VBR TURBINE PARTNERS
support beyond expectation

Netherlands ■ Russia ■ United Kingdom ■ United Arab Emirates

Independent gas turbine consultancy

John de Ruyter – Principal Consultant & Co-founder

2018

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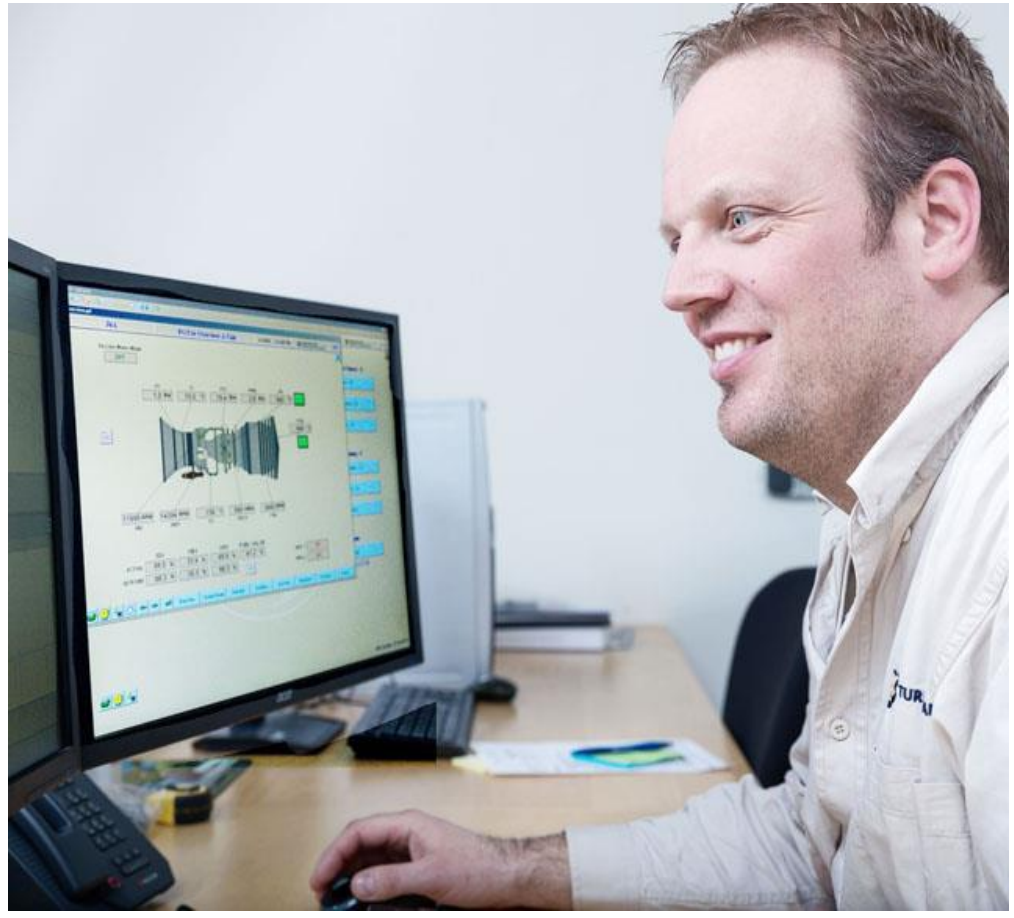
Decision making in gas turbine operation & maintenance

Each and every day plant managers, procurement officers, gas turbine operators & maintenance engineers take many decisions on how to run their gas turbine engines in the best possible way.

The potential profitability of a gas turbine operation depends largely on the quality of this day-to-day decision making by all persons involved.

Systematic improvement of these day-to-day decision making processes will result in a sustainable improvement of total plant operation & maintenance and in a sustainable improvement of profitability.

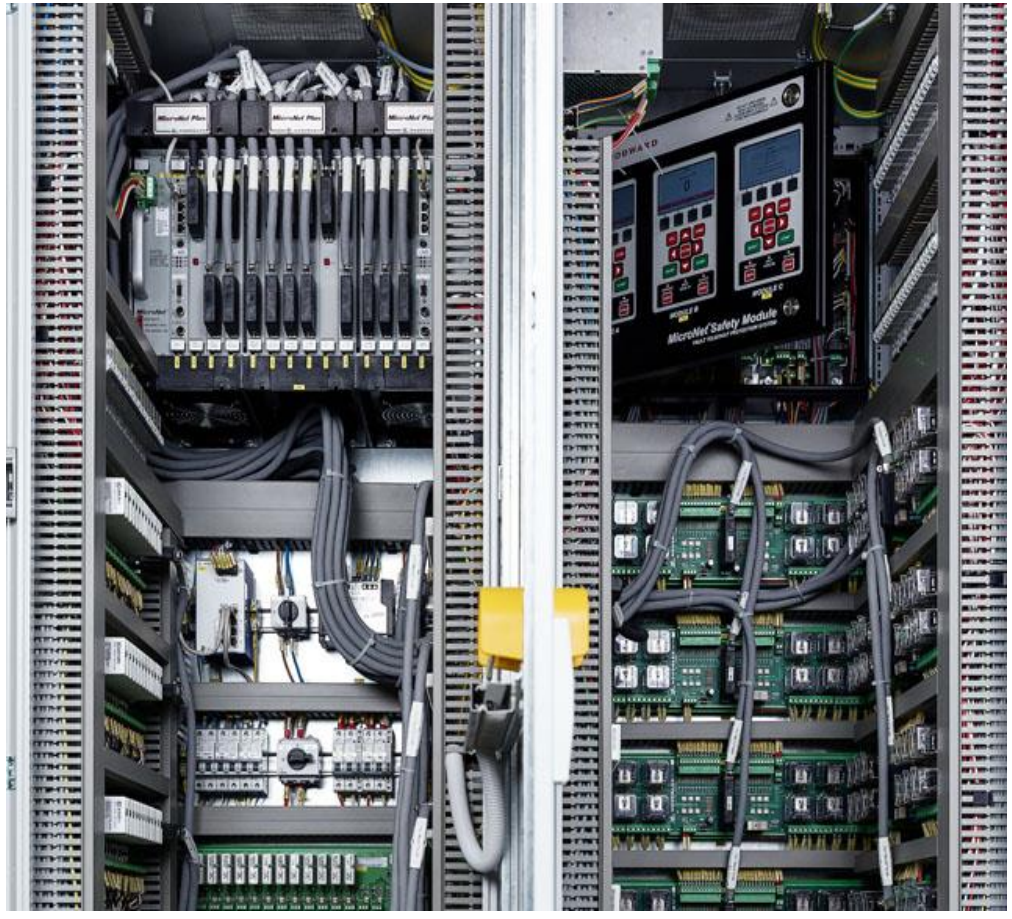


Decision making in gas turbine operation & maintenance

Three common solutions to improve decision making processes:

- Education & training
- Decision support systems
- Consultancy

All three solutions enable better decision making by raising the awareness & knowledge levels of the decision makers so they are better informed and more capable to take the required decisions.



VBR independent gas turbine consultancy

VBR independent gas turbine consultancy enables gas turbine owners, managers, operators, procurement officers and maintenance engineers to take better informed decisions about the operation & maintenance of their gas turbines.

The VBR Turbine Partners consultancy team

Christian Czmok – Consultancy Director
Areas of expertise : hot section exchange, engine overhaul, service interval & life extension, component repair

Rob Overes – Principal Consultant
Areas of expertise : efficiency improvement, power augmentation, emission reduction retrofits

Mohan Thiagarajah – Principal Consultant
Areas of expertise : control systems & instrumentation, digital GT engine modelling, smart remote diagnostics

VBR Turbine Partners consultancy team

Gerrit van Veldhuizen – Principal Consultant
Areas of expertise : hot section exchange, engine overhaul, service interval & life extension, component repair

John de Ruyter – Principal Consultant & Co-founder VBR
Areas of expertise : mechanical & auxiliary GT systems, knowledge development & competence building

Examples of VBR independent consultancy services

- Operational readiness review
- End of warranty assessment
- Technical audit
- Root cause analysis
- Second opinion

Examples of VBR independent consultancy services

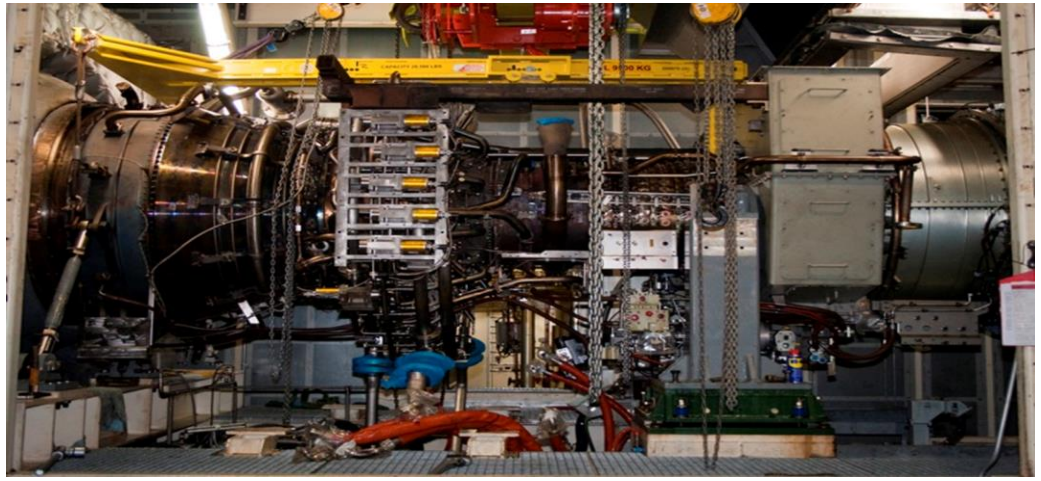
- Engine overhaul consultancy & process management
- Hot section consultancy & process management
- Energy efficiency, power augmentation & emission reduction consultancy & process management

Case study 1: Technical audit LM6000 DLE at an Oil & Gas operator in Europe

An oil & gas company in Europe experienced the following problems with the operation of a relatively new LM6000 DLE:

Unreliable operation, many unpredictable & spurious trips.

Troubleshooting was not effective, no improvement over time.



Case study 1: VBR initial site investigation and conclusions

LM6000 DLE engine, auxiliary systems, instrumentation & cabling and the Woodward Micronet control system were not properly commissioned, even this limited initial assessment already revealed many flaws.

Technical LM6000 DLE & Woodward Micronet know-how & capabilities of the operation & maintenance staff on site were very … very limited …

Case study 1: VBR recommendations based on the site investigation conclusions

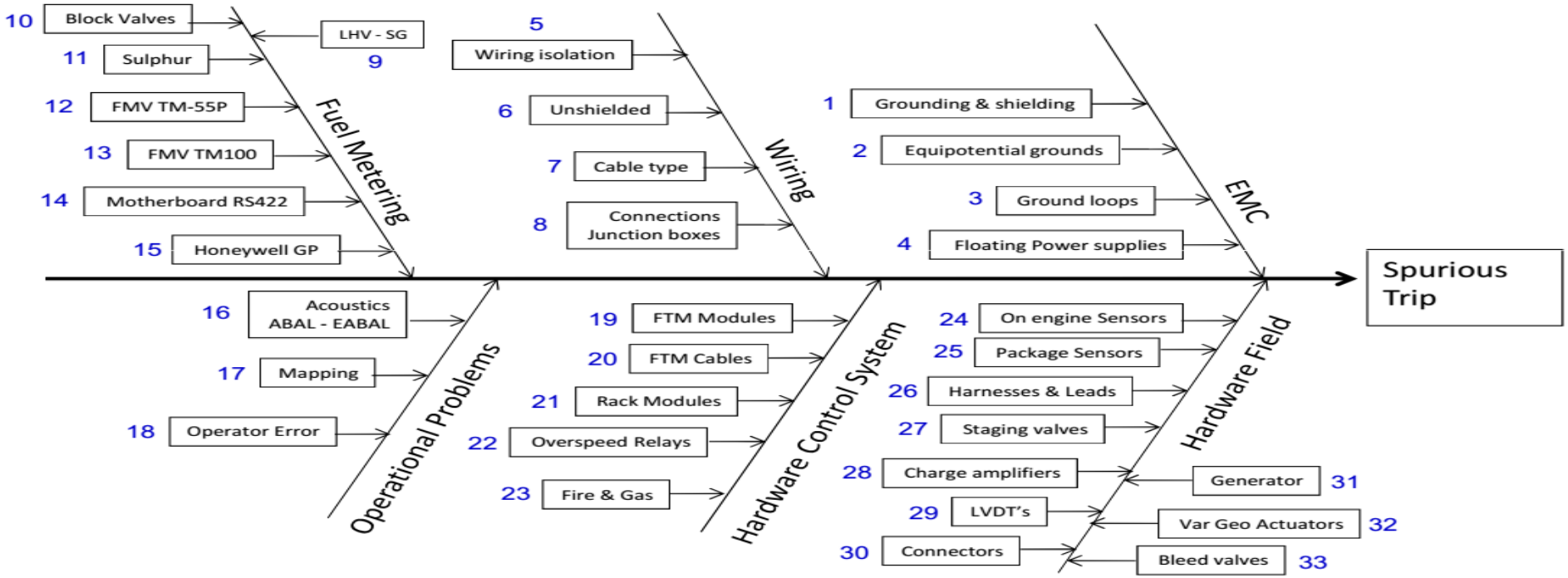
1. Perform a full technical audit to establish a realistic “as-is” technical baseline for the entire system.

2. Develop a technical improvement program addressing all issues identified during the technical audit in a strategic & systematic way.

3. Arrange a competence development program for the on site operation & maintenance staff to improve their LM6000 & Woodward expertise & capabilities.

Case study 1: outcome 1 of the LM6000 DLE technical audit program

Outcome 1:
An inventory of all technical issues regarding the LM6000 DLE engine, auxiliary systems, instrumentation & cabling and the Woodward Micronet control system.



Case study 1: outcome 2 of the LM6000 DLE technical audit program

Outcome 2:

A technical improvement program to solve the identified technical issues in a strategic and systematic way.

Op / Ref No	Item Function - Failure mode	Potential Failure Mode	Potential Effect(s) of Failure	SEV	CLASS	Potential Cause(s)/ Mechanism(s) of Failure	OCC	Current Controls Prevention	Current Controls Detection	DET	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Resulting Actions: Action(s) Taken	SEV	OCC	DET	RPN
1	FMV	FMV partitioning	Trip			Driver Gearbox Wiring	*	None	ALM TRIP	16	**	Replace Trip by ALM Maintenance	RAM Team	RAM	5	1	1	5
2	Anti Icing	Faulty working	Trip			Sensor Connections Wiring	*	None	ALM TRIP	14	**	Maintenance Redesign	RAM Team	RAM	5	1	5	25
3	WS Servo-LVDT Loop	Loss of control Loss of feedback signal	Trip Compressor Stall			Electrical connections Component failure Overhaul gaps	*	None	ALM TRIP	10	**	Instrumentation check Loop check Calibration Maintenance	RAM Team	RAM	5	1	1	5
4	PX26 Loop	Reading too High Reading too Low Fuel flow disturbance	Stage Down Stop to Idle Trip			Loss of signal Sensor failure	6	EABAL	ALM SI Stage Down	6	***	Instrumentation check Loop check Maintenance Intelligent software	RAM Team	RAM	5	0	1	0
5	Vib-Instr-Loop	Reading too High Reading too Low	Stop to Idle Loss of vibration monitoring			Loss of signal Sensor Failure Loop	6	None	ALM SI	6	***	Instrumentation check Loop check Maintenance	RAM Team	RAM	5	1	1	5

Case study 1: outcome 3 of the LM6000 DLE technical audit program

Outcome 3:
A LM6000 DLE & Woodward Micronet competence development & training program for the onsite operation & maintenance staff.

Mechanic/fitter	Junior engineer	Engineer	Senior Engineer	Specialist / Manager
• Trainee position – provide on the job training to developing required skills and knowledge	• Entry-level position requiring basic and/or quantitative skills and knowledge	• Requires skills within a specific technical area	• Requires specialized and quantitative skills	•Has advanced and specialized expertise, typically developed through extensive experience
• Work is completed with close supervision	• Works within clearly set operating procedures and adheres to quality guidelines	• Troubleshoots a range of issues and determines appropriate solutions	• Completes a variety of complex assignments	• Completes the most complex assignments and mentors less experienced technicians
	• Works with a moderate degree of supervision	• Completes work with a limited degree of supervision	• Works autonomously within established procedures and practices	• Works autonomously with minimal guidance
			• Provides guidance to colleagues with less experience	• Serves as "go to" resource in area of specialization

Case study 1: lessons learned from this LM6000 DLE technical audit program

The OEM seems to have a challenge to mobilize sufficient dedicated LM engine & control system expertise & capabilities to realize a reliable operation from start for newly commissioned DLE engines and packages.

To ensure reliable LM DLE operation, both from start and over time, the technical baseline of a LM operation must be good and the operation & maintenance staff must be well educated & capable for the job.

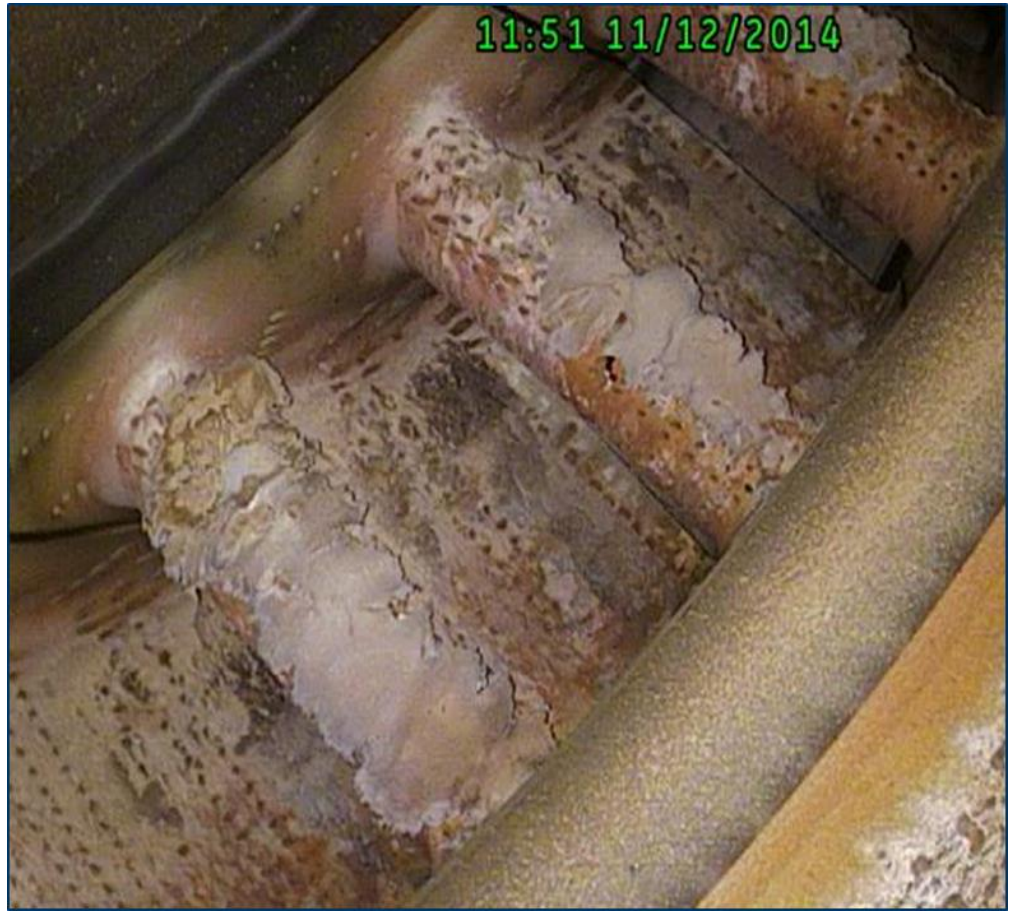
Case 2: LM2500+G4 RCA & consultancy project at an Oil & Gas operator in the Middle East

An Oil & Gas company in the Middle East experienced the following problems in the operation of a relatively new LM2500+G4 DLE:

1. Speedtronic MK6E control system not performing reliable, effective troubleshooting very hard to do.

2. Sand intake in the engine.

3. Hot section severely contaminated with deposits on nozzles & blades within 8.000 hrs. of operation.

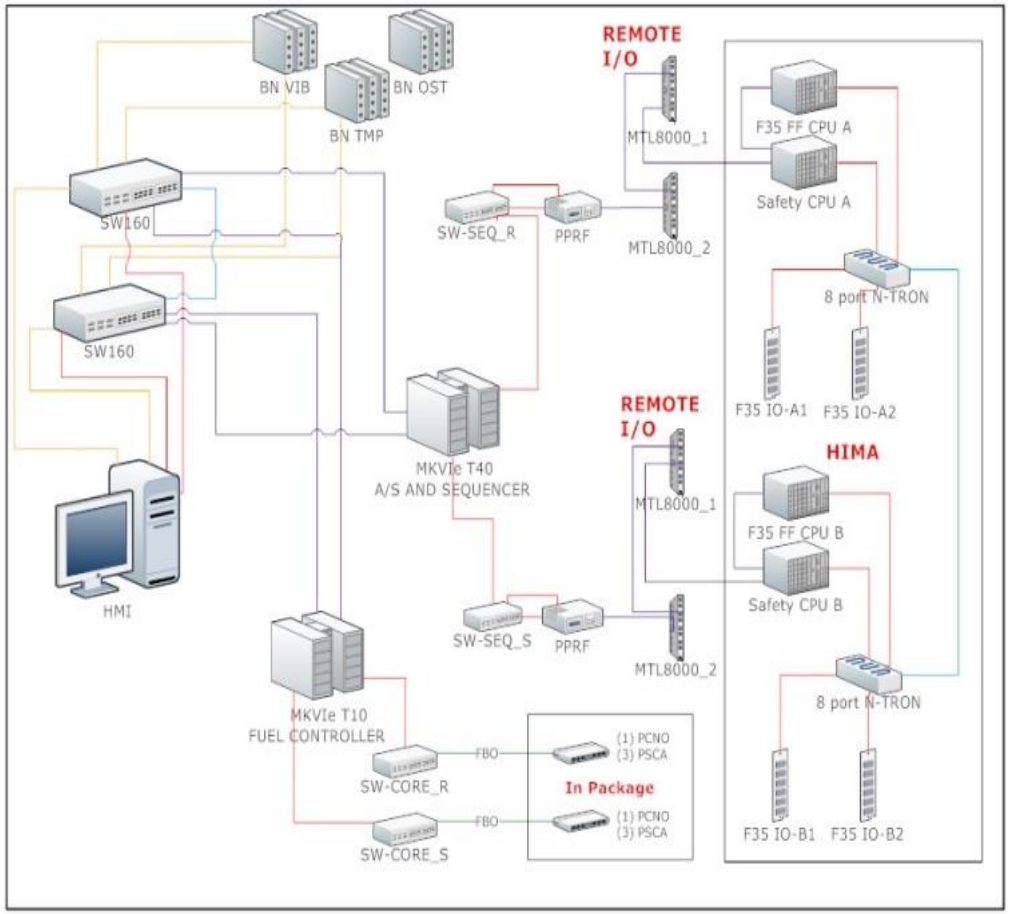


Case 2: VBR initial site investigation and RCA conclusions

Speedtronic MK6E control system configured in an unnecessary complex, not fully redundant & partly closed way which blocked effective troubleshooting.
(see picture)

Air inlet filtration not performing well resulting in sand ingestion in the engine.

Hot section severely contaminated with accumulated sand/glass deposits on the blades & nozzles.



Case 2: OEM recommendations based on the site investigation & RCA conclusions

Speedtronic MK6E control system configured according to specifications, assign a OEM controls specialist to this site for 6 months to solve any issues.

Extend the existing single air intake housing to a double air intake housing containing an additional set of air filters to improve air filtration.

Scrap the severely contaminated hot section and replace it with a new hot section.

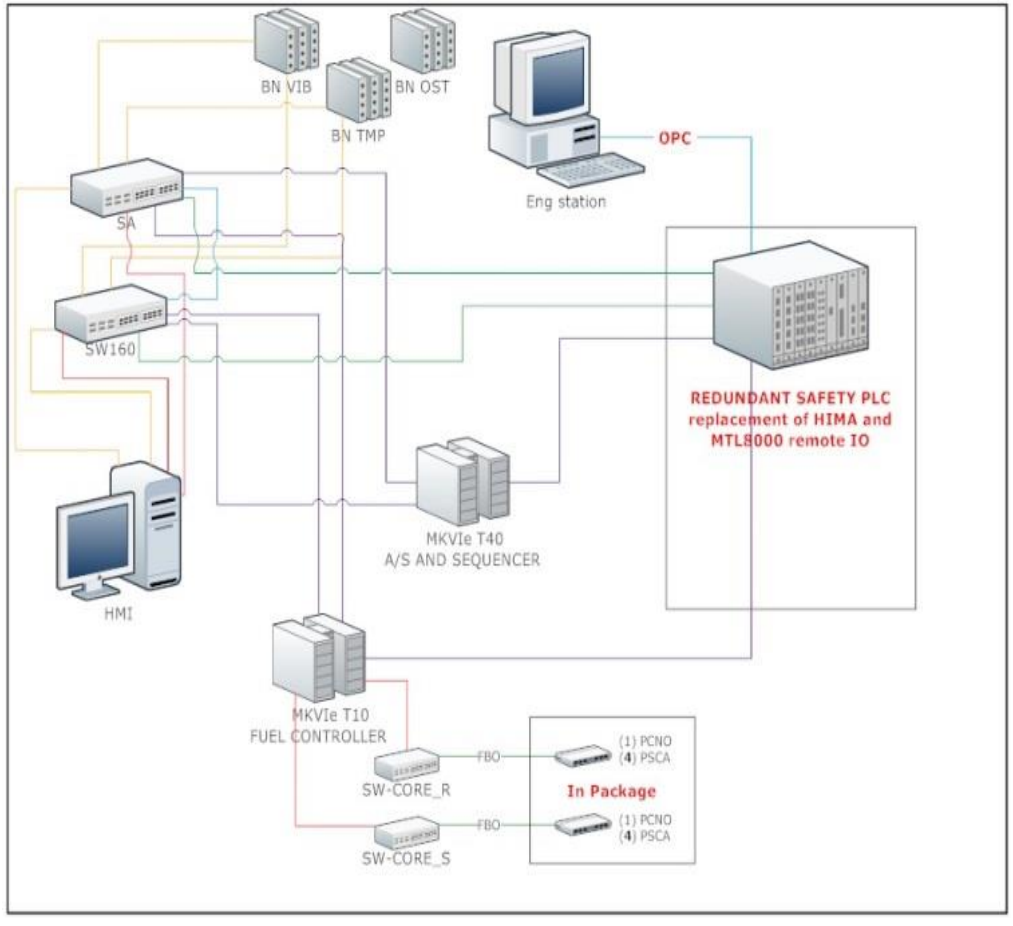
Case 2: VBR “second opinion” recommendations based on the investigation & RCA conclusions

Simplify the Speedtronic MK6E control system architecture to make it fully redundant and more reliable in a sustainable way. (see picture)

Modify the inlet filtration to HEPA 12 within the existing single inlet filter housing.

Attempt to clean the severely contaminated hot section blades & nozzles with dry ice blasting.

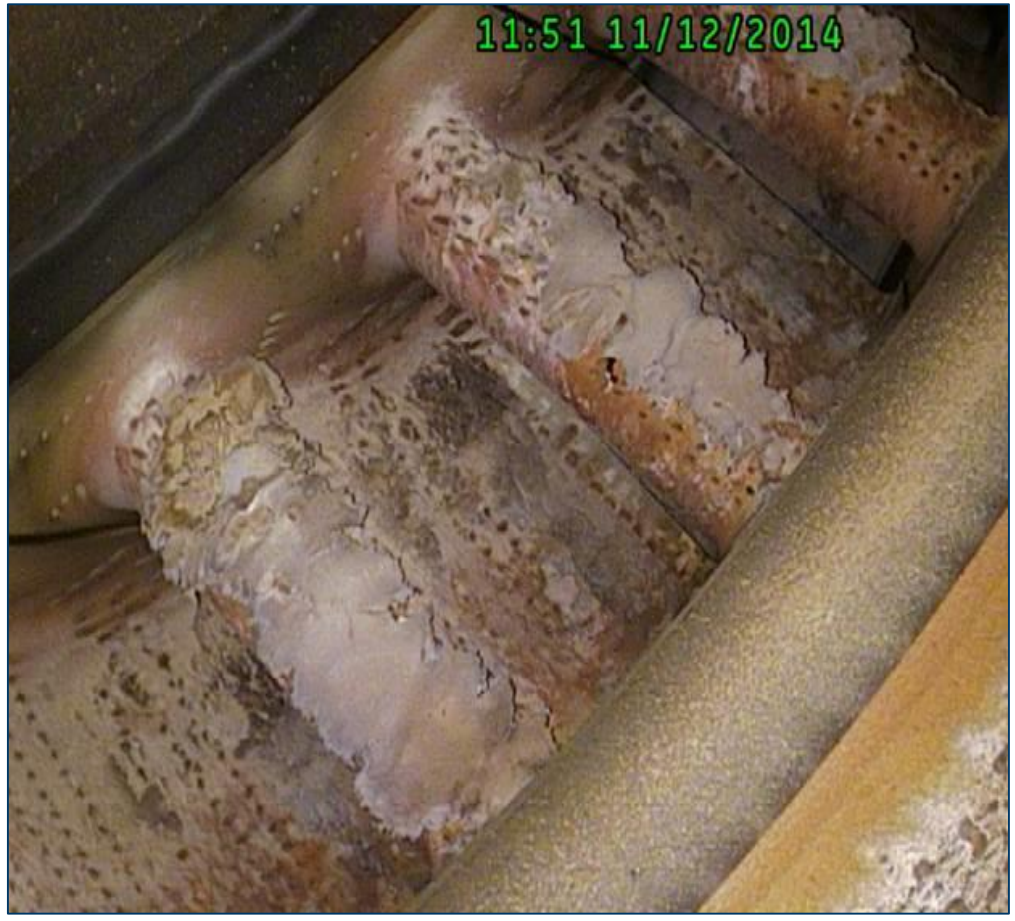
After the presentation VBR was asked to perform the hot section cleaning attempt.



Case 2: Projected outcome of the LM2500+G4 hot section cleaning project

To bring the engine back to a serviceable condition again by cleaning the severely contaminated hot section with the purpose of using up the remaining lifetime of this hot section.

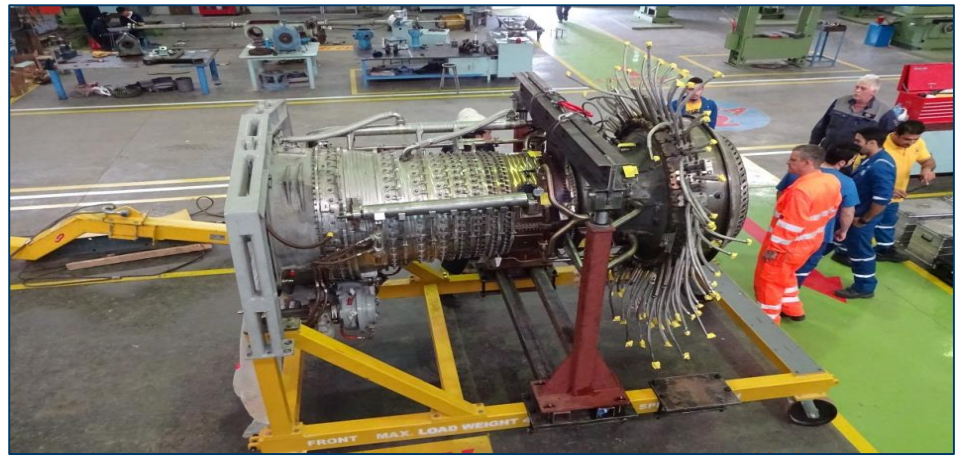
This will enable the customer to realize a huge maintenance cost savings compared to the OEM recommendation of scrapping the contaminated hot section and replacing it with a new hot section.



Case 2: Creating conditions to perform the hot section cleaning at a local workshop

LM2500+G4 maintenance dolly

The VBR engineering department supplied all drawings to modify the storage dolly of the customer into a fully functional maintenance dolly.



LM2500+G4 hot section tooling and dry ice blasting equipment

VBR provided a full set of LM2500+G4 hot section tooling and full set of dry ice blasting equipment with an experienced operator.

Case 2: disassembly & condition assessment of the engine and the removed hot section

Engine condition assessment:

Hot section with heavy deposits

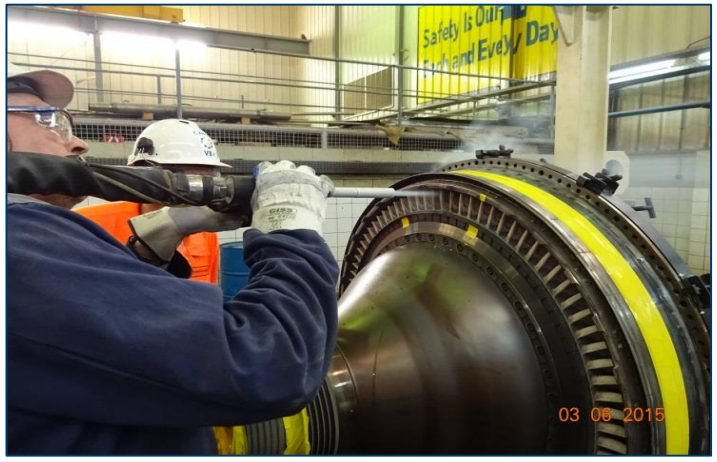
Bearing no. 5 damaged

VSV torque shaft bearings worn out

Damper sleeve severely damaged

Instrumentation, brackets & cabling missing

Case 2: on-site cleaning of the contaminated hot section by dry ice blasting



Case 2: short term delivery of missing parts & parts rejected after the disassembly

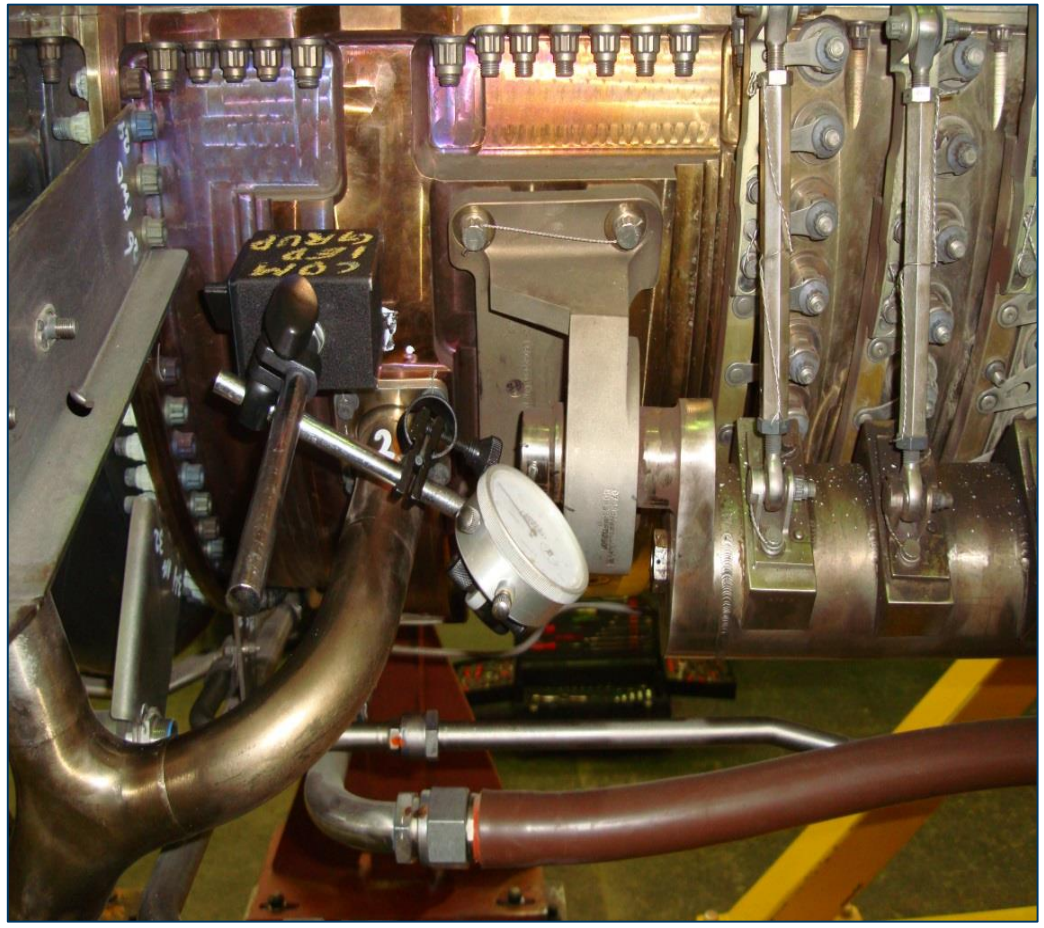
Missing parts:

- **Instrumentation**
- **Brackets**
- **Cabling**

Rejected parts:

- **Bearing no. 5 damaged**
- **VSV torque shaft bearings worn out**
- **Damper sleeve damaged**

VBR supplied these parts within a very short lead time, mostly out of the existing stock at the VBR warehouse in Elst.



Case 2: classroom & ‘on-the-job’ training incorporated in this hot section project

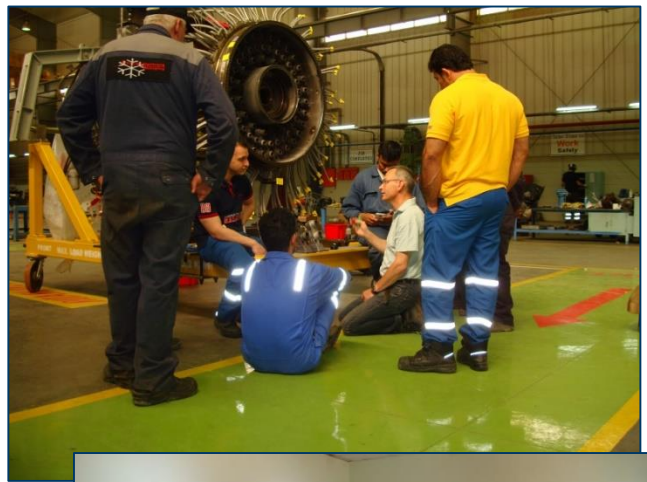
On-site LM2500+G4 DLE classroom training course for 10 operators & maintenance engineers.

(Tailor-made for LM2500+G4 DLE, Speedtronic MK6E and all auxiliary systems.)

Additional level 1 and level 2 ‘on-the-job’ maintenance training for 6 maintenance engineers at the local workshop.

(Hands-on training back-to-back with the VBR field service engineers.)

Case 2: re-assembly and completion of the engine back into serviceable condition



Case 2: engine put back into operation after repair and performing well since then

Case 2: lessons learned from this LM2500+G4 DLE consultancy, RCA & hot section project

An independent second opinion on major maintenance activities can provide proven and very cost-effective alternative solutions that go beyond the scope, guidelines and service portfolio of the OEM.

Well-informed decisions on major maintenance activities can save a lot of money …

Benefits of independent gas turbine consultancy

- Better gas turbine operation & maintenance results through better informed decision making
- Improved reliability, availability & maintainability
- Reduced operation & maintenance costs

Questions?

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Thank you for your attention!

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