Implementation of Quality Assurance Programs for the Exterior Building Envelope through the Design Process

ABSTRACT

The use of Quality Assurance Programs for the Exterior Building Envelope in the Design Process

Appropriate levels of Quality in the exterior building envelope can be accomplished only by the application of proper design, appropriate manufacture and fabrication of materials and systems, and correct application and installation techniques. The question we need to ask is very straight forward and to the point: What procedures and tools are available to control the required level of quality in the completed construction? In other words, how do we assure that the first three points mentioned above are attained - 1) proper design, 2) appropriate manufacture and fabrication, and 3) correct application and installation?

The primary method to attain effective quality management is implementation of a Quality Assurance Program. Through the studied, organized, and controlled use of a project specific Quality Assurance Program, appropriate levels of performance and quality are much more likely to be attained. The Quality Assurance process can be implemented for any portion of a project from design through construction and acceptance. However, the process is most effective when implemented as a continuum starting during the design process and running through the entire design, procurement, and construction program. This process has proven effective in the past and is capable of greatly impacting the level of quality attained. While certain aspects of any Quality Assurance Program will be consistent from project to project it is critical to understand that the program to be implemented for any building project should be designed and implemented specific to that building.

This paper addresses the means and methods a designer can employ for the phases of a construction process of either a traditional design/bid/build or a design-build delivery method. The paper will identify means and methods available to designers for project specific Quality Assurance Programs for the Exterior Building Enclosure for each project stage. Included in the discussion will be: recommendations for establishing appropriate levels of performance, procedures to be implemented during the technical design process, critical quality concerns during the procurement process, appropriate requirements of the submittal process, mock-up and testing procedures, inspection and observation during construction operations, the importance of schedule adherence, and final acceptance procedures.

Paul G. Johnson, FAIA, NCARB
Director, SmithGroupJJR Building Technology Studio
Detroit, Michigan
March, 2012

INTRODUCTION

Appropriate levels of quality and performance in the exterior building envelope can be accomplished only by the practice of proper design, appropriate manufacture and fabrication of materials and assemblies, and the use of correct application and installation techniques for materials and assemblies. As a building or building enclosure systems designer the question you need to ask yourself is very straight forward and to the point: What procedures and tools can I use and implement to attain the required level of quality and performance in the completed construction?

In other words, how do I assure that the first three tasks mentioned above are accomplished?

- **proper design**
- **appropriate manufacture and fabrication**
- **correct application and installation**

One tool available to help attain the desired level of quality and performance is the effective implementation of a project specific Quality Assurance Program (QAP) throughout the entire project; from concepts through to building occupancy. This program must not only be project specific, but must also include all parties to the design and construct process. This includes: the building owner, designer, construction team, and in some cases even those in charge of regulatory or code compliance. Through the studied, organized, and controlled use of a project specific Quality Assurance Program, appropriate levels of performance and quality are more likely to be attained. The QAP, (or process), can be implemented for any portion of a project from design through construction and acceptance. However, the process is most effective when implemented as a continuum starting in design and running through the procurement, construction, and acceptance portions of the project. This process is capable of greatly impacting the level of quality attained. While certain aspects of any QAP will be consistent from project to project, it is critical to understand that the program to be implemented for any building project should be designed specific to the building.

This paper identifies procedural tools available to designers for implementation of a project specific QAP for the exterior building enclosure. These tools are always available to the designer and it is their choice, hopefully guided by sound professional judgment, to determine when, how, and to what extent to implement them for any specific project.

This paper offers guidance regarding:

- Recommendations for establishing appropriate levels of performance and quality,
- Procedures to be implemented during the technical design process,
- Critical quality concerns during the procurement process,
- Appropriate requirements to address during the submittal process,
- Mock-up and testing for pre-construction, laboratory and stand alone on-site mock-ups and testing, as well as testing of constructed work on the building,
- Inspection and observation during construction operations,

- The importance of schedule adherence, and
- Final acceptance

The project phases may change by the overall project structure or procurement process; however, those identified are generally followed in most building projects in a manner similar to that presented here.

If the project delivery or procurement process differs, the QAP must change to suit procurement. It is critical that the QAP be matched to the project delivery and procurement approach.

What

Quality is defined by *the American Heritage Dictionary of the English Language (Fourth Edition)* as "Degree or grade of excellence", and "Essential character; nature". In this paper quality is used in both senses, and the measure of this quality is performance. The various performance measures (or metrics) are defined by the designer through the contract documents.

A warning: Too often there will be a great temptation to skip some if not many of the steps recommended. There may also be pressure to avoid the process in its entirety, for many reasons that may seem important at the time. However, the designer should always remember that there is only one opportunity to get a building right, and that is from the beginning! If you do not do your part correctly the probability of the building envelope being correctly accomplished is greatly diminished. Each step along the way is dependent upon the step before.

The first step in the process is for the designer to develop and identify a QAP designed specifically to the project. The designer has the opportunity to not only perform the design work properly, but to also set the basic rules to follow throughout the project to accomplish the building envelope correctly. Once problems occur, you are now in the repair or redesign mode, playing catch up to schedule, budget, and other related "business" pressures. The fact is you almost never win this battle. It is a losing proposition in most all cases, and the building envelope will turn out the way it turns out. Too often this is unsatisfactorily, and you can never change that after the building is constructed. A well prepared and executed QAP will help avoid this situation.

Who

The most common and consistent participant in most building projects, other than the building owner, is the designer. They are often involved in every step of the process from concepts (and sometimes even earlier) through final acceptance of the building by the owner. Some multi-facility building owners have their own QAPs in-place already, however these owners are the minority. In most cases, with regard to project familiarity and understanding the project requirements, the designer is the person or organization who should be in the best position to advise the owner of what steps are necessary to attain the desired quality and performance in the completed building. Unfortunately all too often, their level of technical knowledge, their understanding of all parts of the process, and often their lack of interest in the process after design, leaves the designer with an inadequate background to adequately represent the owner in this area of the project. In these cases the designer must decide what role they

can play in the QAP and discuss the issue with the owner very early in the project. If the designer does not have the appropriate knowledge and commitment, both the designer and owner may be better served to employ the services of a consultant with specialized knowledge and experience in the procedures required to implement a QAP for the exterior building envelope.

For those who may take exception to these observations please be advised that these are not made lightly. In my practice we are Architects and Engineers and we are committed to a comprehensive understanding of all that is involved in the design/construct process for the exterior building envelope. However, that is me and my practice, not everyone. Each designer must make their own, and hopefully informed decision regarding implementation of a QAP for the exterior envelope of their building.

How

This paper addresses the process that is needed (in my opinion) to obtain a project with an exterior envelope that provides the proper performance requirements and meets the owners expectations for the finished product. Some designers will need to commission assistance from others to attain much of what is recommended in this paper. It is always the responsibility of any design professional to understand their abilities and limitations, and obtain assistance when they find themselves faced with a task beyond their ability or capability.

Many of the points discussed here, as well as the recommendations provided, may sound similar to points raised in the commissioning process. In point of fact there is a commonality between the two, even though the roots of this paper go back over twenty years to an article I wrote for a health care magazine in 1990. The primary difference between the process identified in this paper and that espoused for commissioning is fundamental:

- The process I propose is directed to actions the designer should undertake in order to facilitate attaining a properly designed and constructed building envelope through actions of the designer and others.
- An envelope commissioning process is directed to a third party, not directly responsible for design. While this approach may be beneficial in some cases it should not, in my opinion, be required in most cases.

Also note that many of the terms and steps used in the commissioning process represent nothing different than that which has always been required to complete a proper design process. Terms such as “Owners Project Requirements” (OPR) and Basis of Design (BOD) do not represent new concepts. They are simply new terms for tasks that have been in common use for many years.

A QAP should be an integral part of any design process, not only those buildings with defined commissioning requirements. Remember that every building project has a designer, but only selected and relatively few projects are subject to a formalized commissioning process, especially for the exterior envelope portion of the project. Take particular note that the process we are talking about here is specific to actions the designer can accomplish or require by contact. This requires no one’s approval or agreement other than the owner, and this includes both the design and specification process. QAP

requirements should be built into all phases of the project following design by clearly identifying them as requirements of the contract for construction. This includes:

- Procurement,
- Pre-construction,
- Construction, and
- Acceptance of the completed project.

The designer then has the opportunity to address a minimum set of specific and discrete steps the entire project team must follow to accomplish the established quality and performance requirements of the building envelope. This is true of all projects be they the traditional design-bid-build approach, or the relatively new integrated delivery process. This is also true of the many in-between approaches such as design-build often utilized by government agencies.

Some may argue that not all buildings require an organized QAP, especially of the magnitude and complexity described in this paper. To an extent they may be correct. However, the limits are tightly defined. If a designer uses a limited pallet of materials, with a limited catalogue of details, in the same or very similar climate, for buildings of similar size and use, and has used this same set of materials, details, building usage, and exposure conditions successfully over time, then they may be justified in not implementing a QAP for their building envelopes. This approach is recognized and can be defined as following "exemplars" as recognized within ASTM Standards E-1825, Standard Guide for Evaluation of Exterior Building Wall Materials, Products, and Systems.

However, if this is not your circumstance, then I recommended you follow the process identified in this paper.

THE PROBLEM

Exterior walls sometimes do not perform as expected, as intended, or sometimes as required by contract, or even by codes and regulations. Failures may involve any one or more of 15 to 20 separate and independent performance criteria. A simple list of measurable performance issues related to exterior building walls might easily include the following for a typical institutional or governmental building:

- Water resistance
- Structural resistance to wind load
- Structural resistance to seismic load
- Air infiltration/exfiltration resistance
- Fire performance
- Acoustical performance
- Blast/Glass shard resistance
- Ballistic resistance
- Security or forced entry resistance
- Thermally induced movement

- Thermal isolation of exterior and interior
- Moisture migration resistance
- Durability of finishes
- Durability of base materials
- Ability to carry structural loads (such as load bearing masonry)
- Dirt/graffiti resistance,

This list does not begin to address more specialized requirements such as radiation containment, radio frequency isolation, or other unique performance requirements of some buildings.

The point is: The exterior building enclosure is perhaps not quite as simple as we may choose to believe it is, and there are many issues that must be addressed appropriately and completely to obtain the proper results – a building that will meet the owner's expectations and requirements. If we do not meet these expectations and requirements we may expect any number of consequences including:

- Failure with disruption to building occupancy
- Physical damage to building or contents
- Delays in initial occupancy after construction
- Lost business opportunities to occupants/tenants
- Safety and health hazards
- Loss of income to owner and tenants
- Damaged reputations of architects, engineers, owners, suppliers and contractors
- Damaged relationships between the owners and the project team
- Legal action (justified or not)
- Lost opportunities due to time spent resolving failures in the envelope

In addition, the cost of correcting building envelope problems increases dramatically after the design phase. The earlier you correct problems, the more cost effective. [Figure 1]

Causes of failure to perform are many and varied, and may include any of the following contributing factors:

- Incorrectly specified performance criteria
- Inaccurate assumptions regarding exposure conditions
- Inaccurate assumptions regarding interior environment
- Improper function or operation of building mechanical systems
- Improper selection of materials or systems
- Improper or incomplete detailing
- Ineffective procurement process
- Incomplete final engineering and submittals
- Lack of suitable installation instructions
- Inadequate installation or fabrication procedures
- Insufficient communication between trades for coordination of interfaces
- Failure to correctly and thoroughly perform mock-up and testing procedures
- Incompatibility of adjacent materials

- Material failure due to manufacturing problems
- False, misleading, or inaccurate test procedures or reports
- Environmental exposure changes after construction
- Time and exposure related degradation of certain materials
- Failure to properly accommodate thermally induced building or wall system movements
- Improper delivery and storage procedures
- Improper acceptance procedures
- Failure to consider fabrication, construction and installation tolerances

As this list indicates, performance issues and considerations are probably much more complex and extensive than many in the design and construction communities may realize. The goal of this paper is to identify a tool to assist in accomplishing better and less problematic building exterior envelopes.

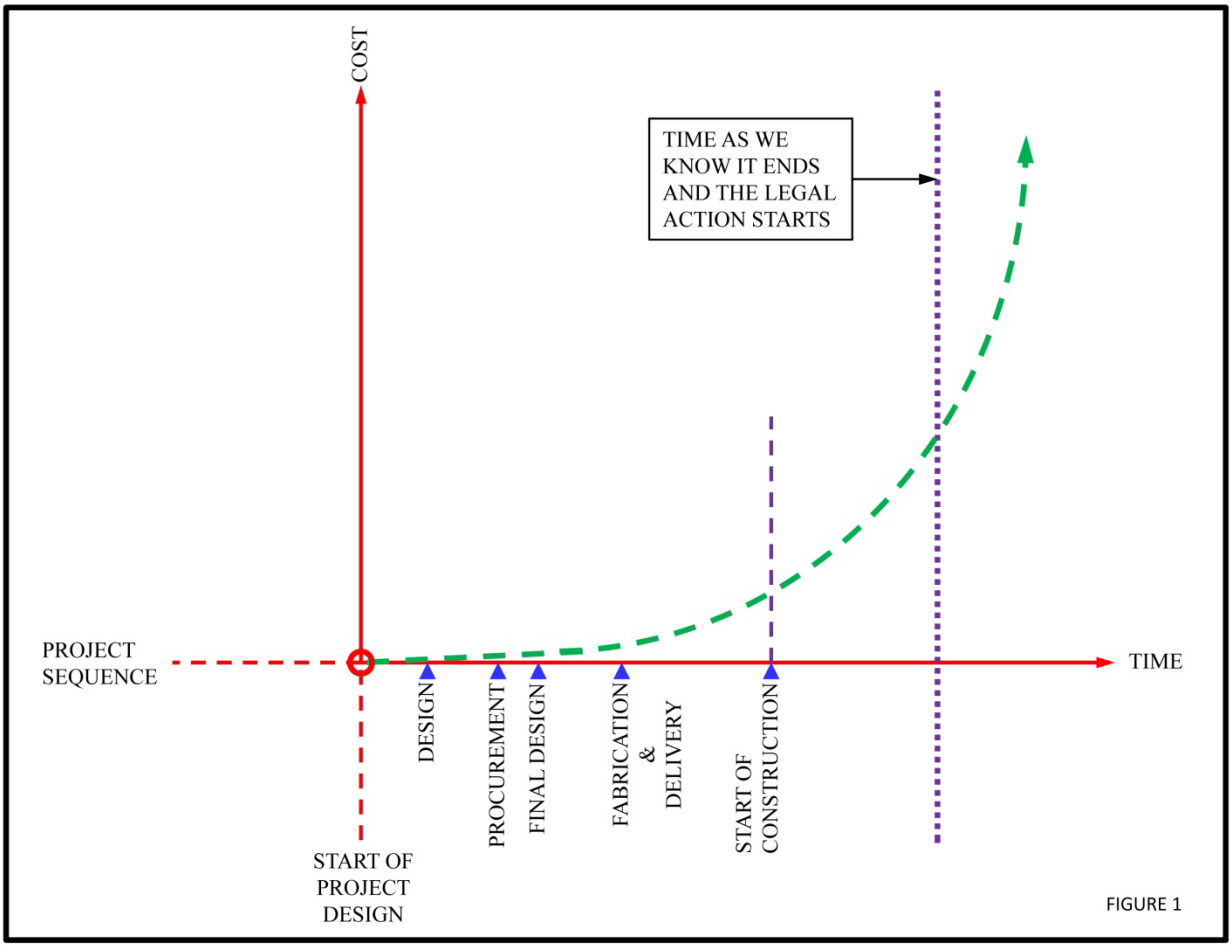

FIGURE 1

THE PROCESS

This paper is addressed specifically to the designers. The reason for this is simple. Other than the owner, the designer is the one entity, be it an individual professional or a corporate practice, which is most often involved from the beginning through to the end of a building project. The designer is also the entity most often involved in assisting the owner in determining:

- Basic parameters of the building and therefore what the exterior walls will be;
- What the exterior walls will look like
- What the materials will be
- How well the walls and components must perform
- Anticipated service life of the walls and components
- Anticipated construction budget
- When the building is needed

The designer is also quite often instrumental in assisting the owner in determining what the procurement process will be for the building. When you consider the previous statements, you will see that the designer touches every single "hot button" of the building process. They also are the entity most often responsible for the project manual, including technical specifications. The project manual is the contractual tool instrumental in defining the process to be followed for procurement and construction. Their role in development of this document gives designers a unique opportunity to influence how, and how well, the exterior envelope construction is accomplished. Unfortunately designers often do not understand the power of this tool and what can be accomplished with it. Part of the purpose of this paper is to remind designers and owners of this.

PROJECT PHASES

The Construction Specifications Institute, *CSI Project Delivery Practice Guide,* indicates 7 stages within the life cycle of a facility:

- Project Conception
- Project Delivery
- Design
- Construction Documents
- Procurement (Bidding/Negotiating/Purchasing)
- Construction
- Facility Management

This paper deals with four of these stages most directly associated with the process of design and construction of the facility:

- Design
- Construction Documents
- Procurement
- Construction

I treat design and construction document stages as a single phase; identified as "Design." The designer's activities identified by the CSI document for the Design and Construction Documentation stages are included within the Design portion of this paper.

This paper also addresses the Construction stage as identified by CSI as a series of more discreet activities labeled:

- Pre-Construction,
- Fabrication and Delivery,
- Construction

Acceptance of the work is also addressed.

The QAP has different objectives during each phase of the project, all directed to obtaining a specific and singular goal: **an exterior envelope which performs as desired.** This paper identifies six basic phases for purposes of explaining a method to develop and implement a QAP directed to accomplishing a better building envelope:

- Design
- Procurement
- Pre-Construction
- Fabrication and Delivery
- Construction
- Acceptance

While this indicated approach may need to be adjusted to accommodate a specific project or delivery system, it provides a basic framework to establish a QAP for any project.

DESIGN PHASE

The design phase starts with concept development by the designer and continues through the completion of documents for bidding or negotiating. During the design phase the appearance, configuration, basic system selections, terminations, materials, performance criteria and interface conditions with other building systems are established. There is a set of procedures which the designer must follow at this time to make sure the exterior envelope systems are appropriately considered, designed, specified, and drawn to attain an envelope that performs properly.

The majority of the basic decisions regarding the wall have been made by the completion of this phase. Depending upon the wall system, erection/construction procedures may also be determined directly or indirectly by the choices made regarding materials, systems, configuration, and performance requirements.

Early in the design phase it is necessary for the designer to clearly establish some very fundamental criteria with the owner. These criteria are critical to determining several issues related to the level of performance and anticipated service life of the building envelope. The level of performance can be based upon many factors, including physical performance (such as indicated throughout this paper) as

well as design appearance. Service life, of the building envelope is a simple enough concept, however this can be more difficult to determine than physical performance. The concept of service life includes consideration of the various factors which will determine how well the exterior building envelope will perform over time, and when should it be anticipated that significant repair or replacement of systems or components will be required to maintain the exterior enclosure at, or close to, the original design parameters for performance. This will include consideration of issues such as durability of materials, anticipated maintenance, exposure, and required performance levels, at minimum.

You may apply various terminologies to this process, but at bottom the goal is to determine what the owner's requirements are for the exterior building envelope. This step should be established at varying levels of detail starting with the earliest steps in the design process and continue at increasing levels of detail through completion of the documents for bidding and procurement.

The objectives of the QAP during the design phase should be directed to insure the following considerations have been adequately and appropriately addressed by the designer:

- Wind exposure
- Precipitation conditions
- Ambient outdoor conditions of temperature and humidity
- Solar exposure
- Interior pressurization
- Interior temperature and humidity conditions
- Constructability
- Review and approval schedules
- Mock-up and testing requirements
- Manufacture/fabrication schedules
- Construction/erection schedules
- Compatibility with adjacent systems
- Appearance criteria
- Durability/service life
- Initial cost
- Life cycle cost
- Code/regulatory approvals
- Maintenance requirements
- Water resistance
- Ability to carry structural loads
    - wind
    - seismic
    - maintenance
    - gravity
- Air infiltration/exfiltration resistance
- Fire performance
- Acoustical performance
- Blast/glass shard resistance
- Ballistic resistance
- Security or forced entry resistance
- Thermally induced movement

- Thermal isolation of exterior and interior
- Moisture migration resistance
- Durability of finishes
- Durability of base materials
- Chemical resistance

Note that “sustainability” is not included within the list of considerations. This is because, in my opinion, this term (sustainability) has not yet been logically defined within our industry, and it is not currently clearly or consistently measurable in a reliable manner. Also note that a QAP is intended primarily to assist in attaining a desired level of quality and performance. As such, until we can more reasonably, consistently, and rationally identify and measure levels of “sustainability”, I do not believe this is an appropriate target of a QAP for exterior building envelopes.

While it is true that there are metrics (or measurable properties) associated with sustainability and LEED certification, these are highly subjective, again in my opinion, and not reliable as a true measure at this time and in their current level of development. Reducing the impact of a buildings materials, construction, and embedded and operational energy on the environment is clearly a valid and necessary step which we should all be committed to. In my experience and opinion, the issue of sustainability is much more complicated than most realize. It is not merely a matter of substituting one material for another, or providing more insulation, or less glass. This approach can lead to serious deficiencies which serve neither the environment nor the building owner. When the building is completed, it must perform as desired and it must last for the desired service life. If it does not do both of these things – the building is neither successful nor sustainable.

Quality assurance efforts by the designer during the design phase should include the following basic steps:

- Evaluate project criteria which establish characteristics of the acceptable end product.
    - Make sure the items in the list above have been addressed.

- Review the schedule for completion of the project including consideration for:
    - owner reviews
    - design team checking
    - cost estimating
    - manufacturers/fabricators review and comment
    - consultant reviews
    - review by regulatory or code agencies
    - peer reviews, redesign
    - special testing or analysis such as wind tunnel load analysis

A project which is not properly scheduled is likely to experience problems with quality when unanticipated problems and resultant pressures adversely impact the decision making process. Remember, while certain aspects of the design process are based on inspiration and creative thinking, successful implementation is based on logical and ordered analysis and problem solving.

- Confirm that good communication procedures between the project team have been established including:

    - design team
    - owner/tenant
    - contractor/construction manager
    - consultants/testing agencies
    - cost estimators
    - manufacturers/fabricators/erectors

- Implement periodic reviews and sign-off of the criteria and design as they are developed. These can be "on-board" reviews which do not stop the project development, or they can be scheduled for a longer length of time with envelope development halted until the review is completed and the review comments are received. All review comments should be addressed and resolved.

- Require final sign-off for the documents before they are released for bidding or negotiations. The documents will often receive a more conscientious review when formalized sign-off procedures are established.

If the QAP has been successful during the Design Phase, there will be an added degree of comfort that many of the causes of inadequate envelope performance have been avoided. It is important that the continuity of the QAP be preserved into the Procurement Phase.

PROCUREMENT PHASE

The Procurement Phase may include negotiating or bidding, as a means of selecting a contractor to provide the exterior wall construction. In today's construction market there sometimes seems to be as many methods of contracting for construction as there are projects. The specific method selected may depend upon a number of factors including:

- Size of the project
- Cost of the project
- Complexity of the design
- Local or regional market conditions
- Overall project delivery system
- Material availability
- Schedule requirements
- Local or regional practices
- Client purchasing preferences or requirements

At a minimum, the designer may need to be familiar with the following procurement methods to provide adequate service to the owner during this phase of the project:

- Design / Bid / Build – “traditional” in the past
- Design / Build
- Design Assist
- Integrated Project Delivery

This partial list includes the predominant methods being utilized today. However, there may be numerous variations within each of these basic approaches.

While it is not always true, the designer most often participates at some level in the Procurement Phase, at the very least by preparation of “front-end” and technical specifications. When the designer prepares the project manual they have the opportunity to impact the success of procurement by establishing many of the rules for bidding and award.

In any case, there are a number of precautions which can be implemented during this phase to assure that the proper quality is attained. The following precautions are designed to assist in attaining an accurate understanding of the project criteria on the part of the bidders, or in the case of award by negotiation, the parties making proposals, and on the part of those considering the bids and proposals, (the designer and owner). All major issues should be understood by both sides before a contract agreement is reached. To this end, follow these guidelines to assist in the success of the Procurement Phase:

- Allow adequate time for the preparation of bids or proposals.
- Make complete sets of documents available to all bidders.
- Require pre-bid conferences to allow bidders the opportunity to ask questions regarding the documents. If the project is a retrofit or renovation include on-site walk throughs.
- Require mandatory attendance at the pre-bid meeting as a condition of bid.
- Require certification by bidders that their bid is based upon full contract documents including addenda, and that they meet the quality standards of the documents for length and type of prior experience.
- Limit the number of pre-bid addenda to avoid confusion. However, if pertinent and legitimate questions arise during bidding, make sure that they are answered by an addendum communicated to all bidders.
- Do not provide verbal responses to bidders’ questions. If a response is required, include it in an addendum or in some logical manner to assure all bidders have the same information available to them.
- Document the results of the pre-bid meeting to all participants by addendum. Do not allow dependence upon the spoken word. Require that only the written minutes issued by an addendum be relied upon.
- Upon receipt of bids, allow adequate time for evaluation of each bid. Review each bid individually to ascertain that the bid is responsive; is comprehensive in nature; and that the proper bidder certifications are provided.
- Do not base contract award on price alone. Award of contract based on a combination of quality; price, and schedule can provide a more successful selection process.

- Require proposal drawings for performance based bids. Test reports and calculations should also be submitted for evaluation. Fully evaluate these documents and resolve any concerns before contract award.

- Meet with the bidders for a face to face review of their bids during the bid evaluation process. Perform a detailed review of their bids to confirm compliance with project requirements.

- Allow time for the bidders to consider and respond to any questions which may result from the detailed review. If necessary, allow the bidders to modify their bids in response to these issues.

- For projects with complex phasing, scheduling or other special schedule related concerns, provide this information and require the bidders to confirm their ability to comply with these special needs. It is prudent to require the bidders to submit a detailed response indicating their plans on how to handle these conditions.

These procedures may vary from project to project, and may not all be required for, or applicable to, every project. Each project must be evaluated individually to determine which procedures are best suited to the specific conditions. The primary goal is to avoid conditions during the Procurement Phase which will lead to problems later. A contract which is based on an inadequate understanding of project appearance, performance, schedule and job site criteria, or the contractor's abilities to perform, is more likely to result in failure at some level, and ultimately more performance problems due to loss of quality.

If the QAP goals have been attained during the Procurement Phase, it is likely that the next phase will proceed smoothly, or at least with fewer unforeseen difficulties.

PRE-CONSTRUCTION PHASE

As with the Procurement Phase, there are provisions the designer can build into the documents, including drawings, technical specifications, and front end documents for the Pre-Construction Phase, that will help to increase the quality of the completed project and the exterior envelope.

The Pre-Construction Phase covers the activities between award of the contract and delivery of materials, products, and systems to the building site. This includes final design and engineering, completion of mock-up construction and testing necessary before production, and fabrication and delivery of materials and systems for incorporation into the building.

FINAL DESIGN AND ENGINEERING

Following award of a contract for construction of the envelope systems, the successful contractor is normally responsible to demonstrate their knowledge of the required materials, products and systems to be installed through the submittals process. During the course of this process, the contractor will submit material finish and color samples, literature and data regarding materials, products and systems, test reports, detailed shop and fabrication and erection drawings, certifications, fabricator or manufacturer's engineering calculations, and other pertinent data. This process is necessary to assure all

parties that the requirements of the project are understood, and will be met. The contractors and manufacturers or fabricators, will also perform the final design and engineering of the systems during this phase.

This further effort is required to move the enclosure systems forward from the design to the more detailed level of development required to bring together the various components of the exterior envelope into an integrated and constructed building enclosure system. This necessarily includes coordination with other adjacent construction systems which are also moving along a similar and concurrent path of development. Even with the best contract documents, there may be a number of unforeseen conditions to resolve during this phase. It should be remembered that this is often the last opportunity to resolve any problems of design or coordination before fabrication or manufacture of the building envelope systems. This is particularly true of prefabricated systems such as metal and glass curtain walls or precast concrete, which are normally prepared to a high degree of completion off-site and delivered for on-site erection. Generally speaking, the higher the degree of system or component fabrication performed off-site, the more critical the attention to detail and coordination needs to be during this phase. While these systems normally offer a superior degree of quality and workmanship than site fabricated systems (due to the advantages of assembly in a protected and controlled environment), they are difficult, and sometimes impossible, to successfully alter in the field. Therefore, they must be correct as fabricated and delivered.

The critical point regarding quality assurance during this phase is to maintain control of the process through communication and attention to detail. If this control is not maintained, there is an increased risk of loss of quality and performance. When a project encounters problems during this phase, there is likely to be great pressure to proceed with the construction in spite of the problems, due to financial and/or schedule considerations. Techniques which designers can require become contractual through inclusion in the documents they prepare to maintain control of the project and insure adequate attention to detail include:

- A submittal schedule from the envelope contractors should be the first issue to be considered. This schedule needs to provide a comprehensive listing of all expected and required submittals, and should include time for multiple submittals and reviews.

- Require pre-submittal meetings to review submittal requirements and expectations. Review the technical and procedural requirements of the project as well as any revisions which may be required, or which may be found to be helpful as the project develops. Require documentation of these meetings and distribute minutes to those involved.

- Require distribution of approved wall system submittals to contractors of adjacent construction for purposes of coordination review. Conversely, provide submittals of critical construction systems adjacent to the envelope systems for coordination. It is essential that coordination problems be resolved during this phase, not on the job site.

- Identify a requirement to establish and identify means and methods of communications between the construction team members. Whatever the details are to be, make sure that communication is facilitated not hindered. It is not the designers or owners job to manage or control such communication. It is however within their means to encourage, and require contractually, open lines of communication in order to foster a valuable exchange of information and coordination.

- Require regularly scheduled meetings to review project development. These should be designed to keep the team in tune with the progress of development, and identify problems which may require resolution. These meetings serve to notify the team of what level of activity will be required. This will help each team member perform in a timely fashion by providing advance notice of the type and amount of effort required of them. Again, it is not the designer or owner's role to control or run these meetings. However, it is within their purview to require such meetings, and require that it is demonstrated that they occur.

- Encourage separate problem resolution or working meetings outside of the regular progress meetings. These meetings can often be held with fewer people, will be more focused on specific technical or coordination issues, and are more likely to conclude with solutions to specific problems or concerns.

- Establish adequate review, transmittal and response times for each cycle and each item required by the submittal process. Submittals which are prepared or reviewed in a rush are more likely to contain errors or be inadequately prepared or reviewed. This leads to frustration on the part of the team and too often to unacceptable or inadequate construction.

- Evaluate and resolve problems as they are discovered. This is critical! At this stage of the project there is no time available to push problems downstream. Questions which go unanswered at this point are likely to result in delays or unacceptable "field solutions". Additional costs are often the direct result of not adequately addressing issues remaining at this time.

- Require submittal of mock-up, production, fabrication, delivery and erection schedules. These are necessary to ascertain that adequate time will be available to deliver and install the wall system to meet the overall project schedule. These schedules should be provided in a format common to the overall project to allow integration and coordination. Projects which encounter schedule difficulties are likely to have a higher degree of envelope failures.

- Resolve monetary issues as expeditiously as possible. If requests for additional compensation are submitted due to problems discovered during this phase resolve them. If resolution is not possible, at least document the issue thoroughly and fairly for future resolution. Money problems have a way of disrupting good thinking and common sense, often subsequently leading to envelope performance problems.

These procedures are suitable for use with projects of varying size, degree of difficulty and delivery method, with modification to suit the specific project. In all cases, the goals should be to communicate and pay attention to detail. Upon completion of this phase the efforts of the entire project team and the QAP will be tested through the mock-up and performance testing phase of the project.

MOCK-UP/PERFORMANCE TESTING

Many exterior envelope systems will require mock-up or performance testing to confirm that the wall design will conform to the desired appearance and provide performance to meet the criteria of the project. This process is especially important to those systems with appearance, design, or performance criteria which are unusual, or which have not been previously constructed. Mock-ups may be performed and tested under laboratory conditions or on the construction site.

Keeping the mock-up and performance testing on the proper schedule track can be a critical link in avoiding performance problems in the completed envelope. As in many other areas of construction, if the mock-up or performance testing does not keep pace with the overall project schedule, there is likely to be pressure to short cut the process. If this pressure is successful, a valuable tool in discovering potential coordination and thereby performance problems will be lost. Again, it is particularly important to complete this phase of the project for systems which are new or unique. If this is not accomplished in this phase of the project, then the building can become the test facility, which is not acceptable. In many cases, fabrication of the project material has been waiting for the successful completion of the mock-up and performance testing.

The major QAP points the designer must address during this phase of the project include the following procedures:

- Review submittal procedures relative to the mock-up/testing. This process should have been completed in the previous stage and should be confirmed at this point.

- Verify that mock-ups will be erected/constructed by the individuals who will erect/construct the envelope systems on the building.

- Verify location of testing or mock-ups on-site (or on the building) have been fully coordinated. In the interest of the other aspects of the project, all ongoing construction activities must be considered.

- Verify the length of time which the mock-ups are required to be retained has been clearly communicated to the construction team. Premature destruction or removal of mockups can lead to problems.

- Confirm required levels of performance, and test procedures to be utilized are clearly verified with the construction team, including those parties performing the testing.

- Review configuration of the envelope mock-ups and the sequence of testing with the construction team. Sequence is particularly important if any of the testing will be destructive.

- Clearly state conditions to be tested, and the acceptance criteria. Obtain verification from the construction team.

- Address conditions under which re-testing will be required and who will be responsible for the cost of re-testing. Obtain verification from the construction team.

- Meet with owner and construction team to review procedural requirements for witnessing of the testing.

- Re-evaluate and confirm schedules for production of test panel or mock-up material, erection of the mock-up, and how access will be provided for on-site testing.

- Confirm the schedule for testing, whether on the building separate from building on-site or at a separate location such as a testing facility, has been properly addressed by the construction team.

- For on-site mock-up or testing, confirm the conditions if any, for which the mock-ups will be acceptable for inclusion in the finished envelope systems.

After these QAP efforts have been completed the mock-up construction and/or performance testing can proceed. Additional QAP procedures to be followed for the remainder of mock-up/performance testing include:

- Document each step in the mock-up/performance testing. Include photographic as well as video documentation.

- Take special note of any differences between the mock-up/performance testing specimens and the material to be installed. It is critical that the constructed work match the mock-ups as constructed and tested.

- Allow adequate time for sealants and other "wet" components to cure before testing.

- After mock-up construction and prior to testing, remove and reglaze sample panels to demonstrate procedures (metal or glass curtain walls in particular).

- Monitor testing procedures and results to confirm compliance with project criteria. Address and confirm any discrepancies or questions with the construction team.

- In the event of failure, modification to system details and retest may be required. This must be documented in detail.

- After completion of testing, verify shop and erection drawings and installation instructions are revised to indicate required changes.

- Review and confirm that the construction team understands that a final written report of test results from the testing agency or consultant is required. Obtain a firm date for receipt of this information.

Keeping the mock-up and performance testing on the proper schedule track provides a critical link in avoiding performance problems in the completed building envelope. In many cases, fabrication of the project material has been waiting for the successful completion of the mock-up and performance testing. As in many other areas of construction, if the mock-up or performance testing does not keep pace with the overall project schedule, there is likely to be pressure to short cut the process. If this pressure is successful, a valuable tool in discovering potential sources of problems will be lost. It is particularly important to complete this phase of the project for envelope systems which are untried or used in a unique fashion. If this is not accomplished in this phase of the project, then the building can become the test facility, which is not acceptable.

FABRICATION AND DELIVERY PHASE

During the Fabrication and Delivery Phase of the project there is often a tendency for the project team to push the exterior envelope systems out of their minds. Instead, they pay attention to other pressing, and also valid, problems relating to other aspects of the project. It is easy to forget that the envelope systems are proceeding through fabrication for delivery to the project site. However, it must be remembered that there are still opportunities for errors to occur and problems to develop which can dramatically affect the ability of the installed envelope systems to provide the required performance.

As indicated earlier, shop fabricated material and assemblies are normally preferable to field fabricated material, but are often very difficult to revise or replace on-site. Therefore it must be correct and undamaged when received. Generally speaking, the higher the degree of off-site fabrication, the greater the need for continuation of the QAP during this phase of the project. Fabrication or material errors, as well as late delivery dates of material, or delivery of damaged or incorrect materials can lead to an increased probability of performance problems. A QAP can and should be continued at the fabrication facility or facilities, and the building site to reduce the probability of these problems occurring.

By following the proper QAP procedure, during fabrication and delivery, performance problems related to this phase can be minimized or avoided entirely. Action items during this phase should include:

- Periodic inspections of fabricated materials to insure that the required quality is being attained.

- Fabricated products and assemblies should be checked to confirm that they conform to the project requirements, and the wall system as approved by testing and mock-ups. This will include any revisions made as a result of mock-ups and/or testing.

- Review of erection drawings and installation instructions to confirm that any revisions required as a result of the mock-ups and/or testing have been included.

- Monitoring of the procurement of components to be delivered directly to the job site from separate suppliers. Confirm that it will be the correct material, and will fit with other products being fabricated.

- Delivery dates and locations should be confirmed.

- Confirmation that the on-site construction schedule has been considered and accommodated by the fabrication and delivery schedule. The order of on-site erection and/or assembly can be critical.

- Review delivery requirements to confirm that the phasing of materials delivery will accommodate the amount of available and appropriate on-site storage locations. Materials and fabricated systems which are not properly stored are more subject to problems in the finished construction.

- Review of the method of delivery as related to on-site materials handling capability. Fabricated assemblies which are improperly handled on site may be subject to damage which can be avoided by planning ahead.

- Monitoring of packaging practices and procedures. Improperly packaged materials can be damaged to the point of being unusable upon receipt at the job site. This can result in schedule problems and the attendant risk of errors in fabrication as pressure builds for the damaged material to be replaced or worse, incorporated into the wall.

- Review of the packing lists and manifests to confirm that all of the required components are delivered to the correct location, and on time. Missing items may be replaced with the incorrect material or left out completely in the rush to keep the project moving. This can result in problems.

- Verify that products and assemblies are packaged and shipped in a manner which will prevent damage. This is especially true of large metal windows or frames which can move during handling or transport thus possibly opening corner joints. Confirm that needed bracing and/or packaging material is provided, and that these assemblies will be correctly placed and secured in the shipping vehicles. Finished surfaces are also prone to damage by improper packaging and delivery.

- Require the erecting or installing contractor to check or "shake-out" the delivered material and assemblies for completeness and condition as it arrives. Erection or installation should not be started before this process is completed. It is critical to get the process for replacement of damaged or otherwise unacceptable material, or the delivery of missing material started as soon as possible. In this way, problems can be resolved before they become schedule critical.

By following the established procedures for good communication and attention to detail, the goals of the QAP will be facilitated and the required fabricated, delivered, and stored materials should be on site complete, correct and in acceptable condition, and be in the same condition when it is time to incorporate them into the building. By avoiding or limiting problems during the fabrication and delivery phase of the project, the Construction Phase should proceed more smoothly. This is likely to result in fewer problems and better conformance with the project requirements for performance.

CONSTRUCTION PHASE

When implementing quality assurance procedures during the construction phase it may be necessary to explain the intent and process of the QAP to all parties. Many site representatives and tradesmen may not be familiar with the process and may not understand the goals and objectives. However, if you can successfully explain the program and gain their active support and participation, the results can be impressive.

During the construction phase of the project, the previous efforts of the owner, designers, consultants, fabricators, material suppliers, and contractors are brought together for the true test. Will it work, will it fit, will it look right and can the work be completed on time? If the project team has-performed their jobs correctly, and if they have communicated properly, and paid attention to the details the answer will be yes.

However, since this is an imperfect world and within this world is the very complex and even more imperfect world of construction, there is still a need for the continuation of the QAP through the construction phase of the project. The efforts required of the QAP during this phase may vary by the

complexity of the envelope systems, however some general guidelines should be followed for any project. These procedures are suitable to projects of varying size, degree of difficulty and delivery method, with modification to suit the specific project. In all cases, the goals should be to communicate and pay attention to detail:

- Require a pre-construction meeting prior to arrival of envelope material on the job site. Issues to be addressed include:

    - Phasing and schedule of wall construction.
    - Owner occupancy and ongoing use of the facility for existing occupied buildings being repaired or retrofit.
    - Review of previously constructed wall mock-ups where appropriate.
    - Review of erection and installation drawings and instructions and systems interface details.
    - Communications between designer, consultants, owners and contractors.
    - Review of problem resolution techniques and procedures to be followed.
    - Lift schedules where common use of cranes or material hoists is provided.
    - Site access for cranes where common use cranes or material hoists are not provided.
    - Weather limitations for exterior wall work.
    - Meeting schedule for coordination with other work.
    - Review of acceptance criteria for substrates to which wall systems will be attached, and corrective procedure requirements and procedures.
    - Acceptable tolerances of the finished wall work.
    - Cleaning procedures.
    - Protection of completed work.
    - Inspection and acceptance procedures and criteria for work in progress.
    - Acceptance procedures for completed work.

- Convene a pre-installation meeting between the designer, consultants reviewing construction, the general contractor or construction manager, the envelope contractors, and the tradesmen. During this meeting review the envelope systems designs, critical details, acceptable and unacceptable practices, and inspection procedures. This meeting helps to establish a strong working relationship which can provide great benefits, especially for wall systems which are labor intensive on-site, such as masonry.

- Schedule and hold regular progress meetings to review the status of envelope work as it proceeds.

- Review storage conditions periodically to identify and correct deficiencies that may occur.

- Review in-place work regularly to assure conformance to project requirements, including protection as necessary. Notify contractors of required remedial work.

- Review typical detail conditions with contractors and tradesmen as the work is started. This is often the last opportunity to be sure that the work will be performed correctly.

- Identify examples of acceptable work for each envelope condition and review with contractors and tradesmen. When part of the project, the accepted and approved on-site mock-up should be used as the acceptable level of quality.

- Resolve problems as they are identified, do not procrastinate. Once on-site envelope work is started delays are not acceptable and may lead to unacceptable construction if not resolved quickly.

- Require a complete set of project documents be available on site at all times, including submittals, samples, and installation instructions. Refer to these documents regularly.

- Check materials which are being incorporated in the envelopes. Read labels, check manufacturer's precautions and compare to approved submittals and project usage.

- Establish clear lines of communications between the designer, consultants, contractor/construction manager, manufacturers/fabricators, and installing or erection contractors. This is necessary to facilitate identification and resolution of problems with a limited amount of conflict and delay.

- Establish and foster working relationships on individual as well as organizational levels. Good individual working relationships have the potential to provide a very successful quality assurance tool.

- Arrange access for inspection of the work, even and especially at hard to reach locations. If these locations are difficult to access, they may well be difficult to work on also, and represent locations more likely to be a source of problems.

- Establish schedule and requirements for in-situ progress testing and reporting. Involve all parties and distribute the results of meetings and testing.

- Perform “proof” or compliance testing early in the project to detect potential concerns at the earliest possible time. If you do not, a significant amount of non-conforming work may result before detection.

- Require cleaning test areas to establish acceptable methods, tools, and cleaning materials and end results. Document the results and identify an acceptable example area. Manufacturers of chemicals to be used and finished envelope materials should be represented at these meetings and test cleanings.

- Where possible, perform acceptance review of work as the work is completed by area. This will allow corrections to be completed while there is still ready access and help to discover unacceptable conditions which may have been missed. This will also facilitate correction of the problems in the ongoing work.

- Records of job site weather and progress are important and should be rigorously obtained and recorded. These can be valuable in identifying the sources of problems, or likely problem areas.

- Require daily reports of work in progress, problems encountered, crew sizes and individuals, and planned areas of work for all exterior envelope work. These records may also prove valuable in problem resolution and can help the exterior wall contractor in planning their work.

Proper and successful implementation of the QAP during construction and previous phases is the final key to acceptable results.

ACCEPTANCE PHASE

Upon completion of the envelope construction, final acceptance and payment is requested. In order to assure that the owner has received enclosure systems which meet the requirements of the contract documents, the design team and contractor/construction manager are required to review and confirm the completed product conforms to the contract requirements. In some cases, this process may also include final in-situ testing for compliance with the specified performance criteria. This testing is normally performed under the guidance of, or directly by, specialized consultants with experience and expertise in this area.

In order to obtain valid results from the acceptance process the following quality assurance procedures can be implemented:

- Require submission of "as-built" records indicating the final construction of the envelope system. The project documents should contain detailed requirements for submission of these documents.

- Review qualifications of the specialized consultant or testing agency to insure that they possess the proper knowledge and experience required to perform and evaluate the results of the in-situ testing procedures. Perform this review before they proceed.

- Hold a pre-acceptance meeting with the project team to review and confirm the acceptance process and schedule. Document and distribute the results of this meeting to all parties.

- Require that installing contractors, general contractor/construction manager, design team, and manufacturer or fabricator of the building envelope systems be represented at testing and/or acceptance reviews. This will facilitate understanding of written review comments and test reports.

- Require written comments documenting the results of review and inspections. Depending upon the nature of the project, comments or a legend and elevation drawings and details may also be required. Beware of tagging or marking comments directly on completed construction. Tags tend to blow away or wash off, and markings may damage finishes. If tagging or marking are to be used, review proposed methods with contractors and obtain their permission before proceeding.

- Review results of acceptance observations, inspections and testing before corrections are implemented. All corrective procedures should be agreed upon by the project team before they are started.

- If required, perform in-site testing or observations on examples of proposed corrective procedures before they are implemented. This may be limited to critical conditions where there is a serious flaw and doubts regarding the ability of the proposed corrective procedures to perform.

- Require final sign-off of the work by the designer, consultant, envelope systems sub-contractors, owner's representative and general contractor or construction manager.

CONCLUSION

While the list of items and recommendations provided in this paper is extensive, it is not necessarily exhaustive. It is however indicative of the type of approach that will serve well. A well thought out and executed QAP will contribute to the finished quality of the envelope system and avoid or minimize problems which would lead to non compliance with the owner's goals for the building. Hopefully the process will also help to keep the project on schedule and on budget, and avoided potentially damaging conflict and litigation.

If your professional judgment does not lead you to seriously consider the recommendations and opportunities identified in this paper then consider the business implications. All you have to lose if the building goes astray is your reputation, a client, perhaps a LOT of money (depending upon how good your attorney is) and lost opportunity. Even if you are not held legally accountable for a building that is less than the owner expected, consider how much it cost to replace clients instead of keeping existing ones, and how difficult it can be to properly service other projects or clients while you are desperately trying to manage a project which is going badly with an owner that does not really care about your other problems. Although the purpose of this paper is not intended as a "business primer" it identifies not only practices that are professionally sound but they are also good for business.

March 13, 2012

Paul G. Johnson, FAIA, NCARB