Study to Assess the Cooling of Warm Viscous Oils Spilled into Cold Water

for

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Abstract

The objective of the project was to determine the rate of cooling of warm oil discharged onto cold seawater.

Three different oil type and temperature combinations were tested. Ten percent weathered ANS crude oil was pre-heated to 6°C and 20% weathered ANS crude oil was pre-heated to both 46°C and 29°C. The oils were discharged onto 1 to 1.5 °C water and slick temperatures were monitored for up to 1 minute after discharge.

In all tests the most significant drop in temperature occurred when the oil was first poured and submerged into the cold water.

The surface temperatures of the oils as measured by an Infrared thermometer tended to be lower than most of the bulk oil temperature measurements taken using thermocouples. This may be due to cooling of the surface of the slick by the surrounding cold air.

Within ten seconds of being spilled the temperature of the 6°C oil dropped to about 1 to 3°C. The 29°C oil cooled to approximately 1 to 8°C within 10 seconds of being spilled. The 46°C oil cooled to approximately 3 to 7°C within 10 seconds of being spilled.

While none of the oils cooled to ambient water temperatures within 10 seconds of being spilled the data show that their temperatures dropped dramatically in this short period. This is demonstrated best by Figures 1 through 6 in the main body of the report.

Objective

The objective of the project was to determine the rate of cooling of warm oil discharged onto cold seawater.

Background

Dispersant experiments completed at Ohmsett in 2002 and 2003 assessed the dispersibility of fresh and weathered crude oils on cold, near freezing water (SL Ross 2002, SL Ross and MAR 2003). These studies were undertaken to resolve controversies concerning the dispersibility of Alaska North Crude oils when spilled onto cold water. Results suggested that both fresh and weathered ANS crude oils were clearly dispersible at near freezing temperatures. However, there has been criticism of the findings related to the heating of the oil prior to its discharge onto the water surface and subsequent dispersant application.

The viscosity of ANS crude oil is relatively low when fresh, but weathering the oil and the cold temperatures increased its viscosity, making the oil difficult to pump with the equipment available at Ohmsett at the time of the experiments. To overcome this problem during the test program the oil was warmed to reduce its viscosity and improve its pumpability. In the study noted above, researchers warmed 10% weathered ANS crude oil to 6°C and 20% weathered ANS crude oil to 46°C and 29°C prior to discharge onto 0°C water. Researchers considered this procedure to be acceptable, believing that once discharged onto cold water, the very thin oil slicks would cool quickly to ambient temperatures in the 10 seconds that pass prior to spraying with dispersants. However, some stakeholders have questioned this assumption, suggesting that slick temperatures may have been well above 0°C at the time of spraying resulting in much lower oil viscosities than would actually exist in the cold water conditions at the time the dispersant was applied.

Improvements to the pumping and discharge system have been implemented at Ohmsett to eliminate the need to pre-heat the oil to facilitate discharge of viscous oils in cold weather test programs. The objective of this work has been to preserve the value of the experiments already performed.

The original proposal called for a three-step work plan that included additional dispersant effectiveness testing on cold water. The effectiveness testing components were not funded so this report only addresses the measurement of oil slick cooling.

Study Method

The test procedure used to determine the cooling rate of the discharged oil was as follows:

1. Seventy milliliters of warmed oil was discharged from a 20 cm height above a large container of 0 to 1°C salt water in the middle of an oil sorbent containment ring with a 30 cm diameter.
2. The sorbent ring was needed to assist the spreading of the oil to the entire surface of the water inside the containment area. This resulted in a 1 mm thick oil slick which was the estimated thickness of the oil slicks in the original Ohmsett test program.
3. Four thermocouples were carefully positioned at the water surface within the containment ring. The thermocouple outputs were data logged at one-second intervals to record the changing oil temperature. An infrared (IR) thermometer was also used to measure the surface oil temperature. The IR temperature data was recorded by a video camera directed at the oil discharge zone.
4. At the end of each test the oil was carefully sorbed from the water surface using the 30 cm diameter sorbent circle cut out from the containment ring to record the surface area of the discharged slick.

Three different oil type and temperature combinations were tested. Ten percent weathered ANS crude oil was pre-heated to 6°C and 20% weathered ANS crude oil was pre-heated to both 46°C and 29°C. The oils were discharged onto 1 to 1.5 °C water and slick temperatures were monitored for up to 1 minute after discharge.

Test Results

Table 1 summarizes the oil slick temperatures measured when the oil first surfaced and 10 seconds after oil discharge (the approximate time at which dispersant was applied in the Ohmsett test program).

The detailed temperatures measured by the thermocouples and the IR thermometer are shown in Figures 1 through 6. The maximum temperatures shown on the y-Axis of these figures represents the temperatue of the discharged oil. This provides a reference point for the initial temperature drop experienced by the oil when poured into the cold water.

The thermal IR data were collected by reviewing the video of each test and manually recording the temperatures at 2, 5, 10, 15, 20, 25 and 30 seconds after the end of each oil discharge.

The oil slicks that formed during the tests were not of uniform thickness. This was also the case in the Ohmsett test program. As a result the oil temperatures from the four thermocouples vary somewhat.

Table 1. Oil Temperature Summary

ANS Crude Type (% Evaporated)	Initial Oil Temperature (°C)	Initial Slick Temperature (°C)		Slick Temperature 10 Seconds After Release (°C)	
		Thermal IR	Thermocouples	Thermal IR	Thermocouples
10	6	0.8	1.8 to 3.4	0.8	1.2 to 3.0
20	29	4.2	3.0 to 10.0	1.2	2.0 to 8.0
20	46	4.3	4.0 to 10.0	7.2	3.0 to 6.0

In all cases the most significant drop in temperature occurred when the oil was first poured and submerged into the cold water. The following generalizations can be made using the combination of the IR and thermocouple data.

The surface temperatures of the oils as measured by the IR thermometer tend to be lower than most of the bulk oil temperature measurements taken using the thermocouples. This may be due to cooling of the surface of the slick by the surrounding cold air.

Within ten seconds of being spilled the temperature of the 6°C oil dropped to about 1 to 3°C. The 29°C oil cooled to approximately 1 to 8°C within 10 seconds of being spilled. The 46°C oil cooled to approximately 3 to 7°C within 10 seconds of being spilled.

While none of the oils cooled to ambient water temperatures within 10 seconds of being spilled the data show that their temperatures dropped dramatically in this short period.

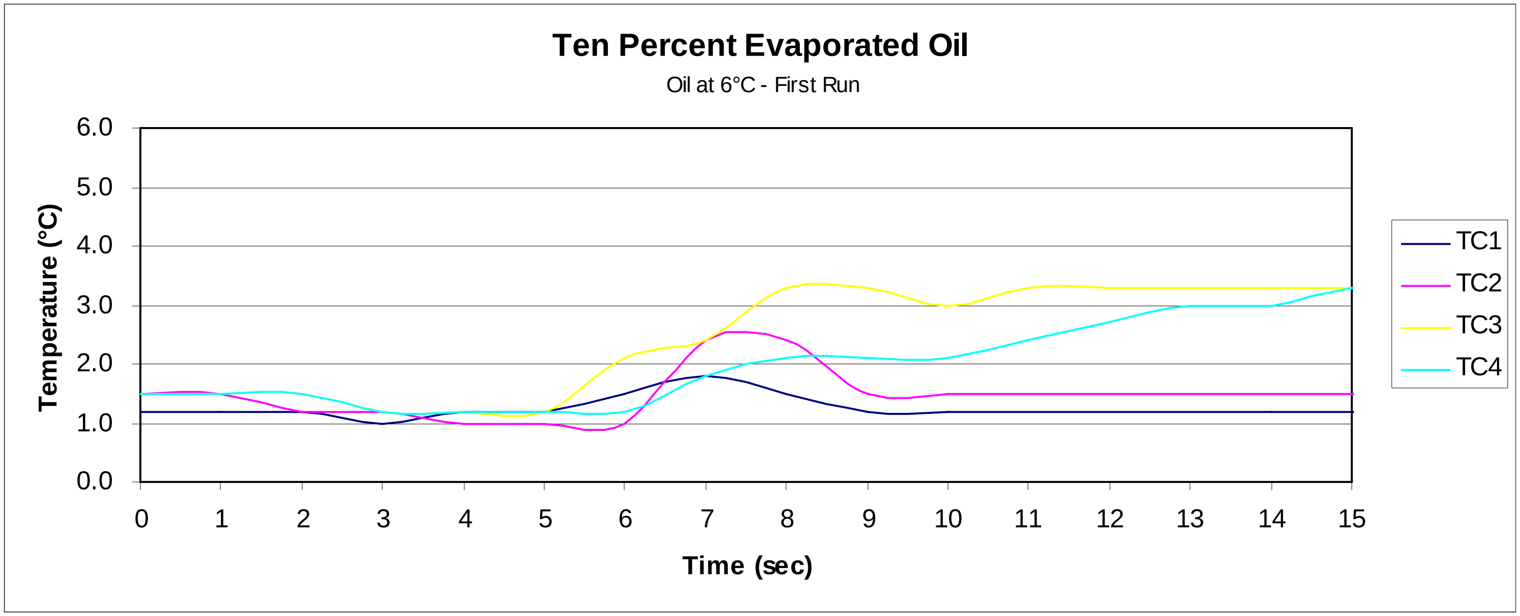

Figure 1. Ten Percent Evaporated, 6°C Oil, Run 1(note: thermal IR not available for this test)

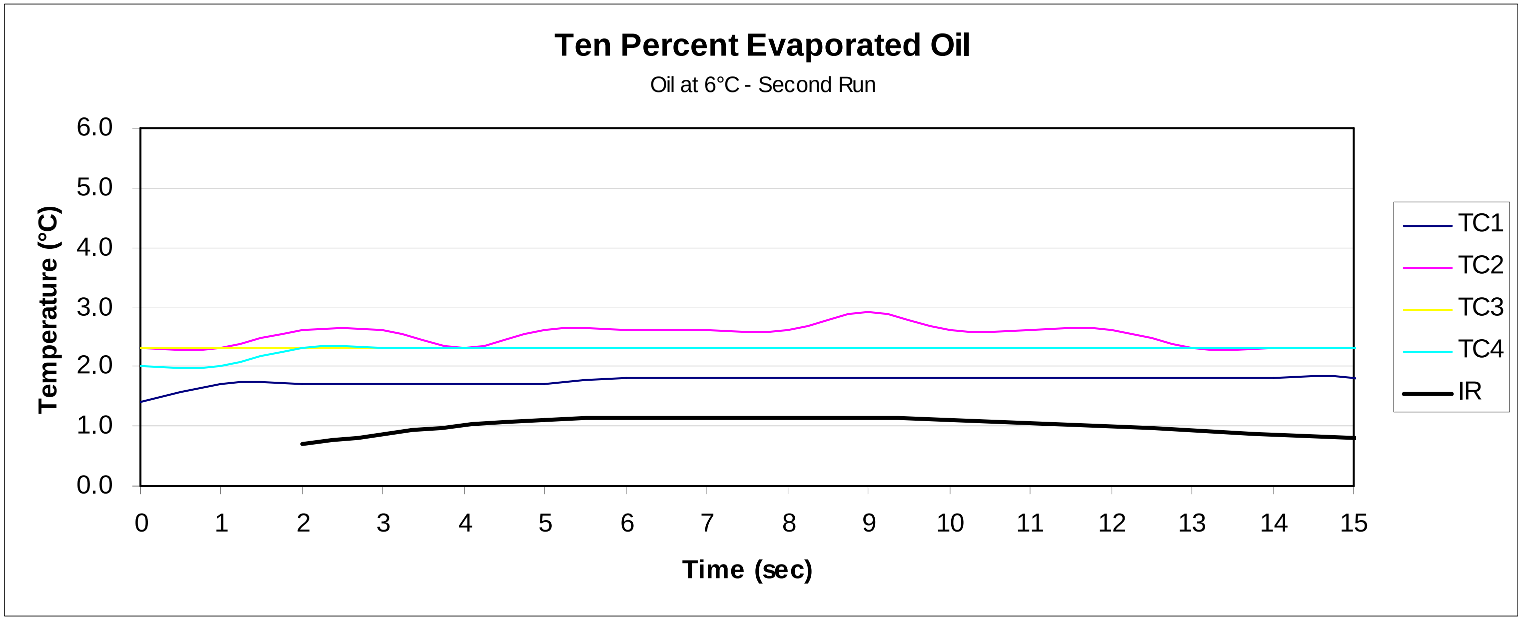

Figure 2. Ten Percent Evaporated, 6°C Oil, Run 2

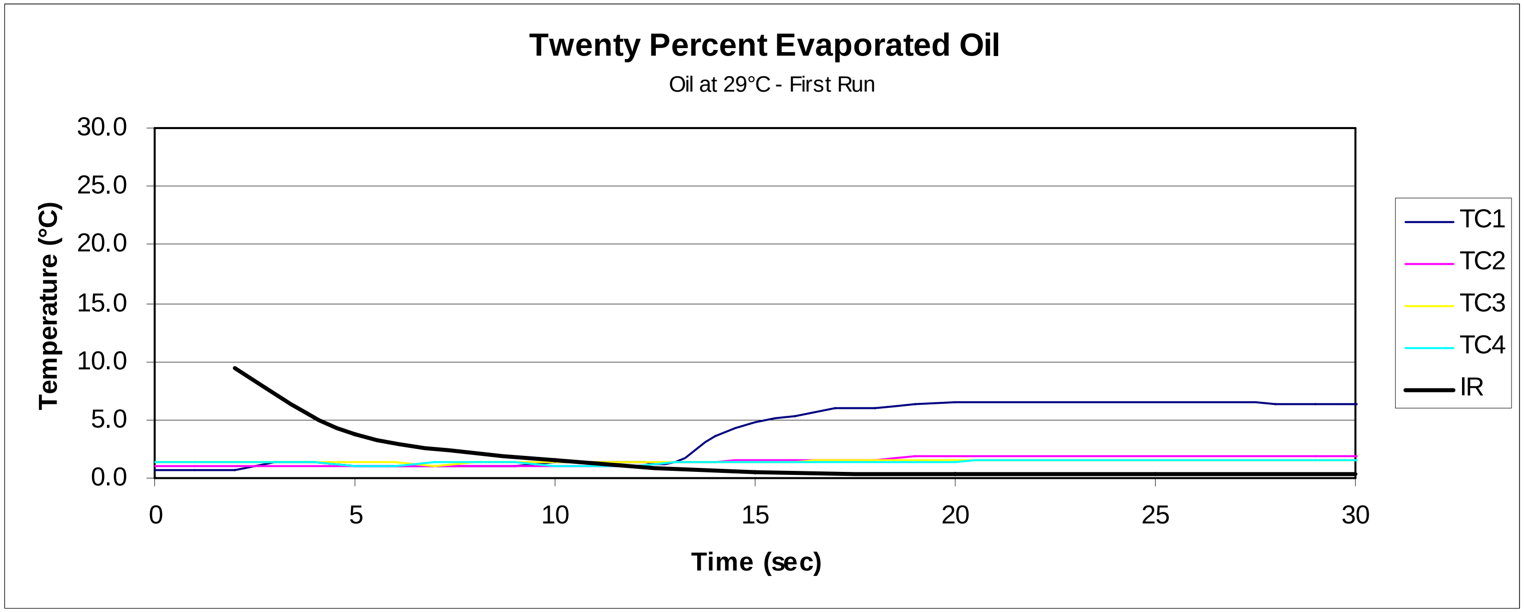

Figure 3. Twenty Percent Evaporated, 29°C Oil, Run 1

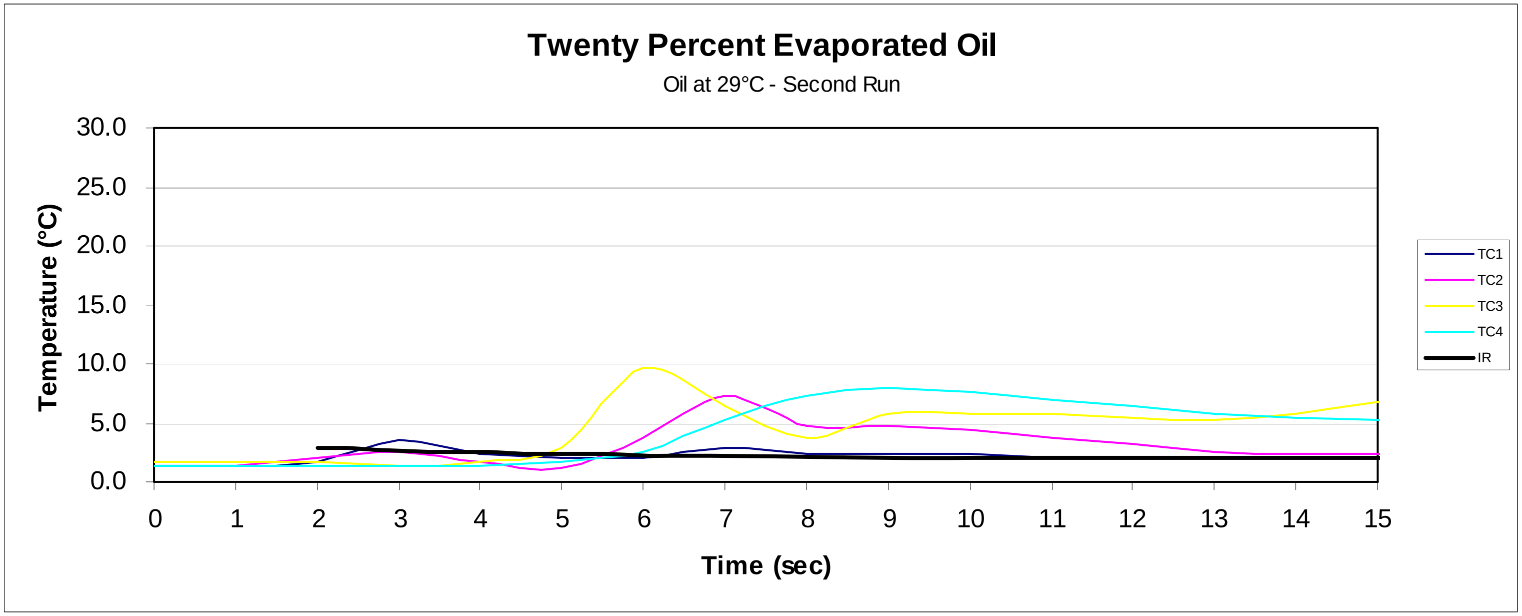

Figure 4. Twenty Percent Evaporated, 29°C Oil, Run 2

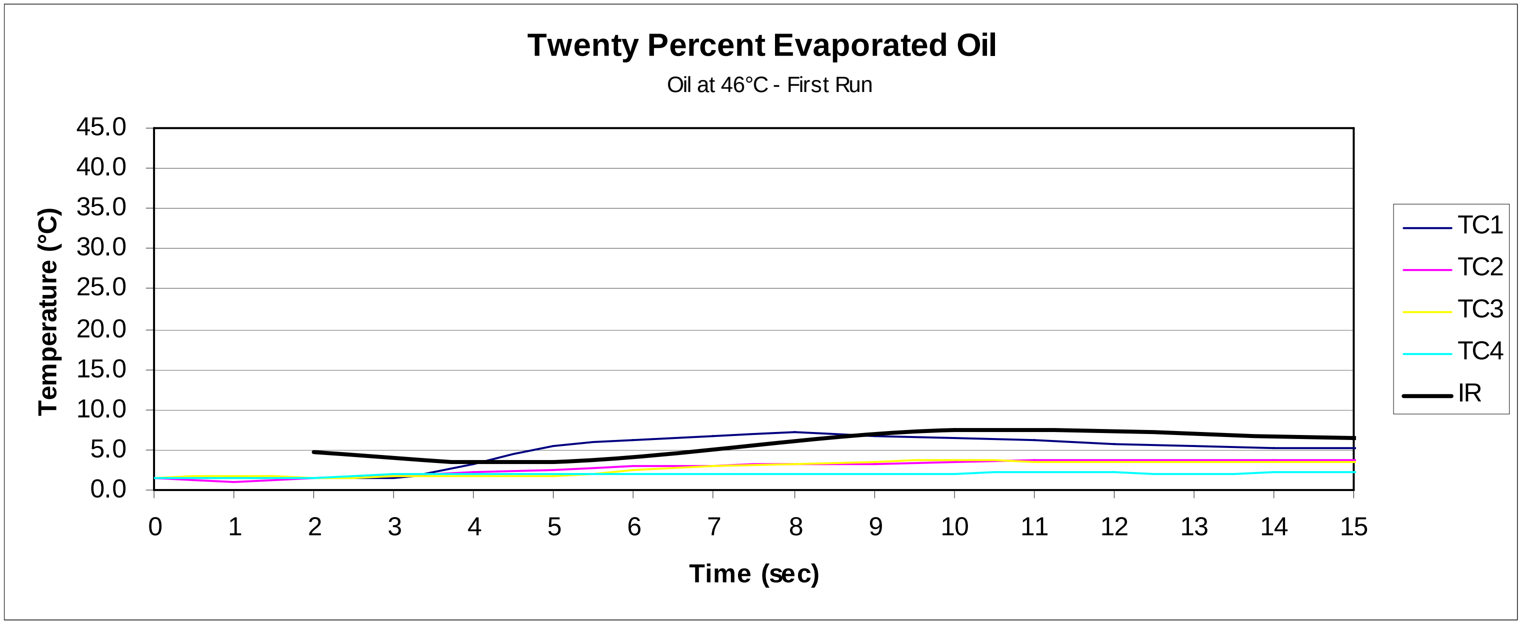

Figure 5. Twenty Percent Evaporated, 46°C Oil, Run 1

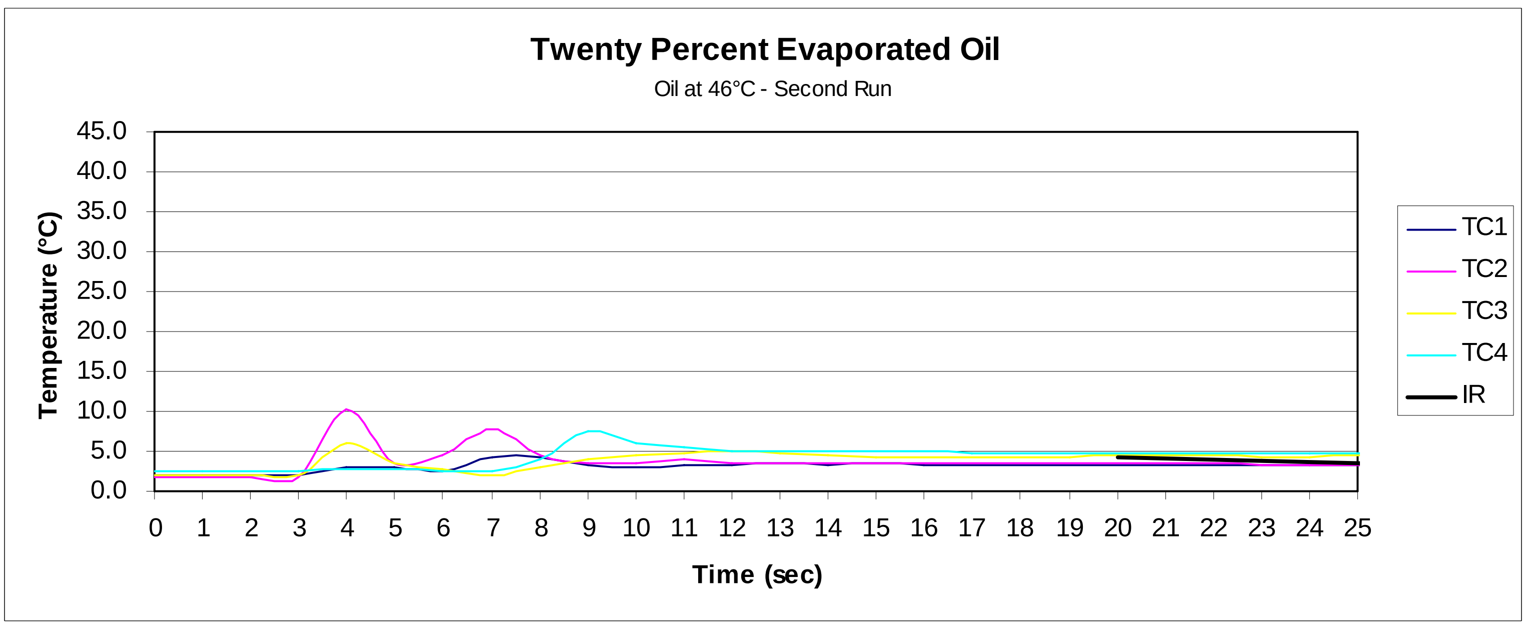

Figure 6. Twenty Percent Evaporated, 46°C Oil, Run 2 (note: IR only available after about 15 seconds)