Measurement and analysis of piping vibrations in turbine feed-water systems

Vibrations in nuclear applications 2020

Energiforsk

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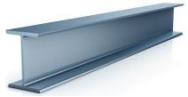
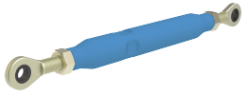
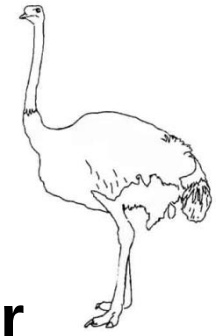
Damage in non-safety systems

Root-cause mainly vibrations

- Damage found often in non-safety systems in recent years (feed-water and re-heater systems in the turbine building)



- Supports (beams, struts and clamps) with damage (displacements, deformations, cracks, wear), loose nuts, broken bolts and loose anchor bolts detected during re-fuelling outages. No piping damage detected



- Root-cause assumed mostly to be vibrations. In some cases high loads due to steam- or water-hammers. Sometimes combinations of high loads and vibrations (initiation & propagation)


Damage in non-safety systems

Why more damage now?

- Some of these systems have had similar problems since licensing but the problems seem to have gotten worse in recent years. Damage history is very important and identifies areas with frequent damage
- The EPU (Extended Power Up-rate) 109%→129% plus life-time extension 40 → 60 years in 2009 seems to be the starting point for the higher damage frequency. Higher flow-rates probably lead to higher vibration amplitudes. New operation conditions and operation for a longer time
- The plant has been in operation for 35 years. The plant has "aged" since 1984

How do we know when loads occur?

By continuous monitoring

- Sometimes there is no clear or plausible event behind detected damage. Therefore in recent years we have installed accelerometers in areas where hard to explain damage has occurred
- Accelerometers are put onto supports instead of onto the piping directly (easier access). We thus measure the support's complicated response to the piping's excitation caused by a load-generating event
- We are only interested in <u>when</u> an event occurs and not the actual amplitude of the measurement
- With a given time we can search the available plant measurement data to identify events and investigate

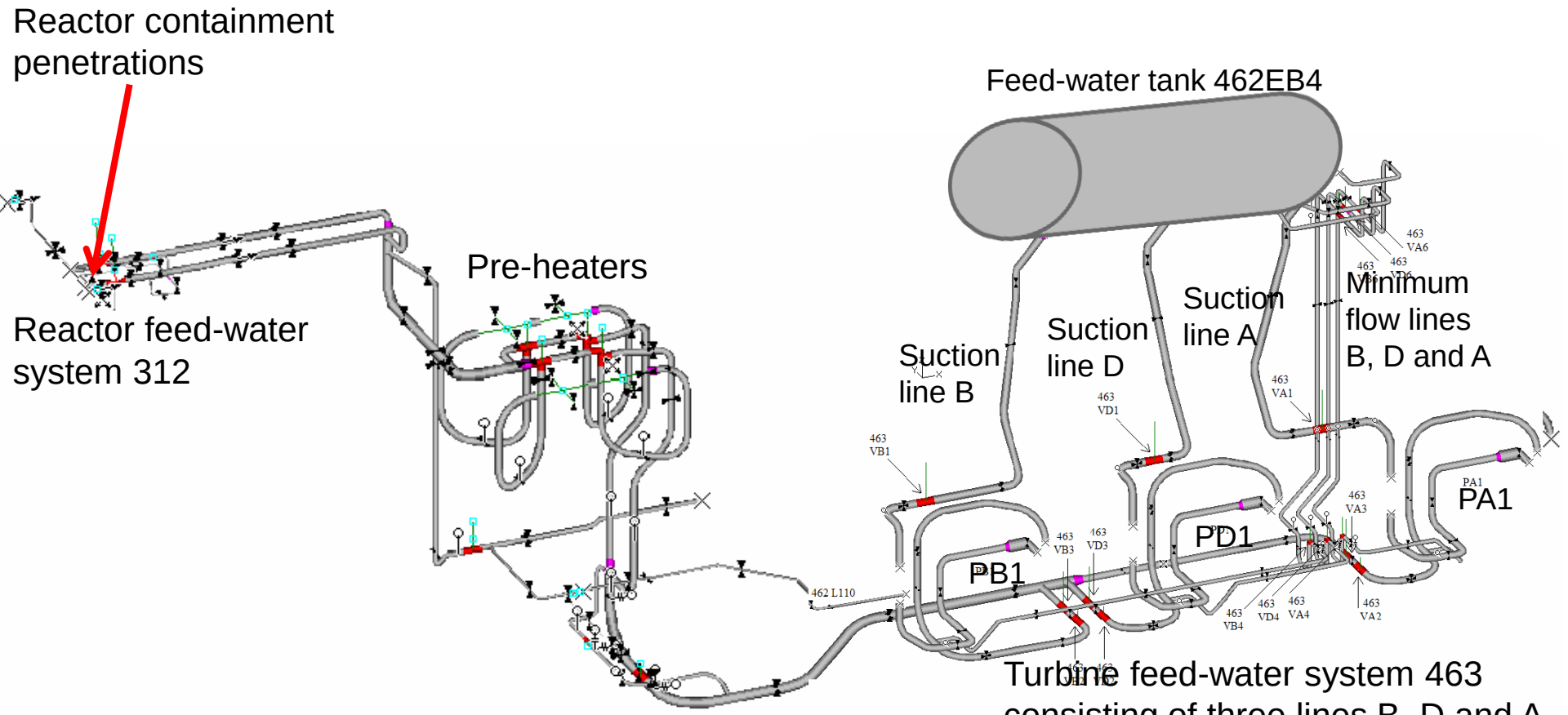
Analysis of measurement data

What will this give us?

- Helps us identify load-generating events
- Helps us identify operation states where vibration levels are higher than normal (for example at start-up, valve testing, shut-down, pump substitution, valve opening, etc)
- We can try to avoid load-generating events
- We can choose to avoid or limit time spent in operation states where higher vibration levels prevail

Focus on system 463

System 463 (The turbine's feed-water system)

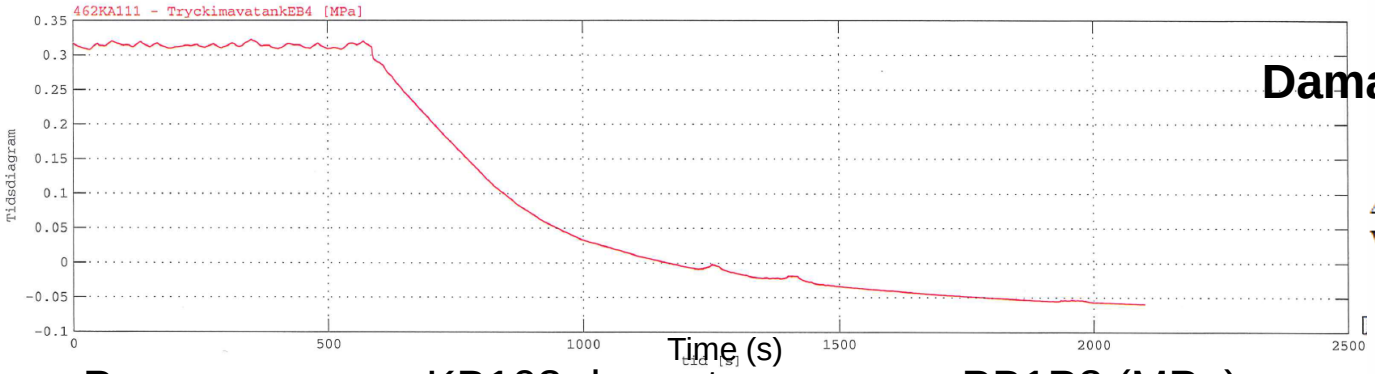


Focus on system 463

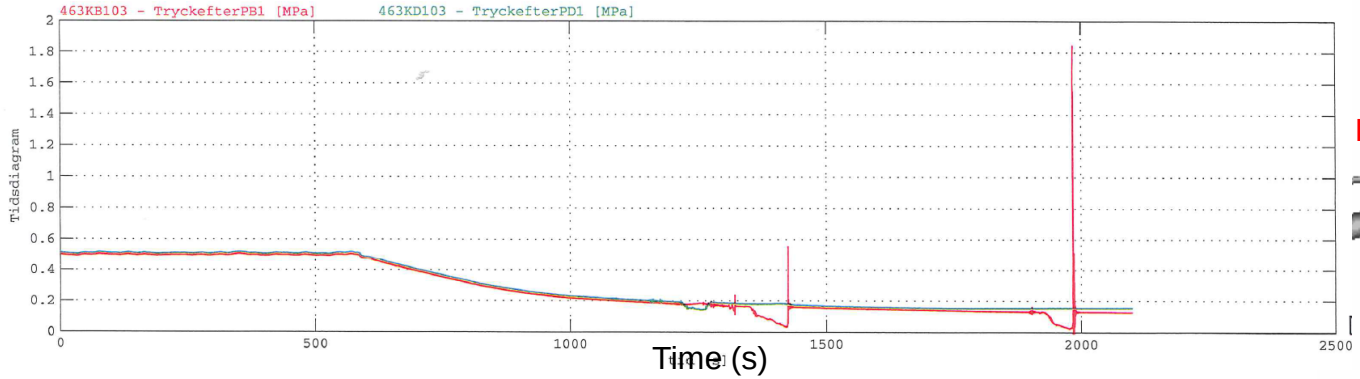
The load that until recently was denoted unknown load

Pressure in the feed-water tank and in loop B downstream PB1P2

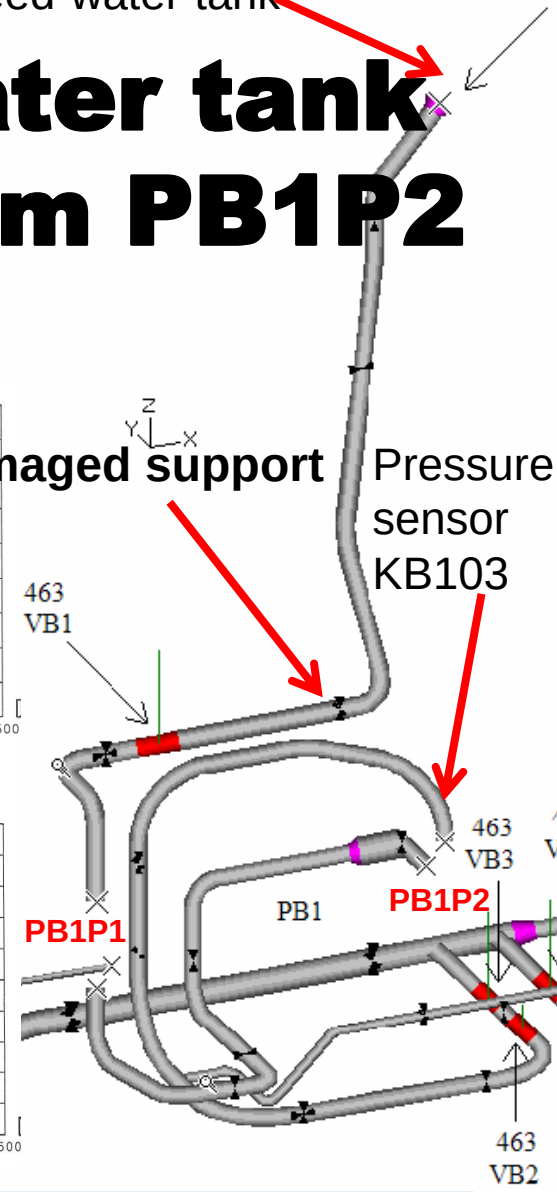
Pressure sensor KA111 in the feed-water tank (MPa)



Pressure sensor KB103 downstream pump PB1P2 (MPa)



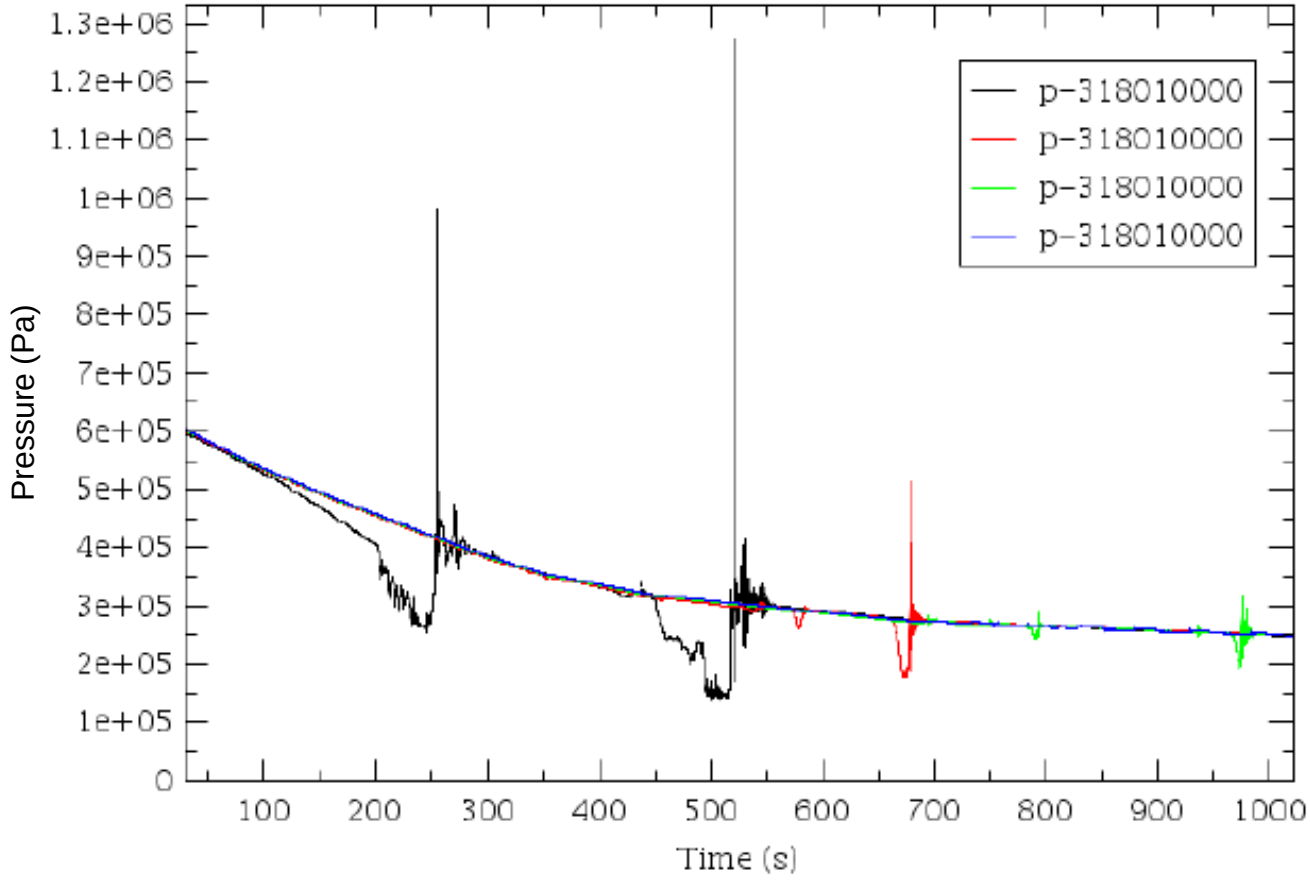
Pressure sensor KA111 in the feed-water tank



Loop temperature dependency

Initial temperature in the loop

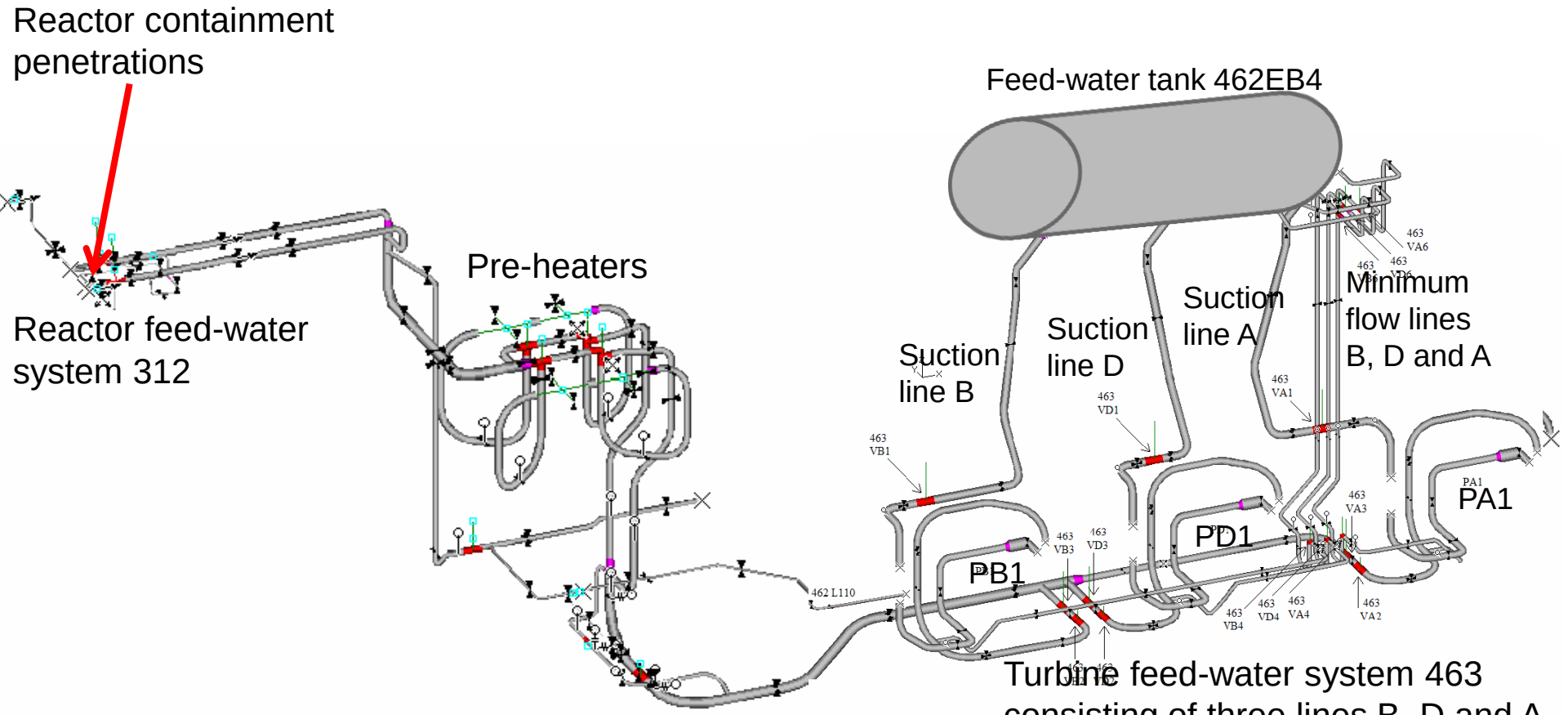
418 K (black)
390 K (red)
380 K (green)
370 K (blue)



Focus on system 463

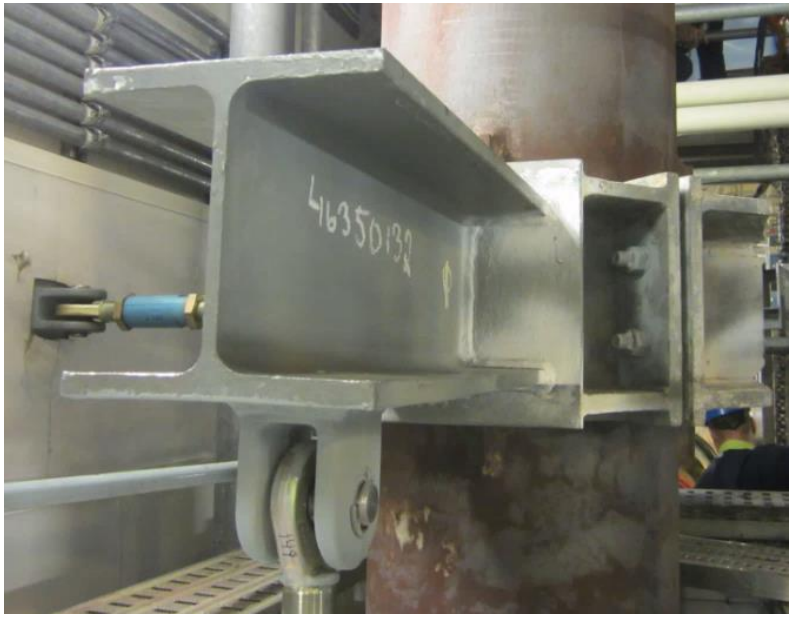
Restoring supports according to as-built drawings

System 463 (The turbine's feed-water system)



Large piping & large supports

Heavy and hard to handle



Applying the correct torque when tightening bolts and locking the nuts correctly

Keeping the piping in the correct position and aligning support clamps correctly (according to the drawings)

Experience from the feed-water system 463 in the turbine building

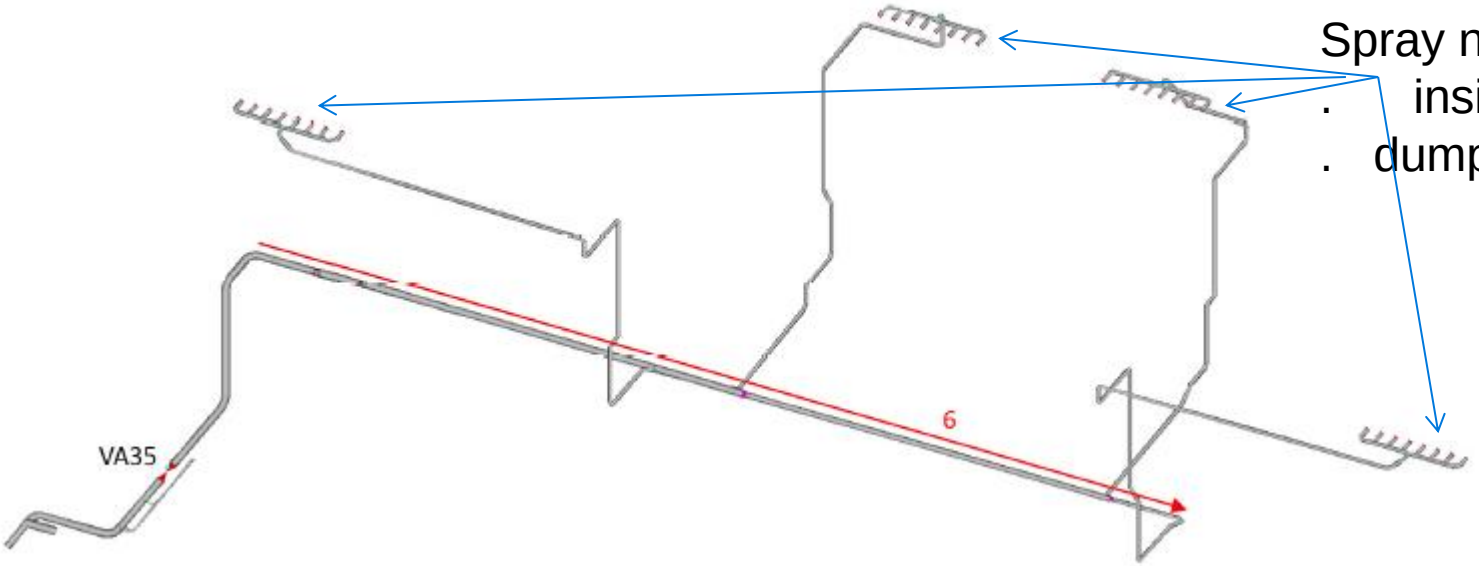
- Not knowing when damage occurs makes it harder to identify a load-generating event
- Not having sufficient information to identify a load-generating event. Information is either missing or has too low resolution
- Not having the whole history of damage of the supports in the system
- Not knowing the current “status” of the supports

Applying the methodology to damage in system 462

Findings in the condensate system 462 during the outage 2018

- Damaged supports were found
- Small bore piping was displaced in several places, some supports had loose expanders and one support was cracked
- The cause was said to be fatigue and displacements due to vibrations and water-hammers. No specific load was identified. More investigation was needed
- We installed accelerometers on the damaged supports and ran the plant for another cycle

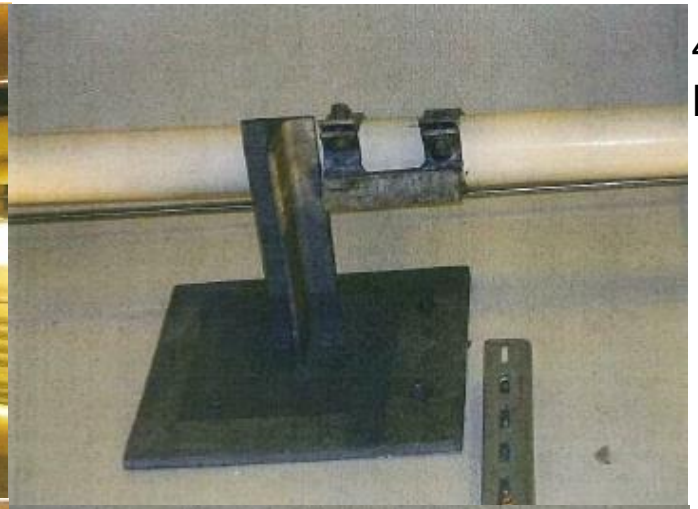
The piping leading to the dump-drums



The system is used to spray water into the dump drums to condensate steam that is dumped there from the steam-lines.

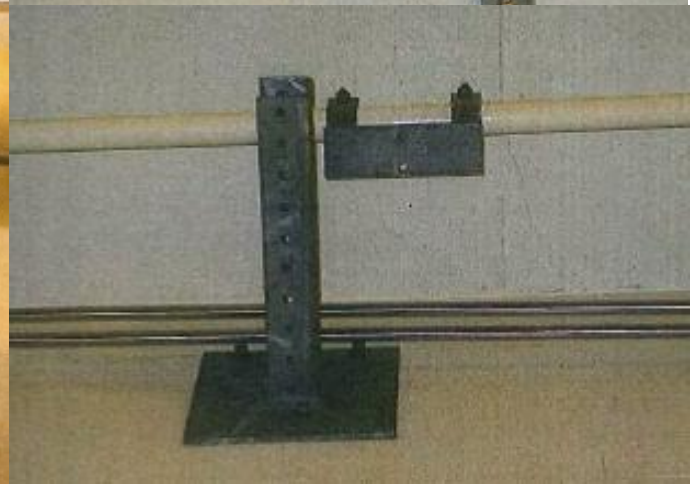
Examples of the damage found

462L63/U2
Vibrations
and
displacements
(loose
expanders)



462L151/U14
Displacement

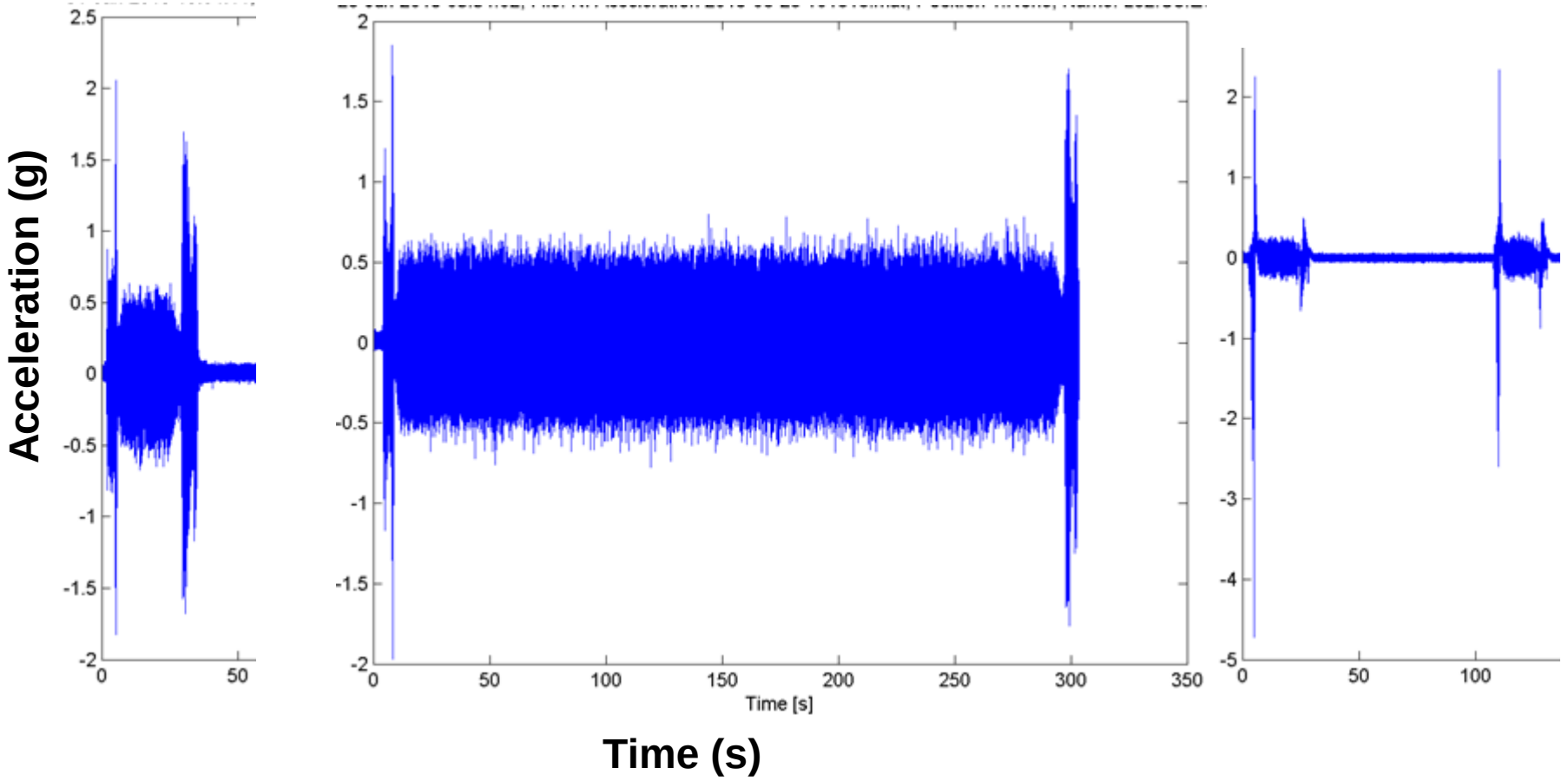
462L151/U5
Vibrations
(loose
expanders)



462L152/U1
Displacement

Measurement results

Accelerations on the supports



Measurement results

”Triggered” every Friday night

- The valve 462VA35 for cooling the dump-drums is opened and closed every Friday night according to DRUS
- According to the night shift’s instructions the valve must be opened and closed every Friday night to ensure its function

Load-generating events

For piping downstream 462VA35

- The fact that 462VB35 is manoeuvred on a weekly basis could be a load-generating event
- The valve opening takes 5 s and valve closing takes 10 s
- If the piping is filled with water when the valve is opened the loads will be small
- If the mass-flow is small through the valve when it closes the loads will be small
- Large loads will only occur if the piping down-stream the valve is gas-filled. This is when either system 473 is malfunctioning or when the pressure in the condenser is low for a longer period of time (when the plant is starting up or shutting down)

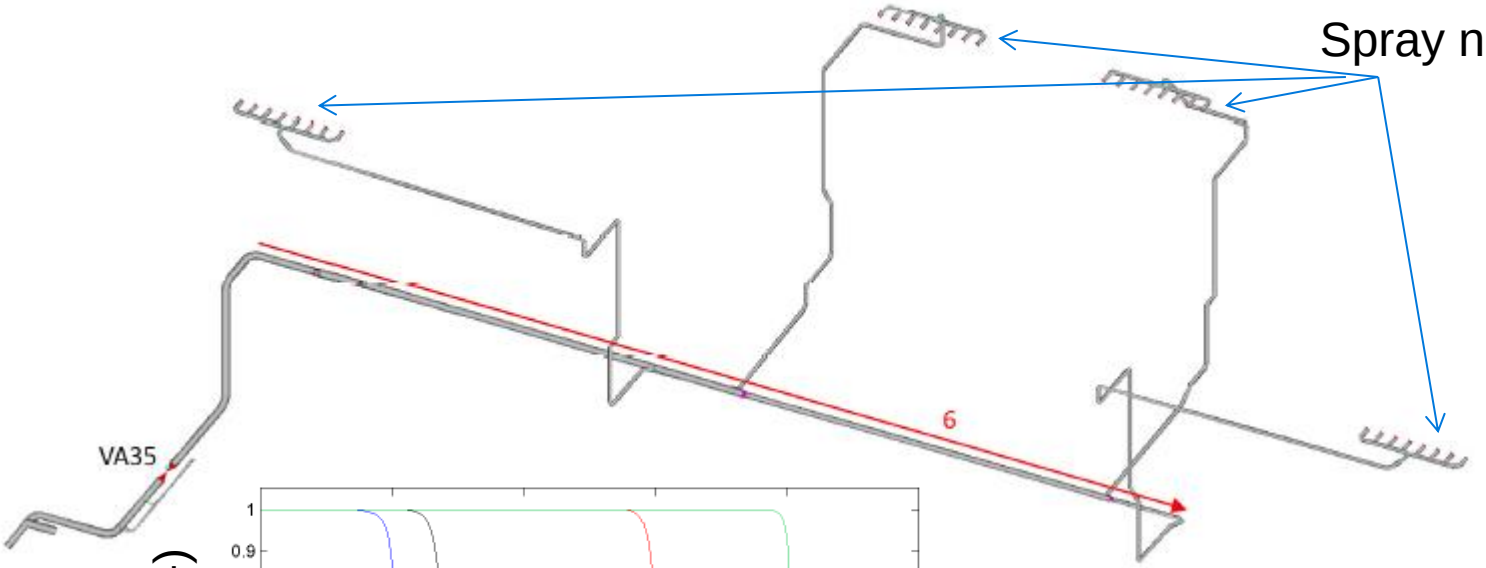
Determining forces in the piping

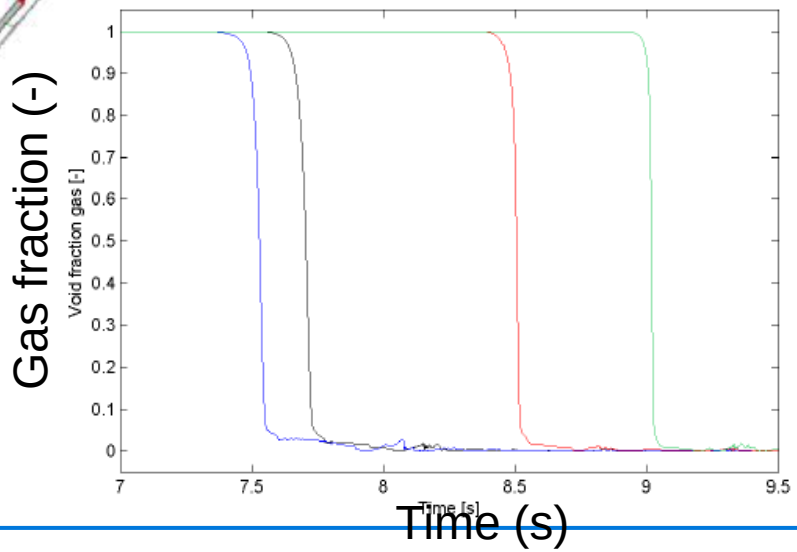
Forces caused by the manoeuvring of 462VA35

The following conclusions can be drawn:

- **No large forces at valve closure. No large forces at valve opening if the piping down-stream is water filled**
- **If the piping down-stream is assumed to be gas-filled then large forces occur when the accelerating water-front impacts the spray nozzles**
- **Variations of the latter case could explain the damage detected in the piping down-stream the valve 462VA35 (vibrations and displacements)**
- **The worst-case scenario that all the water in the piping has evaporated is not that likely. Less evaporation will give lower loads**

The piping leading to the dump-drums





The time when the gas has been pushed out of the piping via the nozzles. This is when the water front impacts the nozzles and causes loads

When is the piping gas filled? 1(2)

- When the plant is starting up or when it is shutting down the pressure in the condenser is low
- If the pressure in the dump-drums is low the saturation temperature will sometimes be lower that the condensate temperature which will cause evaporation at the nozzles and a gradual emptying of water in the piping

When is the piping gas filled? 2(2)

- At shut-down before the outage in 2018 462VA35 was opened/closed when the condenser pressure was roughly 1,2 kPa
- The temperature of the condensate was 13,5°C
- At 1,2 kPa the saturation temperature is 9,7°C
- It is probable that 462VA35 opened when some of the water in the piping had evaporated which caused the damage (vibrations & displacements)
- Work is on-going to avoid this scenario in the future

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Thank you for listening