Taking HDPE Pipes to the Limit

27 July 2017

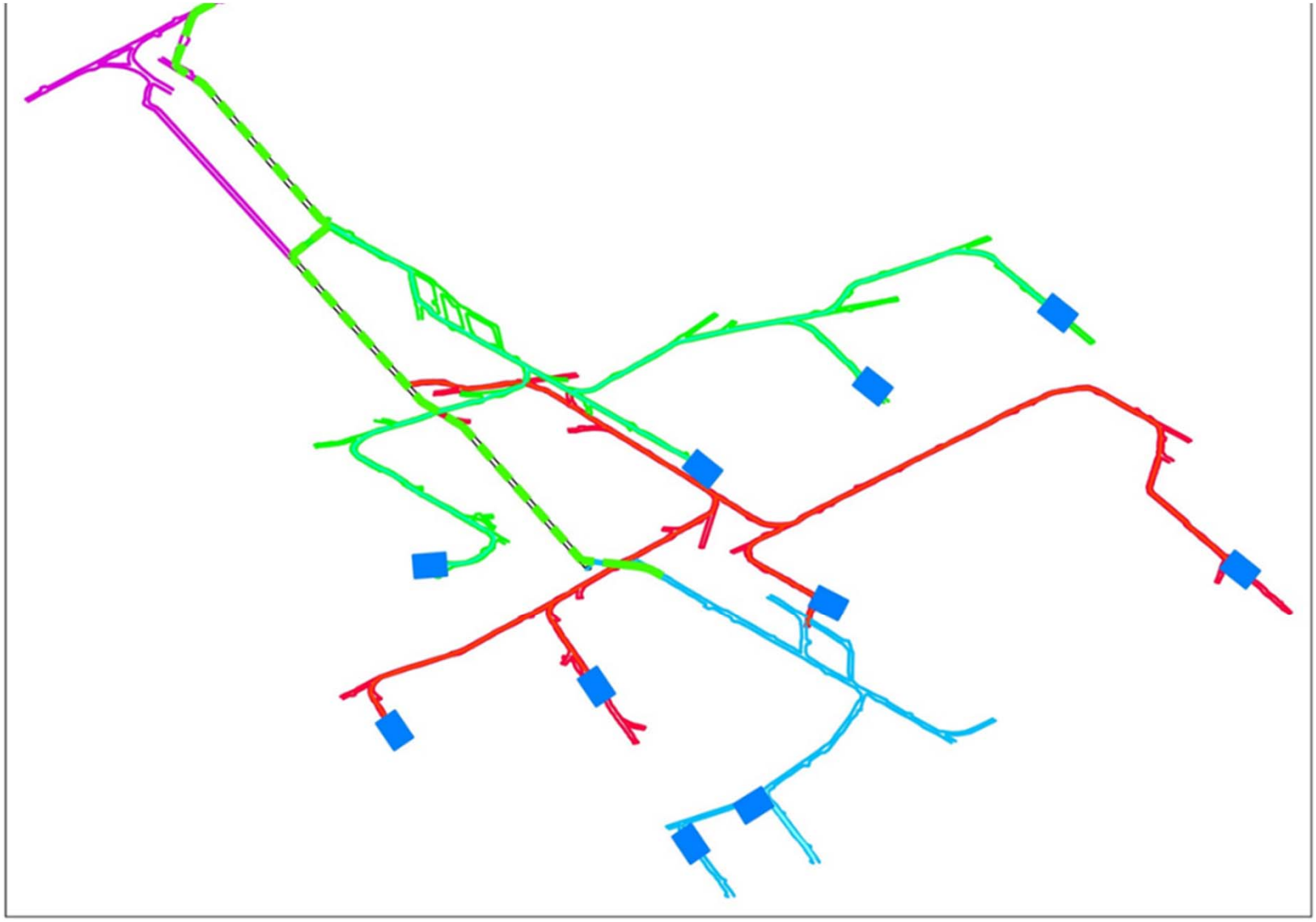
Summary

- Background to Project
- Layout
- Why HDPE was selected
- Couplings and Flanges
- Pressure
- Temperature
- Combination
- Site experiences

Background

- Energy Efficiency Project
  - Remote mining area
    - Ten cooling coils off an open-circuit water supply
  - Chilled water from surface refrigeration plant
    - Temperature of water arriving at cooling coils in the ‘teens
    - Cost of pumping 60 l/s back to surface from 3 000 m (2,4 MW)
- New Underground Plant
  - Positional efficiency – **colder** water, **closer** to coils
  - Closed circuit cooling coils
    - Low pumping costs – friction only, not static head

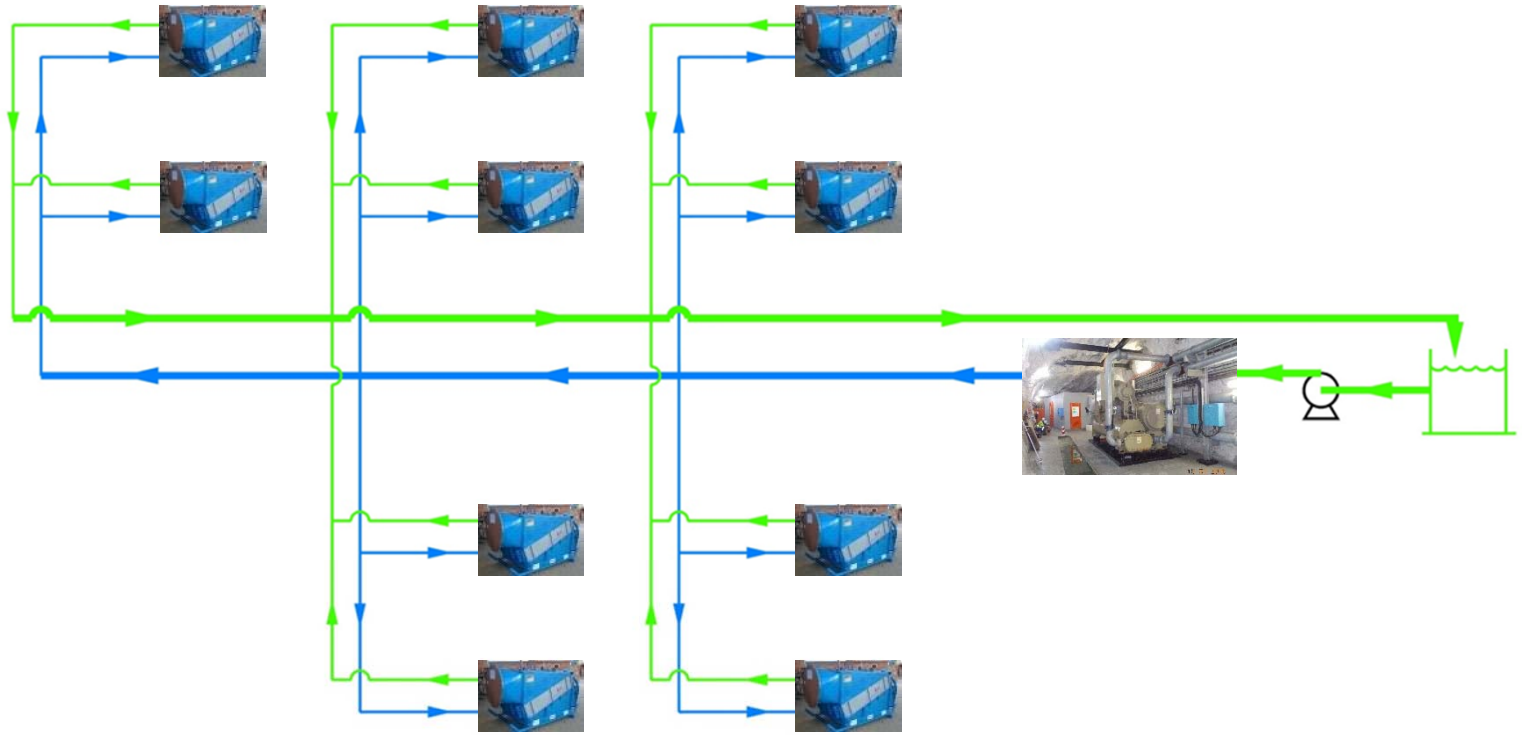
Layout – ten cooling coils over three levels



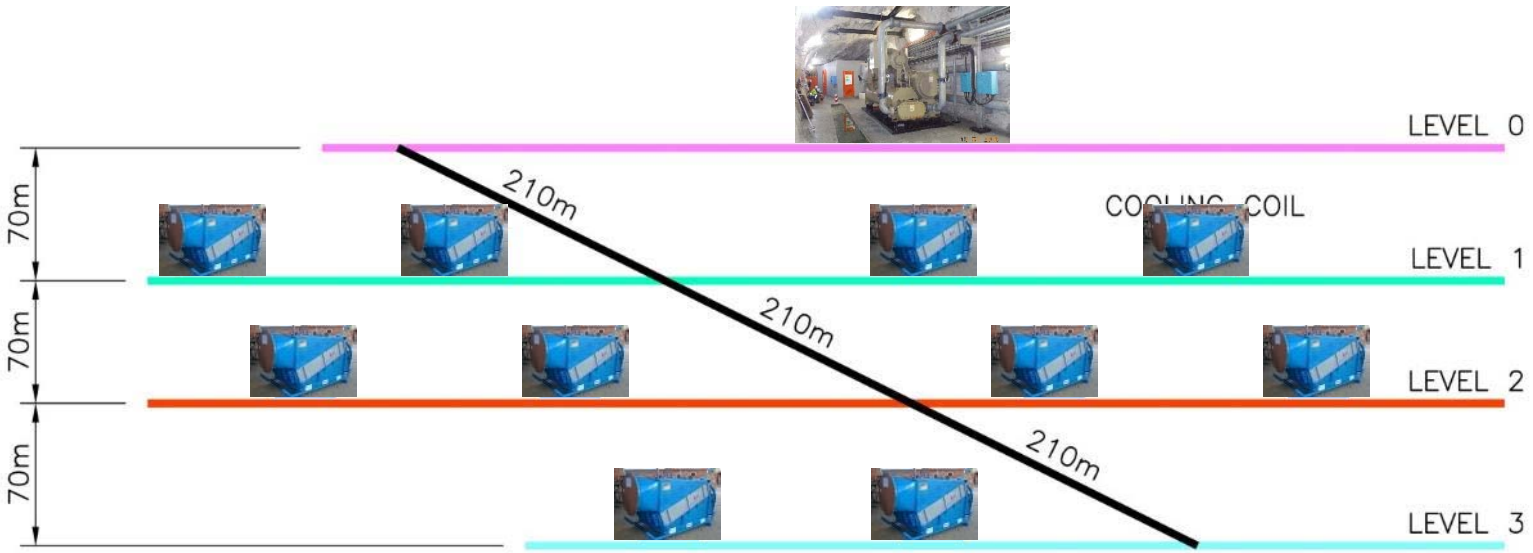
Layout

- New refrigeration plant
  - Remote mining area
- Cold water circulating pump
  - 60 l/s
  - 75 m head
    - 5m per refrigeration machine (three in series)
    - 21 m per cooling coil (in parallel)
- Cooling coils
  - Ten coils distributed over three levels
  - 6 l/s each
- Pipe work
  - Large diameter, low resistance spine
    - to assist even distribution throughout network

System Layout - hydraulically



System Layout - elevation



Why HDPE?

- HDPE Piping
  - Light weight, even at 25 bar (40 mm wall)
    - Bare pipe with flanges (excluding insulation and outer sleeve)
    - 200 mm NB (29 kg/m) vs steel (52 kg/m)
    - Safer handling
  - Corrosion resistance

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- HDPE Piping
  - Light weight, even at 25 bar (40 mm wall)
    - Bare pipe with stubs/flanges, no insulation , no sleeve
    - 200 mm NB (29 kg/m) vs steel (52 kg/m)
    - Safer handling
  - Corrosion resistance
  - Hydraulic properties
    - Lower resistance
  - Thermal properties
    - Assisted by thicker wall
    - 40 mm HDPE ~ 5 mm phenolic foam
  - Flexibility
    - Alignment tolerances
  - Not least – cost

HDPE Pipework

- Main spine
  - 200 NB
  - Maximum pressure on Level 3
    - 25 bar; 21 bar static plus 4 bar hydraulic
    - 280 OD with 40 mm wall
- Feed pipes on levels
  - 150 & 100 NB
- Crosscut to cooling coils
  - 100 NB & 75 NB

Local constraints and logistics

- Level 0 is halfway down a sub-vertical shaft
- Plant is located about 1,5 km from the station
- Limited access to intermediate levels
  - Level 1 – from Level 0
  - Level 2 – from Level 3
  - Level 3 is 2,0 km from station
- Pipe lengths
  - 6 m planned, but slinging proved time-consuming
  - So changed to 3m lengths to fit in cage
    - this doubled the future problem
- Unequipped raise for main spine

Installation – into bare mined raise

Installation – Level 0

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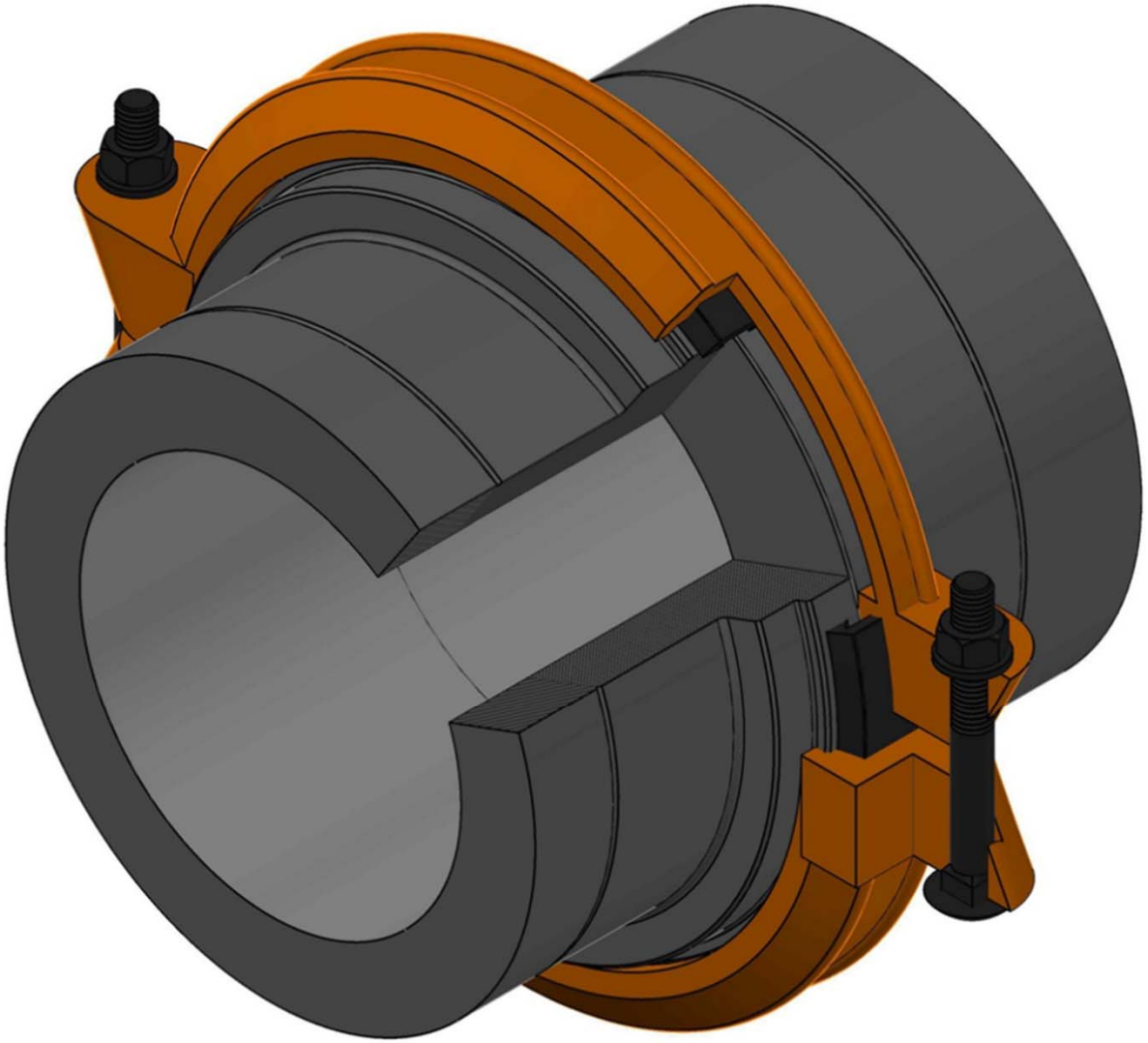


Installation – Level 1

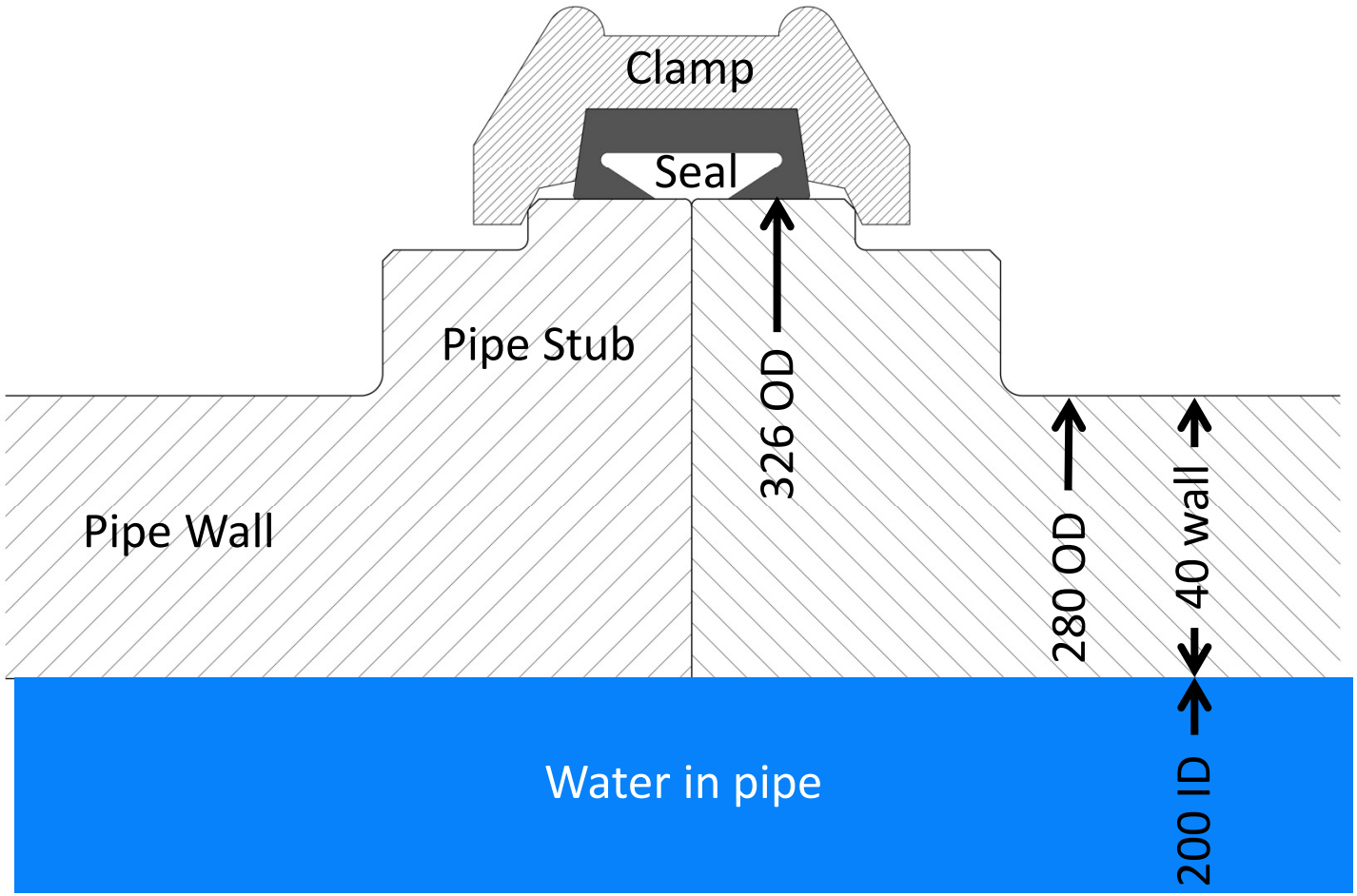
Early warnings

- On Level 0
- Low pressure
- Thermal effects become evident
  - Coefficient of expansion/contraction
- Initially, large diameter (200 NB) pipes
  - Constrained
  - Longer straights
- Later, smaller diameter pipes
  - Constrained

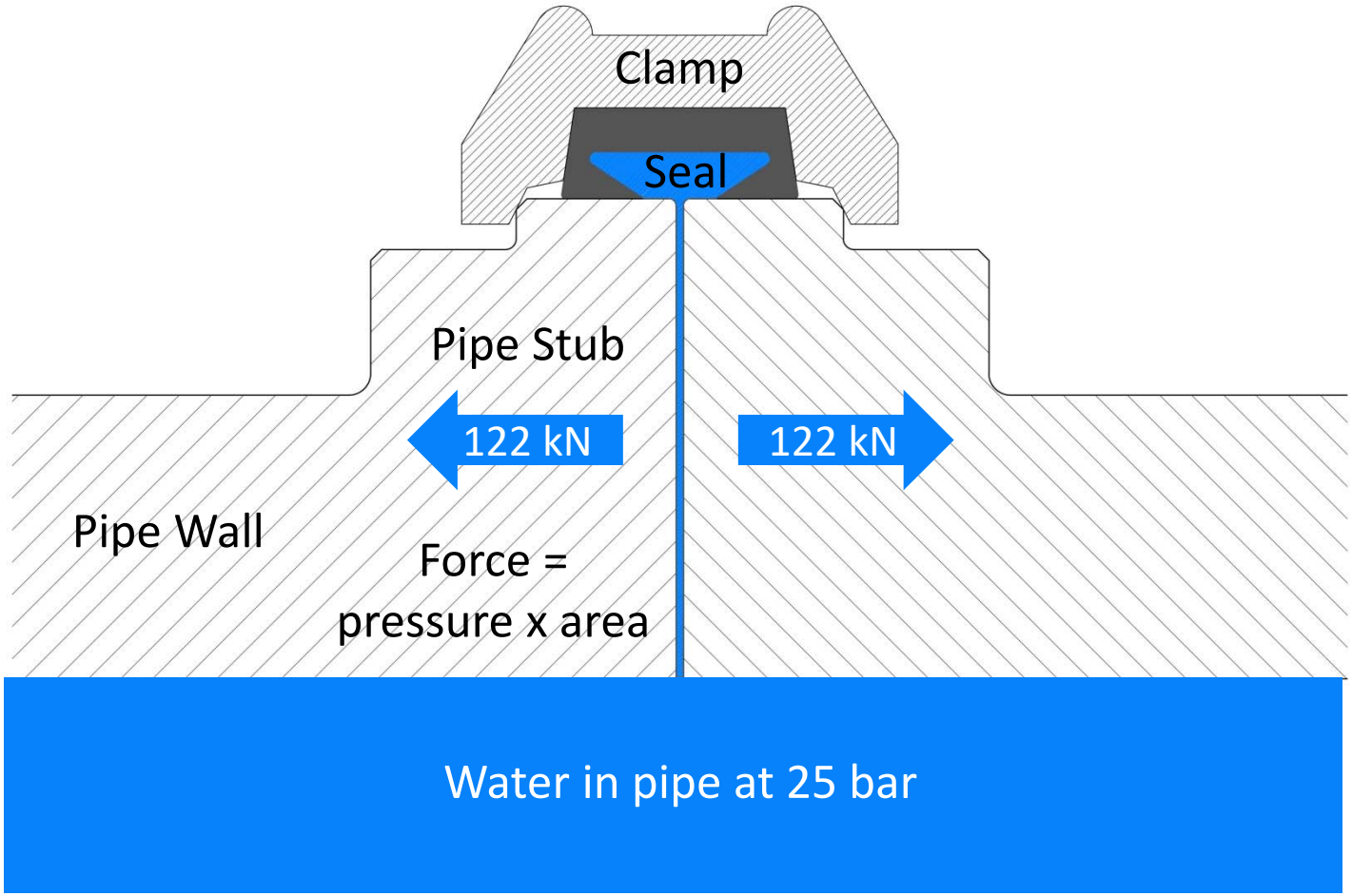
Early symptoms – Level 1

Early symptoms – Level 1

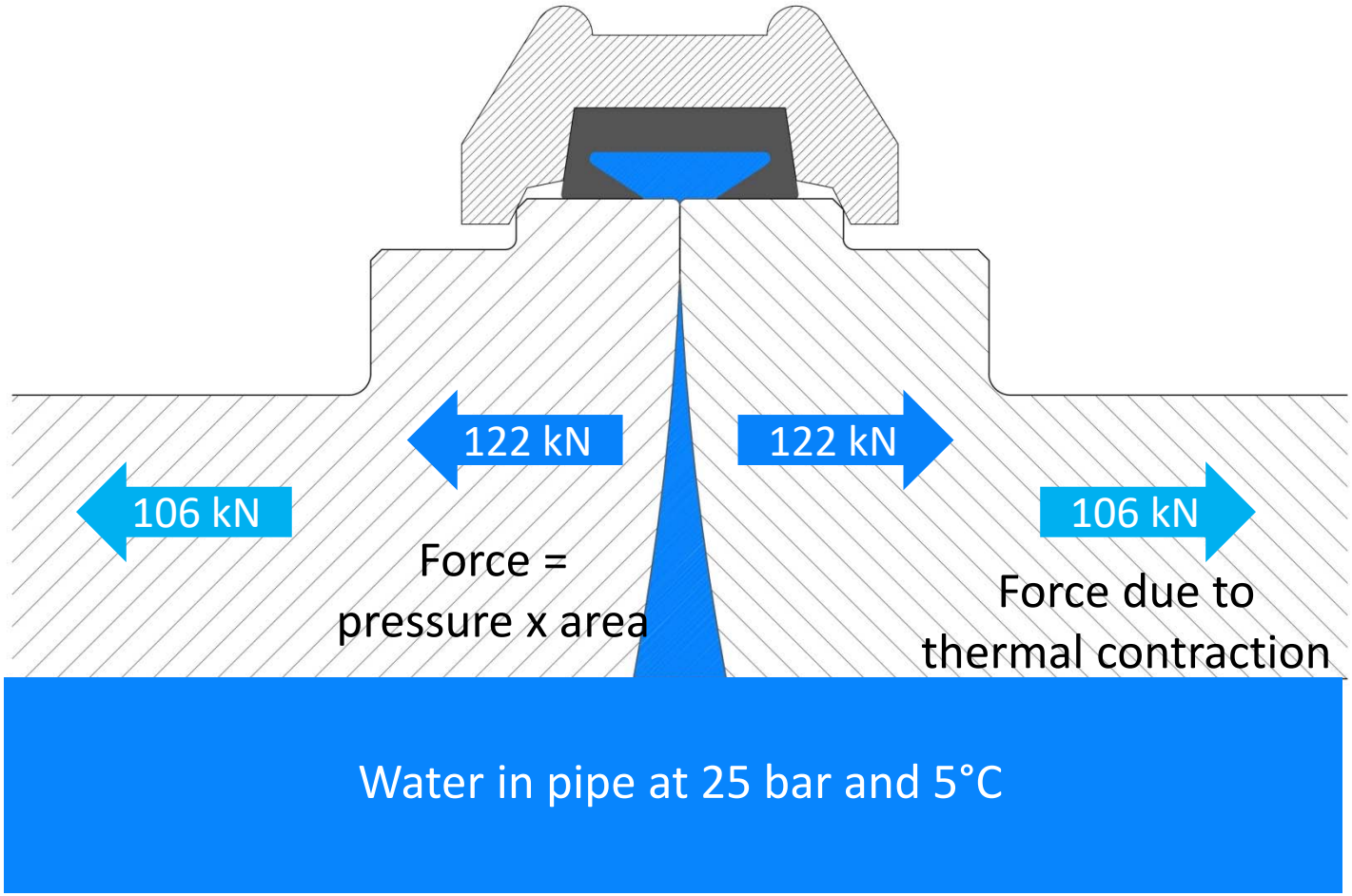
Clamp details



Coupling forces - hydraulic



Coupling forces – thermal tension



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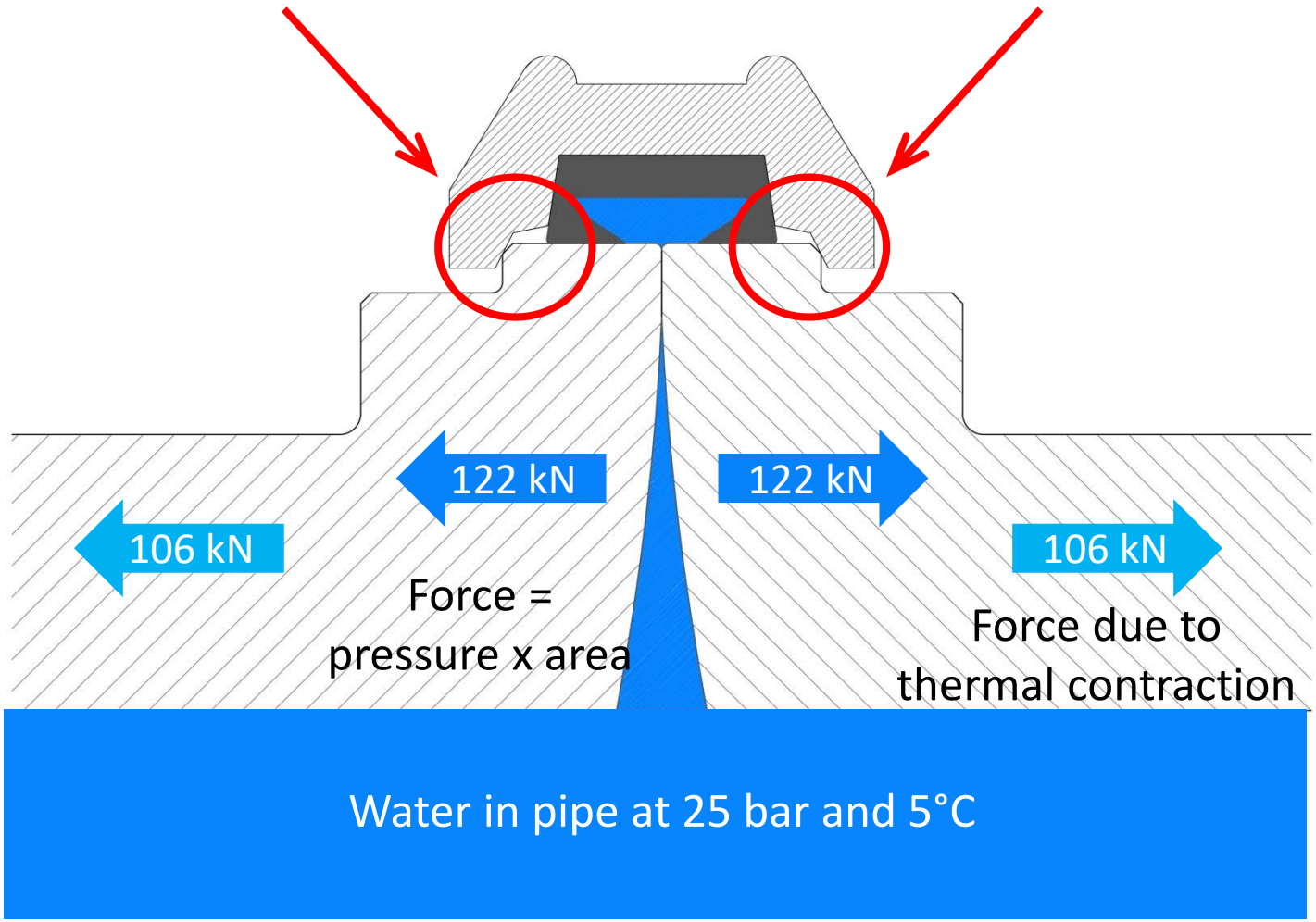
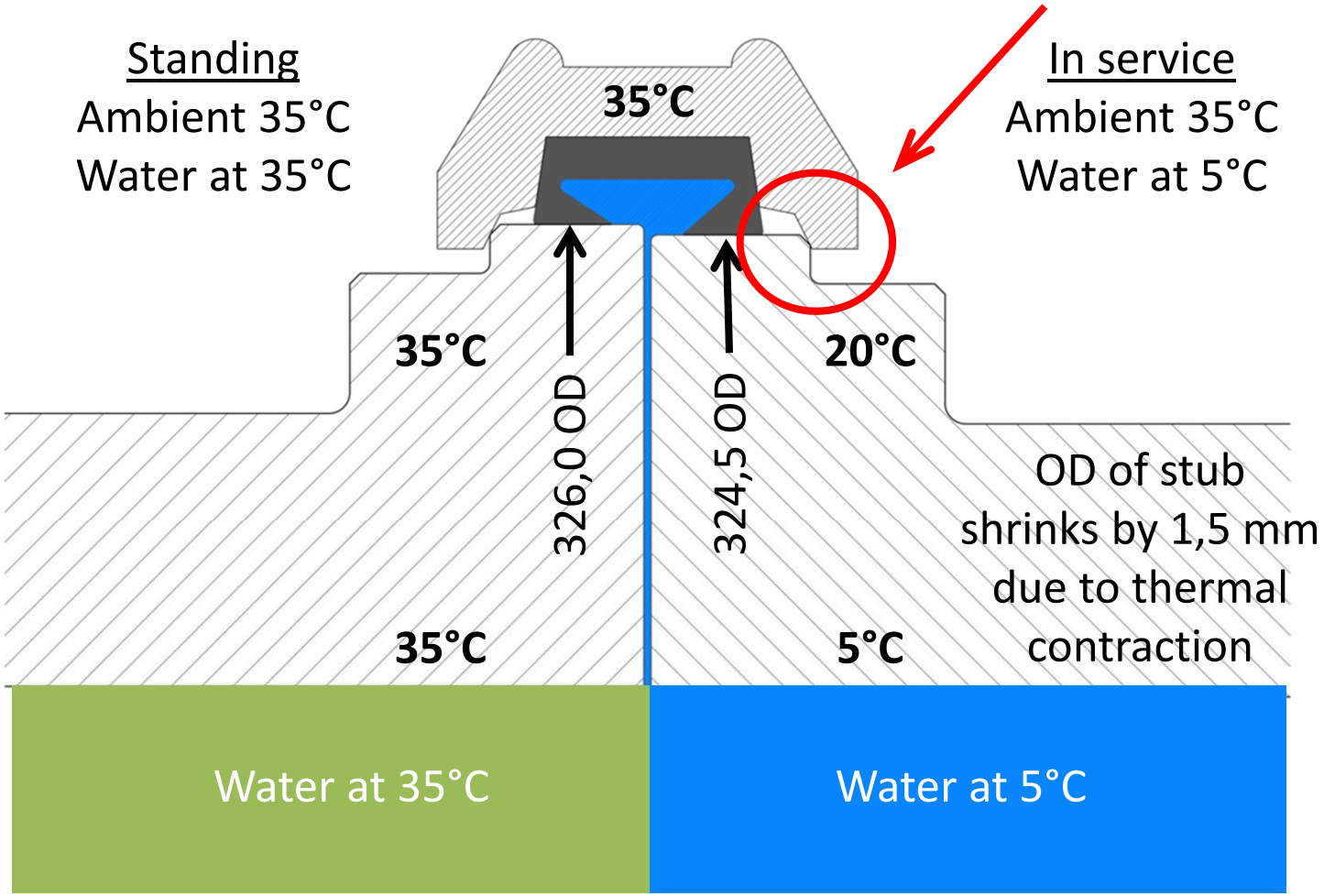


Coupling behaviour – thermal contraction

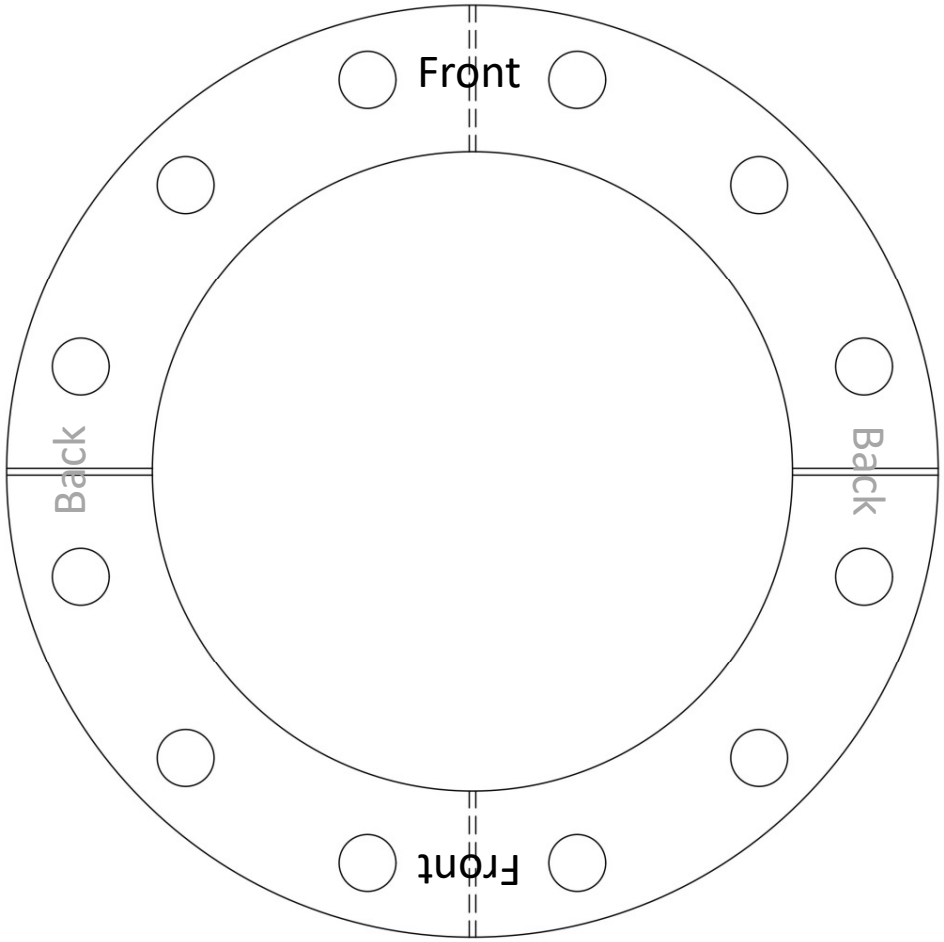


Replace couplings on large diameter pipes

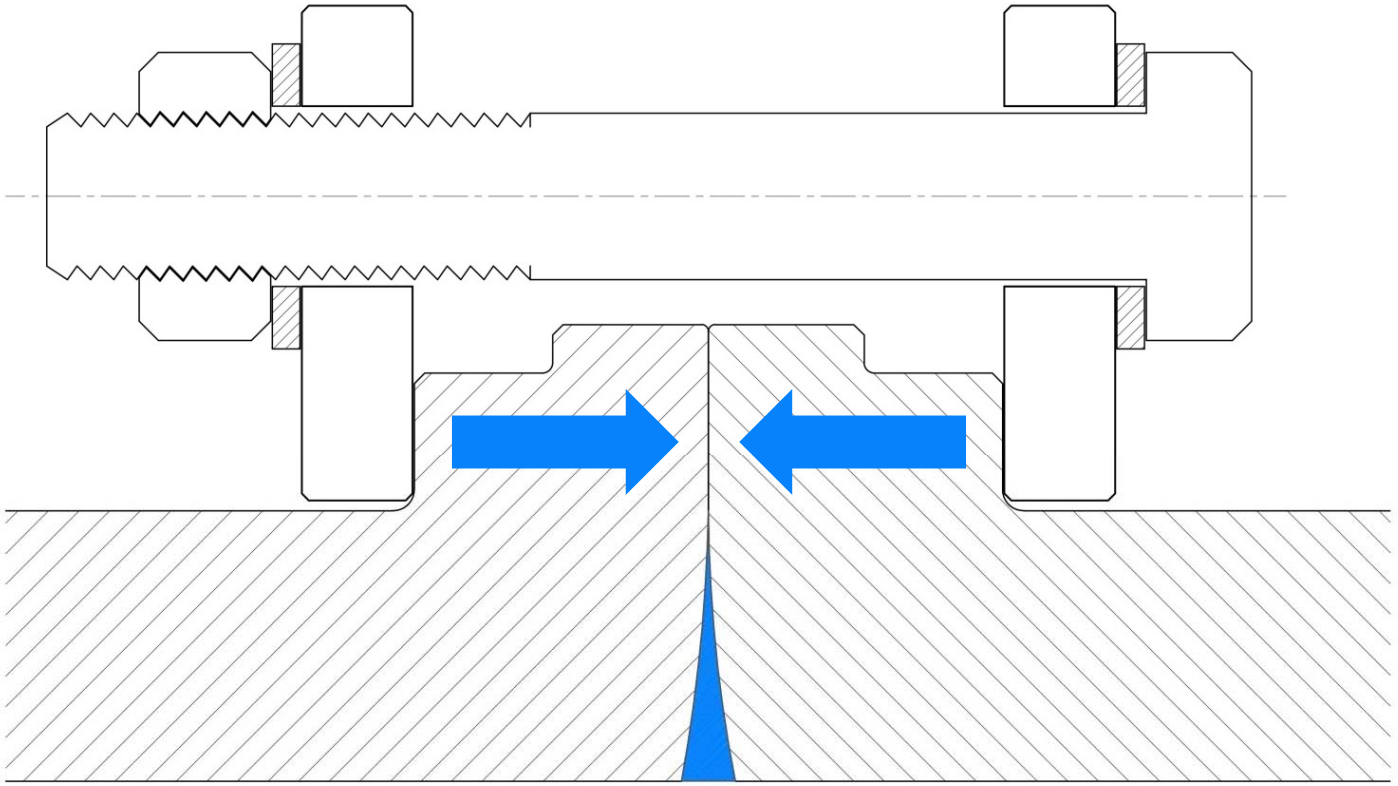
- Thermal cycling of HDPE fittings
- Plastic behaviour
  - Possible deformation of stubs
  - Slowly, over a period of time
- Limited options using existing stubs
  - Flanges
- Flanges
  - Pipes already installed with stubs and in situ
  - Need split flanges
  - Beware of ID to avoid bead from welding of HDPE

Split flanges – in situ

Split flanges – configuration – 12-hole flanges

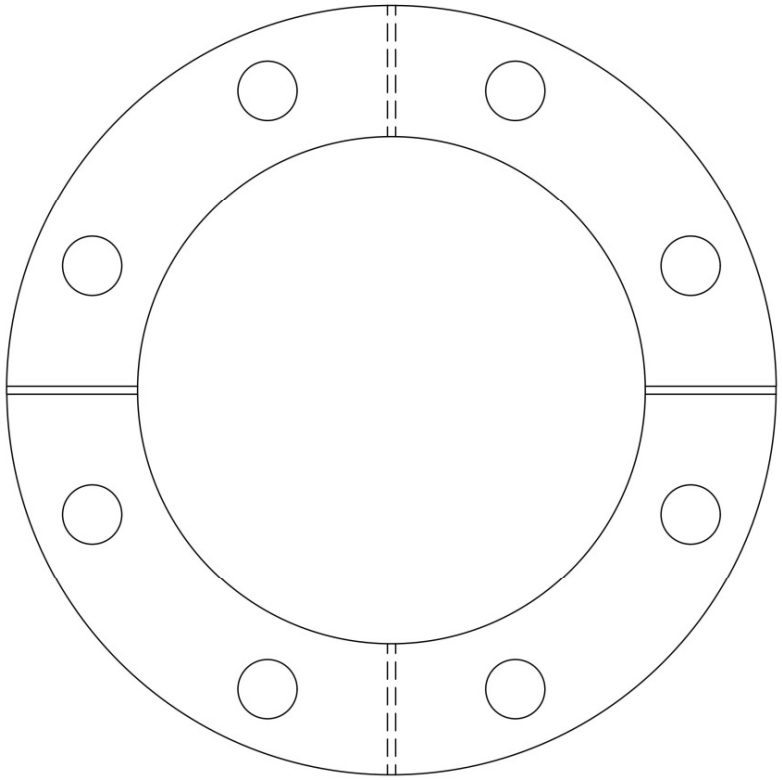


Split flanges – cross-sectional area

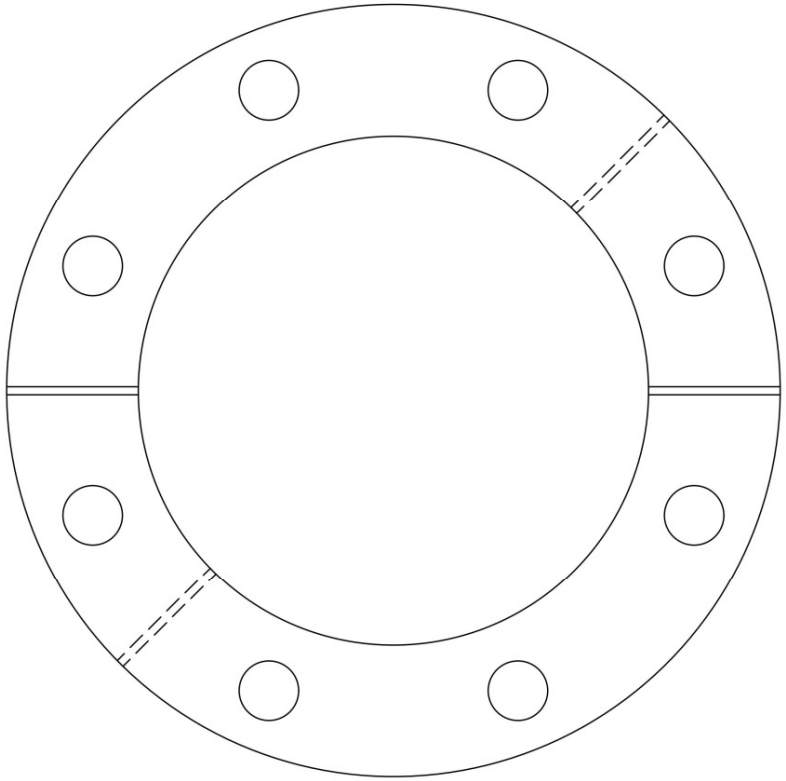


Further distractions

Split flange on 8-hole flanges



Split flange on 8-hole flanges



Compound split flanges for 8-hole flanges

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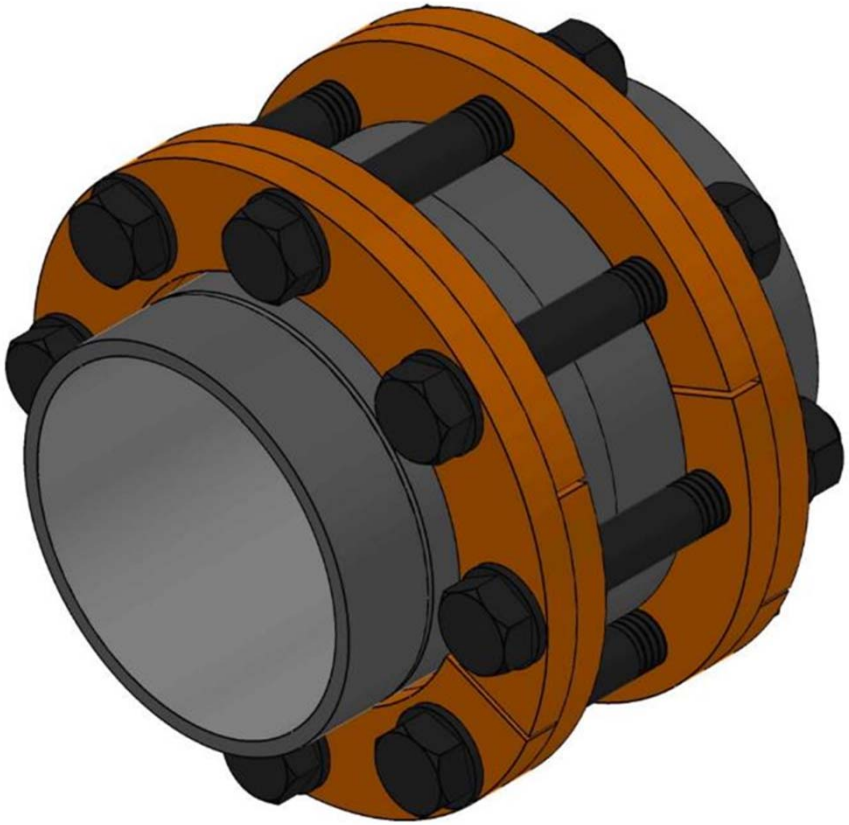
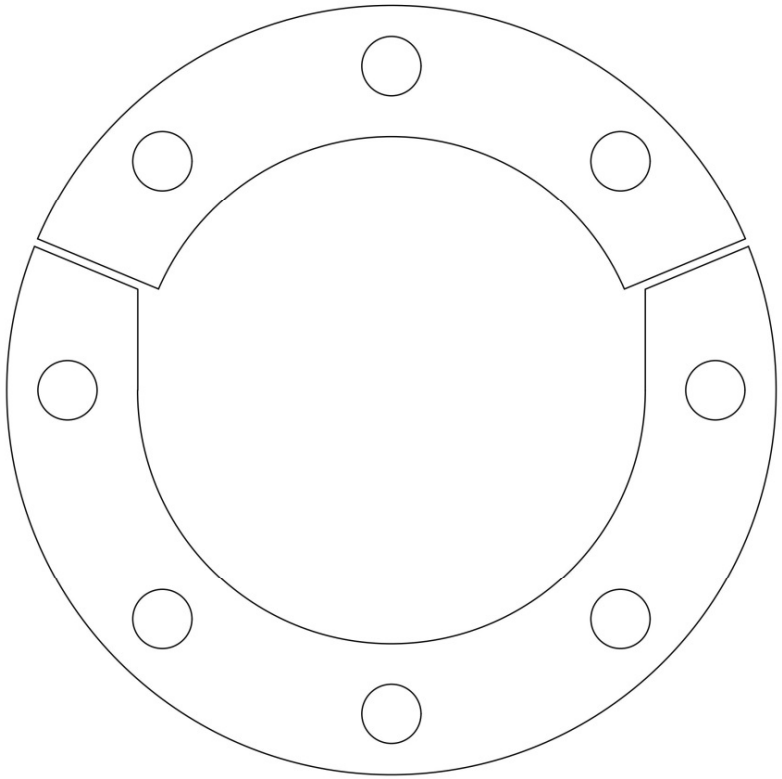


Offset split flange for 8-hole flanges



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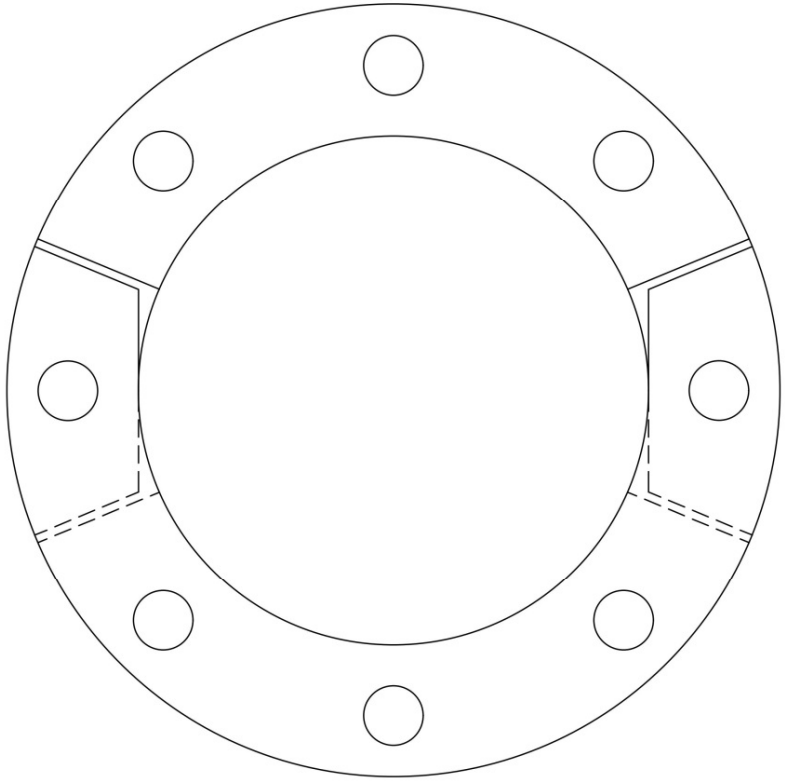
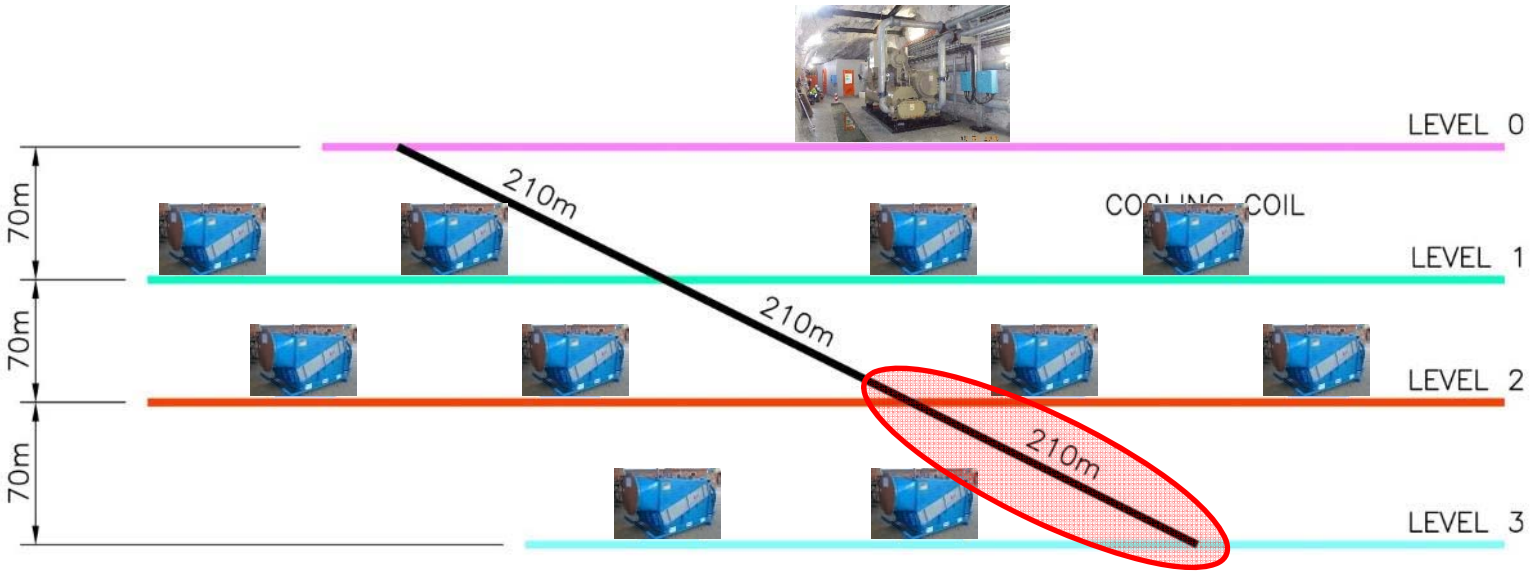


Extend system to Level 3



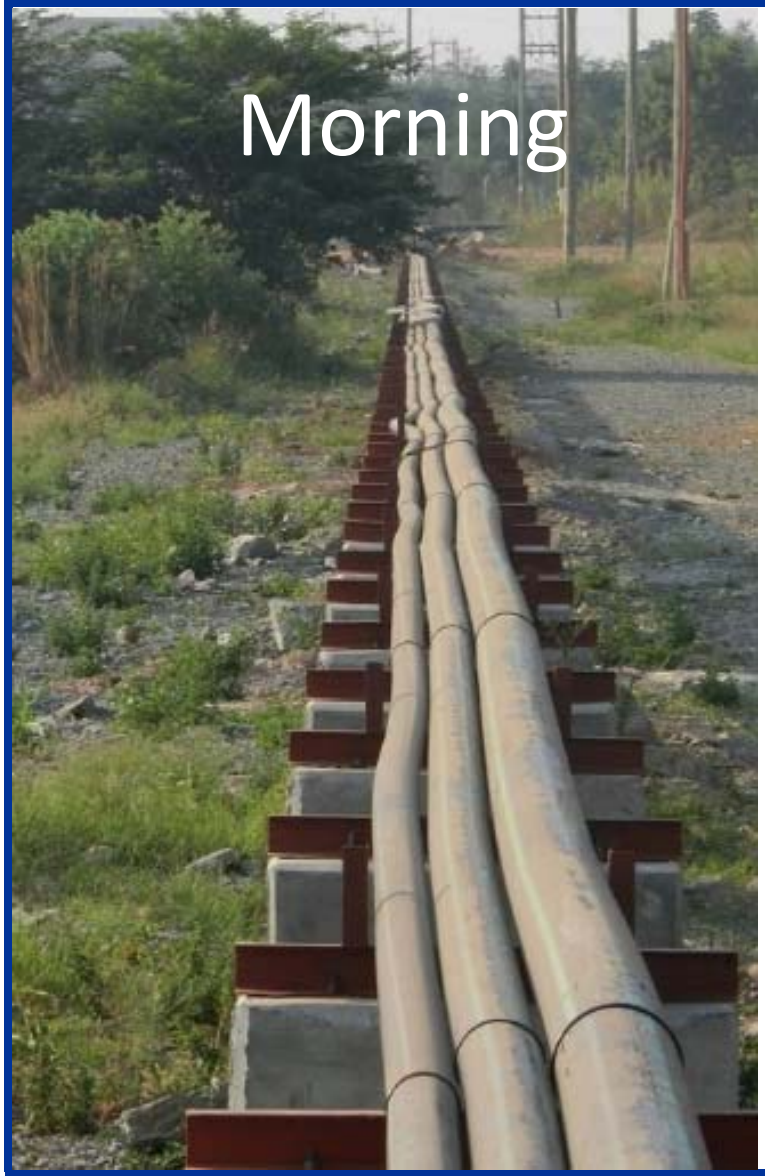
Extend spine from Level 2 to Level 3

Thermal Creep

- Quick diversion
- General rules
  - provide some degree of flexibility
  - minimal anchoring
- Total freedom of movement
  - can have disastrous consequences
- Thermal creep due to
  - daily temperature cycles
  - on a slight downhill slope

Thermal creep - consequences

Thermal creep - causes



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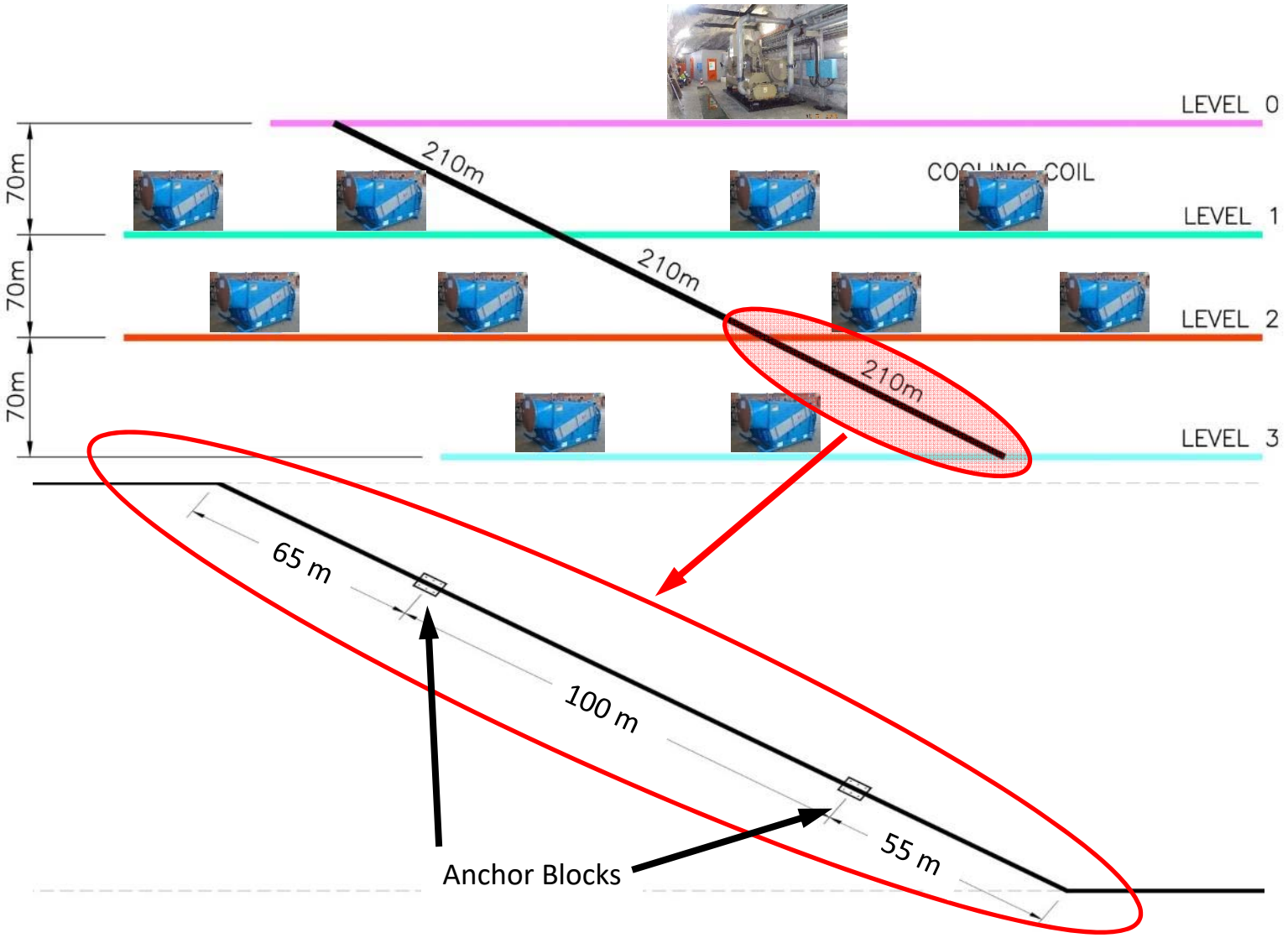


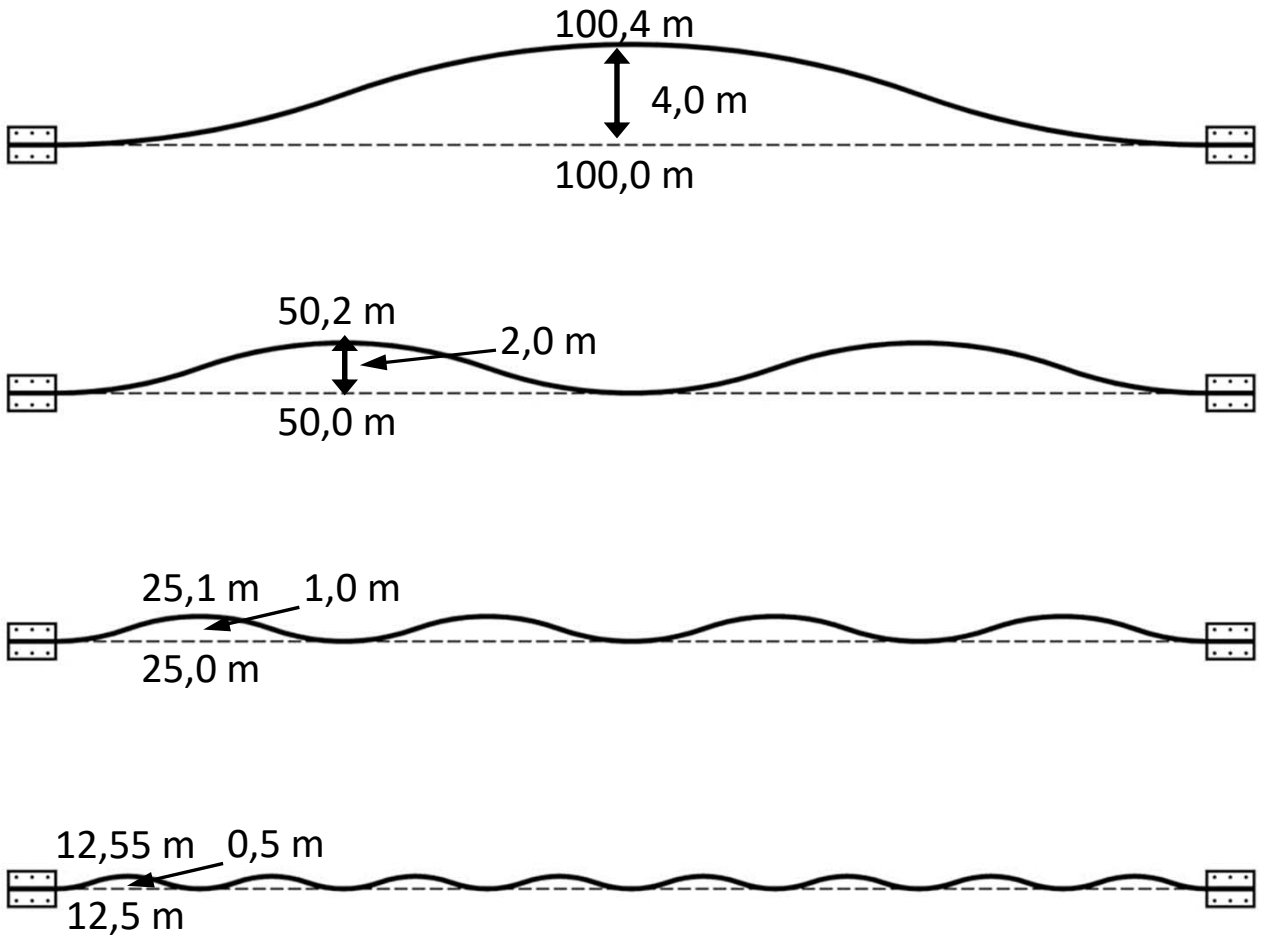
Anchor block in raise

The enemy raises it head again!

Install hot – run cold – rather not

- Most of us used to working with thermal expansion
  - Loops on long compressed air pipe runs
  - Expansion bellows
  - Compressive forces in pipework and couplings
- Thermal contraction
  - Introduces tension into pipework and couplings
  - Need to provide additional length
  - Aggravated by HDPE's high coefficient of expansion
- Ideally
  - Install in cold running condition
  - Allow for expansion during 'off-period'
  - Problem becomes compression rather than tension

Deflection required for expansion/contraction

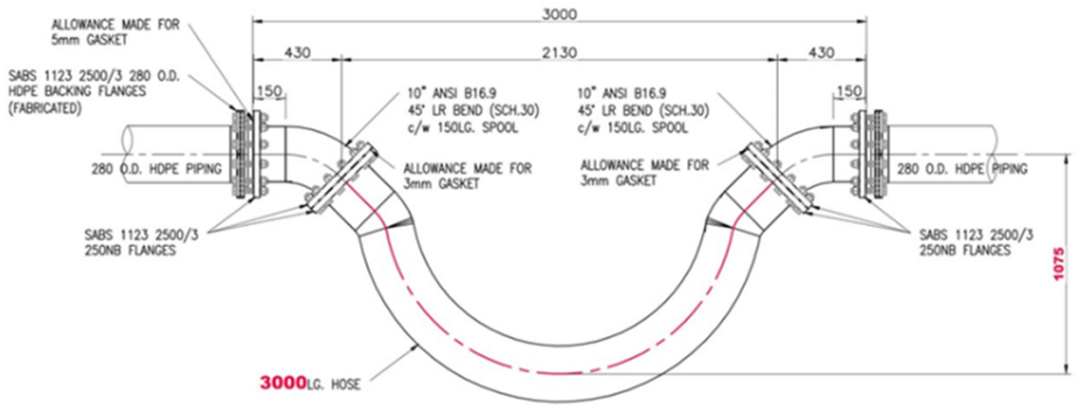


Sometimes bad can be good?

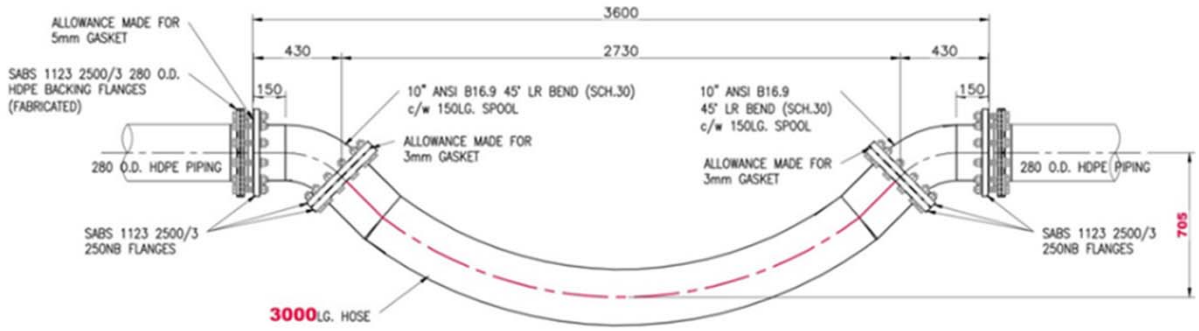
Expansion/contraction devices (25 bar)

- Movement required
  - 400mm (20°C over 100 m)
  - Some slack may be visible, but less useful than you think
- Aspects of the site
  - Difficult access – up from Level 3
  - Installed at an inclination of 20° to horizontal
- Options
  - Bellows
    - Limited travel, need supporting on both sides
  - Telescopic
    - Heavy, expensive, maintenance, inclination
  - Flexible hoses
    - Radius of curvature – stiff at high pressure

Radius of curvature – too much for one 3 m hose

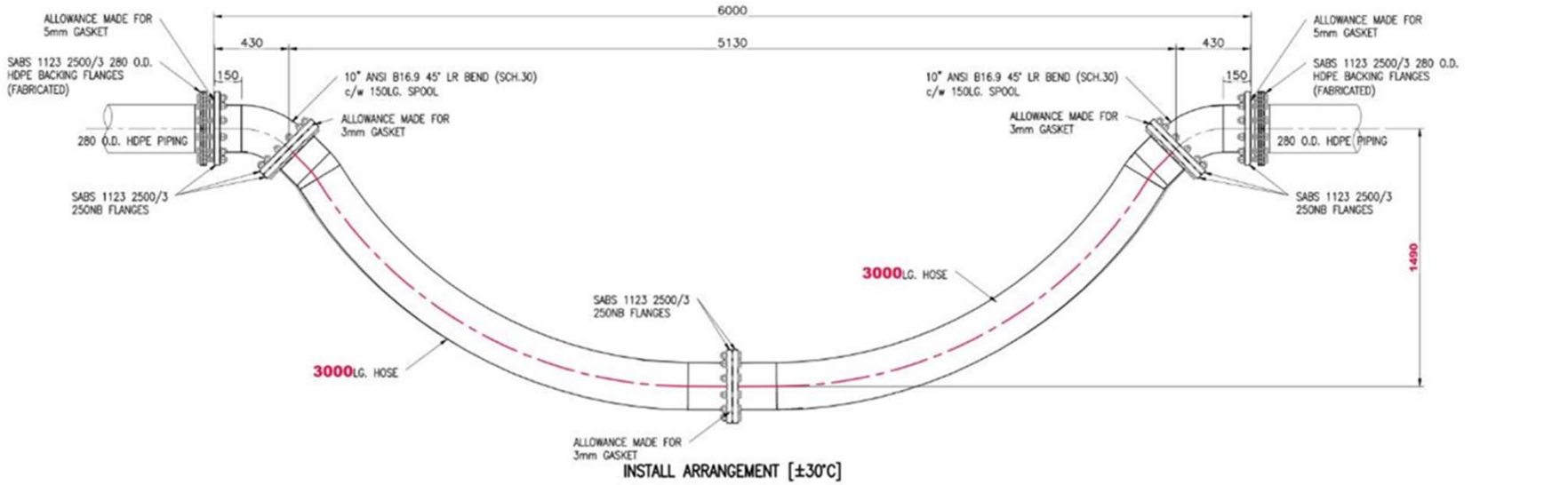


INSTALL ARRANGEMENT [±30°C]

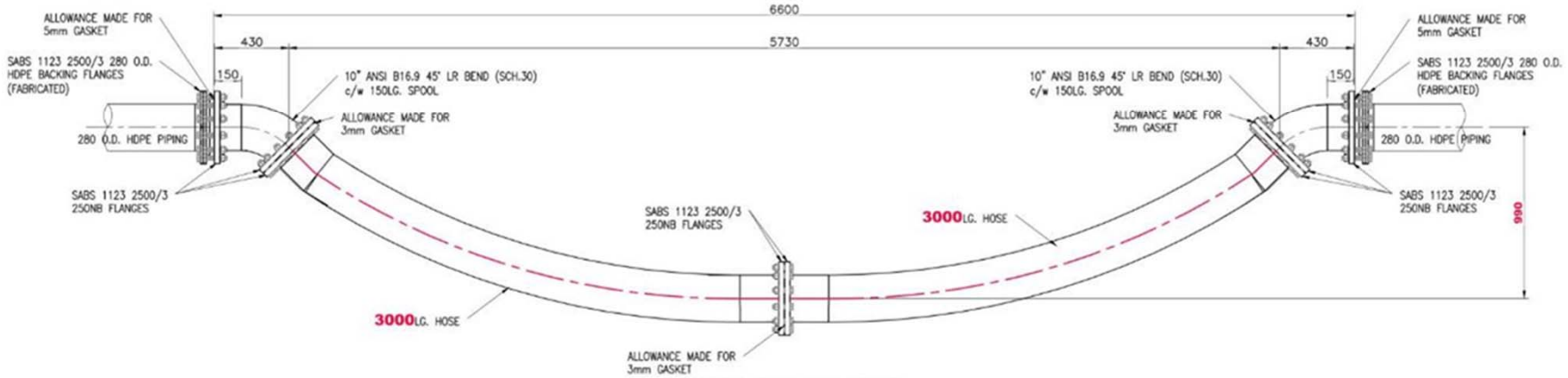


OPERATING ARRANGEMENT [±5°C]

Radius of curvature



INSTALL ARRANGEMENT [±30°C]



OPERATING ARRANGEMENT [±5°C]

Compounded situation

- Large diameter (200 NB) spine
  - Primarily for low hydraulic resistance and equal distribution of water
  - Allows for possible increased population of coolers at depth
  - But makes everything bigger, heavier and stiffer
- Number of joints
  - Doubled, due to change from 6 m to 3 m pipe lengths
- Actual requirement
  - Flow
    - 6 l/s per coil, currently 2 on Level 3 = 12 l/s
    - A 100 NB pipe could supply 16 l/s ~ 3 coils
    - A 150 NB pipe could supply 36 l/s ~ 6 coils

Full bore 200 NB flexible hose

Technically correct – but…..

Technically correct – but…..

Take-away

- Tough Love!
  - To be cruel to be kind.
  - For this project, it was cruel to be kind
- Large diameter spine
  - everything bigger, heavier and stiffer – and more expensive
- Shorter Pipes
  - Doubled number of joints
- HDPE is plastic
  - Aggravated by thermal cycling
- HDPE – coefficient of expansion
  - 16 x steel
- A slack pipe doesn't have as much slack as you imagine
- Install in coldest condition and cope with compression


Questions?
dreamstime.