DAMAGE EXPERIENCE IN SOLAR THERMAL POWER PLANTS

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Allianz

“LESSONS LEARNED FOR 85 YEARS”

Allianz Risk Consulting GmbH – Allianz Zentrum für Technik

1932 founded in Berlin as “**Materialprüfanstalt”** of Allianz Insurance

Since 1969 located at Munich
Allianz Zentrum für Technik

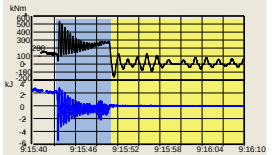
- Commercially operated through Allianz Risk Consulting GmbH
- 2007 integrated into AGCS

Root Cause Analyses | **Lessons Learned** | **Risk Assessments**

Turbo-machines

Materials Corrosion

Monitoring

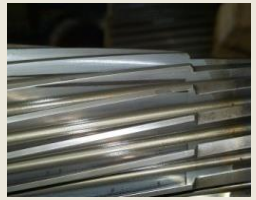


Fire Protection

Electrical Engineering

Non-Destructive Testing

Mechanical Engineering

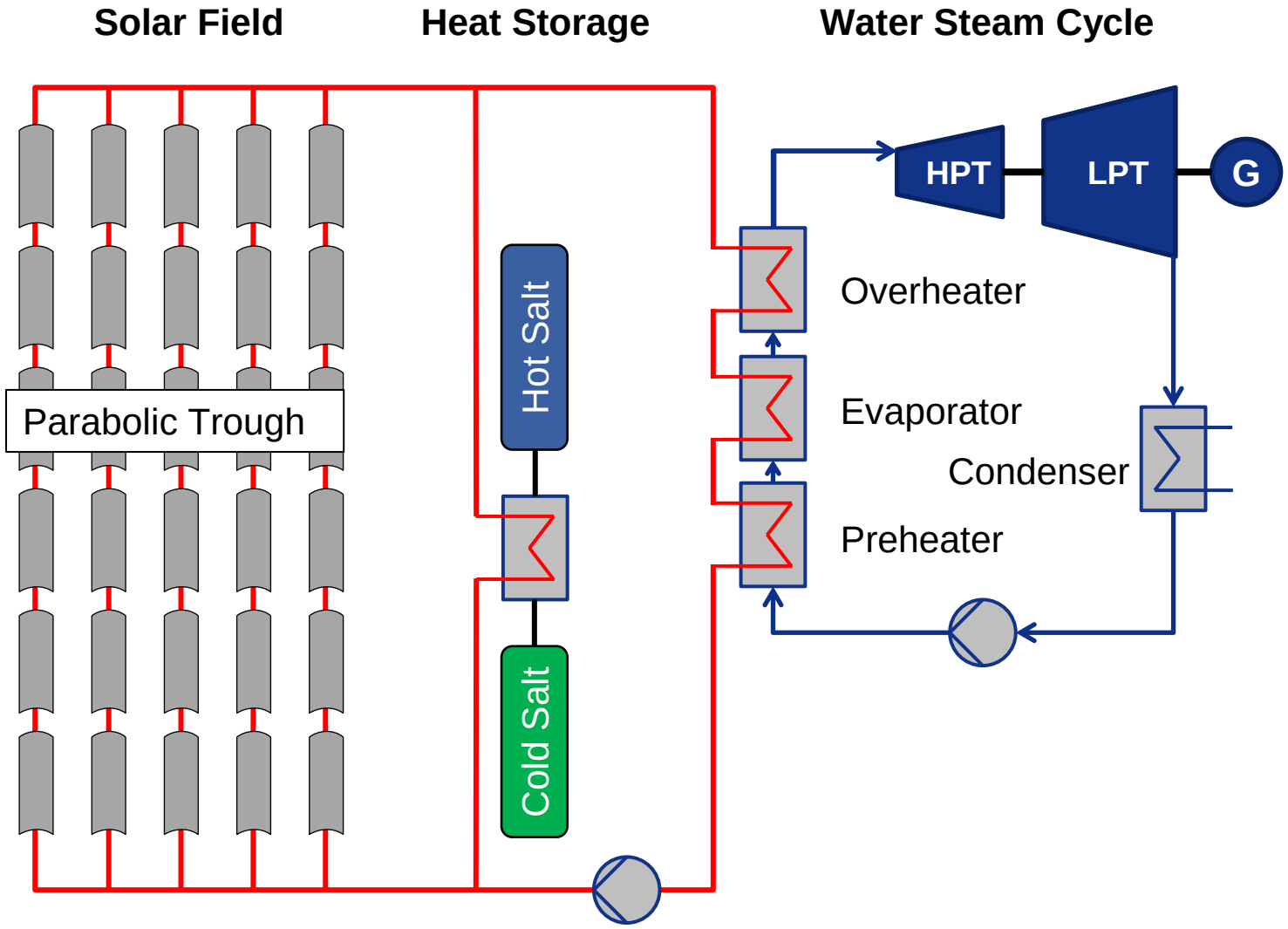


Chemistry, Process Eng.

Laboratory Analyses

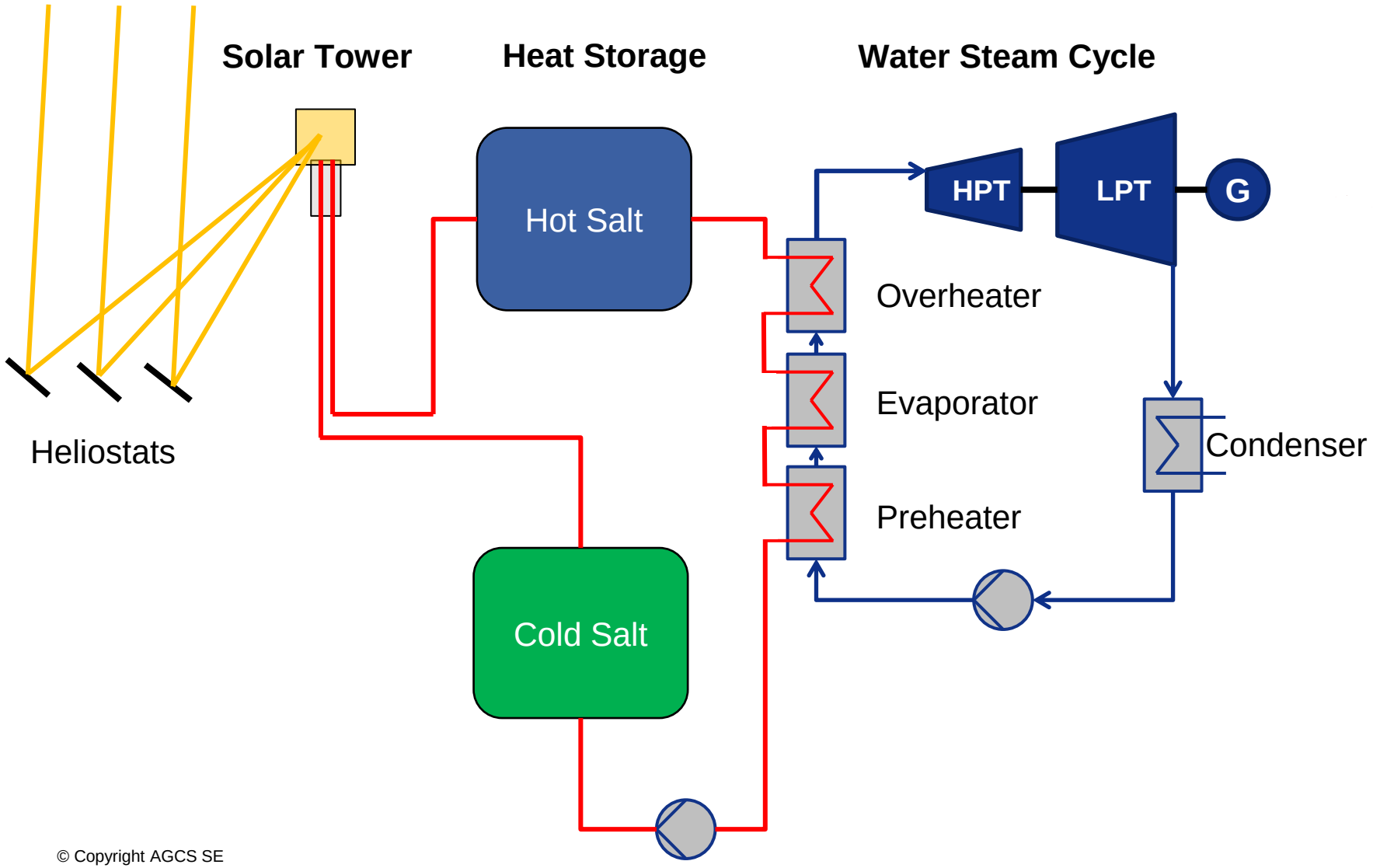
- SEM
- Optical Micr.
- RFA
- Hardness
- Etc.

CONCENTRATED SOLAR POWER (CSP) – 2 MAIN TECHNOLOGIES



Parabolic Trough Power Plant

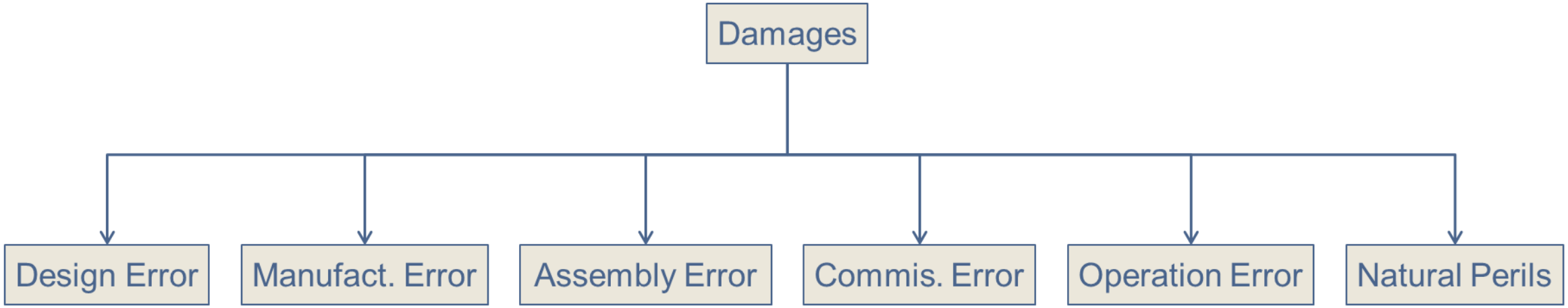
CONCENTRATED SOLAR POWER (CSP) – 2 MAIN TECHNOLOGIES



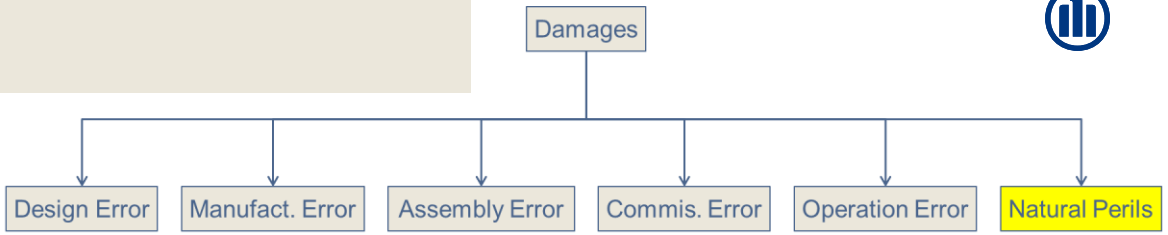
Solar Tower Power Plant

CONTENT

DAMAGE EXAMPLES



NATURAL PERILS

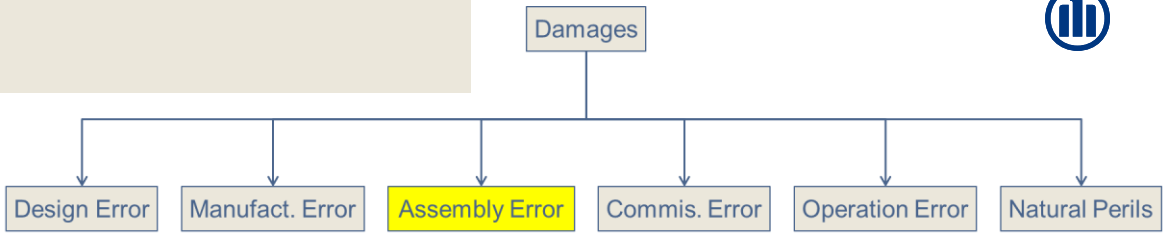


Windstorm

Tornado

Flood

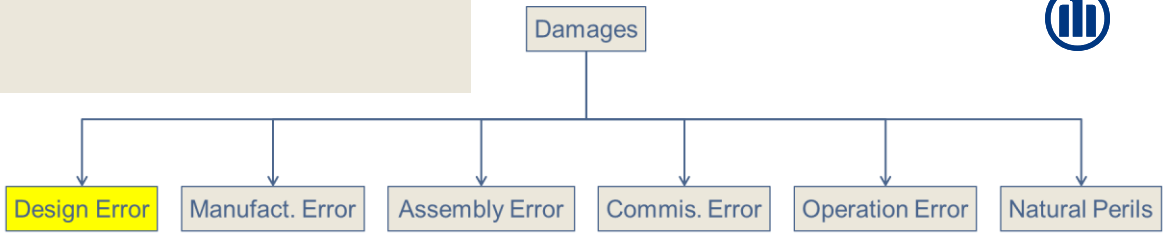
COLLECTOR EXPLOSION



Damage due to:
Welding Error during Assembly

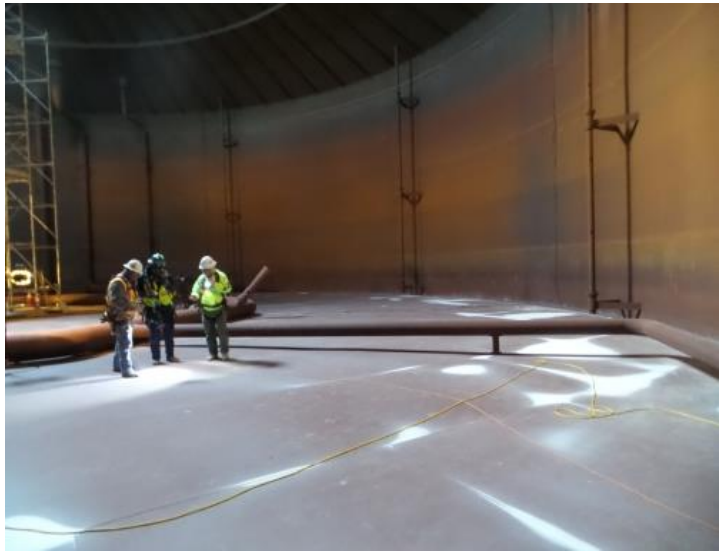
Small leakage lead to Ignition of Heat Transfer Fluid (HTF, thermal oil)

SALT TANKS

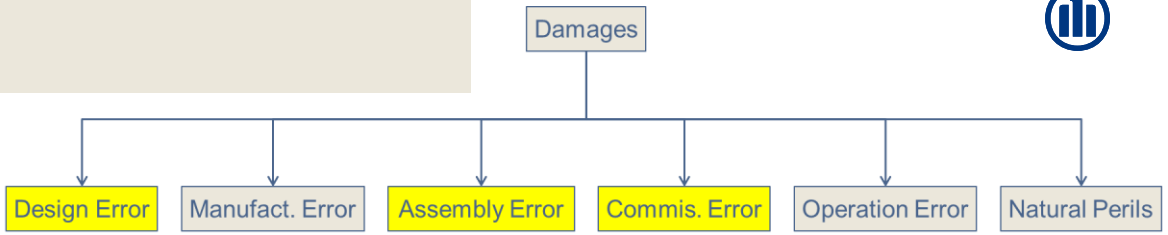


Problem:
- → Cold salt immediately crystalizes
- → Tank only accessible from the top
- → Tank has to be completely drained
- → 6 month standstill

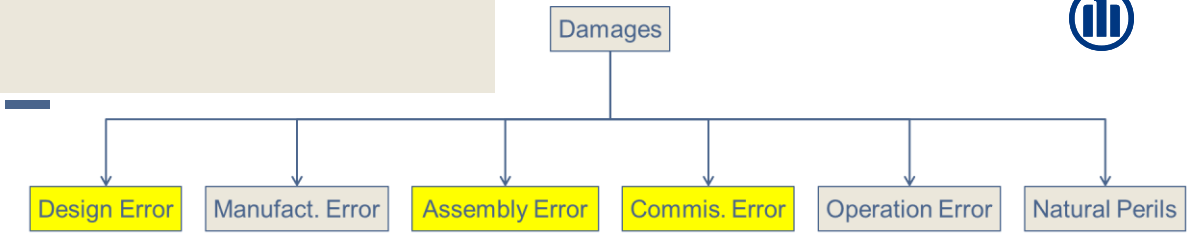
Root Cause:
The salt inlet pipes were welded to the tank.
- → Overdetermined
- → No degree of freedom for thermal growth
- → Crack initiation to the tank

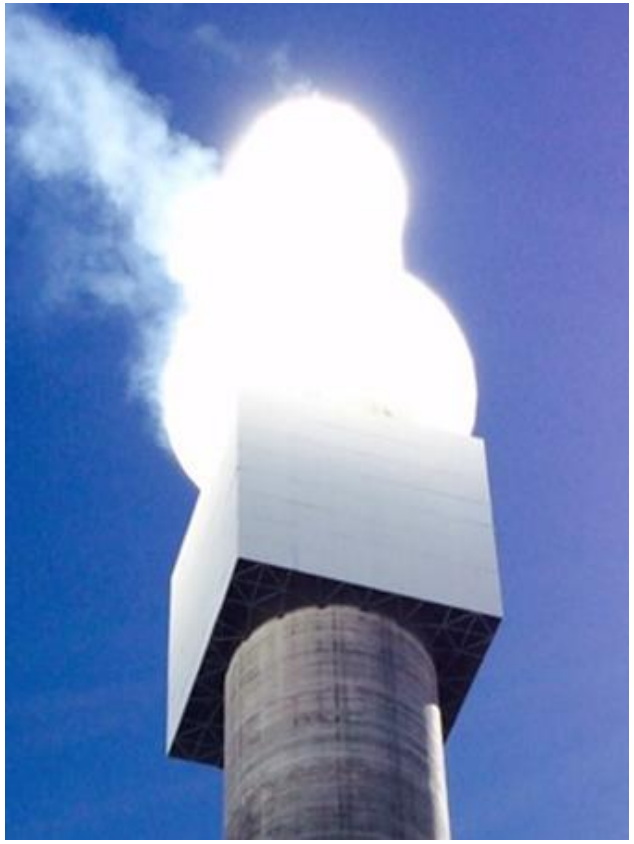


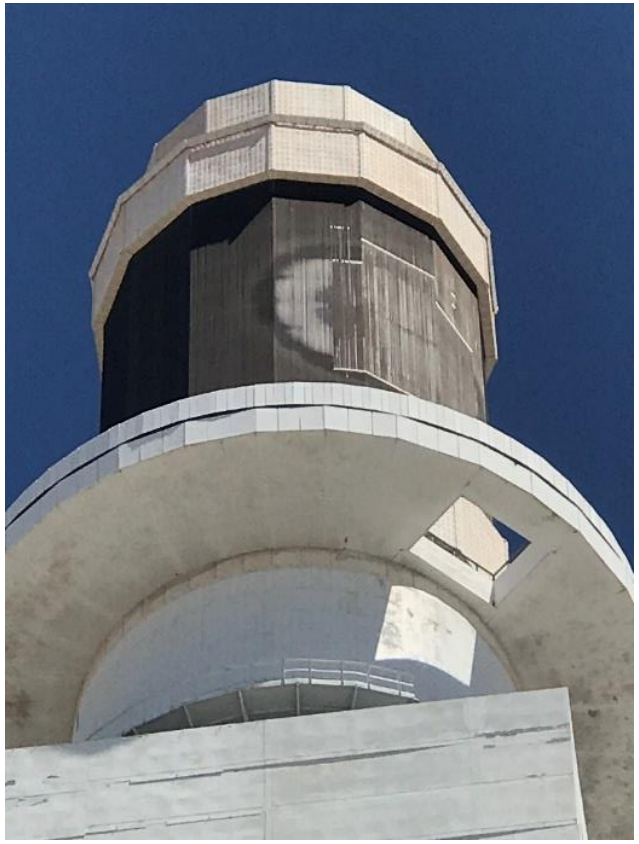
PROBLEMS WITH HELIOSTATS
1. DOUBLE BLOCKING



PROBLEMS WITH HELIOSTATS – 2. ALIGNMENT

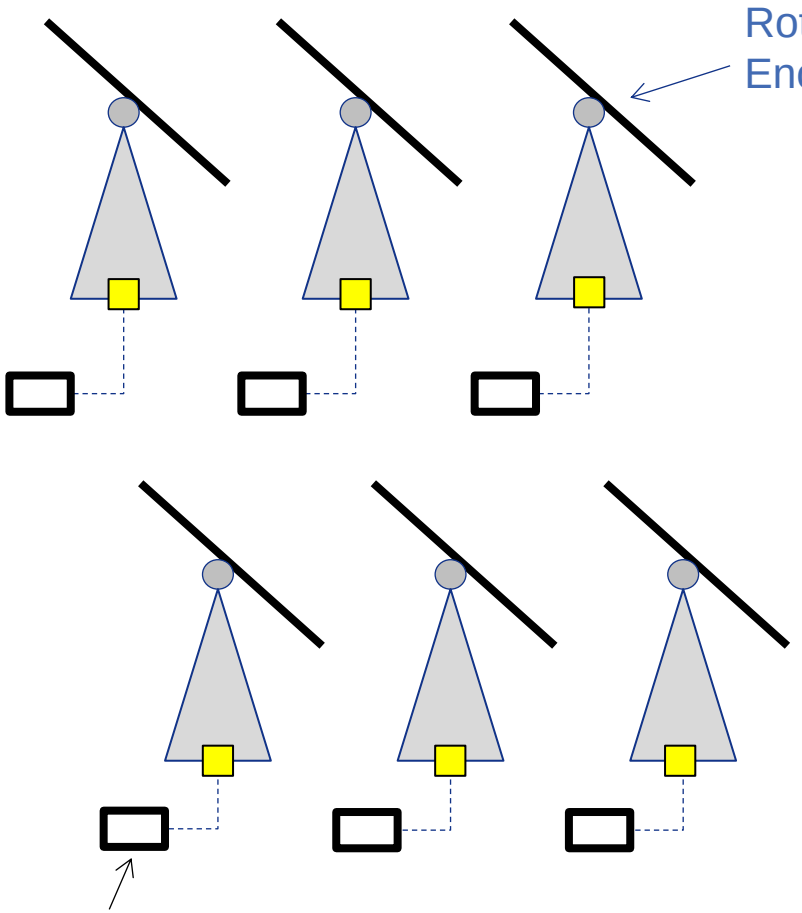


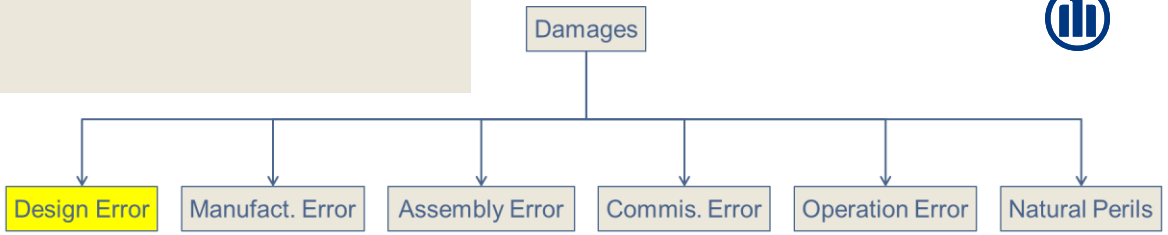




Problems with Alignment:
- Too many heliostats concentrated at one point → energy density too high
- Heliostats are aligned before HTF is flowing through receiver

ALIGNMENT ISSUE





Problem:

The rotating position of several heliostats could not be controlled as requested.

Root Cause:

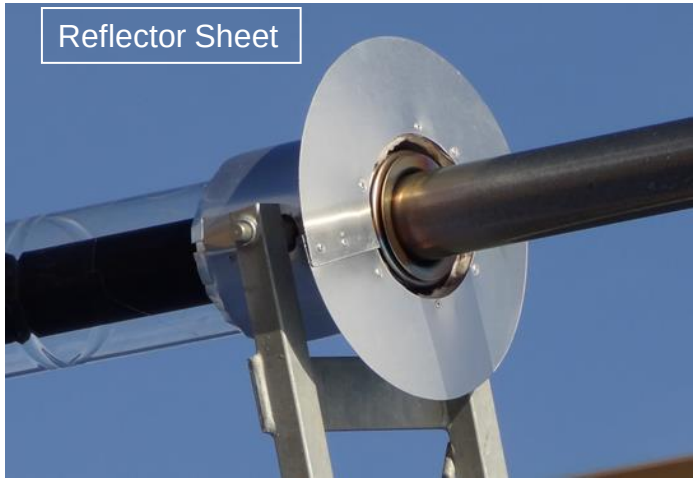
An inappropriate firmware within the encoders led to interruption of the communication between the encoders and the PLCs during start-up.

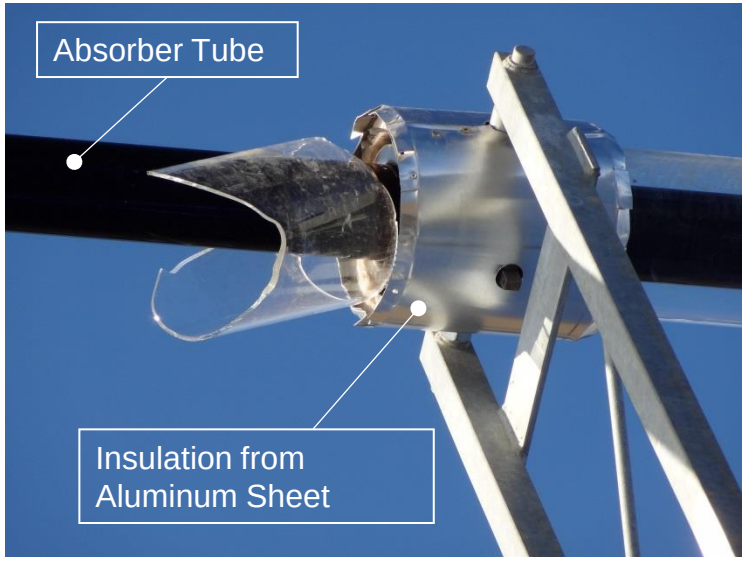
Repair Solutions:

- Change of all encoders → very expensive
- New PLCs → risky
- Implementation of an additional relay in front of each encoder to avoid the communication problem

CONTENT

HTF TUBES



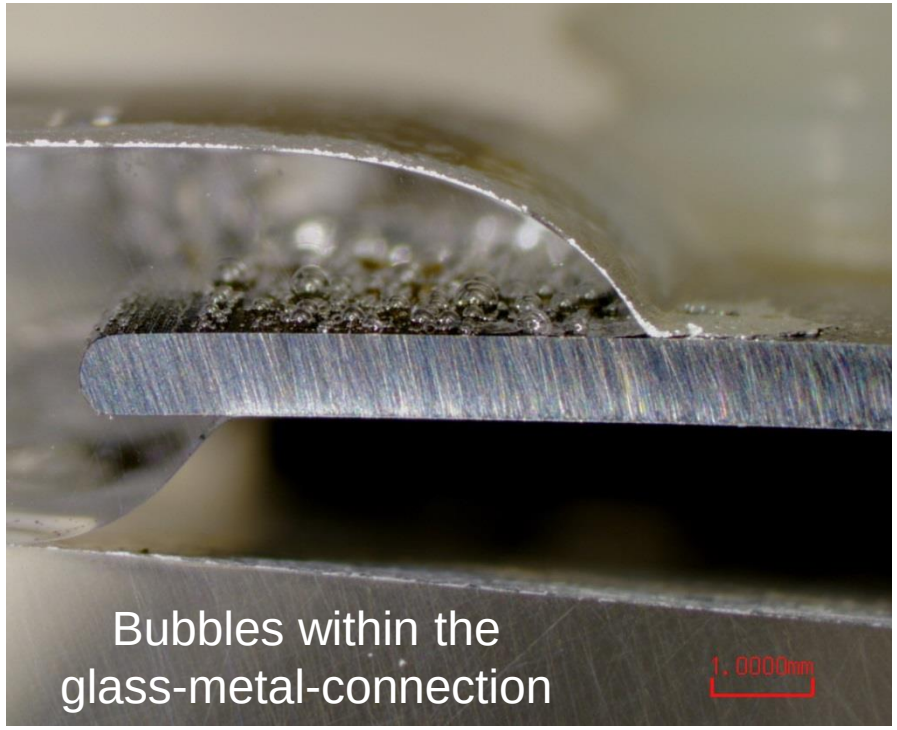


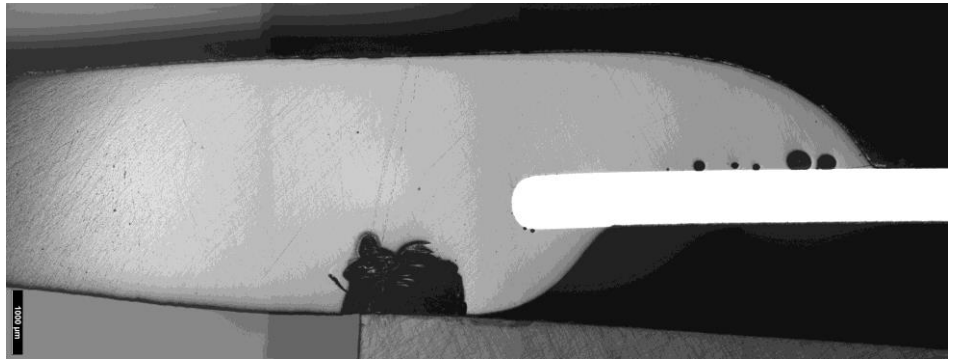
Technical Issue / Loss:

2.500/22.000 cracked glass tubes shortly after commissioning.

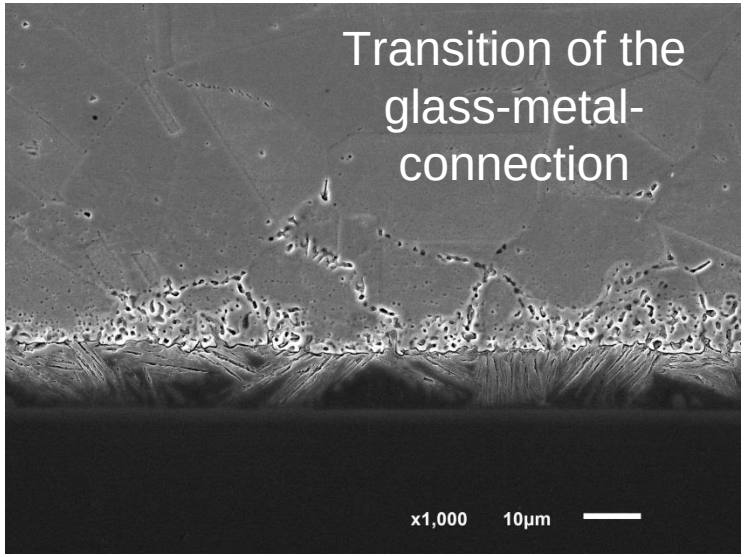
Manufacturing issue or faulty assembling?

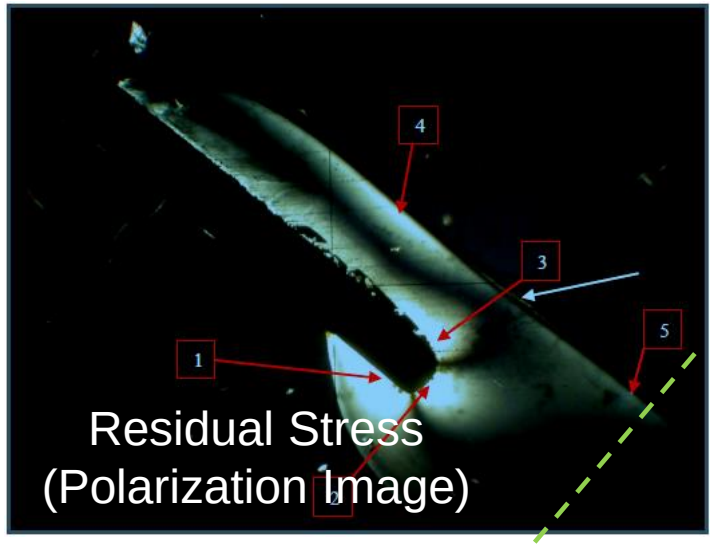
LABORATORY ANALYSES





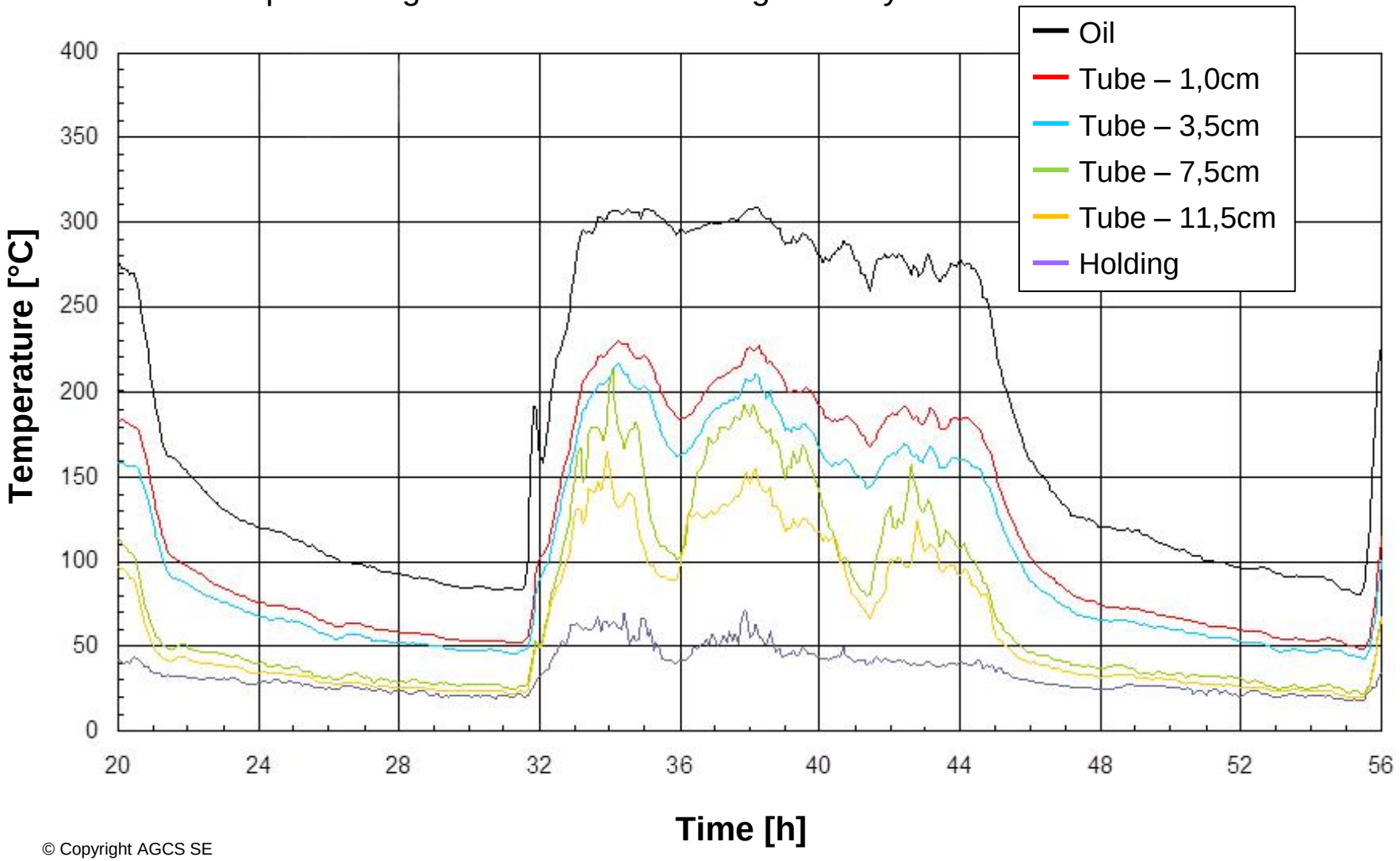
The found defects are not the cause of the damage!





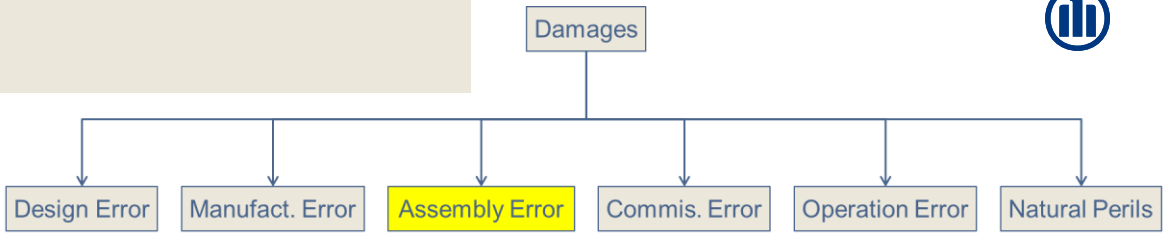
ANALYSES OF OPERATIONAL DATA

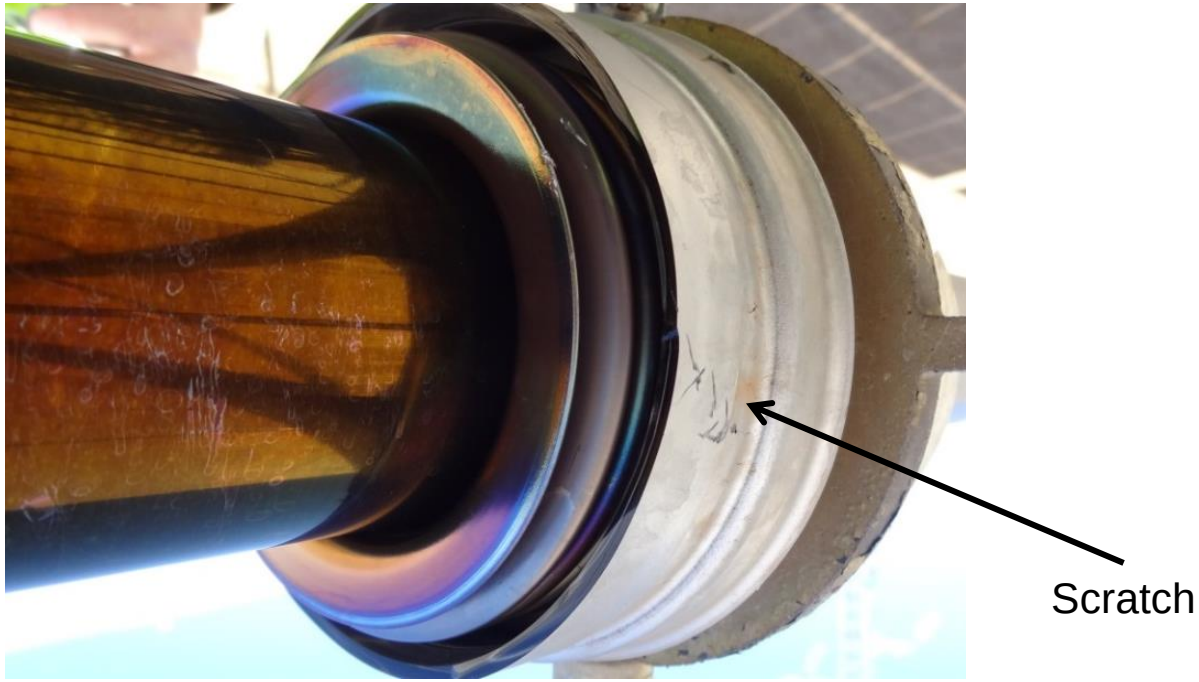
Measured temperature gradients of 200K during one day



FEM calculation showed that the resulting high stresses are not critical for intact glass tubes.

ROOT CAUSE





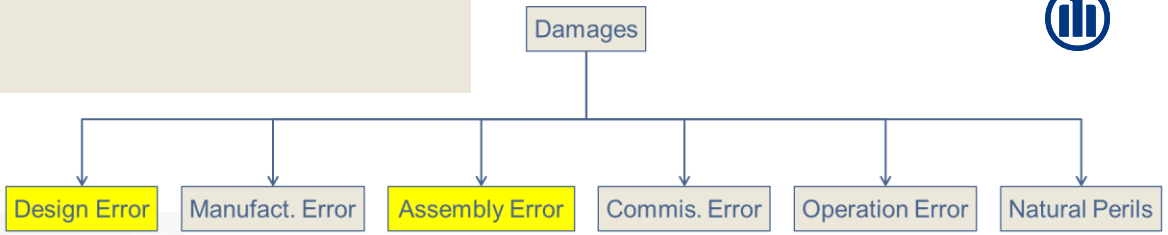
Cause of fractures:

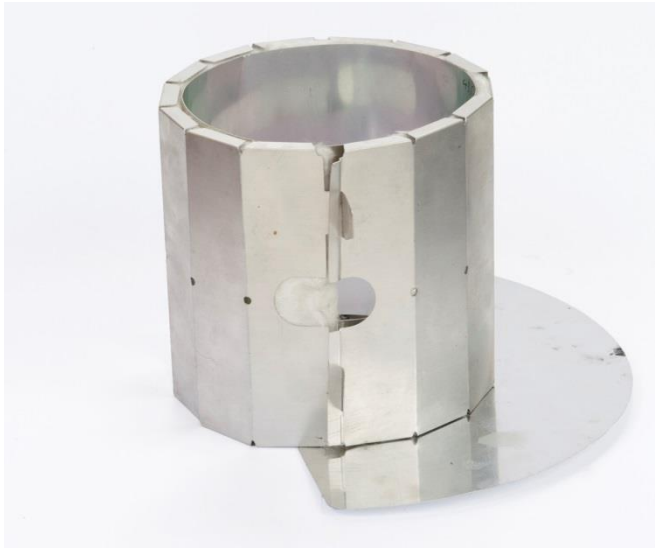
During the installation of the receiver tubes the glass surface was scratched onsite during the assembly of the metal insulation.

Due to the high thermal loads during start and stops the scratched tubes broke.

Why were there scratches at the glass tube surfaces?

FACILITATING EFFECT





Original design

Design of a local sub-contractor

Lessons Learned:

Local sourcing from inexperienced sub-supplier can cause critical quality issues.

No sharp edges, no boreholes, plug-in connection

Many sharp edges, boreholes for the rivet connection

CLOCKED STEAM TURBINE

Steam turbine showed reduced performance after two years of operation.

→ Borescope inspection revealed deposits in few stages in the middle of the steam turbine.

Stage with deposits

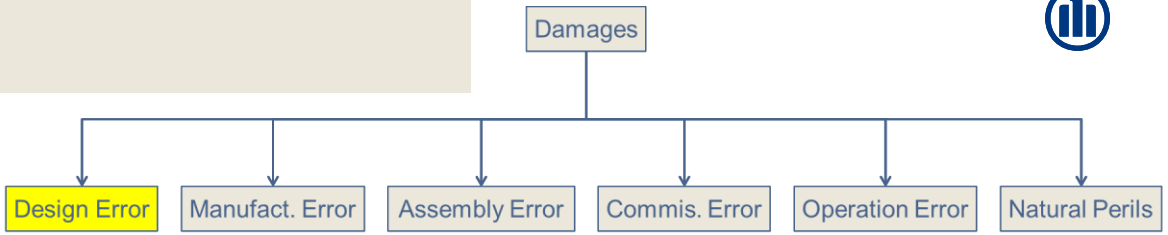
Stage without deposits

Opening of the turbine necessary

→ Analysis of the deposits showed mainly Aluminum

How can there be aluminum in the water steam cycle?

SOURCE OF THE ALUMINUM



In the economizer, aluminum swirlers were implemented to improve the heat transfer.

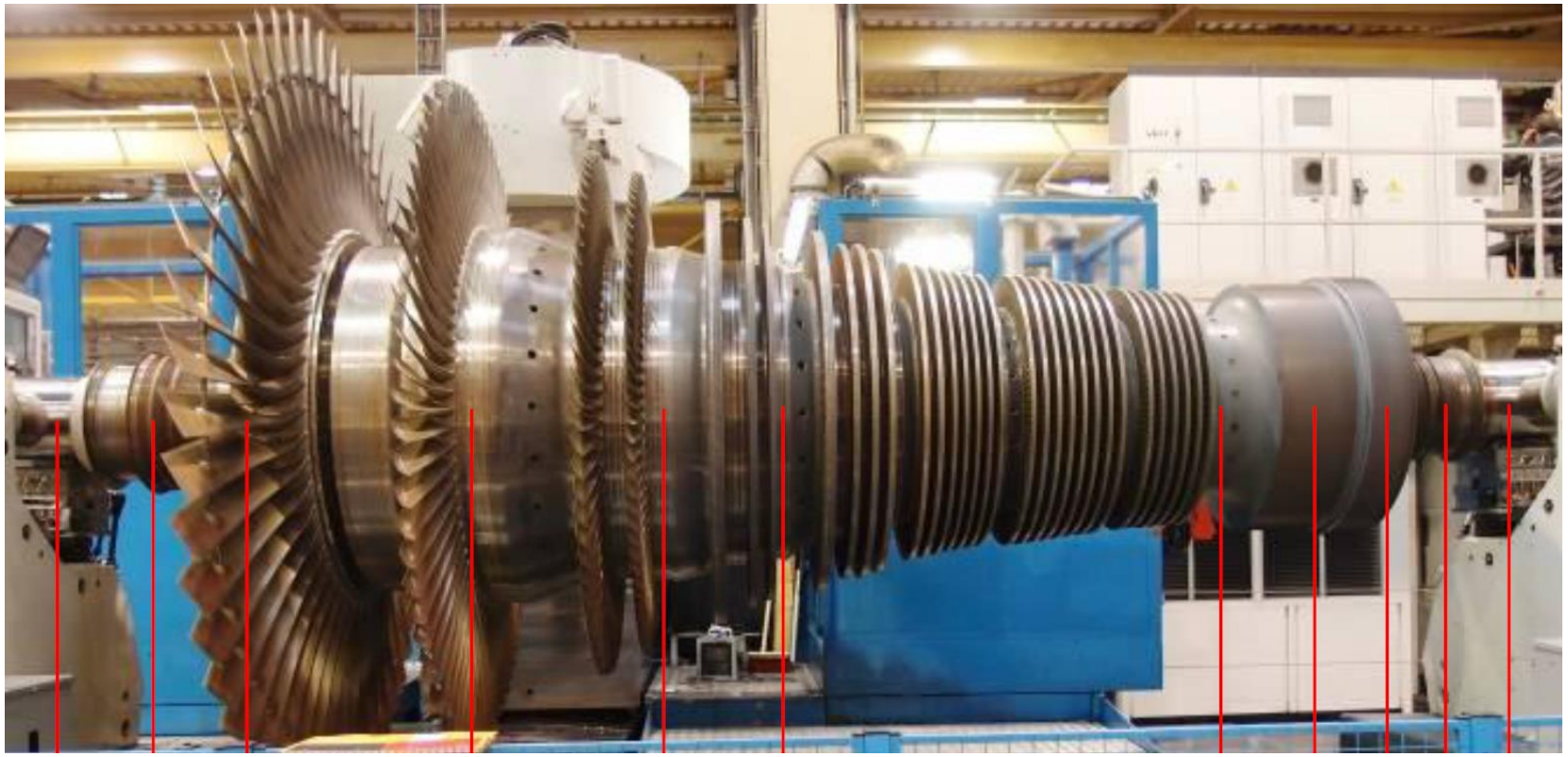
Event reported during commissioning:

„Due to problems with the water treatment the pH-value was too high leading to a rapid degradation (dissolution) of the aluminum swirlers. The system was cleaned and stainless steal swirlers were implemented.“

Residuals of Aluminum stayed in the system. They agglomerated in the affected stages, since the arising temperature of 300°C fits to a level change of the aluminum oxide.

Be careful!!!
This root cause analysis sounds correct for a mechanical engineer (with low knowledge of chemistry and materials).
There must not have been a problem with the pH-value during commissioning. It is generally not possible to adjust the pH-value correctly for aluminum and steal.
→ Design Issue

DAMAGED LOW PRESSURE STEAM TURBINE



Low Pressure Turbine

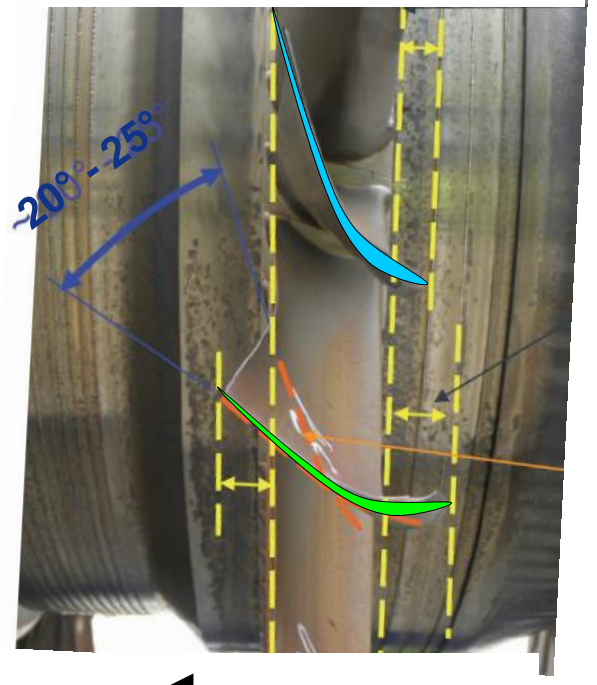
DAMAGE PATTERN

Bended and back-twisted blades (randomly distributed) at second final stage within low pressure turbine from hard contact with casing

rotational direction of turbine

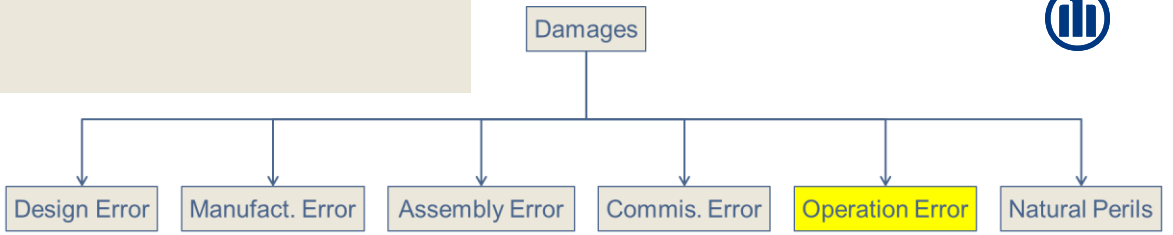
flow direction

White: un-damaged profile
Green: back-twisted profile
Blue: bended profile



flow direction

DAMAGE ROOT CAUSE

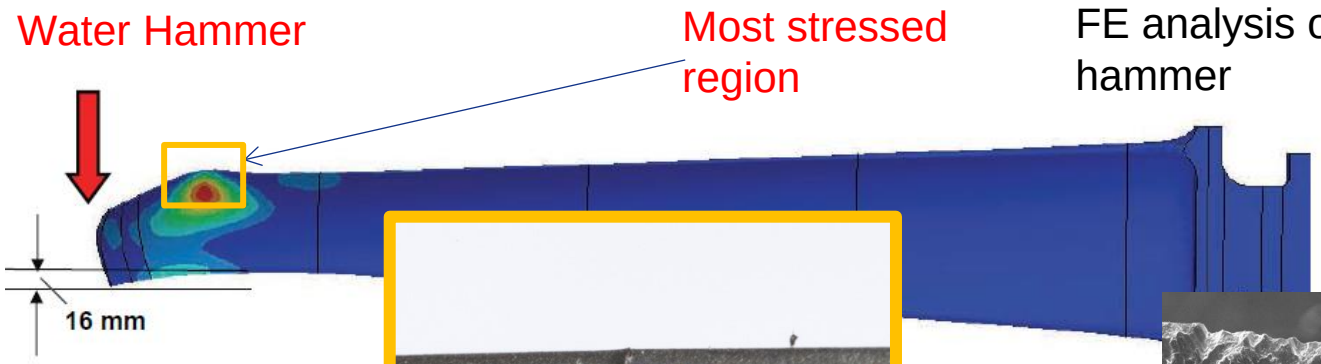


Water / (cool) steam hammer on the blades

The last steam extraction within the turbine was not correctly drained (manually).
→ Water hammer on the blades

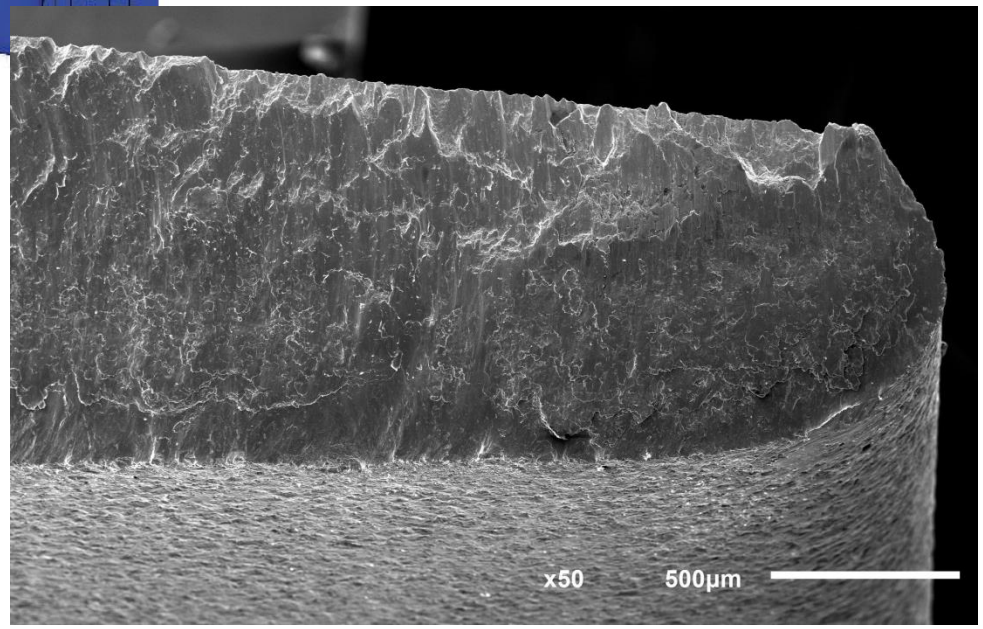
Lessons Learned:

A daily started steam turbine must be equipped with automatically operated valves for drainage!



FE analysis of a water hammer

Crack found at most stressed region



Opened up crack shows only signs of forced fracture

CONTENT

SUMMARY

Specific operation conditions in solar thermal power plants (low steam temperature, high temperature gradients) result in changed stresses of „well-established“ components such as steam turbines or heat exchangers. In combination with design weakness or manufacturing errors, this can lead to significant damages.

A learning curve has to be passed with „new“ components such as heliostats or parabolic troughs. Sub-contractors from another industry sector should be qualified appropriately.

My actual case ☺

THANKS A LOT FOR THE ATTENTION!

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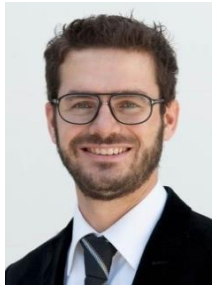

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