68

INLAND WATERS BRANCH

DEPARTMENT OF THE ENVIRONMENT

C.C.I.W. LIBRARY
MAR 12 1973

Arctic Winter Oil Spill Test

United States Coast Guard

E.C. CHEN

TECHNICAL BULLETIN NO.68

GB
707
C338
no. 68

CANADA

TECHNICAL BULLETIN NO. 68

Arctic Winter Oil Spill Test

United States Coast Guard

E.C. CHEN

INLAND WATERS DIRECTORATE
DEPARTMENT OF THE ENVIRONMENT
OTTAWA, CANADA, 1972

Contents

Appendix

Illustrations

Illustrations (cont'd)

Tables

Arctic Winter Oil Spill Test
United States Coast Guard

E.C. CHEN

INTRODUCTION

As part of an arctic pollution control program, the U.S. Coast Guard conducted a series of tests off the northern coast of Alaska during the summer of 1970 to investigate the behaviour of crude-oil spills in the Arctic. Information derived from the tests - such as the inhibitive effect of cold temperatures on oil spreading, the pocketing and migrating of oil under ice, and oil burns on ice - has proved informative and useful. Results of the tests were reported in detail [1] [2].

The winter oil-spill test discussed in this report was a supplemental experiment of the summer test mentioned above. Its purpose was to investigate the physical properties of crude oil spilled in an arctic winter environment. The test took place at Port Clarence, a small peninsula on the Bering Strait, January 14 to February 4, 1972. The U.S. Coast Guard personnel directly involved in the test were Ens. T.J. McMinn (Project Leader), Ens. P. Golden, and two casual helpers from the local Coast Guard Station. The author participated in the first two weeks of the test.

DESCRIPTION AND OBSERVATION OF THE TEST

The general areas of investigation were similar to those of the summer test, namely:

(1) the spreading of crude oil on snow and ice,

(2) the change of the crude oil as a result of aging,

(3) absorption of oil by the ice, and

(4) the effectiveness of burning and use of absorbents as a method of oil removal.

The oil used for this winter test was Prudhoe Bay crude. An analysis of the crude oil is given in Table 1.

Figure 1. The sled and its towing vehicle.

Figure 2. A close look at the sled.

TABLE 1

Physical and Chemical Properties of Prudhoe Bay Crude Oil

Specific gravity: 0.893

Sulphur: 0.82%

Viscosity, Saybolt Universal at 77°F: 111 seconds
at 100°F: 84 seconds

API Gravity: 27.0

Pour Point: 15°F

Nitrogen: 0.188%

Color: brownish black

APPROXIMATE COMPOSITION
(Percent by volume)

Light gasoline	4.7
Total gasoline and naptha	19.0
Kerosene distillate	4.3
Gas oil	18.4
Nonviscous lubricating distillate	11.0
Medium lubricating distillate	8.1
Viscous lubricating distillate	1.8
Residuum	36.3
Distillation loss	1.1

A specially designed apparatus was used in the present test to spill the oil. The apparatus was essentially a welded aluminium sled with dimensions 8' x 3'5" x 2'10". Figures 1 and 2 are photographs of the sled and its towing vehicle. The sled contained an oil storage tanker and a bottle of compressed air. Both were heavily insulated to keep their contents at 70°F - 75°F during the mission. The oil tanker had a capacity of 100 gallons; the air in the bottle was maintained at a constant pressure with a mass-flow rate independent of downstream conditions. When the air was allowed to flow into the oil tanker, the oil was forced out through a hose and on to the snow or ice surface at a rate determined by the pressure of the air. Figure 3 shows the sled in operation.

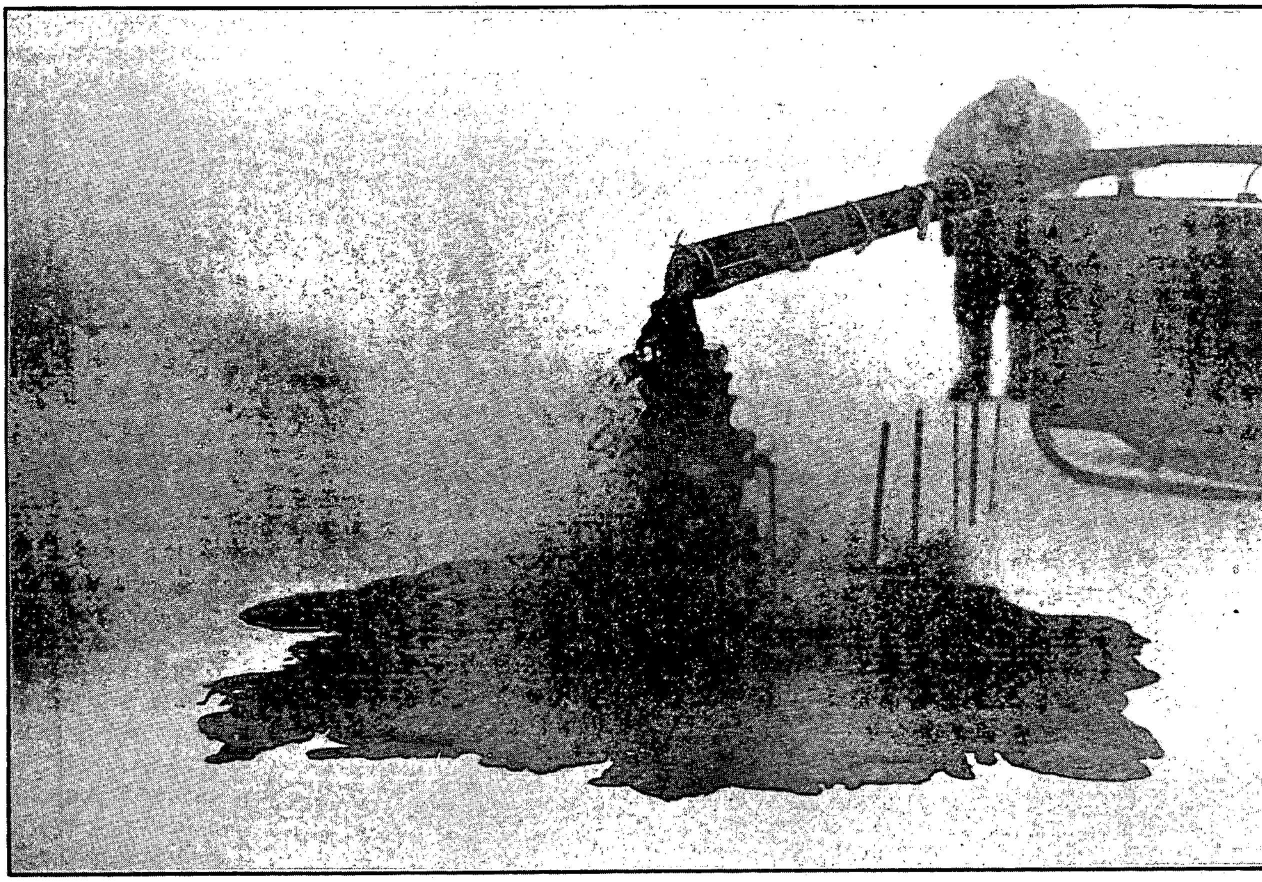


Figure 3. Dumping oil from the sled.

For the spreading experiment, the sled was towed at a known speed over the snow- or ice-covered ground. When it reached the area marked by stakes to provide a length scale, the dump mechanism was activated pouring oil on the snow or ice surface. The motion of the spilled oil was followed by a movie camera to obtain a one-dimensional spreading rate.

The oil patches created by the spreading experiment were used for the other tests. The aging rate of spilled oil was determined by collecting oil samples from the pitch at regular intervals and analyzing the changes in physical properties. The test for absorption of oil by ice was carried out by taking ice cores from oil-contaminated ice and determining the oil content at different depths. The oil patches were also used to test the efficiency of burning and the use of various oil absorbents.

The designated test site was the sea bay area at Port Clarence and the tests were planned originally on the sea ice. However, during the test period, and in fact, during the winter time, snow cover was complete so that the tests had to be conducted on snow rather than ice surfaces. The spreading experiment was carried out on January 16. The temperature was -2°F and the wind speed 12 knots. Six to nine inches of snow were on top of the sea ice while porosity of the snow was 55%. The spill was made at a dumping rate of 0.17 cubic feet per second with a total volume of 60 gallons. It was observed that the oil did not spread on the snow surface except at the very beginning when in addition to being warm, the oil was pushed by the outward pressure forces caused by pouring. This was not unexpected since the viscous force, the force retarding the spreading, was great at low temperatures; as soon as the oil temperature drops to 15°F (the pour point of Prudhoe Bay crude oil) no spreading should occur. The spilled oil formed a slick 3/8 inches thick and penetrated half an inch into the snow. The oil slick was buried under 3 to 5 inches of fresh fallen snow the following day as the temperature on January 17 rose to 16°F with snow, and, a wind speed of 22 knots. The oil temperature under the snow was found to be 6-10°F higher than the surrounding air temperature. Figure 4 shows oil on snow, while Figures 5 and 6 show oil buried under snow.

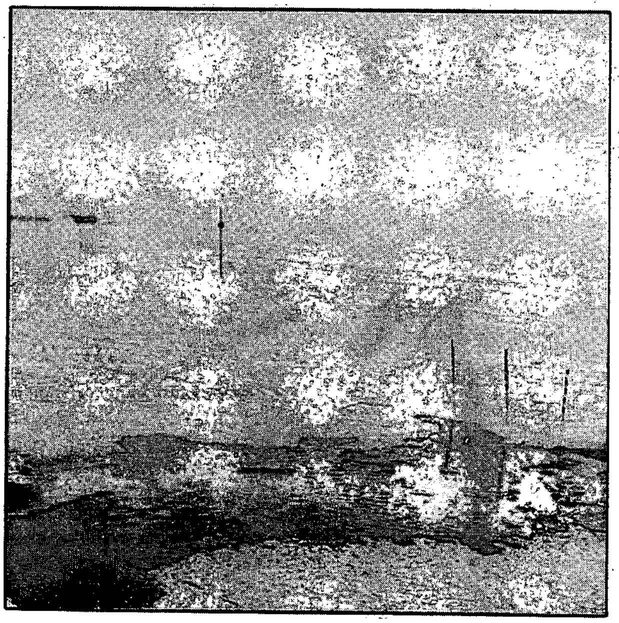


Figure 4. Oil on snow.

Figure 5. Digging oil samples from snow.

Figure 6. Oil sandwiched between snow layers.

On January 19, a spill was made on a small snow-free ice surface which had been located on a lake. The temperature on that day was 7°F and the wind speed 5 knots. About 57 gallons of oil was poured on the ice at a rate of 0.17 cubic feet per second. The oil, when it was warm, spread at a rate of about 0.2 feet per second and formed a slick of approximately 12 feet x 14 feet with a thickness of 5/16 inches. The slick remained free of snow for one day and then was covered by blowing snow. Tests for the absorption of oil by ice were not made due to the breaking down of the ice-coring device. However, the oil showed no visible sign of penetration of the ice. Figure 7 shows oil on ice and Figure 8 is a close look at the ice surface.

In the test of burning oil on snow and ice, ignition was made by soaking a rag with kerosene and tossing the lighted rag into the oil patch. In all cases, the oil quickly ignited and burned furiously without the aid of any burning agent. The burning produced a great amount of black smoke but no fallout was found. About 90% of the oil was burned out leaving a heavy tar-like residue which was difficult to remove once the molten snow or ice, caused by the heat of burning, was refrozen. Figures 9 and 10 are photographs of the burning oil and Figure 11 shows the black smoke resulting from the burning. No observation was made on the test of oil absorbents since the test was conducted after the author left Port Clarence. However, quantitative results of all the tests mentioned above will be available from a U.S. Coast Guard report.

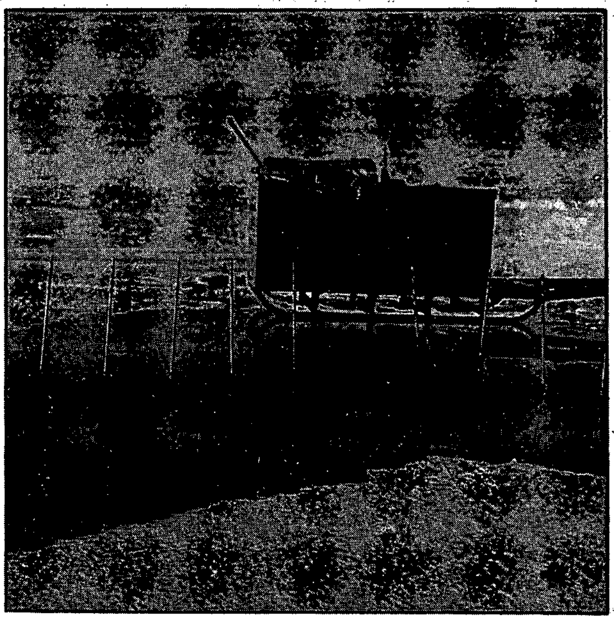
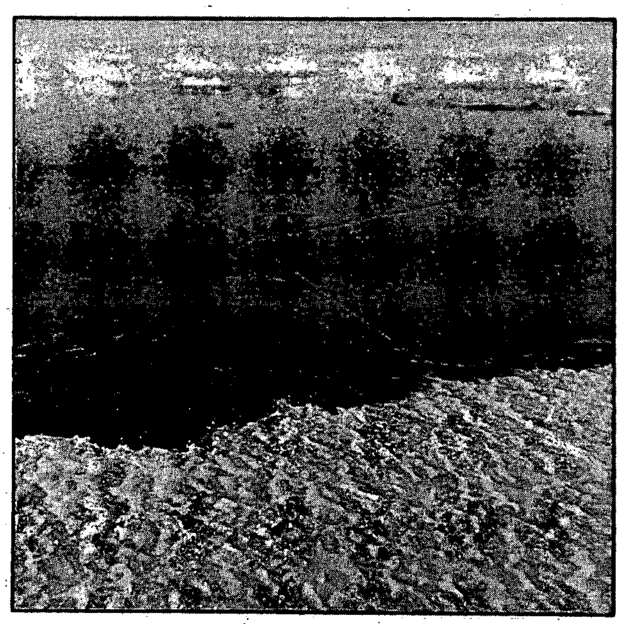


Figure 7. Oil on ice.

Figure 8. A close look at the ice surface.



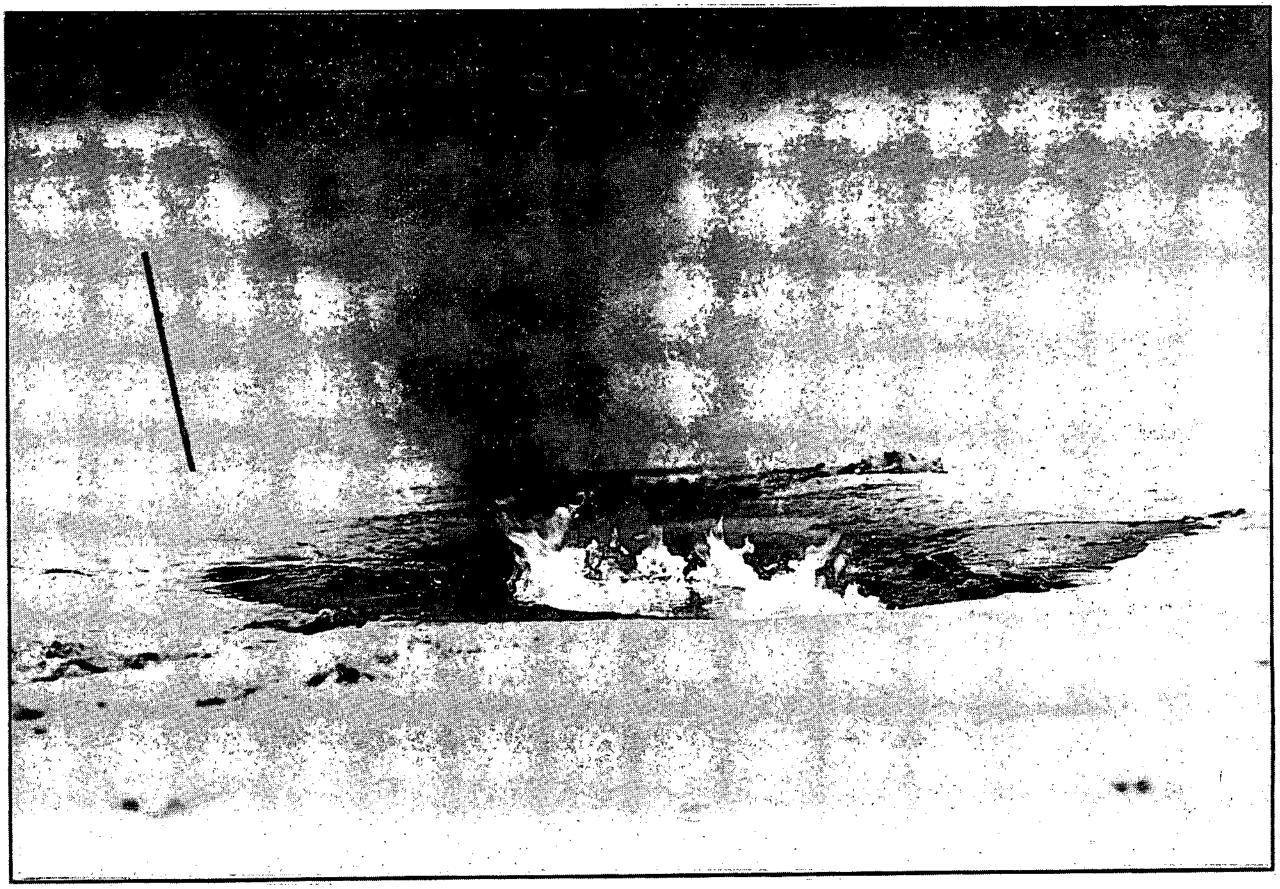


Figure 9. Oil burning on snow.

Figure 10. Oil burning on ice.

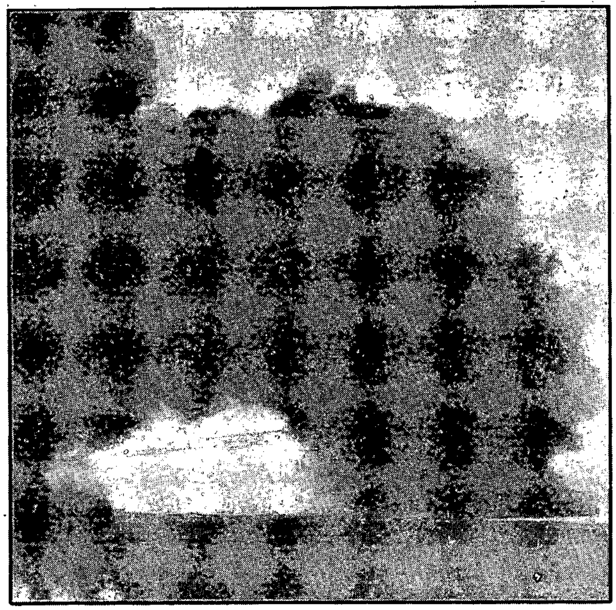


Figure 11. Smoke from burning oil.

RESULTS OF THE OIL-AGING EXPERIMENT

Samples of the spilled oil were collected daily from snow and ice and brought back to Ottawa. They were analyzed for density, surface tension, and viscosity. The densities were measured with a pycnometer, the surface tensions with a du Nouy-type tensiometer, and the viscosities with a Haake Rotovisko. All the measurements were made in a room with a constant temperature of 60°F. Results are given in Table 2 and shown in Figures 12 to 16.

As seen from these Figures, the oil aged at an extremely slow rate. The increase in density after five days of aging on snow or ice accounts only for 0.4%, whereas the corresponding increase in the summer test is 4.5%. The change in surface tension, as shown in Figures 14 and 15, is insignificant while a definite increase was found for the summer test. The difference in aging rate between the present test and summer test is most apparent (see Figure 16). As mentioned previously, the spilled oil on both snow and ice was buried under as much as 5 inches of snow. This cover plus the fact that the oils were "frozen" (as most temperatures were much below the pour point) is the obvious reason for a very slow rate of aging. In fact, the aging rate in the present test is negligible as compared with the aging rate in the summer test. Data of the summer test are given in the Appendix.

SUMMARY AND RECOMMENDATIONS

As a result of the present test, the behaviour of Prudhoe Bay crude oil in an arctic winter environment may be summarized as follows:

(1) The oil does not spread on a snow or ice surface except when warm and under influence of the forces caused by dumping.

(2) The oil, when spilled on a snow surface, penetrates only a small distance.

(3) When spilled on the surface of lake ice, the oil shows no visible signs of penetration.

(4) The rate of aging for spilled oil is extremely slow.

(5) The oil burns easily on snow or ice creating heavy black smoke and leaving a tar-like residue.

TABLE 2

Oil Aging Experiment

Prudhoe Bay Crude Oil on Ice

Age of Sample, days	Weather Condition		Surface Tension Dynes/cm	Density g/ml	Viscosity c.p.
	Temp. °F	Wind Speed knots			
Fresh	-	-	29.5	0.8903	50.2
0.5	7	5	29.3	0.8922	60.2
1	-12	12	29.2	0.8925	59.9
2	- 1	10	30.0	0.8923	71.6
3	- 2	14	29.3	0.8929	72.2
4	2	10	30.0	0.8939	66.1
5	9	12	29.5	0.8935	70.0

Prudhoe Bay Crude Oil on Snow

Age of Sample, days	Weather Condition		Surface Tension Dynes/cm	Density g/ml	Viscosity c.p.
	Temp. °F	Wind Speed knots			
Fresh	-	-	29.5	0.8903	50.2
0.5	- 2	12	30.0	0.8892	65.5
1	16	22	29.4	0.8897	79.5
2	15	20	29.3	0.8909	83.7
3	4	5	29.8	0.8922	85.0
4	-12	12	29.9	0.8935	84.8
5	- 1	10	29.4	0.8936	83.4
6	- 3	14	30.2	0.8920	84.5
7	0	15	30.1	0.8930	88.9
8	9	12	30.1	0.8934	95.4

All the measurements were made at 60°F (±2°F)

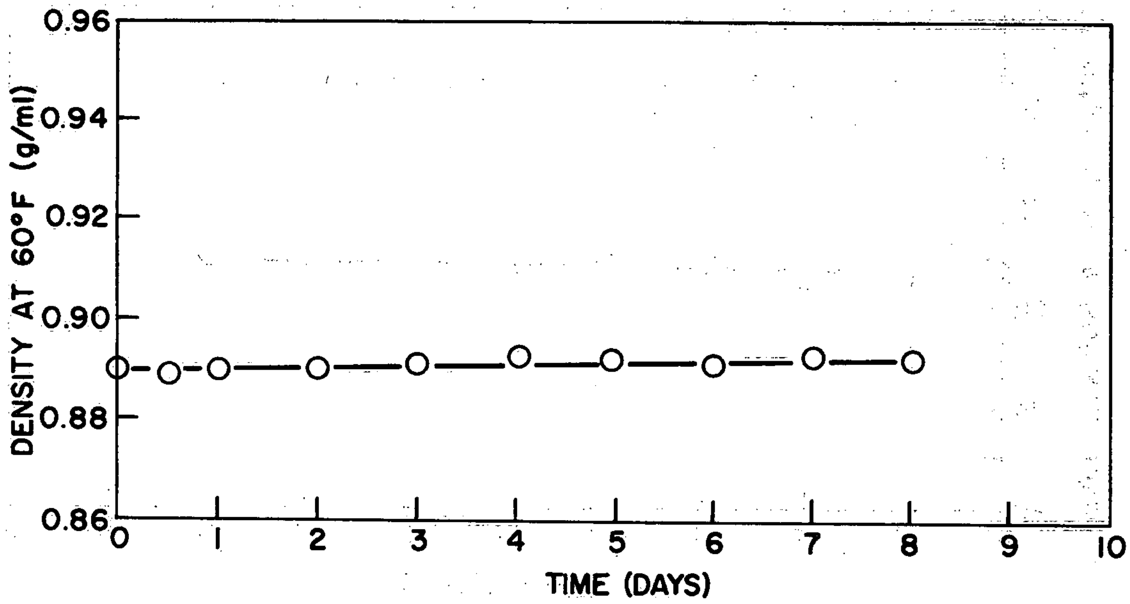


Figure 12. Density of Prudhoe Bay crude oil aged on snow.

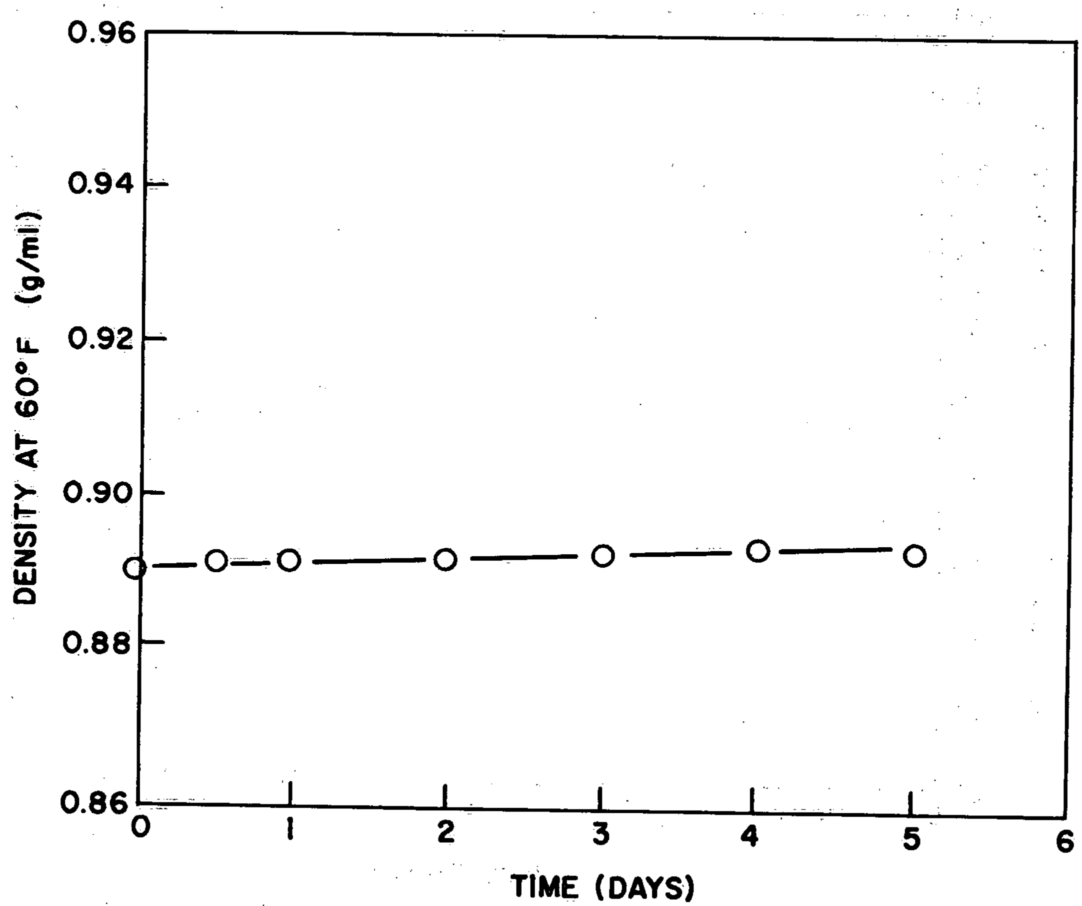


Figure 13. Density of Prudhoe Bay crude oil aged on ice.

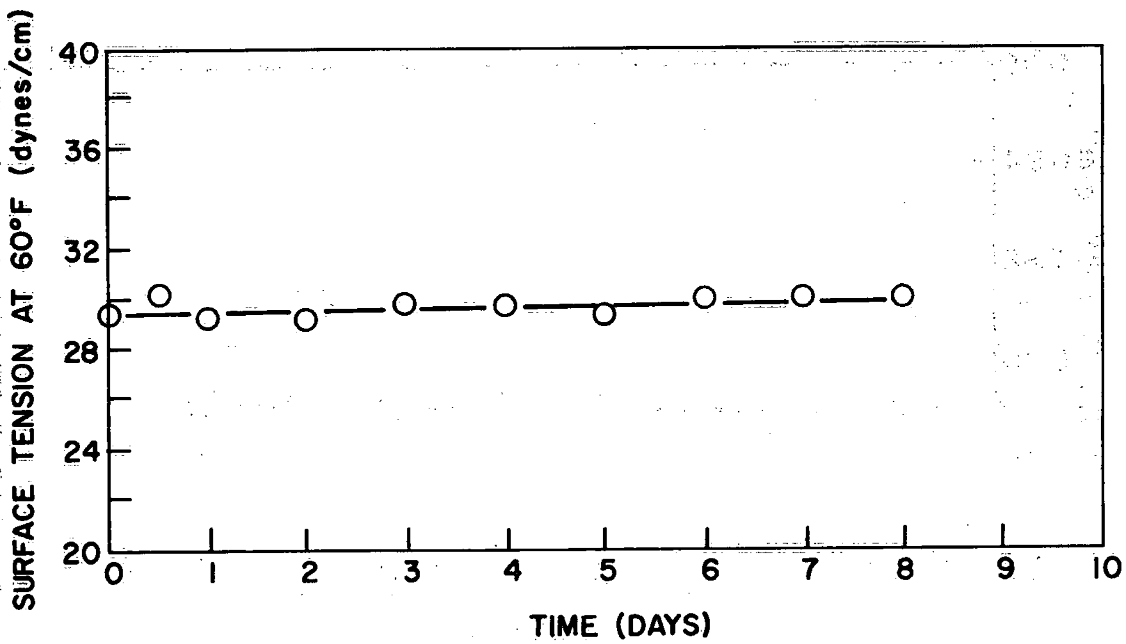


Figure 14. Surface tension of Prudhoe Bay crude oil aged on snow.

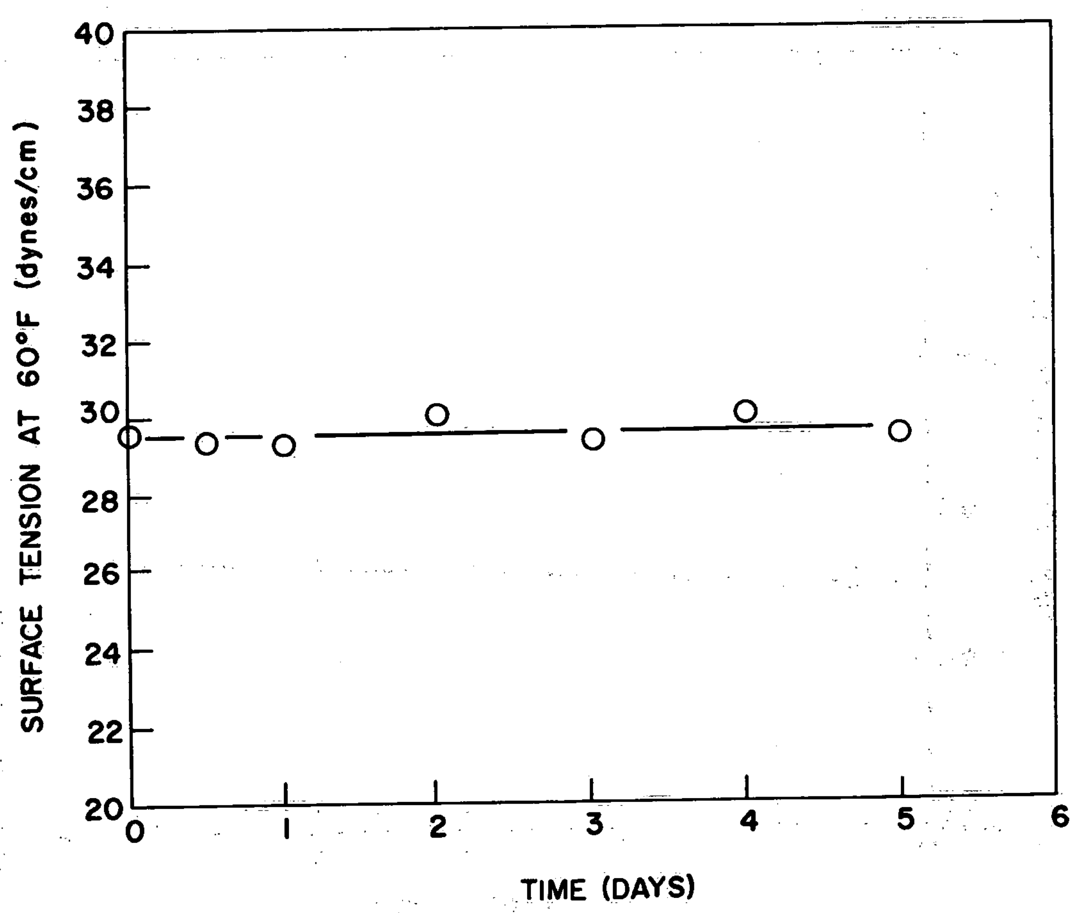


Figure 15. Surface tension of Prudhoe Bay crude oil aged on ice.

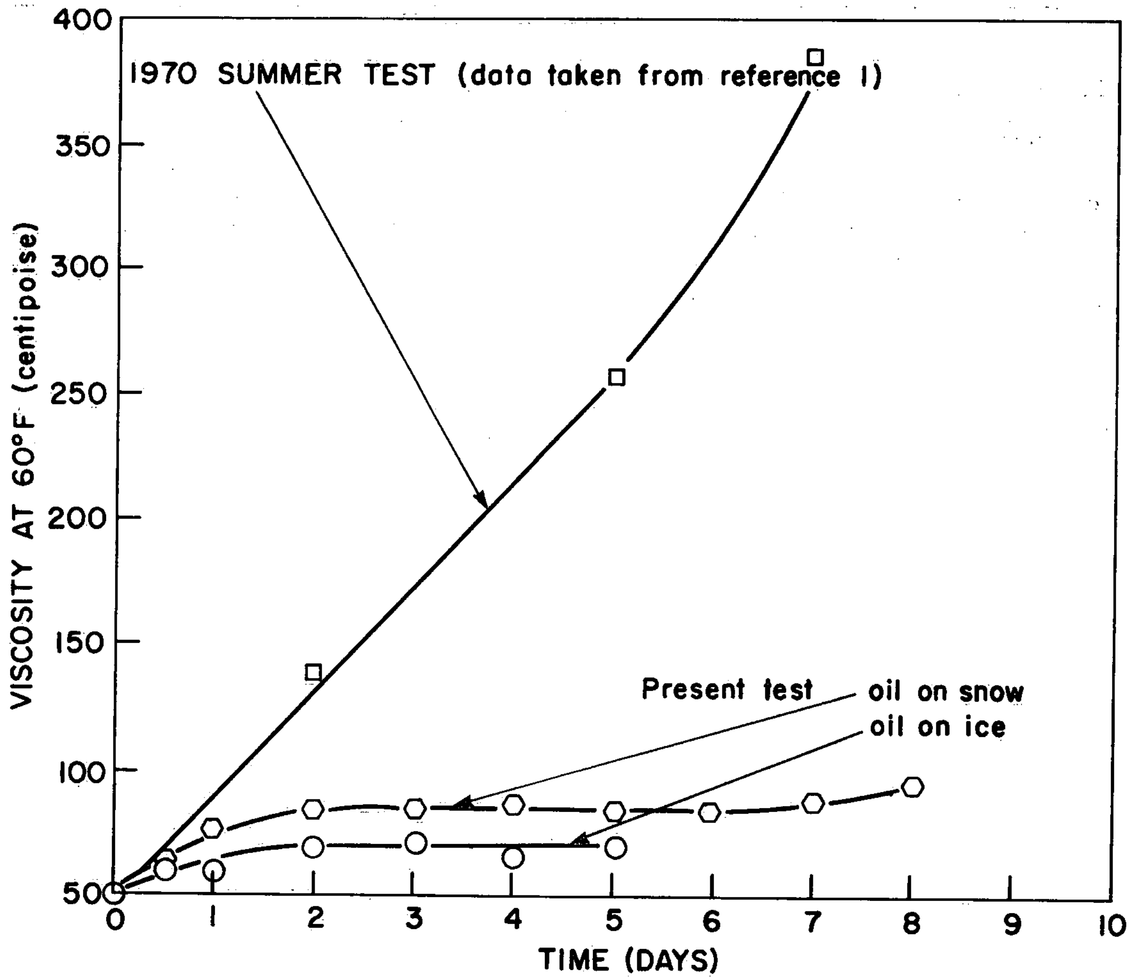


Figure 16. Viscosity of aged Prudhoe Bay crude oil.

Based on the results obtained, the following recommendations for an Arctic winter oil spill are:

(1) Cleanup should be made before spring-thaws as the oil does not spread and does not penetrate deeply into the surface during the winter. Thus, the cleanup can be easier handled and controlled.

(2) In the vast majority of cases, the spilled oil will be on a snow surface as snow covers all the place during the winter season; the "frozen" oil and contaminated snow may be cleaned up simply by plowing the surface and keeping the snow in storage for a later oil and water separation.

(3) Methods are required for detecting oil under snow since the spilled oil will probably be buried under blowing snow and thus be invisible.

(4) If burning is employed as a method of oil removal, the residue must be cleaned up before the molten ice or snow refreezes.

REFERENCES

1. Glaeser, J.L. and G.P. Vance, 1971. A Study of the Behaviour of Oil Spills in the Arctic. AD717142 National Technical Information Service, Springfield, Virginia.

2. Glaeser, J.L., 1971. A Discussion of the Future Oil Spill Problem in the Arctic. Proceedings of Joint Conference on Prevention and Control of Oil Spill, Washington, D.C. (June).

Appendix

Results obtained from experiments on oil aging during the summer test, 1970
(from Reference 1)

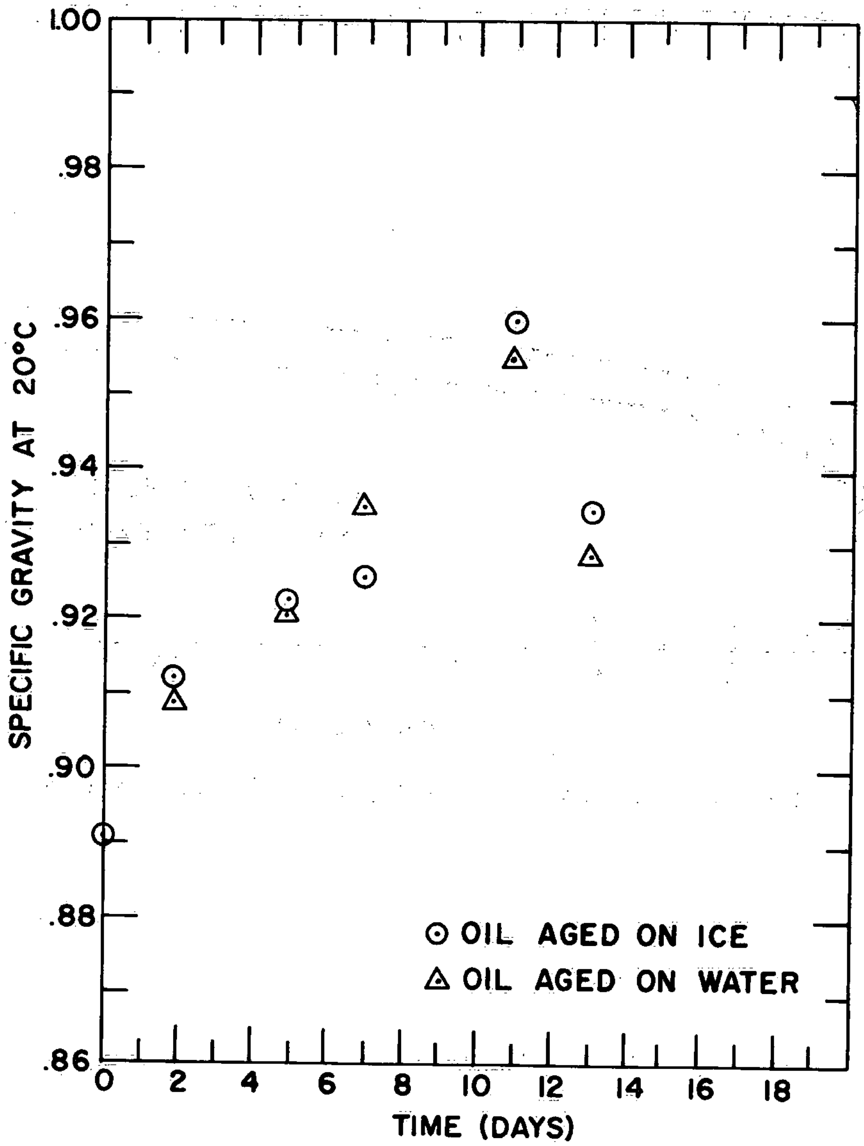


Figure A1. Specific gravity of aged Prudhoe Bay crude oil.

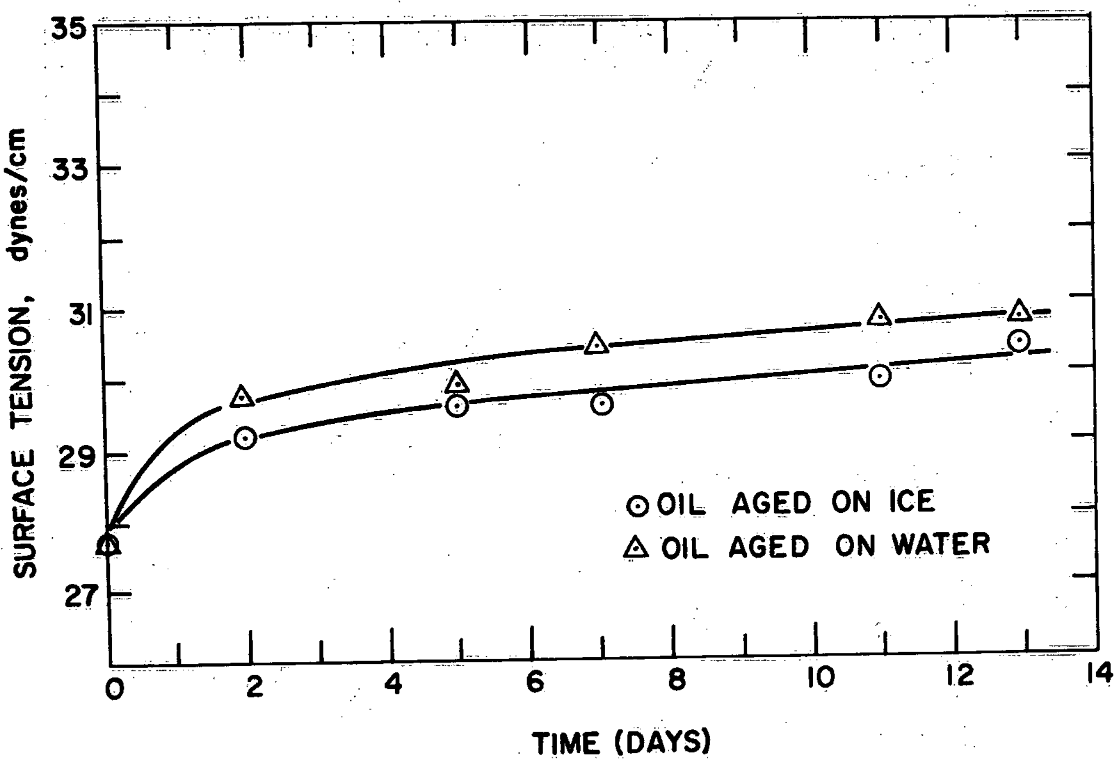


Figure A2. Surface tension of aged Prudhoe Bay crude oil.

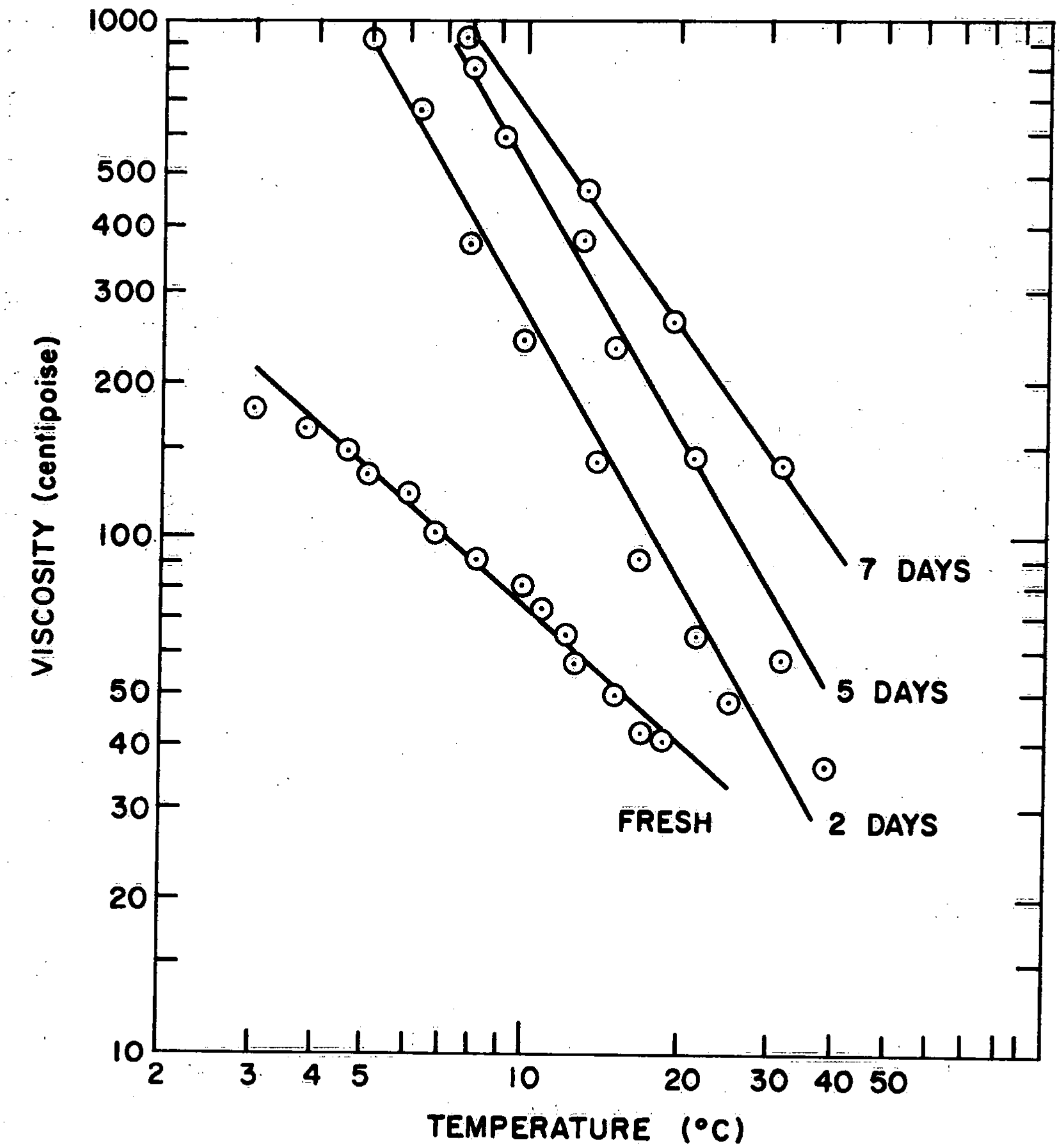


Figure A3. Viscosity of Prudhoe Bay crude oil aged on water.

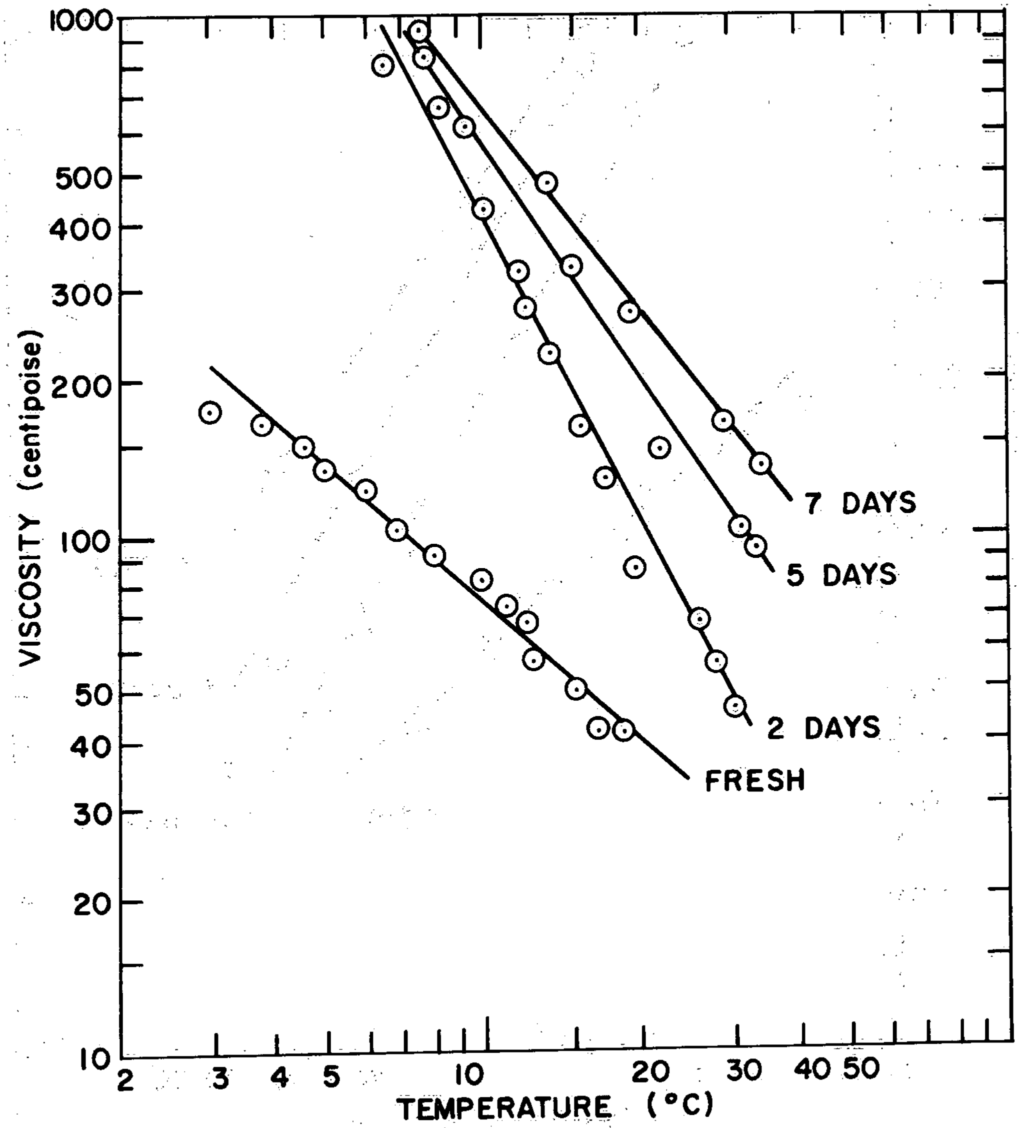


Figure A4. Viscosity of Prudhoe Bay crude oil aged on ice.

Environment Canada Library, Burlington
3 9055 1017 3363 1