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BOOSTER POLARITY STANDARDS

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BOOSTER POLARITY STANDARDS

BOOSTER TECHNICAL NOTE
NO. 180

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I. BOOSTER POLARITY STANDARDS

A. Booster Magnet Polarity Standard

1. The EP&S has a magnet polarity standard that they have been following for twenty years. To the best of its abilities the Booster shall follow that standard. The EP&S standard is summarized in Figure 1 and in paragraph 3.

2. Figure 1 (prepared by C. Pearson in consultation with W. Glenn) shows the EP&S convention. Looking along the beam line, magnets with the polarities shown in the figure are in "A POLARITY". The other case is called "B POLARITY" and has the north and south poles interchanged.

3. A written definition of the standard is:

   a. A "magnet" is a magnet that has no field components along the horizontal midplane, i.e., $B_x\,(x,0) = 0$. Typical "magnets" are shown in the left hand column of Figure 1.

   b. A "skew magnet" is achieved by rotating a "magnet" to the right (clockwise), when looking along the beam direction, through an angle equal to one half of the angle between two adjacent poles. The result is $B_y\,(0,y) = 0$. Typical "skew magnets" are shown in the right hand column of Figure 1. In this terminology a pitching dipole is a skew dipole.

   c. When looking along the beam direction through a "magnet", "A POLARITY" is defined as that polarity for which the right hand pair of poles has the North pole above the South pole. It follows from this definition that a "skew magnet" has a North pole on the midplane on the right hand side.

   d. "B POLARITY" has the North and South poles interchanged.

   e. Any other situations are special cases and must be treated as such.

4. Application of the Standard

   a. Each magnet as it is manufactured is labeled in a uniform way. The labelling designates:

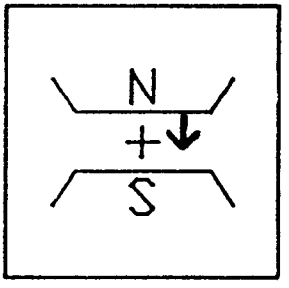
      (i) One of the magnet leads as the "T" lead.

FIGURE 1

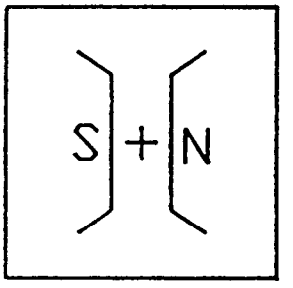
AGS Magnet Polarity Standards

The following magnets are presented in "A" polarity assuming that the beam is traveling into the paper.

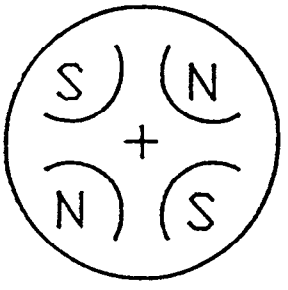
Dipole



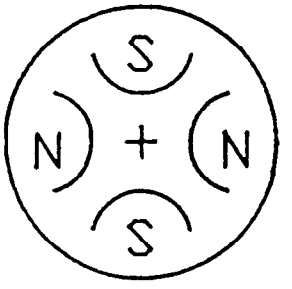
Pitching Dipole



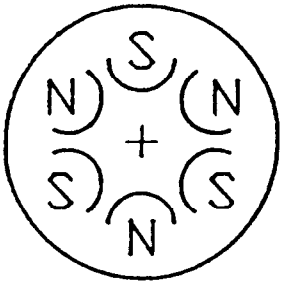
Quadrupole



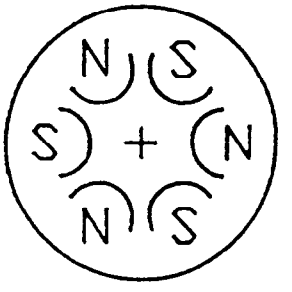
Skew Quadrupole



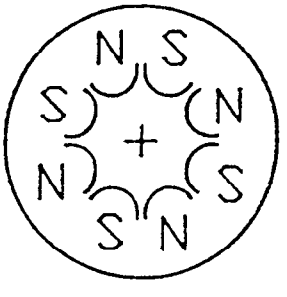
Sextupole



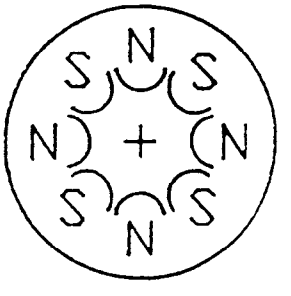
Skew Sextupole



Octupole



Skew Octupole



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(ii) A beam direction through the magnet must be designated for those magnets for which rotation through 180° about the vertical axis produces a change in polarity. Those magnets for which a beam direction must be specified are: quadrupoles, octupoles, etc., skew dipoles, skew sextupoles, etc. Those magnets for which a beam direction need not be specified are: dipoles, sextupoles, etc., skew quadrupoles, skew octupoles, etc.

(iii) If confusion is possible a top and bottom or "up" direction should be designated.

Then the standard is that:

POSITIVE CURRENT INTO THE "T" LEAD PRODUCES

"A POLARITY"

b. The beam designer is now responsible for designating each magnet in his beam line as being in either "A" or "B" polarity.

c. The cable runs must now be designed so that the "T" lead of an "A" magnet is connected to the positive output of a power supply, and so forth. Appendix II deals with special cases.

5. A single steel core may have several independently powered sets of coils - a main coil and one or more sets of trim coils. Each set of coils is viewed as a magnet for the purposes of this note.

B. Booster Power Supply Polarity Standard

1. Monopolar Supply

a. The monopolar supplies are very simple. They have two terminals on the back, labelled plus and minus by the manufacturer. The plus terminal is a source of positive current.

2. Bipolar Supply

a. The bipolar supplies are more complicated. They have two terminals on the back. We shall label these terminals "1" and "2". This choice is based on a desire to avoid confusion with "+" and "-" or "A" and "B" which are already in use. The labelling shall be carried out so

that when a positive signal is given to the power supply it will put out positive current at terminal "1".

b. By convention the polarity of a magnet connected to a bipolar supply shall be designated as the polarity that it has when positive current is coming out of terminal "1".

c. Switches of various sorts do not seem to be pertinent to the Booster at the present time.

II. OBSERVATIONS on BOOSTER POLARITY STANDARDS

The standards given above are intended to be complete and unambiguous. They seem to achieve these goals and to be generally acceptable. This note, therefore, marks their official promulgation. Any complications or insufficiencies should be brought to the author's attention.

The remainder of this section notes certain results that follow from the above and certain mnemonics that may be useful.

A. Dipoles

1. The main "dipoles" in the AGS are "A" polarity. The main dipoles in the Booster are "B" polarity.

B. Quadrupoles

1. In the standard jargon, a "focussing" or "horizontal" quadrupole is a horizontally focussing quadrupole, and a "defocussing" or "vertical" quadrupole is a horizontally defocussing quadrupole.

2. For a positive beam a "focussing" or "horizontal" quadrupole is "A" polarity. A "defocussing" or "vertical" quadrupole is "B" polarity.

3. In a beam line paragraph 1 applies in a clear cut way. In an accelerator a horizontal quad is normally at a maximum in the horizontal beta function. A vertical quad is normally at a maximum in the vertical beta function. Other elements at these locations are sometimes designated "horizontal" or "vertical" because of their location rather than because of their function. No confusion should arise.

4. In the Booster there are complicated families of half integer stop band correctors and skew quads. Their polarities have been assigned consistent with Gardner's requirements.

C. Sextupoles

1. Horizontal sextupoles are located at horizontal beta maximum and control principally the horizontal chromaticity. Vertical sextupoles are located at vertical beta maximum and control principally the vertical chromaticity.

2. To increase the horizontal chromaticity the horizontal string should be in "B" polarity, and to increase the vertical chromaticity the vertical string in "A" polarity. These polarities are opposite to the polarities of the adjacent quadrupoles.

3. The third integer stop band families are in accord with Gardner.

III. RECOMMENDED CONVENTIONS

The only important ambiguities occur when we are dealing with bipolar trim and correction magnets. These ambiguities are not of great practical consequence since they can be resolved by changing a sign in the computer program or by switching leads as appropriate. However, since the hardest thing to get right is the sign, it is desirable to establish some clear cut general principles to guide the designer and to make life easier for the installer and user.

The recommended Booster convention is:

> The general convention for assigning polarities shall be that in cases where there is an option, i.e., for most bipolar supplies, the system shall be hooked up in "A" polarity. For bipolar magnets "A" polarity is defined in paragraph I.B.2.b, above.

IV. OBSERVATIONS ON BOOSTER POLARITY CONVENTIONS

A. In An Accelerator

It is nice in an accelerator if positive current in a secondary (not main) horizontal dipole type magnet kicks the beam to a larger radius (to the outside of the machine).

1. Note that in the AGS where the main "dipoles" are "A" polarity, the secondary dipoles are largely "B" polarity, and thus follow the above precept.

This came about because the AGS convention at the time was to select "B" polarity when there was a choice.

2. In the Booster where the main dipoles are "B" polarity the secondary dipoles will be largely "A" polarity by the convention in Part III above. This fortunately also agrees with the precept above.

3. Bipolar skew or pitching dipoles should all be "A" polarity.

B. In A Beam Line

1. The beam line designer should designate the polarity of the main magnets.

2. We expect that all the main magnets will be monopolar.

3. Independent bipolar correction magnets in a beam line should follow the convention given in III.

V. CHECK-OUT CONVENTIONS

The development of these standards has been very complex since numerous possibilities have been suggested and strongly argued for. The situation is exactly described by the story of the seven Indian fakirs assigned to describe an elephant. Although they were very wise they were also very blind and as we all know each described the elephant from his point of view. So for our Booster. No simple conventions seemed generally useful from all points of view. This is of no particular consequence as long as we achieve our goals of full and complete documentation. The principal means of documentation will be the Booster Data Base, which will include complete documentation on all the wiring lists and on all the polarity assignments. This information will be available as "walking lists" for the detailed check-out of the various systems. The Booster is complex enough so that hardware checking should be done from documentation, not from memory nor from rules of thumb.

From the operators' point of view, the control system will contain two pages, a device page and an operating page. The device page will be coupled to the power supplies in the most transparent straightforward way possible - a positive signal at the device page producing a positive signal at the power supply input. Between the device page and the operating page there may exist sign inversions for many devices, the goal being to make the operating page user friendly. Thus the system we have adopted is to make the hook-up and check-out of the electrical system straightforward and easy but based entirely on complete and suitable documentation. The computer operating pages will be straightforward, easy, and user friendly from the operators' point of view. The hard task will be that of the programmer who will have to make the translation from the device page to the operating

page. The coordinating physicists will have to work very closely with the programmers to be sure that the correct polarity translations are made.

Appendix I

This appendix lists the assigned polarities of all the magnets for the Booster, the Linac to Booster line and the Booster to AGS line.

LTB LINE POLARITIES

MAGNETS	NO.	POLARITY	P.S.	TYPE
DH1	1	B	1	MONO
DH2,DH3,DH4,DH5	4	B	1	MONO
QH1	1	B	1	MONO
QH3	1	B	1	MONO
QH5	1	B	1	MONO
QH6	1	B	1	MONO
QH7	1	B	1	MONO
QH8	1	B	1	MONO
QH10	1	B	1	MONO
QH12	1	B	1	
QV2	1	A	1	MONO
QV4	1	A	1	MONO
QV9	1	A	1	MONO
QV11	1	A	1	MONO
QV13	1	A	1	MONO
DH015	1	A	1	BIP
DH076	1	A	1	BIP
DH088	1	A	1	BIP
DV018	1	A	1	BIP
DV026	1	A	1	BIP
DV082	1	A	1	BIP
DV095	1	A	1	BIP
DV112	1	A	1	MONO

BTA LINE POLARITIES

MAGNETS	NO.	POLARITY	P.S.	TYPE
DH1	1	B	1	MONO
DH2, DH3	2	B	1	MONO
DH4	1	B	1	MONO
DH5	1	A	1	MONO
QV1	1	B	1	MONO
QV3	1	B	1	MONO
QV5	1	B	1	MONO
QV7	1	B	1	MONO
QV9	1	B	1	MONO
QV11	1	B	1	MONO
QV13	1	B	1	MONO
QV15	1	B	1	MONO
QH2A-QH2B	2	A	1	MONO
QH4	1	A	1	MONO
QH6	1	A	1	MONO
QH8	1	A	1	MONO
QH10	1	A	1	MONO
QH12	1	A	1	MONO
QH14	1	A	1	MONO
DV007	1	A	1	BIP
DV141	1	A	1	BIP
DV168	1	A	1	BIP
DV181	1	A	1	BIP
DH127	1	A	1	BIP
DH158	1	A	1	BIP
SPTM F6	1	A	1	MONO
SPTM L20	1	B	1	MONO

BOOSTER MAGNET POLARITIES

MAGNETS	NO.	POLARITY	P.S.	TYPE	MAGNET LOCATION
Main Magnets					
Main Magnet String			1	MONO	
Dipoles DH	36	B			
Hor Quads QH	24	A			EVEN
Vert Quads QV	24	B			ODD
Hor Sext Str SH	24	B	1	MONO	EVEN
Vert Sext Str SV	24	A	1	MONO	ODD
Correction Magnets					
Hor Dipoles DHC	24	A	24	BIP	EVEN
Vert Dipoles DVC	24	A	24	BIP	ODD
Skew Quads QSC					
QS-STR1	6		1	BIP	ODD
QSCE1		A			
QSCE7		A			
QSCA1		A			
QSCA7		A			
QSCC1		A			
QSCC7		A			
QS-STR2	6		1	BIP	EVEN
QSCE2		A			
QSCE8		A			
QSCA2		A			
QSCA8		A			
QSCC2		A			
QSCC8		A			
QS-STR3	6		1	BIP	ODD
QSCD7		A			
QSCF1		A			
QSCF7		A			
QSCB1		A			
QSCB7		A			

MAGNETS	NO.	POLARITY	P.S.	TYPE	MAGNET LOCATION
QSCD1		A			
QS-STR4	6		1	BIP	EVEN
QSCD8		A			
QSCF2		A			
QSCF8		A			
QSCB2		A			
QSCB8		A			
QSCD2		A			
Dipole Trim Magnets					
Proton Inject. Bump					
TDHC4	1	A	1	MONO	
TDHC8	1	A	1	MONO	
TDHD1	1	A	1	MONO	
HI Injection Bump					
TDHB8	1	B	1	MONO	
TDHC1	1	B	1	MONO	
TDHC5	1	B	1	MONO	
Extraction Bump					
TDHF2	1	A	1	MONO	
TDHF4	1	A	1	MONO	
TDHF7	1	A	1	MONO	
TDHA1	1	A	1	MONO	
Dump Bump					
TDHD2	1	B	1	MONO	
TDHD4	1	B	1	MONO	
TDHD7	1	B	1	MONO	
TDHE1	1	B	1	MONO	

MAGNETS	NO.	POLARITY	P.S.	TYPE	MAGNET LOCATION
Quad Trim Magnets					
Hor Tune Str TUQH	24	A	1	BIP	EVEN
Vert Tune Str TUQV	24	A	1	BIP	ODD
½ Integer Stop Bands					
QV-STR1			1	BIP	ODD
TQVD7	1	B			
TQVE1	1	A			
TQVE7	1	A			
TQVF1	1	B			
TQVF7	1	B			
TQVA1	1	A			
TQVA7	1	A			
TQVB1	1	B			
TQVB7	1	B			
TQVC1	1	A			
TQVC7	1	A			
TQVD1	1	B			
QH-STR1			1	BIP	EVEN
TQHD8	1	B			
TQHE2	1	A			
TQHE8	1	A			
TQHF2	1	B			
TQHF8	1	B			
TQHA2	1	A			
TQHA8	1	A			
TQHB2	1	B			
TQHB8	1	B			
TQHC2	1	A			
TQHC8	1	A			
TQHD2	1	B			
QV-STR2			1	BIP	ODD
TQVD5	1	A			

MAGNETS	NO.	POLARITY	P.S.	TYPE	MAGNET LOCATION
TQVE3	1	A			
TQVE5	1	B			
TQVF3	1	B			
TQVF5	1	A			
TQVA3	1	A			
TQVA5	1	B			
TQVB3	1	B			
TQVB5	1	A			
TQVC3	1	A			
TQVC5	1	B			
TQVD3	1	B			
QH-STR2			1	BIP	EVEN
TQHD4	1	B			
TQHD6	1	A			
TQHE4	1	A			
TQHE6	1	B			
TQHF4	1	B			
TQHF6	1	A			
TQHA4	1	A			
TQHA6	1	B			
TQHB4	1	B			
TQHB6	1	A			
TQHC4	1	A			
TQHC6	1	B			
Sext. Trim Magnets					
⅓ Integer Stop Band					
SV-STR1			1	BIP	ODD
TSVE1	½	B			
TSVE3	½	A			
TSVA1	1	A			
TSVA3	1	B			
TSVC1	½	B			
TSVC3	½	A			

MAGNETS	NO.	POLARITY	P.S.	TYPE	MAGNET LOCATION
SH-STR1			1	BIP	EVEN
TSHE2	½	B			
TSHE4	½	A			
TSHA2	1	A			
TSHA4	1	B			
TSHC2	½	B			
TSHC4	½	A			
SV-STR2			1	BIP	ODD
TSVE5	½	B			
TSVE7	½	A			
TSVA5	1	A			
TSVA7	1	B			
TSVC5	½	B			
TSVC7	½	A			
SH-STR2			1	BIP	EVEN
TSHE6	½	B			
TSHE8	½	A			
TSHA6	1	A			
TSHA8	1	B			
TSHC6	½	B			
TSHC8	½	A			
SV-STR3			1	BIP	ODD
TSVF1	½	B			
TSVF3	½	A			
TSVB1	½	B			
TSVB3	½	A			
TSVD1	1	A			
TSVD3	1	B			
SH-STR3			1	BIP	EVEN
TSHF2	½	B			
TSHF4	½	A			
TSHB2	½	B			

MAGNETS	NO.	POLARITY	P.S.	TYPE	MAGNET LOCATION
TSHB4	½	A			
TSHD2	1	A			
TSHD4	1	B			
SV-STR47			1	BIP	ODD
TSVD5	1	A			
TSVD7	1	B			
TSVF5	½	B			
TSVF7	½	A			
TSVB5	½	B			
TSVB7	½	A			
SH-STR4			1	BIP	EVEN
TSHD6	1	A			
TSHD8	1	B			
TSHF6	½	B			
TSHF8	½	A			
TSHB6	½	B			
TSHB8	½	A			
Kicker Magnets					
Heavy Ion Injection					
KDHC1	1	A	1	MONO	
KDHC3	1	A	1	MONO	
KDHC6	1	A	1	MONO	
Proton Injection					
KDHC3	1	B	1	MONO	
KDHC6	1	B	1	MONO	
KDHD1	1	B	1	MONO	
Booster Extraction					
KDHF3	1	A	1	MONO	
Booster Dump					
KDH_DUMP.D3	1	B	1	MONO	

MAGNETS	NO.	POLARITY	P.S.	TYPE	MAGNET LOCATION
Booster Damper					
KDH DAMP.E3	1	A	1	BIP RF	
KDV DAMP.E3	1	A	1	BIP RF	
Booster Tune Meter					
KDV TUNE.E3	1	A	1	MONO	
KDH TUNE.E3	1	A	1	MONO	
Septum Magnets					
Booster Injection					
SPTMC3	1	A	1	MONO ES	
Booster Extraction					
SPTMF6	1	A	1	MONO	

Appendix II

There are three different groups involved in setting the magnet polarity:

1. **The accelerator theorist or beam line designer who assigns to each magnet in his system a polarity, either "A" or "B".**

2. **The factory which marks permanently and irrevocably on each magnet a beam direction, a magnet top and bottom, and a "T" terminal, based on the standards given in this note.**

3. **The wiring group which hooks up each magnet appropriately.**

This appendix consists of a table intended to help the wiring group understand complex situations.

POLARITY TABLE

A. When the:

Beam direction is PARALLEL to the arrow
Magnet is oriented UPRIGHT

Then to achieve the designated polarity for the designated magnet, connect the POSITIVE lead to the terminal marked "T" or to the unmarked terminal "()" as indicated. (The magnet is in its normal orientation.)

A POLARITY			B POLARITY		
TYPE	MAGNET	SKEW	TYPE	MAGNET	SKEW
Dipole	T	T	Dipole	()	()
Quadrupole	T	T	Quadrupole	()	()
Sextupole	T	T	Sextupole	()	()
Octupole	T	T	Octupole	()	()
Decupole	T	T	Decupole	()	()

B. When the:

Beam direction is ANTIPARALLEL to the arrow
Magnet is oriented UPRIGHT

Then to achieve the designated polarity for the designated magnet, connect the POSITIVE lead to the terminal marked "T" or to the unmarked terminal "()" as indicated. (The magnet is rotated from the normal orientation by 180° about the vertical axis.)

A POLARITY			B POLARITY		
TYPE	MAGNET	SKEW	TYPE	MAGNET	SKEW
Dipole	T	()	Dipole	()	T
Quadrupole	()	T	Quadrupole	T	()
Sextupole	T	()	Sextupole	()	T
Octupole	()	T	Octupole	T	()
Decupole	T	()	Decupole	()	T

C. When the:

Beam direction is PARALLEL to the arrow
Magnet is oriented UPSIDE DOWN

Then to achieve the designated polarity for the designated magnet, connect the POSITIVE lead to the terminal marked "T" or to the unmarked terminal "()" as indicated. (The magnet is rotated from the normal orientation by 180° about the beam axis.)

A POLARITY			B POLARITY		
TYPE	MAGNET	SKEW	TYPE	MAGNET	SKEW
Dipole	()	()	Dipole	T	T
Quadrupole	T	T	Quadrupole	()	()
Sextupole	()	()	Sextupole	T	T
Octupole	T	T	Octupole	()	()
Decupole	()	()	Decupole	T	T

D. When the:

Beam direction is ANTIPARALLEL to the arrow
Magnet is oriented UPSIDE DOWN

Then to achieve the designated polarity for the designated magnet, connect the POSITIVE lead to the terminal marked "T" or to the unmarked terminal "()" as indicated. (The magnet is rotated from the normal orientation by 180° about the horizontal axis perpendicular to the beam axis.)

A POLARITY			B POLARITY		
TYPE	MAGNET	SKEW	TYPE	MAGNET	SKEW
Dipole	()	T	Dipole	T	()
Quadrupole	()	T	Quadrupole	T	()
Sextupole	()	T	Sextupole	T	()
Octupole	()	T	Octupole	T	()
Decupole	()	T	Decupole	T	()