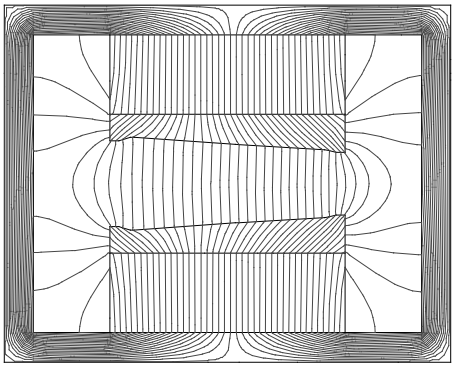
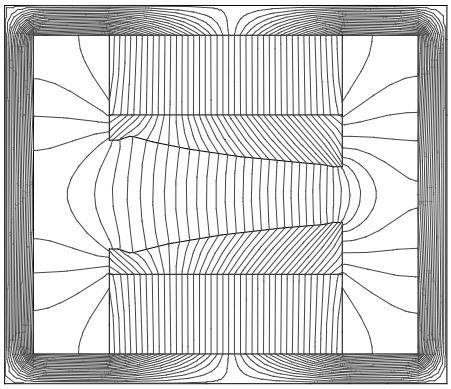
Magnetic Design of Recycler Ring v.18 Gradient Dipoles

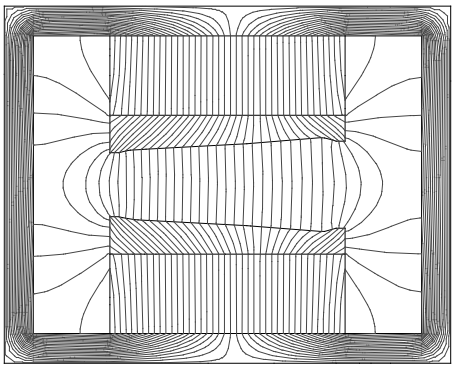
G.W. Foster
January 1998



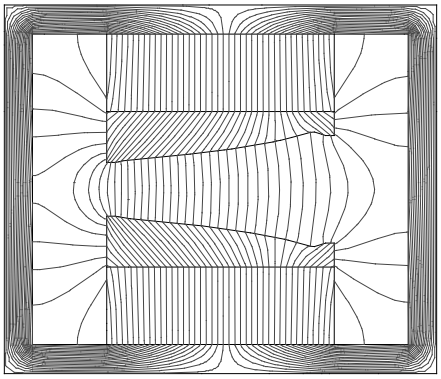
RGF



SGF



RGD



SGD

This note describes the 2-D magnetic design of the Recycler Gradient permanent magnets, which are based on the RR_V18 lattice. Although all numbers in this are believed to be correct, the controlling reference on the RR_V18 magnetic specifications is MI-170, and the Tech Division archives for the mechanical drawings of the individual magnets.

Magnetic Materials - Strontium Ferrite (Br~0.38T, Hc~0.35T) was used. Interspersed in the ferrite were strips of Nickel-Steel "compensator alloy" in an approximately 1:5 ratio of compensator : ferrite. The compensator has a temperature dependence of magnetization which cancels that of the ferrite [Dallas PAC papers by Bertsche, Foster..]. The amount of compensator was adjusted to null out the temperature coefficient of the magnets. The z-distribution of compensator was adjusted to flatten the longitudinal profile of the magnet strength. Details are in the magnet travelers

For the purposes of magnetic modeling, the compensator was accounted for by an ad-hoc reduction in the magnetic strength of the bricks, accomplished via a POISSON "stacking factor" of 0.7 for the ferrite. Since all magnetic materials are located behind the pole tips in the Recycler gradient magnets, the field shape is largely insensitive to the details of the magnetic driving material. In fact, essentially the same field shape can be obtained by replacing the ferrite material by two current sheets along the edges of the ferrite bricks. This allows one to model the magnets with codes that do not have explicit provisions for permanent magnet materials. All of my simulations used PANDIRA, a code provided as part of the POISSON package which does allow for permanent magnets. The results were confirmed using OPERA-2D.

Pole Tip Steel - The pole tips were built using low-carbon 1008 steel, and the magnetic modeling used the B-H curves for 1010 steel provided with POISSON. The choice of 1008 steel (vs. the more commonly available higher-carbon 1018 or A36 grades) was made for conservatism rather than as the result of R&D. Calculations indicated that no significant field shape changes occurred when the B-H curves approximating those of 1018 steel were used. This is not unexpected since the iron is being operated in the 1-2kG range where most iron has high μ. However the higher Br and worse hysteretic properties of higher-carbon steel (which are not calculated in POISSON) argue for the use of lower carbon (1008 or 1010) steel. There is some evidence that magnetic memory of the pole tips has some influence on the field shape: Gerry Jackson was able to introduce a permanent change in the field shape (a few units of sextupole) by running a large current (hundreds of amps?) down the beam pipe while investigating in situ bakeout schemes. However it appears that hysteretic effects are washed out of the pole tips by magnetization occurring in normal assembly procedures, since the measured field shape agrees to a level of 0.01% or better with the POISSON field shape prediction which ignores hysteretic effects.

Extruded/cold drawn steel pole tips were used for the RGF/RGD series, and stacked laminations (with a solid steel plat backbone) were used for the SGF/SGD series. Both performed adequately.

Flux Return boxes were built from 1018 steel 3/4" thick. This keeps the maximum flux density below 0.8T in the flux return shells. One issue which was of concern initially but did not seem to be a problem in practice was that of gaps in the flux return. In production magnets, air gaps of order 0.010" would occasionally open up in the flux return boxes due to non-parallelism of the flux return plates. These would be easily identifiable due to the magnetic attraction of screwdrivers, etc. to the gap between plates. These do not seem to cause non-reproducible behavior in the magnets as they are handled, stacked, etc. My feeling is that the insensitivity of the magnet to gaps in the flux return is due partly to the conservatively large thickness of iron in the flux returns, which allows the flux to redistribute (longitudinally and transversely) to avoid cracks in the flux return shell.

Pole Tip Shape Optimization was performed using a purpose-built set of FORTRAN programs, after struggling and failing to get useable results from the MIRT pole tip optimizer built into the POISSON package.

The pole tip gap shape Y(x) was parameterized as:

$$Y(x) = 1.000" / (1 + ax + bx^2 + c\,x^3 + d\,x^4)$$

This parameterization forces the gap to be 1.000" at X=0. The parameters a, b, c, and d are to first approximation the gradient, sextupole, octupole, and decapole terms in the field shape. (The reciprocal is because the field goes as 1/Gap_Size). In addition, six cosine-like "bumps" were allowed at the edges of the aperture to terminate the fields at the edges of the pole tips as smoothly as possible. Thus the gap formula was

$$Y(x) = (\text{formula above}) + e\,C(x - 3.0") + f\,C(x - 2.2") + g\,C(x - 1.8") + h\,C(x + 3.0") + i\,C(x + 2.2") + j\,C(x + 1.8")$$

Where

$$C(x) = 1+\cos(\pi x/0.6") \quad \text{if } ABS(x/0.6) < 1.0 \quad \text{otherwise} \quad C(x)=0.$$

These formulas parameterized the pole tip shape, which was specified at 0.1" intervals across the pole tip. The pole shape was forced to satisfy the mechanical constraints:

- The width of the pole tip was +/-3.03", corresponding to the long dimension of a 4" x 6" ferrite brick, plus assembly tolerance.

- the pole shape must have a flat region outside of X=3" to provide a solid contact region for the pole tip supports,

- the back sides of the pole tip must be rectangular, with a thickness at X=0 of 0.750" (RGF & RGD) and 1.000" (SGF & SGD). The SGF/SGD series actually has a small

notch cut out of the back corner which was not modeled but which does not seem to affect the results.

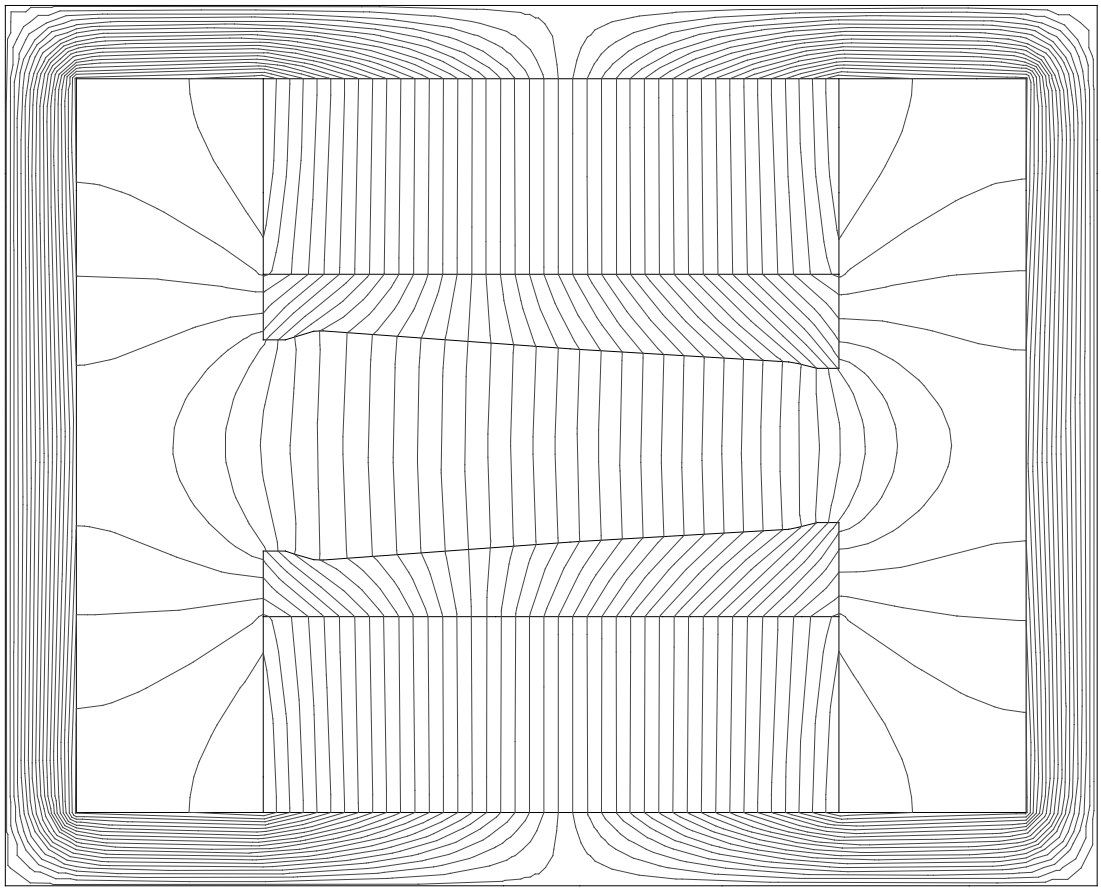
Pole Tip Shape Optimization was performed by a minimization routine analogous to a least-squares curve fitter. The error function that was minimized was the RMS deviation of the normalized bend field By(x,y)/B(0,0) from the design values. The field defect was averaged over a 0.1" rectangular grid in the region X=+/-1.5", Y=+/-0.8". It was not possible to include regions closer to the pole tips due to the POISSON field interpolator screwing up when it gets within a couple of grids of the pole tip.

In the optimization procedure, the FORTRAN program writes a series of POISSON files corresponding to the current (baseline) set of pole shape parameters, plus a set of runs to evaluate the derivative of the field shape with respect to a small change in each of the pole shape parameters. The step size of the derivatives was chosen to correspond to a change of ~0.010" in the pole tip shape in order to obtain good numerical accuracy. For each of the runs, the field defect was evaluated and a matrix was inverted to obtain new values of the parameters which minimize the predicted mean-square defect. Given reasonable starting values, this procedure converged within 4-5 iterations.

Some care was necessary in choosing the size of the region in which to optimize the field. Convergence problems occurred when the field optimization region was chosen too small. This made the fit residuals insensitive to what was going on out at the edges of the poles (i.e. there were multiple solutions to the shaping at the edge of the poles which still provided good field quality in a small central region). Conversely, if the field quality optimization region was made too big, the fit would find a solution which included some "ringing" in the By vs. X curve due to inadequately terminated edge fields.

The original optimization considered only By vs. X on the midplane (Y=0). J-F Ostiguy pointed out that this was producing a non-optimal result (and significant harmonics) since the fitter was finding a solution that maintained a flat By vs X curve at the expense of the field quality away from the midplane. Switching to a 2-D grid for the optimization region eliminated this behavior and reduced the harmonics to the noise level detectable by the POISSON harmonic fitter (see attached fig.). Representative scans of the calculated field defect in By vs. X for the RGF magnets are also attached. The field error is at the level of 1E-4 or below out to +/-1.5" (for the RGF/RGD) and +/-1.4" (for the SGF/SGD) magnets.

RGF

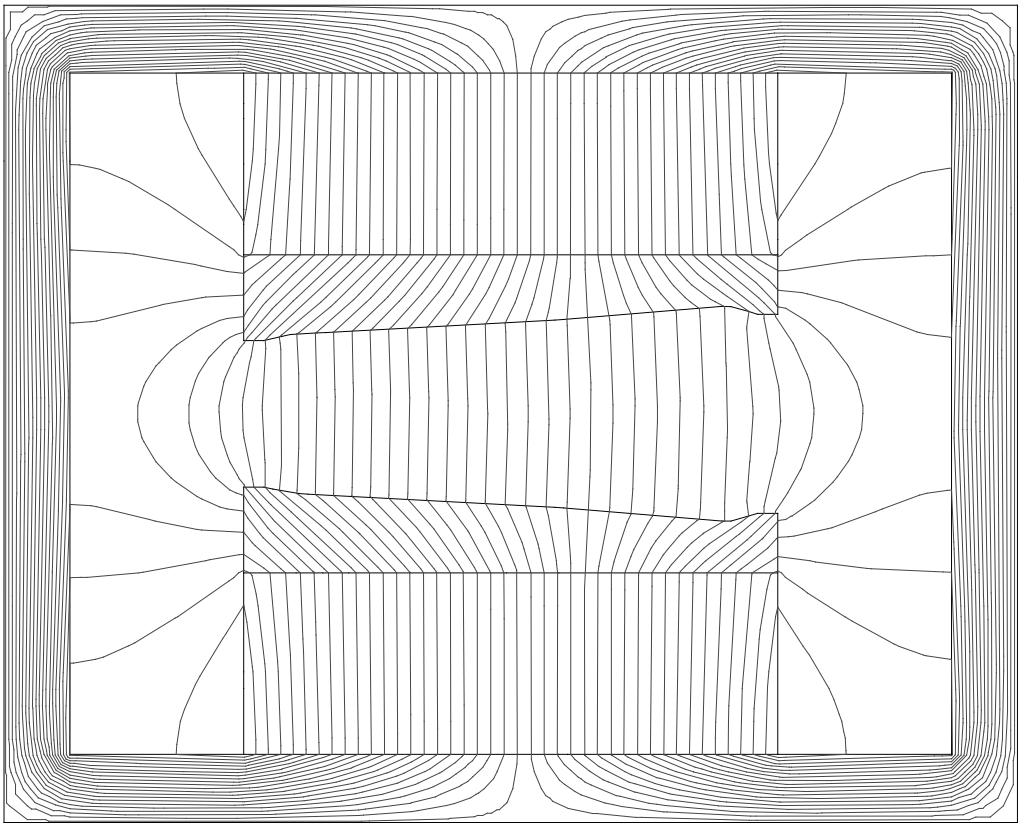


Recycler v18 RGF F-Gradient Magnet

```
 Quantity:                108
 Width:                11.500 in.  = 29.2 cm
 Height:                9.000 in.  = 22.9 cm
 Magnetic Length:       177.0 in.  = 4.496 m
 Physical Length:       184.0 in.  = 4.673 m
 Weight:                2820. lbs. =1226. kg
 Bend Angle:              21. mrad.
 Beam Sagitta:            12. mm.
 Dipole Field B0=       1.375 kG
 Gradient     B1=       3.355 kG/m =  619.7 units @ 1"
 Sextupole    B2=        3.71 kG/m^2 =  8.7 units @ 1"

    Flux Return: 28.5in**2  96.lbs/ft. 1479.lbs./magnet
       Pole Tip:  9.1in**2  31.lbs/ft.  472.lbs./magnet
 Ferrite Bricks: 20.6in**2  43.lbs/ft.  660.lbs./magnet
    Compensator:  3.6in**2  12.lbs/ft.  189.lbs./magnet
Total:103.5in**2 184.lbs/ft. 2820.lbs./magnet
```

RGD

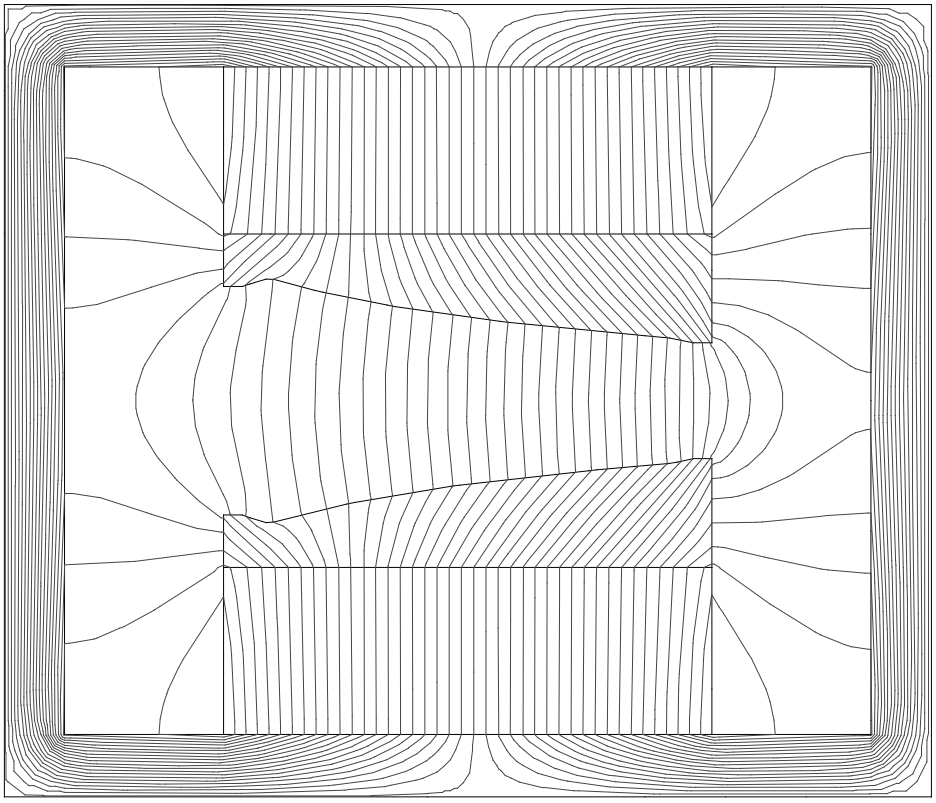


Recycler v18 RGD Gradient Magnet

```
Quantity:                108
Width:                11.500 in.  = 29.2 cm
Height:                9.000 in.  = 22.9 cm
Magnetic Length:       177.0 in.  = 4.496 m
Physical Length:       184.0 in.  = 4.673 m
Weight:                2820. lbs. =1226. kg
Bend Angle:              21. mrad.
Beam Sagitta:            12. mm.
Dipole Field B0=       1.375 kG
Gradient     B1=      -3.238 kG/m = -598.1 units @ 1"
Sextupole    B2=       -6.42 kG/m^2 =-15.1 units @ 1"

   Flux Return: 28.5in**2  96.lbs/ft. 1479.lbs./magnet
      Pole Tip:  9.1in**2  31.lbs/ft.  472.lbs./magnet
Ferrite Bricks: 20.6in**2  43.lbs/ft.  660.lbs./magnet
   Compensator:  3.6in**2  12.lbs/ft.  189.lbs./magnet
      Aluminum:  1.2in**2   1.lbs/ft.   22.lbs./magnet
         Total:103.5in**2 184.lbs/ft. 2820.lbs./magnet
```

SGF

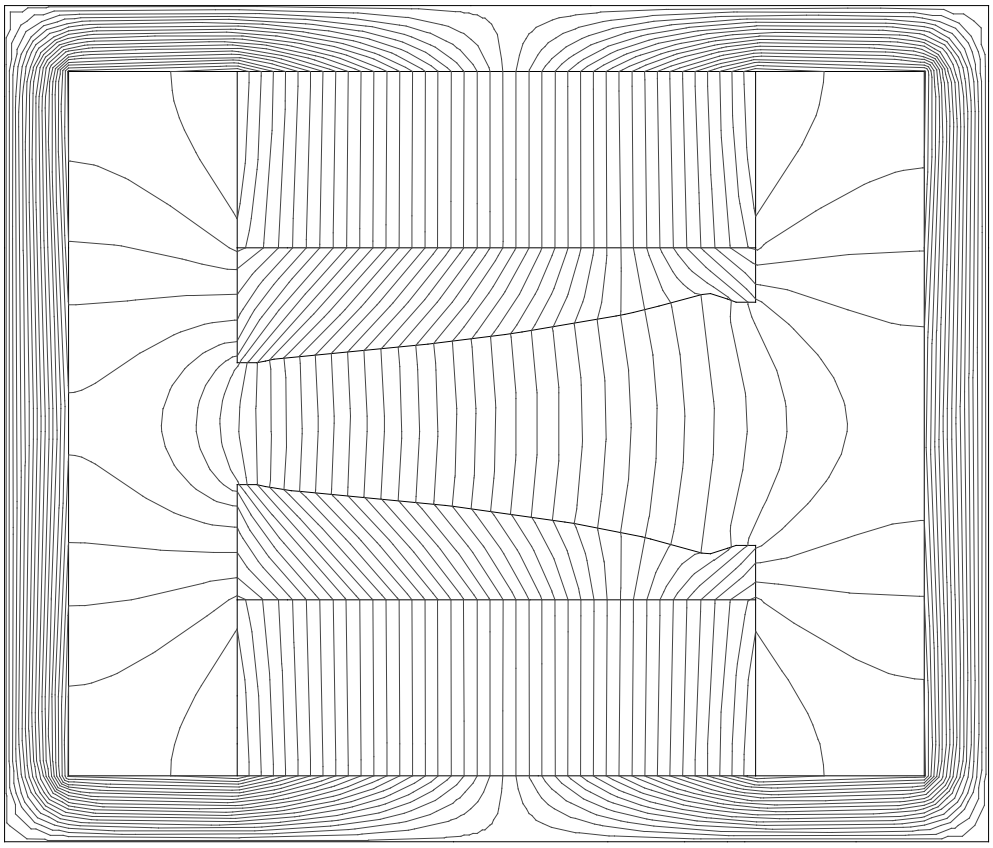


Recycler v18 SGF Supp. F-gradient magnet

```
Quantity:                64
Width:                11.500 in.  = 29.2 cm
Height:                9.500 in.  = 24.1 cm
Magnetic Length:       122.0 in.  = 3.099 m
Physical Length:       129.0 in.  = 3.277 m
Weight:                2115. lbs. = 919. kg
Bend Angle:              14. mrad.
Beam Sagitta:             5. mm.
Dipole Field B0=       1.330 kG
Gradient     B1=       6.682 kG/m = 1276.0 units @ 1"
Sextupole    B2=        0.00 kG/m^2 =  0.0 units @ 1"

   Flux Return: 29.3in**2  99.lbs/ft. 1064.lbs./magnet
      Pole Tip: 12.1in**2  41.lbs/ft.  441.lbs./magnet
Ferrite Bricks: 20.6in**2  43.lbs/ft.  462.lbs./magnet
   Compensator:  3.6in**2  12.lbs/ft.  132.lbs./magnet
      Aluminum:  1.2in**2   1.lbs/ft.   15.lbs./magnet
         Total:109.3in**2 197.lbs/ft. 2115.lbs./magnet
```

SGD



Recycler v18 SGD Supp. D-gradient magnet

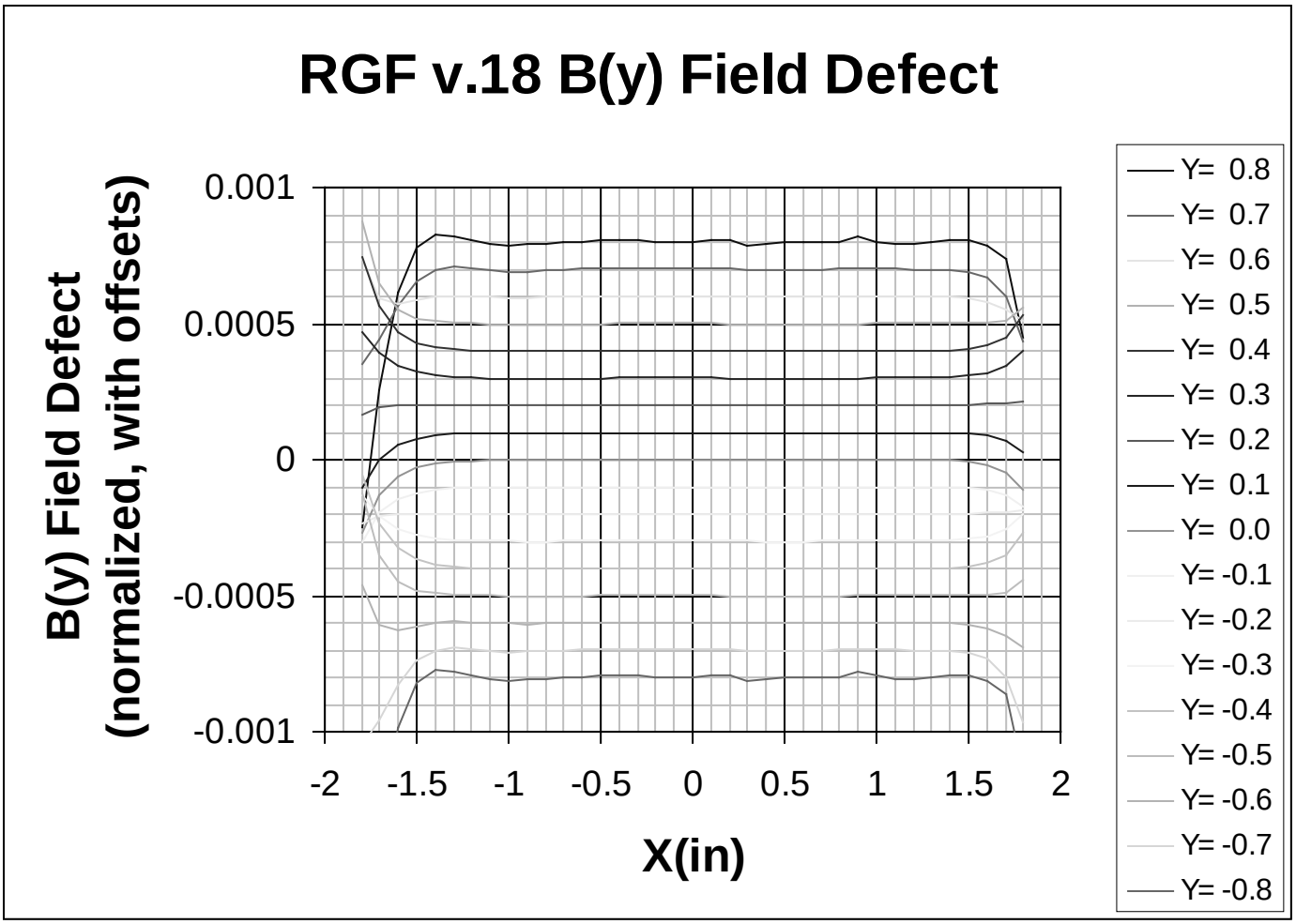
```
Quantity:                64
Width:                11.500 in.  = 29.2 cm
Height:                9.500 in.  = 24.1 cm
Magnetic Length:       122.0 in.  = 3.099 m
Physical Length:       129.0 in.  = 3.277 m
Weight:                2115. lbs. = 919. kg
Bend Angle:              14. mrad.
Beam Sagitta:             5. mm.
Dipole Field B0=       1.330 kG
Gradient     B1=      -6.824 kG/m =-1303.1 units @ 1"
Sextupole    B2=       0.00 kG/m^2 =  0.0 units @ 1"

   Flux Return: 29.3in**2  99.lbs/ft. 1064.lbs./magnet
      Pole Tip: 12.1in**2  41.lbs/ft.  441.lbs./magnet
Ferrite Bricks: 20.6in**2  43.lbs/ft.  462.lbs./magnet
   Compensator:  3.6in**2  12.lbs/ft.  132.lbs./magnet
      Aluminum:  1.2in**2   1.lbs/ft.   15.lbs./magnet
         Total:109.3in**2 197.lbs/ft. 2115.lbs./magnet
```

POISSON CALCULATED MULTIPOLES FOR RECYCLER V_18 GRADIENT MAGNETS

	RGF		RGD		SGF		SGD	
	Calc.	Target	Calc.	Target	Calc.	Target	Calc.	Target
Dipole	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
Quad.	619.73	619.73	-598.10	-598.09	1275.96	1275.96	-1303.09	-1303.09
Sextup.	8.69	8.70	-15.05	-15.05	-0.01	0.00	0.00	0.00
Octupole	0.02		-0.01		0.07		-0.07	
10-pole	0.00		0.01		0.05		-0.07	
12-pole	0.00		-0.01		-0.08		0.11	
14-pole	0.01		0.00		-0.12		0.14	
16-pole	-0.04		0.02		0.02		-0.11	
18-pole	-0.01		-0.01		0.15		-0.10	
20-pole	0.08		0.00		0.00		-0.01	
22-pole	0.01		0.01		-0.14		0.03	

1. Multipoles are in Fermilab “units”, i.e. parts in 10,000 at radius of 1”.
2. All Multipoles are evaluated at a "Probe Radius" (Rint in Poisson) of 0.85".
3. All Multipoles are reported at a "Reference Radius" (Rnorm in Poisson) of 1.00".
4. Fit values of all skew multipoles are less than 0.05 units.
5. The grid size in POISSON must be DX=0.050” or smaller to get these results.


RGF v.18 B(y) Field Defect
B(y) Field Defect
(normalized, with offsets)
0.001
0.0005
0
-0.0005
-0.001
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
X(in)
Y= 0.8
Y= 0.7
Y= 0.6
Y= 0.5
Y= 0.4
Y= 0.3
Y= 0.2
Y= 0.1
Y= 0.0
Y= -0.1
Y= -0.2
Y= -0.3
Y= -0.4
Y= -0.5
Y= -0.6
Y= -0.7
Y= -0.8

POLE TIP SHAPES AND MAGNET GAPS FOR RRv18 GRADIENT MAGNETS

	RRv18 RGF		RRv18 RGD		RRv18 SGF		RRv18 SGD	
X(inches)	Y(in.)	Gap(in.)	Y(in.)	Gap(in.)	Y(in.)	Gap(in.)	Y(in.)	Gap(in.)
-3.03	0.6710	2.1580	0.9444	1.6112	0.6318	2.7364	1.3084	1.3831
-2.8	0.6710	2.1580	0.9444	1.6112	0.6318	2.7364	1.3084	1.3831
-2.7	0.6385	2.2229	0.9210	1.6581	0.5977	2.8045	1.2878	1.4243
-2.6	0.6057	2.2887	0.8974	1.7052	0.5611	2.8779	1.2671	1.4657
-2.5	0.5834	2.3333	0.8791	1.7419	0.5397	2.9206	1.2500	1.5001
-2.4	0.5797	2.3405	0.8697	1.7606	0.5471	2.9059	1.2390	1.5220
-2.3	0.5871	2.3259	0.8655	1.7690	0.5714	2.8572	1.2315	1.5370
-2.2	0.5947	2.3107	0.8613	1.7775	0.5962	2.8077	1.2238	1.5524
-2.1	0.6026	2.2948	0.8570	1.7860	0.6217	2.7567	1.2159	1.5682
-2	0.6108	2.2785	0.8527	1.7946	0.6477	2.7047	1.2078	1.5845
-1.9	0.6190	2.2619	0.8483	1.8033	0.6736	2.6528	1.1994	1.6011
-1.8	0.6272	2.2455	0.8439	1.8122	0.6987	2.6026	1.1909	1.6182
-1.7	0.6351	2.2297	0.8394	1.8212	0.7222	2.5557	1.1822	1.6356
-1.6	0.6426	2.2148	0.8348	1.8305	0.7435	2.5131	1.1734	1.6533
-1.5	0.6498	2.2004	0.8301	1.8399	0.7632	2.4736	1.1643	1.6714
-1.4	0.6569	2.1862	0.8253	1.8494	0.7822	2.4356	1.1550	1.6899
-1.3	0.6639	2.1722	0.8205	1.8591	0.8007	2.3987	1.1456	1.7089
-1.2	0.6709	2.1583	0.8155	1.8689	0.8186	2.3628	1.1359	1.7283
-1.1	0.6778	2.1444	0.8105	1.8789	0.8361	2.3278	1.1260	1.7481
-1	0.6847	2.1306	0.8055	1.8891	0.8532	2.2936	1.1158	1.7684
-0.9	0.6915	2.1170	0.8003	1.8994	0.8698	2.2604	1.1055	1.7891
-0.8	0.6982	2.1035	0.7951	1.9099	0.8859	2.2282	1.0949	1.8103
-0.7	0.7049	2.0902	0.7897	1.9205	0.9016	2.1969	1.0840	1.8321
-0.6	0.7115	2.0769	0.7843	1.9313	0.9168	2.1664	1.0729	1.8543
-0.5	0.7181	2.0638	0.7788	1.9423	0.9316	2.1368	1.0614	1.8771
-0.4	0.7246	2.0508	0.7733	1.9535	0.9460	2.1080	1.0498	1.9005
-0.3	0.7310	2.0379	0.7676	1.9648	0.9600	2.0799	1.0378	1.9244
-0.2	0.7374	2.0252	0.7618	1.9764	0.9737	2.0526	1.0255	1.9490
-0.1	0.7437	2.0125	0.7560	1.9881	0.9870	2.0260	1.0129	1.9742
0	0.7500	2.0000	0.7500	2.0000	1.0000	2.0000	1.0000	2.0000
0.1	0.7562	1.9876	0.7440	2.0121	1.0127	1.9747	0.9867	2.0265
0.2	0.7624	1.9753	0.7378	2.0244	1.0250	1.9500	0.9731	2.0537
0.3	0.7685	1.9631	0.7315	2.0369	1.0370	1.9260	0.9592	2.0817
0.4	0.7745	1.9510	0.7252	2.0497	1.0488	1.9025	0.9448	2.1104
0.5	0.7805	1.9390	0.7187	2.0626	1.0602	1.8795	0.9301	2.1399
0.6	0.7864	1.9272	0.7121	2.0758	1.0714	1.8571	0.9149	2.1703
0.7	0.7923	1.9154	0.7054	2.0892	1.0824	1.8353	0.8993	2.2015
0.8	0.7981	1.9038	0.6986	2.1028	1.0931	1.8139	0.8832	2.2336
0.9	0.8039	1.8922	0.6917	2.1167	1.1035	1.7930	0.8667	2.2667
1	0.8096	1.8808	0.6846	2.1308	1.1137	1.7726	0.8496	2.3008
1.1	0.8153	1.8694	0.6774	2.1451	1.1237	1.7527	0.8320	2.3359
1.2	0.8209	1.8582	0.6701	2.1597	1.1334	1.7332	0.8140	2.3720
1.3	0.8265	1.8470	0.6627	2.1745	1.1430	1.7141	0.7956	2.4089
1.4	0.8320	1.8360	0.6552	2.1896	1.1523	1.6954	0.7766	2.4468
1.5	0.8375	1.8251	0.6475	2.2049	1.1614	1.6771	0.7570	2.4860
1.6	0.8429	1.8142	0.6397	2.2206	1.1704	1.6593	0.7366	2.5268
1.7	0.8483	1.8035	0.6315	2.2370	1.1791	1.6418	0.7146	2.5709
1.8	0.8535	1.7929	0.6228	2.2544	1.1877	1.6246	0.6903	2.6195
1.9	0.8588	1.7825	0.6137	2.2727	1.1961	1.6079	0.6642	2.6716
2	0.8639	1.7721	0.6044	2.2913	1.2043	1.5915	0.6372	2.7256
2.1	0.8691	1.7619	0.5951	2.3098	1.2123	1.5754	0.6100	2.7799
2.2	0.8742	1.7517	0.5861	2.3279	1.2202	1.5596	0.5833	2.8335
2.3	0.8792	1.7415	0.5772	2.3455	1.2279	1.5442	0.5571	2.8858
2.4	0.8843	1.7314	0.5686	2.3628	1.2354	1.5291	0.5312	2.9376
2.5	0.8944	1.7113	0.5709	2.3581	1.2465	1.5071	0.5230	2.9540
2.6	0.9132	1.6737	0.5921	2.3158	1.2636	1.4728	0.5448	2.9103
2.7	0.9370	1.6261	0.6238	2.2525	1.2842	1.4316	0.5827	2.8347
2.8	0.9607	1.5786	0.6549	2.1902	1.3047	1.3906	0.6177	2.7646
3.03	0.9607	1.5786	0.6549	2.1902	1.3047	1.3906	0.6177	2.7646

RGF POISSON (PANDIRA) FILE

```
 Recycler v18 RGF F-Gradient Magnet
&reg nreg=          15,
 Xmin =   -6.25000    ,
 Xreg1=   -5.00000    ,
 Kreg1=          12,
 Xreg2=    5.00000    ,
 Kreg2=         212,
 Xmax =    6.25000    ,
 Kmax=          224,
 Ymin =   -5.00000    ,
 Yreg1=   -1.75000    ,
 Lreg1=          38,
 Yreg2=   0.000000    ,
 Lreg2=          78,
 Yreg3=    1.75000    ,
 Lreg3=         118,
 Ymax =    5.00000    ,
 Lmax=          156,
  Rint=0.85,RNorm=1.00,NTERM=11,
  ktype=1,Angle=360.,
  NPTC=        1440,
  npoint=           9 &
 &po x= -6.250000, y= -5.000000 &
 &po x= -6.250000, y=  5.000000 &
 &po x=  6.250000, y=  5.000000 &
 &po x=  6.250000, y= -5.000000 &
 &po x=  5.750000, y= -5.000000 &
 &po x=  5.000000, y= -5.000000 &
 &po x= -5.000000, y= -5.000000 &
 &po x= -5.750000, y= -5.000000 &
 &po x= -6.250000, y= -5.000000 &
 &reg mat=2, npoint=          62 &
       POLETIP
 &po x= -3.030000, y= -1.750000 &
 &po x= -3.030000, y= -1.079009 &
 &po x= -2.800000, y= -1.079009 &
 &po x= -2.700000, y= -1.111462 &
 &po x= -2.600000, y= -1.144340 &
 &po x= -2.500000, y= -1.166652 &
 &po x= -2.400000, y= -1.170264 &
 &po x= -2.300000, y= -1.162926 &
 &po x= -2.200000, y= -1.155331 &
 &po x= -2.100000, y= -1.147418 &
 &po x= -2.000000, y= -1.139244 &
 &po x= -1.900000, y= -1.130960 &
 &po x= -1.800000, y= -1.122769 &
 &po x= -1.700000, y= -1.114869 &
 &po x= -1.600000, y= -1.107399 &
 &po x= -1.500000, y= -1.100217 &
 &po x= -1.400000, y= -1.093120 &
 &po x= -1.300000, y= -1.086094 &
 &po x= -1.200000, y= -1.079123 &
 &po x= -1.100000, y= -1.072196 &
 &po x= -1.000000, y= -1.065321 &
 &po x= -0.900000, y= -1.058511 &
 &po x= -0.800000, y= -1.051766 &
 &po x= -0.700000, y= -1.045084 &
 &po x= -0.600000, y= -1.038464 &
 &po x= -0.500000, y= -1.031905 &
 &po x= -0.400000, y= -1.025406 &
 &po x= -0.300000, y= -1.018967 &
 &po x= -0.200000, y= -1.012587 &
 &po x= -0.100000, y= -1.006265 &
 &po x=  0.000000, y= -1.000000 &
 &po x=  0.100000, y= -0.993792 &
 &po x=  0.200000, y= -0.987640 &
 &po x=  0.300000, y= -0.981543 &
 &po x=  0.400000, y= -0.975501 &
 &po x=  0.500000, y= -0.969514 &
 &po x=  0.600000, y= -0.963581 &
 &po x=  0.700000, y= -0.957701 &
 &po x=  0.800000, y= -0.951874 &
 &po x=  0.900000, y= -0.946100 &
 &po x=  1.000000, y= -0.940378 &
 &po x=  1.100000, y= -0.934708 &
 &po x=  1.200000, y= -0.929089 &
 &po x=  1.300000, y= -0.923518 &
 &po x=  1.400000, y= -0.917996 &
 &po x=  1.500000, y= -0.912526 &
 &po x=  1.600000, y= -0.907107 &
 &po x=  1.700000, y= -0.901751 &
 &po x=  1.800000, y= -0.896465 &
 &po x=  1.900000, y= -0.891242 &
 &po x=  2.000000, y= -0.886069 &
 &po x=  2.100000, y= -0.880936 &
 &po x=  2.200000, y= -0.875834 &
 &po x=  2.300000, y= -0.870759 &
 &po x=  2.400000, y= -0.865714 &
 &po x=  2.500000, y= -0.855645 &
 &po x=  2.600000, y= -0.836852 &
 &po x=  2.700000, y= -0.813053 &
 &po x=  2.800000, y= -0.789320 &
 &po x=  3.030000, y= -0.789320 &
 &po x=  3.030000, y= -1.750000 &
 &po x= -3.030000, y= -1.750000 &
 &reg mat=           6, npoint=5 &
             TOP BRICK           0
 &po x= -3.030000, y= -1.750000 &
 &po x= -3.030000, y= -3.750000 &
 &po x=  3.030000, y= -3.750000 &
 &po x=  3.030000, y= -1.750000 &
 &po x= -3.030000, y= -1.750000 &
 &reg mat=           2, npoint=
7 &    FLUX RET TOP
 &po x=  5.000000, y= -4.500000 &
 &po x= -5.000000, y= -4.500000 &
 &po x= -5.000000, y= -3.750000 &
 &po x= -3.030000, y= -3.750000 &
 &po x=  3.030000, y= -3.750000 &
 &po x=  5.000000, y= -3.750000 &
 &po x=  5.000000, y= -4.500000 &
 &reg mat=2, npoint=5 &
       FLUX RET RIGHT SIDE
 &po x=  5.750000, y= -4.500000 &
 &po x=  5.000000, y= -4.500000 &
 &po x=  5.000000, y=  0.000000 &
```

```
&po x=  5.750000, y=  0.000000 &
&po x=  5.750000, y= -4.500000 &
&reg mat=2, npoint=5 &
     FLUX RET LEFT
&po x= -5.750000, y= -4.500000 &
&po x= -5.000000, y= -4.500000 &
&po x= -5.000000, y=  0.000000 &
&po x= -5.750000, y=  0.000000 &
&po x= -5.750000, y= -4.500000 &
&reg mat=2, npoint=          62 &
     POLETIP
&po x= -3.030000, y=  1.750000 &
&po x= -3.030000, y=  1.079009 &
&po x= -2.800000, y=  1.079009 &
&po x= -2.700000, y=  1.111462 &
&po x= -2.600000, y=  1.144340 &
&po x= -2.500000, y=  1.166652 &
&po x= -2.400000, y=  1.170264 &
&po x= -2.300000, y=  1.162926 &
&po x= -2.200000, y=  1.155331 &
&po x= -2.100000, y=  1.147418 &
&po x= -2.000000, y=  1.139244 &
&po x= -1.900000, y=  1.130960 &
&po x= -1.800000, y=  1.122769 &
&po x= -1.700000, y=  1.114869 &
&po x= -1.600000, y=  1.107399 &
&po x= -1.500000, y=  1.100217 &
&po x= -1.400000, y=  1.093120 &
&po x= -1.300000, y=  1.086094 &
&po x= -1.200000, y=  1.079123 &
&po x= -1.100000, y=  1.072196 &
&po x= -1.000000, y=  1.065321 &
&po x= -0.900000, y=  1.058511 &
&po x= -0.800000, y=  1.051766 &
&po x= -0.700000, y=  1.045084 &
&po x= -0.600000, y=  1.038464 &
&po x= -0.500000, y=  1.031905 &
&po x= -0.400000, y=  1.025406 &
&po x= -0.300000, y=  1.018967 &
&po x= -0.200000, y=  1.012587 &
&po x= -0.100000, y=  1.006265 &
&po x=  0.000000, y=  1.000000 &
&po x=  0.100000, y=  0.993792 &
&po x=  0.200000, y=  0.987640 &
&po x=  0.300000, y=  0.981543 &
&po x=  0.400000, y=  0.975501 &
&po x=  0.500000, y=  0.969514 &
&po x=  0.600000, y=  0.963581 &
&po x=  0.700000, y=  0.957701 &
&po x=  0.800000, y=  0.951874 &
&po x=  0.900000, y=  0.946100 &
&po x=  1.000000, y=  0.940378 &
&po x=  1.100000, y=  0.934708 &
&po x=  1.200000, y=  0.929089 &
&po x=  1.300000, y=  0.923518 &
&po x=  1.400000, y=  0.917996 &
&po x=  1.500000, y=  0.912526 &
&po x=  1.600000, y=  0.907107 &
&po x=  1.700000, y=  0.901751 &
&po x=  1.800000, y=  0.896465 &
&po x=  1.900000, y=  0.891242 &
&po x=  2.000000, y=  0.886069 &
&po x=  2.100000, y=  0.880936 &
&po x=  2.200000, y=  0.875834 &
&po x=  2.300000, y=  0.870759 &
&po x=  2.400000, y=  0.865714 &
&po x=  2.500000, y=  0.855645 &
&po x=  2.600000, y=  0.836852 &
&po x=  2.700000, y=  0.813053 &
&po x=  2.800000, y=  0.789320 &
&po x=  3.030000, y=  0.789320 &
&po x=  3.030000, y=  1.750000 &
&po x= -3.030000, y=  1.750000 &
&reg mat=          6, npoint=5 &
          TOP BRICK          0
&po x= -3.030000, y=  1.750000 &
&po x= -3.030000, y=  3.750000 &
&po x=  3.030000, y=  3.750000 &
&po x=  3.030000, y=  1.750000 &
&po x= -3.030000, y=  1.750000 &
&reg mat=          2, npoint=
7 &    FLUX RET TOP
&po x=  5.000000, y=  4.500000 &
&po x= -5.000000, y=  4.500000 &
&po x= -5.000000, y=  3.750000 &
&po x= -3.030000, y=  3.750000 &
&po x=  3.030000, y=  3.750000 &
&po x=  5.000000, y=  3.750000 &
&po x=  5.000000, y=  4.500000 &
&reg mat=2, npoint=5 &
     FLUX RET RIGHT SIDE
&po x=  5.750000, y=  4.500000 &
&po x=  5.000000, y=  4.500000 &
&po x=  5.000000, y=  0.000000 &
&po x=  5.750000, y=  0.000000 &
&po x=  5.750000, y=  4.500000 &
&reg mat=2, npoint=5 &
     FLUX RET LEFT
&po x= -5.750000, y=  4.500000 &
&po x= -5.000000, y=  4.500000 &
&po x= -5.000000, y=  0.000000 &
&po x= -5.750000, y=  0.000000 &
&po x= -5.750000, y=  4.500000 &
&reg mat=1,cur=1., npoint=2  &
PANIDRA CURRENT LINE
&po x=  3.030000, y=  1.750000 &
&po x=  3.030000, y=  3.750000 &
&reg mat=1,cur=1., npoint=2 &
PANIDRA CURRENT LINE
&po x= -3.030000, y=  3.750000 &
&po x= -3.030000, y=  1.750000 &
&reg mat=1,cur=1., npoint=2  &
PANIDRA CURRENT LINE
&po x=  3.030000, y= -1.750000 &
&po x=  3.030000, y= -3.750000 &
&reg mat=1,cur=1., npoint=2 &
PANIDRA CURRENT LINE
&po x= -3.030000, y= -3.750000 &
&po x= -3.030000, y= -1.750000 &
```

RGD POISSON (PANDIRA) FILE

```
   Recycler v18 RGD Gradient Magnet
Point =  0
 &reg nreg=          15,
  Xmin =   -6.25000    ,
  Xreg1=   -5.00000    ,
  Kreg1=  12,
  Xreg2=    5.00000    ,
  Kreg2= 212,
  Xmax =    6.25000    ,
  Kmax=  224,
  Ymin =   -5.00000    ,
  Yreg1=   -1.75000    , Lreg1= 38,
  Yreg2=   0.000000    , Lreg2= 78,
  Yreg3=    1.75000    , Lreg3=118,
  Ymax =    5.00000    , Lmax= 156,
  Rint=0.85,RNorm=1.00,NTERM=11,
  ktype=1,Angle=360.,NPTC=  1440,
  npoint=           9 &
   &po x= -6.250000, y= -5.000000 &
   &po x= -6.250000, y=  5.000000 &
   &po x=  6.250000, y=  5.000000 &
   &po x=  6.250000, y= -5.000000 &
   &po x=  5.750000, y= -5.000000 &
   &po x=  5.000000, y= -5.000000 &
   &po x= -5.000000, y= -5.000000 &
   &po x= -5.750000, y= -5.000000 &
   &po x= -6.250000, y= -5.000000 &
   &reg mat=2, npoint=          62 &
  POLETIP
   &po x= -3.030000, y= -1.750000 &
   &po x= -3.030000, y= -0.805609 &
   &po x= -2.800000, y= -0.805609 &
   &po x= -2.700000, y= -0.829050 &
   &po x= -2.600000, y= -0.852576 &
   &po x= -2.500000, y= -0.870947 &
   &po x= -2.400000, y= -0.880318 &
   &po x= -2.300000, y= -0.884508 &
   &po x= -2.200000, y= -0.888737 &
   &po x= -2.100000, y= -0.893003 &
   &po x= -2.000000, y= -0.897310 &
   &po x= -1.900000, y= -0.901671 &
   &po x= -1.800000, y= -0.906101 &
   &po x= -1.700000, y= -0.910617 &
   &po x= -1.600000, y= -0.915228 &
   &po x= -1.500000, y= -0.919927 &
   &po x= -1.400000, y= -0.924700 &
   &po x= -1.300000, y= -0.929548 &
   &po x= -1.200000, y= -0.934470 &
   &po x= -1.100000, y= -0.939469 &
   &po x= -1.000000, y= -0.944546 &
   &po x= -0.900000, y= -0.949704 &
   &po x= -0.800000, y= -0.954943 &
   &po x= -0.700000, y= -0.960265 &
   &po x= -0.600000, y= -0.965672 &
   &po x= -0.500000, y= -0.971166 &
   &po x= -0.400000, y= -0.976748 &
   &po x= -0.300000, y= -0.982421 &
   &po x= -0.200000, y= -0.988185 &
   &po x= -0.100000, y= -0.994045 &
   &po x=  0.000000, y= -1.000000 &
   &po x=  0.100000, y= -1.006054 &
   &po x=  0.200000, y= -1.012209 &
   &po x=  0.300000, y= -1.018467 &
   &po x=  0.400000, y= -1.024831 &
   &po x=  0.500000, y= -1.031302 &
   &po x=  0.600000, y= -1.037885 &
   &po x=  0.700000, y= -1.044581 &
   &po x=  0.800000, y= -1.051394 &
   &po x=  0.900000, y= -1.058326 &
   &po x=  1.000000, y= -1.065381 &
   &po x=  1.100000, y= -1.072562 &
   &po x=  1.200000, y= -1.079858 &
   &po x=  1.300000, y= -1.087262 &
   &po x=  1.400000, y= -1.094788 &
   &po x=  1.500000, y= -1.102455 &
   &po x=  1.600000, y= -1.110281 &
   &po x=  1.700000, y= -1.118481 &
   &po x=  1.800000, y= -1.127214 &
   &po x=  1.900000, y= -1.136331 &
   &po x=  2.000000, y= -1.145624 &
   &po x=  2.100000, y= -1.154882 &
   &po x=  2.200000, y= -1.163948 &
   &po x=  2.300000, y= -1.172763 &
   &po x=  2.400000, y= -1.181398 &
   &po x=  2.500000, y= -1.179056 &
   &po x=  2.600000, y= -1.157922 &
   &po x=  2.700000, y= -1.126229 &
   &po x=  2.800000, y= -1.095097 &
   &po x=  3.030000, y= -1.095097 &
   &po x=  3.030000, y= -1.750000 &
   &po x= -3.030000, y= -1.750000 &
   &reg mat=           6, npoint=5 &
         TOP BRICK           0
   &po x= -3.030000, y= -1.750000 &
   &po x= -3.030000, y= -3.750000 &
   &po x=  3.030000, y= -3.750000 &
   &po x=  3.030000, y= -1.750000 &
   &po x= -3.030000, y= -1.750000 &
   &reg mat=           2, npoint=
7 &      FLUX RET TOP
   &po x=  5.000000, y= -4.500000 &
   &po x= -5.000000, y= -4.500000 &
   &po x= -5.000000, y= -3.750000 &
   &po x= -3.030000, y= -3.750000 &
   &po x=  3.030000, y= -3.750000 &
   &po x=  5.000000, y= -3.750000 &
   &po x=  5.000000, y= -4.500000 &
   &reg mat=2, npoint=5 &
  FLUX RET RIGHT SIDE
   &po x=  5.750000, y= -4.500000 &
   &po x=  5.000000, y= -4.500000 &
   &po x=  5.000000, y=  0.000000 &
   &po x=  5.750000, y=  0.000000 &
   &po x=  5.750000, y= -4.500000 &
   &reg mat=2, npoint=5 &
  FLUX RET LEFT
```

```
 &po x= -5.750000, y= -4.500000 &
 &po x= -5.000000, y= -4.500000 &
 &po x= -5.000000, y=  0.000000 &
 &po x= -5.750000, y=  0.000000 &
 &po x= -5.750000, y= -4.500000 &
 &reg mat=2, npoint=          62 &
POLETIP
 &po x= -3.030000, y=  1.750000 &
 &po x= -3.030000, y=  0.805609 &
 &po x= -2.800000, y=  0.805609 &
 &po x= -2.700000, y=  0.829050 &
 &po x= -2.600000, y=  0.852576 &
 &po x= -2.500000, y=  0.870947 &
 &po x= -2.400000, y=  0.880318 &
 &po x= -2.300000, y=  0.884508 &
 &po x= -2.200000, y=  0.888737 &
 &po x= -2.100000, y=  0.893003 &
 &po x= -2.000000, y=  0.897310 &
 &po x= -1.900000, y=  0.901671 &
 &po x= -1.800000, y=  0.906101 &
 &po x= -1.700000, y=  0.910617 &
 &po x= -1.600000, y=  0.915228 &
 &po x= -1.500000, y=  0.919927 &
 &po x= -1.400000, y=  0.924700 &
 &po x= -1.300000, y=  0.929548 &
 &po x= -1.200000, y=  0.934470 &
 &po x= -1.100000, y=  0.939469 &
 &po x= -1.000000, y=  0.944546 &
 &po x= -0.900000, y=  0.949704 &
 &po x= -0.800000, y=  0.954943 &
 &po x= -0.700000, y=  0.960265 &
 &po x= -0.600000, y=  0.965672 &
 &po x= -0.500000, y=  0.971166 &
 &po x= -0.400000, y=  0.976748 &
 &po x= -0.300000, y=  0.982421 &
 &po x= -0.200000, y=  0.988185 &
 &po x= -0.100000, y=  0.994045 &
 &po x=  0.000000, y=  1.000000 &
 &po x=  0.100000, y=  1.006054 &
 &po x=  0.200000, y=  1.012209 &
 &po x=  0.300000, y=  1.018467 &
 &po x=  0.400000, y=  1.024831 &
 &po x=  0.500000, y=  1.031302 &
 &po x=  0.600000, y=  1.037885 &
 &po x=  0.700000, y=  1.044581 &
 &po x=  0.800000, y=  1.051394 &
 &po x=  0.900000, y=  1.058326 &
 &po x=  1.000000, y=  1.065381 &
 &po x=  1.100000, y=  1.072562 &
 &po x=  1.200000, y=  1.079858 &
 &po x=  1.300000, y=  1.087262 &
 &po x=  1.400000, y=  1.094788 &
 &po x=  1.500000, y=  1.102455 &
 &po x=  1.600000, y=  1.110281 &
 &po x=  1.700000, y=  1.118481 &
 &po x=  1.800000, y=  1.127214 &
 &po x=  1.900000, y=  1.136331 &
 &po x=  2.000000, y=  1.145624 &
 &po x=  2.100000, y=  1.154882 &
 &po x=  2.200000, y=  1.163948 &
 &po x=  2.300000, y=  1.172763 &
 &po x=  2.400000, y=  1.181398 &
 &po x=  2.500000, y=  1.179056 &
 &po x=  2.600000, y=  1.157922 &
 &po x=  2.700000, y=  1.126229 &
 &po x=  2.800000, y=  1.095097 &
 &po x=  3.030000, y=  1.095097 &
 &po x=  3.030000, y=  1.750000 &
 &po x= -3.030000, y=  1.750000 &
 &reg mat=           6, npoint=5 &
      TOP BRICK          0
 &po x= -3.030000, y=  1.750000 &
 &po x= -3.030000, y=  3.750000 &
 &po x=  3.030000, y=  3.750000 &
 &po x=  3.030000, y=  1.750000 &
 &po x= -3.030000, y=  1.750000 &
 &reg mat=           2, npoint=
7 &      FLUX RET TOP
 &po x=  5.000000, y=  4.500000 &
 &po x= -5.000000, y=  4.500000 &
 &po x= -5.000000, y=  3.750000 &
 &po x= -3.030000, y=  3.750000 &
 &po x=  3.030000, y=  3.750000 &
 &po x=  5.000000, y=  3.750000 &
 &po x=  5.000000, y=  4.500000 &
 &reg mat=2, npoint=5 &
  FLUX RET RIGHT SIDE
 &po x=  5.750000, y=  4.500000 &
 &po x=  5.000000, y=  4.500000 &
 &po x=  5.000000, y=  0.000000 &
 &po x=  5.750000, y=  0.000000 &
 &po x=  5.750000, y=  4.500000 &
 &reg mat=2, npoint=5 &
  FLUX RET LEFT
 &po x= -5.750000, y=  4.500000 &
 &po x= -5.000000, y=  4.500000 &
 &po x= -5.000000, y=  0.000000 &
 &po x= -5.750000, y=  0.000000 &
 &po x= -5.750000, y=  4.500000 &
 &reg mat=1,cur=1., npoint=2  &
PANIDRA CURRENT LINE
 &po x=  3.030000, y=  1.750000 &
 &po x=  3.030000, y=  3.750000 &
 &reg mat=1,cur=1., npoint=2 &
PANIDRA CURRENT LINE
 &po x= -3.030000, y=  3.750000 &
 &po x= -3.030000, y=  1.750000 &
 &reg mat=1,cur=1., npoint=2  &
PANIDRA CURRENT LINE
 &po x=  3.030000, y= -1.750000 &
 &po x=  3.030000, y= -3.750000 &
 &reg mat=1,cur=1., npoint=2 &
PANIDRA CURRENT LINE
 &po x= -3.030000, y= -3.750000 &
 &po x= -3.030000, y= -1.750000 &
```

SGF POISSON (PANDIRA) FILE

```
 Recycler v18 SGF Supp. F-gradient
magnet   Point =  0
&reg nreg=          15,
Xmin =   -6.25000    ,
Xreg1=   -5.00000    ,
Kreg1=          12,
Xreg2=    5.00000    ,
Kreg2=         212,
Xmax =    6.25000    ,
Kmax=          224,
Ymin =   -5.25000    ,
Yreg1=   -2.00000    ,
Lreg1=          38,
Yreg2=   0.000000    ,
Lreg2=          84,
Yreg3=    2.00000    ,
Lreg3=         130,
Ymax =    5.25000    ,
Lmax=          168,
Rint=0.85,RNorm=1.00,NTERM=11,
ktype=1,Angle=360.,
NPTC=        1440,
npoint=           9 &
 &po x= -6.250000, y= -5.250000 &
 &po x= -6.250000, y=  5.250000 &
 &po x=  6.250000, y=  5.250000 &
 &po x=  6.250000, y= -5.250000 &
 &po x=  5.750000, y= -5.250000 &
 &po x=  5.000000, y= -5.250000 &
 &po x= -5.000000, y= -5.250000 &
 &po x= -5.750000, y= -5.250000 &
 &po x= -6.250000, y= -5.250000 &
 &reg mat=2, npoint=          62 &
      POLETIP
 &po x= -3.030000, y= -2.000000 &
 &po x= -3.030000, y= -1.368173 &
 &po x= -2.800000, y= -1.368173 &
 &po x= -2.700000, y= -1.402269 &
 &po x= -2.600000, y= -1.438940 &
 &po x= -2.500000, y= -1.460311 &
 &po x= -2.400000, y= -1.452930 &
 &po x= -2.300000, y= -1.428589 &
 &po x= -2.200000, y= -1.403834 &
 &po x= -2.100000, y= -1.378350 &
 &po x= -2.000000, y= -1.352344 &
 &po x= -1.900000, y= -1.326400 &
 &po x= -1.800000, y= -1.301309 &
 &po x= -1.700000, y= -1.277847 &
 &po x= -1.600000, y= -1.256552 &
 &po x= -1.500000, y= -1.236811 &
 &po x= -1.400000, y= -1.217775 &
 &po x= -1.300000, y= -1.199340 &
 &po x= -1.200000, y= -1.181401 &
 &po x= -1.100000, y= -1.163876 &
 &po x= -1.000000, y= -1.146796 &
 &po x= -0.900000, y= -1.130211 &
 &po x= -0.800000, y= -1.114099 &
 &po x= -0.700000, y= -1.098440 &
 &po x= -0.600000, y= -1.083214 &
 &po x= -0.500000, y= -1.068403 &
 &po x= -0.400000, y= -1.053989 &
 &po x= -0.300000, y= -1.039957 &
 &po x= -0.200000, y= -1.026291 &
 &po x= -0.100000, y= -1.012976 &
 &po x=  0.000000, y= -1.000000 &
 &po x=  0.100000, y= -0.987349 &
 &po x=  0.200000, y= -0.975010 &
 &po x=  0.300000, y= -0.962974 &
 &po x=  0.400000, y= -0.951227 &
 &po x=  0.500000, y= -0.939761 &
 &po x=  0.600000, y= -0.928566 &
 &po x=  0.700000, y= -0.917631 &
 &po x=  0.800000, y= -0.906950 &
 &po x=  0.900000, y= -0.896512 &
 &po x=  1.000000, y= -0.886310 &
 &po x=  1.100000, y= -0.876336 &
 &po x=  1.200000, y= -0.866582 &
 &po x=  1.300000, y= -0.857039 &
 &po x=  1.400000, y= -0.847703 &
 &po x=  1.500000, y= -0.838568 &
 &po x=  1.600000, y= -0.829630 &
 &po x=  1.700000, y= -0.820883 &
 &po x=  1.800000, y= -0.812319 &
 &po x=  1.900000, y= -0.803934 &
 &po x=  2.000000, y= -0.795725 &
 &po x=  2.100000, y= -0.787689 &
 &po x=  2.200000, y= -0.779820 &
 &po x=  2.300000, y= -0.772114 &
 &po x=  2.400000, y= -0.764568 &
 &po x=  2.500000, y= -0.753552 &
 &po x=  2.600000, y= -0.736408 &
 &po x=  2.700000, y= -0.715782 &
 &po x=  2.800000, y= -0.695293 &
 &po x=  3.030000, y= -0.695293 &
 &po x=  3.030000, y= -2.000000 &
 &po x= -3.030000, y= -2.000000 &
 &reg mat=           6, npoint=5 &
             TOP BRICK           0
 &po x= -3.030000, y= -2.000000 &
 &po x= -3.030000, y= -4.000000 &
 &po x=  3.030000, y= -4.000000 &
 &po x=  3.030000, y= -2.000000 &
 &po x= -3.030000, y= -2.000000 &
 &reg mat=           2, npoint=
7 &    FLUX RET TOP
 &po x=  5.000000, y= -4.750000 &
 &po x= -5.000000, y= -4.750000 &
 &po x= -5.000000, y= -4.000000 &
 &po x= -3.030000, y= -4.000000 &
 &po x=  3.030000, y= -4.000000 &
 &po x=  5.000000, y= -4.000000 &
 &po x=  5.000000, y= -4.750000 &
 &reg mat=2, npoint=5 &
       FLUX RET RIGHT SIDE
```

```
&po x=  5.750000, y= -4.750000 &
&po x=  5.000000, y= -4.750000 &
&po x=  5.000000, y=  0.000000 &
&po x=  5.750000, y=  0.000000 &
&po x=  5.750000, y= -4.750000 &
&reg mat=2, npoint=5 &
     FLUX RET LEFT
&po x= -5.750000, y= -4.750000 &
&po x= -5.000000, y= -4.750000 &
&po x= -5.000000, y=  0.000000 &
&po x= -5.750000, y=  0.000000 &
&po x= -5.750000, y= -4.750000 &
&reg mat=2, npoint=          62 &
     POLETIP
&po x= -3.030000, y=  2.000000 &
&po x= -3.030000, y=  1.368173 &
&po x= -2.800000, y=  1.368173 &
&po x= -2.700000, y=  1.402269 &
&po x= -2.600000, y=  1.438940 &
&po x= -2.500000, y=  1.460311 &
&po x= -2.400000, y=  1.452930 &
&po x= -2.300000, y=  1.428589 &
&po x= -2.200000, y=  1.403834 &
&po x= -2.100000, y=  1.378350 &
&po x= -2.000000, y=  1.352344 &
&po x= -1.900000, y=  1.326400 &
&po x= -1.800000, y=  1.301309 &
&po x= -1.700000, y=  1.277847 &
&po x= -1.600000, y=  1.256552 &
&po x= -1.500000, y=  1.236811 &
&po x= -1.400000, y=  1.217775 &
&po x= -1.300000, y=  1.199340 &
&po x= -1.200000, y=  1.181401 &
&po x= -1.100000, y=  1.163876 &
&po x= -1.000000, y=  1.146796 &
&po x= -0.900000, y=  1.130211 &
&po x= -0.800000, y=  1.114099 &
&po x= -0.700000, y=  1.098440 &
&po x= -0.600000, y=  1.083214 &
&po x= -0.500000, y=  1.068403 &
&po x= -0.400000, y=  1.053989 &
&po x= -0.300000, y=  1.039957 &
&po x= -0.200000, y=  1.026291 &
&po x= -0.100000, y=  1.012976 &
&po x=  0.000000, y=  1.000000 &
&po x=  0.100000, y=  0.987349 &
&po x=  0.200000, y=  0.975010 &
&po x=  0.300000, y=  0.962974 &
&po x=  0.400000, y=  0.951227 &
&po x=  0.500000, y=  0.939761 &
&po x=  0.600000, y=  0.928566 &
&po x=  0.700000, y=  0.917631 &
&po x=  0.800000, y=  0.906950 &
&po x=  0.900000, y=  0.896512 &
&po x=  1.000000, y=  0.886310 &
&po x=  1.100000, y=  0.876336 &
&po x=  1.200000, y=  0.866582 &
&po x=  1.300000, y=  0.857039 &
&po x=  1.400000, y=  0.847703 &
&po x=  1.500000, y=  0.838568 &
&po x=  1.600000, y=  0.829630 &
&po x=  1.700000, y=  0.820883 &
&po x=  1.800000, y=  0.812319 &
&po x=  1.900000, y=  0.803934 &
&po x=  2.000000, y=  0.795725 &
&po x=  2.100000, y=  0.787689 &
&po x=  2.200000, y=  0.779820 &
&po x=  2.300000, y=  0.772114 &
&po x=  2.400000, y=  0.764568 &
&po x=  2.500000, y=  0.753552 &
&po x=  2.600000, y=  0.736408 &
&po x=  2.700000, y=  0.715782 &
&po x=  2.800000, y=  0.695293 &
&po x=  3.030000, y=  0.695293 &
&po x=  3.030000, y=  2.000000 &
&po x= -3.030000, y=  2.000000 &
&reg mat=           6, npoint=5 &
          TOP BRICK           0
&po x= -3.030000, y=  2.000000 &
&po x= -3.030000, y=  4.000000 &
&po x=  3.030000, y=  4.000000 &
&po x=  3.030000, y=  2.000000 &
&po x= -3.030000, y=  2.000000 &
&reg mat=           2, npoint=
7 &    FLUX RET TOP
&po x=  5.000000, y=  4.750000 &
&po x= -5.000000, y=  4.750000 &
&po x= -5.000000, y=  4.000000 &
&po x= -3.030000, y=  4.000000 &
&po x=  3.030000, y=  4.000000 &
&po x=  5.000000, y=  4.000000 &
&po x=  5.000000, y=  4.750000 &
&reg mat=2, npoint=5 &
     FLUX RET RIGHT SIDE
&po x=  5.750000, y=  4.750000 &
&po x=  5.000000, y=  4.750000 &
&po x=  5.000000, y=  0.000000 &
&po x=  5.750000, y=  0.000000 &
&po x=  5.750000, y=  4.750000 &
&reg mat=2, npoint=5 &
     FLUX RET LEFT
&po x= -5.750000, y=  4.750000 &
&po x= -5.000000, y=  4.750000 &
&po x= -5.000000, y=  0.000000 &
&po x= -5.750000, y=  0.000000 &
&po x= -5.750000, y=  4.750000 &
&reg mat=1,cur=1., npoint=2  &
PANIDRA CURRENT LINE
&po x=  3.030000, y=  2.000000 &
&po x=  3.030000, y=  4.000000 &
&reg mat=1,cur=1., npoint=2 &
PANIDRA CURRENT LINE
&po x= -3.030000, y=  4.000000 &
&po x= -3.030000, y=  2.000000 &
&reg mat=1,cur=1., npoint=2  &
PANIDRA CURRENT LINE
&po x=  3.030000, y= -2.000000 &
&po x=  3.030000, y= -4.000000 &
&reg mat=1,cur=1., npoint=2 &
PANIDRA CURRENT LINE
&po x= -3.030000, y= -4.000000 &
&po x= -3.030000, y= -2.000000 &
```

SGD POISSON (PANDIRA) FILE

```
 Recycler v18 SGD Supp. D-gradient
magnet
 &reg nreg=          15,
 Xmin =   -6.25000    ,
 Xreg1=   -5.00000    ,
 Kreg1=          12,
 Xreg2=    5.00000    ,
 Kreg2=          212,
 Xmax =    6.25000    ,
 Kmax=           224,
 Ymin =   -5.25000    ,
 Yreg1=   -2.00000    ,
 Lreg1=          38,
 Yreg2=   0.000000    ,
 Lreg2=          84,
 Yreg3=    2.00000    ,
 Lreg3=          130,
 Ymax =    5.25000    ,
 Lmax=           168,
  Rint=0.85,RNorm=1.00,NTERM=11,
  ktype=1,Angle=360.,NPTC=        1440,
  npoint=           9 &
 &po x= -6.250000, y= -5.250000 &
 &po x= -6.250000, y=  5.250000 &
 &po x=  6.250000, y=  5.250000 &
 &po x=  6.250000, y= -5.250000 &
 &po x=  5.750000, y= -5.250000 &
 &po x=  5.000000, y= -5.250000 &
 &po x= -5.000000, y= -5.250000 &
 &po x= -5.750000, y= -5.250000 &
 &po x= -6.250000, y= -5.250000 &
 &reg mat=2, npoint=          62 &
      POLETIP
 &po x= -3.030000, y= -2.000000 &
 &po x= -3.030000, y= -0.691564 &
 &po x= -2.800000, y= -0.691564 &
 &po x= -2.700000, y= -0.712158 &
 &po x= -2.600000, y= -0.732866 &
 &po x= -2.500000, y= -0.750037 &
 &po x= -2.400000, y= -0.761013 &
 &po x= -2.300000, y= -0.768507 &
 &po x= -2.200000, y= -0.776206 &
 &po x= -2.100000, y= -0.784114 &
 &po x= -2.000000, y= -0.792233 &
 &po x= -1.900000, y= -0.800558 &
 &po x= -1.800000, y= -0.809077 &
 &po x= -1.700000, y= -0.817774 &
 &po x= -1.600000, y= -0.826641 &
 &po x= -1.500000, y= -0.835696 &
 &po x= -1.400000, y= -0.844966 &
 &po x= -1.300000, y= -0.854448 &
 &po x= -1.200000, y= -0.864140 &
 &po x= -1.100000, y= -0.874045 &
 &po x= -1.000000, y= -0.884174 &
 &po x= -0.900000, y= -0.894541 &
 &po x= -0.800000, y= -0.905155 &
 &po x= -0.700000, y= -0.916023 &
 &po x= -0.600000, y= -0.927154 &
 &po x= -0.500000, y= -0.938556 &
 &po x= -0.400000, y= -0.950240 &
 &po x= -0.300000, y= -0.962215 &
 &po x= -0.200000, y= -0.974493 &
 &po x= -0.100000, y= -0.987083 &
 &po x=  0.000000, y= -1.000000 &
 &po x=  0.100000, y= -1.013255 &
 &po x=  0.200000, y= -1.026863 &
 &po x=  0.300000, y= -1.040837 &
 &po x=  0.400000, y= -1.055194 &
 &po x=  0.500000, y= -1.069951 &
 &po x=  0.600000, y= -1.085124 &
 &po x=  0.700000, y= -1.100734 &
 &po x=  0.800000, y= -1.116801 &
 &po x=  0.900000, y= -1.133346 &
 &po x=  1.000000, y= -1.150394 &
 &po x=  1.100000, y= -1.167969 &
 &po x=  1.200000, y= -1.186000 &
 &po x=  1.300000, y= -1.204441 &
 &po x=  1.400000, y= -1.223398 &
 &po x=  1.500000, y= -1.243005 &
 &po x=  1.600000, y= -1.263399 &
 &po x=  1.700000, y= -1.285438 &
 &po x=  1.800000, y= -1.309740 &
 &po x=  1.900000, y= -1.335777 &
 &po x=  2.000000, y= -1.362783 &
 &po x=  2.100000, y= -1.389965 &
 &po x=  2.200000, y= -1.416739 &
 &po x=  2.300000, y= -1.442897 &
 &po x=  2.400000, y= -1.468784 &
 &po x=  2.500000, y= -1.477015 &
 &po x=  2.600000, y= -1.455165 &
 &po x=  2.700000, y= -1.417335 &
 &po x=  2.800000, y= -1.382290 &
 &po x=  3.030000, y= -1.382290 &
 &po x=  3.030000, y= -2.000000 &
 &po x= -3.030000, y= -2.000000 &
 &reg mat=           6, npoint=5 &
      TOP BRICK           0
 &po x= -3.030000, y= -2.000000 &
 &po x= -3.030000, y= -4.000000 &
 &po x=  3.030000, y= -4.000000 &
 &po x=  3.030000, y= -2.000000 &
 &po x= -3.030000, y= -2.000000 &
 &reg mat=           2, npoint=
7 &    FLUX RET TOP
 &po x=  5.000000, y= -4.750000 &
 &po x= -5.000000, y= -4.750000 &
 &po x= -5.000000, y= -4.000000 &
 &po x= -3.030000, y= -4.000000 &
 &po x=  3.030000, y= -4.000000 &
 &po x=  5.000000, y= -4.000000 &
 &po x=  5.000000, y= -4.750000 &
 &reg mat=2, npoint=5 &          FLUX
RET RIGHT SIDE
 &po x=  5.750000, y= -4.750000 &
```

```
 &po x=  5.000000, y= -4.750000 &
 &po x=  5.000000, y=  0.000000 &
 &po x=  5.750000, y=  0.000000 &
 &po x=  5.750000, y= -4.750000 &
 &reg mat=2, npoint=5 &          FLUX
RET LEFT
 &po x= -5.750000, y= -4.750000 &
 &po x= -5.000000, y= -4.750000 &
 &po x= -5.000000, y=  0.000000 &
 &po x= -5.750000, y=  0.000000 &
 &po x= -5.750000, y= -4.750000 &
 &reg mat=2, npoint=          62 &
      POLETIP
 &po x= -3.030000, y=  2.000000 &
 &po x= -3.030000, y=  0.691564 &
 &po x= -2.800000, y=  0.691564 &
 &po x= -2.700000, y=  0.712158 &
 &po x= -2.600000, y=  0.732866 &
 &po x= -2.500000, y=  0.750037 &
 &po x= -2.400000, y=  0.761013 &
 &po x= -2.300000, y=  0.768507 &
 &po x= -2.200000, y=  0.776206 &
 &po x= -2.100000, y=  0.784114 &
 &po x= -2.000000, y=  0.792233 &
 &po x= -1.900000, y=  0.800558 &
 &po x= -1.800000, y=  0.809077 &
 &po x= -1.700000, y=  0.817774 &
 &po x= -1.600000, y=  0.826641 &
 &po x= -1.500000, y=  0.835696 &
 &po x= -1.400000, y=  0.844966 &
 &po x= -1.300000, y=  0.854448 &
 &po x= -1.200000, y=  0.864140 &
 &po x= -1.100000, y=  0.874045 &
 &po x= -1.000000, y=  0.884174 &
 &po x= -0.900000, y=  0.894541 &
 &po x= -0.800000, y=  0.905155 &
 &po x= -0.700000, y=  0.916023 &
 &po x= -0.600000, y=  0.927154 &
 &po x= -0.500000, y=  0.938556 &
 &po x= -0.400000, y=  0.950240 &
 &po x= -0.300000, y=  0.962215 &
 &po x= -0.200000, y=  0.974493 &
 &po x= -0.100000, y=  0.987083 &
 &po x=  0.000000, y=  1.000000 &
 &po x=  0.100000, y=  1.013255 &
 &po x=  0.200000, y=  1.026863 &
 &po x=  0.300000, y=  1.040837 &
 &po x=  0.400000, y=  1.055194 &
 &po x=  0.500000, y=  1.069951 &
 &po x=  0.600000, y=  1.085124 &
 &po x=  0.700000, y=  1.100734 &
 &po x=  0.800000, y=  1.116801 &
 &po x=  0.900000, y=  1.133346 &
 &po x=  1.000000, y=  1.150394 &
 &po x=  1.100000, y=  1.167969 &
 &po x=  1.200000, y=  1.186000 &
 &po x=  1.300000, y=  1.204441 &
 &po x=  1.400000, y=  1.223398 &
 &po x=  1.500000, y=  1.243005 &
 &po x=  1.600000, y=  1.263399 &
 &po x=  1.700000, y=  1.285438 &
 &po x=  1.800000, y=  1.309740 &
 &po x=  1.900000, y=  1.335777 &
 &po x=  2.000000, y=  1.362783 &
 &po x=  2.100000, y=  1.389965 &
 &po x=  2.200000, y=  1.416739 &
 &po x=  2.300000, y=  1.442897 &
 &po x=  2.400000, y=  1.468784 &
 &po x=  2.500000, y=  1.477015 &
 &po x=  2.600000, y=  1.455165 &
 &po x=  2.700000, y=  1.417335 &
 &po x=  2.800000, y=  1.382290 &
 &po x=  3.030000, y=  1.382290 &
 &po x=  3.030000, y=  2.000000 &
 &po x= -3.030000, y=  2.000000 &
 &reg mat=           6, npoint=5 &
      TOP BRICK           0
 &po x= -3.030000, y=  2.000000 &
 &po x= -3.030000, y=  4.000000 &
 &po x=  3.030000, y=  4.000000 &
 &po x=  3.030000, y=  2.000000 &
 &po x= -3.030000, y=  2.000000 &
 &reg mat=           2, npoint=
7 &    FLUX RET TOP
 &po x=  5.000000, y=  4.750000 &
 &po x= -5.000000, y=  4.750000 &
 &po x= -5.000000, y=  4.000000 &
 &po x= -3.030000, y=  4.000000 &
 &po x=  3.030000, y=  4.000000 &
 &po x=  5.000000, y=  4.000000 &
 &po x=  5.000000, y=  4.750000 &
 &reg mat=2, npoint=5 &          FLUX
RET RIGHT SIDE
 &po x=  5.750000, y=  4.750000 &
 &po x=  5.000000, y=  4.750000 &
 &po x=  5.000000, y=  0.000000 &
 &po x=  5.750000, y=  0.000000 &
 &po x=  5.750000, y=  4.750000 &
 &reg mat=2, npoint=5 &          FLUX
RET LEFT
 &po x= -5.750000, y=  4.750000 &
 &po x= -5.000000, y=  4.750000 &
 &po x= -5.000000, y=  0.000000 &
 &po x= -5.750000, y=  0.000000 &
 &po x= -5.750000, y=  4.750000 &
 &reg mat=1,cur=1., npoint=2  & PANIDRA
CURRENT LINE
 &po x=  3.030000, y=  2.000000 &
 &po x=  3.030000, y=  4.000000 &
 &reg mat=1,cur=1., npoint=2 & PANIDRA
CURRENT LINE
 &po x= -3.030000, y=  4.000000 &
 &po x= -3.030000, y=  2.000000 &
 &reg mat=1,cur=1., npoint=2  & PANIDRA
CURRENT LINE
 &po x=  3.030000, y= -2.000000 &
 &po x=  3.030000, y= -4.000000 &
 &reg mat=1,cur=1., npoint=2 & PANIDRA
CURRENT LINE
 &po x= -3.030000, y= -4.000000 &
 &po x= -3.030000, y= -2.000000 &
```