F-technology Gas Turbine Retrofit with EPA Filters (Case Study)

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Site environment and contaminants

Environment

- **Mediterranean sea coast**
- **Nearby sea port with trucks traffic**
- **Nearby city**
- **Industry**
- **Temperature 0 – 40^{o}C; Relative humidity 20 – 100%**
- **Khamsins - hot desert winds with high atmospheric dustiness (similar to Sirocco)**

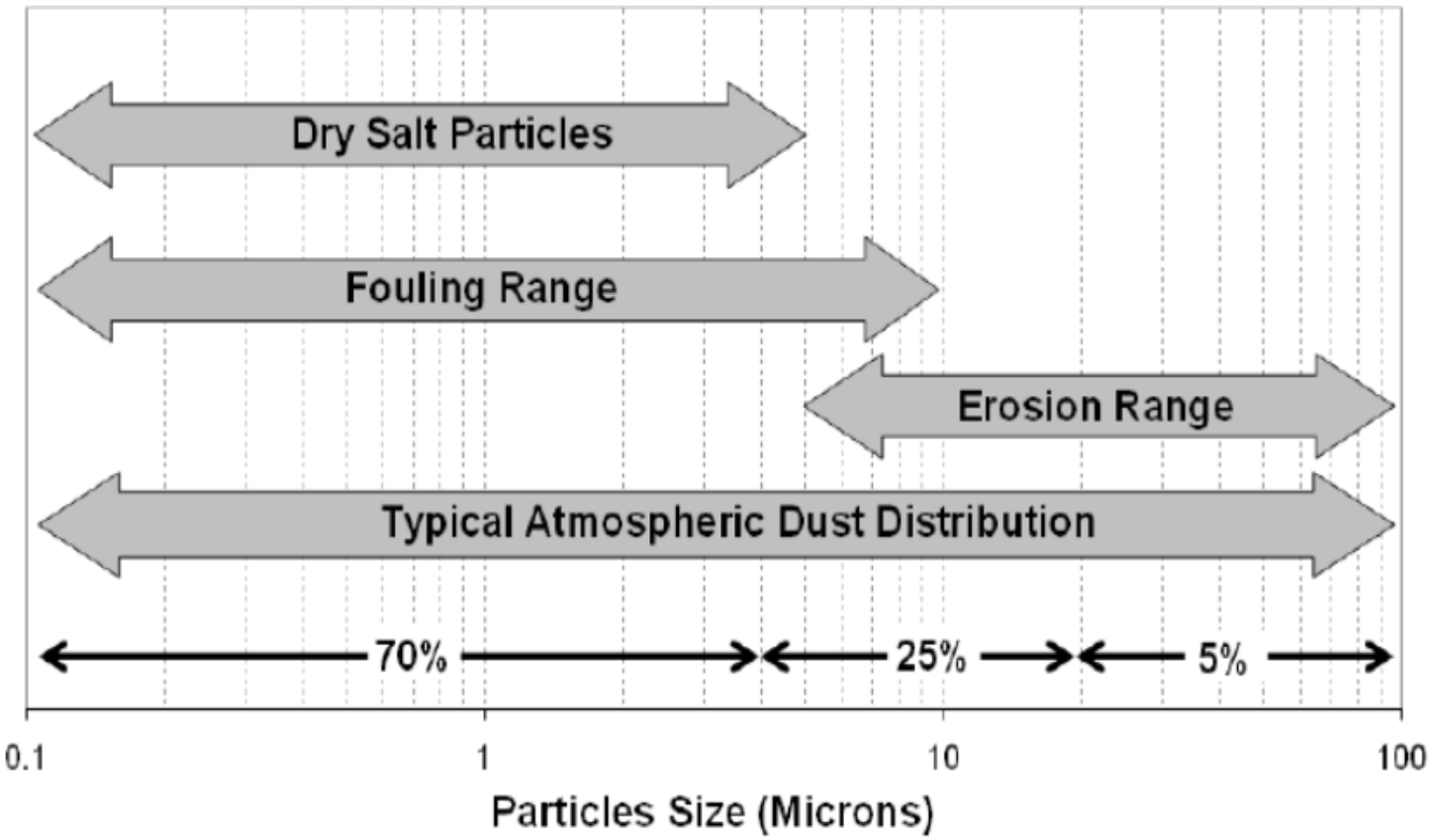
Air contaminants

➢ **Atmospheric dust, sea salts, soot, oil vapors**

Gas turbine unit

❖ **250-MW class gas turbine in a two-shaft Combined Cycle**
❖ **Operation mode – BASE**
❖ **Operation start – July, 2004**

Air cleaning: usual approach



Typical Particles Size Distribution for Erosion and Fouling Range

Requirements

- ❑ **Full filtration of erosion-risk particles (> 5 µm)**
- ❑ **Good filtration of particles in the fouling range (<5 µm)**
- ❑ **Pulse-cleaning provides low pressure loss on the filter**
- ❑ **Performance degradation caused by fouling is restored by periodical compressor washings**

Result

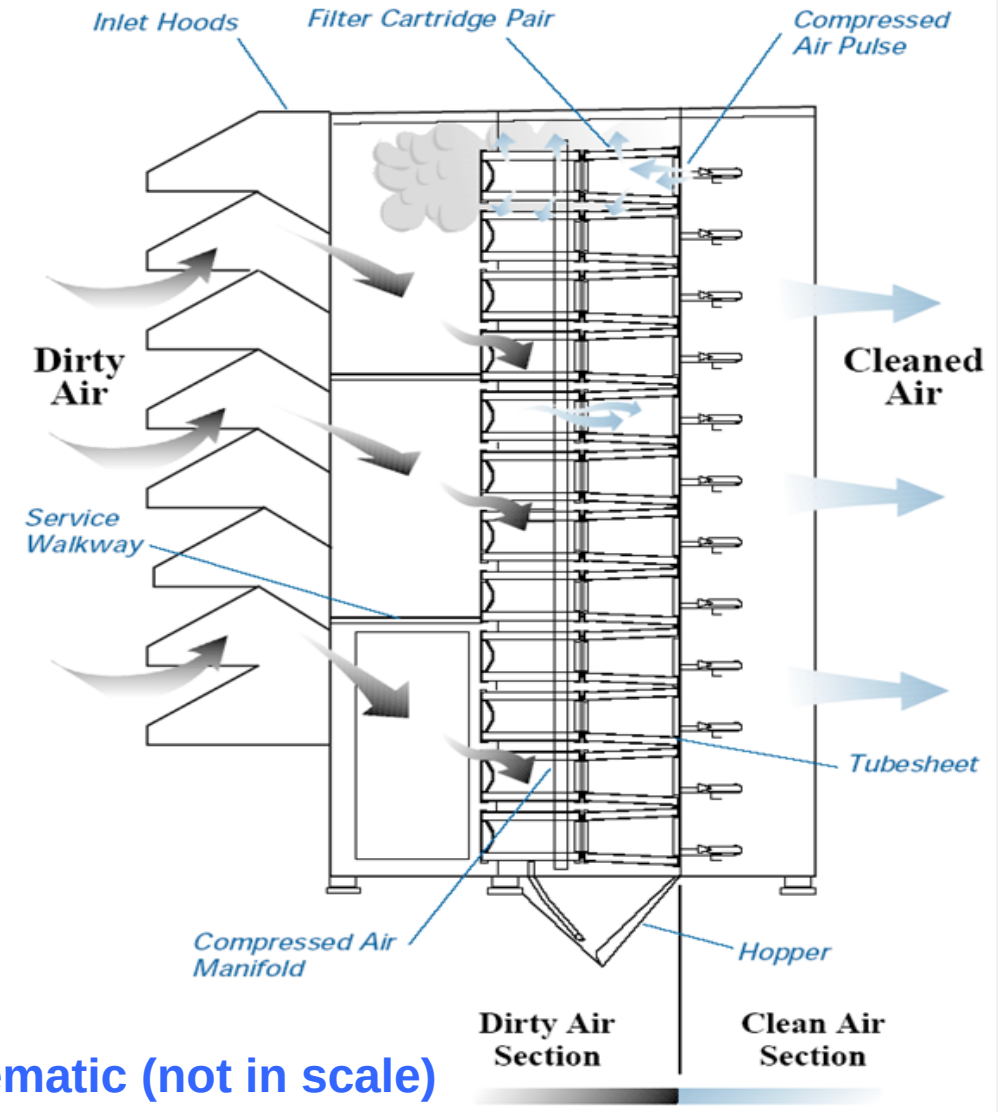
- ✓ **No blade erosion**
- ✓ **Low filter pressure loss**
- ✓ **Acceptable filter life-time – two-three years of GT operation**

IEC had good long-term experience with 16 E-technology type turbines (120-150 MW class)

Filter system arrangement

The system comprises

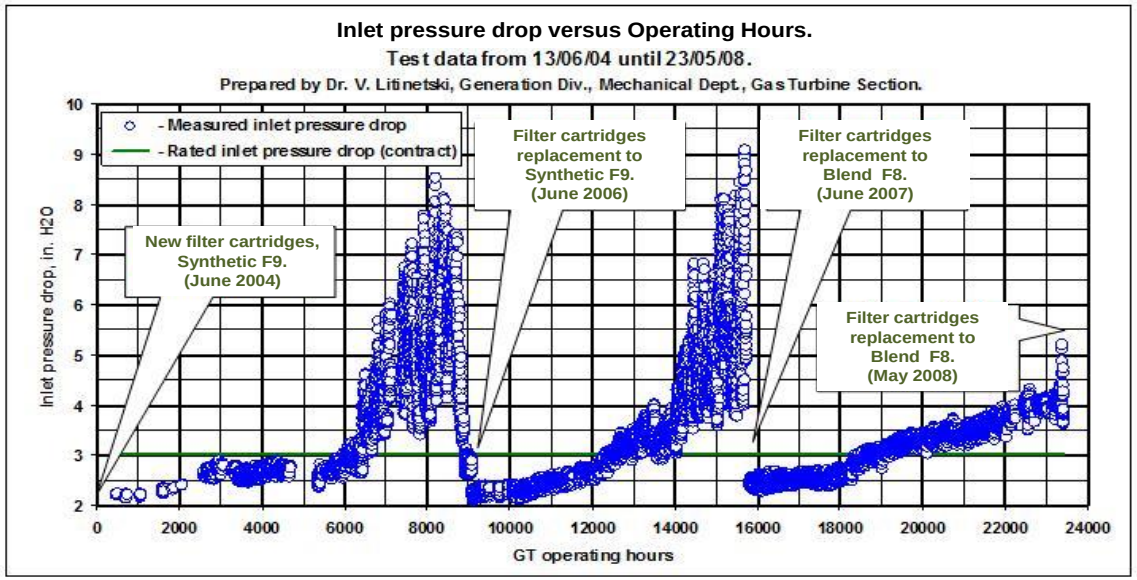
- **Filter house**
- **Inlet weather hoods with *moisture separators***
- ***Single filtering stage F9 class***
- **Horizontally arranged filter cartridges**
- **Cone-cylinder filter pairs (700 pairs)**
- ***Pulse air system* – cleaning with air blasts**
- **Dimensions: H12 m * W15.8 m * D7.6 m**



Filter system schematic (not in scale)

Usual approach: field experience

- Ineffective pulse-cleaning that resulted in the fast increase of the filter pressure drop and shortened life-time of the filter
- Strong performance degradation due to compressor fouling (up to 15 MW loss)



- Soot and sea salt ingression through the filter. This could initiate corrosion of the compressor blades.
- Compressor stator blades failure and cracks as a result of pitting corrosion

Filter upgrade: main goals

- **Prevent or substantially decrease sea salt ingression into compressor**
- **Minimize ingression of dust, oil, soot**
- **Avoid or minimize a filter house reconstruction required for the upgrade**
- **Increase actual life-time of the filter for up to two years or more**

These goals could be met by usage of high efficiency filters with hydrophobic media.

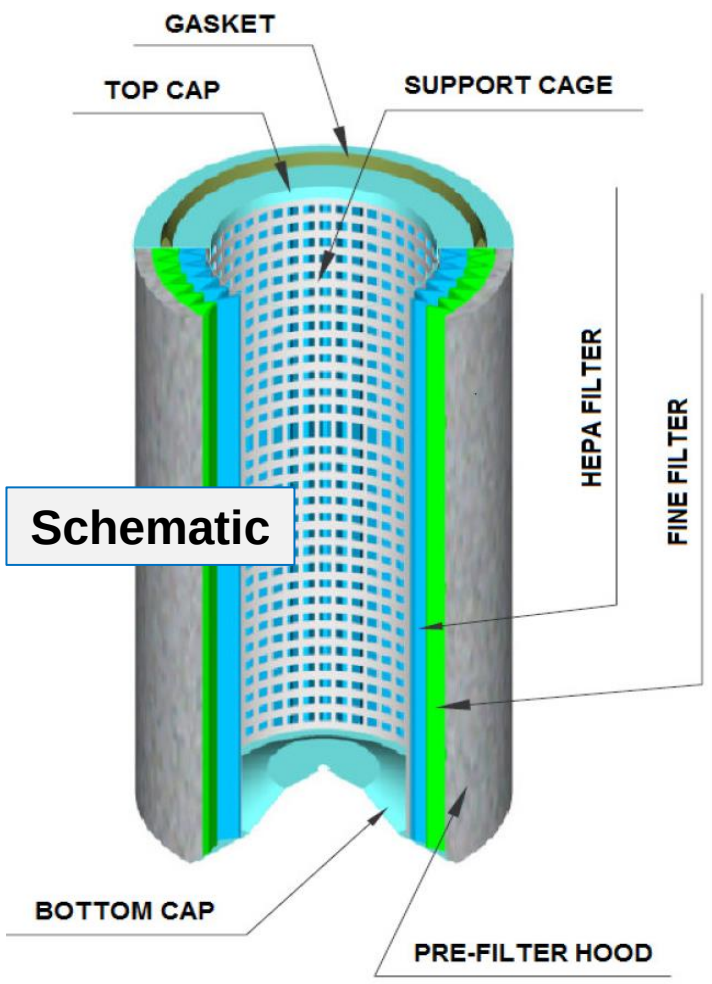
Possible solutions and the final decision

Proposals:

1. **Retrofit of the whole filter house to three-stage F9-class filter with combined pulse-cleaning/static filtration stages, with the hydrophobic last stage (OEM's proposal).**
2. **Upgrade filters to hydrophobic F9-class static filters with no filter house retrofit (IEC's proposal).**
3. **Move to EPA static hydrophobic filter with no changes of the filter house arrangement (third party proposal).**

The third option was finally chosen as providing an achievement of all goals of the upgrade at a reasonable cost.

Initial stage: EPA-1 filter system



Schematic

Main filter: EPA E11
Fine F8
Pre-filter: M5 Hoods
(Socks)

Installed

Socks:

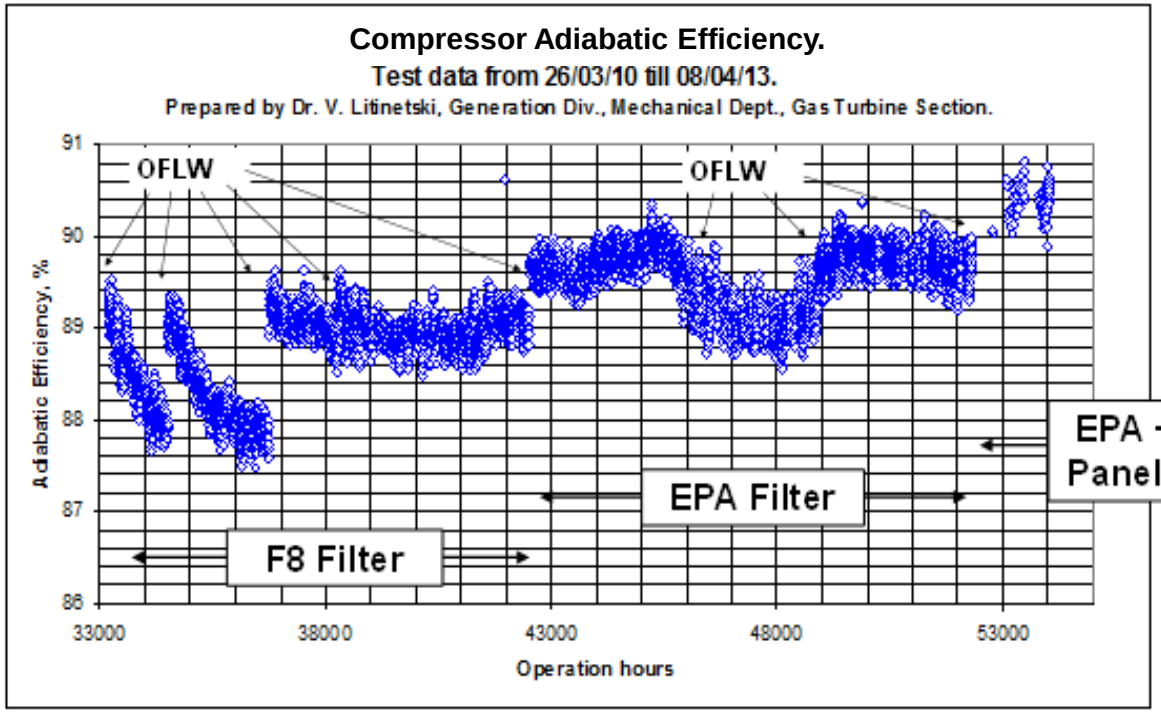
- ✓ Cheap
- ✓ Simple to replace
- ❖ Too low filtering area

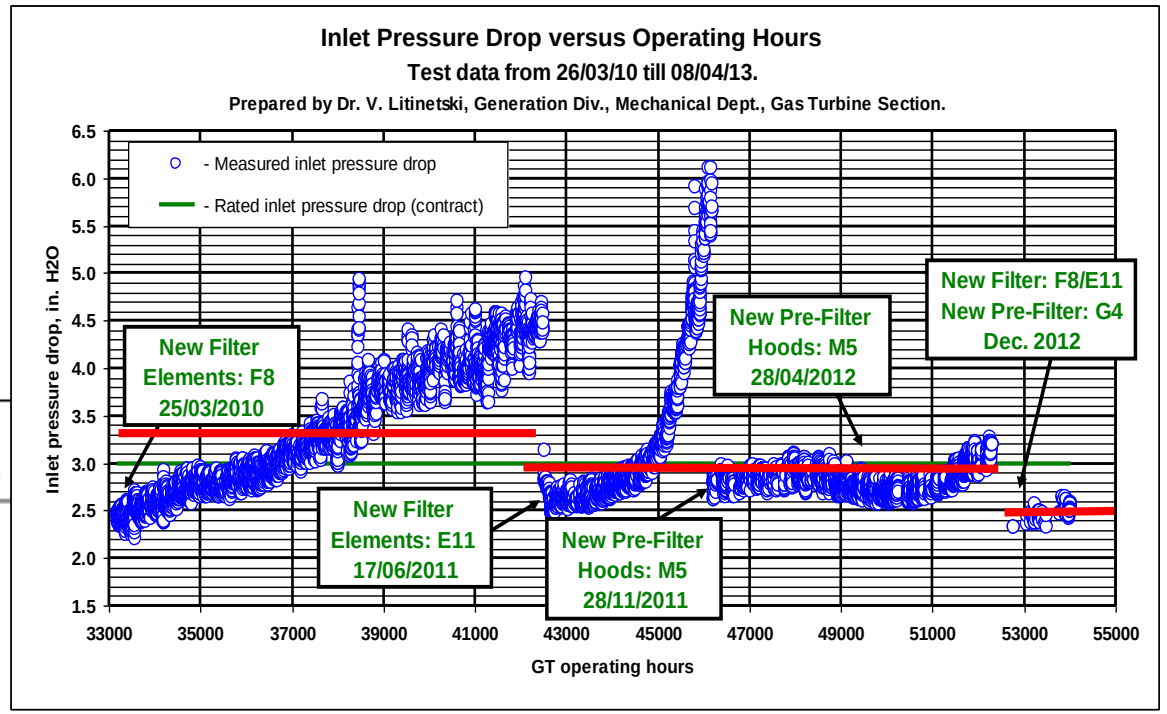
Maintenance plan:

During a year operation of the main filter, one or two replacements of the pre-filters.

The replacements were planned with the main filter in place and probably on operated GT unit. This was not achieved in actual operation.

Initial stage: Performance data





Compressor adiabatic efficiency

- ❑ Compressor efficiency does not degrade that points on virtual absence of fouling
- ❑ On-line washings were totally eliminated
- ❑ Off-line washing were not required (performed due to regular maintenance plan)

Filter performance

- ❑ On average, EPA filter Δp was lower than that of the previous conventional filter
- ❑ Pre-filter hoods (socks) feature very fast increase of Δp in dusty atmosphere
- ❑ Hoods replacement is too time-consuming

Initial stage: Summary of Results

- ✓ **The EPA-1 system was replaced after about 9800 operational hours of the main filter and two replacements of the pre-filter hoods. The replacement was not forced by the filter differential pressure limitations.**
- ✓ **The pressure drop of the main filter (F8/E11) remained almost unchanged that pointed out on much longer life-time of the main filter.**
- ✓ **The EPA filter has a lower average pressure loss than the previous conventional F8 filter.**
- ✓ **Turbine Power Output and Heat Rate were remarkably better with EPA filter. This provided a returned investment of the EPA filter within the first year of the filter operation.**
- ✓ **The pre-filter hoods should be replaced with the pre-filter panels, in order to increase the life time of the pre-filter.**

Second stage: EPA-2 filter system

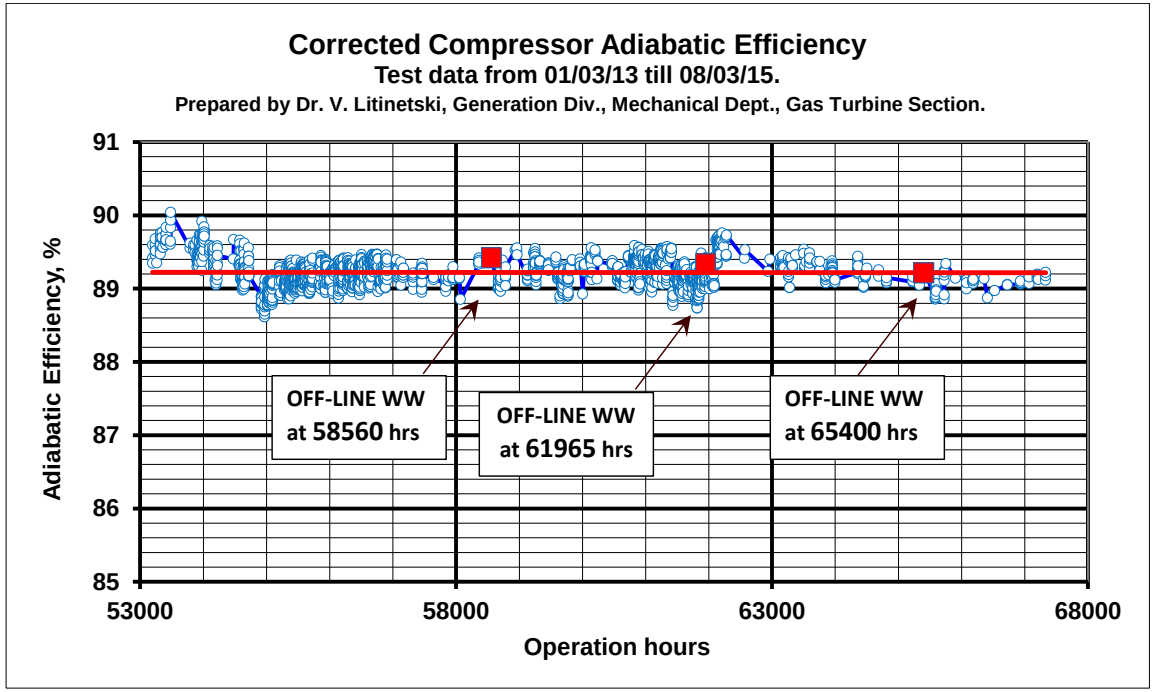
Improvements of EPA-1 system

- ❑ Pre-filter hoods were replaced with panels (G4-class) installed in the weather hoods instead of the moisture separator.
- ❑ Cone-cylinder pairs were implemented in 20% of cartridges
- ❑ Cartridges were upgraded with guiders providing better assembly
- ❑ Upgraded gaskets were implemented for better sealing of the main filter
- ❑ Pre-filter panels enforced with stiffening ribs (on the last stage of the project)
- ❑ Differential pressure measurements downstream of the pre-filter

With the these improvements, anticipated life-time of pre-filter was estimated as 5000-6000 hours and of the main filter as 16000 hours.

EPA-2 system: Performance results

- ✓ Operation - as was anticipated.
- ✓ Main filter: ~ 15200 hours in operation (27 months).
- ✓ Pre-filter: Two replacements.
- ✓ The system was replaced earlier than required maximum Δp.
- ✓ Compressor fouling virtually absent.
- ✓ Overall GT performance – good.
- ✓ Retrofit goals – achieved.



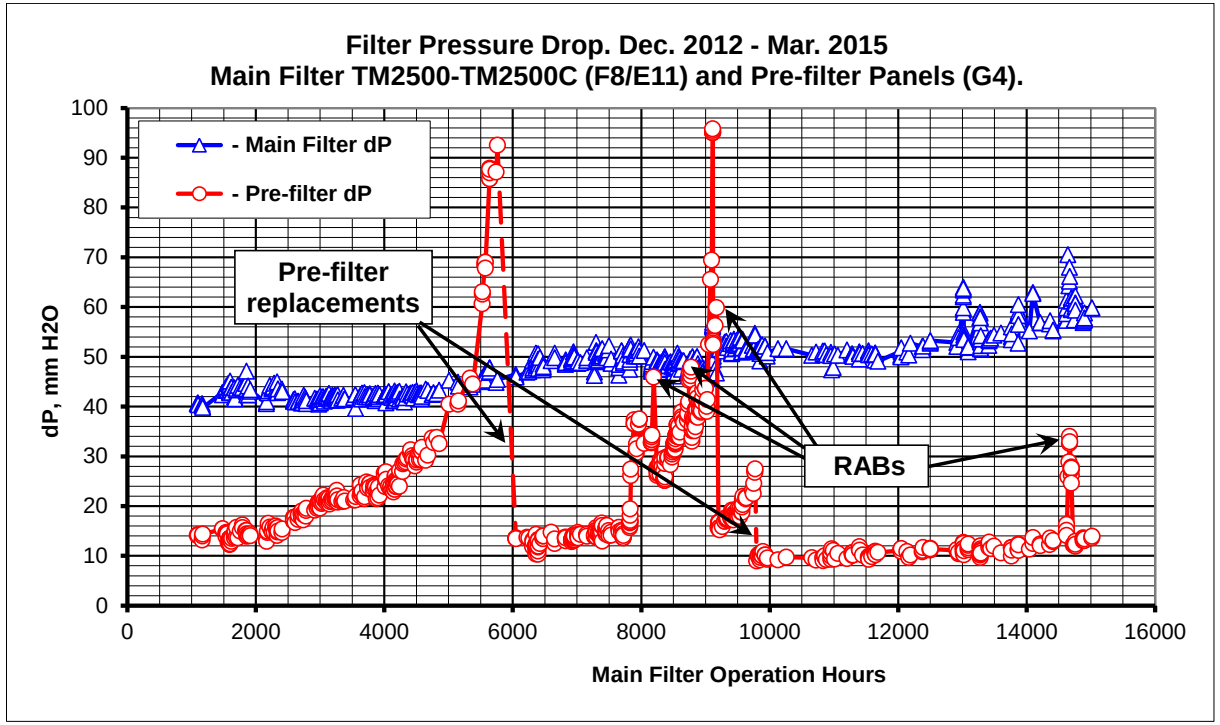
Compressor adiabatic efficiency

- ❑ Compressor efficiency does not degrade
- ❑ On-line washings were totally eliminated
- ❑ Off-line washings were reduced

EPA-2 system: Filter data

Filter performance

- ❑ On average, EPA-2 filter Δp was about the same as that of the previous EPA-1 filter
- ❑ Two pre-filter replacements as was planned
- ❑ Life-time is estimated as ~16000 hours or higher
- ❑ Implemented RAB of the panels provides more operational flexibility and increases life-time by more than 1000 hours



Pre-filter and Main filter differential pressure (RAB – Reverse Air Blowing)

Peaks of the pre-filter Δp are results of the Khamsins

Main conclusions

1. **The final EPA filter version represents a three-stage static air filter with *panel-type pre-filter of G4 class*, and cartridge-type *main filter of F8/E11 class*. Pre-filter is mounted separately in the place of the original moisture separator.**
2. **Based on the collected experience, life time of the main filter has been estimated as 16000 hours and the average life time of the pre-filter panels as 5500 hours.**
3. **The EPA filter operation provided high profits on the fuel economy. Additional profits are: no on-line and less frequent off-line washings, less compressor corrosion, *lower filter differential pressure drop*, longer life time of the filter.**
4. **Each new type of EPA filter should be initially checked in actual or similar environment conditions for its performance and life time. Some non-standard tests are required for EPA filters evaluation.**

The END