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MUON STORAGE RING PROJECT - IV

Engineering design of the ring magnet

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GENERAL

The magnet design is conditioned by the requirement of a very high field uniformity and stability to be achieved all along the ring and by the need of making use, as excitation power, of the existing dc groups, in particular those which provide the dc power for the large bubble chamber magnets.

Furthermore it is reasonable to foresee another use of the magnet or of its parts in other experiments (as bending magnets in beam transport for instance); so a construction allowing a certain flexibility is to be preferred.

The c-shape for the yoke cross-section has to be adopted because it is essential to the proposed experiment and the value of the field in the centre of the gap has to be chosen reasonably high to reduce the over-all dimension of the apparatus without making it too difficult, because of iron saturation, to realise the desired field shape and uniformity. The field chosen (15000 gauss) and the gap size (10×30 cm^2) determine then the thickness of the yoke (36 cm). The induction in the iron has been chosen to be about 17000 gauss and about 12% of the total ampere turns are required to compensate the magnetic drop in the iron. As the reluctance of iron might easily change by a large fraction in different iron samples, we expect field differences as large as 1% along the ring, and we have to provide for their compensation.

YOKE

In the present design the yoke consists of ten equal magnet sectors mounted closely one near the other, each one with its own excitation windings (a "main winding" which is connected in series for all the sectors and an auxiliary winding much smaller with independent excitation for fine adjustment). Each "sector" will be formed mainly by two large top and bottom plates, see Fig. 1, three lateral yoke pieces and two tapered poles. The structure will be assembled by bolts. To reduce deformation by magnetic forces, and to determine accurately the magnet gap, there will be non-magnetic spacers between the poles.

With the chosen dimensions the yoke will weigh about 6.2 ton/m, that is in total about 130 ton. With an n value of 0.1, the gradient will be 5 gauss/cm and the pole surface will be inclined by 1.7 mrad with respect to the medium planes. By correct shaping of the pole edges the effect of stray field on the useful region (10×10 cm^2) can be reduced to 10^{-4}. There is no need for very special machining of the various pieces of the yoke: the tolerances required are normally achievable in any good workshop.

WINDING

Hollow copper conductor, cooled by demineralized water, will be used for the winding. In the present design the magnet can be powered by one of the groups (consisting in two dc generators driven by a single synchronous motor) producing 500 amps at 600 volts, which are available in both South Hall and East area. These groups have a current stabilization of 10^{-3}.

The winding will consist, for each magnet sector, of two coils, each one formed by three pancakes cooled in parallel. The total number of turns foreseen is 30. With the chosen conductor cross-section (18.5 × 24 mm^2 with an internal hole Ø 14) the total power consumption will be 2.5 MW and the total copper weight for the ten sectors will amount to 3.6 ton. The water pressure drop in the winding will be less than 3 kg/cm^2 with a flow equal to 25 lt/sec, which corresponds to a water temperature increase of 25° C. These figures are easily realized.

To allow the contiguous sectors to be mounted as close as possible one to the other, the coils are folded up at their ends; for this purpose the top and bottom plates of the yoke have apertures to permit the passage of the conductors. The correspondingly increased reluctance of the yoke can be easily compensated by the addition of a suitably placed equivalent quantity of iron.

In this way we expect the field in the gap at the junction between contiguous sectors to be practically identical to the field in the middle of the sectors.

A compensating winding has been foreseen in each sector,

i) to correct the unavoidable reluctance differences among different sectors;

ii) to adjust the magnetic medium plane close to the geometrical one;

iii) to reach the required field stabilization (10^{-4}).

The maximum number of ampere turns produced by the compensating winding will be 2 or 3% of the main winding ampere turns (136000). The total power consumption of the compensating winding will be less than 1% of the main winding power.

The compensating winding will, as the main one, consist of two coils (one per polar piece) but the current flowing in them will generally be different (a shunt will be connected in parallel to one or the other coil); in this way the magnetic medium plane will be adjusted.

The compensating winding of each sector will be driven by an independent power supply with transistor stabilization, controlled by a nuclear resonance system.

PRICE

According to the recent experience in CERN*) the iron yoke should cost a maximum of 3 SF/kg and the copper winding a maximum of 25 SF/kg.

We estimate then:

iron yoke (130 ton)	390,000 SF
main winding (3.6 ton)	90,000 SF
compensating windings and their power supplies ..	50,000 SF
general installation (cables, controls, water pipes and valves)	30,000 SF
	560,000 SF

No special foundations are required if the magnet is assembled in one of the existing experimental areas.

TIME SCHEDULE

complete design	four months
placing of the contracts	two months
delivery time	ten months
assembly and testing	two months
	eighteen months

*) For instance the 2 metre HBC magnet has cost 2 SF/kg for the iron yoke and 20 SF/kg for the copper winding, this last price including various controls, the piping and the busbars on the magnet.

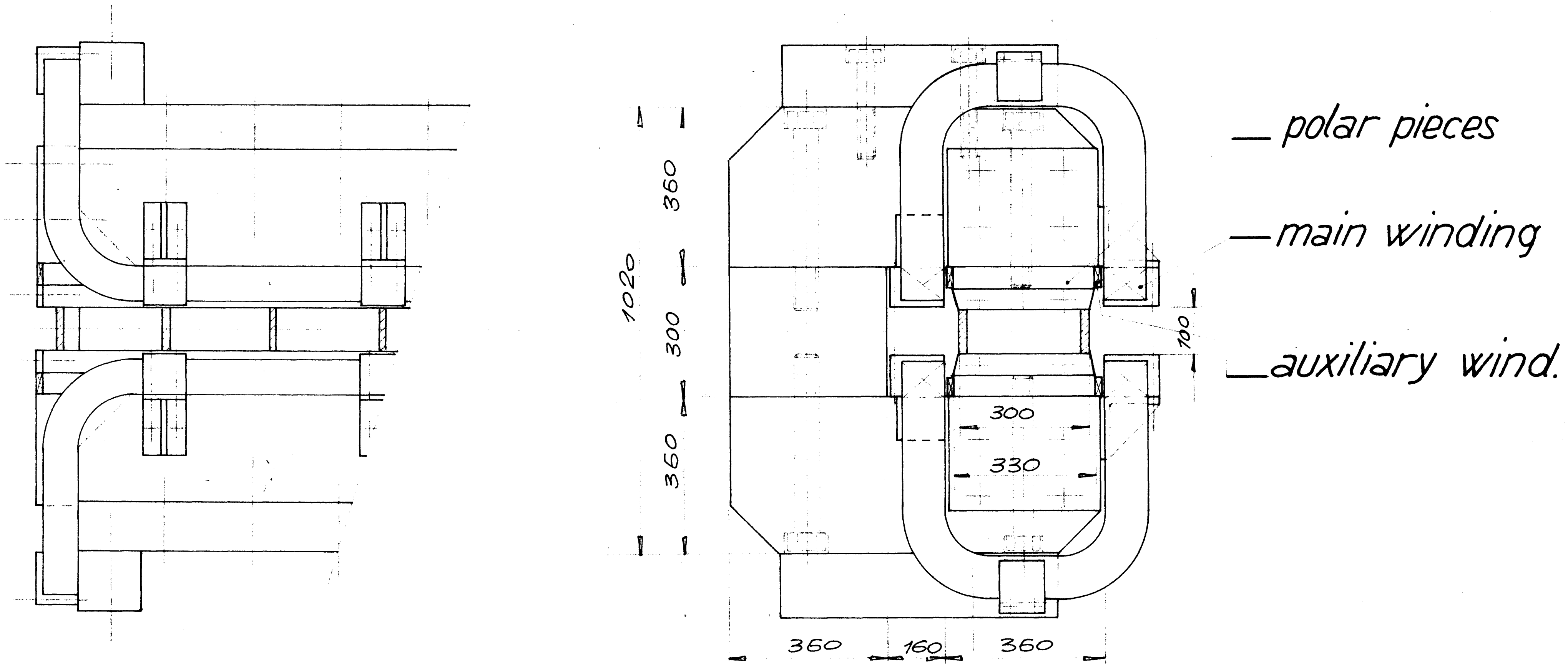

Fig.1 Magnet cross-section and sector end