Methanol as a low cost alternative fuel for emission reduction in gas turbines

Joint Venture between IEC and Dor Chemicals

THE 13TH ISRAELI SYMPOSIUM ON JET ENGINES AND GAS TURBINES
Thursday, November 6, 2014
The Need for Methanol

- Dramatic increase in regulatory requirements for reduced emissions.
- Traditional methods of reducing NOx emissions, such as:
  - modification of the firing system (DLN – Dry Low NOx)
  - injection of water into the firing system (WLN – Wet Low NOx)
  - post combustion treatment of the flue gas to remove NOx (such as SCR – Selective Catalitic Reduction)

All are very expensive!
Low cost alternatives should be checked!
Methanol as an Option

Methanol is a synthetic alcohol

Properties:
• Chemical Formula CH3OH
• Molecular weight 32.04
• Flash point 12 C (to 41 C)
• Auto-ignition temperature 464 C
• Combustion (Adiabatic) temperature 2045 C
• Low heating value 4777 kcal/kg
• Density 793 kg/ M³ at 30 C
Methanol is an Attractive Option

Methanol can achieve:

- Reduced NOx emissions - lower flame temperature and no Fuel-Bound Nitrogen (FBN)
- No SO2 emissions - has no sulfur
- Clean heat surfaces and lower maintenance - clean burning characteristics of methanol (better than with HFO or even with LFO)
- Higher power output relative to NG and FO - higher mass flow in GT engines
Methanol Firing at FT4C
TWIN PAC 50 MW GT Unit

Two stage tests:
1 – to prove feasibility (Caesarea)
2 – to restore capacity and gain operational experience (Eilat)
Caesarea Power Plant Site

Tested unit
TP -1 Base Plate Assembly
Liner
Fuel Spraying Nozzles
Predicting the NOx Formation

Calculated Flame Temperature Distribution at 100% Load

Flame temperature distribution through liner length

- **Temperature, C**
- **Calculation zone number**
- **Fuel oil#2**
- **Methanol**
Predicting the NOx Formation

Comparison of **Calculated** NOx Formation Through Liner Length for FO#2 and for Methanol Firing at 100% Load

![Graph showing NOx emission formation through liner length](image-url)

**Graph Details:**
- **X-axis:** Calculation zone number
- **Y-axis:** NOx emission (mg/dNm³ @15% O₂)
- Lines represent:
  - Fuel oil#2, calculated
  - Methanol, calculated
  - Fuel oil#2, measured
  - Log. (Fuel oil#2, calculated)
  - Log. (Methanol, calculated)
Diagram for Methanol Firing Test
Methanol Tank With Dike
Methanol Connection Junction
Emission Measurements Instruments
Test Results

NOx Reduction
Test Results

CO
Test Results

Particulates

Graph showing particulates emission as a function of GT load, with data points for Oil#2 and Methanol.
Test Results

SO2

SO2 emission as function of GT load

SO2, mg/dm³@15%, O2

GT load, Mw

Oil#2  Methanol  Power (Oil#2)
Following Stage Modification for a Long-Term Methanol Firing Test in Eilat

**The Plan**
A project to convert FT4C TWIN PAC 50 MW GT Unit in Eilat to Methanol firing (identical to the unit in Caesarea).

**Objectives**
- To restore the full capacity of the machine
- To gain long-term operating experience of working with methanol-fueled GT.

**Schedule**
Following summers for two years.
How To Restore Capacity?

The flow must be doubled.
There are a few bottle necks, as follows:

- HP pumps (Gear Box Driven) – external pumps assembled on a skid
- Modulating Valve – omitted – flows are controlled by a Variable Speed Drive (VSD)
- Pressure & Dump (P&D) valves – replacement of strainer
- Firing nozzles – Excello Nozzles are replaced by set of High Flow Delevan Nozzles (which were developed for water injection to enable doubling the flow).
External High-Pressure Pumps
Replacing Nozzles to Delevan High Flow

Delevan Nozzles

Exxcello Nozzles
Restoring Capacity – Fuel Control & External Pumps

Fuel Control for dual fuel - FO & methanol system (one skid per engine)

Control Air 250-110 psi

Fuel oil
Inlet piping both fuels 3”

Methanol

Filters
By others

Motor power wire from VSD

400V 50Hz ~75KVA

75 HP VSD
30 HP VSD

Control House
Fuel Control

Engine

Fuel SOVs (shut-off valves)

Mixing Block

1.25” SS pipe
1.5” SS pipe

Control wires:
2 digital outputs
6 digital inputs
5 analog inputs

Control wires:
2 digital outputs
2 analog inputs
2 analog outputs

- Fuel Control &
- External Pumps
Two-Phase Test (in Eilat)

- **Short-term:**
  Check feasibility of the system and validate performance and low emissions (2-3 weeks).

- **Long-term:**
  Gain operational experience and confidence in the system (2-3 years, 1500-2000 hours each year).
Adapting Fuel Unloading and Storage System

- New unloading piping
- Tank adaptation – floating roof
Adapting Fire-Fighting System
Fuel Unloading Platform
The unit prior adaptation to methanol
Methanol filters
Skid - methanol pumps
Skid – FO pump & SVA
Direct connection to P&D Valve
Control screen
GT Performance after conversion

Average TT7 as function of GT load
P&W GT, Eilat

- ▲ Oil#2, Engine A, 06.02.12, Tamb=23 C
- ○ Oil#2, Delavan, High Flow, Engine B, 09.14
- ◆ Oil#2, High Delavan Flow, Engine A, 03.14
- ■ Methanol, Delavan High flow, Engine A, 03.14
- × Methanol, Delavan, High Flow, Engine A, After P&D replacement, 30.04.14
- * Methanol, Delavan High Flow, Engine B, 09.14
GT Emission performance after conversion

NOx emission as function of GT load
P&W GT, Eilat

GT Emission performance after conversion
GT Emission performance after conversion
GT Emission performance after conversion
GT Emission performance after conversion
GT Emission performance after conversion

SO2 emission as function of GT load
P&W GT, Eilat

SO2, mg/dNm\textsuperscript{3}@15%O\textsubscript{2}

GT load, MW

Methanol
Oil#2
GT Emission performance after conversion

Formaldehyde as function of GT load

<table>
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Requested level

- Oil#2, Delavan High flow, Engine A
- Methanol, Original atomizers, Cesarya
- Methanol, Delavan, High Flow, Engine A, 09.14
- Methanol, High Flow Delavan, Engine A
- Oil#2, Delavan, High flow, Engine B, 09.14
Summary

The results presented here clearly show that with minor low cost fuel system retrofit, methanol firing leads to significant NOx, SO2, and particulates emission reduction, without affecting performance.

We believe that the results of the present work can be applied to other boilers and gas turbines.