ETN

European Turbine Network

Position Paper

The Impact of Natural Gas Quality on Gas Turbine Performance

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This paper has been produced to be a consensus view of the participants in ETN Working Group 2: Fuel Flexibility and Emissions.

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EXECUTIVE SUMMARY

Of all the conventional fossil fuel based power generation systems, natural gas fired combined cycle plant produces the lowest carbon emissions per Megawatt of electricity produced. Typical gas fired combined cycle plant produces of the order of half the carbon emissions of conventional coal fired plant because of the lower carbon content of the fuel and the higher plant efficiency. Because of this natural gas fired gas turbines used in combined cycle configurations have played an important part in the reduction of carbon emissions from electricity generation and form a significant part of new power generation plant being commissioned throughout Europe.

Gas turbines are sensitive to variations in natural gas composition, but variation of fuel composition within current national specifications has not historically caused major problems because these variations have typically been much less than allowed by the specifications. However, increasing imports of pipeline natural gas and LNG and increased cross-border trading of natural gas have resulted in some gas turbine plant experiencing problems due to fuel quality variations and the risk of such problems is likely to increase. The EASEE-gas specification, produced to simplify European natural gas trading, allows greater variation in fuel properties than allowed by some of the current national specifications and greater variation than can be accommodated by most modern gas turbines without re-tuning.

In addition to issues associated with changes in the average composition of the fuel, the rate of change of composition may also be important, but this is an area that is not well understood either from the perspective of the capability of gas turbines' controls to deal with change or from the perspective of maximum rates of change that can realistically occur in a natural gas distribution system. The EASEE-gas specification and European national specifications do not address this issue.

For the gas turbine operator, the most likely issues associated with fuel composition variation are associated with the combustion system in the gas turbine and include:

- high levels of pollutant emissions, especially oxides of nitrogen and carbon monoxide
- component life and integrity issues due to factors such as flame flashback and unstable combustion
- operability issues such as ignition problems and flame failure

Potential costs associated with operability issues and failures are difficult to quantify because of the variation in problems that can occur and variation in electrical power trading regimes. However, for a large utility power generation combined cycle gas turbine with of the order of 350MW electrical output, penalties incurred and other costs for single engine trip would typically be in excess of 100,000 Euros.

Additional costs and lost revenue in the order of 200,000 Euros per day (depending on trading regime and electricity and natural gas price) would be incurred while investigating the cause of the trip. In the worst case if serious damage occurred (for example due to flashback) resulting in consequential damage to the turbine, then a major overhaul of the gas turbine would be necessary with costs potentially of the order of tens of millions of Euros.

In addition to the cost impact on operators, lost generating capacity would probably be replaced by plant producing higher carbon emissions and should such failures occur at times of high demand, then security of supply could be compromised.

Original Equipment Manufacturers (OEMs) are starting to address the issue, but solutions are in the early stages of development and may not be viable for all existing gas turbines.

Therefore, ETN invites the European Commission to initiate a study investigating the following areas in more detail:

- current and potential future rates of change of Wobbe Index in distribution networks
- actual capability of gas turbines to accommodate changing fuel composition
- methods of compensation for changes in fuel composition such as:
    - Ø controlled gas heating as a retrofit Wobbe Index control system
    - Ø manufacturers' control system modification for automatic Wobbe Index compensation and the potential for applying solutions developed across the existing gas turbine fleet
    - Ø application of H-Gas to L-Gas switching experience to range switching in nominally single fuel areas
- rapid fuel composition measurement methods
- issues associated with increased H-Gas to L-Gas switching
- the potential for changes or additions to the EASEE-gas requirements to address the issues of Wobbe Index range, rate of change of Wobbe Index and high levels of higher hydrocarbons.

The security of energy supply in Europe calls for diversifying the supply sources of energy. Building more LNG ports is one of the strategies identified by the European Commission. However, the European gas turbine operators as well as OEMs would like to see **a convergence of the quality specifications for imported natural gas throughout Europe** in order to allow continued development of clean and efficient power generation from gas turbine in Europe.

1. INTRODUCTION

The European natural gas transmission system stretches from the North Sea and the Baltic down to the Mediterranean and from the Atlantic to Eastern Europe. It is made up of the transmission systems of different European gas companies linked by interconnections. Increased gas demand and depletion of traditional stocks are leading to a growing requirement for the transport of gas around the system and import of gas to the system. This has led to increased import of gas from Russia and Eastern Europe and the Near East via pipelines and from around the world in the form of LNG.

Currently, there is a wide range of specifications and normal gas compositions throughout Europe. Figure 1 show typical gas compositions for a number of European countries together with some national specifications, the European standard, EN 437 for H-gas and the EASEE-gas specification (see below). With the increase in imports and gas transport the variations in gas composition are likely to increase.

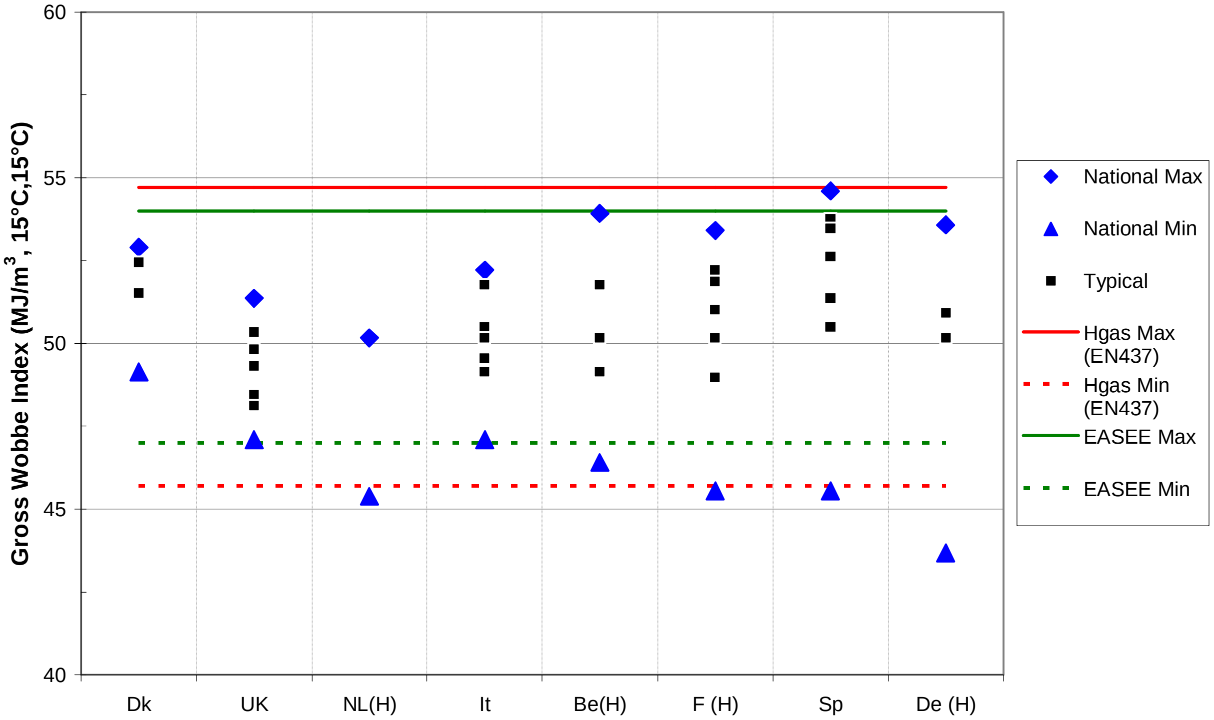

Figure 1: Typical Variations in European Gas Specifications and Normal Compositions (Derived from References 1, 2 and 3)

The significant differences in national specifications shown in Figure 1 may cause problems for the international trading of natural gas. To maintain the standards may mean fuel treatment when passing from one system to another (adding cost) while relaxing the standards may result in operability problems for existing gas appliances. To aid Europe-wide trading of gas, harmonisation of fuel quality standards may be desirable and in response to this issue, the European Association for Streamlining of Energy Exchange (EASEE) set up a gas group, EASEE-gas, in 2002 to *"develop and promote the simplification and streamlining of both the physical transfer and the trading of gas across Europe"*.

EASEE-gas has produced a specification (see Table 1, Reference 2 and Figure 1) which aims to maximise the flexibility of natural gas transfer without compromising operability of gas appliances. **However, the majority of the assessments of operability of gas appliances are based on domestic appliances and may not be applicable to complex equipment such as gas turbines.**

Table 1: EASEE-gas Specification

Parameter	Unit	Min	Max
Wobbe Index	MJ/m^3 (See Note 1)	47	54
Relative Density	m^3/m^3	0.555	0.70
Total Sulphur	mg/m^3	-	30
Hydrogen Sulphide (H_2S) + Carbonyl Sulphide (COS)	mg/m^3	-	5
Mercaptans (R-S-H) (quoted as Sulphur)	mg/m^3	-	6
Oxygen	mole %	-	0.01
Carbon Dioxide	mole %	-	2.5
Water Dew Point	°C at 70 Bar A	-	- 8
Hydrocarbon Dew Point	°C at 1 to 70 Bar A	-	- 2
Hydrogen			Insignificant (See Note 2)

Note 1:
The values of Wobbe index have been converted from the reference conditions in the original document to 15°C, 15°C, 101.325 kPa. EASEE-gas recommends that work on safety consequences be initiated to investigate the possibility of changing the lower limit towards 46.45 MJ/m^3.

Note 2:
EASEE-gas states that: "Future gas operations may lead to use of gases containing significant levels of hydrogen or other synthetic/manufactured gases. Appliance malfunction can occur with the presence of hydrogen or other high flame speed gases. As natural gas does not contain any hydrogen, the recommendations in this CBP are valid only for insignificant levels of hydrogen in order to control risk of flashback. If synthetic/manufactured gases are anticipated to become a cross-border issue, the proposed set of parameters needs to be re-evaluated."

Relaxation of the current local standards could cause gas turbine operability problems, but even without relaxation of current standards increased fuel composition variability within the existing standards is an issue.

This paper considers, from a gas turbine operator's perspective, the issues associated with relaxing the fuel supply specification and increased fuel variability.

2. BACKGROUND: GAS TURBINE COMBUSTION

There is a common misconception that gas turbines can burn almost any combustible gas and that gas fuel variability is not a significant issue. There are gas turbines firing a very wide range of gases including: natural gas (including gas with high inerts and high non-methane hydrocarbons); syngas (from coal, biomass and wastes); steelworks gases (coke oven gas and blast furnace gas); and gases with very high hydrogen content (such as refinery gases); **but each individual gas turbine can only tolerate limited changes in gas composition and properties, depending on the gas turbine design and the set-up of the gas turbine hardware and controls.**

With regard to the operation of a gas turbine on a fuel of varying composition, the most significant part is the **combustion system**. There are various types of combustion system, the two main types being:

- conventional (or diffusion flame) combustors and
- Lean Premix combustors.

Lean Premix combustors are often referred to as Dry Low NO_X (DLN) or Dry Low Emissions (DLE) combustors. The majority of gas turbine capacity installed since 1995 has some version of a lean premix combustion system.

Lean premix combustors tend to be more sensitive to fuel variation because their operation has been optimised for a narrow range of conditions to minimise emissions of pollutants, particularly the oxides of nitrogen (NO_X). Because of this and the predominance of lean premix combustors in the modern power generation gas turbine fleet, discussions in this paper about the issues associated with fuel variability will concentrate on lean premix systems. However, it must be remembered that although conventional combustors tend to be less sensitive they can still suffer problems due to fuel variations.

For the gas turbine operator, the key issues for gas turbine operation are:

- Emissions [particularly Oxides of Nitrogen (NO_X) and Carbon Monoxide (CO)]
- Operability including part load operation
- Reliability
- Component Life

An extensive white paper produced for the US Federal Energy Regulatory Commission (Ref. 4) concluded that in gas turbines, varying natural gas composition (beyond acceptable limits) can result in **increased emissions, reduced reliability/availability, and decreased parts life.** Thus the key issues for the operator can be significantly affected by fuel variability.

The way in which fuel quality and its effect on the combustion system can influence these key factors will be considered. Figure 2 shows the typical features of a lean premix burner/injector firing into a gas turbine combustor. Fuel is introduced into a swirling air flow (upstream and/or downstream of a swirl generator). The fuel is widely distributed to ensure an even fuel distribution and the swirling flow tends to enhance mixing and generate the correct aerodynamic conditions for flame stabilisation in the combustor. Fuel injection is followed by an air/fuel mixing zone to allow time for good mixing to occur. This mixing is essential to ensure an even temperature distribution in the flame which leads to low NO_X emissions.

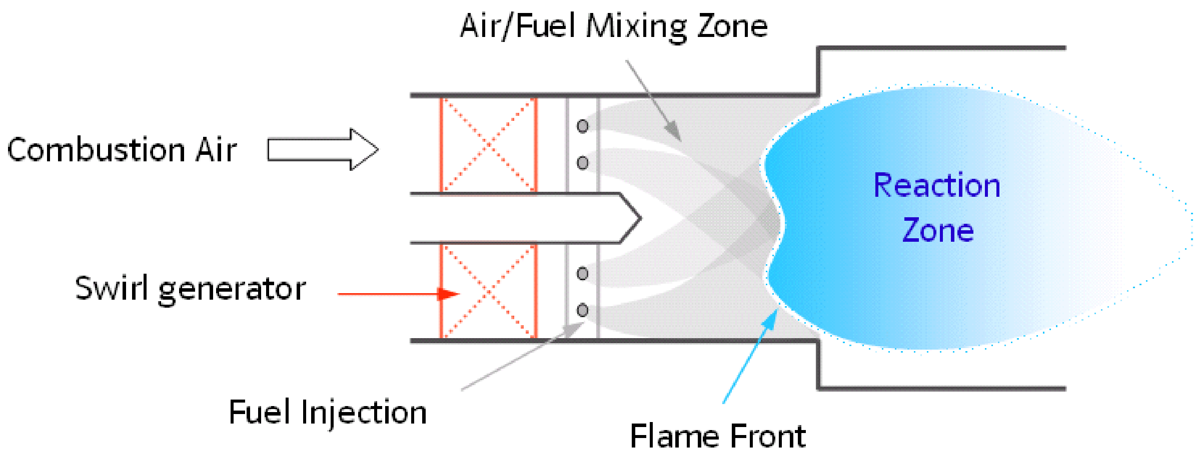

Figure 2: Typical Elements of a Lean Premix Burner
(From Reference 5)

For acceptable operation of the gas turbine the flame must:

- stabilise at the burner exit at the upstream end of the combustor without propagating upstream into the mixing zone (flashback) or lifting from the burner, propagating downstream and blowing-out
- not produce excessive combustion dynamics
- have flame temperature and temperature distribution which does not deviate significantly from design values (to prevent component overheating or excessive thermal stresses)
- produce low levels of pollutant emissions (particularly NO_X and CO)

Combustion dynamics, acoustic pressure fluctuations within the combustor, can occur in any combustion device, but lean premix gas turbine combustors are particularly susceptible to this phenomenon.

Combustion dynamics occur due to the coupling of pressure oscillations in the combustion system with the energy release within the flame. These pressure oscillations can reach high amplitudes and can induce vibration in the combustor components leading to increased wear, reduced component life or in extreme cases catastrophic component failure.

Fundamental properties of the fuel and air/fuel mixture are:

- Heat content
- Flame speed
- Autoignition temperature
- Autoignition delay time
- Flammability limits
- Stoichiometric flame temperature

These together with the air fuel ratio, flow properties (e.g. flow speed, turbulence etc), fuel placement and mixing quality in the mixing zone may have a significant influence on flame behaviour (flashback, blow-out, dynamics and emissions). **All these fundamental properties are affected directly by the composition of the fuel and changes in composition and can affect flame behaviour.** For example increased flame speed will increase the risk of flashback.

Indirect effects can also occur. For example, variations in fuel composition may affect the fuel distribution by a number of mechanisms, one being the effect of varying heating value. A fuel with a higher heating value than normal would require less fuel for a given operating condition. This may lead to the fuel jets having lower momentum and thus not penetrating as far into the air flow. Thus the fuel distribution at the flame would not be the same as the design optimum. This could lead to incorrect temperature distribution leading to increased emissions, component overheating (reducing life) or increased combustion dynamics. In extreme cases incorrect fuel placement can lead to the flame propagating back into the mixing zone (flashback). This can rapidly lead to catastrophic failure.

The details of how all these primary and secondary effects influence combustion performance depend on the combustion system design and are outside the scope of this paper; however because of this, different gas turbine manufacturers have different fuel specifications and use a range of parameters to specify acceptable fuel quality.

3. GAS TURBINE MANUFACTURERS' FUEL SPECIFICATIONS

Gas turbine original equipment manufacturers' (OEMs') fuel specifications are not typically published in the open literature and are often contractual documents applying to particular installations and thus cannot be referenced directly here. Even though these specifications are in principle installation specific, individual manufacturers tend to use the same specifications across a range of sites, and there is a significant amount of commonality between manufacturers' specifications. Typical requirements are discussed in this section.

The **Wobbe Index (WI)**, as used in Figure 1 is the most commonly used parameter for specifying the acceptability of a gas fuel and is typically given by:

$$WI = \frac{\text{heating value}}{\text{relative density}^{0.5}}$$

The terms Wobbe Index and Wobbe Number are often used interchangeably and different manufacturers and workers in the field use different definitions and reference conditions, thus care should be taken when comparing information. In this paper the Wobbe Index is based on the gross (higher) heating value expressed in MJ/m^3 at both metering and combustion reference conditions of 15°C and 101.325kPa (see Ref.13). The significance of the Wobbe Index is that for given fuel supply and combustor conditions (temperature and pressure) and given control valve positions two gases with different compositions, but the same Wobbe Index, will give the same energy input to the combustion system. Thus the greater the change in Wobbe Index the greater the degree of flexibility in the control and combustion systems that is needed to achieve the design heat input.

The Wobbe Index as defined above **does not take into account differences in fuel supply temperature** and some manufacturers state that the Wobbe Index should be calculated at actual supply temperature rather than at reference conditions or use modified definitions that include supply temperature. Supply temperature is a variable and these temperature dependent definitions of the Wobbe Index are not intrinsic properties of the fuel gas whereas the Wobbe Index calculated at stated reference condition is. Thus temperature dependent definitions of the Wobbe Index are not used in fuel supply specifications.

Manufacturers may also specify limits on the Heating Value of the fuel. Again care must be taken when comparing information as different units and reference conditions are used and both Lower (Net) and Higher (Gross) Heating values are used.

Gas turbine manufacturers typically specify that their turbines are capable of operating over a wide range of Wobbe Index and Heating Value. Ranges in excess of ±10% of mid-range values are normal. However, **minor hardware changes may be required to cover all the range and individual gas turbines are unlikely to be able to accommodate all the range without re-tuning.** For a particular gas turbine installation a range of ±5% of the commissioned/tuned value of Wobbe Index and/or Heating value is typical. For some gas turbines a range as low as of ±2% of the commissioned/tuned Wobbe Index has been specified.

The national specifications shown in Figure 1 have allowable variations in Wobbe Index from their mid points ranging from approximately ±4% to ±10%. The proposed EASEE-gas specification is in the middle of this range allowing a variation of approximately ±7%. It can be seen that many of these national specifications allow ranges wider than typical manufacturers' specifications. However, historically in any particular location the gas properties have been reasonably constant with variations not normally exceeding those of the "Typical" values shown in Figure 1. Also in some countries there is local control of the gas properties to tighter limits than the national limits. Thus in the past, problems due to excessive variation in Wobbe Index have been rare. With the increased fuel variations some occurrences of operational problems and failures of gas turbines close to LNG terminals have been reported and this is likely to increase.

In addition to the Wobbe Index alone, the composition affects flame speed, autoignition properties and the chemical kinetics of the flame, affecting in particular emissions, flashback and ignition properties. There is a wide range of manufacturers' specifications for composition, but they typically specify maximum levels of higher hydrocarbons (individually or as C2+, C4+ etc), minimum methane and/or maximum inerts. These specifications aim to ensure that the fuel gas is predominantly methane, and that gases which contain both high levels of inerts and higher hydrocarbons but are still within Wobbe Index limits are not allowed.

In addition to the effects on chemical kinetics, high levels of higher hydrocarbons can under some fuel supply conditions result in the fuel temperature being below the hydrocarbon dew point, resulting in the condensation of hydrocarbon liquids in the supply. These can accumulate, particularly at low points in the fuel supply and can then be forced by the incoming gas into the burner as a slug of liquid hydrocarbons. For a brief period during passage of the slug, the fuel distribution is disrupted, the level of higher hydrocarbons entering the burner is dramatically increased and the heat input to the burner is increased (due to the higher volumetric heating value of liquid hydrocarbons). These effects can lead to flashback, control problems and a range of other issues, therefore most manufacturers specify that the incoming fuel should be above the hydrocarbon dew point by a specified margin. Typically this margin is about 20°C.

Although less serious, water condensation may also cause problems and most manufacturers specify that the incoming fuel should be above the water dew point by a specified margin. Typically this margin is again about 20°C.

Because of its effect on flame speed, and thus flashback potential, most manufacturers specify a limit on hydrogen content. This can be from a "Trace" to over 10% by volume depending on the type of combustor, however **most modern gas turbines should be capable of tolerating of the order of 1-2% hydrogen by volume.** Most natural gas contains much lower levels of hydrogen and therefore this has not been an issue, but with increasing pipeline gas from unconventional sources (such as Synthetic Natural Gas (SNG) from gasification of biomass, waste, etc) this may become an issue. **Proposals to transmit hydrogen mixed with natural gas in the distribution network in the EC FP6 project "Naturalhy" (Ref. 6) would be of major concern to gas turbine users.**

Manufacturers have a very wide range of specifications for **sulphur containing compounds**, however from a gas turbine perspective, levels of sulphur well in excess of normal pipeline supply limits have little or no effect on corrosion/oxidation rates of hot turbine parts except in the presence of high levels of alkali metals. However, other problems can be exacerbated by sulphur content, such as corrosion of components downstream of the gas turbine (e.g. the Heat Recovery Steam Generator in combined cycle plant). The presence of elemental sulphur vapour in the natural gas supply can cause problems with sulphur deposition on control valves and in fuel distribution systems. This is not normally part of manufacturers' fuel specifications and is typically dealt with by appropriate control of fuel temperature. Some manufacturers have however specified that there must be no elemental sulphur. This is not feasible to guarantee as even with very low levels of sulphur compounds in the natural gas under some pipeline conditions, the gas can become saturated with elemental sulphur vapour. This is at very low concentration (of the order of parts per billion), but will be there and is the cause of sulphur deposition in gas turbine fuel control systems (Ref. 7).

In addition to the steady state properties of the fuel, manufacturers may specify **the rate of change of properties**. This is typically the rate of change of Wobbe Index or Heating Value. This is because even within an acceptable Wobbe Index (or heating Value) range, the gas turbine control system has to be able to respond to the changes, for example:

If the Wobbe Index increases this will increase the heat input (for a particular control valve position) and this will lead to an increase in combustion temperature. The control system must be able to detect and compensate for this change to prevent damage due to excessive temperatures.

However, the speed of control system response depends on factors including the control philosophy, the method of detecting over-temperature, and the size of the gas turbine and its fuel supply. Because of the very wide range of gas turbine designs there is a very wide range of acceptable rates of change of Wobbe Index or Heating Value ranging from of the order of 0.5% per second to of the order of 0.5% per minute. Currently European gas delivery specifications do not include rate of change of Wobbe Index.

4. PIPELINE SPECIFICATIONS

As indicated by Figure 1, there is a wide range of specifications and it is outside the scope of this paper to review or list them all. However, as indicated in Section 1, EASEE-gas have produced a specification (see Ref.2) which aims to maximise the flexibility of natural gas transfer without compromising operability of gas appliances. This specification attempts to address the same issues as the individual pipeline specifications although specified limits may be less restrictive. In principle it also addresses most of the critical issues in the manufacturers' specifications discussed in Section 3, but again the specified limits may be less restrictive.

Table 1 shows the main elements of the EASEE-gas specification. The range of acceptable fuels may be represented on a plot of Heating Value against Relative Density (RD) as show in Figure 3. Fuels will generally be acceptable if they fall within the region bounded by the lines representing:

- WI = 54 MJ/m^3
- WI = 47 MJ/m^3
- R D = 0.555
- R D = 0.7

It can be seen that this also effectively limits the range of acceptable heating values.

Of course, the other elements of the specification must be met in addition to this, but plotting fuels on Figure 3 gives a good indication of their acceptability. A number of typical natural gases (from the UK) have been added to Figure 3 (green diamonds) and it can be seen that they fall comfortably within the acceptable region.

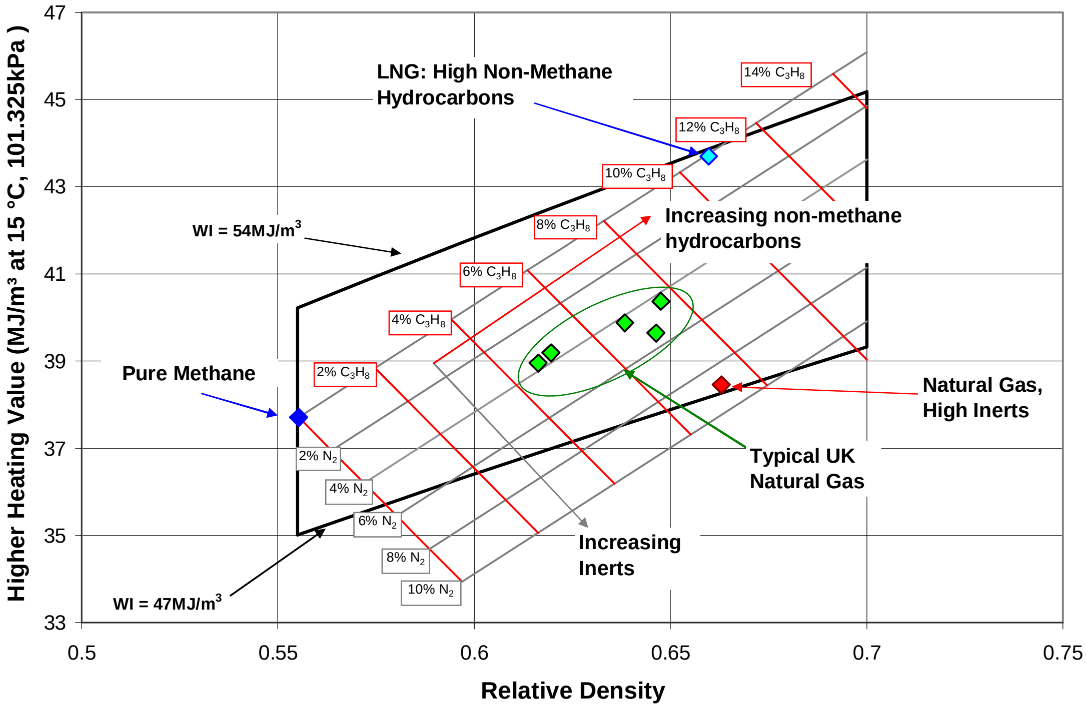

Figure 3: Plot Showing the Range of Gases Acceptable under the EASEE-gas Specification and Contours of Nitrogen and Propane Concentration (mole %) for Methane/Propane/Nitrogen Mixtures.

The exact position of a gas on the chart will depend on the full details of the fuel composition, but it is possible to identify trends by considering idealised gases consisting of only methane, propane and nitrogen. Nitrogen is used to indicate trends associated with the concentration of inerts in the fuel gas and propane is used to indicate trends associated with higher hydrocarbons.

Contours of nitrogen and propane concentration are included on Figure 3. It can be seen that the upper Wobbe Index and the upper Relative Density determine the maximum level of propane and the lower Wobbe Index and the upper Relative Density determine the maximum level of nitrogen in the mixture. Taking propane and nitrogen as indicative of higher hydrocarbon and inert content respectively, it can be seen that this effectively limits their concentrations. Although real fuels are more complex with many more components they follow the same trends and the specification does have the effect of limiting both higher hydrocarbons and levels of inerts. However, the allowable levels exceed the requirements of many manufacturers' specifications, particularly with regard to higher hydrocarbons.

The EASEE-gas requirements relating to sulphur compounds are generally in line with manufacturers' specifications. The limits on hydrocarbon and water dew point should allow acceptable design of fuel delivery and control systems to prevent condensation issues. The hydrocarbon dew point restriction will also tend to limit the presence of the heavier hydrocarbons.

Currently the EASEE-gas specification does not allow any significant amount of hydrogen, but does not specify what is significant. As mentioned in Section 3 this is currently not an issue. However, with increasing pipeline gas from unconventional sources and proposals to transmit hydrogen mixed with natural gas in the distribution network (Ref. 6) a clear definition of maximum acceptable hydrogen would be beneficial.

It can be seen that the EASEE-gas specification does, to some extent, limit all the major fuel composition factors that can significantly affect gas turbine operation, performance and reliability, but the limits may be less restrictive than typical gas turbine specifications. The major concerns are:

- **The width of the acceptable Wobbe Index range**
- **The possibility of unacceptably high levels of higher hydrocarbons**

In addition to the composition requirements, there is currently **no restriction on the rate of change of composition**. As discussed in Section 3, rapid rates of change in composition can result in problems with gas turbine control.

The only precedents for the specification of rate of change of composition in natural gas transmission entry or exit requirements are a series of decisions by the US Federal Energy Regulatory Commission (FERC) (e.g. Ref. 8) which proposes that specifying a maximum rate of change in Wobbe Index of 2% per six minutes is not unreasonable. This limit should allow most modern gas turbines to operate acceptably. Thus an equivalent specification should be considered.

5. METHODS OF ACCOMMODATING COMPOSITION CHANGES

A number of gas turbines have a gas chromatograph in the control system which takes into account the fuel composition to minimize the risk of adverse effects. This effectively allows the control system to re-tune or re-optimize the gas turbine in response to fuel changes. However, because of the long measurement time constant of a gas chromatograph, such systems cannot respond to very rapid changes. Because of this, ALSTOM have developed a measurement system that can quickly determine key fuel properties (e.g. higher hydrocarbons) to allow control without the full gas analysis provided by a gas chromatograph (Ref.9).

Such measuring and control systems could in principle be developed for other gas turbines if necessary, but would have to be developed specifically for each gas turbine type as the control solution would be different for each one.

Where the sensitivity to fuel variation is driven by the bulk fuel properties as represented by the Wobbe Index, rather than details of the composition such as the concentration of higher hydrocarbons, control of fuel properties rather than automatic modification of the control concept is feasible. The most common way of achieving this is by control of fuel temperature which is used to control the effective Wobbe Index.

This approach can in principle accommodate significant variations in fuel composition and has been used successfully on a number of gas turbine types including GE heavy duty gas turbines (e.g. Ref.10). This method however depends on a gas chromatograph for composition measurement and thus suffers from the problem of slow response time. However, this concept could be applied to a wide range of gas turbines.

Because variations in fuel composition have an effect on gas turbine behaviour, in principle it may be possible to use changes in gas turbine behaviour to detect fuel composition variation and modify the control system to compensate. The GE OpFlex Wide Wobbe control system is an example of this approach. The system is described in Reference 11 and requires no hardware changes as it is implemented within the control system. Similar concepts could be developed for other gas turbines.

While not specifically developed for fuel composition effects, automatic protection systems aimed at protecting the gas turbine from high levels of combustion dynamics may give some benefits. Such systems are usually designed to prevent excessive combustion dynamics under adverse environmental conditions (e.g. low ambient temperatures) and automatically reduce load if dynamics levels approach limit values. This may also be of benefit if fuel composition variation has an adverse impact on combustion dynamics.

Systems such as Siemens' Integrated Fuel Gas Characterization (IFGC) system (Ref.12) include a hybrid of automatic re-tuning in response to measured fuel changes and control system response to gas turbine behaviour.

In locations where both L-gas (low heating value) and H-gas (high heating value) may be delivered, there is experience of fuel gas switching. This requires a control system with two sets of parameters; one for H-gas and one for L-gas. Advance warning of change from one gas to another allows switching to occur.

However, it is likely that the requirement to switch may become more frequent and thus automatic systems will become of increasing importance. With the increased variability within areas with gas of a single type, it may also be appropriate to consider a similar switching approach. Switching between two set points (either control system settings or fuel heater set points) with overlapping ranges may be used to accommodate such composition variation.

It can be seen that there are a range of potential control methods available and Original Equipment Manufacturers (OEMs) are starting to address the issue. However, solutions are in the early stages of development and may not be viable for all existing gas turbines.

6. CONCLUSION

It is apparent that there are significant potential problems associated with increases in variability in gas supply, with LNG import being a significant contributor to these problems. Parameters such as Heating Value and Wobbe Index alone are insufficient to characterise the gas. Properties relating to fundamental combustion behaviour such as flame speed and autoignition delay are important, but the importance of these factors depends on the specific gas turbine combustor design. These properties are strongly dependent on the presence of higher hydrocarbons.

Pipeline specifications do not usually have direct limits on higher hydrocarbons, but limits on other parameters such as relative density and hydrocarbon dew point may go some way towards limiting very high levels of higher hydrocarbons.

Original Equipment Manufacturers (OEMs) are starting to address the issue, but solutions are in the early stages of development and may not be viable for all existing gas turbines.

It is important that the following areas are better understood. Therefore, the European Turbine Network (ETN) would like to invite the European Commission to carry out a study in the following aspects:

- Currently there is limited information on distribution issues such as rate of change of composition especially rate of change of Wobbe Index. Information on current and potential rate of change of Wobbe Index is essential to understand whether this poses a real risk to turbine operation.
- The wide variation of acceptable rates of change of composition in manufacturers' specifications is of concern. Information on the actual capability of gas turbines to accommodate changing fuel composition would be of significant benefit.
- For most gas turbines, the use of gas heating for Wobbe Index control would be simpler than automatic re-tuning or model based control and the potential for gas heating to be used as a retrofit Wobbe Index control system should be investigated.
- Experience of H-gas to L-gas switching should be shared between ETN members and the issues relating to increased switching frequency should be investigated.
- The potential for application of H-gas to L-gas experience to range switching in nominally single fuel areas should be investigated.

- Manufacturers' control system modification for automatic compensation (e.g. GE OpFlex and Siemens IFGC) should be reviewed
- For most Wobbe Index control systems gas chromatograph time constants limit the speed of control. Rapid fuel measurement methods should be investigated.
- EASEE-gas requirements (Ref. 2) allow a wider range of Wobbe Index and higher levels of higher hydrocarbons than can be tolerated by many gas turbines. Also there is no specified rate of change of composition. The potential for changes or additions to these requirements should be investigated.

The security of energy supply in Europe calls for diversifying the supply sources of energy. Building more LNG ports is one of the strategies identified by the European Commission. However, the European gas turbine operators as well as OEMs would like to see a convergence of the quality specifications for imported natural gas throughout Europe in order to allow continued development of clean and efficient power generation from gas turbines in Europe.

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