27. QUALITY ASSURANCE

27.1 INTRODUCTION

The high-tech nature of the CMS Magnet, its size and complexity, and the huge number of partners involved from all over the world call for a Total Quality Management system. This is based on defect prevention and continuous process improvement and relies on a Quality Assurance Plan as foreseen for the whole of the LHC Project, including the Experiments.

Total Quality Management means an approach based on quality, beginning at the design stage and continuing through the complete project. This includes all the manufacturing, handling, delivery, testing, commissioning, operation and maintenance together with the necessary documentation for the above mentioned phases and the associated planning and scheduling programmes.

The essence of quality assurance is: describing what must be done and doing what has been described. The purpose of the Quality Assurance Plan is to provide a framework, as well as guidelines, to make collaboration possible and successful. This eases the work and enables the numerous CMS Magnet Project partners to work to the same standards therefore making communications and understanding easier.

The Quality Assurance Plan for the CMS Magnet project is being completed in parallel with the finalisation of the magnet design. Concerning the Coil Project, the Saclay team has written a draft standard QA plan which is being integrated in the general CMS QA Plan.

Nevertheless it has been recognise that the high dedication of each person involved in the project is a key element to insure quality.

Training will be provided whenever judged appropriate for the success of the implementation of the CMS Magnet QAP.

27.2 THE QUALITY ASSURANCE PLAN (QAP)

The final CMS Magnet Quality Assurance Plan will be based on the recommendations stated in the "ISO 9001 Quality system". This plan presents a written description of the procedures and structures that are being implemented for CMS. The CMS Quality Assurance Plan presents the following four-level structure:

- level A: Introductory information,
- level B: Quality Assurance Management,
- level C: Quality Process Management,
- level D: Quality Result Management.

27.3 LEVEL A - INTRODUCTORY INFORMATION

This section covers all the basic procedures of product naming and identification, document writing standards and the identification system, and the various codes to ease communication throughout the project.

The purpose of this section is to efficiently identify documents for the Magnet Project and to be able to efficiently identify and locate any item (products and components) in its final position, as long as it is included in the PBS (Product Breakdown Structure).

In addition this section outlines the Quality Assurance Categories (QAC) and provides

guidelines for determining the QAC for each item.

The objective of the document numbering system is to ensure the document traceability during the whole life of the project.

27.4 LEVEL B - QUALITY ASSURANCE MANAGEMENT

This section covers the organisational matters necessary for the co-ordination and management of the Magnet Project: this means, Management Plan, Breakdown Structures, Scheduling Process and Standards, Configuration Management and Change Control.

The first tasks in a large project are to define a planning system and the Product, Assembly, Work and Organisational Breakdown structures.

In the planning phase the work activities are viewed against the project time scale: every activity gets its starting and ending dates and any relationship with other activities. It is crucial, for the detailed project follow-up, to integrate the planning system with all the relevant technical, human resource, material management and financial data.

27.4.1 Breakdown structures

The breakdown structures are the basis for the overall project organisation and the definition of the relationship between systems; they describe the whole project in a structured way, by providing an *organised part list* (PBS), an *assembly sequence list* (ABS) and a *work packages list* (WBS); with these three tools it is then possible to find the right resources and structures people to perform all the defined tasks (OBS) and finally outline a general plan (Management Plan).

The Product Breakdown Structure (PBS) includes the following information:
- product tree structure describing the configuration of the project,
- technical description of the elementary parts of the project,
- instructions on manufacturing, machining, quality control for each level and each branch of the structure.

The Assembly Breakdown Structure complements the PBS and provides the WBS and the planning phase with the relevant constraints. It displays the assembly sequence and contains the following information:
- a description of the time sequence of the different activities,
- all information about the site, the installation tasks and the movement of the items during the processes and finally to the experimental area at P5.

The Work Breakdown Structure (WBS) provides the framework for defining the work to be accomplished.

Its main aims are to:
- insure that all the work required, and only the work required to complete the project, has been identified planned and put under the responsibility of someone,
- inform everyone involved in the collaboration of the possible interfaces and interferences,
- start up the CMS Project planning, scheduling and budgeting process,
- report project control information (physical progress) to the Project Management.

The Organisational Breakdown Structure (OBS) provides a detailed framework for people and their organisational relationship.

27.4.2 Configuration Management and Change Control

The aim of this section is to:

- insure that all technical requirements are clearly defined, documented and controlled throughout the whole project life cycle,
- provide a scheme for a systematic review of all changes,
- assure that the impact of proposed changes in performance, cost and schedule are identified, evaluated and appropriately approved prior to incorporation and implementation,
- maintain the integrity between the project progress and the original project baseline (the Technical Design Report) in regard to performance, cost and schedules,
- to get every project partner working at any given time to the same configuration parameters and objectives of the CMS detector.

27.5 LEVEL C - QUALITY DURING PROCESSES

This section deals with the definition of the Quality Assurance implementation strategy of the processes during the whole product life cycle, from the design phase to the delivery phase; it takes into account the design, the contract, the purchasing, the entire fabrication and the various logistics (handling, storage, packing, delivery).

With respect to the call for tender, a procedure has been established for the call and placing of orders (Chapt. 31). CERN or another CMS Collaborating Institute will be responsible for issuing the price enquiry, placing the order and assuring the financial monitoring.

27.6 LEVEL D - QUALITY RESULT MANUAL

This section covers all matters concerning the quality control procedures to be defined and implemented by the various CMS sub-systems. The quality results are expressed in terms of:

- inspection and acceptance testing,
- control of measuring and test equipment,
- control and quality records,
- internal quality audit.

With respect to the *reception procedure*, a series of tests is defined for every product. In case of non-conformity, a report will be made to decide what should be done

With respect to the *manufacture control*, the supplier will be asked to comply with National Quality Standard or ISO 9000 (the certification will be appreciated but not mandatory). Check points will be defined and the magnet team members will be authorised to visit the manufacturing company.

27.7 QUALITY CONTROL

In order to give the reader a feeling for what happens in a real case, we have listed below the control tests which are foreseen to ensure the final quality of a crucial item during the industrial production of the coil conductor.

Superconducting Strand

- chemical analysis of source materials,
- eddy current measurements of all the final conductor,
- continuous strand diameter check, spot measurements of Cu/SC ratio,
- RRR of the copper matrix,
- critical current of the strands before cabling, after cabling, after extrusion of the insert.

Rutherford type cabling

To control the cable quality and its current degradation, checks on filaments will be carried out on samples taken from the beginning and from the end of the cable.

- measurements on single strands have to show that the degradation is within the tolerances,
- during the manufacturing process, on-line dimensional measurements and the control of the pulling force are foreseen, to make sure that the cable is not damaged.

Extrusion

During the extrusion process of the conductor the following tests are due to be performed:

- temperature control of the billet pre-heating,
- extrusion temperature,
- stop duration time,
- pressure applied,
- speed.

Bonding at the Rutherford-pure aluminium interface

After extrusion, short 250 mm samples will be prepared for tensile tests from the extruded conductor and ultrasonic tests will be carried out on short samples prepared from both ends of the insert. For these tests the pulse-echo ultrasonic method will be used, however, for the on-line bond measurement a new method is proposed.

Off line the following tests will be performed:

- Bending tests.
- Macro and micro photography, electron micro probe analysis for bond quality.
- Measurement of the residual resistivity ratio (RRR).
- Ic measurements on single strand.
- Ic and MQE on full conductor.
- RRR measurements under cyclic strain.

All these tests will have to be organised, followed and recorded in the framework of the Quality Assurance Plan.