
# Use of Lifetime Monitoring for Flexible Plant Operation

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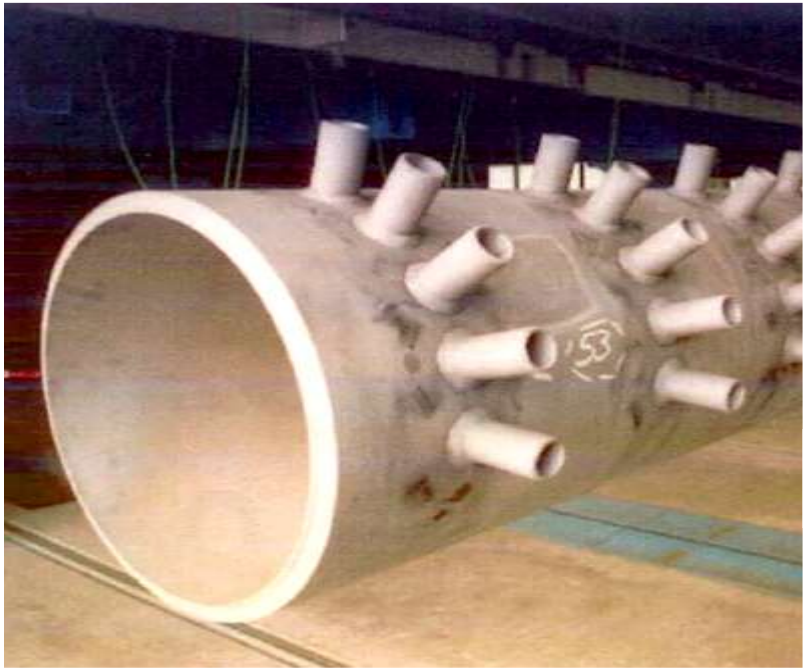
# Content

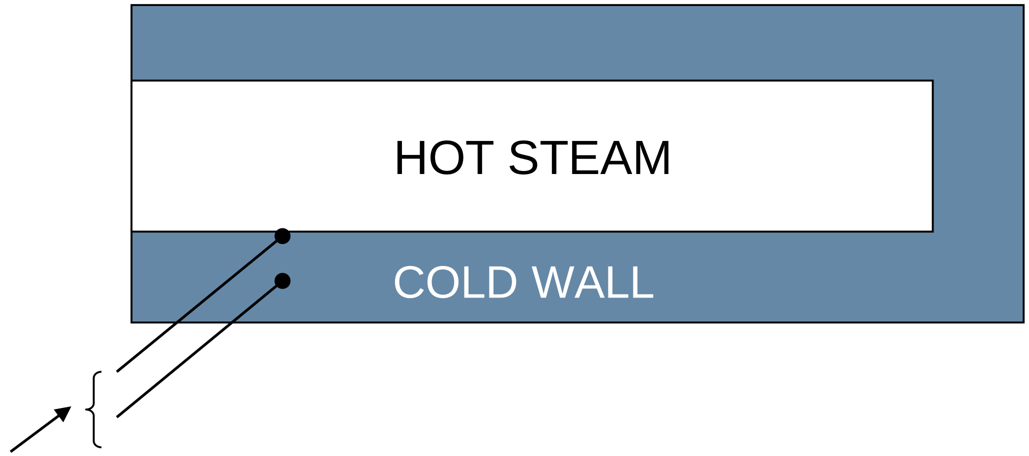
# Energy Generation / Installed Capacity in Germany 2016

| | Renewable % | Thermal % | Others % |
|---|---|---|---|
| Energy Generation | 29.5 | 52.2 | 18.3 |
| Installed Capacity | 50.5 | 38.4 | 11.1 |

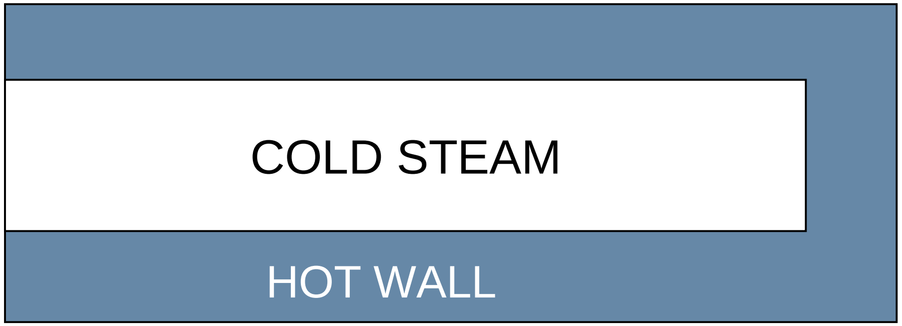
# Highly Loaded Thick-Walled Components Limit the Flexibility



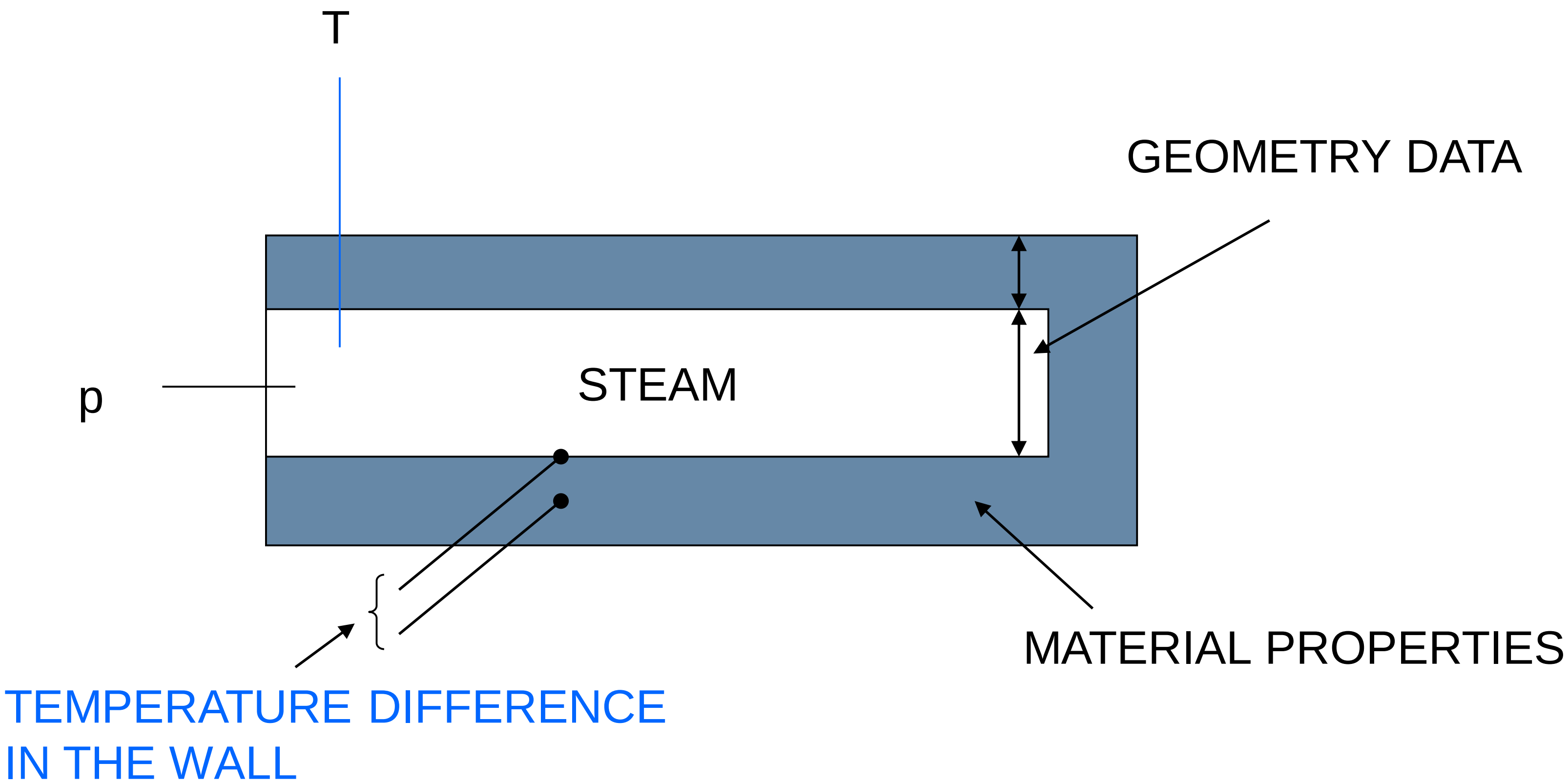
# Thermal Stresses in Header‘s Wall during Start-Up and Shut Down




TEMPERATURE DIFFERENCE IN THE WALL OF THE HEADER CAUSES THERMAL STRESS



# Measurements and Parameters for Automatic Life Time Monitoring



# Increased Stress Due to Load Changes

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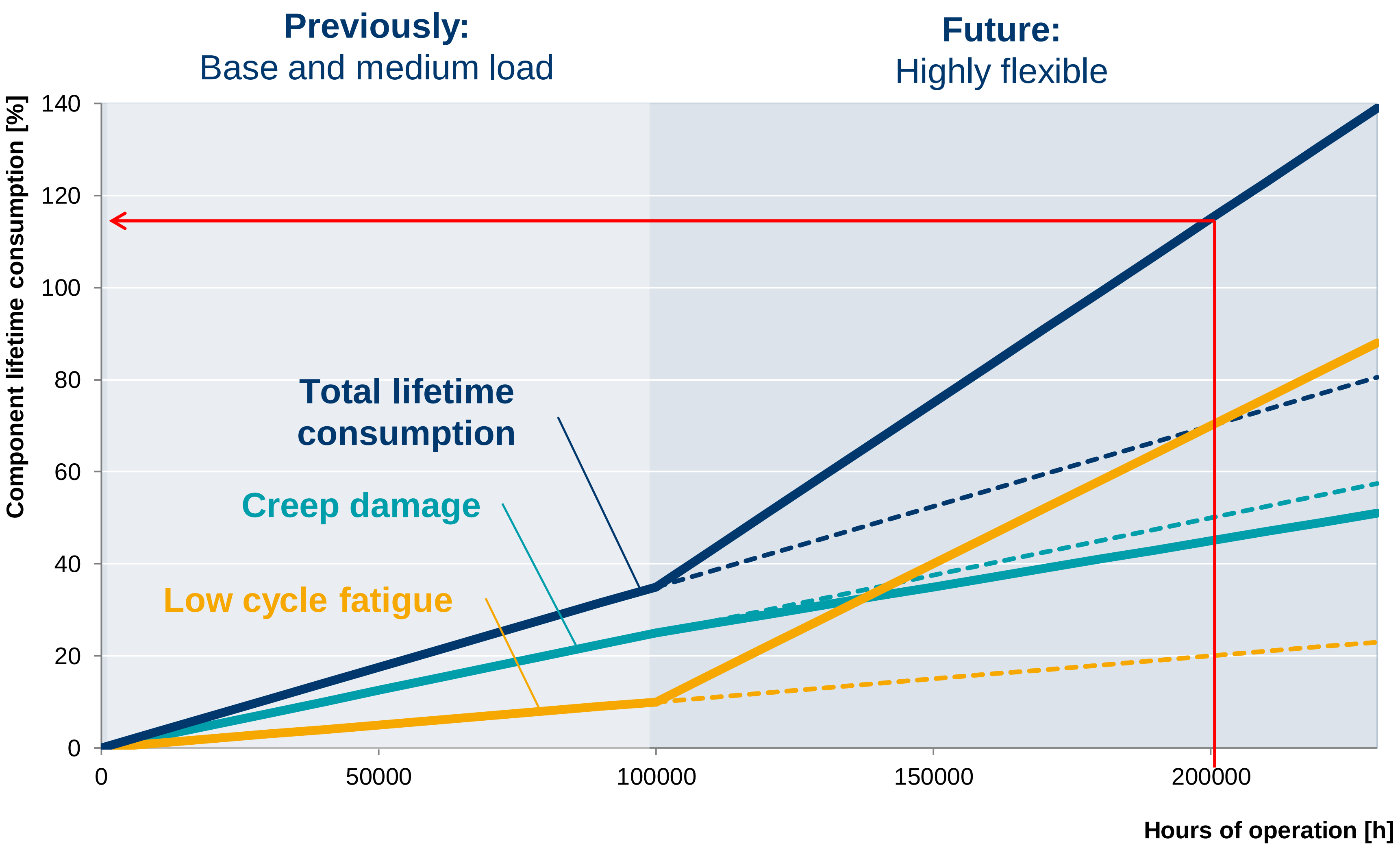
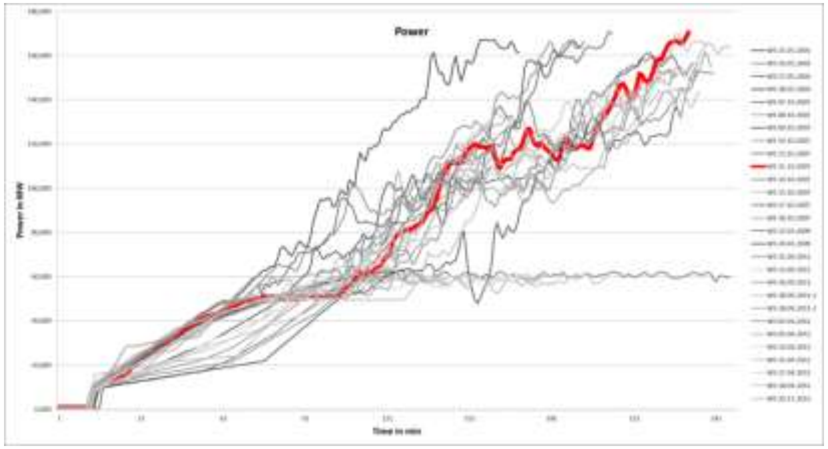
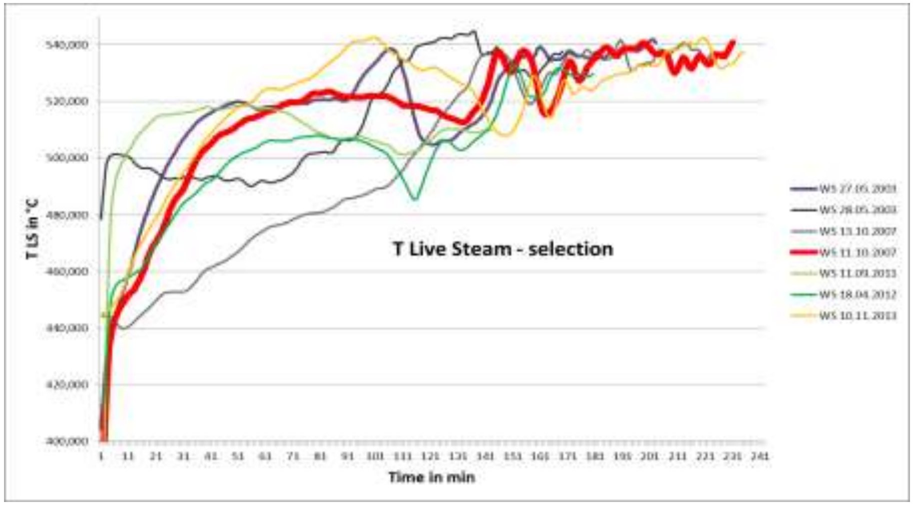
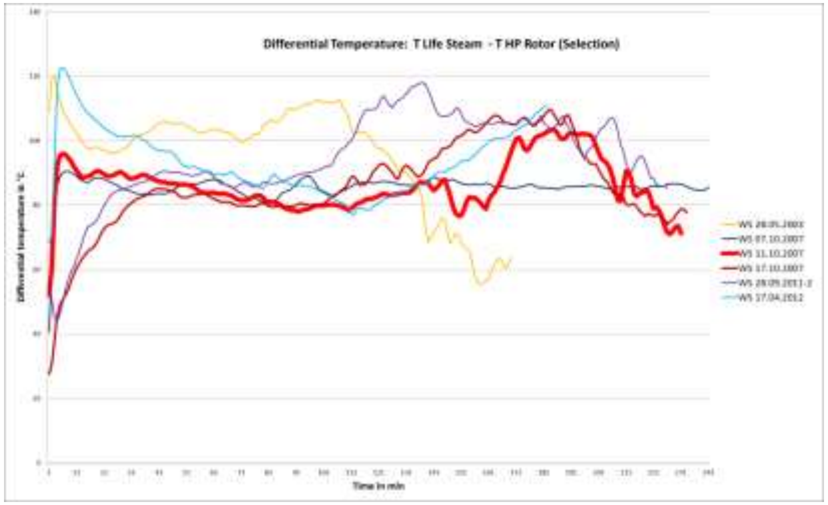


# Start-up Procedures Often Differ Significantly

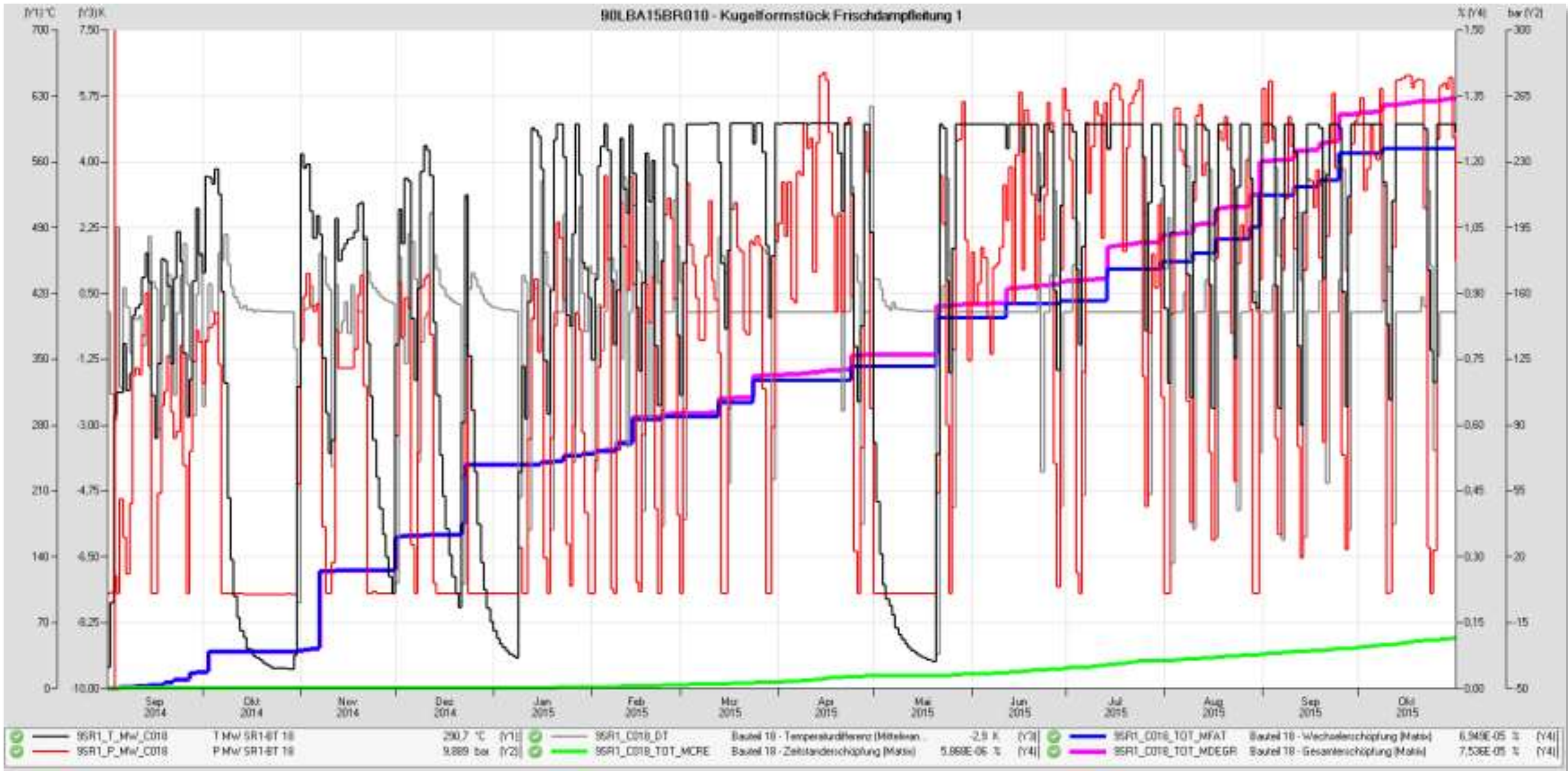



Analysis Termopaipa power plant, 2014



# Life Time Monitoring in PADO System: Trend of Fatigue of Y-Piece



# Life Time Monitoring Results

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01/31/2015 23:59

**COMPONENT WITH HIGHEST DEGRADATION**

17 - 1 HAH70BB011 SH3 OUTLET HEADER LEFT

55 % $D_C$ in 200.000h

79 % $D_f$ in 200.000h

12088 h Total Monitored Time

**QUICKLINKS**

- SR1 Overview
- Creep of Component 17
- Fatigue of Component 17
- Data Sheet Component 17

**UNIT SUMMARY**

PP DEMO, UNIT 1

| No | Caption | $D_{C,Mat}$ / % | $D_{F,Mat}$ / % | $D_{total}$ / % | $D_{200,000h}$/% | $D_{F\,RSE}$ / % |
|---|---|---|---|---|---|---|
| 17 | 1 HAH70BB011 SH3 outlet header left | 3.27 | 4.75 | 8.03 | | 3.31 |
| 14 | 1 HAH52BB001 Con. pipe spray attemperator 2.2 | 1.54 | 0.96 | 2.51 | | 0.26 |
| 18 | 1 HAH70BB011 SH3 outlet header right | 0.90 | 1.46 | 2.37 | | 1.12 |
| 12 | 1 HAH42BB021 SH2 outlet header | 1.65 | 0.63 | 2.27 | | 4.91 |
| 11 | 1 HAH41BB021 SH2 outlet header | 1.38 | 0.58 | 1.95 | | 0.20 |
| 13 | 1 HAH51BB001 Con. pipe spray attemperator 2.1 | 1.13 | 0.46 | 1.59 | | 0.07 |
| 21 | 1 HAJ30BB021 RH2 outlet header left | 1.17 | 0.04 | 1.21 | | 0.01 |
| 26 | 1 LBA20BR020 T-piece (dT based on wall T) | 0.87 | 0.22 | 1.09 | | 0.10 |

# Life Time Monitoring Results

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COMPONENT 17 - LARGE LOAD CHANGES

1 HAH70BB011 SH3 OUTLET HEADER LEFT

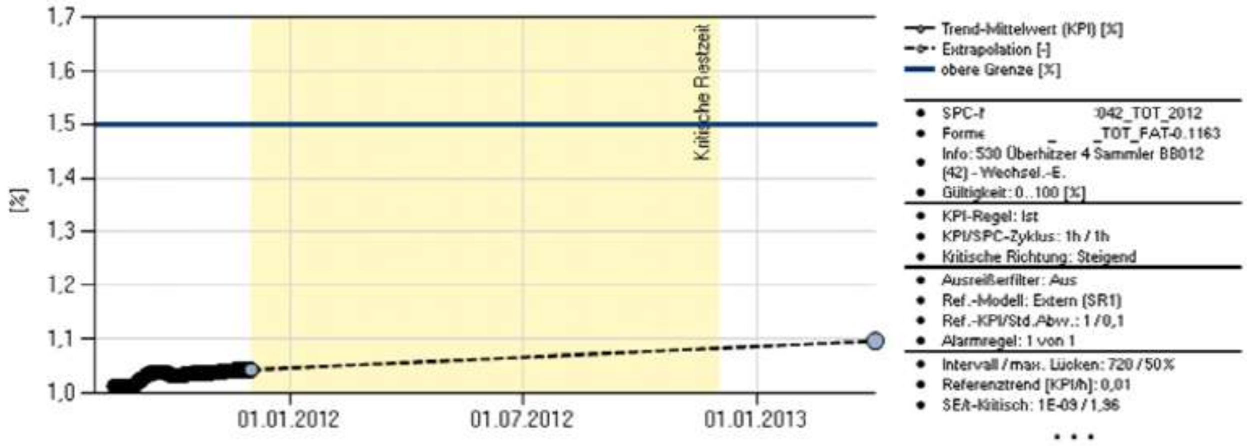
| Time | T / °C | p / MPa | ΔT / K | σ / MPa | 2fa* / MPa | $D_F$ / % |
|---|---|---|---|---|---|---|
| − 43577 | | | | | | |
| 7/3/2013 7:41:00 AM | 335.0 | 3.5 | -87.4 | -522.4 | 1496.2 | 0.19 |
| 8/7/2013 12:33:30 PM | 355.6 | 14.9 | 109.9 | 765.3 | 1496.2 | 0.19 |
| 8/7/2013 6:13:30 PM | 432.3 | 3.3 | -49.5 | -285.3 | 1496.2 | 0.19 |
| 8/10/2013 2:08:00 PM | 422.3 | 15.5 | 125.5 | 859.7 | 1496.2 | 0.19 |
| − 79849 | | | | | | |
| 10/11/2013 2:44:00 PM | 397.8 | 14.5 | 143.8 | 969.8 | 2158.7 | 0.45 |
| 11/3/2013 5:01:30 PM | 428.7 | 9.8 | -71.4 | -383.6 | 2158.7 | 0.45 |
| 11/6/2013 12:29:00 AM | 372.2 | 17.0 | 126.2 | 877.8 | 2158.7 | 0.45 |
| 11/19/2013 8:53:00 PM | 375.9 | 8.1 | -97.2 | -556.0 | 2158.7 | 0.45 |
| − 117496 | | | | | | |
| 10/11/2013 2:44:00 PM | 397.8 | 14.5 | 143.8 | 969.8 | 2890.5 | 0.75 |
| 12/8/2013 3:19:00 PM | 363.6 | 5.5 | -112.8 | -668.3 | 2890.5 | 0.75 |

# Low Cycle Fatigue
# Detecting Unplanned States Continuously

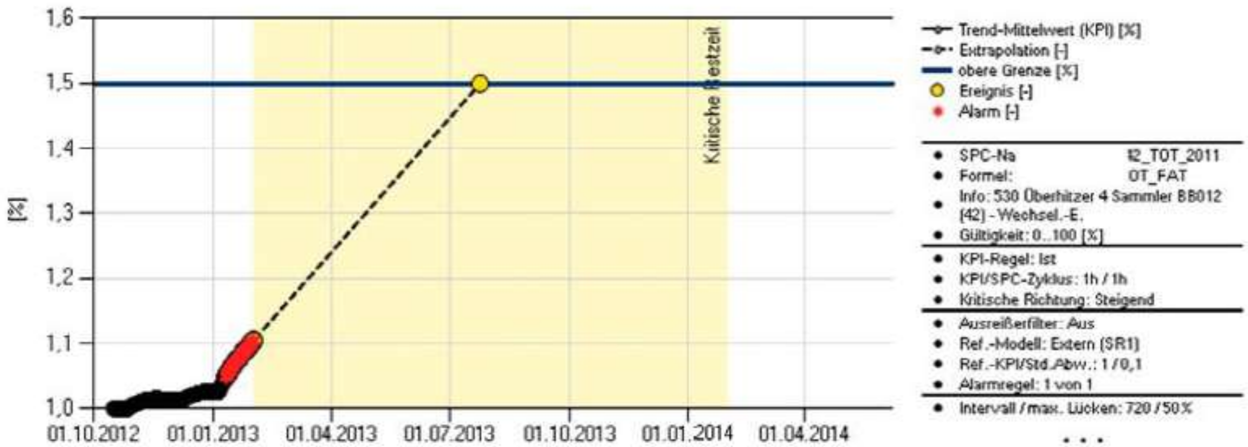

**Trend of the damage due to low cycle fatigue [%]**


**Trend of the low cycle fatigue gradient [%/h]**

# Forecast of Low Cycle Fatigue „Base Load“ vs. „Energy Turnaround“




“Base load“




“Energy turnaround“

**The additional consumption can be economically assessed and one can react with a more moderate mode of operation.**

# Can the present number of start-ups per year be doubled?

# Calculatory Component Lifetime Consumption
## Extrapolation of the Stress

| Year | Operating Hours [h] | $D_F$ [%] | $D_{F,RES}$ [%] | $D_C$ [%] | $D_{TOTAL}$ [%] |
|---|---|---|---|---|---|
| 2014 | 7735 | 1,88 | 1,02 | 1,89 | 3,77 |

Table 1: Lifetime consumption for a selected component

| Operating Hours [h] | $D_f$ [%] | $D_c$ [%] | $D_{total}$ [%] |
|---|---|---|---|
| **200.000h** | 48,6 | 48,9 | 97,5 |

Table 2: Linear extrapolation of the component lifetime consumption for 200,000 h

**At first, apparently no potential for doubling the number of start-ups**

# Analysis of the Mode of Operation
## Actual Stress Collectives

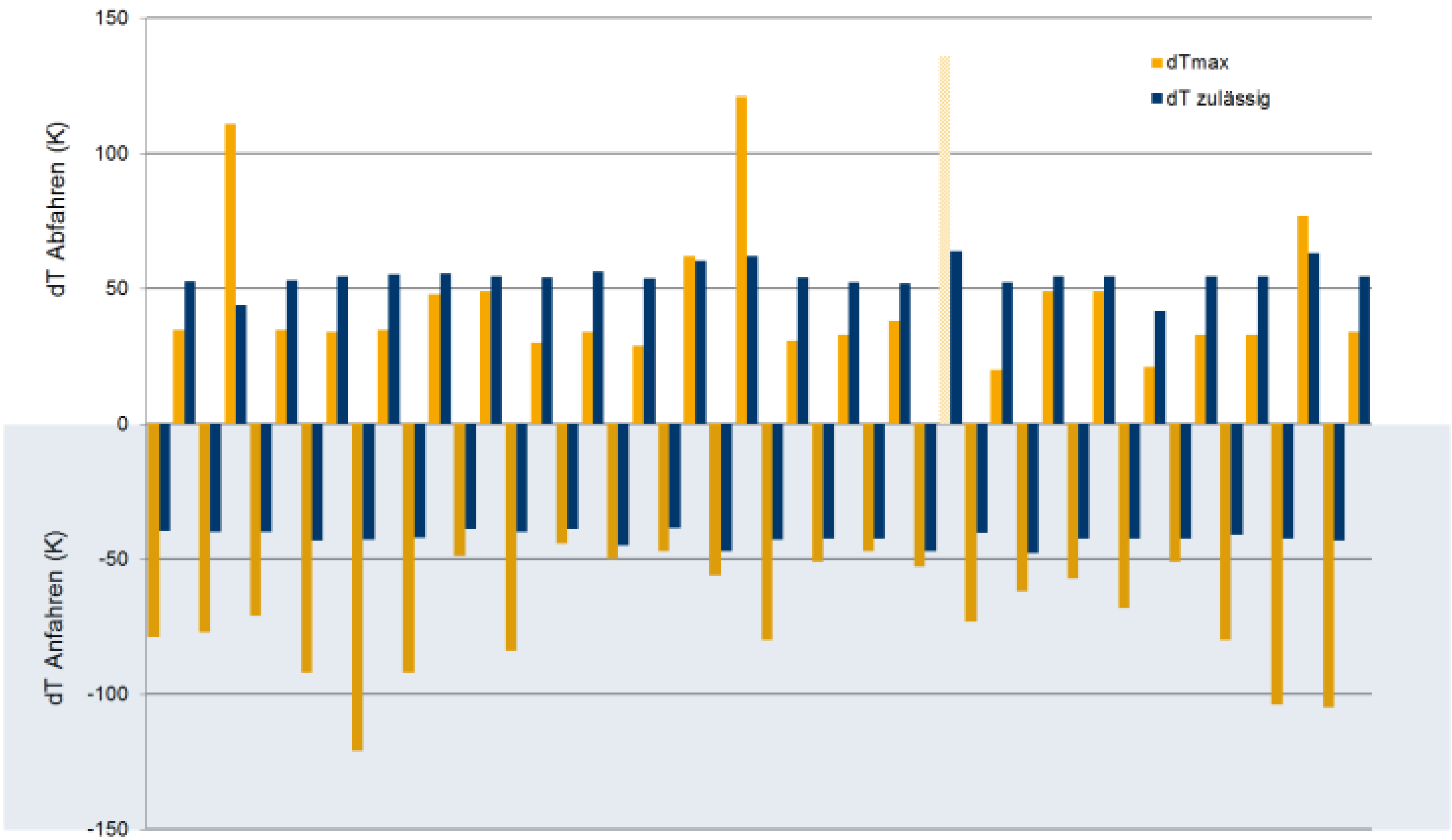
| Start Type | Minimum Cycle Pressure | Minimum Cycle Temperature | Down Time |
|---|---|---|---|
| Cold Start | 0 bar | >20 °C | >48h |
| Warm Start | 0 bar | >80 °C | <48h |
| Hot Start | 0 bar | >250 °C | <8h |

Table 1: Criteria for the classification of cold, warm, and hot starts (downtime most important)

| Start Type | Number | $dT_{max}$ [K] | $dT_{max,mean}$ [K] | $Sigma_{max}$ [N/mm²] | $Sigma_{max,mean}$ [N/mm²] |
|---|---|---|---|---|---|
| Cold Start | 4 | -84 | -76 | -502 | -432 |
| Warm Start | 17 | -121 | -69 | -709 | -389 |
| Hot Start | 3 | -77 | -70 | -436 | -396 |
| Shut Down | 24 | 111 | 49 | 804 | 347 |

Table 2: Actual stress collective of a thick-walled component

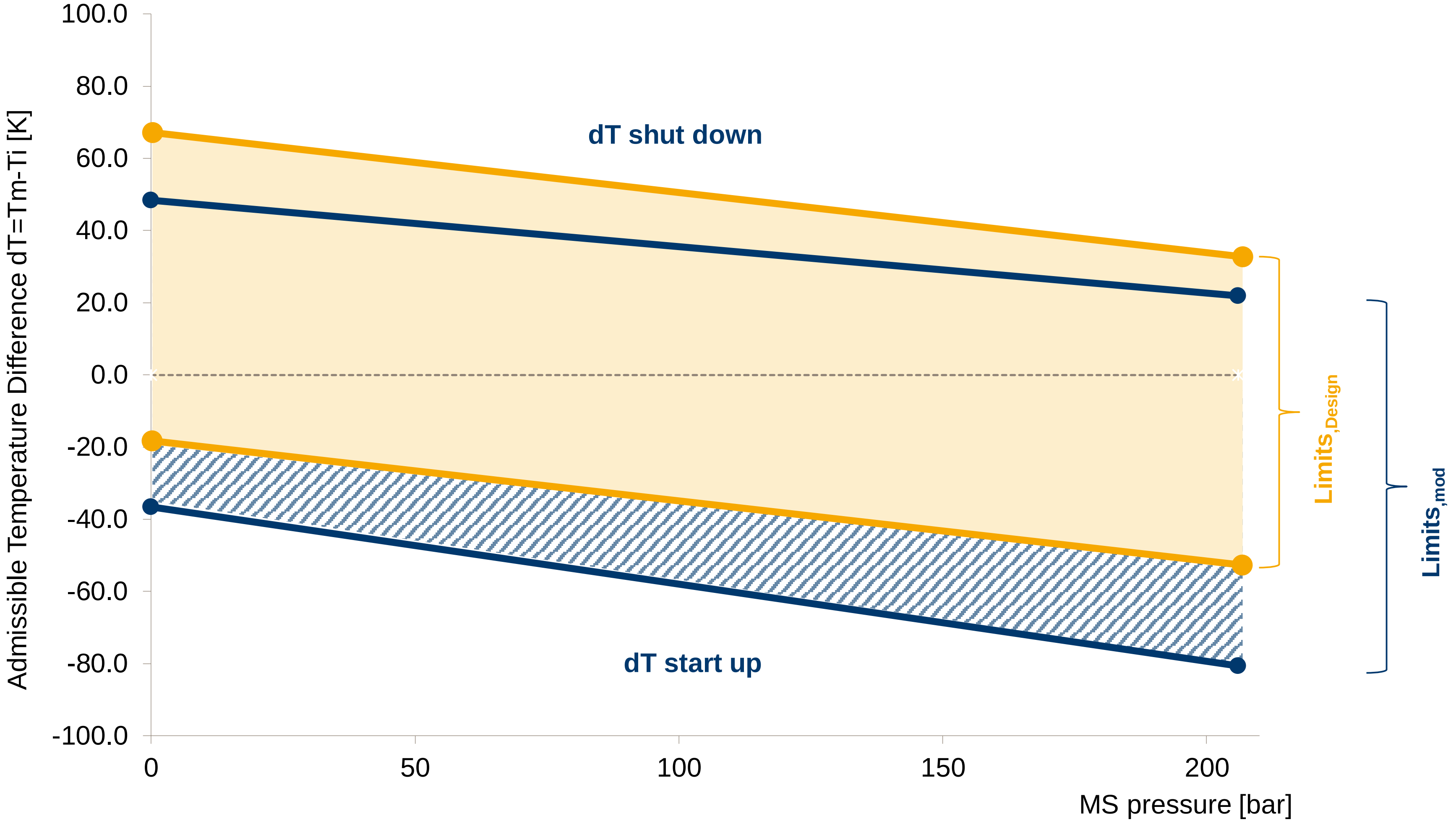
# Temperature Difference Actual / Reference
per Start-up and Shutdown Procedure




**Exceedance of the admissible temperature difference during start-up, shortfall during shutdown**

**Potential for adjusting the admissible limits exists.**

# Modified Admissible Temperature Differences



# Lifetime Consumption per Warm Start at Optimized Mode of Operation

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| Event | Df [%] | Number per Year | Df per Year [%] |
|---|---|---|---|
| $WS_{,max}$ + Shut Down$_{,max}$ | 0,58 | 2 | 1,16 |

Table 3: Lifetime consumption due to critical cycle (warm start + shutdown)

**Reduction of the lifetime consumption per year by 1.16% conceivable.**

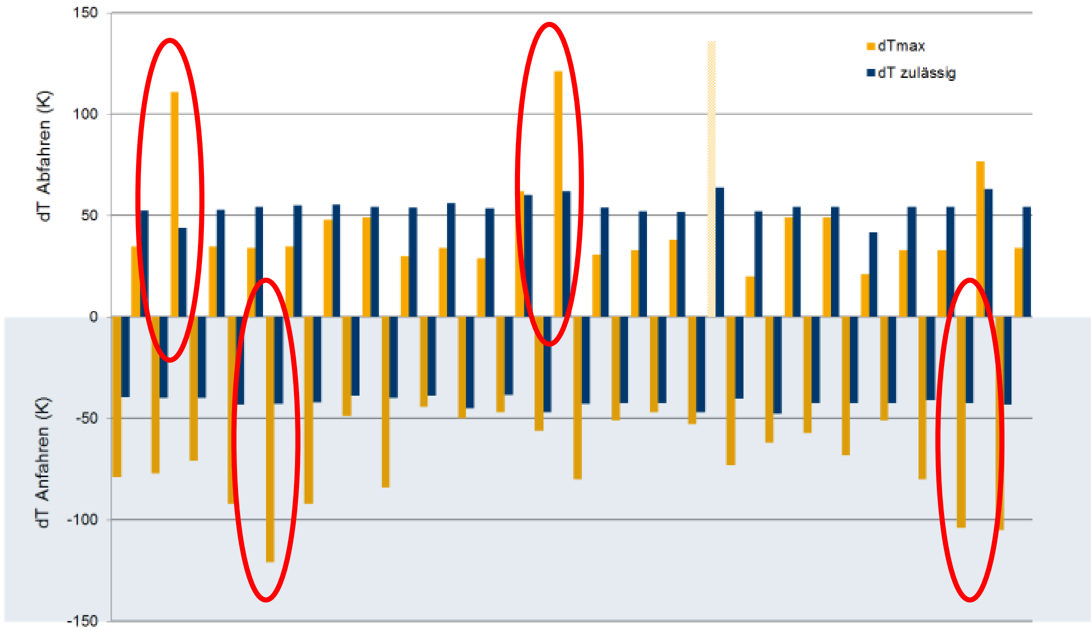
| Operating Hours [h] | $D_f$ [%] | $D_{total}$ [%] | $D_{f,optimiert}$ [%] | $D_{total,optimiert}$ [%] |
|---|---|---|---|---|
| **200.000h** | 48,6 | 97,5 | **18,6** | **67,5** |

Table 4: Linear extrapolation to 200,000h of the stress determined in 2014 (with and without consideration of an optimized mode of operation)

**By avoiding critical conditions, reserves for doubling the number of start-ups can be generated.**

# Result of the Analysis

1. **Temperature differences of current start-up and shutdown procedures can be legitimized** (adjustment of the ratio)
2. **An increase in the number of start-ups is only conceivable by avoiding modes of operation that involve high stress.**



# Summary and Conclusions

1. **Rapid growth of renewable energy requires more flexible operation of thermal power plants**

2. **Flexible operation requires knowledge of life time consumption to ensure safe and economical operation**

3. **Online monitoring of fatigue with predictive analitics provides this knowledge to plant engineers**

# THANK YOU

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