Recycler Quadrupole Magnetic Designs

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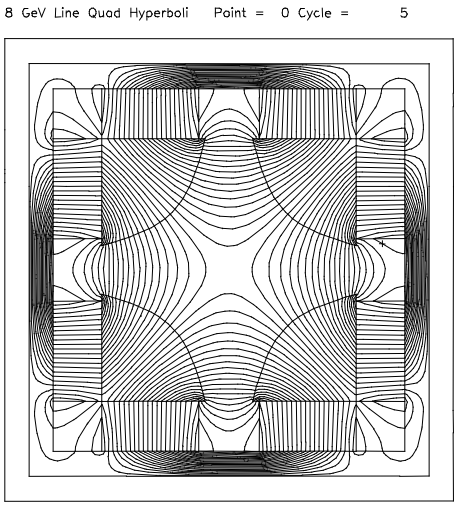
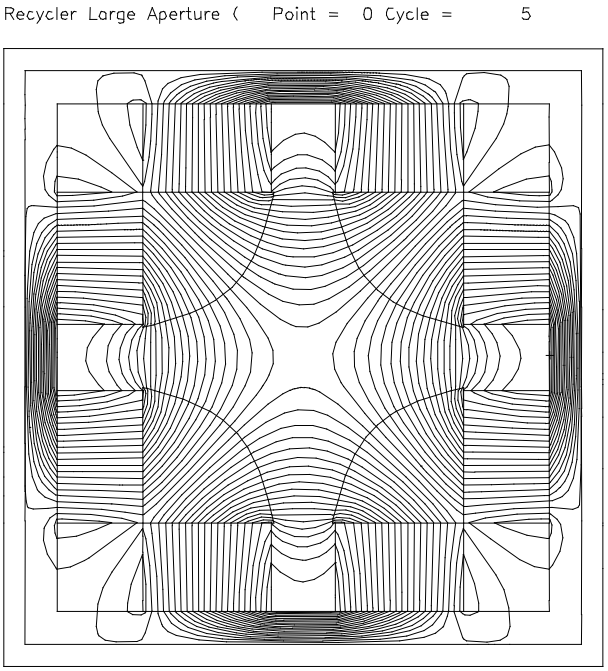
24 September, 1998



20" RQxx Quads
(RQMF,RQMD,RQTF,RQTD,RQME,RQSA,
RQSB,RQSC,RQSD,RQAA,RQAB,RQAC…)



40" RQEx Quads

Introduction

This note describes the 2-D magnetic design of the Recycler Ring permanent magnet quadrupoles. Two basic designs exist. The RQxx series are copies of the 8 GeV line quads and have a 20" pole tip length and a pole tip radius of 1.643" (the same as the Main Ring/Main Injector quads). The RQEx series have 40" pole tips and a larger aperture (2.300" Pole tip radius) needed for the high-β insert for electron cooling. Both series come in a variety of strengths depending on how much ferrite is installed.

The original magnetic specifications for these quads were based on the Recycler RR_V18 lattice. The final list of quadrupole strengths evolved since then and is not reproduced here. The mechanical drawings of the individual magnets are in the Technical Division archives. The magnetic measurements (multipole defects, etc.) are being stored in the MTF database and hardcopies are included in the travelers.

RQxx (20" Small Aperture Quad)

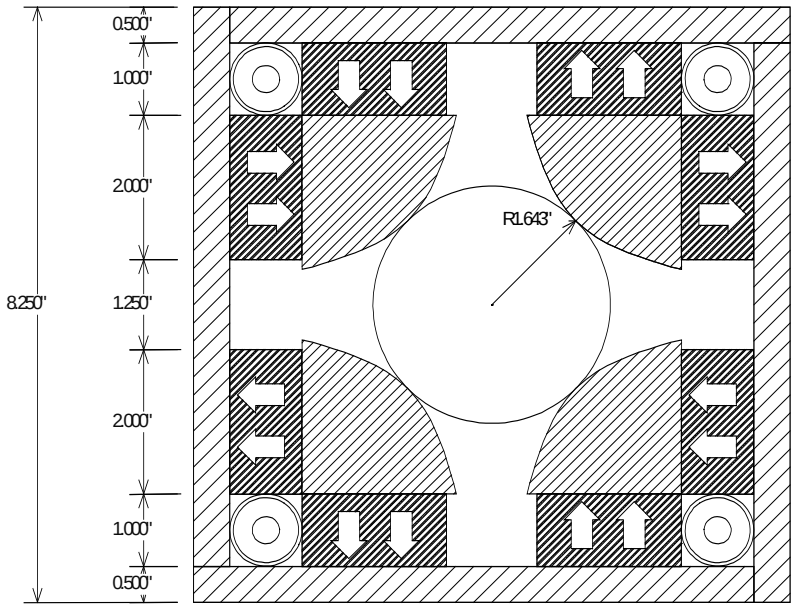


Fig. 1 - 8 GeV Line/Recycler 20" Quadrupole Cross Section

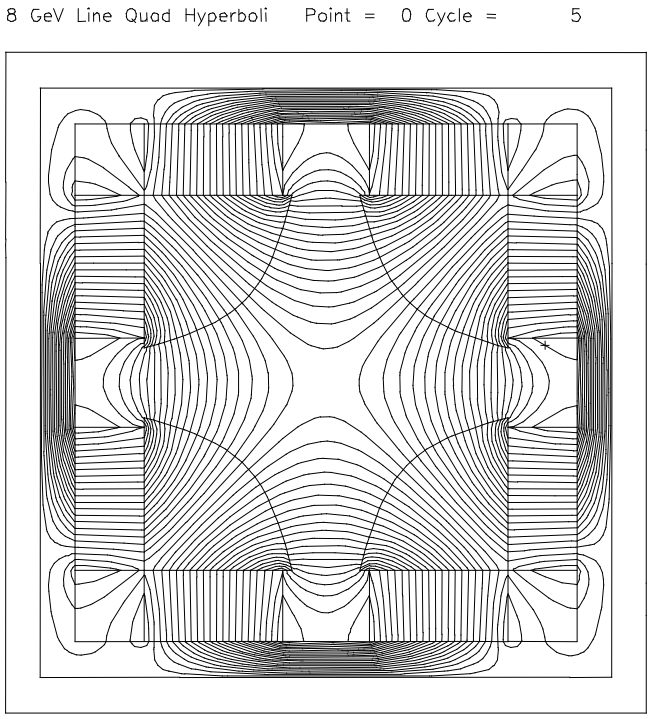


Fig. 2 - 8 GeV Line/Recycler 20" Quadrupole Field Map

RQEx (40" Large Aperture Quad)

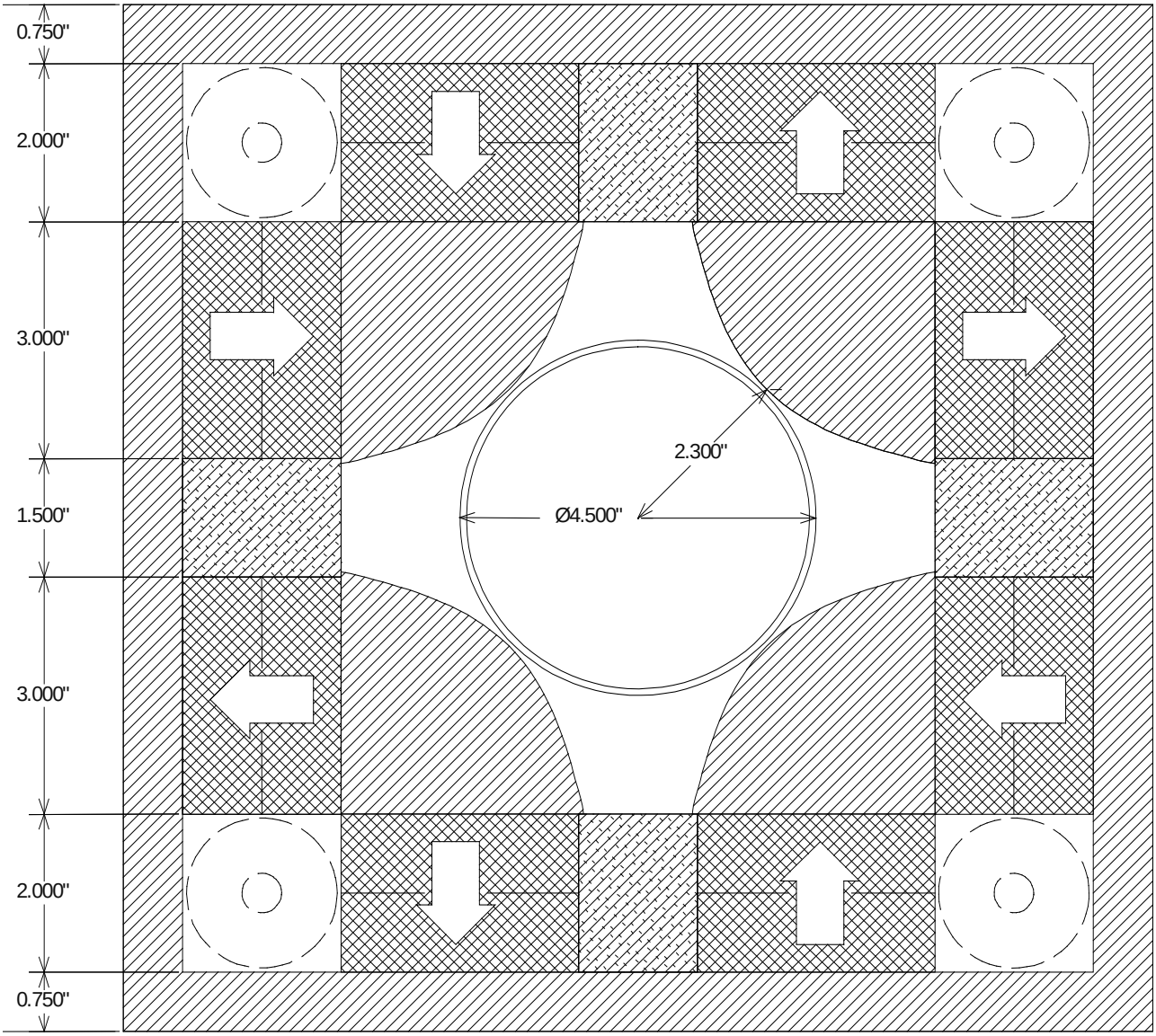


Fig. 3 - RQE quadrupole cross-section. The field shape is determined by accurately shaped low-carbon steel pole tips. Arrows indicate polarization of permanent magnet bricks. Two layers of 1" thick bricks are used in the RQE series and a single layer is used in the RQx series. Aluminum spacers on the horizontal and vertical midplanes control the positions of the bricks. A flux return box surrounds the magnet. The pole tips are supported by nonmagnetic (aluminum or stainless steel) plates at the ends (and in the case of the RQEx, the middle) of the magnet. Strips of "compensator alloy" were interspersed transversely between the ferrite bricks to null out the temperature coefficient. Stainless steel shafts with adjustable numbers of washers or iron slugs were placed in the corners behind the pole tips to equalize the magnetic potential of the four pole tips.

Magnetic Materials - Strontium Ferrite (Br~0.38T, Hc~0.35T) was used. The properties of this material are discussed in the 8 GeV line section of the Main Injector design report, the Recycler design report, and various MI notes. 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. Details of the final compensator pattern for each magnet are in the travelers.

In some of the RQE's, a small number of steel strips were included among the bricks and compensator. This served to reduce effective strength of the ferrite and was a practical alternative to cutting fractional bricks to reduce the magnet strength. It was found that the strength could be tuned this way without affecting the temperature compensation, which is mainly a function of the ratio of bricks to compensator in the system.

The amount of ferrite and compensator installed does not significantly affect the harmonic content due to the shielding effect of the pole tip steel. The magnetic designs were calculated assuming the magnets were fully stuffed with Ferrite. The harmonic content of weaker, partially stuffed magnets was identical. This is because the steel is being operated at the kGauss level where the permeability is in the vicinity of 1000.

Magnet Strength - The POISSON ".CON" file specifying the magnetic properties is reproduced below. There are four magnetic materials corresponding to the four orientations of the ferrite material. To approximately predict the strength of a temperature compensated magnet one can reduce the average density of the Ferrite by 30% (a Poisson "stacking factor" of 0.7). In this example the stacking factor is 1.00.

POISSON ".CON" FILE SPECIFYING MAGNETIC PROPERTIES
OF FERRITE AND COMPENSATOR ALLOY
(see POISSON documentation for explanation)

```
0  (0=Dump # to be read in from lattice)
*18 4 *6 0  *42 1 41  1 1  *54 0.0 4.0 0.0 1.0 s
6     1.00000     -1   mat stack type  (right block)
00.0 1.0 s
   -3500.00        3800.00        hcept bcept
7     1.00000     -1   mat stack type  (top block)
90.0 1.0 s
   -3500.00        3800.00        hcept bcept
8 1.0 -1   mat stack type   (left block)
180.0 1.0 s
   -3500.00        3800.00        hcept bcept
9 1.0 -1   mat stack type   (Bot block, if used)
270.0 1.0 s
   -3500.00        3800.00        hcept bcept
end
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Pole Tip Steel - The quad pole tips were built using low-carbon steel. 1018 steel was used for the 20" quads and 1008 steel was used for the 40" RQEx quads. The magnetic modeling used the B-H curves for the default 1010 steel provided with POISSON.

Pole Tip Fabrication - Two techniques were used for the shaped pole tips. The small aperture 20" quad pole tips were extruded, cold drawn, and cut to length. The large aperture quad (RQE) pole tips were machined using a specially ground "form cutter" which matched the profile of the pole tip. The vendor for the extrusion/cold drawn poles was Moltrup Steel in Pennsylvania (represented locally through Ryerson). The vendor for the form cutting was HiTech (a local job shop).

Pole Tip Construction Tolerances produce harmonic defects larger than those expected from POISSON. An overall window of +/-0.002" was specified (and, typically held) for the shape of the inside surface of the pole tips. Deviations larger than this were tolerated as long as they varied smoothly across the pole tip and thus did not couple to higher harmonics. A similar tolerance in the positioning of the pole tips was expected (but never verified) from the roll pins used to support the poles on the end plates. Most of the effects of pole tip positioning and shape defects were removed by the field trimming described below.

Flux Return Boxes were built from common grades of low-carbon steel (1018 or A36). The thickness was 1/2" for the small aperture quads and 3/4" for the large aperture quads. This keeps the maximum flux density below ~0.8T in the flux return shells. The amount of flux which must bridge the corner joint of the box is small, ideally zero (see fig. 2). This makes the quad design insensitive to construction tolerances that result in gaps at the corners of the flux return box. This is in contrast to the dipole designs in which a large amount of the flux must bridge the corner gap. The corner joints were overlapped in a "windmill" or "swastika" or pattern so that all four flux return plates could be identical (see fig. 1). This design also allowed the box to close up tightly around the bricks.

Pole Tip Shape Optimization was performed using a modified version of the Recycler pole tip optimizer codes that are described in the MI note on the magnetic design of the Recycler RRv18 arc magnets. The basic pole tip profile was hyperbolic, with polynomial deviations (and for the RQE, an end "Bump") which allowed the corners of the pole tip to bump outwards to terminate the end fields of the pole tip. The optimizer minimized the field defect (B(y) vs. X) on the midplane out to a distance roughly equal to the pole tip radius. The procedure converged rapidly and robustly.

Subsequent experience with pole tip design suggests that it might have been a slightly better procedure to minimize something else besides the field defect on the midplane. With only the midplane field considered, the pole tip optimizer adds a small amount of additional higher harmonic content in order to extend the "horizontal good field region" near the midplane. Better choices might have been to minimize either the field defect over a 2-d grid inside the good-field aperture (this was done for the Recycler dipoles) or to directly minimize the allowed harmonics calculated by POISSON. This second approach

was attempted, but the attempt was defeated by numerical noise in the POISSON harmonic fitter that made the taking of derivatives very noisy.

The spurious multipoles added by the midplane optimization are 12-pole and 20-pole, the lowest multipoles allowed by quadrupole symmetry. The amount of multipole defect is ~1 unit or less, which turns out to be less than the end-field defects that were cancelled by trim washers at the ends of the pole tips.

The body field harmonics calculated by POISSON for the final pole tip are given in table 1. These multipoles were calculated with a 4-quadrant simulation with a grid spacing of 0.050" (DX=0.05) in POISSON. All harmonics were fit, and the amplitudes of the "non-allowed" harmonics (basically everything except normal 4-pole, 12-pole, 20-pole…) give some indication of the noise level of the POISSON harmonics fitter. The POISSON harmonics fitter also has an option (ktype=4) that causes all of the non-allowed harmonics to be reported as zero. This makes a better looking result but does not change the values (or presumably the accuracy) of the allowed harmonics.

The calculated harmonics for the large aperture (40-inch RQE) quad are given at both 1" and 2" reference radius since the expected beam sizes in the high-beta insert are 2-3x larger.

Table 1:

POISSON CALCULATED MULTIPOLES FOR RECYCLER QUADRUPOLE MAGNETS

	RQxx (Rnorm = 1")			RQE (Rnorm = 1")			RQE (Rnorm = 2")		
	Target	Normal	Skew	Target	Normal	Skew	Target	Normal	Skew
Dipole	0	-3.9	-3.28	0	-3.06	-1.94	0	-1.53	-0.97
Quad.	10000	10000	-0.07	10000	10000.00	0.06	10000	10000	0.06
Sextup.	0	-1.06	0.89	0	-0.49	0.27	0	-0.97	0.54
Octupole	0	0.03	0.00	0	0.01	0.03	0	0.03	0.12
10-pole	0	-0.08	-0.06	0	-0.01	-0.01	0	-0.05	-0.08
12-pole	0	-1.9	-0.01	0	-0.06	0.00	0	-0.92	0.05
14-pole	0	0.02	-0.02	0	0.00	0.00	0	0.04	-0.05
16-pole	0	0.00	0.00	0	0.00	0.00	0	0.00	0.01
18-pole	0	0.00	0.00	0	0.00	0.00	0	-0.03	-0.01
20-pole	0	0.34	0.00	0	0.01	0.00	0	1.51	-0.01
22-pole	0	0.00	0.00	0	0.00	0.00	0	-0.02	0.00
24-pole	0	0.00	0.00	0	0.00	0.00	0	-0.01	0.04
26-pole	0	0.00	0.00	0	0.00	0.00	0	0.05	0.00
28-pole	0	0.00	0.00	0	0.00	0.00	0	-0.48	0.01

Field Trimming was an important production aspect for the quadrupoles. This technique took place in several stages. First, the strength and temperature compensation was adjusted by assembling the proper amount of ferrite and compensator into the magnet. The target value was ~1% above the nominal strength.

In the second trimming step a variable number of washers were installed on stainless threaded rods located behind each pole tip. See figures 1 and 3. This was used to independently adjust downwards the magnetic potential of each pole. These four "knobs" allow us to null out four multipole errors. These were chosen to be the quad strength, the normal sextupole, the skew sextupole, and the skew octupole. (Errors in the normal and skew dipole, and the skew quadrupole, are normalized out of existence by the choice of magnetic center and quadrupole orientation angle). Trimming out these low multipole errors had the side effect of bringing the magnetic center very close (<~1mm) to the geometric center of the magnet.

The trimming procedure was developed by measuring the effect on these multipoles of one washer in each of the pole positions. This produced a "transfer matrix" from washers to multipoles. This matrix was inverted and applied to the residual multipole errors to determine the number of washers to be added or subtracted to each pole to correct these defects.

Thirdly, higher multipoles could also be trimmed using "end washers" located on bolts in tapped holes at the ends of each of the pole tips. The 12-pole error (which is the lowest "allowed" multipole error) was cancelled by adjusting the total number of end washers installed on the pole tips. Adding washers had the effect of strengthening the magnetic field near the corners of the pole tips. This was necessary to cancel the end-field 12-pole as well as the small amount of body field 12-pole introduced by the pole tip optimizer as discussed above.

Finally, the normal octupole could be nulled out by transferring pole tip end washers from positions near the vertical midplane into positions near the horizontal midplane. These procedures typically allowed trimmed harmonics to be reduced to the small-fractional unit level.

Appendix 1 - RQxx 20" Small Aperture Quad POISSON (PANDIRA) FILE

```
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 &po x= 4.125000, y= -4.125000 &
 &po x= 0.000000, y= -4.125000 &
 &po x= 0.000000, y= -3.625000 &
 &po x= 3.625000, y= -3.625000 &
 &po x= 3.625000, y= 0.000000 &
 &reg mat=1,cur=5., npoint=2 &   PANIDRA
CURRENT LINE
 &po x= 2.625000, y= 2.625000 &
 &po x= 3.625000, y= 2.625000 &&
```

Appendix 2 - RQEx 40" Quad POISSON (PANDIRA) FILE

```
RQE 40-inch quadrupole
&reg nreg= 18,dx= 0.800000E-01,
xmax= 7.00000 ,ymax= 7.00000 ,
xmin= -7.00000 ,ymin= -7.00000 ,
NBSLF=0, NBSLO=0,
Rint=2.0,RNorm=2.00,NTERM=14,
ktype=1,Angle=360.,NPTC=360,
npoint = 33 &
&po x= 7.000000, y= 0.000000 &
&po x= 7.000000, y= 3.750000 &
&po x= 7.000000, y= 5.750000 &
&po x= 7.000000, y= 6.500000 &
&po x= 7.000000, y= 7.000000 &
&po x= 6.500000, y= 7.000000 &
&po x= 5.750000, y= 7.000000 &
&po x= 3.750000, y= 7.000000 &
&po x= 0.000000, y= 7.000000 &
&po x= -3.750000, y= 7.000000 &
&po x= -5.750000, y= 7.000000 &
&po x= -6.500000, y= 7.000000 &
&po x= -7.000000, y= 7.000000 &
&po x= -7.000000, y= 6.500000 &
&po x= -7.000000, y= 5.750000 &
&po x= -7.000000, y= 3.750000 &
&po x= -7.000000, y= 0.000000 &
&po x= -7.000000, y= -3.750000 &
&po x= -7.000000, y= -5.750000 &
&po x= -7.000000, y= -6.500000 &
&po x= -7.000000, y= -7.000000 &
&po x= -6.500000, y= -7.000000 &
&po x= -5.750000, y= -7.000000 &
&po x= -3.750000, y= -7.000000 &
&po x= 0.000000, y= -7.000000 &
&po x= 3.750000, y= -7.000000 &
&po x= 5.750000, y= -7.000000 &
&po x= 6.500000, y= -7.000000 &
&po x= 7.000000, y= -7.000000 &
&po x= 7.000000, y= -6.500000 &
&po x= 7.000000, y= -5.750000 &
&po x= 7.000000, y= -3.750000 &
&po x= 7.000000, y= 0.000000 &
&reg mat=2, npoint= 45 &     POLETIP
&po x= 3.750000, y= 3.750000 &
&po x= 0.750000, y= 3.750000 &
&po x= 0.685585, y= 3.750000 &
&po x= 0.701592, y= 3.643817 &
&po x= 0.726763, y= 3.537635 &
&po x= 0.756989, y= 3.431452 &
&po x= 0.787732, y= 3.325269 &
&po x= 0.815967, y= 3.219086 &
&po x= 0.845015, y= 3.112904 &
&po x= 0.876294, y= 3.006721 &
&po x= 0.909788, y= 2.900538 &
&po x= 0.945593, y= 2.794356 &
&po x= 0.983908, y= 2.688173 &
&po x= 1.025031, y= 2.581990 &
&po x= 1.069356, y= 2.475807 &
&po x= 1.117380, y= 2.369625 &
&po x= 1.169702, y= 2.263442 &
&po x= 1.227044, y= 2.157259 &
&po x= 1.290268, y= 2.051076 &
&po x= 1.360408, y= 1.944894 &
&po x= 1.438715, y= 1.838711 &
&po x= 1.526724, y= 1.732528 &
&po x= 1.626346, y= 1.626346 &
&po x= 1.732528, y= 1.526724 &
&po x= 1.838711, y= 1.438715 &
&po x= 1.944894, y= 1.360408 &
&po x= 2.051076, y= 1.290268 &
&po x= 2.157259, y= 1.227044 &
&po x= 2.263442, y= 1.169702 &
&po x= 2.369625, y= 1.117380 &
&po x= 2.475807, y= 1.069356 &
&po x= 2.581990, y= 1.025031 &
&po x= 2.688173, y= 0.983908 &
&po x= 2.794356, y= 0.945593 &
&po x= 2.900538, y= 0.909788 &
&po x= 3.006721, y= 0.876294 &
&po x= 3.112904, y= 0.845015 &
&po x= 3.219086, y= 0.815967 &
&po x= 3.325269, y= 0.787732 &
&po x= 3.431452, y= 0.756989 &
&po x= 3.537635, y= 0.726763 &
&po x= 3.643817, y= 0.701592 &
&po x= 3.750000, y= 0.685585 &
&po x= 3.750000, y= 0.750000 &
&po x= 3.750000, y= 3.750000 &
&reg mat= 6, npoint=5 & BRICK for
Quadrant 1
&po x= 3.750000, y= 3.750000 &
&po x= 3.750000, y= 0.750000 &
&po x= 5.750000, y= 0.750000 &
&po x= 5.750000, y= 3.750000 &
&po x= 3.750000, y= 3.750000 &
&reg mat= 7, npoint=5 &      BRICK
for Quadrant 1
&po x= 3.750000, y= 3.750000 &
&po x= 0.750000, y= 3.750000 &
```

```
 &po x= 0.750000, y= 5.750000 &
 &po x= 3.750000, y= 5.750000 &
 &po x= 3.750000, y= 3.750000 &
 &reg mat=2, npoint=7 &       FLUX
RETURN Quadrant 1
 &po x= 5.750000, y= 0.000000 &
 &po x= 6.500000, y= 0.000000 &
 &po x= 6.500000, y= 6.500000 &
 &po x= 0.000000, y= 6.500000 &
 &po x= 0.000000, y= 5.750000 &
 &po x= 5.750000, y= 5.750000 &
 &po x= 5.750000, y= 0.000000 &
 &reg mat=2, npoint= 45 &     POLETIP
 &po x= -3.750000, y= 3.750000 &
 &po x= -0.750000, y= 3.750000 &
 &po x= -0.685585, y= 3.750000 &
 &po x= -0.701592, y= 3.643817 &
 &po x= -0.726763, y= 3.537635 &
 &po x= -0.756989, y= 3.431452 &
 &po x= -0.787732, y= 3.325269 &
 &po x= -0.815967, y= 3.219086 &
 &po x= -0.845015, y= 3.112904 &
 &po x= -0.876294, y= 3.006721 &
 &po x= -0.909788, y= 2.900538 &
 &po x= -0.945593, y= 2.794356 &
 &po x= -0.983908, y= 2.688173 &
 &po x= -1.025031, y= 2.581990 &
 &po x= -1.069356, y= 2.475807 &
 &po x= -1.117380, y= 2.369625 &
 &po x= -1.169702, y= 2.263442 &
 &po x= -1.227044, y= 2.157259 &
 &po x= -1.290268, y= 2.051076 &
 &po x= -1.360408, y= 1.944894 &
 &po x= -1.438715, y= 1.838711 &
 &po x= -1.526724, y= 1.732528 &
 &po x= -1.626346, y= 1.626346 &
 &po x= -1.732528, y= 1.526724 &
 &po x= -1.838711, y= 1.438715 &
 &po x= -1.944894, y= 1.360408 &
 &po x= -2.051076, y= 1.290268 &
 &po x= -2.157259, y= 1.227044 &
 &po x= -2.263442, y= 1.169702 &
 &po x= -2.369625, y= 1.117380 &
 &po x= -2.475807, y= 1.069356 &
 &po x= -2.581990, y= 1.025031 &
 &po x= -2.688173, y= 0.983908 &
 &po x= -2.794356, y= 0.945593 &
 &po x= -2.900538, y= 0.909788 &
 &po x= -3.006721, y= 0.876294 &
 &po x= -3.112904, y= 0.845015 &
 &po x= -3.219086, y= 0.815967 &
 &po x= -3.325269, y= 0.787732 &
 &po x= -3.431452, y= 0.756989 &
 &po x= -3.537635, y= 0.726763 &
 &po x= -3.643817, y= 0.701592 &
 &po x= -3.750000, y= 0.685585 &
 &po x= -3.750000, y= 0.750000 &
 &po x= -3.750000, y= 3.750000 &
 &reg mat= 6, npoint=5 &      BRICK
for Quadrant 2
 &po x= -3.750000, y= 3.750000 &
 &po x= -3.750000, y= 0.750000 &
 &po x= -5.750000, y= 0.750000 &
 &po x= -5.750000, y= 3.750000 &
 &po x= -3.750000, y= 3.750000 &
 &reg mat= 9, npoint=5 &      BRICK
for Quadrant 2
 &po x= -3.750000, y= 3.750000 &
 &po x= -0.750000, y= 3.750000 &
 &po x= -0.750000, y= 5.750000 &
 &po x= -3.750000, y= 5.750000 &
 &po x= -3.750000, y= 3.750000 &
 &reg mat=2, npoint=7 &       FLUX
RETURN Quadrant 2
 &po x= -5.750000, y= 0.000000 &
 &po x= -6.500000, y= 0.000000 &
 &po x= -6.500000, y= 6.500000 &
 &po x= 0.000000, y= 6.500000 &
 &po x= 0.000000, y= 5.750000 &
 &po x= -5.750000, y= 5.750000 &
 &po x= -5.750000, y= 0.000000 &
 &reg mat=2, npoint= 45 &     POLETIP
 &po x= -3.750000, y= -3.750000 &
 &po x= -0.750000, y= -3.750000 &
 &po x= -0.685585, y= -3.750000 &
 &po x= -0.701592, y= -3.643817 &
 &po x= -0.726763, y= -3.537635 &
 &po x= -0.756989, y= -3.431452 &
 &po x= -0.787732, y= -3.325269 &
 &po x= -0.815967, y= -3.219086 &
 &po x= -0.845015, y= -3.112904 &
 &po x= -0.876294, y= -3.006721 &
 &po x= -0.909788, y= -2.900538 &
 &po x= -0.945593, y= -2.794356 &
 &po x= -0.983908, y= -2.688173 &
 &po x= -1.025031, y= -2.581990 &
 &po x= -1.069356, y= -2.475807 &
 &po x= -1.117380, y= -2.369625 &
 &po x= -1.169702, y= -2.263442 &
 &po x= -1.227044, y= -2.157259 &
 &po x= -1.290268, y= -2.051076 &
 &po x= -1.360408, y= -1.944894 &
 &po x= -1.438715, y= -1.838711 &
 &po x= -1.526724, y= -1.732528 &
 &po x= -1.626346, y= -1.626346 &
 &po x= -1.732528, y= -1.526724 &
 &po x= -1.838711, y= -1.438715 &
 &po x= -1.944894, y= -1.360408 &
 &po x= -2.051076, y= -1.290268 &
 &po x= -2.157259, y= -1.227044 &
 &po x= -2.263442, y= -1.169702 &
 &po x= -2.369625, y= -1.117380 &
 &po x= -2.475807, y= -1.069356 &
 &po x= -2.581990, y= -1.025031 &
```

```
 &po x= -2.688173, y= -0.983908 &
 &po x= -2.794356, y= -0.945593 &
 &po x= -2.900538, y= -0.909788 &
 &po x= -3.006721, y= -0.876294 &
 &po x= -3.112904, y= -0.845015 &
 &po x= -3.219086, y= -0.815967 &
 &po x= -3.325269, y= -0.787732 &
 &po x= -3.431452, y= -0.756989 &
 &po x= -3.537635, y= -0.726763 &
 &po x= -3.643817, y= -0.701592 &
 &po x= -3.750000, y= -0.685585 &
 &po x= -3.750000, y= -0.750000 &
 &po x= -3.750000, y= -3.750000 &
 &reg mat= 8, npoint=5 &      BRICK
for Quadrant 3
 &po x= -3.750000, y= -3.750000 &
 &po x= -3.750000, y= -0.750000 &
 &po x= -5.750000, y= -0.750000 &
 &po x= -5.750000, y= -3.750000 &
 &po x= -3.750000, y= -3.750000 &
 &reg mat= 9, npoint=5 &      BRICK
for Quadrant 3
 &po x= -3.750000, y= -3.750000 &
 &po x= -0.750000, y= -3.750000 &
 &po x= -0.750000, y= -5.750000 &
 &po x= -3.750000, y= -5.750000 &
 &po x= -3.750000, y= -3.750000 &
 &reg mat=2, npoint=7 &       FLUX
RETURN Quadrant 3
 &po x= -5.750000, y= 0.000000 &
 &po x= -6.500000, y= 0.000000 &
 &po x= -6.500000, y= -6.500000 &
 &po x= 0.000000, y= -6.500000 &
 &po x= 0.000000, y= -5.750000 &
 &po x= -5.750000, y= -5.750000 &
 &po x= -5.750000, y= 0.000000 &
 &reg mat=2, npoint= 45 &     POLETIP
 &po x= 3.750000, y= -3.750000 &
 &po x= 0.750000, y= -3.750000 &
 &po x= 0.685585, y= -3.750000 &
 &po x= 0.701592, y= -3.643817 &
 &po x= 0.726763, y= -3.537635 &
 &po x= 0.756989, y= -3.431452 &
 &po x= 0.787732, y= -3.325269 &
 &po x= 0.815967, y= -3.219086 &
 &po x= 0.845015, y= -3.112904 &
 &po x= 0.876294, y= -3.006721 &
 &po x= 0.909788, y= -2.900538 &
 &po x= 0.945593, y= -2.794356 &
 &po x= 0.983908, y= -2.688173 &
 &po x= 1.025031, y= -2.581990 &
 &po x= 1.069356, y= -2.475807 &
 &po x= 1.117380, y= -2.369625 &
 &po x= 1.169702, y= -2.263442 &
 &po x= 1.227044, y= -2.157259 &
 &po x= 1.290268, y= -2.051076 &
 &po x= 1.360408, y= -1.944894 &
 &po x= 1.438715, y= -1.838711 &
 &po x= 1.526724, y= -1.732528 &
 &po x= 1.626346, y= -1.626346 &
 &po x= 1.732528, y= -1.526724 &
 &po x= 1.838711, y= -1.438715 &
 &po x= 1.944894, y= -1.360408 &
 &po x= 2.051076, y= -1.290268 &
 &po x= 2.157259, y= -1.227044 &
 &po x= 2.263442, y= -1.169702 &
 &po x= 2.369625, y= -1.117380 &
 &po x= 2.475807, y= -1.069356 &
 &po x= 2.581990, y= -1.025031 &
 &po x= 2.688173, y= -0.983908 &
 &po x= 2.794356, y= -0.945593 &
 &po x= 2.900538, y= -0.909788 &
 &po x= 3.006721, y= -0.876294 &
 &po x= 3.112904, y= -0.845015 &
 &po x= 3.219086, y= -0.815967 &
 &po x= 3.325269, y= -0.787732 &
 &po x= 3.431452, y= -0.756989 &
 &po x= 3.537635, y= -0.726763 &
 &po x= 3.643817, y= -0.701592 &
 &po x= 3.750000, y= -0.685585 &
 &po x= 3.750000, y= -0.750000 &
 &po x= 3.750000, y= -3.750000 &
 &reg mat= 8, npoint=5 &      BRICK
for Quadrant 4
 &po x= 3.750000, y= -3.750000 &
 &po x= 3.750000, y= -0.750000 &
 &po x= 5.750000, y= -0.750000 &
 &po x= 5.750000, y= -3.750000 &
 &po x= 3.750000, y= -3.750000 &
 &reg mat= 7, npoint=5 &      BRICK
for Quadrant 4
 &po x= 3.750000, y= -3.750000 &
 &po x= 0.750000, y= -3.750000 &
 &po x= 0.750000, y= -5.750000 &
 &po x= 3.750000, y= -5.750000 &
 &po x= 3.750000, y= -3.750000 &
 &reg mat=2, npoint=7 &       FLUX
RETURN Quadrant 4
 &po x= 5.750000, y= 0.000000 &
 &po x= 6.500000, y= 0.000000 &
 &po x= 6.500000, y= -6.500000 &
 &po x= 0.000000, y= -6.500000 &
 &po x= 0.000000, y= -5.750000 &
 &po x= 5.750000, y= -5.750000 &
 &po x= 5.750000, y= 0.000000 &
 &reg mat=1,cur=5., npoint=2 &
      PANIDRA CURRENT LINE
 &po x= 3.750000, y= 3.750000 &
 &po x= 5.750000, y= 3.750000 &
```