

A STUDY TO ESTABLISH THE COMPOSITION AND SELECTED  
PHYSICAL CHARACTERISTICS OF AGED AND  
EMULSIFIED OILS

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1.0 INTRODUCTION

During the early history of a marine oil spill, hydrocarbon evaporation and the formation of water-in-oil emulsions are two significant processes that can significantly alter the characteristics of the spilled oil. The work performed in this study is concerned with both processes.

1.1 Hydrocarbon Evaporation

Hydrocarbon evaporation is a diffusion process, in which the lighter (volatile) components escape into the atmosphere (leaving the heavier components in the oil layer), and ultimately results in a decrease in the volatility and volume of a spill, and an increase in the specific gravity and viscosity of the spilled oil. One definition of the volatile hydrocarbon components (Pilpel, 1968) are the paraffin, naphthalene, and aromatic fractions having boiling points up to 150°C and hydrocarbon chains of up to 10 carbon atoms. Evaporation is accelerated at increased environmental temperatures, since higher temperatures at the oil/air interface create higher vapour pressures. Increasing wind velocities also serve to accelerate hydrocarbon evaporation, since the evaporation rate is directly proportional to the removal rate of hydrocarbon vapours from the area adjacent to the oil/air interface (McMinn, 1972). Mathematical models (Blokke, 1964 and Mackay/Matsugu, 1973) have been developed to describe the evaporation rates of various petroleum products over water, as affected by temperature, wind speed, and other parameters. In recent work (Mackay/Nadea, 1978), evaporative losses for several oils were established and presented graphically for a wide range of temperatures. The parameters of wind speed, spill area and volume, and aging time were incorporated in this work.

Environment Canada. Arctic and Marine Oilspill Program (AMOP) Technical Seminar, 2nd. Proceedings. March 7-9, 1979, Edmonton, Alberta, Canada, Environment Canada, Ottawa, Ontario, 184-205 pp, 1979.

A limited amount of work has been devoted towards evaluating the characteristics of Arctic marine oil spills as a function of the aging period. This information would be important for the effective and safe cleanup of such spills. In this work, six crude oils (Norman Wells, Sweet Bl., Sour Bl., Bow River, Lloydminster, and Weyburn-Midale) and two fuel oils (Marine Diesel and Bunker C) were exposed to Southern Ontario winter conditions for aging intervals ranging from 6 hours to 4 weeks. The composition and evaporative loss was determined for the oils after each aging interval. In-situ combustion, wicking tests, and the determination of several physical properties (flash/fire point, specific gravity, pour point, viscosity, distillation data, and tensions at oil/air and oil/water interfaces) were carried out on the oils for each aging interval. Attempts were made to correlate the evaporative loss data with the present models for hydrocarbon evaporation.

## 1.2 Formation of Water-in-Oil (W/O) Emulsions

The formation of a stable water-in-oil emulsion requires the presence of an emulsifying agent in the oil, and sufficient mixing energy (or agitation). Crude oils and unrefined fuel oils (Bunker fuel, for example) are known to contain emulsifying agents. Such oils spilled in a marine environment would be emulsified easily as a result of wave action. Water-in-oil emulsions have been reported to form following oil spill incidents involving the ARROW and TORREY CANYON tankers (Mackay et al, 1973) and the supertanker METULA (Hann, 1977). Water-in-oil emulsions are known to be extremely stable (or "persistent"), and of high viscosity, and such emulsions created after a marine oil spill have often been referred to as "chocolate mousse". The experimental work in this area has been obtained primarily from isolated tests or spill incidents, and little work has been done to summarize the property changes of crude oil as a result of emulsification with water, the stability of such emulsions, and the effect of aging (or "weathering") upon such emulsions. In the event of an Arctic marine oil spill, additional handling difficulties are anticipated with the formation of W/O emulsions. In-situ combustion (if feasible) would probably be the most effective method technique for their disposal, as compared to the use of sorbents, incin-

eration, the use of oil/water separators, and the use of burners.

As the secondary objective of this work, water-in-oil (W/O) emulsions were prepared in varying proportions with Lloydminster, Sweet Bl., Weyburn-Midale, and Norman Wells crude oils under laboratory conditions. The stability and ignitability of these emulsions was determined, and the viscosity and pour points of these emulsions are currently being established. In order to assess the suitability of a sorbent for the cleanup of W/O emulsions, wicking tests have been performed. Combustion tests will be carried out to determine the effectiveness of in-situ combustion for disposing of W/O emulsion layers.

## 2.0 EXPERIMENTAL WORK CONCERNING OIL AGING

### 2.1 Weather Parameters and Evaporative Loss of Hydrocarbons

An oil-aging facility was set up at the North Campus Research Station in North Waterloo. The oils were aged in metal pans (each pan having an area of 1 square yard) for the following intervals from October to December of 1978:

- 6 hours
- 1 day
- 2 days
- 1 week
- 2 weeks
- 4 weeks.

The initial oil layers were approximately 1 cm in thickness (10 litres of fresh oil were poured into each pan). Following each aging interval, the oils were recovered from the pans, and stored in containers. The evaporative losses were determined by measuring the recovered oil volumes, and expressing the last volume as a function of the original (fresh) oil volume. Air temperatures (maximum, minimum, and average) were obtained from information provided by the Waterloo-Wellington airport. Additional weather data was obtained from the Elora Gorge Research Station (courtesy of the Dept. of Land Resource Science, University of Guelph). Oil samples were later withdrawn from these containers for wicking tests and in-situ combustion tests, and for laboratory analyses. Fresh oil samples were also subjected to the same tests and analyses.

The evaporative losses and weather parameters estimated for each aging interval are presented in Table 1. Marine diesel fuel and Bunker C fuel were considered to have negligible evaporative losses during the aging intervals. This was attributed to the absence of volatile hydrocarbon components in their composition. Most of the volatile hydrocarbon components of the six crude oils were lost after an aging interval of 2 weeks, during which approximately 50 percent of the original oil volume had evaporated. During the aging intervals of 6 hours, 1 day, and 2 days, the lighter crude oils (Norman Wells, Sweet Bl. and Sour Bl.) generally exhibited higher evaporative losses than did the heavier crude oils (Bow River, Lloydminster, and Weyburn-Midale). Since the aging intervals were not simultaneous for each of the oils, differences in weather parameters for the same aging interval (but over different dates) had clearly affected the evaporative losses of the oils. During the aging intervals of 2 weeks and 4 weeks, significant amounts of precipitation had been entrained in the oil layers. As a consequence, the oil layers tended to increase in volume to some degree (the layer of Bunker C fuel increased to approximately twice its original volume over 2 weeks). The oil volumes for these aging intervals were determined after the water had been separated from the oil. Samples of these oils are presently being analysed to determine the content of any remaining water.

## 2.2 Physical Characteristics of Aged Oils

Physical characteristics were determined for the oils aged over each interval. Data obtained for Norman Wells crude oil is shown in Tables 2 and 3. As may well be expected, the specific gravity and viscosity of the oils significantly increase with increased aging intervals. The pour points of the oils were considerably increased with increased aging intervals, which (along with the viscosity data) would indicate that handling difficulties with these oils in a cold environment would definitely be increased with longer aging intervals. The combustibility of the oils (as noted by their flash and fire points) is notably reduced after an aging interval of 6 hours, and is reduced further by longer aging intervals. However, the flash and

fire points obtained clearly indicate that this oil can be burned after being aged for intervals of up to four weeks.

For Norman Wells crude oil, the surface tension values ranged between 13.1 and 22.7 dynes/cm, and the oil/water interfacial tension values ranged between 26.8 and 31.9 dynes/cm.

The distillation data for Norman Wells crude oil (shown in Table 3) indicates a relatively rapid loss of the low-boiling (or lighter) hydrocarbon components over an aging interval of 6 hours. After this period, the evaporative loss of low-boiling components appears to take place at somewhat lower rates. Gas chromatography analyses are being carried out on the oil samples, and this data will be available in the near future.

### 2.3 Wicking Tests with Aged Oils

Wicking tests were performed at room temperature with confined oil slicks (5 mm in thickness), using 3M Brand (type 157) Oil Sorbent sheets. In each test, the sheets (of polyethylene composition, cut to an area of approximately 900 cm<sup>2</sup>) were allowed to float on the oil layer for a period of 15 minutes. After this period, the sheets were removed from the slick, and excess (or unabsorbed) oil was allowed to drip away from the material. Most of the absorbed oil was recovered from the sheets by squeezing, and the weight of the unrecoverable oil was determined by subtracting the dry sorbent weight from the weight of the squeezed sorbent.

Results from several wicking tests are shown in Table 4. These results reveal that 3M Brand oil sorbent was capable of absorbing between 5.3 and 12.6 times its weight in oil, depending upon the oil type and the aging interval for the oil. This range of absorption capacities is agreeable to those reported in other wicking tests performed with 3M Brand Oil Sorbent (described in Robertson et al, 1976).

### 2.4 In-situ Combustion Tests with Aged Oils

Slicks of the oils recovered after each aging interval were burned over a large pool of water, approximately 2 feet in depth. By means of a metal square partially suspended in the water, the slicks were confined to an area of 1 m<sup>2</sup>. For each test, the following para-

meters were recorded:

- preheating time (the time required for the oil to ignite)
- ignition time (the time required for the flame to spread over the entire slick surface)
- combustion time (the time between the moment the entire slick surface is burning and the moment the flames are quenched)
- the volume, weight, and specific gravity of the remaining residue.

Results from the in-situ combustion of Norman Wells crude oil are presented in Table 5. At sub-zero ambient air temperatures (as low as  $-20^{\circ}\text{C}$ ), it was possible to ignite and successfully burn aged oil slicks having initial thicknesses of 5 mm. A slick of oil aged for longer periods of time required relatively longer preheating and ignition times. The aging period of the oil did not appear to affect the thickness of the residual oil layer remaining after combustion.

### 3.0 EXPERIMENTAL WORK CONCERNING W/O EMULSIONS

#### 3.1 Formation and Stability of W/O Emulsions

The W/O emulsions were formed at two different stages during this project. In the first stage, emulsions were formed outdoors during November and December of 1978. In this stage, W/O emulsions were prepared (with varying water contents) with all six crude oils on hand (Norman Wells, Sweet Bl., Sour Bl., Bow River, Weyburn-Midale, and Lloydminster). After their formation, the emulsions were left exposed to winter conditions (with temperatures near  $0^{\circ}\text{C}$ ) for a period of several weeks. In the second stage, W/O emulsions were prepared indoors (during January and February of 1979) with Norman Wells, Sweet Bl., Weyburn-Midale, and Lloydminster crude oils. These emulsions were prepared with water contents of 70, 60, 50 and 20 percent (by volume) and were to be incorporated with the wicking tests, the pour point and viscosity determinations, and the in-situ combustion tests. For both phases, the emulsions were prepared with the use of impeller pumps, in which oil and water were drawn together, and intimately mixed together through a spray nozzle. Following their preparation the emulsions were stored in closed containers.

All of the emulsions (prepared in the first stage) tended to separate after aging several weeks in sub-zero temperatures. It should be noted that wide temperature fluctuations were encountered during this time, and the emulsions were consequently exposed to numerous freeze-thaw cycles during their aging. Due to the poor prevailing weather conditions over this aging period, it was not possible to obtain quantitative data concerning emulsion stability.

The characteristics of the emulsions prepared in the second phase are shown in Table 6. The W/O emulsions prepared with the heavy crude oils (Norman Wells and Sweet Bl. crudes) were not found to be completely stable, and had to be periodically reformed. With Weyburn-Midale crude oil, the emulsions formed with water contents of 50, 60 and 70 percent were extremely viscous. It was noted that all of the W/O emulsions with higher water contents (70 and 60 percent) were relatively more viscous than those emulsions prepared with lower water contents (50 and 20 percent).

Pour point and viscosity determinations on the emulsions prepared in the second stage are presently being carried out.

### 3.2 Flash and Fire Point Data for W/O Emulsions

Flash and fire points were determined for emulsion samples using the Cleveland Open Cup method. These determinations were carried out on the stable emulsions, and for several emulsions that would remain stable for the purpose of a flash/fire point test.

Flash and fire point data is presented in Table 7. For Lloydminster, Weyburn-Midale, and Sweet Bl. crude oils, it was noted that flash and fire points increased with the percentage of emulsified water in the sample. This was the expected trend, which indicates that increasing amounts of emulsified water tend to make W/O emulsions more difficult to ignite. However, the relatively low fire points of all W/O emulsions tested suggests that fresh oil slicks emulsified with water can be ignited. In-situ combustion tests will be carried out with fresh W/O emulsions in the future.

### 3.3 Wicking Test Data for W/O Emulsions

Wicking tests were performed with the W/O emulsions, in the same manner as described in Section 2.3. The W/O emulsions that were not considered to remain stable for the duration of a wicking test were not tested.

The results of these tests are shown in Table 8. The emulsions containing 70 and 80 percent oil generally were wicked up to a greater extent by 3M Brand sorbent than were those emulsions containing 50 and 40 percent oil. This fact can be attributed to (a) the relatively higher viscosities of emulsions having higher water contents and (b) the hydrophobic ("water repelling") nature of the sorbent itself.



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TABLE 1

Evaporative Losses and Cumulative Weather Data for Oil Aging Intervals

Aging Period and Time Interval	Oil Type	Volumetric Loss Due to Evaporation (% of original volume)	Daily Air Temperatures (°C)		Total Number of Bright Sunlight Hours (approx.)	Approx. Total of Daily Solar Radiation (MJ/m <sup>2</sup> )	Daily Wind Speed (km/h)		Total Precipitation (mm)	
			Max.	Min.			Ave.	Max.	Rain	Snow
<u>6 Hours</u>										
Nov. 13	Norman W.	27.2								
	Swt. Bl.	16.0								
	Sour Bl.	16.2	4	-1	1.5	2.0	35.8*	36.3*	14.5	Nil
	Bow Riv.	11.3								
Nov. 15	Wey.-Mid.	16.0								
	Lloyd.M.	14.5	3	1	2	2.8	10	18	Nil	Nil
	Marine D.	Nil								
	Bunker C	N.T.								
<u>1 Day</u>										
Nov. 1-2	Norman W.	33.0								
	Swt. Bl.	25.0								
	Sour Bl.	27.6								
	Bow Riv.	19.5	14	-1	6.5	12.2	11.5	24	Nil	Nil
	Wey.-Mid.	17.5								
	Lloyd.M.	16.8								
	Marine D.	Nil								
<u>2 Days</u>										
Nov. 4-6	Swt. Bl.	25.0								
	Sour Bl.	22.5	19	-2	8.8	14.5	12.3	31	0.2	Nil
	Bow Riv.	19.0								

(Cont'd)

TABLE 1 (Cont'd)

Aging Period and Time Interval	Oil Type	Volumetric Loss Due to Evaporation (% of original volume)	Daily Air Temperatures (°C)	Max.	Min.	Ave.	Total Number of Bright Sunlight Hours (approx.)	Approx. Total of Daily Solar Radiation (MJ/m <sup>2</sup> )	Daily Wind Speed (km/h)	Ave.	Max.	Total Precipitation (mm)	Rain	Snow
<u>2 Days (Cont'd)</u>														
Nov. 7-9	Norman W.	36.0												
	Lloyd.M.	20.0		13	-7	3.8	16.4	22.0	13.3	29		Nil	Nil	Nil
	Marine D.	Nil												
Nov. 8-10	Wey.-Mid.	22.5		13	-7	4.8	12.3	18.3	13.0	29		Nil	Nil	Nil
<u>1 Week</u>														
Oct. 30-Nov. 6	Lloyd.M.	23.5		19	-3	7.7	52.7	72.2	11.7	31		2.4	Nil	Nil
	Bunker C	Nil												
Nov. 1-8	Norman W.	18.0												
	Swt. Bl.	15.5		19	-7	6.4	46.8	65.7	11.6	31		2.4	Nil	Nil
	Sour Bl.	40.3												
	Bow Riv.	9.0												
Nov. 8-15	Wey.-Mid.	24.0		14	-7	4.2	16.8	38.3	15.2	35		14.5	Nil	Nil
	Marine D.	Nil												
<u>2 Weeks</u>														
Oct. 27-Nov. 10	Norman W.	58.8												
	Bow Riv.	53.2												
	Lloyd.M.	65.5		19	-7	6.2	95.8	136.7	12.1	31		2.4	Nil	Nil
	Marine D.	Nil												
	Bunker C	N.T.												

(Cont'd)

TABLE 1 (Cont'd)

Aging Period and Time Interval	Oil Type	Volumetric Loss Due to Evaporation (% of original volume)	Daily Air Temperatures (°C)		Total Number of Bright Sunlight Hours (approx.)	Approx. Total of Daily Solar Radiation (MJ/m <sup>2</sup> )	Daily Wind Speed (km/h)	Total Precipitation (mm)			
			Max.	Min.				Ave.	Rain	Snow	
** <u>2 Weeks</u> (Cont'd)											
Oct. 30- Nov. 13	Swt. Bl. Sour Bl.	52.3 66.2	19	-7	5.2	78.6	120.2	12.0	31	2.4	Nil
Nov. 8-22	Wey.-Mid.	48.8	13	-8	4.7	34.2	72.0	17.0	53	31	11
** <u>4 Weeks</u>											
Oct. 27- Nov. 24	Norman W. Bow Riv. Lloyd.M. Marine D. Bunker C	47.7 44.0 48.0 N.T. N.T.	19	-8	4.1	118.1	193.0	15.0	53	48.5	2.3
Oct. 30- Nov. 27	Swt. Bl. Sour Bl.	43.3 48.9	19	-10.6	3.0	105.8	178.9	15.7	53	50.6	41
Nov. 8- Dec. 6	Wey.-Mid.	49.2									

Notes

N.T. - value was not successfully established.

\* Wind speed values obtained from weather data taken at the Waterloo-Wellington Airport, near Breslau, Ontario.

\*\* Evaporation loss values obtained from samples having an original (fresh) oil volume of 20 litres. Due to precipitation, water-in-oil emulsions had formed in the oil layers, thereby increasing the actual oil volume. The evaporative losses in this case were based upon the oil volume remaining after water and ice had been extracted from the collected oil.

TABLE 2

## Physical Characteristics Determined for Norman Wells Crude Oil

Aging Interval	Specific Gravity at Room Temperature	Flash Point (°C)	Fire Point (°C)	Oil Viscosity (Centipoise)			Surface (Oil/Air Interface) Tension at Room Temperature (Dynes/cm)	Oil/Water Interfacial Tension at Room Temperature (Dynes/cm)	Pour Point (°C)
				10°C	10°C	20°C			
0 Hours (fresh)	0.83	-	13.5	14.2	8.7	5.9	22.7	26.8	-85 (or lower)
6 Hours	0.83	47	51	39.4	16	11.3	16	28.3	-35
1 Day	0.87	69	74	164	65.5	21.4	20	29.6	-36
2 Days	0.89	101	105	440	90.6	29	18	30.6	-33
1 Week	0.89	110	112	560	121	46.1	14.8	31.8	-9
2 Weeks	0.90	109	124	680	125	42.3	14.4	31.9	-16
4 Weeks	0.93	111	125	862.5	240	89	13.1	31.0	-8

TABLE 3

Distillation Data and Pour Points for Norman Wells Crude Oil

	<u>Oil Aging Interval</u>				
	0 Hours	6 Hours	1 Day	2 Days	4 Weeks
Initial Boiling Point (°C)	50	125	115	55	215
10% Distillation Range (°C)	85	150	115	199	250
20% "	125	185	230	231	280
30% "	155	220	263	265	310
40% "	220	270	293	300	330
50% "	275	305	-	330	365
60% "	335	350	-	337	380
70% "	360	375	-	356	400
80% "	375	-	-	-	420
90% "	-	-	-	-	-
100% "	-	-	-	-	-
Loss (%)	19	30	61	30	20
Residue (%)	16.8	30.5	60.2	28.5	20.3

TABLE 4

## Oil Sorption Capacities for 3M Brand Oil Sorbent

Oil Type	Aging Interval	Recovered* Oil Weight from Sorbent (g)	Ave. Non- Recoverable Oil Weight in Sorbent (g)	Total Oil Weight in Sorbent (g)	Ave. Dry Sorbent Weight (g)	Ratio of Oil Absorbed to Sorbent Weight (g of Oil/ g of Sorbent)	Reported in this Study	Reported by Robertson ** et al.
Bow River Crude	6 Hours	347.2	103.5	450.7	37.4	12.1	9, 10	
Sour Bl. Crude	6 Hours	361.9	103.5	465.4	37.4	12.4	9, 10	
Weyburn-Midale Crude	1 Day	191.3	103.5	294.8	37.4	7.9	9, 10	
Marine Diesel Fuel	1 Day	367.6	103.5	471.1	37.4	12.6	9, 10	
Lloydminster Crude	2 Days	246.4	103.5	349.9	37.4	9.4	9, 10	
Weyburn-Midale Crude	1 Week	93.8	103.5	197.3	37.4	5.3	9, 10	
Sweet Bl. Crude	1 Week	133.5	103.5	237.0	37.4	6.3	9, 10	
Norman Wells Crude	4 Weeks	204.7	103.5	308.2	37.4	8.2	9, 10	

(Cont'd)

TABLE 4 (Cont'd)

Notes

\*The weight of recovered oil is determined by multiplying the volume of oil squeezed out of the sorbent by the specific gravity of the oil.

\*\*In this experimental work (Robertson et al., 1976), sheets of 3M sorbent were allowed to wick up oil from 1 mm-thick slicks of oil, under laboratory conditions. A sorption capacity of 9 was obtained with fresh crude oil, and a sorption capacity of 10 was obtained with crude oil aged for 7 days.



TABLE 5

In-situ Combustion Data for Norman Wells Crude Oil

Aging Period	Initial Oil Layer Thickness (mm)	Preheating Time (min:sec)	Ignition Time (min:sec)	Combustion Time (min:sec)	Residual Oil Layer Thickness (mm)	Comments
6 Hours	5	0:26	0:28	1:52	0.39	-intense flame with dense, black smoke
1 Day	5	0:45	0:40	1:50	0.85	-medium density black smoke
2 Days	5	0:51	1:20	1:47	0.38	-intense flame with medium grey smoke
2 Weeks	5	0:55	1:55	1:41	0.85	-medium density smoke
4 Weeks	5	3:03	3:57	1:29	0.73	-weak, slow spreading flame -low density smoke

These tests were performed with ambient air temperature of approximately - 20°C.

TABLE 6

Characteristics of W/O Emulsions

Emulsion Composition (by volume)	<u>Oil Type</u>			
	Lloydminster Crude	Weyburn-Midale Crude	Sweet Bl. Crude	Norman Wells Crude
80% Oil 20% Water	Stable	Stable	Partially Stable	Stable for Several Hours
70% Oil 30% Water	Stable	Stable	Partially Stable	Stable for Several Hours
50% Oil 50% Water	Stable (extremely viscous)	Stable (extremely viscous)	Partially Stable	Stable for Several Hours
40% Oil 60% Water	Stable (extremely viscous)	Stable (extremely viscous)	Partially Stable	Stable for Several Hours
30% Oil 70% Water	N.P.	Stable (extremely viscous)	N.P.	N.P.

N.P. - Emulsion not prepared.

TABLE 7

Flash and Fire Points (°C) for W/O Emulsions

Emulsion Composition (by volume)	<u>Oil Type</u>				
	Lloydminster Crude	Weyburn-Midale Crude	Sweet Bl. Crude	Norman Wells Crude	
80% Oil 20% Water	19.5	17 (or less)	19 or Less)	-	Flash Pt.
	28	23	20.5	-	Fire Pt.
70% Oil 30% Water	23	18 (or less)	28.5	-	Flash Pt.
	55	24	32	-	Fire Pt.
50% Oil 50% Water	45	32	28	-	Flash Pt.
	78	71	33	-	Fire Pt.
40% Oil 60% Water	67	63	31.5	-	Flash Pt.
	76	73	37.5	-	Fire Pt.
30% Oil 70% Water	-	50	-	-	Flash Pt.
	-	58	-	-	Fire Pt.

TABLE 8  
Sorption Capacities\* of 3M Brand Oil Sorbent  
with W/O Emulsions

Emulsion Composition (by volume)	<u>Oil Type</u>			
	Lloydminster Crude	Weyburn-Midale Crude	Sweet Bl. Crude	Norman Wells Crude
80% Oil 20% Water	9.86	6.15	9.77	10.96
70% Oil 30% Water	10.68	9.52	9.2	11.26
50% Oil 50% Water	8.81	3.53	5.91	6.46
40% Oil 60% Water	6.37	-	5.48	-
30% Oil 70% Water	-	-	-	-

\* Sorbent Capacity was evaluated as the weight of W/O emulsion absorbed divided by the average weight of a sorbent sheet (37.57 g).

### DISCUSSION

- Q. What was the flame propagation time over that one square meter area for the emulsion, what was it generally for a 30% water in oil?
- A. I don't remember offhand but 30% of water wasn't that substantial - 2 to 5 minutes, but when you go to higher water content it decreases dramatically. It could go to 15 - 20 minutes, so it's a very substantial increase in propagation time and also it is important what the initial size of the flame is, so if you don't generate a flame about a half a meter in diameter it won't propagate at all.
- Q. On those shots you showed us, it didn't look like you had half a meter in diameter in flame.
- A. No, but that was 20% of water and 80% of oil, so for this type of emulsion it was no problem. It was fresh crude and fresh emulsion so there was lots of volatile component present, but once you go to a heavier crude the propagation time is profoundly affected.
- Q. What was the largest water and oil emulsion content you were able to burn?
- A. The largest content was 50% so far but we are working on it right now and we are looking at 60% water content and 80% water content. The thickness might be a little larger and ignition might be a little bit difficult but I believe it would be possible to burn at that.
- Q. What was the required ignition time for that?
- A. Which one?
- Q. The 50%
- A. I shouldn't really talk about ignition time for this emulsion because we couldn't ignite with our ignitor. What I had to do was pour some gasoline on the top to increase the flame size.
- Q. Which ratio were you able to burn with the ignitor?
- A. 30%

Q. What effect did the wind have on the ignition and the subsequent burn?

A. During the test we performed, the wind was pretty calm. We were burning in a confined area so it is difficult to establish.

Q. What was the coldest temperature that you burned at?

A. Emulsion?

Q. Whatever.

A. We performed some tests at minus 20 but that didn't affect substantially at all.

Q. In your conclusions you made the comment that the evaporative losses were much larger from crude oil than they were from distilled fuel. I was just wondering what distilled fuel you were referring to.

A. Bunker C and Marine diesel. With Bunker C there is almost no evaporative loss at all. It was very difficult to see any change in the composition of crude. It is so heavy. There are no light components present in that crude at all.