Chapter 9

Magnet System

This chapter discusses the parameters and the design of the magnets to use at KEKB. Plans on the magnet power supply systems, magnet installation procedure and alignment strategies are also presented. Special magnets required near the beam collision point are discussed in a separate chapter on the Interaction Region.

9.1 Magnets in the Arc and Straight Sections

Tables 9.1 and 9.2 tabulates the magnets that are required for KEKB. The tolerances on the multipole field errors for the dipole and quadrupole magnets have been determined from studies on the expected dynamic aperture and emittance coupling. Table 9.3 summarizes the required field qualities. It has been found that these requirements are well met by existing magnets in the TRISTAN Main Ring (hereafter abbreviated as "TR"). Table 9.4 shows the field quality achieved by TR magnets for reference.

From considerations on the cost and schedule, a decision has been made to make maximum use of magnets from the existing TR. However, it is still necessary to fabricate new magnets to fill the requirements for KEKB. When new magnets are built, they will be all made of lamination (the TR magnets to be re-used are also all lamination-type). Steering correction magnets will be also built with lamination, since very fine and rapid beam control is required at KEKB. The core material will be 0.5 mm-thick silicon steel, with inorganic insulation layers on both sides. The specifications for the lamination include: induction $B^{50} > 1.6$ T and coercive force $H_c^{1.5} < 70$ A/m with $\Delta B^{50}/B^{50} < \pm 1$ % and $\Delta H_c^{1.5}/H_c^{1.5} < \pm 5$ %.

Compared to the TR magnets, the LER magnets generally will have a wider gap, larger bore and shorter length. The HER magnets have similar dimensions as TR.

Designation	Half gap or bore radius (mm)	Lamination length (m)	B (T), B' (T/m), or B'' (T/m^2)	Number of magnets	Usage	Comments
Dipole magnets						
B$_{arc}$	57	0.76	0.848	108	normal bend	new
	57	0.76	0.848	8	half bend	new
	57	0.76	0.08	2	crossing	new
	57	0.76	0.848	16	chicane	new
B$_{lc}$	57	2.5	0.42	30	local correction	new
B$_{v}$	57	1.5	0.2	4	vertical bend	new
B$_{t}$	57	0.3	0.65	3	near IR	new
Quadrupole magnets						
Q$_{arc}$	55	0.4	10.3	436	arc, straight	new
Q$_{rf}$	80	0.5	6.6	16	RF section	new
Sextupole magnets						
SxF	56	0.39	350	52	focus	recycle
SxD.1	56	0.39	350	44	defocus	recycle
SxD.2	56	0.54	350	8	defocus	recycle

Table 9.1: LER Magnet types.

Designation	Half gap or bore radius (mm)	Lamination length (m)	B (T), B' (T/m), or B'' (T/m^2)	Number of magnets	Usage	Comments
Dipole magnets						
B$_{arc}$	35	5.804	0.3	112	normal bend	recycle
	35	5.804		2	crossing	recycle
Quadrupole magnets						
Q$_{arc}$	50	0.6	10.9	144	arc, straight	new
Q$_{rf}$	80	1.0	6.6	32	RF section	new
QA	50	0.762	8.5	184	arc, straight	recycle
QB	50	0.95	8.5	92	arc, straight	recycle
Sextupole magnets						
SxF	56	0.54	350	52	focus	recycle
SxD	56	0.80	350	52	defocus	new

Table 9.2: HER Magnet types.

	Tolerance at 50 mm radius
Dipole magnets	$B_3/B_1 < 0.12$ %
	$B_5/B_1 < 0.45$ %
Quadrupole magnets	$B_6/B_2 < 0.12$ %
	$B_{10}/B_2 < 0.14$ %

Table 9.3: Tolerances of systematic multipole errors

Dipole		
Field uniformity within the aperture (±60 mm)	$< \pm 2 \times 10^{-4}$	
Integral dipole strength error $\Delta L_B/L_B$	$\sigma = 4.1 \times 10^{-4}$	for $B = 0.97$ kG
	4.0×10^{-4}	4.2
	4.8×10^{-4}	5.2
	0.028	remanent
Gap error $\Delta g/g$	$\sigma = 2.8 \times 10^{-4}$	
Core length error $\Delta L/L$	$\sigma = 0.8 \times 10^{-4}$	
Quadrupole (QA)		
High multipoles at aperture / Quadrupole field	$< 2 \times 10^{-4}$	with end shim
Integral quadrupole strength error $\Delta L_q/L_q$	$\sigma = 4.2 \times 10^{-4}$	for $g = 4.7$ T/m
	7.9×10^{-4}	18.2
	9.6×10^{-4}	21.
	0.046	remanent
Bore error $\Delta r/r$	$\sigma = 1.2 \times 10^{-4}$	
Core length error $\Delta L/L$	$\sigma = 1.7 \times 10^{-4}$	
Quadrupole (QB)		
High multipoles	almost the same as QA	
Integral quadrupole strength error $\Delta L_q/L_q$	$\sigma = 4.0 \times 10^{-4}$	for $g = 4.7 \sim 21.7$ T/m
Insertion Quadrupole Magnets		
Integral quadrupole strength error $\Delta L_q/L_q$	$\sigma = 5.0 \times 10^{-4}$	for $g = 3.5 \sim 16$ T/m
Sextupole Magnets		
High multipoles at aperture / Sextupole field	18 poles $< 3 \times 10^{-3}$	
	others $< 1 \times 10^{-3}$	
Integral sextupole strength error $\Delta L_s/L_s$	$\sigma = 2.1 \times 10^{-3}$	for SXF at 350 T/m^2
	2.3×10^{-3}	for SXD

Table 9.4: Performance of the TRISTAN magnets for reference.

Shorter magnets are known to have inferior field qualities, because of increased end-field effects. In addition, the accuracy of 2-dimensional calculations will be less reliable for shorter magnets. However, we believe that the field qualities similar to the TR magnets would be possible with a careful design and fabrication process control.

The physical designs have been made for the main dipole and quadrupole magnets, the sextupole and vertical steering magnets used for the LER and HER. The 2-dimensional magnetic field code POISSON and the 3-dimensional code OPERA-3d have been used for field calculations. The full engineering design of the KEKB magnet system will be completed as soon as the final beam optics design is finalized.

9.1.1 LER

Table 9.1 summarizes the magnets that are required for the LER. Four types of dipole bend magnets are needed in the LER: B_{arc}, B_{lc}, B_v and B_t. The LER also requires two types of quadrupole magnets (Q_{arc} and Q_{rf}), and two types of sextupole magnets (SxF_{TR} and SxD_{TR}). All of them except the sextupole magnets will be newly fabricated. The LER sextupole magnets will be recycled from the TR.

Dipole Magnets

The LER requires 171 dipole magnets in total. They include 134 B_{arc}, from which 108 B_{arc} will be used for normal bends, 8 for half bends, 2 for beam crossing (the LER-HER cross-over) and 16 for the chicane structure. From the special dipole magnets, 30 B_{lc} will be used for local chromaticity correction, 4 B_v for vertical bends and 3 B_t for special use near the IR section located near the Tsukuba experimental hall.

The mechanical and electric parameters of B_{arc} are listed in Table 9.5. The lamination core length in the table does not include the side plates and electrodes. Thus the physical magnet sizes will be larger. A cross section view of the preliminary design of a LER dipole magnet (B_{arc}) is shown in Figure 9.1. The final designs of the special dipole magnets have not been fixed yet. We will proceed with physical designs of these magnets as soon as their final parameters are finalized.

Quadrupole Magnets

There are 452 quadrupoles in the LER. The 436 Q_{arc} will be used for the arc and the straight sections, except for the beam line that includes RF cavities. For the RF sections, 16 Q_{rf} which have larger aperture will be used. The mechanical and electric parameters of Q_{arc} and Q_{rf} are listed in Tables 9.6 and 9.7. Figure 9.2 shows a cross section view of the preliminary design of a LER quadrupole magnet (Q_{arc}).

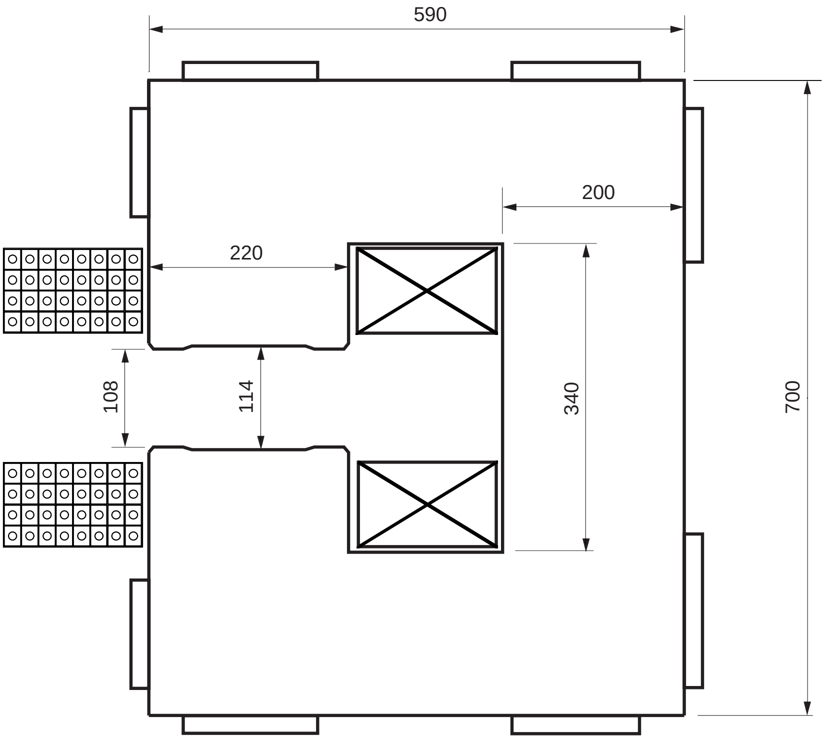

Figure 9.1: A cross section view of the preliminary design of a LER dipole magnet (B_{arc}).

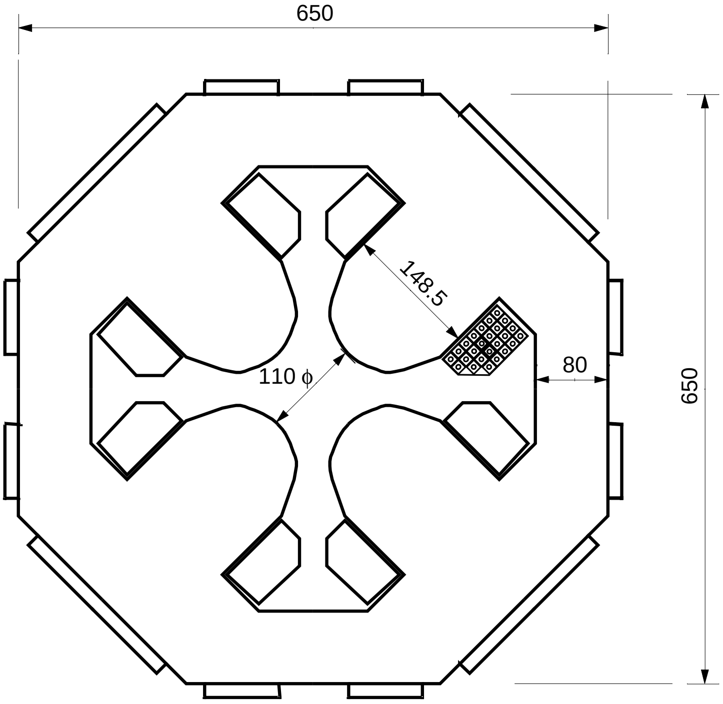

Figure 9.2: A cross section view of the preliminary design of a LER quadrupole magnet (Q_{arc}).

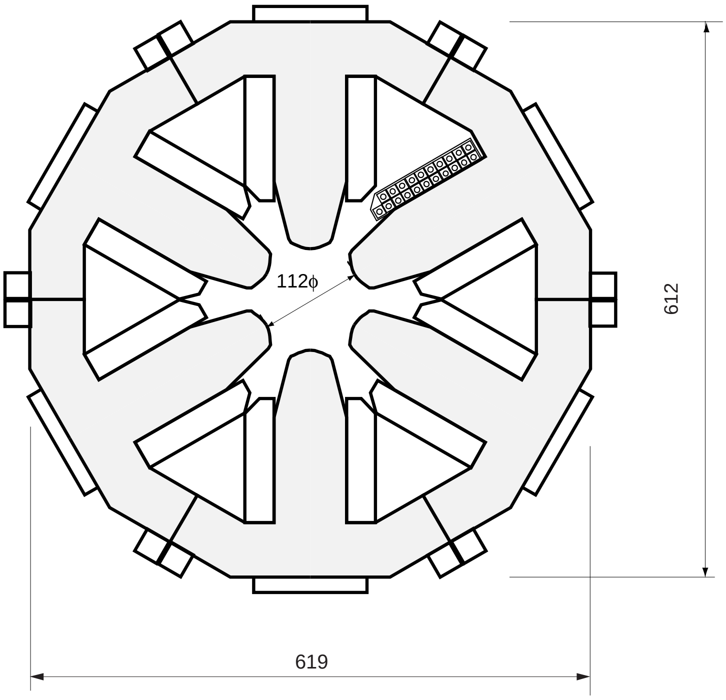

Figure 9.3: A cross section view of the preliminary design of a LER sextupole magnet.

Sextupole Magnets

The mechanical and electric parameters of the sextupoles are listed in Table 9.9. The LER will require 104 sextupoles, which consist of 56 SxF's and 48 SxD's. The present plan is to re-use the TR sextupoles, SxF_{TR} and SxD_{TR}. For each of SxF_{TR} and SxD_{TR} from TRISTAN, 96 units out of 120 are expected to be negligibly radio-active and thus adequate for re-use. The 96 SxF_{TR}'s will be recycled to provide all of the 56 SxF's and 40 SxD's. The remaining 8 SxD's will come from SxD_{TR}'s.

Radiation damages on the TR magnets will be closely inspected in the summer of 1995. Exactly which part (iron core and the coils) of the TR magnets should be reused will be decided based on the results of this inspection.

Figure 9.3 shows a cross section view of the preliminary design of a LER sextupole magnet. The HER sextupole magnets will have a similar cross section shape.

Steering Correction Magnets

The parameters of the vertical steering magnets are given in Table 9.10. The LER will require 450 vertical steering magnets, which will be located adjacent to each quadrupoles. The maximum kick angle of 1 mrad is assumed for the vertical steering magnets. Almost same number of horizontal steering magnets would be necessary in the future.

Wiggler Magnets

The wiggler magnets will be used for the LER to control the radiation damping time. The field strength of the wiggler is the same as the arc dipole magnets. The total length of wigglers will be 96 m. This is close to the total length of the arc dipoles. Detailed design of the wiggler magnet is being worked out.

9.1.2 HER

Table 9.2 summarizes the magnets that are required for the HER. There will be one type of bending magnet called B_{arc}, 4 types of quadrupoles Q_{arc}, Q_{rf}, QA and QB, and 2 types of sextupoles SxF and SxD. The Q_{arc}, Q_{rf} and SxD will be newly fabricated, while the others will be recycled from TR. Details of the recycle plan will be determined after the inspections on the TR magnets planned in the summer of 1995.

Dipole Magnets

The HER needs 114 B_{arc}'s, in which 112 B_{arc} will be used for the arc and 2 for beam crossing. The TR bending magnets will be recycled for these dipole magnets. The mechanical and electric parameters of B_{arc} are listed in Table 9.5.

Quadrupole Magnets

The HER requires 452 quadrupole magnets in total. The 144 Q_{arc} and 32 Q_{rf} will be newly fabricated. The 184 QA and 92 QB will be recycled from TR for the arc and straight sections except the beam line that includes the RF cavities. The Q_{rf}'s, which have 80 mm bore radius, will be used for the RF sections. The mechanical and electric parameters of these quadrupole magnets are listed in Tables 9.6, 9.7 and 9.8.

Sextupole Magnets

There will be 104 sextupoles in HER; 52 SxF's and 52 SxD's. At present, the SxF's will use the SxD_{TR}'s recycled from TR, while 52 SxD's with 0.8 m length will be newly fabricated. The mechanical and electric parameters of the sextupoles are listed in Table 9.9.

Dipole : B$_{arc}$	**LER**	**HER**
Number of Magnets	134	114
Half gap	57 mm	35 mm
Minimum half gap	54 mm	33.15 mm
Lamination core length	0.76 m	5.804 m
Total length	$<$ 1.27 m	$<$ 6.18 m
Full width (without electrodes)	$\sim$ 0.8 m	$\sim$ 0.62 m
Required field strength	0.76 T	0.258 T
Current × turns/pole	1250 A × 32	840 A × 10
$B_{0,max}$	0.848 T	0.3 T
Resistance	10.0 mΩ	14.0*, 10.1^{tr} mΩ
Inductance	11 $\sim$ 12 mH	12.3 mH
Voltage	12.5 V	11.76*, 8.48^{tr} V
Power	15.6 kW	9.9*, 7.1^{tr} kW
Correction coil/pole	10 A × 40	10 A × 10
Weight (core + coil)	$\sim$ 3000 kg (2400 kg + 540 kg)	$\sim$ 9600 kg

Table 9.5: Parameters of the dipole magnets for the LER and HER. The tag '*' indicates the value for new coils. The tag 'tr' is for the coils recycled from the TRISTAN Main Ring.

Steering Correction Magnets

The HER will require 450 vertical steering correction magnets. A vertical correction magnet will be installed adjacent to each individual quadrupole magnet. The requirement on the kick angle is maximum 1 mrad. Approximately the same number of horizontal steering correction magnets will be necessary in the future. The parameters of the steering correction magnets are listed in Table 9.10.

9.1.3 Magnetic Field Measurement

Newly fabricated and recycled magnets will be exercised on a test bench, and their field qualities and magnetic axes will be measured. Since the magnetic field strength is very sensitive to the temperature of the magnet and the cooling water, close attentions will be paid to measure and control such temperature during the test.

Quadrupole : $\mathbf{Q}_{arc}$	**LER**	**HER**
Number of Magnets	436	144
Bore radius	55 mm	50 mm
Lamination core length	0.4 m	0.6 m
Total length	< 0.63 m	< 0.83 m
Half width (without electrodes)	~ 0.35 m	~ 0.35 m
Required field strength	8.5 T/m	11 T/m
Current × turns/pole	500 A × 25	500 A × 22
$B'_{0,max}$	10.3 T/m	10.9 T/m
Resistivity	25.1 mΩ	32.2 mΩ
Inductance	~ 22 mH	~ 30 mH
Voltage	12.6 V	16.1 V
Power	6.28 kW	8.04 kW
Correction coil/pole	10 A × 12	10 A × 12
Weight (core + coil)	~ 1230 kg (1100 kg + 130 kg)	~ 1750 kg (1550 kg + 160 kg)

Table 9.6: Parameters of the arc quadrupole magnets for the LER and HER.

Quadrupole : $\mathbf{Q}_{rf}$	**LER**	**HER**
Number of Magnets	16	32
Bore radius	80 mm	80 mm
Lamination core length	0.5 m	1.0 m
Total length	< 0.75 m	< 1.25 m
Half width (without electrodes)	~ 0.40 m	~ 0.40 m
Required field strength	5.1 T/m	6.0 T/m
Current × turns/pole	500 A × 34	500 A × 34
$B'_{0,max}$	6.6 T/m	6.6 T/m
Resistivity	52 mΩ	86 mΩ
Inductance	~ 27 mH	~ 49 mH
Voltage	26 V	43 V
Power	12.9 kW	21.5 kW
Correction coil/pole	10 A × 17	10 A × 17
Weight (core + coil)	~ 1700 kg (1480 kg + 200 kg)	~ 3150 kg (2820 kg + 300 kg)

Table 9.7: Parameters of the quadrupole magnets in the RF sections for the LER and HER.

Quadrupole : QA, QB	**HER: QA** (recycled from TR)	**HER: QB** (recycled from TR)
Number of Magnets	184	92
Bore radius	50 mm	50 mm
Lamination core length	0.762 m	0.95 m
Total length	< 1.0 m	< 1.2 m
Half width (without electrodes)	0.42 m	0.42 m
Required field strength	T/m	T/m
Current × turns/pole	500 A × 17	500 A × 17
$B'_{0,max}$	8.5 T/m	8.5 T/m
Resistivity	13.0 mΩ	15.2 mΩ
Inductance	15.5 mH	19 mH
Voltage	6.5 V	7.6 V
Power	3.25 kW	3.8 kW
Correction coil/pole	10 A × 10	10 A × 10
Weight (core + coil)	~ 4500 kg	~ 5600 kg

Table 9.8: Parameters of the QA and QB quadrupole magnets for the HER. Calculations have been made with an assumption that these magnets are recycled from the TRISTAN main ring.

Sextupole	**LER**	**HER**
	Sx: 0.39 m long (recycled from SXF$_{TR}$)	**SxF: 0.54 m long** (recycled from SXD$_{TR}$)
Number of Magnets	96	52
Bore radius	56 mm	56 mm
Lamination core length	0.39 m	0.54 m
Total length	< 0.51 m	< 0.66 m
Half width (without electrodes)	~ 0.36 m	~ 0.36 m
Required field strength	350 T/m^2	350 T/m^2
Current × turns/pole	425 A × 21	425 A × 21
$B''_{0,max}$ measured	350 T/m^2	350 T/m^2
Resistivity	32.8 mΩ	40.9 mΩ
Inductance	15.5 mH	19 mH
Voltage	13.9 V	17.4 V
Power	5.9 kW	7.4 kW
Correction coil/pole		
Weight (core + coil)	830 kg $(720 + 110)$	1100 kg $(960 + 140)$
	Sx: 0.54 m long (recycled from SXD$_{TR}$)	**SxD: 0.8 m long** (new)
Number of Magnets	8	52
Bore radius	56 mm	56 mm
Lamination core length	0.54 m	0.8 m
Total length	< 0.66 m	< 0.92 m
Half width (without electrodes)	~ 0.36 m	~ 0.36 m
Required field strength	350 T/m^2	350 T/m^2
Current × turns/pole	425 A × 21	425 A × 21
$B''_{0,max}$ measured	350 T/m^2	350 T/m^2
Resistivity	40.9 mΩ	56.6 mΩ
Inductance	19 mH	28 mH
Voltage	17.4 V	24.1 V
Power	7.4 kW	10.2 kW
Correction coil/pole		
Weight (core + coil)	1100 kg $(960 + 140)$	1590 kg $(1390 + 200)$

Table 9.9: Parameters of the sextupole magnets for the LER and HER.

	LER	**HER**
Steering: STV		
Number of Magnets	450	450
Bore radius	80 mm	80 mm
Lamination core length	0.2 m	0.2 m
Total length	< 0.3 m	< 0.35 m
Required kick angle	1 mrad	1 mrad
Current × turns/pole	5 A × 760	5 A × 1700
Steering: STH		
Number of Magnets	450	450
Bore radius	80 mm	80 mm
Lamination core length	0.2 m	0.2 m
Total length	< 0.3 m	< 0.35 m
Required kick angle	1 mrad	1 mrad
Current × turns/pole	5 A × 760	5 A × 1700

Table 9.10: Parameters of the steering correction magnets for the LER and HER.

Dipole Magnets

A long flip coil and a small flip coil will be used for measurements of dipole magnets. The integral dipole field is obtained by measuring the voltage induced on the long flip coil which rotates in the magnetic field. The small flip coil is used for field mapping. This small flip coil system is mounted on 3-axes mover, and it measures the magnetic field in the fiducial volume point by point.

The absolute values of the integral and the center field strength will be also measured by using some devices. These measurement systems will be developed soon.

Quadrupole and Sextupole Magnets

The magnetic field of quadrupole and sextupole magnets of KEKB will be measured by harmonic coil (rotating coil) systems. Each harmonic coil system consists of one long coil and three short coils located at the center and both ends. The long coil measures the integral field strength directly and its quality. The center field is measured by the middle short coil. The two short coils at both ends are used to assess the end effects and to locate the magnetic axis to the measuring system.

Before conducting field measurements, the magnet should be pre-aligned to the measuring bench. A laser beam is used as the reference axis. A 3-axes magnet mover

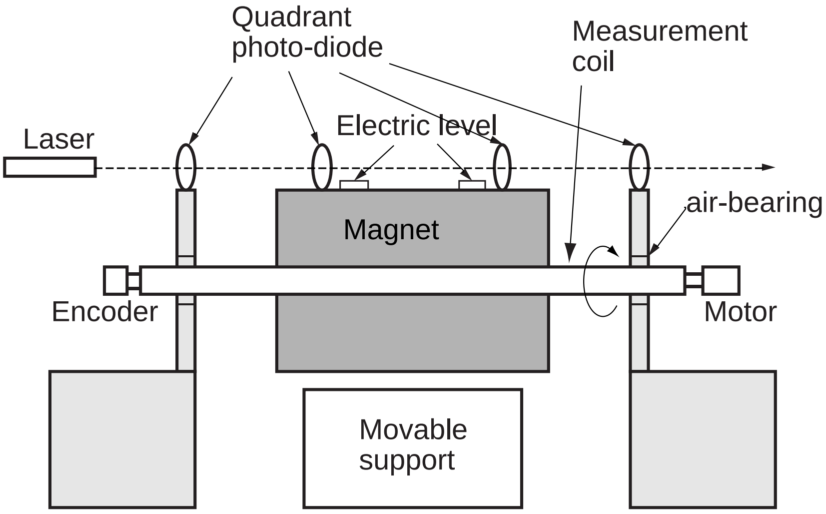

Figure 9.4: A schematic view of the magnetic field measurement system using a rotating coil.

is used to control the magnet position, which is monitored by electric level gauges. The laser beam is also used for checking the positions of surveying targets on each magnet relative to the magnetic axis. Figure 9.4 shows the principle of field measurements with a rotating coil.

The small flip coil for the dipole field mapping can be also used for field mapping of the quadrupoles and sextupoles. These harmonic coil systems, some devices for the absolute value measurements and the 3-axes magnet movers should be developed soon.

9.1.4 Near-Future Plans

Conceptual designs have been done on the main dipole, quadrupole, sextupole and vertical steering magnets for both the LER and HER. As soon as the beam optics design is finalized, we will proceed with complete engineering designs of all the magnets. Various cost saving measures will be taken, in as much as requirements on the accelerator performance allows. Optimization of the magnet parameters will be made to make maximum use of the existing power supplies, which will be recycled from TRISTAN.

Since KEKB accelerator must handle high intensity beams with small bunch sizes, the magnet system needs a very precise control. Temperature measurements of the magnets, cooling water and tunnel air are planned to analyze variations of beam parameters. Magnetic flux monitors may be also useful.

9.2 Magnet Power Supplies and Cabling

9.2.1 Magnet Power Supply

The magnet power supply units required at KEKB are listed in Table 9.11. The total number of large power supplies for the dipole, quadrupole and sextupole magnets is 382. From the existing TRISTAN facility about 80 units will be recycled for operating the dipole and quadrupole magnets at KEKB. Thus the remaining 300 units, which include most of the sextupole magnet power supplies, need to be newly installed.

The output voltage and the current from the power supplies have been determined by considering the impedance of power feeding cables with adequate margins for the output voltage. The designs of the power supply units assume that a substantial fraction of dipole, quadrupole and sextupole magnets will be recycled from TRISTAN, as stated earlier. It should be noted that the specifications for the HER magnet power supplies are subject to change, if the coils are rewound for those TRISTAN magnets.

The maximum output current of the majority of large power supplies is set to be 500 A for two reasons: (1) the cost of power feeding cables, which are very long, can be reduced by using relatively thin cables, and (2) the room that is available on the cable ladders in the tunnel is limited, such that not much thick cables can be used. With this system design choice, both the DC output voltage and the current of large power supplies are smaller than the case with TRISTAN.

For the power supplies that are recycled from TRISTAN, the DCCT (DC Current Transformer) heads will be replaced by new units, which have an optimized range for current measurements at KEKB. If it is found necessary for improved power factor and better regulation, three-phase AC transformers will be applied to the input of some of the power supplies.

Table 9.12 shows a list of stability requirements and limits on the ripple content for magnet power supplies at KEKB.

The requirements on the steering correction magnets at KEKB are much more stringent than the case with TRISTAN. Adequate power supplies for the steering correction magnets will be newly developed and will be fabricated.

9.2.2 Installation

Along the TRISTAN tunnel there exist 8 power supply stations: 4 big and 4 small. Most of the TRISTAN magnet power supplies that are housed in the 4 big supply stations will be re-used for KEKB with some improvements, as discussed earlier.

Ring	Magnet type	Voltage (V)	Current (A)	Number of units	Total
LER	Dipole	1400	1250	1	
		120	1250	2	
		70	1250	2	
		30	1250	2	
			1250	15	
	Wiggler		1250	8	
					30
	Quadrupole	700	500	4	
		600	500	1	
		400	500	2	
		90	500	5	
		60	500	21	
		40	500	26	
		30	500	59	
				2	120
	Sextupole	40	425	52	
			425	2	54
	Steering			886	886
HER	Dipole	1400	840	1	
		40	840	4	
		20	840	3	
			840	9	17
	Quadrupole	900	500	1	
		500	500	3	
		400	500	4	
		300	500	3	
		100	500	10	
		60	500	12	
		30	500	46	
		20	500	29	
			500	1	109
	Sextupole	60	425	24	
		40	425	28	52
	Steering			886	886

Table 9.11: The list of magnet power supplies required at KEKB.

Magnet type	Stability	Ripple content
Dipole	1×10^{-4} / 8 h	5×10^{-5}
Quadrupole	1×10^{-4} / 8 h	1×10^{-5}
Sextupole	5×10^{-4} / 1 h	5×10^{-4}
Steering correction	5×10^{-4} / 8 h	5×10^{-5}

Table 9.12: Stability requirements and limits on the ripple content for magnet power supplies at KEKB

The four small power supply stations will house the power supplies as follows: 12 units for quadrupole, 26 for sextupole and 443 for steering correction magnets.

In addition, a part of Oho, Fuji, and Nikko experimental halls, and the Tsukuba RF power station will be used for remaining dipole, wiggler and quadrupole magnet power supplies. A multi-stage structure will be built in each of these halls to make maximum use of available areas.

9.2.3 Cooling Water

The large power supplies in the existing 4 big power supply stations are all cooled by pure water. The consumption of pure water has been about 750 ℓ/min for each power station in the TRISTAN MR operation. The requirement will be reduced to roughly a half for KEKB.

In a new power supply station in the Oho experimental hall, 14 large power supplies (a few hundred KW each) need to be installed. Those power supplies will be water-cooled, considering the limited air conditioning capacity of the station.

All other power supplies that are newly built will be air-cooled for improved handling in the maintenance work.

9.2.4 Electric Power

The maximum total electric power of the magnet power supplies is 19 MW. Considering the power factor, the capacity of the input power line will somewhat exceed 20 MVA. However, during actual accelerator operation the total electric power is estimated to be less than 15 MW. Overall, it is not considered necessary to increase the power of the input power line.

9.2.5 Wiring of DC Power Feed Cables

Approximately 500 km of 2-core cables in total is required for the steering correction magnets in the entire KEKB. The total length of the cables for quadrupole magnets will be roughly 100 km. Thus the cabling cost can be quite large. As discussed earlier, the maximum DC current of most of large power supplies is kept below 500 A to alleviate this situation. Still the weight of cable bundles can exceed 300 kg/m in the most crowded areas.

9.2.6 Power Supply Controls

All power supplies will be controlled by distributed VME computers. Since KEKB has a large number of steering correction magnets, the cost of their control interface is a non-trivial problem. To address this issue, a specialized interface will be developed, where control set points are serially sent to the power supply units.

9.2.7 R & D for Magnet Power Supplies

Two prototype power supply units will be built in JFY 1995. One is a relatively low-power magnet power supply with a power of 20 kW. A switch-mode power supply will be developed for reducing the physical size of the unit, while increasing the power factor. The other is a power supply for steering correction magnets. The techniques required for satisfying the tight tolerance and stability specifications will be studied.

9.2.8 Schedule

The bulk of magnet power supply units will be built in 1997 and 1998. The wiring of the DC power cables and the installation of the control system will be carried out before installing the power supply units. The work is coordinated with the rest of the accelerator construction schedule.

9.3 Installation and alignment

About 300 primary network reference points will be installed on the floor inside the ring tunnel. The interval of the reference points is roughly 10 m. The work will be done by using a laser tracker system. The overall precision for those primary network points is expected to be about 2 mm.

After all the old TRISTAN accelerator elements are brought out of the tunnel and the floor is cleared, reference points will be marked on the floor by referring to those primary network points.

Two points will be marked for each dipole magnet in arc sections, one at the position of the upstream edge and another at the downstream edge. By connecting those points the lines will be created on which other individual magnets should be installed. The positions to install all these magnets can be easily obtained by measuring the distance along those connection lines. In straight sections, reference points will be marked on the floor every 10 m in distance.

Magnets for the straight sections can be brought in from both experimental halls and from carry-in entrances in the arc sections. The magnets for the arc sections are brought into the tunnel from carry-in entrances by using magnet carriers.

Magnets are aligned by using a laser tracker and reflector targets. According to the vendor catalog, the precision for the position measurement is 1 ppm for the distance and 10 ppm for the angle. The precision of the angle measurement is improved to 5 ppm by averaging the data taken at the same position. The data can be collected at the rate of 500 Hz. The relative precision of alignment in the distance of 50 m is expected to be about 0.1 mm.

In the straight sections, magnets are also aligned by using the laser tracker. The location along the beam line is measured by a mekometer, a polarization modulated laser interferometer. With this technique, the expected precision for the distance is 0.2 mm in the distance of 200 m.

9.3.1 Layout for arc and straight sections

Both the LER and HER rings consist of four arc sections and four straight sections. Each arc quadrant consists of 7 regular cells, each of which includes 5 dipole magnets B_{arc}.

Portions of the plan view of the arc sections are shown in Figure 9.5. In the part (A) the LER is placed outside and the HER, and in the part (B) the LER is outside the HER.

The two rings of the LER and HER cross each other in the north (Tsukuba) and the south (Fuji) straight sections. The electron and the positron beams collide in the Tsukuba experimental hall and cross each other in the Fuji region.

The RF cavities for the low energy ring are located in the Fuji region, and those for the high energy ring in the Nikko and the Oho region. Wiggler magnets are placed in the Nikko and the Oho region to adjust the beam dumping times. A schematic layout view of the Nikko straight section is shown in Figure 9.6

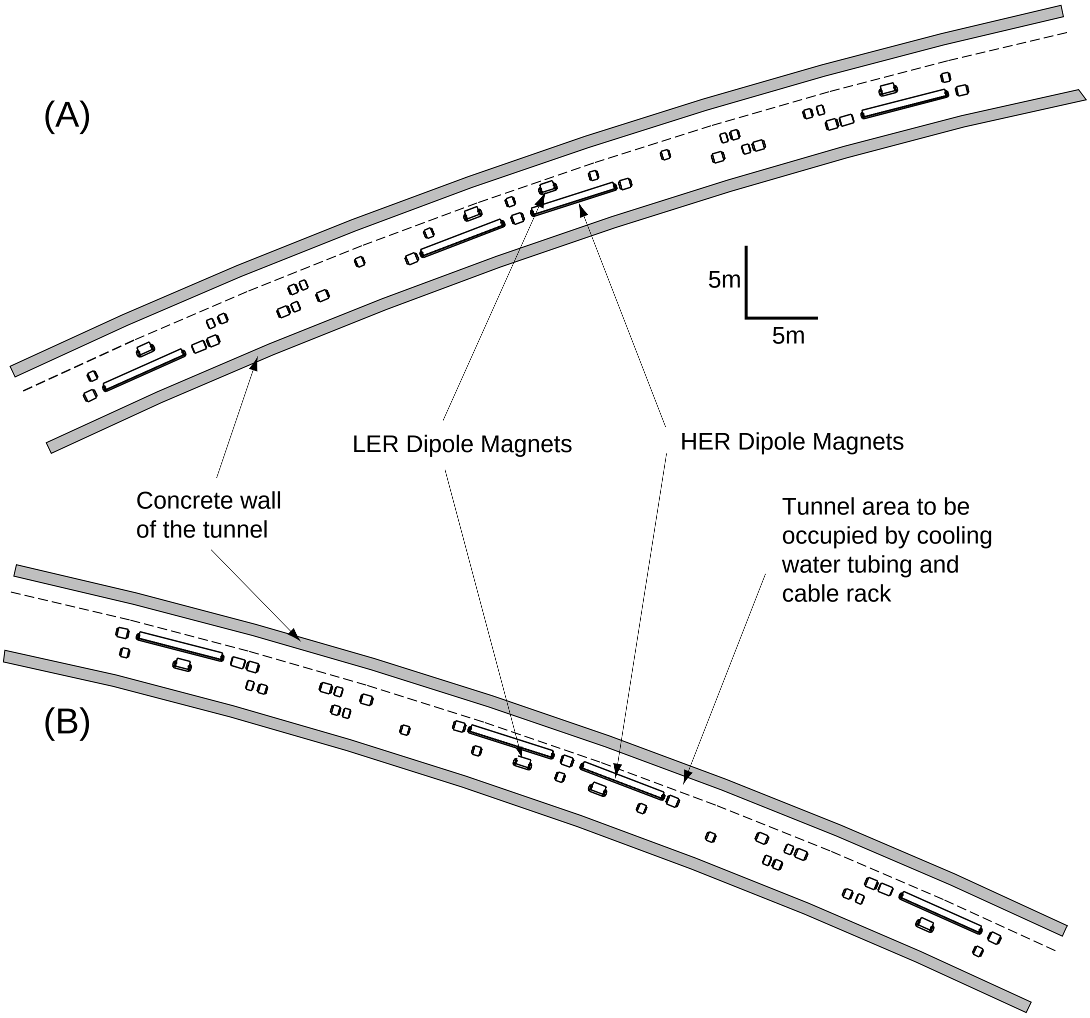

Figure 9.5: The magnet layout diagram in arc sections. The dipole, quadrupole and sextupole magnets for the LER and HER are shown. The outline of the tunnel walls is also indicated. The part (A) shows a portion where the LER is built outside the HER. The part (B) is for a portion where the LER is outside HER.

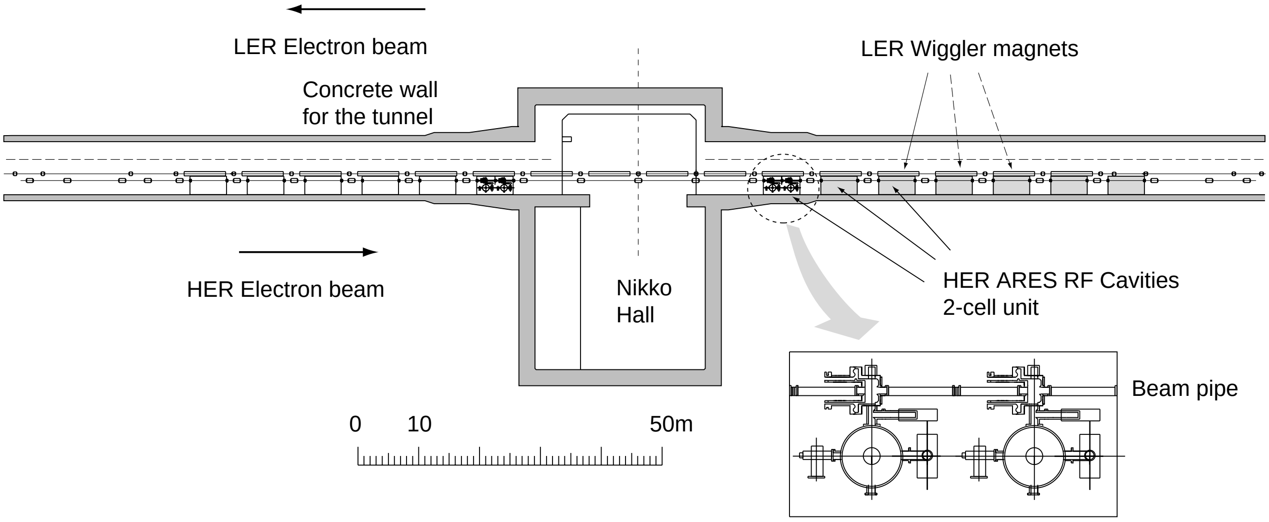

Figure 9.6: Layout of the Nikko straight section which includes RF acceleration cavities for the HER and wiggler magnets for the LER.