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Critical Restarting Time Window
Wax concentration effect for reducing waxy crude transportation risk

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Resuming the steady transportation of waxy crude after unexpected or scheduled flow interruptions is a high-risk production operation component. The critical restarting time window (CRTW) is field/location specific and indicates the maximum allowed shut-in time for normal resuming steady flow conditions.

This study using field wax compositions (Table 1) and extreme but realistic offshore temperatures and pipe diameters demonstrate the salient effect of wax composition-WAT on CRTW.

For a certain pipe diameter and boundary temperature conditions, the CRTW versus wax appearance temperature (WAT), (Figure 1), is a result of two competing factors controlling the transient heat transfer during shut-in periods: a. heat released during wax crystallization (increasing the CRTW with WAT) and b. time to extend the jelly layer to a predetermined annular zone (reducing the CRTW with increasing the WAT).

Proper assessment of WAT [1] and of radial time-temperature curves during transient cool-down with releasing crystallization latent heat [2] are essential background information required for this study.

A finite element heat transfer model (FEHT) was adapted [2] to include the effect of releasing crystallization heat (for a number of field samples with WAT ranges from 40 to 60 ^oC – Table 1). In the property files used for modelling the cool-down, the latent heat (100....150 kJ/kg – Table 1) was “assigned” as a pseudo-specific heat to a zone of $\pm$ 2.5 ^oC around the specific WAT value using a normal distribution procedure. The transient heat model, adapted to the specific pipe geometry was further used to calculate radius-specific time-temperature functions.

The CRTW was calculated as time required to reach the WAT (sample-specific) value at a radius determined for a jelly layer occupying 55% of initial flow area.

Calculated results summarized in Figure 1 for 6” and 15” pipes operating at deepsea and shallow offshore conditions indicates both general features and geometry-temperature specific values.

The “4-Zone” shut-in general features indicated in Figure 1 as: Z1 – low WAT/low wax – of constant, high CRTW, Z2 – the CRTW is significantly increased with WAT decreasing, Z3 – CRTW is (again) almost independent of WAT (note: the effect of heat crystallization release and WAT are in balance), Z4 – extreme high WAT – reducing WAT/Wax will (somehow) increase the CRTW; for very high diameters (pipelines or trunklines) this zone is not observed). Depressing the WAT (through chemical additive) without reducing the amount of wax in solution will not fit into this generalized 4-zone concept.

Results of this study are further guiding a complex of mitigation technologies used to reduce the CRTW for offshore production operations.

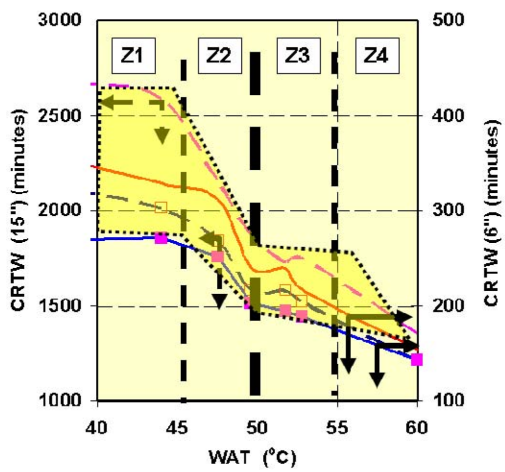

Fig. 1. Critical Restarting Time Window (CRTW) versus local WAT – 4-Zone (calculated values for 6” and 15” using shallow and deepsea temperature conditions)

Table 1. Composition of six waxy crude samples used in the modelled cases

Case	1	2	3	4	5	6
WAT ^oC	40.4	44.7	47.5	49.2	50.7	52.8
$<C_{n=30}$ (%)	10.0	20.0	31.1	40.0	50.0	55.0
Tot. wax (%)	50.0	55.2	61.1	66.4	72.0	74.8
Lat. Heat (kJ/kg mix)	97	110	123	135	148	154

References

[1] Sansot, J. M., Daridon, J.L. and Couthino, J.A.P. Modelling High-Pressure Wax Formation in Petroleum Fluids, (2005) AIChJ v. 51, 7, 2089-2097.

[2] Finite Element Heat Transfer (FEHT), developed by F-Chart Software (transient heat transfer with latent heat of solidification) – adapted for waxy crude by P.Toma, PRT