Performance Monitoring of IEC Industrial Gas Turbines

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Mechanical Department

Presentation Scope

1. IEC performance monitoring approach
2. Case Study 1. Compressor failure
3. Case Study 2. Control system problem
4. Case Study 3. Compressor washing optimization
5. Case Study 4. GT Inlet Air Filter upgrade
6. Summary

Part 2.

7. Case Studies in details

Performance Monitoring: Introduction

Today, industrial gas turbines already have become one of the main engines for electricity generation.

Modern industrial gas turbines have output 250 – 350 MW (up to 470 MW in developments). Combined-cycle applications on their base have outstanding thermal efficiency approaching 62%.

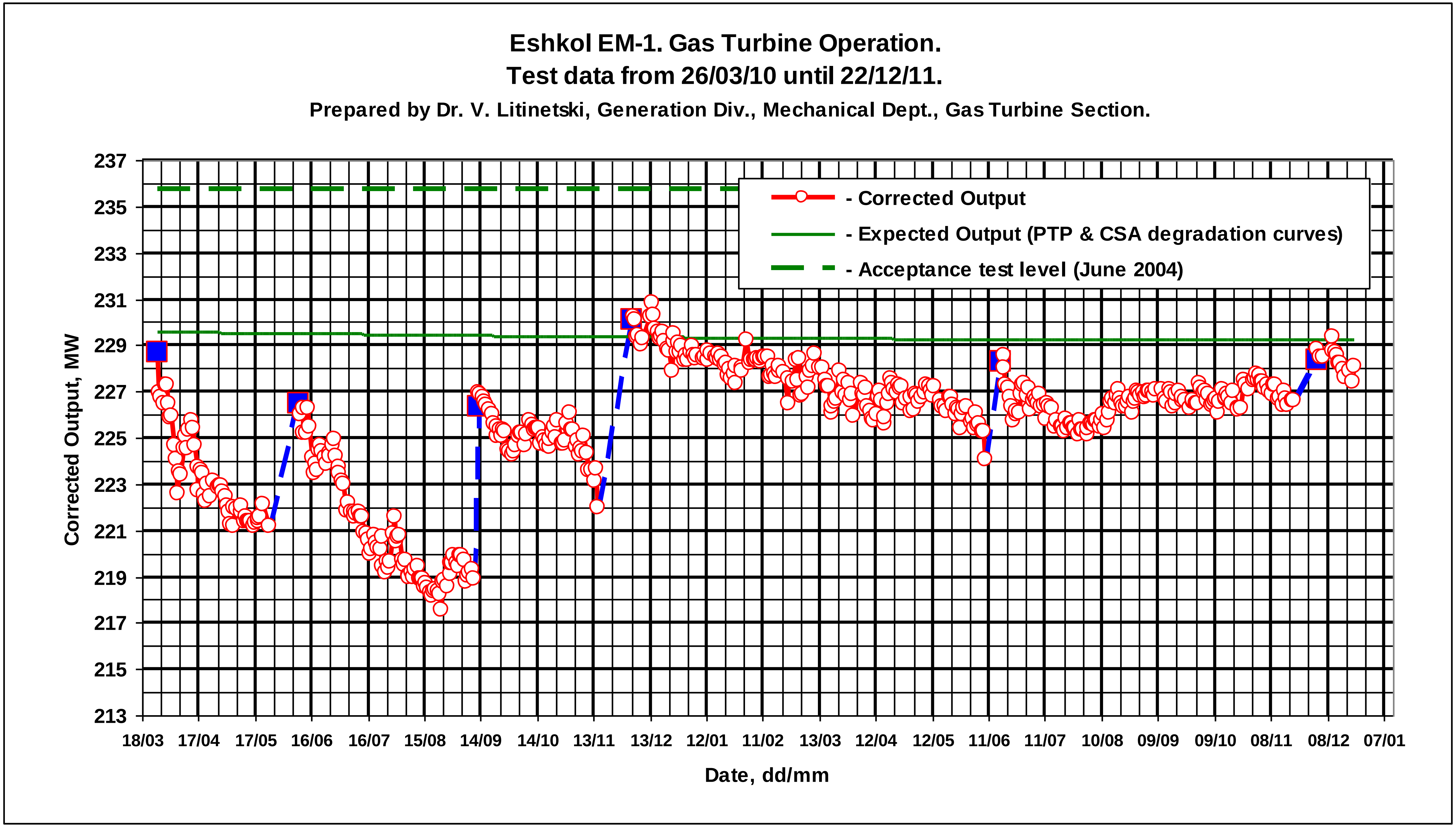
Even small degradation of their performance (efficiency, power output etc.) could result in noticeable loss of profitability.

Thus, performance monitoring of operational characteristics is especially important for effective and reliable operation of such engines.

Performance Monitoring: Main Goals in IEC (Generation Div. Headquarters, Mechanical Dept.)

- **Provision of continuous data on power output and heat rate of IEC's industrial gas turbines.**
  - ✓ **Both power output and heat rate are completely corrected to GT reference conditions.**
  - ✓ **Only use of the corrected performance allows proper interpretation and analysis of the monitoring results.**
- **Observation of the important turbine parameters such as turbine exhaust temperature, inlet air filter dP, compressor efficiency etc.**
- **Optimization of inlet air filters operation and maintenance.**
- **Optimization of compressor washing procedures and schedule.**

Performance Monitoring: Actual Example
Trend of corrected power output



Blue dashed lines denote compressor washings

Performance Monitoring: IEC approach

Performance monitoring systems are being developed in IEC Generation Division more than 10 years. Now the 5-th version of the monitoring software is used in IEC as a result of continuous long-term advancement to answer actual operation requirements.

In-house development of these monitoring systems was inspired by unsuccessful implementation of purchased monitoring software from a well-known developer. Time consuming implementation had revealed inconsistency of the purchased system with the goals of performance monitoring.

In this presentation, an IEC (Generation Division) performance monitoring experience is described for large industrial gas turbines. This experience is illustrated by several case studies.

Case Studies

GT performance monitoring approach is illustrated by several case studies.

Case Study 1. Short description

Case Study 1. Compressor Failure

Sequence of events:

- Performance monitoring data indicated a compressor problem **43 hours before the failure**.
- Waiting a response from OEM monitoring team.
- Catastrophic failure occurred in field.

The failure was a result of unfortunate combination of technical and organizational drawbacks.

IEC own performance monitoring data would allow to prevent the disaster.

Case Study 2. Short description

Case Study 2. Control System Problem

- After a control system upgrade from Simple Cycle configuration to Combined Cycle configuration an unexpected increase of GT output was revealed.

  Since modern gas turbines are designed for maximum achievable capacity, this pointed at a possible decrease of safety margins of the turbine materials.

- Detailed investigation on the base of monitoring data was undertaken by IEC's Mechanical Department.

- Analysis of the operational data revealed an error in the control system software.

- After IEC application to OEM with the explanation of the problem, the error was corrected. <u>This had allowed to prevent future failures of the turbine internal parts.</u>

Case study 3. Short description

Case Study 3. Compressor wash optimization

The task was imposed by a power station, regarding a need of early compressor off-line water washing (OFLWW) – how much it would be profitable?.

The power station requested an analysis based on actual performance monitoring data and experience.

The result of analysis: The disputable early OFLWW is UNPROFITABLE.

In this particular case, NOT performing OFLWW has saved about $80,000 and a number of man-hours.

Case study 4. Short description

Case Study 4. GT Inlet air filter upgrade

The tasks:

1. Substantiate an upgrade of the current inlet air filter to the **advanced technology Efficient Particulate Air (EPA) filter of a peculiar compact design.**
2. Evaluate performance of the filter during one-year operation in field.

The filter met expectations of the project team. It provided much better air filtration that led to substantial improvement of GT performance.

Use of this filter allowed to save several millions dollars on filter house reconstruction + very high profit on improvement of GT performance.

Summary

Only use of the corrected GT performance allows proper interpretation and analysis of the performance monitoring results.

GT performance monitoring allows effective solutions of various operational problems.

It might provide high profits on performance improvements and prevent equipment failures.

Part 2. Case Studies in details

PART 2

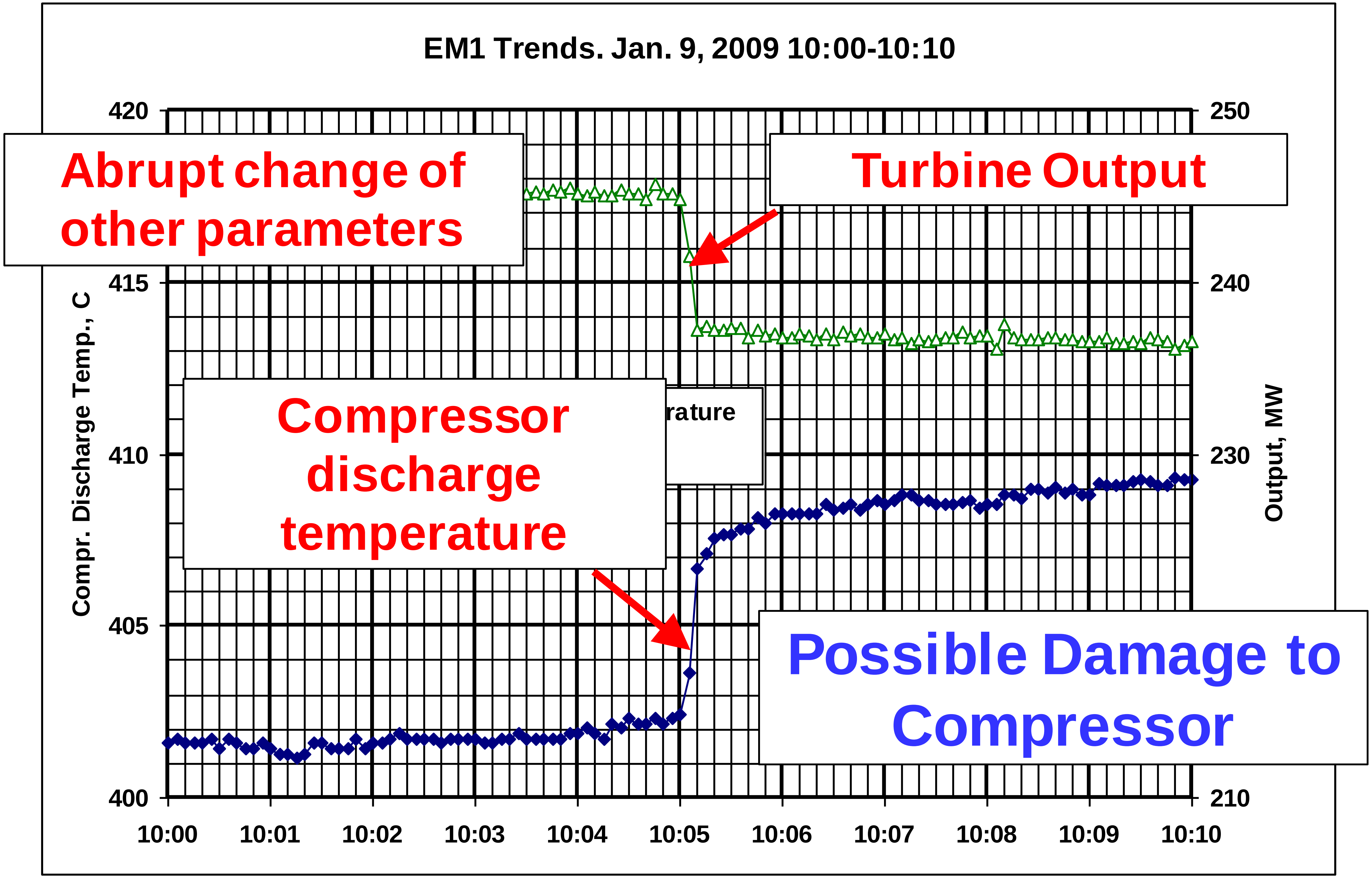
Case Study 1. Compressor Failure

Sequence of operational events (performance monitoring data):

- **Clear indications of a compressor problem were seen 43 hours before the failure.**

- **Strong indications of possible damage to compressor were seen 5 hours before the failure (next slide).**

Case Study 1. Compressor Failure: 5 hours before…

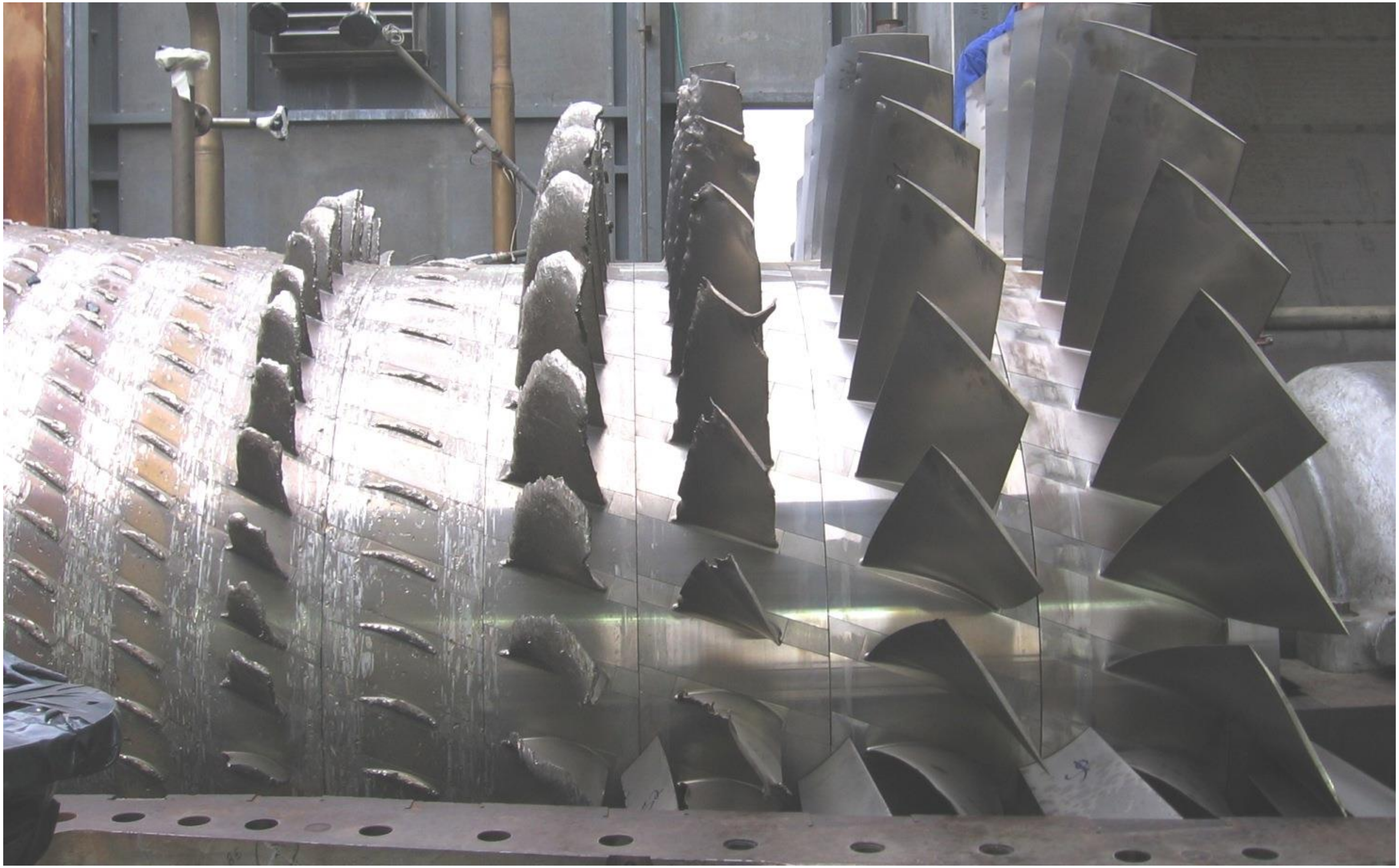


Case Study 1. Compressor Failure

Nevertheless, the catastrophic failure occurred in field

(next slide).

Case Study 1. Compressor Failure: Rotor after failure



Case Study 1. Some conclusions

Conclusions:

Catastrophic failure of the compressor was a result of unfortunate combination of technical and organizational drawbacks.

Additional in-house GT condition monitoring software has been developed

Case Study 2. Sequence of operational events

Case Study 2. Control System Problem

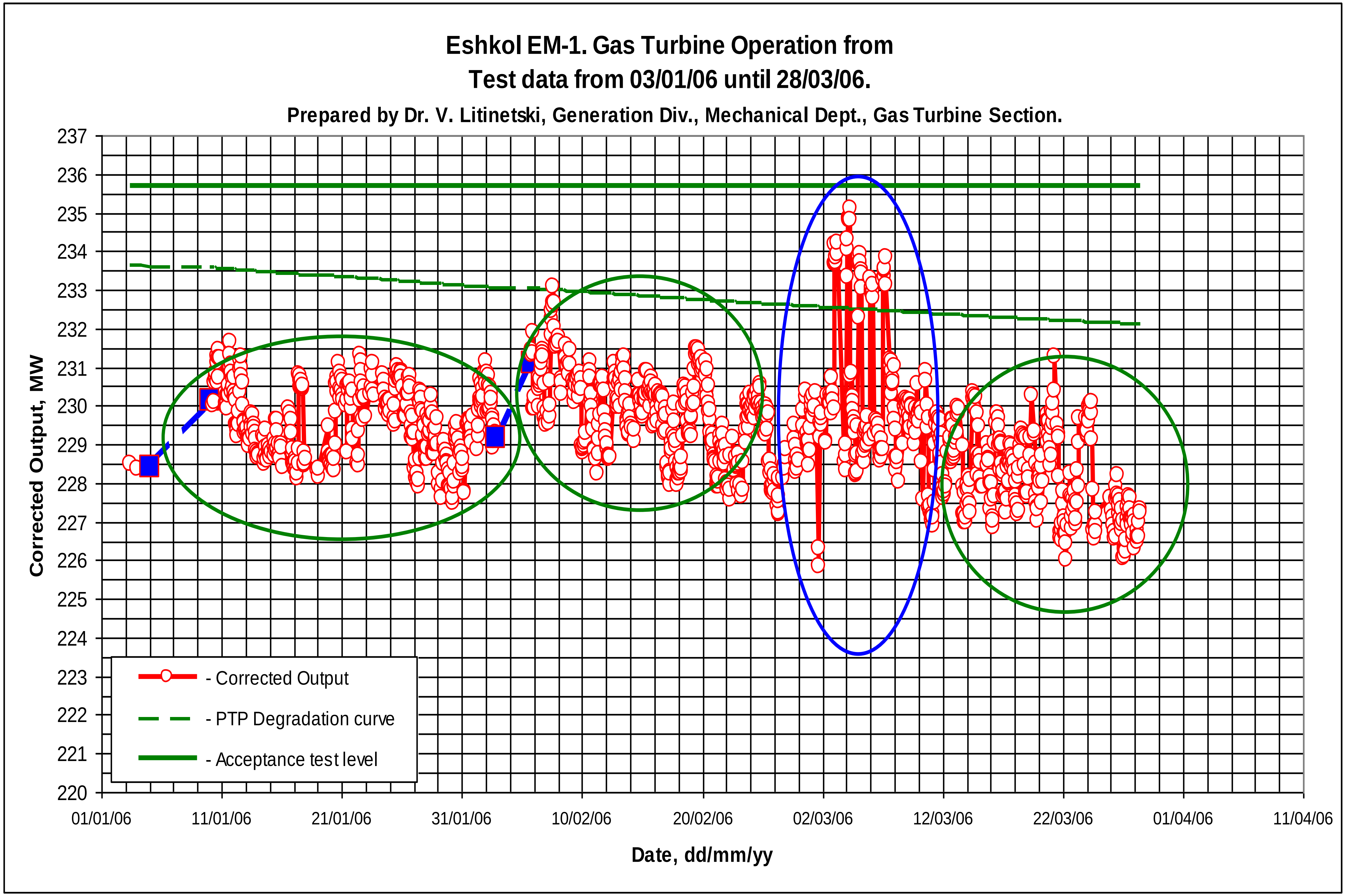
After a control system upgrade from Simple Cycle (SC) configuration to Combined Cycle (CC) configuration some operation anomalies were revealed.

Irregular increases of the power output by 10-15 MW above the expected maximum were detected in about two months after the upgrade (Figure below).

The event continued during a week and after that disappeared.

Since modern gas turbines are designed for maximum achievable capacity, this pointed at a possible decrease of safety margins of the turbine materials.

Case Study 2. Power output scattering

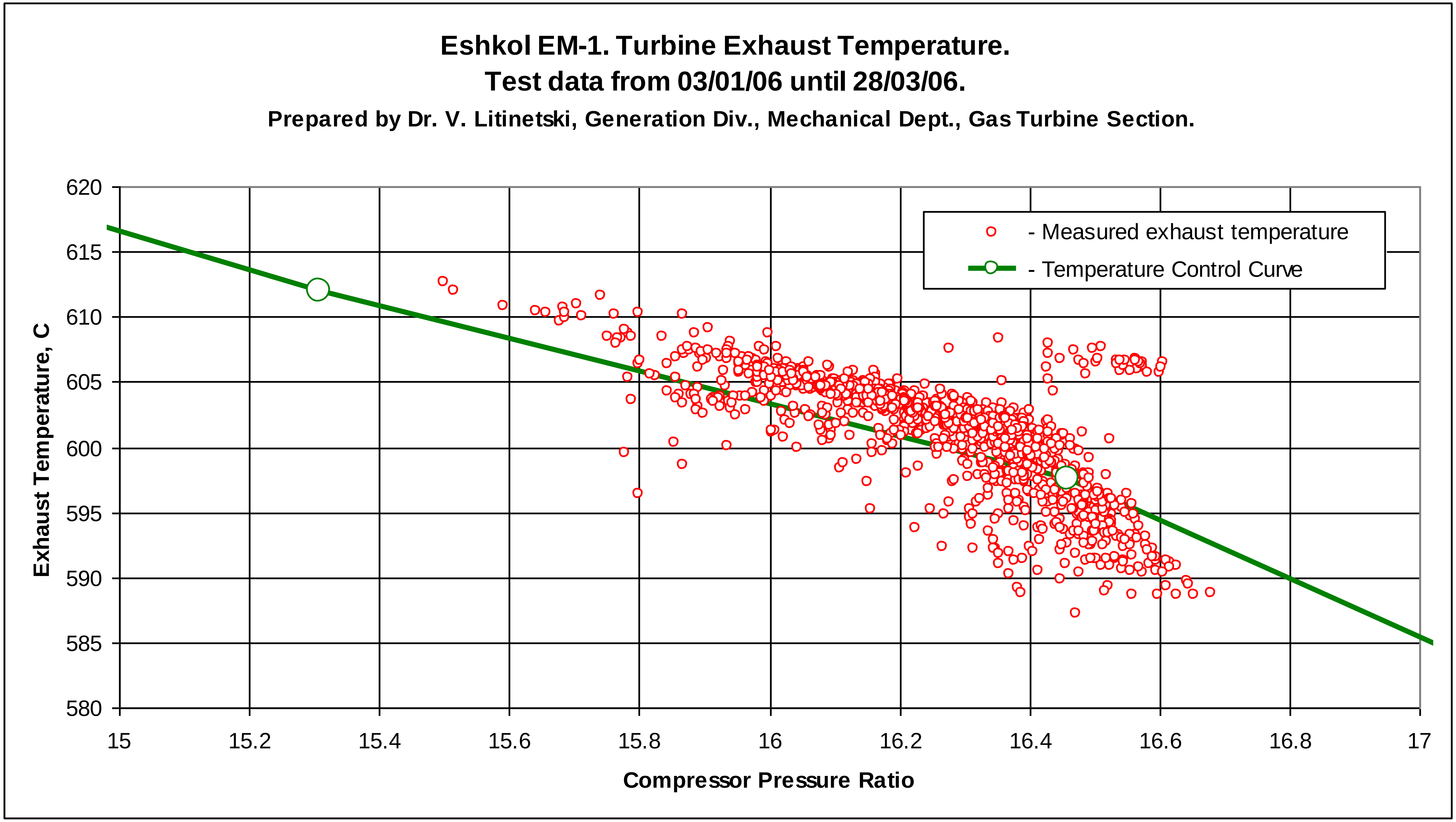


Case Study 2. IEC investigation of the problem

Detailed investigation was undertaken by IEC's Mechanical Department

Performance monitoring data showed that the irregular increases of power output were accompanied by significant scattering of the turbine exhaust temperature (Figure below)

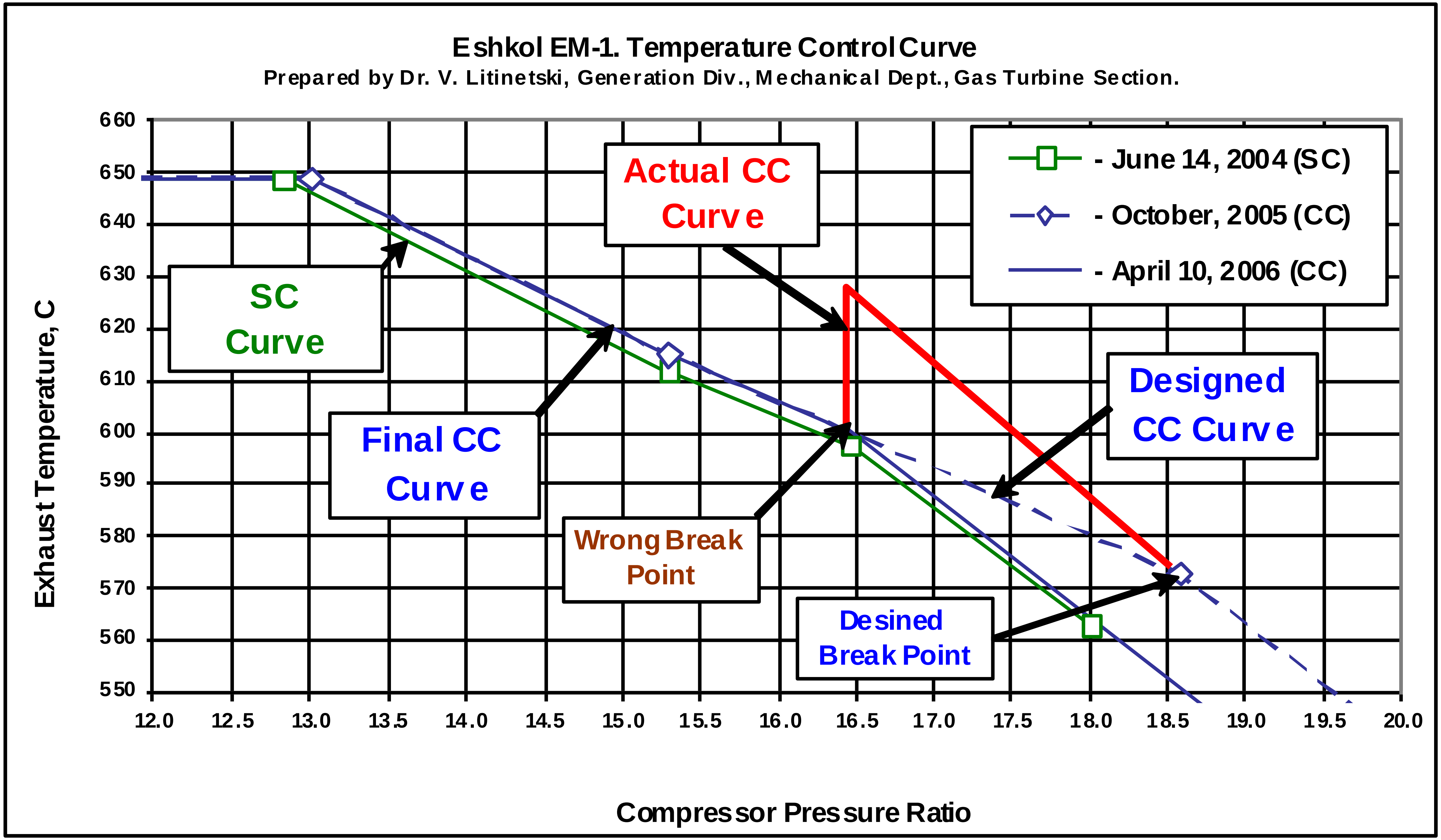
Case Study 2. Scattering of exhaust temperature



Case Study 2. Performance data analysis

Thorough analysis of the data revealed an error in the control system software, namely, an incorrect definition of so called Temperature Control Curve, which is an important element of the turbine load control, fuel efficiency and protection (Figure below).

Case Study 2. Error in control system software

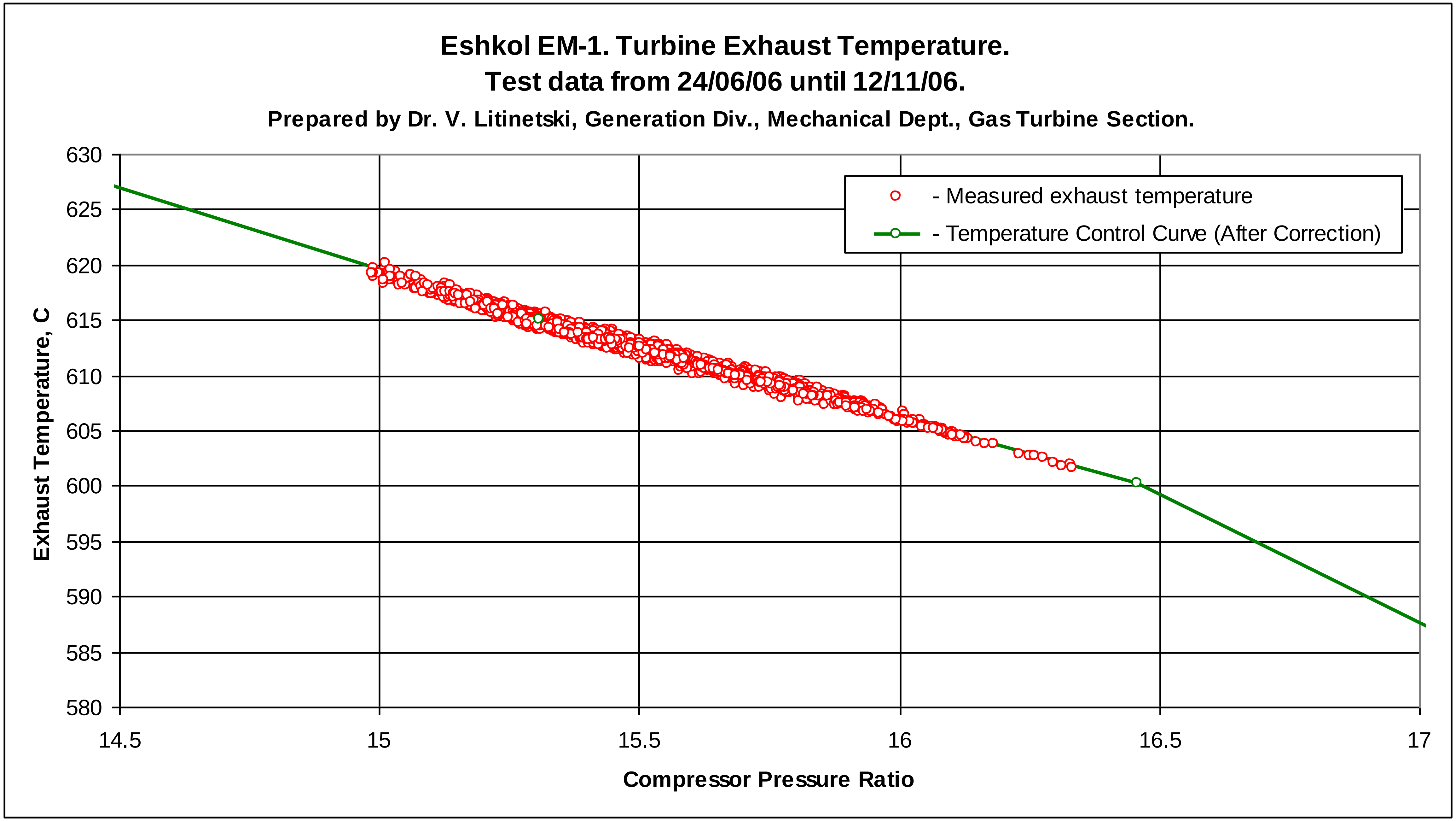


Case Study 2. Correction of the problem

After IEC application to OEM with the explanation of the problem, Temperature Control Curve definition was corrected.

Figure below shows the turbine exhaust temperature trend after correction.

Case Study 2. Exhaust temperature after correction



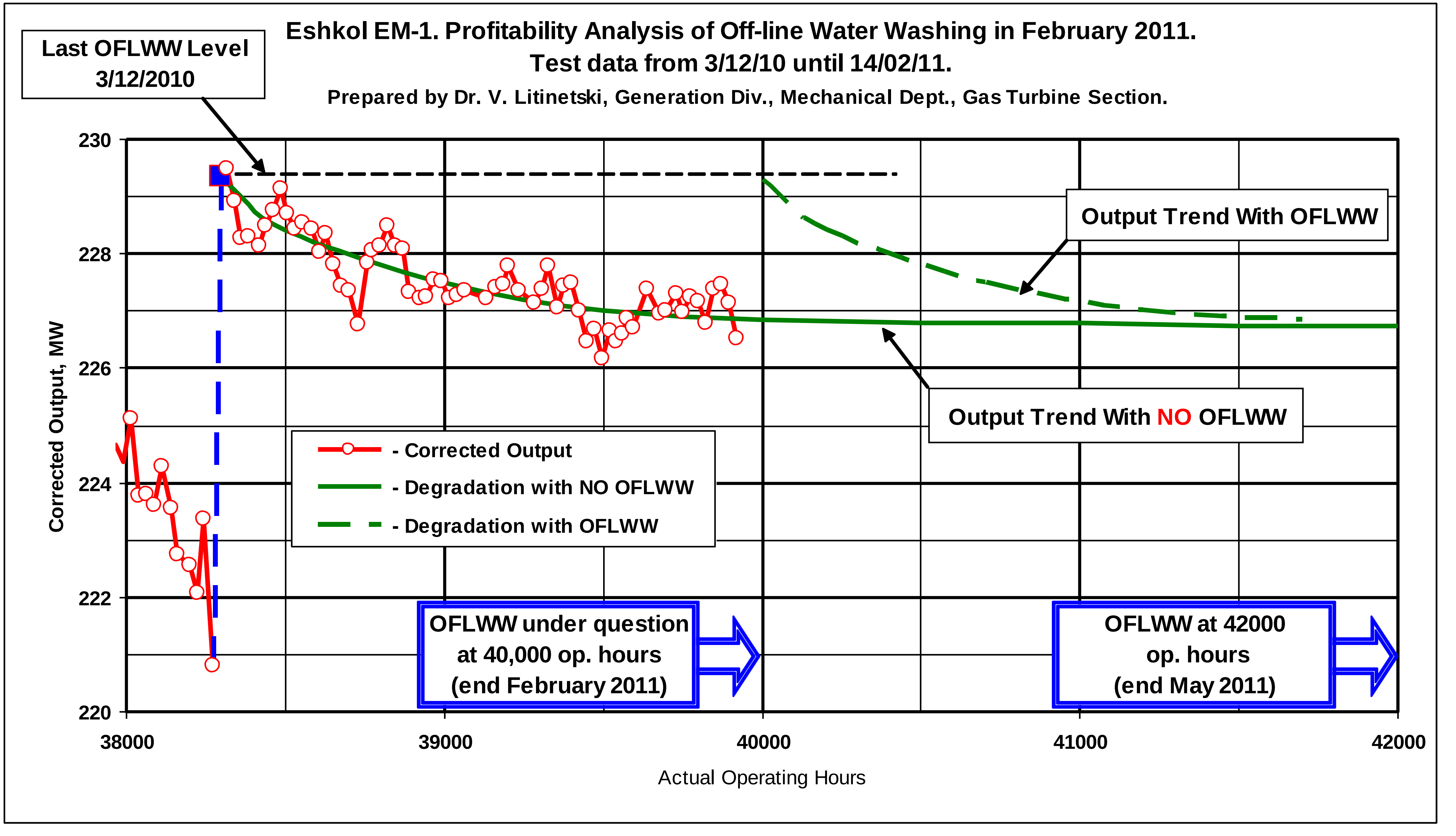
Case Study 3. Compressor wash optimization

The task was imposed by a power station, regarding a need of performing compressor off-line water washing (OFLWW).

The station question was: whether the station could save money if it performed OFLWW earlier than planned by ~2000 operating hours of the GT.

The power station asked for an analysis based on current performance monitoring data and accumulated monitoring experience.

Case Study 3. Data use & approximation



Case Study 3. Conclusions

The following conclusions were made:

Early OFLWW (at 40,000 op. hours) is UNPROFITABLE considering current air filter condition and GT performance degradation trends.

Not performing OFLWW might save about $128,000 in this particular case.

Actually, the OFLWW was performed after 42,500 operating hours of GT. Corrected power degradation was slightly higher than predicted but the main result remained unchanged – the early OFLWW (if any) would be unprofitable.

Case Study 4. The task

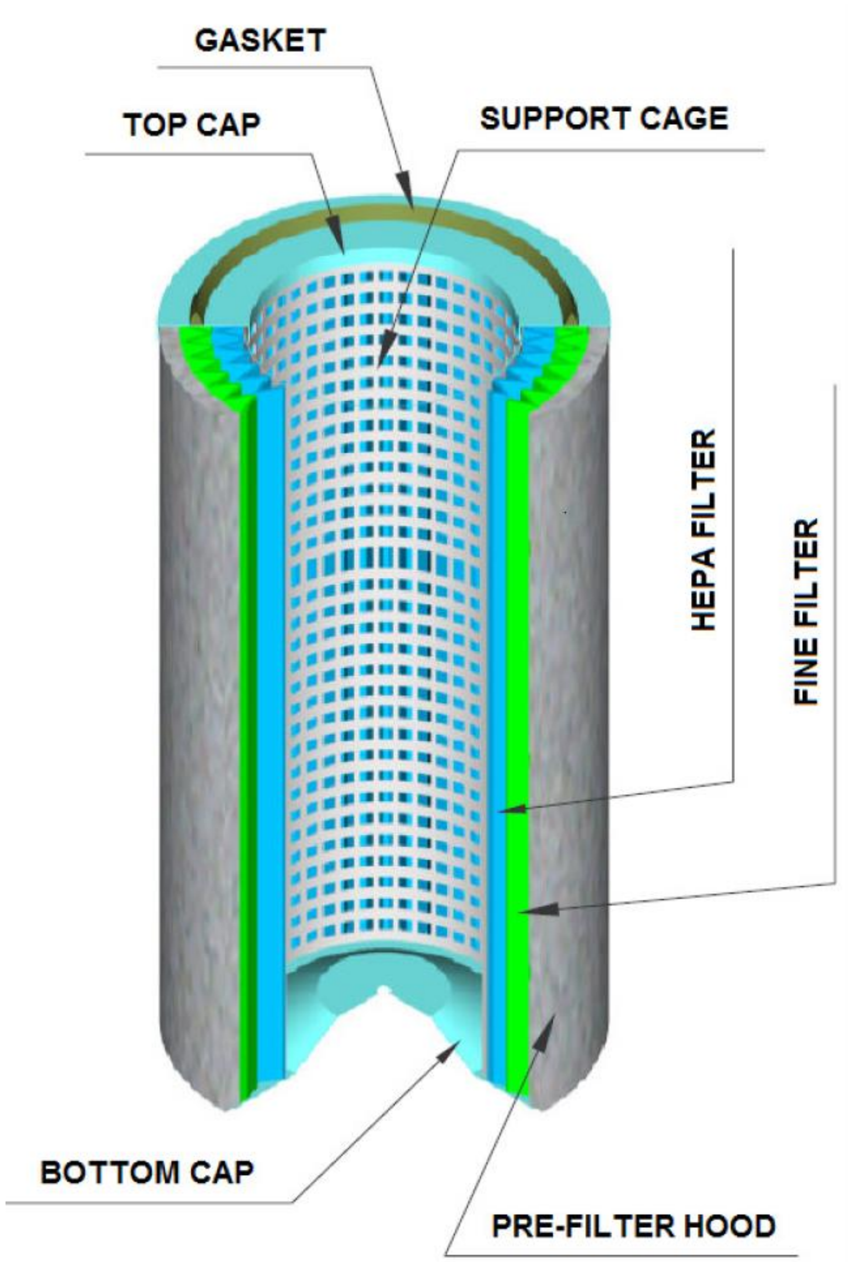
Case Study 4. GT Inlet air filter upgrade

The following tasks had been raised with operation and maintenance needs:

1. Substantiate an upgrade of the current inlet air filter to the advanced technology Efficient Particulate Air (EPA) filter.
2. After 1 year of EPA filter operation, evaluate actual performance of the GT with EPA filter and compare with actual performance of the GT with the regular air filter during the same operational term.

Conclusions should be made on the base of actual performance monitoring data

Case Study 4. View of the installed filter



Three-layer compact design EPA cartridges

Case Study 4. Conclusions

The tasks were performed on the base of accumulated performance monitoring data during one-year operation with EPA filter.

The filter met expectations of the project team. It obviously provided much better air filtration that led to substantial improvement of GT performance.

Use of this filter allowed to save several millions dollars on filter house reconstruction.

Summary in details

1. An actual approach to continuous performance monitoring of 250MW-class industrial gas turbines is described in this presentation.
2. The described performance monitoring practices may be useful in development, improvement and support of monitoring systems.
3. The most important outcome of performance monitoring is a detailed analysis of GT operation events, providing a basis for solution of operational problems and decision making as well.
4. Effective and reliable analyses of monitoring results could be performed only by highly educated personnel having strong knowledge in GT theory, equipment and operation. Monitoring team should include such persons.
5. <u>In-house</u> development of the monitoring systems in IEC was inspired by unsuccessful implementation of purchased monitoring software from a well-known developer.
6. The monitoring systems was gradually developed in Generation Division of IEC and successfully used for more than 10 years in actual gas turbines operation.
7. The presented in this presentation performance monitoring approach has a general importance; it could be helpful for other gas turbine operators and used in actual performance monitoring of various gas turbine types.

THE END