A testing procedure for software calculating heat gain and heat loss using CSA F280-12

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Abstract

The Canadian National Building Code requires heating systems to be sized using CSA Standard F280-12 for low-rise residential (NBC Part 9) buildings. Although, heating system sizing is a Code requirement, most municipal jurisdictions outside of Ontario do not enforce it as some provinces lag on code adoption or the municipalities choose not to for a variety of reasons. CSA F280 clearly defines the heating and cooling system capacity calculations. There are a number of commercial software or custom in house software methods that claim to replicate the F280-12 calculation; however, there is no third-party verification for these software packages. It is therefore difficult for industry and municipalities to confirm compliance to the requirements in the Standard. A testing procedure for F280-12 software packages is developed and verified using several archetype houses. The compliance procedure, if adopted, would enable housing industry to gain confidence in F280-12 heat loss and gain calculations. A novel method to test these software packages is proposed. Different Canadian house archetypes, envelope specifications, climate zones, and house orientations are considered. Software packages are tested and compared to manual calculations and available experimental data for one of the archetype houses.

Introduction

Canada is strategically moving towards net-zero housing for all new builds by 2030 (PCF 2016). This ambitious goal will require speedy transformations with adoption of new methods and technologies for the building industry in Canada. On the building envelope side, improved levels of insulation, better air tightness and more efficient windows would significantly lower heating and cooling energy use. These changes will also result in lower peak heating and cooling loads

Despite these reduced heating and cooling loads, it remains common in the industry for mechanical system trades to use conservative heat loss and gain estimates to determine required system capacity. These often come in the form of multiplication factors based on house area and rule-of-thumb estimates. Often, these conservative estimate lead to oversizing of equipment so that the installed equipment has as much as twice the required heating capacity (LEEP, 2018). Further improvement in lowering heating and cooling load intensity with the adoption of net zero housing as described in the pan Canadian framework (PCF 2016) is likely to widen the gap between installed equipment capacity and actual peak heating and cooling loads.

Part 9 of the national building code of Canada (NBC, 2015), is concerned primarily with low rise wood construction dwellings and requires that heating system capacity be sized according to the standard CSA F280-12 (CSA 2017). CSA F280-12 provides a method for calculating peak heat loss and heat gain values which are intended to be used to determine heating & cooling equipment capacities. The standard is a substantial revision to its predecessor CSA F280-90. The revised standard has been shown to be less conservative and provides a more accurate estimate of the actual heat loss at the peak wintertime temperature condition.

Overall, more accurate results mean that heating systems can be designed with lesser capacities without fear of under-sizing. New home builders have been able to reduce the capacity of the installed heating systems by 50% in some cases after becoming aware of the more accurate load estimate provided by CSA F280-12. This not only contributes to savings on the equipment purchase, but also reduces the size of the ductwork, and has comfort implications when considering that the appliances run for longer durations with continuously circulating air. Equipment purchase price savings are more apparent when using a heat pump as compared to furnaces. Their cost tends to be more sensitive with respect to heating capacity.

In spite of the published code requirement to use CSA F280-12 to select heating and cooling equipment capacities, many municipalities have not enforced this requirement for sizing heating equipment outside of Ontario. In some cases, provincial building codes have not kept up to date with national codes. In other cases, the provincial code is up to date, but municipalities fail to enforce the requirement due to a lack of resources, awareness, or local industry capacity to deliver.

In Ontario, enforcement of HVAC Design requirements ranges from a simple check that the calculation was done by a competent individual, to a full review of the CSA F280-12 calculations. The latter is far more resource intensive and not all municipalities will have budget or resources to conduct full F280-12 calculation review.

Municipalities need a quick and reliable method of determining if a load calculation has been correctly completed. The stamp of an engineer would suffice, but this often comes at additional cost to industry. Without a professional engineer intervention, and short of doing a detail calculation review, it is proposed that there are two main questions municipalities may ask to verify if a calculation is valid:

- Is the calculation method used valid? It should follow CSA F280-12, but does the software being used produce accurate results relative to the F280-12 standard?
- Is the user of the method competent? For example, a BCIN number is required on mechanical drawings submitted in Ontario. The BCIN number is given out to competent individuals who have training on building code requirements have successfully passed the required written examinations and in some cases are required to have insurance. Training in F280-12 is implied and not mandatory. The BCIN Syllabus & exams do not include heat loss and gain questions except perhaps as to the standard to be used for Part 9 Residential Dwellings for example.

This paper primarily deals with the first of the two issues and proposes a novel method of testing software for compliance with CSA F280-12.

The existence of a method for third party verification of software, will provide confidence that verified software can be trusted to produce accurate results. This verification process will benefit:

a) Municipalities when enforcing building code requirements, and

b) Designers who use the software frequently and may be liable for mistakes in their submitted designs, and

c) The industry as a whole by reducing system costs and increasing comfort levels.

This paper provides the F280-12 software testing procedure and examples of its use for typical houses.

The software testing method will be tested on for five popular HVAC design software packages that produce heat loss and heat gain estimates and which claim to replicate the CSA F280-12 calculation method. The results produced by the software packages are then compared to a manual calculation as well as measured heat loss.

F280-12 software testing procedure

To test the F280-12 software packages it is proposed that a collection of archetypes houses, envelope specifications and climate conditions be used as test examples. In this paper, the Canadian Center for Housing Technology (CCHT) archetype is used as a reference point and chosen archetype as this house has been heavily monitored and experimental data for heating requirements at the winter design condition is available.

The testing procedure would include three other archetype models created using standard take offs from standardized house plans. Once the four archetype models are created, the house envelope specification, location and orientation are varied, and heat loss and gain calculated for each case.

The method includes testing for four distinct vintages which are listed following. Envelope specification sets have been created to represent the different vintages.

- Net zero house
- Current built house, build post 2012
- Old, built in the late 1970’s or 1980’s
- Older, built prior to 1960

In each case, the houses are tested in the following four representative locations:

- Mid-Continent, Ottawa, Ontario
- Coastal, Vancouver B.C.

For each location, the four archetypes and four vintages will be tested.

For the CCHT in the Ottawa location showcased as part of this work, the specifications used in software testing are provided in the table bellow

Table 1: CCHT Research and Test House Specifications

Feature	Details
Construction Standard	R-2000 (2004)
Livable Area	210 m^2 (2260 ft^2), 2 storeys, wood frame construction
Insulation	Attic: RSI 8.6 (R-49), Walls: RSI 3.5 (R-20), Rim joists: RSI 3.5 (R-20)
Basement	Poured concrete, full basement. Floor: Concrete slab, no insulation. Walls: RSI 3.5 (R-20) in a framed wall.
Garage	Two-car, recessed into the floor plan; isolated control room in the garage
Exposed floor over the garage	RSI 4.4 (R-25) with heated/cooled plenum air space between insulation and sub-floor.
Windows	Area: 35.0 m^2 (377 ft^2) total, 16.2 m^2 (174 ft^2) South Facing. Double glazed, high solar heat gain, low emissivity coating on surface 3. Insulated spacer, argon filled, with argon concentration measured to 95%.
Air Barrier System	Exterior, taped fiberboard sheathing with laminated weather resistant barrier. Taped penetrations, including windows.
Airtightness	1.5 air changes per hour @ 50 Pa

Five HVAC designers were hired to perform F280-12 heat loss and heat gain calculation of the CCHT using the specification in table 1, i.e. the same specification as the experimental test house. Each designer used a different software package all claiming to provide CSA F280-12 compliant calculations, and most popular with residential HVAC designer in Canada. Careful attention to input in each software package was taken to ensure that every model was setup in the same way and avoid difference due to varied input. These results were compared to a manual calculation carried out in accordance with the HRAI Residential Heat Loss & Gain Manual. This manual calculation follows the procedure in the CSA F280-12 standard closely and each step in the process is recorded in a detailed format.

Results

The five software package results, and the manual calculation and the experimental result for heat loss at the CCHT are compared in Figure 1 below.

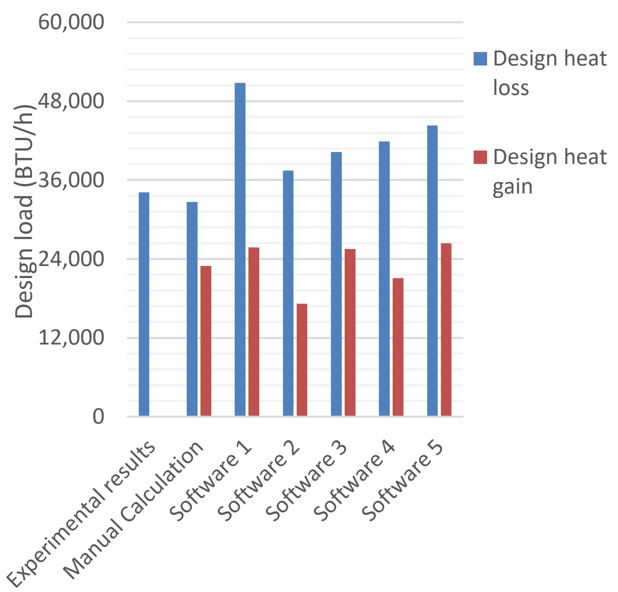

Figure 1: Whole house heat loss and heat gain calculations summary

The manual calculation is 4% less than the measured heat loss for the CCHT.

Comparing to the manual calculation, software 1, 2, 3, 4, and 5 overestimated the heat loss by a factor 55%, 15%, 23%, 28% and 35% respectively. The manual calculation is closest to the experimental estimate heat loss.

All software package would lead to heating equipment selection that are not undersized, but may lead to a different equipment selection given a more than 40,000 BTU/h difference between software 1 and 2.

Comparing the cooling loads. Software 2 and 4 underestimated the cooling load by 25%, and 8%. Software 1, 3, and 5 overestimated the cooling load by 12% , 11% and 15%.

The CSA F280-12 standard specifies that the cooling equipment be selected between 80 and 125% of the calculated cooling load. Software 2 is significantly outside these boundaries but software 1, 3, 4 and 5 are not. Cooling systems that are sized close to the actual load tend to run longer, providing more dehumidification which can contribute positively to comfort.

Cooling load calculations are varied and range from 17,164 BTU/h to 26,400 BTU/h, a variation of less than 12,000 BTU/h or 1 ton of cooling. The CSA F280-12 Standard requires that cooling system be sized between 80 and 125% of the design cooling load. The graph below shows acceptable equipment selection based on the maximum and minimum design cooling load found by the varied software packages.

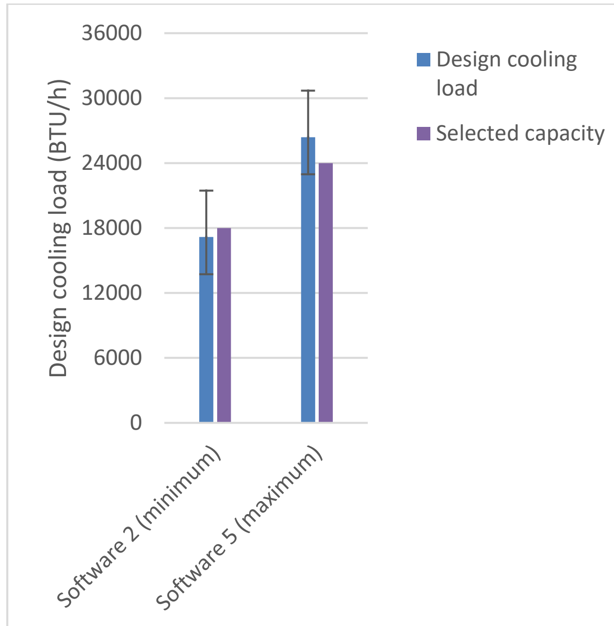

Figure 2: Whole house heat loss and heat gain calculations summary

If using software package 2, one would have selected a smaller cooling system (1.5 Ton) following the 80% to 125% rule. Using software package 5, a 2 or 2.5 ton system would be selected. These varied cooling results are significant enough to change equipment size, and this can be considered unacceptable from a design perspective. Acceptable methods should lead to a similar equipment size. Moreover, software 2 would have significantly undersized the cooling system leading to comfort issues.

There is a clear need for more consistent results when using software packages for computing cooling and heating loads. Although it is common for different energy simulations to provide a range of results, there is a fundamental difference in the software packages claiming to follow CSA F280-12, where the calculation method is defined and should be the same for each package. As such it is expected there would be strong alignment between the different software packages.

The results of testing software packages is clearly showing that the heat loss and heat gain design loads produced by software packages are not consistent one to another despite claiming to follow CSA F280-12 load calculations which details the calculation method.

There is a clear need for verification of software packages so that results are sufficiently consistent one to another so as to lead to consistent equipment sizing.

Conclusion

A testing method for CSA F280-12 software packages is proposed. Using the testing method for the CCHT in the Ottawa location and for one set of envelope specification, we have shown that the testing method could be used to compare software packages. For a more thorough test, multiple locations and envelope vintages should be tested and was not completed as part of this work.

The results from the CCHT at the Ottawa location shows that the manual CSA F280-12 calculation is .close to the measured heat loss Comparing these results with software packages manually calculated results showed a wide range of results even for the software packages that claim to follow the same standard calculation method. The cooling loads results of two of the software packages would lead to different cooling (or heat pump) equipment selection. It is clearly unacceptable to have such a wide range of results.

The highlighted lack of accuracy in these software package could also be a barrier to proper integration of heat pump technology in housing as sizing is a much more critical issue for these systems. Without third party testing, it would be difficult for industry to know which method is valid. This finding highlights the need for a software package testing method. Ideally an extension of the CSA F280-12 standard for compliant calculation software packages should be created.

The novel method for testing F280-12 software can be used by industry to determine which tools can be trusted for calculating heat loss and heat gain in the context of Canadian residential housing. The method can serve as a base for a certification of software, so that compliant software could be easily identified by user groups such as municipalities, designers, and builders. Having easily identified compliant software could allow municipalities to quickly identify which calculations come from a trustworthy source, reducing the resource burden of their enforcement duties. Future work could include proposing an amendment to the existing CSA F280-12 standard to include a software compliance method. Along with software certification, there is also a need for the professionalization of the part 9 residential HVAC design industry as it scales up across Canada.

Further work will also include testing software packages on other archetypes, vintages, and locations to further investigate the current state of software package accuracy.

There is also a gap in knowledge to assess the importance of load calculation accuracy relative to design selection. Some divergence in load calculation results can be tolerated, but excessive divergence could lead to different equipment, selection as shown, or changes in duct or hydronic sizing affecting the overall distribution system.

Acknowledgement

The authors would like to acknowledge the contributions of its industry partner Ecolighten Energy Solutions, Design HVAC Experts, FM Residential Designs, Building Knowledge Canada, and Homesol Building Solutions who have provided models using the software being tested.

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