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

Paul Johnson, FAIA, NCARB

April 2011
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
- Correct Application and Installation

For materials and systems
As a building or building enclosure systems designer, the question you need to ask yourself is very straightforward and to the point:

- **What can I do to accomplish this goal?**

One method is the effective implementation of a project specific Quality Assurance Program. = QAP
An important definition: (for purposes of this presentation)

**Desired**: The level of quality and performance established by construction documents prepared by the designer.
This paper identifies:

- Procedural tools available to designers to implement 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.
The project stages identified are generally followed in most building projects in a manner similar to that identified. However...

- If the procurement process is different, then the QAP must change to suit procurement.

- It is critical that the QAP be matched to the project procurement and delivery systems.
What? Quality

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.

Remember - The various performance measures (or metrics) are defined by the designer through the contract documents.
A warning (Before we even start!):

There may be a great temptation to skip some (if not many) of the steps recommended.

• There will also be pressure, in some cases, to avoid the process completely.

• It may even seem important at the time.

• However the designer should always remember - There is only one opportunity to get a building right, and that is from the beginning!

• Each step along the way is dependent upon the step before.
The first step:

• The designer must first develop and identify a QAP designed specifically to the project.

• You have the opportunity to not only do the design work properly, but to also set the tone and rules that will assist in accomplishing the envelope correctly:

If you do not do your part correctly, the probability of the building envelope being correctly accomplished is greatly diminished.
If there are problems after the design phase you are now in the repair 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.

The building will turn out the way it turns out. Too often this is unsatisfactorily, and you can NEVER correct the disruption and bad feelings associated with these problems after they occur.
**FIGURE 1**

“To infinity and beyond!”

**Building Technology Studio**

**TIME AS WE KNOW IT ENDS AND THE LEGAL ACTION STARTS**
Who? The Designer

The most common and consistent participant in most building projects, other than the building owner, is the designer.

- Concepts
- Programming
- Schematic Design
- Budgeting
- Design Development
- Contract Documents
- Bidding
- Construction Contract Administration
How?  A Process

QAP = a process to assist in obtaining a project with an exterior envelope that will provide the proper performance requirements and will meet the owners expectations.

• Some designers may need to commission assistance from others to accomplish some of what is recommended in this paper.
Designer’s tools to effect a QAP:

• Design
• Selection of Systems
• Technical Specifications
• Drawings
• Contract “Front end” (Division 1)
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,
- 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” (examples), and is recognized within ASTM Standards E-1825: Standard Guide for Evaluation of Exterior Building Wall Materials, Products, and Systems.  

5.4.1 Review published information about the materials, products, or systems, or similar generic products and their limitations. Record specific examples of buildings where these or similar materials, products, or systems have been used successfully.

The Problem (Finally)

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

• 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,
And some buildings may have more!
The point is:

The exterior building enclosure is perhaps not quite as simple as we sometimes think 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 of a number of consequences including:

- **Failure and disruption** to occupancy
- **Damage** to building or contents
- **Delays** in initial occupancy
- **Lost** business opportunities
- **Safety and health** hazards
- **Loss** of income to owner and tenants
- **Damaged** reputations of designers, owners, suppliers and contractors
- **Legal action** (justified or not)
Causes of failure to perform are many, and may include any of the following:

- 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
(Continued)

- 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 movements
- Improper delivery and storage procedures
- Improper acceptance procedures
- Failure to consider fabrication, construction and installation tolerances
Moving on…

The point of this paper is to address actions the designer can take to help avoid problems.

• Some actions are solely the responsibility of the designer.

• Some actions the designer requires of others through provisions of the contract.

And

• Some actions deal with the way in which all parties in the process relate as the project proceeds. - Communication
The QAP has different objectives during each phase of the project, all directed to obtaining a singular goal: an exterior envelope which performs as desired.

This paper includes designer actions for six basic project phases.

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

The objective during the design phase is to insure the following considerations have been adequately and appropriately addressed:

- Wind exposure
- Precipitation conditions
- Outdoor temperature and humidity
- Solar exposure
- Interior pressurization
- Interior temperature and humidity
- Constructability
- Review and approval process
- Mock-up and testing
- Manufacture/fabrication lead times

Remember the earlier list?
• Construction 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

And there are more!
• 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

And still more!

Do you consider all of these?
Quality assurance efforts by the designer during the DESIGN phase should include the following basic steps:

1. **Evaluate** project criteria which establish characteristics of the acceptable end product.

   - Make sure the items in the list above have been addressed
2. **Review** the schedule for completion of the project including consideration for:

- Owner reviews
- 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
3. 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
  - Design Build
  - Design Assist
  - Integrated Project Delivery
4. **Implement** periodic reviews and sign-off for the criteria and design as they are developed.

- These can be "on-board" reviews which do not stop the project development.

- These 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.**
5. **Require** final sign-off for the documents before they are released for bidding or negotiations. The documents will often receive a more conscientious review if sign-offs are required.

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.**
Procurement Phase

The following precautions are designed to insure that there is an accurate understanding of the project criteria on the part of the bidders.

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.

1. **Allow** adequate time for the preparation of bids or proposals.

   - Document the results of the pre-bid conferences by addendum to all participants.
2. **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 walkthroughs.
- Make complete sets of documents available to all bidders.
3. Require mandatory attendance at the pre-bid meeting as a condition of bid.

4. Require certification by the bidder 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.

5. Limit the number of pre-bid addenda to avoid confusion.
6. Do not provide verbal responses to bidders questions.

- If a response is required, include it in an addendum to assure all bidders have the same information.

7. 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.
8. **Base** contract award on a combination of quality, price, and schedule.

9. **Require** proposal drawings for performance based bids. Include test reports and calculation.

   - Fully evaluate these documents and **resolve any concerns before contract award**.

10. **Meet** with the bidders for a face to face.

    - Review bids during the bid evaluation process.
    - Perform a detailed review of bids to confirm compliance with project requirements.
11. **Allow** time for the bidders to consider and respond to any questions which may result from the detailed review.

- Allow the bidders to modify their bids in response to these issues.

12. **Require** the bidders to confirm their ability to comply with these special needs.

- Complex phasing, or schedule related concerns.
- It may be prudent to require the bidders to submit a detailed response.
Pre-Construction Phase

The Pre-Construction Phase covers the activities between award of the contract and delivery of materials, products, and systems to the building site.

- Final Design and Engineering
- Mock-up/Performance testing
- Fabrication and Delivery
Final Design and Engineering

Following award of a contract for construction of the envelope, the successful contractor is required to demonstrate their knowledge of the materials, products and systems to be installed through the submittals process.

It is essential that problems be resolved during this phase, not on the job site.

• 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.
Designers can require procedures to be contractual by including them in the documents they prepare. These include:

- **Require** a submittal schedule with a comprehensive listing of all expected and required submittals, including time for multiple submittals and reviews.

- **Require** pre-submittal meetings to review submittal requirements and expectations.
  
  — Review of technical and procedural requirements as well as any revisions which may be required, or which may be found to be helpful as the project develops.

  — Document these meetings and distribute minutes to those involved.
• Distribute approved wall system submittals to contractors of adjacent construction for coordination review. Conversely, provide submittals of critical construction systems adjacent to the envelope systems for coordination.

• Establish and identify means and methods of communications between the construction team members. Make sure that communication is facilitated not hindered.
• **Require** scheduled meetings to review project development. These should be designed to keep the team in tune with the progress of development, identify problems which may require resolution, and notify all 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.

• **Require** separate problem resolution (working meetings) outside of the regular progress meetings with fewer people more focused on specific technical or coordination issues.

• **Establish** adequate review, transmittal and response times for each submittal cycle.

  — Submittals which are prepared or reviewed in a rush are more likely to contain errors or be inadequately prepared or reviewed, leading to frustration and unacceptable or inadequate construction.
• Evaluate and **resolve** problems as they are discovered. There is never time available to push problems downstream. Questions which go unanswered are likely to result in delays or unacceptable "field solutions", and/or time and schedule problems.

• **Submit** 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 systems. Projects which encounter schedule difficulties are likely to have a higher degree of envelope failures.

• **Resolve** monetary issues as expeditiously as possible. 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, leading to envelope performance problems.**
Mock-Up/Performance

Some exterior envelope systems will require mock-up or performance testing to confirm that the wall design and installation will conform to the desired appearance and provide performance to meet project criteria.

This process is especially important to those systems with appearance, design, or performance criteria which are unusual, or which have not been previously constructed.

• If this is not accomplished in this phase of the project, then the building can become the test facility. ....... Is this acceptable?
The major **QAP** points the during this phase of the project:

- **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.

- **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.
• **Verify** required levels of performance, and test procedures to be utilized with the construction team.

• **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.

• **Confirm** conditions to be tested, and the acceptance criteria.

• **Conditions** under which re-testing will be required and who will be responsible for the cost of re-testing.

• **Procedural** requirements for witnessing of the testing.
• **Confirm** schedules for production of test panel or mock-up material, erection of the mock-up, and 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.

• **Confirm** the conditions if any, for which mock-ups will be acceptable for inclusion in the finished envelope systems.

**Not Done Yet!**
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.

- **Identify** differences between the mock-up/performance testing specimens and the materials and systems approved 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.
• **Monitor** testing procedures and results to confirm compliance with project criteria. Resolve discrepancies or questions immediately.

• **Require** modification to system be documented in the event of changes required due to test failure. This must be documented in detail.

• **Verify** shop and erection drawings and installation instructions are revised to indicate required changes after completion of testing,

• **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.

Now we are done

(With this part)
Fabrication and Delivery

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.
Fabrication and Delivery

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.
Fabrication and Delivery

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.

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.
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:

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

• **Require** inspections of fabricated materials to insure that the required quality is being attained.

• **Monitor** 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.
• **Confirm** delivery dates and location.

• **Confirm** 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 may 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.

• **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.
• **Monitor** packaging practices and procedures. Improperly packaged materials can be damaged to the point of being unusable upon receipt at the job site.

• **Review** the packing lists and manifests to confirm that all of the required components are delivered to the correct location, and on time.

• **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.

• **Require** 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.
Construction Phase

Since this is an imperfect world (and within this world is the very complex and sometimes more imperfect world of construction) there is still a need for the continuation of the QAP through the construction phase of the project.

At the start of the construction phase it is advisable to explain the intent and process of the QAP to all parties. Some 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 support and participation, the results can be impressive.
The efforts required of the QAP may vary by the complexity of the envelope systems, however some general guidelines should be followed for any 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. Address:
  - Phasing and schedule of wall construction.
  - Owner occupancy and ongoing use of the facility (for existing occupied buildings being repaired or retrofit).
  - Review previously constructed wall mock-ups.
  - Review erection and installation drawings and instructions, and systems interface details.
  - Communication between designer, consultants, owners, and contractors.
— Review problem resolution techniques, procedures to be followed.

— Lift schedules where common use of cranes or material hoists is provided.

— Site access for cranes and other equipment.

— Weather limitations for exterior wall work.

— Meeting schedule for coordination with other work.

— 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 procedures and criteria for work in progress.

— Acceptance procedures for completed work.
• **Review** the envelope systems designs, critical details, acceptable and unacceptable practices.

• **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.

• **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. The accepted and approved on-site mock-up demonstrates the acceptable level of quality.

• **Resolve** problems as they are identified, do not procrastinate.

• **Require** a complete set of project documents be available on site at all times, including:
  — Submittals
  — Samples
  — Installation instructions

• **Check** materials which are being incorporated in the envelopes.
  — Read labels
  — Check manufacturer's precautions
  — Compare to approved submittals and project usage.

Refer to these regularly.
• **Establish** clear lines of communications between the designer, consultants, contractor/construction manager, manufacturers/fabricators, and installing or installing contractors.

• **Establish** and foster working relationships with individual as well as organizations.

• **Arrange** access for inspection of the work especially at hard to reach locations.

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

• **Require** “proof” or compliance testing early in the project to detect potential concerns at the earliest possible time.
• **Require** cleaning test areas to establish acceptable methods, tools, and cleaning materials and end results. Document the results and identify an acceptable example area.

  — Involve the manufacturers!

• **Require** acceptance review of work as the work is completed by area.

• **Require** job site weather and progress records.
• **Require** daily reports of work in progress, problems encountered, crew sizes and individuals. These records may prove valuable in problem resolution and can help the exterior wall contractors in planning their work.
Acceptance Phase

To insure the owner has received enclosure systems which meet the requirements of the contract documents:

• **Require** 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** submission of "as-built" records indicating the final construction of the envelope system.
  
  — The project documents should contain detailed procedures for submission of these documents.
• **Review** qualifications of the specialized consultant or testing agency to insure they possess the proper knowledge and experience required to perform and evaluate the results of the in-situ testing procedures.

• **Require** 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.

• **Require** written comments documenting results of reviews and inspections.
  
  — 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.

• **Perform** on-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.
Conclusions

• 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.

• 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.

Although the purpose of this paper is not intended as a “business primer” it identifies not only practices that are professionally sound but are also good for business.
Thank You