**Emissions**

**G. Terzer, P. Kutne, ENEL (tbc)**

Comments from the PB meeting

S. Sigali stated that he will check internally if a colleague from ENEL could check this chapter as he is not an expert on emissions.

C. Björkqvist mentioned that E.ON has chaired in the past the ETN IED Committee and they could provide support on this topic.

G. Terzer:

* Part load emissions are the biggest challenge

M. Ruggiero, P. Kutne:

* BHGE and DLR are working on flameless combustion and this could be mentioned in this chapter

The NOx emission level of gas turbine engines has continuously been reduced over the last few decades. Even though 25ppm NOx (corr. to 15%vol. O2) is still accepted as industry standard (for gaseous fuel firing), more and more projects adopt 15ppm NOx as a emission target, and even single digit ppm NOx levels are being asked for in certain regions. For liquid fuel operation, 42ppm NOx has long been accepted as the emission limit, but recently a new version of the Industrial Emission Directive (IED) of the EU has been drafted which calls for 25ppm NOx also for liquid fuels. Legislation for CO emissions has been less stringent (usually less than 100ppm CO is acceptable), but in some cases CO emission limits (at base load) have been put as low as those for NOx (e.g. 25ppm). Subsequent to the publication of the IED, the Best Available Techniques Reference document (BREF) has set an expectation for further reduction in NOx levels for both existing and new plant.

Individual issues which should be addressed in the near future are:

**Emission limits at part load**

As gas turbines are much more often required to run at (low) part load and to cover a lot of cycling duties, including starts and stops, emission limits at part load are being given much more attention and emphasis. Maintaining low emission val- ues (e.g. 25ppm) for NOx (as well as for CO) down to very low part load and during transient load operation has become an important selling argument for gas turbine products. Issues to be addressed are safe combustion performance (flame stability, thermoacoustics) in combination with maintained low emission (NOx, CO) characteristics over a wide load range (from below 50% up to 100% load).

**Liquid fuels (emission of NOx, CO and particulates)**

Extremely low NOx emission limits (less than 25ppm) for liquid fuel operation of gas turbines pose a significant technical challenge if they should be achieved by combustion measures alone (no additional flue gas treatment via selective catalytic reduction (SCR)). Issues to be addressed are liquid fuel atomization/evaporation and pre-mixing fuel with air for homogeneous combustion in the gas phase as a prerequisite for low NOx formation. Combustion performance (flame stability) should not be compromised, either with or without addition of water/steam, and a combined minimum of emission species (NOx, CO, particulates) has to be targeted. As particulate emissions are typically very low, the challenge of measuring such low levels in a reliable way is not yet fully resolved.

**Exhaust gas recirculation**

Exhaust gas recirculation (EGR) applied to gas turbine engines can be a viable method to address a couple of issues: EGR can help to mitigate NOx emission (via moderation of peak flame temperatures and a reduced oxygen level) or keep NOx emission low even for increased turbine inlet temperatures (TIT). Additionally post combustion CO2 capture systems can be operated more effectively (lower specific energy consumption per ton of CO2 removed) due to an increased concentration of CO2 in the gas turbine exhaust. Critical is- sues with high EGR rates are combustion performance (flame stability) and potentially high CO emission.

**Dilute combustion / wet combustion / flameless combustion**

As alternatives to conventional lean premix combustion for which heat release is localized in a distinct flame front, other combustion technologies which target spatially distributed heat release offer potential advantages such as low NOx emission even if the premixing quality is imperfect. Volumetric heat release also provides more favourable conditions to avoid thermoacoustic feedback loops which can cause catastrophic pressure fluctuations. Possible means for achieving distributed heat release are strong dilution with steam (so-called wet combustion; e.g. related to Cheng cycle combustion conditions) or strong internal recirculation of exhaust gas leading to so-called flameless combustion conditions. Issues such as reduced burnout/increased CO emission and low load operating conditions need to be carefully addressed and managed.

**H2-rich fuel gases / NG-H2 mixtures**

Combustion of fuel gas mixtures containing high hydrogen concentrations (> 50%vol.) tend to show higher NOx emissions and require significant changes to the design of fuel-air mixing/burner/combustor systems in order to avoid this. If dilution with steam or nitrogen (N2) is not an option, issues regarding safe combustion performance (flame stability, flashback, combustor cooling, thermoacoustics) need to be addressed while trying to keep NOx emission low.

As H2 will likely become available more abundantly (via water hydrolysis driven by surplus electricity from RES) and be injected for energy storage reasons in larger amounts (> 2%vol.) into the natural gas grid, unambiguous data is required for such fuel mixtures (up to 20%vol. of H2 in natural gas) concerning combustion properties and emission characteristics in order to define methods and designs which can mitigate the associated risks.