



Prediction of Hot Zone Temperature and its Extension Rate up to Boilover

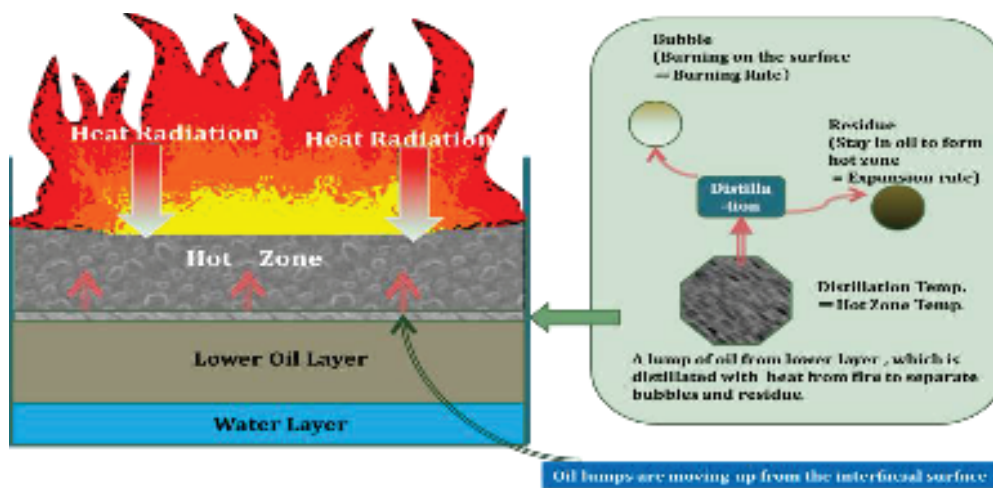
by Yoshiyuki Kato



A simulation program was developed to predict hot zone temperature and its extension rate for a crude oil fire in a large tank. The calculated results are summarized in this report. Possibility of boilover and required time to cool down the hot oil after extinguishment of a crude oil tank fire were also studied by using another simulation program developed separately. In case of a large tank fire, it was found that possibility of boilover occurrence after extinguishment seems too little and so long days are required to cool the hot oil.

1 Hot zone calculation model

The simulation program (EXCEL VBA) had been developed based on the theoretical model as illustrated below.



2 Calculated results of the hot zone formation

2.1 Calculation condition

(1) The crude oils used for the hot zone calculation are eight types having a different distillation curves each other. One of them is Crude oil No. -2.

Crude oil No. -2
 Oil Name Unknown (Crude Oil)
 Density 0.8558 g/cm³ @15°C
 API 33.8 (60° F)
 Sulfur 1.8 %
 Kinematic Viscosity 6.721 cSt @ 30°C

Fraction and Cut Temperature

Temperature		wt	
From (Tf °C)	To (Te °C)	(%)	cum(%)
-89	-0.5	2.3	2.3
36.1	70	6.9	9.2
70	100	3.4	12.6
100	150	8.6	21.2
150	190	7.2	28.4
190	235	7.8	36.2
235	280	7.7	43.9
280	343.3	11.0	54.9
343.3	565	28.2	83.1
565		16.9	100.0

- (2) Tank on fire; 80[m] dia. x 22[m] height, initial oil level; 20 [m], Water level 1 [m]
- (3) Initial oil temp. 30 [degC], water temp. 30 [degC], Ambient temp. 35 [degC]
- (4) Minimum hot zone temperature required for boilover ; 120 [degC]
- (5) Burning rate of 162 [kg/m²/h] is applied for every crude oil.



2.2 Calculated results

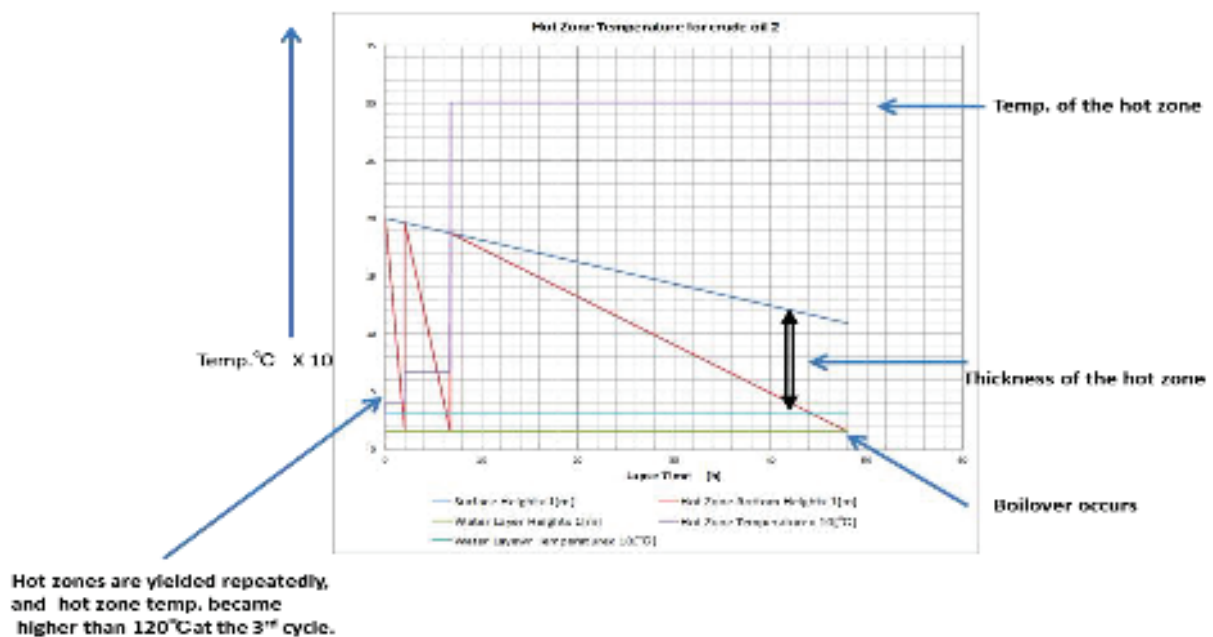
The results are shown in the next graph for crude oil No. 2, and summarized in the associated table for all crude oils. Variations in the hot zone temperature with time, extension rate, lapse time from initiation of fire to occurrence of boilover are just depending on the distillation data.

The simulation model used in this study may not match all experimental results on the hot zone formation due to the assumptions, such as;

- Density of oil is constant against the change in temperature
- Burning rate is constant through whole period of fire

However, it should be noted that most of boilover experiments were performed with small tanks and extremely thin oil layers, which is quite different from an actual tank fire.

Crude Oil	1	2	3	4	5	6	7	8
Initial oil surface height[m]	20	20	20	20	20	20	20	20
Hot zone Temp. [degC]	373.4	300.4	314.4	359.9	399.1	290.3	306.7	283.0
Last oil surface height [m]	7.4	10.7	9.5	7.8	6.4	10.4	9.8	10.7
Lapse time at boilover [h]	68.1	49.4	55.3	66.3	70.8	49.9	54.3	49.4
Hot zone extension rate [m/h]	0.09	0.20	0.15	0.1	0.08	0.19	0.16	0.20
Distillation cycle number	1	3	1	1	1	1	1	1



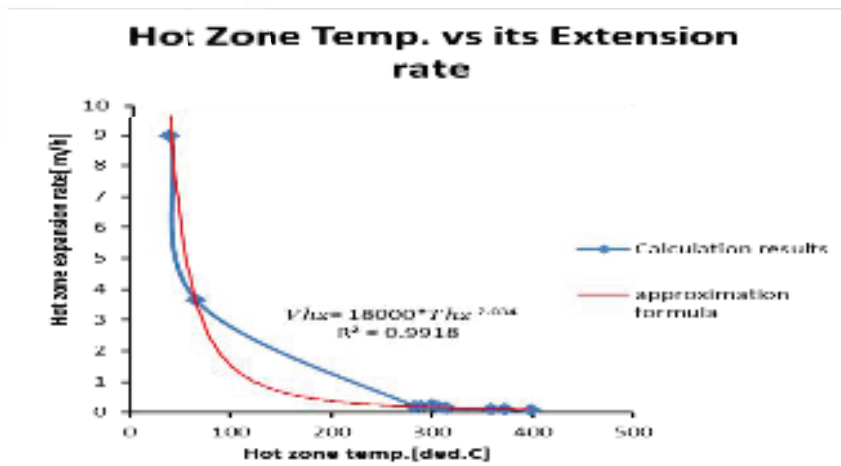
2.3 Extension rate of the hot zone

The following graph shows relation of the hot zone temperature and the extension rate calculated for eight types of crude oils. The approximation formula for relation between the hot zone temperature T_{hz} [degC] and its extension rate V_{hz} [m/h] is;

$$V_{hz} = 18,000 * T_{hz}^{-2.034}$$

When $T_{hz} = 120$ [degC], then $V_{hz} = 1.06$ [m/h].

This means the calculated results well mach with the phenomena in an actual tank fire as reported by LASTFIRE.

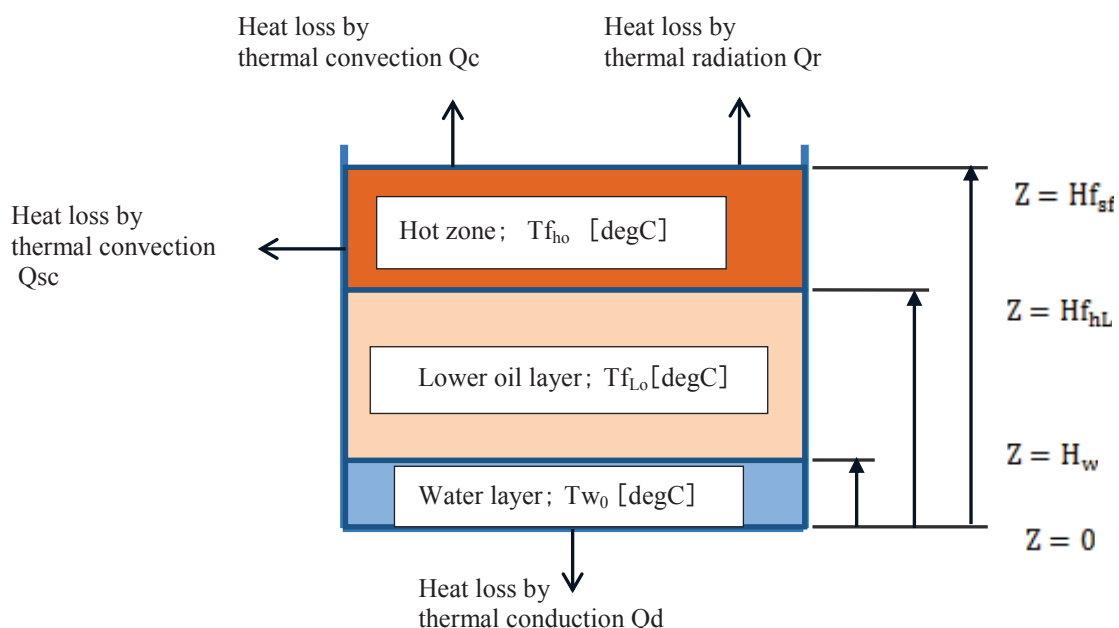


3 Temperature profile in the tank after extinguishment

There are two purposes of this study, one is to predict boilover occurrence, and the other is to predict how long time is required to cool the oil.

3.1 Calculation model

The simulation program (EXCEL VBA) had been developed based on the calculation model shown below.



Just after the extinguishment, the upper side oil is hotter and lighter than the lower oil and water. So convection does not occur likely and the heat transfer is mainly by thermal conduction. Heat loss from the oil surface may be considerable large, so the upper side of the hot zone will be cooled within a short time and its density becomes heavier than the oil just below the surface and also heavier than the lower oil layer, because components of the hot zone are obviously heavier than ones of the lower oil layer. This heavier oil surface zone will spread entirely like a lid of the pan and still remains at the upper position. That means convection may not occur likely and thermal conduction will be continued as a main heat transfer.

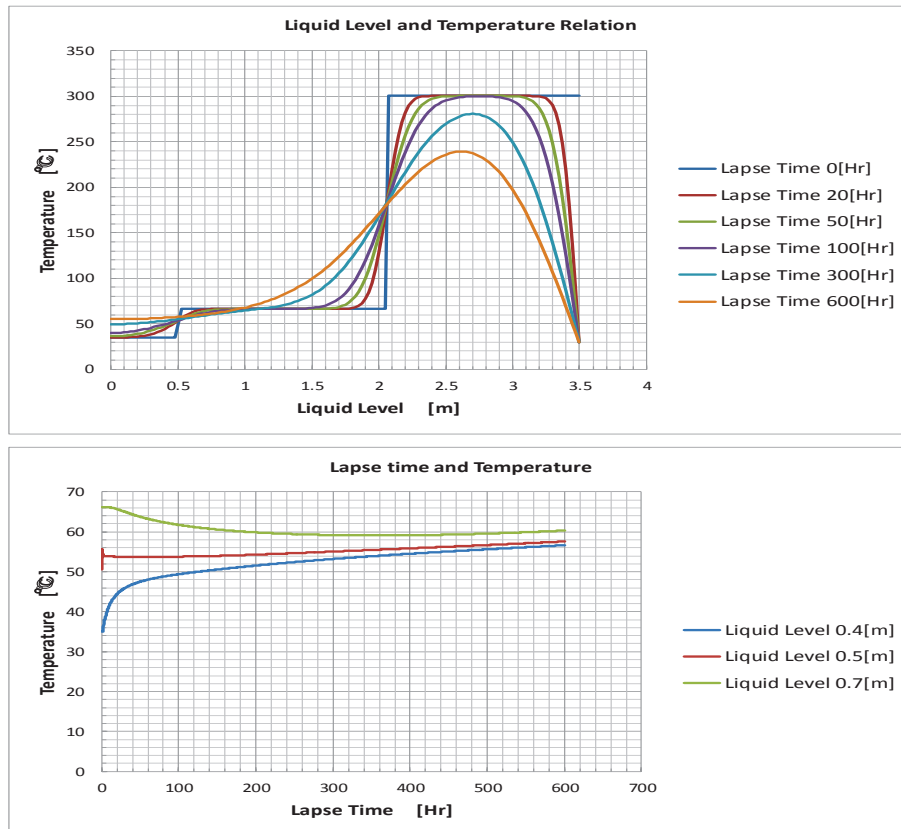
Heat transfer by thermal conduction is too slow in comparison with thermal convection. Therefore so long time is required to heat up the water layer.



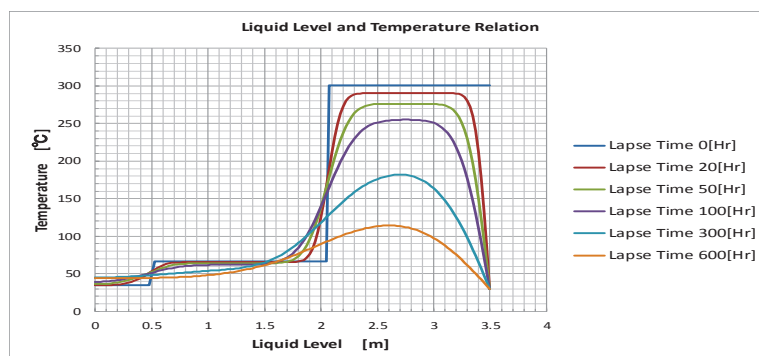
3.2 Calculated results

When the tank (80m diameter) containing Crude Oil No. -2 is on fire, and extinguished after 8 hours burning, oil temperature and oil level in the tank were calculated 300.4 [deg.C] and 3.49 [m] from 5[m] of the initial level respectively. Water temperature was assumed to be 35 [deg.C]. The results are indicated in the following graph.

-Case A; Heat loss through tank wall is not included in the calculation.

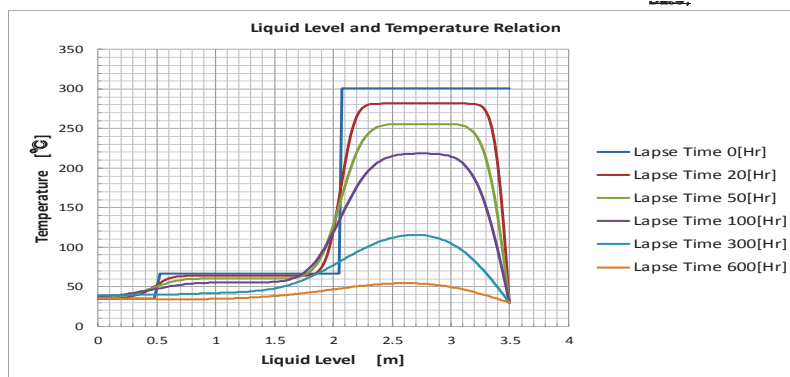


-Case B; Heat loss through tank wall by wind only is included in the calculation.





-Case C; Heat loss through tank wall by water stream is included in the calculation.



3.3 Possibility of boilover occurrence

It is found that temperature near the interface between water and oil is lower than 70 [degC] in any case. So it can be said that in such a large tank fire case, possibility of boilover occurrence after extinguishment seems to little.

3.4 Variation of the oil temperature with time

When a large tank had been fired and extinguished, it is not easy to cool the oil and requires so long time for the cooling. In case of cooling by wind only with its velocity of 6 to 8 m/s, oil temperature is ; -600 hours after extinguishment, oil level is 3.49 m ; 115 [degC], In case of cooling by water streams, oil temperature is ; -300 hours after extinguishment, oil level is 3.49 m ; 115 [degC]

4 Conclusion

The simulation programs seem practical enough for rough prediction of boilover occurrence and for estimation of a required period for cooling the hot oil after extinguishment,

=====

This article is a summary of a more detailed article about this subject written by Mr. Yoshiyuki Kato. The full article is available for free download from the following link on the JOIFF website at <http://www.joiff.com/documents/YoshiyukiKatoArticle.pdf>

Editors Note:

Yoshiyuki Kato is CEO of of JOIFF Member Organisation Corporation FPEC ,Japan,. Mail;yokato@fpec1.co.jp Corporation FPEC URL ;www.fpec1.co.jp