

20th SYMPOSIUM ON INDUSTRIAL APPLICATIONS OF GAS TURBINES



Day 2 : Training session 4

EMISSIONS REGULATORY UPDATE

Lawrence Kaempffer P.Eng.

IAGT Chair 2012-2013

Principal Engineer

Siemens Canada Ltd.

Energy Service Fossil- TurboCare

Stoney Creek, ON, L8E 5Z2

Lawrence.kaempffer@siemens.com

Presented at the 20th Symposium on Industrial Application of Gas Turbines (IAGT)
Banff, Alberta, Canada - October 2013

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GAS TURBINE EMISSIONS REGULATORY DEVELOPMENTS

- **REASONS for REGULATION**
- **AIR TOXICS & PRIMARY POLLUTANTS**
- **EVOLUTION OF REGULATORY LIMITS
(CONVERGENCE of SOME STANDARDS TO
RECOGNIZE PROCESS EFFICIENCY & EMISSION
REDUCTION ON EXISTING UNITS)**
- **ON-GOING ACTIVITY & OBSERVATIONS**

REASONS for REGULATION

- **Human nature is to react when air quality reaches, or exceeds, a maximum tolerable level or critical level**
- **Typical examples would be the 1991 Acid Rain, Canada-US Air Quality Agreement to REDUCE both SO₂ & NO_x emissions**
- **Los Angeles SMOG in 1960's & subsequent vehicle emission standards**
 - **NO_x + Volatile Organic Compounds = photochemical SMOG = Ozone & other toxics**
- **Provide adequate protection against adverse effects on soil , water, vegetation, materials, animals, visibility, personal comfort & well-being (public health)**

REASONS for REGULATION

- **More recent concerns regarding the affect of greenhouse gas emissions (primarily CO₂) on the climate/environment**

AIR TOXICS & PRIMARY POLLUTANTS

- **Canadian National Air Quality Objectives 1989-1990**

Max Acceptable avg. concentration over 1 h period

- Sulfur Dioxide SO₂ 0.34 ppm
- Nitric Oxides NO_x 0.21 ppm
- Carbon Monoxide CO 31 ppm
- Ozone O₃ 0.08 ppm

- The maximum acceptable level was intended to provide adequate protection against adverse effects

- **2012 Canadian Ambient Air Quality Standards**

CAAQS effective 2015:

- **Ozone** action threshold for achieving air zone CAAQS is **63 ppb (0.063 ppm) 8 h average** based on the 3 year average of the annual 4th-highest daily maximum 8 hour average concentrations

EVOLUTION OF REGULATORY LIMITS

- **1979 U.S.** Environmental Protection Agency (EPA) established standards of Performance for **new, modified, or reconstructed** stationary gas turbines (40 CFR Part 60). Generally, for units with a LHV heat **input** of greater than 107.2 GJ/h (approx.10,000 Hp output), gas fuel emission limits were:

Nitric Oxides **NOx** **75 ppm + allowance if fuel N >0.015%**

Sulfur Dioxide **SO2** **150 ppm or fuel < 0.8% Sulfur**

- Reference point was ISO standard day conditions, with turbine exhaust O₂ concentration at 15% on dry basis, and **allowable emissions adjusted upward for units with thermal efficiencies > 25%.(Heat rate adjustment)**

EVOLUTION OF REGULATORY LIMITS

- **1992 CCME** Canadian Council of Ministers of the Environment National Emission Guidelines for Stationary Combustion Turbines. This guideline set an allowable mass of NO_x (grams) per unit output of shaft or electrical energy (Gigajoules) as well as an allowance for an additional quantity of NO_x emitted if useful energy is demonstrated to be recovered from the facility's exhaust thermal energy during normal operation.

For non-peaking gas fueled combustion turbines > 20 MW:

- **Nitric Oxides** **NO_x 140 g/GJ Power + 40 g/GJ Heat recovery**
- Carbon Monoxide **CO 50 ppm** at power rating
- Sulfur Dioxide **SO₂ 800 g/GJ Power**
- Reference conditions for measurement are ISO standard day with turbine exhaust O₂ concentration at 15% on a dry basis.
- 3.6 GJ = 1 MWh

EVOLUTION OF REGULATORY LIMITS

- **2006 U.S. E.P.A** updates standards of performance for stationary combustion turbines. (40 CFR Part 60).

Some changes of interest were:

adoption of the CCME concept of allowable NO_x per useful energy output (more generous in some cases than CCME 92 for heat recovery!)

For units with heat input (HHV) > 850 MMBtu/h & firing natural gas:

NO_x 15 ppm or 54 ng/J of useful output (0.43 lb/MWh)

For units in the range > 50 & ≤ 850 MMBtu/h heat **input** (this can be up to a 110 MW unit at 44% efficiency) there is a less stringent standard for modified or reconstructed turbines. This is an incentive for older high emission units to be retrofitted to reduce air toxics. Firing natural gas :

NO_x 25 ppm or 150 ng/J of useful output (1.2 lb/MWh) for NEW units

NO_x 42 ppm or 250 ng/J of useful output (2.0 lb/MWh) for MODIFIED or RECONSTRUCTED units

Reference conditions for measurement are ISO standard day with turbine exhaust O₂ concentration at 15% on a dry basis.

ng/J = g/GJ

EVOLUTION OF REGULATORY LIMITS

- **ALBERTA NO_x & SO₂ Standards for New Thermal Generation Units.**

from CASA (Clean Air Strategic Alliance) 2003 report
Emissions Management Framework for Alberta Electricity Sector

- Effective **Jan 1, 2006 NO_x** standards for new gas fired units:
 - **0.6 kg/MWh (167 g/GJ) for units less than 20 MW** power capacity
 - **0.4 kg/MWh (111 g/GJ) for units between 20 & 60 MW** capacity
 - **0.3 kg/MWh (83 g/GJ) for units greater than 60 MW** capacity

For Co-generation units, MWh **includes combined steam heat** and electricity

- Effective **Jan 1, 2006**, standards for new coal fired units:
 - **0.69 kg/MWh (192 g/GJ) for NO_x**
 - **0.80 kg/MWh (222g/GJ) for SO₂**

ON-GOING ACTIVITY & OBSERVATIONS

- **BLIERS : (extracts from Bliers Expert Group final report)**

In Canada, the **2011** Combustion Turbine (CT) base level industrial emission requirements (BLIERS) working group was formed under the Air Quality Management System (AQMS) to analyze, discuss, and develop BLIERS for **new** combustion turbines used in various industrial sectors in Canada.

For any outstanding work or issues that were not dealt with and agreed upon in this BLIER process, the Canadian Council of Environment Ministers (CCME) 1992 guideline will continue to be the national emissions reference (e.g. heat recovery allowance for cogeneration systems and emissions standards for liquid-fuelled combustion turbines).

The mandate of the working group is to develop BLIERS for new combustion turbines that should match the stringency of emission levels in leading jurisdictions – inside or outside Canada, that meet a good base level of environmental performance.

ON-GOING ACTIVITY & OBSERVATIONS

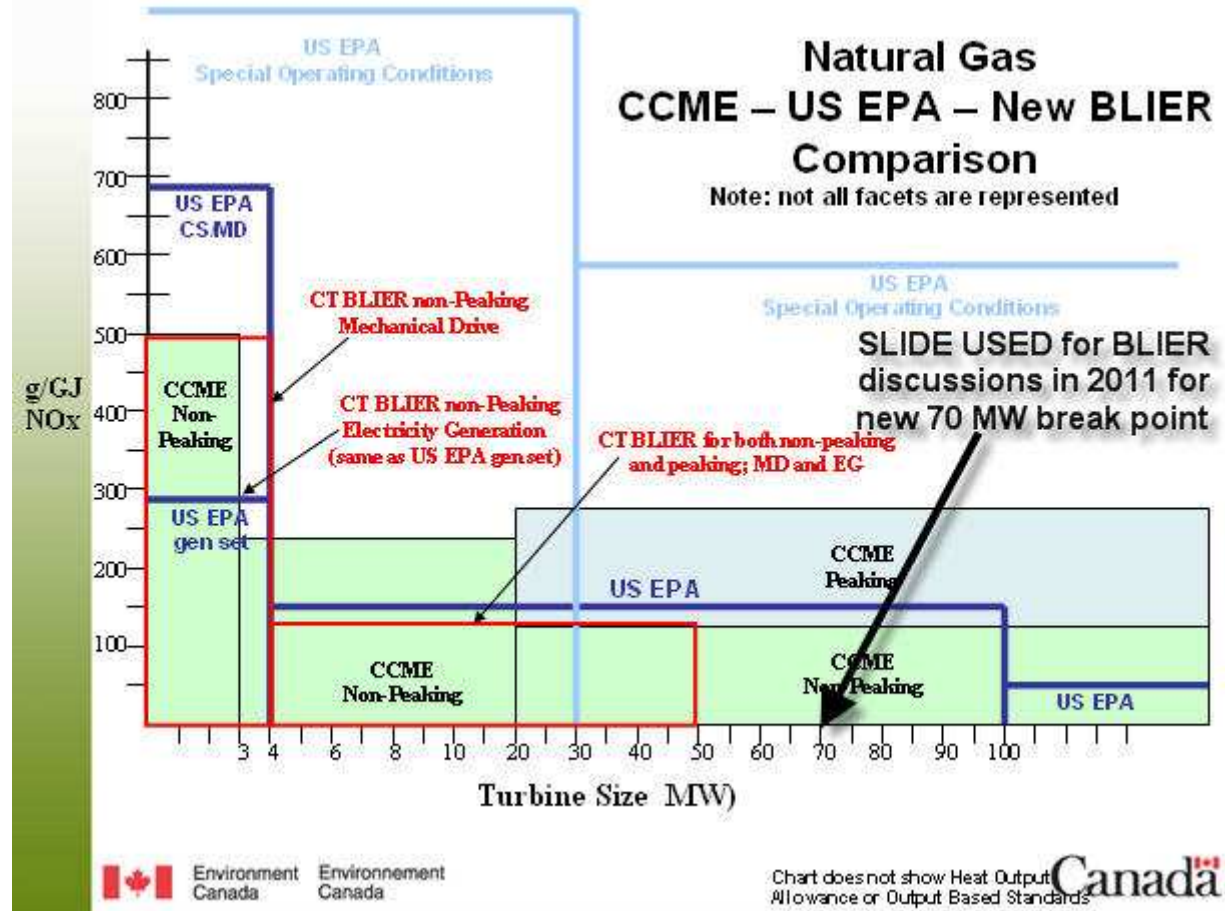
BLIERS cont'd

The scope of this group was to develop BLIERS for:

- **NO_x** from new 50+ MW natural gas-fuelled turbines
- **NO_x** from new natural gas-fuelled combined cycle turbine system
- **NO_x heat recovery allowances** from new natural gas-fuelled cogeneration turbine systems (containing gas turbine(s) and heat recovery steam generator operating with or without duct burners)
- **NO_x, PM, VOCs and SO_x** from new turbines/systems fuelled by liquid fuels such as; diesel, fuel oil, etc. and non-natural gas gaseous fuels such as syngas, refinery gas, landfill gas, etc.

ON-GOING ACTIVITY & OBSERVATIONS

An example of a discussion slide during the BLIER process



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ON-GOING ACTIVITY & OBSERVATIONS

2011 Natural Gas Fuel emissions from BLIER final report

Table 1 –Consensus BLIERs for New Combustion Turbines

Source	Form/Scope		NO _x BLIER emission standard		Degree of Consensus
	Type	Power Rating (MW)	g/GJ (power output)	ppmv (15% O ₂ dry)	
Combustion Turbine	Non-peaking - Mechanical Drive	< 4	500	75	All (CAMS process)
Combustion Turbine System (simple and combined cycle)	Non-peaking- Electricity Generation	< 4	290	42	All (CAMS process)
Combustion Turbine	Peaking	< 4	exempt	exempt	All (CAMS process)
Combustion Turbine System (simple and combined cycle)	Non-peaking and Peaking, Mechanical Drive or Electricity Generation	4 - 70	140	25	All (Combination of CAMS and AQMS processes)
Combustion Turbine System (simple and combined cycle)	Non-peaking, Mechanical Drive or Electricity Generation	> 70	85	15	Partial (non-consensus by one company for the 70-100MW range only)
Combustion Turbine	Peaking	> 70	140	25	All

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ON-GOING ACTIVITY & OBSERVATIONS

- CEPA (Canadian Environmental Protection Act) draft example of emissions Table in approval stage (from BLIER process) 2013.
 - waste heat recovery allowance is similar to CCME 92

Table 1: Natural gas combustion turbines – Output-based method

Application	Turbine Power Rating (MW)	NO _x Emission Limits (g/GJ _(power output))
Non-peaking combustion turbines - Mechanical Drive	≥ 1 and < 4	500
Non-peaking combustion turbines - Electricity Generation	≥ 1 and < 4	290
Peaking combustion turbines – all	≥ 1 and < 4	exempt
Non-peaking combustion turbines and Peaking combustion turbines – all	4 - 70	140
Non-peaking combustion turbines – all	> 70	85
Peaking combustion turbines – all	> 70	140

ON-GOING ACTIVITY & OBSERVATIONS

- **2013 USEPA Proposes CO₂ intensity limits for new fossil plants**
 - **1000 lb (454 kg) CO₂/MWh** for large Gas fuel plants > 850 MW
 - Equates to approximately 40% thermal efficiency HHV on Gas
 - **1100 lb (499 kg) CO₂/MWh** for coal & smaller gas fired plants
 - Equates to approximately 36% thermal efficiency HHV on Gas
 - **Please note that these modest thermal efficiencies are not a good signal to conserve our cleanest fossil fuel! (L Kaempffer)**
- **2013 CO₂ in Atmosphere ~ 400 ppm**
- **2012 IWR (Renewable Energy Industry Institute – Germany) reports 2011 World Carbon Emissions reach 34 billion tonnes**
- **2012 July 1 British Columbia Carbon tax - \$30/tonne of CO₂ equivalent emissions:**
 - **For Natural Gas = \$.057/cubic meter at retail level (5.7¢)**
 - **Dumping waste to atmosphere is analogous to landfill waste. Since we pay for landfill, an emissions tax or fee for exhaust waste is sensible and understandable (L Kaempffer)**

ON-GOING ACTIVITY & OBSERVATIONS

- **Historic reference 1970 LNG in British Columbia**
BC Hydro Gas: Tilbury Island, Delta
Purpose was to take gas from Westcoast Transmission during 8 to 10 warmest months of year for release during cold weather months
 - Liquefaction 2.5 million ft³ per day to 600 million ft³ capacity tank
 - 2,250 HP electric motor compressor & 150 HP boil off compressor
 - **Motor ratings equated to 5.8% of HHV of liquefied gas**
 - Three vaporizers each capable of 50 million ft³/day
- **1976 E.I.T. budgetary feasibility study using LNG for Island “back up” fuel for power generation in British Columbia found:**
 - **Generation Tax of \$.38/MCF (~ 1.3 ¢ / cubic meter)**
 - **Pipeline gas cost approx \$.66/MCF & LNG Plant operating & write-off added approximately 270% to the cost of the fuel gas.**
 - This was a very small LNG facility compared to 2013 Proposals for B.C.

ON-GOING ACTIVITY & OBSERVATIONS

Positive directions noted in the evolution of some regulations.

- **Recognition that mass of pollutant per unit of useful energy output (e.g. g/GJ , kg/MWh, etc) encourages energy efficiency and provides an easy comparison of the relative cleanliness of various thermal energy systems. (EPA also uses it for Diesel Engines)**
 - **Regulations that allow, and hence encourage, existing units to have emission reduction techniques applied when they are upgraded; but not force them to meet new unit requirements.**
 - **Lower the allowable differences in emissions levels permitted depending on fuel type or process chosen to convert energy**
 - **Given that current air quality concerns are largely due to higher polluting “grandfathered” technologies compared to what is available today on new units, there is no intrinsic value in having 2 or 3 significant figures to a very clean standard.**
(e.g. 0.3 kg/MWh or 0.2 kg/MWh output, are good numbers for NOx)
 - **A “Tax” or fee for disposing of waste to atmosphere, is no different to the practice of charging a fee for solid waste to landfill on a \$/kg basis**