Lawrence Berkeley National Laboratory	Cat Code	LBNL Document # DF-1000-4369	Rev A	Page 1 of 22
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Title TFD Coil and Structure Parameters WINDCHILL TECHNICAL NOTE TEMPLATE				

TFD Coil and Structure Parameters

Contents

Revision History

Revision	Issued	Changes
A	2023-01-06	Original issue.
B	-	See Changelog.

Purpose

The purpose of this note is to document the high field test facility dipole (HFTFD) magnet cable, coil, and structural parameters.

Nomenclature and Anatomy

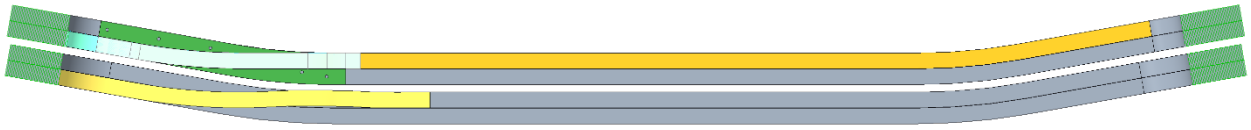


Figure 1: Section view of one pole of the TFD.

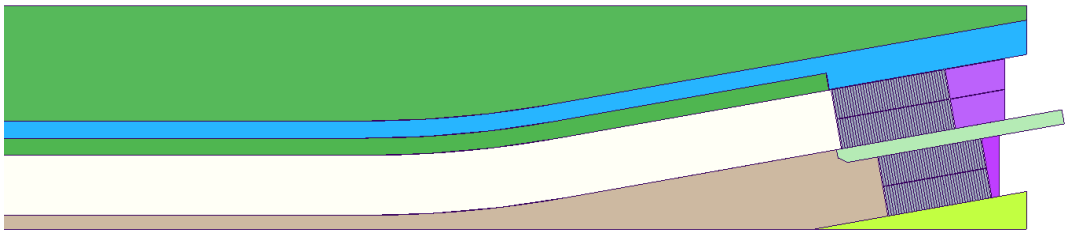


Figure 2: Section view of the return end of one pole of the TFD.

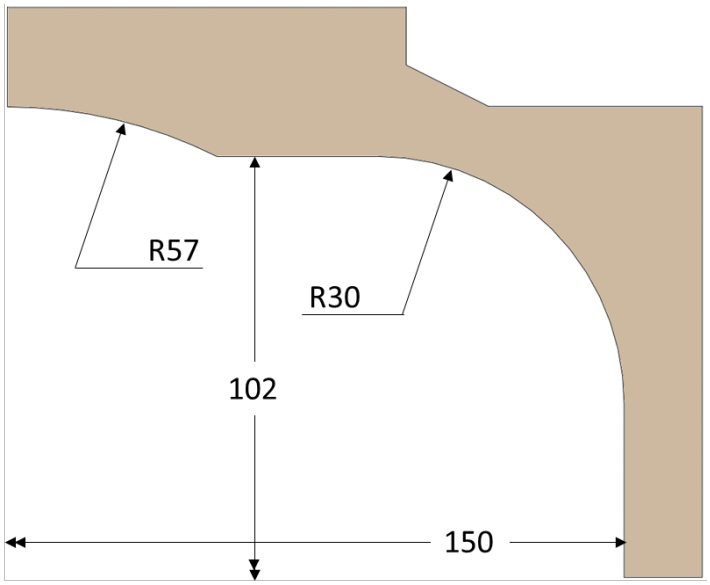


Figure 3: TFD Bore Geometry

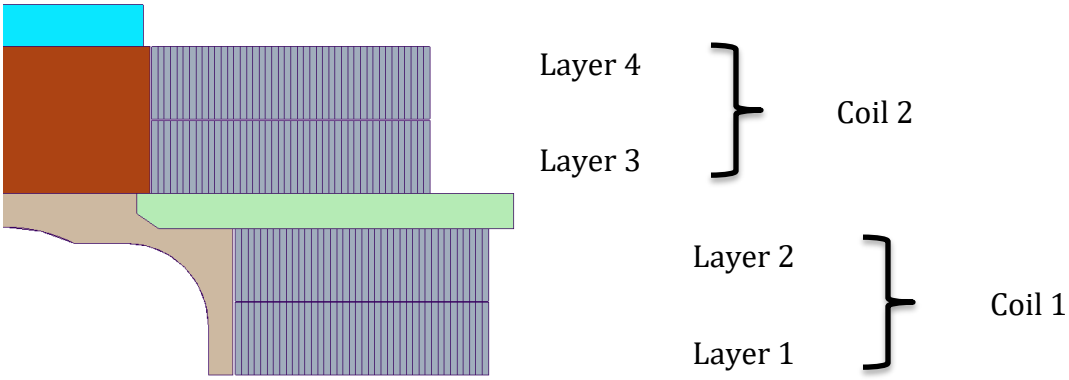


Figure 4: TFD Layer and Coil Nomenclature

Coil Geometry

The position of the 2D vertices is given in Figure 2.

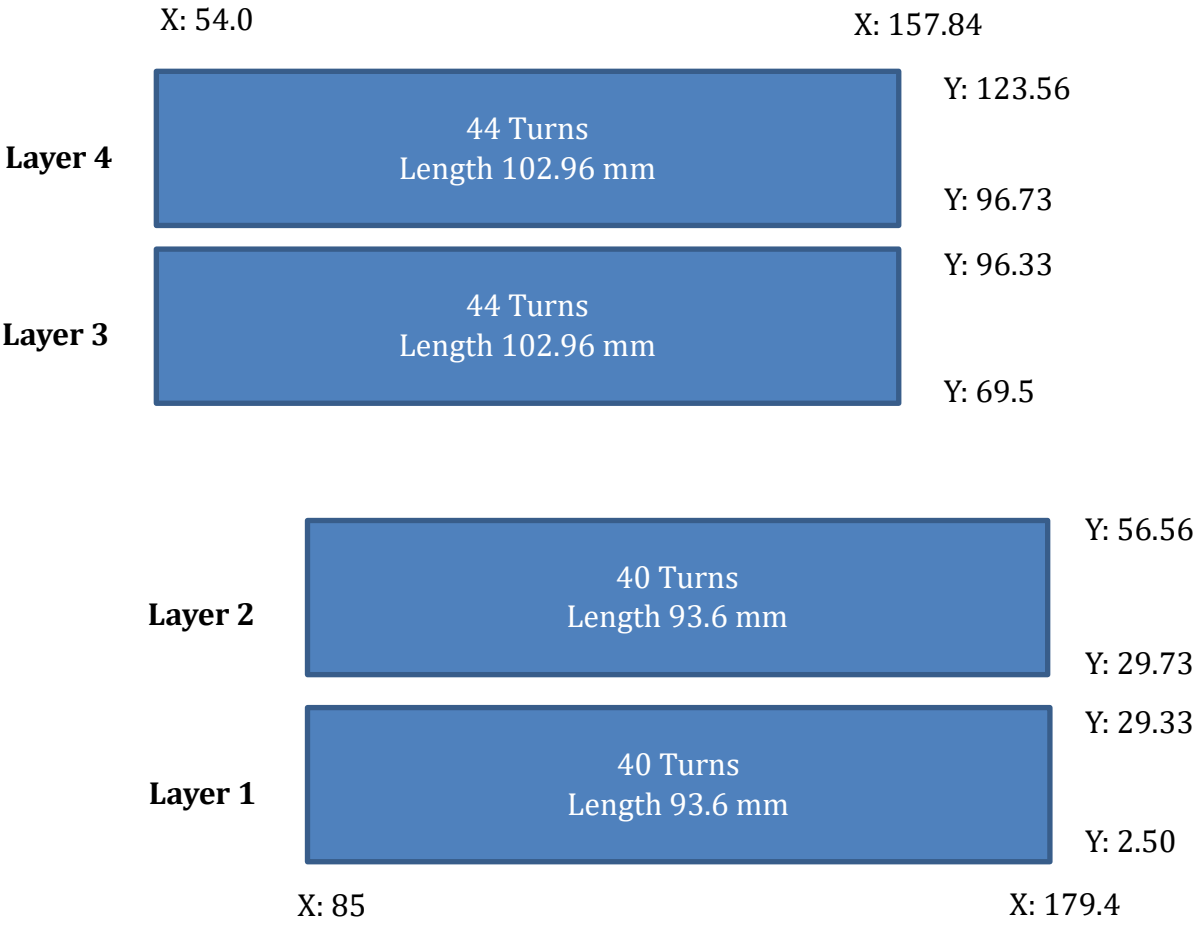


Figure 5: 2D positions of the coil vertices of the magnet quadrant

Table 1: 2D Cable Parameters

Parameter	Unit	Value	Remarks
Strand diameter	mm	1.1	
No. strands	/	44	
Cable transposition pitch	mm	155	
Keystone angle	°	0	
Cable width (bare, before reaction)	mm	26.20	
Cable width (bare, post-reaction)	mm	26.46	1% increase in width
Cable thickness (bare, before reaction)	mm	1.91	
Cable thickness (bare, post-reaction)	mm	1.99	4.2% increase in thickness
Insulation thickness	mm	0.185	
Cable width (insulated)	mm	26.83	Used for CAD: "HC"
Cable thickness (insulated)	mm	2.36	Used for CAD: "TC"
Inter-layer insulation	mm	0.4	

Table 2: 2D Dipole Features

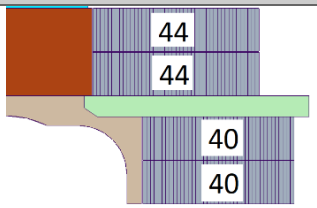
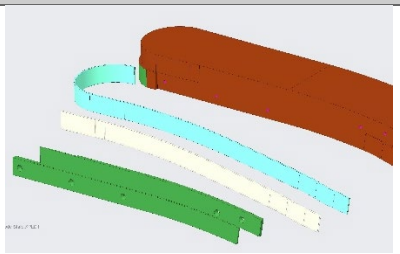
Parameter		Symbol	Unit	Value	Source	Remarks
Number of layers		N_L	/	4		Per pole
Number of Turns	Layer 4	N_4	/	44		
	Layer 3	N_3	/	44		
	Layer 2	N_2	/	40		
	Layer 1	N_1	/	40		
Overall number of turns		N_{tot}	/	168		$= N_1+N_2+N_3+N_4$
Inner coil radius	Layers 1 & 2	EWR_1	mm	85		From centerline to inboard edge of cable insulation
	Layers 3 & 4	EWR_2	mm	54		From centerline to inboard edge of cable insulation
Last turn horizontal position	Layers 1 & 2		mm	179.4		$= EWR_1 + N_1 \cdot TC$
	Layers 3 & 4		mm	157.84		$= EWR_3 + N_3 \cdot TC$
Midplane insulation thickness		t_{mid}	mm	5		*i.e.* 2.5 mm per pole *(excludes individual coil insulation)*
Interlayer insulation		IL_INS	mm	0.4		Layers 1-2 and 3-4
Inter-coil insulation		t_{2-3}	mm	12.98		Layers 2-3
Bore circular radius			mm	57	CAD	
Bore rectangular width			mm	150	CAD	
Bore rectangular height			mm	102	CAD	
Bore rectangular corner radius			mm	30	CAD	

Table 3: 3D Dipole Features

Parameter	Symbol	Unit	Value	Source	Remarks
Magnet module length			2175		Overall
Ramp angle	HBA	°	10		
Hard-way bend radius	HBR_1	mm	1467		Coil 1, minimal value (layer 2)
	HBR_2	mm	1400		Coil 2, minimal value (layer 4)
Inclined straight section length	L_{R1}	mm	165		
	L_{R2}	mm	195		
Straight section length	L_{S1}	mm	750		Straight section + jump
	L_{S2}	mm	750		Straight section + jump
Baseline coil width	w	mm	358.8	CAD	
Baseline coil height	h	mm	200.291	CAD	
Coil 1 length		mm	2013.36	CAD	Coil end-to-end
Coil 2 length		mm	1888.54	CAD	Coil end-to-end
Coil stay-clear half-height	h_1	mm	68.85	CAD	
Layer jump type	-	-	HW 2 chicanes		 Insulation wrap thick.: 150 µm
Layer Jump Hard-Way Bend Radius	R_{LJ}	mm	1000		
Layer Jump EW offset	DX1	mm	6		
Layer Jump EW transition length	DZ1	mm	60		
Total cable length [1]	L_{SC}	m	1337	CAD	For the full dipole, does not include the leads
Total coil volume [2]	V_{SC}	m^3	0.08	CAD	For the full dipole

[1] The individual lengths are as follows: **332.2 m** for coil 1 and **336.3 m** for coil 2.
[2] The 40 turns of coil 1 give 21 035 996 mm^3, and the 44 turns of coil 2 give 21 294 475 mm^3.

Table 4: Component and Part masses

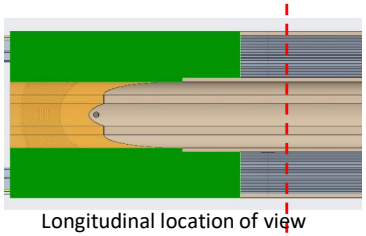
Part Name	Unit	Value	Material	Source	Remarks
Pole Piece (Coil 1)	kg	0			
Pole Piece (Coil 2)	kg	0			
Vertical Pad	kg	0			
Horizontal Pad	kg	0			
Insulated cable density	g/mm	400		Measurement	Cable 1301-B
Coil 1 conductor weight	kg	133		Estimate	
Coil 2 conductor weight	kg	135		Estimate	

Cable Length Details

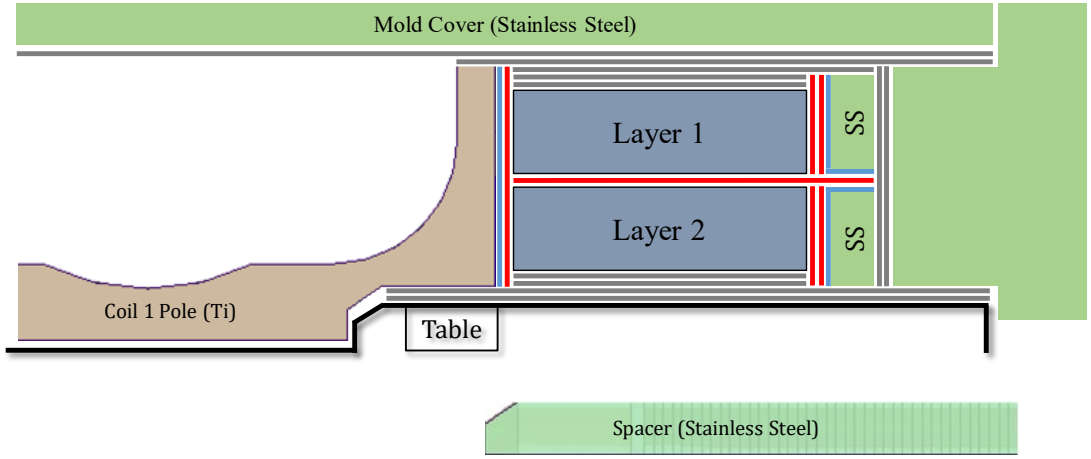
Note cable lengths that remain with magnet, cable lengths overall for winding, lead lengths, insulation setting, extra margin

Insulation Scheme

Winding/Reaction: SS Coil 1



Longitudinal location of view



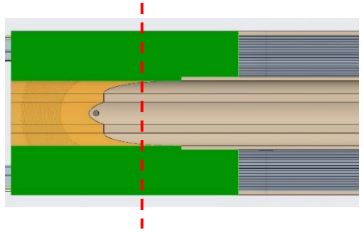
Vertically oriented insulation

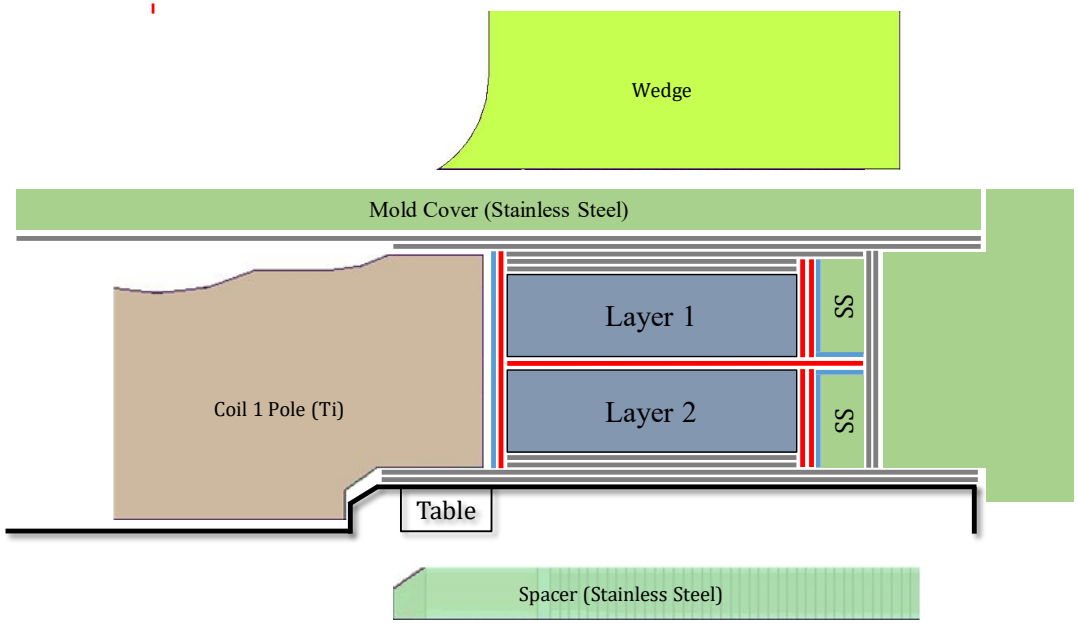
Description	Thickness [mm]	Material
Pusher mica	0.2	Mica
Rail outboard mica	0.2	Mica
Plasma spray insulation	0.15	Al_2O_3
Rail – Coil insulation	0.2	S2 glass
Rail – Coil insulation	0.2	S2 glass
Coil – pole insulation	0.4	S2 glass
Plasma spray insulation	.15	Al_2O_3

Horizontally oriented insulation

Mica under the mold cover	0.2	Mica
Mica atop the coil	0.2	Mica
Wedge extension placeholder	1	Mica layers
Compensating insulation placeholder	0.7	Mica layers
Trace & insulation placeholder	0.3	Mica layers
Interlayer insulation	0.4	S2 glass
Trace & insulation placeholder	0.3	Mica layers
Compensating insulation placeholder	0.5	Mica layers
Mica under the coil	0.2	Mica
Mica on the table	0.2	Mica

Winding/Reaction: Ramp Coil 1





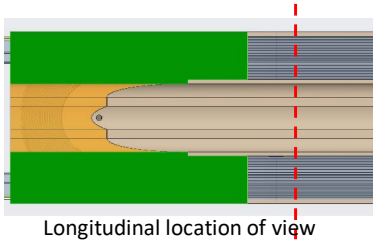
Vertically oriented insulation

Description	Thickness [mm]	Material
Pusher mica	0.2	Mica
Rail outboard mica	0.2	Mica
Plasma spray insulation	0.15	Al_2O_3
Rail – Coil insulation	0.2	S2 glass
Rail – Coil insulation	0.2	S2 glass
Coil – pole insulation	0.4	S2 glass
Plasma spray insulation	.15	Al_2O_3

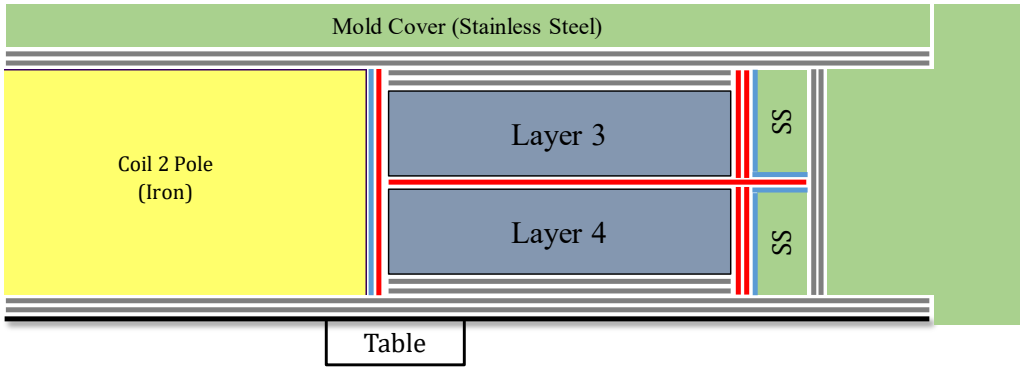
Horizontally oriented insulation

Mica under the mold cover	0.2	Mica
Mica atop the coil	0.2	Mica
Wedge filler placeholder	1	Mica layers
Compensating insulation placeholder	0.7	Mica layers
Trace & insulation placeholder	0.3	Mica layers
Interlayer insulation	0.4	S2 glass
Trace & insulation placeholder	0.3	Mica layers
Compensating insulation placeholder	0.5	Mica layers
Mica under the coil	0.2	Mica
Mica on the table	0.2	Mica

Winding/Reaction: SS Coil 2



Longitudinal location of view



Vertically oriented insulation

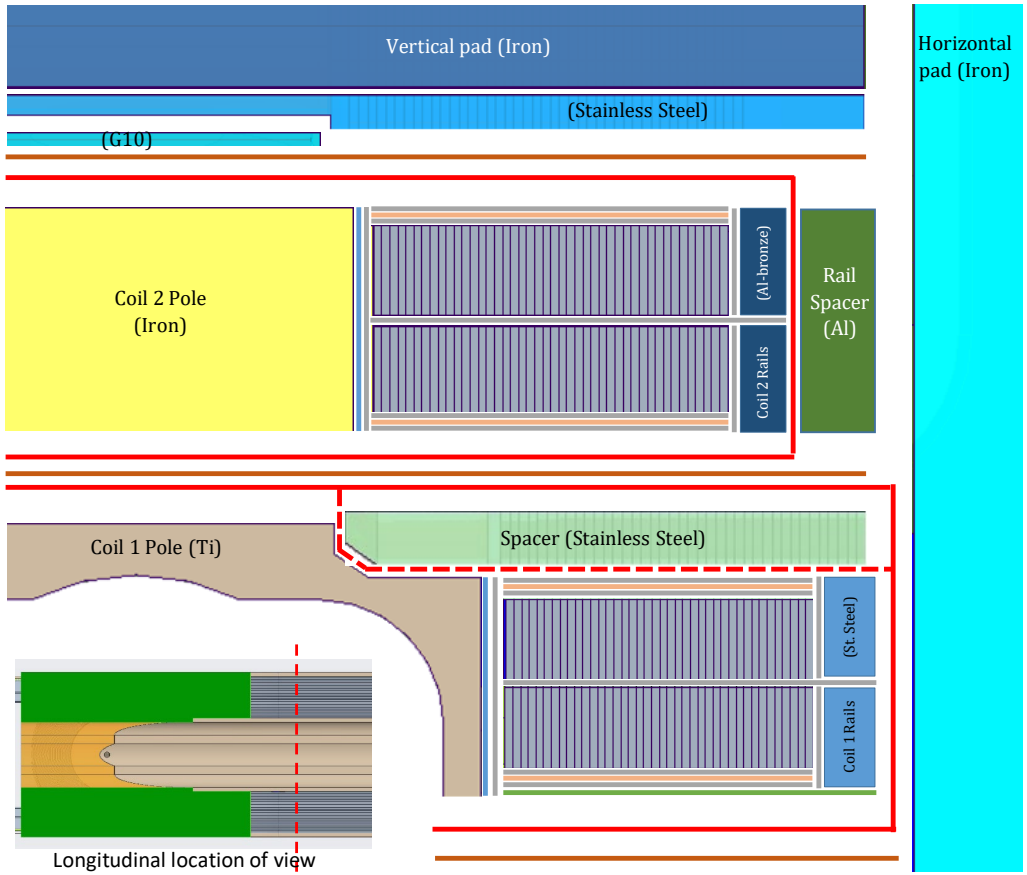
Description	Thickness [mm]	Material
Pusher mica	0.2	Mica
Rail outboard mica	0.2	Mica
Plasma spray insulation	0.15	Al_2O_3
Rail – Coil insulation	0.2	S2 glass
Rail – Coil insulation	0.2	S2 glass
Coil – pole insulation	0.4	S2 glass
Plasma spray insulation	.15	Al_2O_3

Horizontally oriented insulation

Mica under the mold cover	0.2	Mica
Mica atop the coil	0.2	Mica
Compensating insulation placeholder	0.5	Mica layers
Trace & insulation placeholder	0.3	Mica layers
Interlayer insulation	0.4	S2 glass
Trace & insulation placeholder	0.3	Mica layers
Compensating insulation placeholder	0.5	Mica layers
Mica under the coil	0.2	Mica
Mica on the table	0.2	Mica

Figure 6: 2D Cross-section of TFD straight section focusing on winding/reaction layout.

Final Assembly: Straight Section



Vertically oriented insulation

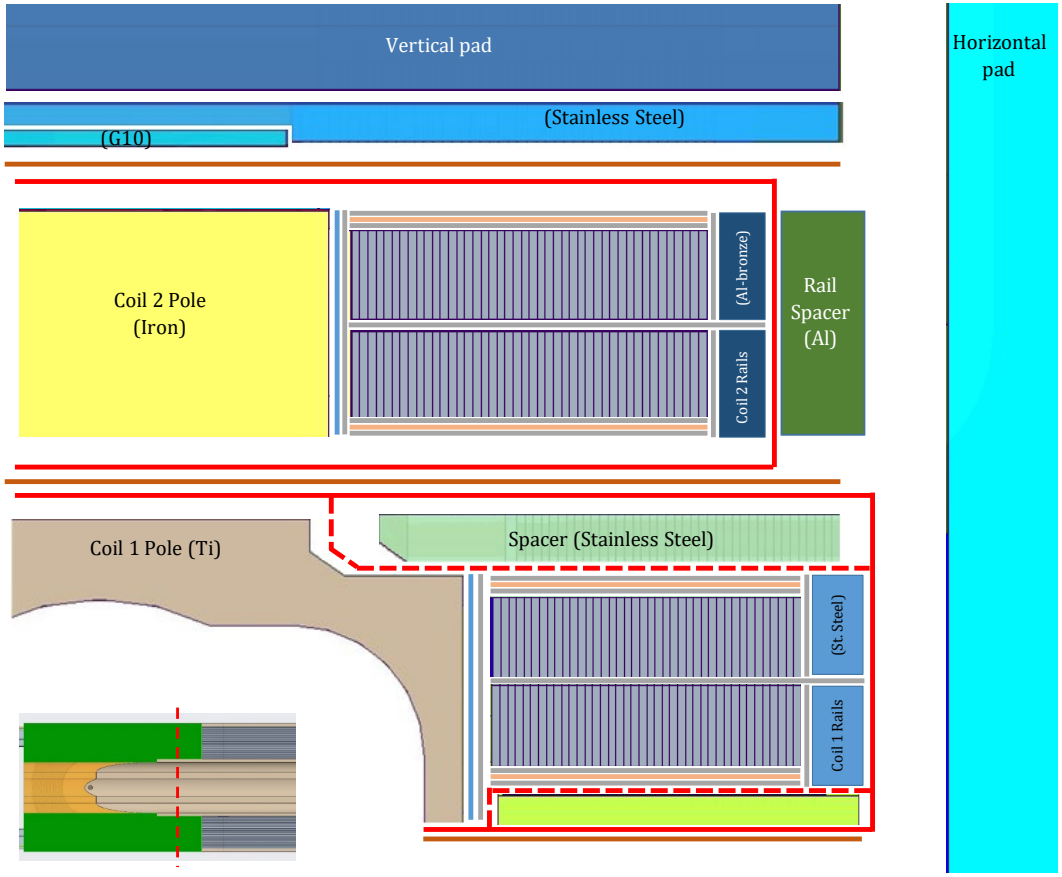
Impregnated volume

	Description	Thickness [mm]	Material
Coil 1	Rail – coil insulation	0.4	S2 glass
	Coil – pole insulation	0.4	S2 glass
	Plasma spray insulation	.15	Al_2O_3
Coil 2	Rail – coil insulation	0.4	S2 glass
	Coil – pole insulation	0.4	S2 glass
	Plasma spray insulation	.15	Al_2O_3

Horizontally oriented insulation

Smart shimsulation	0.7	Kapton/fiberglass
Compensating insulation	0.5	S2 glass
Trace	0.1	Kapton
Trace insulation	0.2	S2 glass
Interlayer insulation	0.4	S2 glass
Trace insulation	0.2	S2 glass
Trace	0.1	Kapton
Compensating insulation	0.5	S2 glass
Intercoil smart shim	0.9	Kapton
Compensating insulation	0.5	S2 glass
Trace	0.1	Kapton
Trace insulation	0.2	S2 glass
Interlayer insulation	0.4	S2 glass
Trace insulation	0.2	S2 glass
Trace	0.1	Kapton
Compensating insulation	0.7	S2 glass
Wedge extension	1	G10 or SS
Midplane smartshim	.5	Kapton

Final Assembly: Ramp „Transition“



Impregnated volume

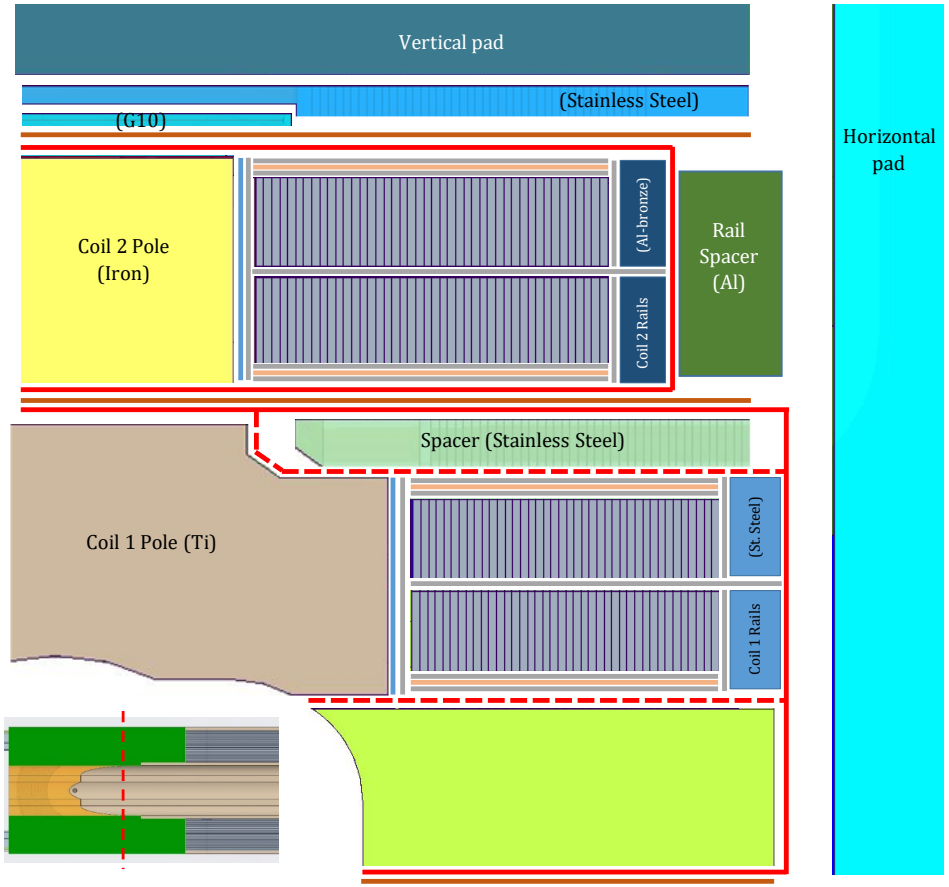
Vertically oriented insulation

	Description	Thickness [mm]	Material
Coil 1	Rail – coil insulation	0.4	S2 glass
	Coil – pole insulation	0.4	S2 glass
	Plasma spray insulation	.15	Al_2O_3
Coil 2	Rail – coil insulation	0.4	S2 glass
	Coil – pole insulation	0.4	S2 glass
	Plasma spray insulation	.15	Al_2O_3

Horizontally oriented insulation

Smart shimsulation	0.7	Kapton/fiberglass
Compensating insulation	0.5	S2 glass
Trace	0.1	Kapton
Trace insulation	0.2	S2 glass
Interlayer insulation	0.4	S2 glass
Trace insulation	0.2	S2 glass
Trace	0.1	Kapton
Compensating insulation	0.5	S2 glass
Intercoil smart shim	0.9	Kapton
Compensating insulation	0.5	S2 glass
Trace	0.1	Kapton
Trace insulation	0.2	S2 glass
Interlayer insulation	0.4	S2 glass
Trace insulation	0.2	S2 glass
Trace	0.1	Kapton
Compensating insulation	0.9	S2 glass
Wedge	-	SS
Midplane smartshim	.5	Kapton

Final Assembly: Ramp Section



Vertically oriented insulation

Impregnated volume

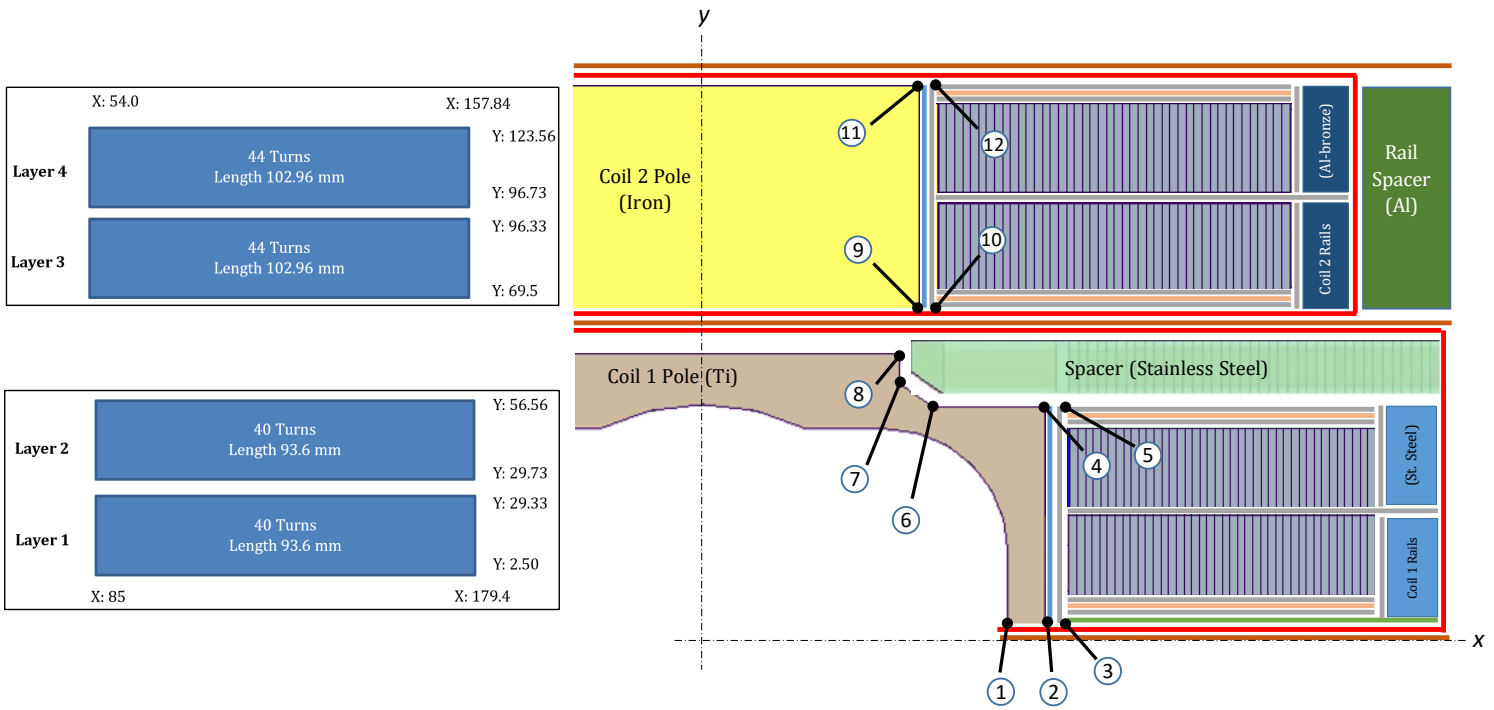
	Description	Thickness [mm]	Material
Coil 1	Rail – coil insulation	0.4	S2 glass
	Coil – pole insulation	0.4	S2 glass
	Plasma spray insulation	.15	Al_2O_3
Coil 2	Rail – coil insulation	0.4	S2 glass
	Coil – pole insulation	0.4	S2 glass
	Plasma spray insulation	.15	Al_2O_3

Horizontally oriented insulation

Smart shimsulation	0.7	Kapton/fiberglass
Compensating insulation	0.5	S2 glass
Trace	0.1	Kapton
Trace insulation	0.2	S2 glass
Interlayer insulation	0.4	S2 glass
Trace insulation	0.2	S2 glass
Trace	0.1	Kapton
Compensating insulation	0.5	S2 glass
Intercoil smart shim	0.9	Kapton
Compensating insulation	0.5	S2 glass
Trace	0.1	Kapton
Trace insulation	0.2	S2 glass
Interlayer insulation	0.4	S2 glass
Trace insulation	0.2	S2 glass
Trace	0.1	Kapton
Compensating insulation	0.9	S2 glass
Wedge	-	SS
Midplane smartshim	.5	Kapton

Figure 7: 2D Cross-section of TFD focusing on impregnation/final layout.

Final Assembly: Straight Section Keypoint Geometry



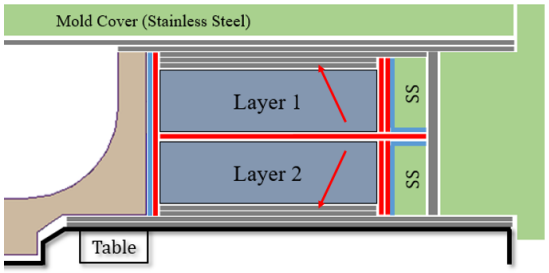
N°	X	Y
1	75.00	0.50
2	84.45	0.50
3	85.00	0.50
4	84.45	57.36
5	85.00	57.36
6	58.50	57.36
7	48.50	62.36
8	48.50	67.40
9	53.45	68.70
10	54.00	68.70
11	53.45	124.36
12	54.00	124.36

Figure 8: Reference geometry keypoints.
Pole geometries are partially determined from coil cross-section and insulation layers.

Changelog

- End 2021: Insulation thickness changed from 175 µm to 185 µm (on paper only)
- 2022-02-24: Updated HW bend radius (coil 2) to 1.4 m and straight section to 930 mm (on paper only). Overall length unchanged.
- 2022-06-03 (Rev. A.8):
  - Addition of changelog to this parameter document
  - Updated straight section to 750 mm
  - Updated HW bend radius (coil 2) to 1.4 m (in model)
  - Added preliminary insulation and mica schemas
- 2022-07-12 (Rev. A.9):
  - Insulation schemes:
    - Interlayer insulation made narrower: no longer passes between rails
    - Correspondingly, made compensating insulation filler and trace insulation narrower to coil width
    - Corrected "compensating insulation filler" thickness to match final assembly
    - Extended coil 2 mica sheets to pass over the iron pole as well
    - Updated coil-pole insulation from 0.2 to 0.5 mm (in all schemas)
  - Added bore size information
  - Updated appendix to include Coil 2 parameter list, including reference to the current revision
  - Included CAD parameter names in 2D and 3D Dipole Features tables where applicable
  - Updated "last turn horizontal position" line to agree with Fig. 4 (coil quadrant vertices diagram)
  - Exchanged "Magnet length" for individual coil end-to-end lengths
  - Added layer jump radius, layer jump easy way offset and layer jump easy way transition length parameters
- 2022-08-08 (Rev. A.10):
  - Corrected "Baseline Coil Width" field in Table 3 to 158.8 mm.
  - Corrected layer jump hard way bend radius (RLJ) for Coil 1 from 1400 mm to 1000 mm in Table 3 and Appendix.
  - Corrected the LR (ramp section length) parameters for Coil 1 and Coil 2 in Table 3 and Appendix. These values had been mistakenly exchanged and are now 165 mm and 195 mm, respectively.
- 2022-09-12 (Rev. A.11):
  - Updated the table corresponding to the winding/reaction layout schema for coil 1 (Figure 6) to include the wedge extension. The immediately adjacent Compensating Insulation Filler was consequently reduced from 1.8 to 0.8 mm. Material was set as Mica for both.
  - Corrected RLJ in of Table 5 (Coil 1) from 1400 to 1000 mm.
- 2022-09-26 (Rev. A.12)
  - Updated the "Transition" and "Ramp Section" diagrams in Figure 7 to correct the Compensating Insulation thickness from 0.9 mm to 0.7 mm.

- 2022-10-05 (Rev. A.13)
  - Updated insulation scheme of winding/reaction of coil 1:
    - The second mica layer that is on the table now goes under the pole and the rest of the components. This change is done to make the reaction assembly consistent with the final assembly straight section schematic.
    - The thickness of all the layers of mica has been uniformized to 0.2 mm.
- 2022-11-17 (Rev. A.14)
  - Updated insulation scheme of winding/reaction of coil 2 to match changes made to coil 1 in version A.13.
  - Added winding/reaction insulation scheme for coil 1 in the ramp section (Figure 6).
  - Added missing compensating insulation under layer 3 in Ramp Section diagram of Figure 7. Corresponding table is correct and therefore left unchanged.
  - Adjusted all remaining 0.3 mm thick mica layers to be 0.2 mm thick
  - Adjusted Coil-pole insulation (vertically oriented) in winding/reaction cross-sections from 0.5 to 0.4 mm thick to be consistent with interlayer insulation. This simplifies the layer jump region.
- 2022-12-08 (Rev. A.15)
  - Updated winding/reaction schemes to extend interlayer S2 glass through the rails.
  - Updated impregnation/final assembly schemes to have separate rails, these being the same rails that went through reaction.
- 2022-12-15 (Rev. A.16)
  - Corrected all winding/reaction schemes so that the mica stack thickness sums match the corresponding layer thicknesses in the final assembly:



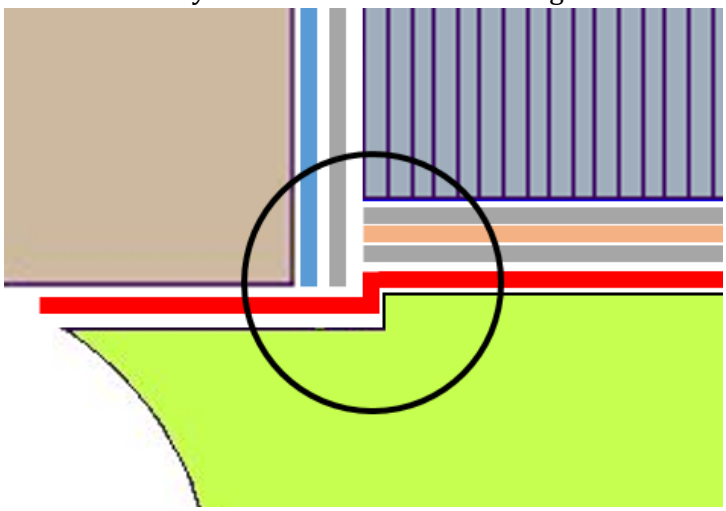
Compensating insulation placeholder
Trace & insulation placeholder
Interlayer insulation
Trace & insulation placeholder
Compensating insulation placeholder

  - Adjusted the thicknesses of these two mica stacks (while maintaining the correct sum) to more clearly reflect their purpose. For example, in Coil 2: Trace (0.1 mm) + Trace insulation (0.2 mm) + compensating insulation (0.5 mm) = 0.8 mm.

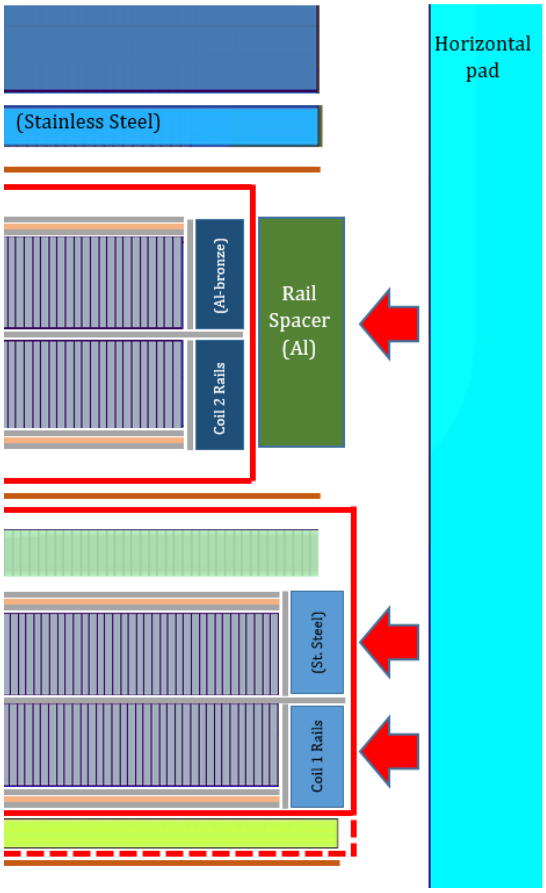
Compensating insulation placeholder	0.5	Mica layers
Trace & insulation placeholder	0.3	Mica layers

  - Removed all measurements in thousandths of an inch.
- 2023-01-17 (Rev. A.17)
  - Addition of bore geometry (Figure 3).
  - Addition of straight section keypoint geometry (Figure 8) to aid in final CAD check.
- 2023-01-30 (Rev. A.18)
  - Corrected y-location of keypoints 9 and 10 in Figure 8 from 68.30 to 68.70 mm.

- 2023-02-03 (Rev. A.19)
  - Removed wedge extension from Final Assembly Transition and Ramp cross sections in Figure 7 (this was an error) and replaced it with a wedge featuring a step. This more accurately reflects the model and design intent.



  - Adjusted visual alignment of rails and spacers in Figure 7 to show that the Horizontal Pad will contact only the parts aligned with the coils:

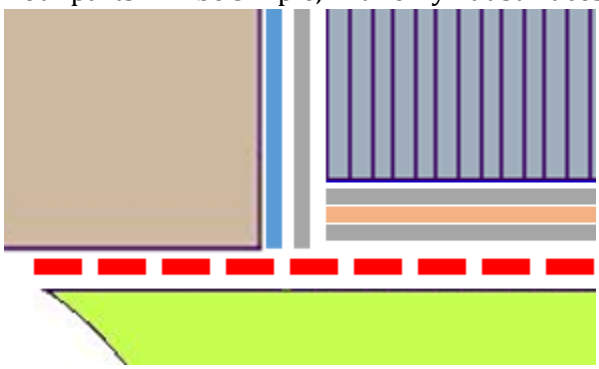


- Corrected the vertically oriented insulation tables in the Final Assembly cross sections of Figure 7: All insulation layers were changed from 0.5 mm to 0.4 mm to be consistent with the mica thicknesses of Figure 6, which themselves were updated in A.13.

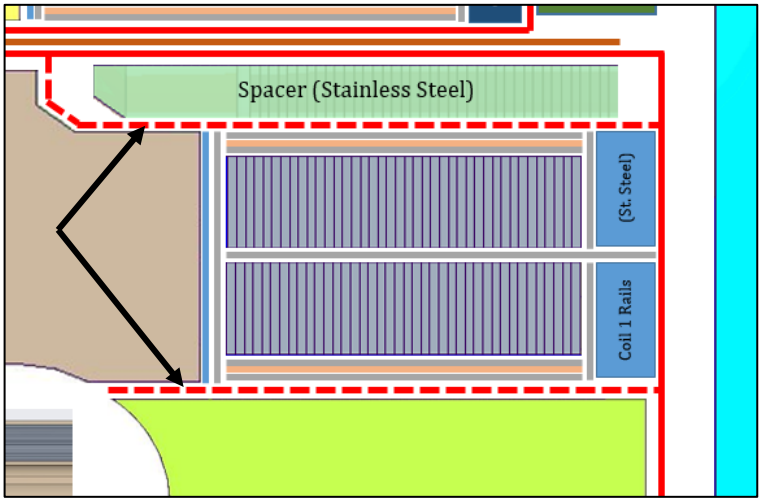
Description	Thickness [mm]	Material
Rail – coil insulation	~~0.5~~ 0.4	S2 glass
Coil – pole insulation	~~0.5~~ 0.4	S2 glass
Plasma spray insulation	.15	Al_2O_3

- Corrected the table in Figure 8 to reflect the insulation thickness change of the previous bullet point: X-coordinates of 9 and 11 changed from 53.35 to 53.45.

- 2023-02-21 (Rev. A.20)
  - Undid the wedge modification of the last revision in Final Assembly Transition and Ramp cross sections (Figure 7), favoring instead a change in geometry of the pole. Both parts will be simple, with only flat surfaces:



  - Adjusted dashed/solid red lines to more clearly indicate the mold released parts



References

1. LD-Cable-coil-param-2021-01-21.pptx

Appendix

The parameter tables used in the Creo Parametric design interface are reproduced here for reference.

Table 5 - Coil 1 Parameters: DF-1000-5650 A.15

Parameter name	Value	Unit	Description
TC	2.36	mm	Cable Thickness Including Insulation
HC	26.83	mm	Cable Width Including Insulation
EWR	85	mm	Easy way bend radius
HBR	1467	mm	Hard way bend radius
HBA	10	°	Hard way bend angle
Y0	0.00	mm	Vertical coil offset
LS	750	mm	Straight section length
LR	165	mm	Ramp section length
LL	300	mm	Lead length
IL_INS	0.40	mm	Inter-Layer Insulation Thickness
RLJ	1000	mm	Layer jump hard way bend radius
DX1	6	mm	Layer Jump easy way offset
DZ1	60	mm	Layer jump length of easy way transition

Table 6 - Coil 2 Parameters: DF-1000-5666 A.9

Parameter name	Value	Unit	Description
TC	2.36	mm	Cable Thickness Including Insulation
HC	26.83	mm	Cable Width Including Insulation
EWR	54	mm	Easy way bend radius
HBR	1400	mm	Hard way bend radius
HBA	10	°	Hard way bend angle
Y0	0.00	mm	Vertical coil offset
LS	750	mm	Straight section length
LR	195	mm	Ramp section length
LL	300	mm	Lead length
IL_INS	0.40	mm	Inter-Layer Insulation Thickness
RLJ	1000	mm	Layer jump hard way bend radius
DX1	6	mm	Layer Jump easy way offset
DZ1	80	mm	Layer jump length of easy way transition