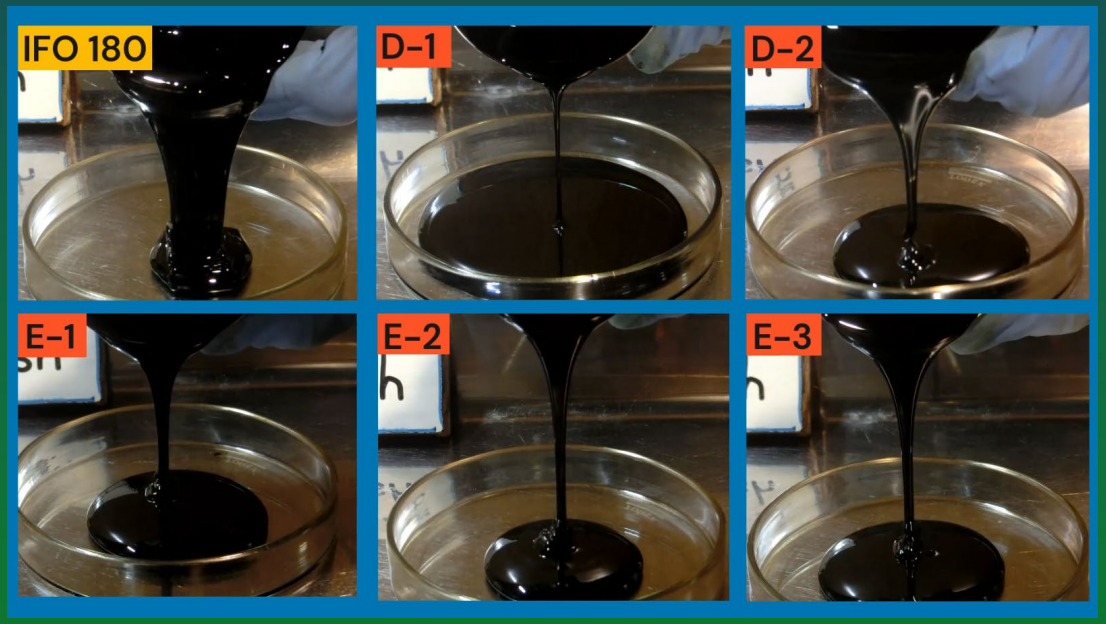
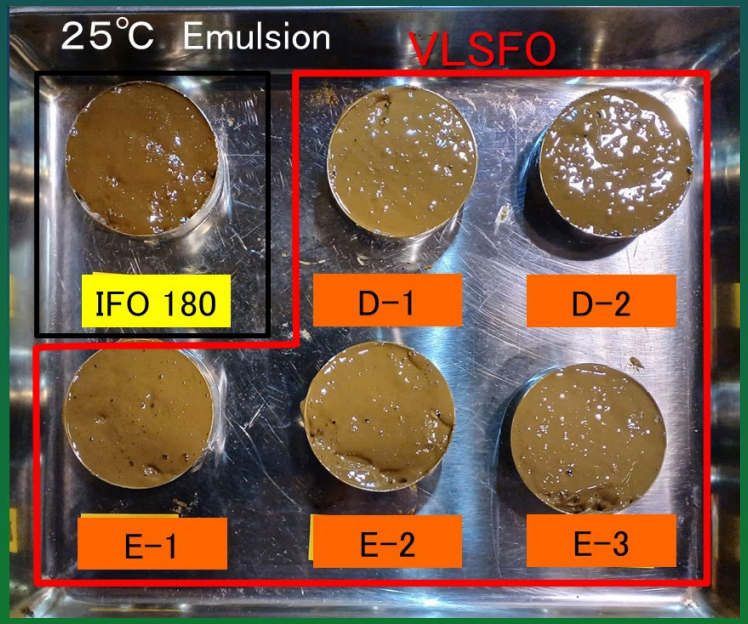
Maritime Disaster Prevention Center

Workshop of the Petroleum Association of Japan

Feb. 22, 2023

Emulsification Properties of VLSFO





Maritime Disaster Prevention Center, Japan
RESERCH & STUDY OFFICE Seiichi HAMADA

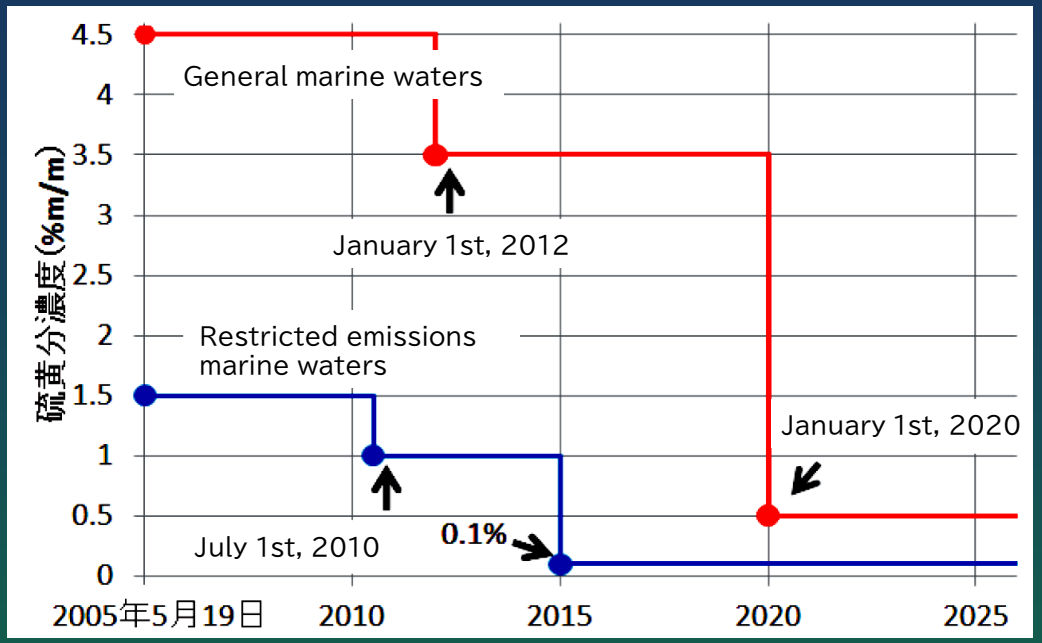
Maritime
Disaster
Prevention
Center

Contents

1. Overview of VLSFO
2. Overview of experiment
3. Changes in water content
4. Changes in viscosity
5. Consideration

(Reference) Change of color

IMO restrictions on the sulfur content of ship fuel oil



General marine waters: No more than 0.5% sulfur content VLSFO

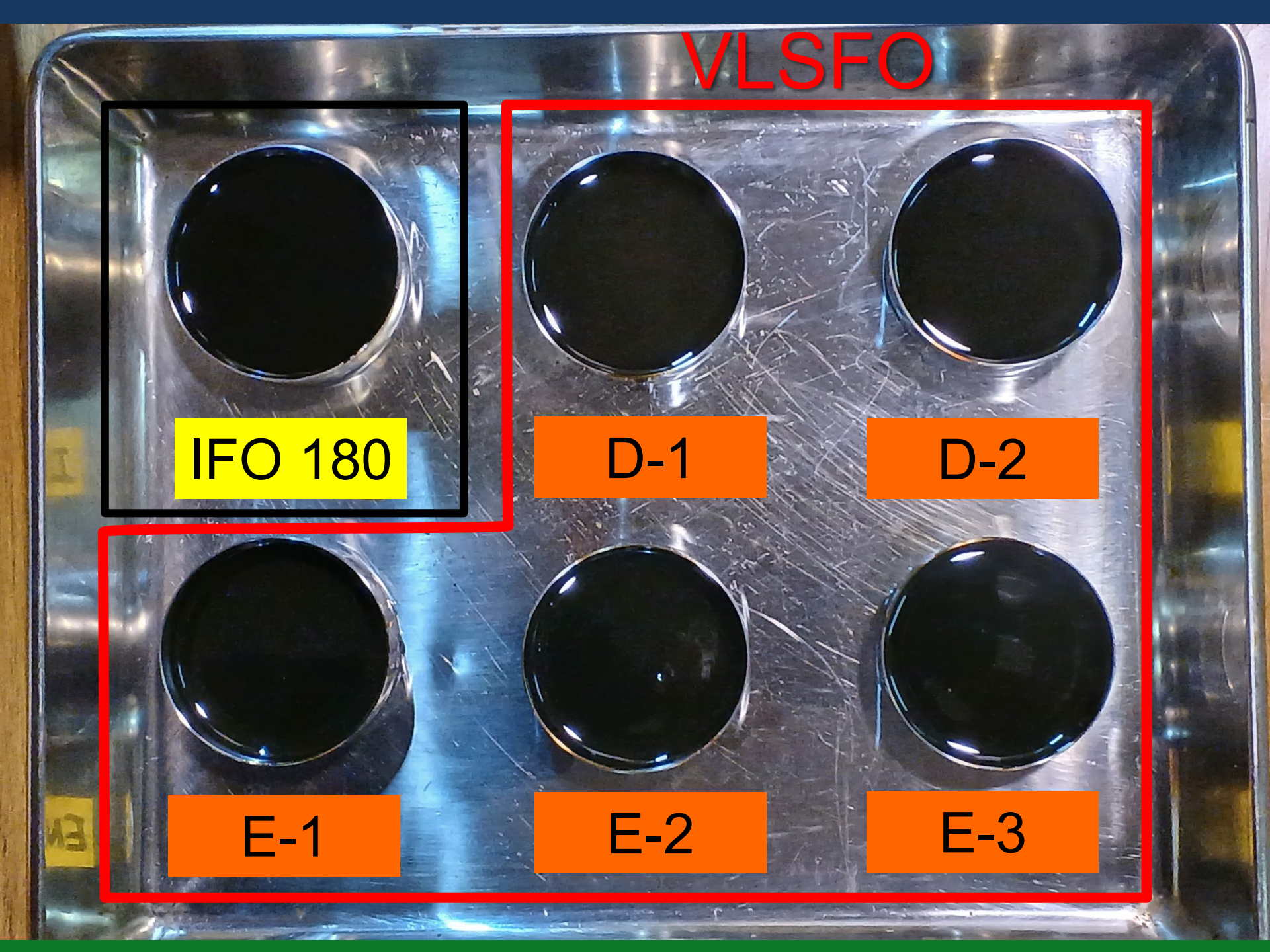
Restricted emissions marine waters: No more than 0.1% sulfur content ULSFO

ECA

Near Europe, U.S.A. and Canada.

Also regulated under domestic laws of China, Korea, etc.

Courtesy of the JOGMEC website


VLSFO
IFO 180
D-1
D-2
E-1
E-2
E-3

Videos showing comparisons of the flow characteristics of samples (19°C)

How VLSFO is produced

Source: Toshiaki Hayashi (2021) "Production Method and Quality of Low Sulfur Fuel Oil"

1. Made from low sulfur crude from Asia and Africa (roughly 10% of world production)

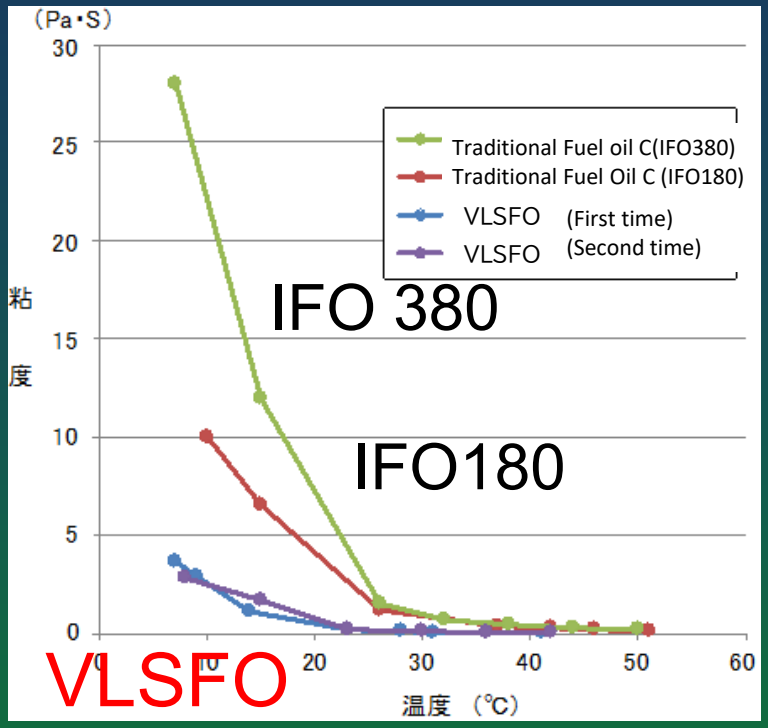
2. Made by processing and blending residual oil from high sulfur crude oil
   - Low sulfur content achieved using hydrogenation desulfurization equipment
   - Heavy oil is cracked into kerosene and diesel oil components using hydrogenation-cracking equipment.

Product characteristics (emulsification characteristics) vary depending on their method of production.

VLSFO viscosity

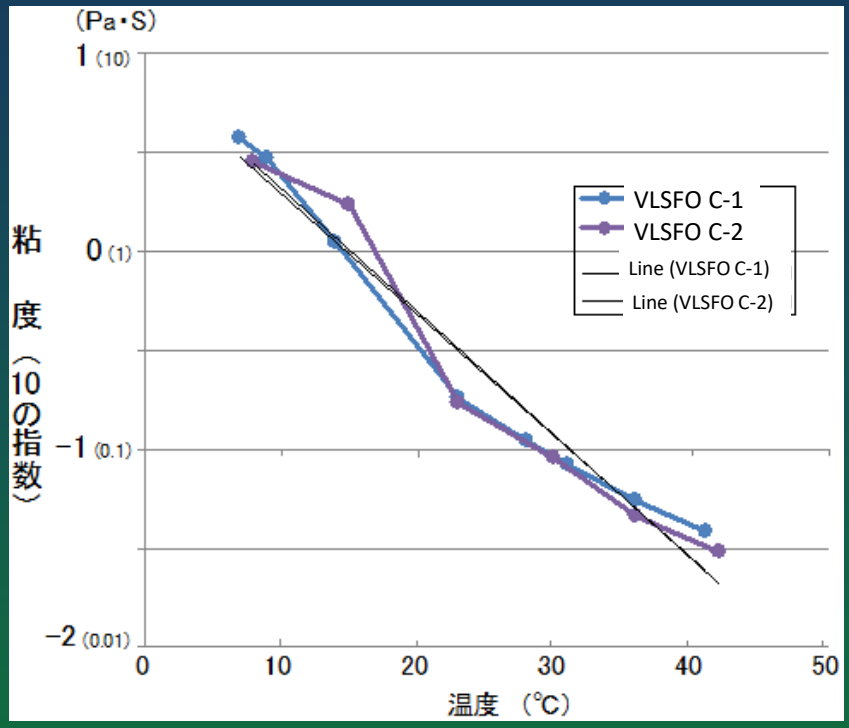
Results

Viscosity (PaS)



Temperature (°C)

Viscosity (PaS) log



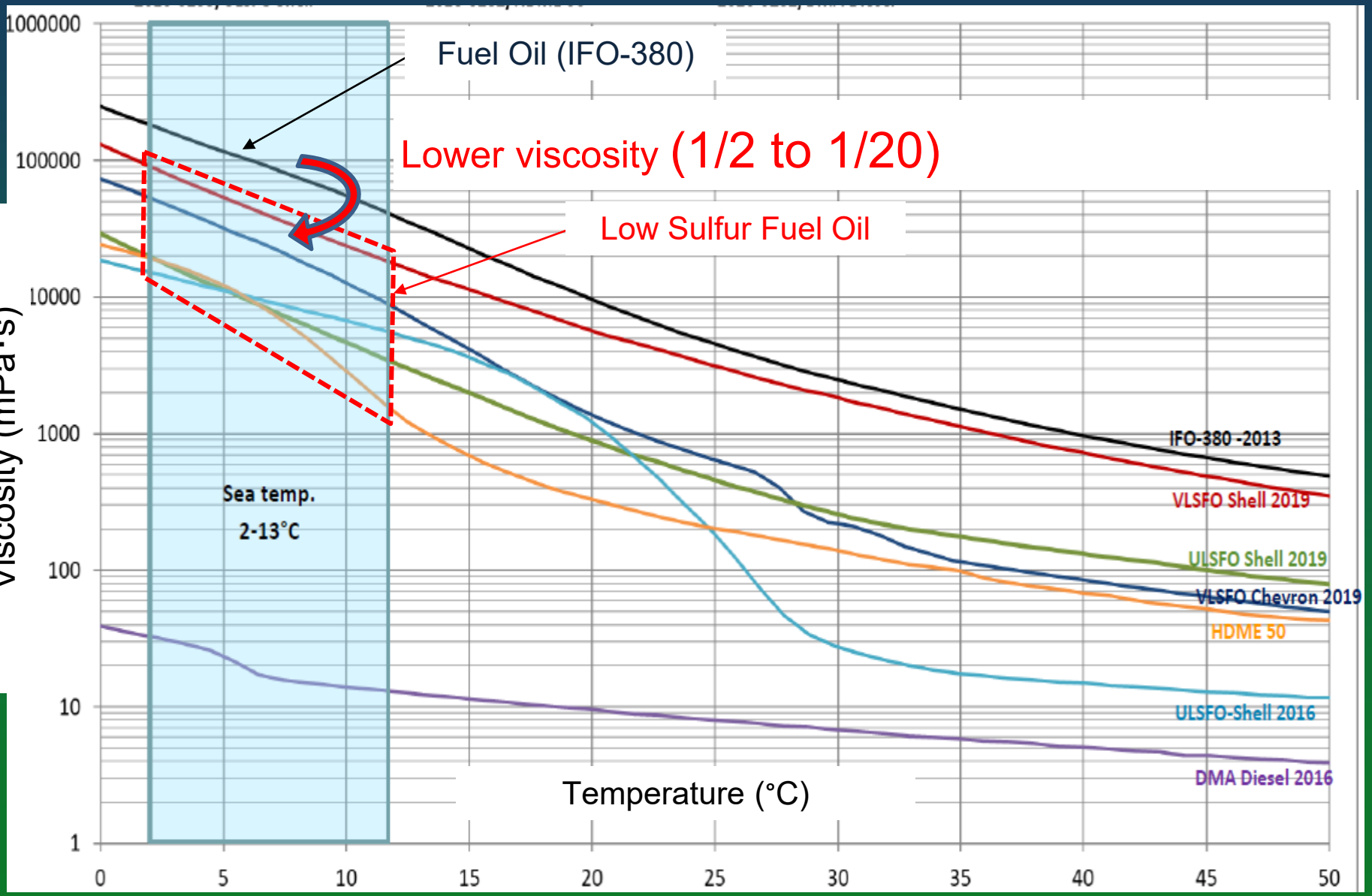
Temperature (°C)

適合油：VLSFO

Viscosity lower than conventional oil

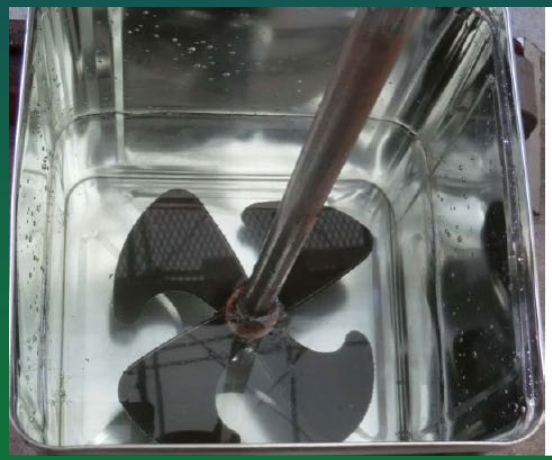
Varies exponentially with temperature

Differences in viscosity



2. Overview of experiment

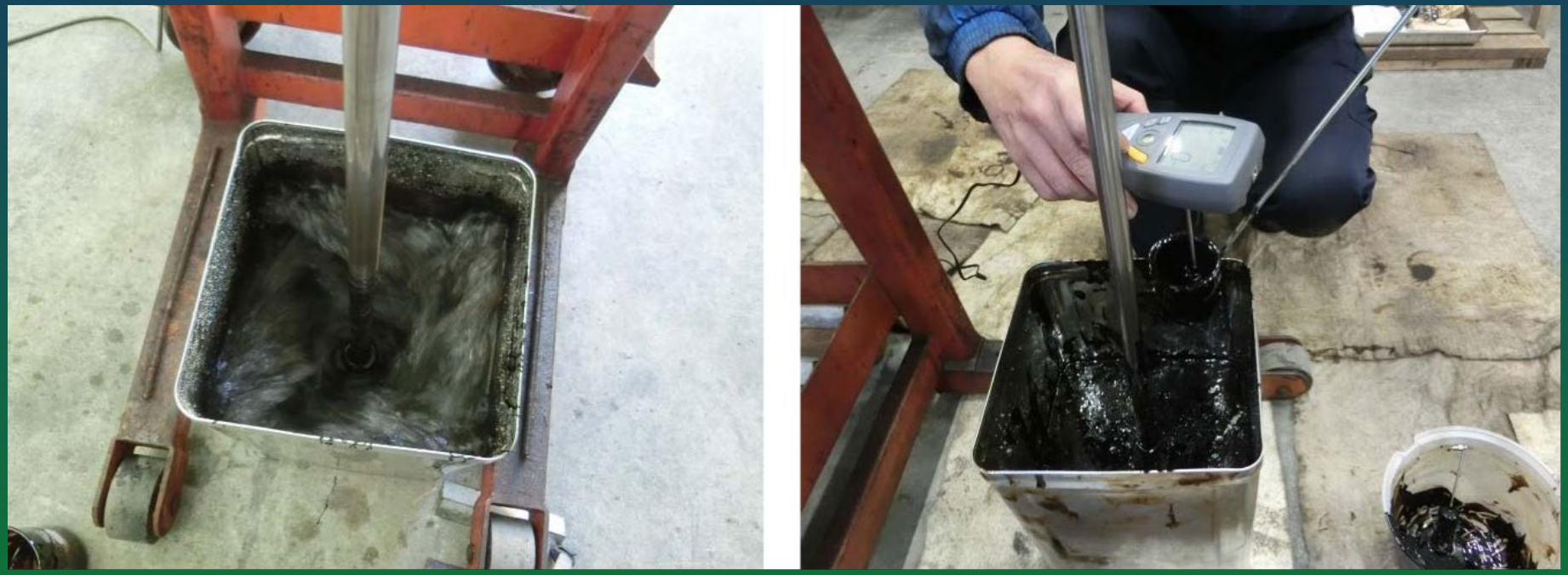
Moussification experiment using water flow agitation (FY2021 preliminary)



Create violent water flow

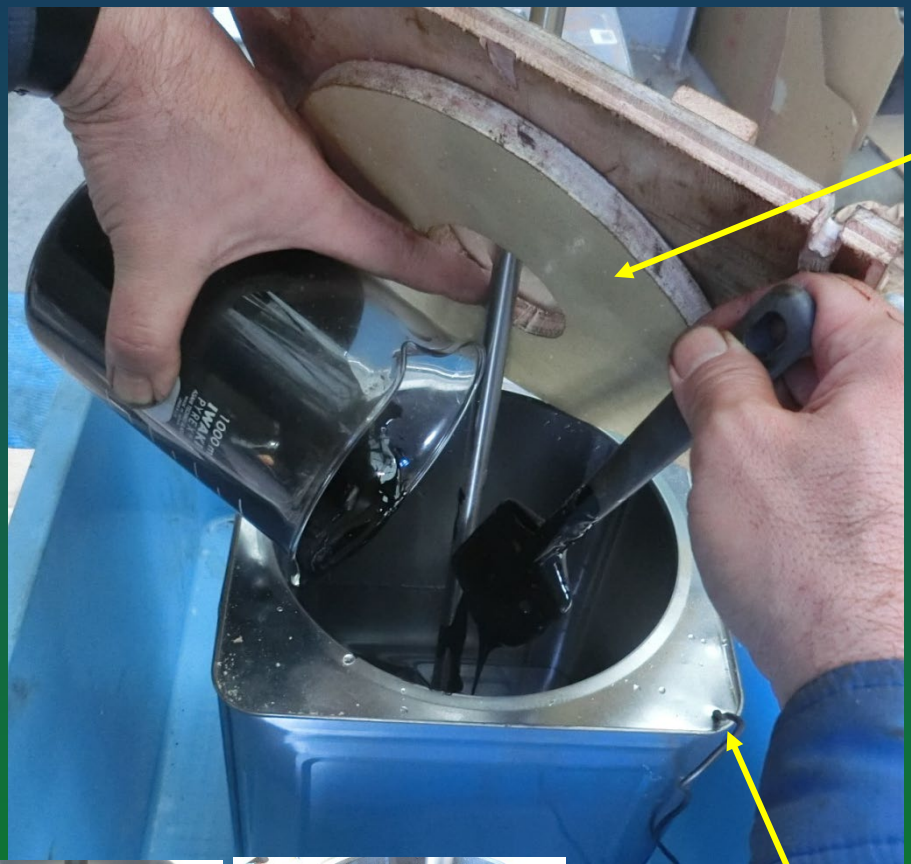
Moussification compared after performing water flow agitation under same conditions

Measuring changes in viscosity (FY2021 preliminary)



Comparison of changes in viscosity in conventional C fuel oil and regulation-compliant VLSFO over a 3-hour period

FY2022 Experimenting equipment (1)



Lid collects droplets (to measure water content)

- Settings: 10°C and 25°C
- Agitate for 96 hours
- IFO180 and 5 types of VLSFO
- Measure viscosity

Agitated at 1300 rpm

Temperature monitored using thermocouples

Temperature control (cold and hot water)

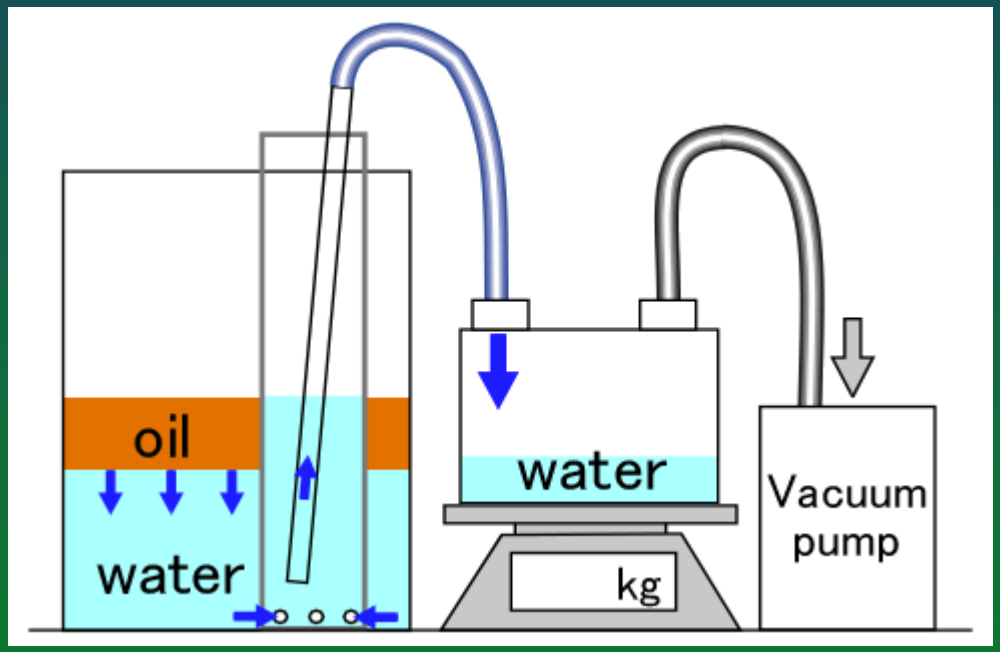
Lid for collecting oil and water droplets

Nearly all droplets were collected on the lid.

FY2022 Experimenting equipment (2)

PVC pipe for preventing oil inflow

Only lower seawater (initial weight: 7.0 kg) is collected by vacuum



Water content is determined from the weight of residual water.

Suctioning residual water

After suction

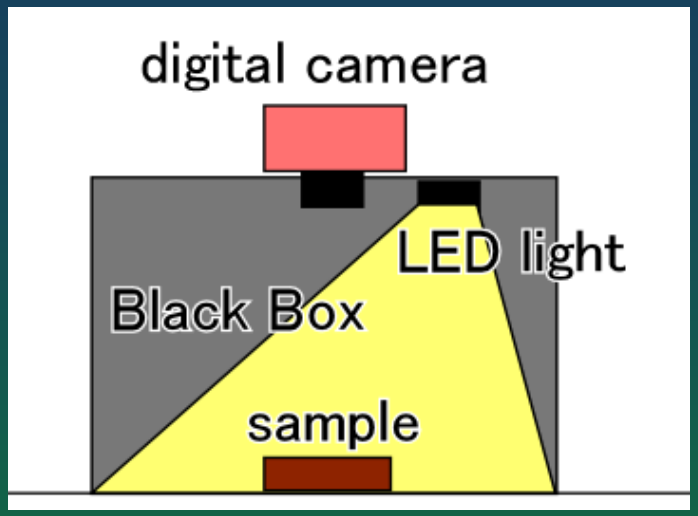
Almost all residual water was suctioned.
(1% error even if 70 g remains)

Residual oil

Some VLSFO samples contained many water droplets.

FY2022 Experimenting equipment (3)

Dark box for blocking out light

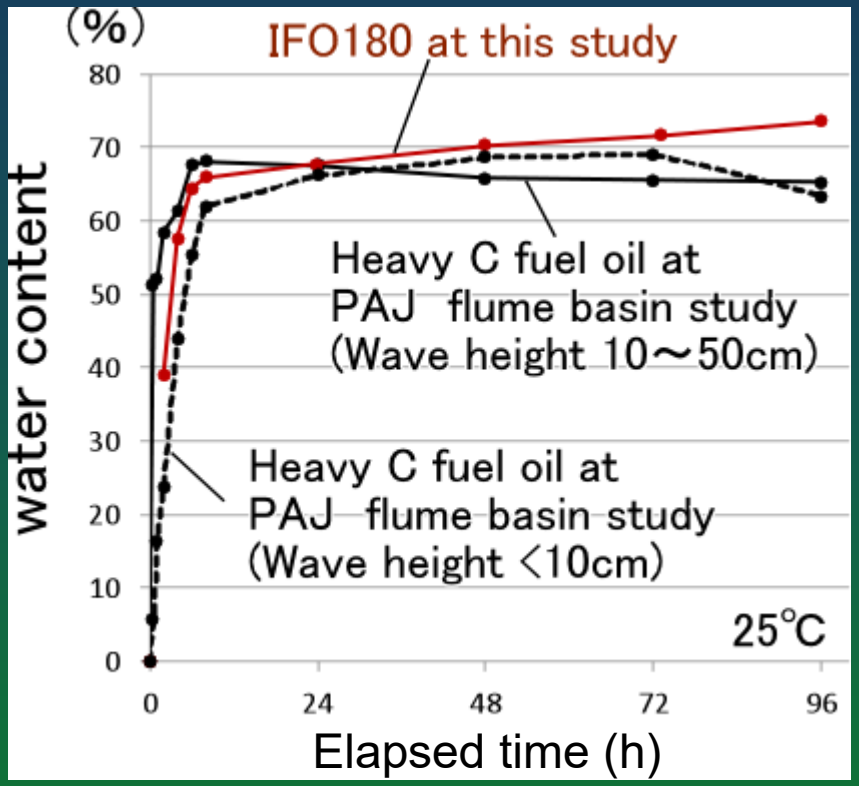


Evaluated changes in color in images taken under fixed conditions.

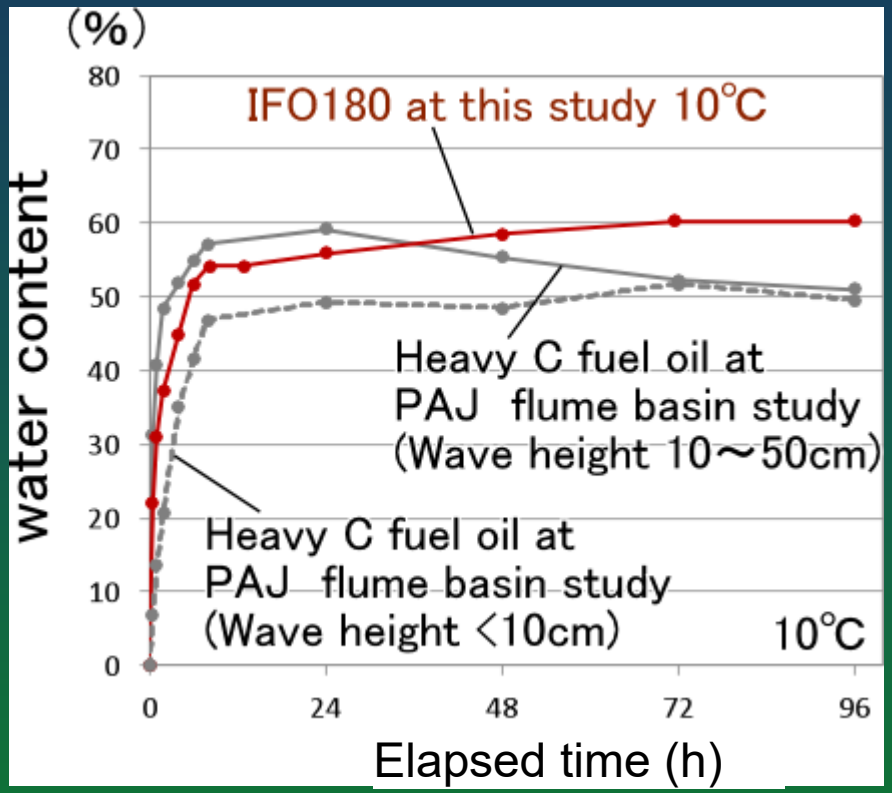
3. Changes in water content

Results

(1) Comparison with flume basin experiment conducted by Petroleum Association of Japan



Temperature: 25°C



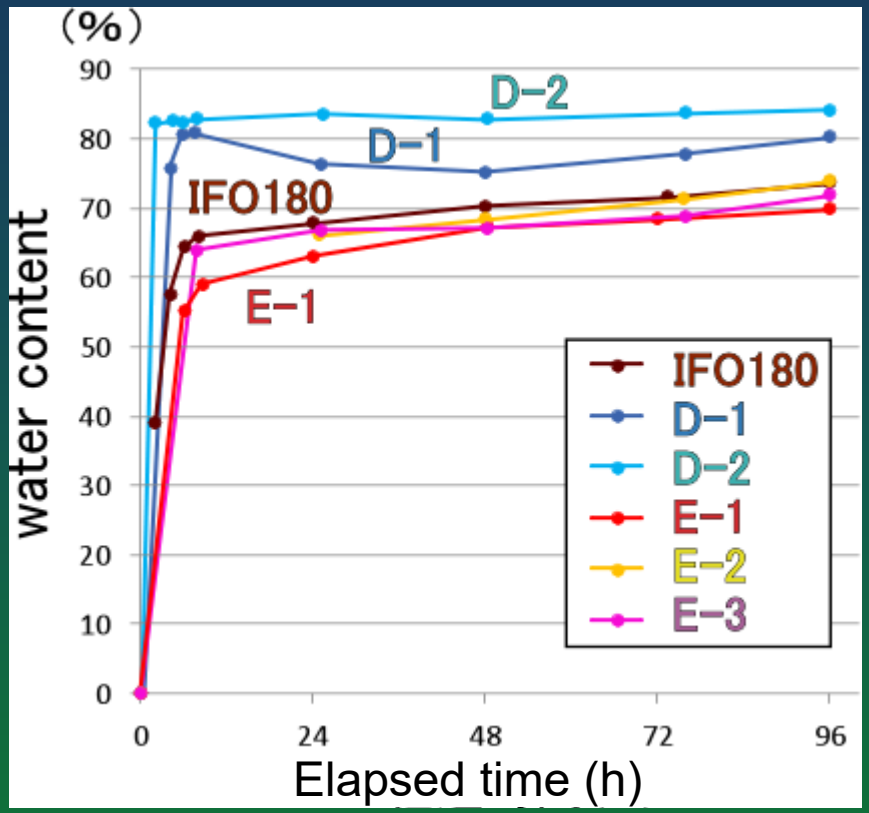
Temperature: 10°C

[1] The water content in IFO180 (previously C fuel oil) approximates the change in water content in C fuel oil in PAJ's flume basin experiment.

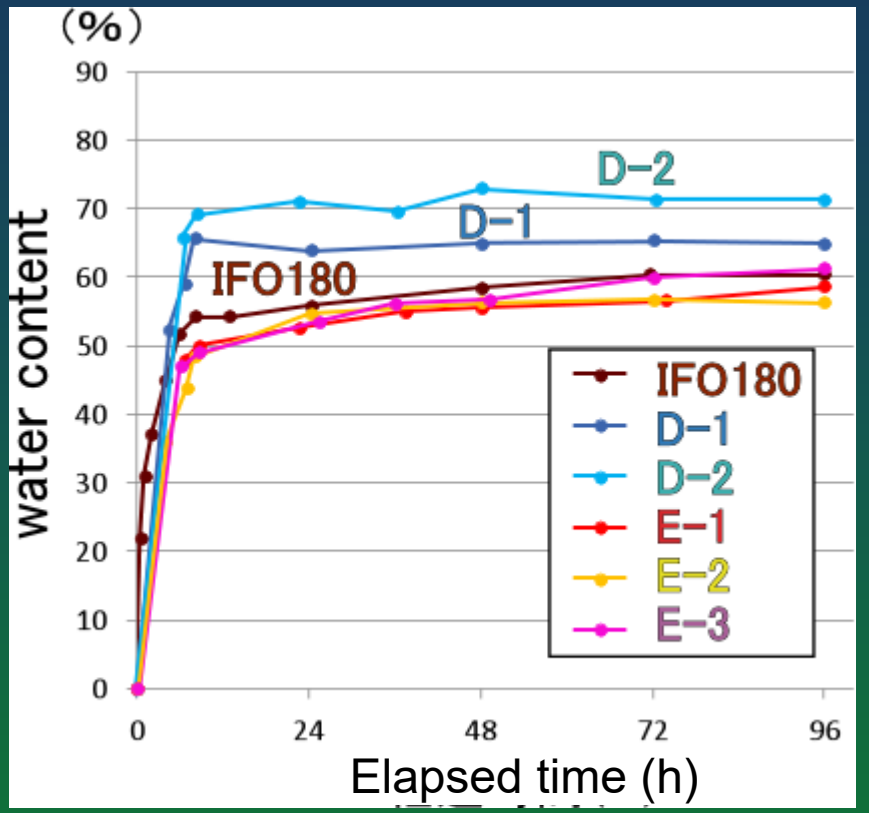
[2] Water content is higher at 25°C

[2] Changes in water content in VLSFO

Results



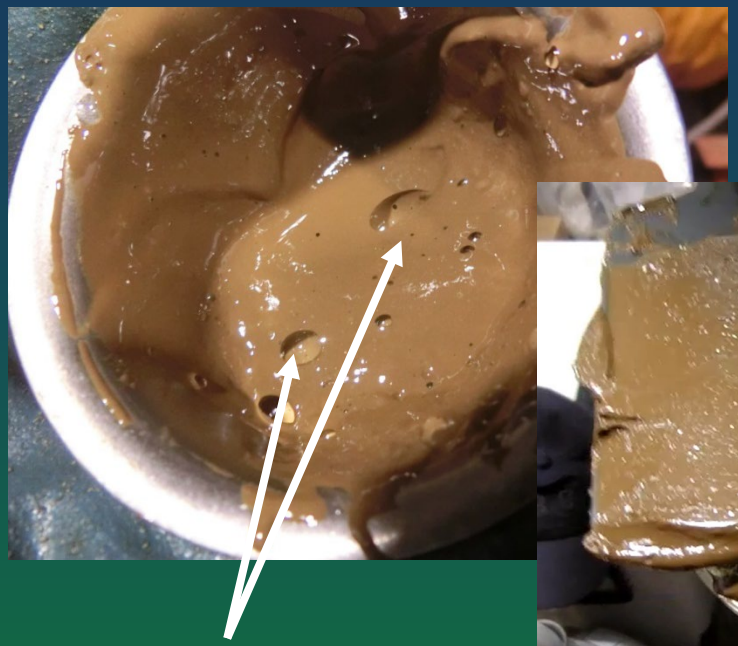
Temperature: 25°C



Temperature: 10°C

① Water content increases rapidly within 12 hours. The rate of increase is faster at 25°C.
② Maximum water content is greater at 25°C.
③ Water content in some products reach higher than in IFO180.

Water droplets included in water content



Water droplets

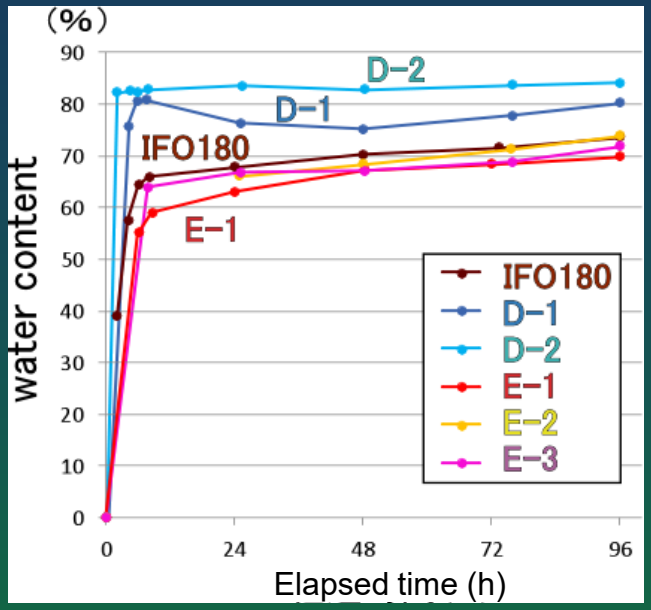
Does not stick

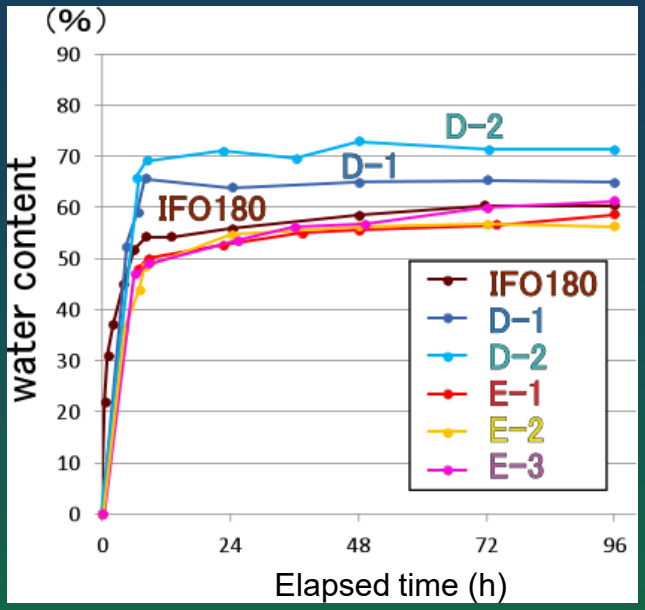
Sticks

[1] Not only emulsification, but also water droplets in oil
[2] Easily separated, already separated
[3] Reduces viscosity.
[4] Non-absorbent, and oil does not stick easily to smooth surfaces.

(3) Water content and asphaltene

Results





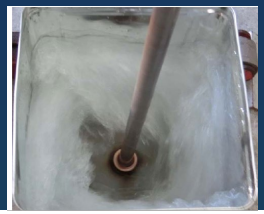
Temperature: 25°C

Temperature: 10°C

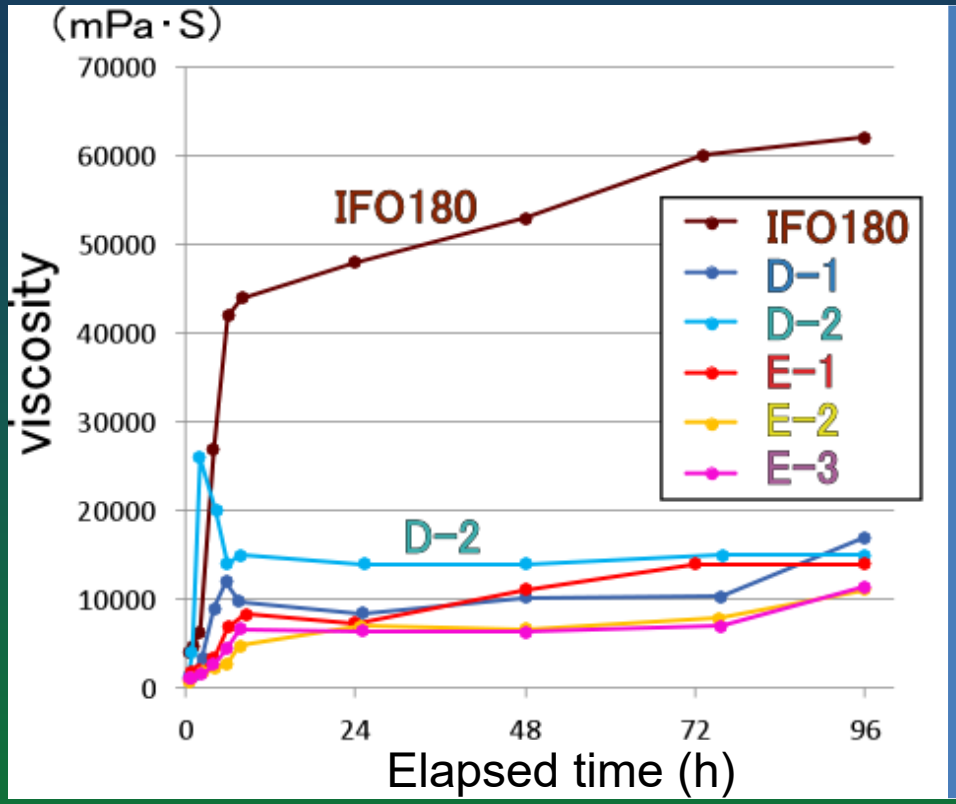
Sample	Asphaltene (wt%)	Wax (wt%)
IFO180	3.9	in analysis
E-1	0.55	
E-2	0.60	
E-3	0.60	
D-1	0.50	
D-2	1.2	

Asphaltene content is high in sample D-2. Currently analyzing wax content.

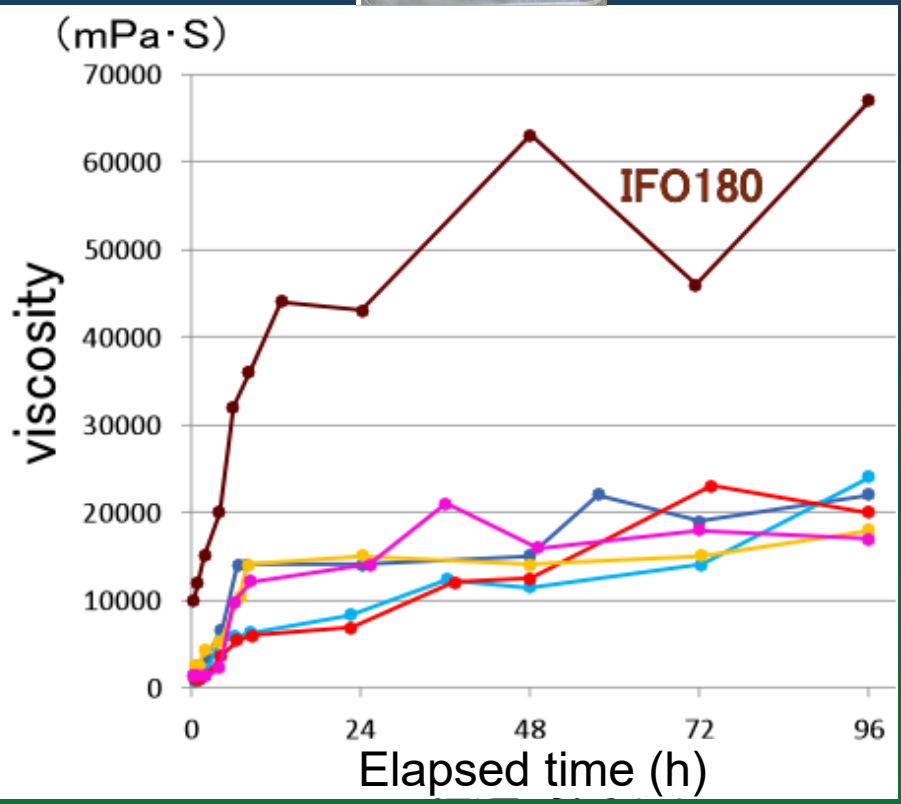
4. Changes in viscosity



Results

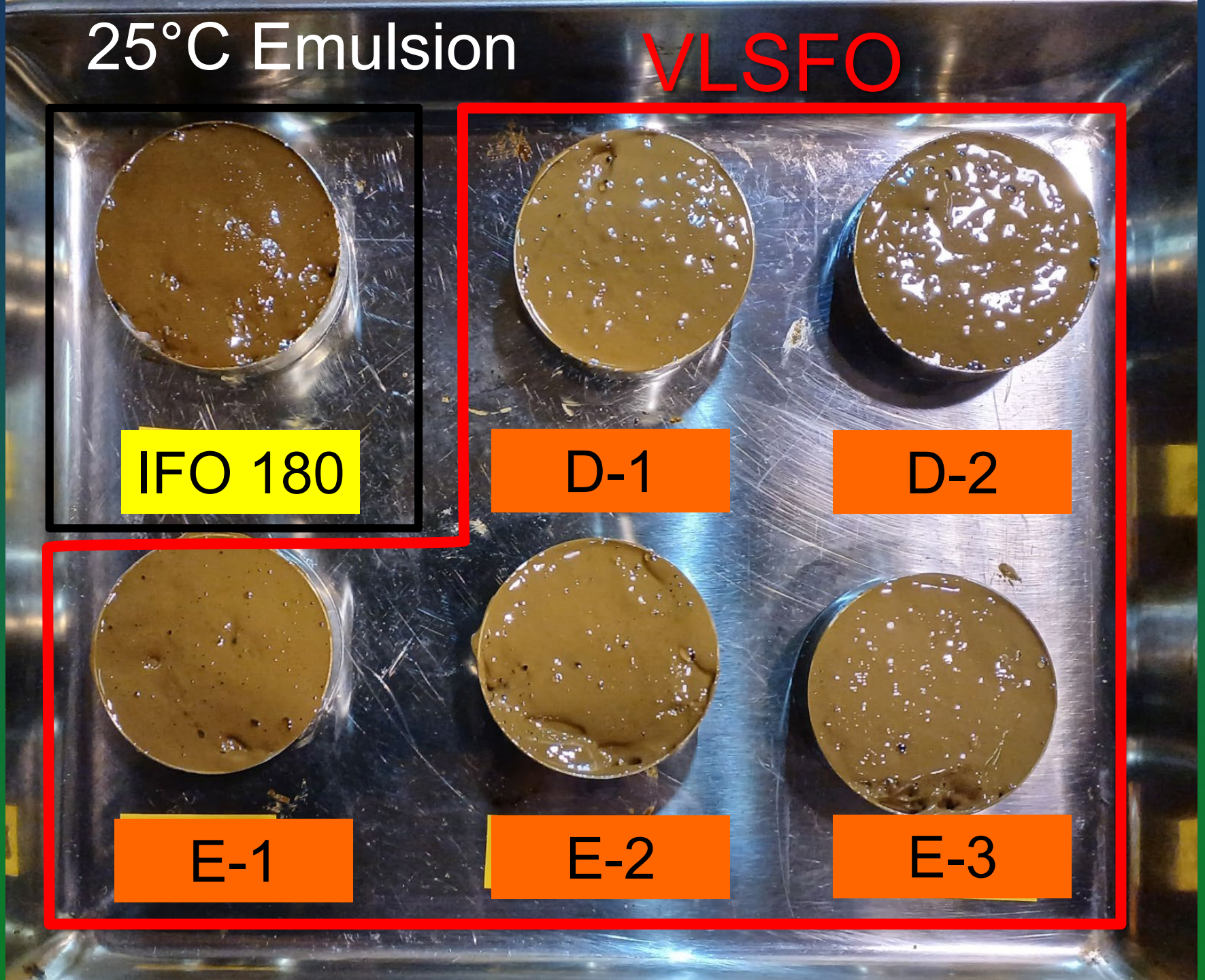


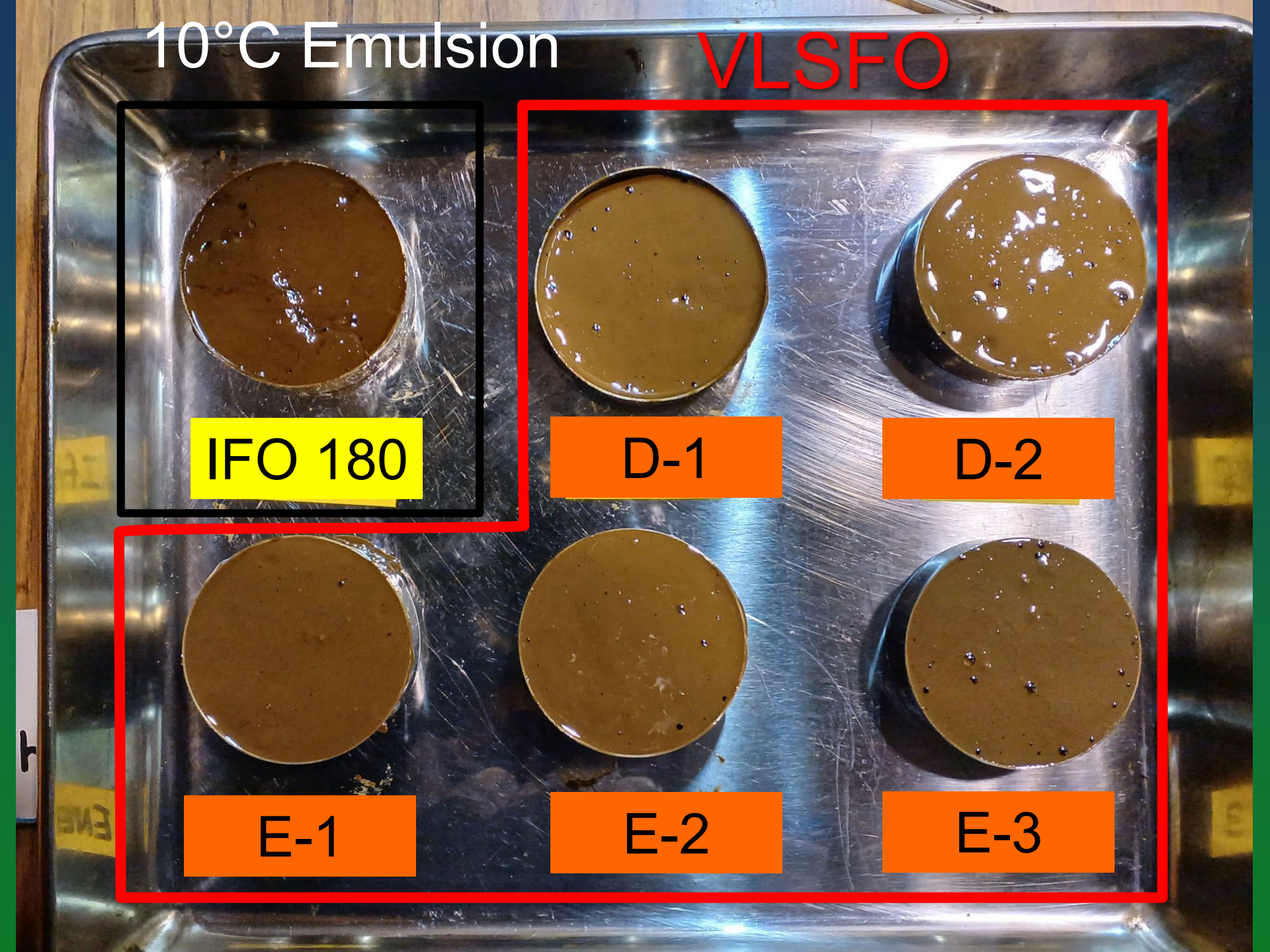
Temperature: 25°C



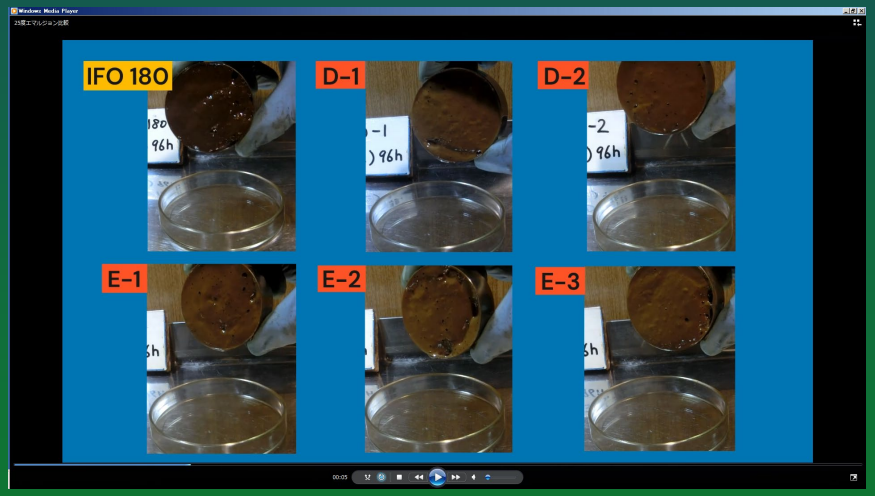
Temperature: 10°C

[1] Emulsified VLSFO has a lower viscosity than IFO 180.
[2] Viscosity is higher at a temperature of 10°C, exceeding 20,000 mPa-S.
[3] 20,000 mPa-S or lower at a temperature of 25°C or lower

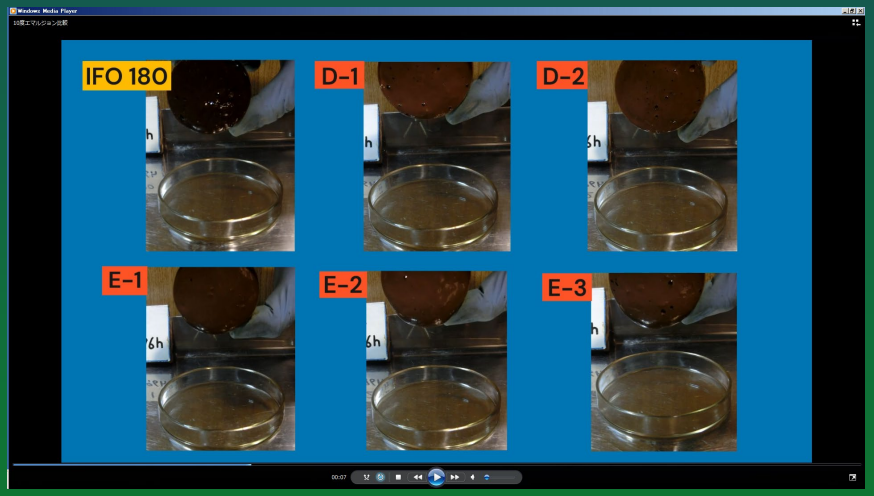

25°C Emulsion
VLSFO
IFO 180
D-1
D-2
E-1
E-2
E-3


10°C Emulsion
VLSFO
IFO 180
D-1
D-2
E-1
E-2
E-3

Videos showing flowability of emulsified oil (flowability at 19°C)



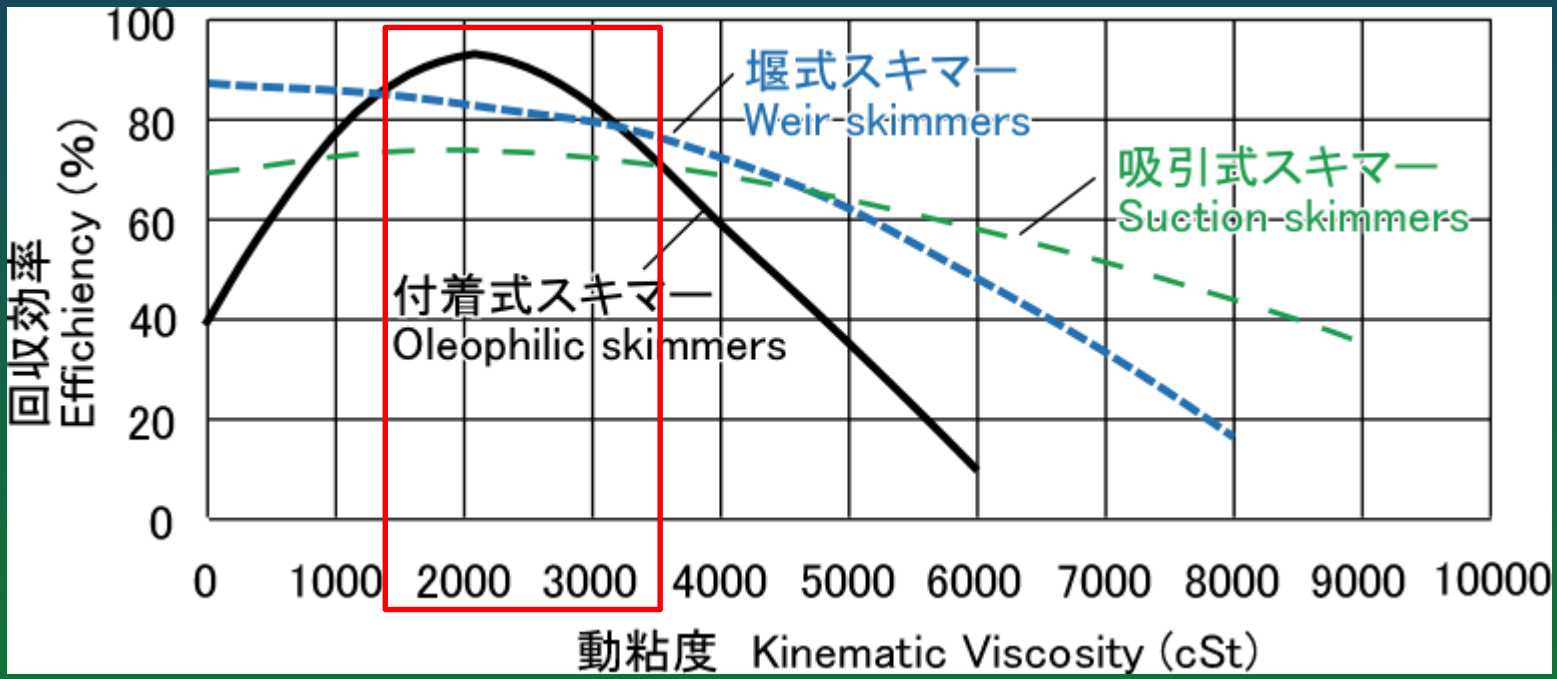
25°C Emulsion



10°C Emulsion

5. Considerations - From the perspective oil removal

(Reference) Skimmer recovery efficiency



Maritime Disaster Prevention Center, oil removal course textbook

Skimmer recovery efficiency is high at 2000-3000 cSt.

（Reference）Applicable viscosity of skimmer

Performance of Skimmer

Product name	system	Capacity	Applicable viscosity	Manufacturer
SeaMop 3060	O	14 t/h	150～22,000 cSt	DESMI
Ro-desk15	O	15 t/h	150～23,000 cSt	DESMI
Komara mini	O	10 t/h	150～23,000 cSt	Vikoma
Seaskimmer50	O	50 t/h	150～23,000 cSt	Vikoma
Seaskimmer100	O	100 t/h	150～23,000 cSt	Vikoma
GT185	W+S	65 t/h	150～23,000 cSt	LAMOR
DESMI 250	W+S	70 t/h	150～23,000 cSt	DESMI
SLURP	W	10 t/h	150～250 cSt	LAMOR
SKIMBOY	W+S	13 t/h	150～250 cSt	World Chemical
Transrec 200	S/O/W	200 t/h	150～23,000 cSt	FRAMO

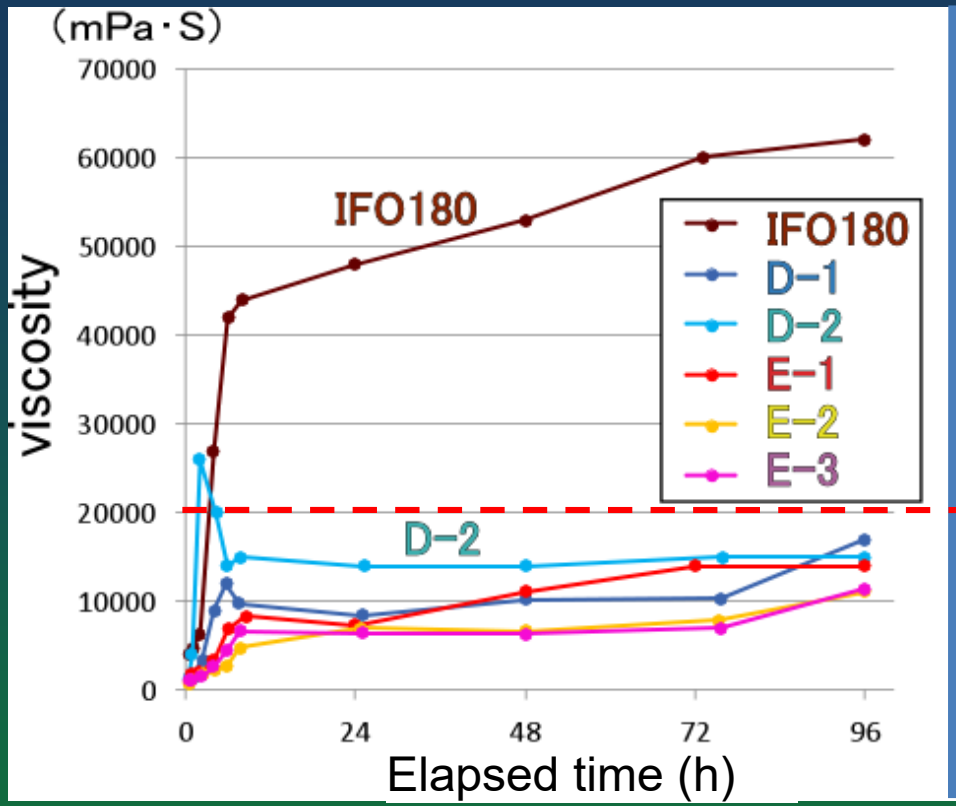
O：Oleophilic skimmer　W：Weir skimmer　S：Suction skimmer

The capacity and applicable viscosity are announced by each company. These are for reference only.

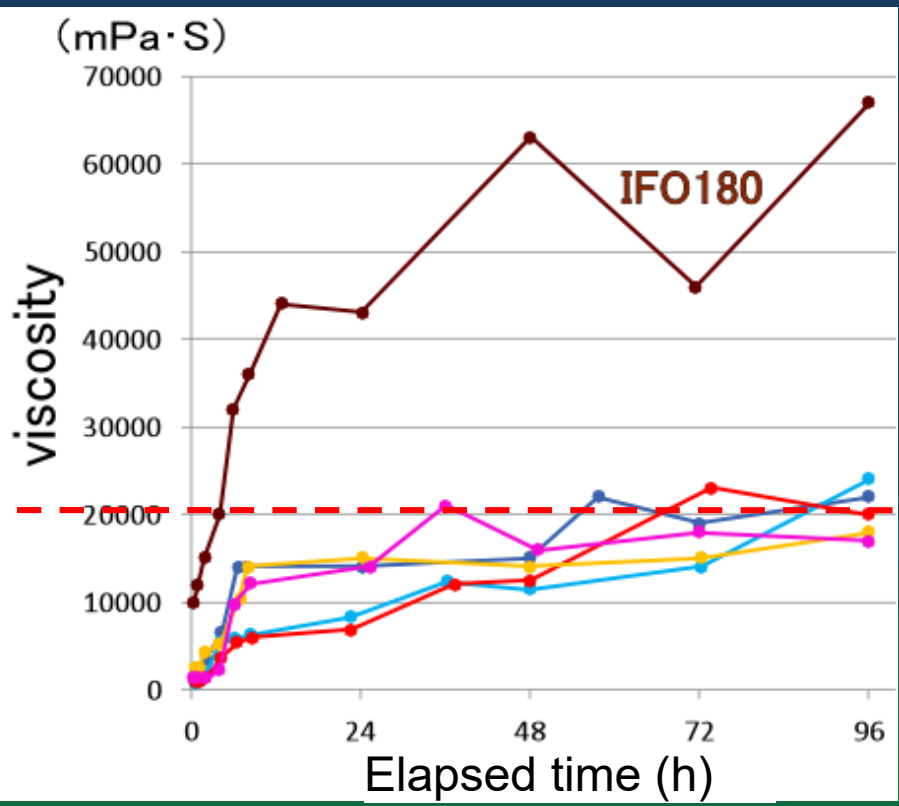
Textbook of Marine Oil Spill Control Course, MDPC

Applicable viscosity of skimmers are up to about 20,000 cSt.

(1) Changes in VLSFO viscosity and skimmer feasibility



Temperature: 25°C



Temperature: 10°C

- Summer (water temperature 25°C): Viscosities are expected to be 20,000 cSt or lower.
  Skimmers are expected to be feasible even after 4 days, depending on the skimmer model.
- Winter (water temperature 10°C): While viscosities 20,000 cSt or lower are expected on the first day after spillage, oils exceeding 20,000 cSt have been observed after the second day, which may make it difficult to use skimmers.

(Reference) Effectiveness of oil treatment agents

"Effectiveness declines at viscosities greater than 2,000 cSt"

"No effects observed once viscosity reaches 5,000 to 10,000 cSt"

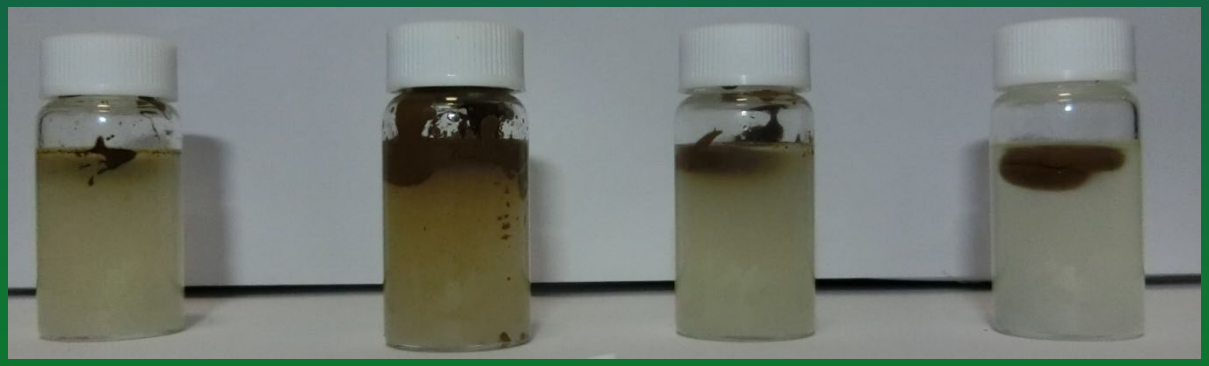
Maritime Disaster Prevention Center, oil removal course textbook

(Comparison)

Dispersion effect: Yes

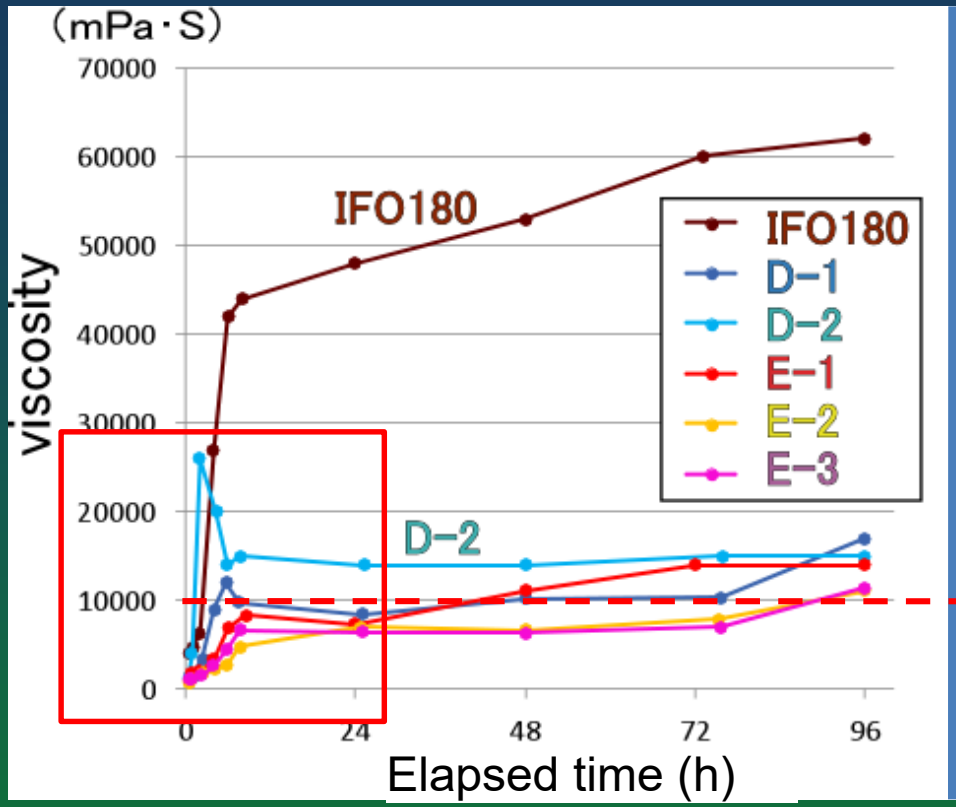
Oil treatment agent added to emulsified VLSFO

(agitated for 96 hours) (using Center's test kit)

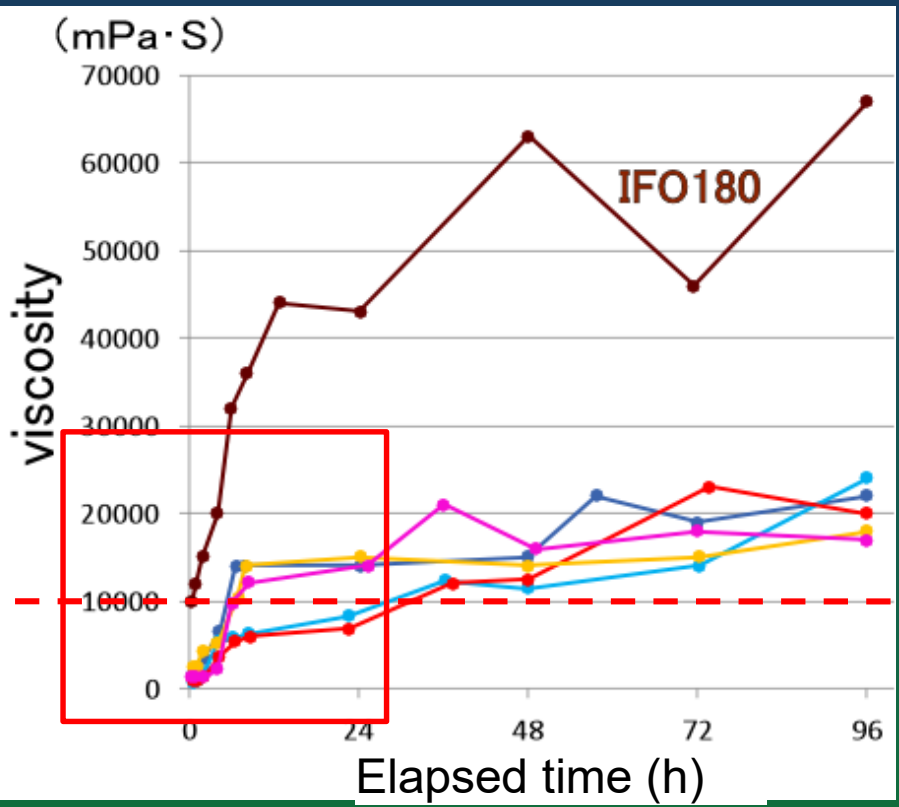


No dispersion effect from treatment agent

(2) Changes in VLSFO viscosity and treatment agent effectiveness



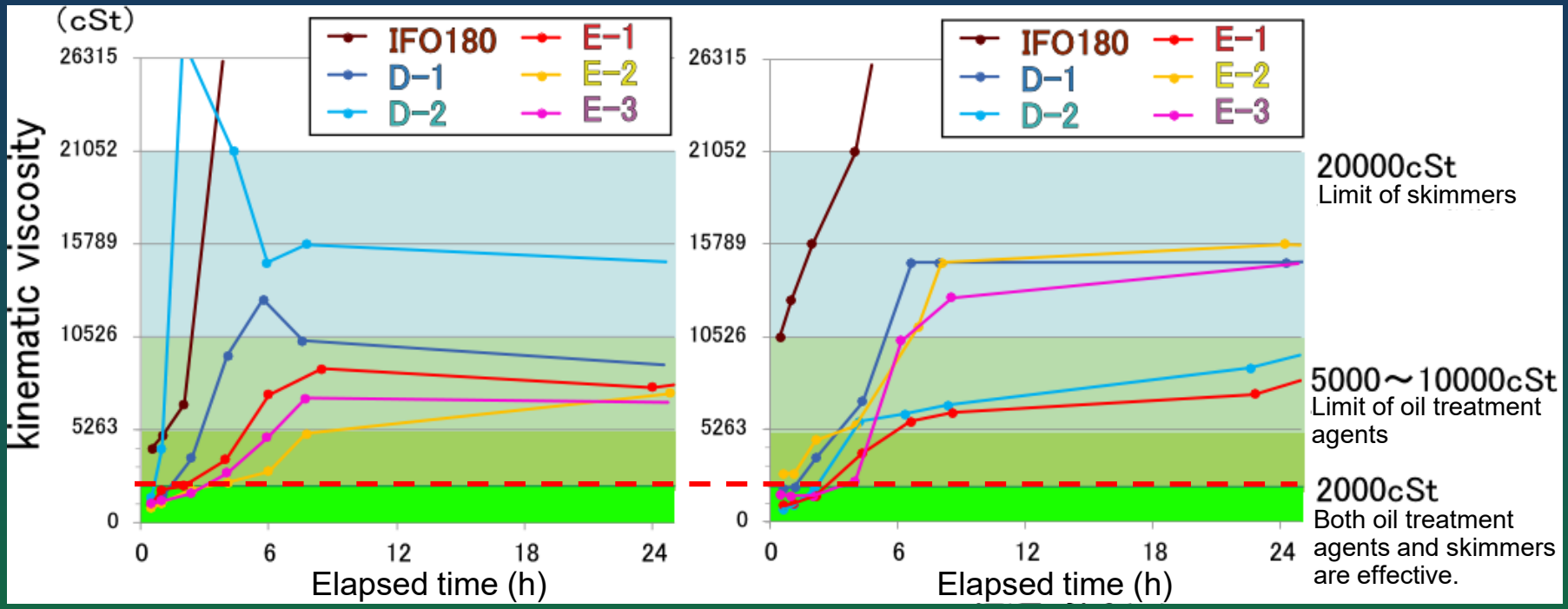
Temperature: 25°C



Temperature: 10°C

- Summer: Effective for some oil types in some cases until after 3 days. After the fourth day, the viscosities of all experimental oil types were at levels that would render agents ineffective.
- Winter: May be effective for some oil types up to 24 hours. After 36 hours, the viscosities of all experimental oil types were at levels that would render agents ineffective.

(2) Changes in VLSFO viscosity and treatment agent effectiveness



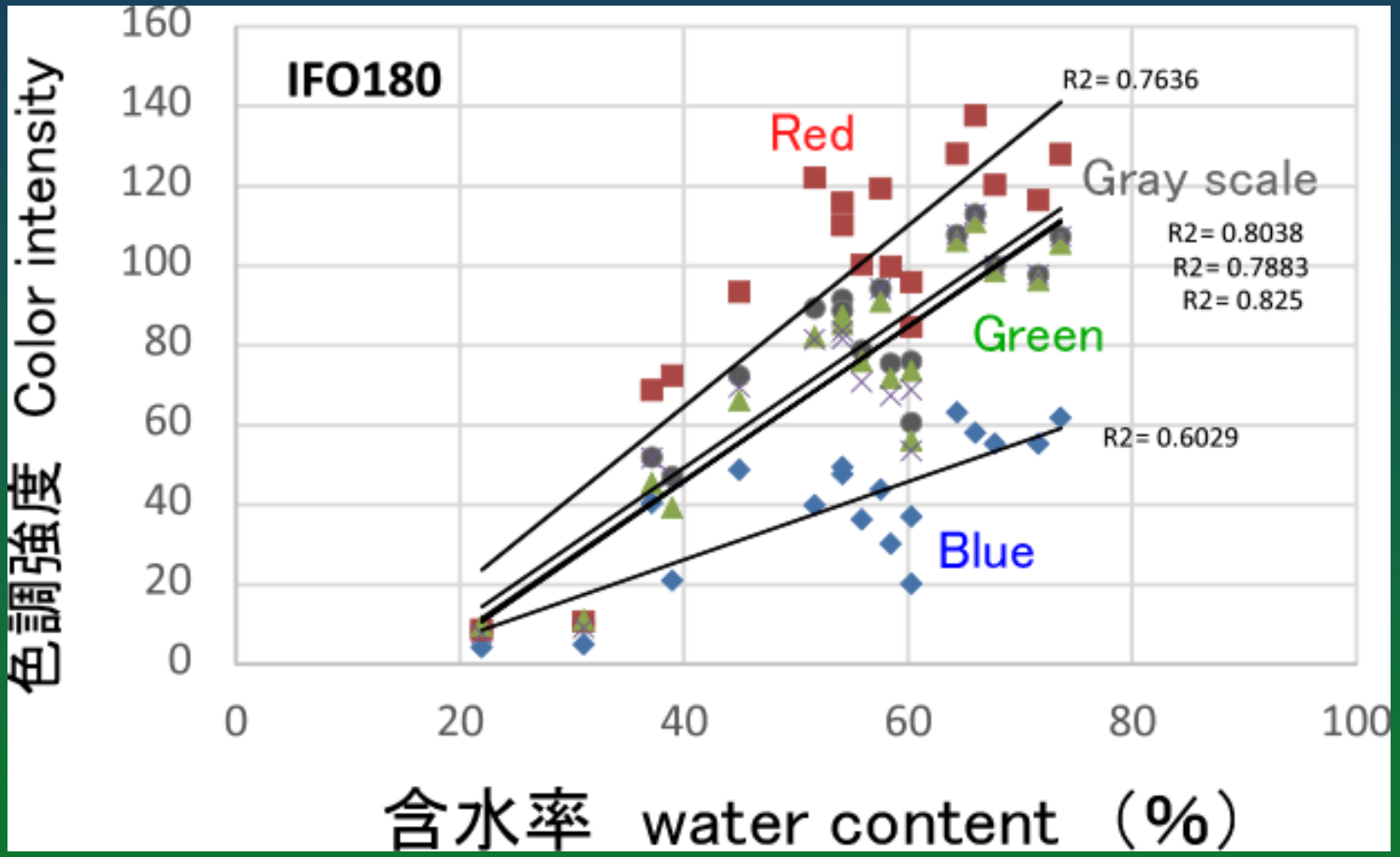
Temperature: 25°C

Temperature: 10°C

- In both summer and winter, oil treatment agents are expected to provide high efficacy in the roughly 1 to 4 hour window after a VLSFO spill (2,000 cSt or lower).

* Based on correlations with results from PAJ's flume basin test, wave conditions are assumed to be between "wave height 10-50 cm" and "wave height less than 10 cm."

(Reference) Change of color



Red hues become more pronounced.
Values converted to gray scale are highly correlated.

Summary

Low sulfur C fuel oil (VLSFO) ...

- Has lower viscosity than conventional C fuel oil.
- Viscosity and emulsion characteristics vary depending on the product.
  (The following statements assume wave conditions with wave heights of several tens of centimeters)
- When subjected to emulsion action for 4 days:
  10,000 to 20,000 mPaS in summer / 15,000 to 25,000 mPaS in winter.
  Roughly the viscosity of ointments
- In winter (10°C), using skimmers may become difficult in some cases after the second day (viscosity reaches 20,000 cSt or higher).
- Both in summer (25°C) and winter (10°C), oil treatment agents are effective until about 1 to 4 hours after the spill (2,000 cSt or lower).
- Oil treatment agents are expected to become ineffective after 4 days in summer and 36 hours in winter (viscosity reaches 10,000 cSt or higher).