Engineering standards and EQC—why bother?

Avoid technical problems that can cause project cost increases or schedule delays

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Many "industry standards" (e.g., the ASME Boiler and Pressure Vessel Code)[1] provide design requirements for mechanical equipment used in the hydrocarbon processing industry (HPI). So, why do owner companies need their own engineering standards to supplement industry standards? The major engineering and construction contractors, and equipment manufacturers have been building process plants and mechanical equipment for years. They have a wealth of experience. So, why should owner companies review their work?

The HPI is a highly competitive and cost conscious environment. Therefore, is it not good business for an owner company to minimize "special" engineering requirements, let engineering contractors and equipment manufacturers alone, and get on with their work with minimal owner-company involvement?

In this author's opinion, owner-company engineering standards and a systematic procedure for engineering quality control (EQC) on capital projects were always necessary ingredients to achieve reliable long-term process plant operation. They are more necessary today because of the changes that industry has undergone in recent years and continues to undergo. The business environment is extremely cost-competitive. Employing this approach will increase the owner company's "up front" engineering costs. However, if properly implemented, the standards should save much more than they cost over the plant's life. They will minimize technical difficulties and delays during project execution, and achieve more reliable long-term plant operation.

A methodology for undertaking EQC on capital projects is described. The examples used in this article relate to fixed mechanical equipment (e.g., pressure vessels) and piping systems. These are items that the author deals with daily. However, the basic concepts discussed generally apply to all process plant equipment (e.g., machinery, process heaters, instrumentation, electrical systems, etc.).

WHY OWNER-COMPANY ENGINEERING STANDARDS?

The best engineers in the business write industry standards. So, why are these standards not good enough to use without supplementing them with additional owner company requirements? There are several reasons.

- Industry standards are "consensus" documents (i.e., requirements that all involved parties can agree as a base case). Individual owner companies may have special requirements that they wish to apply to particular situations. For example, they may have had poor service experience with particular design details. They may also wish to be more conservative to achieve more reliable long-term operation. They may also be willing to make a higher initial capital investment to achieve a smoother new unit startup and a lower total life-cycle cost.
- Industry standards generally have broad applicability and must be tailored to suit specific applications. For example, the ASME Code Section VIII, Division 1, applies to all pressure vessels—from small air or gas cylinders that are used at ambient temperature to major refinery reactors that operate at elevated temperatures and pressures. Applying reactor design requirements to ambient temperature air cylinders is excessive. Design details that are acceptable for the air cylinder are not necessarily acceptable for a process plant reactor.
- Particular service applications in process plants may require special material or design considerations that the industry standard does not address. For example, the ASME Code Section VIII does not address stress-relief requirements that may be necessary due to process considerations (e.g., caustic or wet H_2S services).
- Particular plant site locations may have extreme climatic conditions (e.g., very high-or low-temperature extremes, high winds, etc.) that should be addressed in the engineering design in more detail than in the industry standard.
- Each owner company (and often individual plant sites of the same owner company) has its own particular philosophy of design and operation. They have concluded—based on experience—that their way of doing things is best for them. This individual, corporate phi-

losophy cannot be reflected in a consensus industry standard. For example, a company may impose detailed, piping system design and installation requirements in its standards because of poor experience with pump or compressor piping systems that caused significant startup delays.

• There is often more than one technically acceptable solution to particular engineering design situations. For example, it may be equally acceptable to use either a sheet-type or a spiral-wound gasket for a specific plant application. However, the owner may decide to standardize on using spiral-wound gaskets to eliminate the possibility that a sheet gasket could be used where it would not provide reliable service. Such standardization also reduces the variety of gaskets that must be ordered and stored.

For these reasons and others, using only industry standards may result in unacceptable operating experiences.

Adding owner-company engineering standards to applicable industry standards will result in additional initial-capital cost. However, several things can be done to minimize this increased cost.

• Ensure the additional requirement provides a clear benefit such as improved long-term reliability, maintainability, operability or safety. Additional engineering requirements may also be needed to address environmental considerations. These benefits provide cost "credits" that offset initial increased capital cost, although in many cases, it is difficult to quantify these credits.

• Organize additional requirements logically by topic and ensure that they are clear. For example, each owner standard should contain the following:

► A clear title

► Scope

► Exceptions (if any) where the standard would not apply

► Defined terminology

► Reference to additional relevant documents (e.g., industry standards)

► Clear requirement descriptions

► Standards for measuring quality

► Required documentation.[2]

• Give prime contractors and equipment suppliers all owner-company requirements at the beginning of the job (i.e., at the bidding stage) and ensure that they understand them. This minimizes any cost increases due to owner-company requirements because there is still a competitive bidding situation. Avoid imposing new requirements after contract award. After contract award, the owner has less leverage for price negotiation. If requirements are specified late, some contractor or supplier work might have to be redone.

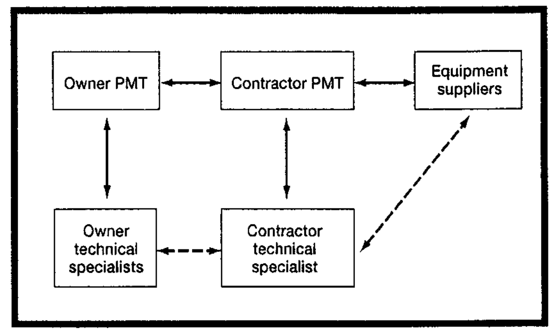

Fig. 1. Lines of communication on a capital project.

EQC ON CAPITAL PROJECTS

Quality control is normally related to the physical inspection process. Is the correct material being used? Are component dimensions and thickness correct? EQC is what should occur well before this physical inspection.

Depending on the particular owner company and the contractor involved, sometimes the owner is over-participating and can actually be a contributing cause of problems on major capital projects.[3] In these cases, the owner can inhibit the contractor from achieving a high degree of engineering quality. For example:

• The owner's engineering standards may be outdated or unclear.

• The owner's engineering and project management staff may be uncomfortable with "trying something new" that could save time and money, and perhaps be technically superior, even when the contractor has proven experience with its use.

• The owner's requirements for the contractor's manning of a project may force the contractor into an inefficient mode of operation that would be more error-prone.

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Items to be reviewed	Contractor's studies and evaluations	Contractor's design specifications	Contractor's equipment specifications	Contractors bid tabulation and evaluation	Purchase order[1]	Manufacturer's drawings and calculations[2]	Contractor's design drawings and calculations	Notes
Pressure vessels								
Kickoff meeting w/contractor								Discuss job requirements and standards
General specification		X						
"Special" vessels (e.g., heavy wall reactors, long delivery time items, etc.)	X	X	X	X	X	X		
Up to ~20% of other vessels, to include minimum of one from each vendor. Number and type based on pressure, temperature, unusual requirements, etc. Percentage reduced for larger projects.					X	X	X	
Heat exchangers								
Kickoff meeting w/contractor								Discuss job requirements and standards
General specification		X						
Same as for pressure vessels for each exchanger type					X	X	X	
Storage tanks								
Kickoff meeting w/contractor		X						Discuss job requirements and standards
General specification Up to ~10% of tankage with a minimum of one from each vendor. Selection based on size and service conditions with the larger size and special service tanks being looked at first.						X	X	
Piping								
Kickoff meeting w/contractor								Discuss job requirements and standards
General material specification		X						
General standards for supports, guides, and anchors		X						
Expansion joints						X		Eliminate wherever possible
Flange boltup philosophy/procedures		X						Agree on basis for when "special" procedures must be followed
Piping analysis program verification		X					X	Verification required if not familiar with it
Review designs and calculations for selected systems. For example:							X	
--~50% of all compressor systems								Include check of nozzle loads
--~20% of all pump and steam turbine systems, including all those NPS 6 and above with design temperatures over 400°F								Include check of nozzle loads
--~50% of all process heater inlet, outlet, and decoking lines								

Figure continued

--20% of all air-cooled exchanger systems								Include check of nozzle loads
-Flare header systems								
-Refractory-lined systems								
-Systems NPS 36 and above								
--10% sample of other systems								

Legend
X = Review required
C = Review completed
PC = Review partially completed

Notes
(1) Technical portion
(2) With contractor's comments shown

Fig. 2. Sample EQC checklist for fixed equipment mechanical engineering.

• Late design changes from the owner can disrupt project schedules and lead to technical errors, as everyone rushes to maintain project schedule.

• The owner may become too involved with supervising the contractor and impose unnecessary requirements.

Although the owner is hardly blameless in many cases, the following are several questions to consider.

• Has your company ever had to solve basic mechanical equipment design problems in the field during a presumed "turnkey" installation? For example, has piping system installation caused compressor alignment problems?

• Have you received systems that were adequate for normal design conditions, but were not designed considering abnormal or upset conditions? For example, have the spring supports in a reactor piping system been designed for normal design conditions, but do not provide adequate travel for a high-temperature regeneration case?

• Are all company standards and preferences adhered to in new equipment designs? For example, has it been found out later that a contractor's piping designers never saw the engineering standards until after the job was bid and the contract awarded?

• Have there been unacceptably high levels of new equipment startup problems or low-unit service factors? For example, have there been field piping alignment problems at rotating equipment?

• Have design errors been made by equipment suppliers that were not identified by the contractor's technical personnel? For example, were specified alternative-operating conditions ignored by a pressure vessel manufacturer? Were incorrect materials used?

If there are more yes answers to these questions than no, then it is time to review how EQC is handled on capital projects.

In an ideal world, an owner company should be able to give an engineering contractor or equipment manufacturer a technical specification and expect everything to be designed correctly, installed, started up and operated smoothly, with minimal owner-company technical intervention. However, this is not an ideal world. Sometimes, corners are cut that should not be. Mistakes are made. Misunderstandings occur. Inexperienced personnel sometimes have inadequate supervision.

These factors are always present and should be guarded against. However, the potential for these situations to occur has increased in the era of corporate downsizing/restructuring, which all portions of the HPI have experienced over the last several years. For example, "The U.S. petroleum industry faces a looming shortage of qualified personnel. Job insecurity of the past 15 years has made it a career to avoid. There are no twenty-somethings to pass the torch."[4] Owner companies, contractors and equipment manufacturers do not have the same depth and average-experience level that they once had. They still must produce cost-competitive results in short-time frames. When problems are uncovered, the end result is loss of time and money.

WHAT IS EQC?

Engineering quality control (EQC) is a periodic sampling of a contractor's or equipment manufacturer's performance during the project. EQC is done by an owner company's technical specialists in support of their project management team (PMT). Typical, technical specialty areas included in an EQC program are:

• Pressure vessels
• Piping systems
• Heat exchangers
• Storage tanks
• Machinery
• Process heaters and boilers
• Instrumentation
• Electrical
• Safety.

EQC begins after contract award and continues throughout the project. This EQC by the owner does not duplicate the contractor's or equipment manufacturer's engineering work and check everything. That is both unrealistic and unnecessary.

The objective of EQC is to check enough of the engineering, using a sampling procedure to make a judgment regarding overall quality. In other words, are contractor and equipment suppliers adhering to technical job requirements? The sampling done is increased or decreased based on results that are seen or other action taken. The ideal situation is to confirm that the contractor's personnel are doing exactly what is expected of them. There is minimal need for further owner technical oversight. Following are two examples to illustrate.

• After spot checking a sampling of the vessels on a major project, it was concluded that the contractor's lead pressure vessel engineer was doing an excellent job to ensure that design requirements were being met by vessel suppliers. Therefore, checking vessel drawings and calculations were ceased. The PMT was advised that they could rely on the contractor in this area. The EQC only needed to become involved if problems arose.

• While checking piping design calculations and details on the same project, confidence was lost in the work of one piping designer, based on a large number of errors. It was, therefore, recommended that the contractor completely review all work done by that designer. They did this, found additional errors, and redid many system designs. EQC did not do the contractor's work in this case. Instead, it was demonstrated—based on the technical facts, not personalities—that the contractor had a serious problem to resolve. This problem was uncovered by focused spot checks.

EQC will, obviously, have a cost associated with it (i.e., the owner company's internal accounting for the technical specialist's time and expenses). However, when done systematically and in a timely manner, this cost is small as compared to that associated with project delays, field problems and unit downtimes that can occur when errors are made during engineering. EQC must be started early in the project's design cycle to achieve maximum cost benefits.

EQC IMPLEMENTATION

The next step is to provide suggestions on how to implement EQC on a major capital project. While the overall approach is applicable to all technical areas, the particular examples used come from technical specialty, fixed equipment mechanical engineering (i.e., pressure vessels, heat exchangers, storage tanks and piping systems).

LINES OF COMMUNICATION AND EQC

Typically, an owner company will assign a project management team (PMT) to a major capital project. Depending on the project's size, this PMT may consist of only a project manager. On large projects, the PMT may be quite large and include several project, cost and schedule engineers, and perhaps permanently assigned technical specialists. The primary work of the PMT is to perform a project management function (i.e., cost control, execution planning, scheduling, etc.). Generally, they will be knowledgeable in technical specialty areas. However, the PMT will, typically, not have the depth and experience to adequately assess technical capabilities and performance of all contractor's and equipment manufacturer's engineering specialty areas. These technical specialty areas include the following:

- Pressure vessels
- Piping systems
- Heat exchangers
- Storage tanks
- Machinery
- Process heaters and boilers
- Instrumentation and controls
- Electrical systems.

The owner company can provide the necessary technical assessment capability to the PMT by assigning appropriate technical specialists to it—either part-time or full-time. Usually, it is not necessary (and certainly not cost-effective) for the technical specialists to be assigned full-time to the PMT. These owner-company technical specialists act as consultants to the PMT in their specialty areas. They provide recommendations to the PMT based on their assessments of contractor and equipment supplier performance.

It is essential that communication lines between the PMT, contractor, equipment suppliers and owner company technical specialists be clearly established and understood by all to avoid confusion. The owner-company technical specialists could certainly get information from their contractor counterparts, but should not give official directions. Official direction must only come from the PMT to the contractor. Similarly, direct communication with the equipment suppliers should only be by the contractor PMT. The contractor has engaged them and is the only one who should give them instructions. With this approach, the lines of responsibility are kept distinct and misunderstandings are minimized. Fig. 1 illustrates this line of communication.

PROCEDURES FOR EFFECTIVE EQC

Effective EQC does not duplicate or usurp contractor work. In fact, these are "traps" that must be avoided. For example, when a problem arises on a project, the PMT and technical specialist should first ask the contractor for assessment and how he proposes to resolve it and why. The contractor is being paid for this. The PMT can then choose an appropriate response (with support from the technical specialist, if needed). Of course, if the owner's PMT or technical specialist can easily resolve the problem, nothing is gained by waiting for the contractor to arrive at the answer. However, the contractor must not assume that the owner will always take the problem-solving lead.

Effective EQC uses a "spot check" of the contractor's work to develop an assessment of his overall performance. It also involves spot checking the work of major equipment suppliers to assess both their performance and that of the contractor in his checking of their work. The ideal situation is to be in a position to tell the owner's PMT that it is no longer necessary to check the contractor's work, everything that is expected of him is being done. In the author's experience, this does not happen often—but it did happen once.

The following provides overall guidelines for performing effective EQC ôn major capital projects.

• Review process design specification for the project to develop a good understanding of the equipment and design conditions. This aids in deciding which items to concentrate on for spot checks.

• Review owner-company engineering standards that apply to the project. Understand why specific requirements are there, which ones are especially important for the project, and which ones have less relevance.

• Based on this initial review, prepare a list of equipment and systems to include in spot checks (i.e., an EQC checklist). This checklist includes items that have the most severe design conditions, unusual design features, are especially critical to plant operation, or have been troublesome on prior projects or in operation on similar units.

For example, in the pressure vessel area, perhaps 10% to 20% of the total number of vessels might be in the list. At least one vessel from each supplier should also be included in the checklist to assess each supplier's performance.

Fig. 2 provides a sample EQC checklist for the mechanical engineering area (i.e., pressure vessels, heat exchangers, storage tanks and piping systems). The checklist for an actual project would have specific equipment item numbers listed.

• Provide the EQC checklist to the owner PMT, so that they know what items the technical specialist will initially concentrate on. Review the checklist with the PMT so that they understand what is being requested, why and overall extent of the review anticipated. Ideally, do not give this list to the contractor to avoid the temptation for him to give these items any "special" treatment. Such extra attention could adversely impact effectiveness of the spot-checking process.

Since the technical specialist is normally not a direct member of the PMT, typically the PMT's responsibility is to advise when particular checklist items are available for review. Depending on the type and quantity of material available for review, the specialist can either schedule a visit to the contractor's office or have the material sent to his "home office" location.

• Soon after contract award, the owner's technical specialists should have initial "kickoff meetings" with their contractor counterparts. To be most effective, hold the meetings after the contractor's personnel have become familiar with the project and the owner's engineering requirements, but before they have done significant engineering.

These meetings are important in achieving effective results and should include the following:

▶ Review specific engineering requirements (especially those that have been troublesome in the past).

▶ Provide any needed clarifications.

▶ Probe the contractor's engineers to ensure that they understand job requirements.

▶ Establish basic-design philosophies to be applied.

▶ Start developing a working relationship with technical specialists.

Although the owner's technical specialists are checking the contractor's work, there should not be an adversarial relationship. Teamwork is essential to complete a major capital project that is ontime, within budget and meets all specified technical requirements.

Like a project planning workshop, EQC kickoff meetings are an early time expenditure (and some money) at a period when those involved have little time available.[5] However, these meetings more than pay for themselves through enhanced team performance, better cooperation, less chance for misunderstandings and reduced likelihood that important technical requirements are overlooked.

• Review engineering specifications that the contractor has prepared for general equipment categories (e.g., pressure vessels, heat exchangers, pumps, compressors, etc.) to ensure that they contain relevant owner requirements. Also, review detailed technical specifications and manufacturer bid conditioning documentation for critical and/or long-delivery equipment items (e.g., heavy wall pressure vessels). This is to identify potential problems early. Participate in the bid conditioning and manufacturer selection process for these critical equipment items.

• During the job, review submitted manufacturer information after the contractor has done his review and has provided comments. For example, in the pressure vessel area, vendor drawings and calculations should be reviewed after the contractor has marked them up with comments. The contractor's work is being checked. It is not being done for him.

• Adjust the number of items on the checklist based on what has been found in the review (e.g., decrease the number or extent of review if confidence in the contractor's work has been developed).

• Remember, that even for the items being reviewed, the contractor's work has not been redone. Concentrate on what is felt to be the most critical details, features and calculations in each situation. For example, when pressure vessel information is reviewed, concentration should be focused on the ASME Code calculations, important design details, adherence to owner requirements and internal consistency—not on items such as nozzle orientations, platforms, ladders, etc.

• As the project and checking progress, update the checklist showing what reviews are complete and communicate this to the owner PMT. In this way, the PMT always knows the review status.

• Provide the owner PMT with written memos documenting the results of periodic reviews, and sequentially number memos for convenient, future reference. These memos should come in two parts.

▶ The first part is a short transmittal memo or letter that highlights what was reviewed and when—any findings that could have a significant project impact and comment on the contractor personnel's performance. The information contained here— supplemented by the second part discussed below—concisely provides the owner PMT a sense of how things are going. They should take some action.

▶ The second part is attached to the first. It should deal strictly with technical comments resulting from reviews, and not contain any confidential information or comments about the contractor's personnel or performance. If constructed in this way, the owner PMT can give the second part directly to the contractor for review, comment and action.

• The contractor should provide a timely, written response to each EQC memo to the owner PMT. The PMT should give the contractor's response to the technical specialist for review. Any areas of disagreement should be identified and resolved.

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