VENTURE

INTRODUCTION

This brief applies to engineering support for engineering-procurement-construction projects, also known as design-bid-build projects, with construction management by others. This brief is intended to be used as an aid to determining the level of engineering support required during construction, from the office and in the field. For purposes of this brief, when the term “engineer” is used, it applies to the engineering firm or its representatives, that were responsible for the design of the project.

Engineering support is typically required for any industrial construction project. The roles of the construction manager and the owner are usually well understood. The role of the engineer during construction needs to complement the roles of the construction manager and the owner. This is not clear cut as the owner and construction manager often have capabilities that overlap with those of the engineer. What divisions of responsibilities represent the best use of resources and best promotes the timely and successful completion of the project?

Further, when owners are looking for ways to control construction costs, one option considered is to reduce costs by restricting or eliminating on-site representation from engineering. There can be serious consequences – especially if on-site engineering is not available when needed.

How much engineering support is reasonable during construction, and at what point does the owner’s risk increase because of a reduced on-site engineering presence? With so many changes in engineering, construction, and technology, do the criteria on which a decision was based five or ten years ago apply today?

ENGINEERING ROLES DURING CONSTRUCTION

Typical construction related engineering tasks are shown in Table 1. General benefits are summarized in the text box (page 3).

The level of engineering effort necessary depends on how the design package was prepared (see text box pg 4), how the project is to be managed, the capabilities of the team, certifications, complexity of the project, available budget, and appetite for risk for all parties concerned. The following develops these points further.

Essential elements for which the engineer is responsible, include:

- Review of submittals and shop drawings
- Review and respond to RFIs.

- Review and respond to change requests
- Certifications required, such as for lending institutions and funding agencies

Table 1: Typical Engineering Responsibilities During Construction*

Activity	**Description of Engineering Scope**	**Office**	**Field**
Pre-Qualification	Equipment suppliers, contractors and subcontractors	X	
Procurement	long lead items, free issue items.	X	
Bid tabulations	Comparison of products against the specification, and recommending the "best value" option	X	
Review contractor submittals	What the contractor represents as conforming to the design documents. Typically stamped as "Approved", "Approved with Modifications", "Revise and Resubmit", or "Rejected" Applies to materials to be purchased. Can apply to O&Ms, as-builts, start-up reports and warrantees as well	X	
Respond to RFI's	Typically means responding to requests for clarifications and substitutions. May include: requests for information that is already provided. Substitutions require analysis for materials compatibility, evaluation of height and access and serviceability. In some cases, a design bulletin may be issued, with sketches or instructions.	X	
Construction Support	Typically each discipline lead is on site for a few days to answer questions, assist in interpretation of the drawings, etc.		X
Field Work Orders	A Field Work Order (FWO) is issued when an item of work needs to be done, but whether it is in scope or not is in dispute, or if there is not time to go through a formal change order process. Occasionally, engineering inputs are required for Field Work Orders.		
Schedule Assistance	During site visits, the engineer can assist the scheduler by reviewing progress against the previous schedule		X
Factory Acceptance Test	Off-site testing of key packages or systems. Typically not done for pumps, conveyors, etc.		SHOP
Construction	The meaning intended here is not full time inspection		X

Monitoring	which is done by the Construction Manager's team. This is periodic review performed by the engineer. Typically occurs before progress payments, to address a recurring problem, or for site visits by the regulators or the owner.		
Non-Conformance Reports (NCRs)	Engineers expertise may be called upon for special problems that are not clear to the owner and the CM.		X
Change order request	Engineer will be asked for an opinion on some change order requests; typically, a request for more time or money from the contractor. The engineer can estimate the value and validity of the change order, or the construction manager can do this task.	X	
Cold commissioning	Testing of equipment and systems before making product. This role is shared with the contractor. Typically planned by the engineer, owner, or third party specialist. Hands-on activity is by the contractor until facility acceptance by the owner.		X
Hot commissioning	Testing of equipment and systems while making product. Typically planned by the owner, and shared with the operator after facility acceptance.		X
Substantial and Final Completion	Punch listing, verification of substantial and final completion		X
Closeout	Listing and tracking of information needed – executed punch lists, warrantees properly dated, as-builts, O&Ms, releases, keys, and settlements.	X	
Certification	Determination of milestones such as substantial completion, and the collateral purpose of substantiating that the facility is sufficiently compliant with the contract documents Providing a certification for a lender, funding agency, or a regulatory agency, or LEED certification		X

*Design-Bid-Build, construction management by owner or third party specialist

It is the owner's best interests to be sure that the engineer does not have rigid budget constraints in the above areas. If the contractor's submittals are poor quality, extra engineering is required for the first, second, and sometimes third review. This effort is necessary to compensate for deficiencies in the submittals and to be sure that the owner gets the right product. Restricting the engineer's ability to adequately review these submittals is the equivalent of a self-inflicted wound.

Other areas for engineering participation include:

Prequalification & Procurement

Prior to construction, the owner may not have resources for bidding and procurement. Accordingly, the engineer may be asked to assemble bid packages, attend a pre-bid meeting, respond to bidder questions, prepare bid tabulations, participate in negotiations/clarifications with the selected bidder, and make award recommendations. Owners need to communicate preferred suppliers, discounts negotiated, and which suppliers are "in the penalty box."

Submittals and Shop Drawings

Submittals and shop drawings need to verified as conforming to design requirements, or to be acceptable substitutions. Further, submittals don't necessarily match what is shipped. Therefore, field verification of nameplate data is important.

Requests for Information

The engineer does not need to be involved in all RFI's, but schedule slip will occur if RFI's are being used as a delaying tactic, or if the contractor is not inclined to properly and carefully review the drawings and specifications. The engineer is best qualified to point out where the subject of the RFI is addressed in the design documents. This is where on-site engineering support is beneficial – legitimate RFIs may need photographs and field sketches to define and facilitate prompt resolution of the problem.

Field Work Orders

The engineer does not need to be involved in all FWO's, but occasionally, engineering inputs are required for Field Work Orders. A Field Work Order (FWO) is issued when an item of work needs to be done, but whether it is in scope or not is in dispute, or if there is not time to go through a formal change order process. Typical examples that may require engineering input – repairs of broken underground

General Benefits of Engineering Support

Checks and Balances:
An on-site engineer and the construction contractor or subcontractors will challenge each other, promoting honesty and keeping everybody playing their "A" game. Properly managed, this tension is healthy for the owner, or the GC in the case of a design-build contract.

Design Familiarity
There will typically be areas in which the contractor or the inspector will not be familiar. So some level of field engineering support is required. An early visit opens communication. A later visit helps the owner or GC get a reality check on the claims of the sub contractors and inspectors/field superintendents.

Contract Familiarity
An on-site presence that is familiar with the specifications is a good idea. It is common for contractors not to read Section 0700 (General Conditions) or Division 1 (General Requirements), and not to pay attention to details such as O&Ms, spare parts and attic stock. Further, on-site engineers are a useful resource when checking an installation against a new code with which the team is not familiar.

lines, and remedying of situations that pose a risk to property, health, of the environment.

Change Orders

It is easier to properly evaluate multiple change order requests with an engineer on-site. Engineers can do a good job of screening the more challenging change order requests.

Legitimate examples of change requests include encountering interferences such as bedrock, hazardous materials, or a conflict in routing of say, a sanitary sewer drain which runs through a structural element or a duct. Requests for items in-scope and alleged to be out-of-scope will likely be clearer to the engineer, such as a valve that does not show on the plans but it shows on the PIDs, or the sanitary sewer line in the example above was routed correctly on the drawings, but the contractor found a short-cut before he realized that the duct work would be in the way.

The engineer does not need to be involved in all change requests, but if the contractor submits a cost saving proposal that requires a significant review effort, it is unlikely to get serious consideration, if the engineer has no budget.

Non-Conformance Reports

Generally speaking, Non-Conformance Reports can be addressed by the on-site team. There are occasions where an engineering eye is needed – for example where two similar pieces of equipment have been transposed. This is not hypothetical – even with a skilled construction team, rooftop air handlers have been transposed, thermal valves have been transposed and the list goes on. Other problem areas – the wrong valve is used for an application, a drilled ball valve is installed backwards, etc. These are easy mistakes to miss and there is no guarantee that the engineer will see them all, but the odds of identification and correction are better with an on-site engineer.

TOOLS FACILITATE BETTER COORDINATION OF DELIVERABLES

AutoDesk and others have provided tools to relieve some of the common drawing coordination problems. Use of X reference files assures that drawing backgrounds match between disciplines, and use of 3 D models with dynamic updating features resolves clashes. Dynamic updating features highlight problem areas; i.e., clashes such as columns through equipment skids, a drain through ductwork, or a diffuser through a light fixture.

Intelligent design tools create associations between section lines on plans and sections, correct drawing numbers on match-lines, proper scaling, and consistency between drawings, valve lists, and instrument lists. The significance of this is that what is purchased matches what is needed for construction. Otherwise, there is likely to be disconnects between what is ordered and what is needed.

Decreasing workstation costs have made it feasible to put a work station with a 3D model in the field, update the model electronically, and manipulate it to show a contractor any feature of interest – a benefit where intricate geometry or tight clearances are involved.

Owners and GC's increasing appreciation of these tools, and their experience that these tools are not detrimental to the budget, is leading to insistence on 3D products from engineers.

Factory Acceptance Tests

Factory Acceptance Tests (FATs) require engineering participation. The engineer will have a clear idea of the functionalities that need to be witnessed and confirmed. Examples of equipment and systems for which FATs are required include: Control Panels, Smart MCCs, Vendor packaged equipment, Prefabricated electrical and control buildings, and Analyzer Buildings (CEMS).

Commissioning

For any project that is complex, involves technology that is early in commercialization, or that integrates multiple technologies, it is better to have the engineer on-site to participate in commissioning. If the engineer did the programming, it is essential for the engineer to be on-site prior to and during commissioning. That engineer needs to be on site in advance of commissioning activity to verify completion and prepare a plan for establishing that functionalities and performance meet the project requirements. In such a circumstance, consider having an engineer on-site for the duration of construction, to verify equipment received and nameplates against submittals, respond to, or expedite RFIs, etc. A third party commissioning specialist may also be used, if the engineer lacks resources to support the commissioning effort. See Venture Technical Brief: Commissioning of Industrial Facilities on our website.

Completion

There are many ramifications to the achievement of mechanical, substantial, or final completion. In recent years there has been a trend away from the mechanical completion definition, towards the substantial completion definition. Many contractual definitions of substantial completion derive from AIA's definition, which is not directly applicable to industrial projects and requires interpretation. In such cases, the engineer is best qualified to evaluate if the project sufficiently conforms to the design intent. See Box at the end of this document.

Closeout

Most elements of construction closeout involve a good document control clerk, and someone who has a reasonable understanding of the project and an aptitude for follow through. Turnover packages typically include manuals, test reports (point-to-point verifications, hydro tests, etc.), warrantees, keys, as-built or record drawings, commissioning documents, permits, executed punch lists, waiver of liens, etc. However, if the turnover packages are complex, or if there are extended or special warrantee requirements, features such as spare parts lists that may not be in the operation and maintenance manuals, then an engineer's participation may be beneficial.

As-Built or Record Drawings

If as-builts are important, they need to be checked. If the as-builts are received with the comment "We built it the way you drew it", then they particularly need to be checked.

Inspector(s) do a good job to the extent that they appreciate the process. Beyond that point, the engineer is best qualified to review as-builts. Consider using both.

Certification/Completion

If a certification is required, such as verifying that the project was constructed in accordance with the design documents; it is difficult to prepare if the engineer has not participated in the construction process.

The engineer needs the opportunity to see that the work is being constructed in conformance to the requirements, if he/she is to be asked to participate in, such as:

- Determination of milestones such as substantial completion, and the collateral purpose of substantiating that the facility is sufficiently compliant with the contract documents
- Providing a certification for a lender or funding agency
- Providing a certification for a regulatory agency
- LEED certification

PROJECT SUCCESS

To assess the benefit of engineering support for construction, the engineer's roles need to be weighed against criteria for project success. A succinct definition of project success will not do the topic justice, but for purposes of this discussion, consider the following:

The classical parameters of success are: cost, schedule, performance, and safety. These can reasonably be expanded and clarified to include: amicable and timely closeout, all contractor's successful, prompt payments, no litigation or liens, and an owner whose reasonable expectations were realized. However, these parameters are too general to assign to one party or another.

A project's potential for success is improved by: planning, adequate funding, careful document management, forecasting and risk analysis, cost and schedule integration, and a claims mitigation strategy. A construction claims mitigation strategy has many elements, but some of the more important ones include: contract type fits the project, well defined scope,

DESIGN/BUILD PROJECTS

This model is sometimes favored by owners because it creates a single point of responsibility, offers schedule benefits, reduces traditional claims, avoids the refereeing between contractor and engineer and accordingly reduces a burden on the owner's limited resources. The project team benefits from having more latitude once the project is awarded (theoretically) and the engineer and contractor are forced into collaboration, not conflict. But nonetheless, design-builds experience litigation.

One of the more successful models for design-build projects is the contractor led team. This works, with caveats. Given that design-build projects are usually associated with an aggressive schedule, design may be rushed, and decisions will be made on the fly in the field. If the contractor has excess hubris, and minimizes engineering participation on site to cut costs, problems may not get attention early enough.

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realistic schedule, no disproportionate penalties such as punitive liquidated damages, selection of qualified suppliers and contractors, realistic expectations, cooperation, timely, clear and effective communication, knowledge of the contract and each parties role, and effective use of tools for logging and sorting of project data (Non-Conformance Reports (NCRs), change requests, Requests for Information (RFIs), design bulletins, correspondence, punch lists, field sketches, etc). Factors that contribute to success are many, but the most important ones are: good communication skills among all project stakeholders, mutual trust, ownership of the project at all levels, the right skills at all levels, and responsiveness at all levels.

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Second, if the owner is knowledgeable and aggressive, the latitude afforded by the contract model can be lost in second guessing, warnings about the implied warrantee of fitness for use, and NCRs from the owner. The engineer's credentials may be valuable for the General Contractor's push-back in such a case. The General Contractor needs to decide where an engineering presence adds the most value, and then staff accordingly.

GCs should track design support and construction services separately, to be sure that a design overrun does not get concealed by shorting the construction services budget. Less engineering support is possible for subs that are not high maintenance. High maintenance subs will need a lot of hand-holding and the owner or GC will not have time.

Contribution of the Engineer to Construction Success

The engineer's influence clearly dominates prior to construction: well defined scope, realistic schedule (Level 0 or level 1), proper funding (or at least a properly prepared estimate on which to base funding), and selection of qualified suppliers, in particular for specialty and long lead items.

Concerning a well defined scope, remember that drawings and specifications are more likely to be generic, rushed, or inaccurate if a project has been fast-tracked, such as in a design/build project, or if an award is purely price driven, without regard to qualifications. Either circumstance points to more engineering support during construction. For more discussion of design-build projects, see box right.

Arguments Against the Use of Engineers During Construction

When considering reducing on site engineering the arguments often include:

1) The contractor and current on-site staff can figure out what needs to be done better than the engineer, so the drawings need to minimally meet requirements, or
2) For small projects, the owner can self manage, and minimize the engineer's contribution during construction, or
3) Engineers are well compensated, their drawings should be right, and if not, the owner has recourse to recover costs from engineering mistakes

With regard to the first and second bullets, this is a judgment call.

Concerning the third bullet, remember that drawings and specifications are more likely to be generic, rushed, or inaccurate if a project has been fast-tracked, such as in a design/build project, or if an award is purely price driven, without regard to qualifications. Sometimes schedule requires the design to be issued before it is complete, or before vendor information is available. The impact on drawings and specifications needs to be understood going in, and managed accordingly. Either circumstance points to more engineering support during construction.

There is an argument sometimes voiced that if an engineer's work product is not entirely clear, the engineer should fix the problem at his/her cost. There are many stories of contractor's legitimately frustrated with careless and incomplete engineering work products. But there are also many stories of contractor's who do not take time to review drawings and specifications, and complain that work elements are out of scope or not addressed in the design package, until the engineer opens the roll of drawings or the specification book and points out the requirement. Unmanaged, this practice continues until the engineer runs out of budget, at which point the contractor complains to the owner that the engineer is unresponsive and won't clean up the mess they made.

Typically, the contract with the engineer limits the engineer's liability to the value of the contract or a stipulated value of errors and omissions insurance required. In debatable areas the engineers will make whatever changes are needed on their own time or a minimal cost to avoid argument.

Engineers should be responsible for their budgets and their solutions. However, there is no contractual obligation for infallibility. From a professional liability stand point, all that is expected or required is to render design services with the ordinary degree of skill and care that would be used by other reasonably competent practitioners of the same discipline under similar circumstances and conditions. In fact, professional liability insurance (errors and omissions) typically will not cover any standard beyond the accepted standard of care, as this enters the realm of warrantees, and more liabilities and associated insurances. Therefore, if the client expects a standard greater than the accepted standard of care, the limit of coverage may just be the value of the assets of the engineering company, which will likely be less than the errors and omissions insurance.

There are many issues for discussion here that go well beyond how much time to budget for engineering during construction. Even when a product has been engineered with the best of ability, experience and intention, there will be questions. The implication for budgeting is that there will be questions and it is prudent to budget for the engineer to respond to those questions.

DISCUSSION AND CONCLUSIONS

The most basic and essential engineering scope consists of:

- Review of submittals and shop drawings.
- Review and respond to RFIs.
- Review and respond to change requests
- Certifications, such as for lending institutions

The next level of participation consists of the above, plus site visits, punchlisting and commissioning, and some or all of the remaining services listed in Table 1. Beyond that, the engineer becomes a full-time construction manager. Budgets for each phase will vary – say 2% of Total Installed Cost (TIC) for essential services, 3% of TIC for "standard" services, and 6% of TIC for full construction management, with the percentages increasing as projects drop below $10,000,000 and for international or complicated projects.

Consider a full-time engineering presence on-site:

- For any project over $20,000,000 TIC
- For projects where owner/construction management involvement is minimal, and for projects with multiple contractors
- For projects that are schedule driven
- For any project that is complex, involves technology that is early in commercialization, or that integrates multiple technologies regardless of how responsibility is assigned
- If finding a qualified contractor is difficult due to market conditions or the location
- If there are many unknowns, such as an older site, where a soft electrical system, environmental legacies, and undocumented underground lines can require design modifications and multiply delays

The degree of engineering support required depends on how the project is to be managed, the capabilities of the team, certifications, complexity of the project, available budget, and appetite for risk for all parties concerned.

An awareness of the benefits of technology is helpful in deciding how to structure the project. This is a big subject, but examples include:

- Project collaboration tools (project websites) have the advantages of an instant courier service with built-in logic to create and track documents, allow red-lining, and expedite communication.
- Camera phones, which allow an inspector to photograph and transmit problem areas to the engineer, without visiting the office trailer or using a courier service.
- Three dimensional models on work stations operated by individuals with rudimentary skills can be hugely informative. It is worth revisiting project staffing in the context of available technology and taking advantage of the possibilities.

Finally, discuss your thinking with the engineer. The engineer should point out where their participation is critical, and ultimately assist the customer in allocating resources wisely.

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Construction Completion

There are legal ramifications to the definition of construction completion, and construction lawyers have made careers based on the nuances of these definitions. “Substantial Completion” is a term that appears with increasing frequency in contract documents, as use of the term “Mechanical Completion” declines. Owners and contractors have questions about the difference between substantial completion and mechanical completion. Is it a distinction without a difference? Here are two simplified definitions:

Mechanical Completion:
All components and systems have been installed, flushed, cleaned, tested, and have been verified as operable safely and continuously without voiding subcontractor warranties. Work still in progress may include: painting, non-critical insulation, final grading and other work not affecting operability, safety and mechanical and electrical integrity. A punch list is generated at this time.

Substantial Completion:
The point at which an area or system is sufficiently complete in accordance with the contract documents so that the owner can occupy or utilize the work for its intended use (adapted from AIA). A punch list is generated at this time.

While the two terms may appear to achieve the same outcome, the first looks back to the contract documents, while the second looks forward to fitness for the purpose. There is an implicit association between substantial completion and beneficial use, which in turn points to:

- Occupancy,
- Transfer of responsibility for the facilities (ownership) from the contractor to the owner,
- The owner assuming maintenance responsibilities and utility costs, and
- Start of the contractor’s warranty period.

Either definition can address areas or systems, as opposed to the total project. In other words, the entire project does not have to be finished for, say, the water treatment plant to be finished. Both definitions are expanded in contract documents to address specific area by area criteria, receiving O&Ms, training, etc.

The substantial completion concept relates better to commissioning, which relates to readiness for use. Both definitions link to inspection. Here are some additional terms that bear on substantial completion.

Beneficial Use:
The point at which the Operator can safely occupy the facility, and use it for production. Or the point at which the Operator can start generating revenue from the facility.

Occupancy:
The point at which a local Building Commissioner or equivalent authority (as opposed to project commissioners) is satisfied that the facility is "suitable to occupy" from a health and safety point of view, has approved the structure as being suitable for occupation, and has issued an occupancy permit. It does not mean that all the building work is complete, and it is not a certificate of compliance with legislation or the contract.

Finally, at what point is the job “finished”? That depends on your vantage point, but here are two more terms that need to be understood when discussing completion.

Final Completion:
Work has been inspected and verified as complete in accordance with the Contract. Punchlist items have been completed. Extra materials and spare parts have been received. Contractor has removed toolboxes, port-a-potties, etc. from the facility.
(Note: Some punch lists items may be closed by handling them as warranty items.)

Closeout:
Elements include:

- Contractor is demobilized.
- Turnover documents have been received; i.e., as-built or record drawings have been received, checked and determined to be accurate. Warranties and guarantees are in hand. Maintenance agreements, special inspection reports, commissioning documents are all in hand. All permits in hand.
- Releases from liabilities and liens received. Tax forms received.
- Final payments have been made.