Chapter 17. Large Aperture Quadrupole

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In several straight sections of the Main Injector, i.e., MI-10, MI-30, MI-40, MI-52 and MI-62, (and also MI-60 when the NuMI extraction beam line is in place) the quadrupoles upstream of the Lambertson magnets limit the physical aperture; the beam is deflected at these locations during injection and extraction. In order to reduce beam losses at these locations, Large Aperture Quadrupoles (LAQ) will be installed replacing the regular quadrupoles. These LAQs have an identical design to regular Main Injector quadrupoles, but the aperture is increased from 83.48 mm in diameter to 102.24 mm and the number of turns per pole from 4 to 6. The main LAQ parameters are listed in Table 17.1.

Table 17.1. Large Aperture Quadrupole Parameters

Aperture diameter	102.24	mm
Length	2.134	m
Strength	19.6	T/m
Integrated strength	41.87	T-m/m
Turns/pole	6	
Peak current	3630	A
RMS current	2000	A
Winding resistance	7.3	mΩ
Inductance	1.5	mH
Peak power	96	kW
RMS power	29	kW
Conductor dimensions	14.35 × 25.4	mm
Conductor hole diameter	6.35	mm
Number of water circuits	4	
Water pressure drop	4	atm
Water flow	16	l/min
Water temperature rise	27	˚C
Weight	5800	kg

Figures 17.1 and 17.2 show the magnetic field distribution and field quality of the LAQ. These LAQs will be on the same bus as the regular quadrupoles. The relative gradient change of the regular quadrupole and the LAQ is shown on Figure 17.3. The LAQ has higher iron saturation in the pole area because of its larger aperture. This ~1% difference between regular quadrupole and LAQ can be compensated by an additional correction coil. Figures 17.4 and 17.5 show the cross-section and end view of the LAQ.

The LAQ is based on MI regular quadrupole materials and technology and will use the same copper conductor, the same low carbon laminated steel and electrical insulation. Nevertheless the separate coil vacuum impregnation technique will be used for better reliability.

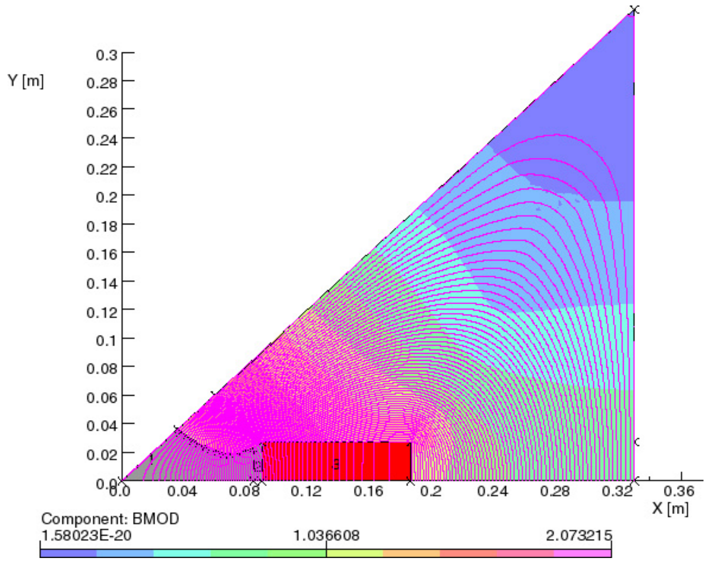

Figure 17.1. Flux lines and flux density distribution.

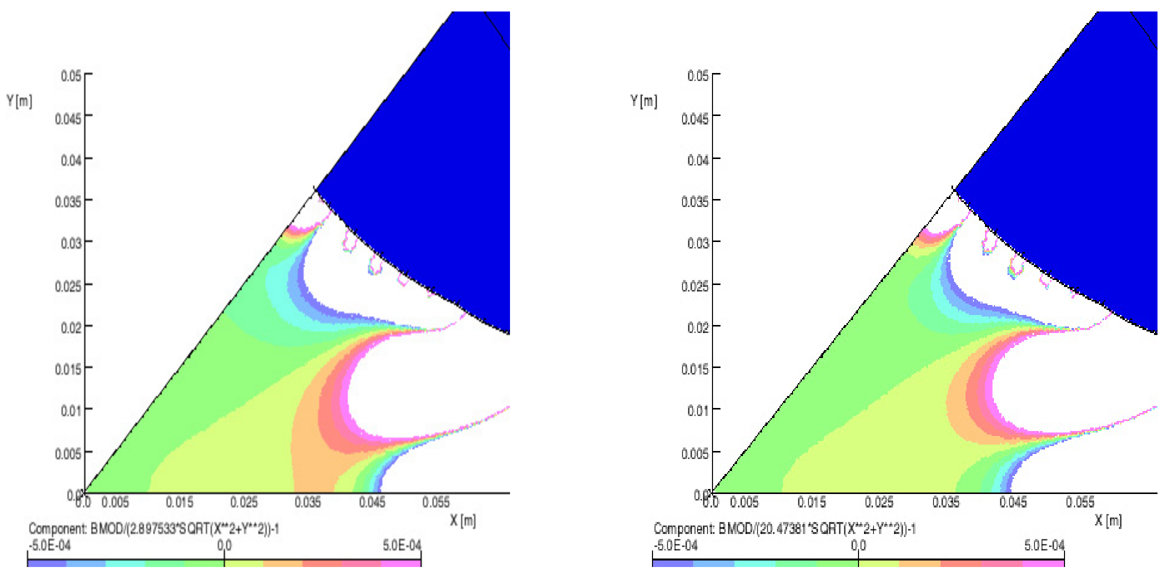

Figure 17.2. Field quality at injection (left) and maximum current (right)

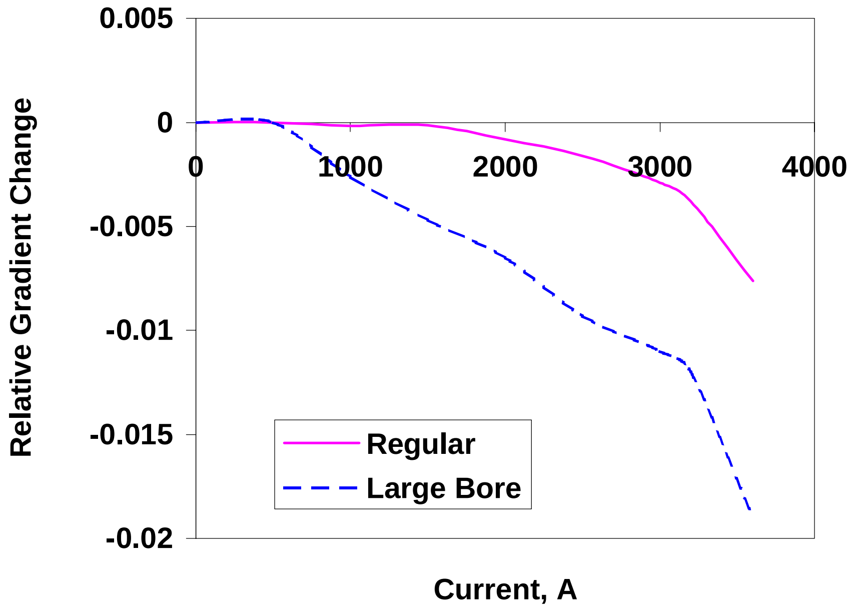

Figure 17.3. Relative gradient change of the regular MI quadrupole and Large Aperture Quadrupole

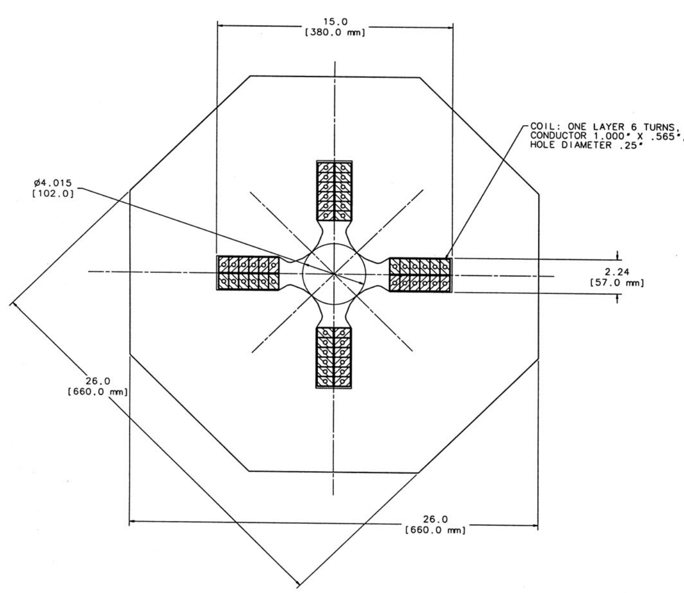

Figure 17.4. Large Aperture Quadrupole cross-section

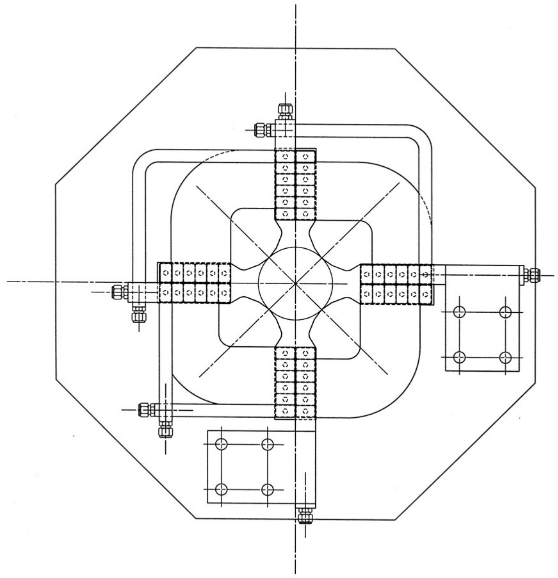

Figure 17.5. Large Aperture Quadrupole end view