EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
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CERN - PS DIVISION

PS/ CA/ Note 97-06

REPAIR AND MODIFICATION OF SMH92

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1. Introduction

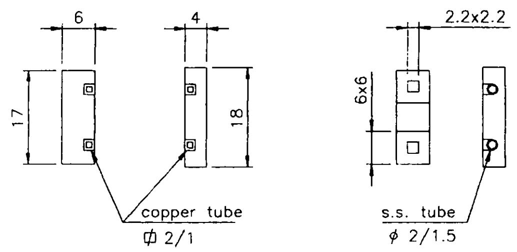
Following the breakdown of septum magnet smh74 in the PS accelerator and the replacement by its spare in July 1996, no spare magnet was available anymore, not for the smh74 nor for the smh92 since these magnets are symmetrical and share the spare magnet. In September 1996 septum magnet smh92 started leaking water from its cooling circuit into the vacuum chamber. A roughing pump was installed on the water circuit to pump it under a primary vacuum, and by restricting operation to one pulse per supercycle of 14.4 s and by avoiding of loosing the beam on the septum blade, operation could be continued until the annual shutdown in December 1996.

By January 1997 the radiation level of the smh74, that was taken out of the machine in July 1996, was almost halved. Work was started to repair it with newly manufactured coils, and convert it into a smh92 to replace the one in the PS that was operating without water cooling. Before installation it was necessary to test the magnet at its nominal and maximum current to establish whether the new coil didn't adversely affect the magnet's performance. Tests were carried out to measure the magnetic performance and to compare with the calculated design values. In this report the differences between the new and the old coil will be presented as well as the results of the tests carried out.

2. Coil design

The original coil design square copper tubes 2 mm exterior 1 mm interior, brazed in the septum blade and the return conductor. The water pressure used on these magnets is approximately 15 bar, and after 10 years of reliable operation, one after the other magnet started leaking, and coils needed to be replaced.

When new coils were to be manufactured, a slightly different design was ordered, to improve its reliability. Instead of brazing thin walled copper tubes everywhere in the coil, the septum blade was cooled with embedded thin walled round stainless steel tubes (∅ 2 x 1.5 mm), and the return conductor as well as the arms were constructed with thick walled square tubes (∅ 6 mm exterior, ∅ 2.2 mm interior), see Figure 1. These modifications necessitated different connecting boxes between septum and rear conductor as well as between the arms and the rear conductor, but the external dimensions of the coil with connecting boxes was still within the limits the yoke allowed for, so no modifications are necessary to the yoke to install the new coil.



Old Coil **New Coil**

Figure 1: cross sections of rear conductor and septum blade of the old and new coil

An important difference with the old coil is the current distribution in the septum blade. Except for the water passage the old septum blade was all copper, so the current distribution was disturbed by a 1 mm square hole. In the new coil the water tube is 1.5 mm interior, but since the tube doesn't conduct the current as well as copper, it can be considered as not conducting as well, therefore the entire cross section of 2 mm diameter isn't carrying any current. An inhomogenous current distribution and the play between septum blade and yoke, are the two most important factors for the existence of the fringe field. Magnetic measurements of the fringe field will have to confirm these modifications.

By increasing the cross sections of the tubes, with the same water pressure on the coil as previously, the water flow will increase and the coil will be cooled slightly more as before. Since the Eletta flow meter were operating at the lower limit of their operating range with the old coils, this can be seen as an additional advantage.

3. Magnetic field measurements

Using the PS/PO power supply in the lab with a pulse repetition rate of approximately 1.2 seconds a series of measurements were recorded in order to determine the magnetic field in the gap, and the fringe field. The field in the gap was measured to determine the actual punctual values and also the integrated field (Bdl) with which we can calculate the equivalent magnetic length of the magnet. Two coils were used: for punctual field values, coil 1, for Bdl measurements, coil 2.

In Figure 2 the positions are indicated where the different magnetic measurements were taken.

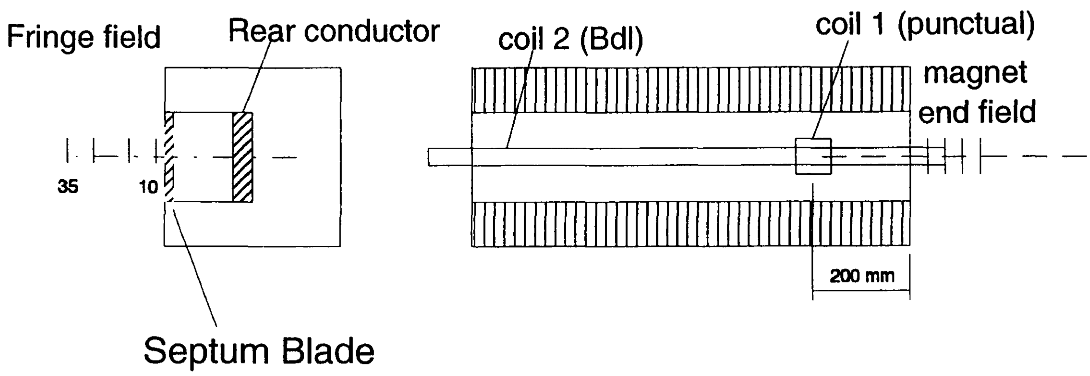


Figure 2: magnetic measurement positions

The measuring equipment used was:

Current Transformer	Pearson Model 1423 (1 V/kA)
Digitiser	Tektronix 7612D
Data handling	486 p.c. with Labview
Measurement coil 1	s = 0.03693m^2 ; ϕ= 5 mm
Measurement coil 2	s = 0.0755m^2; l =1.30 m; width = 10 mm
Scope	H.P. Model 54601 A

With the small measuring coil (coil 1) the field was measured in the middle of the gap and at one quarter of the length of the septum. With the program 'fringefield' running under Labview, the fields were measured. This measurement system is described in note PS/PA 95-13.

3.1 Measurements inside the magnet gap

In this paragraph tables and diagrams are shown of the field in the gap, measured with coil 1, and the integrated field through the gap measured over more than the full length of the magnet to obtain the equivalent length of the magnet. The results for magnet smh74/92-1 are shown in Table 1.

Table 1: Magnetic measurements inside the gap of SMH74/92-1

Magnet current (kA)	Bdl (mT.m)	Bo (T)	L equiv. (mm)
10.7	303.6	0.735	413
13.0	369.4	0.900	411

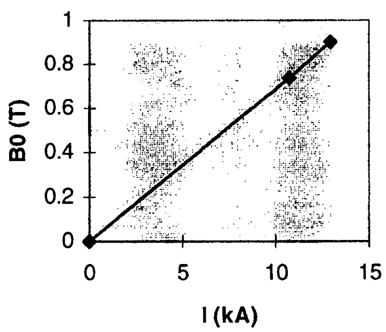


Figure 3: B_0 as function of the current

What can be noticed from Figure 3 is that no measurable saturation occurs.

Also the equivalent length (L_{equiv}) is tabulated in the table. This length is calculated by dividing the integrated field by the corresponding field strength. This length is equivalent to the length of a theoretical magnet with field strength B_0 and no field outside the magnet. The expected equivalent magnetic length is 413 mm and the measured length is within acceptable tolerance of this expectation.

3.2 Measurement of the fringe field next to the septum

Measurements were carried out to determine the magnitude of the integrated fringe field parallel and close to the septum blade in order to assess the effect on the orbiting beam. The results were taken at several separate distances from the septum with results presented in table 2. The relative values of these results are graphically shown in Figure 4.

Table 2: Fringe field measurements on SMH74/92-1

Distance from septum blade (mm)	Bdl (T.m) (at 10.7 kA)	Bdl (T.m) (at 13.0 kA)
25	2.75e-4	4.27e-4
35	1.86e-4	2.65e-4
45	1.20e-4	1.91e-4
55	9.39e-5	1.46e-4
65	6.95e-4	1.15e-4

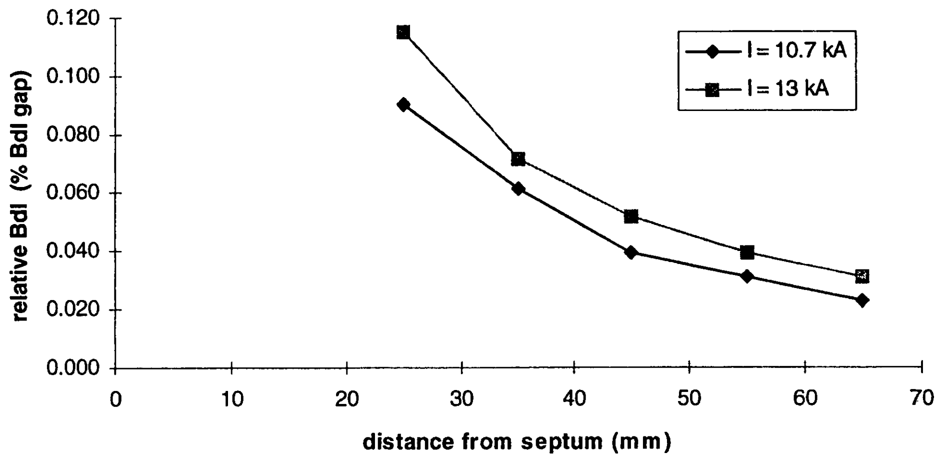


Figure 4: integrated fringe field as function of the distance to the septum blade

4. Miscellaneous modifications

Apart from the repair op the magnet by replacing its coil, thermocouples, and their feedthrough were installed on either extremity of the magnet yoke, on the upside of the outer laminations. These will allow monitoring the temperature of the yoke while baking out the magnet.

Also a deflector was installed between the infra red bake out lamp and the tank wall to reduce the heating of the tank and increasing the efficiency to heat up the magnet. Since the lamp is very close to a 'wheeler' type flange and its 'Helicoflex' seal, this should reduce the risk of overheating the seal and creating a leak.

5. Conclusions

The new coil used to replace the existing coil doesn't change the magnet characteristics very much. The field in the gap is as expected, as well as the magnetic length. The fringe field next to the septum blade of the new magnet is low, already lower then 1‰ at 25 mm distance from the septum.

The cooling requirements for septum 74/92 are modest. With the new coil the design of the water circuit has been increased, to make the coil less vulnerable for possible small particles in the cooling water. Also thicker walls of the tubing and the use of stainless steel embedded tube should make the coil less vulnerable, hence more reliable.

A deflector has been installed on the bake out lamp to reduce overheating the 'Helicoflex' seal and increase its efficiency to heat up the magnet. To monitor the temperature of the magnet during bake out, thermocouples have been installed on the yoke.

Appendix I: Magnetic measurement results

smh 74/92-1 with coil 74.2-09

date measurement 23/1/97

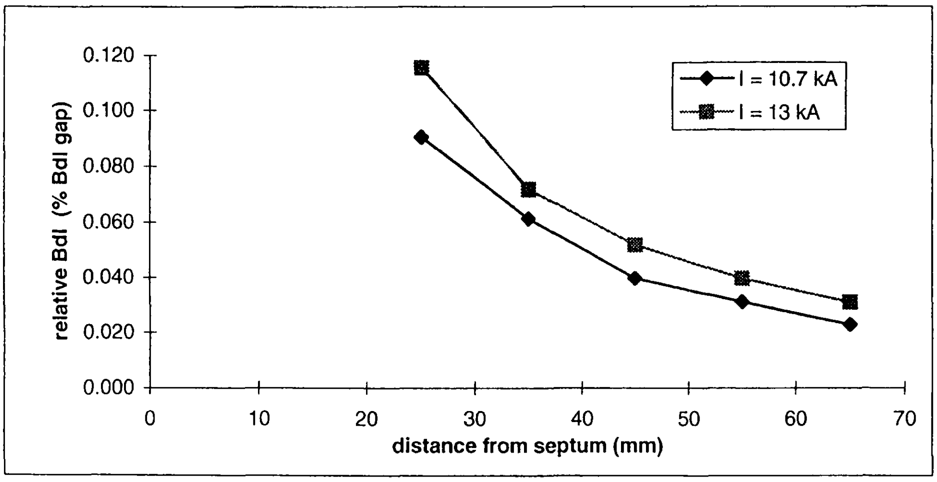
pulse half sine, 2.68 ms, repetition rate 1.2 s
measurements done with pc labview digitiser chain. Coils as on btsmv20 measurement

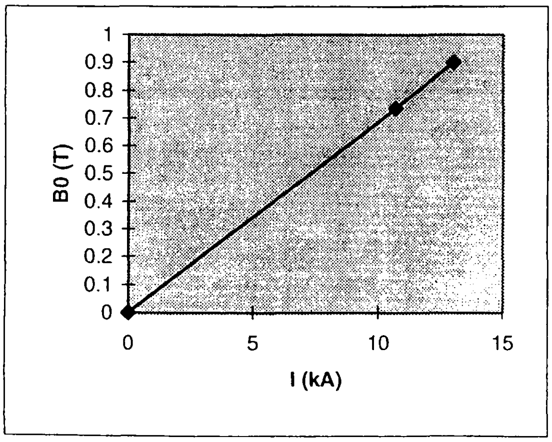
GAP

I (kA)	Bo (T)	Bdl (mT.m)	Leq (m)
0	0	0	
10.7	0.735	303.6	0.413
13.0	0.900	369.4	0.411

FRINGEFIELD

D (mm from septum)	I =10.7 Ka		I = 13 kA	
	Bdl (Tm)	% Bdl gap	Bdl (Tm)	% Bdl gap
25	2.75E-04	0.091	4.27E-04	0.115
35	1.86E-04	0.061	2.65E-04	0.072
45	1.20E-04	0.040	1.91E-04	0.052
55	9.39E-05	0.031	1.46E-04	0.040
65	6.95E-05	0.023	1.15E-04	0.031





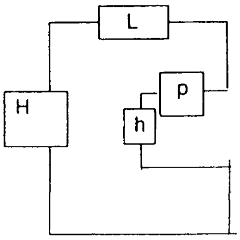
Appendix II: Magnet calculations

smh 74

particularités

DONNEES		
particules electrons : e protons : p	e	
quant.mouvt : MV Energie cin. : EC	ec	
Energie cinétique Ec =	0.6	GeV
Déflexion requise	154	mrad
Epaisseur du septum	4	mm
Hauteur du Gap	18	mm
Profondeur du Gap	80	mm
Longueur magnetique equivalent	413	mm
Espace de glissement	0	m
Monospire donc	1	spire
Epaisseur cond. retour	6	mm
Hauteur de conducteur retour	18	mm
Résistivité du cuivre (1.72E-2	0.0172	mO.mm
module d'Elasticité (12500	12500	daN/mm2
Forme de l'impulsion		
DC , 1/2 sinus : S , trapèze : T	S	
1/2 période de l'impulsion	3.4	ms
Période de récurence (cycle tot.	1.2	s
taux de répétition de l'impulsion de courant		
Systeme de refroidissement		
pression différentielle	12	bar
nombre du circuits	2	
septum		
forme element de refroidissement	circ	
Cote horizontal	4	mm
Cote vertical	9	mm
forme du passage d'eau	circ	
Diametre trou	1.5	mm
conducteur retour		
forme element de refroidissement	rec	
Cote horizontal (mm)	6	mm
Cote vertical (mm)	9	mm
forme du passage d'eau	rec	
Cote horizontal	2.2	mm
Cote vertical	2.2	mm
Matiere		
maximum admissible champ dans le f	1.7	T

RESULTATS	ELECTRONS	
Masse au repos mo	0.000512	Gev/c2
Energie cinétique	**0.6000**	GeV
Quantité de mouvement	**0.6005**	Gev/c
beta	1.0000	
gamma	1172.8750	
beta*gamma	1172.8746	
Déplact. après espace de gliss	31.801	mm
Champ intégré B*L	**0.308**	T.m
Induction dans le Gap	**0.746**	T
Champ magn. H=B/uo	5.94E+05	A/m
Courant nécessaire	**10691**	A
Valeur efficace du courant	402	A
densité de courant eff.	5.88	A/mm2
Résistance de l'aimant	**0.210**	mOhms
Inductance de l'aimant	**2.16**	uH
Puissance dissipée	**0.034**	kW
Energie stockée	124	J



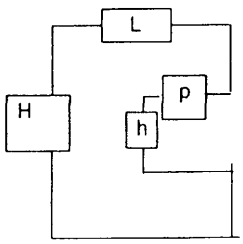
	80	p en mm
	18	h en mm
	115.1	L en mm
	88.2	H en mm
Débit d'eau total	2.51	l/min
Débit dans chaque spire	1.25	l/min
vitesse de l'eau dans septum	11.83	m/s
dT total d'eau	0.22	K
Force septum /cond fond	**164.79**	daN
Flèche max . septum (appui	0.000	mm
moment flech.max. (appui	0.90	mm*daN
contrainte maxi <5 (appui	0.34	daN/mm2
Masse culasse (sans poutre	26	kg
section cond. septum	68.46570826	mm2
Section refroidissement septur	3.534291735	mm2

smh 74

particularités

DONNEES		
particules electrons : e protons : p	e	
quant.mouvt : MV Energie cin. : EC	ec	
Energie cinétique Ec =	0.6	GeV
Déflexion requise	180	mrad
Epaisseur du septum	4	mm
Hauteur du Gap	18	mm
Profondeur du Gap	80	mm
Longueur magnetique equivalent	413	mm
Espace de glissement	0	m
Monospire donc	1	spire
Epaisseur cond. retour	6	mm
Hauteur de conducteur retour	18	mm
Résistivité du cuivre (1.72E-2	0.0172	mO.mm
module d'Elasticité (12500	12500	daN/mm2
Forme de l'impulsion		
DC , 1/2 sinus : S , trapèze : T	S	
1/2 période de l'impulsion	3.4	ms
Période de récurence (cycle tot.	1.2	s
taux de répétition de l'impulsion de courant		
Systeme de refroidissement		
pression différentielle	12	bar
nombre du circuits	2	
septum		
forme element de refroidissement	circ	
Cote horizontal	4	mm
Cote vertical	9	mm
forme du passage d'eau	circ	
Diametre trou	1.5	mm
conducteur retour		
forme element de refroidissement	rec	
Cote horizontal (mm)	6	mm
Cote vertical (mm)	9	mm
forme du passage d'eau	rec	
Cote horizontal	2.2	mm
Cote vertical	2.2	mm
Matiere		
maximum admissible champ dans le fi	1.7	T

RESULTATS	ELECTRONS	
Masse au repos mo	0.000512	Gev/c2
Energie cinétique	**0.6000**	GeV
Quantité de mouvement	**0.6005**	Gev/c
beta	1.0000	
gamma	1172.8750	
beta*gamma	1172.8746	
Déplact. après espace de gliss	**37.17**	mm
Champ intégré B*L	**0.360**	T.m
Induction dans le Gap	**0.872**	T
Champ magn. H=B/uo	6.94E+05	A/m
Courant nécessaire	**12496**	A
Valeur efficace du courant	470	A
densité de courant eff.	**6.87**	A/mm2
Résistance de l'aimant	**0.210**	mOhms
Inductance de l'aimant	**2.16**	uH
Puissance dissipée	**0.046**	kW
Energie stockée	169	J
	80	p en mm
	18	h en mm
	121.1	L en mm
	100.1	H en mm
Débit d'eau total	**2.51**	l/min
Débit dans chaque spire	1.25	l/min
vitesse de l'eau dans septum	11.83	m/s
dT total d'eau	0.30	K
Force septum /cond fond	**225.13**	daN
Flèche max . septum (appui	0.001	mm
moment flech.max. (appui	1.23	mm*daN
contrainte maxi <5 (appui	0.46	daN/mm2
Masse culasse (sans poutre	**32**	**kg**
section cond. septum	68.46570826	mm2
Section refroidissement septur	3.534291735	mm2



Appendix III: Bake out instructions for the SMH 74/92

Consigne pour l'étuvage des septa smh74 / 92

SMH 74/92 -1

1 lampe infra rouge + déflecteur installée :
70 V_{rms} pendant 60 heures (donnant 170 - 120 °C sur les deux extrémités de l'aimant.)
Bride 'wheeler' chauffer avec résistance à 80 °C

SMH 74/92 -3

2 lampes infra rouges sans déflecteurs installées:
60 V_{rms} pendant 60 heures (donnant 180 - 200 °C sur les deux extrémités de l'aimant)
Bride 'wheeler' chauffer avec résistance à 80 °C

Traversée 10 pin installée sur les tanks, avec câble d'adaptation , terminant sur burndy 12 pin.

Traversée Varian	G	H	A	B
	+	-	+	-
(Amphénol)	G	H	A	B
	+	-	+	-
Burndy 12	1	2	3	4
	+	-	+	-

! Utiliser un Voltmètre 'True RMS', pour vérifier la tension sur les lampes. Il y a un différence d'à peu près un facteur 2 avec un voltmètre basé sur la valeur moyenne.

Distribution:

Jean Pierre Riunaud
PS/CA/Septa