TOWARDS A HARMONISED EU SPECIFICATION ON GAS QUALITY: MARCOGAZ CONTRIBUTION.

CONTEXT

One of the hurdles for the constitution of a European gas market has been the differences in gas quality specifications between countries. As a result gas that can circulate and be distributed in one country may not be able to cross national borders to be used elsewhere. This is a hindrance for the application of the EU directive on the energy market (98/30/EC) and this issue is regularly discussed within the Madrid Forum.

Since 2003, this issue has been discussed within EASEE-gas[1] with the objective of improving the interoperability of the gas networks in European Union (EU). The way forward proposed by EASEE-gas has been to specify a set of parameters and limit values that would be acceptable by all stakeholders around the EU. Gas meeting this specification would be allowed to cross any borders, whilst gas outside of this specification could be allowed to circulate so long as agreement between the interested parties is reached. The EASEE-Gas proposals generally take the form of a voluntary Common Business Practice (CBP) and the gas quality CBP was agreed and published in February 2005[2].

Marcogaz, the Technical Association of the Gas Industry in Europe, became involved in this process at a very early stage, because Marcogaz had already formed a Working Group "Gas Quality" in 2002 with the objective of studying the impact of potential changes gas quality on end-users. The working group began by identifying those parameters typically used to specify gas quality in the EU[3]. One of the key findings of this work was that different parameters and limit values were specified when it came to combustion properties.

Contact with EASEE-gas shown that whilst network operators, producers, shippers (and in general most stakeholders within the gas chain) were able to participate in the gas quality discussions, the small users, residential or small commercial, were not represented. However, it is these users that are least able to adjust their appliances and equipment to cope with any variation in the quality of the gas they burn. Marcogaz recognised that in many countries, gas crossing a border without any modification (blending or ballasting) could lead to interchangeability issues if a minimum specification were not agreed. Assistance was therefore provided by Marcogaz to EASEE-gas in order to define a range of gases interchangeable on an EU scale. Interoperability is therefore perceived as a key barrier to the interoperability of a European Gas Market.

HISTORY OF THE INTERCHANGEABILITY IN THE EU

The gas industry in the EU began with manufactured gases; when natural gas started to be used, it was generally in areas close to production fields with a direct link between source and market. Only in the 60's did natural gas networks start to expand, first on a national scale and then at a European level. During this development, interchangeability has been a constant preoccupation - first identified at a local level but very soon at a national level. Most countries resolved interchangeability issues by controlling the quality of gas to allow for its national market of appliances.

As a result, different interchangeability approaches – reflecting the different type and age of appliances in use – were taken. Their objective was to define limits within which gases could be distributed on

[1] *EASEE-gas: European Association for Streamlining Energy Exchange-gas.*

[2] *CBP 2005-001-01 Gas Quality Harmonisation, available at http://www.easee-gas.org/*

[3] *See " Report on National Situations regarding Gas Quality", Nov. 2002, published on Marcogaz website at http://marcogaz.org/information/index_info4.htm*

the current gas appliances while safekeeping the safety of the users. The following issues were identified as potentially dangerous for end users:

- Incomplete combustion, as this leads to the formation of carbon monoxide.
- Flame lift that could lead to carbon monoxide production and to blow off with subsequent escape of unburned gas.
- Flash back that can damage appliances but also will lead to an escape of unburned gas.

Yellow tipping and sooting have also been identified as undesirable defects even if both of these do not present an immediate threat to the consumer. However, both indicate potential for incomplete combustion and sooting may lead to further malfunction by clogging up the appliances.

For example Delbourg's (1950's) approach in France was principally aimed at specifying parameters and values for the interchangeability of manufactured gases, before being extended to natural gases. This led him to define a domain with the Wobbe[4] index as Y-axis and a parameter named *"combustion potential"* as the X-axis. This parameter, calculated by taking into account the hydrogen and unsaturated hydrocarbon content of the gas, is correlated to the stoechiometric flame speed. High *combustion potential* gases are prone to flashback. Using these two parameters Delbourg defined an interchangeability domain by testing various gases against a number of appliances present on the French market at that time. Secondary parameters, such as *yellow tipping index*, were also defined.

Similarly Dutton's (1970') approach in the UK was built on the testing of many different gases on appliances typical of the UK market at that time. However, Dutton approach was developed for natural gases only and hence considered different parameters to those of Delbourg. Stoichiometric combustion speed of alkanes are similar and hence the risk of flash back is quite similar for all natural gases and there is less need for a parameter such as the *combustion potential.* Dutton approach therefore focuses on the sooting and incomplete combustion defects and used as parameters the Wobbe index and the PN number. The PN number represents the non-methane components of a gas mixture *"equivalent to"* a given natural gas, in which all alkanes grouped as an *"equivalent"* propane concentration and all inerts grouped as an *"equivalent"* nitrogen concentration.

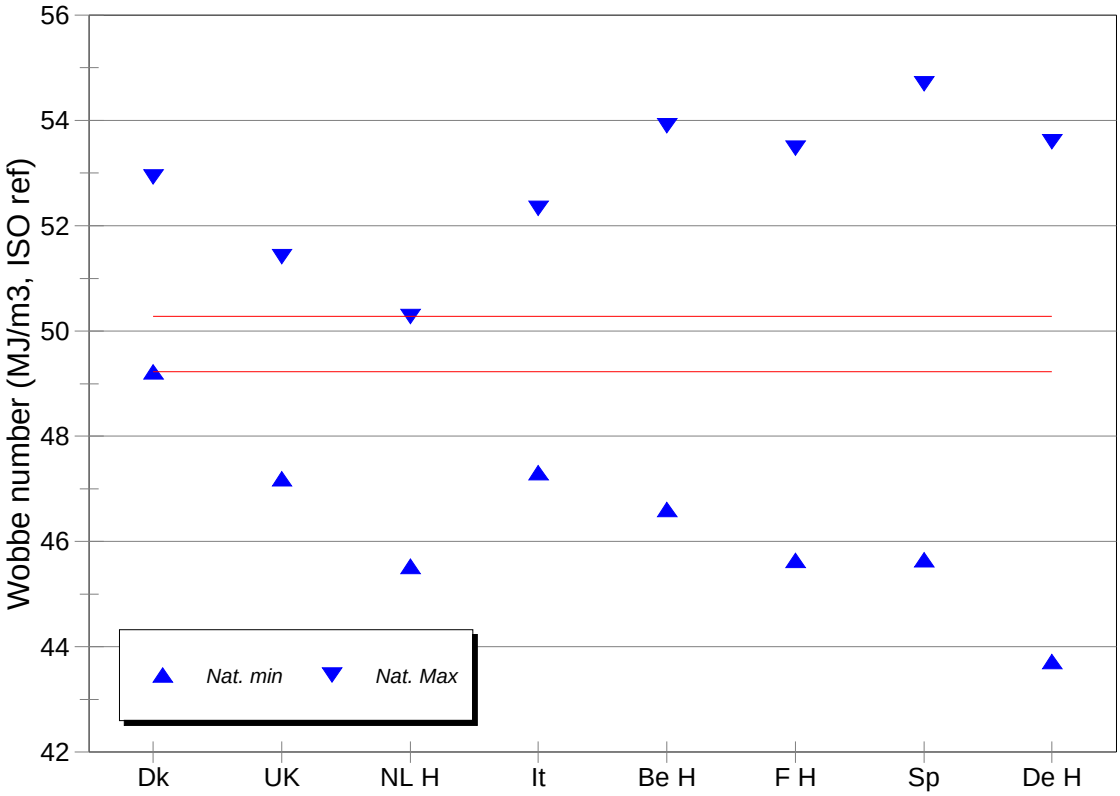
Other approaches have been used in the EU countries with the result that:

- The only common parameter in use is the Wobbe index.
- The national ranges of Wobbe index differ as different appliances were used to assess the interchangeability of different gases composition.
- A second parameter is generally used to define an interchangeability domain.
- Additional parameters may also be used.

The result of such an approach in term of interoperability is that, even taking only the Wobbe index into account, a very limited range of gases, between the two red lines could flow all around Europe without hindrance (see Figure 1).

[4] *The Wobbe number used in this document is based on the Gross Calorific Value. All energy figures are expressed using ISO recommendations, i.e. MJ with reference conditions as 15°C, 15°C and 1013.25 hPa.*

Figure 1: Wobbe range in different EU country for H gases.



THE IMPACT OF THE GAS APPLIANCE DIRECTIVE

The "Gas Appliance Directive", or more formally Directive 90/396/CEE has been published on the community official journal on July 1990. This Directive is applicable to all apparatus for heating, cooking, water heating, etc., which burns gas and, if they heat water, stay below 105°C. It is also applicable to burners and to parts of apparatus that can be assembled or included in equipment for professional use. It specifically excludes those intended for use in industrial applications. Thus it covers virtually all appliances for the domestic, residential and commercial market. This Directive effectively helped the constitution of an efficient European market for gas appliances.

One of the main requirements of the Directive is that, when correctly used, an appliance shall have good flame stability and that the combustion products shall not contains noxious compounds in concentrations deemed unacceptable. This recommendation applies to all appliances regardless of whether they are vented or not. Furthermore a specific requirement for non-vented appliances states that they shall be built so as to prevent carbon monoxide accumulation in the room in which it is used.

The Directive states also the meaning of "correctly used". It is defined as:

- Installed and maintained as specified by the manufacturer,
- Used within normal **variations of the gas quality** and inlet pressure,
- Used in the manner intended by the manufacturer.

The member states had to define type and pressure of the gases used on their territory by January 1991 so that normal variations of the gas quality can be defined. This led to a publication of a list of gas specifications

and pressures distributed in European Member States within the Official Journal of the European Union. However some flaws were apparent in this publication and the industry felt the need to have a better definition of the gas quality that can be found within the member states. Thus, in 1993 the first version of EN 437[5] was published, which defines the test gases and pressures to be used when testing appliances for compliance with the Gas Appliance Directive. This standard defines 3 families of gases, the 2nd one being "natural gas". In this family it defines three groups of natural gases according to their Wobbe index[6]:

- Group L: $39.1 < W < 44.8$ MJ/m^3
- Group H: $45.7 < W < 54.7$ MJ/m^3
- Group E: $40.9 < W < 54.7$ MJ/m^3

For each group a number of test gases are then specified:

- Reference gas that shall be used to assess the nominal performances of the appliance under test,
- Limit gas for incomplete combustion and sooting,
- Limit gas for flame lift,
- Limit gas for light back.

To verify compliance with the Directive appliances are tested using one or more set of gases and at varying pressures according to the prescription of the relevant specific standards. According to the set of gases and pressures used, appliances are given a specific CE marking that defines what group of gas can be used to feed appliances: namely L, H or E. In the EU, appliance CE markings vary from country to country, reflecting the groups of natural gas delivered nationally.

Appliance marking

Appliance marking covers often more than one gas family, which leads to a complicated designation. If one focuses on markings relevant just to the 2nd family ("natural gas") there are 4 different markings that may cover 99% of the appliances falling under the GAD. These markings qualify the appliances as:

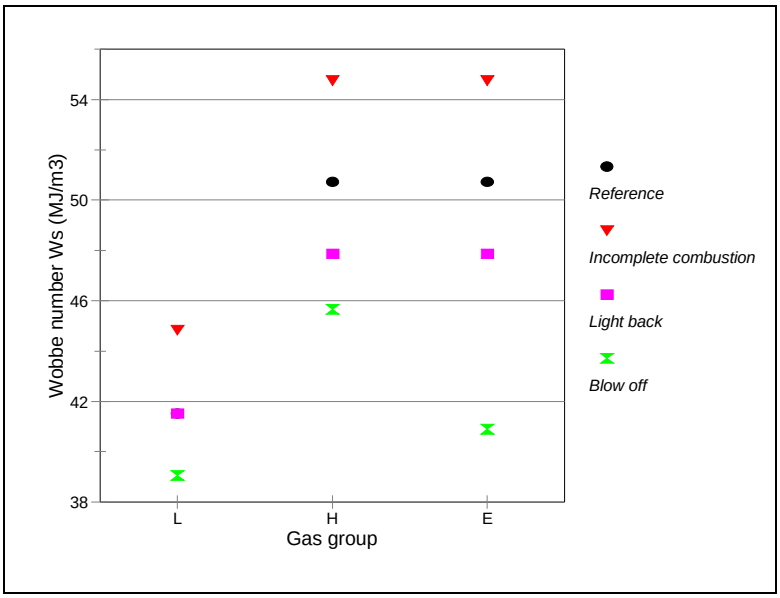
- 2L: To be used with L gases, at a nominal pressure of 25 mbar.
- 2H: To be used with H gases, at a nominal pressure of 20 mbar,
- 2E: To be used with E gases, at a nominal pressure of 20 mbar,
- 2E+: To be used with E gases at nominal pressures of 20 mbar or 25 mbar without any adjustment of the apparatus.

Group H and group L define two distinct Wobbe index ranges and appliances are testing according to markings 2H and 2L with different nominal pressures. Group E is an extension of group H toward L Wobbe index. Marking 2E uses typical H nominal pressure while marking 2E+ uses 2H pressure for high Wobbe index and 2L pressure for low Wobbe index. An appliance bearing a 2E or 2E+ marking might be used as a 2H marked appliance. However it cannot bear gases with the very low Wobbe index that is still convenient for appliances marked 2L. In practice group E allows the use of equipment when gas either in the upper L or H Wobbe index range are distributed. This enables gas transporters to switch the gas in the network (with some restriction) from L to H.

[5] *EN 437:2003, "Test gases – Test pressures – Appliance categories".*

[6] *Wobbe index is the ratio of the Calorific Value by the square root of the relative density. To be in line with EN 437:2003, reference conditions for volume and energy are 15°C, 1013.25 Pa. The use of Gross Calorific Value (GCV) is made.*

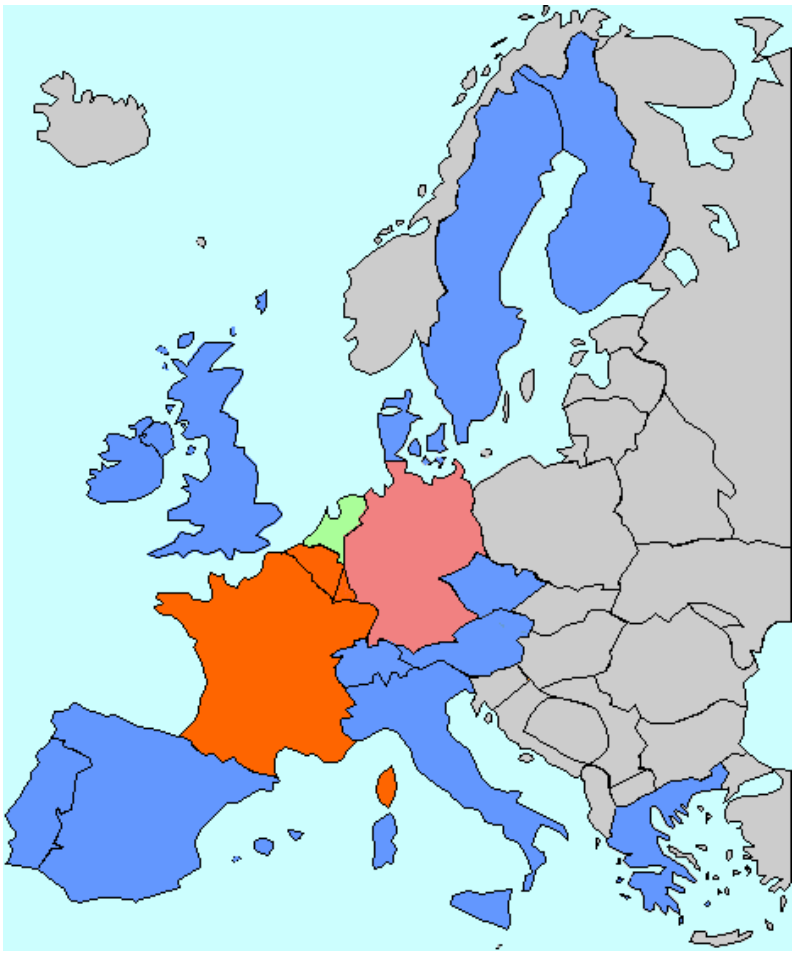
Figure 2: Test conditions according to EN 437 markings



Note: Reference and light back gases are identical for L group.

All EU member states require that appliances are marked according to the gas that may be distributed within their country. Figure 3 shows how these markings are spread out in Europe.

Figure 3: Accepted categories (from EN 437)



This figure reflects the sources of gas found in Europe. The Netherlands, sole supplier of L gas, only requires 2L marking. Surrounding countries (France, Belgium and Germany) have to cope with both L gases and

H gases and have created a single market for their appliances by using the 2E (Germany) and 2E+ markings (France and Belgium with H and L network at different pressure). Other European countries - with no gas from the Netherlands - just ask for H marking.

To ensure that the millions of appliances present in the market continue to work safely for the consumer, the composition of distributed gas must fall within the Wobbe index limits used for testing the appliances. However this necessary condition may not be sufficient.

MARCOGAZ PROPOSAL

Marcogaz decided to take advantage of the harmonised certification scheme created by the GAD to evaluate the possibility of a harmonised specification covering combustion properties and allowing gases to be interchangeable on a EU scale[7]. This decision implies that:

- Appliances not falling within the scope of the GAD cannot be considered and
- Only the essential safety requirements of the GAD would be taken into account as far as interchangeability would be considered.

The first consequence means that appliances older than 1993, generally certified against national standards, may not be integrated in the analysis and thus may not support the gas range proposed by Marcogaz. Note that attempting to integrate these appliances into a harmonised EU specification would have meant that the only possible range of interchangeable gases would be the narrow band presented in Figure 1. Also those appliances not covered by the GAD (engines, fuel cell, etc.) are not included. For these appliances however, the pertinence of the Wobbe number for interchangeability could be questioned.

The second consequence is that the Marcogaz proposal is strictly aimed at defining a range of gases where essential safety requirements are preserved, i.e. innocuous combustion products and good flame stability. Other requirements that can be imposed on appliances such as efficiency or emissions are necessarily ignored. However, we note that the impacts of gas quality variations are:

- Small on efficiency as these appliances are low temperature applications. When compared to the loss of efficiency related to bad design (over powerful boiler) this impact is clearly one order of magnitude lower.
- Not generally predictable with respect to NOx emissions. One appliance may have increased emissions with increasing Wobbe index whereas another one may present an opposite behaviour.

Obviously inserting a constant efficiency and emissions requirement into any specification of interchangeability would mean that, for all appliances without air-gas ratio control, a very narrow range of Wobbe range would result.

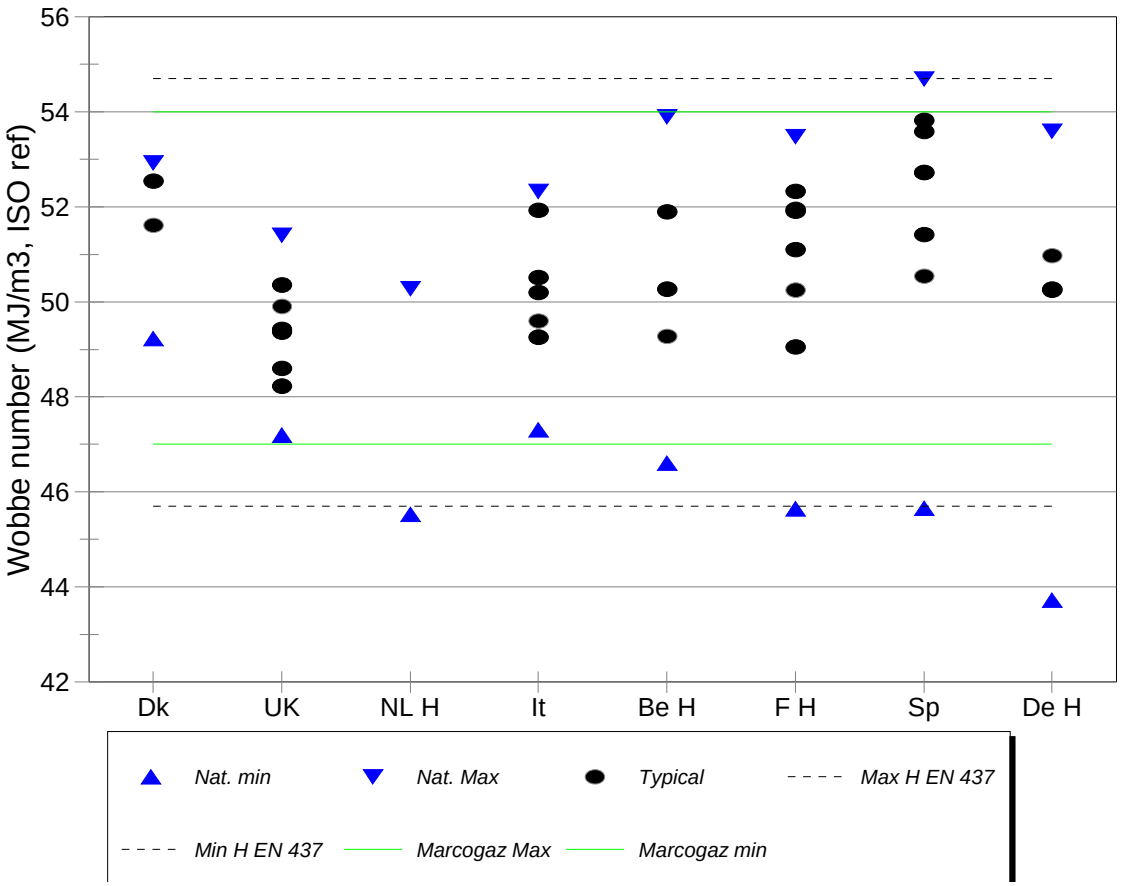
Because appliances sold in all EU countries, save those sold in the Netherlands, are certified against test gases covering at least the range 45,66 to 54.76 MJ/m^3 the proposal for a harmonised range ought to lie within these limits. It was recognised that safety margins may be necessary to cover for aging and National differences in manufacturing, installation and maintenance procedures. These margins were evaluated by the observation of currently distributed gases.

If one considers that all appliances sold in the EU are manufactured to work on the same range of gases, the one defined in EN 437, then all the gas currently distributed in the EU are interchangeable on these appliances insofar as no gas quality related incident or accident are noted. Thus, the combination of all gases

[7] *See "1st Position Paper on European Gas Quality Specifications", February 2003, published on Marcogaz website at http://marcogaz.org/information/index_info4.htm*

currently distributed in EU suggests an interchangeability range that could be used to define safety margins. This is illustrated in Figure 4, the dotted lines representing the maximum and minimum Wobbe number of the H range as defined in EN 437, the black dots gases currently distributed in EU countries and the green lines representing the proposed Wobbe number limits as suggested by Marcogaz (from 47 to 54 MJ/m^3).

Figure 4: Marcogaz proposal based on currently distributed gases.



Acceptance of this proposal would demand an increase in the Wobbe index range in some countries (Denmark, UK, Italy, NL) and a narrowing of the Wobbe number range in others. However, in practice, Wobbe index variations in all EU countries are smaller than the fully accepted range. As no country has seen the full range of Wobbe index variations proposed by Marcogaz, the safety margins that have been achieved here are somewhat theoretical.

Furthermore, whilst a specification in the Wobbe index covers the majority of incomplete combustion and lift off problems, other interchangeability problems - such as sooting or flashback - are not covered. Recognising this, Marcogaz also proposed additional specification of gas relative density. A 0.55 to 0.7 range in relative density of gases, along with the Wobbe index limits proposed above, represents a practical and pragmatic approach to limiting the higher hydrocarbons content of the gas that are at the origin of sooting and related problems.

Finally it is recognised that flashback is not covered by this proposal. Natural gases are generally not prone to flashback. However, hydrogen or unsaturated hydrocarbon addition could sufficiently increase the stoechiometric flame speed to create a problem. Thus this proposal is considered valid only insofar as no hydrogen is added to the gas.

CHALLENGES AND UNCERTAINTIES

The key assumption at the heart of this proposal is that all appliances installed since the introduction of the GAD leads to safe combustion behaviour (as regards the essential safety requirements) over the whole of the H range during testing, and that their behaviour is not modified during manufacturing, installation or maintenance. Any modifications that can influence the settings of the appliance in term of air-gas ratio may change this ability. In particular, adjustments made during installation or maintenance that are based on adjusting the air gas ratio, may be very detrimental.

If adjustments are made in order to optimise combustion and performance of the appliance with that gas distributed at the time of adjustment, then the whole operating range of the appliance may be changed. One consequence of this is that the Wobbe index range indicated by appliance marking when coming out of the factory may be totally distorted with limited ability to accept gases much different from that distributed at the time of adjustment. Over time, therefore, appliances may ”evolve” to suit the historical gas supply and any sudden change in this supply may bring hazards.

Another consideration is that manufacturers, while certifying appliances able to work within the full range of EN 437, may set appliances for the range of gases declared by the countries of final destination. In this case, an appliance sold in UK, for example, may differ to one sold in Denmark. However, both appliances are able to sustain the whole range of gases within the limits defined nationally. In such a situation, the only possible harmonised range would again be the one presented in Figure 1.

The concern, therefore, is that local practices may render the range proposed by Marcogaz not applicable and that the only possible harmonised specification would be the much narrower one shown in Figure 1. This could jeopardize the interoperability of the EU networks could limit the range of gases available to the EU, which could both increase supply cost and a decrease security in supply.

These issues are recognised by EASEE-gas. The Marcogaz proposal has already been challenged by the gas industry on two fronts.

- Spain where there is a compulsory gas appliances inspection and maintenance scheme is asking for the use of the full group H range as defined in EN 437 as an harmonised specification.
- Some producers are asking that the lower limit be lowered from 47 to 46.44 MJ/m^3 to cover for their production.

These aspects have been under discussion for some time and are still continuing. During a workshop organised by Marcogaz in December 2005 the different positions have been presented. It seems that manufacturers may indeed "adjust" their appliances to suit the range of gases of the country of destination. If so the impact of the Marcogaz proposal may differ from country to country according to the current range of gases declared.

As for adjustments made during installation or maintenance, it seems that practices vary widely from country to country. Where such adjustments are practiced, then assessment of the likelihood and degree of future changes in gas quality must be assessed.

CONCLUSION

The involvement of Marcogaz in the development of a harmonised gas quality specification for Europe is aimed at defining an interchangeability range consistent with the European appliance market. As consistent testing of appliance can only be assumed since 1993, there is still National variation in age of existing appliances, and hence their performance with a wider range of gas quality. The magnitude and scope of problems

arising from these older appliances will differ a national level, affecting the ability and timescales for adoption of a harmonised specification.

Consultation with the gas industry shows that the current proposal, a Wobbe range between 47 to 54 MJ/m^3 is being challenged on two different fronts. To increase the security of supply of EU and possibly decrease the cost of gas, some stakeholders would like to enlarge this range. But existing practices during the manufacturing process and during installation and maintenance of the appliances may decrease their ability to burn widely different gases.

Different national practices have been identified. Thus some countries may not be able to accept any gas outside the range of their current historical supplies while other countries may be ready to accept a range of gas within the proposal made by Marcogaz. For example, Spain already accepts gases within the full EN 437 range for H gases. Thus these differences should be studied in detail and their impact evaluated at a national level before any definite proposal for a harmonised interchangeability domain can be drawn for Europe.