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The 4 Fold Symmetric Lattice for the NSNS Accumulator Ring

Y. Y. Lee

February 1997

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

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THE 4 FOLD SYMMETRIC LATTICE FOR THE NSNS ACCUMULATOR RING

BNL/NSNS TECHNICAL NOTE

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February 19, 1997

ALTERNATING GRADIENT SYNCHROTRON DEPARTMENT
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973

The 4 Fold Symmetric Lattice for the NSNS Accumulator Ring

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ABSTRACT

The 4-fold symmetric lattice for the National Spallation Neutron Source(NSNS) replacing original 3-fold symmetric lattice[1] is presented. There are several reasons for new lattice. The lattice is to accommodate realistic beam scraper in the ring, to avoid dangerous structural resonances, and ease of tuning and of installing correction elements.

THE LATTICE

The storage ring consists of four 90^0 arc and long straight sections, schematically shown in the fig. 1. Four FODO cells with a $\pi/2$ phase advance makes the arc section. Each half cell consists of a quadrupole, a .45m space, a 1.5m long dipole, a 1.55m space, and a quadrupole. The total length of the arc half cell is 4 meters. Four full cells of $\pi/2$ phase advance insures the zero dispersion in either side of the arc. Two FODO cell without a dipoles form each long straight section. The cell lengths for the straights are kept same with the 3-fold symmetric[1] case so that the injection and ejection could be kept similar. The half cell length for straights are 5.293 meters. The phase advance in the straights are adjusted to make the tune of the ring to be 5.82 horizontal and 5.8 horizontal. The lattice functions for one super period is shown in fig.2. The relevant ring parameters are given below in table I. A program SYNCH output is attached in appendix A.

Table I NSNS Accumulator Ring Parameter

Kinetic Energy	1.0 GeV
Magnetic Rigidity	5.658 T-m
Circumference	220.688 m
Periodicity	4
Structure	24 FODO
β_{max} X/Y	19.2/19.2 m
$Xp_{max/min}$	4.1/0. m
ν X/Y	4.82/4.82
γ_T	4.933
$\xi_{natural}$ X/Y	-6.5/-7.3

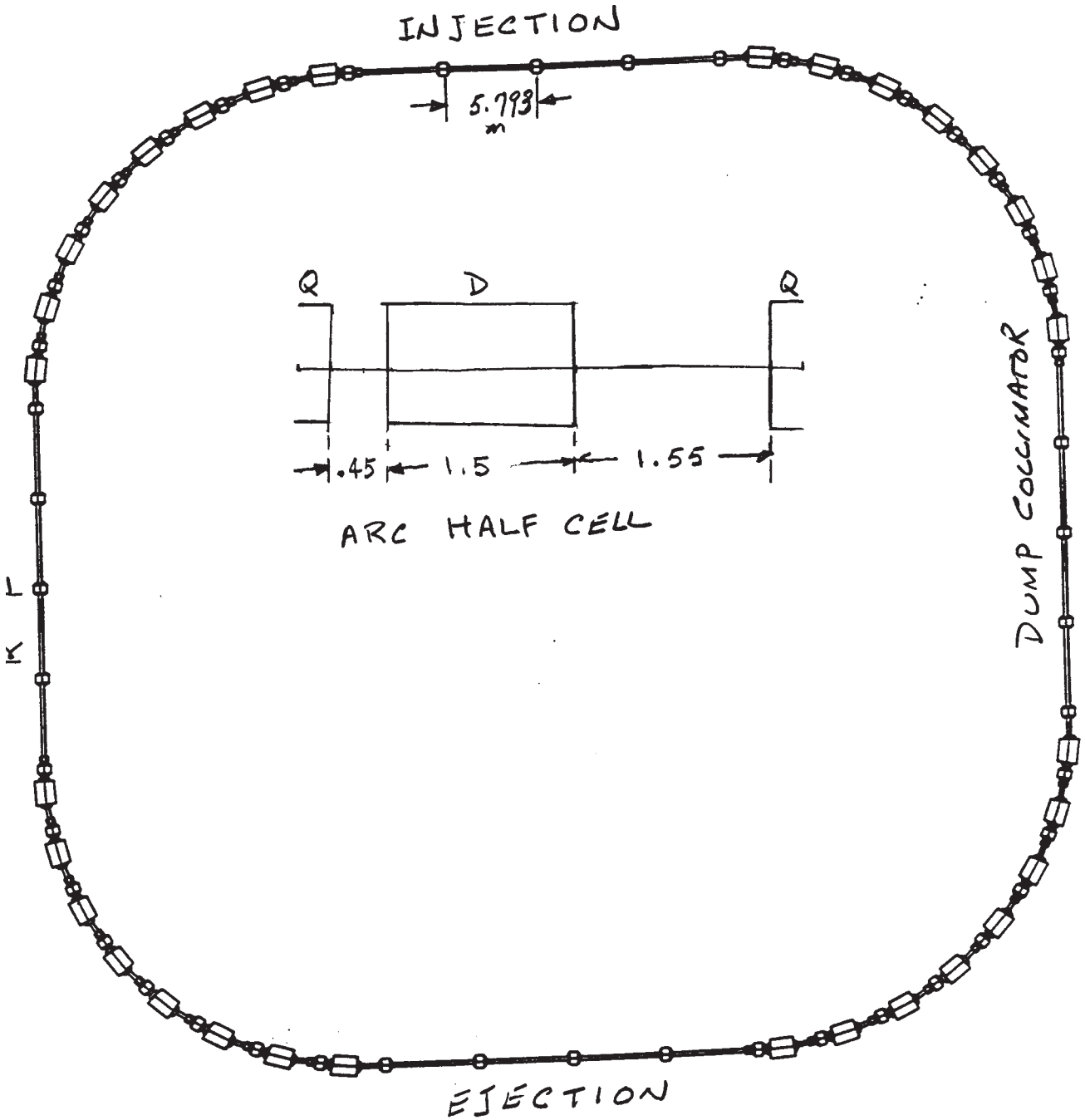

Fig. 1 RING LAYOUT

CHART 4

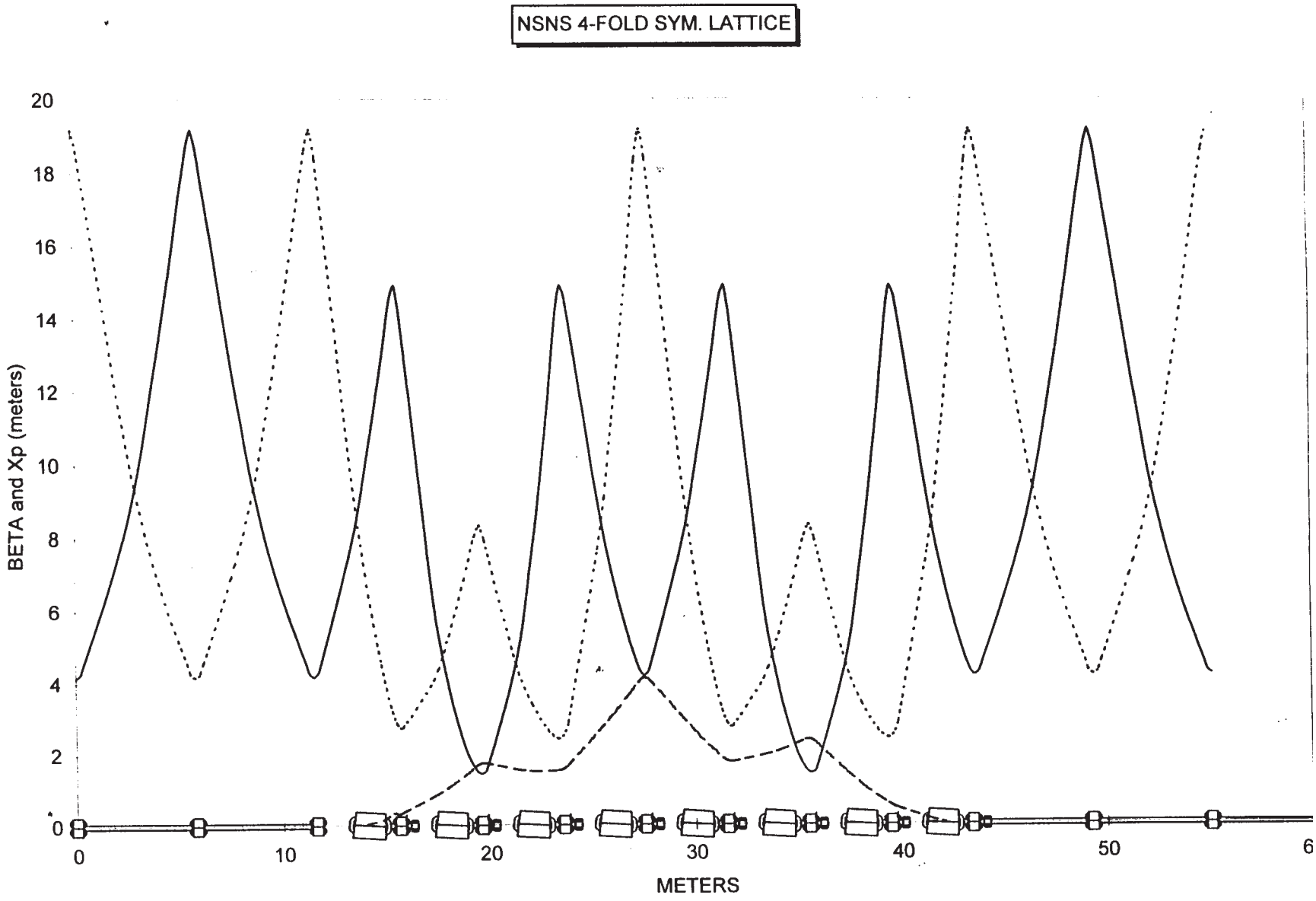
NSNS 4-FOLD SYM. LATTICE
BETA and Xp (meters)
20
18
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
6
METERS

Fig 2

The primary assignment for the long straights are, injection, ejection, rf cavities, and last one for the beam scraping collimators. Any half cells not being used for the primary functions shall be used for other functions such as tune meter kicker, transverse damping system in case needed.

The 1.55m space between a quadrupole and a dipole consists of beam position monitor(pickup electrode), correction dipole and skew quadrupole combination, higher order correctors, and a vacuum pumping port.

TUNABILITY AND CHROMATIC BEHAVIOR

Under certain circumstances, it is desirable for accumulator ring to run different set of a betatron tune. The table II shows the behavior of the beta function for betatron tune change of 0.5 units.

Table II tunability and chromatic behavior

$\Delta P/P$	$\Delta\nu_x$	$\Delta\nu_y$	$\beta_{x,max}$ (m)	$\beta_{y,max}$ (m)	$Xp_{max/min}$ (m)	ΔFQ %	ΔDQ %
0.0	0.0	0.0	19.2	19.2	4.1/0.	0.0	0.0
0.0	-0.5	0.0	21.9	17.8	4.1/0.	-18.1	-4.3
0.0	0.0	-0.5	17.8	21.9	4.1/0.	-4.3	-18.1
0.0	-0.5	-0.5	20.1	20.1	4.1/0.	-24.8	-24.8
0.5%	-0.03	-0.04	19.9	19.3	4.16/-0.1		
1.0%	-0.06	-0.07	20.5	19.5	4.23/-0.2		

As can be seen in the table, half a unit change in the betatron tune results less than 5% change in betafunction while keeping the dispersion same. Because of none linear chromatic behavior, one expects slight change in betatron functions when lattice is looked at the view of off momentum particles. Even at 1% off momentum, which is maximum ever expected, the betatron function and the dispersion function behave reasonable at expected level.

STRUCTURE RESONANCES

The lattice has structure resonances at betatron tune of integer 5 and 6 which is expected from 4 fold symmetry. However, there is no structure resonances in fractional tune between 5 and 6 where as 3 fold symmetric lattice with tune of 3.8 has two 3^{rd} order and 4^{th} order structure resonances between tune of 3 and 4. Especially four of 4^{th} order resonances are right on top of the working point. Although the resonances may not hurt the ring performances, we should not take chances with the performances of the lattice.

ACCUMULATOR RING MAGNETS

The list of proposed magnetic elements required for the accumulator ring is listed in the table III.

Table III NSNS Ring Magnet Parameters

	Dipole	20 Cm Quad	30 Cm Quad
Length*/Number	1.5 m/32	.5 m / 16 .47 m / 12 .394 m / 8 .317 m / 12	.5 m / 4 .336 m / 4
Field	.7406 T	4.124 T/m	4.124 T/m
Aperture(Vert.) (Hor. Good Field)	17 Cm 23 Cm	20 Cm Dia.	30 Cm Dia.
Vacc. Ch. Th.	1.5 Cm	0.5 Cm	0.5 Cm
Therm. Ins. Th.	0.5 Cm	0.5 Cm	0.5 Cm

*The lengths are in magnetic length.

Since the ring is DC, one need not to worry about transients or eddy current effects. Four different length in quadrupoles are chosen such that all the quadrupoles can be powered with single power supply and requires small trim supplies to supplement additional fine tuning. The poles of the quadrupoles with different length to be carefully shaped to eliminate multipole errors. Especially for 30 Cm quadrupole, where the length and pole diameter are comparable to each other, requires special attention.

REFERENCES

1. A. G. Ruggiero, et al., BNL/NSNS Tech. Note No. 0001, 1996

APPENDIX A

```
                                                                                                                    SYNCH VERSION IBM  BNL
          SYNCH RUN SNS           POSSIBLE SPALLATION NUTRON SOURCE LATTICE
          19-FEB-97  15:53:13

=============================================================================================================================================
     1.00 GeV SOTAGE RING WITH TRANSITION GAMMA CLOSE TO BEAM ENERGY
***   BR      =             //  5.6575
***   BZ      =             //  0.740565
***   DLL     =             //  1.5
***   GLL     =             //  0.5
***   DL2     =             //  0.5        *          DLL
***   GL2     =             //  0.5        *          GLL
***   GF      =             //  3.884
***   GD      =             //  -4.12351
***   GFS     =             //  2.61351
***   GDS     =             //  2.61351
***   DO      =             //  0.45
***   O       DRF           //  DO
***   OO      DRF           //  1.55
***   L       DRF           //  2.6465
***   BM      MAG           //  DLL                BR         BZ
***   BM2     MAG           //  DL2                BR         BZ
***   QF      MAG           //  GL2        GF      BR
***   QD      MAG           //  GL2        GD      BR
***   QFS     MAG           //  GL2        GFS     BR
***   QDS     MAG           //  GL2        GDS     BR
***   .HC     BML           //  QF   OO    BM2  BM2  O    QD
***   .RC     BML           //  QD   OO    BM2  BM2  O    QF
***   .C      BML           //  .HC  .RC
***   .EH1    BML           //  QFS  L     L    QDS
***   .EH2    BML           //  QDS  L     L    QFS
***   .EC     BML           //  .EH1 .EH2
***   .AC     BML           //  QFT  L     L    QDT  QDT  L    L    QFT
***   .BC     BML           //  QFT  L     L    QDT  QDT  L    L    QFT
      ARC   BML           .AC  .C   .C   .BC
***   ARC     BML             //  .C   .C   .C   .C
***   SUP     BML             //  .EC  ARC  .EC

***   TUNE    SUB     0    0 //
.............................................................................................................................................
***   QF      MAG             //  GL2        GF      BR
***   QD      MAG             //  GL2        GD      BR
***   MP      MMM             //  .C
***           END     0    0 //
.............................................................................................................................................
```

```
***   MUX     =             //  0.25
***   MUY     =             //  0.25
***   QUX     =             //  0.2275
***   QUY     =             //  0.2275
     FIT FOR THE ARC SECTION FOR THE DISPERSION FREE REGION OUTSIDE OF THE ARC
***   FQ      FITQ          //  TUNE MP   GF   GD       1    1MUX       MUY


PARAMETER REPLACEMENTS MADE BY FITTING
       1  OF  GF   =       3.882896082407             1  OF  GD   =      -4.123287471834

***           CALL          //  TUNE

     THIS PORTION FIT THE STREIGHT SECTION CELLS

***   TU1     SUB     0    0 //
.....................................................................................................
***   QFS     MAG           //  GL2       GFS       BR
***   QDS     MAG           //  GL2       -GDS      BR
***   MH1     MMM           //  .EC
***           END     0    0 //
.....................................................................................................

***   FQ2     FITQ          //  TU1  MH1  GFS  GDS      1    1QUX       QUY


PARAMETER REPLACEMENTS MADE BY FITTING
       1  OF  GFS  =       2.637465916711             1  OF  GDS  =       2.637465916711

***           CALL          //  TU1

***   SUP     BML           //  .EC  ARC  .EC
***           CYC         4 //  SUP
-----------------------------------------------------------------------------------------------------
```

BETATRON FUNCTIONS OF

POS		S(M)	NUX	NUY	BETAX(M)	BETAY(M)	XEQ(M)	YEQ(M)	ZEQ (M)	ALPHAX	ALPHAY	DXEQ	DYEQ
0		0.0000	0.00000	0.00000	19.18841	4.07042	0.00000	0.00000	0.0000	0.00000	0.00000	0.00000	0.00000
1	QFS	0.2500	0.00209	0.00967	18.63795	4.20568	0.00000	0.00000	0.0000	2.18039	-0.54628	0.00000	0.00000
2	L	2.8965	0.03438	0.07937	9.25947	9.25950	0.00000	0.00000	0.0000	1.36334	-1.36334	0.00000	0.00000
3	L	5.5430	0.10408	0.11166	4.20567	18.63802	0.00000	0.00000	0.0000	0.54628	-2.18040	0.00000	0.00000
4	QDS	5.7930	0.11375	0.11375	4.07042	19.18848	0.00000	0.00000	0.0000	0.00000	0.00000	0.00000	0.00000
5	QDS	6.0430	0.12342	0.11584	4.20568	18.63802	0.00000	0.00000	0.0000	-0.54629	2.18040	0.00000	0.00000
6	L	8.6895	0.19312	0.14813	9.25953	9.25950	0.00000	0.00000	0.0000	-1.36335	1.36334	0.00000	0.00000
7	L	11.3360	0.22541	0.21783	18.63808	4.20568	0.00000	0.00000	0.0000	-2.18041	0.54628	0.00000	0.00000
8	QFS	11.5860	0.22750	0.22750	19.18854	4.07042	0.00000	0.00000	0.0000	0.00000	0.00000	0.00000	0.00000
9	QF	11.8360	0.22960	0.23713	18.38035	4.26311	0.00000	0.00000	0.0000	3.18640	-0.78174	0.00000	0.00000
10	OO	13.3860	0.24788	0.28104	9.96035	7.59447	0.00000	0.00000	0.0000	2.24586	-1.36752	0.00000	0.00000
11	BM2	14.1360	0.26232	0.29485	6.85770	9.85834	0.03679	0.00000	0.0012	1.87771	-1.65097	0.09802	0.00000
12	BM2	14.8860	0.28417	0.30559	4.36335	12.54737	0.14679	0.00000	0.0096	1.43740	-1.93441	0.19509	0.00000
13	O	15.3360	0.30335	0.31092	3.21198	14.36487	0.23458	0.00000	0.0096	1.12119	-2.10447	0.19509	0.00000
14	QD	15.5860	0.31667	0.31364	2.82735	14.76425	0.28909	0.00000	0.0096	0.44066	0.53130	0.24262	0.00000
15	QD	15.8360	0.33104	0.31640	2.75782	13.84956	0.35681	0.00000	0.0096	-0.15835	3.07173	0.30124	0.00000
16	OO	17.3860	0.40687	0.34328	4.14172	6.13746	0.82373	0.00000	0.0096	-0.73449	1.90382	0.30124	0.00000
17	BM2	18.1360	0.43217	0.36842	5.40500	3.70557	1.08211	0.00000	0.1026	-0.94447	1.33870	0.38724	0.00000
18	BM2	18.8860	0.45165	0.41152	6.95697	2.12136	1.40365	0.00000	0.2242	-1.11817	0.77358	0.46950	0.00000
19	O	19.3360	0.46124	0.45107	8.02883	1.57772	1.61493	0.00000	0.2242	-1.26372	0.43451	0.46950	0.00000
20	QF	19.5860	0.46607	0.47750	8.32320	1.47062	1.69695	0.00000	0.2242	0.10312	0.00000	0.18435	0.00000
21	QF	19.8360	0.47094	0.50393	7.92863	1.57772	1.70645	0.00000	0.2242	1.45252	-0.43451	-0.10867	0.00000
22	OO	21.3860	0.51336	0.59990	4.36813	4.73496	1.53800	0.00000	0.2242	0.84457	-1.60242	-0.10867	0.00000
23	BM2	22.1360	0.54501	0.61990	3.28735	7.56243	1.48601	0.00000	0.3721	0.59183	-2.16754	-0.02987	0.00000
24	BM2	22.8860	0.58620	0.63286	2.60402	11.23758	1.49327	0.00000	0.5179	0.31635	-2.73266	0.04923	0.00000
25	O	23.3360	0.61498	0.63860	2.40485	13.84956	1.51543	0.00000	0.5179	0.12625	-3.07173	0.04923	0.00000
26	QD	23.5860	0.63143	0.64136	2.47781	14.76425	1.56247	0.00000	0.5179	-0.42253	-0.53130	0.32857	0.00000
27	QD	23.8360	0.64657	0.64408	2.84032	14.36487	1.68096	0.00000	0.5179	-1.04946	2.10447	0.62294	0.00000
28	OO	25.3860	0.69972	0.66615	7.87111	8.74896	2.64652	0.00000	0.5179	-2.19621	1.51869	0.62294	0.00000
29	BM2	26.1360	0.71227	0.68179	11.48350	6.68350	3.13701	0.00000	0.8014	-2.60483	1.23525	0.68400	0.00000
30	BM2	26.8860	0.72117	0.70240	15.63547	5.04321	3.67087	0.00000	1.1352	-2.91334	0.95181	0.73848	0.00000
31	O	27.3360	0.72540	0.71787	18.38036	4.26311	4.00318	0.00000	1.1352	-3.18640	0.78174	0.73848	0.00000
32	QF	27.5860	0.72750	0.72750	19.18854	4.07042	4.10093	0.00000	1.1352	0.00000	0.00000	0.04072	0.00000
33	QF	27.8360	0.72960	0.73713	18.38036	4.26311	4.02340	0.00000	1.1352	3.18640	-0.78174	-0.65878	0.00000
34	OO	29.3860	0.74788	0.78104	9.96035	7.59447	3.00230	0.00000	1.1352	2.24586	-1.36752	-0.65878	0.00000

35	BM2	30.1360	0.76232	0.79485	6.85770	9.85834	2.53134	0.00000	1.4065	1.87771	-1.65097	-0.59611	0.00000
36	BM2	30.8860	0.78417	0.80559	4.36334	12.54737	2.10957	0.00000	1.6339	1.43740	-1.93441	-0.52770	0.00000
37	O	31.3360	0.80335	0.81092	3.21198	14.36487	1.87211	0.00000	1.6339	1.12119	-2.10447	-0.52770	0.00000
38	QD	31.5860	0.81667	0.81364	2.82734	14.76425	1.78198	0.00000	1.6339	0.44066	0.53130	-0.19606	0.00000
39	QD	31.8360	0.83104	0.81640	2.75782	13.84956	1.77333	0.00000	1.6339	-0.15835	3.07173	0.12661	0.00000
40	OO	33.3860	0.90687	0.84328	4.14172	6.13746	1.96958	0.00000	1.6339	-0.73449	1.90382	0.12661	0.00000
41	BM2	34.1360	0.93217	0.86842	5.40500	3.70557	2.09168	0.00000	1.8328	-0.94447	1.33870	0.19875	0.00000
42	BM2	34.8860	0.95165	0.91152	6.95697	2.12136	2.26722	0.00000	2.0463	-1.11817	0.77358	0.26897	0.00000
43	O	35.3360	0.96124	0.95107	8.02882	1.57772	2.38826	0.00000	2.0463	-1.26372	0.43451	0.26897	0.00000
44	QF	35.5860	0.96607	0.97750	8.32320	1.47062	2.40398	0.00000	2.0463	0.10312	0.00000	-0.14364	0.00000

POS	S(M)	NUX	NUY	BETAX(M)	BETAY(M)	XEQ(M)	YEQ(M)	ZEQ (M)	ALPHAX	ALPHAY	DXEQ	DYEQ
45 QF	35.8360	0.97094	1.00393	7.92863	1.57772	2.31695	0.00000	2.0463	1.45252	-0.43451	-0.55010	0.00000
46 OO	37.3860	1.01336	1.09990	4.36813	4.73496	1.46429	0.00000	2.0463	0.84457	-1.60242	-0.55010	0.00000
47 BM2	38.1360	1.04501	1.11990	3.28736	7.56243	1.08211	0.00000	2.1708	0.59183	-2.16754	-0.46822	0.00000
48 BM2	38.8860	1.08620	1.13286	2.60402	11.23758	0.76309	0.00000	2.2609	0.31635	-2.73266	-0.38184	0.00000
49 O	39.3360	1.11498	1.13860	2.40485	13.84956	0.59126	0.00000	2.2609	0.12625	-3.07173	-0.38184	0.00000
50 QD	39.5860	1.13143	1.14136	2.47781	14.76425	0.50859	0.00000	2.2609	-0.42253	-0.53130	-0.28202	0.00000
51 QD	39.8360	1.14657	1.14408	2.84032	14.36487	0.44918	0.00000	2.2609	-1.04946	2.10447	-0.19509	0.00000
52 OO	41.3860	1.19972	1.16615	7.87112	8.74896	0.14679	0.00000	2.2609	-2.19621	1.51869	-0.19509	0.00000
53 BM2	42.1360	1.21227	1.18179	11.48351	6.68350	0.03679	0.00000	2.2693	-2.60483	1.23525	-0.09802	0.00000
54 BM2	42.8860	1.22117	1.20240	15.63548	5.04321	0.00000	0.00000	2.2705	-2.91334	0.95181	0.00000	0.00000
55 O	43.3360	1.22540	1.21787	18.38036	4.26311	0.00000	0.00000	2.2705	-3.18640	0.78174	0.00000	0.00000
56 QF	43.5860	1.22750	1.22750	19.18855	4.07042	0.00000	0.00000	2.2705	0.00000	0.00000	0.00000	0.00000
57 QFS	43.8360	1.22959	1.23717	18.63809	4.20568	0.00000	0.00000	2.2705	2.18041	-0.54628	0.00000	0.00000
58 L	46.4825	1.26188	1.30687	9.25953	9.25950	0.00000	0.00000	2.2705	1.36335	-1.36334	0.00000	0.00000
59 L	49.1290	1.33158	1.33916	4.20568	18.63802	0.00000	0.00000	2.2705	0.54629	-2.18040	0.00000	0.00000
60 QDS	49.3790	1.34125	1.34125	4.07042	19.18848	0.00000	0.00000	2.2705	0.00000	0.00000	0.00000	0.00000
61 QDS	49.6290	1.35092	1.34334	4.20568	18.63802	0.00000	0.00000	2.2705	-0.54628	2.18040	0.00000	0.00000
62 L	52.2755	1.42062	1.37563	9.25948	9.25950	0.00000	0.00000	2.2705	-1.36334	1.36334	0.00000	0.00000
63 L	54.9220	1.45291	1.44533	18.63795	4.20568	0.00000	0.00000	2.2705	-2.18039	0.54628	0.00000	0.00000
64 QFS	55.1720	1.45500	1.45500	19.18841	4.07042	0.00000	0.00000	2.2705	0.00000	0.00000	0.00000	0.00000

```
CIRCUMFERENCE =    220.6880 M          THETX =   6.28318515 RAD      NUX =    5.82000      DNUX/(DP/P) =   -6.53402
      RADIUS =     35.1236 M          THETY =   0.00000000 RAD      NUY =    5.82000      DNUY/(DP/P) =   -7.28028
(DS/S)/(DP/P)=  0.0411530              TGAM=(   4.92946,    0.00000)

MAXIMA    --- BETX(   56) =    19.18855    BETY(    4) =    19.18848     XEQ(   32) =     4.10093     YEQ(   64) =     0.00000
MINIMA    --- BETX(   25) =     2.40485    BETY(   44) =     1.47062     XEQ(   54) =     0.00000     YEQ(   64) =     0.00000
```

```
***          FIN     0    0  // CORE USE SUMMARY                          MAXIMUM                 USED          UNUSED
                                  STORE   (ELEMENT STORAGE)                 48000 (LMAX)            1536           46464
                                  INFF    (ELEMENT DEFINITIONS)             2000 (MAX)               80            1920
```

END OF SYNCH RUN SNS