High performance Fujikura tape 4.5K

Boost coil standalone 8.1T peak 77%ss 900A 10 T peak 100%ss 1100A

In 15 Tesla background 22.9T peak 95%ss 900A



Constant inner diameter design

Joints alternate from inner to outer radii.

Viewed from top, Coils alternate between being wound clock-wise to anticlock-wise.

We can increase the good field length by adding coils

Central section has Copper rings joints / spacers.



Collapsible central winding mandrel

Field variation over sample volume



Magnet System overview









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Joints alternate from inner to outer radii.

Viewed from top, Coils alternate between being wound clock-wise to anticlock-wise.

We can increase the good field length by adding coils

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Collapsible central winding mandrel



- Mechanical design completed
- 3D printed mock-up fabricated, assembly sequence validated
- All parts in production
- 3D printed 316L parts delivered





- Collapsible mandrel design, fabricated & validated
- Tooling ready for winding
- First & last turn soldered for mech. support



- Kapton disks with cut-outs for edge joints as tooling
 - Inner edge joints often with voids, difficult to fill reliably with solder
 - Double pancakes could be an alternative to eliminate inner joints





Test Copper coil with edge joints



Outer joint



Inner layer jump





Outer and inner coil insulation with no joint

- Tooling to assemble multiple (double) pancakes into solenoid field booster
- Al tube as inductive shield and mech. support







26 T hts coil , Copper busbars clamped with Indium compression joints test at CERN Nov 2019



HTS Quench

HTS quench in simple coil, we see the evolution of field, temperature, current density, voltage maps, during quench.



DIPOLE HTS MAGNETS AT CERN | G. Kirby | 978 updates | 2 publications | Research Project (researchgate.net)

Thanks to LittleBeast engineering for the modelling Mar 31 2021

Screening currents







9 Results : Lorentz forces distribution in the coil

The Lorentz forces distribution is shown for the case of high-quality cable (1kA critical current, 25 n-value), and it is calculated for t=50s after the current plateau. From left to right: radial and vertical component. The arrows represent the main direction of the forces for the upper pancake.

Misalignment 5 mRad

We looked at misalignment and the effect of screening currents and decay times.

0'0020 225.0 25.0 0092

Source												
Backgroup	d field ran	nn time 1/										
Current rar	nn risetii	me 10s. st	arted 5s after fi	eld plateau (19	is absolute	time)						
Results giv	en in time	after cur	rent plateau	cia plateau (1.	-s absorute	cincj						
nesares pre-	cri in cinic	unter cur	i chi plateaa									
r 16[mm]				Max Lore	ntz Force in	coil						
lc =1 [kA]				lc =1 [kA]								
n=25				n=25								
err = 5 mra	d coil rota	ation										
1	t=10[s]	t=20[s]	t=40[s]									
x [m] e	err[%] 10s	err[%] 20:	err[%] 40s	Time (s)	sqrt((J_ph	i*B_z)^2+(-J_pl	hi*B_r)^2) (N/mm^3	;)			
0	-2.4154	-2.3907	-2.3695	0	0.00E+00							
0.00025	-2.3846	-2.3572	-2.333	2	2.05	Time=64	s F r		Time=	64 s F z		
0.0005	-2.3543	-2.3241	-2.297	4	5.2988	11110-04					-	
		0.5		Q 6	7.1282			N/mm ³			N/mm ³	
		0.3		8	10.557						8	
		0.5		10	15.255							
		0.1		12	10.918			· 1	-			
03 -0.02	-0.01	-0.1 0	0.01 0.02	0.03 14	11.517						6	
		-0.3		16	13.178				_			
		0.5		18	16.175				_		4	
		-0.7	~ \	Q20	17.089							
		-0.9	\	22	19.139			0.5	k alasisi		_	
	/	-11		24	17.817			0.5			2	
		1.2	1	26	53.188							
		-1.5		28	34.056				_		• • 0	
		-1.5		30	29.451				_			_
——e	rr[%] 10s 🔸	err[%]	20s —— err[%] 4	Юз 32	20.08				-		2	_
0.00120	1.0110		1.500	Ô84	13.767			0	-			
0.0045	-1.581	-1.5441	-1.5073	36	13.652							
0.00475	-1.5203	-1.4836	-1.447	38	13.556				_		-4	
0.005	-1.46	-1.4236	-1.3872	40	13.474				_			
0.00525	-1.4064	-1.3695	-1.3327	42	13.404				-		-6	
0.0055	-1.3533	-1.316	-1.2787	44	13.339		-	-0.5	-			_
0.00575	-1.3009	-1.263	-1.2254	46	13.279				-		8	_
0.006	-1.2493	-1.2109	-1.1728	48	13.225				-		-0	
0.00625	-1.2084	-1.1689	-1.1296	50	13.174				_			
0.0065	-1.168	-1.1274	-1.087	52	13.128				_		-10	
0.00675	-1.1282	-1.0864	-1.045	54	13.084		l	1 -1				
0.007	-1.0893	-1.0464	-1.0038	56	13.044			-1	-		-12	
0.00725	-1.0611	-1.0168	-0.9727	58	13.007		l		_			_
0.0075	-1.0333	-0.9876	-0.9421	60	12.974		1					
0.00775	-1.0061	-0.959	-0.9121	62	12.945							
0.008	-0.9797	-0.9313	-0.883	64	12.918							





Voltage difference across coating [V]



ID: 133 WED-P02-616-13 JU72AVL1

Varistor Insulation for HTS Magnets

G, Kirby, T. Galvin, D. Coll, R. Stevenson, P. Livesey

Adamps - A variable revisions and find the intermediation earlier in the second second

bons. In this paper we present the electrical characterization of the in-sulation at room temperature and cryogenic temperatures, along with simulated magnet operation during ramping, normal opera-tion and failure modes. We discuss other features of the VI insula-tion and failure modes. II. VARISTOR PASTE INSULATION CHARACTERISTICS a. We discuss other leatures of the Vi insula-on methods to provide thin layers, and alter-tune its properties. Its ability to act as a dis-er when the voltage threshold is exceeded is ion such as, applica A. Varistor voltage resistance dependance



1. INTRODUCTION

1. **INTEGRATION** The properties the control ratio of development of the properties of the properties

is not controlled so the field quarks in the magnet is also one distribution of the second s

Manuscript receipt and acceptance 30° Nov 2021. This work was supported by CIRN TE: department, Geneva, Switzerland: & Metronil.com Corresponding and Cashva, D.Call, R.Stevenaos, P.Livosey with M&H Materials UK.



become the limiting factor. The circuit design will be set to provide a safety limit against this, of several orders of magni-tude. However, the inherent volume of the coil as the insulation layer starts to switch will limit current density. If this failure can occur by over voltage levels, the insulation is in a closer cuit situation with current passing.

III. APPLICATION TO CONDUCTOR The first development material The active material is suspended in a viscous insu d with the full insulation properties are presented i

planned to characterize this effect.

C. Ideas for the spacer to set the gap between tape

B. Requirements for the thin layer mounting system

Initial testing and quench modelling point towards a th layer on the range 0.02 to 0.1 mm. A thin layer is an advanta, as it keeps the coil current density high, as with standard ins lation systems, even a slightly thinner layer may be impli-mented if amountable. It is not accommodiate insurent and there the here ted if possible. It is also extremely important that the laye is uniform, as the voltage characteristics of the paste are thickness-dependent, so thinner spots would pass more current and The first attempts to apply the paste used no spacer. Two heat unevenly. The gap between adjacent tapes must also be clean tapes were mount paste was applied the or thickness before voltage sectors of having a convince sector depending on the other with a particle barries of having a convince sector depending on the origon converting of the other voluge interving interving the other voluge interving interving the other voluge interving to the other voluge interving the other voluge interving to strolled, to eliminate electrical shorts between tapes ether at IV. TESTING currents the position of the current start to follow the edges of the tapes. Any spacer that is placed to centrol the gap between tapes and hence limit the area over the tape to paste contact to A. Room temperature testing: opening and closing voltages tapes and hences limit the area over the tape to pasts contract to A. Roame temperature texting: specing and clusing voltages for the single of the tape. The voltages of the tape of the tape of the voltages of the tape. The voltages of the tape of the voltages of the tape. The voltages of the tape of the tape of tape of

As mentioned, the space between tapes needs to be controlled carefully and full fill several requirements. Many spacer ideas have been proposed, not all have been tested. Fig. 6 shows some of the ideas. This in ongoing development.

Cloverleaf





MAGNET PARAMETERS									
Parameter	Value	Parameter	Value						
Center field	9.4 T	Length cable/tape per cloverleaf	143/286 m						
Maximum field on conductor	12.2 T	Length cable/tape per racetrack	80/160 m						
Current	2000 A	Total tape length	894 m						
Tape thick- ness/width	0.1/12 mm	Number of cable turns cloverleaf	82						
Number of tapes in cable	2	Number of cable turns racetrack	183						

TABLE I

Fig. 1. Overview of the coil-layout of the short demonstrator magnet. The magnet consists of two poles, with each a cloverleaf coil and a racetrack coil. The colors on the coil indicate the magnetic flux density present on the conductor surface for a current of 2 kA. In this case, the maximum field is reached at the inside of the coil-end of the racetrack and has a magnitude of 12.2 T.



[9]. This can lead to better current sharing between the tapes in the case of a quench, which can improve the stability of the coils.
There is no insulation in-between the tapes.

On the inside and outside surfaces of the *Re*BCO coil windings, 2 mm thick copper tape windings are present. These layers serve as a stabilizer as well as current entry and exits point along the first and the last turn of the coil windings. In Table I, the most relevant coil parameters are listed.

B. Coil-End Design

109

The top and bottom coils of the cloverleaf-racetrack magnet 110 are simple racetrack coils and the center coils are in clover-111 leaf configuration (see Fig. 1). The cloverleaf coils allow the 112 conductor to go over the particle beam pipe. The cloverleaf 113 configuration was first proposed by Gupta *et al.* in 2003 as 114 a design for high field accelerator magnets using "React & 115



Fig. 4 Overview of the magnet assembly. On the left the individual components of a magnet pole are shown. On the right the magnet assembly and a cross-section along the mid-plane of the magnet are shown.

END

Induction of high currents



V-I measurements in coil 2.3

The degradation is visible from VI 2 to VI 3 (after the many extractions in Fresca2) and from VI 4 to VI 5 (after the magnetic measurements to 2 kA in Fresca, 4 kA in Feather).

Also, initial degradation from the standalone test to the first VI performed in this test campaign is visible

