# 28. SAFETY OF THE MAGNET

This chapter provides a safety overview of the magnet project in terms of the safe design of its components at the conceptual and pre-industrialisation stage. This will obviously include hazard evaluation and passive protection systems, also the manner in which the personnel will be invited to react to any potentially dangerous situation. For all other safety aspects related with construction and exploitation a detailed safety plan will be issued.

## 28.1 GENERAL PRINCIPLES

Reference is made to European directives, CERN safety codes and rules, CERN safety policy document SAPOCO/42, European and/or international construction codes for pressure vessels (CODAP; ASME), structural engineering (Eurocode 3; AISC), cryogenics, and lifting equipment (FEM: Fédération Européenne de Manutention).

Special attention will be given to the correct functioning of any safety device that may be subjected to the fringe field (e. g. all detection and alarm systems, relays in the elevators, solenoid valves in cryogenic equipment, safety valves, and circuit breakers, etc.).

The retained technical solutions aiming to get the high safety standard for each system are described in the corresponding chapters.

## 28.2 DESIGN PROBLEMS RELATED TO SAFETY

Intrinsic hazards related to large superconducting magnets, and the CMS magnet is exceptional on account of its dimensions, are coming from: coil axial forces (147 MN), magnetic radial pressure (64 MPa), stored energy (2.7 GJ) and magnetic field (4 T in the centre). These hazards are:

i) dynamic and static structural stress effects;
ii) magnetic field, fringe field and the induced current, all of which affect equipment, materials and personnel (e.g. pace-makers, metallo-plastic prothesis, etc.);
iii) high DC currents on bus-bars and terminal connections during normal operation, and on dump resistors in case of coil discharge;
iv) thermal effects (e.g. loss of vacuum in the coil cryostat, leak of liquid helium, temperature rise on dump resistors);
v) quench effects.

In addition, the large size and weight of the magnet requires specific attention during assembly, transport and handling of its constitutive elements.

Therefore it is essential that safety is taken into consideration at each phase of the project, from the conceptual design of all the magnet components up to their final assembly on the CERN site, and to the subsequent working test of the complete magnet at its nominal operating conditions.

Gravitational forces have been analysed, especially for the central barrel ring (see Chapt. 7) which is by far the heaviest element due to the sum of, its own weight plus the weight of the vacuum vessel, the coil and the inner detectors. This amounts in total to about 2800 tonnes compared to only 1200 tonnes for the four outer rings. Consideration has also been paid to the situation in the experimental cavern where the floor has a slope of 1.23%; different means of displacing the heavy loads and blocking them in place have been studied (see Chapt. 10).

The magnetic forces acting on the barrel rings and on the endcap disks have been computed (see Chapt. 6) and are used for the design of the barrel yoke (see Chapt. 7) and endcap disks (see Chapt. 8).

The return yoke is almost saturated and because of gaps for the passage of cables and services between the barrel rings and the endcap disks, a strong fringe field is present. This field is somehow reinforced by the ferro-metallic structure which surrounds the whole detector and supports the electronic racks. The stray field is expected to reach 0.12 T (see Chapt. 6), consequently only authorised personnel will be permitted to access the area while the magnet is operational. Safety requirements stipulated in CERN Safety Instruction IS 36 will be strictly followed.

Further away from the magnet, the stray field will still be of the order of 100 - 200 G, so special attention must be paid to insure that any safety system within the area will function correctly (e.g. solenoid valves and cryogenic equipment relays, fail-safe valves and circuit breakers, including relays and/or safety protection for the nearby elevators). Value of the stray field, especially in the counting room area, can be inferred from Fig. 6.11, p C-9.

Live conductors will be protected from accidental contact (human, loose metallic objects, etc.).

In case of a quench, the stored energy of the coil must be rapidly discharged, approximately 1000 V will be generated between the electrical terminals and cause the temperature of the dump resistors to rise to about 350°C, (Chapt. 20). This will generate heat inside the coil which in turn will produce a rapid increase of helium pressure inside the cooling circuits and may be followed by a loss of vacuum due to leakage. The cooling circuits are protected against overpressure by a safety valve which opens to vent the cold helium gas into atmosphere.

## 28.3 MECHANICAL SAFETY AND DESIGN STANDARDS

Generally the criteria for safe stress levels will follow the European Eurocode 3 and/or American Institute of Steel Construction (AISC). These codes are not directly applicable to the design of large magnets with very thick sections – no such construction codes exist – they are mostly applicable to conventional steel constructions, but we intend to follow their instructions [28-1; 28-2].

Different FEA’s have been carried out to demonstrate the safety of the iron structure using the above mentioned codes (see Chapt. 7 and 8).

The vacuum tank supporting the inner detectors is sufficiently strong to maintain its stability and to counter the internal stresses caused by the vacuum. However since it has to support the barrel calorimeters (see Chapt. 9) it has been calculated as a structural element. The vacuum tank will be protected against accidental overpressure by safety valves adjusted to 1 bar absolute pressure. As a potential pressure vessel it will be designed according to the French CODAP and/or ASME codes [28-3; 28-4].

For aluminium structures TIS (Technical Inspection and Safety division) recommends to refer to the technical report ISO TR 11069, and refer for the safety factors to the standard for steel construction ISO 10721.1.

The coil has been extensively analysed (see Chapt. 14, 15, and 16) in all its aspects.

On account of possible asymmetric positioning of the coil in the iron yoke the forces exerted on the suspension and tie-rod retaining system have been found to be quite substantial (Chapt. 6). Therefore the possibility of correcting the cold mass position by adjusting its suspension, after an initial measurement performed at low current, has been adopted to counteract these forces (see Chapt. 18).

## 28.4 SAFETY SYSTEM FOR EXPLOITATION

The general safety system will be based on the Magnet Safety System, MSS, (see Chapt. 22.4) and the Detector Control System, DCS, [28-5]. In addition to the Magnet Safety Interlocks (Chapt. 22.4.4), a high level hard wired interlock system, based on the BBL3 alarm matrix originally developed for the L3 experiment [28-6], will ensure the safety of equipment and personnel on or near the magnet under any circumstances. In the case of a fault occurring, all equipment will be brought to a stand-by position in an organised and controlled way.