

CHAPTER IV RESULTS AND DISCUSSION

4.1 Crude Oil Characterization

4.1.1 Crude Oil Composition

Normally the crude oil is a complex chemical system containing several kinds of hydrocarbon such as n-paraffin, branch paraffin, naphthene or aromatic. In this work, crude oil composition was analyzed by simulated distillation gas chromatography (Sim-Dist GC) following ASTM D2887. The chromatograms of LK1 crude and LK2 crude are shown in Figures 4.1 - 4.2, respectively. The new crude oil had the composition similar to the previous crude oil that contain major hydrocarbon component from C9 to C28. However, the Sim-Dist GC can analyzed only n-paraffin because the limitation of Sim-Dist standard reference. Thus, amount of each n-paraffin component was quantified as shown in Table 4.1. the total n-paraffin components of both crude was the same i.e. around 10% wt/wt of crude.

For true boiling point curve comparison shown in Figure 4.3, the TBP curve of previous crude (LK1) was higher than the new crude (LK2) curve indicating the new crude contained lighter components than the previous crude.

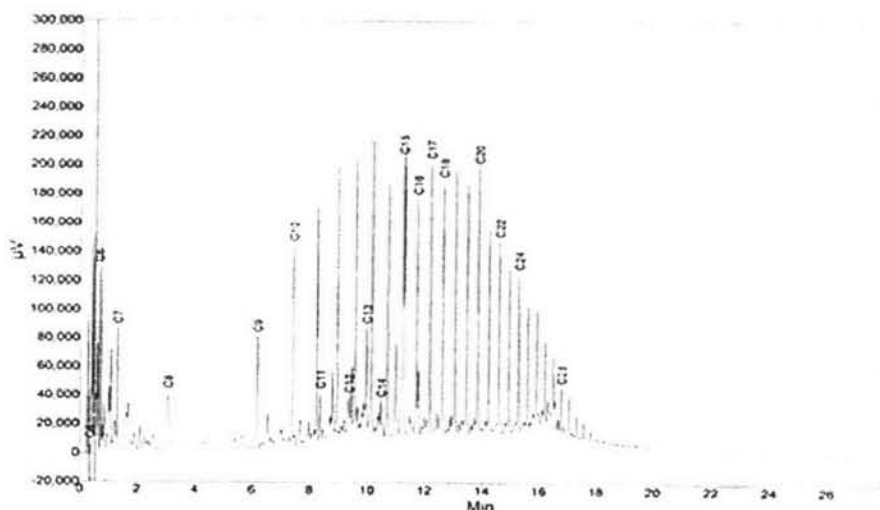


Figure 4.1 Chromatogram of LK1 crude analyzed by Sim-Dist GC.

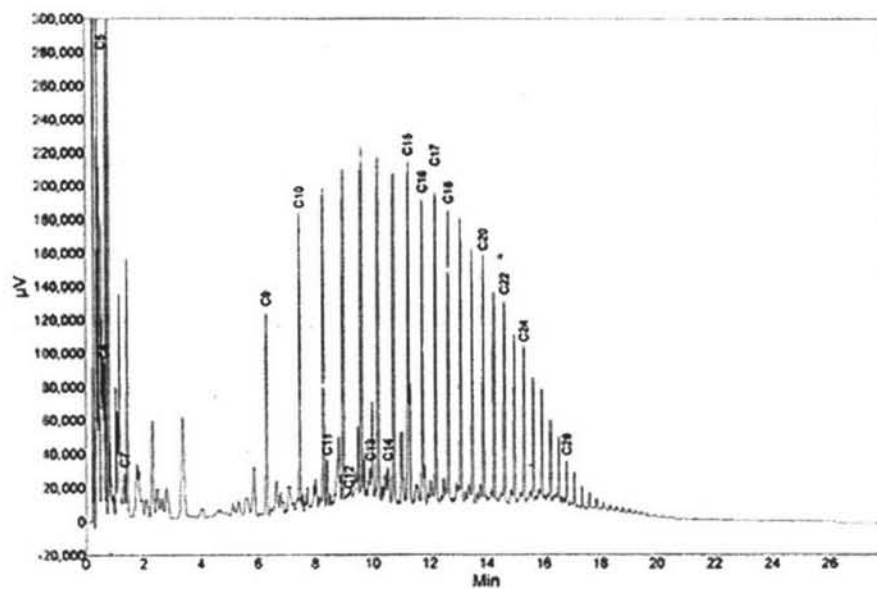


Figure 4.2 Chromatogram of LK2 crude analyzed by Sim-Dist GC.

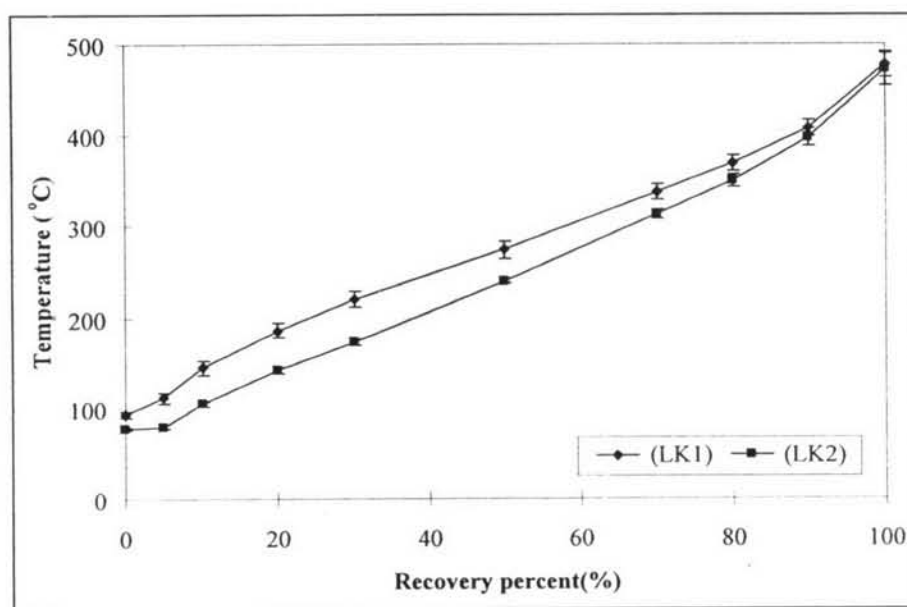


Figure 4.3 True boiling point (TBP) curve of LK1 and LK2 crudes.

Table 4.1 n-Paraffin components of LK1 and LK2

Components	LK1	LK2
C5	0.2245	1.0241
C6	0.1422	0.0865
C7	0.2661	0.1621
C8	0.3897	0.0000
C9	0.3672	0.5962
C10	0.5391	0.7165
C11	0.1673	0.1588
C12	0.2637	0.1128
C13	0.4839	0.1431
C14	0.2848	0.2677
C15	0.8807	1.3802
C16	0.7524	0.9106
C17	1.1863	1.2696
C18	1.0765	1.1085
C20	1.1780	1.0237
C22	0.9140	0.8679
C24	1.1393	1.0350
C28	0.6236	0.4400
C32	0.0000	0.0000
C36	0.0000	0.0000
C40	0.0000	0.0000
C44	0.0000	0.0000
Total	10.8794	11.3033

4.1.2 Crude Properties

The physical properties of crude, i.e. specific gravity (Sp.gr.), pour point, WAT, and WDT were also measured and summarized in Table 4.2. LK2 had lower specific gravity, pour point, WAT, WDT and these properties indicated that LK2 was lighter than LK1, which is consistent with TBP curves.

Table 4.2 Properties of crude oil

Crude oil	Specific gravity (sp.gr)	Pour point (°C)	WAT (°C)	WDT (°C)
LK1	0.879	37.1	39.0	54.0
LK2	0.790	33.0	34.2	46.8

4.1.3 Wax Separation

The modified Nguyen's method was used to separate microcrystalline and macrocrystalline waxes from LK2 crude and then analyzed by Sim-Dist GC. From the chromatograms obtained as shown in Fig. 4.4 – 4.5, microcrystalline contained carbon number ranging from C17 to C28 and macrocrystalline wax composed of heavier carbon number in the range of C17 to C36, respectively. The heavier component of macrocrystalline was confirmed by the TBP curves as illustrated in Figure 4.6.

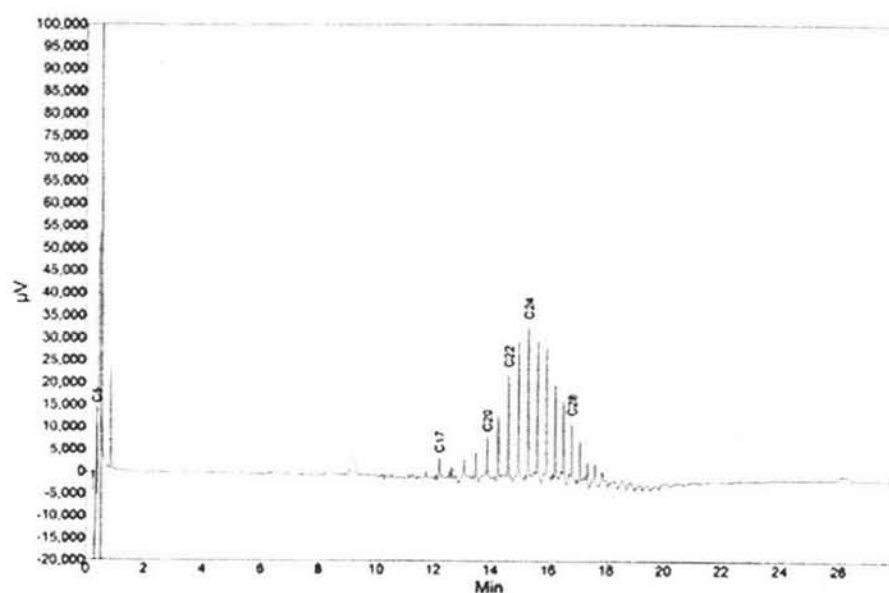


Figure 4.4 Chromatogram of microcrystalline wax in LK2 crude.

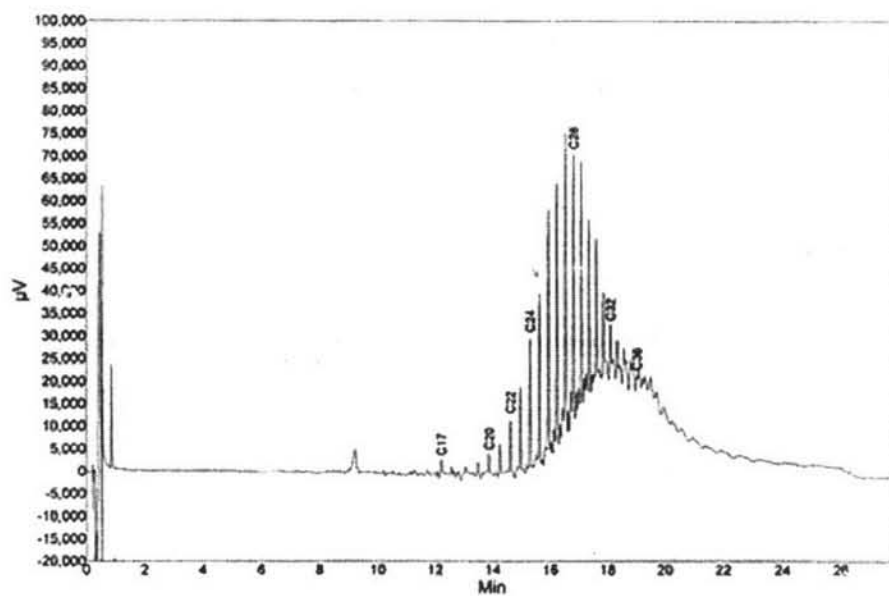


Figure 4.5 Chromatogram of macrocrystalline wax in LK2 crude.

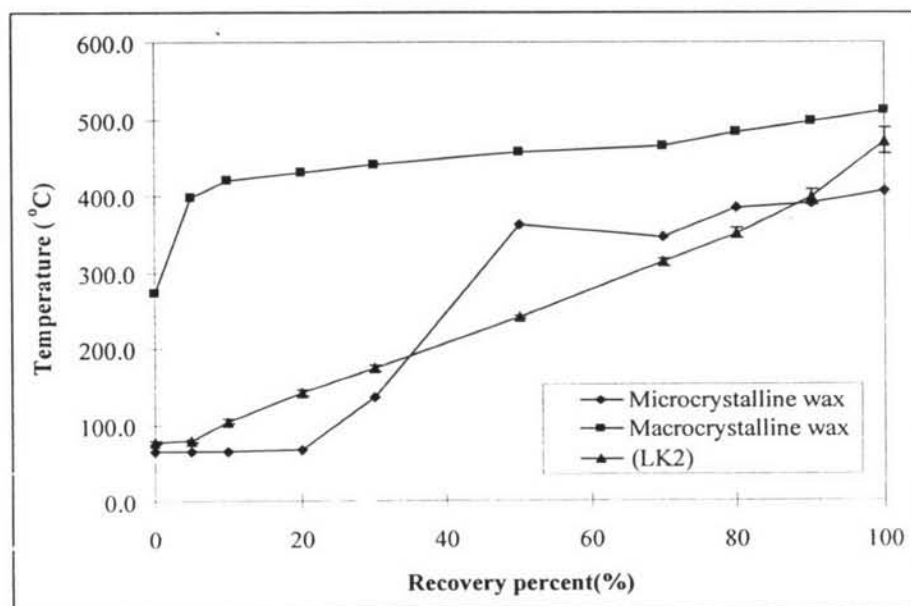


Figure 4.6 True boiling point (TBP) curves of microcrystalline and macrocrystalline wax from LK2 crude, compared with the original crude.

4.1.4 Thermal History

The sensitivity of thermal history refers to the pour point change dependent of heating temperature. LK1 and LK2 crudes were examined by heating to 50, 60, 70, 80 and 90°C without addition of wax inhibitor and maintained at that temperature for 15 minutes. Then each sample was cooled down in pour point apparatus and than measured for its pour point. The result was plotted in Fig. 4.7 which shows that the previous crude (LK1) had a slight difference of pour point around 3°C when heating temperature changed. On the other hand, the new crude (LK2) showed larger difference (around 9°C) indicating that the new crude was more sensitive to thermal change than the previous crude. This experiment was conducted in order to study the effect of heating temperature on pour point reduction. In wax inhibitor test, crude sample was heated to 60°C with wax inhibitor. The pour point reduction of this study might result from both inhibitor and heating temperature influence. The thermal history study showed that at 60°C the LK2 crude was not influenced by heating history. That indicated that the pour point reduction of wax inhibitor test came from the effect of inhibitor only.

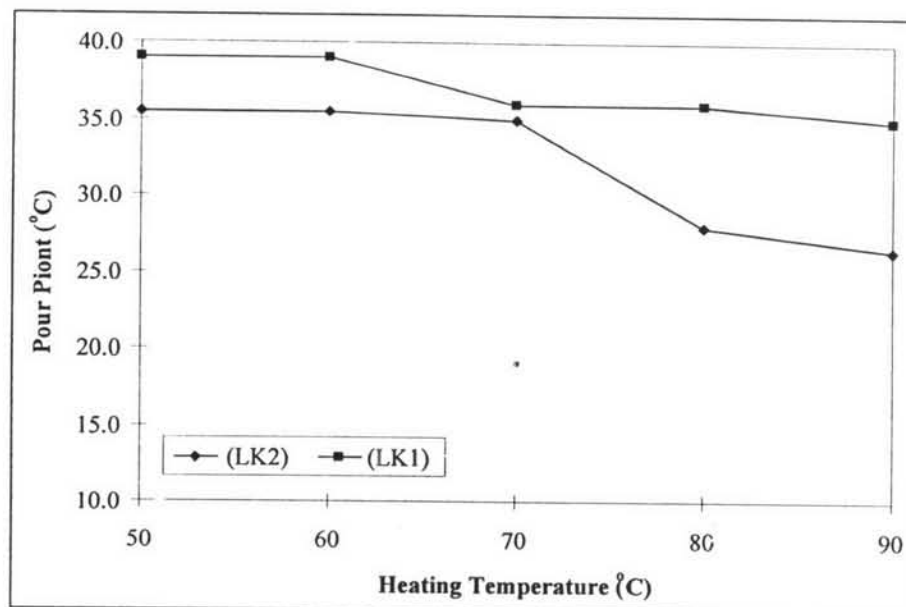


Figure 4.7 Thermal history of LK1 and (LK2) crudes.

Besides, the changing of pour point might be come from a loosely knit wax structure when crude oil was heated. The wax molecule was separated into individual molecule. Then the crude oil was cooled, the wax crystallization become more crystalline that influence on pour point reduction.

4.2 Effect of Single Inhibitors

4.2.1 Effect of Hydrocarbon Solvent Inhibitors

Hydrocarbon solvent can perform as wax inhibitor as it dissolves the wax components in crude oil. In previous work (Numura, 2005) pentane, hexane and heptane were investigated as wax inhibitors. In this work the same hydrocarbon solvents were also tested with LK2 crude. The result is shown in Figure 4.8. Heptane was found to be the most effective solvent for both crude oils, and decreased the pour point around 8°C for the LK1 crude and 10°C for LK2 crude. It must be noted that this experiment was conducted by heating the samples to 80°C so the temperature could exert thermal history effect. However, as the actual operating temperature was

60°C, the effect of heptane on the pour point of the sample heated to 60°C was also tested and the result exhibited less effect, as shown in Figure 4.9.

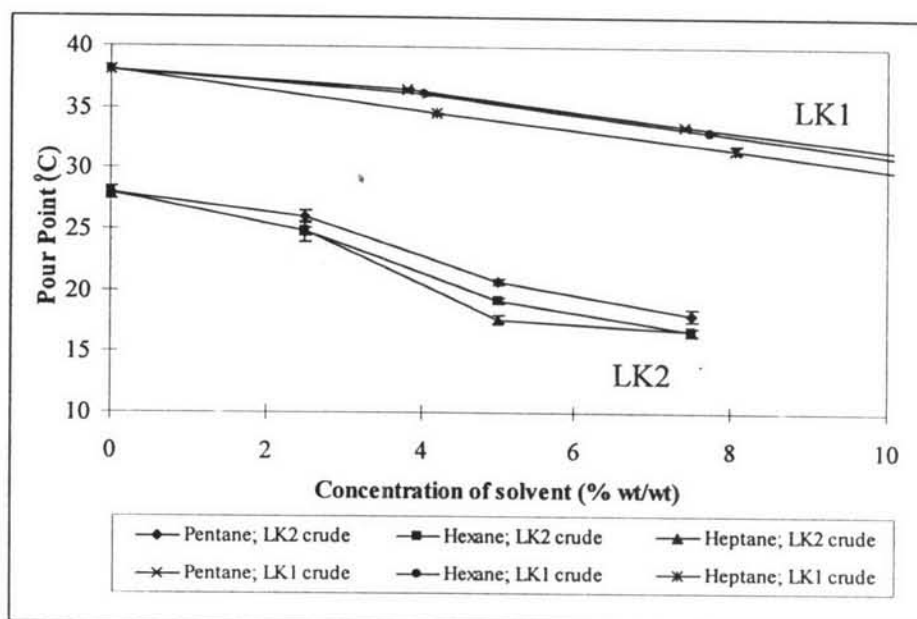


Figure 4.8 Pour point comparison as varied concentration of various solvent between LK1 crude and LK2 crude by heating samples to 80°C.

Other hydrocarbon solvents, toluene and o-xylene were also investigated and the results were similar to that of heptane as shown in Figure 4.10. However at the operating temperature of 80°C, pentane should be the most effective solvent for both crude samples because pentane has the smallest structure that dissolves waxes in crude sample readily. The boiling points of pentane, hexane and heptane are 36, 69, and 98°C, respectively, but the conducting temperature was 80°C. So it is likely that some pentane and hexane vaporized during sample heating that affect its pour point reduction.

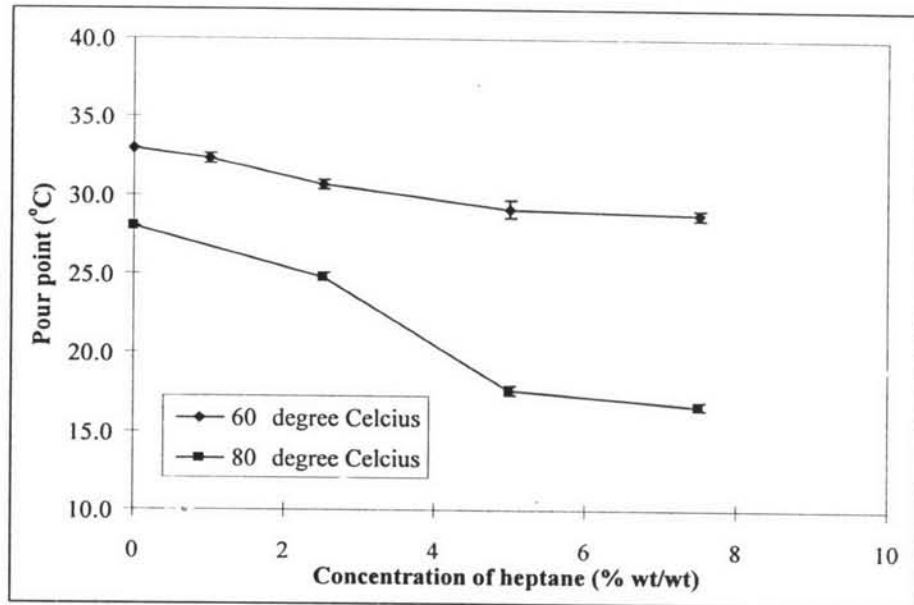


Figure 4.9 Pour point comparison of LK2 crude as varied concentration of heptane between 60°C and 80°C.

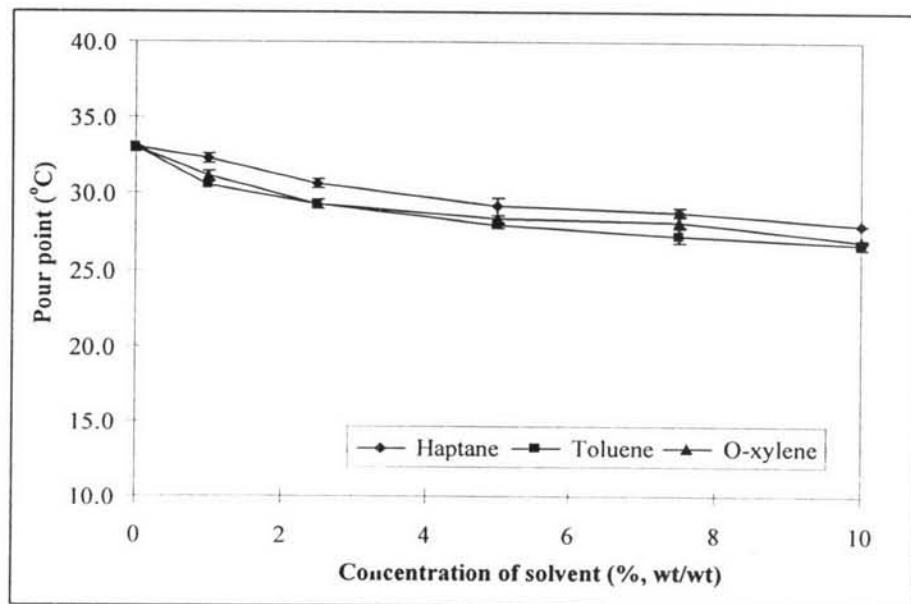


Figure 4.10 Pour point comparison of LK2 crude as varied concentration of haptane, toluene, and o-xylene at 60°C.

4.2.2 Effect of Polymer Inhibitor

In previous work (Numura, 2005) several kinds of polymers were investigated as wax inhibitors at 80°C. The three best effective polymers from the previous work were poly (maleic anhydride-alt-1-octadecane or PMAO, poly(octadecyl methacrylate or POMA and poly(ethylene -co- butyl acrylate -co- maleic anhydride) or PEBAMA. These results are shown in Figure 4.11 for PMAO, POMA and PEBAMA and the pour point decrease as the concentration increased to 18, 24 and 25°C, respectively.

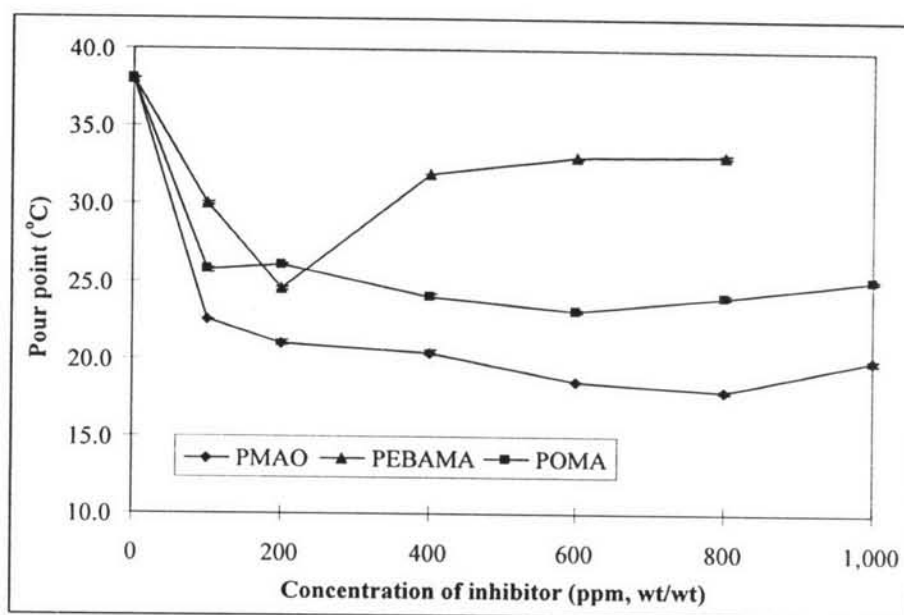


Figure 4.11 Pour point comparison of LK1 crude as varied concentration of PMAO, POMA, and PEBAMA preheated to 80°C (Numura, 2005).

Since field heating temperature was 60°C, in this study, the preheating temperature was reduced from 80°C to 60°C in order to simulate the field condition. The PMAO, POMA and PEBAMA were still expected as the most effective inhibitors for the LK2 crude. Figure 4.12 shows that PMAO, POMA and PEBAMA could not reduce the pour point as effectively as the previous work.

One assumption for ineffective result might be from probably the polymer did not completely dissolve in bulk of crude. Solubility of polymer in the

bulk crude was then improved by dissolving the polymer with solvent before injecting into the crude sample. PMAO was chosen to prove this assumption by dissolving in toluene and o-xylene. The result shows that the pour point reduction was similar to adding PMAO as solid as shown in Figure 4.13. Two other assumptions were made. Firstly, the characteristics of LK1 and LK2 crude samples were different and secondly, that involves the conducting temperature. The low preheating temperature (60°C) might affect the wax network in such a way it was more closely knit than at higher temperature. The structures of PMAO, POMA and PEBAMA have big branches on backbone molecule that make them more awkward to insert or interact into the more closely knit wax network. From assumption, other polymers were chosen as wax inhibitors in this study. The PLMA, PMMA (VH and MD grade), and derivatives of EVA were selected. The result of PLMA and PMMA addition is shown in Figure 4.14. It is apparent then that these polymers chosen were ineffective as well.

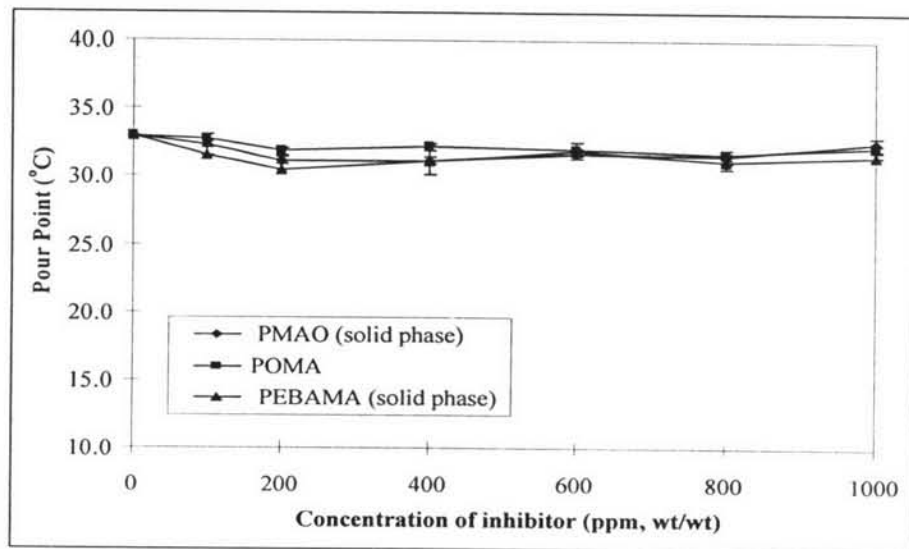


Figure 4.12 Pour point comparison of LK2 crude as varied concentration of PMAO(solid), POMA and PEBAMA(solid) preheated to 60°C.

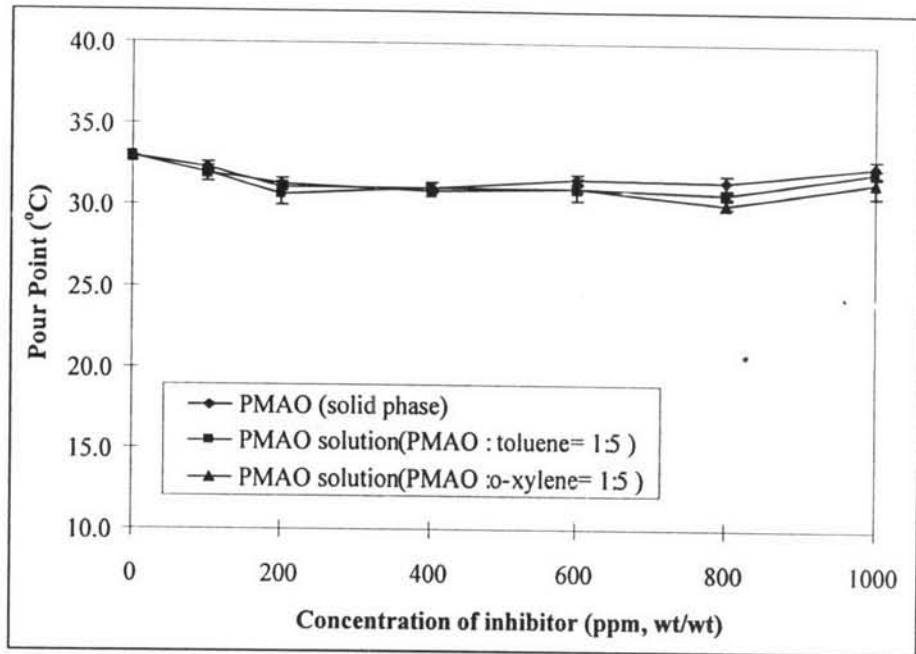


Figure 4.13 Pour point comparison of LK2 crude as varied concentration of PMAO (solid), PMAO in toluene, and PMAO in o-xylene preheated to 60°C.

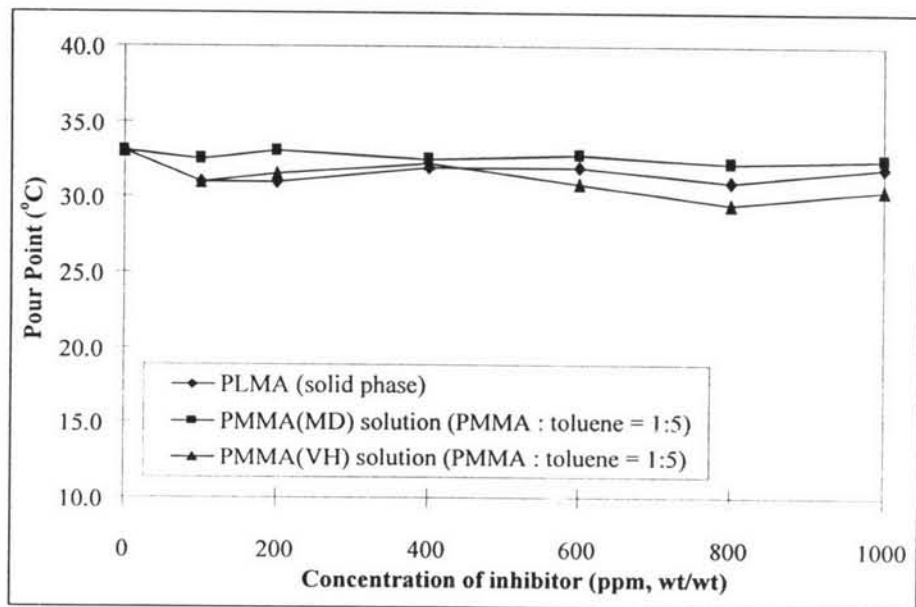


Figure 4.14 Pour point comparison of LK2 crude as varied concentration of PLMA, PMMA(VH and MD grade) preheated to 60°C.

The results of EVA at 18, 25, 33, and 40% vinyl acetate are presented in Figure 4.15. The EVA with 40% vinyl acetate content was the most effective by reducing the pour point to 17°C at 1,000 ppm concentration.

Further wax inhibitor screening was also carried out with polymer surfactant containing branch structure. Figure 4.16 shows that the chosen polymer surfactant, Disponil AFX L1060, Teric PE 64, and Teric PE 87 could not perform inhibiting effect comparable to that of EVA. EVA (40% with vinyl acetate) decreased the pour point to around 17°C, at the same concentration of 1,000 ppm. Additionally, EVA at higher concentration of 2,000 ppm further decreased the pour point to 13°C.

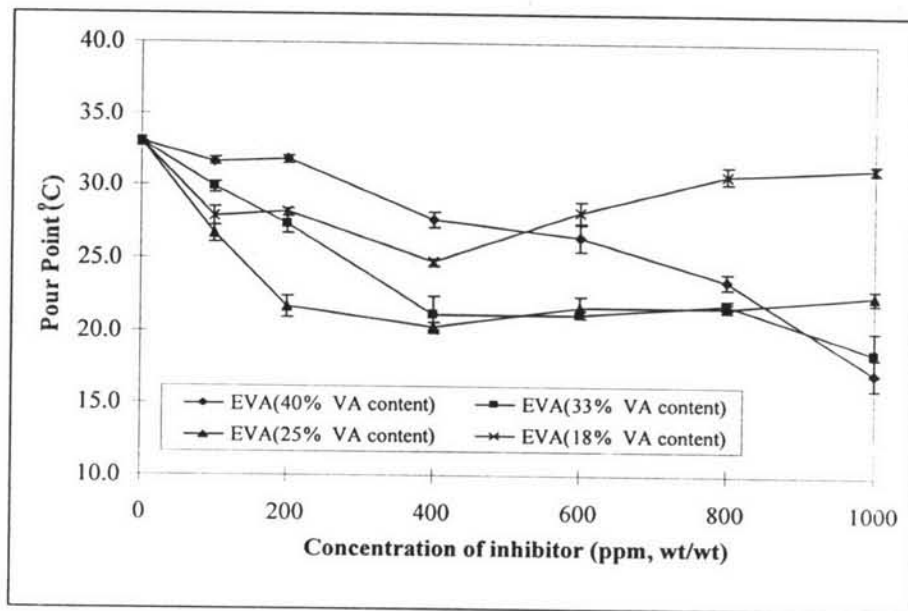


Figure 4.15 Pour point comparison of LK2 crude as varied type and concentration of EVA preheated to 60°C.

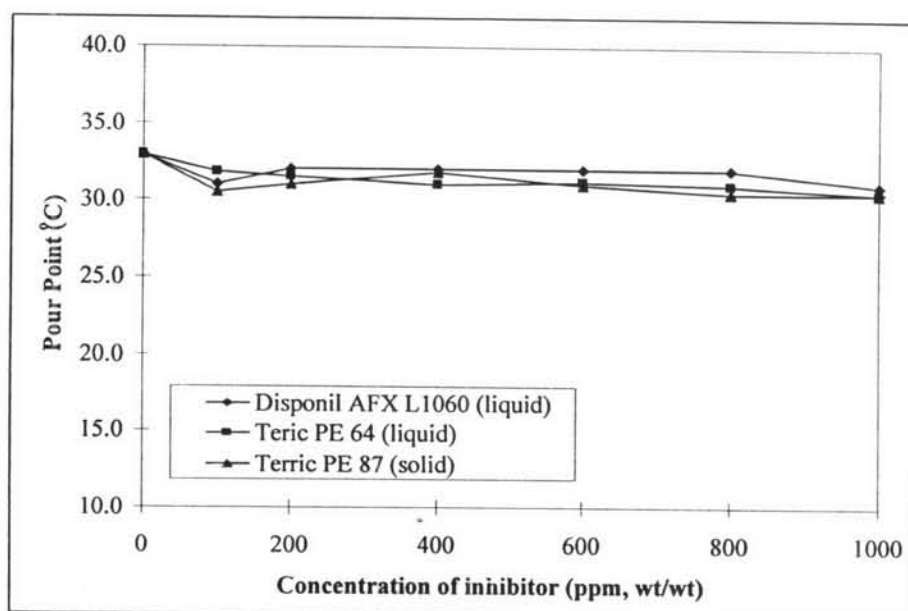


Figure 4.16 Pour point comparison of LK2 crude as varied concentration of various surfactants preheated to 60°C.

From the EVA result at low concentration of inhibitor, the effect of EVA with 25% and 33% vinyl acetate content were higher than EVA with 18% and 40% vinyl acetate. The lower efficiency of EVA 18% in all concentration range might come from the crystallinity of EVA with 18% vinyl acetate. The EVA 18% of vinyl acetate tend to self assembly when adding into crude oil (not interact with wax molecule). The loss of efficiency at higher concentration of EVA with 25% and 33% vinyl acetate content may be ascribed to precipitation of pure polymer or to wax crystallization with induced by copolymer (Machado *et al.*, 2001). However, effect on pour point reduction of EVA with 40% vinyl acetate content tended to increase with concentration, it is possible that the limitation of these EVA did not occur in this concentration range and crystallinity of EVA decreased with increase of vinyl acetate content (Henderson, 1993). The EVA with 40% of vinyl acetate was lowest crystallinity that may be the EVA 40% vinyl acetate was difficult to self assembly and more interact with wax in crude oil. But the one question was raised up that is why the EVA with 25% and 33% vinyl acetate content showed better effect at low concentration. It is denoted by Ashbaugh *et al.*, 2005 and Numura, 2005, the greater

the length of constituent ethylene run that gives a higher degree of selectivity for breaking down wax gel that are made from long chain paraffin.

The difference of result between previous work (Numura, 2005) and current work may come from various factors for example, composition of crude oil, thermal history, and preheating temperature. The difference in crystallizing process of two crudes was the one factor. From DSC curves, on cooling process 80°C to -30°C , between two crude as shown in Figure 4.17 show that the LK2 crude observed more peak than LK1 crude which mean that different crystallizing process had occurred (Zhang *et al.*, 2003).

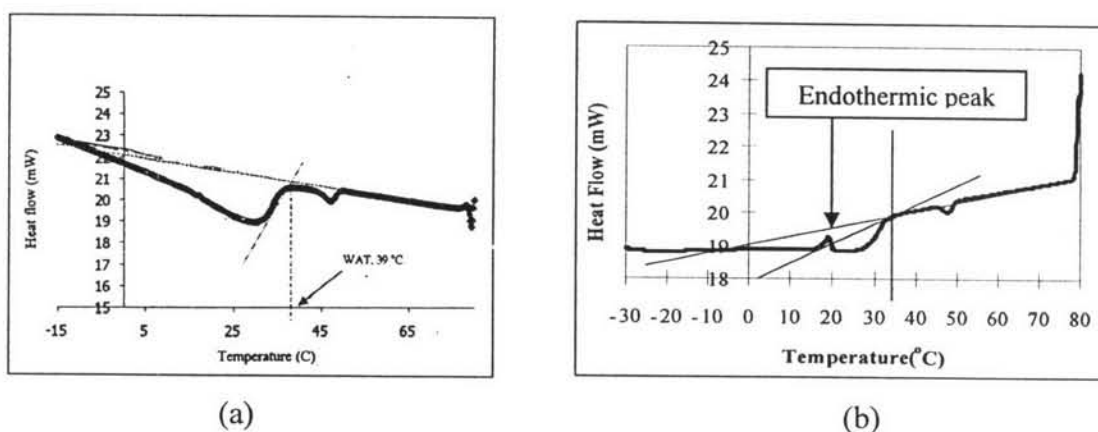


Figure 4.17 Comparison of DSC curves on cooling process from 80°C to -30°C between LK1 (a) and LK2 (b).

4.2.3 WAT and WDT Determination

The best inhibitor EVA was employed to determine WAT and WDT. Figure 4.18 shows the effect of inhibitor concentrations on WAT and WDT. New crude (LK2) was treated by EVA 40% vinyl acetate with different concentration. In the concentration range of EVA up to 1,000 ppm, the concentration of EVA did not significantly change the WAT and WDT. Beyond 1,000 ppm WAT was slightly increased.

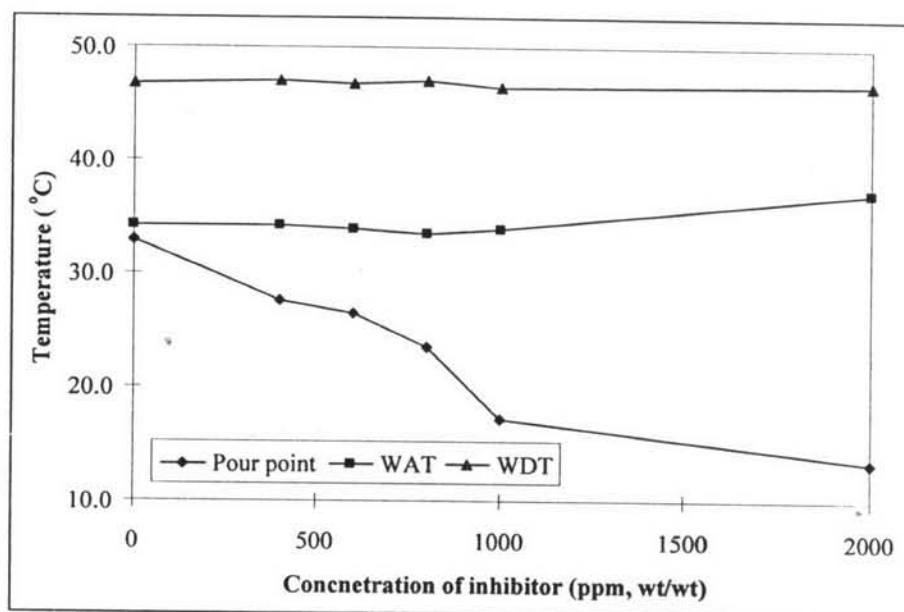


Figure 4.18 Effect of inhibitor concentration, EVA with 40% vinyl acetate content, on WAT, WDT, and pour point for LK2 crude.

Some authors ascribed the relationship between WAT and mechanism of wax inhibitors. Bilderback and Mcdougall (1969) suggest three alternative mechanisms for wax inhibitors. 1) The additive may come out of solution at temperature slightly higher than the oil WAT and cause nucleation and small wax particles. 2) The additive may come out of solution at the oil WAT and co-crystallizes with the wax, forming weak and deformed aggregates. 3) If the additive comes out of solution at the temperature slightly lower than the oil WAT, it adsorb on the wax crystals, inducing the dispersion of the wax crystals. Moreover, Ashbaugh *et al.*, 2005 proposed the mechanism of EVA which produced crystals that are much smaller and more numerous than those found in without additive system. Figure 4.18, beyond 1,000 ppm WAT slightly increased when inhibitor concentration increased, it is denoted by Zhang *et al.* (2003) who explained that the increase of WAT due to the addition of that inhibitor will work well in the primitive molecular orientating and nucleating process that the intermolecular distance is shortened in a relatively shorter time and result to speed up the assembling rate of alkane molecules in oil. Despite a number of proposed mechanism were proposed by several authors,

there is not sufficient scientific information in this work to be one possibility is that conclusion. The mechanism of EVA on LK2 crude may act as a wax dispersant because at 60°C the knit wax structure or wax network was not fully separated into individual molecule. It is possible that the wax network occurred before (WAT of crude was not decreased) after that the inhibitor adsorbed on the wax network and covered the wax network. Then the polarity part of inhibitor was helped to prevent the agglomeration of each wax network by repulsing together which influence on the pour point reduction of system.

4.3 Effect of Combined Inhibitors

The synergistic effect of combined inhibitors on pour point depression was also investigated. EVA with 40% vinyl acetate content as the main component was combined with PMAO, POMA or surfactant Teric 87. The results are shown in Figures 4.19 – 4.21.

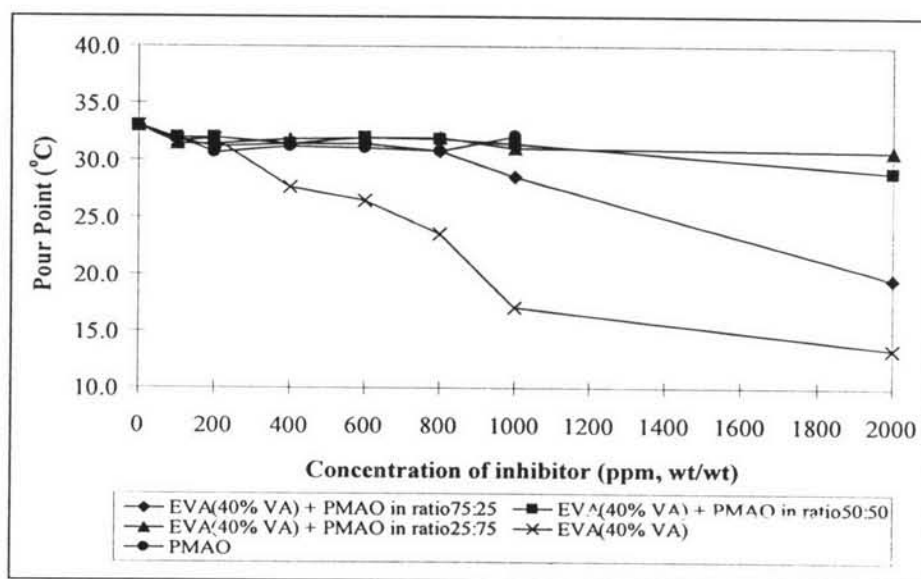


Figure 4.19 Pour point comparison of LK2 crude as varied concentration of combined inhibitor, EVA(40% vinyl acetate) and PMAO in the ratio of 75:25, 50:50, 25:75 in toluene, preheated to 60°C.

The results showed no synergistic effect. For example 2,000 ppm of the combined inhibitor between EVA (40% vinyl acetate content) and PMAO in the ratio of 50:50 wt/wt decrease the pour point to 29.0°C which was less than EVA 1,000 ppm alone (17°C). The other combined inhibitors also showed the same trend. The no synergistic effect of combined inhibitor might come from 2 assumptions. Firstly, the combined inhibitor was coalesced together before interacting with wax component. Another assumption is that the ineffective polymers, in this case, PMAO, POMA and TERIC 87, interfered or constructed the function of effective polymer, EVA with 40% vinyl acetate content. The result of combined inhibitor indicated the polymer selecting was crucial for efficiency of inhibitor. One could not mix several kinds of polymers as inhibitor or in another word the wax inhibitor was very specific and sensitive to crude and condition (one inhibitor was not universal solution for any place or any condition).

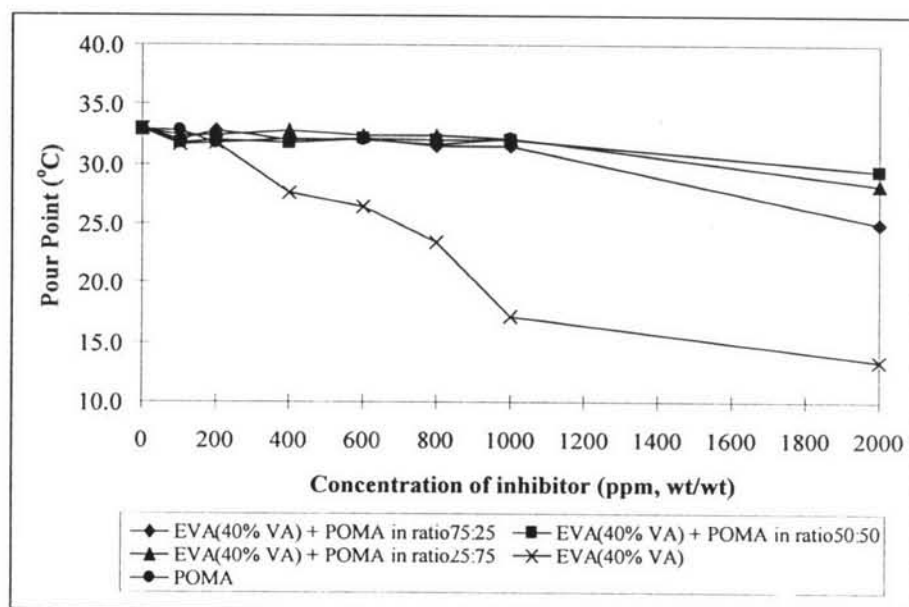


Figure 4.20 Pour point comparison of LK2 crude as varied concentration of combined inhibitors, EVA(40% vinyl acetate) and POMA in the ratio of 75:25, 50:50, 25:75 in toluene, preheated at 60°C.

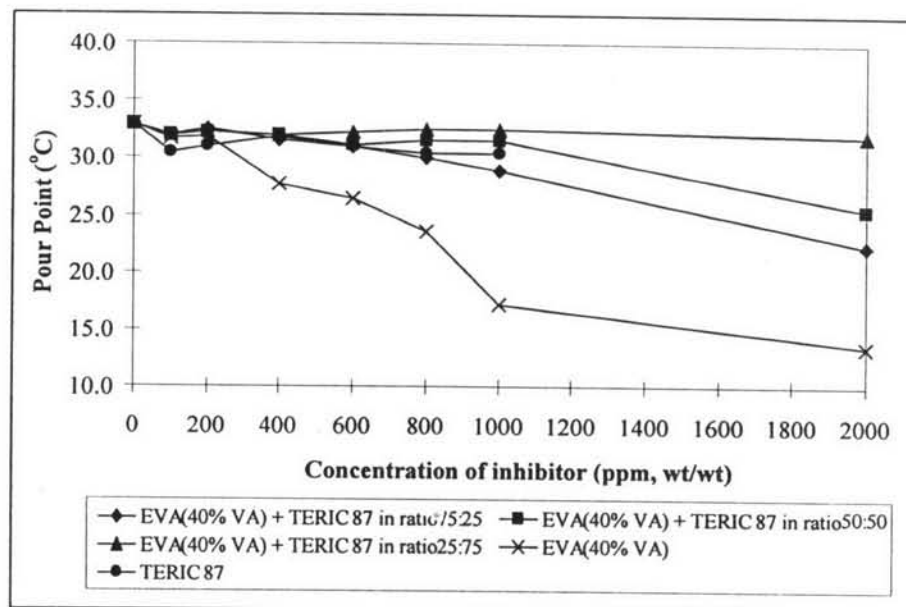


Figure 4.21 Pour point of treated Lamkrabue crude oil by various combination of inhibitors, EVA(40% vinyl acetate) and Teric 87 in the ratio of 75:25, 50:50, 25:75 in toluene at 60°C.

4.4 Inhibiting Stability Testing

4.4.1 Inhibiting Stability Time

New crude (LK2) with EVA 40% vinyl acetate content was observed at room temperature. The wax accumulation at the bottom of the test cell and flow ability was checked every day. Wax accumulation at the bottom of the test cell when the test cell was tilted was observed. When little force was applied to the accumulated wax by slight shaking or by slight stirring with glass rod, the accumulated wax mixed well with the fluid crude oil and became fluid again. The results showed that the treated crude had a flow ability for at least 1 week. Figure 4.22 (a) is the photograph of semi-solid crude (LK2) without inhibitor. On the other hand, Figure 4.22 (b) shows the crude with EVA and evidently shows good flow ability

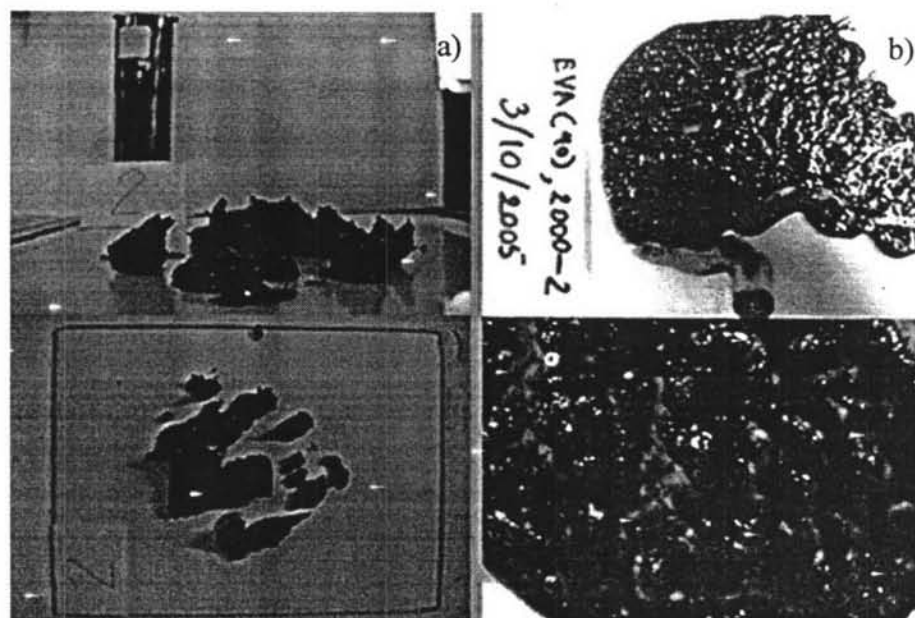


Figure 4.22 Photograph of new crude (LK2): a) without inhibitor; and with EVA (40% vinyl actate) at 2,000 ppm.

4.5 Economic Assessment

Wax deposition in a rail tank wagon (RTW) introduces extra cost for the petroleum company. A method used to remove the existing wax in a RTW by blowing steam jets into the RTW to melt the wax or the remaining on board (ROB). Then the condensate of the steam and the melted wax in the RTW are transferred to a separator to split the condensate and the melted wax. The melted wax is collected as waste for furnace fuel or for wax purification if a process is available. For the condensate water, it is contaminated with oil, and is treated in a water treatment process which the treatment cost is around 3,000 Baht per ton of water.

Accumulation of wax decreases the volume of the wagon tank and increase with number of transportation passes. The ROB volume is increase, and thus the amount of crude transported to refinery becomes less and less and the petroleum company cannot sale ROB as a crude either. The reduction of volume is called opportunity loss because the petroleum company has to pay full transportation cost while less volume of crude can be recovered. The full cost can be implied to the cost

of transportation of crude and the cost of transportation of ROB. Thus, the cost of transportation of ROB is the opportunity loss. Additionally The ROB (wax) is considered a waste for the petroleum company. Therefore, economic assessment of wax problem can be categorized into two parts. The first one is the treatment cost consisting of the steam cost and the water treatment cost. The second category is the opportunity loss cost consisting of the rail transportation cost and the crude oil value loss in ROB. Total cost is summarized in Table 4.3. The opportunity loss from ROB was the most cost that around 52.9% of total disposal cost. The steam cost becomes second rank that 41.2% (see detail in appendix E).

The cost per ton of ROB, which is calculated based on data provided by petroleum company, is used to generate correlation equation of total disposal and cost and ton of ROB.

Under normally operations, the crude oil after water separation is stored in storage tanks where the oil temperature is maintained at 60°C at Lankrabue production station. The oil from the oil storage tanks is trucked to Bung-Phra depot, the distance between Lankrabue production station and Bung-Phra depot was around 50 km. At Bung-Phra depot, the crude oil is loaded onto the rail tank wagons (RTWs) that take the crude oil to refinery. Normally, the crude temperature at Bung Phra depot is around 50°C. When the crude oil arrives at destination the crude temperature is around 40°C. Loading and unloading times at Bung-Phra depot and refinery is around 2 hours. Thus the time taken for one lot of transportation is around 20 hours. In the winter the ROB problem is more crucial than other seasons because the night temperature is lowest, sometimes to around 15°C.

When the crude oil is transported or storage at the temperature below its cloud point then some part of crude oil becomes wax. Since the density of these wax crystals is higher than that of crude oil. The occurred wax gradually sinks onto the bottom of RTW or storage tank.

Table 4.3 Disposal of wax problem

Disposal	Cost			
	Cost per unit*	Cost per ton of ROB	Cost per Year	
		Baht	Baht	(%)
Treatment cost				
- steam cost	20,000 Baht per 3 ton of wax sludge	6,667	15,200,000	41.2
- water treatment cost	3,000 Baht per ton of contaminated water	553	1,260,000	3.4
Opportunity loss cost				
- rail transport cost of ROB	320 Baht per 1,000 liter	400	912,000	2.5
- sale of ROB as crude oil	26.58 US\$ per bbl.	8,574	19,548,085	52.9
Total disposal			36,920,085	100

*Data provided by petroleum company.

By adding an inhibitor, the ROB should be decreased because the inhibitor improves flow ability and pour point of crude that directly affect to reducing of the treatment cost (steam cost and water treatment cost was mentioned in above). Moreover the crude oil value loss in ROB which recovers when ROB reducing and loss the rail transport cost from existing ROB in RTW is less.

However this economic assessment was not obtain any experiment data, correlation between pour point and ROB reducing, that means this assessment was the feasible study for applying inhibitors in field.

4.5.1 Economical Assessment for Using Wax Inhibitor in Real Field

Assumptions of economic assessment:

1. Based on 3 month of production, production rated per day was 20,000 bbl. Thereby the basis was 1,800,000 bbl of crude per 3 month.
2. An inhibitor was added in any transportation.
3. ROB percent based on at destination which varied from 0 to 10% wt/wt of transportation crude oil.
4. Specific gravity of crude was 0.8.
5. Costs of each disposal were constant.
6. Price of each inhibitor was constant.
7. Laborer wage was negligible.
8. Influence of season was negligible.

From Table 4.3, we can found the relationship between total disposal cost and amount of ROB as shown in equation 4.2.

$$[\text{Total disposal cost, Baht}] = 16193 * [\text{ton of ROB}] \quad (4.1)$$

When an inhibitor was added into crude oil, the ROB at the destination should be decreased. We can rewrite equation 4.1 as

$$[\text{Total disposal cost, Baht}]_{\text{after adding inhibitor}} = 16193 * [\text{ton of ROB}]_{\text{after adding inhibitor}} \quad (4.2)$$

We can found the reduction of total disposal cost after adding inhibitor by subtracting equation 4.1 with equation 4.2.

So that, [eq (4.1) – eq (4.2)],

$$[\Delta \text{ Total disposal cost, Baht}] = 16193 * [\Delta \text{ ton of ROB}] \quad (4.3)$$

Equation 4.3 shows the correlation between the reduction of ROB, $[\Delta \text{ ton of ROB}]$, and total disposal cost was economized, $[\Delta \text{ Total disposal cost, Baht}]$, after adding inhibitor.

From equation 4.3, the total disposal cost was economized after adding inhibitor when the reduction ROB percent was varied from 0 to 10% wt/wt of total production rated in 3 months as shown in Table 4.4. In the presence of wax inhibitor in 1,800,000 bbl or 228,960 ton of crude, if ROB decreases by 10% and the total disposal cost decreases around 370.76 million Baht.

Table 4.4 The Reduction of total disposal cost as when ROB percent decreasing, 0 – 10% wt/wt, after adding inhibitor (based on 1,800,000 bbl of crude)

Δ ROB (Decrease) (%)	Amount of ROB (ton)	Steam cost	Contaminated water treatment	Rail transpo rt cost of ROB	ROB cost (sale as crude)	Δ total disposal cost decreasing
0	0	0.00	0.00	0.00	0.00	0.00
1	2,290	15.26	1.27	0.92	19.63	37.08
2	4,579	30.53	2.53	1.83	39.26	74.15
3	6,869	45.79	3.80	2.75	58.89	111.23
4	9,158	61.06	5.06	3.66	78.52	148.30
5	11,448	76.32	6.33	4.58	98.15	185.38
6	13,738	91.58	7.59	5.50	117.78	222.45
7	16,027	106.85	8.86	6.41	137.41	259.53
8	18,317	122.11	10.12	7.33	157.04	296.60
9	20,606	137.38	11.39	8.24	176.67	333.68
10	22,896	152.64	12.65	9.16	196.30	370.76

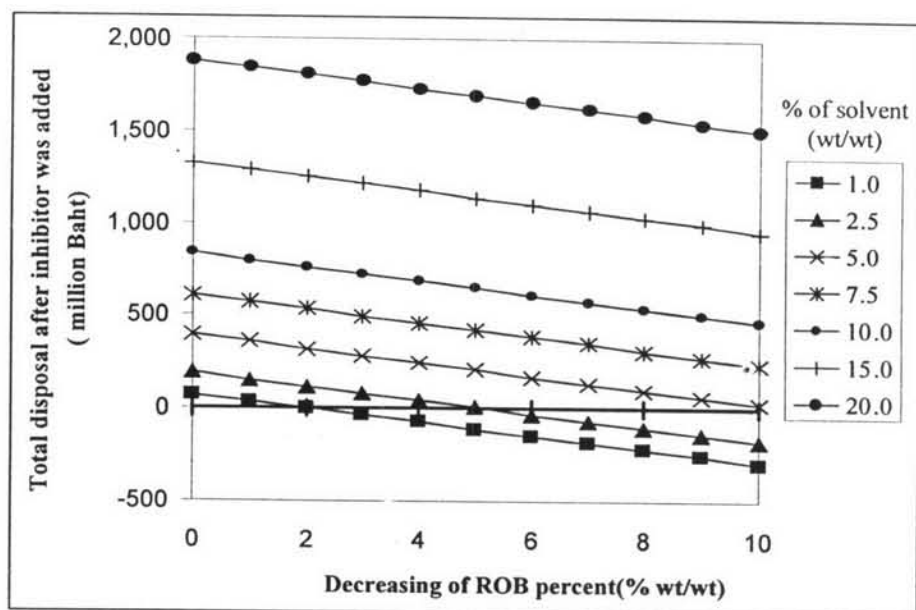


Figure 4.23 Economic assessment by using o-xylene as inhibitor based on 1,800,000 bbl of crude oil.

From Figure 4.23, the economic situation would be occurred when the ROB must decrease 3% and 6% for 1% and 2.5% of o-xylene in crude, respectively. It imply that it is less probable to use o-xylene in real field because addition of 1 or 2.5% of o-xylene causes the pour point of crude decrease only 3-4 degree Celsius, from experiment data. However the data in Figure 4.23 are obtained from the calculation only, it is not correlated with the experimental data, pour point. Therefore, o-xylene cannot be negligible until it is experimental proved by correlating the pour point of crude with ROB.

4.5.1.2 Economic Assessment for Polymer as Wax Inhibitor

EVA derivatives were found as an effective inhibitor. Figure 4.24 shows the economic assessment of EVA. From economic assessment showed that it is possible to apply EVA in real field due to the EVA (40 % vinyl acetate content) showed good effective inhibitor that lowered the pour point of crude below 25°C, when 800 ppm EVA was added. If the EVA was added at 1,000 ppm concentration, the ROB decreased only 2% which this situation is economic. Moreover, the experimental data showed that at 1,000 ppm concentration the pour

pour of treated crude was decreased to 17°C. This experiment data consistently support the possibility of using this inhibitor in real field.

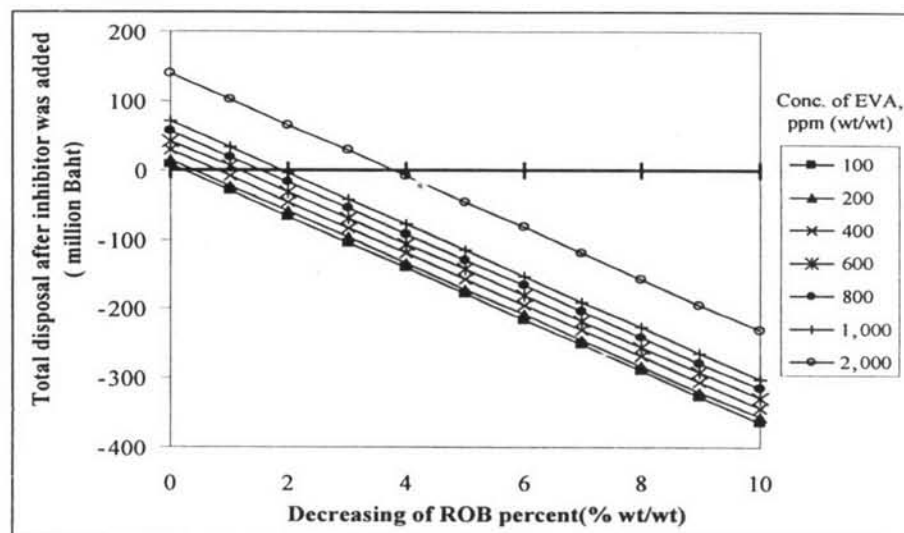


Figure 4.24 Economical assessment by using EVA was used as inhibitor based on 1,800,000 bbl of crude oil.

It is interesting to see the correlation between the pour point and ROB in the presence of EVA, which was not investigated in this study. However the ROB percent is not depended on only pour point, but day and night temperature, roughness of container, agitation, flow rated, horsepower of pump, and performance of worker.