		STANFORD LINEAR ACCELERATOR CENTER	
		SPECIFICATION	
STANFORD SYNCHROTRON RADIATION LABORATORY			
Cat. Code: S30733	Specification No. PS-444-400-25R2		Page 1 of 14
Author(s): Jack Tanabe, Nanyang Li		Date: Sept. 14, 2001	
First Line: SPEAR3			
Second Line: Magnet System			
Title: Horiz/Vert Corrector Magnet Coil Production			
H/V Corrector Magnet		Approved: SLAC Project Engineer Richard Boyce	
COIL		Date:	
Specification		Approved: SPEAR3 Magnet Engineer Domenico Dell'Orco	
垂直 / 水平校正磁铁		Date:	
线圈		Approved: IHEP Administrative Representative Haoyun Zhang	
生产说明书		Date:	
Update / 修改		Approved: IHEP Technical Representative Huamin Qu	
Section 1.3: Change voltage. 条款 1.3 : 改写电压 Section 4: Rewrite, 4.1.1, 4.1.2 and 4.1.3 are new. 条款 4 改写, 4.1.1, 4.1.2 和 4.1.3 为新条款。 Section 4.2: Request to record the winding turns in the traveler. 条款 4.2 要求 跟踪卡记录绕 线圈 数。		Date:	

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1. GENERAL / 概括

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 fabrication, inspection and testing of the coils for the SPEAR3 H/V corrector magnets prototype, production and spare coils.

本说明书概括了 SPEAR3 工程垂直/水平校正铁样机、生产铁线圈以及备用线圈的制造、检验和测量的基本要求。

1.1.1 Applicable Document / 使用文件

Drawing SA444-406-10 C0	Corrector Magnet Coil Assembly
Drawing SA444-406-11 C0	Coil Winding Assembly; 2 sheets
Drawing PF444-406-12 C0	Solid Cu Insulated Conductor

1.1.2 Reference Document / 参考文件

Engineering Note M361 Horiz/Vert Corrector Magnet Engineering Design Summary /校正铁工程设计总图
Engineering Note M 338A National Pipe Thread Manufacturing Note/美国国家标准管螺纹加工说明

1.2 Scope of Work / 工作范围

IHEP shall fabricate all the coils required for the SPEAR3 corrector magnets and spare coils called out in Attachment 5. IHEP shall design and fabricate tooling required to wind and vacuum impregnate the coils; purchase the coil copper conductor and pre insulated hollow conductor used for the water cooling circuit, purchase the cloth and tape insulation required for ground insulation and specify the epoxy formulation for potting coils. IHEP shall write the technical specification for the purchase of the China made copper conductor. This specification shall be reviewed by SLAC. IHEP shall provide assembly drawing of coil winding fixture and potting mold. IHEP shall develop inspection documentation (travelers) and perform all inspection, tests and measurements and record the test data on the travelers.

高能所应生产附件 5 规定数量的 SPEAR3 校正铁所需要的所有线圈和备用线圈。高能所应设计绕线和真空环氧浇注线圈所需要的工装；采购线圈和预绝缘冷却通水铜导线、绝缘带和制定线圈浇注的环氧配方。高能所还应书写采购中国制造铜线的技术要求，这一材料需经 SLAC 审阅。高能所还应提供给 SLAC 线圈的绕线模和浇注模的总图。高能所应制定质检文件（跟踪卡），并实施检验，测试和测量。所有测量数据应记录于跟踪卡。

1.3 Coil Design Parameter / 线圈设计参数

Coil/ 线圈	Vertical / 垂直	Horizontal/水平
Bare Conductor Size (Max.) / 裸线最大线规	1 mm x 5.31 mm	

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Insulated Conductor Size (Max)/带绝缘导线线规 (最大)	1.16 mm x5.48 mm with Grade 2 polyesterimide /Thermal class 180° or higher insulation	
Bare Water Cooling Conductor Size/ 水冷裸导线线规	4.76x4.76xΦ3.18mm	
Insulated Water Cooling Conductor Size (Max) 水冷导线加预绝缘后线规 (最大)	5.24x5.24mm 0.19mm pre glass fiber-dacron thread insulation	
Number of Turns per Coil// 匝数	169	96
Voltage at 30amps/30 安培时电压	14V	8V
Max. Steering Current (Amps) /最大电流	30	
Resistance at 40 (Ω) / 40° C 电阻	0.4511 Ω	0.2562 Ω

2. MATERIALS AND PARTS /材料和零部件

2.1 Conductor/导线

The maximum cross section of the conductor including pre-insulation shall be no bigger than the called out in section 1.3 of this specification. The minimum length of segments of copper conductor ordered must be long enough to wind a single winding with no brazed joints in the potted coil assembly and provide enough material for clamping and tensioning the conductor during winding. The total quantity of copper conductor delivered must be sufficient to cover possible damage, loss or coil failure.

导线的截面加预绝缘层厚度的最大尺寸绝不应大于本说明条款 1.3 的要求。订购导线的分段长度要能保证每个绕组的连续缠绕，在环氧浇注层内不留焊点，并外加足够端部拉紧余量。导线的总采购量一定要考虑到损耗、损伤和线圈报废等各种意外情况。

2.1.1 Conductor Test /导线检验

The following tests are requested for the hollow conductor delivered from Outokumpu.

从瑞典订购的空心导线要进行下述检验。

2.1.1.1 Ball Test for the /球试

In order to verify the continuity of the cooling channel, a ball test shall be performed on each conductor segment. A steel ball with 60% to 70% of the hole diameter is blown through the conductor using pressurized dry air.

为了检验导线冷却水孔的连续性，每一分段导线都应用干燥压力气将直径为孔径 60% 或 70% 的钢球从其水孔内吹过。

2.1.1.2 Hardness Test /硬度检测

Annealed copper conductor is required in order to minimize winding and bending difficulties. A Rockwell hardness test for annealed copper shall be specified to assure that the delivered conductor is fully annealed.

为了便于线圈的缠绕和弯转，导线是经退火处理的软铜导线。应规定软铜的洛氏硬度指标，对到货导线进行检验。

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2.1.1.3 Visual Inspection / 导线绝缘检验

Visual inspection of the conductor before the winding of each coil shall be performed to locate any insulation damage, which will cause turn to turn short.

每个线圈绕制前，都应对导线的预包绝缘层进行检验，以发现会引起匝间短路的绝缘层损伤。

2.2 Insulation / 绝缘

2.2.1 Pre – Insulation / 预绝缘涂层

2.2.1.1 Hollow Conductor / 空心导线

Double polyester glass fiber per NEMA spec MW46-C, 0.19mm thick.

双层涤纶玻璃纤维预绝缘层，预绝缘层厚度 0.19 毫米，需符合 NEMA 手册 MW46-C 款性能要求。

2.2.1.2 Solid Conductor / 实心导线

0.08 mm thick pre- insulated polyester insulation, thermal class 180°C or higher.

0.08 毫米厚聚脂绝缘漆，耐温 180 摄氏度或更高。

2.2.2 Ground Wrap Material / 对地绝缘材料

Ground Wrap Insulation 1.0" wide x 0.01" thick CNF Fiberglass Woven Tape

对地绝缘带： CNF 玻璃纤维布胶带 1.0 英寸宽，0.01 英寸厚

2.2.3 Fillers / 填充物

Voids in the coil winding and large spaces between the ground wrapped coil and the potting mold must be filled in order to avoid large volumes of unfilled epoxy. These voids must be filled with glass cloth, glass roving or cut pieces of NEMA G-10 only. Do not use unfilled epoxy pieces or blocks.

线圈绕制换匝部位的空间和对地绝缘和环氧浇注模之间的较大空隙部分应加填充物，以避免过厚的纯环氧层。这些填充材料只能是玻璃丝带、布或 NEMAG-10 形块，绝对不允许使用纯环氧条或块。

2.2.4 Epoxy / 环氧材料

The following coil potting system has been specified by IHEP and accepted by SLAC for the SPEAR3 gradient dipole, quadrupole and sextupole coils. The same epoxy formulation shall be used to vacuum impregnate the corrector magnet coils.

Element	Vendor	Parts by Weight
i. Resin Epoxy 616 (eq. To DER 332)	Shanghai Epoxy Co.	100
ii. Hardener HY906 (NMA)	CEBA-Geigy Co. Switzerland	94
iii. Flexibilizer Polyester 304	Shanghai Epoxy Co.	30
iv. Accelerator DMP-30	Fluka Co. Germany	0.7

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v. Filler		
Alumina (Al ₂ O ₃)	Henan Micro Powder Co.	180
Silicon Powder (SiO ₂)	Huzhou Sili Powder Co.	40
Decolorizing Carbon (H ₂ O n SiO ₂)	Henan Micro Powder Co.	6

以下为经 SLAC 认可，高能所规定用于 SPEAR3 梯度二极铁和四、六极铁线圈的环氧配方。该配方应用于校正铁线圈的真空环氧浇注。

配料	厂商	配比
i. 树脂		
环氧 616 (等同于 DER 332)	上海环氧厂	100
ii. 固化剂		
HY906 (NMA)	CEBA - Geigy Co. 瑞士	94
iii. 软化剂		
304 聚脂	上海环氧厂.	30
i.v 催化剂		
DMP-30	Fluka Co. 德国	0.7
v. 添加剂		
白刚玉 (Al ₂ O ₃)	河南微粉厂	180
硅微粉 (SiO ₂)	湖州硅粉厂	40
白炭黑 (H ₂ O nSiO ₂ 分散剂)	河南微粉厂	6

2.2.5 IHEP Impregnation Curing Cycle / 高能所环氧固化循环

- Bake mold with installed coil 100° C for four (4) hours before pouring epoxy.
- 120° C cure for four (4) hours plus 160° C cure for ten (10) hours.
- After cure, decrease temperature at a maximum rate of 10° C per hour until sufficiently cool to remove the coil safely from oven.
- 浇注前线圈入浇注模加温至 100 摄氏度，保温四小时。
- 浇注后 120 摄氏度固化四小时，升温至 160 摄氏度保温十小时。
- 以最大每小时 10 摄氏度速率降炉温直至冷却到线圈可安全出炉。

2.3 Water Fittings / 水接头

The water connector blocks shall be machined from OFHC copper and brazed to the coil lead using high temperature solder specified in Section 3.5. The water fittings attached to the finished coils shall be US standard fittings listed in the call out of General Assembly drawing which will be supplied by SLAC.

与线圈引出头焊接在一起的水嘴应用无氧铜制作，焊接采用 3.5 款规定的高温焊条。与其相接的水接头应为总装图明细表中所规定的美国标准件该标准件由 SLAC 提供。

3. COIL FABRICATION / 线圈制造

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3.1 Coil Winding / 线圈缠绕

3.1.1 Environment / 环境

Coils shall be insulated and wound in an area free of metallic chips, dirt, and welding or chemical fumes. Conductors, insulation materials and wound coils shall be protected from dirt, moisture and damage during fabrication, handling and storage. Wound and ground wrapped coils shall be wrapped and protected from dirt, moisture and damage until installation into potting molds.

线圈的绕制现场应没有铁削和其他不清洁物，应远离焊接操作和其他化学气雾。导线、绝缘带和绕好的线圈应妥善保管，避免制造、运送和储存过程中被污染、弄潮或受损。绕好并包好对地绝缘的线圈在浇注之前应有外包装，避免污染、弄脏或损伤。

3.1.2 Conductor Preparation / 导线准备

Conductors shall be cleaned before winding. One length of conductor shall be used for each length of one coil segment. Internal splices shall not be allowed in finished coils.

导线绕制前要擦拭干净。导线的截断长度应足够绕制一个完整的线圈分层，绝不允许有接头。

3.1.3 Winding / 绕线

The coil conductor shall be pulled with sufficient tension during winding to minimize keystoneing and to assure that the coil is tightly wound and will fit into the potting mold. Care must be taken to avoid conductor pre-insulation damage.

应对导线施加足够拉紧力，以最大限度减小弯转处梯形畸变和确保线圈的紧密性，使其顺利装模。同时操作人员要十分小心，不可损伤预绝缘层。

3.1.4 Ground Insulation Wrapping / 包对地绝缘

After winding, a ground wrap with half overlap shall be applied to secure the horizontal, vertical and the cooling winding together prior to installation in the potting mold.

线圈绕好后，用半迭绕对地绝缘方式将水平和垂直线圈以及水冷绕层捆绕成一体，确保进浇铸模前不会散开。

3.1.5 Coil Dimension Inspection / 线圈外形尺寸检验

The coil outer dimension shall be inspected after ground wrapping to insure it will fit in the impregnation mold.

线圈包对地绝缘后检验其外形尺寸，以确保能够在自然状态装入浇注模。

3.2 Coil Impregnation / 线圈浇注

3.2.1 Environment / 环境

Impregnation coil shall be in an area free of metallic chips, dirt, and welding or chemical fumes. Impregnation compounds and ground wrapped coils shall be protected from dirt, moisture and damage during storage and handling. Temperature of impregnation facility shall be kept at $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$ and shall be baffled to reduce excess air circulation.

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环氧浇注环境应没有铁削，不洁物品和焊接或化学品烟雾。环氧配料和绕好对地绝缘的线圈应妥善保管，保证操作和储存过程中不被污染、弄潮和损伤。环氧浇注场合的温度要保持在 25°c ±5°c，要有阻断气流直接侵入的屏障物。

3.2.2 Impregnation / 浇注

Standard procedures for vacuum impregnation shall be followed. These include mixing of the components at prescribed temperatures; vacuum deaeration of the epoxy mixture while mixing at an elevated temperature to remove bubbles which might form at the curing temperature; delivery of the epoxy to the mold under vacuum and successive venting and evacuation of the filled mold to remove bubbles. The filled mold shall be vented with suitably placed vent tubes and tipped in the curing oven to assure that bubbles can escape in these tubes. The vent tubes act like standpipes and should have sufficient fluid capacity to compensate for epoxy shrinkage in the mold during curing. The filled mold shall be cured using 2.2.5 curing temperature cycle for the 2.2.4 epoxy formulation. All pertinent production information or data shall be filled in the traveler at the site by the person conducting the procedure.

真空固化过程应遵循标准固化循环工艺。这包括在工艺要求的温度下混料，在混胶过程中在温度有所提高的状态下抽真空去除可能在固化温度下形成的气泡；真空浇注，模具排气去泡。模具在适当位置安有出气管，充好胶的模具在炉内应适当倾斜，确保气泡可从排气管排出。排气管需直立，并有足够容积供补胶之用。充好胶的模具，要按为 2.2.4 款配方的环氧设计的 2.2.5 款固化循环固化。所有有关工艺过程和数据都要在生产现场由操作者即时填入跟踪卡。

3.3 Inspection and Repairs / 检验和返修

The impregnated coil shall be visually inspected for cracks, bubbles and voids. Easily accessible surface bubbles and voids shall be filled with epoxy. The crack(s) shall be repaired by drilling out or otherwise removing the cracked insulation and filling with epoxy. All repaired cracks and voids in the finished coils shall be noted and described in the traveler which accompany each coil. Consistent cracking among many coils shall be studied by responsible engineer and the IHEP technical representative shall inform the SLAC technical representative. The coil potting shall be halted until the IHEP and SLAC technical representative have agreed on a procedure to correct the defect.

浇注后的线圈应进行外观检验，观察是否有裂痕、气泡和空穴及表面浅层气泡和空穴可直接用环氧修补。环氧裂缝应先用钻或其他方式将裂损周围环氧清除，而后补环氧。所有经修补的裂痕或空穴都应在该线圈完工后记录在其跟踪卡内。对于多个线圈连续出现的环氧开裂，主管工程师要进行研究，高能所技术代表应通知 SLAC 技术代表。在对修正措施达成共识之前，应暂停线圈的浇注。

3.4 Rejections / 报废

If, as a result of visual inspection, the impregnated coil has unreparable cracks or voids which represent a risk of turn-to-turn or ground shorts during tests or operation, the coil shall be rejected. Any such rejection shall be reported to the SLAC technical representative.

如果线圈外观检查中发现难以修复的裂痕或空穴，这些缺陷很可能导致测试或运行中出现匝间或对地短路，线圈应于报废。报废处理应告知 SLAC 技术代表。

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3.5 Brazing / 钎焊

The impregnated coil leads shall be bent to the prescribed shape outlined in coil assembly drawing. The copper thermal switch mounting plates, copper water blocks and busses for power lead connections shall be hard soldered to the conductors. US standard braze filler rod BcuP-5 shall be used for brazing those connections. The appropriate cleaning and fluxing procedure for the hard solder shall be followed in order to guarantee a good braze joint. Special attention shall be paid to the thermal switch mounting plate brazing to insure solid connection between the plate. The area of the conductor insulated by epoxy shall be suitably protected to prevent burning during brazing by wrapping with wet cloth.

线圈的引出头应该按照线圈组装图所示尺寸委弯。温控开关固定板和水接头以及电源连接母板的焊接应使用美国制造的无熔剂钎焊焊条 Bcup-5。应按要求正确清洗焊接表面，选择正确焊接工艺，以确保焊点的可靠。焊接温控开关板时要特别注意，确保所有与该板相连的绕组出头确实焊实了。导线环氧绝缘的部分应用湿布加以保护，使其在焊接过程中不被烧伤。

3.6 Pipe Hose Tapping / 水接头管螺纹加工

The pipe hole on the water block shall be tapped using the procedure outlined in SLAC Engineering Note M336. The water fitting shall be installed at the water block of the finished coil using Loctite PST 580 in the pipe joints. Loctite shall not be used in the connection between the standard Swagelock parts (water fitting and the adapter crimped on the water hose). The built in configuration of those parts will guarantee the seal. Installation must be done carefully in order to prevent any dirt or chips from getting into the cooling channel which can clog the channel.

水接头件上的管螺纹应严格按 SLAC 提供的工程说明书 M336 的规定加工。水接头应拧在完工线圈的水连接件上并用 LoctitePST580 密封。安装时要十分小心，Loctite 和其他脏物或碎屑不能进入水孔而阻碍水循环。必须提醒的是，标准 Swagelock 水连接部件间（水接头和挤压在水管上的水嘴之间）不允许使用 Loctite 加强密封，这些标准件的结构已确保了密封的可靠（多余的涂料反而破坏密封）。

3.7 Identification / 身份号

Each coil shall be identified with its production serial number. This number shall be temporarily attached to the coil with a tag after winding, ground wrapping, and before impregnation. After impregnation, this identification number shall be stenciled to the potted surface in permanent ink or paint in a location which shall be visible after the coil is installed in the magnet assembly.

每个线圈都应以生产序号为其身份号。线圈绕制好并包好对地绝缘后，环氧浇注前应该将此身份号用标签拴在线圈上。环氧浇注后，这一身份号应该用永久墨水或漆写在线圈磁铁总装后仍易见处。

4. QUALITY ASSURANCE, TESTING & DOCUMENTATION/ 质量保证，检测和记录

4.1 Tests and Measurements / 检测和测量

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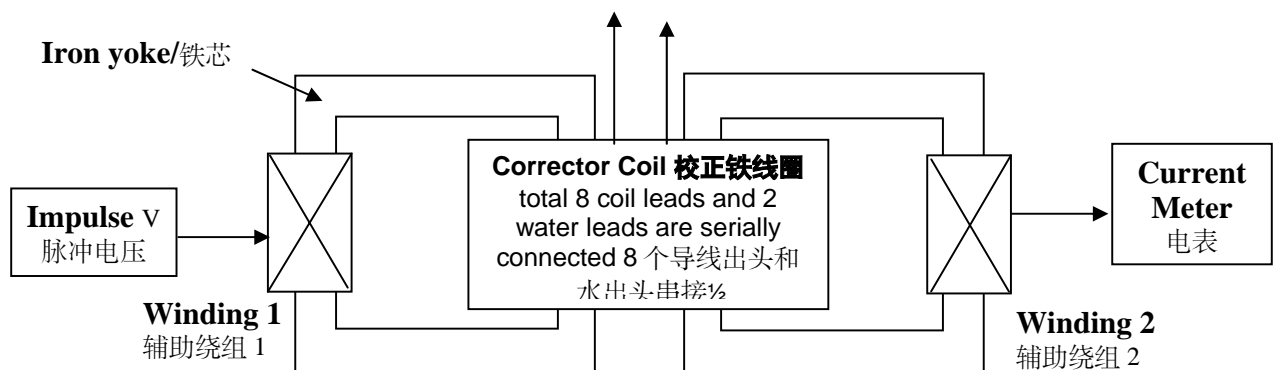
The table below lists required minimum tests. The horizontal and vertical winding shall be measured and recorded separately.

下表列出了需要检测的最起码项目。水平和垂直绕组的测量应分别进行和分别记录。

TEST ITEM 检测项目	TEST REQUIREMENT 检测要求	DEVICE 检测设备
Pre-Potting 环氧浇注前		
Dimension 外形尺寸	Measure after ground wrap 包对地绝缘后进行	
Impulse test 脉冲测量	Low Voltage: 250 V 测量电压	Oscilloscope & Camera 示波仪和相机
Turn to turn short test 匝间短路检测	Impulse Voltage: 250 V 脉冲电压 : 250 V	See section 4.1.1 见 4.1.1
Post-Potting 环氧浇注后		
Resistance 电阻测量	Record measurement at least 3 significant figures and correct the resistance to 40°C. Use average value of first 4 production coils of each type of winding at 40°C as a criterion for the production coil resistance measurement. (Calculated resistance = 0.45 Ω for vertical steering coil and 0.26 Ω for horizontal steering coil.) 记录测量电阻至少至三位有效数字，计算 40°C 的修正值。以每种绕组最初 4 个产品 40°C 的平均值做生产线圈的测量标准（垂直、水平线圈理论电阻值分别为 0.45 Ω 和 0.26 Ω）	Double bridge 双桥电路
Impulse 脉冲测量	L voltage 低压: 500 V H voltage 高压: 1.1 kV Rise time 升压时间 >2 μsec Attach the oscilloscope photo for both the low and high voltage tests. 需附照片	Oscilloscope & Camera 示波仪和相机
Hipot 高压检测	Voltage 电压 : 1.1 kV Leakage Current 漏电流 <2 μA	
Turn to turn test 匝间短路检测	Impulse Voltage: 1k V 脉冲电压 : 1k V	See section 4.1.1 见 4.1.1
Visual 外观检测	Observed crack and other flaw shall be recorded 所有观察到的开裂和其他问题要作记录	
After Braze 焊后		

Bending Dimension & Welding Position 委弯尺寸和焊接位置 检验	This measurement is extremely important, especially for the very tight configuration of the girder assembly. 由于支架组装空间十分紧凑，该项检验十分重要	Special gauge 特制样板
Pressure test 保压检测	Time duration 保压时间: 1h Water pressure 水压: 450 psi	
Water flow 水流量测量	Pressure drop 测量压差: 150 psi Water flow 水流量 > 0.35 gpm	
Check coil turns 检验线圈匝数	Use reference coil having correct turns 使用正确匝数的线圈做参考线圈	See section 4.1.2 见 4.1.2
Thermal test 温度检测	Conducted by magnet measurement group 磁铁测量组负责	See section 4.1.3 见 4.1.3

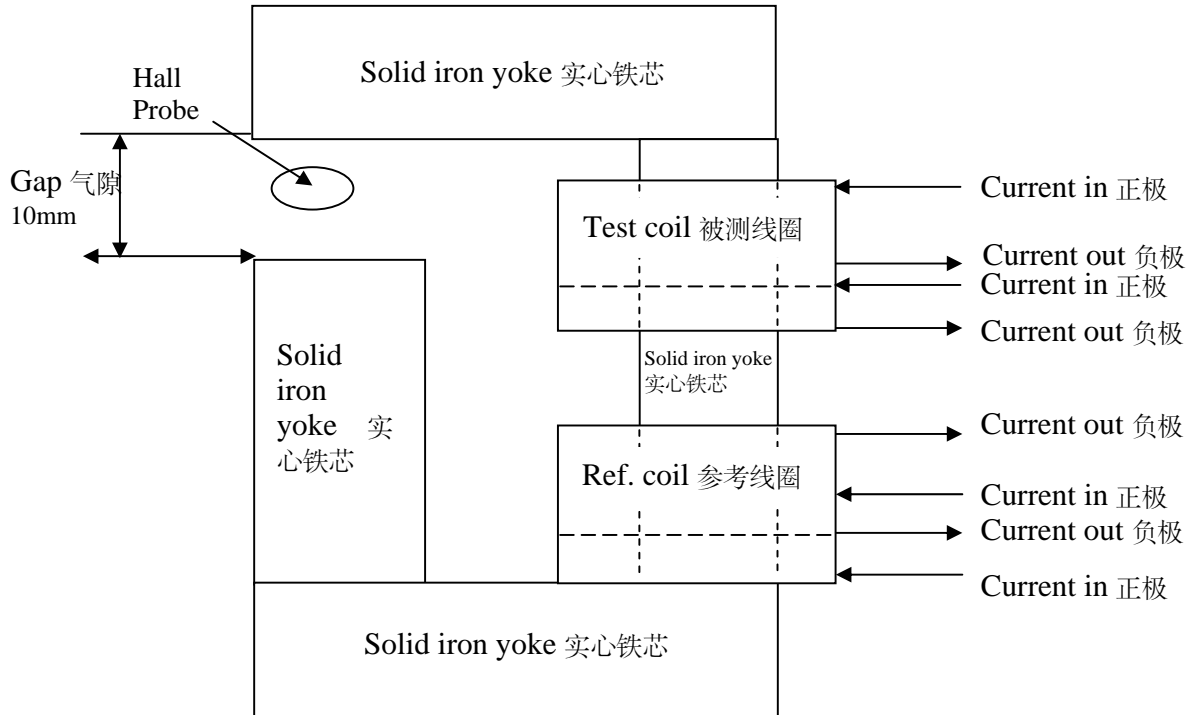
4.1.1 Turn to Turn Short Test / 匝间短路检测



Refer to the figure showed above; use two yokes that are kept a reasonable distance from each other, and two reference windings. Connect one winding to an impulse power supply while another to a current meter. Install a corrector coil through one leg of each yoke, with all 8 solid conductor winding leads and 2 hollow conductor winding leads connected serially and leave two leads to the air. For the test that is conducted before the potting, the coil shall be well clamped, the clamps that are used to tighten the coil should be insulated from the coil. Add impulse voltage to one reference coil and read the current meter, the needle of the meter shall not move. Any readable current will indicate a partial or dead turn to turn short. The coil shall be rejected.

参见上图。检测手段包括两个彼此保持一定距离的铁芯，两个辅助线圈。一个辅助线圈接电源，一个接电表。将被测线圈套入两个铁芯临近的两条腿，所有的实心导线和空心导线绕组出头串接在一起，留两个出头敞开。如果测量的是未浇注的线圈，线圈一定要保持夹紧状态，夹紧用的夹子要与线圈切实绝缘。加脉冲电压，电表读数应为 0。任何可读出的指针移动，都说明该线圈有半、或全短路，应予报废。

4.1.2 Check Coil Turns / 检验线圈匝数



Refer to the figure showed above. This test is performed after coil potting with all leads connected per the design specifications. The reference coil shall have the correct number of turns, shall be clearly labeled as reference coil and shall be used as the reference coil throughout the entire corrector coil production. Connect the power of the reference coil and the test coil as showed in the figure, the field that is read by the Hall Probe that is displaced at the gap should be zero. A reading of greater than 4 Gauss shall be deemed as unacceptable and cause for rejection.

参照上图。该项检测应该在线圈浇注后，所有出头都焊好的情况下进行。参考线圈应该是一个确知匝数正确的线圈，并且用记号清楚标明是参考线圈。该线圈在校正铁线圈生产的全过程都应用作参考线圈，不得更换。按图示方法接通电源，放在铁芯气隙处的霍尔片测到的场强应为0，任何读数高于4高斯的线圈都应作为不合格品，予以报废。

4.1.3 Thermal Test / 温度检测

This test is to assure that a coil is wound under appropriate tension and kept tight layer to layer and the conductor will be efficiently cooled. First ten (10) production coils shall conduct the thermal test. Thereafter, one coil shall be tested after each ten (10) production coils. The test procedure is as follows:

该项检验是为了确保线圈的绕制拉紧力适度，层间贴和紧密，以使导线能得到有效的冷却。最初的10个批量生产线圈应进行温度检测。之后，每10个线圈测量一个。测量步骤如下：

- 1) Attach water circuit and ensure that a minimum flow of 0.35gpm is established at Delta P <= 150psi.

线圈通水。水压降为150psi，水流量不应低于0.35gpm。

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- 2) Serial connect the vertical and horizontal windings and excite the coil to 30 Amps.
串接水平和垂直绕组，通 30 安培电流。
- 3) Hold the current for both coils at 30 Amps.
电流稳定在 30 安培。
- 4) In the first 15 minutes at 2 min. time intervals, thereafter, at 5 min. time intervals for another 30 minutes, measure and record:
最初的 15 分钟，每两分钟，以后每间隔 5 分钟，全程 30 分钟测量、记录：
 - Horizontal coil and vertical voltage respectively;
水平和垂直绕组各自的电压；
 - Coil temperature, directly locate a thermometer on the epoxy near by the lead of the horizontal winding;
线圈温度，将温度计直接放在水平绕组出头附近的环氧表面测量；
 - Water inlet and outlet temperature.
进、出水温度。
- 5) Compute the difference between each measure and initial resistances for each coil and normalize these values to the initial resistances.
计算两个绕组各测量时刻和初始时刻的电阻值差，按初始电阻值做归一化处理。
- 6) Compute the conductor temperature difference consistent with the differences in normalized resistances and record this value for each coil. The temperature coefficient of resistance of copper is 0.00393.
计算对应于归一化处理后所得电阻值差的各测量时刻温度差，记录所得数据。铜的电阻温度系数为 0.00393。

During 45 minutes,

- The voltage in the coils should not increase by more than 4%.
- The average temperature rise (both calculated and directly measured) should be $\leq 9^{\circ}\text{C}$ above the average water temperature.
- Maximum directly measured temperature rise in the conductor should be $\leq 18^{\circ}\text{C}$ above the average water temperature.

The raw voltage and results of the computed resistance and temperature changes along with the coil identification serial number should be recorded to the thermal test traveler.

45 分钟期间内，

- 电压升幅不应超过 4%。
- 温度升高平均值（计算和直接测量所得）不应超过平均水温的 9°C 。
- 直接温度最大温度升高值不应超过平均水温的 18°C 。

原始电压测量数据和计算所得电阻值和各测量温度变化值以及线圈身份号应填写进温度测量跟踪卡

4.2 Traveler / 跟踪卡

The traveler shall include pertinent fabrication records, inspection results and electrical and pressure test data. The information included in the traveler shall include at minimum the following data.

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- Coil Serial Number.
- Winding turns of each winding group and complete coil.
- Potting procedure.
- Results of test and measurement listed in the section 4.1.
- Visual inspection result and possible repair record.
- Names of technicians winding the coil and dates.
- Names of technicians impregnating the coil and dates.
- Name of technicians brazing the connections and dates.

跟踪卡应包括相应的生产记录，检验结果和电、压力测量数据。跟踪卡至少要含以下内容：

- 线圈序号；
- 各绕组匝数和线圈最后匝数；
- 浇注工艺过程；
- 款 4.1 要求的测量和检验结果；
- 外观检查结果和可能的返修记录；
- 绕线操作人姓名和日期；
- 环氧浇注人员姓名和日期；
- 焊接操作人姓名和日期。

4.2.1 Filling out the Traveler / 填写跟踪卡

The traveler shall be filled out at the site, signed and dated by the technicians performing the winding, potting, inspection, electrical tests and measurements and pressure tests and measurements of the coil. The completed traveler shall be signed and dated by the technician supervisor signifying approval of the coil for final magnet assembly.

跟踪卡应由绕线，浇注，检验，电、压力检测和测量的各操作人员在操作现场填写并签名，注明日期。填写完毕的跟踪卡应由有关负责人签准，将线圈发往下一道磁铁总装工序。

4.2.2 Traveler Original / 跟踪卡原件

The original of the completed, signed and approved traveler shall accompany the coil until final magnet assembly. After magnet assembly, the completed original traveler shall be filed at IHEP.

填写完毕并经签批的跟踪卡原件应随线圈运转直至磁铁最后总装。磁铁总装完后，跟踪卡原件应由高能所保存。

4.2.3 Traveler Copies / 跟踪卡复印件

A copy of a traveler for each coil shall be packaged with other copies of completed travelers for each completed magnet and delivered to SLAC along with the magnet.

每个线圈应有一份跟踪卡复印件，与完工后磁铁的其他跟踪卡复印件汇总，随磁铁一起转交 SLAC。

5. FINISHED COIL STORAGE / 线圈保管

After the water pressure test and before magnet assembly, the water in the cooling channel shall be completely drained by blowing dry air through the cooling channel. The channel shall be plugged and the finished coil shall be wrapped or otherwise protected from the environment until it is needed for magnet assembly.

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做完水压测量后，磁铁总装之前，线圈水路需空净残留水份并用干燥空气吹干，水嘴应随即封死。线圈应包起来或用其他方式保护使其不受环境污染直至转入总装。