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APPENDICES

Appendix A Characterization of Crude Oil Samples

Characterization of Crude Oil Samples

1. Water content in crude oil samples

The amount of water in the crude oil that was determined by Karl-Fischer method by following ASTM D 4928, are shown in Table 1

Table A. 1 Amount of water in the crude oil by KF method

Wells	%Water	% SD
W05T	0.50	0.03
F 09T	4.32	0.07
A 15T	4.90	0.39
W09T	6.25	0.06
C 09T	8.32	0.26
A02T	30.54	0.27
D 12T	43.55	1.53
X09T	50.68	0.26
B15T	52.94	0.16
X12T	61.25	0.35
B02T	71.31	0.57
B24T	80.19	0.32

2. Viscosity of crude oil samples

The amount of water in crude oil was related to its viscosity of crude oil. The results of viscosity at 33-47°C with the spindle No. 21 are shown in Table 2. The higher the water content, the higher the viscosity of the crude oil.

Table A. 2 Viscosity of crude oil by Brookfield viscometer

Wells	Temp. (°C)	Speed (rpm)	Torque (%)	Viscosity (cP)
W05T	33.8	100	96.5	132
F09T	33.5	100	97.3	262
A15T	33.6	100	94.7	141
W09T	34.1	100	95.9	150
C09T	33.7	100	95.8	307
A02T	34.3	100	96.3	228
D12T	46.7	100	96.0	227
X09T	34.7	100	95.3	325
B15T	34.6	100	96.2	204
X12T	34.9	100	94.6	301
B02T	34.5	100	95.3	270
B24T	34.1	100	97.0	320

3. Density of crude oil samples

The density of the crude oil was determined by following ASTM 1298-85. Density of the crude oil at 40°C is shown in Table 3. The higher the water content, the higher the density of the crude oil.

Table A. 3 Density of crude oil by ASTM 1298-85 at 40°C

Wells	Density
W05T	0.810
F 09T	0.980
A 15T	0.845
W09T	0.850
C 09T	0.985
A02T	0.940
D 12T	-
X09T	-
B15T	0.915
X12T	0.990
B02T	0.980
B24T	-

4. Asphaltenes and Sediments

The amount of asphaltenes and sediments in crude oil from different well were investigated and shown in Table 4. The amounts of asphaltenes found in all crude were varied from 1% to 12%. Normally asphaltenes, resins, waxes and small solid particles are strongly stabilized water-in-oil emulsion by prevent droplets coalescence by forming a rigid film around the water droplets. So, from the results, asphaltenes have an effect on emulsion stability.

Table A. 4 The amount of asphaltenes and sediments in the crude oil

Wells	% Asphaltenes*	% Sediments*
W05T	8.80	1.10
F09T	12.49	3.99
A15T	8.82	1.22
W09T	2.30	1.31
C09T	10.42	3.86
A02T	1.59	0.33
D12T	12.14	4.73
X09T	4.64	1.64
B15T	4.85	2.63
X12T	8.54	1.60
B02T	3.14	0.40
B24T	1.19	0.78

* Based on weight of crude oil

Appendix B Experimental Data of Demulsification Study

Experimental Design Study

By using this standard order, the contrast coefficients used for estimating the effects are just the product of the corresponding coefficients for the two main effects. The contrast coefficient is always either +1 or -1, and a table of plus and minus signs as shown in Table 3.5, can be used to determine the proper sign for the treatment combination. The column headings in Table 3.5 represent the main effect, the interaction effect, and I, which represents the total or average of the entire experiment. To find the contrast for estimating any effect, the signs in the appropriate column of the table are simply multiplied by the corresponding treatment combination. For example, to estimate A, the contrast is $-(1) + a - b + ab - c + ac - bc + abc$. The larger the estimated contrast, the more pronounce the effect of the factor on the experiment.

Table B. 1 Algebraic signs for calculating the effects in 2^3 design

Treatment combination	Factorial effect							
	I	A	B	AB	C	AC	BC	ABC
(1)	+	-	-	+	-	+	+	-
a	+	+	-	-	-	-	+	+
b	+	-	+	-	-	+	-	+
ab	+	+	+	+	-	-	-	-
c	+	-	-	+	+	-	-	+
ac	+	+	-	-	+	+	-	-
bc	+	-	+	-	+	-	+	-
abc	+	+	+	+	+	+	+	+

The method of analysis provided a simple way to determine the factor effects. A normal probability plot of the estimates of the effects was suggested. The negligible effects are normally distributed, with mean zero and variance σ^2 and tend to fall along the straight line on this plot, whereas significant effects have non-zero means and do not lie along the straight line. Thus, the preliminary model is specified to contain those effects that are apparently non-zero, based on the normal probability plot. The apparently negligible effects are combined as an estimate of error.

Sums of squares for the effect are easily computed, because each effect has a corresponding single-degree of freedom contrast. In the 2^3 design with n replicates, the sum of square for any effect is

$$SS = \frac{(Contrast)2}{8n}$$

Then, to confirm the magnitude of these effects, the analysis of variance table was built to see *Mean square*, F_0, and *P-value*. In order to see the effect of each factor, if the calculated p-value is higher than 0.05, and thus the null hypothesis is not rejected, this experiment can be stated as being "not statistically significant at the 5 % level". If the p-value is lower than 0.05, the null hypothesis is rejected, this experiment can be stated as being "statistically significant at the 5 % level".

Water Remaining (%) in Crude Oil Phase by KF Method

In addition to measure free water separated by reading at a graduated scale of centrifuge tube, the water remaining in crude after separation was determined for more accurate determination of water and material balance for later calculation.

The Method to Calculate KF Equation

Find the H_2O titer for determine the water content in KF solution reagei 67 waiting for the drift value reach or below 20 μl/min then injected the 10 microliters of distilled water by microsyringe. Input the volume of water sample (10 microliters) then the water content in the reagent is obtained.

Formula for titer determination.

$$RS1 = C00*C01/EP1 \qquad \text{.............................1)}$$

Where: RS1= titer (It should be less than 5mg/ml if less than 3 mg/ml change KF solution)

EP1= volume of the KF solution at the end point

C00= sample size (10 micoliters)

C01= factor (in this case we use 1 because density of water [g/ml] is 1.) The factor depends on type and water content of standard.

Table B. 2 The factors used to calculate in titer equation

Standard	Sample size in	Factor
Water	g	1000
Water	μl	Density of H_2O[g/ml]=1
Methanol	ml	Water content in methanol in [mg/ml]
Methanol	μl	0.001*water content of methanol in [mg/ml]
$Na_2Tart*2H_2O$	g	156.6
$Na_2Tart*2H_2O$	mg	0.1566

Finding the water content in the crude oil sample after blend oil with toluene 50%vol by recalling method KF, then enter the sample size (g). Allow the instrument memorize formula.

RS1 = (EP1-C01)*C02*C03/(C00*C04) ....2)

Where: RS1= water content

EP1= volume of the KF solution at the end point

C00=sample size (g)

C01= initial water (0.00)

C02= titer

C03= factor (0.1) see also appendix 6

C04= divisor

Enter all the parameter and wait for conditioning the instrument. When it shows "drift OK", the sample is withdrawn into a syringe and placed on the 5 digits balance and tare. The sample is injected into KF solution then the syringe is weighed again. The weight of the injected sample is determined. Allow the instrument titrate until the end point. The amount of water content is shown.

Table B. 3 The factors used to calculate in KF equation

Unit	Sample size	Factor	divisor
%	g	0.1	1
%	mg	100	1
%	ml	0.1	Density of sample[g/ml]
ppm	g	1000	1
ppm	ml	1000	Density of sample[g/ml]
ppm	µl	1000000	Density of sample[g/ml]
mg/ml	g	Density of sample[g/ml]	1
mg/ml	ml	1	1
g/l	g	Density of sample[g/ml]	1
g/l	ml	1	1

mg	1	1	1
ml	1	1	1000
mg/pc	pc	1	1

Demulsifier Preparation

Table B. 4 Demulsifier Preparation

Demulsifier : Xylene = 1.5 : 1 (wt/wt)

Demulsifiers	Weight of demulsifiers (g)	Weight of xylene (g)
Teric PE 61	24.0013	16.0187
Teric PE 62	24.0185	16.0341
Genapol EP 2584	24.0308	16.0014
Genapol ED 3060	24.0347	16.0076

Mixed demulsifiers

Table B. 5 Mixed demulsifiers

Demulsifier : Xylene = 1.5 : 1 (wt/wt)

%	Weight of Teric 61 (g)	Weight of ED 3060 (g)	Weight of xylene (g)
0% Teric PE 61	0	24.0347	16.0076
20% Teric PE 61	3.0052	12.0038	10.0512
40% Teric PE 61	6.0013	9.0026	10.0073
60% Teric PE 61	9.0040	6.0009	10.0234
80% Teric PE 61	12.0022	3.0132	10.0106
100% Teric PE 61	24.0013	0	16.0187

Calculate weight of used solution (demulsifier + xylene) (g)

Example: Using demulsifier concentration of 500 ppm, weight of crude 9.0467 g

Demulsifier : Xylene = 1.5 : 1 (wt/wt)

Crude 9.0467 g → demulsifier concentration 500 ppm

Weight of demulsifier → $\frac{9.0467 \times 500}{1,000,000} = 0.0045$ g

Demulsifier 1.5 g → solution (demulsifier + xylene) 2.5 g

Demulsifier 0.0045 g → ∴ used solution (demulsifier + xylene)

$$= \frac{0.0045 \times 2.5}{1.5} = 0.0075 \text{ g}$$

Calculate the used xylene (ppm)

Example: Using demulsifier concentration of 500 ppm, weight of crude 9.0467 g

Demulsifier : Xylene = 1.5 : 1 (wt/wt), total weight of demulsifier + xylene = 0.0075 g

Solution (demulsifier + xylene) 2.5 g → weight of demulsifier 1.5 g

Solution (demulsifier + xylene) 0.0075 g → weight of demulsifier

$$= \frac{0.0075 \times 1.5}{2.5} = 0.0045 \text{ g}$$

weight of xylene = (total weight of demulsifier + xylene) - weight of demulsifier

$$= 0.0075 - 0.0045 = 0.0030 \text{ g}$$

∴ used xylene $= \frac{0.0030 \times 1.5 \times 1,000,000}{2.5 \times 9.0467} = 198.97$ ppm

Preparation of mixed crude

1. Mixed crude (W05T, water cut = 0.5% and B02T, water cut = 71.3%) at 6 different ratios for study the relationship between viscosity and %water content and study the effect of water-to-oil ratio

Table B. 6 Mixed crude (W05T, water cut = 0.5% and B02T, water cut = 71.3%) at 6 different ratios

%water content	W05T (water cut = 0.5%) (ml)	B02T (water cut = 71.3%) (ml)
0.5	200	0
14.7	160	40
28.8	120	80
43.0	80	120
57.1	40	160
71.3	0	200

2. Mixed crude (W05T, water cut = 0.5% and B02T, water cut = 71.3%) at 3 different ratios for study the relationship between viscosity and demulsifier concentration and study the effect of temperature, demulsifier concentration, separation time, mixed surfactant, and large scale test

Table B. 7 Mixed crude (W05T, water cut = 0.5% and B02T, water cut = 71.3%) at 3 different ratios

water cut	%water content	W05T (water cut = 0.5%) (ml)	B02T (water cut = 71.3%) (ml)
low	14.7	160	40
medium	43.0	80	120
high	71.3	0	200

3. Four-mixed crude (B15T : X12T : B02T : B24T = 1 : 1 : 2 : 2) with water content of 70.24% for study the effect of separation time, mixed surfactants, and large scale test.

B15T : X12T : B02T : B24T = 100 ml : 100 ml : 200 ml : 200 ml

Table B. 8 Relationship between viscosity and demulsifier concentration

Crude oil/ demulsifier conc.	Temp. (°C)	Speed (rpm)	Torque (%)	Viscosity (cP)	Shear stress (d/cm^2)	Shear rate 1/sec
middle water cut	34.5	100	94.9	278	320	93.0
middle water cut + 50 ppm ED 3060	34.2	100	95.2	243	297	93.0
middle water cut + 250 ppm ED 3060	34.6	100	96.3	164	189	93.0
high water cut	34.5	100	97.0	281	279	93.0
high water cut + 50 ppm ED 3060	34.7	100	96.1	249	257	93.0
high water cut + 250 ppm ED 3060	34.4	100	94.8	141	170	93.0
mixed crude	34.4	100	96.0	310	326	93.0
mixed crude + 50 ppm ED 3060	34.5	100	97.2	267	280	93.0
mixed crude + 250 ppm ED 3060	34.4	100	95.4	148	176	93.0

Table B. 9 Screening of Demulsifiers with Original Water in Crude

	0.5 hr					1 hr					2 hr				
	free water separated out (%)					free water separated out (%)					free water separated out (%)				
wells	Teric 61	Teric 62	EP 2584	ED 3060	Blank	Teric 61	Teric 62	EP 2584	ED 3060	Blank	Teric 61	Teric 62	EP 2584	ED 3060	Blank
A15T	3.00	0.00	0.00	0.00	0	3.00	0.00	0.00	0.00	0	3.00	0.00	0.00	0.00	0
C09T	3.00	2.00	2.00	2.00	0	3.00	3.00	3.00	2.00	0	3.00	5.00	3.00	2.00	0
D12T	33.30	2.00	47.67	5.00	0	37.00	2.00	50.00	11.67	0	42.33	5.00	50.67	25.67	0
F09T	0.00	0.00	0.00	0.00	0	0.00	2.00	0.00	0.00	0	2.00	3.00	2.00	0.00	0
W05T	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0

(a)

wells	3 hr												
	free water separated out (%)					water remaining in c/o (%)				water in emulsion (%)			
	Teric 61	Teric 62	EP 2584	ED 3060	Blank	Teric 61	Teric 62	EP 2584	ED 3060	Teric 61	Teric 62	EP 2584	ED 3060
A15T	3.00	0.00	0.00	0.00	0	0.00	1.52	0.00	0.00	1.90	3.38	4.90	4.90
C09T	5.00	5.00	3.00	2.00	0	0.03	0.88	0.03	0.03	3.29	2.44	5.29	6.29
D12T	46.00	5.00	50.67	41.00	0	0.00	27.03	0.02	0.03	0.00	11.52	0.00	2.52
F09T	2.00	3.00	2.00	0.00	0	0.02	2.01	0.01	0.02	2.30	0.00	2.31	4.30
W05T	0.00	0.00	0.00	0.00	0	0.00	0.31	0.00	0.00	0.50	0.19	0.50	0.50

(b)

wells	0.5 hr					1 hr					2 hr				
	free water separated out (%)					free water separated out (%)					free water separated out (%)				
	Teric 61	Teric 62	EP 2584	ED 3060	Blank	Teric 61	Teric 62	EP 2584	ED 3060	Blank	Teric 61	Teric 62	EP 2584	ED 3060	Blank
W09T	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0	1.0	2.0	0.0
A02T	16.0	12.0	14.0	22.0	0.0	19.0	13.0	15.0	23.0	0.0	22.0	16.0	19.0	25.0	0.0
X09T	2.0	5.0	0.0	28.0	0.0	5.0	5.0	0.0	35.0	0.0	12.0	5.0	0.0	37.0	0.0
B15T	40.0	8.0	35.0	40.0	0.0	42.0	12.0	37.0	41.0	0.1	42.0	20.0	40.0	41.0	0.1
X12T	61.0	50.0	38.0	62.0	0.0	61.0	52.0	42.0	62.0	0.0	61.0	55.0	50.0	62.0	0.0
B02T	60.0	52.0	25.0	63.0	0.0	62.0	54.0	37.0	64.0	0.2	62.0	57.0	49.0	64.0	0.2
B24T	70.0	64.0	65.0	69.0	0.0	71.0	66.0	68.0	70.0	0.1	73.0	66.0	70.0	72.0	0.2

(c)

wells	3 hr												
	free water separated out (%)					water remaining in c/o (%)				water in emulsion (%)			
	Teric 61	Teric 62	EP 2584	ED 3060	Blank	Teric 61	Teric 62	EP 2584	ED 3060	Teric 61	Teric 62	EP 2584	ED 3060
W09T	2.0	2.0	2.0	2.0	0.0	0.0	1.0	1.1	0.0	4.3	3.3	3.2	4.3
A02T	26.0	20.0	24.0	26.0	0.0	0.3	0.5	0.0	0.0	4.3	10.0	6.5	4.5
X09T	20.0	7.0	3.0	37.0	0.0	0.3	0.0	3.6	0.3	30.3	43.7	44.1	13.4
B15T	43.0	28.0	40.0	42.0	0.2	0.0	0.0	0.0	0.0	9.9	24.9	12.9	10.9
X12T	61.0	60.0	55.0	62.0	0.0	0.0	0.0	2.3	0.2	0.0	1.3	0.0	0.0
B02T	62.0	63.0	62.0	64.0	0.3	0.2	0.0	0.0	0.0	9.2	0.0	9.3	7.3
B24T	73.0	67.0	70.0	74.0	0.2	0.0	0.6	0.1	0.0	7.2	0.0	10.1	6.2

(d)

Table B. 10 Effect of Water-to-oil Ratio

Crude	0.5 hr		1 hr		2 hr	
	free water separated out (%)		free water separated out (%)		free water separated out (%)	
	Teric 61	ED 3060	Teric 61	ED 3060	Teric 61	ED 3060
0.5	0.0	0.0	0.0	0.0	0.0	0.0
14.7	5.0	7.0	7.0	9.0	9.0	10.0
28.8	17.0	20.0	19.0	22.0	20.0	22.0
43.0	22.0	28.0	25.0	40.0	34.0	40.0
57.1	50.0	53.0	51.0	53.0	53.0	54.0
71.3	71.0	72.0	71.0	72.0	71.0	72.0

(a)

Crude	3 hr							
	free water separated out (%)		water remaining in c/o (%)		water in emulsion (%)		% water separation	
	Teric 61	ED 3060	Teric 61	ED 3060	Teric 61	ED 3060	Teric 61	ED 3060
0.5	0.0	0.0	0.23	0.24	0.3	0.3	0.0	0.0
14.7	9.0	10.0	0.27	0.16	5.4	4.5	61.2	68.0
28.8	21.0	22.0	0.27	0.19	7.5	6.6	72.9	76.4
43.0	37.0	41.0	0.34	0.11	5.7	1.9	86.0	95.3
57.1	55.0	55.0	0.40	0.28	1.7	1.8	96.3	96.3
71.3	71.0	72.0	0.03	0.01	0.3	0.0	99.6	100.0

(b)

Table B. 11 Effect of temperature by using mixed of 2 crudes (W05T=0.50% & B02T=71.3%) at 3 water cut
demulsifier conc. = 500 ppm, 60°C

water cut	water content (%)
low	14.7
meduim	43.0
high	71.3

		0.5 hr			1 hr			2 hr		
	Crude	free water separated out (%)			free water separated out (%)			free water separated out (%)		
		Teric 61	ED 3060	Blank	Teric 61	ED 3060	Blank	Teric 61	ED 3060	Blank
45°C	low	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	meduim	0.0	0.0	0.0	1.0	2.0	0.0	2.0	5.0	0.0
	high	27.0	31.0	0.0	35.0	40.0	2.0	37.0	40.0	3.0
50°C	low	0.0	0.0	0.0	5.0	6.0	0.0	6.0	8.0	0.0
	middle	2.0	5.0	0.0	21.0	23.0	0.0	25.0	27.0	0.0
	high	65.0	70.0	0.0	67.0	70.0	2.0	68.0	70.0	3.0
55°C	low	5.0	6.0	0.0	7.0	8.0	0.0	8.0	9.0	0.0
	meduim	8.0	9.0	0.0	15.0	17.0	0.0	28.0	32.0	1.0
	high	67.0	71.0	2.0	70.0	71.0	5.0	70.0	71.0	5.0
60°C	low	5.0	7.0	0.0	7.0	9.0	0.0	9.0	10.0	0.0
	meduim	22.0	28.0	0.0	25.0	40.0	2.0	34.0	40.0	2.0
	high	71.0	72.0	5.0	71.0	72.0	7.0	71.0	72.0	10.0

(a)

	Crude	3 hr free water separated out (%)			water remaining in c/o (%)		water in emulsion (%)	
		Teric 61	ED 3060	Blank	Teric 61	ED 3060	Teric 61	ED 3060
45°C	low	0.0	0.0	0.0	4.1	3.6	10.6	11.1
	meduim	2.0	5.0	0.0	22.4	13.8	18.6	24.2
	high	38.0	40.0	3.0	21.1	18.5	12.2	12.8
50°C	low	6.0	8.0	0.0	1.2	1.0	7.5	5.7
	meduim	26.0	29.0	0.0	1.4	1.1	15.6	12.9
	high	68.0	70.0	3.0	3.3	1.5	0.0	0.0
55°C	low	8.0	9.0	0.0	0.4	0.3	6.3	5.4
	meduim	34.0	37.0	1.0	0.5	0.3	8.5	5.7
	high	70.0	71.0	5.0	0.2	0.1	1.1	0.2
60°C	low	9.0	10.0	0.0	0.3	0.2	5.4	4.5
	meduim	37.0	41.0	2.0	0.3	0.1	5.7	1.9
	high	71.0	72.0	10.0	0.0	0.0	0.3	0.0

(b)

Table B. 12 Effect of demulsifier concentration by using mixed of 2 crudes (W05T=0.50% & B02T=71.3%) at 3 water cut
vary demulsifier conc. = 20, 50, 100, 250, 500 ppm, 55°C

water cut	water content (%)
low	14.7
medium	43.0
high	71.3

	55°C														
water cut/ demulsifier	free water separated out (%)					water remaining in crude (%)					water in emulsion (%)				
	20 ppm	50 ppm	100 ppm	250 ppm	500 ppm	20ppm	50 ppm	100 ppm	250 ppm	500 ppm	20 ppm	50 ppm	100 ppm	250 ppm	500 ppm
low water cut/Teric 61	5.0	6.0	6.0	7.0	8.0	1.13	1.02	0.64	0.51	0.44	8.6	7.7	8.1	7.2	6.3
low water cut/ED	7.0	7.0	8.0	9.0	9.0	0.92	0.59	0.46	0.30	0.29	6.8	7.1	6.2	5.4	5.4
med water cut/Teric 61	13.0	15.0	21.0	25.0	34.0	0.55	0.50	0.52	0.48	0.53	29.5	27.5	21.5	17.5	8.5
med water cut/ED	22.0	25.0	27.0	30.0	37.0	0.47	0.32	0.34	0.29	0.32	20.5	17.7	15.7	12.7	5.7
high water cut/Teric 61	32.0	37.0	45.0	50.0	70.0	0.40	0.29	0.24	0.20	0.15	38.9	34.0	26.1	21.1	1.1
high water cut/ED	68.0	67.0	68.0	70.0	71.0	0.32	0.20	0.26	0.23	0.07	3.0	4.1	3.0	1.1	0.2

Table B. 13 Effect of separation time by using mixed of 2 crudes (W05T=0.50% & B02T=71.3%) at 3 water cut & mixed crude (w/c =70.2%)
demulsifier conc. = 20, & 50 ppm, 55°C, vary time at 0.5, 1, 2, & 3 h

water cut	water content (%)
low	14.7
medium	43.0
high	71.3
mixed crude	70.2

<u>mixed of 4 crudes</u>
B15T : X12T : B02T : B24T = 1 : 1 : 2 : 2

water cut/ demulsifier	0.5 h					
	free water separated out (%)		water remaining in crude (%)		water in emulsion (%)	
	20 ppm	50 ppm	20 ppm	50 ppm	20 ppm	50 ppm
low water cut/Teric 61	0.0	0.0	9.12	6.04	5.6	8.7
low water cut/ED	0.0	0.0	8.37	5.68	6.3	9.0
med water cut/Teric 61	0.0	0.0	36.32	20.24	6.7	22.8
med water cut/ED	4.0	4.0	15.23	10.13	23.8	28.9
high water cut/Teric 61	0.0	0.0	38.39	15.01	32.9	56.3
high water cut/ED	4.0	4.0	10.67	7.31	56.6	60.0
mixed crude/Teric 61	3.0	5.0	30.08	21.14	37.1	44.0
mixed crude/ED	8.0	26.0	24.78	17.02	37.4	27.2

(a)

water cut/ demulsifier	1 h					
	free water separated out (%)		water remaining in crude (%)		water in emulsion (%)	
	20 ppm	50 ppm	20 ppm	50 ppm	20 ppm	50 ppm
low water cut/Teric 61	0.0	0.0	7.22	4.78	7.5	9.9
low water cut/ED	4.0	4.0	6.07	4.01	4.6	6.7
med water cut/Teric 61	0.0	0.0	17.43	10.98	25.6	32.0
med water cut/ED	20.0	20.0	9.45	7.90	13.6	15.1
high water cut/Teric 61	20.0	20.0	18.21	3.26	33.1	48.0
high water cut/ED	20.0	40.0	7.05	2.84	44.3	28.5
mixed crude/Teric 61	5.0	7.0	17.44	10.43	47.7	52.7
mixed crude/ED	16.0	47.0	11.57	8.36	42.6	14.8

(b)

water cut/ demulsifier	2 h					
	free water separated out (%)		water remaining in crude (%)		water in emulsion (%)	
	20 ppm	50 ppm	20 ppm	50 ppm	20 ppm	50 ppm
low water cut/Teric 61	2.0	2.0	4.04	3.56	8.7	9.1
low water cut/ED	4.0	4.0	3.35	2.17	7.4	8.5
med water cut/Teric 61	4.0	4.0	9.67	3.32	29.3	35.7
med water cut/ED	30.0	30.0	4.13	0.36	8.9	12.6
high water cut/Teric 61	40.0	60.0	3.46	0.67	27.8	10.6
high water cut/ED	40.0	60.0	2.03	0.31	29.3	11.0
mixed crude/Teric 61	5.0	12.0	8.92	5.96	56.3	52.2
mixed crude/ED	24.0	56.0	5.67	3.25	40.5	10.9

(c)

water cut/ demulsifier	3 h					
	free water separated out (%)		water remaining in crude (%)		water in emulsion (%)	
	20 ppm	50 ppm	20 ppm	50 ppm	20 ppm	50 ppm
low water cut/Teric 61	4.0	4.0	1.07	0.83	9.6	9.9
low water cut/ED	8.0	8.0	1.02	0.61	5.7	6.1
med water cut/Teric 61	16.0	16.0	0.60	0.49	26.4	26.5
med water cut/ED	40.0	40.0	0.38	0.19	2.6	2.8
high water cut/Teric 61	60.0	70.0	0.43	0.24	10.9	1.1
high water cut/ED	70.0	70.0	0.35	0.10	1.0	1.2
mixed crude/Teric 61	7.0	17.0	4.34	3.07	58.8	50.1
mixed crude/ED	37.0	66.0	1.63	0.06	31.5	4.1

(d)

Table B. 14 Demulsification by mixed demulsifiers (ED 3060 and Teric 61) with 2 water cut and mixed crude (70.2% w/c) @ 55°C & 50 ppm

100% ED 3060, 80% ED 3060, 60% ED 3060, 40% ED 3060, 20% ED 3060 and 100% Teric 61

water cut	water content (%)
medium	43.0
high	71.3
mixed crude	70.2
X12T	61.2

<u>mixed of 4 crudes</u>

B15T : X12T : B02T : B24T = 1 : 1 : 2 : 2

water cut	0.5 h free water separated out (%)						1 h free water separated out (%)						2 h free water separated out (%)					
	100% ED	80% ED	60% ED	40% ED	20% ED	100%Teric	100% ED	80% ED	60% ED	40% ED	20% ED	100%Teric	100% ED	80% ED	60% ED	40% ED	20% ED	100%Teric
med water cut	25.0	32.0	34.0	39.0	34.0	17.0	34.0	35.0	35.0	39.0	35.0	21.0	36.0	36.0	36.0	39.0	36.0	27.0
high water cut	42.0	45.0	49.0	45.0	35.0	23.0	58.0	55.0	58.0	60.0	49.0	29.0	61.0	57.0	60.0	62.0	60.0	38.0
mixed crude	32.0	22.0	25.0	27.0	10.0	7.0	49.0	45.0	30.0	26.0	20.0	12.0	62.0	54.0	42.0	45.0	33.0	17.0
X12T	24.0	22.0	22.0	23.0	20.0	16.0	30.0	28.0	26.0	29.0	24.0	20.0	43.0	41.0	42.0	40.0	38.0	32.0

(a)

water cut	3 h																	
	free water separated out (%)						water remaining in crude (%)						water in emulsion (%)					
	100% ED	80% ED	60% ED	40% ED	20% ED	100%Teric	100% ED	80% ED	60% ED	40% ED	20% ED	100%Teric	100% ED	80% ED	60% ED	40% ED	20% ED	100%Teric
med water cut	40.0	38.0	37.0	39.0	36.0	30.0	0.07	0.27	0.36	0.22	0.84	3.04	2.9	4.7	5.6	3.8	6.2	10.0
high water cut	69.0	62.0	65.0	65.0	57.0	59.0	0.00	0.31	0.13	0.06	0.51	0.47	2.3	9.0	6.2	6.2	13.8	11.8
mixed crude	68.0	61.0	56.0	58.0	47.0	44.0	0.03	0.29	0.48	0.55	2.06	2.98	2.1	8.9	13.7	11.6	21.1	23.2
X12T	57.0	54.0	53.0	54.0	50.0	47.0	0.10	0.26	0.31	0.25	0.46	0.52	4.1	6.9	7.9	7.0	10.7	13.7

(b)

Table B. 15 Demulsification of large scale test with mixed crude (70.2% w/c) (250 ml) @ 55°C & demulsifier concentration of 50 ppm
using 100% ED 3060, and 40% ED 3060

water cut	water content (%)
mixed crude	70.2

mixed of 4 crudes
B15T : X12T : B02T : B24T = 1 : 1 : 2 : 2

water cut	0.5 h		1 h		2 h	
	free water separated out (%)		free water separated out (%)		free water separated out (%)	
	100% ED	40% ED	100% ED	40% ED	100% ED	40% ED
mixed crude	0.0	5.0	5.0	10.0	50.0	30.0

water cut	3 h					
	free water separated out (%)		water remaining in crude (%)		water in emulsion (%)	
	100% ED	40% ED	100% ED	40% ED	100% ED	40% ED
mixed crude	67.5	60.0	0.04	0.25	2.6	9.9

Economic Assessment

PTT-EP data

demulsifier injection 30 ppm/gross product

gross product = 60,000 bbl/day

cost of demulsifier (PT 5135) = 14,617 baht/ 200 L or 73.35 baht/ L

$$1{,}000{,}000 \text{ bbl} \rightarrow 30 \text{ bbl}$$

$$60{,}000 \text{ bbl} \rightarrow \frac{30 \times 60{,}000}{1{,}000{,}000} = 1.8 \text{ bbl/day}$$

$$1 \text{ bbl} \rightarrow 159 \text{ L}$$

$$1.8 \text{ bbl} \rightarrow \frac{159 \times 1.8}{1} = 286.2 \text{ L/day}$$

$$200 \text{ L} \rightarrow 14{,}617 \text{ baht}$$

$$286.2 \text{ L} \rightarrow \frac{14{,}617 \times 286.2}{200} = 20{,}916.93 \text{ baht/day}$$

In this study diluted demulsifiers with solvent in the ratio of demulsifier : solvent = 1.5 : 1. Cost of demulsifier injection can calculate in this below.

Example

Demulsifier concentration (Genapol ED 3060) used 25 ppm

Cost of Genapol ED 3060 = 140 baht/ kg, specific gravity of Genapol ED 3060 = 1.03

Basis gross product 60,000 bbl/day

$$1{,}000{,}000 \text{ bbl} \rightarrow 25 \text{ bbl}$$

$$60{,}000 \text{ bbl} \rightarrow \frac{25 \times 60{,}000}{1{,}000{,}000} = 1.5 \text{ bbl/day}$$

$$1 \text{ bbl} \rightarrow 159 \text{ L}$$

$$1.5 \text{ bbl} \rightarrow \frac{159 \times 1.5}{1} = 238.5 \text{ L/day}$$

Genapol ED 3060 1 kg (140 baht); V = M/D

$$V = 1/1.03 = 0.971$$

0.971 L → 140 baht

238.5 L → $\frac{140 \times 238.5}{0.971}$ = 34,391.70 baht/day

1,000,000 bbl → 10.1 bbl

60,000 bbl → $\frac{10.1 \times 60,000}{1,000,000}$ = 0.606 bbl/day

1 bbl → 159 L

0.606 bbl → $\frac{159 \times 0.606}{1}$ = 96.35 L/day

Xylene 1 kg (31.57 baht); V = M/D

$$V = 1/0.86 = 1.16$$

1.16 L → 31.57 baht

96.35 L → $\frac{31.57 \times 96.35}{1.16}$ = 2,611.89 baht/day

Cost of demulsifier injection (Baht per day)

10 ppm of demulsifier			
Demulsifier Type	10 ppm of demulsifier	4.0 ppm of solvent	Total Cost
Teric PE 61	12,127.73	1,044.76	13,172.49
Teric PE 62	12,306.60	1,044.76	13,351.36
Genapol EP 2584	13,222.44	1,044.76	14,267.20
Genapol ED 3060	13,756.68	1,044.76	14,801.44
15 ppm of demulsifier			
Demulsifier Type	15 ppm of demulsifier	6.1 ppm of solvent	Total Cost
Teric PE 61	18,191.59	1,567.14	19,758.73
Teric PE 62	18,459.90	1,567.14	20,027.04
Genapol EP 2584	19,833.66	1,567.14	21,400.80
Genapol ED 3060	20,635.02	1,567.14	22,202.16
20 ppm of demulsifier			
Demulsifier Type	20 ppm of demulsifier	8.1 ppm of solvent	Total Cost
Teric PE 61	24,255.45	2,089.52	26,344.97
Teric PE 62	24,613.20	2,089.52	26,702.72
Genapol EP 2584	26,444.88	2,089.52	28,534.40
Genapol ED 3060	27,513.36	2,089.52	29,602.88
25 ppm of demulsifier			
Demulsifier Type	25 ppm of demulsifier	10.1 ppm of solvent	Total Cost
Teric PE 61	30,319.31	2,611.89	32,391.20
Teric PE 62	30,766.50	2,611.89	33,378.39
Genapol EP 2584	33,056.10	2,611.89	35,667.99
Genapol ED 3060	34,391.70	2,611.89	37,003.59
30 ppm of demulsifier			
Demulsifier Type	25 ppm of demulsifier	10.1 ppm of solvent	Total Cost
Teric PE 61	36,383.18	3,134.27	39,517.45
Teric PE 62	36,919.80	3,134.27	40,054.07
Genapol EP 2584	39,667.32	3,134.27	42,801.59
Genapol ED 3060	41,270.04	3,134.27	44,404.31

50 ppm of demulsifier			
Demulsifier Type	50 ppm of demulsifier	20.2 ppm of solvent	Total Cost
Teric PE 61	60,638.63	5,223.79	65,862.42
Teric PE 62	61,533.00	5,223.79	66,756.79
Genapol EP 2584	66,112.20	5,223.79	71,335.99
Genapol ED 3060	68,783.40	5,223.79	74,007.19

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Presentations:

1. U. Udomthada, C Saiwan, S. Jongpatiwut, and E. Behar (2006, December 3-5) Study of Demulsification of Water-in-oil Emulsion for Phet Crude Oral presented at the 13th RSCE 2006, Nanyang Technological University, Singapore.