.000
200	110.000	30.000	120.000
201	110.000	-30.000	120.000
202	110.000	-30.000	60.000
203	110.000	-30.000	0.0
204	110.000	-30.000	-60.000
205	110.000	-30.000	-120.000
206	110.000	30.000	-120.000
207	110.000	90.000	-120.000
208	95.000	90.000	120.000
209	95.000	-30.000	120.000
210	95.000	-30.000	0.0
211	95.000	-30.000	-120.000
212	95.000	90.000	-120.000
213	80.000	90.000	120.000
214	80.000	30.000	120.000
215	80.000	-30.000	120.000
216	80.000	-30.000	60.000
217	80.000	-30.000	0.0
218	80.000	-30.000	-60.000
219	80.000	-30.000	-120.000
220	80.000	30.000	-120.000
221	80.000	90.000	-120.000
222	105.000	90.000	135.000
223	105.000	-30.000	135.000
227	85.000	90.000	135.000
228	85.000	-30.000	135.000
232	100.000	90.000	150.000
233	100.000	30.000	150.000
234	100.000	-30.000	150.000
241	95.000	90.000	150.000
242	95.000	-30.000	150.000
246	90.000	90.000	150.000
247	90.000	30.000	150.000
248	90.000	-30.000	150.000
255	100.000	90.000	160.000
256	100.000	-30.000	160.000
260	90.000	90.000	160.000

261	90.000	-30.000	160.000
265	100.000	90.000	170.000
266	100.000	30.000	170.000
267	100.000	-30.000	170.000
274	95.000	90.000	170.000
275	95.000	-30.000	170.000
279	90.000	90.000	170.000
280	90.000	30.000	170.000
281	90.000	-30.000	170.000
288	100.000	90.000	190.000
289	100.000	-30.000	190.000
293	90.000	90.000	190.000
294	90.000	-30.000	190.000
298	100.000	90.000	210.000
299	100.000	30.000	210.000
300	100.000	-30.000	210.000
307	95.000	90.000	210.000
308	95.000	-30.000	210.000
312	90.000	90.000	210.000
313	90.000	30.000	210.000
314	90.000	-30.000	210.000

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