10. PRE-INDUSTRIALISATION AND TESTS FOR THE YOKE CONSTRUCTION

Different issues have been studied for the yoke construction and for the displacement of the magnet elements in the surface assembly hall and in the cavern.

10.1 HIGH PRESSURE AIR PAD MOVING SYSTEM

As explained later in Chapt. 26, the magnet will be built in heavy segments (up to 2000 tonnes) which will have to be displaced during the assembly process to insert the coil and the vacuum tank inner shell. These heavy pieces will also be moved more than 100 m over the shielding plug before being lowered to the underground area. Once installed inside the underground area, access for maintenance of the subdetectors will require the endcap disks to be retracted. Maintenance of the barrel muon chambers will also require the outer barrel rings to be moved (see Chapt. 4). A heavy duty moving system is therefore required.

An air pad suspension system has been chosen which due to very low friction allows easy displacement of the heavy loads in all directions. Modern techniques using high working pressures have made these machines small and reliable. The choice of the system was straightforward since there is only one manufacturer in Europe if not in the world. These high pressure heavy duty air pads, used in civil engineering and in shipbuilding construction, are manufactured by the firm Noell. A labyrinth type rubber seal of 1.1 m dia. in contact with the floor surface and working at 30 bar gives a nominal lift of 250 tonnes. These air pads are usually coupled with hydraulic jacks to equalise their individual lifts and to raise and/or to lower the suspended load once it has reached its prescribed position.

Four such air pads and built-in jacks have been purchased, and a platform for a nominal 1000-tonne load has been constructed at CERN (see photographs in Fig. 10.1-A and Fig. 10.1-B, p. C-36).

Several tests have been carried out on a flat floor in order to learn how to use the pad system and to measure the friction coefficient. This was measured on different floor surfaces (plain concrete, painted concrete, steel plates, etc.), with the help of a lubricant e.g. glycol emulsion. Results were always in the order of 0.2%.

Some dynamic tests have also been made in order to simulate a sudden braking action (either a lack of air pressure or by hitting an obstacle). The system behaves as a mass supported on springs, represented by the air layer inside the air pads themselves, fully over damped.

To prepare for the displacement inside the underground area, a more realistic test has been set up, using an inclined cast concrete floor with a slope of 1.23% corresponding to the situation in the cavern. The first results, as predictable from results obtained on a horizontal floor, show that the friction is not sufficient to retain the load on the cavern floor. Consequently some form of retaining action will be needed when displacing the magnet elements in the negative Z direction.

The present retained concept is to use two pairs of hydraulic winches working in opposition (one pair on each side of the heavy elements to be displaced) and connected by their cables which will always be pulled in tension. The connections will be first fastened to the load and the air pads will be pressurised, then the winches will move the system up or down the slope. After reaching the correct position the air pads will be depressurised and the connections removed from the load. The cables could then be connected to another load or stored into the cable drums fixed to the winches thus freeing the area of the temporary obstruction.

The development of 350-tonne air pads is being carried out by Noell. Four of these units will have the capacity of moving the first endcap disk YE1. A full series of qualification tests is foreseen for these units. If successful it is also planned to use the air pad system to move the endcap disks. This would considerably simplify the logistics inside the surface hall, and more important, inside the underground hall.

10.2 DRILLING OF DOWEL HOLES

It has been explained in Chapt. 7 that the barrel rings need doweling between their constitutive iron slabs and assembly brackets to withstand the shear forces generated by gravity loads. In order not to require high machining tolerances it has been decided to drill the locations for these dowels after each layer of slab has been assembled. Drilling must thus be performed in-between matched iron blocks of different grades.

Three drilling tests have been performed using a special drilling head (see photograph in Fig. 10.2-A, p. C-37) to drill the holes of 70 mm dia. and 800 mm deep between matched iron blocks of the same grade and of different grades. The first series was between St 360 / St 360; the second between St 360 / St 560; and the third between St 360 / high resilient StE 500. Results were very good with a hole diameter tolerance of 0.1 mm and an almost perfect straightness of the hole, less than 0.3 mm over the total depth of 800 mm (see photograph in Fig. 10.2-B, p. C-37).

A fourth test will be conducted to prove the validity of the technique using a lower grade steel, e.g. St 310, which is still acceptable for the barrel ring construction. This test will be carried out for the worst cases, St 310 / St 560 and St 310 / StE 500.

10.3 ASSEMBLY TECHNIQUES

Different tests are under consideration or development to determine the final assembly of the barrel rings and the endcap disks. These tests should also indicate the working behaviour of the components. They are aimed at two major objectives:

i) to ensure sufficient reaction against the magnetic forces in beam direction Z (about 1800 tonnes, as explained in Chapt. 6). These forces develop between the corresponding slabs of the second and third layers of the barrel rings due to the fact that they are not retained by Z-stops as is the case in the first layer;
ii) to make the endcap disks (supporting the large magnetic forces of 12000 tonnes, see Chapt. 8) almost like solid disks.

The first objective will be achieved in two different ways: circumferential welding of the 70 mm dia. dowel pins, and partial gluing (epoxy resin and/or anaerobic glue) of the surfaces in contact between the slabs and the assembly brackets. Tests showed that welding and/or gluing will be able to withstand all the applied forces by itself, thus giving a safety coefficient of 2 should both techniques be applied.

Concerning the second objective, several tests have been carried out during the last three years to see if the endcap disks could be assembled, on the CERN site, using the Electroslag technique. Tests have been done in collaboration with ESAB and TTS [10-1]. These tests have been done on 600 mm thick blocks, using two opposite welding shoes rising vertically and moving the melting baths upward at a speed of 0.75 m per hour (see photograph in Fig. 10.3-A, p. C-38). An iron spacer of section 300 x 30 mm^2 was inserted between the blocks to maintained their geometry after welding (see photograph in Fig. 10.3-B, p. C-38). The gaps left on both sides of the spacers were the starting points of the baths which were fed with the usual metallic wires and fluxes. First results were promising in terms of overall deformation which was kept small, however cracks were discovered by macro inspection. They were mainly due to grain growth during solidification and by too much constraint induced by the spacer.

More tests have recently been done to understand the reason for the crack formation. EMPA and ESAB have just finished examination of a fairly good weld [10-2 and 10-3], presenting only microcracks which may be due to the fact that the base material is of low quality. Nevertheless it has been judged that the Electroslag process, although very attractive [10-4], will take too much time to be operational and too complicated to use in the assembly hall, so it has been abandoned. As explained in Chapt. 8 the present solution for assembling the disks, which are now made in sectors, is by mechanical fastening with bolts and/or pre-stressing techniques.