REPORT

Commissioning Plan For The Building Envelope

Presented to:

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NOTE: **DISPONIBLE AUSSI EN FRANÇAIS SOUS LE TITRE:**

PLAN DE MISE EN SERVICE DE L'ENVELOPPE DU BÂTIMENT

EXECUTIVE SUMMARY

Inadequate building envelope performance associated with air leakage, vapour diffusion, water leakage and poor thermal performance has substantial consequences for building owners and users. Energy costs increase, user comfort decreases and the owner's repair and capital replacement budgets soar.

Commissioning the building envelope can help control these consequences. The term commissioning, understood by many to be a process which starts at the completion of a project has been modified significantly. Within this document, the commissioning plan extends the building envelope commissioning process from the project brief, through validation of the design, to progressive certification during and possibly following construction.

At the project brief stage the owner must define clear performance requirements for the building envelope. The project design team responds with a progression of validated details from concept to final tender documents which ensures the performance specified in the project brief can be achieved if constructed as specified. During construction, progressive certification of the performance of critical materials, components and assemblies is required to assure the project as constructed meets the same performance requirements. At completion the building envelope may or may not be commissioned as a whole.

Throughout the building envelope commissioning process, from project brief to final construction, the design team requires the guidance of an individual to define initial performance objectives, complete design validation assessments and witness performance tests during and following construction. This individual may be the project architect or another specialist retained by the design team to assume these responsibilities.

The commissioning process described is intended to provide an owner with a building envelope suitable for the particular building at the completion of construction.

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1. INTRODUCTION

The performance characteristics of building envelopes dramatically affect the service lives of many buildings. At the same time building owners' expectations for quality of their indoor environment and durability of their enclosures are rising. It has been suggested that commissioning building envelopes can both improve their long-term durability and improve indoor environment. Commissioning is normally associated with mechanical and electrical systems in a building. It is the process of verifying the performance of completed systems to determine if it complies with the design documents and the specified performance ratings.

To apply commissioning concepts to building envelopes, we need to establish the performance requirements of the installed system and develop methods of evaluating the design to ensure that if constructed as designed, the intended performance will be achieved. These pre-construction steps do not fall into many accepted definitions of commissioning. For this reason alternate terminology has been used in this document such as validation of design concepts and certification of envelope systems during construction. The term "commissioning" has been reserved for the completed system.

This document provides an approach to assuring the required performance of building envelopes. The process begins during development of the design brief and continues through conceptual design during which the building envelope concepts are defined, validated and audited. The tender document phase further defines materials, components and systems together with associated testing requirements during and following construction. During the construction phase, the testing schedule must be approved and mock-ups and test results reviewed to ensure the performance objectives are met.

Throughout the building envelope commissioning process from project brief to final construction, the design team requires the guidance of an individual to define initial performance objectives, complete design validation assessments and witness performance tests during and following construction. This individual may be the project architect or another specialist retained by the design team to assume these responsibilities.

The process of performance assurance extends the concepts found in a previous report entitled "Commissioning and Monitoring the Building Envelope for Air Leakage". The contents of each section of the plan are followed by an example based on the development of a building envelope for a twenty storey brick and steel stud residential building in Ottawa. The final contents of a commissioning plan would include the actual building drawings, specifications and test reports referred to throughout the text.

2. PROJECT BRIEF - ENVIRONMENTAL LOADS AND SPECIFICATIONS FOR THE BUILDING ENVELOPE

Contents:

The project brief must define the environmental design loads on the building envelope. To do so the brief must provide or make reference to other sources that define the exterior environment and interior operating conditions. Since the building envelope includes elements both below and above grade, the environmental loads must be defined accordingly. Expectations of the service life of key envelope components and their performance with respect to air leakage, vapour diffusion, water penetration and energy use must also be defined. The owner's requirements with respect to assuring the performance of the building envelope are also made clear in the project brief, allowing the design team to budget adequate resources to respond during design and construction.

Example

Exterior Environment

- Thermal
  - ⇒ 2 $^1/_2$ % January Design Temperature -25°C
  - ⇒ 2 $^1/_2$ % July Design Temperature 30°C
  - ⇒ Degree Days Below 18 °C 4634
  - ⇒ Soil temperature at 2 m 10°C
- Moisture
  - ⇒ 15 minute rain 23 mm
  - ⇒ one day rain 93 mm
  - ⇒ total annual rain 846 mm
  - ⇒ driving rain index 3 (See Reference 1)
  - ⇒ snow load (S_S) 2.2 kPa
  - ⇒ snow load (S_R) 0.4 kPa

- Wind

⇒ 1/10 hourly pressure	0.30 kPa
⇒ 1/30 hourly pressure	0.37 kPa
⇒ 1/100 hourly pressure	0.46 kPa
⇒ prevailing winter wind direction	NW
⇒ prevailing summer wind direction	SW

- Ground (see test bore data)

⇒ soil type to 2 m	sandy silt
⇒ soil type 2 m - 6 m	bedrock
⇒ water table	3 m

<u>Interior Environment</u>

- Temperature/Humidity

⇒ Residential suites		
	winter	22 °C, 30% R.H.
	summer	25 °C, 80% R.H.
⇒ Swimming pool		
	winter and summer	28 °C, 55% R.H.

- Pressure

⇒ Corridor pressurization with respect to suites	5 Pa

<u>Building Envelope Performance Objectives</u>

- Air Leakage

⇒ Overall building envelope air leakage not to exceed	0.2 L/(s * m^2) @ 75 Pa
⇒ Air leakage of the penthouse walls not to exceed	0.15 L/(s * m^2) @ 75 Pa
⇒ Wall air leakage (excluding windows and patio doors) not to exceed	0.1 L/(s * m^2) @t 75 Pa

⇒ Window and patio door air leakage	not to exceed the limits prescribed in CAN/CSA-A440.1, "User Selection Guide" of the CSA A440 standard on windows
⇒ Soffits and overhang air leakage not to exceed	0.1 L/(s * m^2) @ 75 Pa
⇒ Air leakage at joints between air barrier components not to exceed	0.25 l/s * m @ 75 Pa

- Vapour Diffusion

⇒ No accumulation of moisture within wall roof and soffit sections detrimental to material, component or system durability	
⇒ Permeability of the finish on the high vapour pressure site of wall and roof assemblies	$\leq$45 ng/(Pa * s * m^2)

- Water Penetration

⇒ No water shall penetrate the building envelope leading to material, component or system durability problems, or affect the serviceability of interior space at design wind pressures or at the exterior environmental conditions noted for below grade space

⇒ Water penetration shall be controlled through application of pressure equalized rainscreen principles for all wall, window and skylight systems, and walls shall achieve 95% pressure equalization

⇒ Water penetration through windows and sliding door assemblies shall conform to CAN/CSA-A440.1, "User Selection Guide" for windows.

⇒ Surface water flow over the building envelope will be minimized through architectural design, and selection of moisture resistant materials

- Energy Use and Comfort

⇒ The building envelope must control interior surface temperatures such that no condensation exists on glazing at design relative humidities at an exterior temperature of -15 °C or on any opaque element at the winter design exterior temperature

⇒ The building envelope design must meet all the basic requirements of ASHRAE Standard 90.1

⇒ The purchased energy must not exceed 55% of the energy budget of the reference building defined in Section 13 of ASHRAE Standard 90.1

- Performance Assurance

⇒ Design concepts and details shall be validated during the design process to ensure the performance required can be achieved. Validation may take the form of recognized computer simulation, documented field performance or testing.

⇒ Tender specifications will define details critical to achieving building envelope performance

- Durability

⇒ Key elements of the building envelope must provide 35 year durability (where maintenance is expected during this period to assure this durability, maintenance requirements for the various envelope components must be outlined in the operation and maintenance manual)

1. Boyd, D.W. Driving Rain Map of Canada, National Research Council of Canada, Division of Building Research, Technical Note. No. 398, 1963.

3. BUILDING ENVELOPE CONCEPTUAL DESIGN AND VALIDATION PROCESS

Contents:

Each of the key building envelope systems including the air barrier, vapour barrier, the approach to water penetration control and energy control requires development during the conceptual design process. Many of these elements interact in the building envelope necessitating checks on capability of materials, functions of systems and validation to ensure they will perform as intended if they are constructed as drawn and specified. There is a separate conceptual design and validation process for each element.

Air Barrier System Design and Validation

The air barrier system design process includes the following key steps:

- specification of air barrier materials with known air permeability characteristics.
- assessment of air pressure loads and details of the air barrier system to allow transfer of these loads to the structure.
- specification of overall building air leakage restrictions and air leakage restrictions on key elements such as curtain walls and windows.
- general requirements regarding continuity of airtightness throughout the envelope. Specific contractual responsibilities for making the various connections between elements may or may not have been defined.
- air barrier system design must be validated for basic characteristics of air impermeability, continuity, structural capacity and durability; and
- an audit process must be completed at the conclusion of the design stage which determines that the air leakage rates of all the elements proposed will, in combination, fall within the overall building specifications for total air leakage.

Other Envelope Components

Similar design and validation processes would apply to the other envelope components.

Example

Air Barrier System

Documenting the design and validation process results in the following record of material system design and validation with respect to airtightness:

- Air Permeability

  The primary air barrier material to be used on this project is to be 1.3 mm modified asphalt self-adhesive membrane applied over exterior grade glass fibre reinforced gypsum board on exterior walls of the residential suites, and applied on concrete block back-up walls for the swimming pool.

  The air permeability for this material is 0.0 $L/(s*m^2)$ @ 75 Pa from manufacturer's tests.

  The membrane system on the exterior walls is penetrated by brick ties and insulation fasteners. An identical system, tested on site, according to the modified ASTM E783 procedures for the same owner demonstrated an air leakage rate of 0.12 $L/(s*m^2)$ @ 75 Pa. The test rest results are recorded in a report titled "Air Leakage of Wall System for the ABC Building" dated May 5, 1992.

- Continuity

  At windows and doors, the self adhesive modified asphalt membrane is carried into the rough opening prior to window and door installation. The space between the window or door frame and the adhesive membrane is filled with two component foamed in place polyurethane to maintain continuity at these locations.

  The testing program on the windows was extended to cover the window/wall junction constructed in accordance with these details. Leakage at the window perimeter was shown to be 0.18 $L/(s*\ m)$ at 75 Pa. The test results are recorded in a report titled "Air Leakage Test - CDE Windows Inc." dated July 6, 1990.

  Differential movement due to creep of thebuilding's concrete frame is accounted for in the steel stud exterior wall and by leaving a small horizontal fold in the membrane of each floor line. This detail has been mocked-up in a laboratory and tested for airtightness of 75 Pa; the detail met the air leakage criterion of 0.1 $L/(s * m^2)$ specified for walls.

- Structural Capacity

  The proposed self-adhesive membrane was tested under positive and negative pressures of 2.5 kPa and reported in the documents referred to above. No loss of airtightness was recorded.

  The structural engineer must determine loads on the air barrier and substrate and confirm the loads can be adequately transferred to the structure via back-up material s and fastenings.

- Durability

  Self-adhesive modified bitumen membranes have been in use as air barriers for at least the past eight years. The owner has recorded no durability problems with these membranes provided the original construction was of good quality.

Once the performance of materials, components and assemblies in the air barrier have been validated, an audit of the overall design is to be undertaken to establish if it meets the specification for complete building air leakage as described in the project brief.

Table 1 shows a typical spread sheet devised to allow iteration between the allowable leakage required by the design brief and actual leakage rates for each element that emerges from the design validation described above. Care must be taken at this stage to identify all elements and their intersections correctly. If the actual total envelope leakage does not exceed the total specified in the project brief, the design meets the owner's requirements for total air leakage.

Table 1

	Area	Allowable Air Leakage Rate l/s	Total Allowable Element Leakage l/s	Actual Air Leakage Rate l/s	Total Actual Element Leakage	Validation Method
North Wall	750	0.30	225	0.12	90	1
South Wall	750	0.30	225	0.12	90	1
East Wall	1200	0.30	360	0.12	144	1
West Wall	1200	0.30	360	0.12	144	1
Punched Windows	3900	0.10	390	0.08	312	2
Main Roof	900m²	0.15	135	0.13	117	3
Penthouse Roof	100m²	0.15	15	0.13	13	2
Roof/Wall Junction	210	0.20	42	0.18	38	4
Window/ Wall Junction	8600	0.20	1720	0.18	1548	2
Total envelope			3472		2496	

Table 1

1. Report titled "Air Leakage of Wall System for ABC Building" dated May 5, 1992.
2. Report titled "Air Leakage Test - CDE Windows Inc." dated July 6, 1990.
3. Manufacturer's test data of July 10, 1991.
4. Field test on same detail XYZ Building — March 1991.

This simplified example shows how the audit confirms that the air leakage limits established in the project brief are met within the design. Notes on the design validation method are also necessary for record purposes.

Vapour Barrier Selection and Validation

- Materials and Permeability
  - ⇒ The vapour barrier on this project is composed of the paint system on the drywall within the residential suites (alkyd primer and two finished coats)
  - ⇒ Exterior walls of the swimming pool are composed of concrete block with an epoxy paint interior finish (1.5 mm dry thickness)
  - ⇒ The permeability of each paint film has been validated by manufacturer's tests for the coating thickness specified. Permeability has been verified at 45 ng/(Pa * s * m^2) for the suites and 15 ng/(Pa * s * m^2) for the swimming pool following CGSB 0.15 and modified CGSB 0.15.
  - ⇒ The vapour barrier in the roof system is made up of the two-ply torch applied roofing membrane applied to the concrete decks.
  - ⇒ The vapour barrier between the floor of suites and the parking garage below is composed of the structural concrete 200 mm in thickness.
  - ⇒ CMHC's "Emptied" program run (to be attached) indicates no condensation planes or moisture accumulation
  - ⇒ The paint finishes would be expected to be re-coated at ten year intervals with an inspection carried out every 5 years.

Water Penetration Design and Validation

- Water penetration control is achieved with this design through the application of rainscreen principles in all wall and window elements.
  - ⇒ The wall air barrier (peel and stick membrane over glass reinforced gypsum board) forms a watertight barrier flashed to the exterior at shelf angles as well as a stiff plane of airtightness at the back of the drained cavity. The brick cladding placement provides a cavity of 25 mm vented and drained to the exterior. Rainscreen compartment boundaries are established by the use of vertical sheet metal baffles that coincide with brick control joints, 600 mm from the exterior corners of the principle elevations, and by extending the line of the window jambs down in each suite. Sketch "A" (to be attached) shows the rainscreen compartment boundaries. The area of venting connecting the cavity air space and exterior has been calculated using the CMHC "RAIN" program and provides 98% pressure equalization. Venting arrangements are also shown in Sketch A.

Windows have been selected based CAN/CSA A440.1, "User Selection Guide". Each section has been selected to provide a drained and vented glazing rabbet to increase sealed unit life. Test results for water penetration in accordance with CAN/CSA A440 are attached.

⇒ The joints between above grade windows and walls are accomplished with a combination of peel and stick membrane backed by sheet metal and sealed with compatible sealants. These connections were validated for air and water leakage by extending the standard CAN/CSA A440 test protocol to include the window/wall connection.

⇒ Below grade walls are water proofed with a liquid-applied polymer-modified asphalt applied at a dry thickness of 3 mm. Manufacturers test results regarding water tightness are attached.

⇒ The roof deck is concrete sloped 2% to internal drains. Waterproofing is provided by a torch applied two-ply SBS modified asphalt membrane which is carried across the deck and up and over the parapet. Connections between the wall air barrier and roof membrane are made at both parapet and penthouse locations. Roofs using this waterproofing have been in service for at least 20 years with good results.

<u>Energy Use and Comfort Design and Validation</u>

Our building is designed to operate at 55% of the energy cost budget for the reference building on our site calculated in accordance with ASHRAE 90.1. The following envelope thermal characteristics have been included:

⇒ RSI 3.5 low density insulation in the suite exterior wall studs

⇒ RSI 1.32 rigid glass fibre insulation external to the air barrier

⇒ RSI 3.5 polystyrene roof insulation located above the membrane

⇒ Suite windows with ER ratings of -10

⇒ Thermal bridges have been minimized at shelf angles by employing stand-off brackets at the floor slabs

⇒ Brick ties wrap around the studs with their slotted ends buried in the exterior insulated sheathing

Condensation potential at windows has been limited to design requirements based on appropriate selections from CAN/CSA-A440.1 rated windows. Window sills and jambs have also been reviewed for thermal bridges caused by window connection details.

4. TENDER DOCUMENTS: BUILDING ENVELOPE DETAILS AND SPECIFICATIONS

Contents:

Tender drawings for most buildings will include key sections of all walls, roofs and soffits in the project. Details (often best provided in isometrics) of window/wall junction, wall/roof junction, and all major penetrations of walls and roofs are employed to show transitions from one plane to the next to ensure a contractor and the respective trades can understand how air barrier systems, vapour barriers, rain penetration control and thermal insulation are co-ordinated and accomplished. The specifications contain details on the type of materials, preparation of substrates and appropriate installation procedures. Requirements for quality compliance during and following construction of the key envelope elements are also called up together with responsibilities of the contractor, designer and sub-trades.

<u>Example</u>

Air Barrier Details and Specifications

- Drawings show a continuous air barrier around the entire building envelope perimeter including slabs-on-grade, suspended slab between the suites and parking garage, foundation, above-grade walls and roofs, windows and skylights. This has been confirmed by following the line of airtightness around the building without raising the pencil.

- Drawings clearly indicate which material, component or system is required to provide the required air barrier performance by noting "air barrier" behind the material, component or system label.

- Details showing air barrier penetrations and junctions include:
  - ⇒ slab-on-grade to foundation wall
  - ⇒ penetrations of suspended slab between suites and parking garage for mechanical/electrical
  - ⇒ electrical service entry
  - ⇒ main wall and wall/window connections (isometric)

⇒ main wall at exterior columns, slabs and roof/wall connection

⇒ duct penetration of exterior wall for typical suite

⇒ swimming pool exterior walls and wall/roof detail

⇒ entry soffits

⇒ garbage room doors

⇒ penthouse to roof connection

⇒ where required, trade sequence and responsibility is shown

- Specifications provide minimum material qualities for air barrier materials, tapes and sealants including thickness or gauge, air permeability, reinforcement or structural back-up, limits with respect to temperature, humidity or wetness, application procedures and required compatibility checks for adjacent materials. This information has been taken mainly from manufacturer's data.

- Construction of mock-ups of key details is required at the earliest possible stage in the construction process including: typical wall area inclusive of membrane brick ties and insulation fasteners; window/wall junction; ventilation duct penetration; roof/wall junction; penthouse to roof connection. These mock-ups are part of finished construction and all mock-up costs are to be carried by the contractor.

- Visual review of the mock-ups for conformance with drawings and specifications will be followed by air leakage and structural air barrier testing. (These tests will be conducted in substantial conformance with ASTM E783-91 "Field Measurement of Air Leakage Through Installed Exterior Windows and Doors" or ASTME-1233-88 "Standard Test Method for Structural Performance of Exterior Windows, Curtainwalls and Doors by Cyclic Static Pressure Difference" as appropriate). The contractor is to provide a unit price for the construction of airtight steel stud and drywall boxes to isolate exterior wall elements for testing. Each box will be approximately 3 m in width, 1 m in depth and extend from floor slab to floor slab.

- The mock-ups must meet the following requirements for air leakage:

⇒ wall area 0.1 $L/(s * m^2)$

⇒ all joints/connections 0.25 $L/(s * m^2)$

- Testing will be paid for by the owner except that where the test results are not achieved, in which case additional testing shall be paid for by the contractor.

Vapour Barrier Details and Specifications

- The drawings indicate clearly that the paint finish forms the vapour barrier on this project.
- The specifications provide detailed material properties with respect to vapour permeability and coating thickness. Substrate preparation, application conditions and drying requirements are specified.
- During construction, paint application and film thickness will be monitored.
- The owners maintenance manual highlights the need to maintain the vapour barrier paint finish based on monitoring of the quality of the finish at five year intervals.

Water Penetration Details and Specifications

- Drawings show flashings of SBS modified air barrier material connected to the air barrier membrane and sloped to the exterior at the shelf angles and above windows and doors. End joints in this flashing require overlapping and sealant.
- Window-wall details include head, jamb and sill details indicating how the air barrier and wall flashings work together to shed any water to the exterior. Within the window section, drainage is indicated from the glazing rabbet.
- At parapets, the roof membrane is made continuous with a flexible flashing (sealed at side and end joints) that carries across the top of the parapet and down the exterior cladding 50 mm.
- At duct penetrations in suite walls, a flashing carries water to the outside face of the brick.
- At soffits above the entrance, a drip is formed in sheet metal flashing to ensure water drops clear of the linear metal soffit.
- Foundation wall details show the application of liquid applied waterproofing and separation board.
- The specifications provide flashing and waterproofing material specifications, compatible sealants, substrate conditions and application requirements.
- Overall water leakage will be tested on the mock-ups described under the air barrier specification above in substantial conformance with ASTM E 1105 when tested at a pressure difference of 75 Pa and with a water application rate of 3.4 L/m^2min, no water shall penetrate the envelope assembly.

Energy Use and Comfort Details and Specifications

- The drawings indicate insulation materials, continuity and fastening systems. The responsibility for each trade is noted, particularly around service penetrations and junctions between walls and windows, and windows and roofs.
- Details of the shelf angle offsets and brick-ties are provided to ensure thermal bridging is no greater than that included in the ASHRAE 90.1 calculations.
- Specifications include minimum RSI values for each type of insulation, board sizes, and application requirements including fastening type and frequency & compatibility with other materials.
- The mock-ups described under the previous section on air barrier details will be reviewed for compliance with drawings and specifications.

5. BUILDING ENVELOPE CERTIFICATION DURING CONSTRUCTION AND FINAL COMMISSIONING

Contents:	This section should contain an approach to carrying out the envelope testing during construction and if specified, testing of the overall building envelope. Key elements of the plan will include identification of who is designated to call for the testing or certification, who must witness the tests, how results are reported and what follow-up action is to be taken.

Example

Vapour Barrier, Water Penetration and Thermal Performance Certification During Construction

- The design team will nominate one individual to call for certification of each of the key elements of the building envelope during construction.
- The contractor shall provide time frames within the construction schedule for mock-up construction, visual evaluation and testing as per the specifications.
- Mock-ups will be reviewed by representatives of the design team and a building envelope specialist (if required) to establish the mock-ups conform to the drawings and specifications based on visual inspections.
- Testing of each element will commence at the call of the design team. Analysis of the test results will be reported to the owner and the contractor. If performance objectives have not been achieved, the contractor shall undertake remedial work and assume the cost of re-testing.
- Mock-up construction that is accepted as constructed and tested will form the basis for the remainder of construction.
- The design team will carry out periodic field reviews during the remainder of construction to assure the building envelope meets the performance objectives.
- No full building post-construction commissioning of the building envelope has been specified.