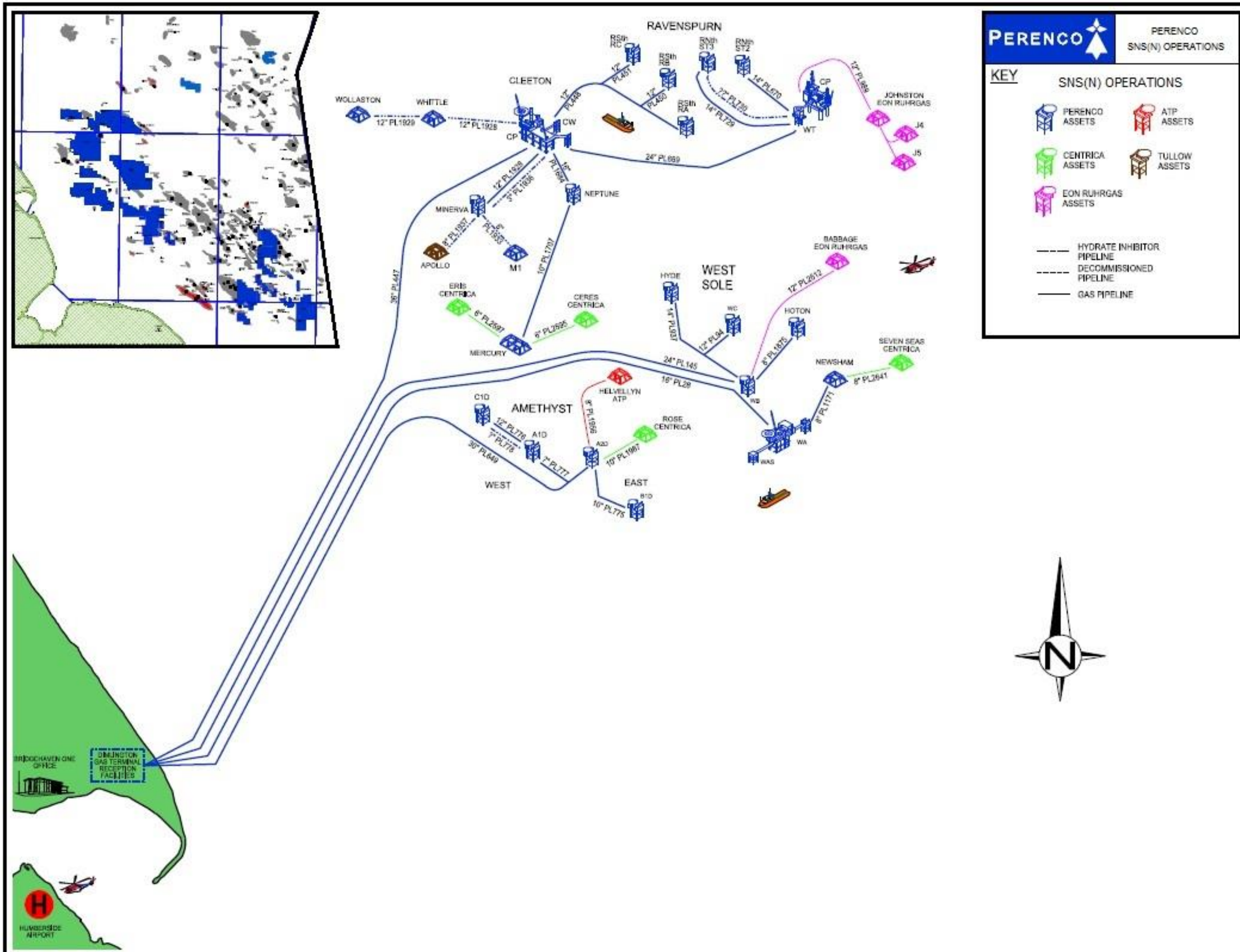
PERENCO UK

Dimlington Terminal Low Temperature Study



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PERENCO SNS(N) OPERATIONS
KEY
SNS(N) OPERATIONS
PERENCO ASSETS
ATP ASSETS
CENTRICA ASSETS
TULLOW ASSETS
EON RUHRGAS ASSETS
HYDRATE INHIBITOR PIPELINE
DECOMMISSIONED PIPELINE
GAS PIPELINE
RAVENSPURN
RSth RC
RSth RB
RSth RA
RNth ST3
RNth ST2
CP
WT
JOHNSTON EON RUHRGAS
J4
J5
CLEETON
CW
CP
WOLLASTON
WHITTLE
12" PL1929
12" PL1928
12" PL451
12" PL450
12" PL448
14" PL670
14" PL729
24" PL669
NEPTUNE
MINERVA
APOLLO
M1
10" PL1707
36" PL447
ERIS CENTRICA
6" PL2597
MERCURY
CERES CENTRICA
6" PL2595
WEST SOLE
HYDE
WC
14" PL937
12" PL94
BABBAGE EON RUHRGAS
12" PL2612
HOTON
8" PL1675
24" PL145
16" PL28
WB
NEWSHAM
SEVEN SEAS CENTRICA
8" PL2641
8" PL1171
WA
WAS
HELVELLYN ATP
AMETHYST
C1D
A1D
A2D
ROSE CENTRICA
8" PL1966
10" PL1987
12" PL776
7" PL778
7" PL777
30" PL649
WEST
EAST
B1D
10" PL775
DIMLINGTON GAS TERMINAL RECEPTION FACILITIES
HUMBERSIDE AIRPORT
H
N


NGT
Langeled
Dimlington
Easington
Centrica

Background Information

- Design of Dimlington Terminal (DT) in 1989 made use of ASTM A333 Gr 6 Post Weld Heat Treated Killed Carbon Steel piping specifications for temperatures down to -119^{o}C
- Original design temperature was based upon piping section of BS5500, an approach which not used today.

- Before gas is supplied to National Grid, it passes through one of four Hydrocarbon Dew-point Reduction (HCDP) skids which ensure no drop-out across the grid from heavy ends/condensate/water. These skids are predominantly made up of ASTM A333 Gr 6 piping specifications
- DT has Emergency Shut Down (ESD) and Emergency Depressurisation (EDP) system installed to protect the Terminal from over pressure, minimise gas inventory and minimise uncontrolled release of flammable fluids

Scope of Investigation

- An ‘Emergency Depressurisation study’ was completed to model fluid characteristics during depressurisation following an emergency event.
- The study highlighted the HCDP skid tailpipes and vent header downstream of Emergency Depressurisation Valve (EDV) as experiencing low temperatures due to Joules-Thompson effect.
- A review of line list and process conditions was completed to investigate any other potential sections of DT pipework likely to experience low temperatures. Pipework highlighted in initial study were found to be only locations.

PSE Investigation (Simulation)

- The initial study looked purely at gas temperatures, not focussing on temperature within the metal itself.
- Process System Enterprise (PSE) were consulted to perform dynamic simulations of DT pipework metal temperatures.
- HCDP skid F was modelled first as this was the one which had the most information readily available.
- Simulation was carried out using PSE's proprietary Advanced Modelling technology gFLARE.
- 1 Base Case and 9 Sensitivity calculations were performed initially on Skid F (varying input temperatures/pressures etc)

PSE investigation
Skid F - system schematic

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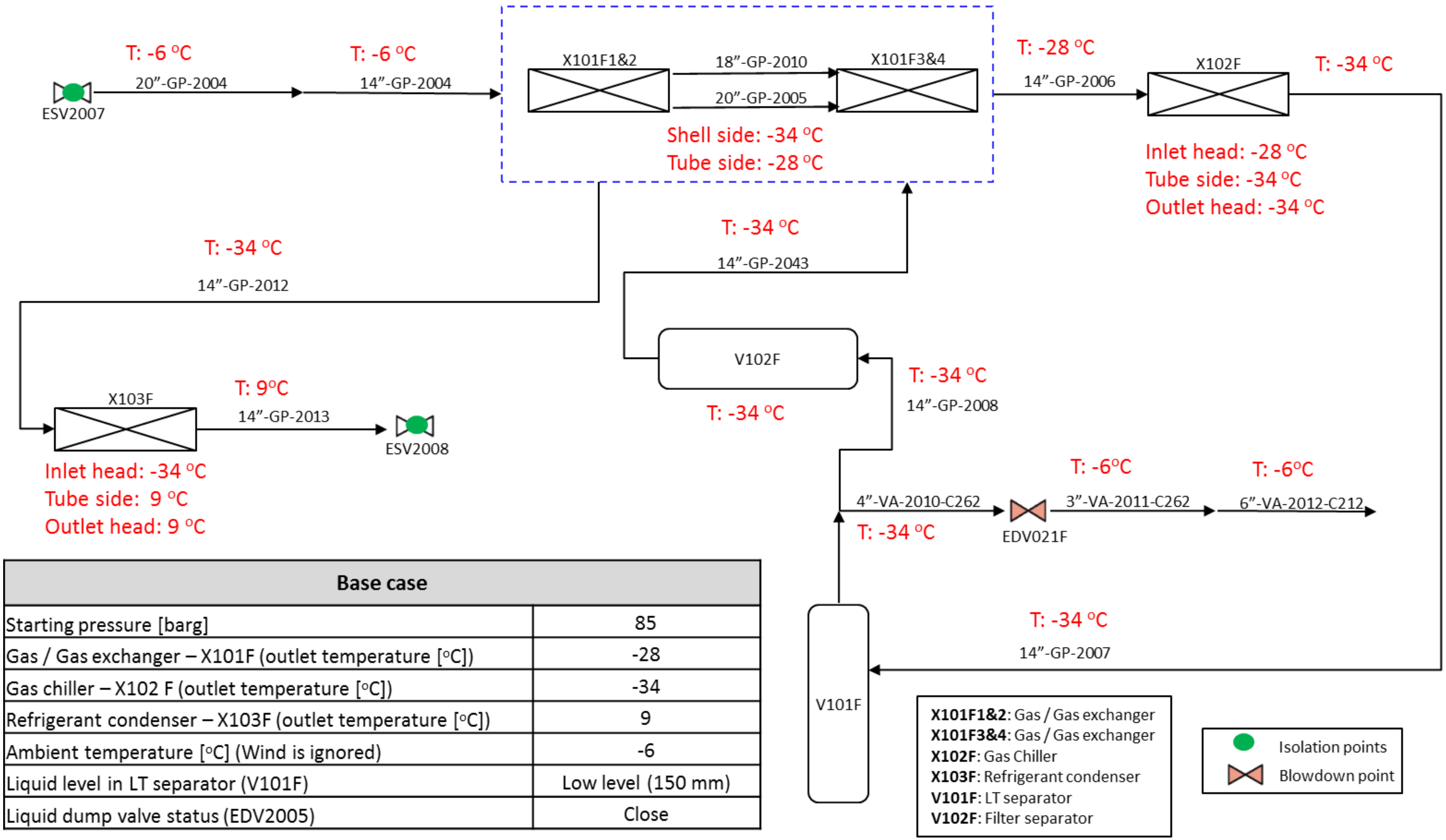
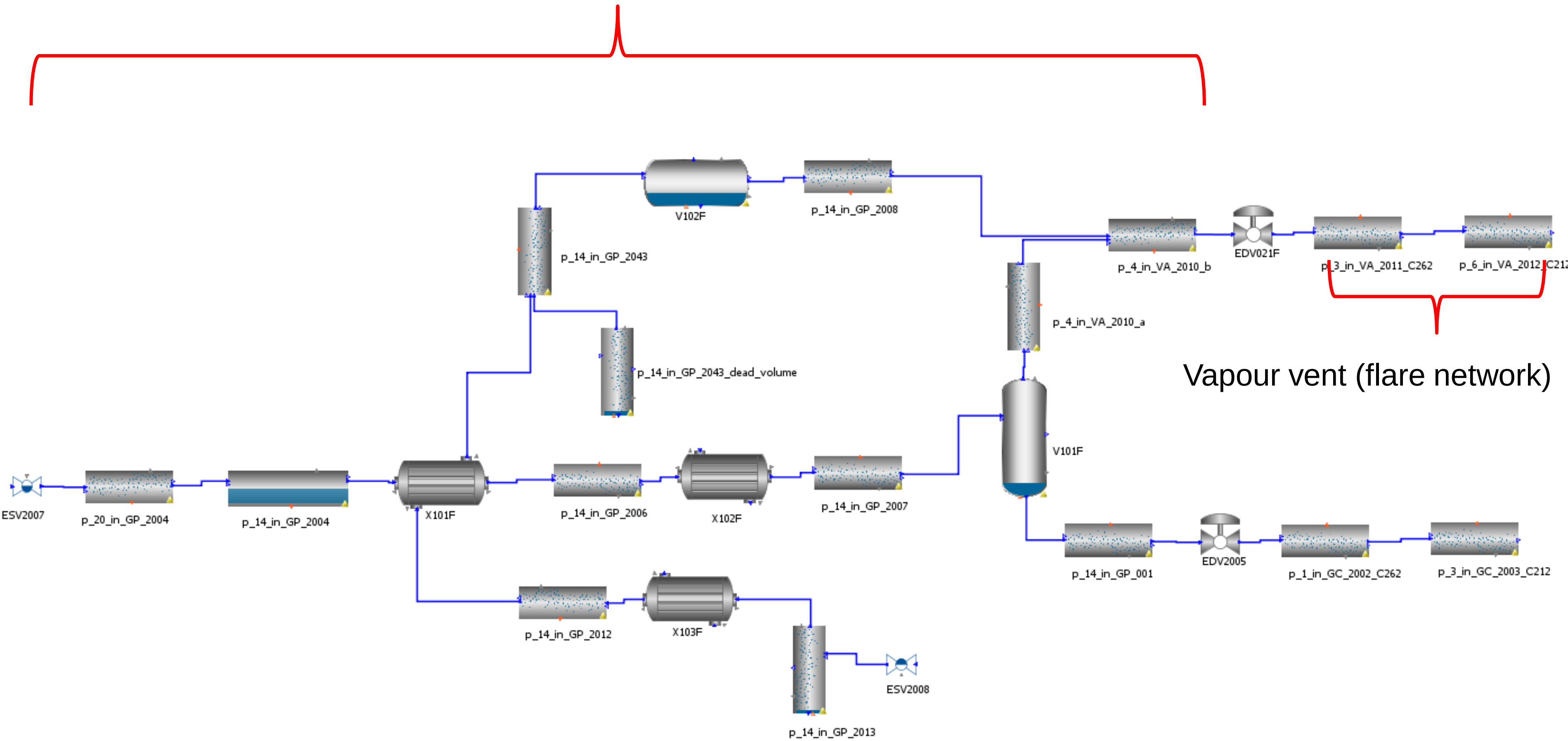


Base case	
Starting pressure [barg]	85
Gas / Gas exchanger – X101F (outlet temperature [°C])	-28
Gas chiller – X102 F (outlet temperature [°C])	-34
Refrigerant condenser – X103F (outlet temperature [°C])	9
Ambient temperature [°C] (Wind is ignored)	-6
Liquid level in LT separator (V101F)	Low level (150 mm)
Liquid dump valve status (EDV2005)	Close

PSE investigation
System representation in gFLARE

Blowdown segment (process side)



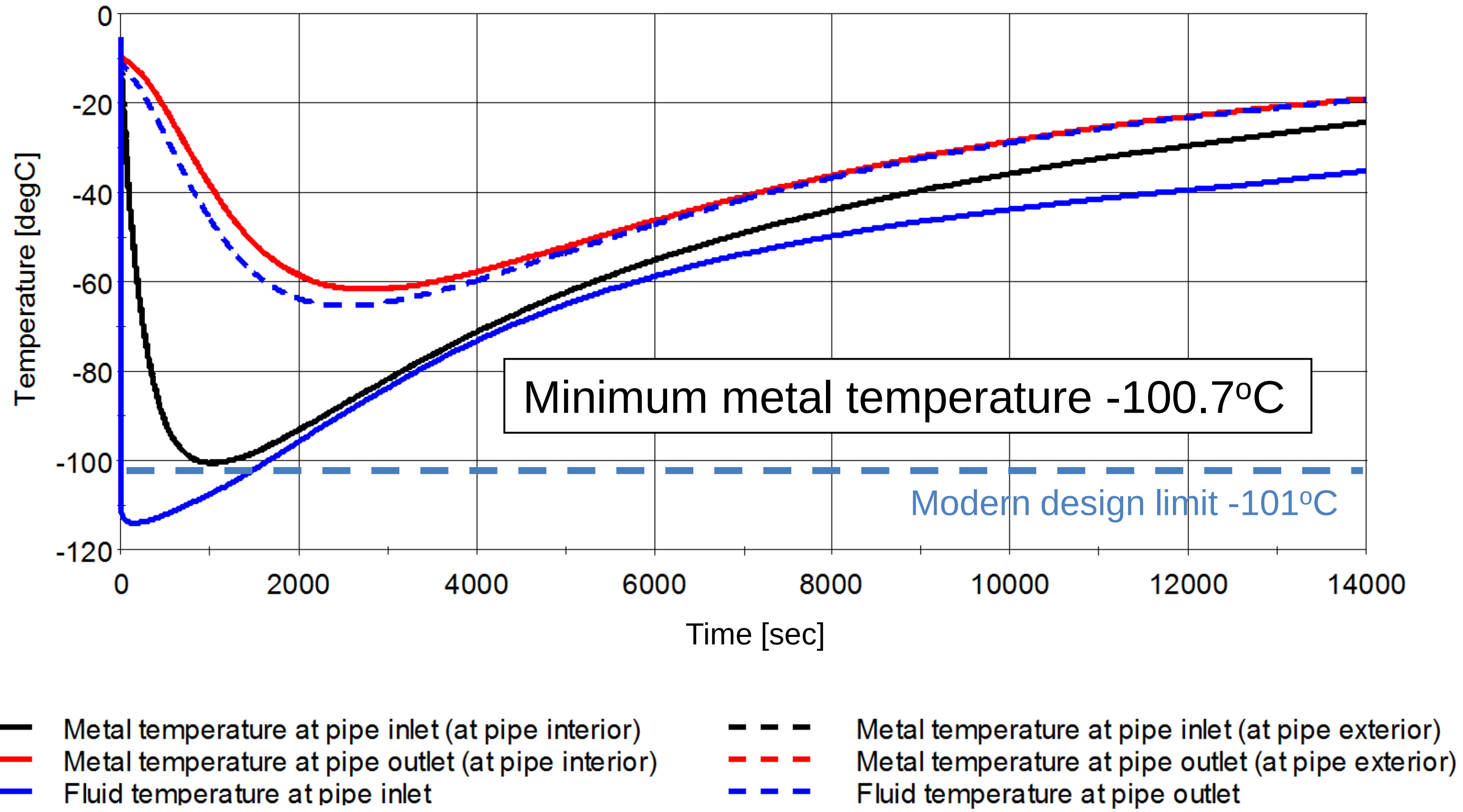
PSE Investigation
Key findings

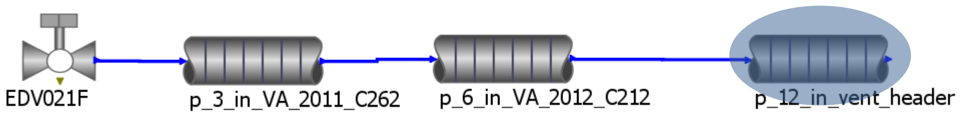
- Process side
  - Metal temperatures of LT separator remain above design limit (-55°C)
- Vapour vent tailpipes
  - Metal temperatures are below modern design limit (-101°C)
  - Prolonged choked flow

- Further analysis was then completed to investigate low temperature risks in the flare header
  1. Assessment of flare header temperatures when only one skid (Skid F) is depressurised and vapour vent tailpipe material remains low temperature carbon steel

PSE Investigation
Flare header temperatures

Case 1: venting from Skid F only





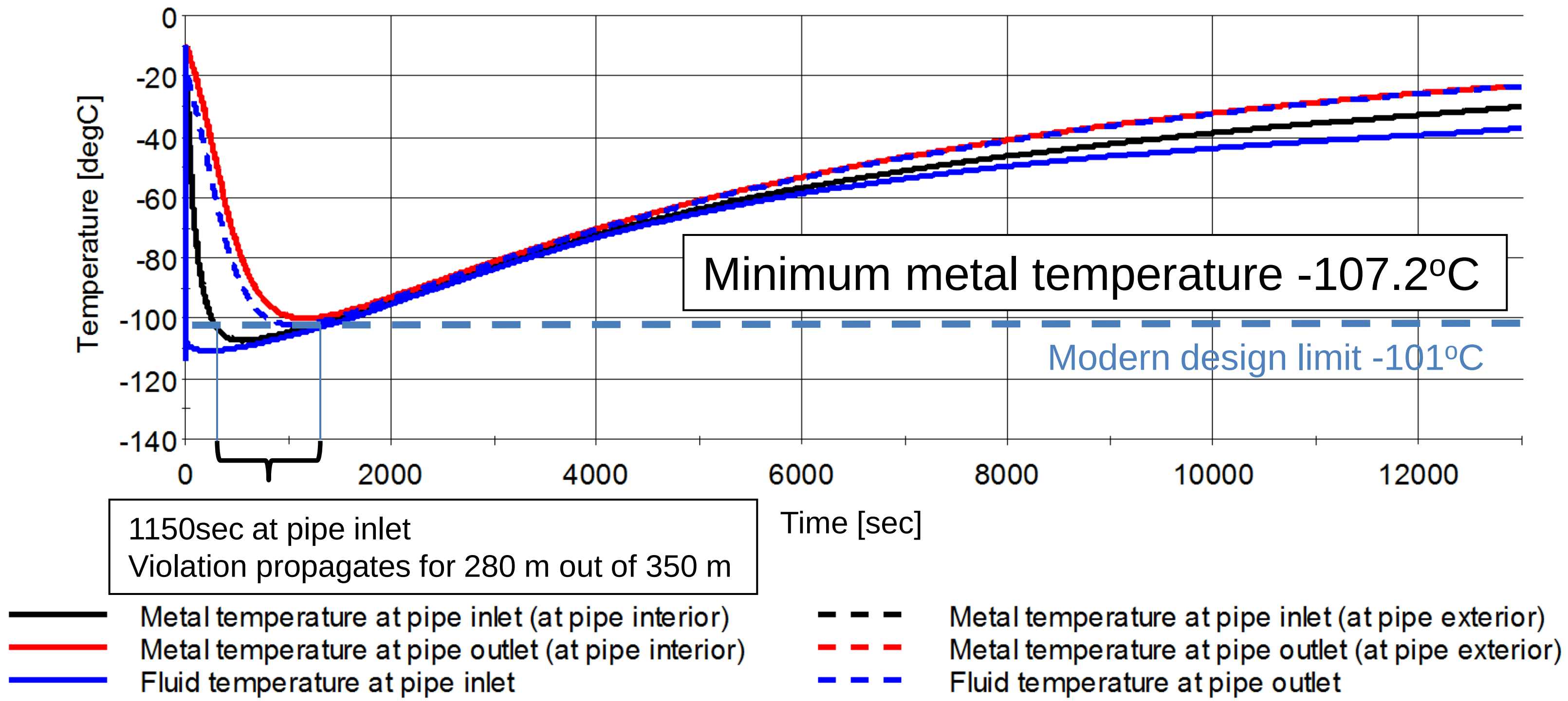
PSE Investigation
Key findings

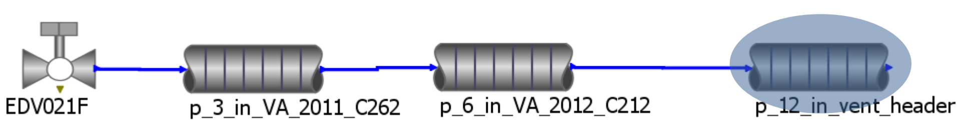
- Process side
  - Metal temperatures of LT separator remain above design limit (-55^{o}C)
- Vapour vent tailpipes
  - Metal temperatures are below modern design limit (-101^{o}C)
  - Prolonged choked flow

- Further analysis was then completed to investigate low temperature risks in the flare header
  1. Assessment of flare header temperatures when only one skid (Skid F) is depressurised and vapour vent tailpipe material remains low temperature carbon steel: header metal temperature remains above -101^{o}C
  2. Assessment of flare header temperatures when three identical skids (to Skid F) are depressurised simultaneously and vapour vent tailpipes are changed of stainless steel

PSE Investigation
Flare header temperatures

Case 2: simultaneous venting from 3 identical skids; vapour vent tailpipes changed to stainless steel





PSE Investigation
System analysis

- Factors that are expected to increase metal temperatures in tailpipes and 12” header
  - Upstream conditions
    - Starting temperature and pressure
    - Blowdown point location (temperature and pressure vary across the system
  - Lower velocities
    - Smaller kinetic energy contribution d/s of blowdown points -> higher fluid temperatures
    - Lower heat transfer coefficient between fluid and wall
  - Metal mass
    - The thicker the pipe wall is the longer it takes to cool it down
    - The longer the pipe is the higher are the temperatures at its exit -> prevent low temperatures propagate to d/s lines (headers)
  - Wall material
    - Material with a lower LDT

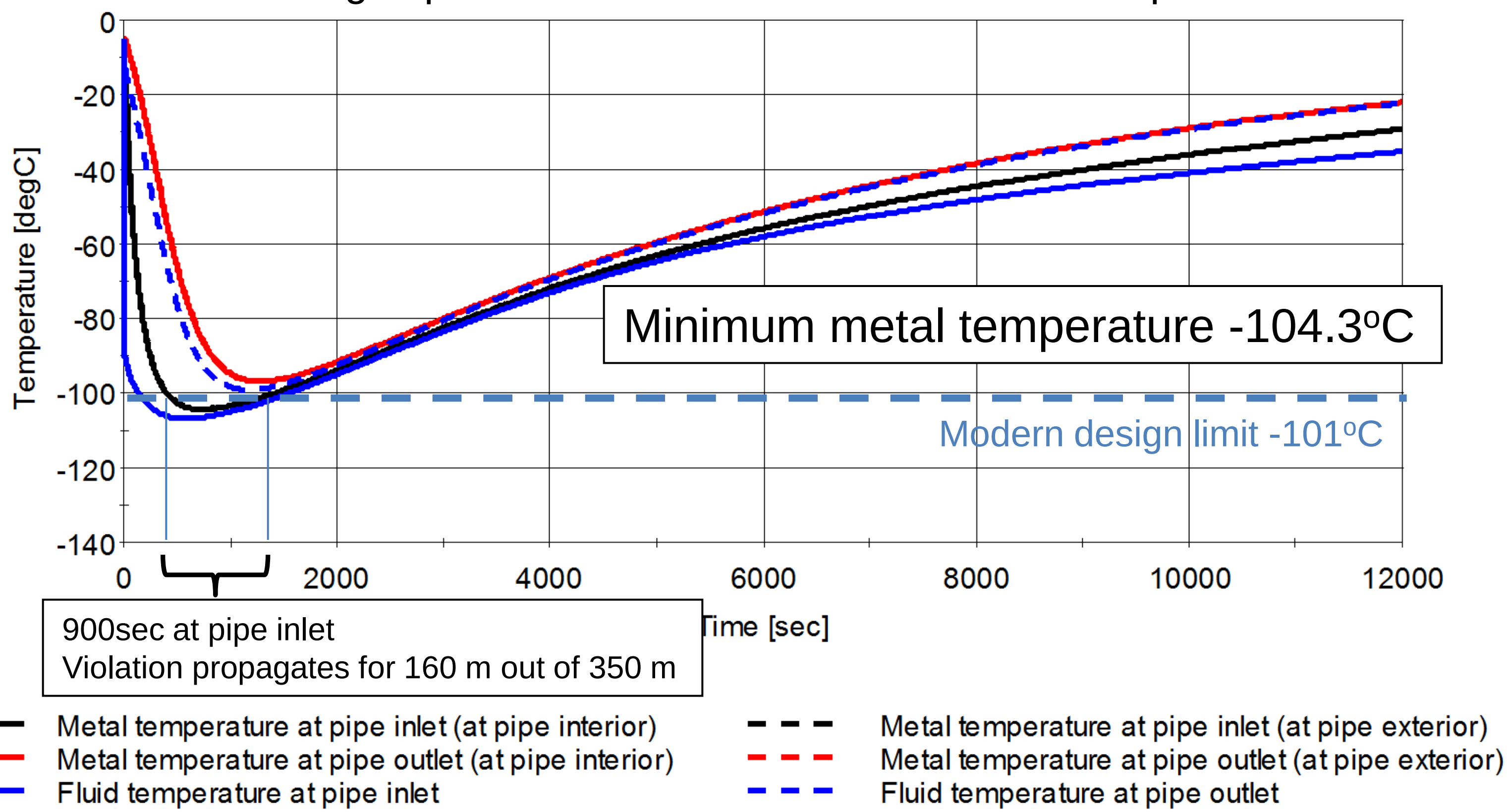
PSE Investigation
Key findings

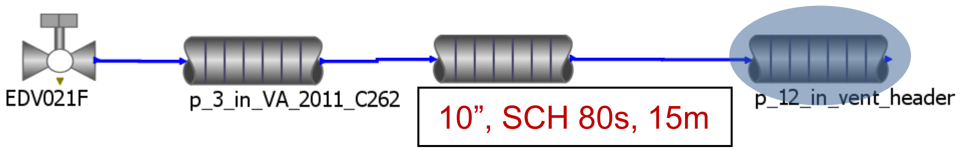
- Process side
  - Metal temperatures of LT separator remain above design limit (-55°C)
- Vapour vent tailpipes
  - Metal temperatures are below modern design limit (-101°C)
  - Prolonged choked flow

- Further analysis was then completed to investigate low temperature risks in the flare header
  1. Assessment of flare header temperatures when only one skid (Skid F) is depressurised and vapour vent tailpipe material remains low temperature carbon steel: header metal temperature remains above -101°C
  2. Assessment of flare header temperatures when three identical skids (to Skid F) are depressurised simultaneously and vapour vent tailpipes are changed of stainless steel: header metal temperature can be lower than -101°C
  3. Investigation of the impact of stainless steel tailpipe design specifications on flare header metal temperatures

PSE Investigation
Flare header temperatures

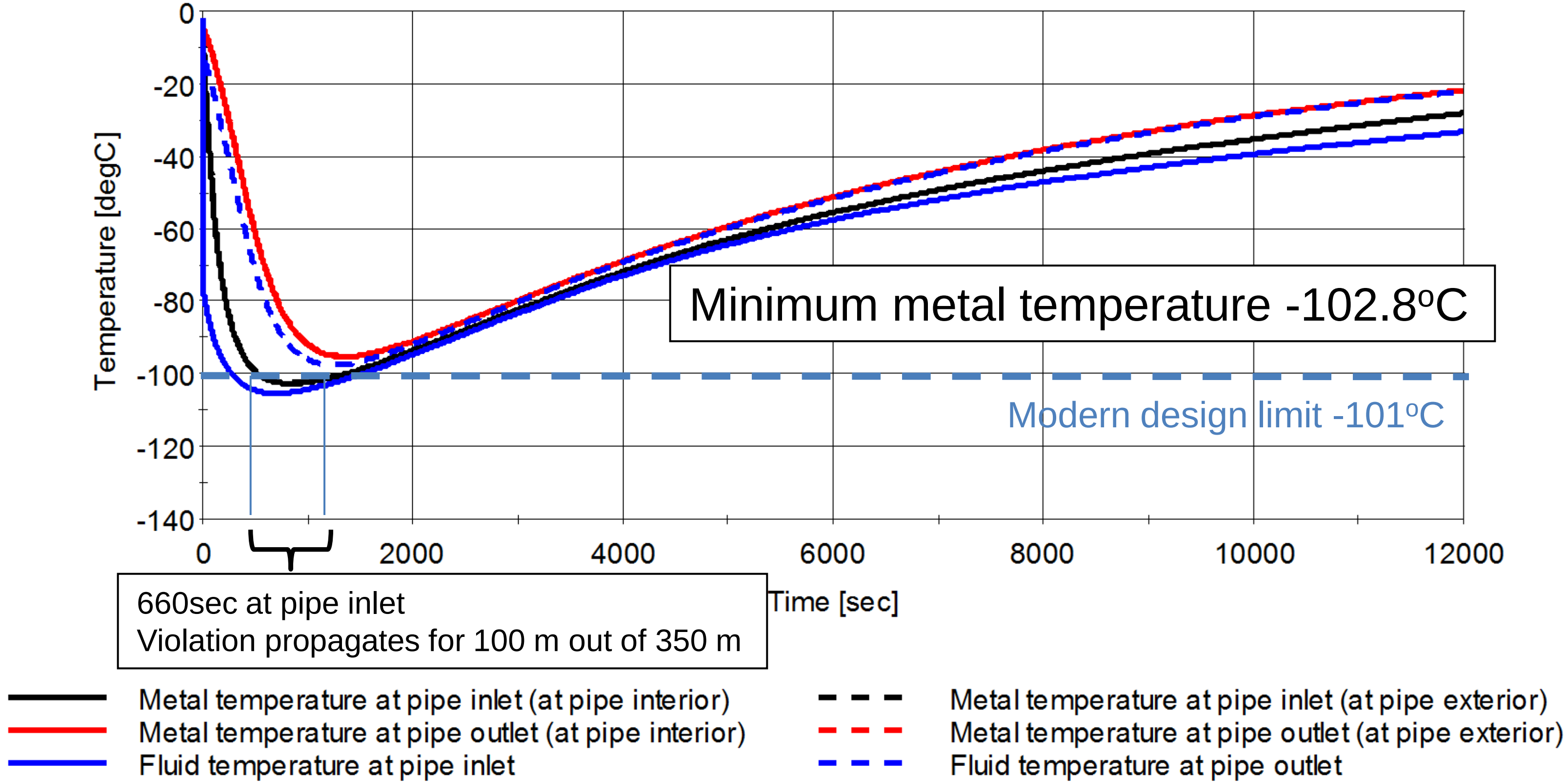
Case 3a: Investigation of the impact of stainless steel tailpipe design specifications on flare header metal temperatures

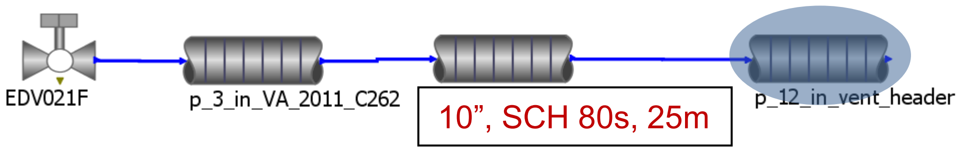




PSE Investigation
Flare header temperatures

Case 3b: Investigation of the impact of stainless steel tailpipe design specifications on flare header metal temperatures





PSE Investigation
Flare header temperatures

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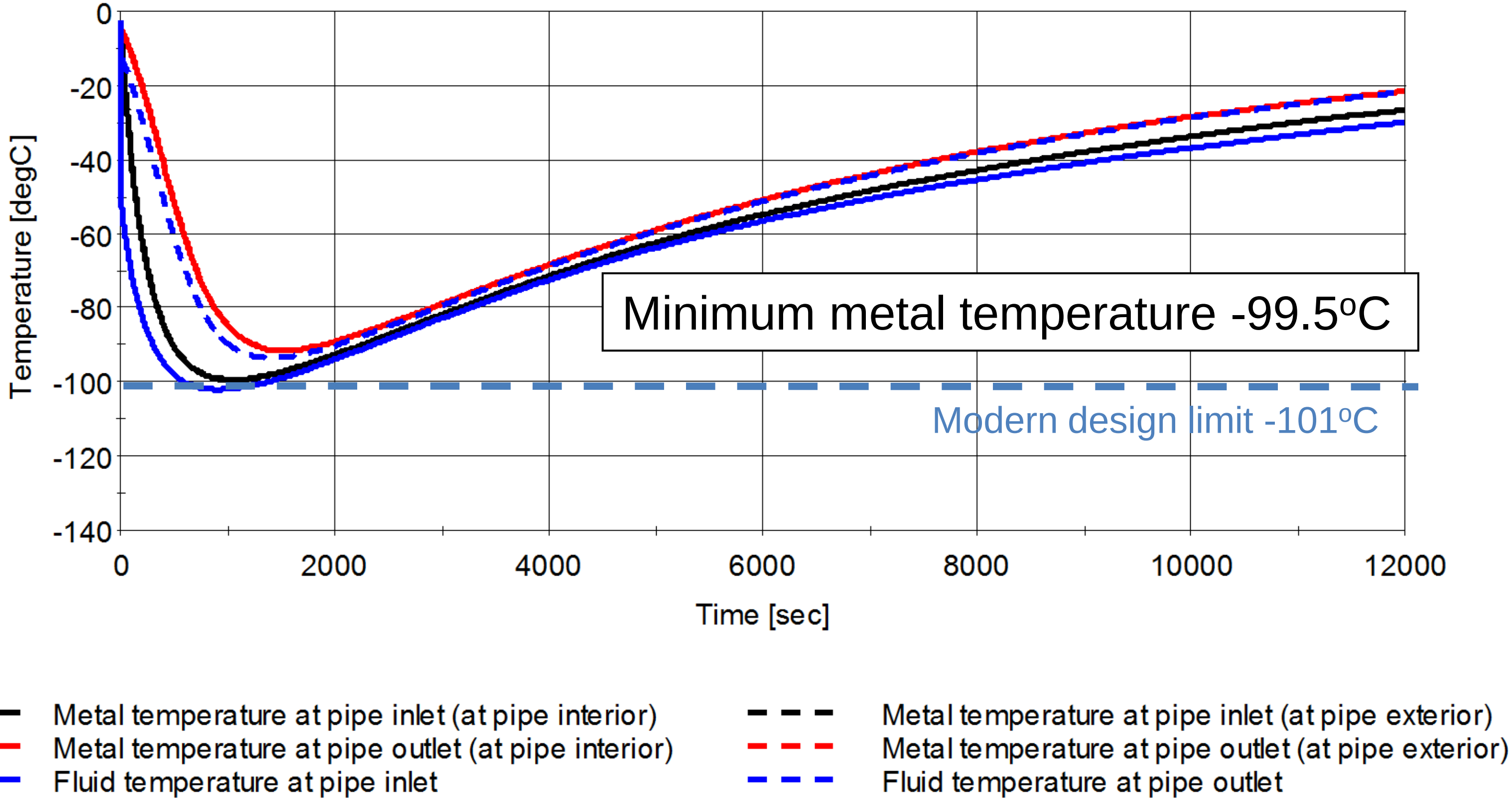
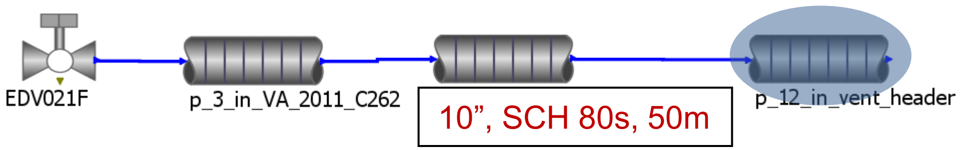
Case 3c: Investigation of the impact of stainless steel tailpipe design specifications on flare header metal temperatures





PSE Investigation Results summary

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Case	Number of skids	Line	Length [m]	Material	SCH	Minimum metal temperature [ºC]
1	1	3”-VA-2011	0.242	Carbon steel (insulated)	80	-120.2
		6”-VA-2011	0.818	Carbon steel	40	-114.9
		12”- Vent header	350	Carbon steel (A333 Grade 6)	40	-100.7
2	3	3”-VA-2011	0.242	Stainless steel	80	-122.6
		6”-VA-2011	0.818	Stainless steel	40	-109.3
		12”- Vent header	350	Carbon steel (A333 Grade 6)	40	-107.5
3a	3	3”-VA-2011	10	Stainless steel	80S	-122.1
		10”-VA-2011	15	Stainless steel	80S	-102.2
		12”- Vent header	350	Carbon steel (A333 Grade 6)	40	-104.3
3b	3	3”-VA-2011	10	Stainless steel	80S	-121.7
		10”-VA-2011	25	Stainless steel	80S	-102
		12”- Vent header	350	Carbon steel (A333 Grade 6)	40	-102.8
3c	3	3”-VA-2011	10	Stainless steel	80S	-121
		6”-VA-2011	50	Stainless steel	80S	-101.6
		12”- Vent header	350	Carbon steel (A333 Grade 6)	40	-99.5

Mechanical Investigation (Charpy Impact test)

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- Several sections of pipework were removed from the redundant HCDP skid D for impact testing downstream of EDV.
- Material specification ASTM A333 Gr 6 requires charpy impact testing to result in at least 9J average and 7J from and individual test (based on 55mm x 5mm x 10mm sample)
- Samples were taken from Weld Centre Line (WCL), Fusion Line (FL) on Weld Neck Flange (WNF) and FL on tee.
- Samples passed ASTM A333 impact test at -121^{o}C

Position	Energy Absorbed (J)			
	Test 1	Test 2	Test 3	Average
WCL	9	31	35	25
FL WNF	18	9	41	23
FL Tee	36	51	35	41

Further Investigation by Mechanical Department

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- Full Stress Analysis of Tailpipes and Vent Header (On-going)
- As part of Stress analysis, confirm stresses are in line with original design at low temperature.

Membrane Pressure Stress Criteria

The Design Minimum Temperature shall correspond to the lowest metal temperature of the part under consideration coincident with being subjected to calculated tensile membrane pressure hoop stress exceeding $50N/mm^2$ ($7250lbf/in^2$). (This being the stress level below which, historically, brittle fracture has not occurred).

- Further Charpy Impact tests to take place.
- Scope of remedial work to be confirmed following completion of the above.
- HCDP skids have never been depressurised in an emergency, but this will not form the basis of any decision going forward, as timing of an emergency depressurisation event can not be predicted.

Conclusion

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- Original static model predicted low fluid temperature directly downstream of EDV whereas PSE's study also considered metal temperatures.
- This study allowed Perenco to assess how the low fluid temperatures affected the adjacent pipework and extent of low temperature propagation away from EDVs throughout the vent system.
- The work performed by PSE has provided Perenco with a detailed understanding of the transient behaviour of the Dimlington Terminal with respect to low temperatures.