

Polarized deuterons

The CERN Polarized Target Group has obtained within the last few months very high polarization rates for protons bound in alcohols and has built operating targets of sizeable volume. The group has more recently tackled the polarization of deuterium nuclei bound in the same type of alcohols.

A first test at a temperature of 1°K , using 'heavy' ethanol ($\text{C}_2\text{D}_5\text{OD}$) mixed with 8% heavy water (D_2O) and 2% of porphyrine (the free radical which is responsible for high polarization of spins in alcohols) gave a 6.5% polarization.

However, it was possible to predict from these results and previous experience on polarized protons and according to a new theory, that a 20% polarization could be obtained at 0.5°K in heavy butanol (M. Borghini and K. Schaeffer, Physics Letters A, 31, 535, 1970). Such a result was achieved at CERN on 10 July in a mixture of heavy butanol (98% deuterated) mixed with 5% heavy water and doped with 1% porphyrine, using a

newly developed helium 3 cryostat (see CERN COURIER vol. 10, page 112).

The difference between the figure achieved with protons (65% in the same conditions) is due to the smaller magnetic moment of the deuteron (deuterium nucleus) which is only $1/6$ that of a proton.

This is not the first attempt to polarize deuterium. In 1965 a Dubna group, using heavy LMN, achieved a polarization of the order of 10%. But this could be used for useful experiments only with slow neutrons which have a low interaction rate with the other nuclei in the complex target molecule. In 1969, a Yale group obtained a 3.75% polarization in solid deuterium.

The new targets developed at CERN could be useful for studying spin effects in elastic scattering on deuterium, such as in $\pi d \rightarrow \pi d$, or as polarized neutron targets, or for polarization measurements on pion photoproduction. In order to study the effects of the deuteron nuclear structure on polarization measurements which would use a deuteron as a target, the

CERN-Orsay-Pisa group has performed a short test run with a beam, of 10 GeV/c negative pions on a 4 cm^3 target of heavy butanol, cooled to 0.55°K , with 20% polarization.

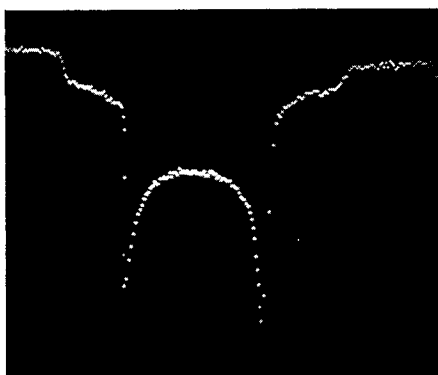
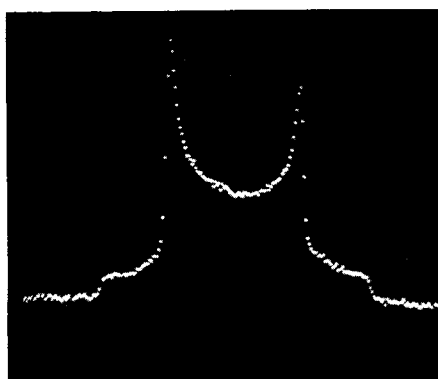
PS magnet replaced

It became necessary in 1966 to replace magnet No. 1 of the PS ring because of damage caused by radiation, which is intense at that point downstream of an internal target. The only spare magnet available at the time, No. 102, was installed.

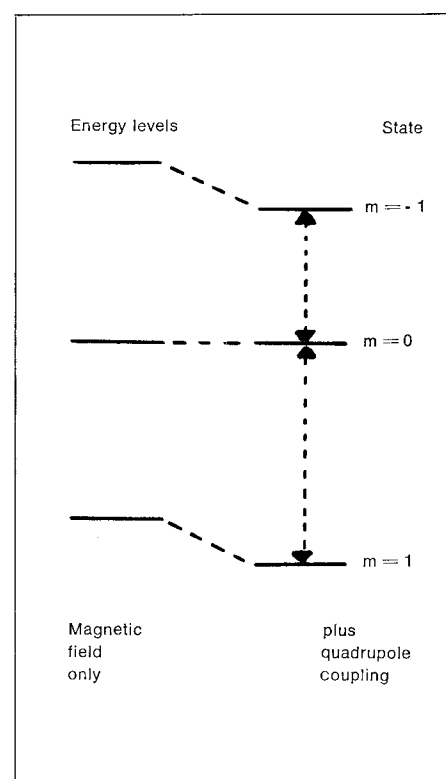
A fault occurred in this replacement magnet at the end of February of this year. The 2500 metal foils forming the yoke of a PS magnet are stuck together with araldite and, under the effect of radiation (assessed at 10^9 rad from 1966 to 1970 in this region), the adhesive weakened and about thirty foils at the end of the yoke became detached at the edges. The movement of these foils, as the magnet pulsed, broke the welds securing the pole face windings to their

Figure 1 shows the nuclear magnetic resonance signals from deuterons in butanol, under positive and negative polarizations. In a magnetic field (25 kG in this case) each deuterium atom has three possible energy levels, corresponding to its magnetic quantum number (m) being 1, 0 or -1. These levels (as illustrated in Figure 2) are evenly split by the interaction of the magnetic moment with the magnetic field by an amount proportional to m , (giving a splitting of the order of 16 MHz) and, to a smaller extent (about 50 kHz) by the coupling of the deuteron quadrupole moment with electrical gradients within the solid, by a quantity proportional to m^2 . Magnetic resonance measures the frequency of transitions between the levels.

The splitting between the levels depends on the orientation of the electrical field with the magnetic field; as these orientations are random in frozen alcohols, the pattern observed is the sum of the pairs of lines corresponding to all possible orientations. One of the two peaks is mainly due to transitions between $m = 1$ and $m = 0$ levels, and the other between $m = 0$ and $m = -1$ levels. When deuterons reach a sizeable positive polarization, they spend more time in the $m = 1$ state, than in $m = 0$, and more time in the $m = 0$ state than in $m = -1$. Consequently, the peak corresponding to 1/0 transitions is higher than that corresponding to 0/-1 transitions. When the polarization is negative, the reverse situation occurs. This makes it possible to compute the degree of polarization (20% in this case) from relative intensities of the peaks.



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1. The five cooling towers for the cooling system of the Intersecting Storage Rings. The tower on the left is used in connection with the cooling for the air-conditioning plant; the four others are used in connection with the cooling for the magnets of the rings and the beam transfer lines.

2. The ISR cooling system plant room. On the left in the foreground are two small groups of refrigerators for the air-conditioning system, then three large groups of refrigerators for the magnet cooling. Partly hidden are the water-water heat exchangers. In the background are the water treatment units. On the right are the pumps which distribute the cooled water.

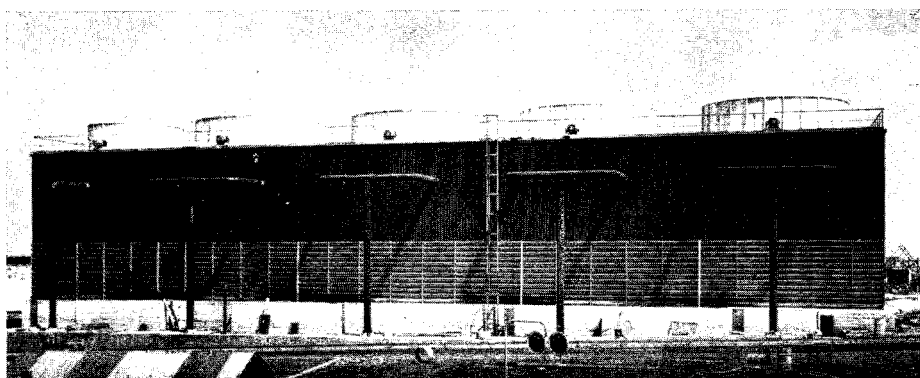
supply cables. An electric arc ensued, in turn burning the winding insulation, allowing white-hot materials to fall on to an aluminium vacuum chamber window, breaking the vacuum, etc...

The magnet could not be changed immediately because, although materials were available to build spare magnets, there was no assembly unit of the required type available. The defective magnet was kept in use temporarily as the irregularities in the field were relatively insignificant. Work began as soon as possible on building new magnets and, after two months of testing, magnet 103 was installed during a machine shutdown. Some of the foils from the yoke of magnet No. 1, removed from the machine in 1966, were used again for the new magnet.

The number of spare magnets built was restricted to four because of the limited number of foils remaining from the original production batch of steel. However, inspections which have recently been made of the edges of yokes have shown that there are now about ten ring magnets showing signs of coming apart at the end foils. These will have to be replaced within a few year's time. It will be possible to repair a hundred or more yokes by using new foils only for the ends. Adhesives which are much more radiation resistant than the previous types will be used.

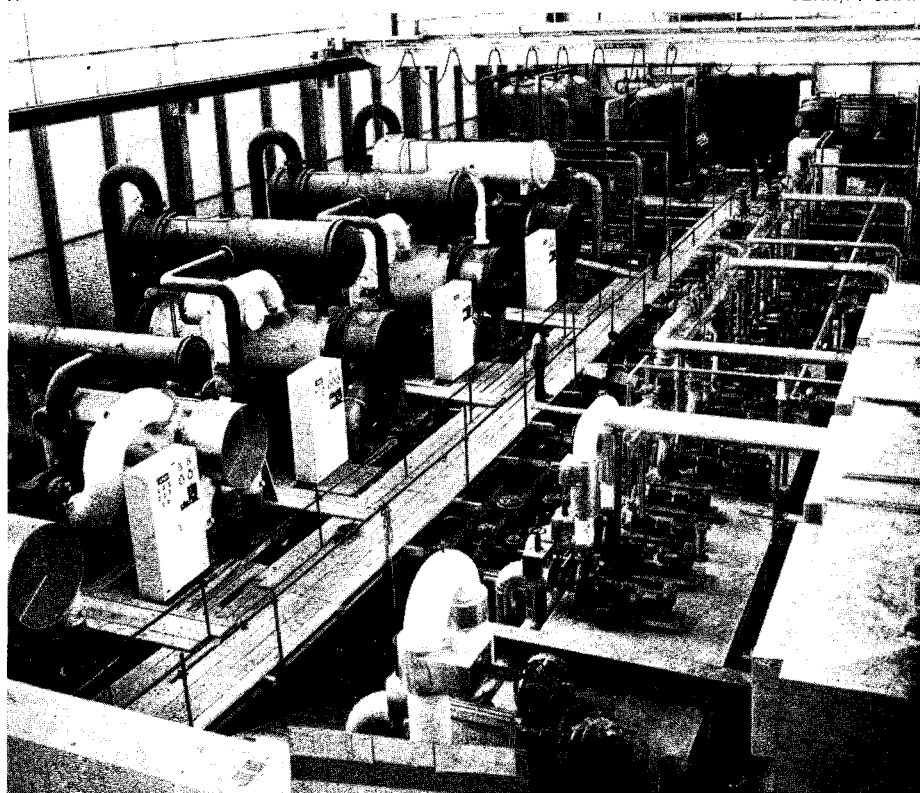
In view of the increasing intensity of the PS with the improvement programme, it is likely that magnets will deteriorate more quickly than before, although the deterioration will not be proportional to the intensity because the size of the beam will hardly change as a result of the higher injection energy.

Various methods are being examined to prolong the useful life of the magnets, with the aim either of improving the adhesion between the end foils (using screws and welds, etc.) or of replacing the end foils by thicker, one-piece blocks. The eddy currents and the remanent field would thus be locally increased, but would probably still remain within acceptable limits. These studies have become particularly important in view of the proposal to use the PS as an injector for the 300 GeV accelerator.



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CERN/PI 35.7.70



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CERN/PI 54.7.70

ISR Cooling System

At full power, the cooling system for the Intersecting Storage Rings (not including the experimental areas) needs to have a capacity of about 27 Gcal/h, which is almost ten times that necessary for the PS. The difference is mainly due to the large beam transfer system and to the fact that the magnets in the two rings have a d.c. power supply.

An exchanger of the type used in the PS, with a total-loss water circulation system, would require an increase in the water supply to CERN of some 1200 m³/h which, by itself, could cost about 20 millions Swiss francs. Preference was therefore given to a less costly system using cooling towers associated with water-water heat exchangers and refrigerating machines, probably representing the first application of such a system to the cooling of a large machine. There are two separate systems, one (23.4 Gcal/h) for the ring magnets and the transfer lines with their power supplies, and the other (3 Gcal/h) for the air-conditioning plant.

There is a closed circuit (referred to as the secondary circuit) of demineralised water for the magnets and power supplies, cooling the various components directly. At full power, water enters the magnets at 13°C and leaves at 33°C. It then passes through the water-water heat exchanger, on the primary side of which cooled water flows through the towers. The water will thus be cooled by at least 7°C at the height of summer. The secondary circuit water then flows in succession through the evaporators of three large refrigerating machines, leaving at 12°C. The condensers of these machines are themselves cooled by water taken from the primary circuit.

The water consumption is thus limited to 70 m³/h lost by evaporation and percolation in the towers. To be precise, the word 'lost' is incorrect, for the water used for this circuit is itself taken from the surface water of CERN, which would otherwise run to waste, and which it is merely necessary to filter and decarbonise.

The water from the evaporators is sent to a manifold from which it is either re-circulated or injected into the eight different networks (two for the main