Specifying Infrared Thermographic Services For Large Buildings

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ABSTRACT

The commercial building industry employs generic formats for written specifications that form part of the contract tender documents. The Canadian National Master Construction Specification (NMS) is the generic specification format used extensively in the Canadian construction industry for new and retrofitted commercial building projects. The NMS Secretariat, through consultations with the building industry and departmental experts in Public Works and Government Services Canada (PWGSC) contracted the development of four new specification sections for commonly implemented infrared thermographic services associated with building construction and maintenance. These include inspection services for building envelopes, roofs, mechanical equipment, and electrical systems. This paper will highlight the important differences of each type of inspection service, explaining the need to develop individual specification sections to correspond to each type of infrared thermographic inspection service. These sections include all aspects of such services.

The NMS maximizes protection against duplication and errors, while minimizing the chance of risk, misunderstanding and liability. NMS is adaptive, and can be adjusted to any size and type of construction project, and for either the government or the private sector. Building owners and property managers can integrate these thermographic specifications into their Project Manuals or incorporate them into contractual documents to call up services for building condition studies. Although the NMS was designed primarily for use in the commercial and light industrial building industry, the residential construction industry can benefit as well, by modifying any section for their use. This paper will discuss these differences, and provide suggestions for the development of such a residential specification format.

INTRODUCTION

Although some standards and guidelines have been developed for the used of infrared thermography in specific applications over the last 30 years, there has not been any concerted effort by specification writers to standardize call up for services in the building industry. The NMS Secretariat within the Canadian Federal Government's Department of Public Works and Government Services Canada (PWGSC) felt that there was sufficient information within the industry to produce generic specifications for the use of infrared thermographic equipment in building inspections and assessments.

NATIONAL MASTER SPECIFICATION (NMS): WHAT IT IS, WHAT IT DOES FOR THE INDUSTRY AND HOW IT IS USED

For over 30 years, the Canadian National Master Construction Specification (known as the NMS) has been leading the way, providing the Architectural, Engineering and Contracting (AEC) community with the largest bilingual generic master construction specification commercially available in North America. Since the 1970's, the NMS has spearheaded many Federal Government initiatives, which resulted in many improvements to the construction industry in Canada. Achievements include changes to building accessibility, sustainable development in construction practices, LEED® requirements, performance specifications for design-build type contracts, and building communications and security. The latest innovation for specification writers and practitioners of building sciences is a tool for *Specifying Infrared Thermographic Services for Large Buildings*.

The NMS is a comprehensive library of construction specification sections used by government and private industry. Specification writers and other construction specialists use it as a tool to produce clear, complete and accurate specifications for inclusion into construction project manuals. As a guide specification and as a delete master, the NMS is designed to produce construction contract documents that are easy for contractors to understand, reducing the risk of misunderstandings and litigation.

All Canadian Government retrofit and new construction is mandated by Departmental Policy 039 – *The Use of the NMS*, in using the latest version as the basis for developing the Project Manual, or more specifically the project construction specifications. The Department of National Defense (DND) uses the NMS for all of its construction work, including military quarters, even though the document is intended for commercial applications. In addition, the NMS is used throughout Canada by non-federal government organizations, by architectural and engineering design offices either directly or as a tool for updating their “office” master specification system.

OTHER MASTER SPECIFICATION SYSTEMS IN USA

The two most well know master specification systems in the USA are:

- MASTERSPEC®, published by Architectural Computer Services Inc., (ARCOM) exclusively for the American Institute of Architects (AIA).
- SPECLINK®, published by Building Systems Design Inc., (BSD).
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NMS FORMAT STRUCTURE

The style, language and format of the NMS follows the recommendations of the Construction Specifications Canada (CSC), *Manual of Practice*, published in 2006. In the United States of America, the counterpart of CSC is the Construction Specifications Institute (CSI). CSC and CSI have jointly produced a master list of numbers and titles for the construction industry in North America called *MasterFormat™ 2004* (MF04).

The structure of the NMS follows a standard filing and retrieval scheme allowing specification sections to be classified by work results and construction practices. The Groups, Subgroups and Divisions are in accordance with this classification system, and use the MF04 as a basis for its Section Numbers and Titles. The NMS follows the recommendations of CSC/CSI’s *PageFormat™* and *Section Format™* documents to ensure consistency in the way information, article names and paragraphs and the layout of content of individual sections appear.

WHY GENERIC SPECIFICATIONS FOR THERMOGRAPHIC SERVICES

Over the past decade there has been resurgence in the use of infrared thermographic equipment for assessments of building systems performance. The 1990’s saw the development of truly portable equipment aimed at electrical and mechanical systems assessments. Now, these applications are well established throughout North America. The refinement of equipment for these market sectors has put low cost, portable, user-friendly imagers and radiometers into the hands of more people, who may or may not be trained in the operation of the equipment. In addition, these users may not have the suitable disciplinary or professional expertise to render accurate analysis and provide clients with adequate assessments.

The time was right to develop a series of sections within the NMS that dealt with the complexities and variables newly introduced to the market place by equipment manufacturers and the building industry. With the establishment of the methodologies as relevant building condition assessment and commissioning procedures, it was important to define not only what type of equipment was suitable for each application, but also what the qualification requirements should be for equipment operators and report authors. This type of information would allow for better self-regulation of the industry and ensure adequate services by all infrared thermographic service providers.

BUILDING SYSTEMS THAT UTILIZE THERMOGRAPHIC ASSESSMENT PROCEDURES

Different applications of infrared technology were examined, and we determined that there was sufficient diversity within four distinct building systems that each required their own section to deal with thermographic assessment services. The NMS has developed four separate sections on thermographic assessments for a) electrical systems, b) mechanical equipment, c) roofing and d) building envelopes. The electrical and mechanical systems sections are relatively straightforward and cover all components of these systems that could be inspected with infrared thermographic equipment. The roofing section focuses on the inspection of low-sloped roof assemblies with permeable insulation. The section on building envelopes is the most complex because it deals with applications related to detection of defective insulation, air leakage, voids and moisture on surfaces and interstitial spaces within the building envelope. In most cases, specific standards and guidelines are available for quotation in these sections to define inspection methodologies. Where standard procedures have not yet been developed, (as in the case of moisture detection by means of phase change), procedures had to be spelled out in the appropriate section.

THERMOGRAPHIC EQUIPMENT USED IN BUILDING SYSTEM ASSESSMENTS

Current infrared systems can be broken down into various generic types based on the following general criteria:

- Detector Image Size: (FPA row/columns of: 80 x 60, 100 x 100, 160 x 120, 320 x 240, or 640 x 480 pixels)
- Wave Length: Short Waveband (1.5 – 3 μ); Mid Waveband (2 – 6 μ); or Long Waveband (7 – 14 microns)
- Detector Type: Thermal (Microbolometers, Ferroelectric), Photon (InSb, PtSi, QWIP)

The level of complexity increases exponentially once you factor in all the hardware and software considerations that need to be taken into account for these types of imaging and measurement systems. Table Number 1 lists the technical specs along with optional features offered for present day infrared equipment:

TECHNICAL SPECIFICATIONS	OPTIONAL FEATURES
Detector Array Size and Type	Weight, size, ergonomics
Lens Field of View and Interchangeability	Batteries
Spatial Resolution (IFOV expressed in milliradians)	Display; LCD, Viewfinder, both
Measurement Resolution (Distance to Measurement Spot Ratio)	Visual Imaging and Fusion capabilities
Detectable Temperature Range	Video, flash capture
Calibration range (may be different from Temperature Range)	Supplemental lenses
Radiometrics (Accuracy and repeatability)	Text and Voice Annotation
Operating Temperature Range	Manual vs motorized focus
Thermal Sensitivity (NETD)	Laser Pointer
	Image Storage Capacity and Media
	Onboard Software Features
	Image Analysis and Reporting Software

Table #1: Technical specifications versus optional features for infrared equipment.[14]

Over the past few years, commercial infrared thermographic equipment manufacturers have introduced a wide range of low cost imagers and radiometers with varying specifications for a wide range of applications. These new systems (generally with 20,000 detectors or less) primarily target the predictive maintenance fields of electrical and mechanical systems inspections, along with conventional roofing assembly inspections. Confusion within the market place arose when operators with these types of equipment branched out into other large building inspection services without regard for the necessary technical requirements of equipment used in exterior inspection work.

Given the broad range of infrared thermographic equipment on the market today, the intent of inspection and assessment specifications is to ensure that suitable equipment is used in each type of applications to meet current standards and guidelines. Where these practices are not presently defined, suitable procedures are specified related to specific equipment and their use.

With the current resurgence of the building inspection market, it is important that specifications deal with the technical requirements of the equipment, the thermographer, and the professional requirements of the person analyzing the thermal imagery and providing recommendations to clients. In the building industry, there is a clear delineation between the roles and responsibilities of trades people, technicians, and professionals from each discipline. Different groups in the residential and commercial building sectors meet these responsibilities. In most cases, warrantee and liability issues dictate who assumes jurisdiction.

The specific sections dealing with thermographic assessments within the NMS identify the varying requirements for equipment, equipment operators and report authors providing analysis and recommendations for future actions and retrofit options. Each of these requirements differs within each section since the disciplinary expertise required comes from different professional and technical authorities. The NMS specifically targets commercial building projects where professional jurisdiction is exercised according to building ordinances. For the most part NMS specifications are not used in low-rise residential projects but are applicable in the high-rise sector where professional jurisdiction is required by law.

DIFFERENCES BETWEEN RESIDENTIAL AND COMMERCIAL APPLICATIONS

There are clear differences in the requirements for equipment specifications, equipment operator knowledge and qualifications and report author disciplinary knowledge and qualifications for low-rise residential applications compared to large commercial buildings and high-rise residential. Although NMS' primary market is the commercial building sector, understanding these differences allows the NMS format to be modified for use in the low-rise residential sector.

On the equipment side, the primary difference is the shorter distance to target surfaces for all applications (electrical, mechanical and building envelope) in residential inspections. This allows for the use of smaller focal plane array (FPA) infrared equipment. Interior inspections are the norm since most relevant information can be obtained easily with these inspection procedures. Low temperature operating specifications for equipment used inside are less stringent than equipment required for use outdoors during cold winter months. Equipment used for commercial building applications requires larger FPA's and telephoto lenses to deal with greater distances to target surfaces. Greater variability in job site conditions for electrical and mechanical systems may require the use of wide-angle lenses as well as mandatory personal protective clothing due to greater system loads. The design of equipment for use with protective clothing and gloves set them apart from residential inspections that do not necessarily require such clothing protection.   Exterior inspections are the norm for large building envelope studies and low operating temperature requirements are a primary requirement for cold weather testing.

Equipment manufacturers today make equipment dedicated to specific applications and it is imperative that specifications detail the appropriate requirements for equipment used for each type of application for either low-rise small buildings versus large or high-rise commercial buildings.

The level of professional or disciplinary knowledge required to carry out infrared thermographic assessments between low rise residential and high-rise commercial buildings is significantly different, and specifications need to address these issues. In many instances, complex building system inspection procedures and assessments are not defined by present standards and guidelines. Thus more qualified professionals are required to develop inspection and assessment procedures specific to the job at hand.

STANDARDS GOVERNING INFRARED THERMOGRAPHY

In Canada, standards for infrared thermography are developed through the Canadian General Standards Board (CGSB) and Non Destructive Testing Board (NDT). In the United States, these standards are developed through the American Society for Testing and Materials (ASTM) and American Society for Nondestructive Testing (ASNT).   These organizations joined with the American National Standards Institute (ANSI) to become a part of a national body coordinating standards development. ANSI has become an umbrella standards organization coordinating the development of worldwide standards.   The International Standards Organization (ISO) is another organization developing worldwide standards. Both ANSI and ISO work independent of each other, but much of their work overlaps in many fields. Canada and the USA provide representatives to many of the standards being produced by both organizations.   In Europe, thermographic standards are developed through the ISO. ISO standards are used to develop national standards in European countries. All these organizations operate as truly voluntary consensus groups. Standards from each organization are written by groups of end users representing customers, service providers and general interest groups.

The NMS references over 400 consensus standards throughout the 750 individual specification sections, and include predominantly: the American Society for Testing and Materials International (ASTM), the Canadian Standards Association (CSA International), the Canadian General Standards Board (CGSB) and Underwriters' Laboratories of Canada (ULC). Of concern to this paper, are the four types of ASTM standards: Test Methods, Specifications, Practices and Guides.

- **Test Methods**: a definitive procedure to produce a specific result with a specified precision. (i.e. ANSI/ASTM E1213 Standard Test Method for minimum resolvable temperature difference for thermal imagers)
- **Specifications**: are explicit sets of requirements for materials, products, systems or services. (i.e. ANSI/ASTM CP-189 ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel)
- **Practices**: are a definitive set of instructions for performing specific operations that do not produce a definitive test result (i.e. ANSI/AST C1153 Standard Practice for location of wet insulation in roofing systems using infrared imaging)
- **Guides**: are tutorials indicating how something is meant be done and provide recommended but non-mandatory guidelines on things to be considered. (i.e. E1934 Standard Guide for examining electrical and mechanical equipment using infrared thermography)

The purpose of these documents is to establish a set of uniform expectations between people who want the work done and those doing the work. For this reason, they are the corner stones of information used by all sections of the NMS.

ASNT is also under the ANSI umbrella. Its function is to promote standards for personnel qualifications and certification in nondestructive testing technologies. It publishes the authoritative standards for personnel training and qualifications in nondestructive testing. These include SNT-TC-1A and CP-189.
ASNT-CP-198 is an ANSI/ASTM specification. To conform to this standard, a person must comply with all of the requirements within CP-189 plus any additional specific requirements requested by the user.
ASNT-SNT-TC-1A is an ANSI/ASTM guide. It is similar to a specification in content but meant to be modified by users to meet specific needs. The actual requirement to be compliant with SNT-TC-1A is to have a written practice, keep records in accordance with your written practice and do what you say you will do.

Standards provide a basis for common understanding among people. They are completely voluntary to users unless they are legislated into law. One such recognized standard in some states and provinces in North America is the National Electric Code (NEC) administered by the National Fire Protection Association (NFPA). Another such standard is NFPA 70E, Standard for Electrical Safety in the Workplace. This standard is legislated by the federal government and adopted into law in the Code of Federal Regulations (CFR).
The NMS, in its quest to produce a set of uniform expectations between people who want the work done and those doing the work, utilizes the guidelines and standards developed by ASNT to specify the qualifications of personnel providing services.[16]

NMS CONTENT STRUCTURE:

When calling up requests for services for infrared thermographic assessments, it is important to specify the following items for each type of inspection:

- Reference the appropriate standards having relevance to the work to be performed
- Definition of the most relevant terms found in the request for services
- State the submittals being requested; include relevant information to be included in the report along with appendices and additional back up documentation.
- Reference qualifications required by equipment operators, analyzers and report authors.
- Itemize the scheduling requirements.
- Itemize specifications for equipment required to carry out work.
- State requirements for examinations of relevant bid and as built documents.
- List required items to be carried out in preparation of field inspections.
- List general field inspection requirements.
- List specific inspection requirements for each type of infrared thermography inspection methodology being requested.
- List data and information to be recorded as part of the inspection services.
- List re-inspection requirements if remediation work is carried out.
- State cleaning requirements and job site status after inspection services.

Since the technical requirements for the four basic types of infrared thermographic assessment within buildings vary significantly, each should be specified separately. The personnel qualifications required for residential inspections will vary from those required for large building inspections. The qualifications of technical and professional personnel for each of the applications for large buildings are unique, and need to be made explicit.

Equally important are the technical specifications of the equipment used in each type of assessment and the limitations of each type of equipment used in a specific inspection procedure. Each part of the four sections dealing with thermographic assessments has unique requirements that do not necessarily relate to the other sections.

THERMOGRAPHIC ASSESSMENT: ELECTRICAL SYSTEM

Section 02 27 23 of the NMS deals with all the items listed above in the NMS content structure. Appropriate references are provided, along with standard definitions. All submittals by the contractor are listed along with quality assurance and qualification requirements of operators, reporters and report authors. It is important to note that Level II thermographer certification is proposed as a minimum requirement for both equipment operators and report authors dealing with large building electrical system assessments. For low-rise residential electrical equipment assessments, Level I thermographer certification is acceptable.

Equipment requirements are listed not only for infrared thermographic equipment but also for all other related equipment needed to carry out assessments. This section does not limit the use of low-resolution radiometers in assessments, but does place maximum distance restrictions on specific types of infrared equipment based on spot size resolution and measurement resolution of critical components. These limitations are listed in the thermographic inspection procedures because they are not spelled out definitively in referenced guidelines and standards. Interior inspections are suitable with 3 mrad IFOV radiometers while exterior inspections are limited to 1.5 mrad IFOV radiometers. 3 mrad IFOV equipment need to limit distance to target surfaces to 2 m, while 1.5 mrad IFOV equipment is limited to 4 m distance to target surfaces. Distances greater than these require the use of a telephoto lens to ensure accurate temperature measurements.

Appropriate inspection and re-inspections procedures are defined, along with a list of recorded data necessary for inclusion in the deliverables as indicated in the submittal section.

THERMOGRAPHIC ASSESSMENT: MECHANICAL EQUIPMENT

Section 02 27 19 of the NMS deals with all the items listed above in NMS content structure. For the most part, the technical details for qualifications of equipment operators and report authors and specifications for infrared and other related equipment are almost identical to those found in section 02 27 23, electrical equipment. It is important to note that Level II certification is proposed as a minimum requirement for both equipment operators and report authors when dealing with large building mechanical system assessments. For low-rise residential mechanical equipment assessments, Level I thermographer certification is acceptable.

This section does not limit the use of low-resolution radiometers in assessments but does place maximum distance restrictions for specific types of infrared equipment based on spot size resolution and measurement resolution of critical components. These limitations are listed in the thermographic inspection procedures because they are not spelled out definitively in referenced guidelines and standards. Interior inspections are suitable with 3 mrad IFOV radiometers while exterior inspections are limited to 1.5 mrad IFOV radiometers. 3 mrad IFOV equipment need to limit distance to target surfaces to 2 m, while 1.5 mrad IFOV equipment is limited to 4 m distance to target surfaces. Distances greater than these require the use of a telephoto lens to ensure accurate temperature measurements.

Sections 02 27 19 and 02 27 23 both stress temperature measurement procedures as the primary means of fault detection and assessment of severity. Spot size resolution is critical to temperature measurement and assessment of fault severity.

THERMOGRAPHIC ASSESSMENT; ROOFING

Section 02 27 16 deals with all the items listed above in NMS content structure. The significant difference between the electrical and mechanical equipment sections and this one is that this section is focused on qualitative fault detection only. Since the methodologies primarily employed to detect moisture in roof insulation are transient heat flow procedures, absolute temperature measurement is not relevant. As such spatial resolution of equipment is the key equipment specification requirement. Most roof inspections are carried out from the exterior. As such, 3 mrad IFOV imagers are suitable for roof inspections where maximum distance to target surface is limited to 10 m. These are appropriate distances for walk on roof inspections. Where inspections are carried out from other rooftops or by aerial means (fixed wing airplanes or helicopters) telephoto lenses or imagers with greater spatial resolution are required to maintain acceptable levels of spatial resolution for pattern recognition of detailed faults.

It is important to note that Level I thermographer certification is proposed as a minimum requirement for equipment operators and level II thermographer certification along with expert knowledge of roofing assemblies is required for report authors when dealing with large building low sloped roof assessments. There is little requirement for low-sloped roof inspection services in low rise residential and therefore is not addressed in the specifications.

THERMOGRAPHIC ASSESSMENT: BUILDING ENVELOPES

Section 02 27 13 is by far the most complex of all the sections dealing with thermographic assessment of building systems. Even though the procedures are primarily qualitative (due to the transient heat flow characteristics of envelope assessments), there are still some procedures that can be carried out in which steady state conditions apply and quantification of data is necessary for the determination of fault severity.

Imagers with 3-mrad IFOV spatial resolution are acceptable for work on interiors, provided they are operated within 5 m of their target surfaces. Imagers with greater spatial resolution are required for exterior inspections where distances to target objects increase to more than 50 m and larger FPA's or telephoto lenses help to ensure acceptable levels of spatial resolution for potential faults. Another important issue that is specific to building envelope inspections relates to the need for greater thermal resolution requirements for the detection of certain faults related to imbedded moisture and convective heat flow within assemblies. Imagers are required to have a minimum of 0.1^{o}C and preferred 0.05^{o}C thermal resolution specification for all types of spatial resolution imagers used in both interior and exterior inspections.

This section deals with a number of different assessment procedures that are related to one another. These include inspection procedures for the determination of insulation defects, thermal bridges, detection of surface and interstitial moisture, detection of air leakage and convection heat loss, and voids in composite and homogeneous materials. The methodologies for the assessment of each fault type are very specific, and minimum environmental conditions are specified to provide guidance to service providers where gaps in present day standards and guidelines exist.

Because of the complex nature of the inspection methodologies and the variety of building enclosure assemblies one must be capable of inspecting, this kind of inspection absolutely require Level II thermographer certification for both equipment operators as well as report authors. In addition, expert professional knowledge of building science is required for the analysis of enclosure problems in large buildings. Expert building science knowledge related to residential construction is required for low rise residential, and therefore Level I thermographer certification is acceptable for both the equipment operator as well as report authors, providing they have expert building science knowledge to draw from

FUTURE APPLICATIONS: MOISTURE, THERMAL COMFORT, MATERIALS, STRUCTURAL, BIOLOGICAL ASSESSMENTS

The present NMS sections dealing with thermographic assessments represent the current state of the art known standards and guidelines. There are other building applications that infrared thermography is being used in that could develop into separate sections within the NMS. These include but are not limited to detailed detection of: interstitial trapped moisture within various materials found in walls, floors, ceilings of buildings, thermal comfort problems within perimeter zones of buildings, material deterioration (organic and inorganic composite assemblies), structural defects (voids in concrete), biological infestations and voids in structural organic members.

As equipment evolves, newer data collection, storage and display methodologies will appear as a result of consumer requests and market forces. These will result in the heightening of existing standards and guidelines and the development of new ones. As these occur, the NMS will be constantly upgraded to include the latest version of applicable reference material.

AMENDMENT FOR USE IN RESIDENTIAL CONSTRUCTION

The use of the NMS sections for application in the low-rise residential market place to request the services of home building inspectors can be accommodated, but will be dictated by the requirements of owner, lending institutions and the cost of the service that the market will bear.

Although the technical requirements for equipment and qualification requirements for operators may not be as demanding as those for commercial buildings, there is still a need within the industry to ensure that expectations for service by both the client and the service provider are similar. To this end, the NMS can certainly address the potential problems that may arise in such a fractured home inspection market.

SUMMARY

The applications and equipment considerations can be summarized in the following table:

Small Building	Detection	Measure-ment	Field of View	Thermal Sensitivity	Operator Knowledge*	Author Knowledge*
Electrical	< 3mrad	>100:1	>20 degrees	<0.3C @ 30C	L I	L I
Mechanical	<3mrad	>100:1	>20 degrees	<0.3C @ 30C	L I	L I
Interior	<3mrad	>100:1	>20 degrees	<0.1C @ 30C	L I	L I
Exterior	<3mrad	n/a	>20 degrees	<0.1C @ 0C	L I	L I
Large Building						
Electrical	<3mrad (Outdoors<1mrad)	>100:1 Outdoors 300:1	>60 degrees if through IR window	<0.3C @ 30C	L I	L II
Mechanical	<3mrad	>100:1	>45 degrees on large equipment	<0.3C @ 30C	L I	L II
Interior	<3 mrad	>100:1	>20 degrees	<0.1C @ 30C	L II	L II
Exterior	<0.5mrad	n/a	>45 degrees preferred <10 degrees to meet IFOV	<0.1C @ 0C	L II	L II
Low slope roof	<3mrad	n/a	>20 degrees	<0.2C @ 30C	ASNT L I	L II

*Table #2: Summary of spatial resolution, measurement resolution, field of view, thermal sensitivity, operator and report author requirements for building types and system/applications assessments.[15] *Certification level follows ASNT Guidelines.*

There are similarities in the inspection procedures and requirements for carrying out interior electrical and mechanical system inspections for both low-rise residential and large buildings. However the level of complexity with large building components and the potential for exterior inspections necessitates the use of cameras with high spatial resolution and wide field of view, especially when distances to target surfaces become greater than 5 m. In addition, these complexities require the expertise of a professional high voltage electrician or engineer to determine fault severity. Residential systems are straightforward enough that trained home building inspectors could determine fault severity with lower cost/lower resolution equipment. Low-sloped roofing inspections for low-rise residential and large building are similar enough that a trained roofer or home inspector can carry out the inspection and provide appropriate reporting and documentation of faults. Low cost imagers are acceptable for this application, provided that roofs are not inspected from a distance greater than 10 m. In these cases, higher resolution (e.g.: 320 x 240 FPA's or greater) may be required to provide detailed information.

The major difference in infrared thermographic inspections procedures, analysis and reporting come into play when looking at the building envelopes of low-rise residential and large buildings. Residential inspections, carried out from the interior, can be carried out during daytime. Large building thermographic inspections are carried out from the exterior since interior enclosure surfaces are obscured from view due to suspended ceilings and perimeter heating systems. These inspections can only be carried out at night for non-transient heat flow methodologies and at daybreak or sunset for transient heat flow methodologies.

The variety of assembly types and configurations and levels of professional liability involved in the inspection of assemblies found in large building and the types of remediation recommendations require the services of professional architects or building science engineers. In most cases, architectural and structural technologists will not have the required liability insurance to carry out such work. Their level of liability may be acceptable for low-rise residential building inspections, but liability insurers for large building projects will most certainly discount these people from the process.

In addition to these professional limitations, the use of low cost, low resolution imagers (e.g. 160 x 120 FPA's or less) in large building inspection is limited due to their spatial resolution at distance greater than 10 m. Buildings up to 4 stories in height are best inspected with high resolution (e.g.: 320 x 240 FPA's or greater) radiometers while taller buildings may require additional telephoto lenses to achieve suitable spatial resolution to detect fine detailed thermal signatures. These detailed inspection procedures also require that thermal patterns from one section of the elevation be related to others, and thus composite mosaics are beneficial in large building inspections.

Similar specifications can be used for the low-rise residential market, but much of the demand for quality control of services will be overkill for that market sector due to current market service rates. Creating a level playing field for infrared thermographic service providers specializing in large building inspections requires that specific standards be identified for types of equipment suitable for inspection activities, qualifications of service providers, type of information to be provided by the inspection report and the procedures required to obtain suitable results. This will go a long way to creating a level playing field in the industry to ensure that proper services are provided for all projects.

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The principle author, an architect by profession (B. Arch >78, Carleton U.), has over 27 years of experience in the area of building science and infrared thermography. He has worked for PWGSC developing non-destructive techniques to evaluate building performance in architectural disciplines in addition to acting as departmental expert advisor on building envelopes. He is an active voting member in over a dozen CGSB standards, executive director of the Building Envelope Council Ottawa Region, director of the National Building Envelope Council (Canada) and authored numerous papers on the subject of infrared thermography and building diagnostics.

The co-author, Michel Theauvette, T.P. is a professional technologist and an elected member of the Board of Directors of "L'Ordre des technologues professionnels du Québec (OTPQ), has over 30 years experience in the construction industry and building sciences in North America, mostly in the manufacturing sector of building materials directly related to the building envelope. An active member of Construction Specifications Canada, he has occupied many positions within the CSC Ottawa Chapter, is Chair for the Advisory Board of La Cité collégiale's Architectural Technology Faculty in Ottawa, Ontario and has, for the past 6 years been working with PWGSC's National Master Specification Secretariat. He is currently Acting Manager of the NMS.