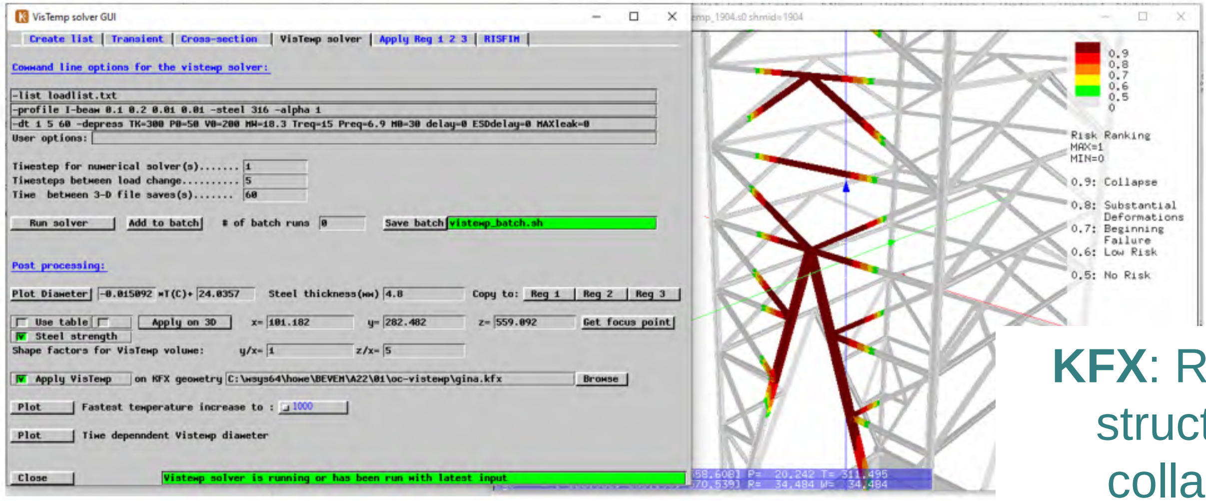
VISTemp and Temperature ball applications



Command line options for the vistemp solver:

```
-list loadlist.txt
-profile I-beam 0.1 0.2 0.01 0.01 -steel 316 -alpha 1
-dt 1 5 60 -depress TK=300 P0=50 V0=200 MW=18.3 Treq=15 Preq=6.9 M0=30 delay=0 ESDdelay=0 MAXleak=0
User options:
```

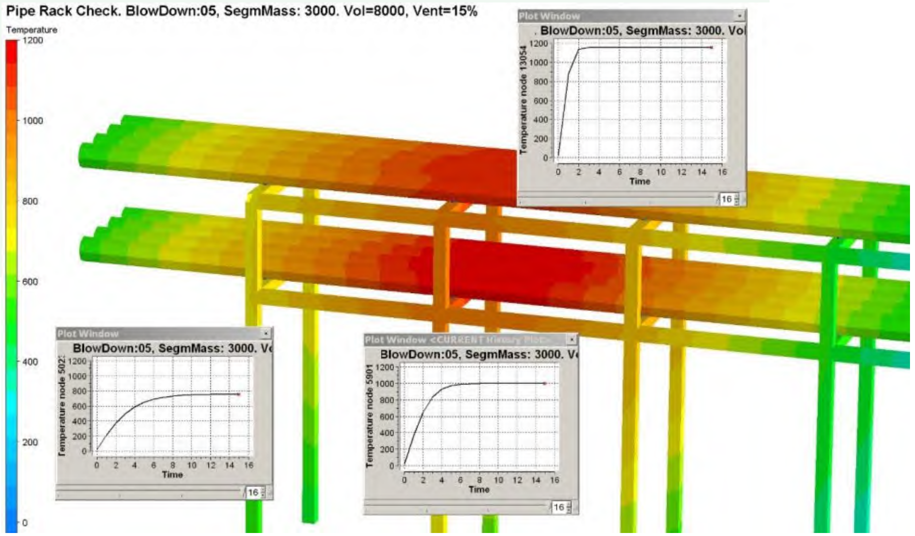
Timestep for numerical solver(s)....... 1
Timesteps between load change.......... 5
Time between 3-D file saves(s)....... 60
\# of batch runs 0
Save batch vistemp_batch.sh

Post processing:

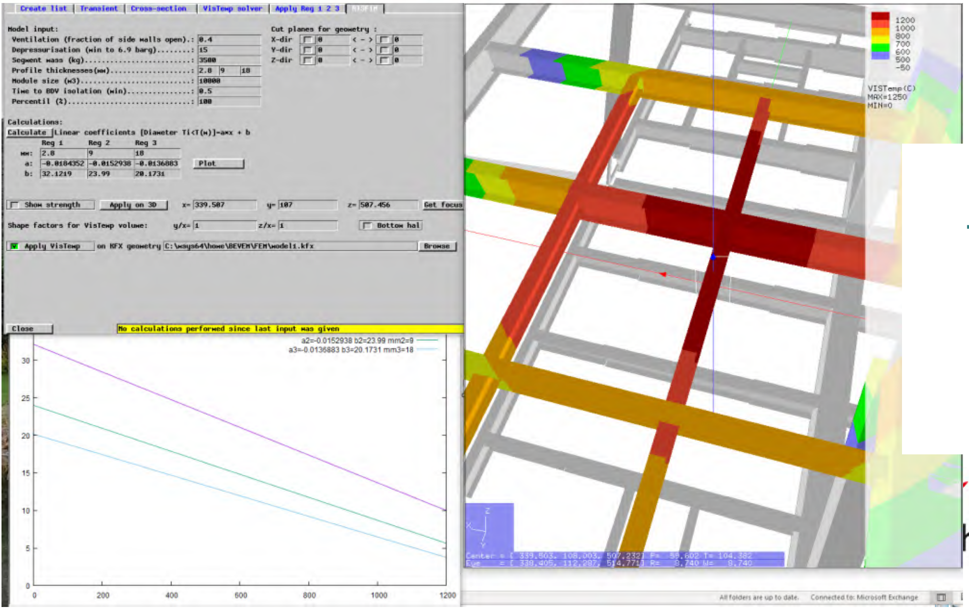
Plot Diameter -0.015092 *T(C)+ 24.0357 Steel thickness(mm) 4.8 Copy to: Reg 1 Reg 2 Reg 3
☐ Use table ☐ x= 101.182 y= 282.482 z= 559.092
☑ Steel strength
Shape factors for VisTemp volume: y/x= 1 z/x= 5
☑ Apply VisTemp on KFX geometry C:\msys64\home\BEVEM\A22\01\oc-vistemp\gina.kfx
Plot Fastest temperature increase to : 1000
Plot Time dependndent Vistemp diameter
Vistemp solver is running or has been run with latest input

Figure 32: Risk of structural collapse projected on a structure. Grey is unaffected by heating.

KFX: Risk for structural collapse



USFOS: Temperature response of pipe rack and global structure



Model input:
Ventilation (fraction of side walls open).: 0.4
Depressurisation (min to 6.9 barg)........: 15
Segment mass (kg).........................: 3500
Profile thicknesses(mm)...................: 2.8 9 18
Module size (m3)..........................: 10000
Time to BDV isolation (min)...............: 0.5
Percentil (%).............................: 100

Cut planes for geometry :
X-dir ☐ 0 < - > ☐ 0
Y-dir ☐ 0 < - > ☐ 0
Z-dir ☐ 0 < - > ☐ 0

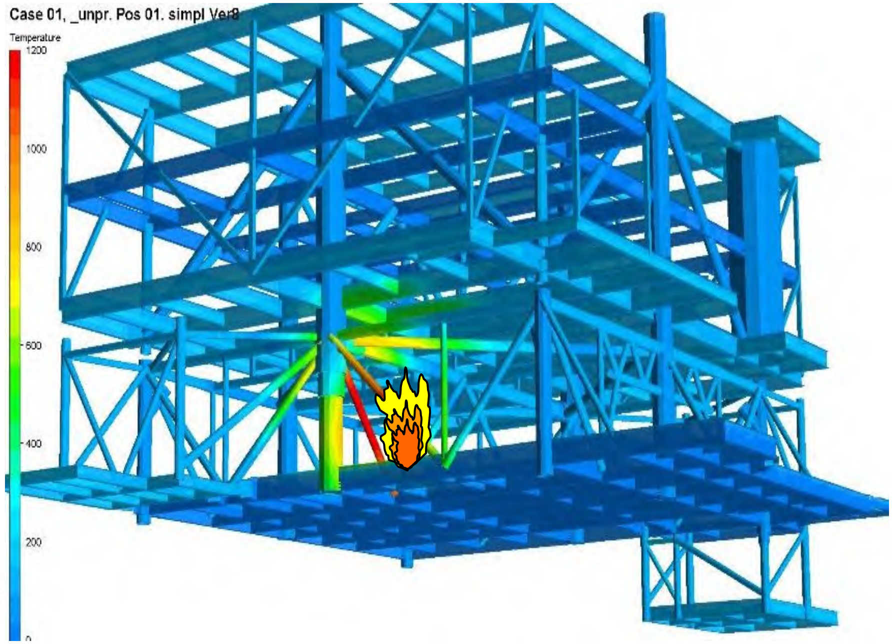
Calculations:
Linear coefficients [Diameter Ti<T(m)]=a*x + b

	Reg 1	Reg 2	Reg 3
mm:	2.8	9	18
a:	-0.0184352	-0.0152938	-0.0136883
b:	32.1219	23.99	20.1731

☐ Show strength x= 339.507 y= 107 z= 507.456
Shape factors for VisTemp volume: y/x= 1 z/x= 1 ☐ Bottom hal
☑ Apply VisTemp on KFX geometry C:\msys64\home\BEVEM\FEM\model1.kfx
No calculations performed since last input was given

a2=-0.0152938 b2=23.99 mm2=9
a3=-0.0136883 b3=20.1731 mm3=18

KFX: Temperature response in actual deck structure



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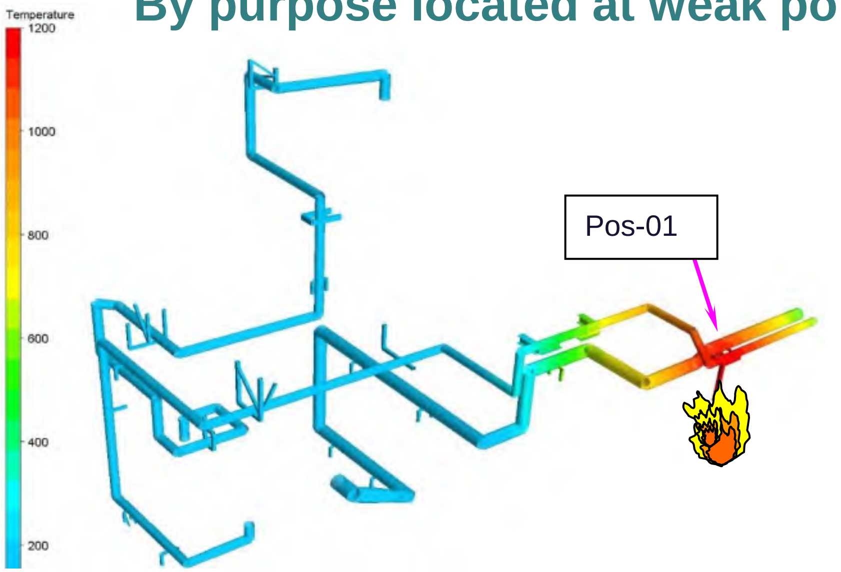
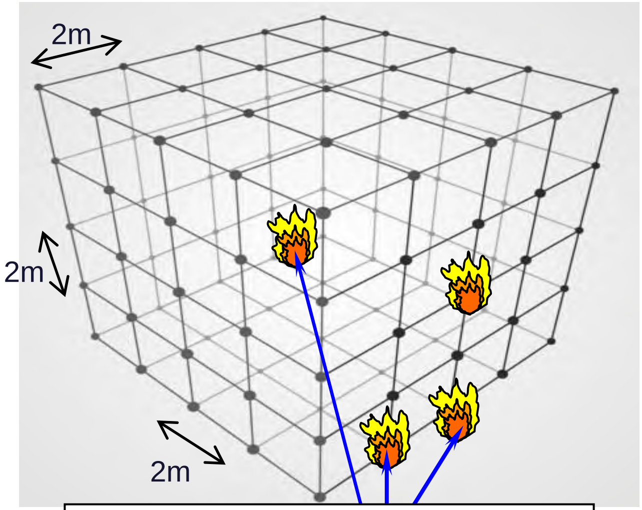
VISTemp and Temperature ball application in response analysis

By purpose located at weak points



Randomly in grid



The RISFIM fire is placed with centre of the sphere in the grid points.

- Tests in RISFIM project concludes
  - that using worst position (at the pipe supports) gives most damage to the pipe system
  - direct simulations (KFX) gives less damage compared to the temperature ball
  - **Temperature ball Placed “by purpose” at pipe supports, one by one, give conservative results**

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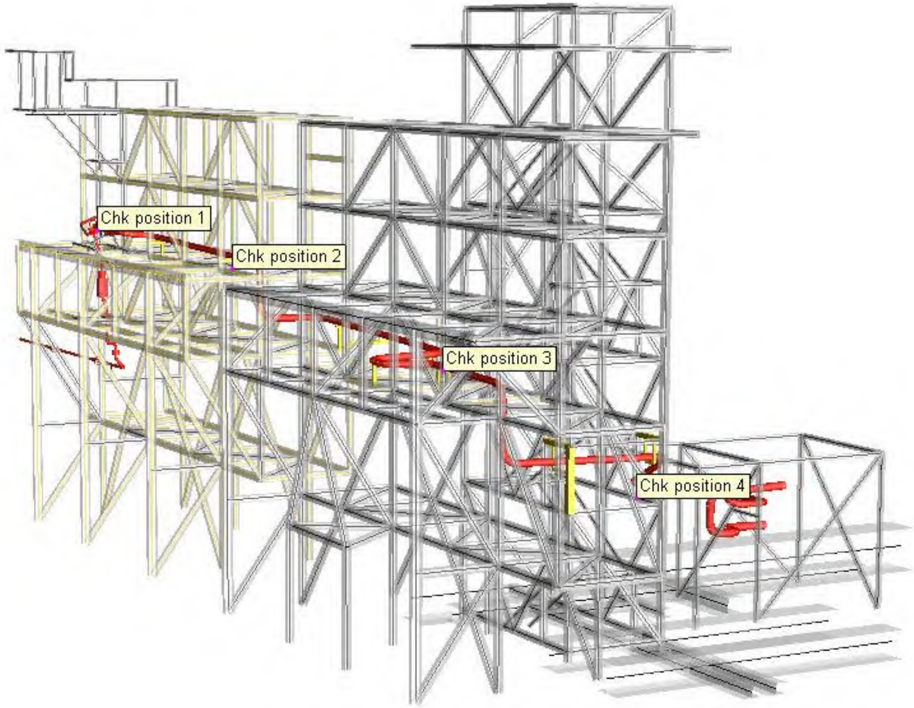
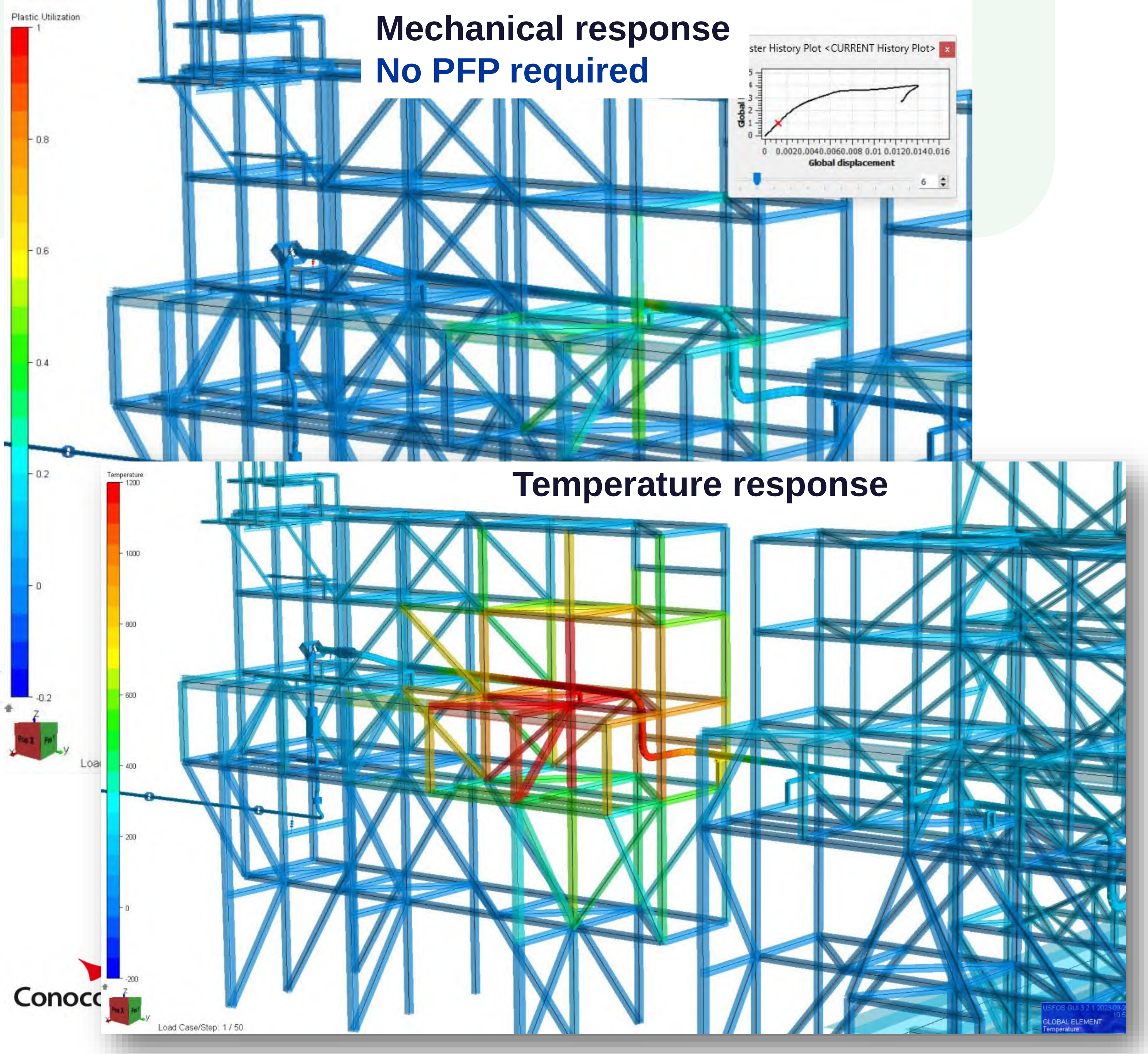
Pipe-rack
Example pos 2

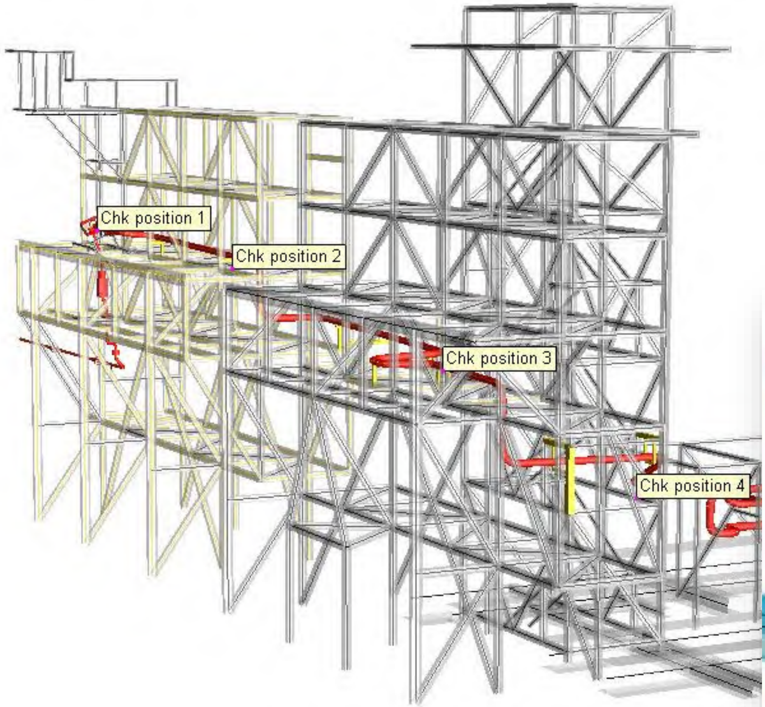


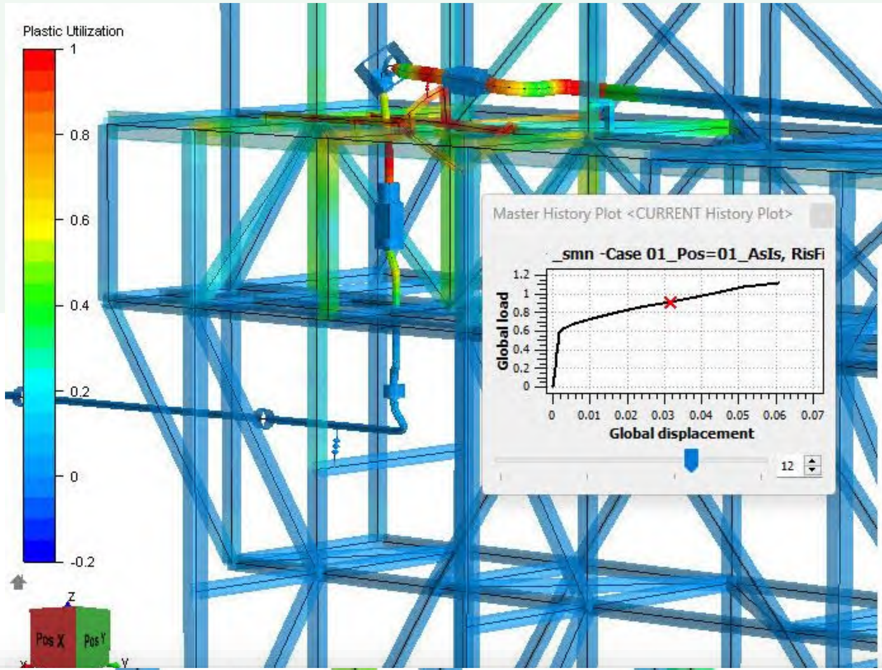

Mechanical response

No PFP required

Temperature response

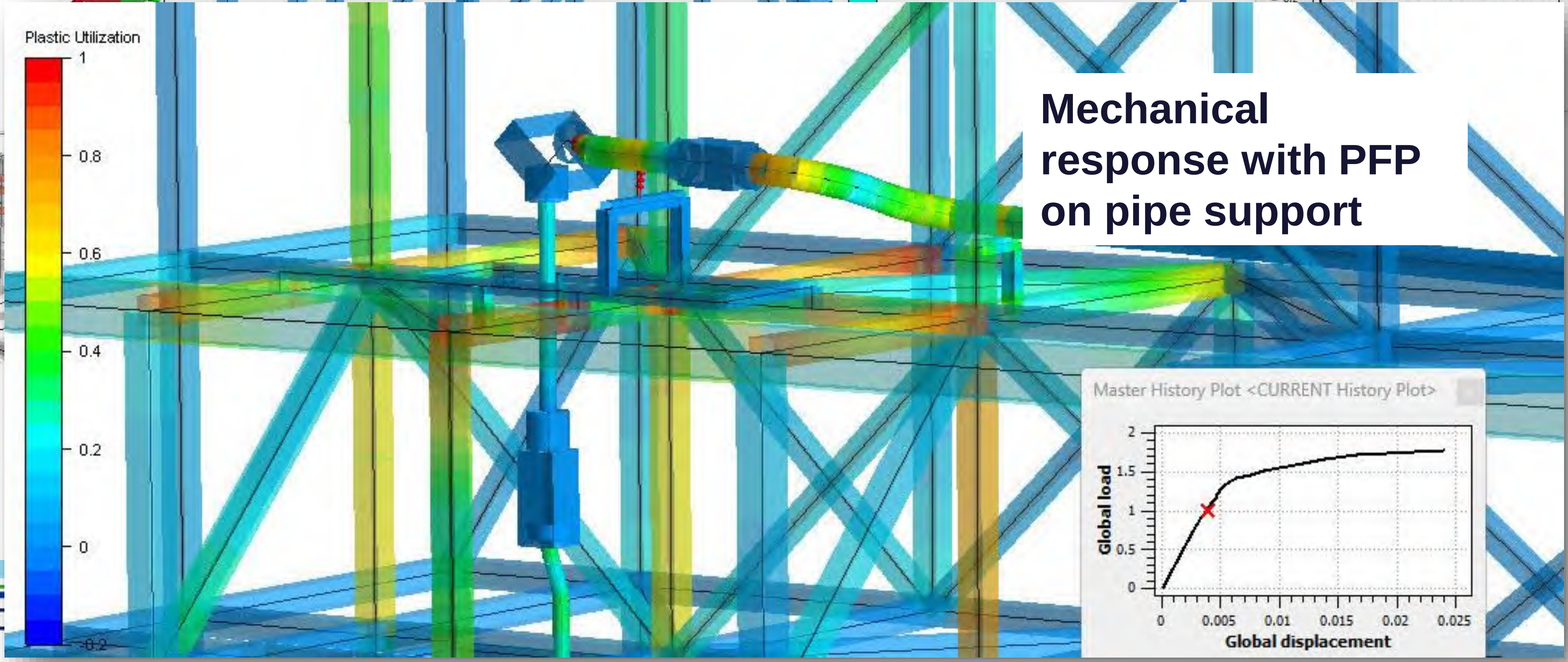
Pipe-rack
Example pos 1





Mechanical response without PFP on pipe support

PFP required

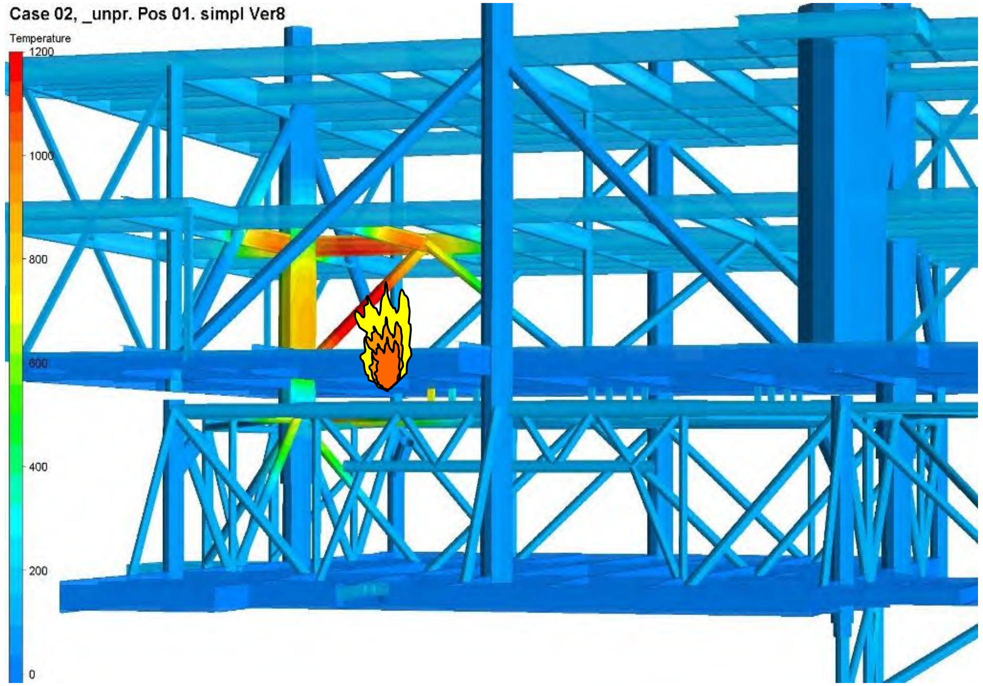


Mechanical response with PFP on pipe support

safetec AkerBP

VISTemp and Temperature ball application in response analysis

- the Temperature ball is developed for use with smaller structures, but the model could also be used for screening of larger structures.
- Since the fire does not go through the proof deck (and the RISFIM model generates spheres unaffected by possible proof decks), the model must reflect that the structure is only exposed on the side where the fire occurs
- Note that the Worst Credible Temperature ball is recommended for screening



Elevation 39

Elevation 34

Elevation 26

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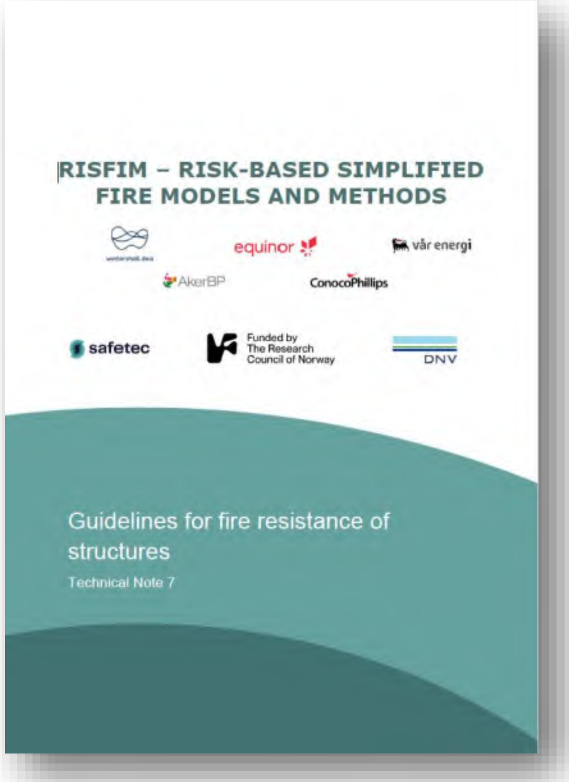
General guidelines for fire resistant structures

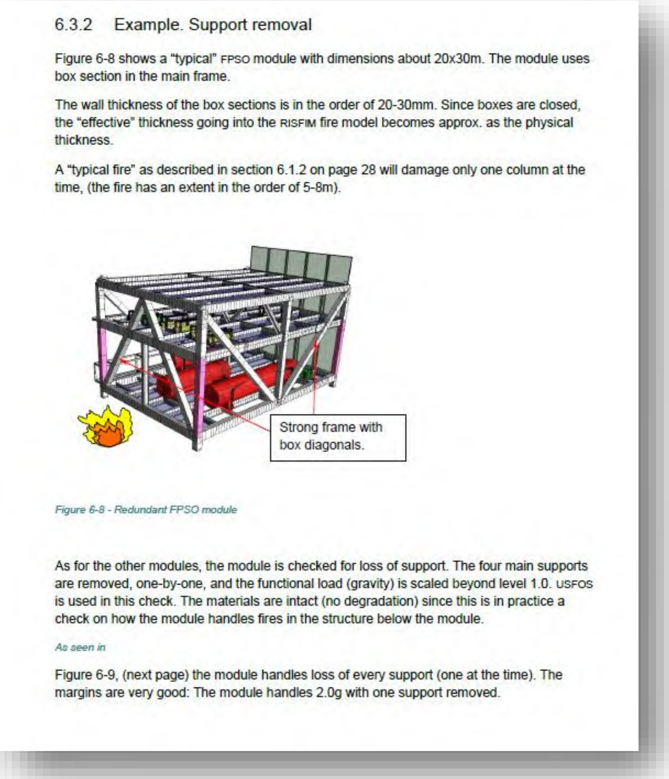
- With the slogan: “Good steel design is the best PFP”, this document will give hints how to enhance a structures ability to handle fires
- Negative effects of pfp:
  - Is a relatively costly “paint”.
  - Need to be maintained throughout the entire platform’s lifetime
  - Welds cannot be checked for cracks. Means stricter fatigue life requirements
  - Increases explosion loads
- Positive effects of robust structure
  - Simplifies the construction phase
  - Easier to modify since no PFP must be removed
  - Handles fires with durations longer than what normal PFP is certified for



RISFIM – RISK-BASED SIMPLIFIED FIRE MODELS AND METHODS

Guidelines for fire resistance of structures

Technical Note 7



6.3.2 Example. Support removal

Figure 6-8 shows a “typical” FPSO module with dimensions about 20x30m. The module uses box section in the main frame.

The wall thickness of the box sections is in the order of 20-30mm. Since boxes are closed, the “effective” thickness going into the RISFIM fire model becomes approx. as the physical thickness.

A “typical fire” as described in section 6.1.2 on page 28 will damage only one column at the time, (the fire has an extent in the order of 5-8m).

Strong frame with box diagonals.

Figure 6-8 - Redundant FPSO module

As for the other modules, the module is checked for loss of support. The four main supports are removed, one-by-one, and the functional load (gravity) is scaled beyond level 1.0. USFOS is used in this check. The materials are intact (no degradation) since this is in practice a check on how the module handles fires in the structure below the module.

As seen in

Figure 6-9, (next page) the module handles loss of every support (one at the time). The margins are very good: The module handles 2.0g with one support removed.

Example 8-leg topside

- The topside has a continuous strong main frame (note the continuous diagonals), which rests on all 8 legs. The modules (yellow and orange in the sketch) are resting on this (green) frame
- If one or more legs are removed, the continuous (green) frame will ensure load transfer to the remaining supports without failing. The modules on the top will therefore not be affected.

Figure 5-5 - Robust topside design regarding fire from platform underside.

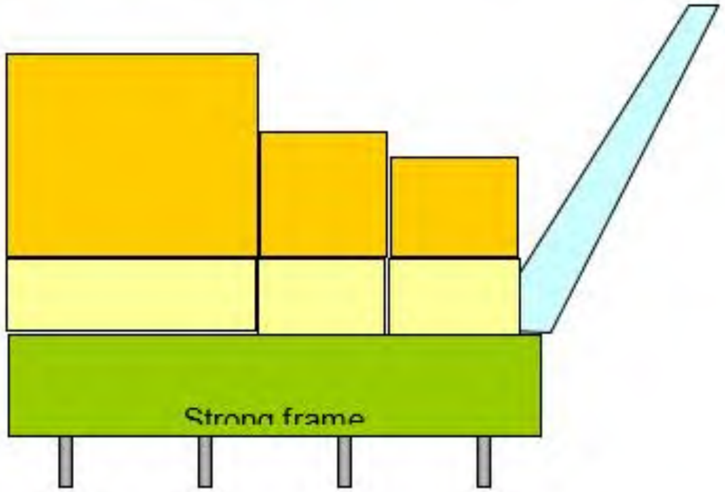
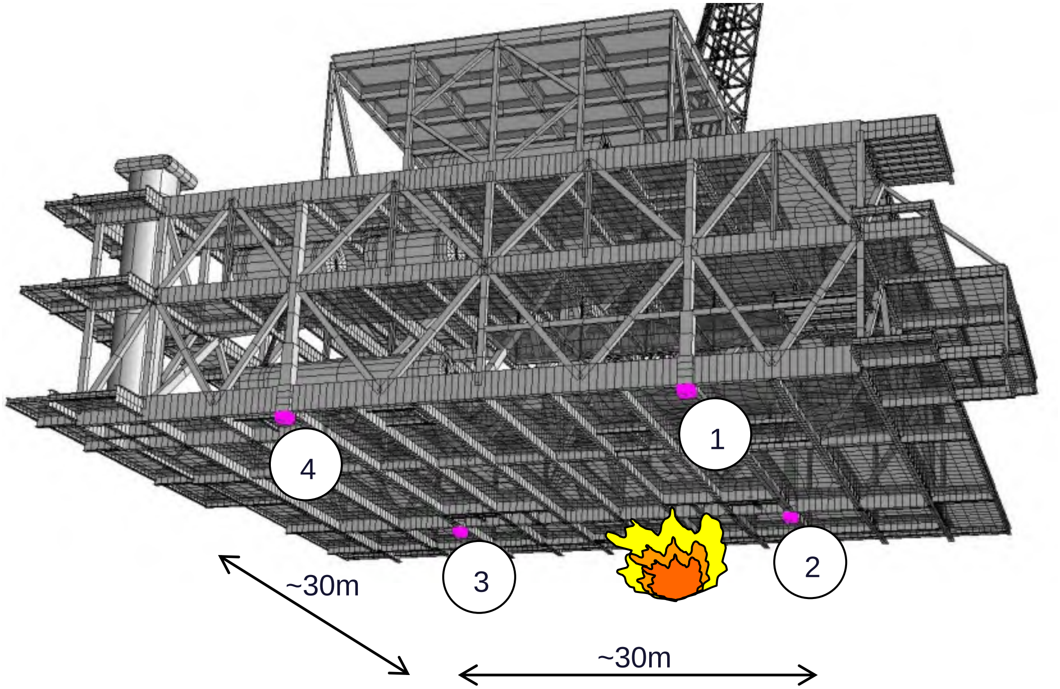


Figure 5-6 - Principal sketch. The green frame is continuous. Modules rest on this frame.

Example floater

- In contrast to fixed platforms, modules on a floater will be exposed to cyclic, sideways accelerations caused by the roll- and pitch movements of the floater caused by waves
- As a positive "side-effect", the structure becomes stronger, and more robust in a fire situation.



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Guidelines for pressurized systems exposed to fire

- VISTemp has been utilized in combination with the RISFIM fire risk model to calculate the frequency for exposure to the NORSOK heat loads – results demonstrates the local peak incident heat fluxes are reasonable
- A method with guidelines for probabilistic estimation of a specific peak heat load has been outlined
- Furthermore, a method for probabilistic estimation of the global average heat load has been suggested.

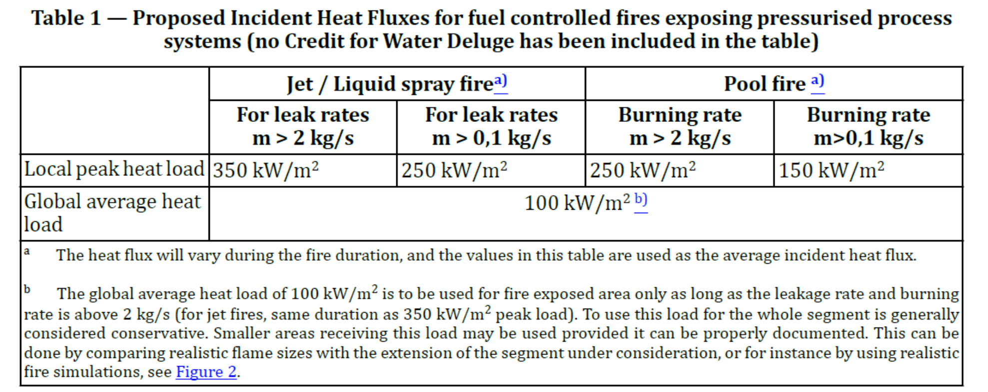

Table 1 — Proposed Incident Heat Fluxes for fuel controlled fires exposing pressurised process systems (no Credit for Water Deluge has been included in the table)

	Jet / Liquid spray fire[a)]		Pool fire [a)]	
	For leak rates m > 2 kg/s	**For leak rates m > 0,1 kg/s**	**Burning rate m > 2 kg/s**	**Burning rate m>0,1 kg/s**
Local peak heat load	350 kW/m^2	250 kW/m^2	250 kW/m^2	150 kW/m^2
Global average heat load	100 kW/m^2 [b)]			

[a] The heat flux will vary during the fire duration, and the values in this table are used as the average incident heat flux.

[b] The global average heat load of 100 kW/m^2 is to be used for fire exposed area only as long as the leakage rate and burning rate is above 2 kg/s (for jet fires, same duration as 350 kW/m^2 peak load). To use this load for the whole segment is generally considered conservative. Smaller areas receiving this load may be used provided it can be properly documented. This can be done by comparing realistic flame sizes with the extension of the segment under consideration, or for instance by using realistic fire simulations, see Figure 2.

RISFIM – RISK-BASED SIMPLIFIED FIRE MODELS AND METHODS

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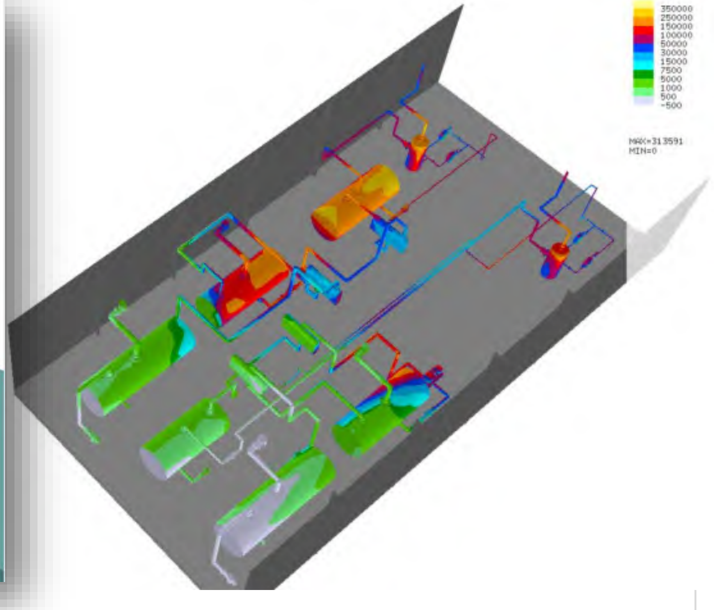
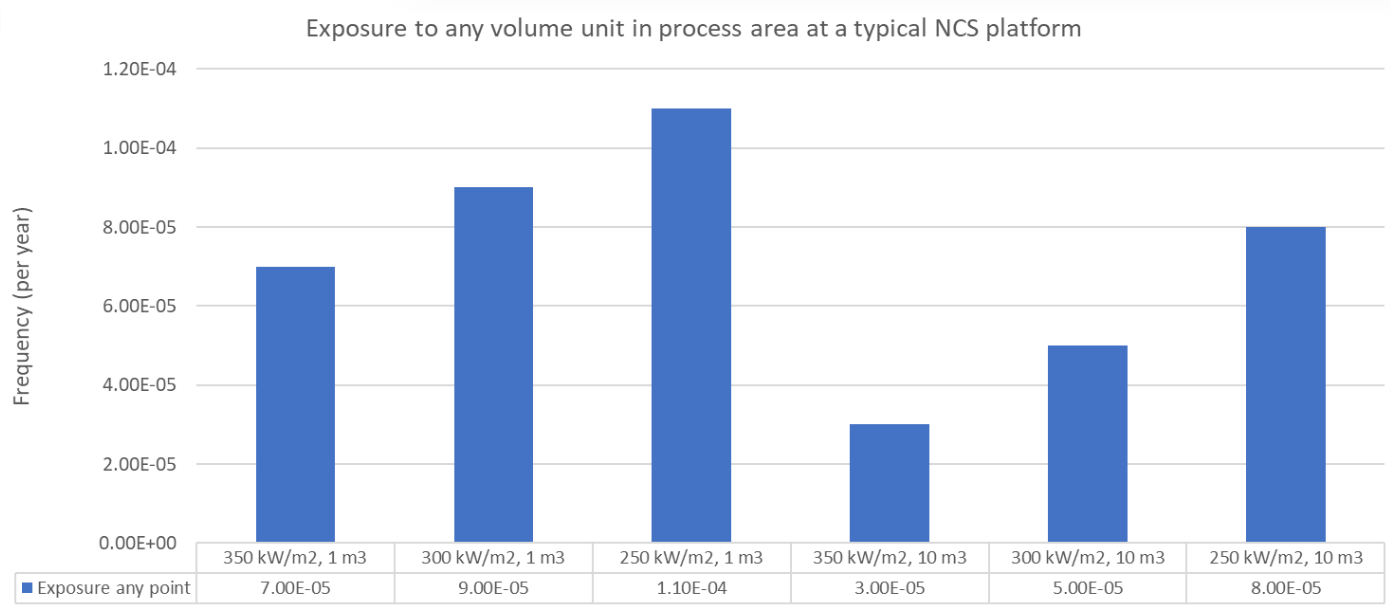
Fire loads for rupture analysis of process equipment

Technical Note 4

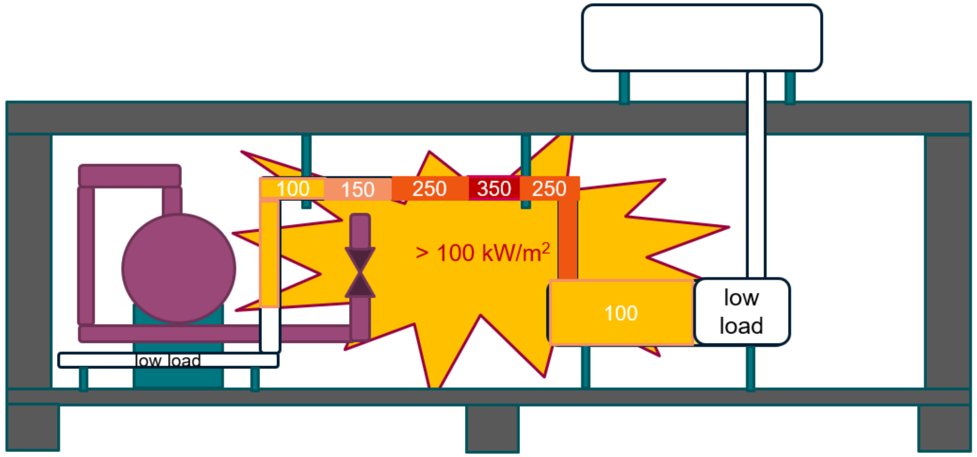


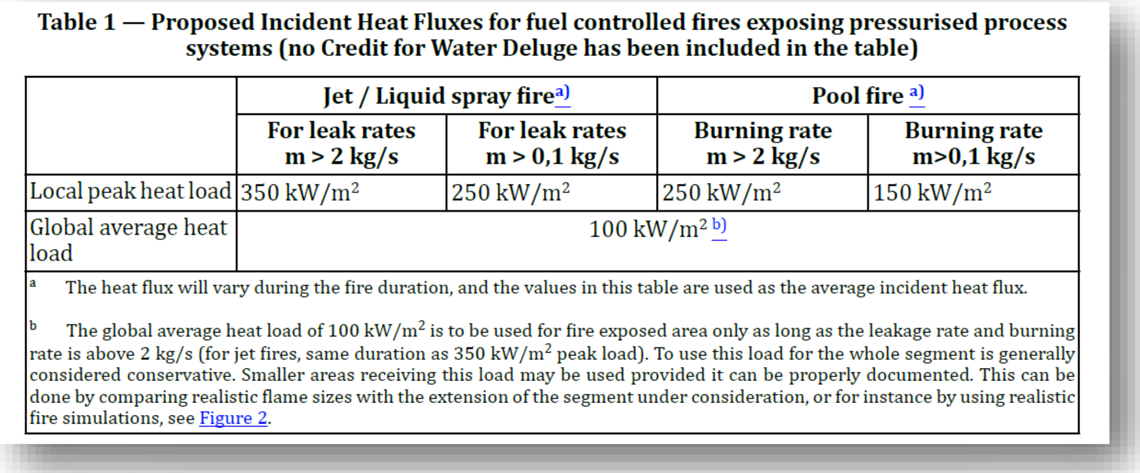


	350 kW/m2, 1 m3	300 kW/m2, 1 m3	250 kW/m2, 1 m3	350 kW/m2, 10 m3	300 kW/m2, 10 m3	250 kW/m2, 10 m3
■ Exposure any point	7.00E-05	9.00E-05	1.10E-04	3.00E-05	5.00E-05	8.00E-05

Guidelines for pressurized systems exposed to fire

- a fire will generate localized fire loads towards exposed targets.
- both the incident flux at a specific location and the global average heat load acting on a segment will vary throughout the fire following fire dynamics and the transient fed of the fire
- the actual transient behaviour of the heat loads may result in a very different response of the pressurized equipment compared to the suggested constant heat fluxes suggested by NORSOK S-001
- Therefore, the possibility to develop a methodology to derive specific heat loads for pressurized equipment has been executed in RISFIM





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Local peak heat load	350 kW/m^2	250 kW/m^2	250 kW/m^2	150 kW/m^2
Global average heat load	100 kW/m^2 [b)]			

[a] The heat flux will vary during the fire duration, and the values in this table are used as the average incident heat flux.

[b] The global average heat load of 100 kW/m^2 is to be used for fire exposed area only as long as the leakage rate and burning rate is above 2 kg/s (for jet fires, same duration as 350 kW/m^2 peak load). To use this load for the whole segment is generally considered conservative. Smaller areas receiving this load may be used provided it can be properly documented. This can be done by comparing realistic flame sizes with the extension of the segment under consideration, or for instance by using realistic fire simulations, see Figure 2.

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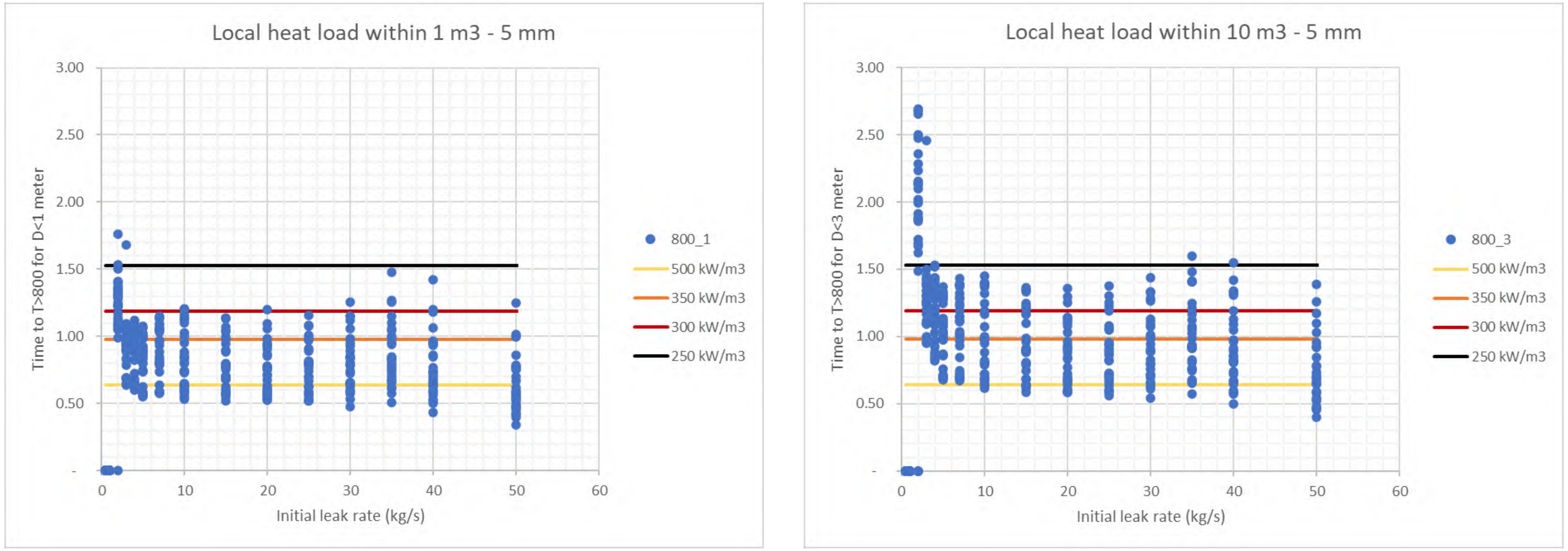
Guidelines for pressurized systems – local load

- It is found that the VISTemp model can provide basis for derivation of a risk-based methodology for specification local incident heat fluxes
- Based on the empirical data in RISFIM, a probabilistic study has been performed for the 8 generic modules

All VISTemp simulations for M132

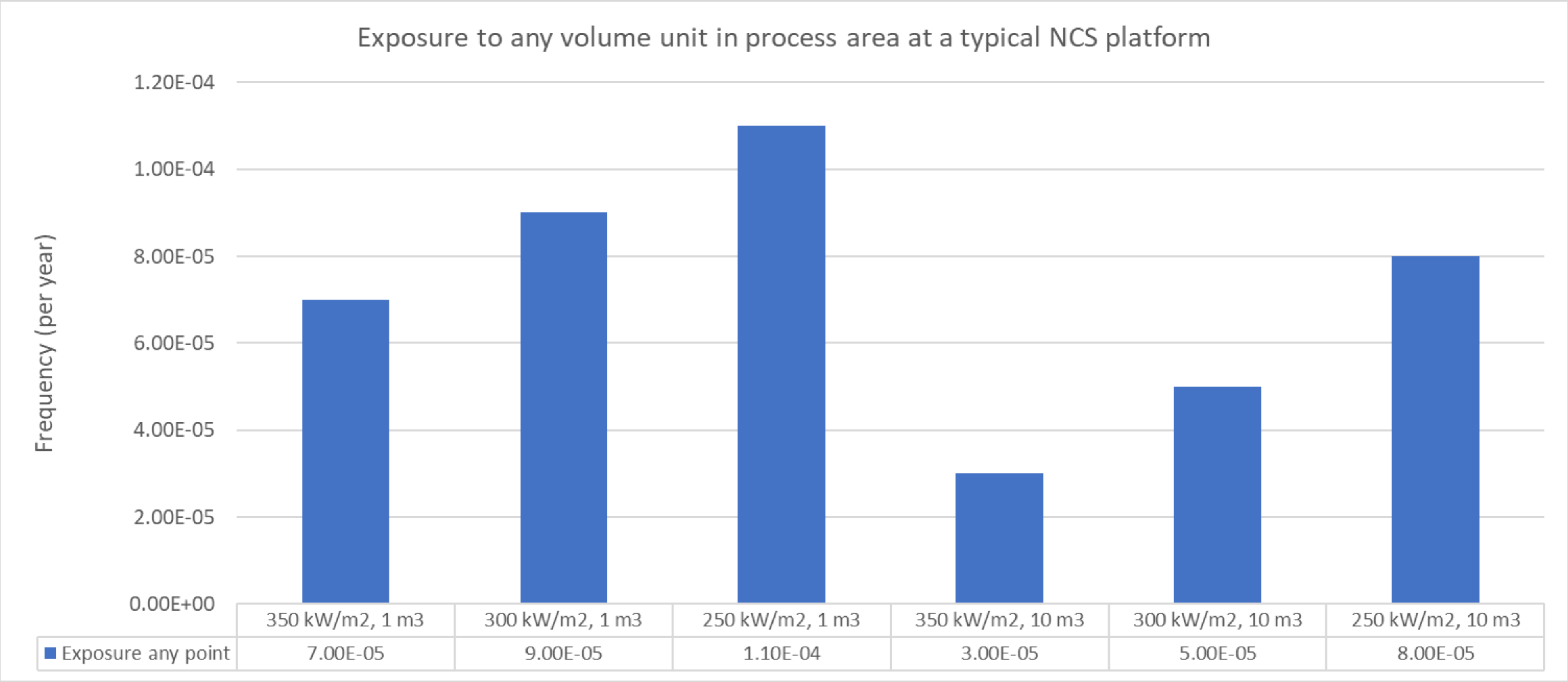


Local heat load within 1 m3 - 5 mm

Local heat load within 10 m3 - 5 mm

Points below given line are heated by a flux above the flux represented by the line

Guidelines for pressurized systems – local load



	350 kW/m2, 1 m3	300 kW/m2, 1 m3	250 kW/m2, 1 m3	350 kW/m2, 10 m3	300 kW/m2, 10 m3	250 kW/m2, 10 m3
■ Exposure any point	7.00E-05	9.00E-05	1.10E-04	3.00E-05	5.00E-05	8.00E-05

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Guidelines for pressurized systems – local load

- the frequency for a heat load of 250 kW/m^2 or higher arising at any point (now considering an exposed volume of 1 m^3) at the installation is around $1 \cdot 10^{-4}$ per year
- this is an upper estimate for the rupture frequency
  - the estimate presumes that the hottest part of all fires generating incidents heat flux above 250 kW/m^2 (note: not all fires generate flux above 250 kW/m^2) exposes process equipment
  - it also presumes that all equipment rupture if the heat load exceeds 250 kW/m^2
- overall, it is argued that a reasonable generic upper rupture frequency for a typical installation designed for an incident heat load of 250 kW/m^2 is $5 \cdot 10^{-5}$ per year
- upper estimate of the rupture frequency for a typical installation is less than $3 \cdot 10^{-5}$ and $4 \cdot 10^{-5}$ per year given a design incident heat load of 350 kW/m^2 and 300 kW/m^2 respectively

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Guidelines for pressurized systems – local load

- The advanced generic probabilistic analysis presented confirms that 350 kW/m^2 and 250 kW/m^2 is a reasonable incident local heat loads that will ensure a robust design
- Despite the relatively high frequencies (< 10^{-4} per year) found in the generic study, it can be argued that a risk-based approach could justify a somewhat lower peak incident heat load than suggested by NORSOK S-001
- This is expected to be useful where only a few pipes or a small pipe segment is vulnerable to high heat loads in the area at hand
- On this basis, a probabilistic method utilizing the VISTemp method and the RISFIM frequency model has been established in RISFIM to justify a specific local load

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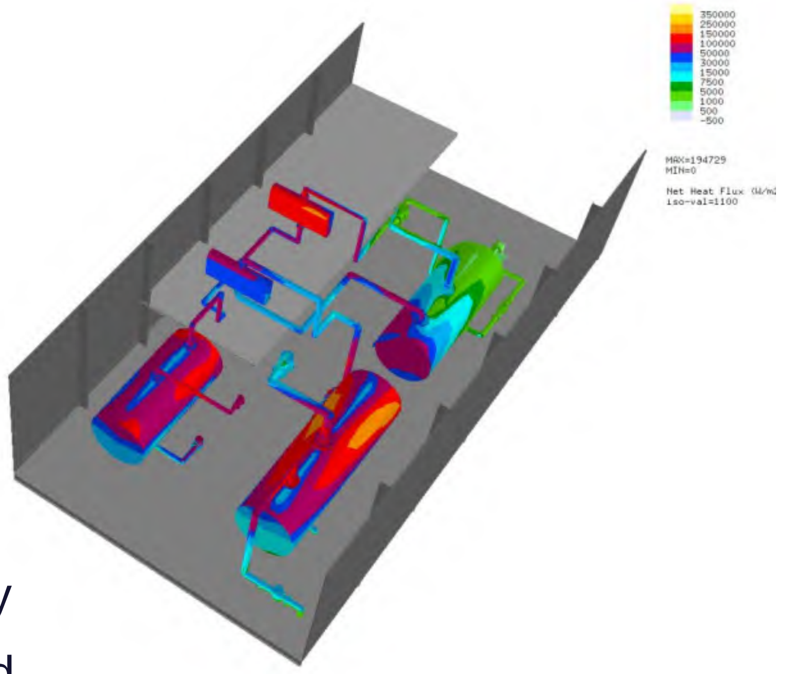
Guidelines for pressurized systems – global load

- The global average heat load acting on typical segments in the generic modules has been investigated
- The simulations demonstrates that
  - the global average heat load of 100 kW/m^2 is a special case
  - a leak rate less than 5 kg/s are unlikely to generate global average heat loads > 100 kW/m^2
  - the global average heat load will vary considerably with time according to the time-dependent behavior of the leak feeding the fire
- Based on the RISFIM frequency model, the NORSOK S-001 global average heat load corresponds to a frequency that is much less than 5·10^{-5} per year
- there is room for a methodology that enable optimization of the global average heat load without violating overarching requirements to fire safety
- a probabilistic method utilizing KFX (or any other applicable CFD tool) and the RISFIM frequency model has been established in RISFIM to justify a specific global load



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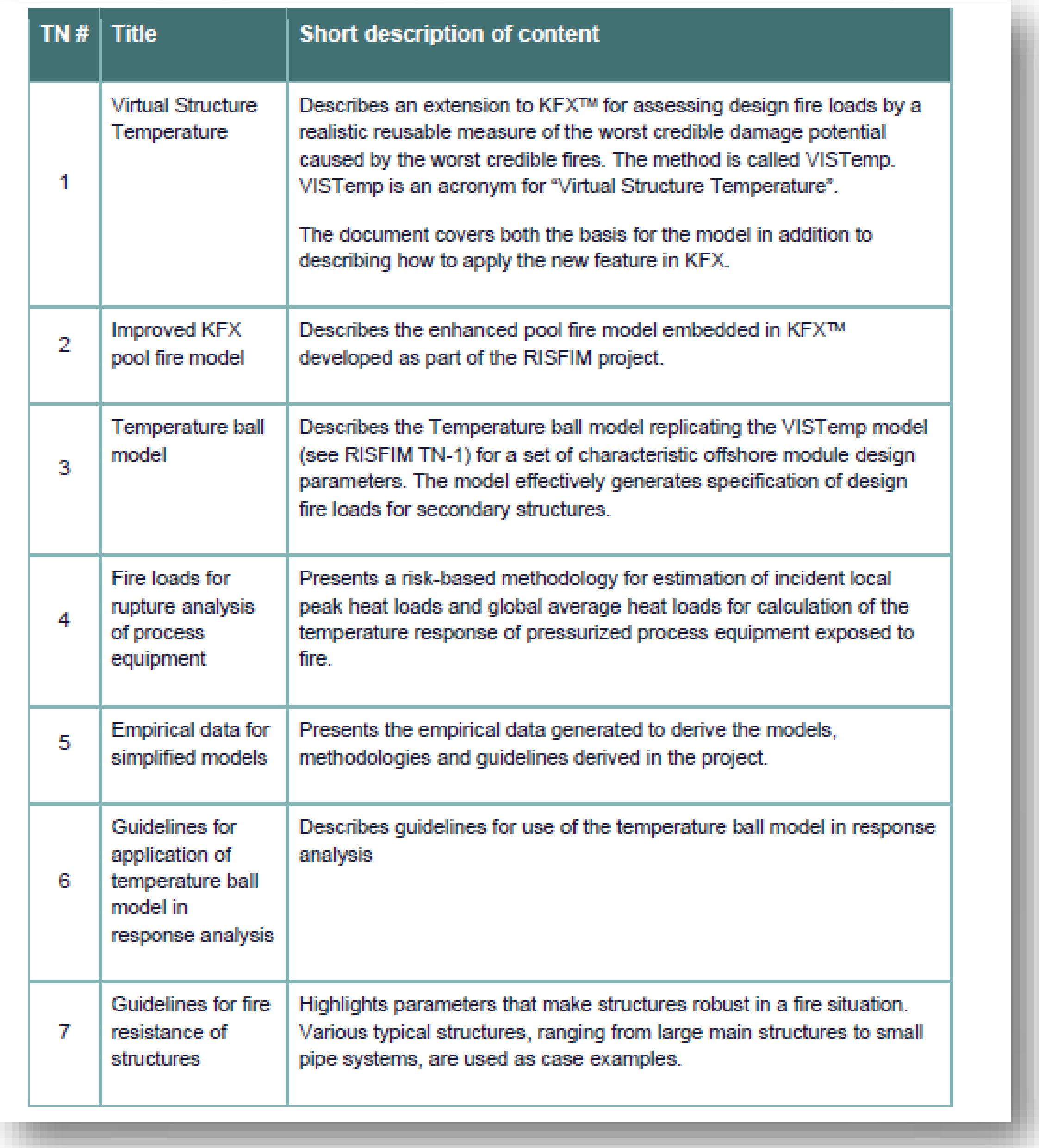
Summary and further reading

- RISFIM reports are openly available
- The Temperature model is straight forward to implement as a software tool. In RISFIM project, we implemented the model in an Excel spreadsheet.
- Safetec will share reports upon request



TN #	Title	Short description of content
1	Virtual Structure Temperature	Describes an extension to KFX™ for assessing design fire loads by a realistic reusable measure of the worst credible damage potential caused by the worst credible fires. The method is called VISTemp. VISTemp is an acronym for "Virtual Structure Temperature". The document covers both the basis for the model in addition to describing how to apply the new feature in KFX.
2	Improved KFX pool fire model	Describes the enhanced pool fire model embedded in KFX™ developed as part of the RISFIM project.
3	Temperature ball model	Describes the Temperature ball model replicating the VISTemp model (see RISFIM TN-1) for a set of characteristic offshore module design parameters. The model effectively generates specification of design fire loads for secondary structures.
4	Fire loads for rupture analysis of process equipment	Presents a risk-based methodology for estimation of incident local peak heat loads and global average heat loads for calculation of the temperature response of pressurized process equipment exposed to fire.
5	Empirical data for simplified models	Presents the empirical data generated to derive the models, methodologies and guidelines derived in the project.
6	Guidelines for application of temperature ball model in response analysis	Describes guidelines for use of the temperature ball model in response analysis
7	Guidelines for fire resistance of structures	Highlights parameters that make structures robust in a fire situation. Various typical structures, ranging from large main structures to small pipe systems, are used as case examples.

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Thank you!

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