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A&T Sector Note

Title: Modifications to the vertical bending magnet MNPA_19 for use in the AD - ELENA transfer line.

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Summary

This report describes the modification and use of three existing MNPA 19 U-shaped vertical dipole magnets for the transfer line from the AD ring to the new foreseen ELENA ring as an alternative to new magnets.

1. Description of the existing magnet (MNPA 19):

The MNPA 19 is a U-shaped DC bending magnet built around 1968 for the PS Experimental Area. There are currently six of these magnets in storage and no magnets in operation. From the magnetic measurement report PS/6782 – NPA/Int. 68-26 [1] the following information is known about the magnets. Table 1 lists the main characteristics, Figure 1 shows a photo of the magnet in storage, Figure 2 shows assembly drawings (full drawings are not available). Figure 3 shows the excitation curve; Figure 4 shows the field distribution and figure 5 shows the relative integrated field error for the horizontal and vertical axis, note that the axis in Figure 3, 4 & 5 are based on those shown in Figure 2.

Length	19	cm
Width	119.4	cm
Height	117.0	cm
Aperture gap	20	cm
Aperture Height	40	cm
Weight	1250	Kg
Number of turns per coil	80	
Resistance at 20 °C	98	mΩ
Inductance	2.5	mH
Maximum Current	250	A
Water flow	5	l/min
Pressure drop	4	bar
Temperature rise	40	°C
Magnetic Length	38.78	cm

Table 1: Main characteristics, PXMCVCBCWC.

Figure 1: The MNPA 19 (PXMCVCBCWC) magnet in CERN storage.

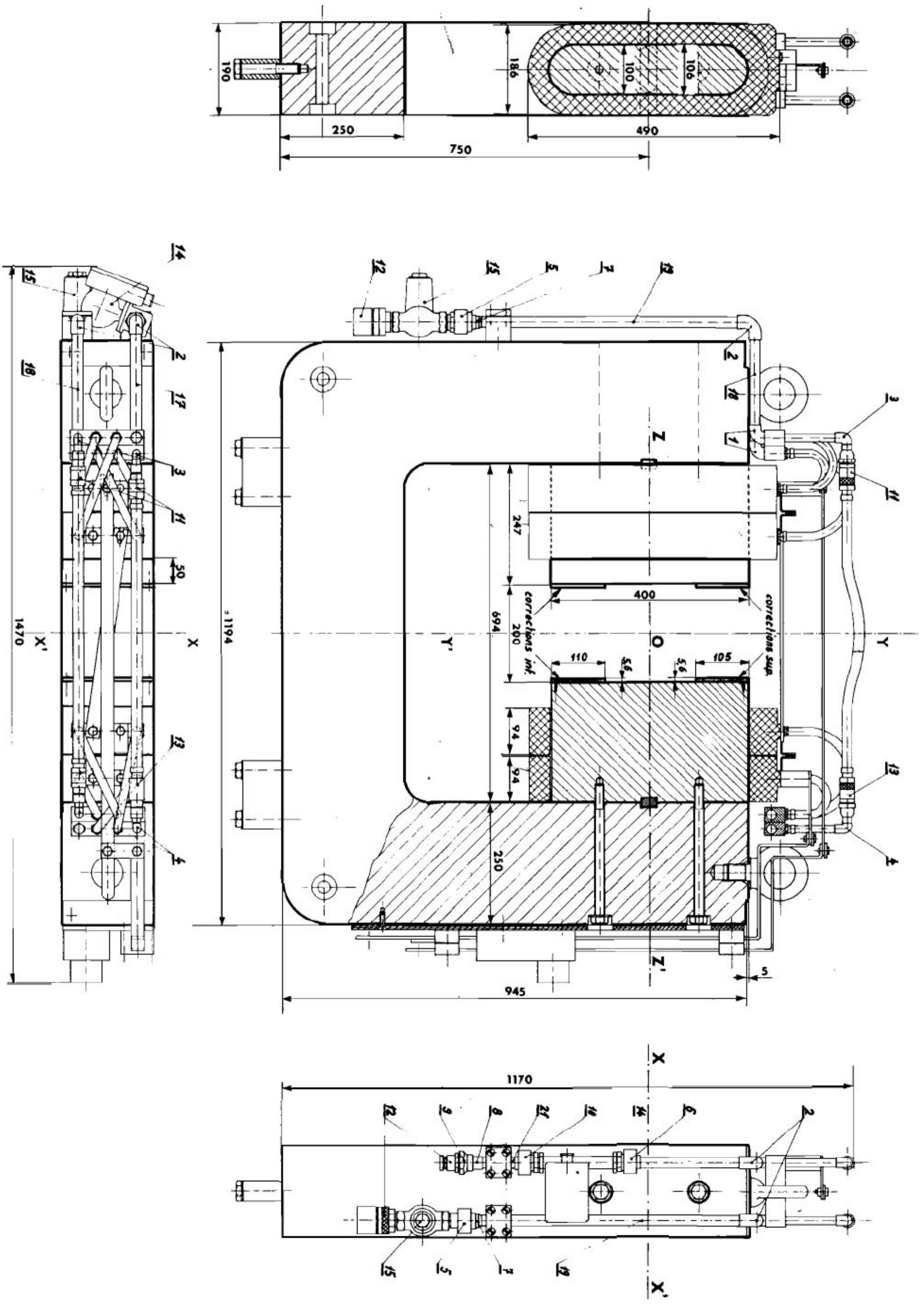

Figure 2: Assembly drawings of the MNPA 19 (PXMCVCBCWC).

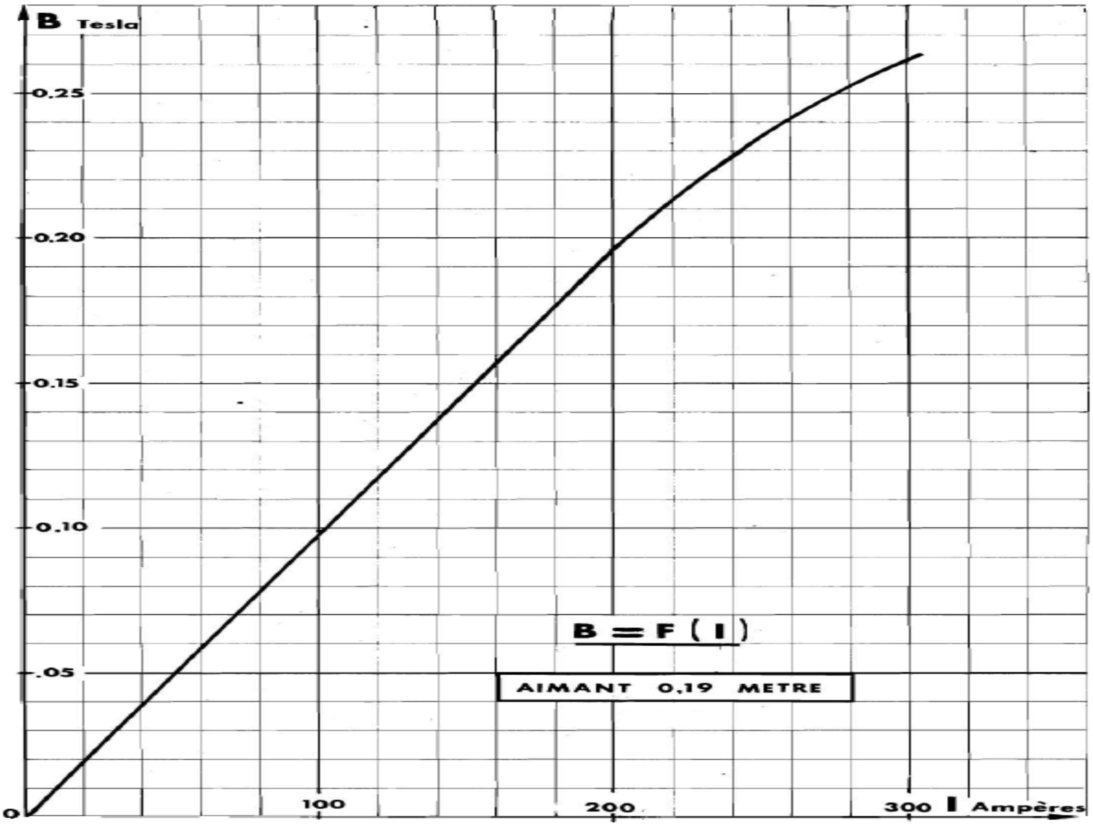

Figure 3: Excitation curve, Current (Amps) vs. Field (Tesla).

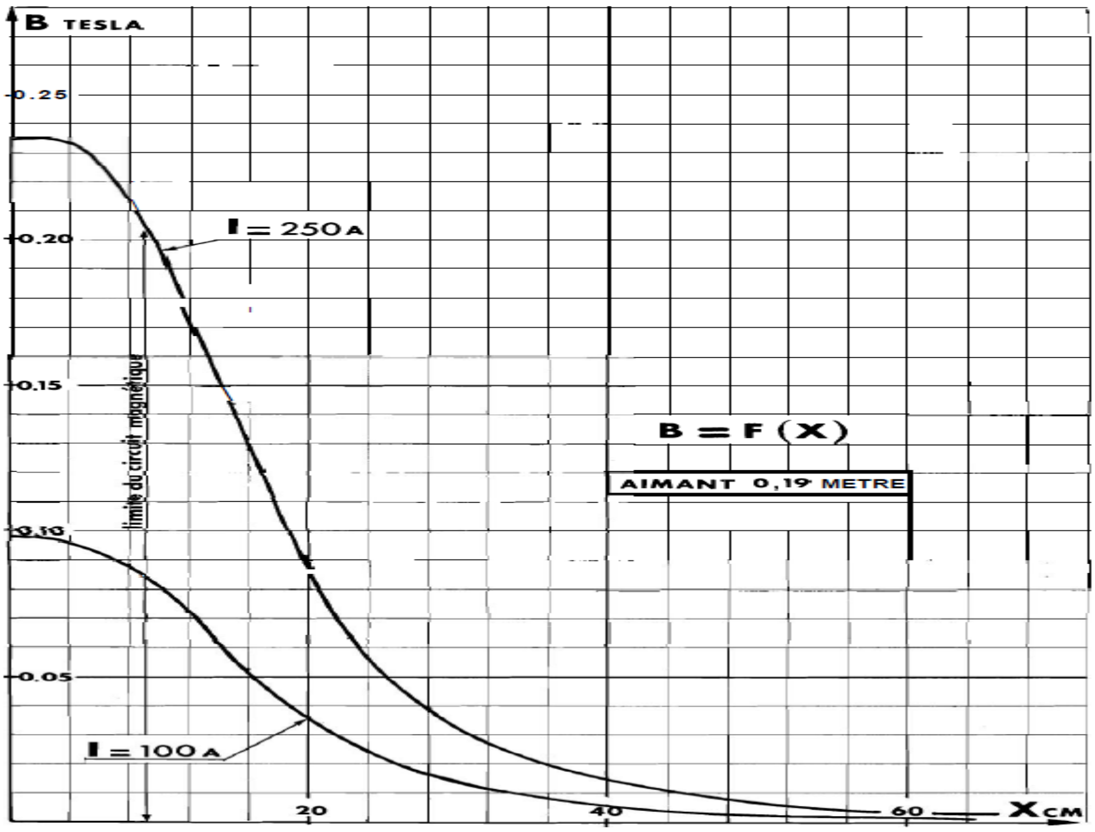

Figure 4: Field distribution inside the magnet.

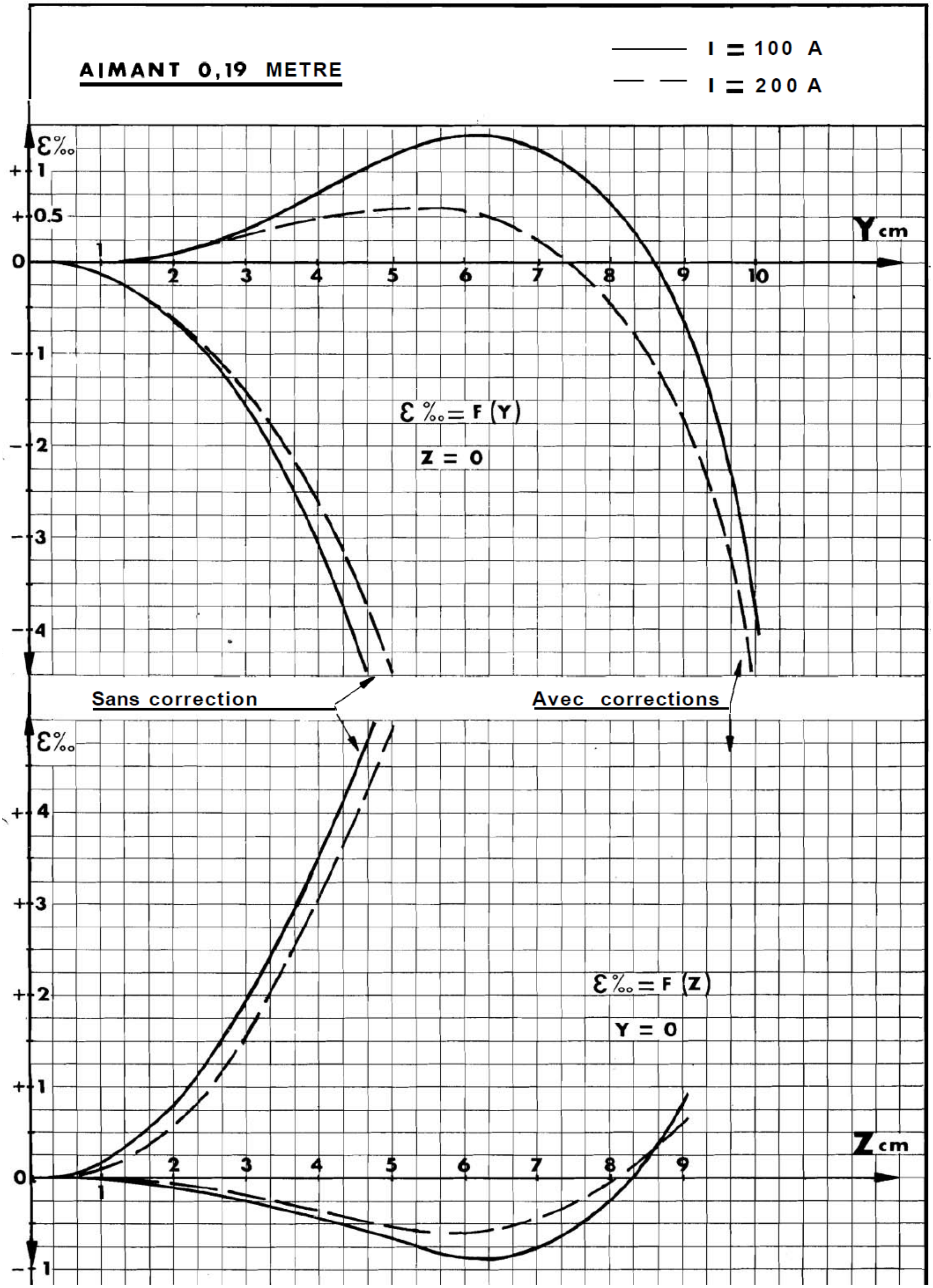

Figure 5: Relative integrated field error for the vertical and horizontal axis from the centre of the magnet, with and without correction shims.

2. Computer Model of the existing magnet:

The Magnet has been studied in its current configuration using Opera 3D from Vector fields. The steel used was 1010 steel, as the exact steel type is unknown. Figure 6 shows the 3D model and Figure 7 shows the excitation curve. Table 2 details the characteristics from the computer model. Figure 8 & 9 show the relative integrated field error on the vertical and horizontal axis's respectively, Note that Figure 8 & 9 use Figure 6 for axis reference.

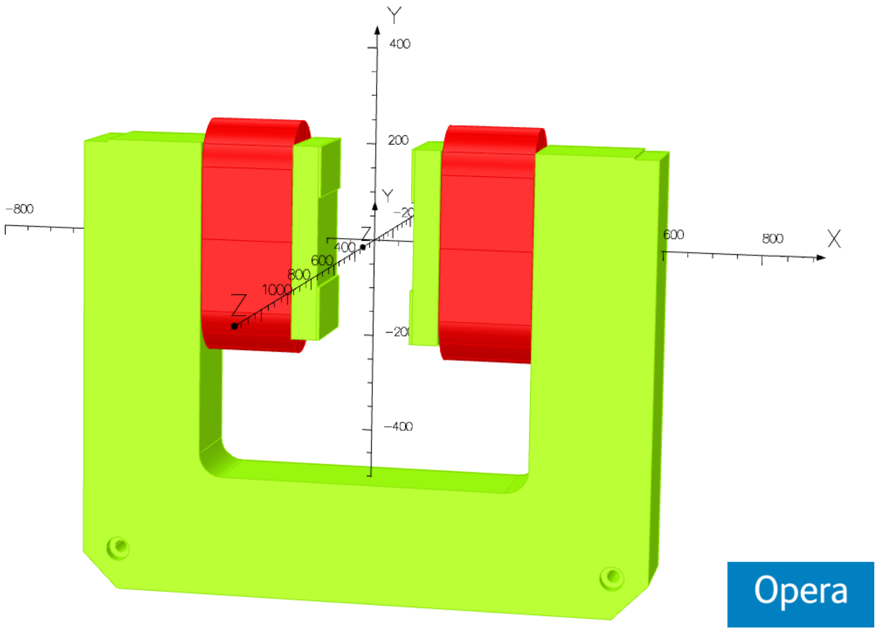

Figure 6: 3D computer model of the magnet before modification.

Self Inductance	41.66	mH
Magnetic Length	38.04	cm
Nominal Field @ 200A	0.18921	T

Table 2: Model Characteristics.

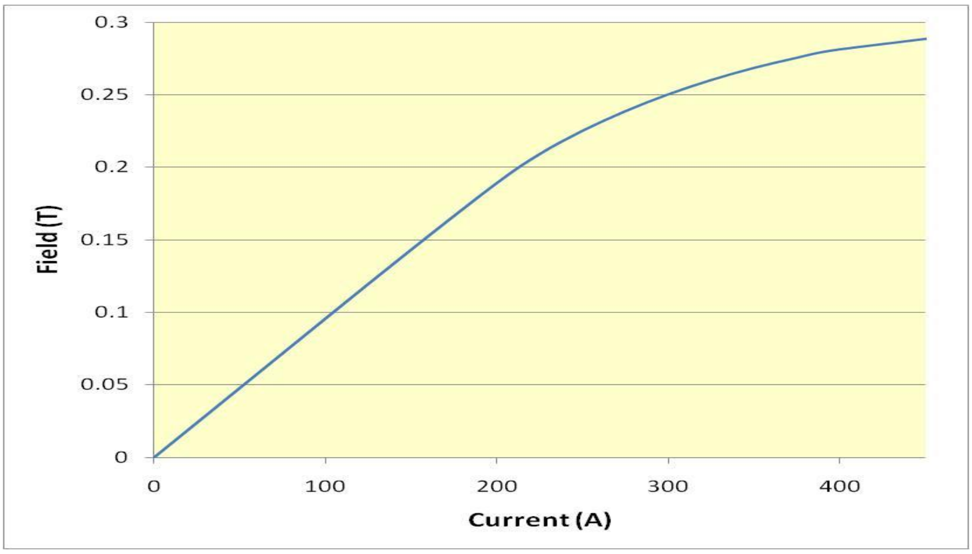

Figure 7: Excitation curve, Current (Amps) vs. Field (Tesla).

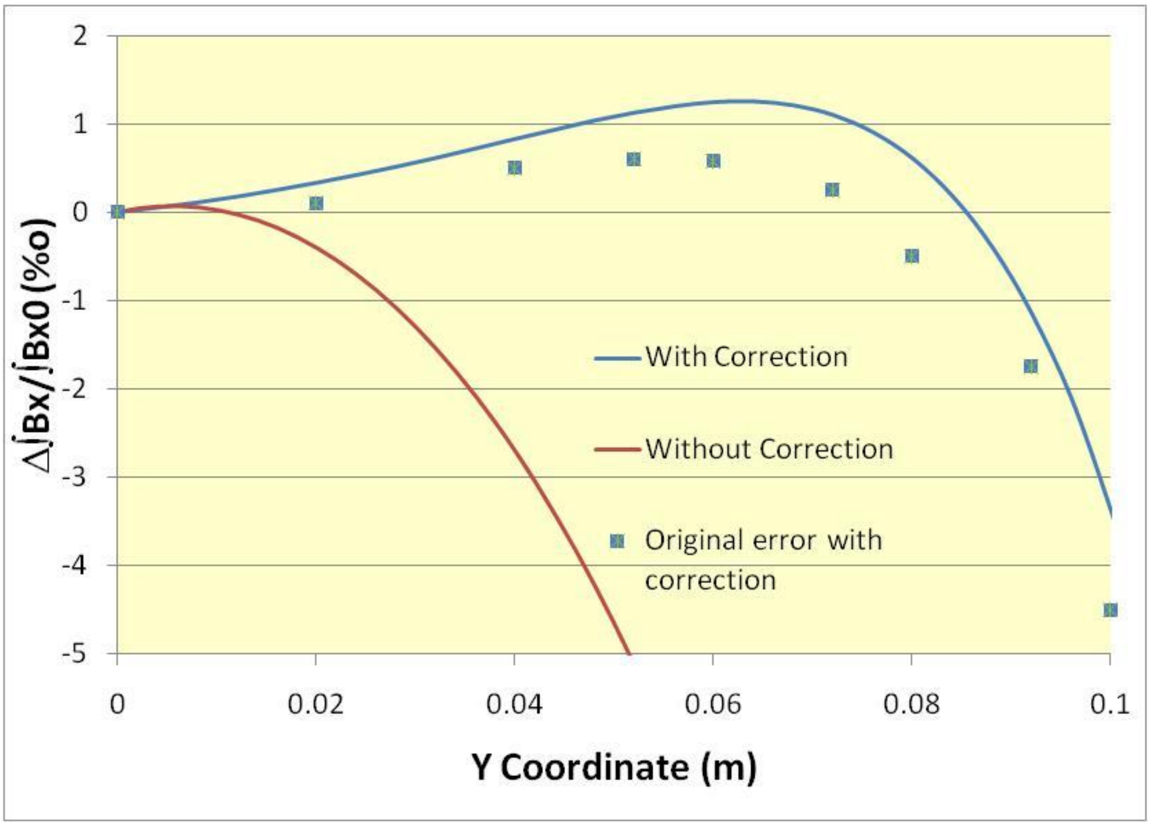

Figure 8: The relative integrated field error on the vertical axis at 200 A.

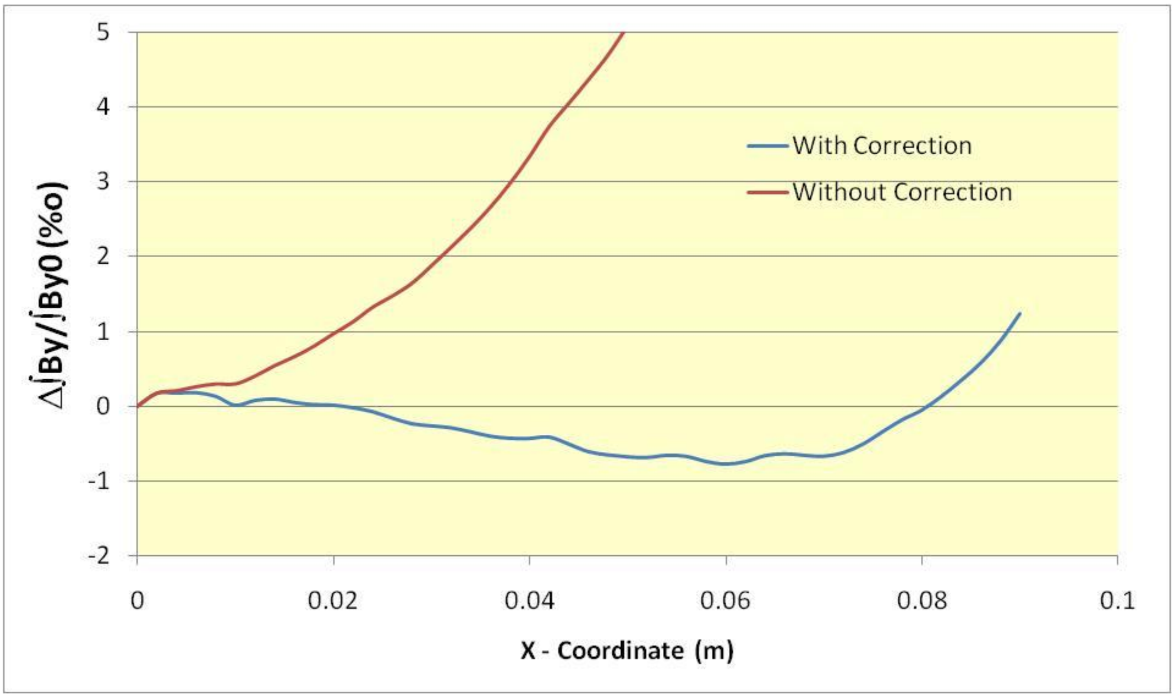

Figure 9: The relative integrated field error on the horizontal axis at 200 A.

The above analysis of the model generally confirms the data in the original documentation. The value of the self inductance calculated using the 3D computer model is 41.7 mH compared to the original report value of 2.5 mH, which is obviously incorrect as the data refers to an A.C. measurement. However, the magnet is to be powered in D.C. so no problems would be expected during operation because of this.

3. Modifications to the magnet:

This proposal allows the magnet to run at a higher field using the same current by reducing the air gap between the two poles from 200mm to 80mm through changing the T-shaped pole with a new longer one, turning the magnet on its side to convert it from a vertical to horizontal deflection (U to C shape), moving the hydraulic and electrical connections to match the new orientation while keeping the same coil. The modifications have been modelled and analysed with new correction shims to optimize the good field region.

Figure 10 shows the 3D model of the magnet with the modification and new pole form. Table 3 details the characteristics after the modification. Figure 11 shows the magnet with the original and proposed poles for comparison; Figure 12 shows the excitation curve; Figure 13 shows the relative integrated field error on the horizontal axis, note Figure 13 refers to the magnet running at 200A level, and use Figure 8 for axis reference.

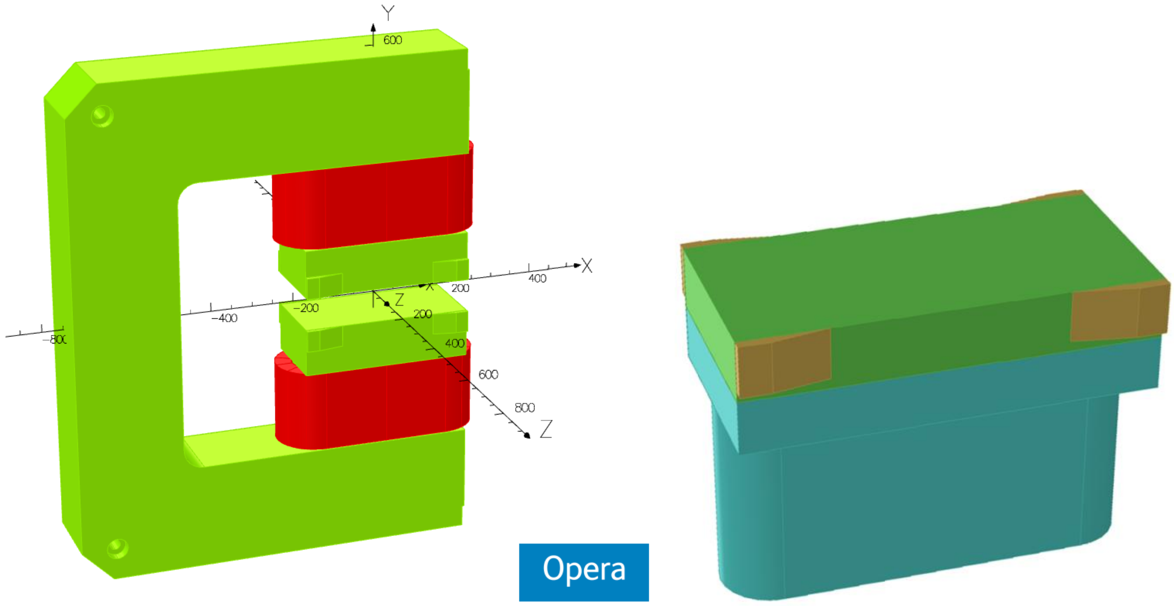

Figure 10: 3D model of the magnet with longer pole and correction shims.

Self Inductance	56.4	mH
Magnetic Length	30.88	cm
Nominal Field @ 200A	0.37308	T

Table 3: Characteristics after modification.

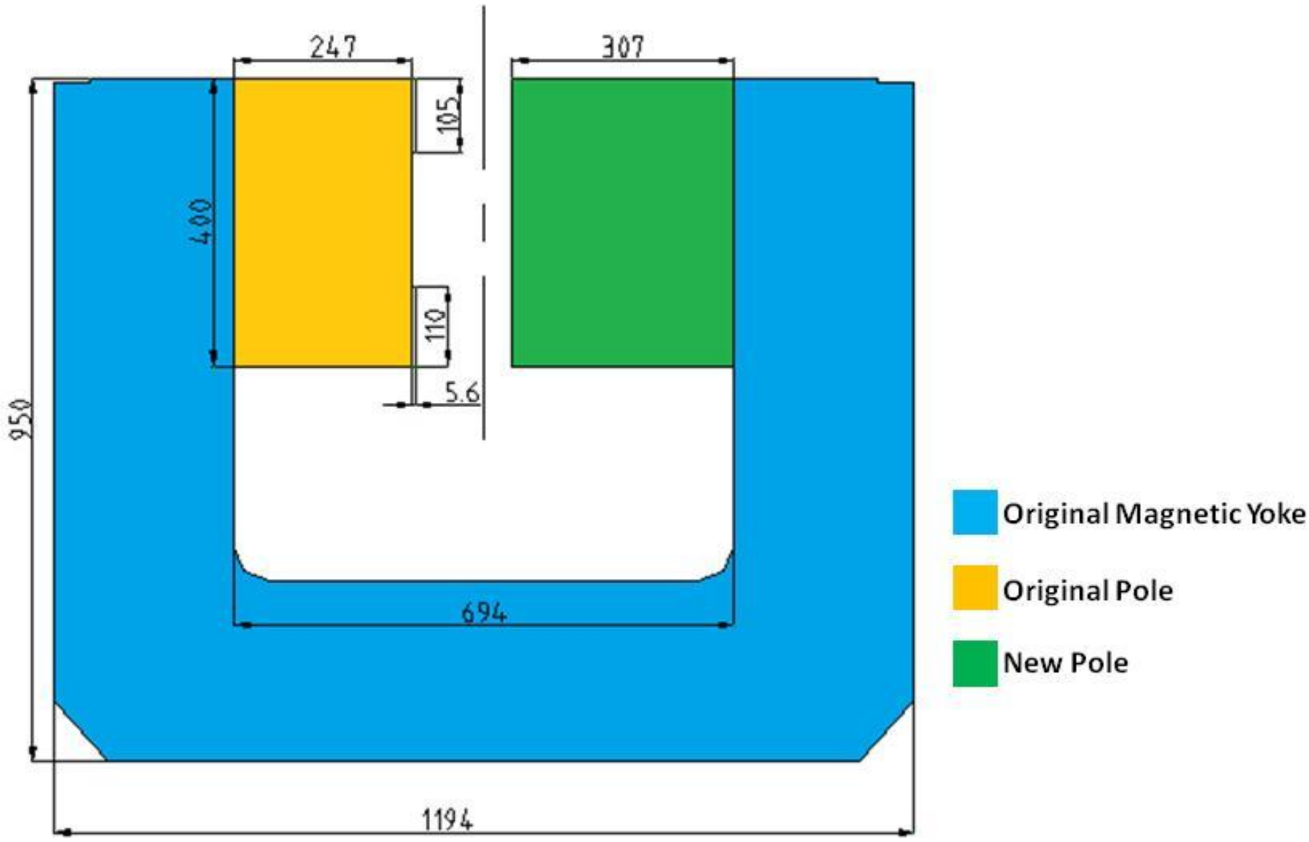

Figure 11: 2D Magnet Section (mm).

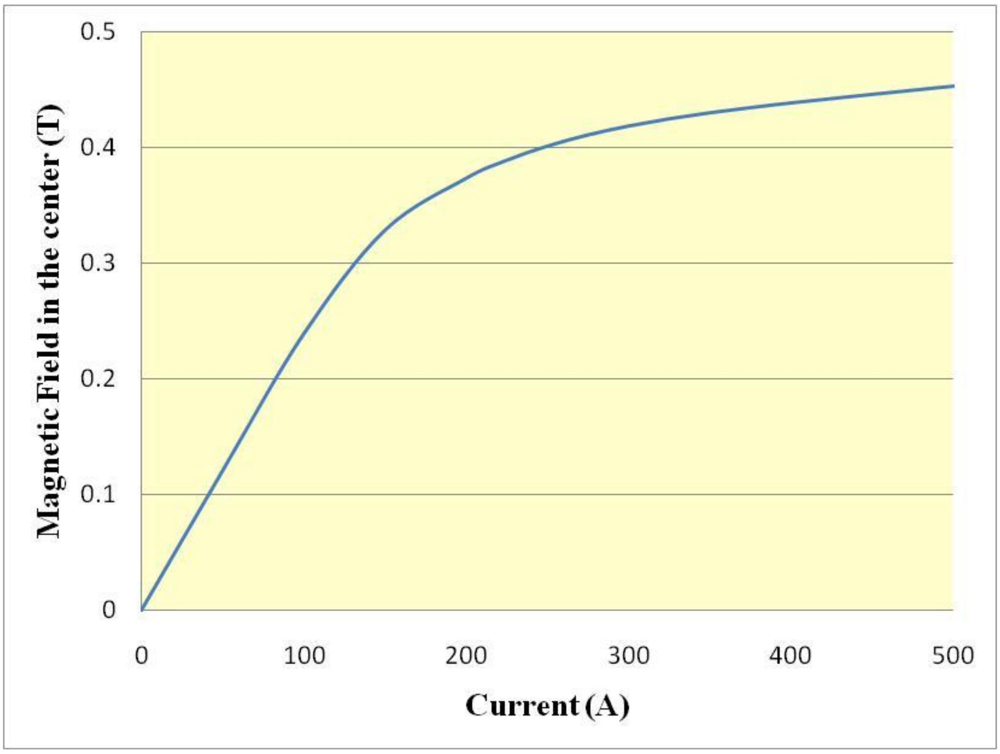

Figure 12: Excitation curve Current (A) vs. Field (T).

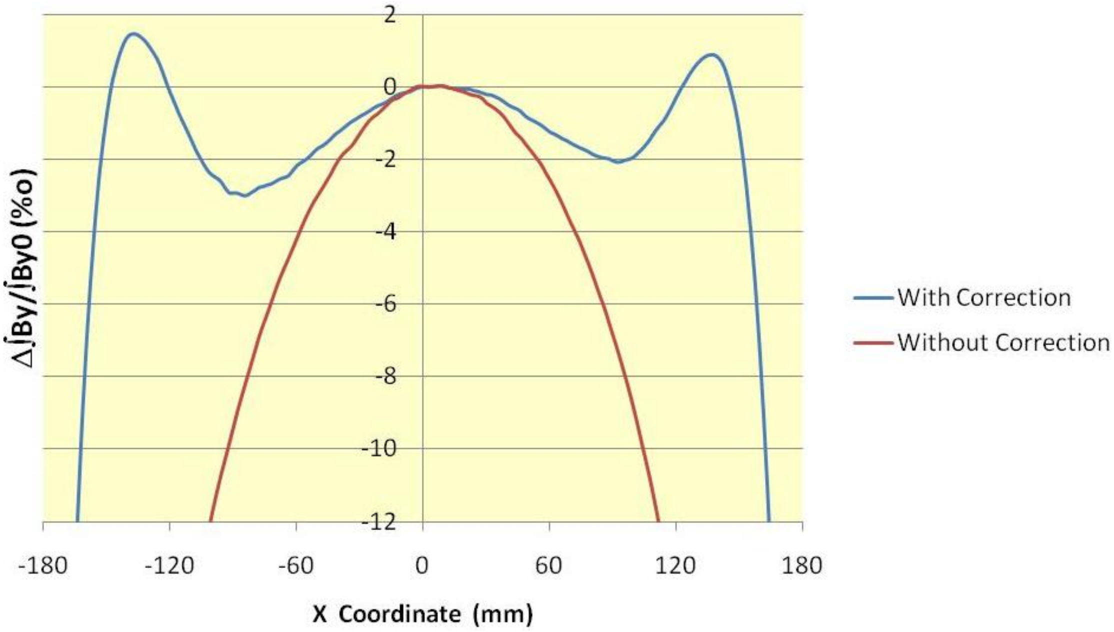

Figure 13: Relative integrated field error on the horizontal axis.

Higher values of the field can be achieved by increasing the current. Calculations show that if the delta pressure across the cooling circuit is increased to 12 bars then 10.8 l/min of total water flow can be achieved. With this flow and an acceptable temperature rise of 35 °C the magnet could be operated at 500 Amps (0.453 T), however from the excitation curve it can be seen that the magnet is already entering into saturation well below this. It should be noted that the forces acting between the poles will increase by a factor of four, from 1.2 to 4.8 kN. Basic calculations show that the deflection caused by this will be in the order of 10 microns causing negligible effects on the field quality and integrity of the assemble.

4. Other Variation of the modification:

This document describes one proposed modification which is to reduce the air-gap from 200 mm to 80mm to achieve a higher field (0.37T). The fact that both of these extremes can be achieved safely indicates that any mid-point values for the air-gap can also be achieved; Figure 15 shows the magnetic field vs. the air-gap.

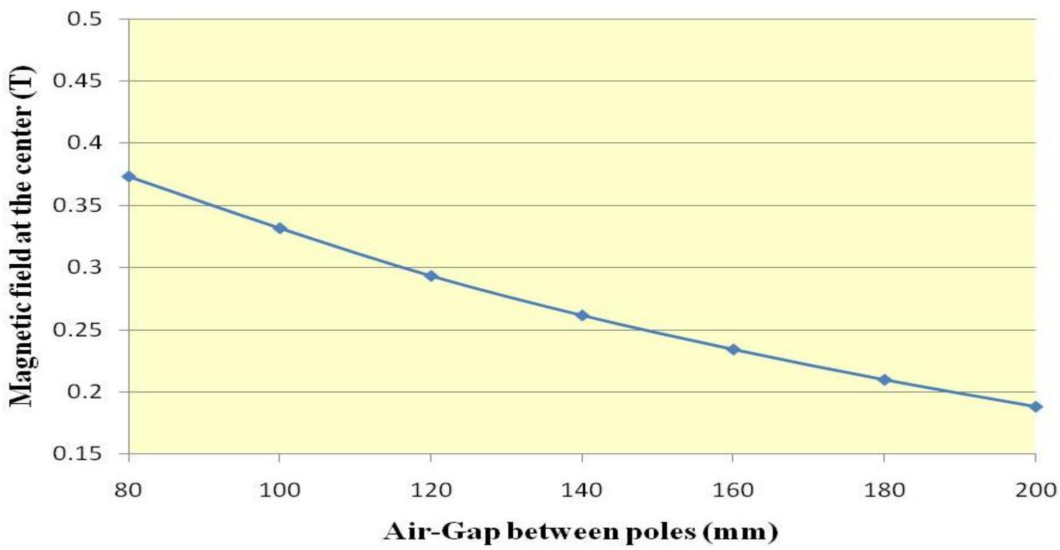

Figure 15: Magnetic field vs. the air-gap with a current of 200A.

5. Cost estimation and schedule:

Cost of new poles per magnet	3 kCHF
Refurbishment price per magnet	5 kCHF
Total price per magnet	8 kCHF
Time delay per magnet	3 Months

Table 4: Cost and time estimations for the proposed modifications.

6. Summary of the proposed new parameters:

Length	190	mm
Width	1194	mm
Height	1170	mm
Weight	1300	kg
Air gap	80	mm
Maximum current	250	A
Nominal current	200	A
Nominal magnetic field	0. 37	T
Voltage drop	20	V
Power consumption	4	kW
Magnetic Length	0.305	m
Water flow	10.8	L/min
Pressure drop	12	bar
Temperature rise @ I max	20	°C
Good field region	300	mm (75%)

Table 5: Summary of the new parameters.

7. References:

[1] PS/6782 – NPA/Int. 68-26 – Les Aimants de compensation des separateurs electrostatiques de 1 et 2 metres.