Worldwide Pollution Control Association

WPCA-Entergy

"Increasing Energy Efficiency of Existing Units" Seminar

January 22, 2014

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WPCA/Entergy Seminar

January 22, 2014

Increasing Efficiency of Existing Units

Michael Smiarowski

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Steam Turbine - Efficiency Improvement Areas Topics

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1. Fossil Fleet Retirements/Service Outlook

2. Steam Turbine Technology Efficiency Application:

   Ibbenburen, Germany: Boiler, Turbine, and Condenser Project

3. Other Efficiency Improvement Areas:
   - Steam Chests and Valves

4. Project Example: Hoosier Energy Merom 1 & 2 HP/IP Turbine Modernization

5. Conclusion

US STPP Fleet Retirements (including Announcements)

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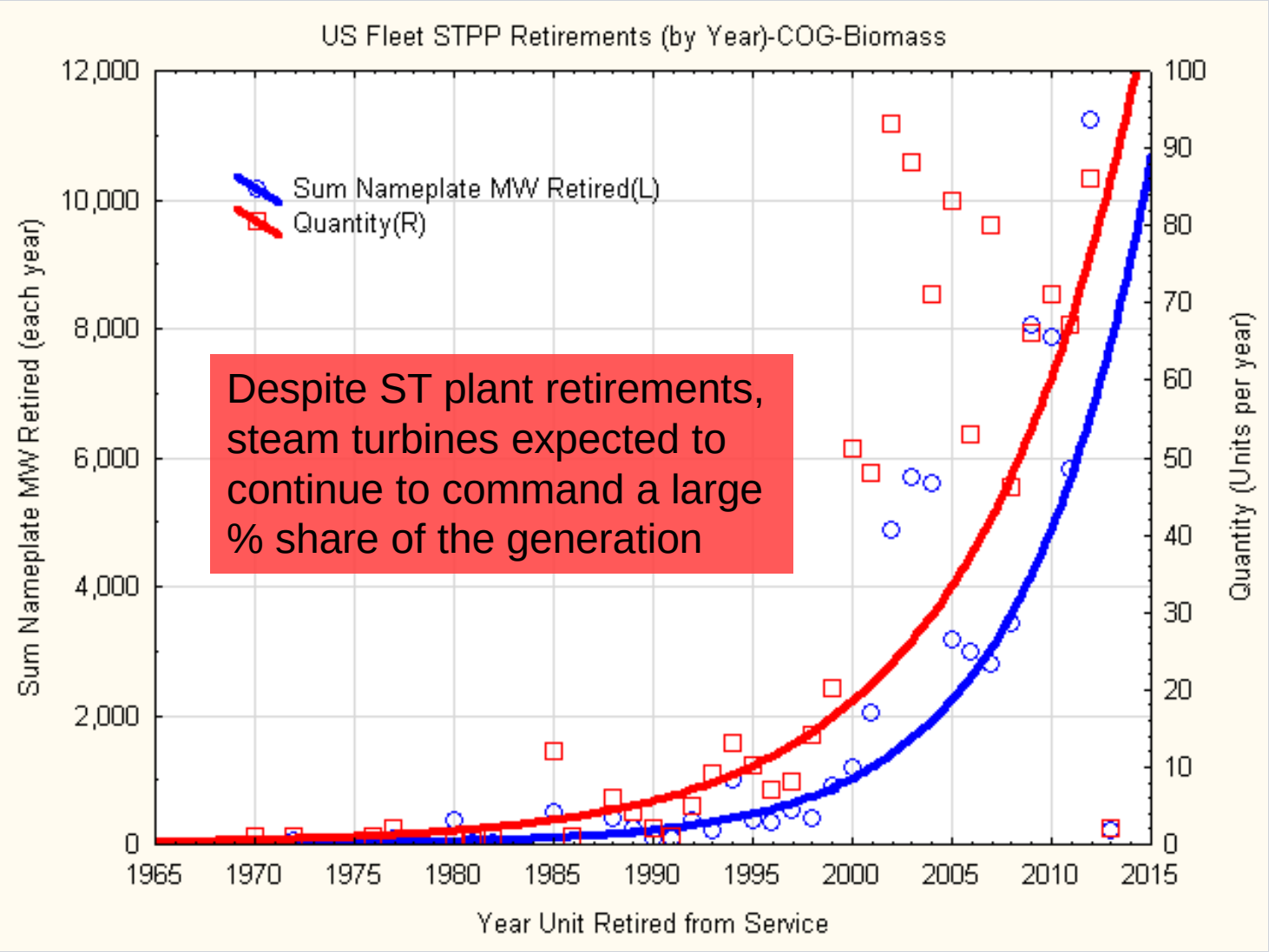
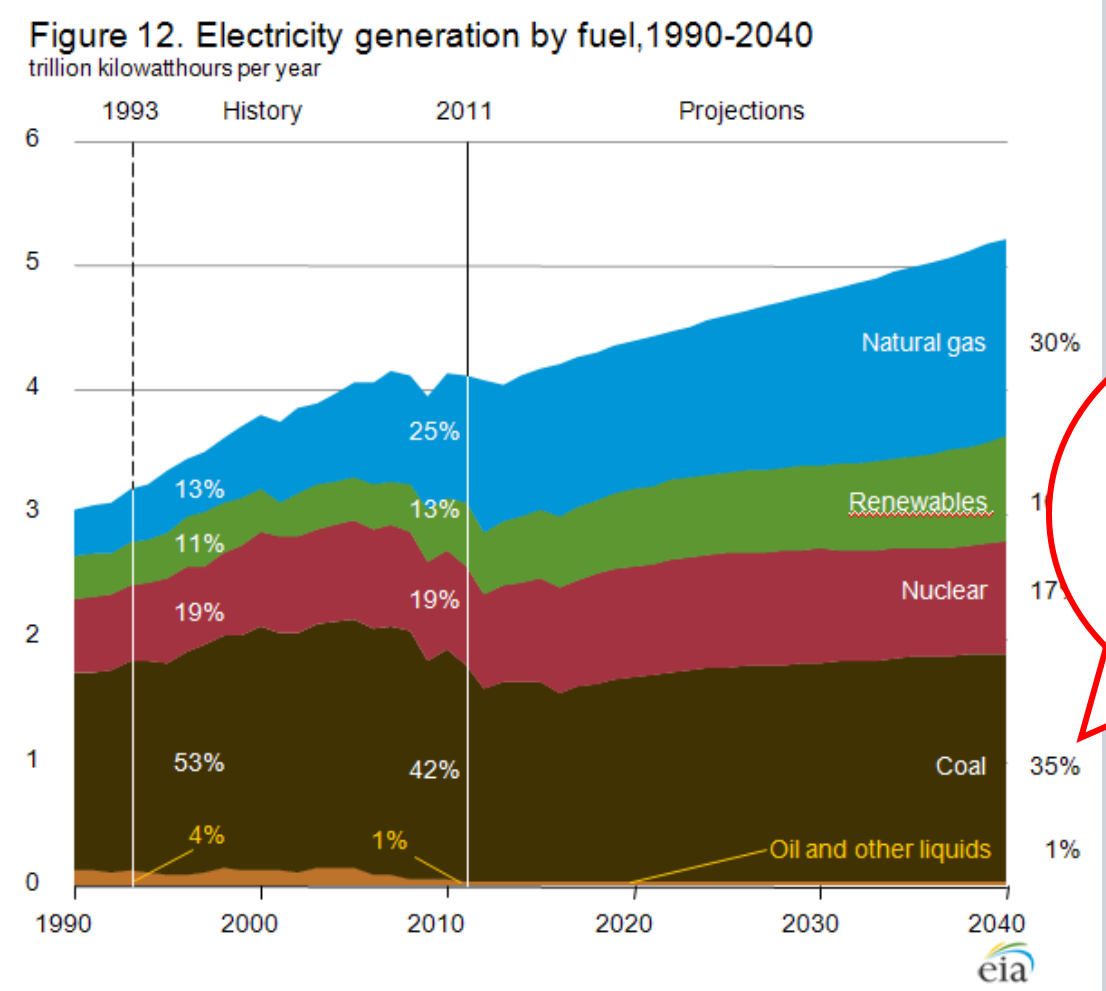


US Electricity Production Mix



Coal Generation ~ 1/3rd of fuel types

May 3, 2013 - US Energy Information Administration "Annual Energy Outlook 2013"

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Design Features that Contribute to an Overall Output Improvement

There are five main design features:

1) Improved interstage shaft sealing
2) Twisted 3-dimensionally shaped drum blades
3) Improved blade profiles
4) Shape of LP Turbine Last Stage
5) Size of the LP Turbine Last Stage

Ibbenburen Project Overview

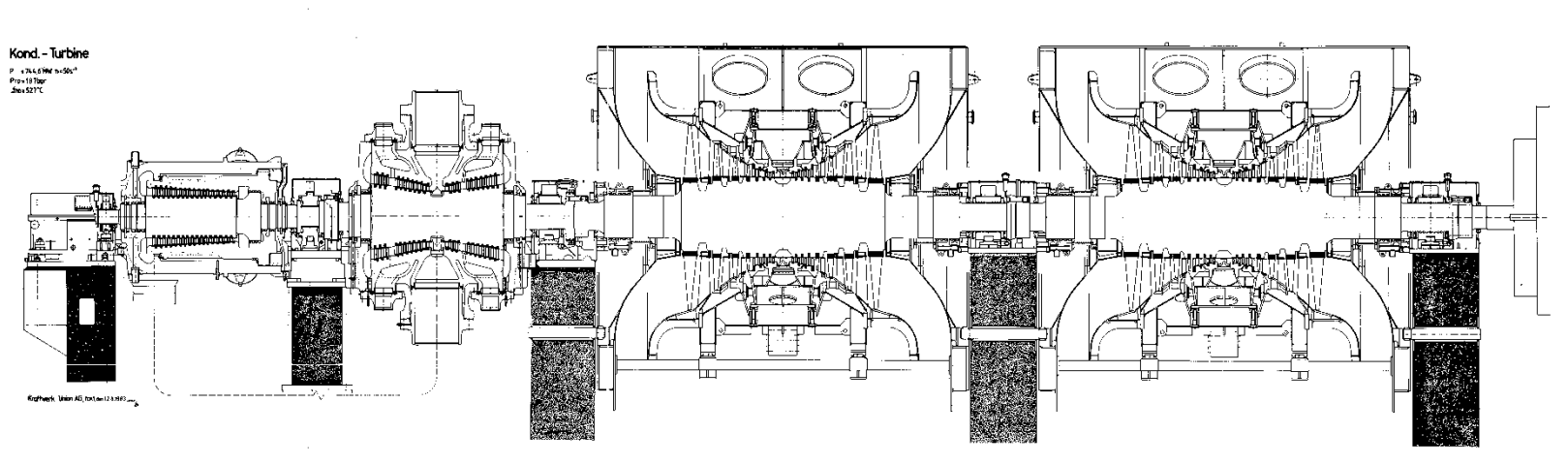
- Introduction
- HP and IP Modernization
- LP and Condenser Modernization

Introduction

Power Plant Ibbenbüren

RWE

- Operator: RWE Power AG
- Commissioning: 1985
- Capacity: 752 MW (before retrofit)
- Fuel: Hard Coal
- Boiler: Coal-fired Benson-Boiler
- Turbine: Siemens HP-IP-LP-LP configuration



Introduction

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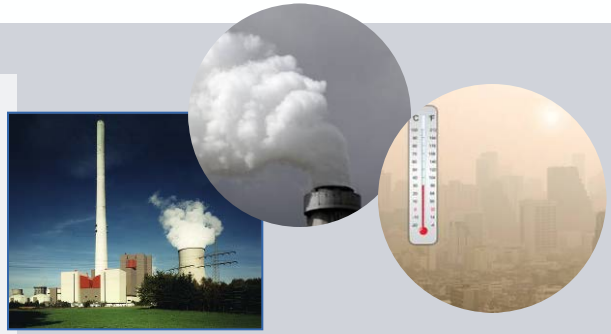
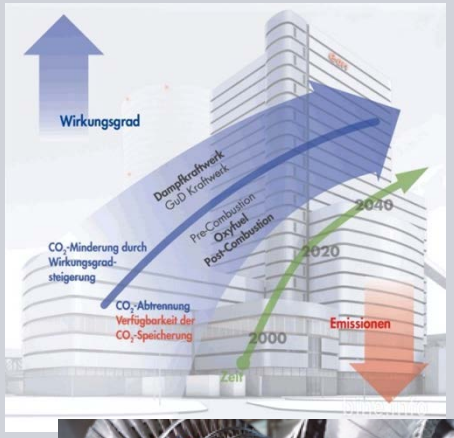
Customer Goals

- Power / Efficiency increase
- Lifetime Extension for up to another 150,000 operating hours
- Long-term availability
- Reduction of specific CO_2 emissions
- Reduced short and medium term maintenance requirements
- Adherence to requested installation time





How can these goals be achieved ?

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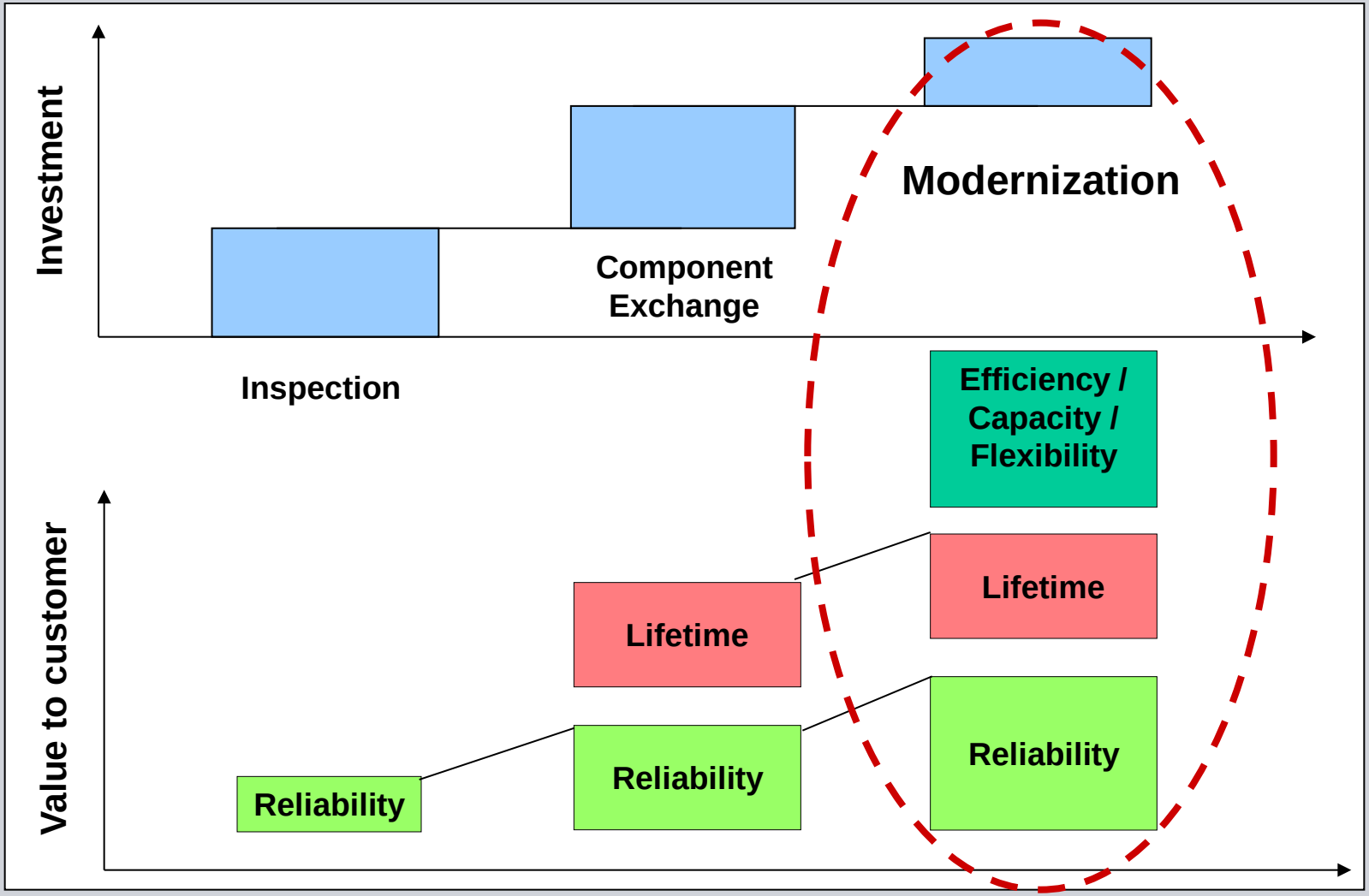
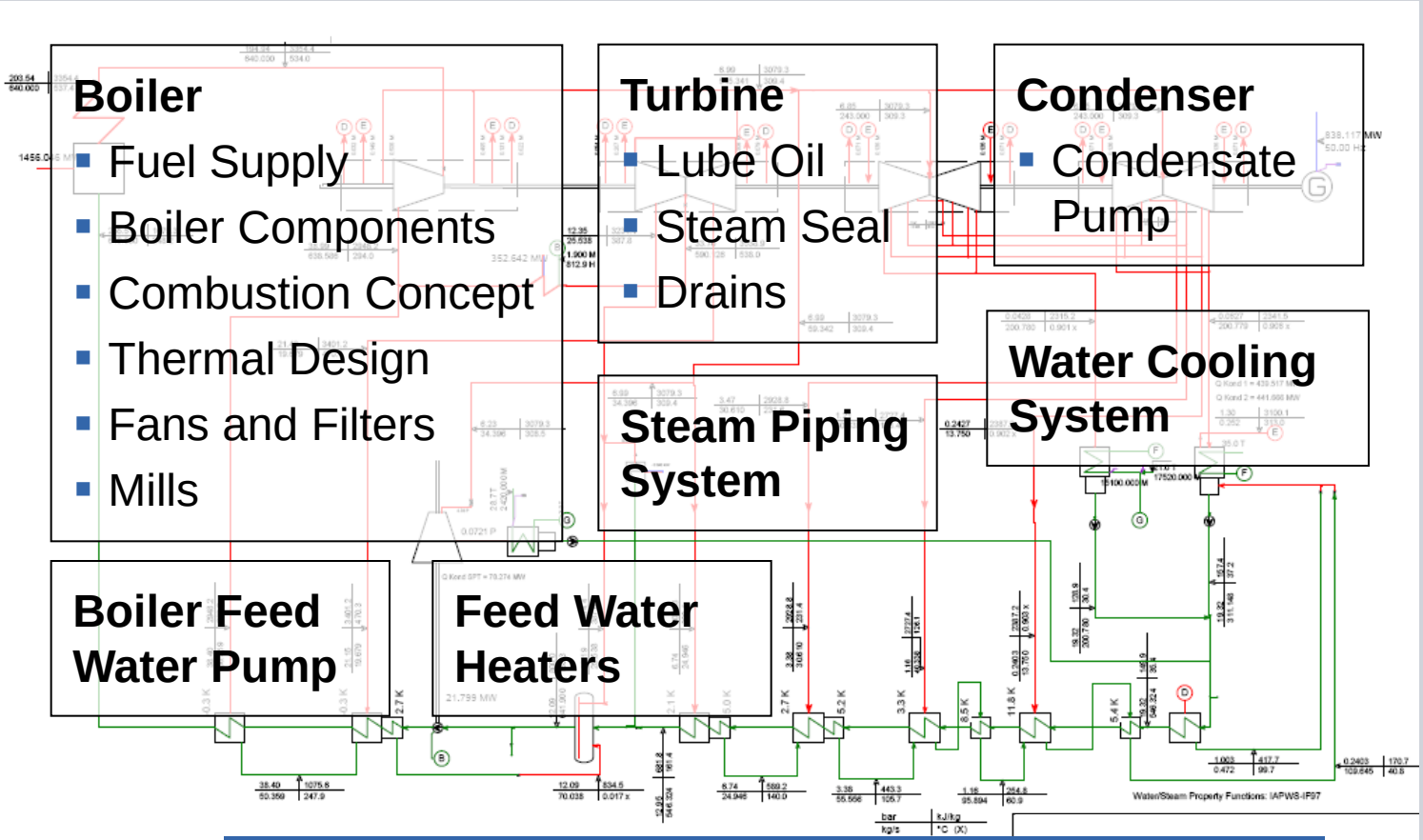
Modernization Benefits



Balance of Plant Assessment



Balance of Plant (BoP) Assessment for Integral Boiler, Condenser and Steam Turbine Approach

Boiler/Turbine Cycle Optimization

Site Assessment

Integral Boiler/Turbine Modernization Study

Integral Boiler/Turbine Cycle Optimization

General Status Quo Inspection

Customer Requirements Detailed Inspection of Defined Areas

	Before Optimization	*After Optimization*
Live Steam	524 °C (972 °F)	534 °C (993 °F)
Reheat Steam	527 °C (981 °F)	538 °C (1000 °F)
Mass Flow	618 kg/s (4.905 mpph)	640 kg/s (5.079 mpph)
Cooling Water	26 °C (79 °F) 10953 kg/s (86.9 mpph)	21 °C (70 °F) 15100 kg/s (119.84 mpph)

Award / Project Kick-off for Optimized Integral Boiler/Turbine Cycle Modernization

Positive Customer Decision

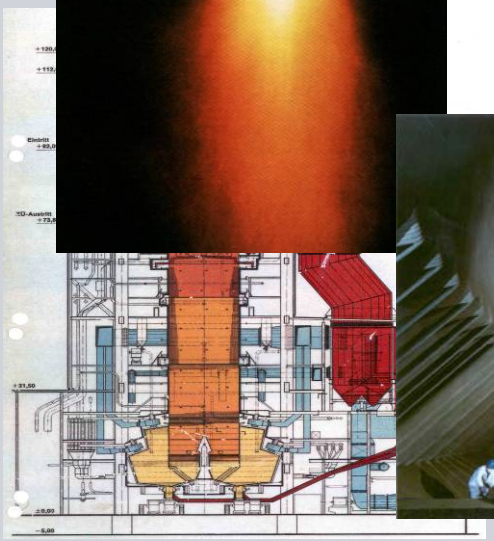
Cost / Benefit

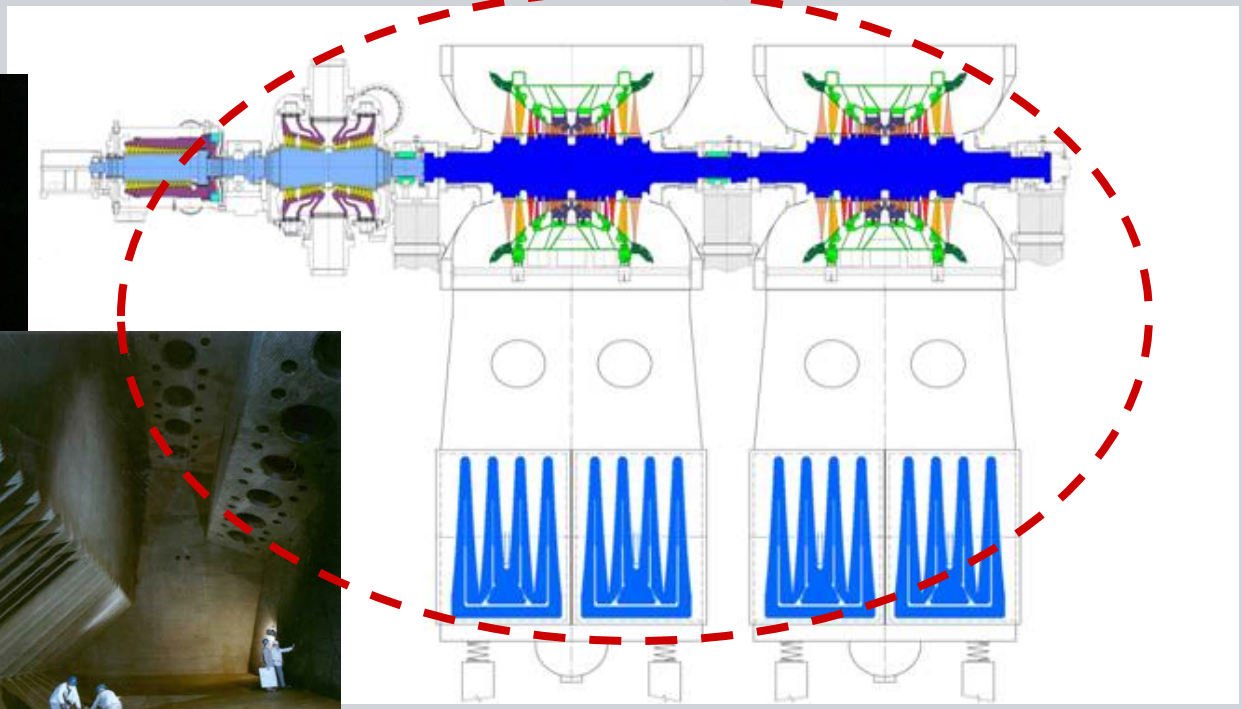
Project Overview

Components for Modernization at Power Plant Ibbenbüren

- **Turbine (HP, IP, LP)**
- **Boiler** -> Mass flow increase

  -> Live steam and reheating steam parameter
- **Condenser**





HP Modernization
Retrofit Measures

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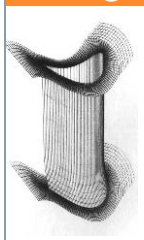
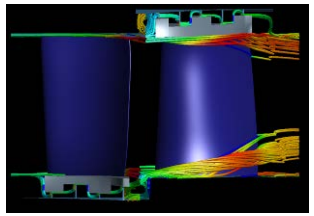
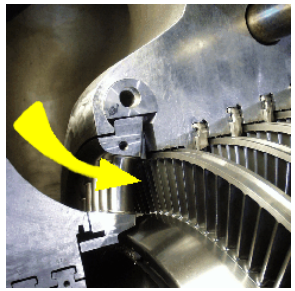
New 3D Blade Design

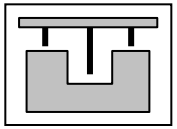


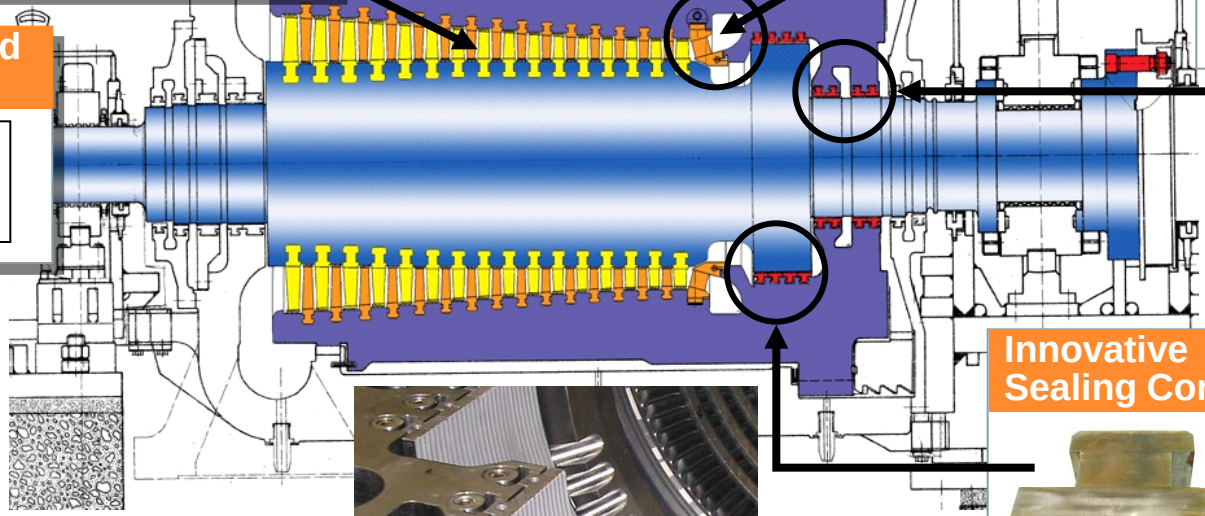


Inlet & Outlet Flow Optimization

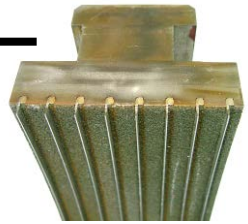


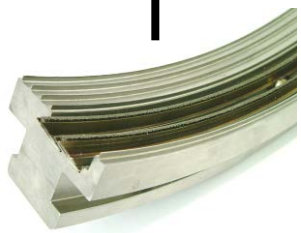
Castellated Sealing





Innovative Sealing Concepts





IP Modernization Summary

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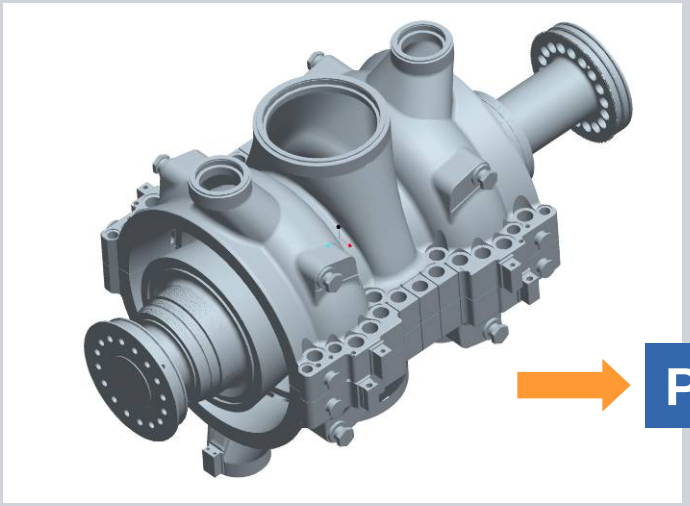
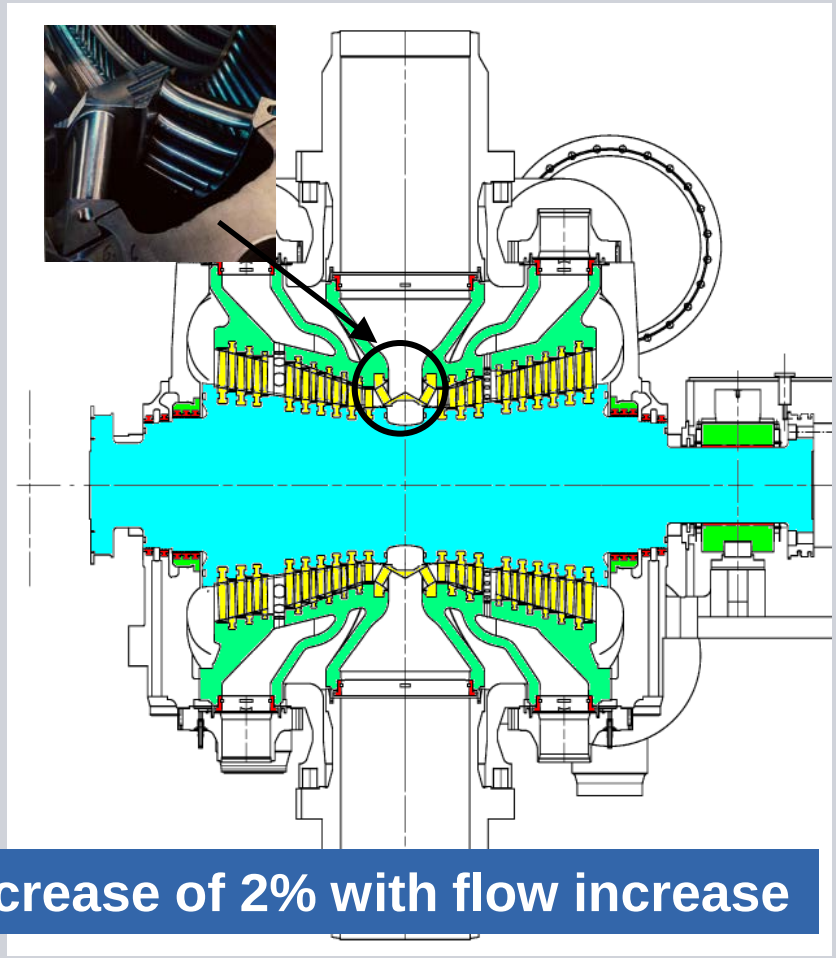
Scope of Supply

- Rotor, inner casing, blades, sealings
- Inlet low reaction stage
- New rotor sealing segments
- New coupling bolts
- New IP bearing (IP3)





Power Increase of 2% with flow increase

Technology and Product Portfolio
LP Retrofit Measures

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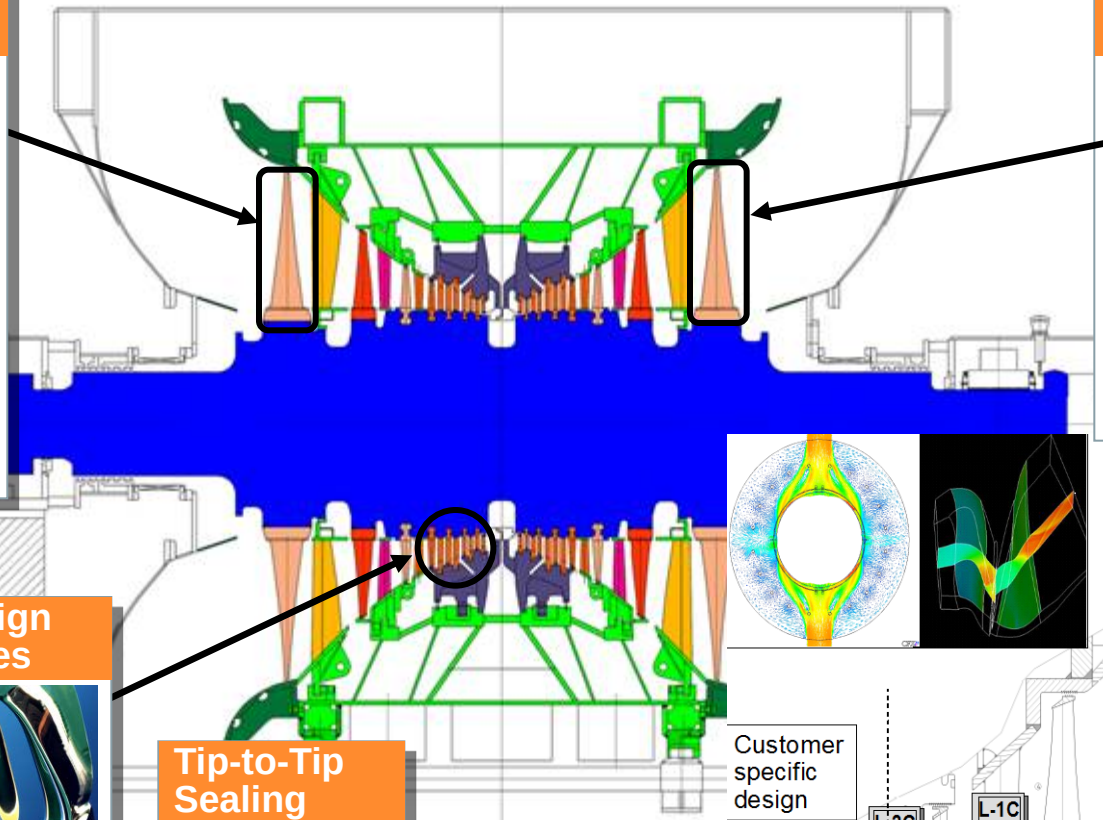
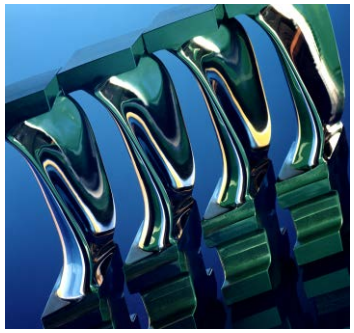
Enhanced Exhaust Outlet Area

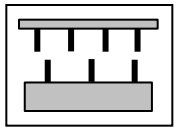
Erosion Protection

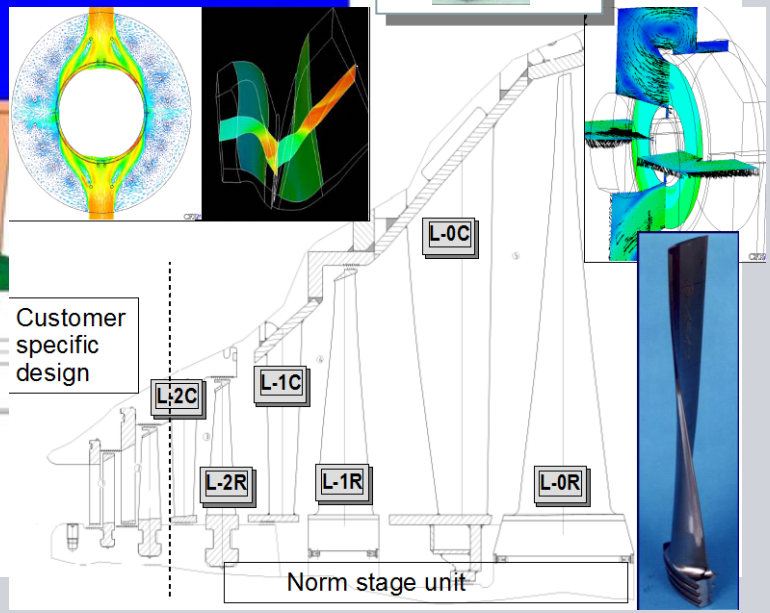


3D Blade Design in Drum Stages



Tip-to-Tip Sealing





Condenser Modernization
Retrofit Measures

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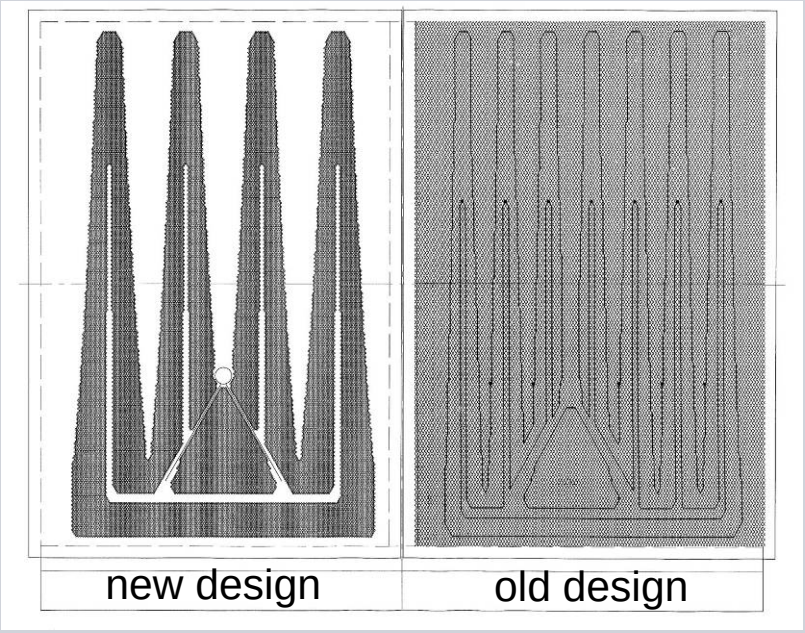
Scope of Supply

- Exchange of the Condenser Modules
  - ➔ Modification of the old tube bundle configuration
- 76,000 stainless steel tube bundles



Benefits

- Reduced pressure loss
- Lower condenser pressure

Condenser Modernization Summary

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Power Increase of 1.7% with flow increase

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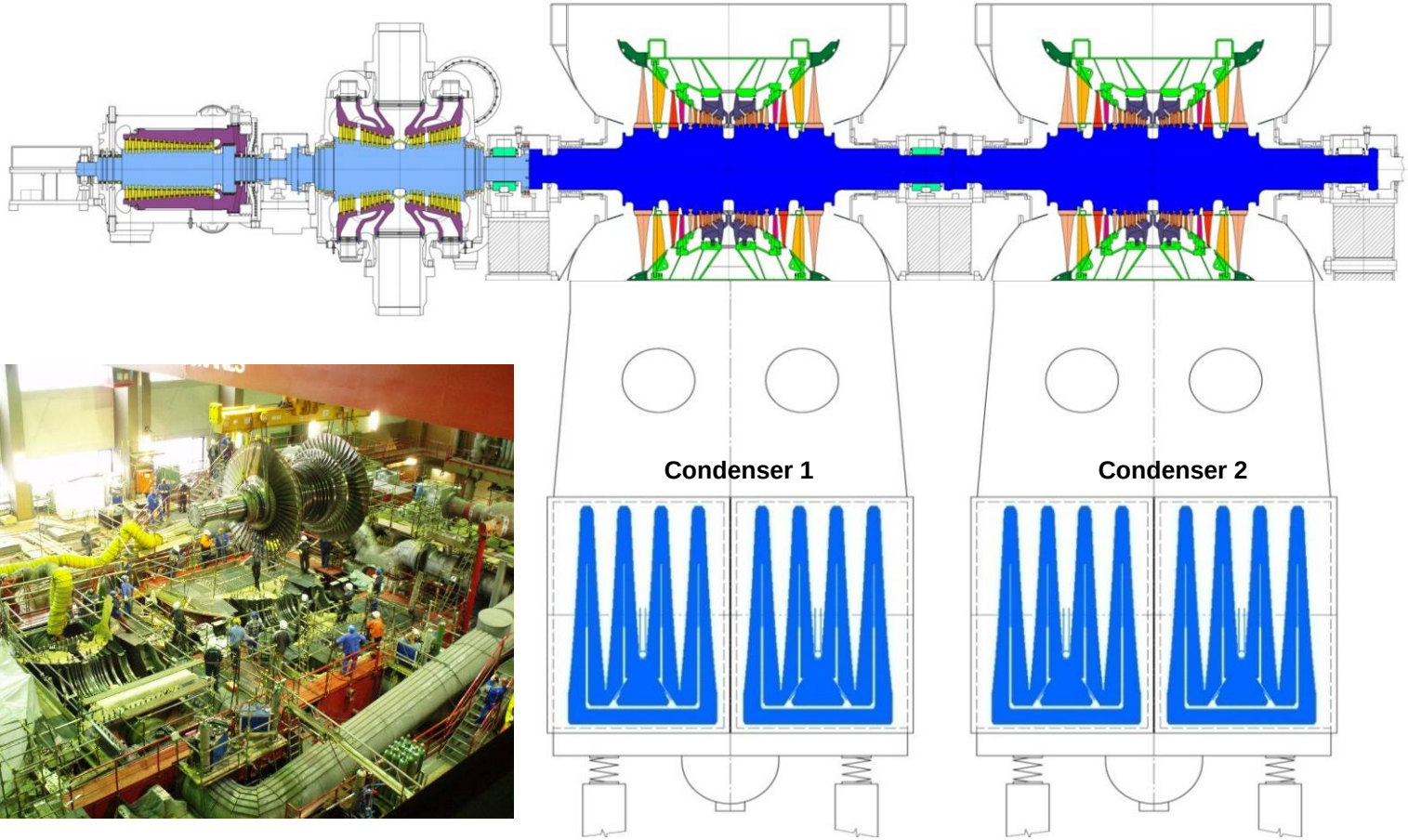
Conclusion

Extended upgrade scope: all turbine sections + condenser + bearing



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Conclusion

Customer Benefits:

- Power increase: over **11%** capacity improvement with flow increase

- 6% increase due to increased thermal efficiency

- Average CO_2 reduction: up to **260,000** t/a
- All requirements fulfilled for:
  - Heat rate
  - Swallowing capacity
  - Rotor & bearing vibrations
  - Start-up and shut-down times
  - Noise emissions

Steam Turbine Modernizations –
Capacity Increases Achieved Through Technology and Flow Uprate

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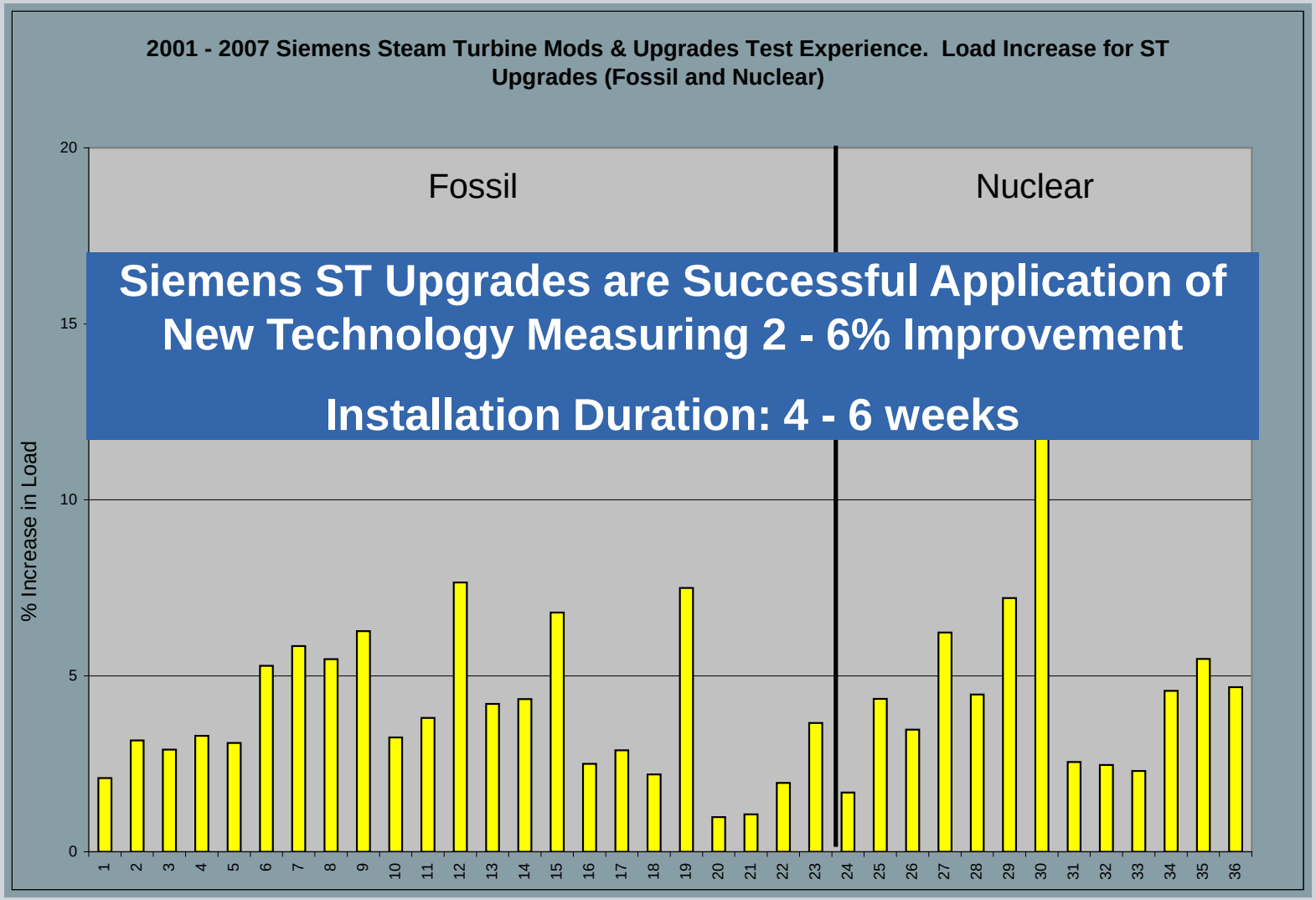

Typical Arrangement of Westinghouse HP/IP Steam Turbine and Main Steam Valves/Steam Chest and Reheat Intercept Valves

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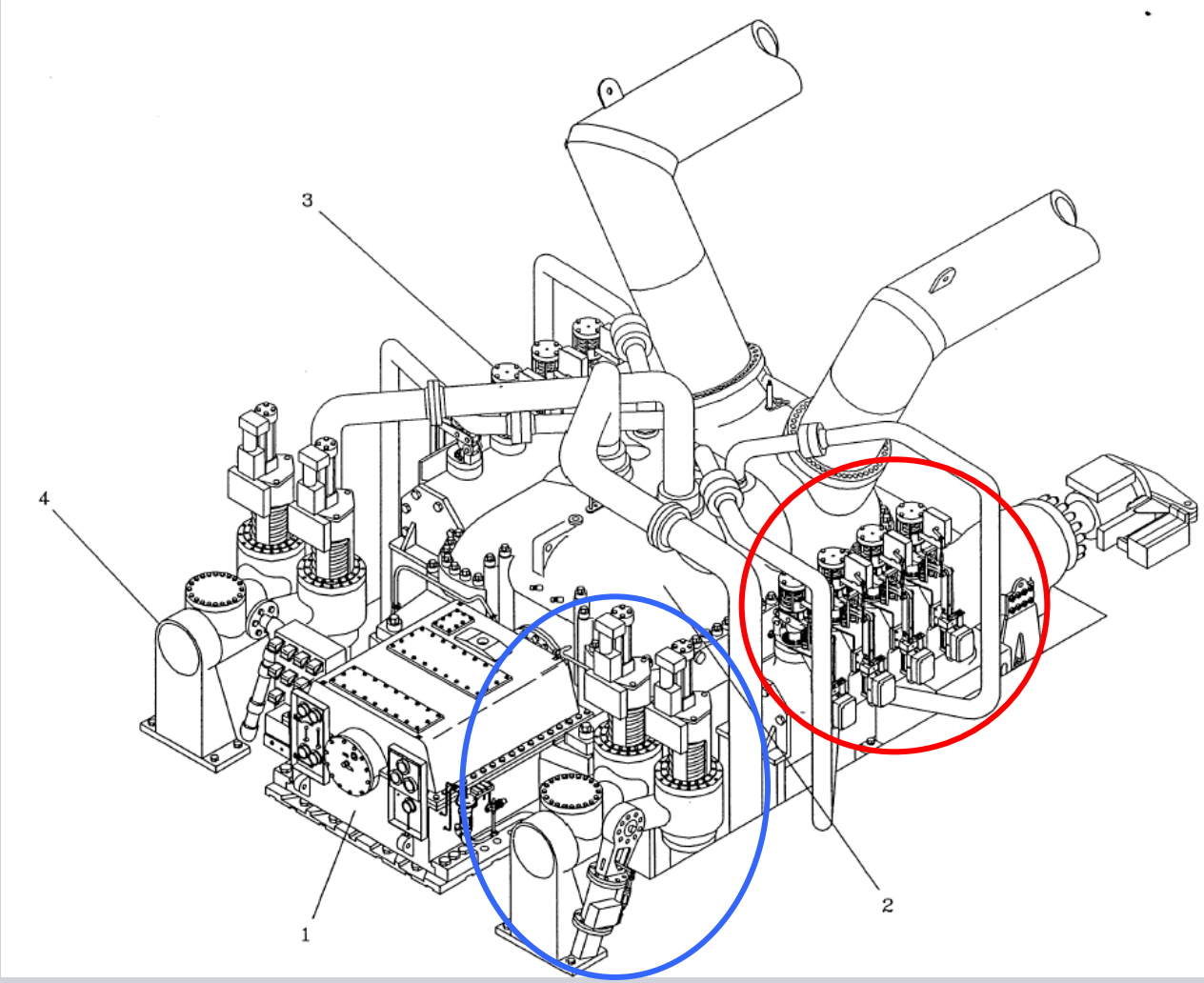

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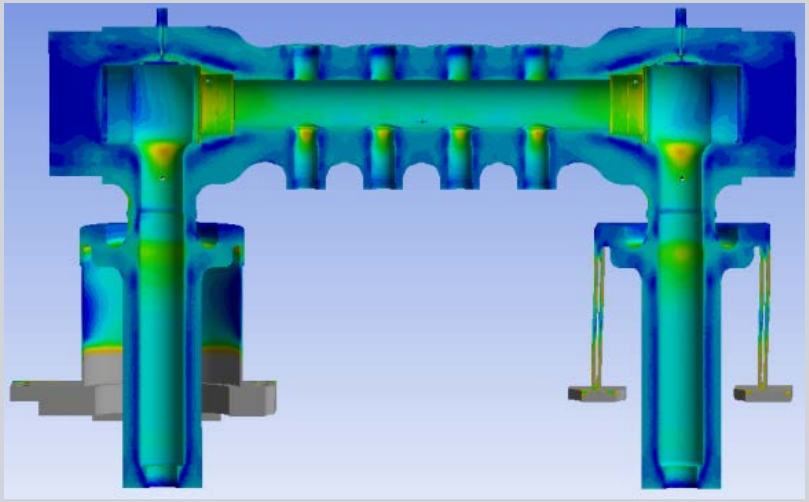
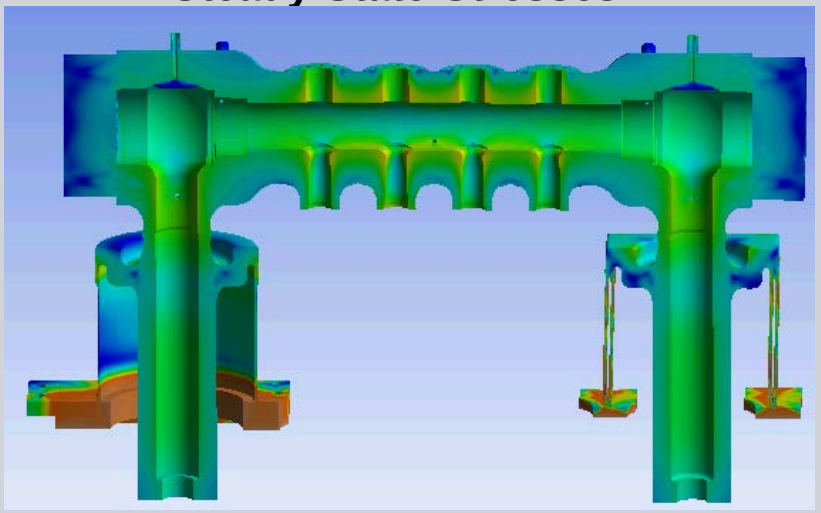
Steam Chest Case Study

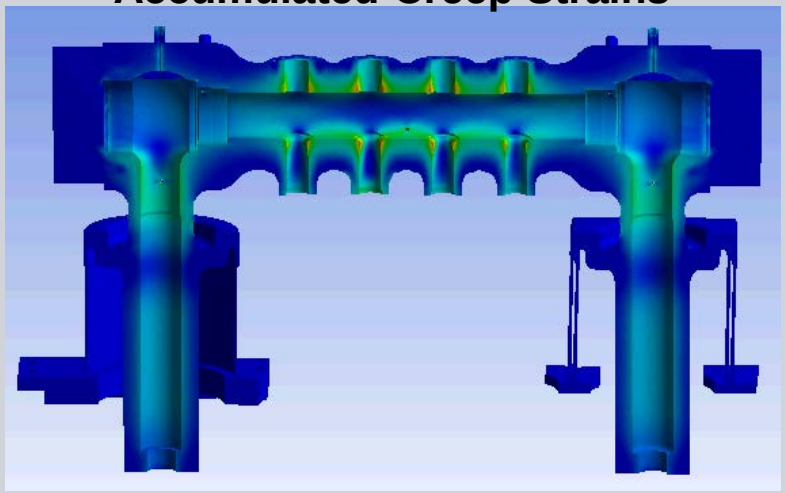
Transient Thermal Stresses



Steady-State Stresses



Accumulated Creep Strains



Success Example
Hoosier Energy – Merom BB44PA

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In Spring 2009, Merom Unit #1 completed all the work identified in the EPA Notice of Violation.

- The Turbine Upgrade Alone +$2MM/year to our members or roughly $0.30/MWhr
- Payback of 2.5 years
- Hoosier Energy recommended to EPA an HP/IP turbine upgrade as a “must do”

Reference: Hochstetler, Rob., Vice President, Hoosier Energy, “Updating Pollution Control at Merom Station”, AREGC Conference Presentation, June 2011.

Advanced Planning is Essential

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- **3 years is a typical planning time for:**
  - project budgeting
  - RFQ, bid preparation, and evaluation
  - contract negotiation

HPs: 20+ months delivery on site

LPs: 20-24+ months delivery on site

- Lead-times are unit specific
- Factory slots are subject to availability and prior sale
- Lead-times are affected by increased forging lead-times, increasing shop load, as well as availability of engineering resources

Modernizations/Upgrades for Fossil/Nuclear Turbines

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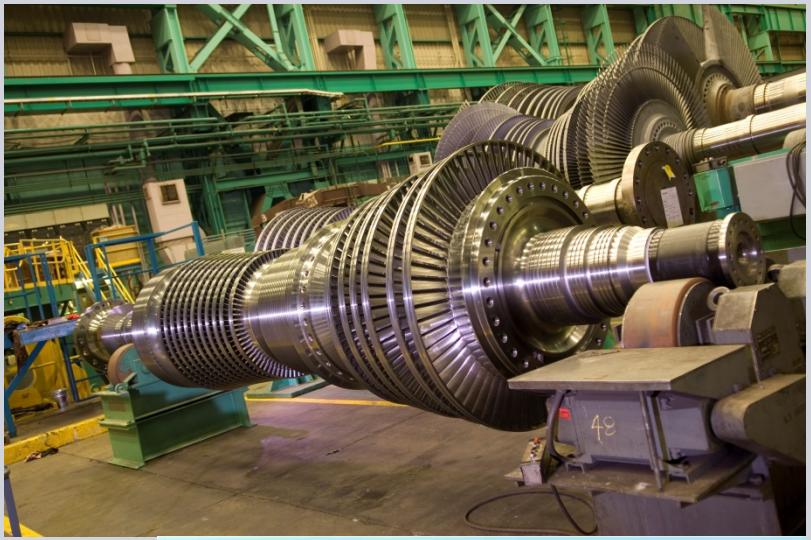
Benefits:

- Increased MW output, efficiency and long-term thermal performance
- Parasitic Load Recovery
- Minimized installation time
- Recommended 10-year maintenance outage inspection intervals (100,000EOH)
- Improved reliability/availability
- Reduced maintenance costs
- Operational Flexibility/Faster start-up time potential
- Greater erosion/corrosion protection
- Reduced Life Cycle Costs
- Environmental (Emissions Benefit)



Efficiency Improvement Areas in Steam Turbines and Auxiliaries

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- Steam Turbine Technology
- Condenser Optimization
- Valves and Steam Chests
- Instrumentation and Controls

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Thank You!

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