RATING SCALES FOR SEASONAL EFFICIENCY OF BOILERS AND CHILLERS

Partners in Innovation 39-3-720

Deliverable 7

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Rating Scales for Seasonal Efficiency of Boilers and Chillers

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EXECUTIVE SUMMARY

This report is Deliverable 7 of DTI Partners in Innovation Project 39/3/720 – 'Seasonal Efficiency Ratings for Non-domestic HVAC Plant'. This report is the final report that brings together the thinking behind the project, the development of the rating systems and the description of the schemes. The report will be used by the project team to publicise the rating schemes to a wider audience, and thereby promote their adoption. It is intended that it can be used by each of the partners to be placed on websites and used more in technical papers such as CIBSE or the Building Services Journal.

In addition to producing a method for deriving a seasonal efficiency we have proposed a 'Labelling Rating' scheme that interprets this data into bands of seasonal efficiency that can be used to rate and compare boilers and chillers as appropriate. It is intended to take this forward in the context of the Market Transformation Programme.

The seasonal efficiency will also enable a better evaluation of the energy performance of a building under the requirements of the Energy Performance of Buildings Directive and therefore within the context of Part L2 of the Building Regulations.

INTRODUCTION

Introduction

This report is Deliverable 7 of DTI Partners in Innovation Project 39/3/720 – 'Seasonal Efficiency Ratings for Non-domestic HVAC Plant'. This report is the final report that brings together the thinking behind the project, the development of the rating schemes and the description of the schemes themselves. The aim of the report is to be used by the project team to publicise the rating schemes to a wider audience, and thereby promote their adoption. It is intended that it can be used by each of the partners to be placed on websites and used more in technical papers such as CIBSE or the Building Services Journal.

At the earliest stage of the project it was realised that the two main issues of heating and cooling would be best addressed separately as although collectively they define the main energy consuming aspects of the HVAC plant they cannot realistically be linked in a single index of seasonal efficiency. Therefore, each issue has been investigated and dealt with by its own sub-set of industry partners. This report contains the results of the project for both boilers and chillers but it has been written so that it can be easily edited to contain information of relevance to either type of plant.

Rating the Seasonal Efficiency of Boilers and Chillers.

Introduction

A recently completed DTI sponsored Partners in Innovation Project has developed methods for assessing the seasonal efficiency of boilers and chillers. Currently, plant performance data is limited to the performance of the boilers or chillers under controlled conditions and fixed levels of full load capacity. The aims of the project were to develop a seasonal efficiency rating scheme that would assist building services engineers in their design of efficient plant and also provide a means of stimulating the market towards a life cycle performance approach rather than a pre-occupation solely with first cost. To this end the project partners have developed a rating scheme so that users of boilers and chillers can make a more informed judgement of the likely seasonal performance of their proposed HVAC plant.

The key factors determining the seasonal performance of the boiler or chiller are the efficiency of the plant at part load and the load that the plant experiences in response to the seasonally varying building heating and cooling demand. The project therefore focussed on investigating these two factors.

Part Load Efficiency

It was recognised that it would be beyond the scope of this project to develop completely new test procedures and standards.. Therefore, the project partners studied existing efficiency standards and test procedures in the UK, Europe and North America in order to rely, as much as possible, on existing industry standards for boiler and chiller efficiencies.

Boilers

For boilers, the EU has a Boiler Efficiency Directive[1], that requires efficiency to be measured at 30% and 100% of output. However, boiler efficiency is comparatively constant over this range of operation and the analysis showed there is little difference between the quoted efficiency at these loads and any seasonally adjusted values. Additionally to this, at the predicted low loads at which the boiler plant may operate for much of the heating season, there is little published information about efficiency but it is clear that it may fall significantly. Consequently the team took a quite pragmatic approach to assessing the efficiency below 30% load and it was decided that an efficiency at 15% load would be more representative of low load operation. As there is no recognised test procedure at this output the efficiency would be either, as determined by the manufacturer, or calculated depending on the burner turndown and control method as follows:

- Fully modulating control to 15%: efficiency at 15% = 30% efficiency x .98
- High/low control below 30% load: efficiency at 15% = 30% efficiency x .95
- On/off control below 30% load: efficiency at 15% = 30% efficiency x .90

Note: the efficiencies quoted here do not include electrical loads associated with the burner.

Chillers

Currently there is no UK standard part load test method but an American Refrigeration Institute (ARI) standard[2] requires statements of efficiency at 25%, 50%, 75% and 100% of full load chiller output. The normal test conditions for these loads are closer to US than UK conditions but when using data for an ambient condensing temperature of 20^{o}C the efficiencies would be appropriate to the UK.

Load Profile Simulation

The load profile of buildings is not well known and little detailed monitored data is available. Therefore, this project used computer simulations to determine the hourly heating and cooling load profiles of typical office type buildings over the heating or cooling season. This approach provided greater scope for the project as a wider range of building forms and climates and the simulation of approximately 60 buildings showed a clear and consistent load pattern with most plant operation (both heating and cooling) being below 25-30% of full load. Heating loads were typically below 15% of full load for approximately 50% of the operating period. Full load operation was observed for less than 2% of the time. Using the plant load profiles developed we have been able to establish a 'typical' load profile that represents office type buildings in the UK. This typical load profile quite accurately reflects the influence of building design, weather, occupancy and location, although naturally the absolute values change significantly.

Seasonal Efficiency

The load profiles generated by the simulation program show the plant requirement for each hour of the year, and these encompass the whole range of plant output from 1% to 100%. This level of detail is not compatible with the measured efficiency of the plant as described above and therefore the hourly load profiles have been partitioned ('binned') into bands compatible with the efficiency bands for the plant. The binning of the hourly loads provides weighting factors that are the fraction of operating hours at which the plant will operate at that percentage of full load. Hence for chillers the load profile is binned into 25%, 50%, 75%, 100% of full load demand.

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[1] Boiler (Efficiency) Regulations (1993, No 3083), otherwise known as the Boiler Directive UK/EU or Council Directive 92/42/EEC

[2] American Refrigeration Institute Standard 550/590-1998: 'Water chilling packages using the vapor compression cycle This standard describes performance test methods for factory designed and prefabricated water chilling packages including one or more hermetic or open drive compressors and lays down the testing methods and conditions.

For boiler plant there is not an equivalent to the ARI method, but there is little reason not to accept the conceptual approach and use weighting factors for heating plant based on the percentage operation at part loads, therefore the hourly heating loads are binned into 15%, 30% and 100% bands.

Boilers

The boiler efficiencies derived, as above, for the 15%, 30% and 100% output can now be put together with the weighting factors to provide seasonal efficiencies. From the simulations carried out on the office type buildings a set of banded weighting factors have been derived. These weighting values, for the 15%, 30%, and 100% efficiencies, are 0.50, 0.20, 0.30 respectively. The seasonal efficiency of a boiler is therefore:

$$\text{Seasonal Boiler Efficiency} = 0.5*(Eff15_{\%}) + 0.20*(Eff_{30\%}) + 0.30(Eff_{100\%})$$

For example, a condensing boiler with BED efficiencies of 96% full load, 98% at 30% load: with fully modulating controls to 15% full load (therefore at 15% load = 98*0.98 = 96%):

Seasonal efficiency of example boiler = 0.5*96 + 0.2*98 + 0.3*96 = 96.4%

Chiller Plant

The project team has adopted the Seasonal Energy Efficiency Rating (SEER) method, as described by the US ARI Standard 550, as the seasonal efficiency measure for chiller plant. This uses the same approach to binned data to develop the Integrated Part Load Value (IPLV). The IPLV (SEER) is derived as below:

$$\text{Seasonal Energy Efficiency Rating (SEER)} = a*(EER_{25}) + b*(EER_{50}) + c*(EER_{75}) + d*(EER_{100})$$

Where: EER (Energy Efficiency Ratio) is that measured at the defined part load conditions of 100%, 75%, 50% and 25%, and a, b, c, and d are the binned load profile weighting factors. The weighting factors values that most closely represent the typical UK office type building are 0.55, 0.33, 0.1, 0.02.

For example, a chiller with: EER_{100} 4.89, EER_{75} 4.42, EER_{50}3.93, EER_{25} 2.59.

Seasonal Energy Efficiency Ratio = (0.55*2.59 + 0.33*3.93 + 0.1*4.42 + 0.02*4.89) = 3.26

In parallel with this PII project a European funded project, entitled 'Energy Efficiency and Certification of Central Air Conditioners' (EECCAC), has been researching the same goal of a measure of seasonal performance for refrigeration plant. They have derived IPLV weighting factors for a London office building and shopping mall and four different types of refrigeration system. Their research suggests weighting factors broadly similar to those of this project. The weighting factors proposals here, however, are most likely more representative of the UK situation because of the greater depth of study of the UK load profiles for cooling over a wider range of building types and weather.

The Rating Scheme

Having established a means of determining seasonal efficiency we have moved on to suggest a rating scheme for boilers and chillers based on the seasonal performance. This approach is in line with the general approach adopted by the Market Transformation Programme that has been developing similar rating scales for a range of products. The rating scales suggested by this project are shown below.

Boilers

The Boiler Efficiency Directive makes provision for a 'Star Labelling' system and defines bands of stars at 3 percentage points increase of efficiency above the base line compliance values. Using this approach, but translating the stars to letter bands, results in the following seasonal efficiency rating system.

Boiler Rating Label	Seasonal Efficiency Range (net efficiency)
A	> 96
B	93 – 96
C	90 – 93
D	87 – 90
E	< 87

Chillers

For chillers a similar range of labels has been suggested. These labels are based on the performance of typical chillers available in the UK working at normal supply and return chilled water temperatures and an ambient condensing temperature of 20^{o}C.

Chiller Rating Label	Seasonal Energy Efficiency Ratio
A	5.5 – 6.0
B	5.0 – 5.5
C	4.5 – 5.0
D	4.0 – 4.5
E	3.5 – 4.0
F	3.0 – 3.5
G	2.5 – 3.0
H	2.0 – 2.5

CONCLUSION

Methods of computing the likely seasonal efficiency of both boiler and chillers are proposed and these have already been included as proposals in the 2005 revision of Part L2 of the Building Regulations.

Rating labels are suggested for industry to adopt as part of their wish to influence the market place to specify more efficient plant with lower life time operating costs and carbon emissions.