<<Oil recovery and oil-on-water exercises in high seas, offshore Norway>>

by

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CONTENTS:

1. INTRODUCTION:

Norway is exposed to nearly all kinds of oil spill threats as a result of an increased oil exploration and exploitation (E&E) which by 1997 covers well over half of the 21.465 km long coastline.

The threats may come from:
-offshore (meaning high seas) oil exploration and exploitation
-tanker accidents inshore as well as nearshore
-pipeline ruptures
-ships' groundings or collisions

Further it should be emphasized that in winter time Norway has very harsh weather conditions that may be the main cause for some of the above incidents. In a very similar manner the winter weather may also be very detrimental to efficient oil recovery operations.

The two main incidents that triggered government action in the seventies were the <<Torrey Canyon>> disaster and the EKOFISK BRAVO blowout.

The Ministry of Environment through SET, its Pollution Control Authority, issued a set of very demanding rules requiring the oil companies drilling on the Norwegian continental shelf to build up a **mechanical** oil spill response capability with the following requirements:

- there must be available a total oil spill response capability which can contain, recover and store an acute oil spill of 8.000m3 **emulsion** per 24 hours
- 25 % of this capability must be operative inside 24 hours
- the balance of the response equipment must be operative inside 48 hours
- the oil recovery equipment must be dimensioned for efficient operations in at least 2,5m significant (Hs) wave height and in currents up to 1,5 knots

At the time neither the infrastructure nor the equipment existed to meet these requirements. The oil companies invited the industry to develop the mechanical oil spill response equipment - for a new and very promising market.

The government through SFT had given permission to the oil companies to join forces in meeting the capital demanding requirements and it was in 1978 that they founded **NOFO**, Norwegian Offshore Clean Seas Association for Operating Companies.

NOFO soon took an active lead in the general R&D as well as a practical development of what over a 10 to 15 years period became a very efficient, large scale offshore oil spill contingency.

While NOFO was mainly responsible for the offshore E&E activities SFT through its Oil Spill Control Dept. in Horten was responsible for coastal spills caused by traditional ship groundings and collisions or third party mystery spills. Later this role has changed and SFT plays a more active role in developing and building up oil spill contingencies for coastal as well as inshore response operations.

2. Status for the Norwegian oil spill response capability after the EKOFISK BRAVO blow-out in 1977.

Phillips Petroleum, the owner of the EKOFISK field, was nearly unprepared for a long week's blow-out in March 1977. Only prototype mechanical oil spill response equipment was available for oil containment in high seas offshore.

The booms were operated in U-configuration requiring three vessels i.e. two vessels for boom towing and the third one, the OILREC vessel, to operate the disc skimmer attached to a hydraulic suspended crane. A total of 24.000 tonns blew out from the BRAVO platform (no fire), 40 % evaporated rather quickly. The weather was moderate and the waves never exceeded 2 - 2,5 m Hs in max. 12m/sec. winds. One may say this was a good lesson learnt and a good kick-off point for NOFO to develop oil recovery systems

- for two boat operations
- with dynamic, freefloating high capacity skimming systems
- with booms operated in improved configurations to feed more oil to the skimmers
- with booms that could contain oil above the classic limitation of 0,7 to 0,9 knot towing speed.

3. Oil recovery and oil-on-water exercises in high seas.

Backed by abundant economic resources made available by the parent companies in the late seventies/early eighties NOFO set out to develop the new offshore oil spill contingency such as

- equipment
- vessels (on a standby basis)
- crews (not permanently employed)
- onshore equipment bases (hired)
- relevant exercise and training programs

And NOFO was met with an additional challenge when offshore drilling for oil was opened up in northern Norway in 1982. The operational requirement for the mechanical equipment was then increased to 3 m Hs wave height.

From 1980 until 1996 NOFO has carried out a total of appr. 23 full scale, realistic oil-on-water exercises offshore Norway. During the same period Norway experienced a high number of oil spill incidents from ships that to a large extent supplemented the know-how that NOFO had built up.

It ought to be added that SFT participated with their own vessels and resources in most of the oil-on-water exercises. Sometimes SFT served as back-up and more recently in the frontline with their new vessels and equipment that needed real life testing and training.

Typically a NOFO oil-on-water exercise in the mid eighties included the following resources:

- one J-shaped 500 m long high seas boom with a high capacity freefloating skimmer operated by one supply vessel (60 m) and one fishing vessel (40m)
- three back-up systems (one with a V-shaped boom system and two with a U-shaped boom system, all operated by three vessels each)
- a significant amount of measuring instruments and over flight surveillance.

In the first years of testing volumes of up to 500m3 emulsion were discharged. More recently the volumes have been reduced to 250/125m3 emulsion. NOFO intentionally mixed from exercise to exercise various crude oils from the Norwegian offshore fields with sea water. Thus the discharges consisted of typically 65% seawater and 35% crude oil. This was done in order to simulate the situation of a blow-out where the crude would mix with the seawater before NOFO's response fleet would be on site to begin oil recovery operations.

4. Significant oil-on-water exercises and real life oil spill incidents - which have contributed to the improvement of the Norwegian oil spill response capability in high seas offshore from 1980 to 1995.

4.1 PFO's full scale testing of V-shaped boom systems, in-hull and over the side skimming systems in 1980.

PFO- Oil Pollution Control Research and Development - was initiated by the Ministry of Environment in 1978. It is fair to say that it was the state's follow up of the defficiencies detected after the EKOFISK BRAVO blowout. The program lasted for 4 years. 22 mill. NOK were allocated to development projects and 25 mill. NOK to R&D projects. The Norwegian Industry Association funded parts of these means.

The Norwegian maritime industry had responded actively to the BRAVO blowout, eager to develop new equipment capable of containing and recovering oil in high seas, offshore conditions.

PFO therefore supported a large scale three week oil-on-water test in June 1980. The equipment tested by four different makers were:

1. a 35 m long V-shaped boom system with a built-in overflow skimmer pump

2. a 40 m long V-shaped boom system with a purpose built recovery section including a centrifugal pump

3. a single ship, onboard skimming/settling system supplemented by a side sweep boom

4. a single ship, over the side skimming system supplemented by a side sweep boom

See drwgs. 1 - 4

All four systems included pumps which theoretically could recover from 400m3 to 700m3 water per hour.

The first week of the test program covered physical endurance tests in high seas. In wind forces of 10 - 12 m/sec. and up to 2 m Hs several weaknesses were detected and most of them corrected. - But vortex motions in front of the V-shaped booms at the connection point between the guiding booms and the V-shaped boom could not be adjusted.

The oil emulsion used had the following basic characteristics:

Period	% seawater	Viscosity (cp) at 1 s -1	density (g/cm3)
1st week	50	11.000	0,93
2nd week	65	25.000	0,94

A lube oil, SAE 30, was chosen as basis oil. While this was a none Newton liquid it was chosen because it was close to the characteristics of a crude oil that had been drifting in the ocean for 1/2 to 3 days. The mixing with seawater into an emulsion was done as per a formula developed by SINTEF.

The wave and wind conditions during the oil-on-water tests were:

Period	Sign. wave height	Max. waves	Wave periods (average)	Winds (m/sec)
1st week	2,2 - 3,1 Hs	3,0-5,2 Hmax	7,0-9,3 sec	2,8-5,3
2nd week	1,2 - 2,0 Hs	1,8-3,0 Hmax	4,2-5,1 sec	5,0-9,7

This means that during the first week there was mostly ocean swells and during the second mostly wind driven waves. - The oil emulsion was discharged from a vessel in front of the systems through a 100 m long 6 inch dia. hose kept floating by buoys. At the end of the hose was a polystyren box 2 x 2 x 0,5 in. The emulsion simply poured out on top of the box and into the ocean. The discharge rates were kept at 60 m3/hour.

The recovery results from the **1st week tests** were as follow:

	1. 35 m V-boom with pump	**2. 40 m V-boom w/recovery section**	**3. Inboard settling + side sweep**	**4. Over the side skimmer + side sweep**
Emulsion disch.	30 m3	30 m3	30 m3	20 m3
Oil content	15,4 m3	15,4 m3	15,3 m3	10,6 m3
Total recovery	42 m3	41 m3	25 m3	26 m3
Water content	82%	71%	74%	71,5%
Oil content	7,5 m3	12 m3	6,5 m3	7,4 m3
Efficiency **Variations x**	49% 30 - 70%	78% 60 - 85%	42% 30 - 60%	70% 50 - 80%
Emulsion recovery for entire test period	27,9 m3/hour	26,1 m3/hour	16,7 m3/hour	28,2 m3/hour
Peak recovery	**48,4 m3/hour**	**38,5 m3/hour**	**41,6 m3 hour**	**37,2 m3/hour**

The test results from the **second week** tests were as follows:

	1. 35 m V-boom with pump	**2. 40 m V-boom w/recovery section**	**3. Inboard settling + side sweep**	**4. Over the side skimmer + side sweep**
Emulsion disch.	30 m3	30 m3	18,5 m3	20 m3
Oil content	9,9 m3	-	6,8m3	10,2 m3
Total recovery	23,4 m3	-*	22,5 m 3	20,5 m3
Water content	69%	-	78%	70%
Oil content	7,3 m3	-	4,9 m3	6,1 m3
Efficiency **Variations x**	73% 50 - 80%	- -	72%** 50 - 80%	60% 40 - 75%
Emulsion recovery for entire test period	31,2 m3/hour	-	23,4 m3/hour	28,2 m3/hour
Peak recovery	**46,8 m3/hour**	-	- ***	**36,6 m3/hour**

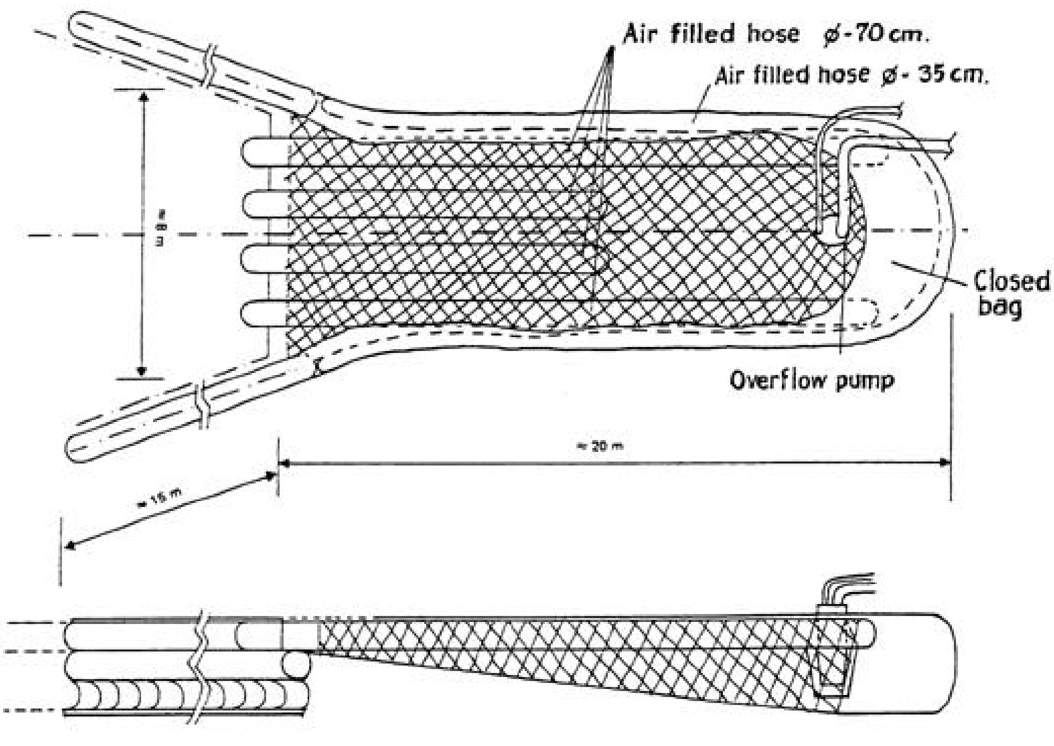
x Variations is an expression for the overall uncertainties of all measurements i.e. from discharge from the front vessel to recovery into tanks of the OILREC vessel.

*** No oil recovered because the pump was not powerful enough to pump the emulsion!**

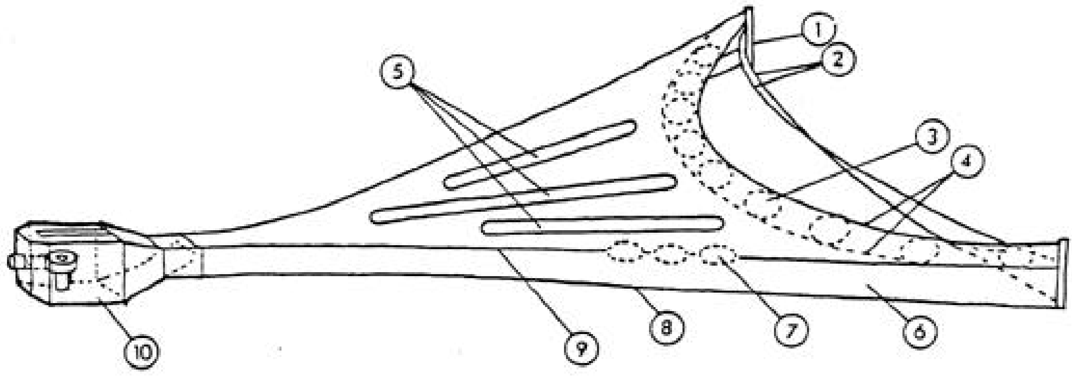
**** This may be too high because the discharge was only 18,5 m3. It was designed to be 30m3 (like the others) but there was a pump failure onboard the discharge vessel.**

***** No peak measurements because of incorrect bypass hose connection!**

Drwg. no. 1:
35 m. long V-shaped boom system w/overflow pump



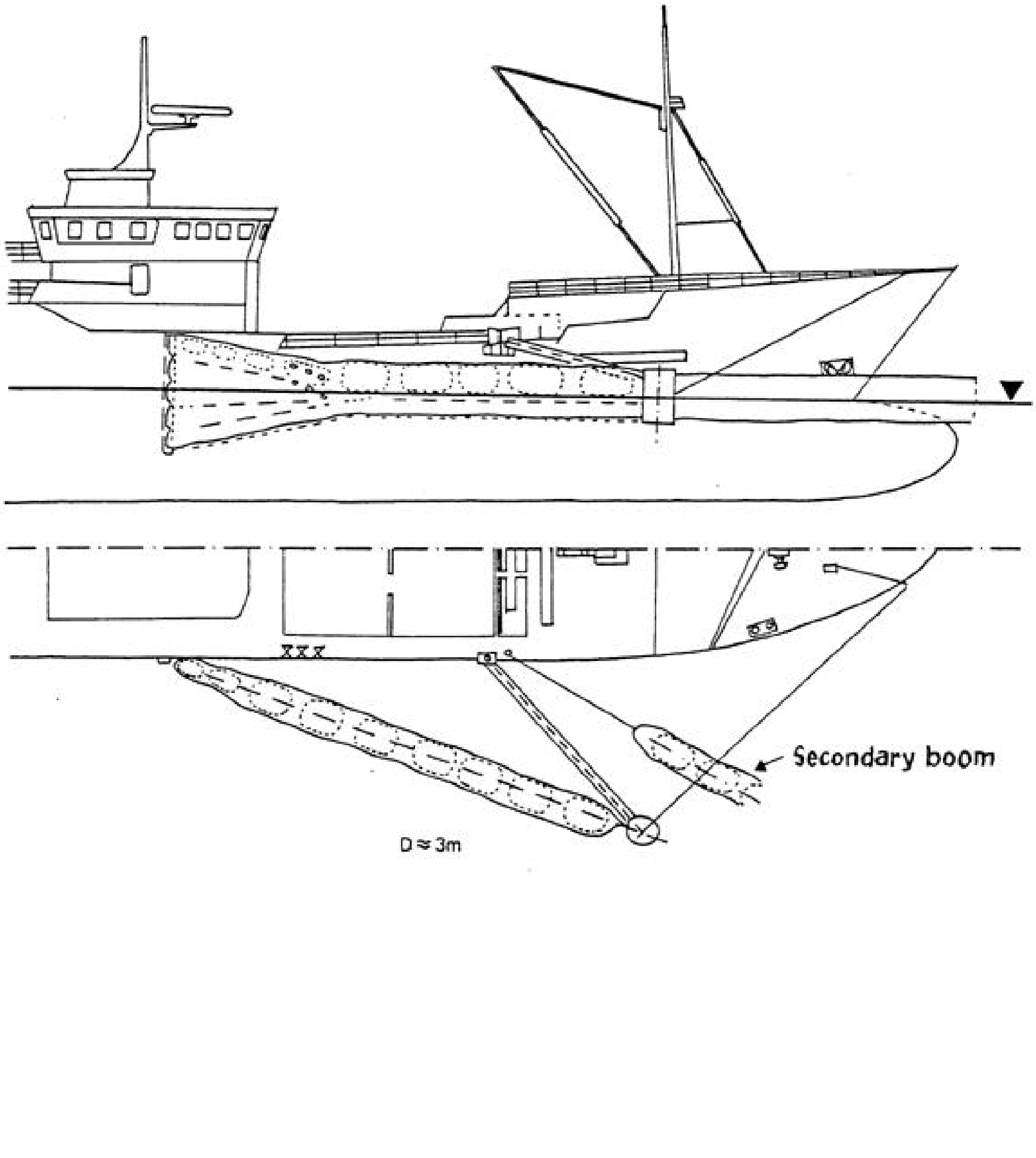
Drwg. no. 2.
40 m. long V-shaped boom system w/centrifugal pump



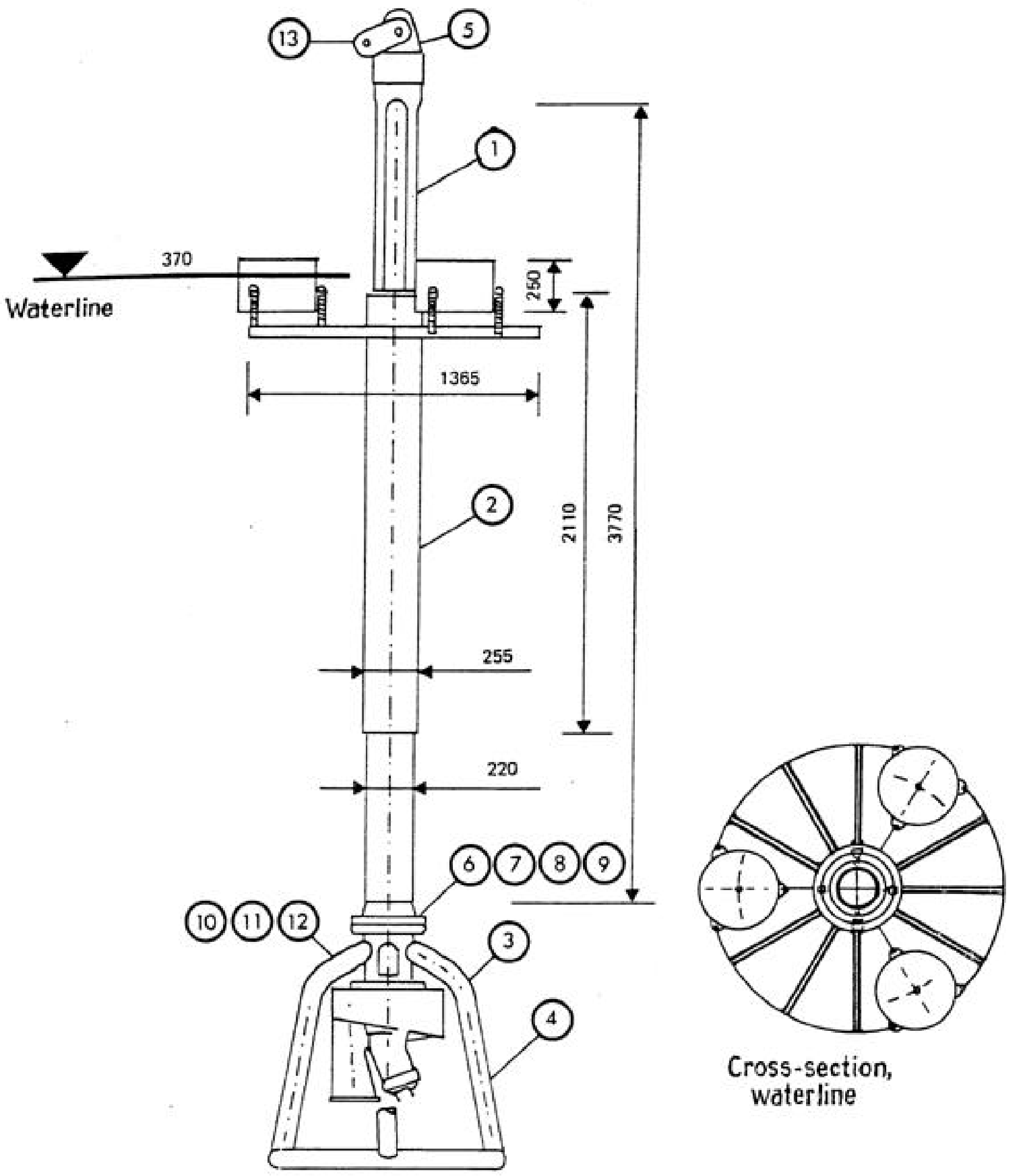
Length: 40 m.
Width: 17 m.

1 Connection for guide boom
2 Front ropes- water line and bottom
3 Front buoy- ø 0,9 m.
4 Front tension ropes
5 Three longitudinal vent openings
6 Skirt depth 0,9 m
7 Buoy elements
8 Leadline 0,6 kg/m
9 Bottom net
10 Recovery section

Drwg. no. 3:
Single ship, onboard skimming & settling system and side sweep boom



Drwg no. 4:
Single ship, over the side skimmer.



Observations and discussions:

When evaluating the results obtained from this very comprehensive oil-on-water test program it is useful to remember that this was the very first time that such an ambitious (and costly) program had been launched in high seas, offshore conditions in Norway. - While PFO would have preferred the seastate to have been fully developed into 2,5 m Hs waves and 12 - 13 m/sec winds they were not very far from this goal. The biggest challenge faced was the number of accurate measurements to be taken. That is why the above tables refer to <<Efficiency variations>> **x**. It shows the Test Director's overall reservations with regard to potential errors. He deserves credit for that!

The recovery rates of **emulsion** are by today's North Sea standards not very high, i.e. 40 - 50 m3 per hour. The towing speed exceeded 1,0 knot most of the time for the V-shaped booms. This must be considered a success in view of the classic limitation for booms towed in a U-shape and where the oil will escape under the boom at 0,7 to 0,9 knot.

The usefulness of this kind of real life testing was also proven. Example:
During the physical endurance testing the bark (simulated for oil) appeared not to be capable of concentrating around the **no 4** <<over the side skimmer>> whereas the oil testing demonstrated no such deficiency.

The entire test program left the 4 makers with promising challenges and opportunities for improvements that seemed achievable. The two makers of the V-booms (**no 1 and no 2**) since <<merged>> what they considered the best features of the two designs. They subsequently built a unit with a freeboard of **1,5m** which became a very important oil containment tool in the Norwegian oil spill contingency of the 1980'es. And it supported the development of a unique high capacity, free floating overflow skimmer that needed a good concentration of oil to operate at its maximum capacity. Ref. the following chapters on NOFO' s oil-on-water tests.

4.2 NOFO's oil on water exercise in June 1985.

While NOFO began their regular oil-on-water exercises in 1980 with essentially the same type of mechanical oil recovery equipment that was used during the BRAVO blowout in 1977 it was not until 1984 - 1985 that the first major improvements in new equipment were made and put to test. In this section the major and very comprehensive oil on water exercise carried out in June 1985 is described and discussed in some detail.

The June 1985 oil-on-water exercise was a joint venture between NOFO and SFT. A total of 13 large vessels were mustered:

- 11 oil spill response vessels of which 4 acted as OILREC vessels and 7 as towing vessels.
- 1 tanker
- 1 observation vessel

Further a total of 4 (1 primary and 3 back-up) mechanical oil recovery systems were in operation as shown on drwg. no 5:

NOFO's primary:

A two-boat system operating with:

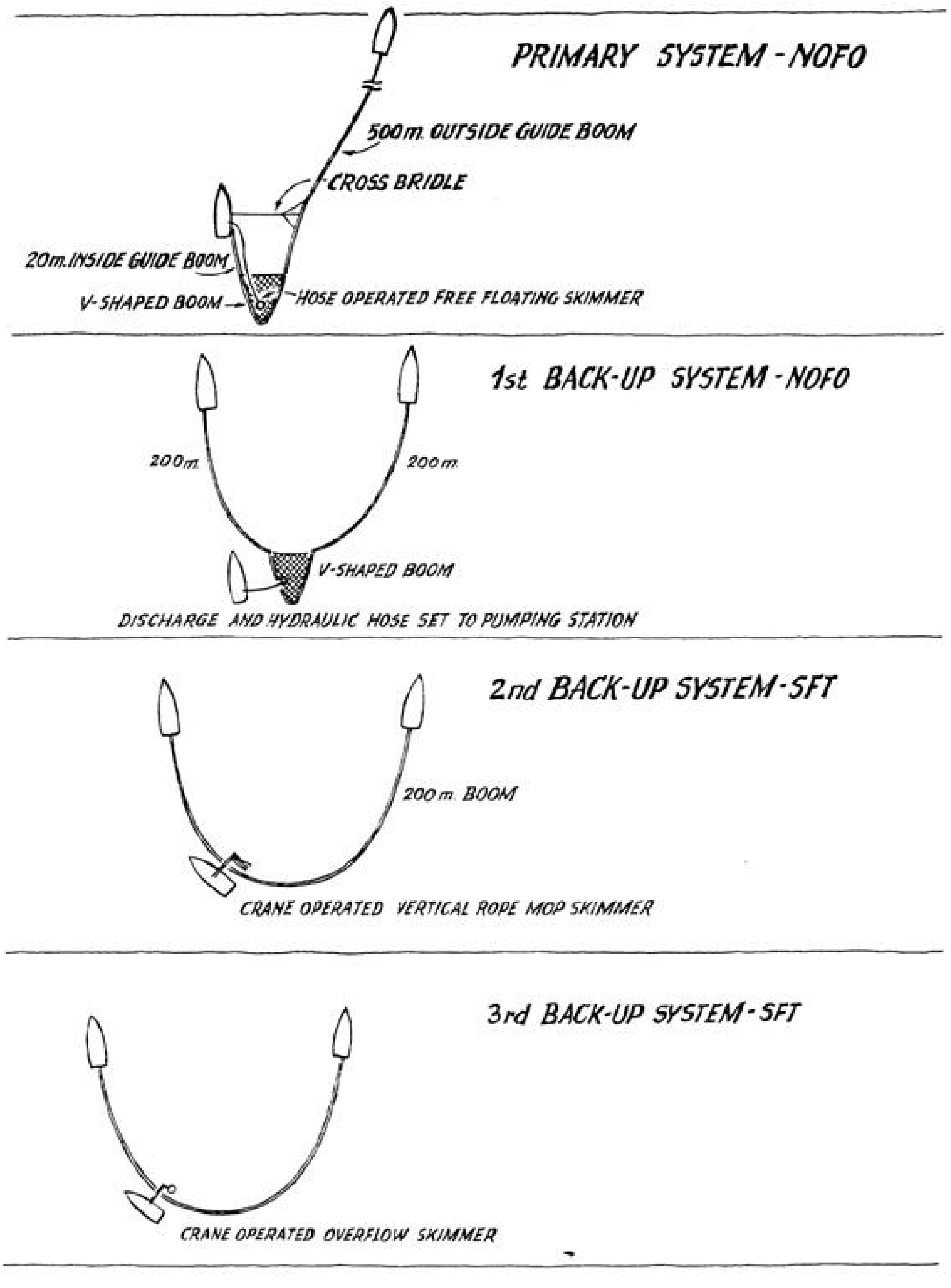
a new fully integrated oil containment system consisting of 500 m guide boom with 85 cm freeboard (fence type) supported by a Cross Bridle and a V-shaped boom of 1,3 m freeboard and with a submerged, horisontal net bottom.

And

a new freefloating overflow skimmer with a built-in screw as well as centrifugal pumps and a cutting device against debris. Surrounding the overflow skimmer was a flexible skirt w/floaters designed to maintain a near constant overflow level in high seas. The skimmer was connected to a 100m long floating hose with a built-in set of discharge and hydraulic hoses plus an emulsion breaker hose. The floating hose was stored on and deployed from a hose drum with a crane that would feed the hose with the skimmer at the end down into the apex area of the V-shaped boom.

TESTS 1 AND 2: JUNE 1985

Drwg. no 5



NOFO's 1st back-up:

A three-boat system operating with:

A 2 x 200m 85 cm freeboard guide booms on each side of a V-shaped boom of 1,3m freeboard and with a submerged, horisontal net bottom.
An overflow pump station with a combined discharge and hydraulic hose assembly in a net stocking - running over the side of the V-shaped boom and onto the nearby OILREC vessel.

SFT's 2nd and 3rd back-up:

Three-boat systems operating with:

400m inflatable oil booms towed in a U-configuration. The boom had 80cm freeboard and a draft of 1m skirt and 50cm feather net to give the boom improved dynamic (heave) response in high seas.
For oil recovery in the 2nd back-up system a crane operated, vertical rope mop skimmer was used.
For oil recovery in the 3rd back-up system there was a crane operated overflow skimmer w/seawater injector to ease off the friction in the discharge hose. Thus it was expected that the recovery capacity would be increased with less hose friction.

Measurements and recordings:

For optimal and correct measurements and recordings of oil thicknesses, oil recovery rates and the overall exercise performance NOFO had included a series of hardware and software such as:

For visual observations and recordings:

Film and video cameras in the air (including an IR-camera for night recordings) and on the bridge of the OSC/OILREC vessel.

For underwater observations:

An ROV with video camera that operated inside the primary boom system.

For recordings and measurements:

A 40 ft. lab container on the deck of the OSC/OILREC vessel in which continuous registrations through bypass lines were made first of all of pump rates from the new overflow skimmer, amount of free water and emulsion and sampling equipment for the emulsion's water content and emulsion. Moreover the skimmer's hydraulic pressure, hydraulic flow rate and temperatures in the power packs and hydraulic pumps were measured. The monitors also took in the continuous incoming weather reports from the oceanographic buoy such as wind speed and direction, wave heights, current and its drift direction plus air and ocean temperature.

Finally, the oil thicknesses around the freefloating skimmer head were measured manually from a small workboat!

The emulsion used during the exercise was an evaporated crude oil from the STATFJORD offshore oil field premixed with seawater to simulate a 12 hours crude oil slick. The viscosity varied from 7.800 to 10.000cp. The emulsion was pumped into the ocean by a tanker in front of the Primary System after the Back-up Systems had been towed in position behind. A total of 550m3 were discharged while the single discharges were maximum 100m3 - for the less significant tests the volumes were reduced to 30m3 and used in testing of the Back-up Systems.

Weather:

Over the entire test period a strong breeze blowed out of the southwest resulting in a significant wave height of 1,5 m (Hs). These were fair test conditions for first time trials of new equipment.

Recovery results of oil emulsion:

System tested:	2-boat	Primary	3-boat	1st Back-up
Description / Test number	1	2	3	4A
Emulsion discharged	104 m3	69 m3	102 m3	82 m3
Emulsion recovered	80 m3	83 m3 1)	72 m3	66 m3
2) System loss in crude oil	17 m3	-11 m3 1)	19 m3	10 m3
3) Efficient skimming time	37 mins.	67 mins.	118 mins.	238 mins.
4) System capacity	130 m3/hr.	74 m3/hr.	37 m3/hr.	17 m3/hr.
5) Real skimmer capacity	185 m3/hr.	170 m3/hr.	85 m3/hr.	50 m3/hr.
6) Max. capacity emulsion	220 m3/hr.	215 m3/hr.	130 m3/hr.	120 m3/hr.
7) Max. capacity emulsion + seawater	280 m3/hr.	225 m3/hr.	185 m3/hr.	240 m3/hr.

Note: There may be variations in the measured recovery results of minus to plus 10%!

1. More emulsion was recovered than discharged. This was due the increased percentage of seawater in the emulsion - and there were some leftovers from Test no 1. The negative figure (-11) means that more oil was recovered than discharged for the Test no 2.

2. System loss refers to the loss from this test only, i.e. what was recovered by the Back-up systems has **not been included.**

3. Efficient Skimming Time means the time the hydraulic motor on the recovery pump has been operating.

4. The system capacity is a result of the **average recovery capacity** for the entire Efficient Skimming Time.

5. Real Skimmer Capacity expresses the average plateau value over 15 ins, during which the emulsion flow into the skimmer has not restricted the capacity.

6. Max. Emulsion Capacity is the highest emulsion flow rate maintained during a 3 mins. period.

7. Max. Total Capacity is the highest emulsion plus water flow rate during a 3 mins. period.

From other sources than the Lab Container the following was recorded:

- oil thicknesses up to 50cm in towing speeds at 1 knot.
- when the towing speed was increased up towards 1,5 knot the oil thickness increased significantly in the Apex area of the V-shaped boom. Thus an improved flow into the overflow skimmer was noted.
- The photos taken from the air with an ordinary camera showed small leakages of emulsion in the form of blue shine which spread over a wide area and some long streaks of emulsion strectching longitudinally behind the Apex.
- the underwater video from the ROV showed:
  - a pump-like movement from the boom's skirt likely caused by the wave actions.
  - the boom skirt's outward inclination (caused by the shorter bottom tension line.
  - a leakage of very small particles (droplets) of emulsion and small water droplets covered with a thin oil film.

Discussions:

This discussion focuses around the two most promising oil recovery systems tested i.e.:

- the two-boat Primary System, and
- the three-boat 1st Back-up System.

It was the first time ever that the max recovery capacity (seawater + emulsion) had approached 300m3/hr., and correspondingly the emulsion capacity had passed 200m3/hr.by a good margin. These breakthrough results were achieved only with the Primary System tested.

The Primary System's freefloating skimmer deployed by means of a 100m crane operated floating hose was very easy to manoeuver (only 1 person). This was also the case in positioning of the skimmer head inside the V-shaped boom at the Apex area where the oil emulsion showed best concentrations. And the interim recovery of the skimmer head (for declogging of debris and possible repairs) was equally simple. The Skimming System's independence from the Boom System was thus demonstrated to be a major benefit - and with only two vessels!

While the skimmer head was not subjected to marginal weather conditions the skirt fitted with floats provided a fully adjustable overflow in relation to the wave movements. - While the exercise revealed that minor technical adjustments had to be done the results had been so promising that **NOFO decided to go for a full series of new skimmers of this kind.**

Boom towing configurations:

This exercise demonstrated the V-shaped boom's good capability to concentrate thicker layers of oil around skimmer head - better than the U-or J-configured boom systems.

- The configuration with a short <<Inside>> guide boom from the OIREC vessel to the V-shaped boom permits the freefloating skimmer head attached to the end of the 100m hose to drift into the Apex area.
- The <<outside>> guide boom gives the system an optimal sweep width (area coverage) while the Cross Bridle adjusts the angle of the guide boom to max. 25 degrees as per NOFO's own findings.
- The submerged horisontal net bottom - apart from maintaining the shape of the V-shaped boom - also tends to even out or spread the vertical currents of at the back of the V over a larger area. Thus the towing speed may be increased to a higher level than for the U- or J-configured boom systems. before oil escapes under the boom.

To operate such a fully integrated oil containment system requires two vessels with good manoeuvering capabilities and well trained personell in the wheelhouse. Ideally the OJLREC vessel should have both a bow thruster and two variable pitch propellers. The two persons at the helm (OILREC and towing vessels) must communicate very closely in order to make course adjustments. This is important in order to avoid deformation of the V-shaped boom.

During the tests it was found that the freefloating skimmer head tended to get entangled in the net protection around the freeboard of the V-shaped boom. This net protection as it turned out later could simply be removed. Improvement in the deck handling of the fully integrated oil containment system seemed necessary - too many deckhands were required during deployment and recovery and it was too time consuming!

The three boat 1st Back-up System also benefitted from the V-shaped boom in the centre giving equally good concentration of oil. But the system's pumping station was very exposed to debris clogging plus the towing of the combined discharge and hydraulic hose set by a third vessel was somewhat sensitive.

The pumping station had to be hoisted out of the Apex area for declogging. This was a time consuming and somewhat risky operation because the OILREC vessel had to move very closely to the boom and use its own crane to get the pumping station out of the ocean. - The discharge and hydraulic hose set had to pass over the side of the boom which also could be critical with a potential for mechanical damages.

In general the three boat 1st Back-up System had less pumping capacity and did not perform as well as the two-boat Primary System.

This was the costliest and most comprehensive NOFO oil-on-water exercise carried out since the first one in 1980. As it appears from the statistics and the discussions, it proved, however, a very successful one.

4.3 The Occidental Pipeline rupture in the British sector of the North Sea in November 1986.

On 26 November Occidental Petroleum company's Piper/Claymore subsea pipeline in the British sector of the North Sea spilled appr. 2.500 tonnes of crude oil. After one day's drift in the ocean the spill appeared as 26km2 slick. While the British reported that the oil slick had dissipated significantly by 29 November it appeared that what remained was drifting into the Norwegian sector in heavy westerly winds.

On 4 December the flight surveillance carried out by SFT reported slicks containing what appeared to be heavily weathered oil. The slicks were so near the coast just south of Bergen (where a large number of salmon farms would be threatened)that SFT ordered one NOFO system and 2 SFT systems to be mobilized. - Occidental had previously chartered a Norwegian vessel with a single ship, side sweep system that together with two tugs had followed the slick for a few days. These vessels had tried to break up the slicks in the heavy weather by hosing them down with water and steaming through them.

The NOFO system was quickly mobilized and arrived on scene in the early morning hours of 5 December: i.e. one OILREC vessel (S/V Gullbas) and one towing vessel (F/V Knester). The single slick then consisted of a dominant part blue shine and thick emulsion cakes spread over an area of appr. 5 x 2km. SFT had indicated based on overflights and observations from the on-scene commanding vessel that the slick contained 2000 tonnes oil emulsion. Samples of the emulsion cakes were measured to contain 45 to 47% seawater and the viscosity was appr. 28.000 cp.

NOFO's OJLREC vessel deployed its 500m long fence boom with 85cm freeboard in a J-formation with a cross bridle inside 55 ins. The wind was blowing from NE at 10 - 11 m/sec and the waves were high due to the previous days' gale conditions. The towing speed was 1,2 knots when the boom system approached the slick.

The log record from Dec. 5, 1986 then shows:

1240 hours: Oil begins to build up in thick layers and the towing speed is reduced to 1 knot.

1400 hours: Winds 7 m/sec. out of the NE. The freefloating skimmer with the crane operated 100 m hose system was deployed.

1405 hours: The skimmer's pumps were started up.

1430 hours: 23rn3 recovered (average pump rate 55m3/hour)

1445 hours: 42m3 recovered (average pump rate 76m3/hour)

1500 hours: Winds increased to 13,5 m/sec.

1510 hours: The skimming was stopped, the boom was empty.
A total of 72m3 had been recovered - average pump rate was 96m3/hour.

1515 hours: Turning the 500m boom system towards the SW.

1540 hours: Turned to SW 250 degr. into another slick area spotted by the OSC vessel.

1600 hours: The Cross Bridle wire broke.

1610 hours: Began recovery of the 500m boom system.

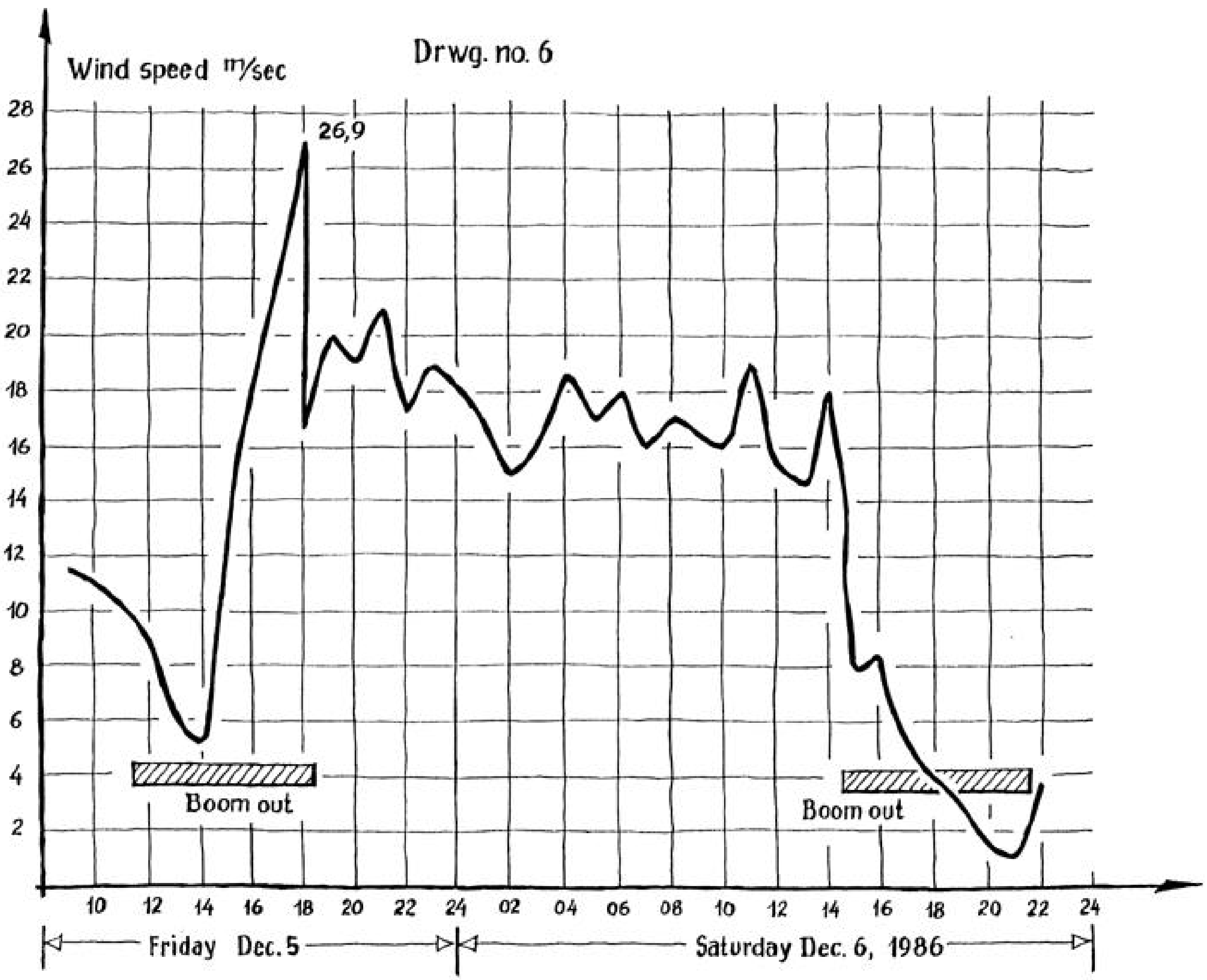
1700 hours: Winds 24m/sec. out of WNW 300 degr.

1805 hours: The entire boom system back on deck - final recovery in full gale winds - 27m/sec.

1 hr. 35 mins. towing and 1 hr. 5 mins. skimming with an average pumping rate of 66,5 m3/hour had been required. During this period the winds had increased from 9m/sec. to 13,5m/sec. in waves that probably approached 3m Hs. See drwg. no 6.

NOFO's system was deployed also the following day (Dec. 6, 1986). A full gale had been blowing during the night breaking up the emulsion cakes even further. At mid day an oil slick was detected from the SFT's aeroplane - the slick appeared to consist mostly of blue shine. Until 1400 hours it was still blowing hard (18m/sec. out of the NW). While the wind decreased the 500m J-shaped boom system was deployed at 1440 hours and towed into the slick over a 4,5 hours period. Very little oil was built up inside the boom and a SFT vessel was brought alongside the bottom of the J of the boom and used a vertical rope mop skimmer to recover 2 m3 oil emulsion and very little free water.

Drwg. no. 6


Wind speed m/sec
28
26
24
22
20
18
16
14
12
10
8
6
4
2
26,9
Boom out
Boom out
10 12 14 16 18 20 22 24 02 04 06 08 10 12 14 16 18 20 22 24
Friday Dec. 5
Saturday Dec. 6, 1986

Discussion:

This real life oil spill demonstrated clearly that the high seas 500m J-shaped boom system together with the freefloating skimmer with the 100m crane operated floating hose worked well in strong winds and waves that in all likelihood exceeded 2,5 m Hs. While the tension on the Cross Bridle wire that broke during the recovery of the boom must have been extremely high (in excess of 10 tonnes) the physical strength of the boom had proven to be very satisfactory. The freefloating skimmer system also stood up to the rough weather without any technical or physical damages.

In total NOFO's longterm development of a high seas, offshore oil containment and recovery system had satisfied the requirements of the Norwegian environmental authorities from 1976.

4.4 NOFO's oil-on-water exercise in Sept. 1990.

As usual this exercise took place in offshore conditions appr. 120 n. miles from the Norwegian west coast, this time in the vicinity of BP's Ula-field. This was a NOFO exercise where SFT's only system served as back-up except for a smaller 20m3 discharge where SFT's vertical rope mop skimmer was tested with an excellent result.

A total of 3 complete NOFO systems (of which one included a brand new automatic inflated oil boom), 1 SFT system and one BP single ship, side sweep system with an in-hull skimming device were in operation.

The UK participated with a surveillance plane and a dispersant plane, Norway with a helicopter and a surveillance plane while Denmark, the Netherlands, Sweden and France each participated with part time surveillance planes. An observer vessel carried a large number of national as well as international observers.

This chapter describes the equipment, vessel and airborne input during the most important discharge i.e. **discharge no 6 being a 250 m3 oil emulsion** (appr. 70% seawater content) from the Gullfaks field. On the one hand this was by far the biggest discharge during the exercise and on the other hand it was of special importance because for the first time it was a large **night discharge**. A helicopter surveyed the drift pattern from the tanker's discharge position 1000m in front of the boom systems and then gave instructions to the OSC/OILREC vessel how to attack the slick, based on the FLIR system's (Forward Looking Infrared camera) observations

NOFO's Primary two-boat System consisted of:

- A fully integrated oil containment system being a divided 420m long guide boom with 100cm freeboard (cylindrical) supported by a cross bridle, and a V-shaped boom of 1,5 m freeboard and with a submerged, horistontal net bottom.
- NOFO's free floating 350m3/hr. skimming system which had become their standard since 1985/6.

This equipment was operated by the OSC/OILREC vessel <<Far Turbot>>.

NOFO's 1st Back-up two-boat System consisted of:

- Identical equipment as per above.

SFT's 2nd Back-up three-boat System consisted of:

- 200m long 80cm freeboard boom (cylindrical) towed in a U-configuration
- A crane operated 85m3/hr. vertical rope mop skimmer (the system was deployed from the third vessel alongside the wide apex of the U)

NOFO's 2nd Back-up System was deployed but never came in operation due to a failure in the new boom's inflation hoses.

In addition to the FLIR and the other air surveillance receiving equipment <<Far Turbot>> carried NOFO's 40' Lab Container with improved measurement intstrumentation compared with the 1985 package. Other means to aid and observe the exercise were:

- current and drift prognosis radioed in from an oceanographic buoy
- night glasses and night binoculars
- SLAR (side looking airborne radar) and IR installations in the planes.

The discharge no 6.

The tanker discharged appr. 250m3 emulsion at an hourly rate of 120m3/hour between 1935 hours and 2230 hours (in complete darkness).

Weather.

The weather was not as strong as one might have preferred:

- mean wind speed 6 m/sec. out of NW
- waves 1,5m Hs with 2,7m H max.
- wave periods 5 secs.
- mean current 0,1 knot

Oil recovery and oil recovery results:

The oil recovery began nearly two hours after the tanker had begun its discharge and lasted for 85mins. - from 2128 hours until 2253 hours.

The oil recovery results into the **Primary System** as measured in the Lab Container onboard <<Far Turbot>> were:

- Total volume (incl. seawater) acc. to the flowmeter:	322 m3
- Of this the emulsion (with 76% seawater) amounted to:	162 m3
- Recovery percentage calculated back to crude oil	61,1 %
- Max. pump rates over a 3 min. period	310 m3/hr.
- Max. pump rate over a 15 min. mean period	300 m3/hr.
- Max. emulsion rate over a 3 min. period	263,6 m3/hr.
- Max. emulsion rate over a 15 min. mean period	235,2 m3/hr.

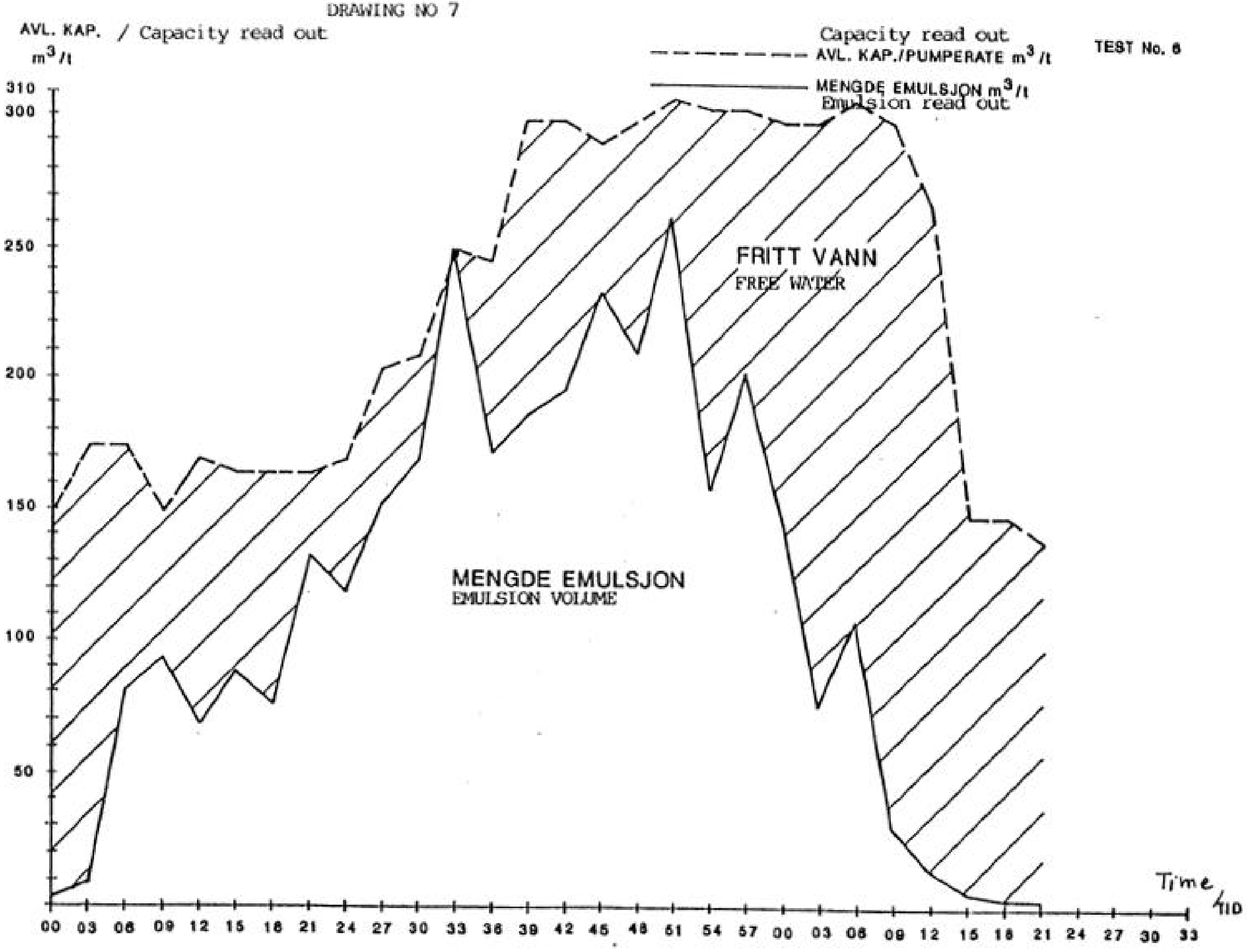
Nothing was recovered by the **1st Back-up System** due to a shut pump valve. SFT's **2nd Back-up System** recovered 4m3 emulsion with 81% seawater.

See drwg. no 7 as an illustration of pump rates, both totals and emulsions.

Discussions:

This was a success for NOFO's first FUR directed oil-on-water exercise in full darkness. The helicopter's video from the FUR clearly showed that some oil emulsion escaped under the towing line before entering the boom system. The slick spread significantly in width - most likely due to the relatively calm weather and weak current. Therfore oil also escaped on the port side of the OILREC vessel <<Far Turbot>>. The FLIR video did not show any significant leakages under the Primary System's boom (neither the guide booms, nor the V-shaped boom).
While the helicopter operated FLIR did assist in the good performance there is no doubt that the darkness alone with oil emulsion escaping unnoticed caused more losses than would have been the case in broad daylight.
When including some more details from this night operation it is worthwhile mentioning that the first overflights should be made at 1000 ft. to 1500 ft. level **without zooming the FLIR camera.** Thus one gets a good overview. Later flights should include flying at lower altitudes and with zooming of the camera. - The emulsion thicknesses were measured at sea surface level and in the light brownish areas the thicknesses varied between 1,3 and 2,1mm. However, inside the slick the variation in thickness is significant. For estimation of the emulsion during the night discharge (no 6) 1mm thickness may be considered an average for small, freefloating slicks. Calculations of the thickness in the main slick indicated an average thickness of appr. 3mm. These calculations

DRAWING NO 7



Kurveblad nr. 8

PETCON A/S

were based on a slick measured by IR at 36.000m3 and the amount of discharged emulsion of 110m3. A lot of reservations should be taken into account because these estimations refer to the first experiences gained by NOFO from an oil recovery operation in full darkness.
Finally a comment on a different subject. It was found that the drift prognosis for the slicks were very useful. But they were presented in tables during the exercise. The operators would have preferred map presentations of the slick.

4.5 NOFO's oil-on-water exercise in 1995.

Background:

This exercise took place at the Frigg field in August and the weather was a pleasant westerly wind at 2,7m/sec. with a 1m Hs wave condition. The current was a very moderate 0,1 knot.

NOFO's fleet consisted of two systems each with one OILREC vessel and one towing vessel. SFT joined the exercise with the Coastguard vessel <<Nordsjobas>> that operated as OILREC vessel and F/V <<Smaragd>> that operated both as a towing vessel and an OILREC vessel.

On NOFO's OSC vessel the contingency comprised:
- a 400 m long heavy duty boom system (1,3m freeboard) towed in J-configuration supported by a Cross Bridle
- a 350m3/hr freefloating skimming system
- a 40 ft. Lab Container
- an Aerostat for on site surveillance (the Aerostat was deployed from the deck and permanently moored at a 300 ft. level)
- Receiving station for helicopter down link transmissions
- Equipment for measuring environmental data (transmitted from a buoy)
- Oil drift model program

Air support was also given from a surveillance plane (w/SLAR/IR/UV) and a helicopter with FLIR camera.

This paper concentrates on **Discharge 3** in the exercise plan. (The two first discharges covered dispersant tests and Discharge no 4 in darkness was reduced significantly due to problems with an unstable emulsion).

Discharge 3 aimed at a full system test for SFT's Coast Guard vessel <<Nordsjobas>>:

- tow tests of the 800mm dia. 235m long fuily integrated oil containment system with a V-shaped boom section (0,5 -1,0-1,5 knots)
- testing of a new high frequency transducer for continuous measurements of the oil thickness in the Apex area of the V-shaped boom section
- testing of the 250m3/hr. freefloating skimmer system
- pumping of the recovered oil through an onboard manifold onto a towed temporary oil storage bladder
- discharging the towed temporary oil storage bladder at sea into a trailing OILREC vessel.

It was the first time that SFT carried out this kind of complete system test where a potential shortage of tank capacity on the OILREC vessel would require offloading into an ocean going temporary oil storage bladder.

One of NOFO's vessels discharged the oil emulsion at a distance of appr. 400m ahead of CG/V Nordsjobas. The log recorded the following:

Start up	:1605 hours
Stop	:1626 hours (total discharge time 21 ins.)
Total discharge	:50m3 (at a rate of 143m3/hr.)
Oil emulsion	:29 m3 with a seawater content of 52%*
Viscosity	:900 cst
Net oil volume	**:14 m3**
Free seawater	:21 m3

* The emulsion had destabilized from the previous 67,5 %.

Boom towing:

The boom system was deployed at 1230 hours and according to the log data the boom was towed in the oil emulsion as follows.

Tow tests in oil	:1626 - 1640 hours (14 mins.)
Oil recovery from the boom's apex	:1640 - 1739 hours (59 mins.) w/ the 250m3/hour skimmer
Last oil recovery from the boom	:1830 hours*

* when the 250m3/hr skimmer was stopped there was still some oil emulsion left inside the apex and this was recovered by the other SFT vessel with the vertical rope mop skimmer nearly one hour later.

Volumes pumped into the temporary oil storage bladder from the boom:

The measurements were made at the manifold aboard the CG/V Nordsjobas.

Total volume	97 m3 hereof:
Free water	56,4 m3
Oil emulsion	40,6 m3
Water content	66% (which was checked in the Lab Container)
Net oil recovery	13,8 m3 (40,6 x 34/100)
Against discharge	14,0 m3
Percentage rec.	98,5%

Note: There is a plus/minus 10% margin in the correctness of the measurements!

Volumes pumped from the temporary oil storage bladder into the OILREC vessel:

Total volume	78 m3 hereof:
Free water	47,4 m3
Oil emulsion	30,6 m3
Water content	66%
Oil pumped	10,4 m3 (30,6 x 34/100)
Percentage rec.	74%

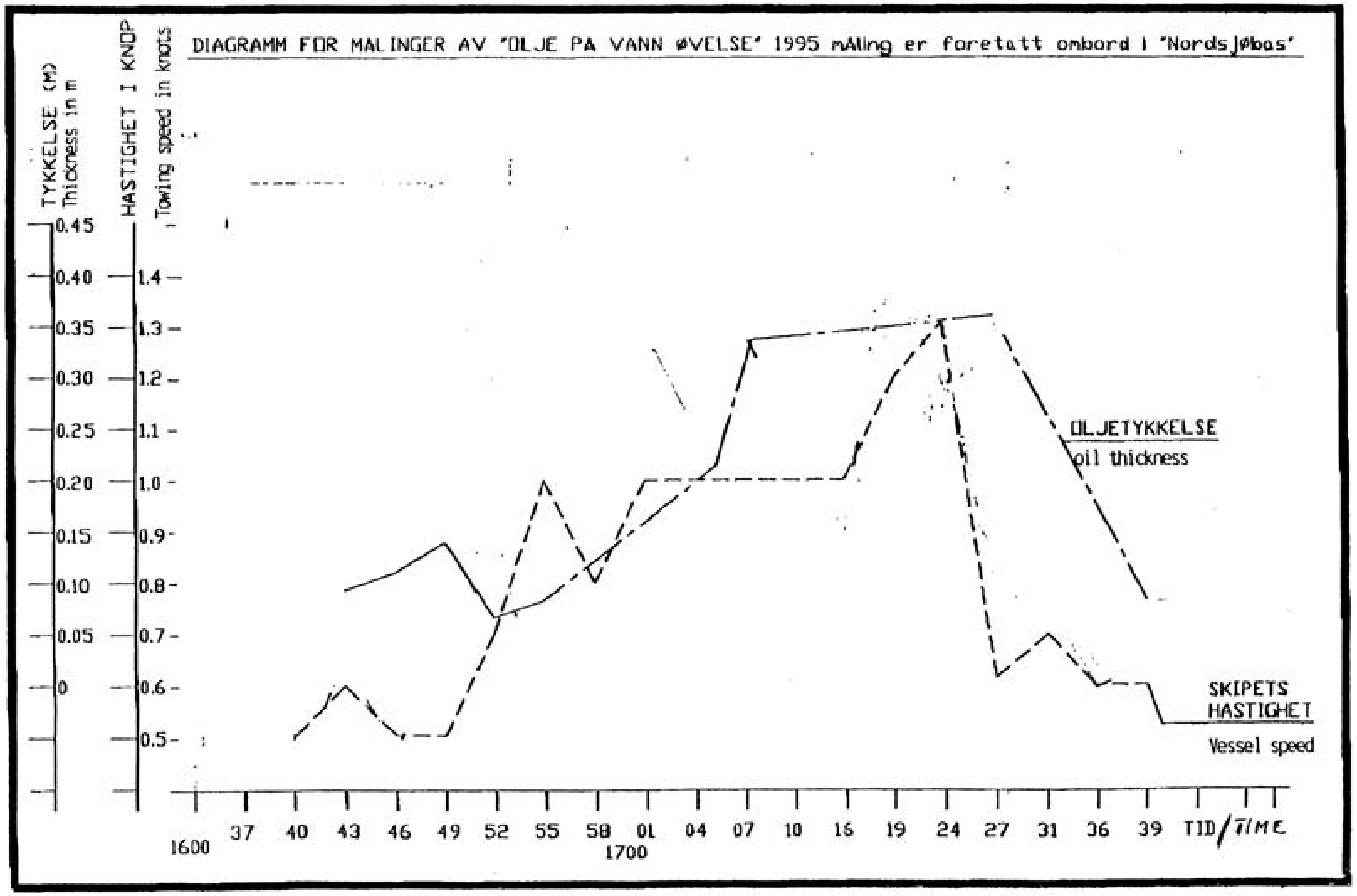
The **differences** between what was recovered aboard CG/V Nordsjobas and pumped into the bladder and then pumped aboard NOFO's OILREC vessel is explained by two incidents.

The temporary storage bladder got a small cut caused by CG/V Nordsjobas unfortunate manoeuvering and the aft end overload links burst due to incorrect handling during emptying of the bladder.

Towing speeds and oil thickness measurements:

The new transducer had been connected to the skimmer head and measured the oil thickness in the apex area. Enclosed is drwg. no 8 showing the relationship between the vessel's towing speed through the ocean and oil thicknesses measured in the apex area of the V-shaped boom.

DRAWING no 8
Recordings made by NPCA personnel onboard CG/V "Nordsjøbas" during discharge no 3



Data were recorded every 3rd minute. And the most interesting period is the peak period between 1701 hours and 1724 hours when the towing speed increased from 1 knot to 1,3 knot. Prior to this period the oil thickness was less than 11cm at 0,5 knot while during the peak period the oil thickness increased to an average well over 30cm. Higher towing speed pushed more oil into the apex area of the V-shaped boom and more oil was fed to the skimmer. This can also be seen quite clearly form the records of the amount of free water pumped. Free water decreased significantly while the amount of oil emulsion recovered during this 23 minutes' period was by far the highest.

Summary:

First 24 minutes (1637 - 1701 hours):	11,2 m3 emulsion recovered
Next 23 minutes (1701 - 1724 hours):	19,4 m3 emulsion recovered
Final 15 minutes (1724 - 1739 hours):	10,0 m3 emulsion recovered

During the first period the boom system was still being filled and during the last period it was being emptied. - The recovery rates averaged 100m3/hr from 1637 hours to 1701 hours, then decreased to 80 m3/hr. from 1701 hours to 1724 hours and subsequently averaged 110m3/hour.

Final remarks:

While the entire exercise suffered somewhat from the difficulties with the unstable emulsion this part of the exercise was performed as planned but with a reduced amount of emulsion which might have given more conclusive results. And SFT had reason to be satisfied with the overall performance of their total oil containment, recovery and temporary storage system.

5. Advances in the Norwegian oil spill preparedness since EKOFISK BRAVO in 1977 until today.

The Norwegian oil spill preparedness has progressed significantly over a 20 year period and this is no doubt much thanks to NOFO's oil-on-water exercises. This kind of real life experience has offered unique opportunities for understanding what goes on during a spill. However, it may be a potential weakness that much of the Norwegian efforts have focused around crude oil spills. This because no spill is alike and the heavy oil (f.ex. Bunker oil) spills are much more costly and difficult to handle compared with crude oil spills. This is why SFT in recent years has taken a more active role in developing an oil spill response strategy incorporating both an efficient high seas capability along the coast and an inshore and onshore beach cleaning capability.