



STANFORD LINEAR ACCELERATOR CENTER

**SPECIFICATION**

STANFORD SYNCHROTRON RADIATION LABORATORY

Cat. Code: S30732	Specification No. PS-444-400-12R0	Page 1 of 10
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First Line: <b>SPEAR3</b>
Second Line: <b>Magnet System</b>
Title: <b>Quadrupole Magnet General Assembly</b>

<p><b>Quadrupole</b></p> <p><b>General Assembly</b></p> <p><b>Specification</b></p> <p><b>四级铁</b></p> <p><b>总装</b></p> <p><b>生产说明书</b></p>	Approved: SLAC Project Engineer <b>Richard Boyce</b>  Date: <i>10/15/99</i>
	Approved: SLAC Magnet Group Leader <b>Domenico Dell'Orco</b>  Date: <i>10/26/99</i>
	Approved: IHEP Administrative Representative <b>Yanling Jiang</b>  Date: <i>11/16/99</i>
	Approved: IHEP Technical Representative <b>Huamin Qu</b>  Date: <i>10/28/99</i>

Update / 修改

SPEAR3 SPEC QUAD MAG GEN ASM

## 1. GENERAL / 概况

This document is presented in both English and Chinese text; in case of differences, the English version shall be used.

本文含中英文两种文字，如有不符之处，以英文为准。

### 1.1 Scope of the Specification / 说明书范围

This specification outlines the minimum requirements governing the assembly and testing of the SPEAR3 quadrupole magnets. This specification further outlines the minimum requirements for packaging and shipping the completed and tested magnet from IHEP to SLAC.

本说明书概括了SPEAR3四极铁批量生产总装和检测的基本要求，对完工后的磁铁从高能所运送到SLAC的包装和运输的基本要求也做了说明。

#### 1.1.1 Applicable Document / 使用文件

Drawing SA444-403-23, 19	Quadrupole Magnet Assembly 15Q1, 15Q2
Drawing SA444-403-21, 17	Quadrupole Magnet Assembly 34Q1, 34Q2
Drawing SA444-403-22, 18	Quadrupole Magnet Assembly 50Q1, 50Q2
Drawing SA444-403-24, 20	Quadrupole Magnet Assembly 60Q1, 60Q2

#### 1.1.2 Reference Document / 参考文件

Engineering Note M320 Quadrupole Magnet Engineering Design / 四级铁工程设计总括

### 1.2 Scope of Work / 工作范围

IHEP shall design and fabricate all required assembly hardware and any required assembly tooling. IHEP shall assemble, wire and test thermal interlock continuity. IHEP shall specify and purchase all material and equipment for the magnet assembly including US standard water fittings, hoses and fasteners. IHEP shall assemble, test and package for shipment the quantity of quadrupole magnets outlined in Attachment 2 for the SPEAR3 as per drawings listed in section 1.1.1 in this specification. Tests described in this specification shall include all electrical tests and measurements and hydraulic measurements. Magnetic measurements, described in a separate specification PS-444-400-13, are required. IHEP shall develop assembly and test procedures, quality assurance (QA) procedures and test documentation (travelers) and shall record all pertinent assembly information and test records.

高能所应设计和制造总装需要的所有零部件和工装并负责连接温控系统和检查其线路。高能所应负责选择和采购磁铁总装所需要的所用材料和装置，包括美国产水接头、水管和紧固标准件。高能所应根据本说明书1.1.1款所列图纸，按SPEAR3附件2规定数量总装四级铁，并负责检测和包装。检测项目应包括本说明书所列所有电测试、测量以及水测量。所有要求的磁测项目在另一生产说明书PS-444-400-13单独列出。高能所应制定总装和检测工艺，质量保证程序和质量检验文件（跟踪卡）并记录有关总装数据和检验数据。

### 1.3 Magnet Design / 磁铁设计

Quadrupole Type	60Q	50Q	34Q	15Q
<b>Main Coil</b>				
Maximum Current (Amps) / 最大电流	74.1	88.3	88.3	88.3
Maximum String Voltage (kV) / 最大串联电压	600			
Maximum Power (kW) / 最大功率	5.72	7.12	5.6	3.72
Resistance at 40° C (Ω) / 40° C电阻	1.039	0.914	0.715	0.479
Maximum Water Pressure (psi) / 最大水压	250			
Design Water Δp (psi) / 设计水压降	150			
Water Flow at Design Δp (gpm) @ 20°C / 设计水流量	1.24	1.32	1.56	1.96
<b>Modulation System</b>				
Maximum Current (DC Amps) / 最大电流	3.65	7.07	11.86	16.42
Maximum Power (W) / 最大功率	5.24	17.08	36.04	42.12
Resistance at 40° C (mΩ) / 40° C 电阻	394.2	341.2	256.2	156.08

## 2. TOOLING / 工装

### 2.1 Handling Devices / 起吊工装

In order to protect the core and coils against damage during handling and protect personnel working with these heavy elements, proper handling and turning devices are required. The core lifting and turning device may be the same as used for the core fabrication and described in specification PS-444-400-11 Sec. 2.3. Addition of any holes or other features on the core assembly for attachment of handling devices not already described in the core drawing shall be approved by SLAC.

为了防止安装过程中造成铁芯、线圈和人身伤害，设计和制造适当的翻转和操作工装是十分必要的。铁芯的起吊和翻转工装可与生产说明书PS-444-400-11，2.3款要求铁芯制造时使用的相同。如需增加铁芯图纸上没有的，为安装起吊设备用的工艺孔或其他设计应事先得到SLAC同意。

### 2.2 Test and Measurement Equipment / 检测和测量设备

Electrical and hydraulic tests and measurements required in this specification may use the same equipment used in similar tests and measurements for the quadrupole coil and described in specification PS-444-400-10 Sec. 4.2.

本说明书所要求的检测和测量可使用生产说明书PS-444-400-10中4.2款四级铁线圈类似检测和测量所用的设备。

## 3. MATERIAL / 材料

### 3.1 Mechanical Fasteners / 机械紧固件

All fasteners shall adhere to US standards for size and strength.  
所用紧固件应符合美国尺寸、强度标准。

### 3.2 Electrical Bussing / 母线

Electrical connections between coils and to terminal blocks for power lead connections shall be fabricated using OFHC copper and shall be designed with sufficient cross sectional area so that connections can be cooled by natural convection and can operate at safe handling temperatures. The maximum net current density for the design cross section shall be no more than 150 Amps/cm<sup>2</sup> at maximum magnet design current. The terminal blocks for the power lead connections shall be attached to the core so that power lead weights are entirely carried by the core. The busses shall be electrically insulated from the core with US designation NEMA G-10 epoxy fiberglass block, or equivalent.

线圈和磁铁电源母板之接的连接板的材料应为无氧铜板，其截面尺寸要保证连接板在磁铁按最大设计电流运行时不会过热，最大纯电流密度不可超过150安培/平方厘米。电源母板应通过铁芯固定，由铁芯承载其重量。母板应用美国NEMAG-10环氧玻璃纤维层压板或等同物与铁芯绝缘。

#### 3.2.1 Electrical Bus Connection Fasteners / 电源母板连接紧固件

All fasteners required for mechanical connection between bus connections shall be steel and adhere to US dimensional and strength requirements. Split or conical (Belleville type) washers shall be used with the fasteners in order to ensure stored energy in all electrical joints carrying large currents (energy storage joints shall not be required for thermal interlock connections). All fasteners shall be appropriately torque using the torque values listed in the travelers.

所有电连接板之间的机械连接紧固件应为钢件，符合美国尺寸和强度要求。连接点需加弹簧或蝶形垫圈，以保证连接点的储能承载大电流（温控开关的连接不需采用储能连接方式）。紧固件的锁紧应严格按照跟踪卡所列扭矩操作。

### 3.3 Hydraulic Circuits / 水循环

Hoses and water fittings shall use US standards in callout of quadrupole magnet assembly drawing. Water manifolds shall be fabricated using 304 passivated stainless steel or equivalent.

水管和水接头应为四极铁总装图零部件明细表所列美国标准件。分水器材料应为304钝化不锈钢或等同物。

### 3.4 Seal Material / 密封材料

Teflon tape is not allowed for water fitting joins. Loctite PST shall be used for joints sealing purpose.

不可使用太佛龙胶带密封水接头，应使用Loctite PST管胶密封。

## 4. Magnet Assembly / 磁铁总成

The magnet assembly shall consist of the following main components:

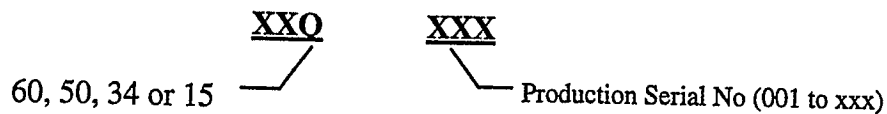
- Two (2) Core halves,
- Four (4) inner coils potted with modulation system coils, four (4) outer coils and coil supports,
- Electrical power bussing, thermal interlock and wiring,
- Hydraulic assembly including a supply and return water manifold.

磁铁总成包括以下主要元件：

- 两个（2）半铁芯，
- 四（4）个铸为一体的内线圈与调制线圈，四（4）个外线圈和线圈支撑件，
- 电源母线板和连接板，温控开关和导线，
- 水路总成，包括进出水分水器。

#### 4.1 Identification / 身份号

Each quadrupole magnet shall be identified with a unique number. The number shall be stamped on the magnet nameplate. The identification number shall consist of three (2) parts: Family of quadrupole and Production serial number. All quadrupoles with four different lengths shall share the same production serial number.



每个磁铁都有自己独有的身份号。身份号应打印在每个磁铁的铭牌上。身份号由2部分组成：磁铁的名字和生产序号。四种不同长度的四极铁使用统一连续序号。

### 5. QUALITY ASSURANCE, TESTING AND DOCUMENTATION / 质量保证，检验和记录

#### 5.1 Traveler / 跟踪卡

An inspection sheet (traveler) shall be devised by IHEP and approved by SLAC. This traveler shall include pertinent magnet assembly records, inspection results and electrical and hydraulic test data. The information included in the traveler shall include at minimum the following data.

- Magnet identification number.
- Serial number of core.
- Serial number of coils.
- Electrical Test and Measurement Results
- Hydraulic measurement results.
- Names of technicians installing coils and dates.
- Names of technicians assembling bus bars and interlocks and dates.
- Names of technicians assembling hydraulic circuits and dates.
- Names of technicians performing the magnetic measurements and dates.
- Name of supervising technician approving the magnet for delivery and date.

The original of the completed, signed and approved traveler shall be filed at IHEP. A copy of a traveler for each completed magnet shall be delivered to SLAC along with the magnet.

高能所应设计总装用跟踪卡，经SLAC核准后使用。跟踪卡应包括适当的总装数据，检验结果和电、水测试数据，至少要含以下内容：

- 磁铁身份号，
- 铁芯号，

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- 线圈号，
- 电测结果和数据，
- 水测结果，
- 安装线圈技工姓名和日期，
- 安装母线和温控开关技工姓名和日期，
- 安装水系统技工姓名和日期，
- 磁测人员姓名和日期，
- 批准磁铁检验合格的负责人姓名和日期。

## 5.2 Tests and Measurements / 检测和测量

The following tests and measurements shall be conducted on completed magnet in order to assure its adequate performance in the accelerator during operation.

总装后的磁铁应进行如下检测和测量，以保证磁铁的正常运行。

### 5.2.1 Hydraulic Test / 水系统检测

#### 5.2.1.1 Water Flow Test / 水流量检测

The test equipment may be the same as used to test the finished quadrupole coils. With the water temperature in the range of 20 to 25° C and with the water flow adjusted so that the difference between the supply and return manifold pressure is 150 psi, the flow rate shall be measured and no less than 90% of design value listed in section 1.3 of this specification.

可使用测量四级铁线圈的同一设备进行此项测量。调整进出水压差至150psi，水温为20至25° C，测量水流量。在此条件四种四极铁的实际水流量不应低于本说明书1.3款所列设计水流量的90%。

#### 5.2.1.2 Pressure Test / 压力检测

After the flow test, blow all the water out of the circuits, pressurize with dry gas to 450 psi. There shall be no change in pressure after one hour.

完成流量检测后，吹干水路内水分，充450psi干燥气体。一小时后不应有压力泄漏。

### 5.2.2 Electrical Tests / 电检测

#### 5.2.2.1 Hipot Test / 高压检测

The hipot test voltage shall be at least twice the operating (string) voltage plus one (1) kV. A hipot test shall be performed on the quadrupole magnet main and modulation system coil system by applying a 2.2 kV DC and 1.0 kV DC respectively to power lead bus with the core and non measured coils system grounded for a minimum period of one minute. The measured leakage current shall not exceed 2  $\mu$ A.

高压检测的电压至少为系统串联电压的二倍加1千伏之和。故四极铁的主和调制线圈系统高压检测电压分别为2.2和1.0千伏直流电压。检测时铁芯和不被测线圈系统应接地，测试电源与磁铁电源母线板连接，通电时间至少为一分钟。测出的漏电流不应大于2 $\mu$ A。

#### 5.2.2.2 Resistance Measurement / 电阻测量

Magnet resistance shall be measured with a "double bridge" connected at the power lead busses. A double bridge is used to eliminate the inaccuracy due to current in the measurement circuit. The type and model number of the bridge used shall be noted in the test records. The measurement shall be made with the magnet temperature uniform throughout and steady state conditions prevailing. The coil temperature shall be recorded and the resistance measurement shall be to at least three significant figures. The acquisitive resistance of a production coil system might be different from the normal value listed in section 1.3, but the deviation should not be significant. An average value of first four (4) production quadrupole magnet main and modulation system coils of each type magnet at 40° C shall be used as a criterion for the production quadrupole magnet main and modulation system coil system resistance measurement. Variations of resistance greater than 3% of the criterion value when corrected to 40° C indicates a possible assembly error. If the variation exceeds 3%, first check the individual coil resistance to determine whether a bad coil has been installed before checking the bussing connections.

将双桥电阻仪与磁铁电源母板连接，测量电阻。双桥电路是为了消除测量电路内的电流影响。电阻仪的类别和型号应记录在跟踪卡上。测量时磁铁的温度要保持基本不变。线圈的温度要作记录，所测电阻值至少要有三位有效数字，并作40° C标准化处理。生产四极铁线圈系统实测值很可能与1.3款所列设计值有出入，但偏差不应很大。实际应用时，应用每种磁铁头4块生产铁主线圈和调制线圈系统所得40摄氏度标准化处理后电阻值的平均值作为该种铁的标准值。凡生产铁主线圈或调制线圈系统与标准值数据相差3%以上，可能组装有误。在检查母线连接前，首先要检查是否使用了有问题的线圈。

### 5.2.3 Fiducialization / 定标测量

Fiducialization shall be performed at SLAC.

SLAC负责定标测量。

### 5.2.4 Magnetic Measurements / 磁测

IHEP shall perform magnetic measurements for all magnets. The magnetic measurements are described in a separate specification and must be completed prior to the final inspection, packaging for shipment and shipment to SLAC.

高能所应对所有磁铁进行磁测。磁测要求另文说明。磁铁终检、装箱发运之前，所有磁测项目都要逐一完成。

### 5.2.5 Final Inspection / 终检

Upon completion of the magnetic measurements, a careful final inspection shall be carried out. This inspection shall consist of a physical inspection as well as verification that all documentation is in proper order.

磁测完成后，对磁铁终检。此项检测包括检查硬件和文件的汇总、装订。

#### 5.2.5.1 Physical Inspection / 硬件检查

A visual inspection shall be made of the core, coil, bussing, and water connections. Procedures shall be followed to verify that all fasteners are properly torqued, the interlocks

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are properly seated, and wiring is undamaged. All hydraulic circuits shall be thoroughly drained and dried. Open fittings for hydraulic circuits shall be properly sealed. Unpainted core surfaces shall be checked to see that they are properly coated and protected against moisture and rust.

对铁芯、线圈和水循环连接进行最後目检。要依次检查所有紧固件是否拧紧，温控开关位置是否正确，连接导线有没有损伤。水路内残留水分要彻底空净，吹干，封口。不喷漆铁芯表面妥善防锈处理。

#### 5.2.5.2 Documentation / 文件

The required documentation collected at the end of magnet assembly shall consist of the following travelers and recorded data for each magnet (total of 21 documents). Copies of all these travelers shall be packaged with the magnet prior to shipment to SLAC or mailed to SLAC separate from the magnet shipment as required. Originals of all travelers shall be permanently filed at IHEP.

- Coil travelers (4 of inner main coils, 4 of outer main coils, 4 of modulation system coils and 4 of inner coil).
- Core traveler (2 half cores).
- Assembly traveler.
- Magnetic field measurement data and floppy disk(s) containing the data.
- Quality certification signed by IHEP technical representative and other relative authority.

每个即将发运的磁铁所汇总的文件应包括如下跟踪卡和数据记录（共二十一份文件）。所有这些文件的复印件应随铁装箱或如需要，随磁铁发出同时寄往SLAC。文件的原件应由高能所存档。

- 线圈跟踪卡（内主线圈4份，外主线圈4份，调制线圈4份，内线圈4份），
- 铁芯跟踪卡（2个半铁芯），
- 总装跟踪卡，
- 磁测数据和记录这些数据的磁盘，
- 由高能所技术代表和其他有关负责人签发的质量合格证书。

## 6. PACKAGING AND SHIPPING / 包装和运输

### 6.1 Prototype Magnet / 样机铁

Immediately after the completion of the prototype measurement, the prototype magnet shall be packaged and shipped to SLAC. Its documentation listed in 5.2.5.2 shall be airmailed to SLAC. The final inspection described in sections 5.2.5.1 and the packaging and shipping standards and procedures described in sections 6.2 to 6.4 shall be applied. The hardcopies final magnetic measurement results as well shall be delivered to SLAC along with the prototype:

样机磁测完毕，立即逐一实施5.2.5.1所述终检项目，按6.2至6.4款所述装箱标准装箱，发运SLAC。除5.2.5.2款所列文件应用航空邮件寄往SLAC外，样机磁测数据报告应与样机一同交SLAC：



## 6.2 Shipping Crate / 包装箱

No more than one magnet shall be packed in a shipping crate. The shipping crate shall be attached to a pallet so that it can be moved using standard handling devices (forklift or pallet jack). The design for the proposed shipping crate shall be reviewed and approved by SLAC. After receiving the prototype magnet, the shipping crate design shall be reevaluated by SLAC. If necessary, a redesigned shipping crate shall be used to ship the remaining production quadrupole magnets. The design of the revised shipping crate shall be approved by both SLAC and IHEP.

每个包装内只允许装一块磁铁。包装箱底设计应该能用标准起货机械，如叉车或千斤顶之类移动箱体。高能所建议采用的包装箱设计应交SLAC会审、批准。在样机运至SLAC后，SLAC将进一步审核包装箱的设计合理性，如必要，批量四级铁的包装箱可能需重新设计。新结构应得到高能所和SLAC双方认可。

## 6.3 Environmental Protection / 包装保护

The magnet shall be covered or wrapped to protect it from moisture within the shipping crate. It shall be properly braced and cushioned within the shipping crate so that it will not shift within the crate during handling and shipment.

磁铁本身应有防潮包装，与箱体之间加防冲击软隔断并与箱体底座牢固连为一体，使其在起运过程中不会上下左右窜动。

## 6.4 Packing List / 装箱单

A packing list shall be installed in the crate. It should contain the following information:

- Identification of the crate which shall consist of serial number of crate and serial number of shipment.
- Identification number of the magnet contained in the shipping crate.
- Date of packing.
- Name of the inspector who conducts the final inspection and his/her signature.

每个包装箱内应有一份装箱单，其内容应包括：

- 包装箱号，该号应能指明该包装箱属于X次发货的XX号箱。
- 该箱内所装磁铁身份号。
- 装箱日期。
- 终检员签字和日期。

## 6.5 Marking / 包装箱外标记

Identification of the crate, identification number of the magnet contained in the crate and name of the receiver and final destination (SLAC) shall be clearly marked on at least two sides of the shipping crate. Arrows shall be conspicuously marked on the exterior surface of the crate to indicate its upright position.

包装箱至少要在两个外箱面清楚标明箱号，箱内所装磁铁身份号，收件人和发往地址（SLAC），并在显著位置标明箱体直立向上放置箭头。

包装箱至少要在两个外箱面清楚标明箱号，箱内所装磁铁身份号，收件人和发往地址（SLAC），并在显著位置标明箱体直立向上放置箭头。

### 6.6 Installation in Shipping Container / 集装箱内放置

Several magnet crates will be installed in shipping containers for shipment to SLAC. These crates shall be braced in the container such that they will not shift during shipment. The crate orientation within the container shall be such that all crates can be accessed with a standard handling devices (forklift or pallet jack) without rotating or moving.

发往SLAC的集装箱内会放置多个包装箱。这些包装箱应在集装箱内妥善固定，使其不会在起运过程中窜动。包装箱在集装箱内的朝向，应能保证不做转、移动，就可使标准起运机械，如叉车或千斤顶进入其箱底。

### 6.7 Spare Coils / 备用线圈

The same standards for shipment protection and handling described for the quadrupole magnet crates shall be applied for spare coils. The crate shall be conspicuously marked on the outside with a description of the contents.

四级铁的包装要求同样适用于这些备用线圈。包装箱外应在显著位置标明箱内所装物品。

### 7. NAME PLATE / 铭牌

Each quadrupole magnet shall attach a name plate show as below. Its position shall not interfere magnet operation.

每个四级铁都应钉如下图所示铭牌，其位置不应影响磁铁的运行性能造成影响。

SPEAR3 MAGNET
Magnet ID No.
Net Weight:
SPEAR3 Drawing #: SA444-403- 17 or 18,19,20,21,22,23,24
Date:
Made in IHEP, China

