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Computer-aided fire integrity analysis of pipe flanges

Dr. Geir Berge
www.petrell.no
post@petrell.no

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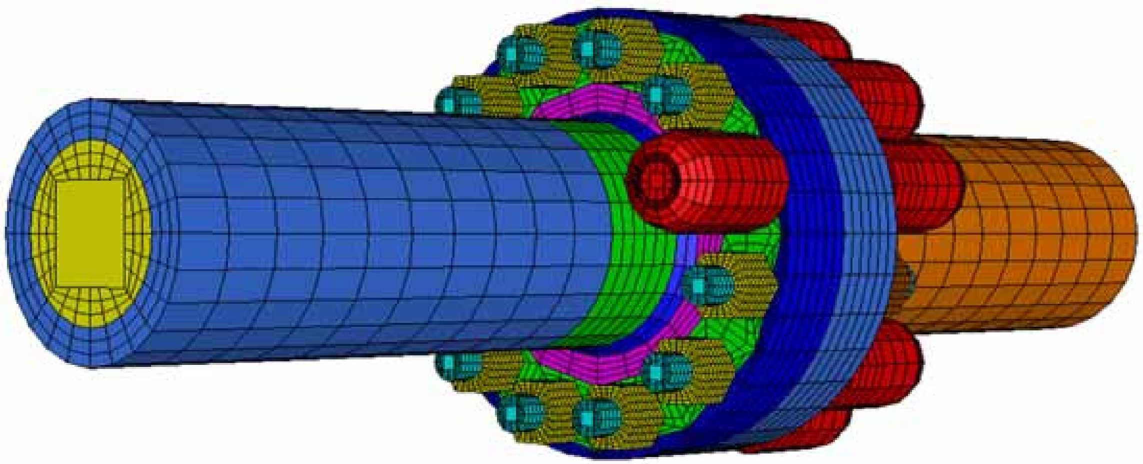
Introduction

- Subjects
  - Background: Why fire integrity of flanges
  - Modelling and verification (fire test)
  - Evaluation method in project
  - Example



About flanges

- The weakest point of a flange is the connection between the nuts and the bolts.
- The pretension is the dominating load to the bolts. Hang-off forces might contribute to increase the tension and so does the internal pressure. However, both are normally small compared to pretension.
- Not all experiments show complete opening of a failing flange. A leak is sometimes the result.

Basic

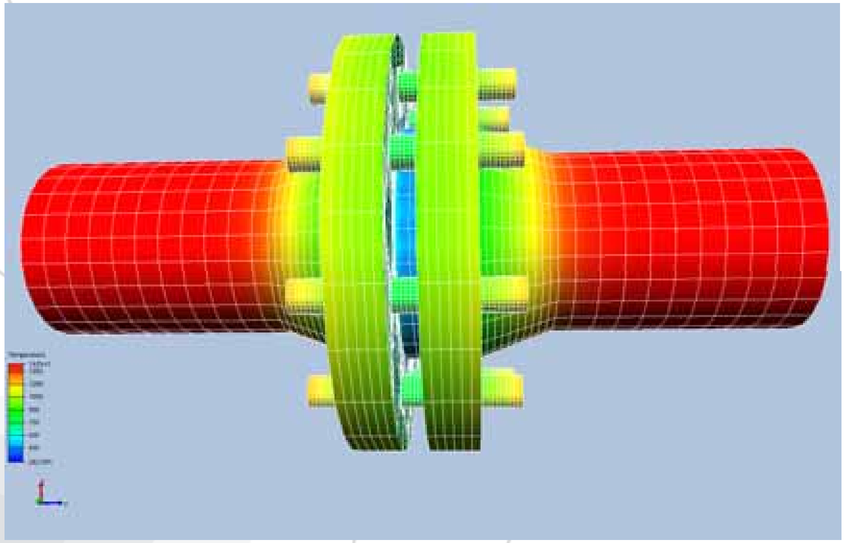
- In case of accidental events, escalation should be avoided.
  Small fires should not turn into large fires.
- Flanges and pipes should maintain the same level of integrity if exposed to fire.
- To reduce use of PFP, only flanges with potential to exceed given acceptance criteria should be insulated.

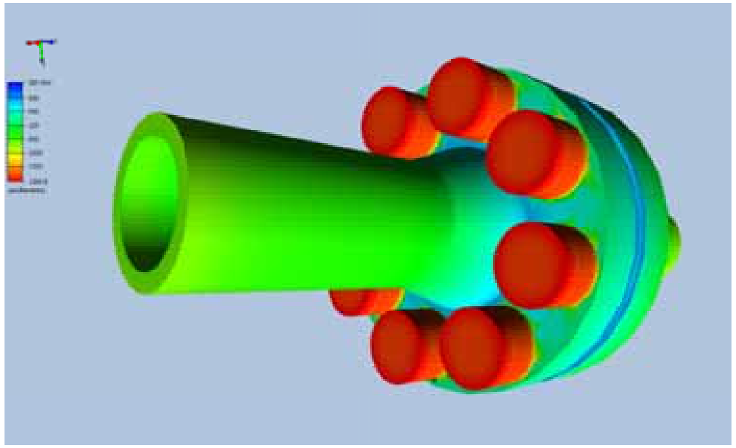
Guidelines

- Scandpower Guideline (2004) sec. 4.3:
  - “Flanges and valves located in pipes that need to be fire insulated shall normally be insulated. Flanges/valves located in piping, which is not insulated, should be evaluated for the need to insulate as they may rupture prior to the pipes”
- Statoil TR3003 sec. 2.6.3.4:
  - “The integrity of bolted connection shall be included in the fire depressurization evaluation”.

Temperature calculation of flanges

- The flange is modelled according to standard measures and material
- Bolts and nuts are according to standard size and material
- The flange is evenly exposed to relevant heat load
- Time-temperature curve is calculated for all threads in contact between the bolt and the nut.





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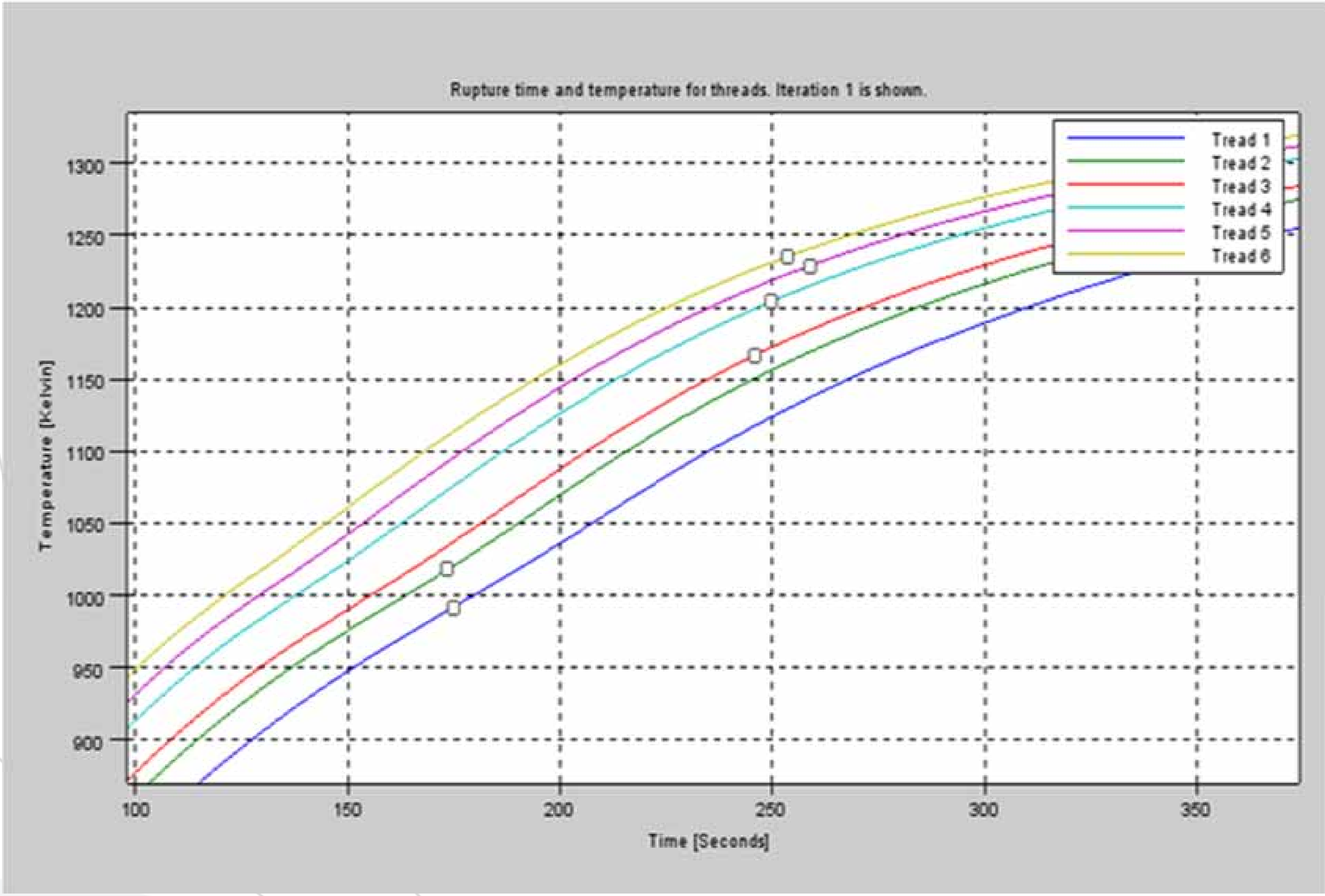
Temperature profile for each thread



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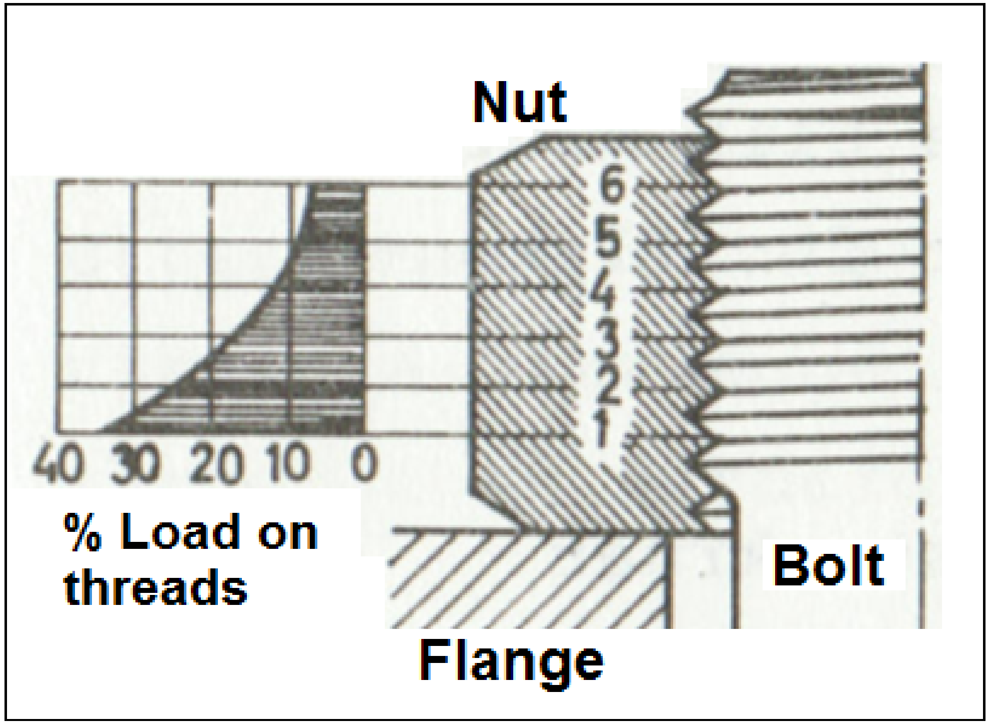
Stress distribution

- Pretension is set according to the standard
- Stress for each thread is calculated according to load distribution curve
- From the weakening curve, find temperature when yield stress corresponds to pretension stress for each thread.
- From the yield temperature, find time to yielding for each thread.
- The first thread yielding will leave its load to the remaining threads. That leads to increased load for the remaining threads which in turn can lead to failure of the flange.

Load distribution curve



From: Klein. H-Ch. «Hochwertige Schraubenverbindongen. Einige Gesteltungsprinzipen und Neuentwicklungen». Konstruction. H.6. 1959 s. 201-212 and s. 259-264.

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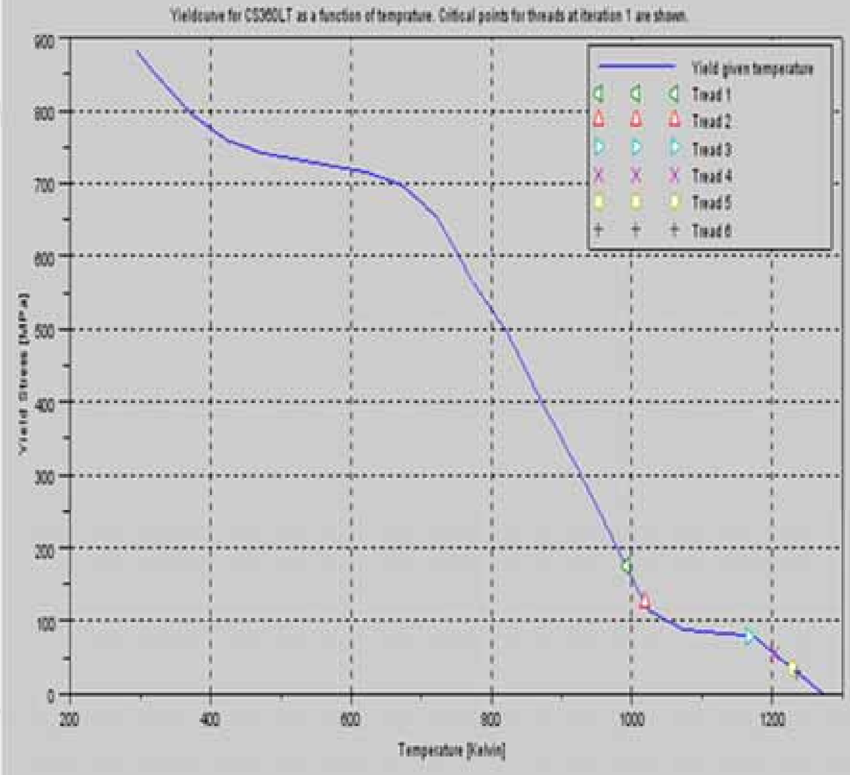
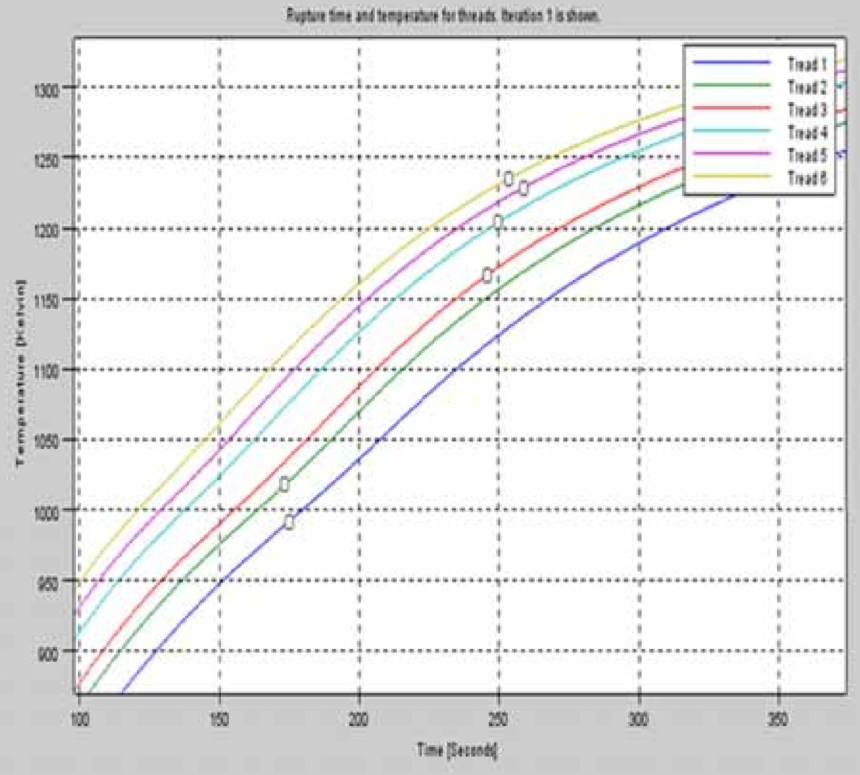
The innermost thread fails





Yield stress weakening curve for bolt or nut material

Time temperature curve for threads

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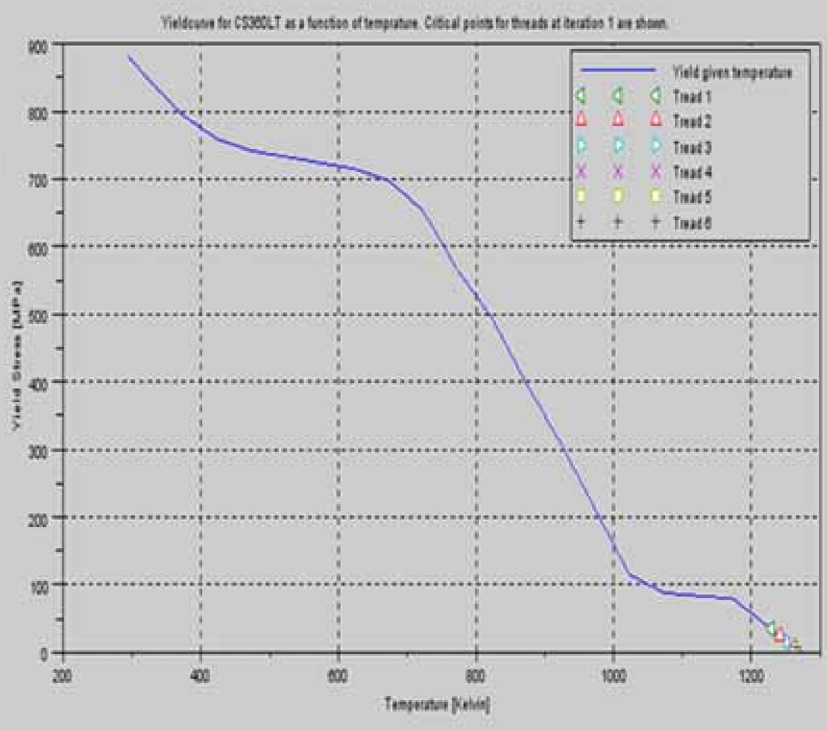
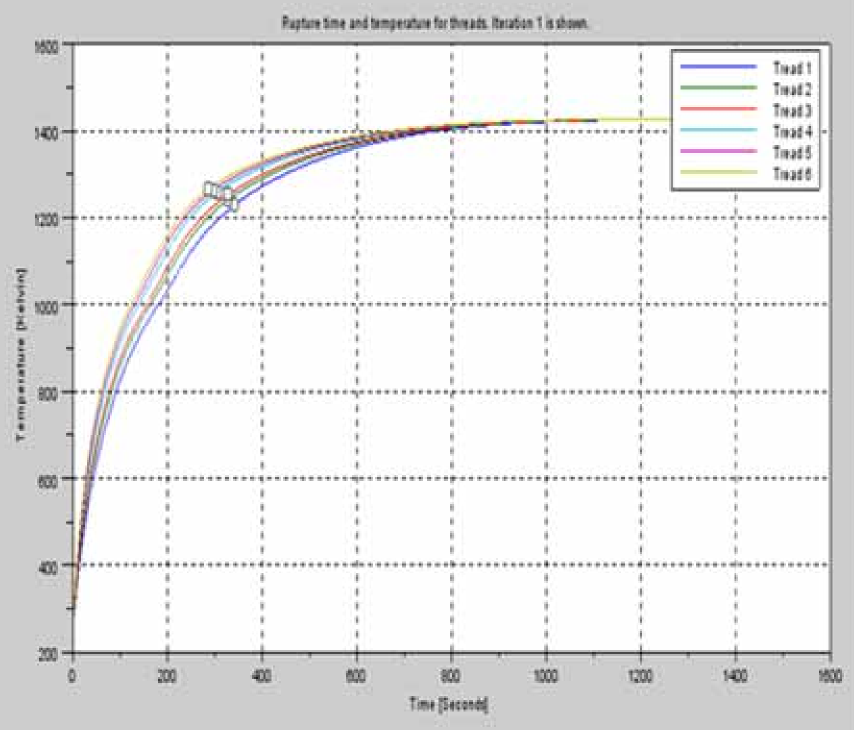
The outermost thread fails



Yield stress weakening curve for bolt or nut material



Time temperature curve for threads

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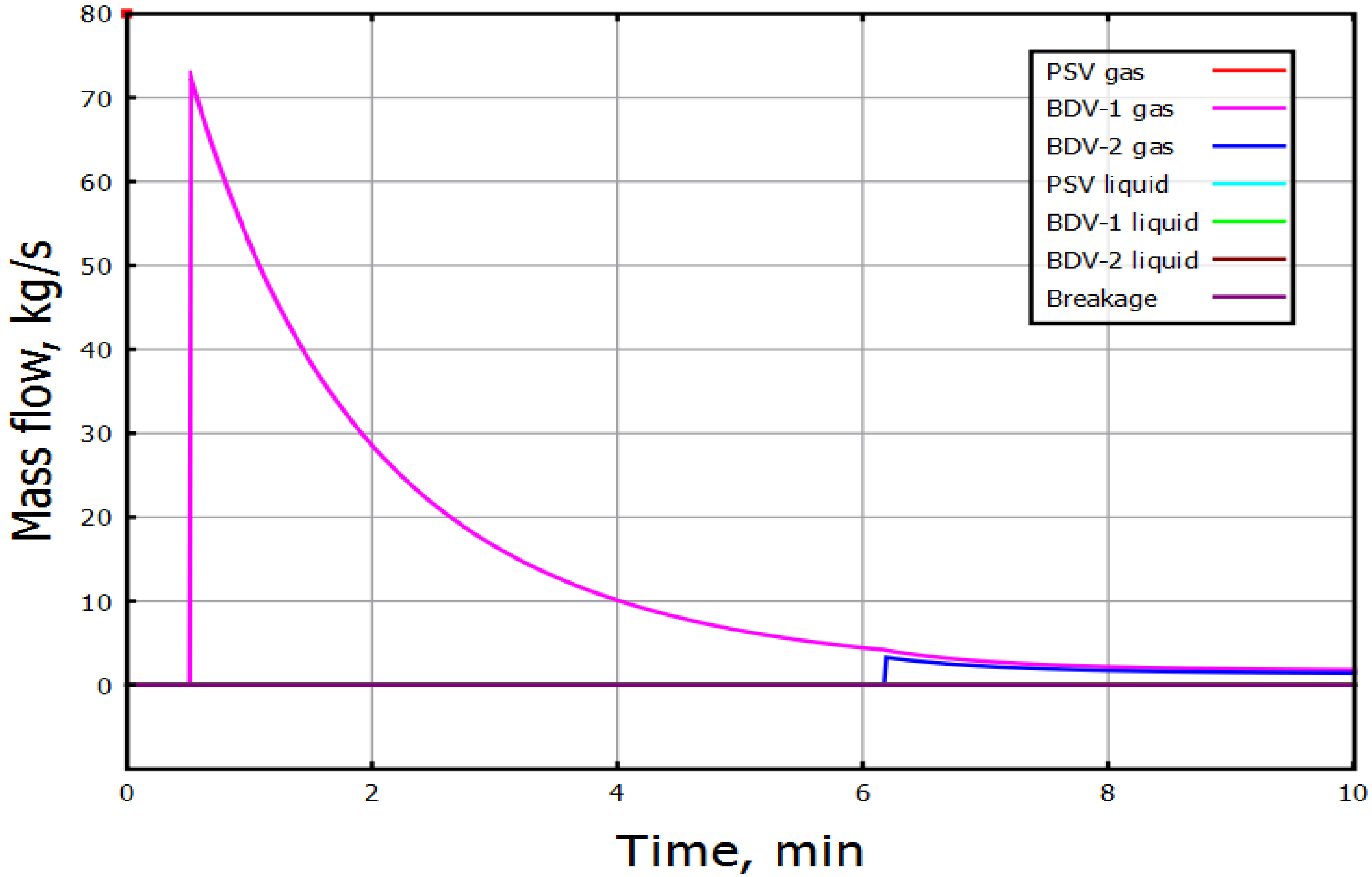
Leak rate at disintegrating time



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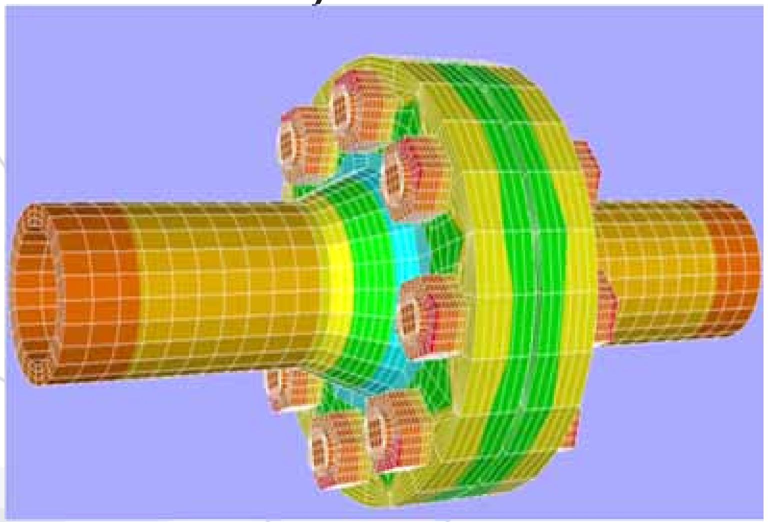
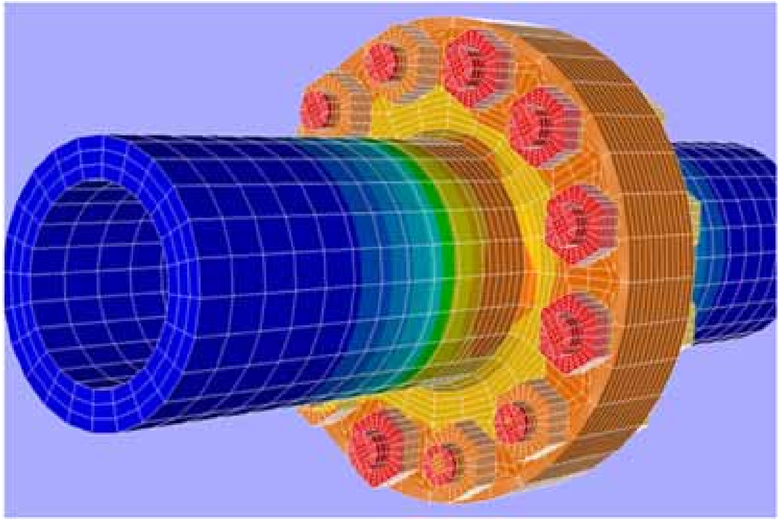
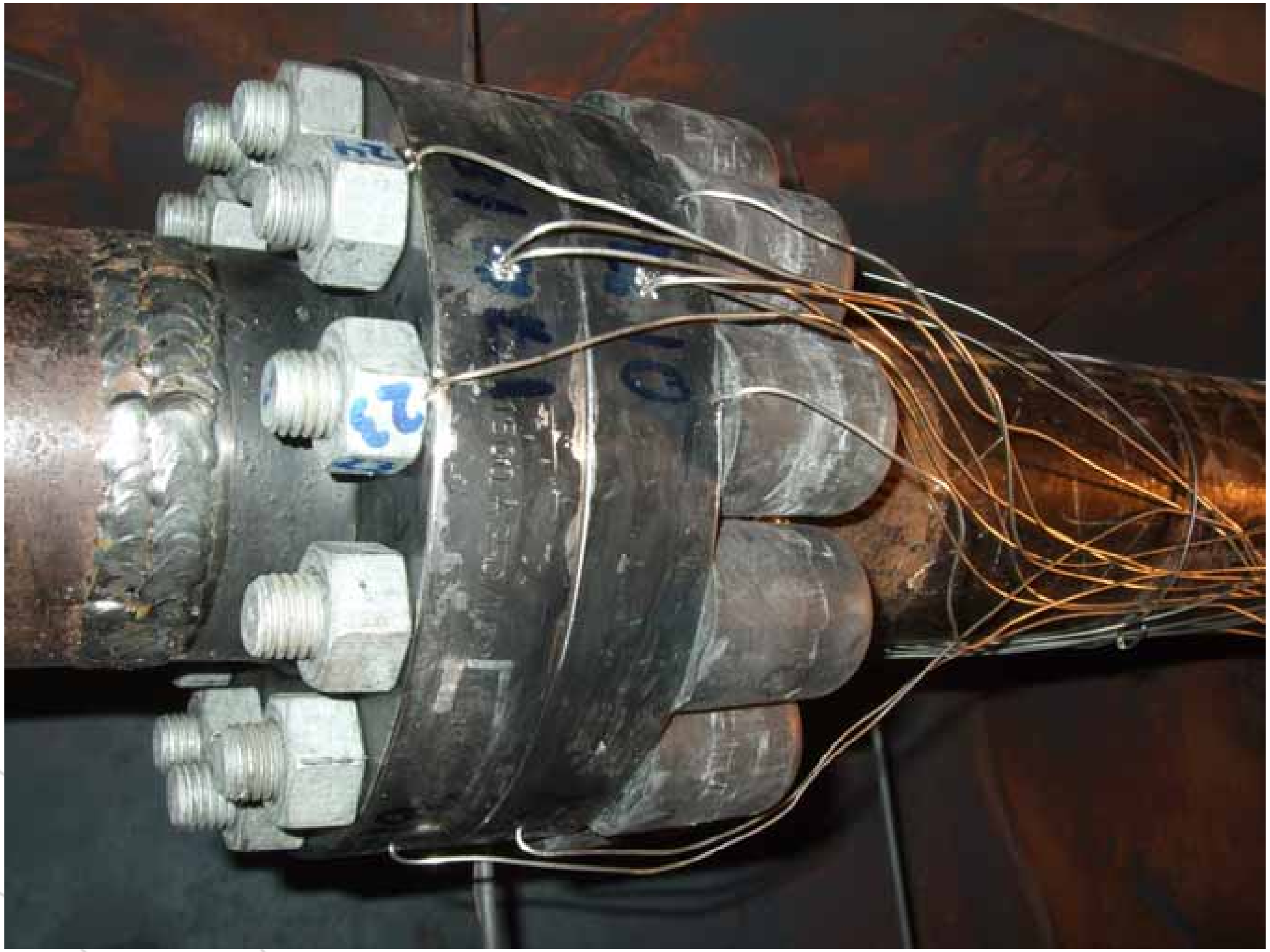
Verification

- Verification against experiments was supported by Statoil
- The models are validated against fire tests of ASME WN and COMPACT flanges
- Tests performed at SINTEF NBL (presently SP Research)





Instrumentation of flange



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Flame and environmental temperature

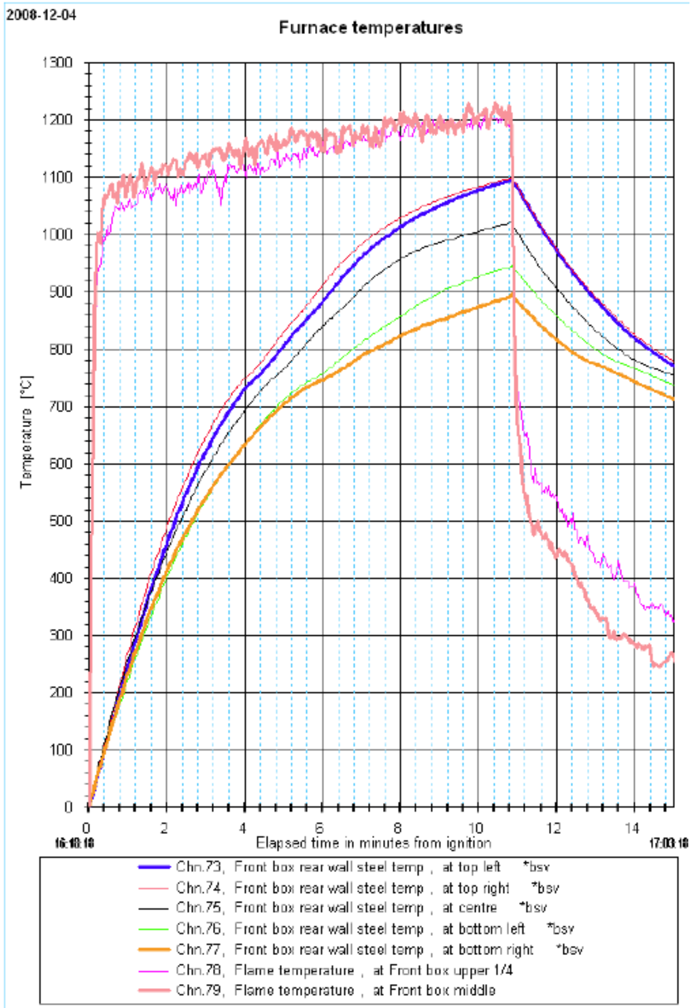
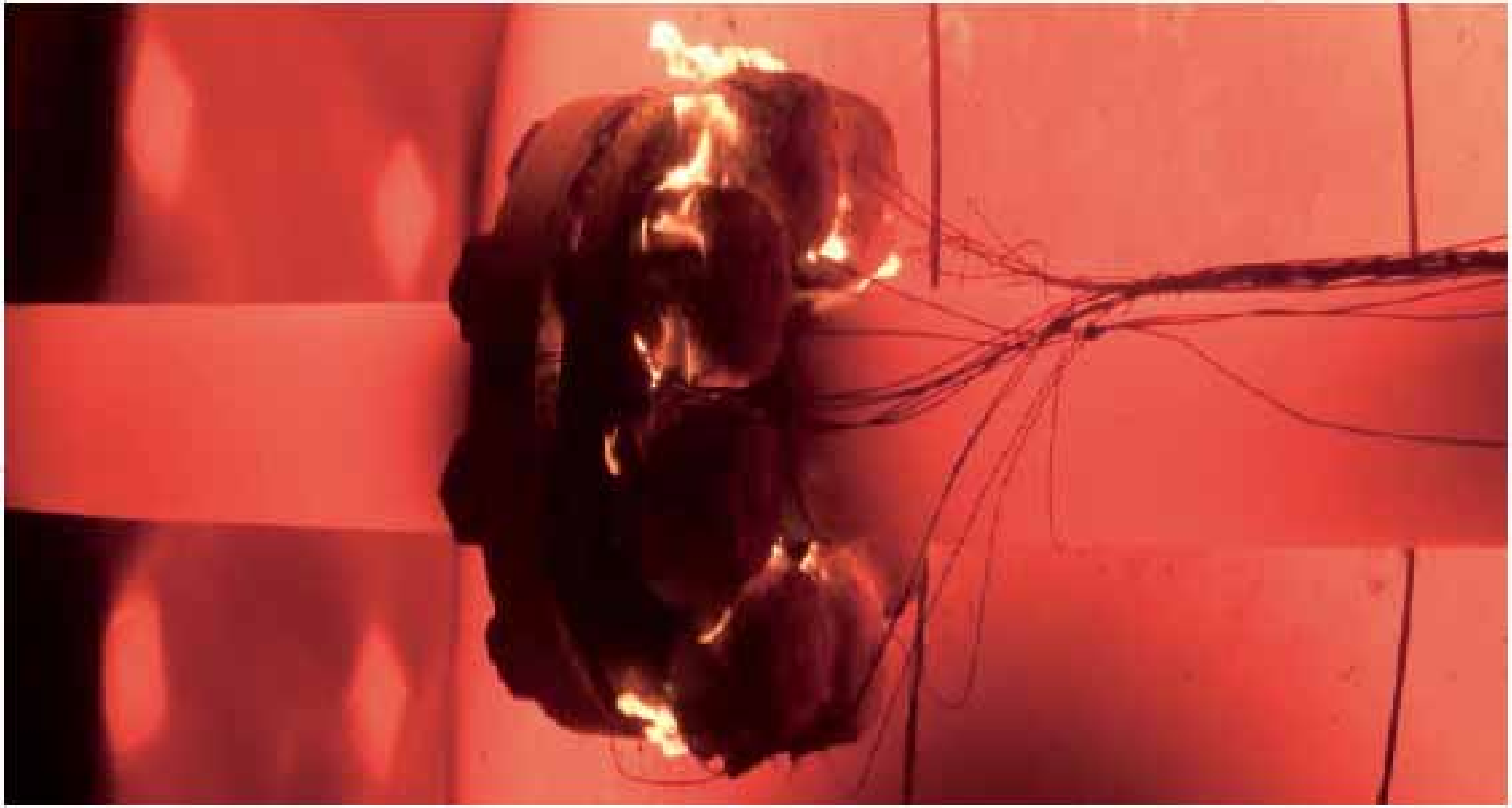


*Figure 1.17 Furnace flame temperatures and rear steel wall temperatures. *bsv=back side v*

SINTEF NBL as ***(Norwegian Fire Research Laboratory).*** Clie

Fire exposure



Test performed with and without use of fire FireNuts

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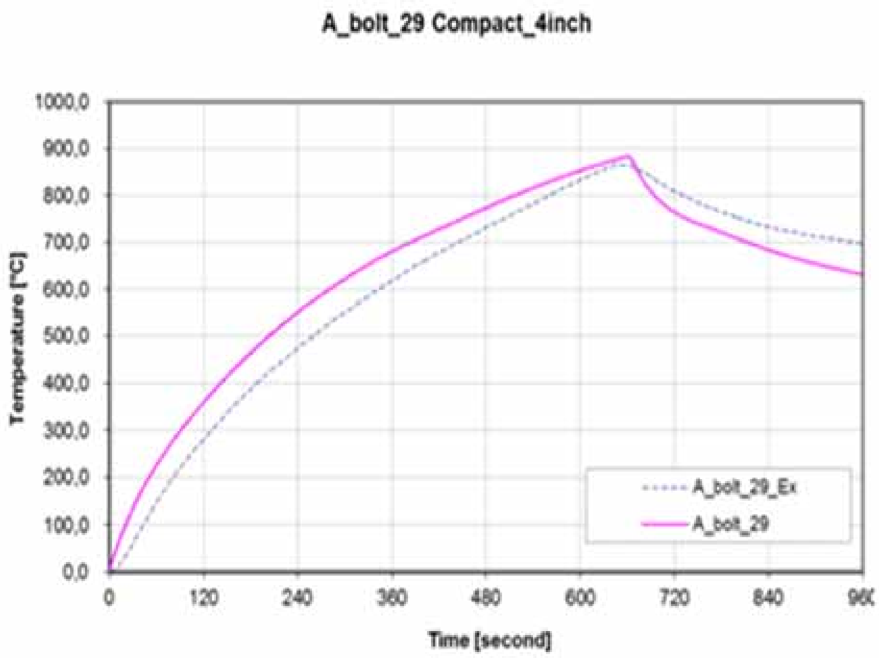
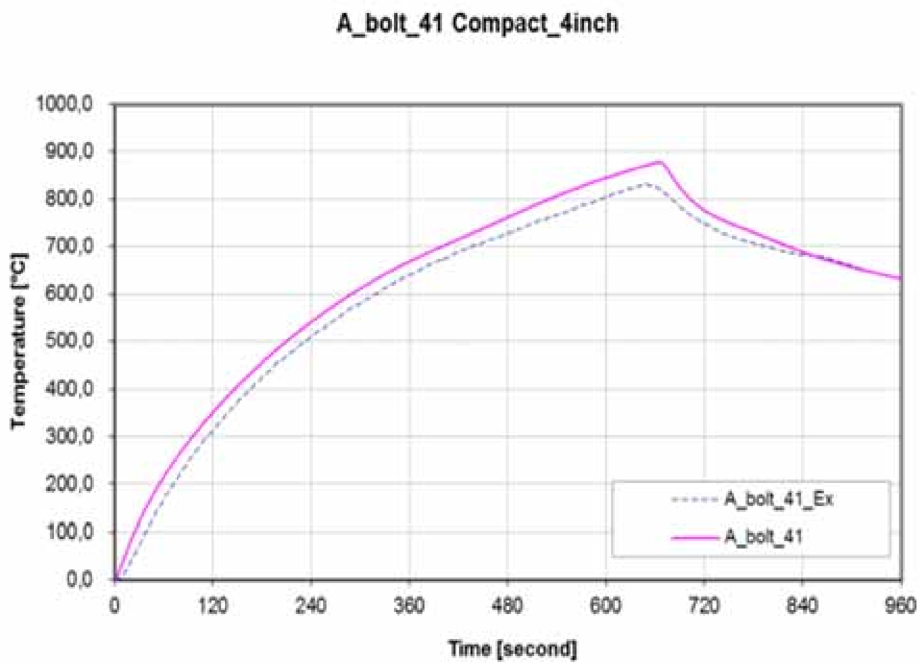
Validation of Brilliant

Thread temperature in unprotected nut/bolt

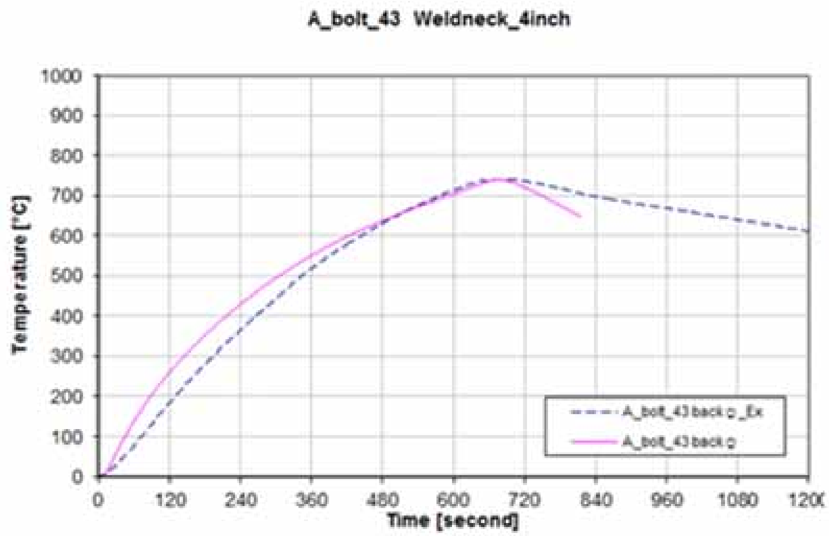


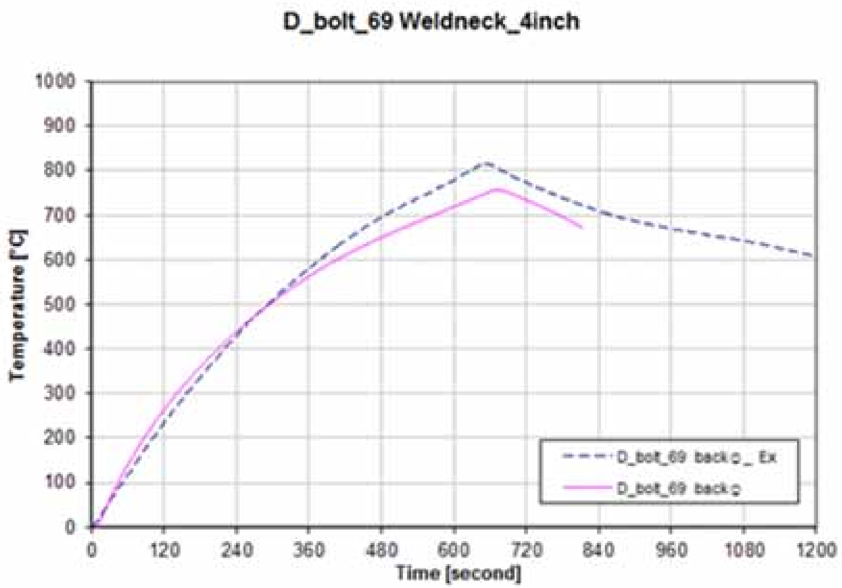


Compact flange

Validation of Brilliant

Thread temperature in unprotected nut/bolt

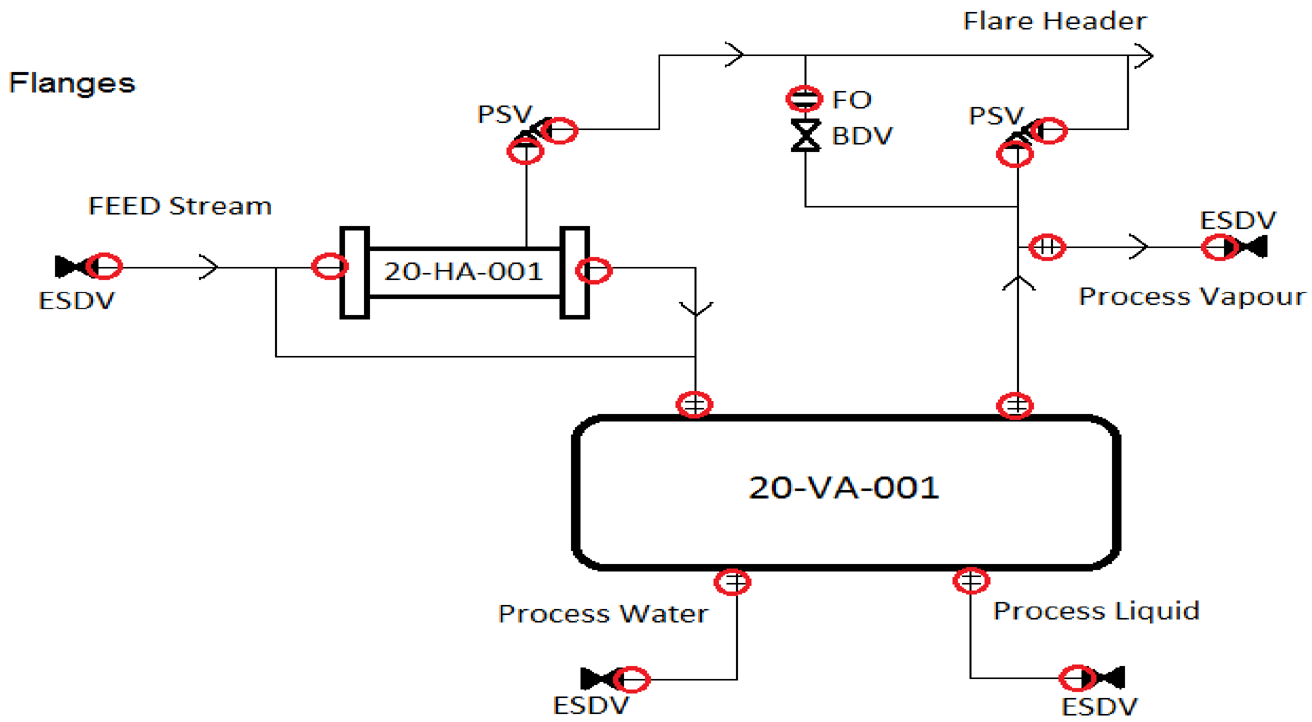




Weldneck flange

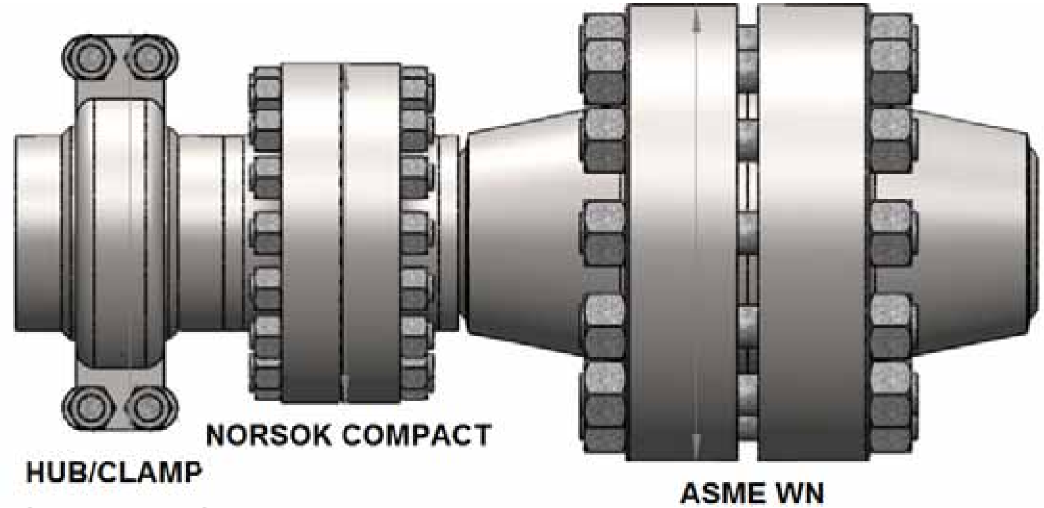
The method applied in projects

- Identify all flanges in each segments
  - Flanges outside segments are usually not of interest due to low escalation potential given rupture



Sorting flanges in groups

- The identified flanges are categorized according to
  - o Flange type (Compact or ASME etc.)
  - o Material group (carbon steel, duplex, stainless etc.)
  - o Pressure class (#150, #300 etc.)
  - o Nominal pipe size
- It is anticipated that flanges on valves, equipment and pipeline can be represented as regular flange
- HUC/CLAMP flanges are not yet a part of analysis method



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Evaluation of results versus acceptance criteria

- Time to disintegration for each group of flanges is calculated using the method described above
- Leak rate at the time of disintegration is calculated using VessFire
- Evaluate consequence of flange rupture against acceptance criteria
  - Statoil has developed a set of acceptance criteria for use in project.
  - The criteria are described in Project development (PD) Guideline, GL3003 chapter 2.5
- Flanges having unacceptable disintegration must be insulated

Treatment of unacceptable rupture

- Flanges with unacceptable rupture must be simulated with use PFP and the result shall be assessed against acceptance criteria
- Since flanges do not have TAG, care must be given when reported
  - o Flanges with need for PFP should be marked-up on the P&ID

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Project experience

- Valemon Topside
  - 5 shutdown segment and HP flare header to be analysed
  - From 10 to 25 types of flanges in each segment
  - About 30% of the flanges in each segment where advised protected
  - Most small sized flanges require insulation

Benefits

- Documented fire integrity
- Economical savings on PFP
- Uninsulated flanges and pipes require less space

- Less cost for the same safety level

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Thank you!