

DEPARTMENT of NUCLEAR TECHNOLOGY
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CIDA COURSE ON QUALITY MANAGEMENT

" QUALITY in CONSTRUCTION "

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1. Objective of Presentation :

This presentation deals with Quality in Construction as applied to large capital projects or large modifications to existing facilities, such as power plants, refineries, steel mills, railroads, airfields, large buildings and similar.

Specifically, the following considerations for assuring quality of construction will be addressed :

- organization
- planning
- key elements of the Quality Program
- safety and security
- performance of work
- turn over to commissioning
- assessment

2. Introduction .

Construction of a major project is a complex undertaking, the management of which requires considerable experience and skill. Many diverse activities have to be managed and coordinated over an extended period of time. Construction management is a key component of Project management team and must be fully integrated into it. Good communications between Project Managers, Design, Procurement, Operations and Construction organizations are a necessary pre-requisite to success

The key outputs of a construction organization are :

- delivery of a product (structure) within the **specified budget and time objectives**
- assurance of meeting the **quality requirements** as specified by the Design authority
- meeting the overall corporate and national objectives with respect to **personnel safety and environmental considerations.**

Financial and schedule considerations play a key role in determining the economic viability of the project. Long delays cause interest on capital payments to accumulate above those anticipated. Cost overruns arising from lack of control of labor, materials and

construction processes add to overall cost of the project, as well as frequently requiring re-work, and thus adding to project delays.

The importance of **assuring quality in construction** arises from the fact that no design can function satisfactorily in the longer term unless the design requirements with respect to quality of materials, workmanship and assembly have been satisfied. Satisfaction of these requirements requires having in place an effective Quality Assurance (QA) program.

Corporate and National targets with respect to **personnel safety and environmental performance** must also be satisfied. This implies not only an effective industrial safety program at the construction site, but also including items such as adequate and safe food, accommodation and medical care. Environmental considerations include minimizing the impact of the project on the environment and ensuring satisfactory clean-up once the work has been completed.

3. Organization

Organization of a construction project usually has two main groups :

- an **performance group** , who are responsible for directing and controlling the work being done at the site
- an **oversight group** , who ensure that the work is being done in accordance with the design requirements. The "**oversight group**", sometimes called the "**resident engineering**" carries out verification and ensures, on a daily basis, that work is done in accordance with design requirements.

Both of these groups report to the construction manager and are typically located at the construction site.

"Performance group"

The "**performance group**" controls the workers at the site and has the authority to assign work, approve schedules, purchase construction materials and equipment, regulate the number of tradesmen working at any given time and manage and supervise work done by contractors.

They are responsible for the administration of the construction tradesmen and the planning and control of their work. They are also responsible for ensuring that work meets the quality requirements of drawings, specifications and procedures.

Additionally, this organization is responsible for ensuring that construction and installation work is coordinated, conducted and completed in accordance with planned programs of work, especially with respect to quality, cost and schedule. This includes work done by contractors.

Construction organization is usually also divided by their engineering disciplines, such as:

- civil
- mechanical
- electrical
- control and instrumentation, including computers
- architectural

Competence in all these areas must be assured, in respect of performing the work as well as in oversight and verification.

Special fabricating shops are often set up to better control quality of the product. Typical of those are :

- pipe fabrication
- structural steel fabrication
- concrete mixing plant
- valve testing and set-up

Oversight group (resident engineering)

Resident Engineering are the main interface between Construction and Design with respect to changes, concessions and departures from design. Completed work must meet the approval of the Resident Engineer, who also has the authority to suspend work which he deems not to be satisfactory.

Written procedures, personnel qualifications, materials and equipment must comply with the applicable specifications, codes and standards and are subject to the approval of the Resident Engineer prior to work being performed. He has the authority to assess and recommend changes to Construction Quality program, interpret inspection and test results and provide code interpretations.

Records are kept of qualified personnel, procedures, equipment, material certificates and test results, and material traceability where required

4. Planning

Construction activities , including verification activities and those important to personnel safety during construction should be planned, documented and approved. The plan should define activities to be performed in manageable work units (**work breakdown technique**) their sequential order, duration and resource allocation for each activity.

There are several techniques for "work breakdown", but in general they are all product-oriented, family-tree division of hardware, software, facilities, systems and other items which organizes, defines and displays all of the work to be performed.

Each work package represents a well defined scope of work that terminates in deliverable products or completion of services. Work packages must be measurable and controllable.

To complete a work package, one or more tasks will be performed. Thus, a work package may encompass the work of more than one crew or staff.

Thus an essential part of planning is to break-up the work into well defined components to an appropriate level of detail. At each level of detail, responsibility is assigned for management of each component. Through this hierarchical arrangement, management of the total scope of construction work is possible.

Planning includes :

- review of code requirements, design specifications, design documentation, materials and equipment, manufacturer's specification and drawings.
- preparation of schedules, fabrication plans, inspection and test plans, check lists and quality control procedures.
- ✕ assuring adequate numbers of trained and qualified personnel
- confirming that work schedules coincide and dovetail with availability of material and equipment
- establishing requirements for records required by the Quality Program

Whilst the Construction organization retains the responsibility for coordinating and planning the over-all construction, contractors should be responsible for producing detailed plans for the work they will be carrying out and for obtaining Construction's approval for these plans.

5. Quality program.

A construction quality program encompasses all the usual Quality Management components, the most important of which are :

- training and qualifications
- verification - both supervisory and by the resident engineer
- change control (configuration management)
- interface control
- deficiencies and corrective action
- information/experience feedback

The Quality group at the site is responsible for upkeep of the Quality program and for continuous assessment of its effectiveness.

Training and qualification.

Where requirements for personnel qualifications have been specified in applicable codes and standards, the individual's qualification should be documented and should indicate the period for which it is valid.

Personnel should be qualified by suitable education and experience and receive the necessary training in order to develop proficiency in the tasks they perform, e. g. welding, heat treatment or non-destructive examination. They must also familiarize themselves with work products, special equipment, QA program requirements and procedures.

Skills and knowledge should be refreshed, kept up and reconfirmed on a continuing basis.

Change control (configuration management).

A change is a modification to the approved project baseline. It can involve addition of work, deletion, demolition and rework or changes to specifications. Changes within the agreed on scope of work are referred to as "construction development changes". Anything else is a "scope change".

The purpose of change control is to ensure that:

- revisions to scope, cost, material and schedule arising from changes are identified
- requested changes have the appropriate level of approval
- impact of the project, and the program as a whole is recognized and understood
- there is effective communication of approved changes to all concerned parties

With a well defined project, a good construction and project organization and a good control structure, changes are readily classified and controlled. Construction development changes can be evaluated and tracked against appropriate control accounts. Change requests which affect the **scope of the project** are obvious and are particularly scrutinized and challenged.

It is important for good project control to minimize changes. Changes should be made based on needs not wants, and only if the team consensus is that they are unavoidable, beneficial and necessary.

Interface control.

Interface arrangements should be agreed and documented between the construction organization, contractors and other organizational units performing the work.

The following interfaces between organizations are of particular importance :

- Contractor and Construction
- Contractor and Commissioning
- Operations and Construction
- Construction and Design
- Construction and the Regulatory Authority - if applicable

Deficiencies and corrective action .

All deficiencies should be identified, documented, reported, reviewed, dispositioned and controlled. Non-conforming items are to be clearly identified and segregated, and the details of non conformance recorded.

In the case of major non-conformances or when a trend is established an investigation as to the root cause is carried out and corrective action is implemented to prevent reoccurrence. Corrective action may involve revision to design, rework or replacement.

Information feedback

Construction experience is fed back to Design and other Construction departments and is used to promote design and construction improvements. This information should be transmitted formally. Matters relating to difficulties encountered during construction are of special interest to Design organization

6. Safety and security

Management must establish a "Safety Policy" to which it is totally committed. This policy must be communicated to all employees and enforced.

Safety is enhanced through following practices :

- demonstrated management commitment and example
- continuous reinforcement of safety regulations through :
 - training of all personnel
 - inspections of work locations by safety officers
 - reinforcement by supervisors
 - establishment of "joint safety committees" with employee representatives

An effective safety program at a construction site is a necessity, and that usually requires creation of a "safety department", whose only responsibility is the enhancement of personnel safety.

Security of the construction site must also be assured. It is usually assured through a security organization which:

- controls access to the site, with only personnel who have received authorization and training in industrial safety regulations being permitted unaccompanied access.
- protects equipment and materials from theft and willful damage
- investigates infractions

7. Performance of work.

Procedures

Construction activities must be performed in accordance with approved drawings and specifications. For complex or specialized work, additional instructions may be prepared and augmented by special training.

Construction procedures for the various activities should deal with :

- specific, special instructions addressing work execution
- personnel qualification requirements
- sequence of fabrication and installation
- "hold points" at which special inspections and verification must be conducted
- special equipment and tools to be used
- precautions and potential problems
- references to associated documents
- documentation requirements
- test and inspection requirements
- acceptance criteria

Control of special processes:

Special processes are those which cannot be directly examined or in which evidence generated during the process must be used to verify conformance

Typical special processes which need to be controlled include :

- piling back filling and compacting
- concrete mixing and placement
- welding
- heat treatment
- cleaning (pipe, tubing and fittings)
- protective coatings
- non-destructive examinations

Material management :

Measures should be established and implemented to control the receiving, storage and handling of material and equipment, to prevent their abuse, misuse, damage, deterioration or loss of identification .

The following activities for control of materials have to be addressed :

- receiving
- storage
- handling

- issue

Of special concern is the issue of material traceability. Traceability is maintained by physical identification or, where this is impractical, by segregation or by records traceable to the item. A material identification system ensures that only the correct material is used.

Upon receipt, materials and items are :

- visually inspected for damage
- checked to confirm that required documentation accompanies shipment
- quarantined if discovered non-conforming
- stored and protected from damage
- maintained and handled in accordance with specified requirements

Contracting

During planning of construction work, decisions are made as to what will be contracted out and under what arrangements. Contractors employed to construct the plant should be selected from those who can demonstrate that they are suitably qualified and experienced to carry out the work.

Contractors should be asked to provide a listing of documents which require approval.

Typical documents might be :

- contractors QA program
- inspection and test plans
- description of installation methods
- "special process" procedures

The following issues should be considered in development, establishment and management of contracts :

- the total agreement between the parties is of paramount importance, but the language of the individual contract clauses merits careful consideration
- the contract should result in allocation of risk between the parties such that each risk is assumed by the party best positioned to manage it.
- incentive clauses can be used to fine tune the contract to bring the contractor's goals and objectives more nearly coincident with those of the owner.
- consideration should be given to including contractor representatives as active participants in planning of construction.
- consideration should be given to applying the concept of partnering with external suppliers and contractors in situations where it is most cost effective to have an external organization provide long-term support.

It should be noted that inconsistencies and ambiguities in a contract breed misunderstandings, delays and increased costs. Clauses related to work scope definitions, changes and project control are the most frequent sources of disputes and poor project performance

Inspection and test control

Inspection activities should be planned and requirements established and documented prior to the start of work. Results are to be recorded and evaluated. Work should not proceed beyond "hold points" until test results are accepted by the Resident Engineer. Sampling inspections, when appropriate, are carried out in accordance with recognized statistical methods and standards.

All measuring and test equipment must be calibrated, maintained and controlled. Equipment is to be calibrated to known standards at specified intervals, or when accuracy is suspect. Results and maintenance of calibrations must be documented.

Housekeeping and cleanliness

Measures should be established and implemented for performing housekeeping operations. These should include methods and techniques for control of the site area, the facilities and the material and equipment being incorporated into the facility.

Cleanliness standards for housekeeping activities should be established. These should take into account control of environmental conditions and personnel access. Where zoning is used to achieve this control, zone boundaries should be clearly marked and procedures be issued to ensure conformance.

Of particular importance is the necessity to assure cleanliness of the installation and special measures must be undertaken to keep foreign material out of equipment, such as for example :

- piping
- heat exchangers
- pumps, turbine, generator

Documents and records.

All work done must be documented and recorded. Records of work done must be maintained and transferred to the Commissioning and Design organizations as appropriate.

Occasionally, due to Design oversight, equipment cannot be installed as per drawings due to, for example, interference. Construction is then empowered to make the necessary modifications - with the approval of the Resident Engineer. All such modifications must be recorded on "as built" records and the information transmitted to the Design for assessment and inclusion on drawings.

The commissioning organization is particularly interested in records pertaining to material history, calibrations and settings of equipment and the final arrangement of equipment.

8. Turn-over form Construction to Commissioning

Provision should be made by the Construction organization to control and coordinate the hand-over of completed work from one contractor to another and to the commissioning/operating organization.

The following requirements must be satisfied:

- documentation related to the transferred items should be jointly reviewed for completeness and accuracy.
- Of special significance are :
- material certificates (material history)
 - results of construction tests
 - records of calibrations and equipment settings
 - deficiencies should be identified, recorded and the method and timing of their resolution should be agreed upon
 - status of systems and components being transferred must be clear and documented
 - joint inspection of the system/components by construction and Operations should be conducted
 - a formal turn-over document should be signed by both parties
 - the boundaries of responsibilities should be clearly identified in the field, usually by means of turn-over tags

There are also certain operational requirements which must be satisfied before an effective turn-over can take place. These refer specifically to readiness of commissioning organization to assume responsibility for and exercise control over equipment/systems being turned-over.

9. Assessments.

The Construction organization should assess its own performance at regular intervals through having an effective self-assessment program in effect. Self-assessment reviews should address execution of work - by observing it - and effectiveness of management controls.

Typical topics might be :

- performance of welding
- control of wiring
- execution of testing
- calibrations
- housekeeping and cleanliness

Additionally, there should be periodic independent audits by an organization external to Construction, such as for example a Corporate Quality organization. These audits should address the performance with respect to programmatic procedures, and especially assess the functioning of management processes.

The Quality group at the site should continuously evaluate performance with respect to the requirements of the Quality program.

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