EPA FILTRATION OFFSHORE

Impact of EPA Filtration Air Intake Filtration on Gas Turbines Operating in Middle East Offshore Applications and Fueled with Sour Gas.

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FIELD INTRODUCTION

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FIELD INTRODUCTION AND OPERATIONAL PARAMETERS

Total Abu Al Bukhoosh (TABK) field is located offshore Abu Dhabi (UAE), in shallow waters of the Persian Gulf. The field was discovered in late sixties and developed till production started in early seventies.
Total is for more than 40 years operator for the oil production and operates the gas production on behalf of the UAE government.

The offshore complex installed gas turbines differs in 3 types, 3 manufacturer and ensure critical functions for gas compression and power generation. The following units are installed :

- 3 x 10Mw heavy duty Gas Turbine for Gas lift and gas injection on GLP platform
- 1 x 26Mw aero derivative Gas turbine for gas recovery on KPP platform
- 3 x 12Mw Light industrial Gas turbines for power generation (1 dual fuel) on NKPP and PPSP platform

TABK offshore **environmental conditions** are classified as **being aggressive** through the;

- high levels of **salt & humidity** ,
- **fog /mist**
- **seasonal sand storms from shamal** (“Harmattan”)
- Sea spray aerosols
- Local sources of offshore generated pollutions (exhaust gas of Diesel engines and furnaces)
- Sour fuel gas with a **hydrogen sulfide content of 2%**

Those circumstances constitute a hard operating environment for the gas turbine

FIELD INTRODUCTION AND OPERATIONAL PARAMETERS

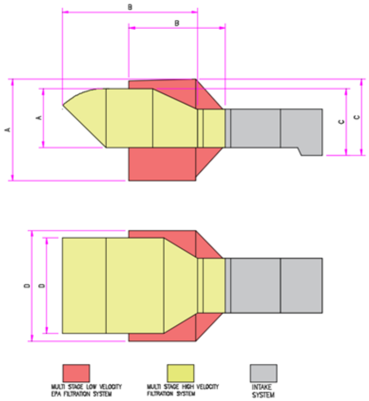
- **operational data & maintenance records demonstrated that low performance of the air filtration system resulted in:**
    - Recurrent trips due to air filter blockage (High Dp),
    - Reduced performance of axial flow compressor due to fouling and irreversible erosion
    - High failure rate (premature) of hot gas path components (< 2500FH's on combustors, heat shields and burners)
    - Excessive maintenance schedule.(bore scope inspections every 2000 FH's, Engine exchange every 4000 FH's)
    - Intense offline washing regime on 4 to 6 weeks intervals. (50+ detergent washes on annual basis)

Hence reduced availability & reliability with increased profit loss and Opex.

FIELD INTRODUCTION AND OPERATIONAL PARAMETERS

As part of the rotating machinery availability & reliability road map, the option of; **low velocity high performance particle arrestance (EPA) air filtration system** was recommended as best application for TABK Turbines operating environment to resolve the reoccurring issues, but with operational Considerations to be taken:

- **Equipment weight and dimensional envelope**
  Particularly for offshore applications both can be a constraint. The original design of the platform does not always allow weight increase (structural design limitations) and/or dimensional increase due to space constraints.



Air Filtration	SGT400 (Kg)	RB211 (Kg)	PGT10 (Kg)
High Velocity	1800	10650	2030
Low Velocity	5940	14500	4450
Variation in Weight %	+330%	+136%	+219%

FIELD INTRODUCTION AND OPERATIONAL PARAMETERS

- **Project execution in a life plant (SIMOPS)**

  A project of this magnitude requests for a thorough preparation, planning and risk assessment to minimize any interference of the day to day operation that can lead to safety matters or production constraints.

  - Project execution within 1200 working hours with ZERO accidents
  - Approximately 8 working days per unit. (Unit S/D clubbed with routine maintenance)

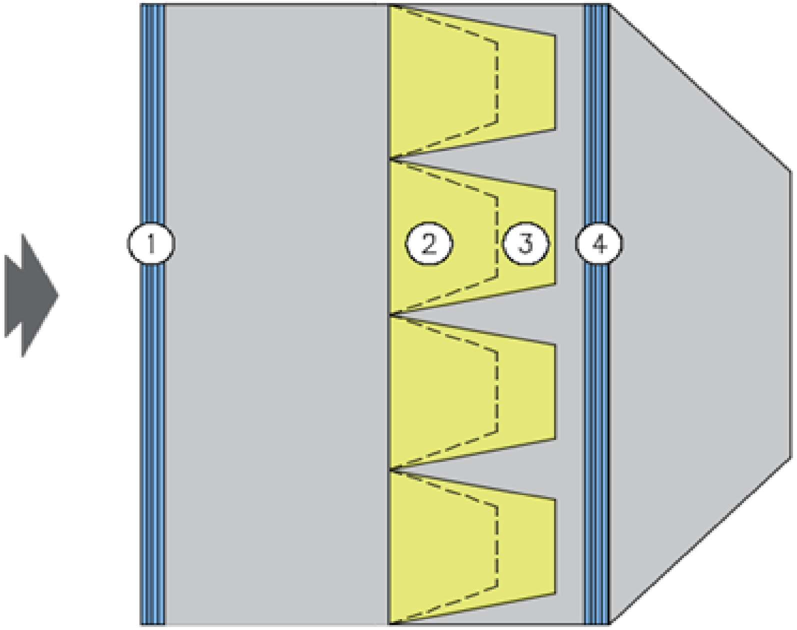
- **Logistic / other challenges:**

  Typically on an offshore platform, lifting capacity is limited to the platform crane capabilities (tonnage and boom reach). The use of an (external) barge crane can overcome capacity limitations , but is expensive. Modular component build up of the filter system, adapted to platform lifting capacities was implemented. Sea transport (weather) and climate conditions (+50ºC) are potential threads to planning.

EPA E12 FILTRATION

S.TAYLOR

Original high velocity filtration system

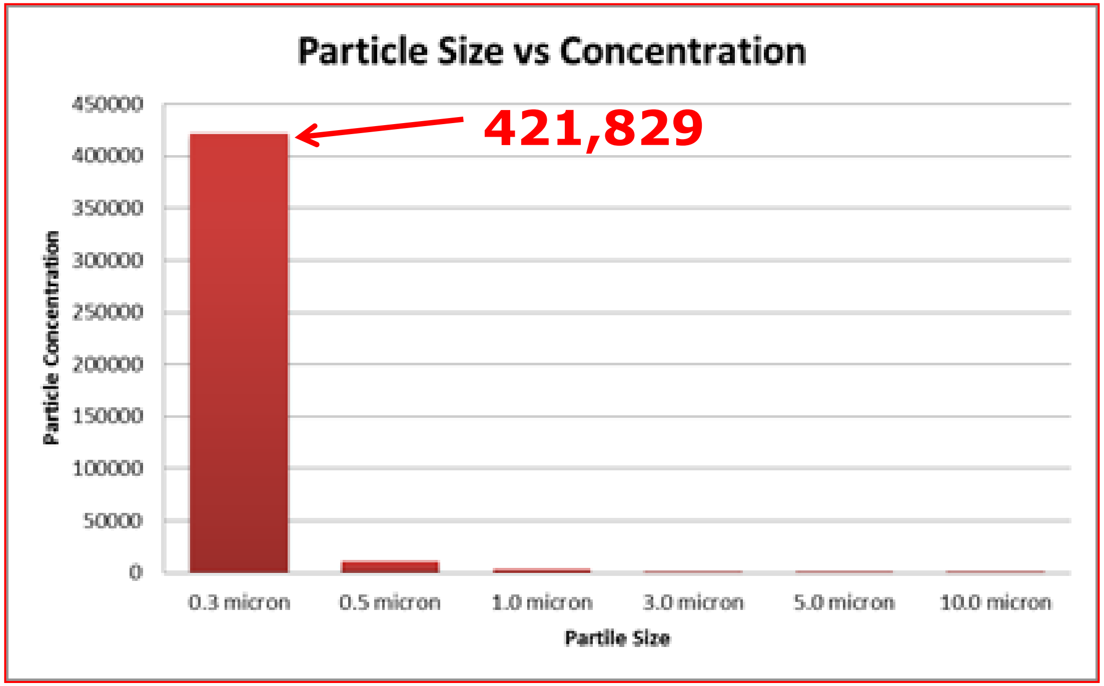


- The upstream vane separator removes the majority of large airborne water droplets, such as sea sprays, fogs, mists and large aerosols.

- The pre-filter bags **(G3 classification in accordance with EN779:2012)** and medium efficiency bags **(M5 classification in accordance with EN779:2012)** remove airborne particulates and also coalesce small aerosols that have passed through the upstream vane separator, whereby the small aerosols coalesce into larger droplets which can be captured by the downstream vane separator.

- The downstream vane separator captures the large coalesced droplets which pass through the pre-filter and medium efficiency filter bags, which are then removed from the air intake filtration system via a sealed manometric drain.

Air sampling at ABK



Size (microns)	0.3	0.5	1.0	3.0	5.0	10.0
Percentage (%)	96.77	2.455	0.703	0.045	0.022	0.005

From this average air sample data, it can be seen that **96.77%** of the particles collected were **0.3µm**, and it can be calculated that **99.828%** of the airborne particles are in the **0.3µm to 1.0µm range.**

FILTRATION EFFICIENCY CLASSIFICATIONS

EN779:2012 & EN1822:2009

Standard	Contaminant Type	Class	Average Arrestance	Average Efficiency	Minimum Initial Efficiency 0.4µm	Minimum Initial Efficiency (MPPS)
EN-779 (2012)	Coarse Dust Filter	G1	<65	--	--	--
		G2	65<80	--	--	--
		G3	80<90	--	--	--
		G4	>90	--	--	--
	Fine Dust Filter	M5	--	40<60	-	--
		M6	--	60<80	-	--
		F7	--	80<90	35	--
		F8	--	90<95	55	--
		F9	--	>95	70	--
EN-1822 (2009)	Efficiency Particulate Air Filter (EPA)	E10	--	--	--	85
		E11	--	--	--	95
		E12	--	--	--	99.5
	High Efficiency Particulate Air Filter (HEPA)	H13	--	--	--`	99.95
		H14	--	--	--	99.995
	Ultra Low Penetration Air Filter (ULPA)	U15	--	--	--	99.9995
		U16	--	--	--	99.99995
		U17	--	--	--	99.999995

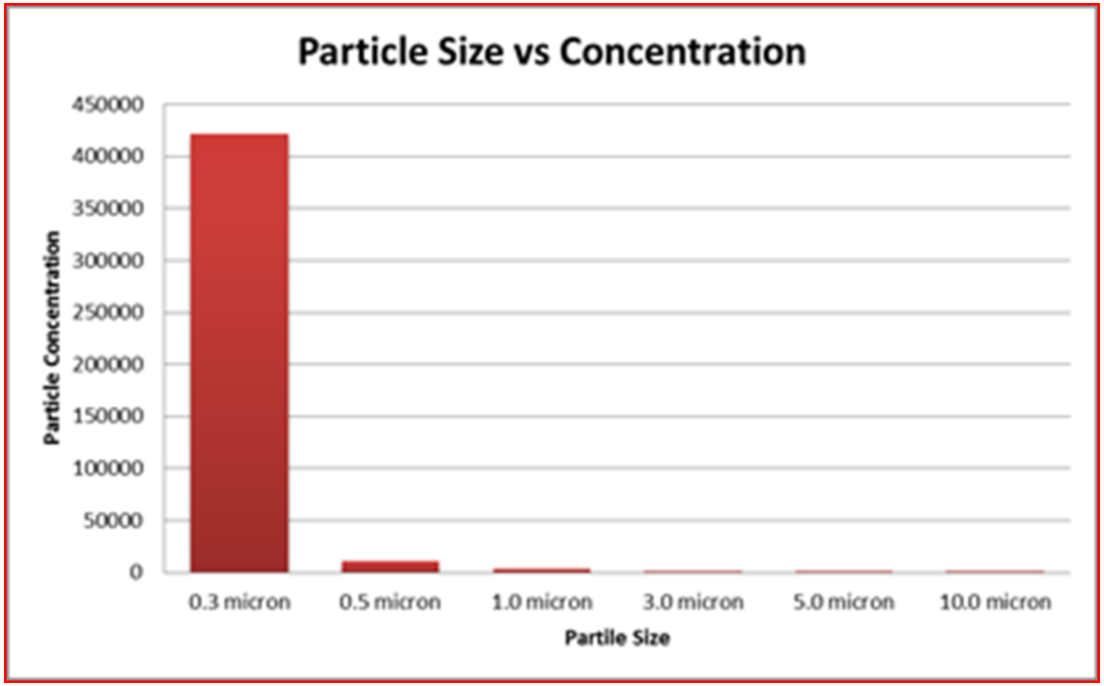
High velocity bag systems
M5-F7

Traditional filtration to meet GT OEM requirements
F8 to F9

Enhanced filtration
(H)EPA E10 – E12

Filtration classification vs efficiency

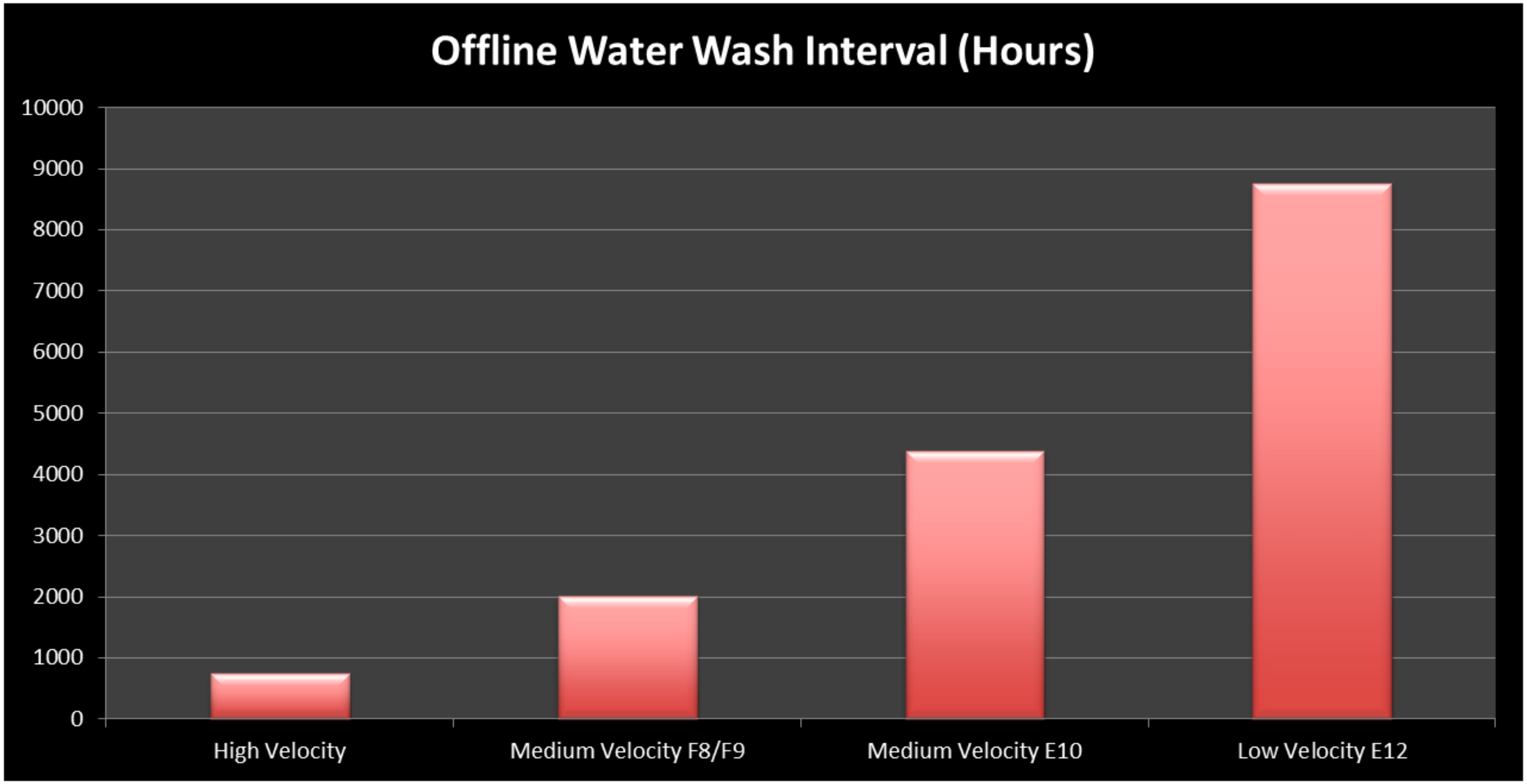
Filtration eff. class	Efficiency @ 0.3 micron
M5 (high velocity)	30%
F9	60%
E10	97%
E12	99.993% (HydroCel)



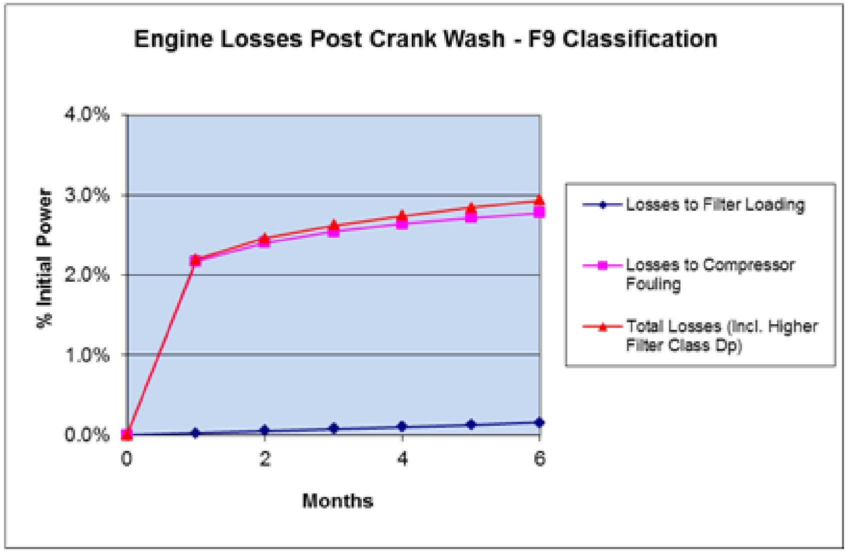
Filtration classification ratio of air cleanliness @ 0.3 micron

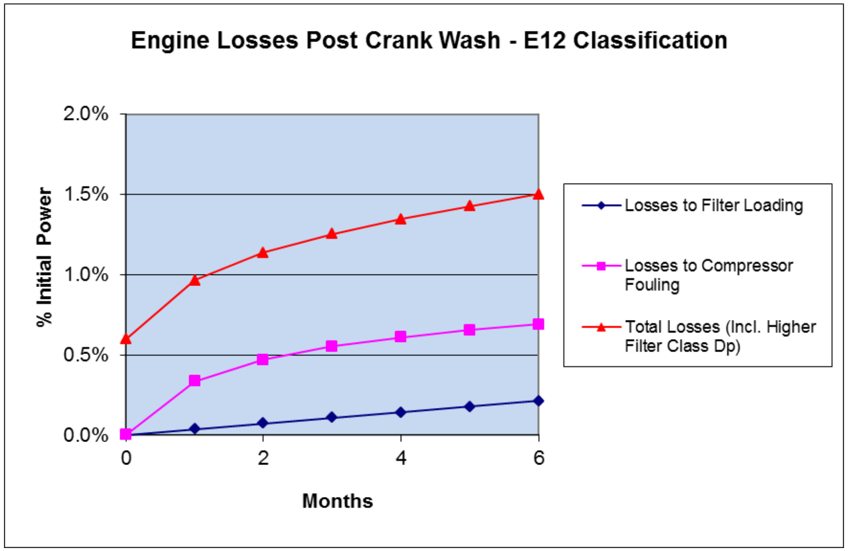
Filtration efficiency class	0.3 micron particles in air	Particles arrested	Particles penetrated	Cleanliness ratio vs M5
M5	421,829	126,549	295,280	N/A
F9	421,829	253,097	168,732	X 2
E10	421,829	409,174	12,655	X 23
E12	421,829	421,534	295	**X 1,000**

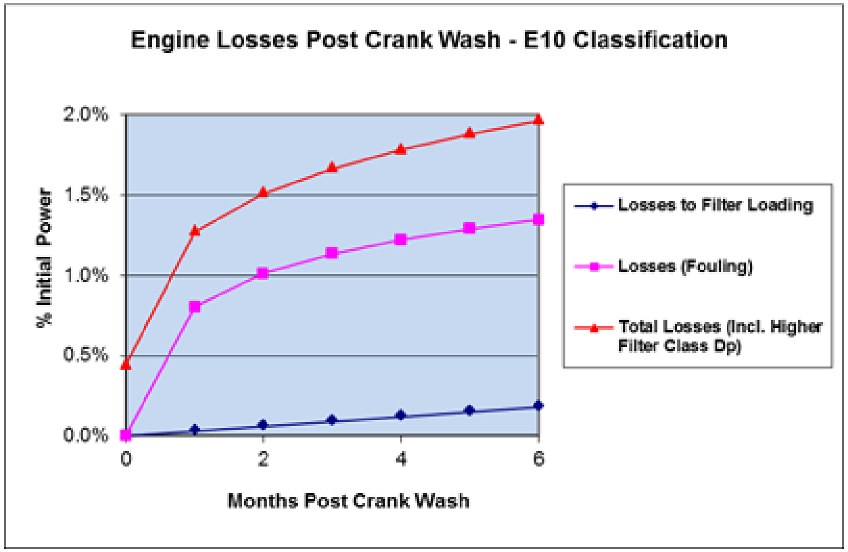
Filter classification vs wash frequency



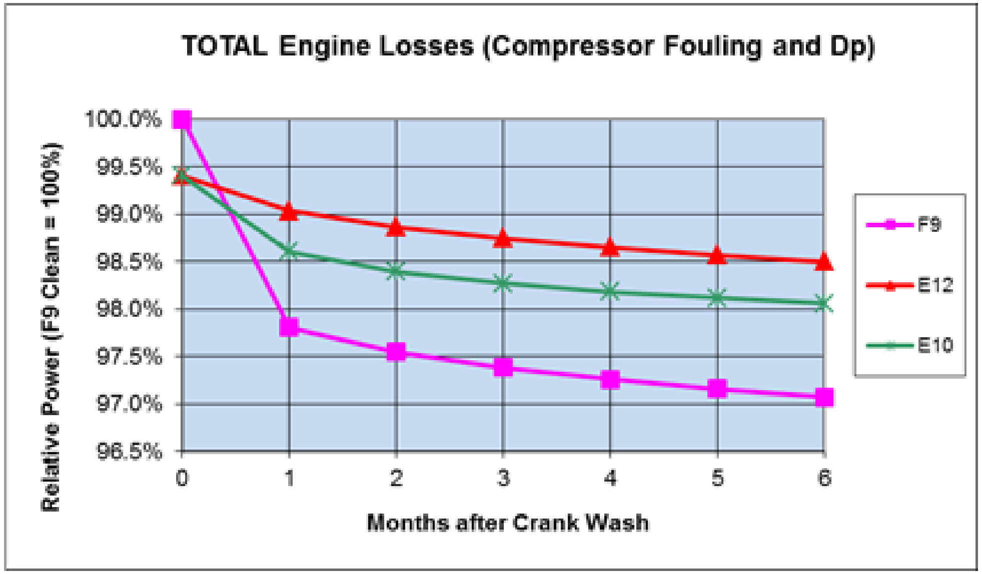
Filtration classification vs GT losses







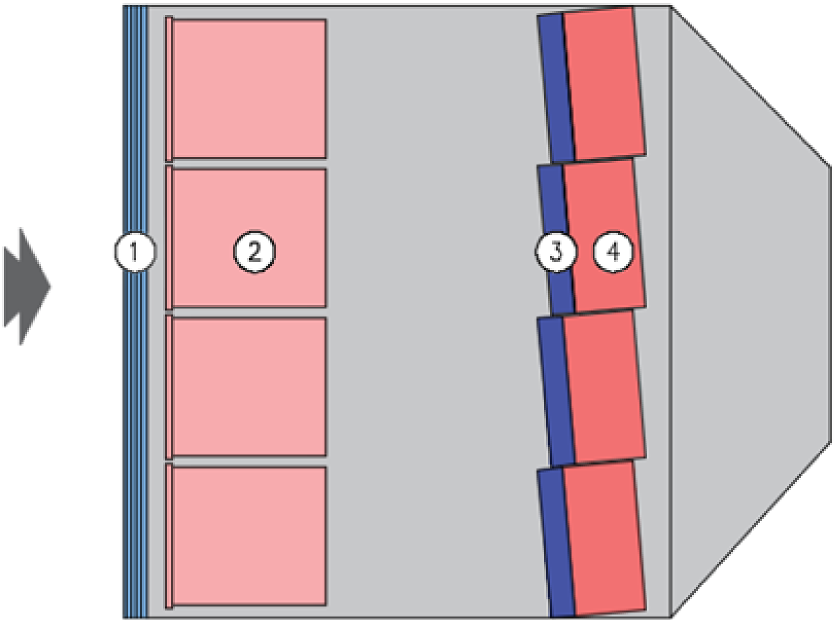
Filtration classification vs GT losses



Filter Classification	Losses (Filter Dp)	Losses (Fouling)	*TOTAL Loss (6 Months)
F9	0.15%	2.78%	2.93%
E10	0.18%	1.34%	1.96%
E12	0.21%	0.69%	1.5%

***TOTAL losses include Dp penalty for higher filtration classification i.e. E10 or E12 in lieu of F9.**

Retrofit (H)EPA E12 filtration system



- The upstream vane separator removes the majority of large airborne water droplets, such as sea sprays, fogs, mists and large aerosols.

- The sacrificial extended surface Dripak GT60 **F6** filter bags (being a hybrid filtration stage addition for Middle East applications, temporarily installed during annual high dust concentration periods), remove sand and dust particulate that are carried from the Middle Eastern deserts out to sea by Harmattan like winds, and prevent the AmerKleen M80 **G4** pre-filter coalescer pads and AAF HydroCel **EPA E12** high efficiency panel filters reaching an undesirable premature terminal resistance during these cyclical high dust load conditions.

- The AmerKleen M80 pre-filter pads remove airborne particulates and also coalesce small aerosols that have passed through the upstream vane separator, whereby the aerosols coalesce into larger droplets and due to gravity drain freely from the pad fibre structure.

- The HydroCel EPA E12 panel filters remove small and sub-micron airborne particulates and also capture any sub-micron aerosols that may have passed through the upstream pre-filter coalescing pads.

High velocity vs (H)EPA E12 Dp

	High Velocity	Low Velocity
Vane Separator	70	23
*Temporary Sacrificial Filter	N/A	55
Pre-filter	100	96
High Efficiency Filter	310	N/A
EPA Filter	N/A	370
Vane Separator	70	N/A
TOTAL (Pa)	550	544

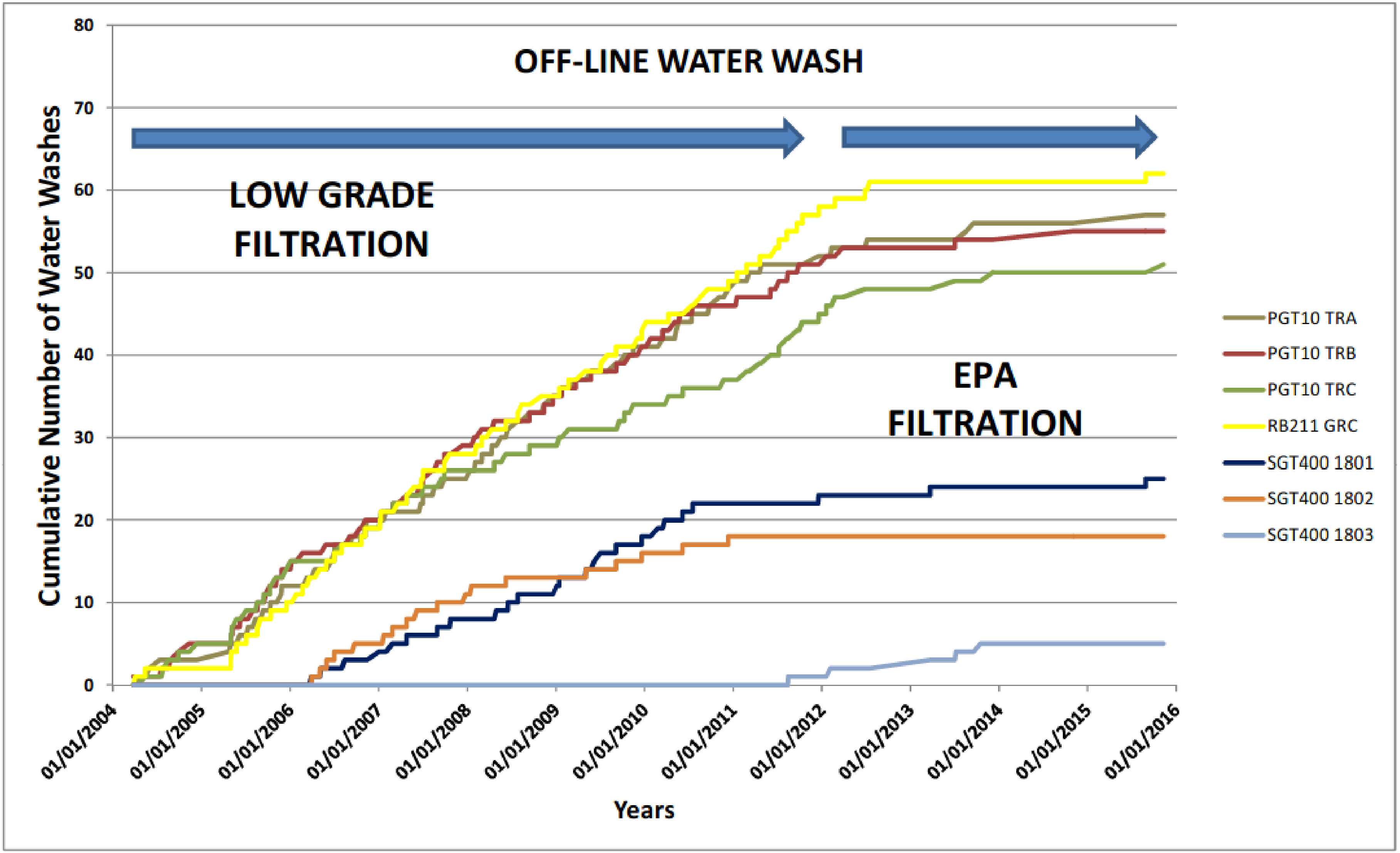
FIELD OUTCOMES WITH EPA E12 FILTRATION

D.ORHON

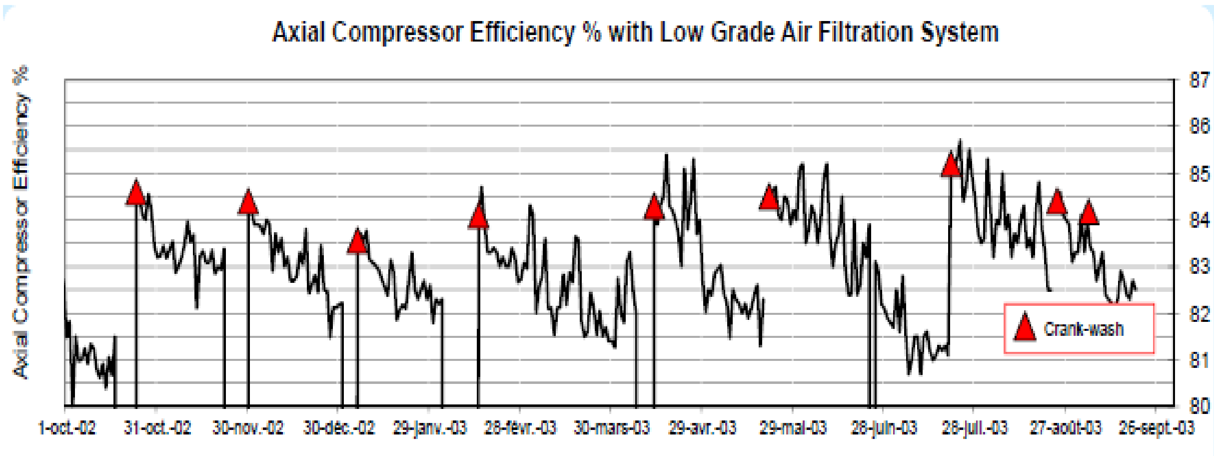
PARTICLES FOUND IN E12 FILTER AFTER 8000 HRS

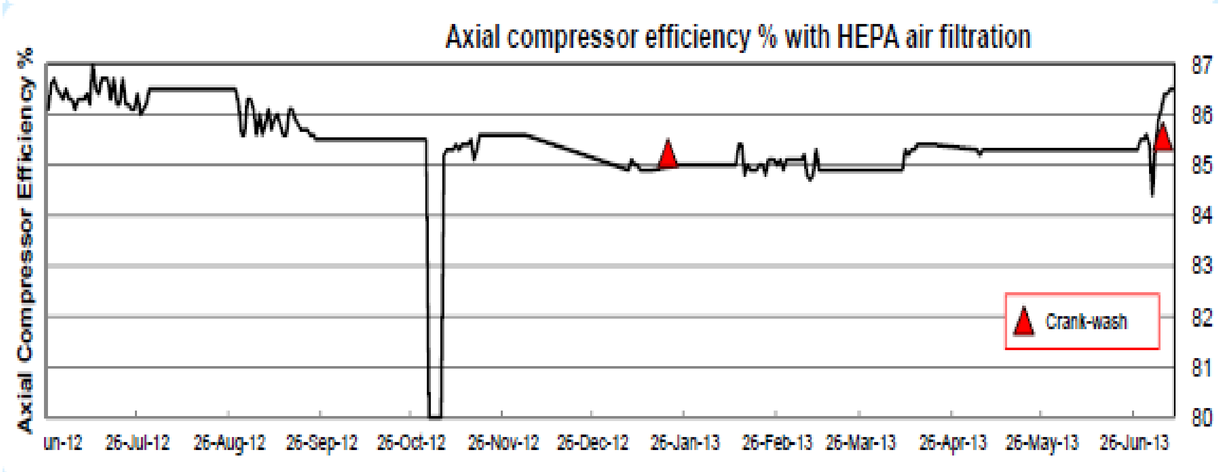
- Inorganic Materials
  - Silicates (Sand)
  - Aluminium Silicates (Al_2SiO_5)
  - **Calcium Sulphate ($CaSO_4$)**
  - Sodium Sulphate (Na_2SO_4)
  - Sodium Chloride (NaCl)
  - Iron Oxide
- Aspect
  - Bound in Agglomerates
    - Micron particles size
    - sub-micron particles size
- Organic Materials
  - Insect Parts
  - Polymeric Debris
  - Large shards of wood
  - Feathers

REDUCTION OF WATER WASHES



AXIAL COMPRESSOR FOULING

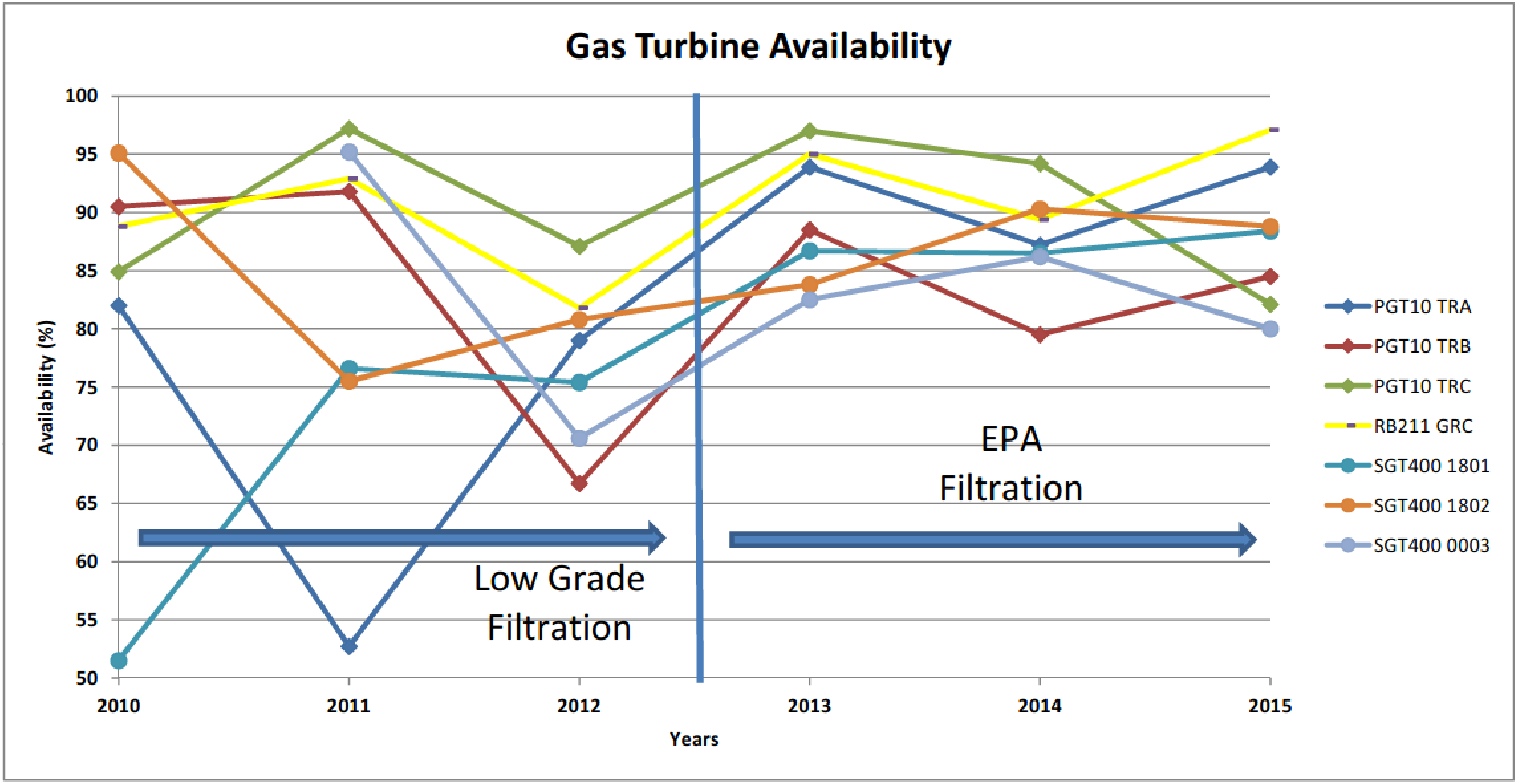




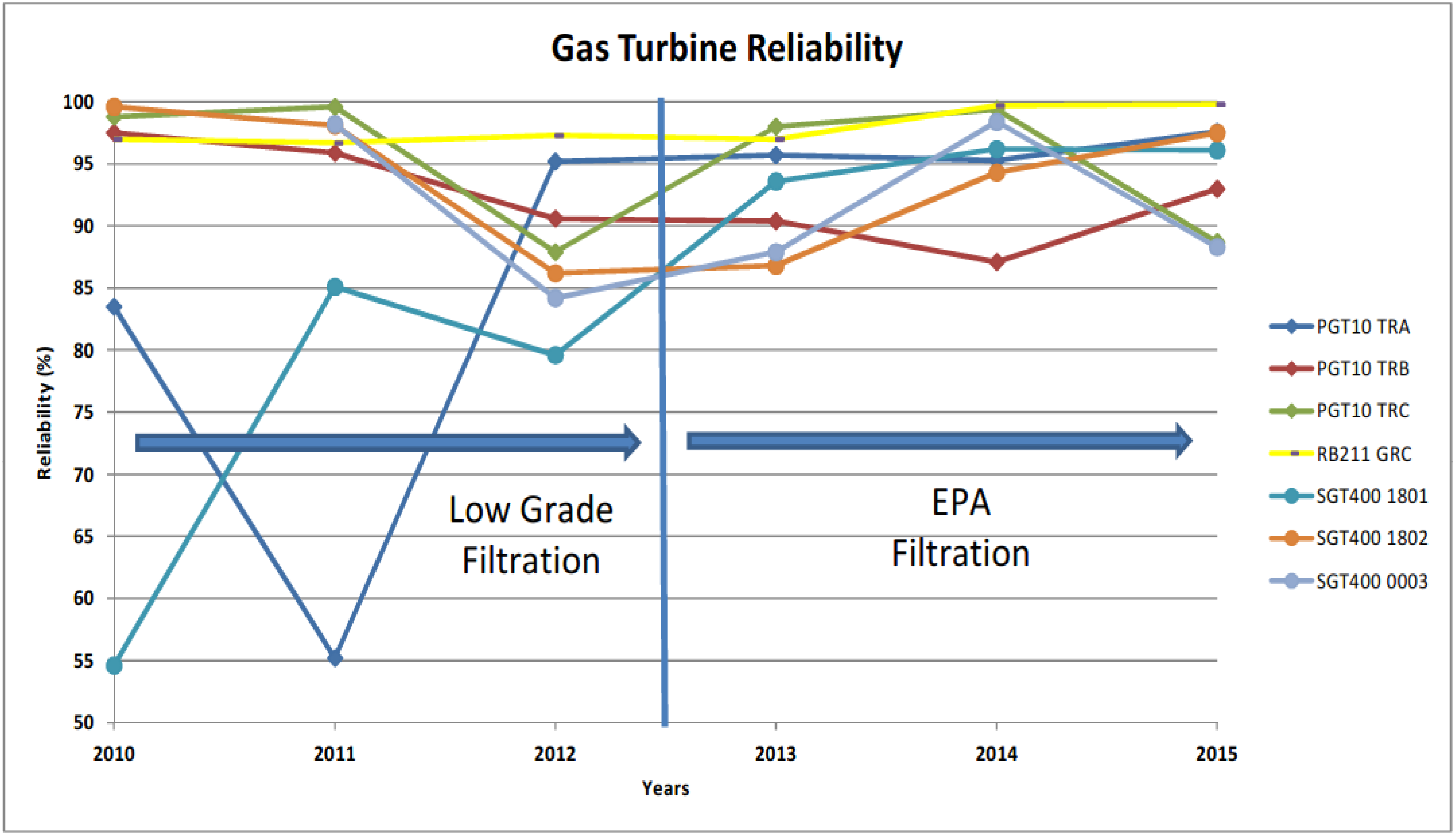
M5 - 4000 Hrs

E12 - 5300 Hrs

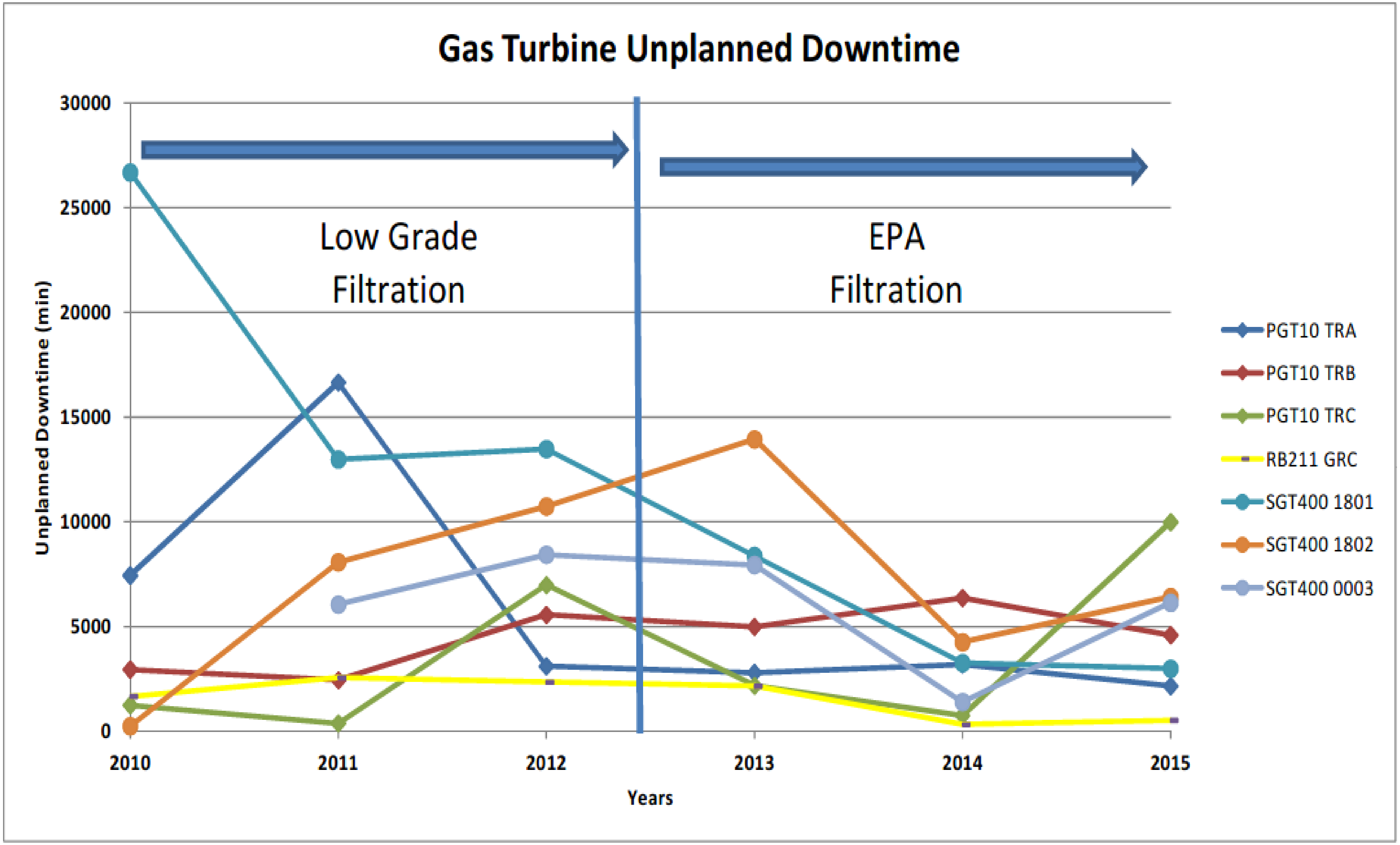
AVAILABILITY VERSUS E12 FILTRATION



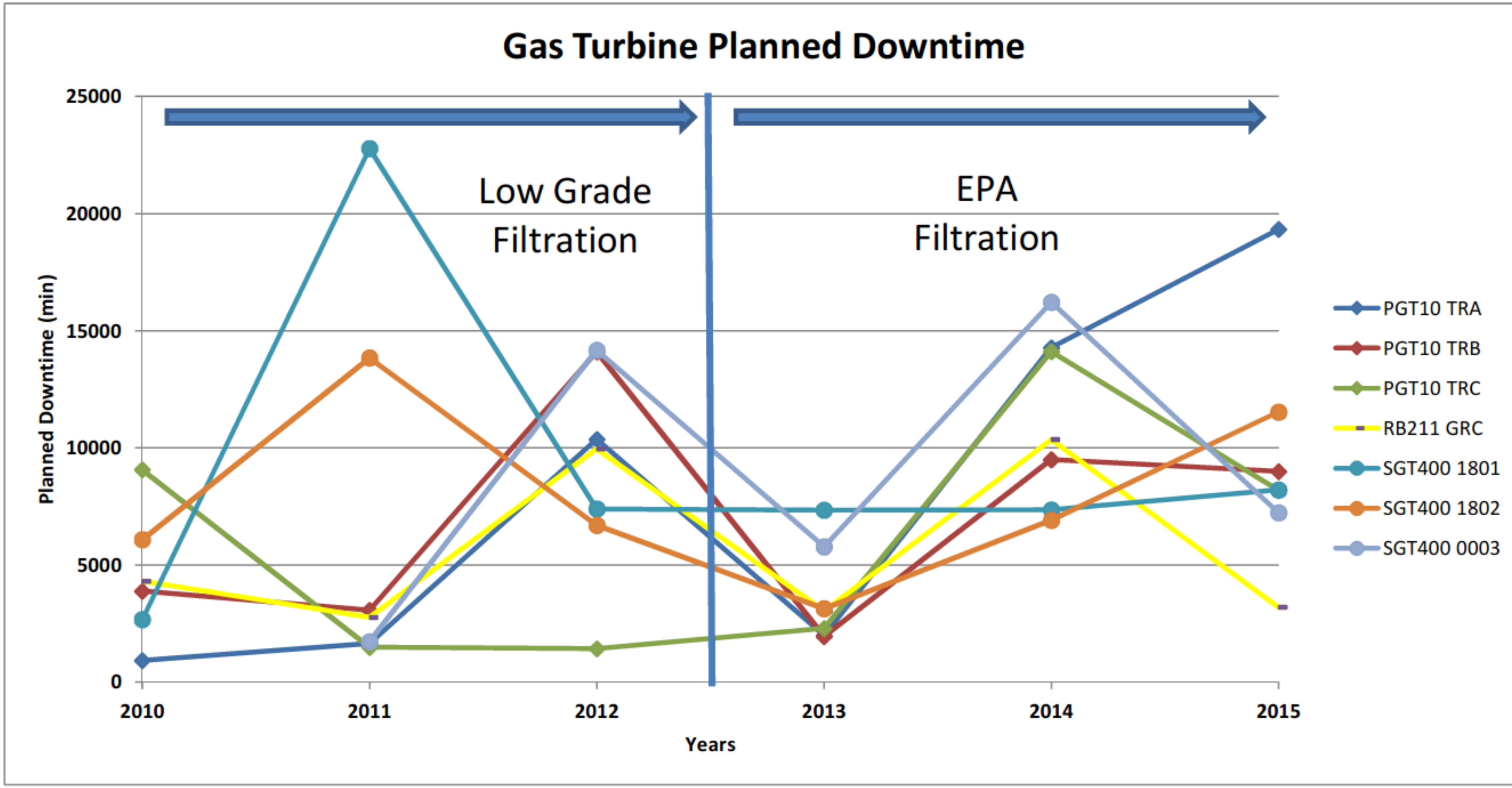
RELIABILTY VERSUS E12 FILTRATION



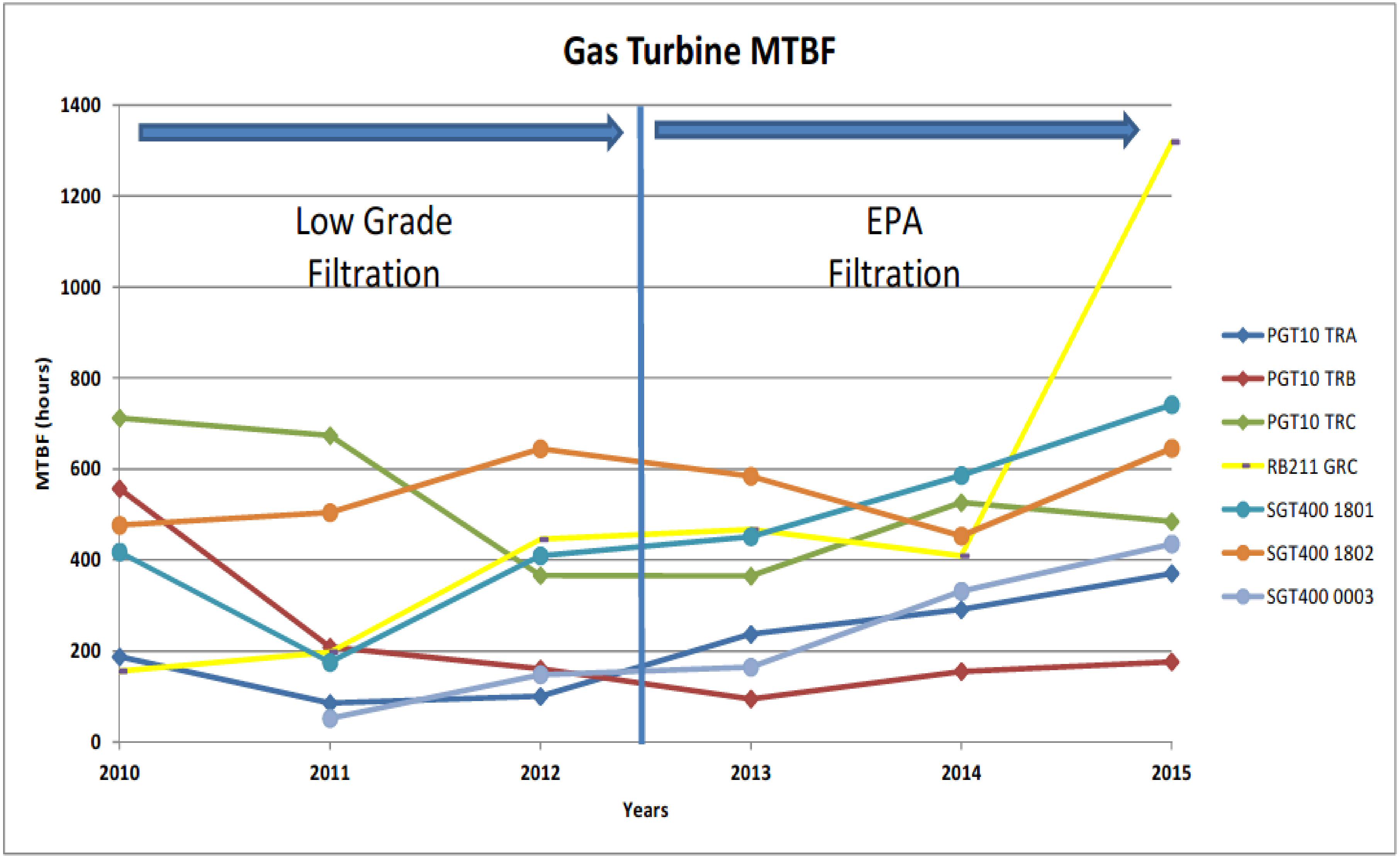
UNPLANNED DOWNTIME VERSUS E12 FILTRATION



PLANNED DOWNTIME VERSUS E12 FILTRATION



MTBF VERSUS E12 FILTRATION



PARTS INTEGRITY VERSUS E12 FILTRATION

- Aeroderivative, Combustion Liner
- Heavy Duty, Combustion Liner

M5

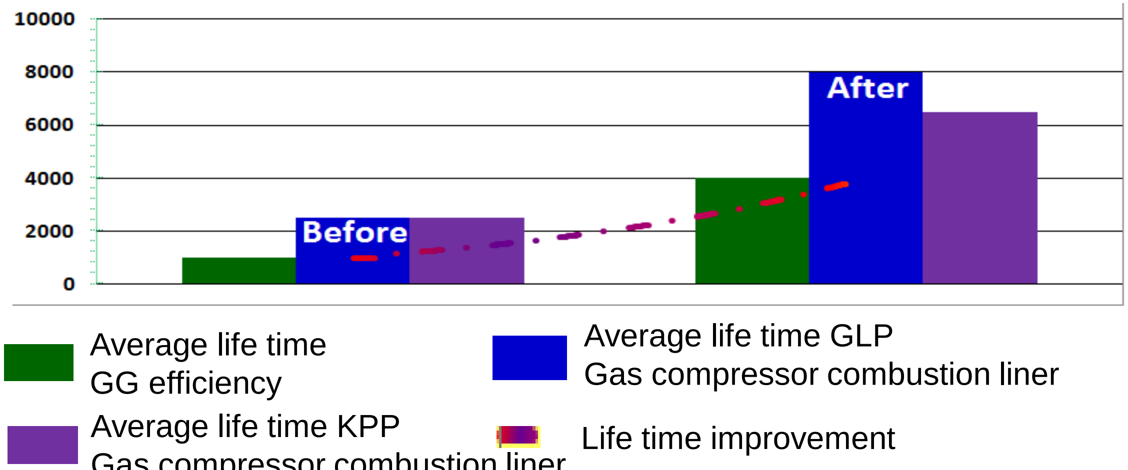
Expected Life 25 000 Hrs

Expected Life 16 000 Hrs

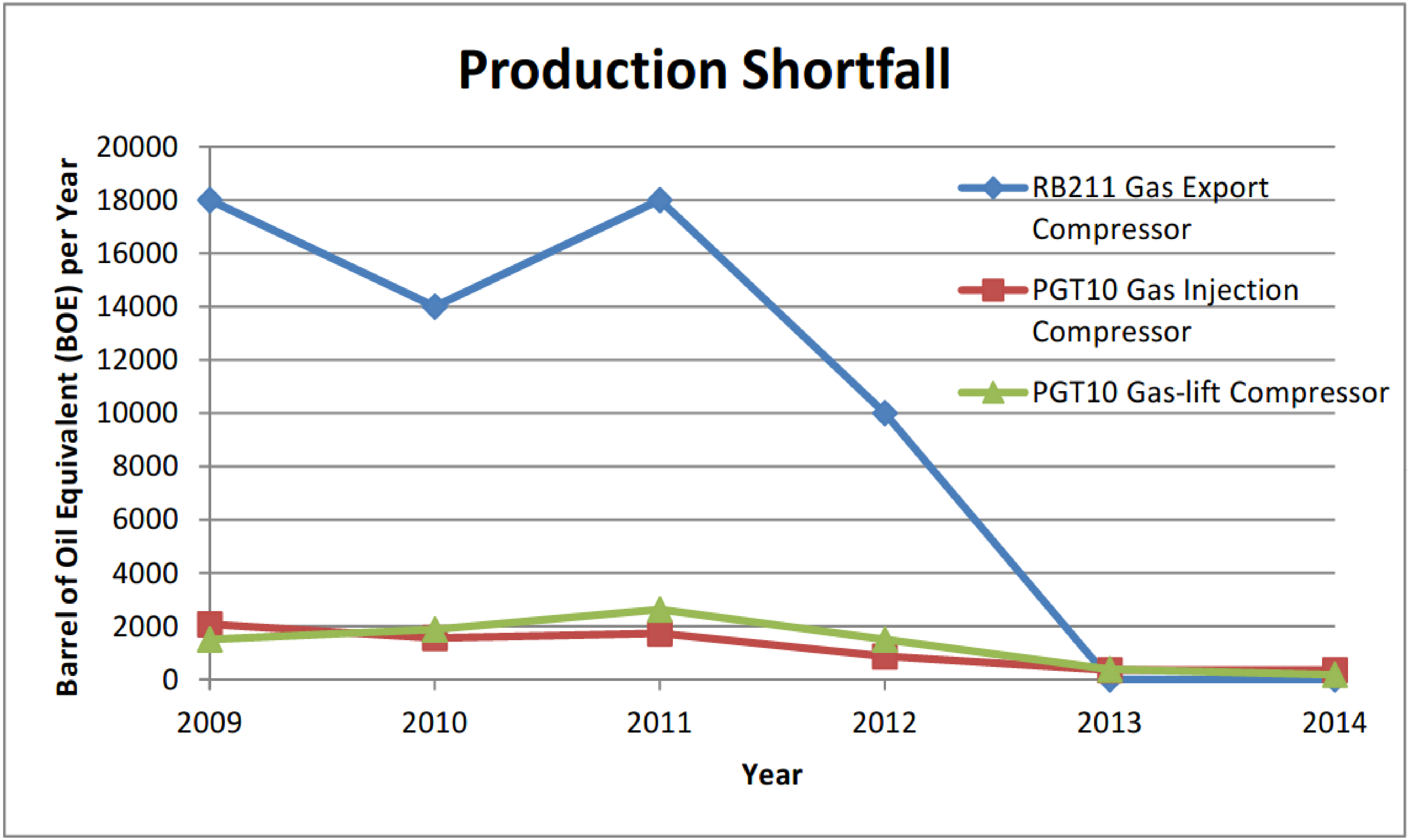
Exchange Date	June 2013	February 2014	November 2014	October 2015
Running Hours	3,800	4,500	6,300	7,300
Improvement	0%	+18%	+66%	+92%

Filtration	M5	E12
Running Hours	2 600	8 000
Improvement	0%	+210%

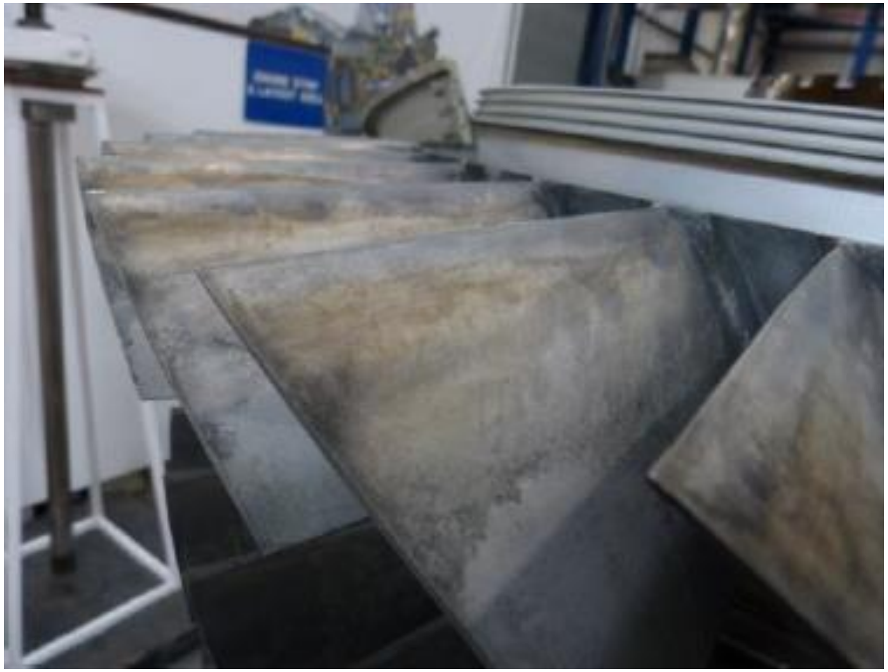
E12



PRODUCTION SHORTFALL VERSUS E12 FILTRATION



FOULING WITH E12 FILTRATION AFTER 8000 HRS

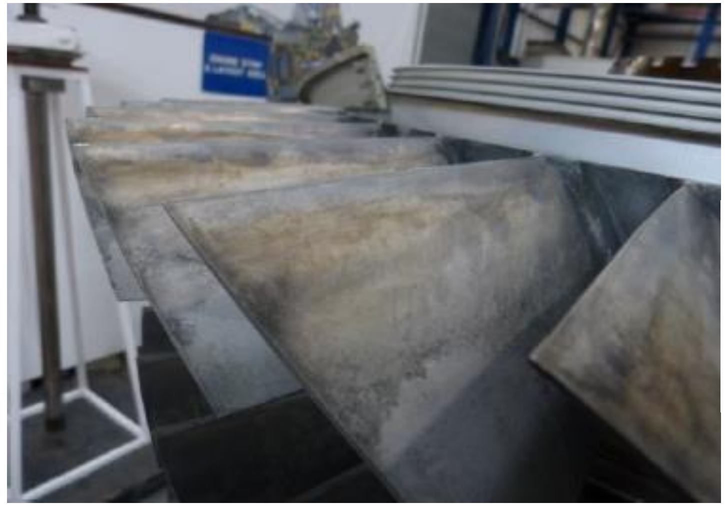


- E12
- Oil Staining
- Minor Erosion
- Minor Coating Loss
- Corrosion
- Airborne Contamination
- Carbon Built up
  - less than 1 micron
  - Majority around 0.1 micron close to MPPS

DISCUSSIONS

- *Hot Corrosion*
  - Despite EPA E12 air filtration, hot corrosion continues in marine environments.
  - Gas turbines are not able to reach their expected life span.
  - Alkali, such as salt, are still passing through the air filters even when they are EPA and hydrophobic.
  - Industry standards and codes do not consider the efficiency of the filter regarding salt and dissolved salt in water in humid environments.
  - The alkali filtration remains a matter of interest knowing hot corrosion eradication is still a strong driver for future Opex and Capex cuts.
- *Soot and Oil Ingestion*
  - According to this 3-year ABK experience, gas turbine cleanliness is highly sensitive to the installation location.
  - Locations which are more exposed to oil fumes and soot have an impact on axial compressor efficiency.
  - The pointing question is how oleophobic filters are and what the optimum size would be for the MPPS (Most Penetrating Particle Size) value.
- *Filter Exchange*
  - Complementary experience is necessary in order to have a good understanding of filter ageing. Additional data are needed to optimize the air filter exchanges on ABK.

TOTAL
COMMITTED TO BETTER ENERGY



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Many Thanks For Your Attention

Any Question ?