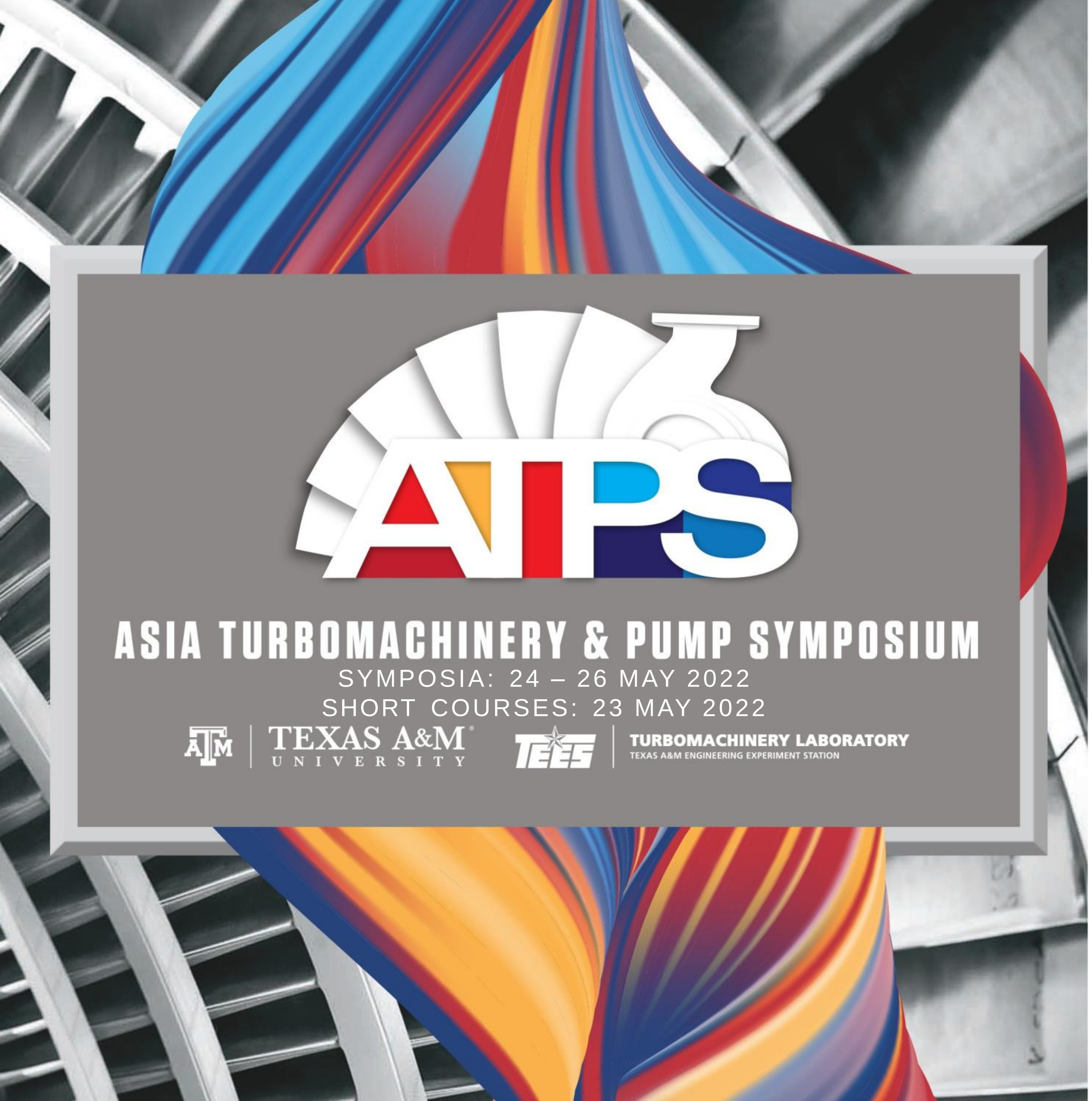

Gas Turbine Load Limited due to High Exhaust Temperature Deviation

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Authors

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Abstract

This case study presents an incident of sudden exhaust temperature spread increase of a medium power range Gas Turbine Generator (GTG) during normal operation. The analysis of exhaust temperature spread, field troubleshooting and recommended solution are presented to share the key learnings.

A routine planned inspection on the GTG was conducted to assess the machine condition. The external fuel gas filter coelescer was swung from the running Filter B to standby Filter A due to increase in differential pressure. After GTG restart and running for a month, the turbine exhaust temperature (T7) deviation was found increased from 15^{0}C up to 40^{0}C which then caused GTG auto unloading to about half load.

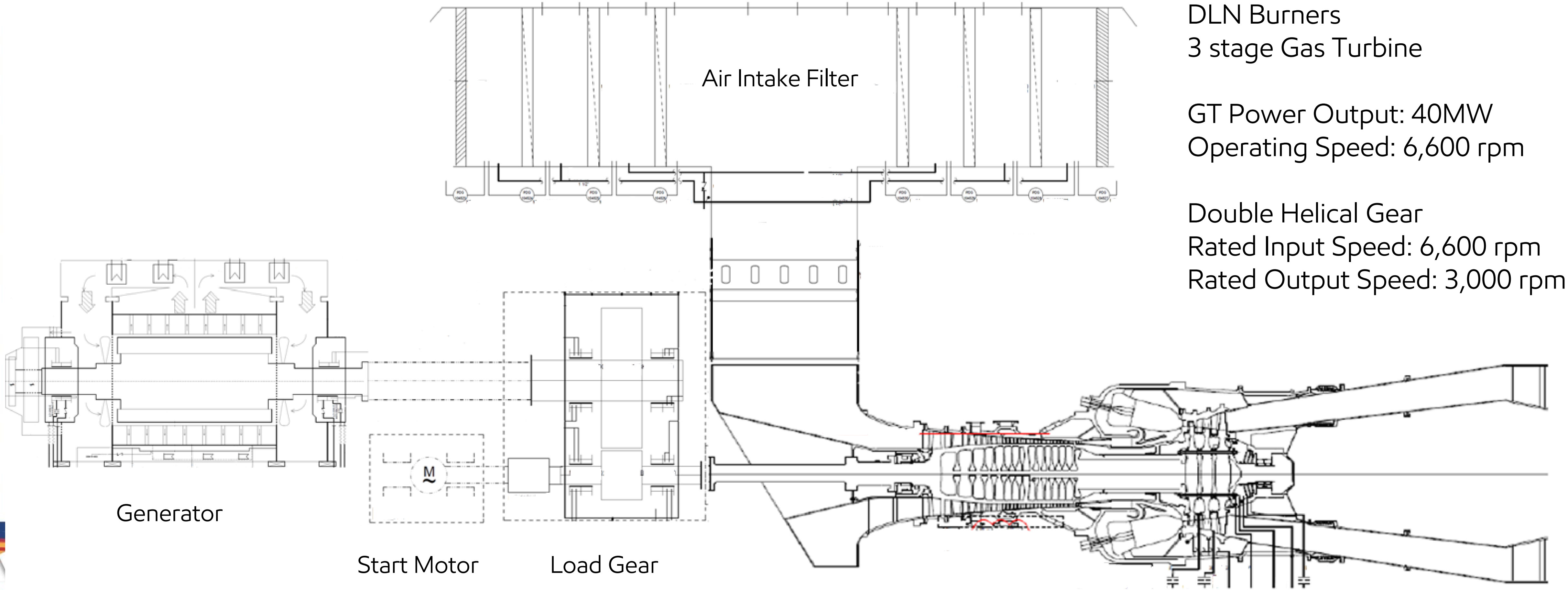
In the process of troubleshooting, the exhaust temperature spread at different loading was tested and the results rendered were analyzed systematically by both user and OEM. Cold spots were indicated from the spread which suggested burners clogged up. It was a challenge to identify the clogged burners due to the complexity of turbulent flow at the turbine exhaust.

A thorough fuel gas manifold inspection was performed and particles were found downstream at different sections of the system. Sample collected and sent for EXD testing which revealed presence of rust particles. The internal and external fuel gas system were clean purged with instrument air in the subsequent planned maintenance window. GTG restarted back successfully after the corrective action and the average turbine exhaust had been normalized to ~10^{0}C.

Agenda

1	Case Study Background
2	Problem Description
3	Analysis
4	Mitigation Implemented and Results
5	Key Learning

Equipment General Info

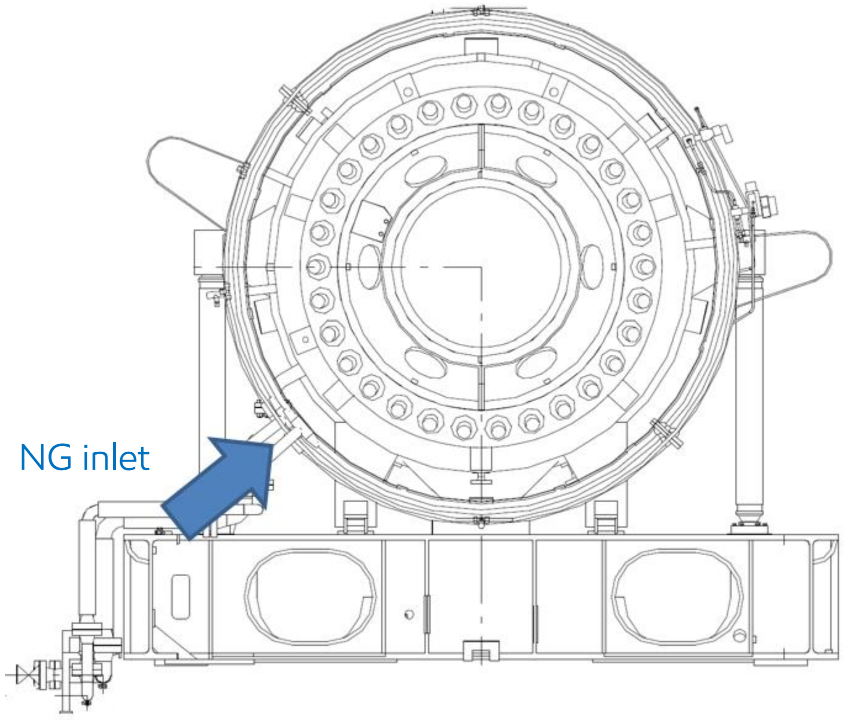


GTG Details
3-stage Air Intake Filters
15 stage Air Compressor
DLN Burners
3 stage Gas Turbine

GT Power Output: 40MW
Operating Speed: 6,600 rpm

Double Helical Gear
Rated Input Speed: 6,600 rpm
Rated Output Speed: 3,000 rpm

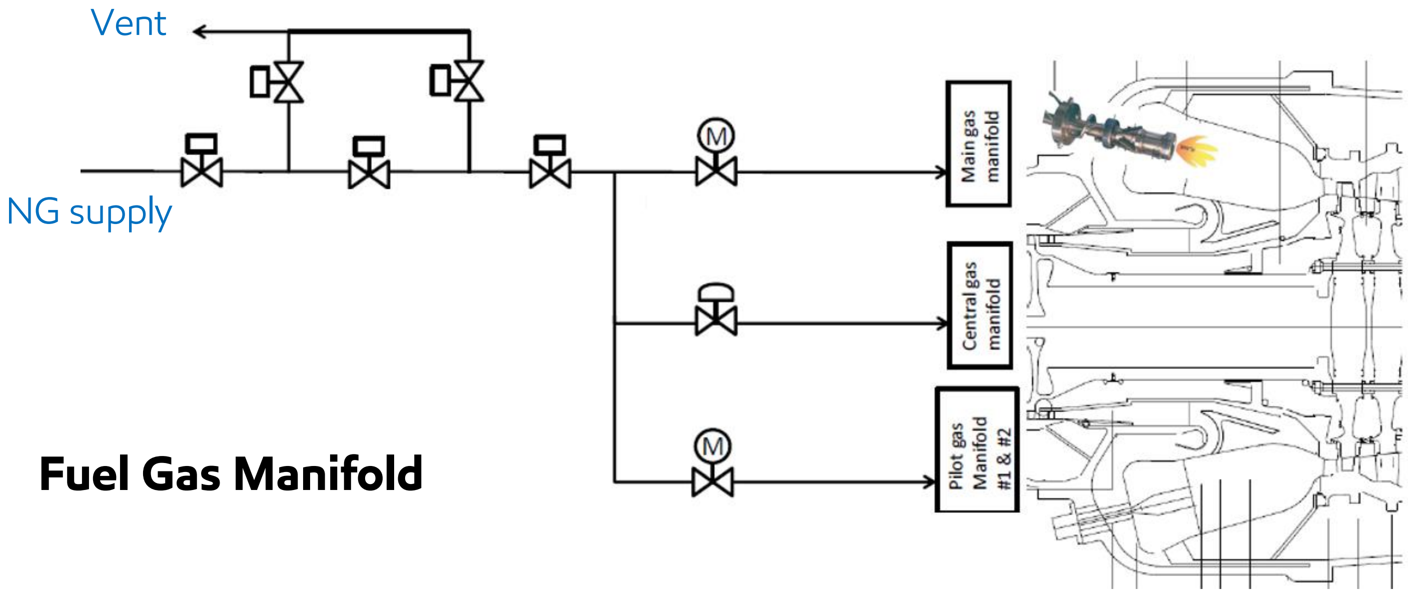
Fuel Gas System



The DLN burners are firing with natural gas.

Fuel Gas System
Fuel gas type: Natural gas
Supply pressure: 24 barG
Supply temperature: 40^0C

The fuel gas is split to main gas line, pilot gas line and center gas line before directing to combustors.

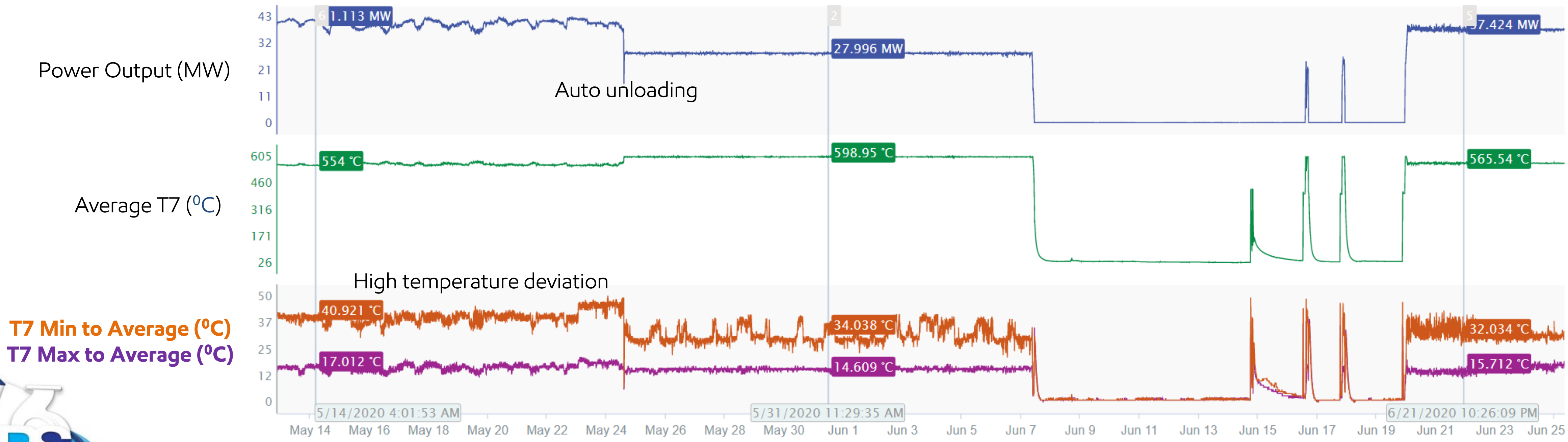


Fuel Gas Manifold

Problem Description

The GTG was shutdown for planned maintenance (PM). During GTG restart, Turbine Exhaust Temperature (T7, Min to Avg) increased instantaneously from ~10^{0}C to ~40^{0}C but the GTG was capable of delivering up to full load for ~1 month until hitting alarm.

That triggered protection logic to auto unload the machine to part load due to cold spot. GTG power was then kept at part load 30MW to control the exhaust temperature deviation.



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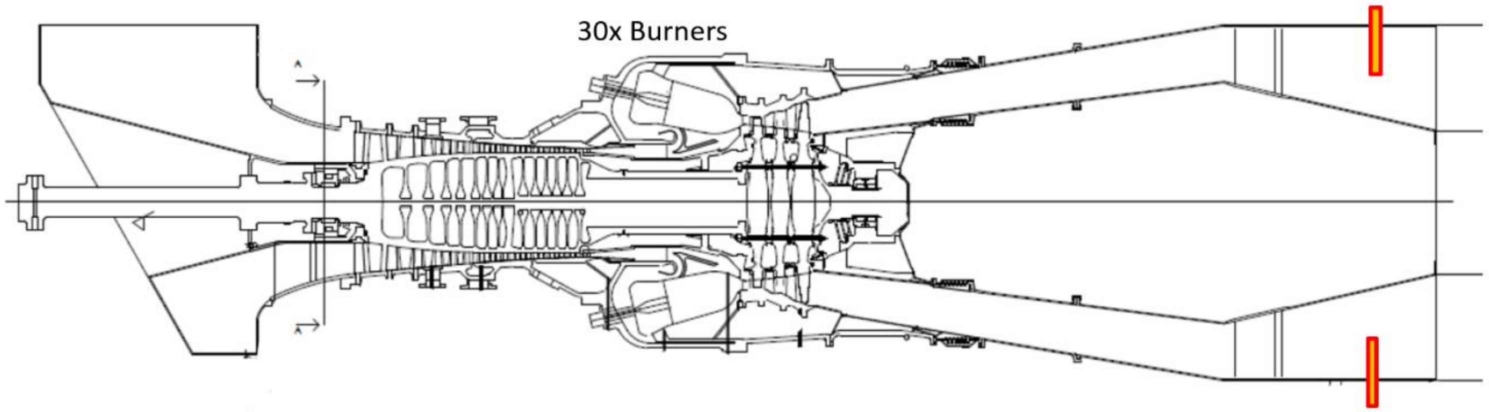
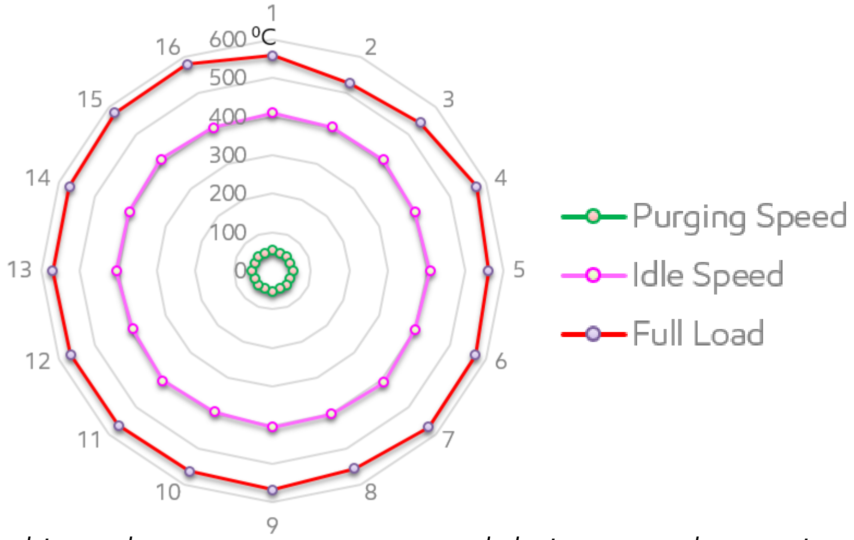
Analysis

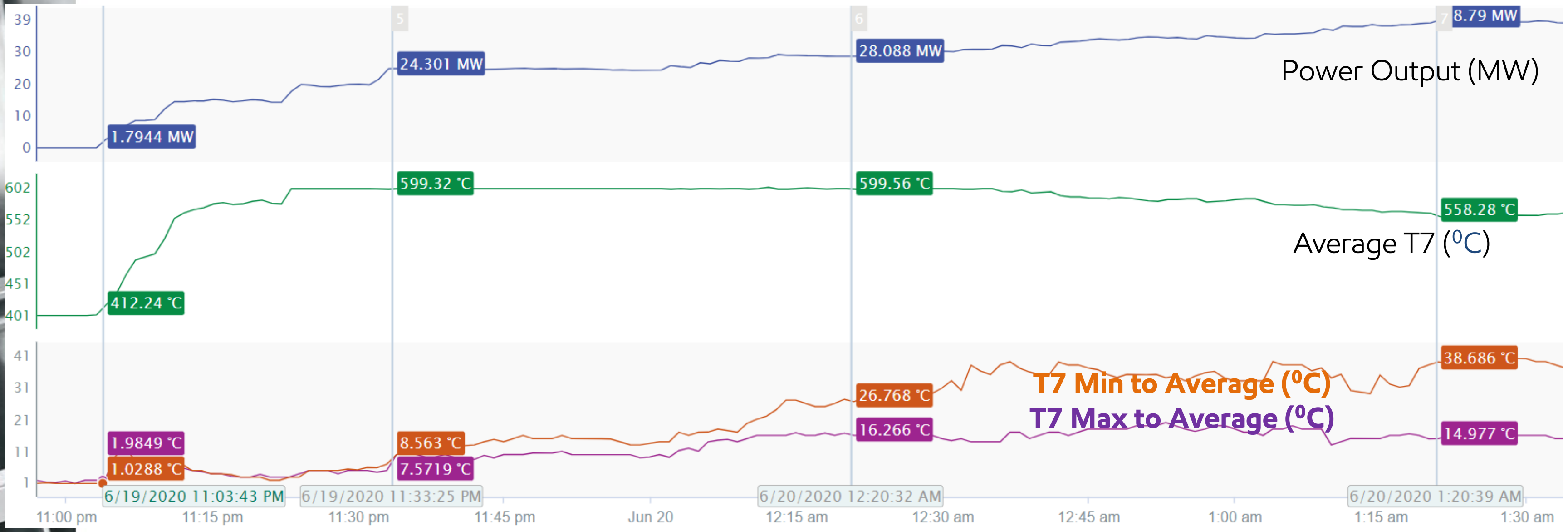


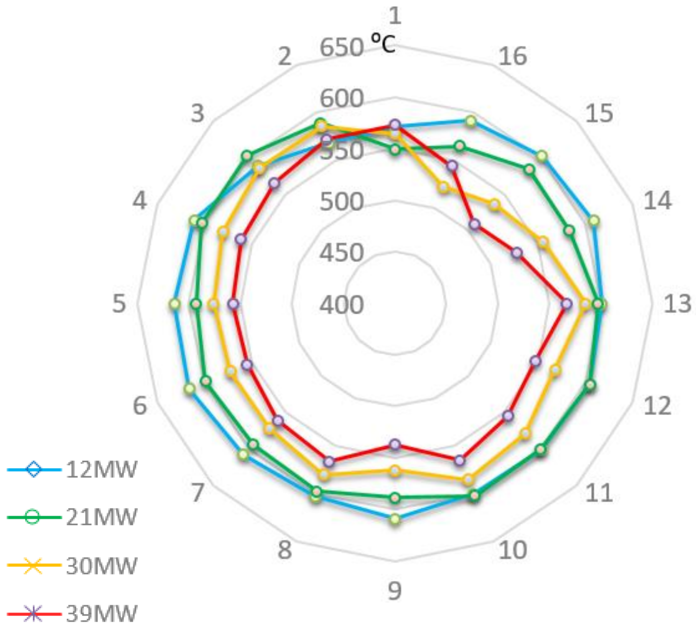


Turbine exhaust temperature spread during normal operation in May 2020

1. The turbine exhaust temperature (T7) is measured by 16 thermocouples installed at about 5m away from the 30 burners.
2. The overall T7 trends prior to auto unloading was studied and used as a base line reference.
3. The T7 distribution was presented in polar plot to provide an overview of the temperature spread.
4. The exhaust temperature deviation is within acceptable range and the overall temperature profile is close to circular shape at any loading.

Analysis

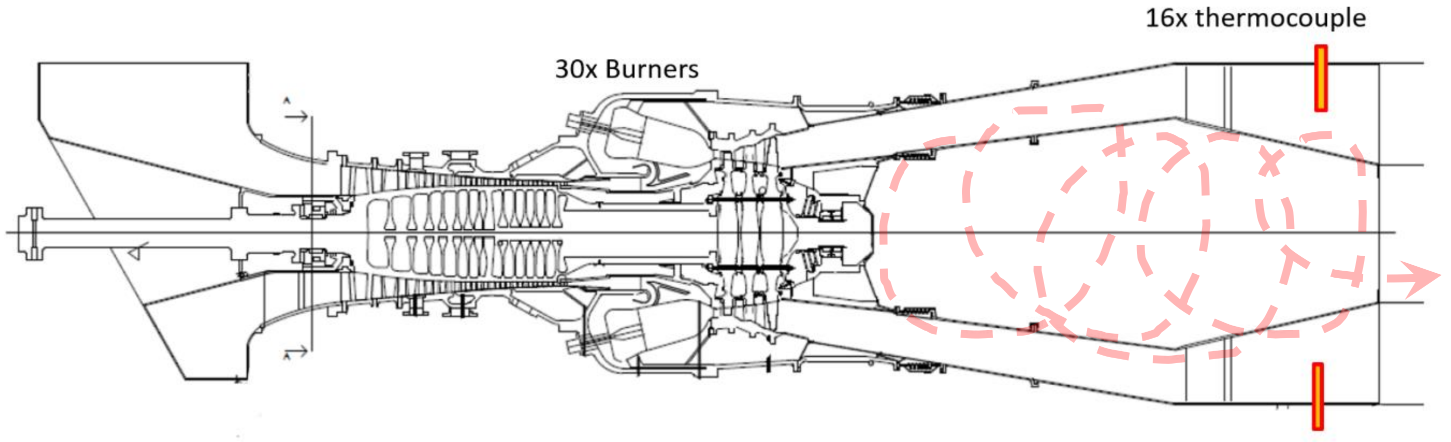


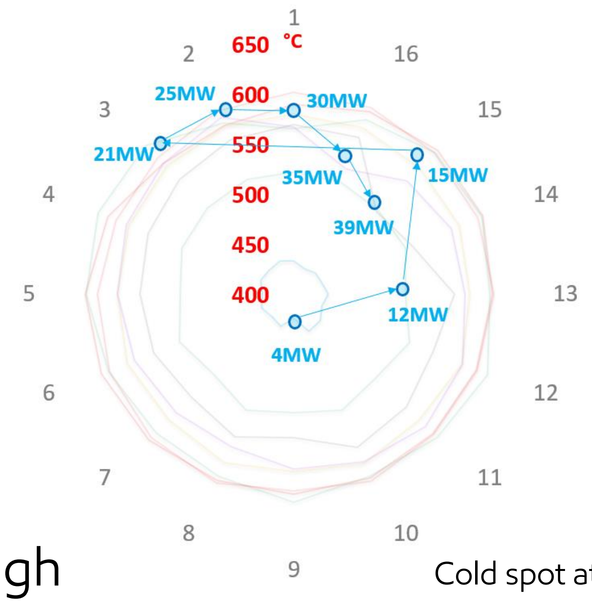


Turbine exhaust temperature spread at different loads

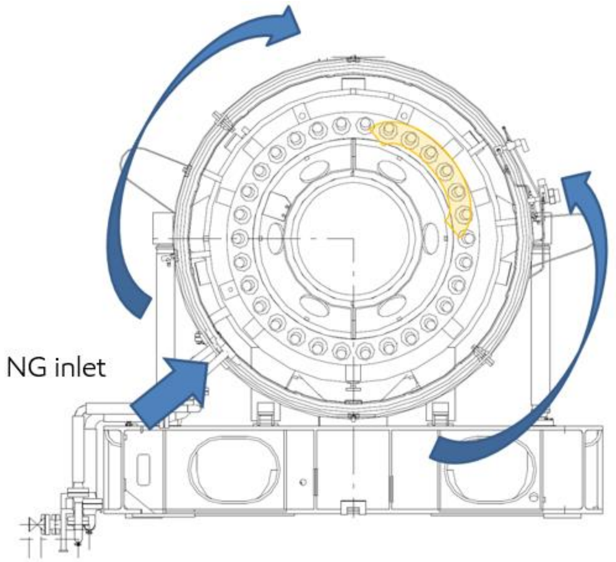
1. The turbine exhaust temperature (T7) when auto unloading occurred was then analyzed.
2. At low load, the T7-to-max (hot spot) and T7-to-min (cold spot) deviation were low below 10⁰C
3. Above 50% load, the T7-to-max (hot spot) and T7-to-min (cold spot) deviation increased with load drastically.
4. The T7 spread profile deformed significantly at high load operation.

Analysis





Cold spot at different loads



1. At low load operation, the T7 spread is almost uniform; at high load operation, the T7 spread profile is deformed.
2. The cold spots at different loadings were provided to OEM to perform a joint diagnosis.
3. The thermocouples readings are not directly linked to the firing from burners at their physical location. This is due to the swirling effect of the exhaust flow in the diffuser ducting.
4. Coupled with the understanding of the gas flow path into the manifold, a number of burners were removed for inspection in the subsequent planned maintenance window.

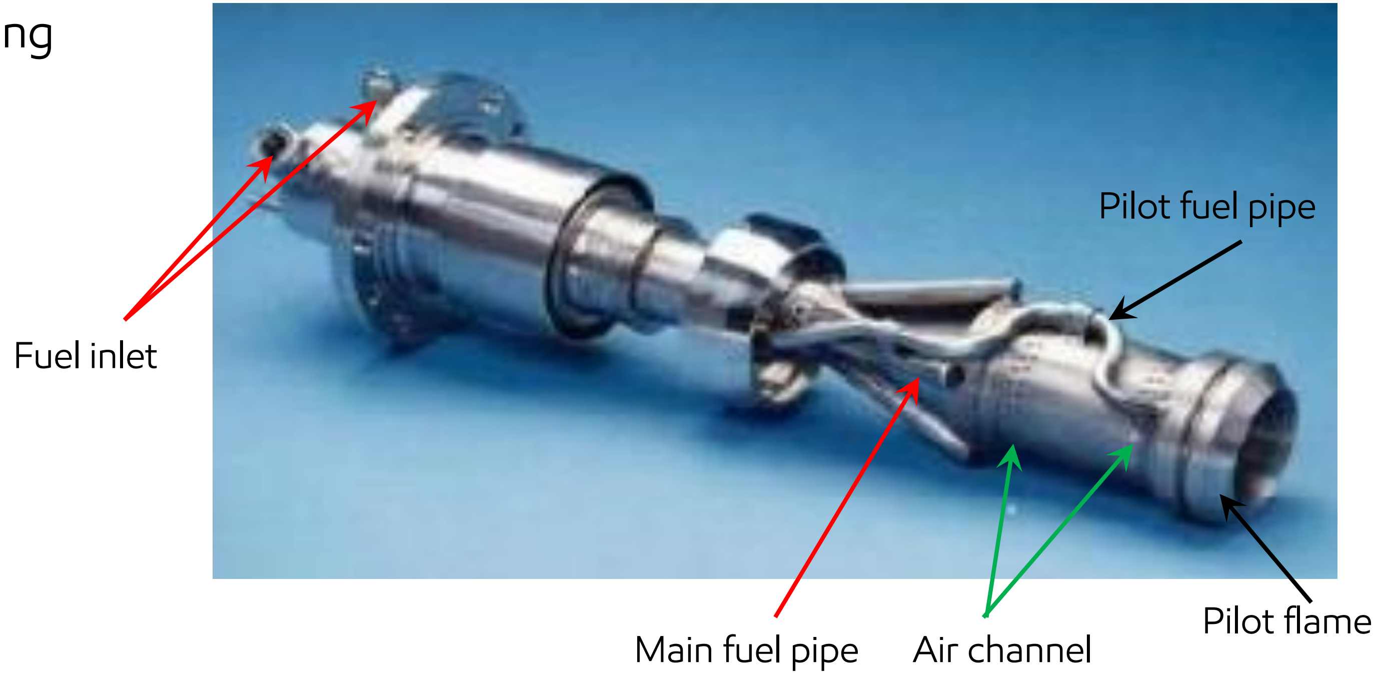
Findings

During PM window, the following observations were made:

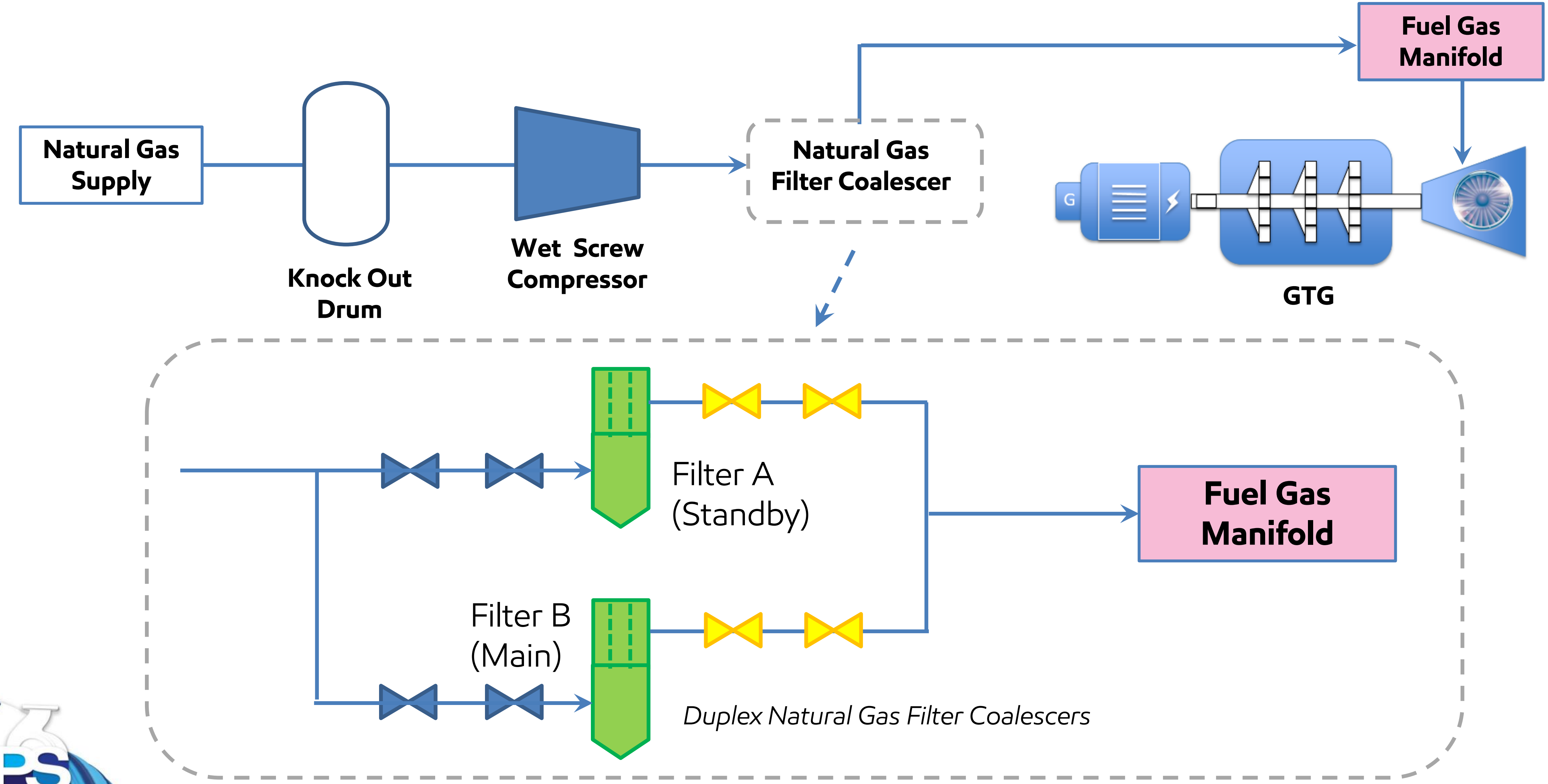
1. At the fuel gas manifold, residue dirt was observed sticking to wall.
2. A number of burners orifice plates were found plugged with particles
3. Sample collected and sent for EXD testing which revealed presence of rust particles.

Magnetic particles

Dirt in fuel gas manifold

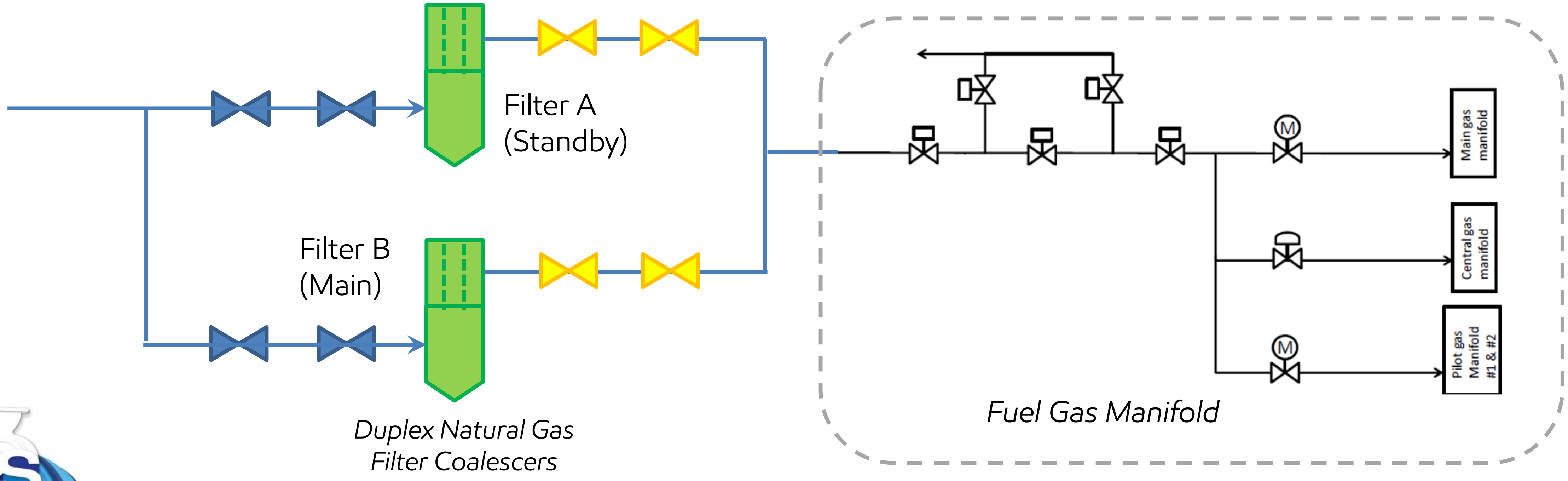


Overall System Line Up

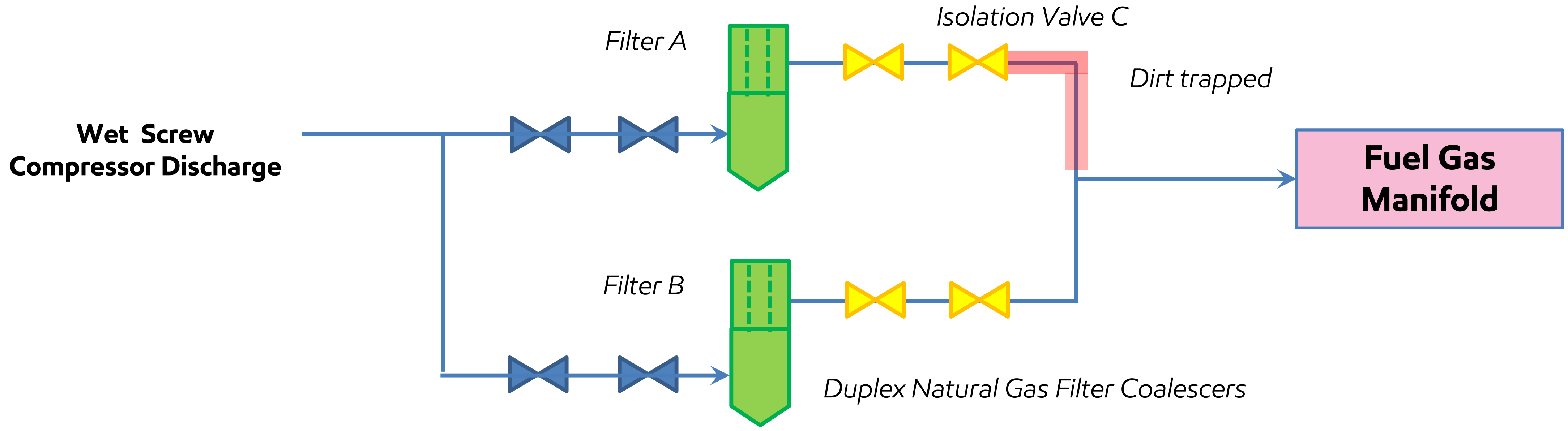


Mitigation

1. 11 number of burners were also removed, inspected and purge clean with instrument air.
2. Vacuum was used to suck the dirt and particle.
3. Multiple purging with plant nitrogen was also performed from the filter coalescers up to fuel gas manifold.



Root Cause Analysis



- Based on operation record, the external fuel gas filter coalescer was swung from Filter B to Filter A prior to startup in April 2020.
- Remnant dirt was found on the section downstream of the Isolation Valve C as shown above.
- Prior to GTG first commissioning, both lines of natural gas filter coalescer lines was purged clean. Temporary strainer was in place to trap dirts.
- One of the lines was purged up to GTG full load operation, however, the other line was purged at GTG idle speed. The temporary strainer was removed after that.
- Dirt was most probably pushed to fuel gas manifold and burners when Filter A was put in operation.

Key Learnings

1. Turbine exhaust flow is swirling and unpredictable. Monitoring the cold spot for the full range of loadings helped to track the affected burners.
2. Understanding the natural gas flow path to the fuel gas manifold helps to predict the location of plugged burners.
3. Natural gas line purging at high flow or GTG full load is important to ensure most of the dirt was clear.
4. For duplex filter coalescers, it is recommended to swing the coalescer several times after GTG full load operation (maximum fuel flow) until the temporary strainer is clean.
5. Oil injected screw compressor had possibly caused stickiness in the pipeline. Purging with dry gas (bypass compressor) in the initial stage should be considered.
6. Fuel gas manifold had been effectively cleaned using ultrasonic bath.

End of Presentation
Questions?

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