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QUALITY ASSURANCE AS A SYSTEM OF MANAGEMENT CONTROL IN NUCLEAR POWER PLANTS

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ABSTRACT

When embarking on nuclear power project the plant owner in developing countries should be able to execute in the first place the planning and control functions of management. These are probably the unique functions which cannot be delegated to the foreign contractor. For this reason in building industrial infrastructure for national participation in nuclear power project establishment of management control systems both by the plant owner and by all national participants should be of prime importance.

Quality assurance is considered as a mangement control system which the owner of nuclear power plant has to establish for nuclear power project for ensuring that a plant is built as designed and that defects are corrected. The building up of such system should start early enough in project activities and before the plant design and construction, in order to ensure correct performance of all activities related to selection of site for nuclear power plant, bid specification and evaluation and procurement of services. The QA is a regulatory requirement, but the prudent plant management would create such a system as part of their total project management systems irrespective of formulation of requirement. In fact regulatory requirement should be considered as the criteria to be used by the regulatory organization for evaluation of licencee's QA system and not as an objectives to be reached.

In this paper the needs for QA system are justified as the part of development of industrial infrastructure for nuclear power project. Elements of the system are described such as documented QA programme and organizational structures with defined responsibility and functions of individual organizational units, and with control of information flow across the interfaces. The goals and objectives or the project organizations related to achievement and verification of quality are defined as well as system functions in attainting those objectives. This includes the feedback of information to the management on monitoring of

performance in project activities, identifying deficiencies and initiating corrective actions. Domestic participation in the nuclear power plant construction will depend on the ability of local construction and manufacturing organizations to achieve high quality standards of products and services that can affect safety and performance of nuclear power plant. Besides technical competence, skill and ability to perform the work, capability to establish and maintain effective control over production or execution of services will be decisive for this participation. Introduction of QA systems in project organizations, development of QA programme and implementation of control functions can contribute to early incorporation of local industry in the nuclear project activities and facilitate nuclear technology transfer in developing country.

Introduction

In the process of nuclear technology transfer from an industrialized to a developing nation it is of prime interest to identify the industrial infrastructure that would be necessary for an effective and timely introduction of nuclear technology into national industry. In principle, a country with an intention to develop an important nuclear power programme may wish to develop as much as possible of nuclear technology and achieve in the course of planned period of time autonomy in nuclear electricity production. Introduction of the nuclear technology can be achieved only progressively and national priorities should be established early in the course of initial planning of nuclear power project activities.

Already for the first nuclear power project it will be necessary to develop domestic capabilities in all those areas of project activities where project functions and responsibilities cannnot be delegated to a foreign contractor. These are in the first place some functions of the management such as planning, scheduling, management controls as well as all functions of the governmental organization. Also, a developing country may wish to include early in the project activities domestic participation in all those areas where adequate national capabilities exist or can be timely developed. This may be a participation in construction, manufacturing, some engineering activities etc. Scope and intensity of these participations will depend on the ability of local engineering, construction and manufacturing organizations to achieve high quality standards of the products and services that can affect safety and performance of nuclear power plants. Besides existance of purely technical capabilities such as possession of manufacturing equipment and qualified personnel, ability to establish and maintain an effective management control over quality in production or execution of services will be decisive for this participation.

Development of national capabilities to implement management functions both for the project as the whole and for each specific project activity will be the first task of a country wishing to introduce nuclear technology. With the term management functions we are considering those planning, and administrative control functions in one organization, that are implemented by assigned groups or persons being qualified by education and training for this task. In order to be able to implement these functions efficiently an organization will establish necessary management control systems with the purpose of assisting management in allocation of its resources so as to facilitate the attainment of the goals and objectives of the project. In principle, development of management control systems is the primary task of an assigned management and one of the first steps in establishment of needed infrastructure for a nuclear power project. Some of these control systems are customary in all industrial organizations such as system of financial control, but some systems are specific for nuclear power project and nuclear activities in general. Also, some of these systems will be established formally, others will be a part of general aspects of organizations administration that are related with the performance of such functions as: planning and scheduling, coordinating plans of various organizational units, processing information, personnel policies etc.

A formal management control system that is required in nuclear power project activities to be established and used by the management in implementing control over technical aspects of the project is the system of quality assurance. This system should be used by the management in attainment of goals and objectives of the organization defined for a nuclear power project as a safe, reliable and economic electricity production. These ultimate goals and objectives should be achieved by implementing the following quality assurance functions:

(1) Achieving quality objectives of equipment and activities through identifying and prescribing the quality and safety standards, and by inposing their implementation by qualified personnel under rigorous management control.

(2) Verification of achieved quality through a series of complementary or independent methods such as inspection, testing, surveillance, auditing, reviews and assessment and generation of objective evidence of achieved quality.

(3) Ensuring feed-back of information to the management on identified deficiencies and their causes, and initiation of corrective actions to eliminate root causes of quality related problems.

In all countries with a nuclear power programme quality assurance is also established as a regulatory requirement. The nuclear power plant owner is responsible to establish the QA programme on the basis of the existing requirements. The QA requirements such as those defined in the IAEA Code of Practice on QA (50-C-QA) will be used by the regulatory organizations to evaluate existance and effectiveness of the licencee's QA programme.

QA as a management control system

By identifying the QA as a management control system it is considered that it will have all the elements of a management control system to be able to implement given functions. It will be based on a defined organizational structure with assigned autonomy, responsibility and authority of various organizational units and persons. The organizational units and each person in the organization are performing delegated functions that are prescribed by a documented QA programme. As a basis for establishment of this programme regulatory requirements on QA and respective industrial standards are used. Broad scope and orientation to both achieving of quality and qualification verifications require that QA programme should be implemented by all personnel performing quality related activities. QA is, therefore, not a responsibility of a single group that may be formally identified as a QA unit but this responsibility shall be shared by all performers and verifiers in project activities.

The QA should be used by the management at all levels as a closed loop system of management control. From the management itself will depend how much this system will be efficient. Inability or failure of some management to implement the QA system efficiently can have severe consequences on quality of equipment and activities related to construction and operation of nuclear power plants.

To have a correct understanding of QA as a management control system, constituent elements of this system and their role in implementing of system functions should be defined.

Organization: In an organization with established QA system a documented organizational structure should be established with clearly defined functional responsibilities, level of authority and lines of internal and external communications for management, direction and execution of project activities. Implementation of the QA programme is the responsibility of all individuals and groups participating in activities. However as a general rule, the functions of establishing of the QA system and supervision of its functioning are assigned to a specialized group of personnel usually named QA unit that is reporting to the management. The verifications, including quality control functions, are performed by individuals or groups who have not directly participated in the activities being verified. Organizationally, they may belong to the QA unit or be associated with the organizational groups responsible for performance of activities.

QA Programme: Goals, objectives and functions of the QA system are defined and documented in the QA programme. For a nuclear power project an overall QA programm will be established by the plant owner. It consists of constituent QA programmes of all project participants performing activities affecting quality of the plant. The overall QA programme will define all those items and activities to be subject to control and verification.

Establishment and documentation of the QA programme is one of the first functions of an organization's management after decision is made to perform activities related to a nuclear power project. This task includes: a thorough analysis of the work to be performed and identification of all items and activities influencing safety and performance of nuclear power plant; development and qualification of procedures and instructions for performing activities affecting quality of these items; development of inspection and test plans as a constituent part of manufacturing, construction and installation plans; development of inspection and test procedures and specifying acceptance criteria; last, but not least, development of training and qualification programmes for all personnel performing quality related activities. The QA programme is documented in programme description, QA procedures, inspection and test plans, including procedures and instructions for performing and verification of activities. The QA manual is a document containing a set of policies and procedures that prescribe the functioning of the QA system.

QA system functions: All participants in a nuclear power project should perform their QA functions according to the requirements layed down in the QA programme. These functions are both managerial or administrative and technical. Through implementation of these functions the management control systems is exercising necessary controls over activities affecting quality of a nuclear power plant.

The IAEA Code of Practice on QA, and other similar documents elaborate the QA system functions in form of QA requirements or criteria. In principle all these requirements shall be implemented in all activities related to quality of all items and activities covered by the QA programme. However, intensity or level of programme implementation will depend much on safety classification of items and other relevant factors. The following are those QA functions specified in the IAEA Code of Practice on QA:

Document Control: Document preparation, approval, issue and distribution are subject to control.

Design Control: Design process and design documents are subject to control in order to assure that applicable regulatory requirements, codes and standards are correctly translated into specifications, drawings, procedures and instructions.

Procurement Control: Procurement process shall be controled. Contacts shall be awarded only to qualified suppliers with established QA programme. Procurement shall be controled through verification of manufacturing processes and products using inspections, test, surveillance and audits.

Control of Purchased Material, Equipment and Services: Purchased material and equipment shall conform to quality requirements specified in procurement documents. Control measures shall include both the examination of products upon delivery and examination of objective evidence concerning quality during the process of procurement, source evaluation and surveillance.

Control of Processes: Special processes such as welding, heat treatment, non-destructive examination, etc. shall be accomplished under controlled conditions using qualified procedures and by qualified and skilled personnel.

Inspection and Test Control: Inspection and testing of items as a part of quality control activities shall also be subject to control to assure that these activities have been adequately administered.

Identification and Control of Materials, Parts and Components: Identification and control of items shall be ensured through appropriate markings on the items, or on records traceable to the item. These measures should also provide means for tracing items back to the materials and ahead to their location within an assembly.

Non-Conformance Control: Non-conforming materials should be subject to control to prevent their inadvertent use or installation.

Corrective Action: Conditions identified as adverse to quality shall be corrected and appropriate measures taken to prevent recurrence.

Quality Assurance System Audits: Regular and unscheduled audits of the quality assurance programme within the organization (internal audits) and of suppliers and other contractors (external audits) shall provide confidence in effectiveness of the QA programme.

The basic methods of implementing these QA functions are: (1) performance of activities affecting quality on the basis of established qualified procedure and instruction. (2) performance of activities under controled conditions by qualified personnel. (3) performance of activities in a planned and systematic way. (4) verification of conformance to established requirements and required quality characteristics through series of complementary verifications such as inspections, test, surveillance of activities or QA audits programme audits. (5) control of nonconformances and implementation of corrective actions, to eliminate root causes of unsatisfactory conditions.

Manpower requirement and qualification

Manpower requirements for QA depends on the scope of the QA programme of an organization. In principle the workload for QA/QC will be proportional to the work activities directly related to the manufacturing, installation and construction of the nuclear power plant. For the work on the nuclear power plant site related to construction and installation of equipment ration of craft workers to inspection and test personnel (QC staff) is approximately 10 to 1. For typical QA functions, QA programme preparation and maintenance, evaluation of procedures and auditing, ratio in some situations can be 50 to 1. In the manufacturing industries manpower requirement for QA/QC will very much depend on the type of product, its safety relevance, complexity, degree of automatization of the production etc. A highly automated process, such as fuel fabrication, will need much of quality control staff in relation to the production staff, for other technological processes this may be the opposite. For a nuclear power project the overall QA programme will be

the responsibility of the utility (plant owner). QA organization of a plant owner may widely vary in respect of how much of the QA programme activities the owner delegates to other organizations and how much it retains for itself. As a minimum, a utility must retain activities related to the overall supervision of the work. In this case the plant owner is normally establishing two organizational units to perform the QA activities, i.e. home office and site QA organization with a total number of approximately 10 engineers that are responsible for the following QA functions:

Home office: development of the overall QA programme including procedures, quality plans and work schedules; review and approval of procurement documents; review of equipment specifications; auditing of all major suppliers, constructors and installers.

Site unit: surveillance and audits of construction activities; review and approval of construction and installation procedures; witnessing of all important inspections and test; initiation of corrective actions, etc.

Usually, some of the QA functions of the plant owner are delegated to an A/E organization or to consultants. The QA organization of an A/E is usually structured in a similar way as that of the plant owner, i.e. home office and site unit. These functions are mainly oriented to control of the technical aspects of plant design and construction. The home office of an A/E is responsible for QA during design of nuclear power plant and for review and approval of design specifications, and surveillance of all important vendors. Site unit is engaged in surveillance of constructors, NSSS suppliers and installers inspection and test activities. This unit establishes also coordination between site and home office activities. Number of QA/QC specialists that an A/E may engage in a nuclear power project will be 10 - 20. In addition, this organization should establish all technical supports at the site such as laboratories; storage, handling and management of QA records, etc.

Various organizations involved in plant construction and installation of equipment will have their QA/QC units. Their functions will be mainly planning and performance of first line inspections and after installation testing of equipment. For implementation of these functions inspection and test personnel with specialized qualification in inspection of mechanical equipment, electrical equipment or civil structures will be needed. Qualification in various techniques of non-destructive examination will also be necessary for implementation of these functions. Manpower requirement for this staff will vary during the plant construction period and at the top of construction activities may consist of 80 - 100 inspection and test specialists qualified in various engineering disciplines and in inspection techniques.

All QA personnel should be qualified on the basis of education, training and experience. It is customary to classify QA staff into two broad groups e.i. QA engineering personnel and inspection and test personnel. QA engineering personnel responsible for performing QA programme operation, preparation and management should be educated in some of the engineering disciplines, and qualified in QA/QC methodology and techniques. This includes knowledge of QA requirements, methods of surveillance and audits, and skill in planning and documenting of QA activities such as inspection and test planning, audit planning and scheduling etc. Inspection and test personnel should be specialized in engineering disciplines and in examination and test techniques. This personnel is usually categorized in several levels of qualification, where the lowest level represents qualification in performing specific examination and tests and documenting the result, but without authorization for acceptance or rejection of items or activities. Higher levels are qualified in performance of examinations and test but also for acceptance or rejection of work.

There are at present several universities in the world offering education in quality related disciplines. However, still most of the QA/QC staff are recruited in conventional engineering disciplines and additionally trained in QA methodology and QA/QC techniques. QA programme of an organization includes as a rule a training and qualification

programme for QA personnel as well an orientation of all staff in quality assurance principles and requirements.

Measuring and Test Equipment

Implementation of quality assurance functions in particular in the area of verification of achieved quality, demands use of equipment which can make measurement of quality characteristics of required precision. Taking into account that the list of quality characteristics to be measured and verified is rather large there is a whole array of various measuring and test equipment that will be necessary to be purchased or developed for satisfactory implementation of the QA functions. The equipment may be generally termed as quality information equipment, because its main role is in providing information on quality characteristics to be used in product or process analysis and control. The increasing importance of such equipment can be demonstrated with the fact that in some industries up to 25% of the industrial plant investment can be assigned to quality-control equipment. One should take into account that the equipment directly used for measurements and test should be supplemented in many cases with digital data evaluation equipment that provides on-line analysis and facilitates the decision making on acceptance or rejection. In the process of development of a quality assurance system, development and supply of measuring and test equipment should be performed in a systematic way. This includes the following steps to be taken:

Equipment specification planning: Taking into account various industrial branches and specialization in manufacturing of specific products or performance of services it will be necessary to establish specification of the quality information equipment which is required in the framework of the quality assurance programme of the organization and inspection and test plan for specific product. This should include specification of required type of equipment, precision, needed automation and data processing equipment.

Design and procurement: Not all necessary equipment will be commercially available. For those to be designed, detailed design and operational requirements, accuracy and calibration, information input and data processing as well as information output will be needed. For the equipment which is commercially available, selection of supplier should be based on quality characteristics of the equipment, suppliers records in providing quality products, testing of samples of the equipment etc.

Installation, checkout and calibration: Before use, the procured equipment should be subject to verification in respect to application and operation. This includes calibration and preparing of instructions for operation, maintenance and calibration. Training of operation personnel in equipment usage should be considered as additional requirement to general training of inspection and test personnel.

For performing specific quality verification functions during plant construction an organization participating in a nuclear power project should be equiped with necessary quality information equipment corresponding to the scope of its activity, and methods to be used in verification.

During plant construction the first line inspections and after installation testing is normally performed by inspection groups (QC group) of the organization performing the work. These groups should be equiped with basic inspection tools specific for the type of activity (mechanical, electrical, civil) and adequate for field use. - It would be impossible to list all required measuring and test equipment needed for each type of inspection activities. Generally they may be grouped under the headings specifying quality characteristics to be measured or tested:

Measuring of dimension: This equipment includes an array of types based on mechanical, optical or electrical principles. From the simple tools such as calipers or gages it may include complicated optical systems such as optical comparative stereo microscopes etc.

Measuring of plant system parameters: In this group of equipment belong all temperature, pressure, level or flow measuring equipment.

Surface examination: This includes various non-destructive examination equipment used for visual examination (gages, telescopes, borescopes, foto or video cameras etc), magnetic particle and liquid penetrant examination equipment.

Volume examination: Whole volume examination for defect in pressure retaining components need NDE equipment for radiography, ultrasonic or eddy current (thin wall components) equipment. A number of equipment specialized for given application are commercially available.

Leak testing: This type of testing includes various methods and requires for each method a special type of equipment. Simple pressure change detection instruments can be sufficient for some application but for others halogen detection or mass spectrometer type of leak testing equipment may be needed.

Hydrostatic testing: This testing requires a set of pressure gages, pressure relief devices as well as specific leak measure devices.

Electrical measurements: For inspection and testing of electrical equipment, instrumentation and control devices a number of instruments and measuring devices are needed such as: voltagetester, ammeter, ohmeter, megger, resistance bridges, breaker testers, probes, cable pulltesters, tensiometers etc.

Laboratory testing: An equiped laboratory will be needed at the construction site to perform all laboratory testing related to construction activities such as testing of soils, rocks, concrete etc. Standard type of laboratory test equipment for chemical and mechanical testing will be needed.

Calibration laboratory: An organization responsible for measuring and test activities using measuring and test equipment, should have a calibration laboratory with all necessary calibration standards to be able to implement QA requirements on control of inspection and test equipment. The standard in the laboratory shall be traceable to well recognized national standards.

To the list of required inspection and test equipment one should add equipment for storing and processing information that may be located centrally in the organization, or might be associated with the specific inspection or test group. This equipment can be of importance for data recording, processing information, analysis and decision. Also, this processing equipment will be of importance for retention and handling of integrated quality information that are important to the nuclear power plant quality data base.

Influence of nuclear QA on quality technology in conventional industries

A country embarking on its first nuclear power project will probably face the QA methodology for the first time. Strict quality assurance requirements for equipment and activities emphasised by safety considerations for nuclear power plants will be unique for a country without much experience in manufacturing of high quality products. However, the QA identified as a management control system is not exclusively designed for nuclear power plants. Each quality product in its design, manufacturing or installation stage will require elements of control of quality related activities to ensure achievement of those characteristics that determine the products performance. Traditional quality control methods that are used in most industries concentrate almost exclusively on manufacturing and have a function to reduce manufacturing imperfections in the product and eliminate the bad products from the lot.

Nuclear QA introduces a concept of total product control, both by quality achieving process and verification of achieved quality of products. Implementation of QA will be necessary in all high technology industries where performance characteristics must be identified, and strictly achieved and maintained.

Quality consciousness established during nuclear power programme implementation will facilitate the acceptance and development of quality technology in conventional industry. Manpower qualified in nuclear power project will represent a nucleus of personnel to introduce quality technology and increase the quality standards in developing countries. However, although QA system in both nuclear and conventional industry will have the same elements, the goals and objectives of this system should be established in each specific case. In a nuclear power project objectives of a QA system are in the first place achievement of safety. In conventional industries QA system should be oriented both to quality and cost control and on achievement of minimal life-cycle costs of a product. This control will be implemented from the stage of design and manufacture to the use and maintenance of the product. Quality characteristics to be controled will include, besides performance parameters also reliability, manufacturability, maintenability and other cost related parameters. These economic oriented objectives will require the QA programme to be cost effective. Cost-benefit consideration not entirely applicable to the nuclear QA, will be used in establishing and evaluation of the QA programme effectiveness in conventional industries.

Experience from a nuclear power project can be transfered into other industries either through direct involvement of an industrial organization in nuclear power activities, or this can be achieved indirectly by acceptance of QA methods and techniques and recruiting trained QA personnel. To participate in nuclear power activities an industrial organization will be obliged to establish and implement the QA programme in order to satisfy regulatory and contractual requirements. Once the QA programme is established, this programme may be used also in activities which are outside of its nuclear power contract although in a modified form. Indirect transfer of QA practices will always be based on

good examples of effective use of the QA programme in nuclear industry. These good examples are probably the best effects of nuclear QA on conventional industry.

Experience acquired in nuclear power project on use of QA as a management control system is likely to become the fundamental approach to quality technology in industrial development of a developing country. QA system will allow the integration of efforts of various groups and individuals that are in modern industry related to the creation, building and maintenance of product quality.