ECUMOIRE II: EVALUATION OF THREE OIL RECOVERY DEVICES OFFSHORE

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ABSTRACT: *In June 1983, three French oil recovery devices were evaluated at sea off Toulon. These tests were conducted by CEDRE with the help of the French Navy, which is responsible for fighting pollution at sea. Skimmers evaluated were the SIRENE 20 skimming boom, the ESCA offshore weir-type skimmer, and the STOPOL oleophilic drum-type skimmer associated with a deflecting boom.*

In the tests 35 m^3 of oil were spilled; 25 m^3 were recovered. The SIRENE and the STOPOL, which are selective skimmers, were towed and used by a supply vessel, whereas the ESCA required a little tanker to settle the large collected mixture of oil and water. During most tests the sea was moderate.

*Average throughput efficiency was about 70 to 80 percent for the three skimmers. Oil recovery efficiency (*i.e.*, the oil content in the recovered product) averaged 80 percent for the STOPOL and 50 percent for the SIRENE. For these skimmers, the recovered oil was stored in a 160-m^3 flexible floating tank towed by the support ship.*

Tests were more qualitative than quantitative owing to the difficulty of monitoring some parameters of the simulated spill. However, the tests permitted a positive conclusion about the ability of the three devices to recover oil effectively in a moderate sea. Some advantages and drawbacks of each system were also demonstrated; for example, SIRENE is the least affected by waves, whereas STOPOL is the most selective and ESCA the least affected by the viscosity of oil.

Pursuant to these trials some improvements were made that will be evaluated in the near future.

CEDRE was created in 1979 to advise French authorities on suitable procedures, materials, and products to control accidental water pollution. For this purpose CEDRE must coordinate and initiate research and development in related fields and test, evaluate, and eventually improve materials and products.

From its creation CEDRE has been interested in a device, the SIRENE 20, developed by the Centre National pour l'Exploitation des Océans (CNEXO), to recover oil at sea. The main advantage of this skimmer is its low inertia, which gives it good wave-following characteristics. The results of tests in test tanks and in harbor were promising enough to prompt an evaluation of the performance of the recovery device at sea under real conditions of use. Tests without oil first permitted improvements of the skimmer so that it became mechanically reliable and behaved well in moderate sea. The next and last step was to ensure the skimmer's ability to recover oil effectively at sea. That was the main purpose of the experiment Ecumoire II, which took place offshore Toulon in June 1983.

Tests were conducted by CEDRE and the Commission d'Etudes Pratiques de Lutte Antipollution (CEPPOL), with the help of the French Navy, which is responsible for fighting pollution at sea, the Port Autonome de Marseille (PAM), the ESCA Company, and the association of two French oil companies, Compagnie Française de Pétroles and Société Nationale Elf Aquitaine, with the French Institute of Petroleum.

Again, the first aim of this series of tests was to evaluate the ability of the SIRENE 20 to recover oil effectively at sea under real conditions of use, in this case from a supply-type vessel of the navy equipped with a jib boom. Previous tests had confirmed the potential utility of this device.

Due to the limited capacities of flexible floating tanks associated with a skimmer operated from a vessel without real storage capacity on board, a second test evaluated the possibility of operating the SIRENE 20 from a ship capable of storing liquids on board, a small tanker. For this test, conducted without oil, two skimmers were towed alongside the *Chasse Marée,* a 600-dead-weight-ton (dwt) tanker, belonging to PAM and under contract with the navy.

Some months before the experiment two oil recovery devices newly developed by French companies were ready for an evaluation of their ability to recover oil at sea. We therefore decided to profit from the different tests of the SIRENE 20 to evaluate the performances of the ESCA and STOPOL skimmers.

Eventually five tests were planned for the experiment Ecumoire II, including one of the behavior of the STOPOL in its new shape, the dimensions and weight of the skimmer being considerably less than those of the device that had been tested before.

Description of the skimmers tested

SIRENE 20. The SIRENE 20 is a direct suction skimmer integrated with an inflatable boom (Figure 1). It is manufactured in France by T. R. Sillinger, a company specializing in inflatable boats. The device comprises a small flexible boom whose central part opens in a slot and whose lower lip limits the entry of water into a pocket that varies in form to ensure thickening of the slick. While water drains freely to the bottom of the pocket, the upper oil-rich layer is transferred to a storage container towed by or integrated into the vessel carrying the pumps. This vessel may be one of the two vessels towing the boom or a third barge, for example. The two double-acting diaphragm pumps are driven by a 70-hp compressor. The SIRENE has a 20-m swath and can travel at from 1 to 3 knots. It travels optimally at 2 knots, so that its encounter rate (*i.e.,* the volume of pollutant it encounters) is around 70 m^3/h for a slick 1 mm thick. The encounter rate can be improved for very thin slicks by adding additional booms since the pumps can collect material at 80 m^3/h.

The skimmer can be towed by two ships in a "U" or even better a "J" configuration, but its use by a single ship, through a jib, diminishes certain difficulties in handling and helps maintain a good configuration. Simple in design and fairly easy to deploy, this system can also be used while moored in a river or estuary facing incoming slicks, and it therefore already equips French agencies.

ESCA offshore skimmer. The ESCA offshore oil recovery device was developed from a harbor skimmer, the ESCA barge, which has been used often by PAM and by the French authorities in conjunction with booms for coastal protection.

Designed to be used with a small coastal tanker, the ESCA offshore skimmer includes a weir skimmer on a catamaran-type support connected directly to the tanks of the ship by a large diameter hose (Figure 2). A valve allows direct flow from the weir toward the tanks

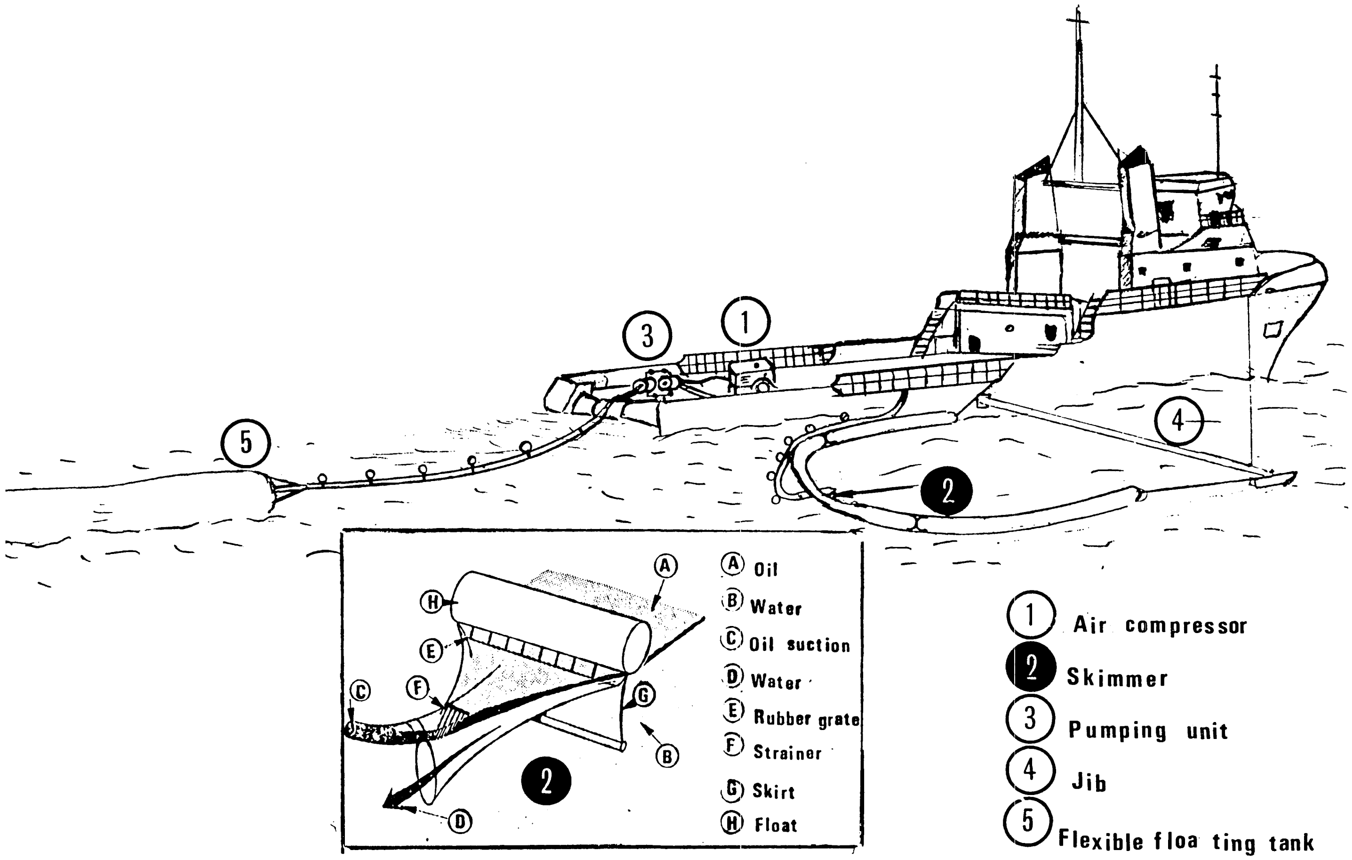

Figure 1. The SIRENE 20

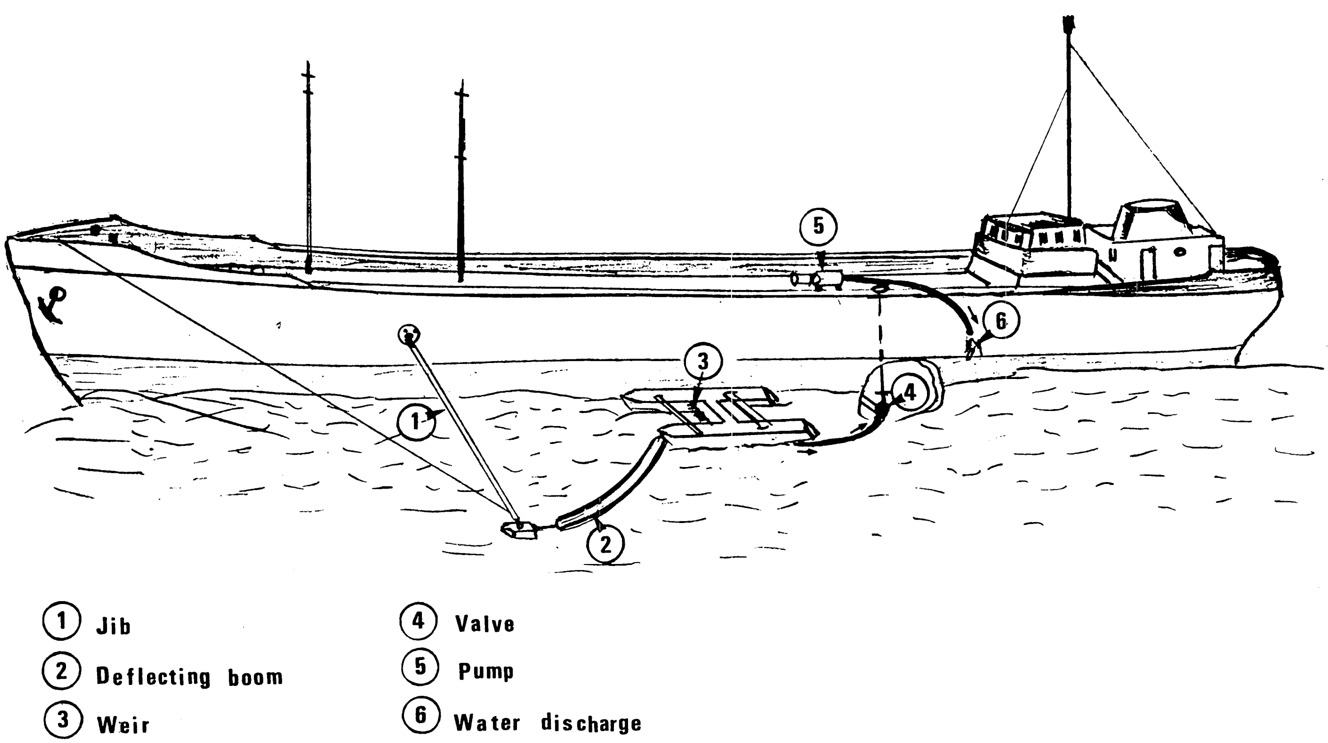

Figure 2. The ESCA offshore skimmer

through a hole in the hull a few meters under the waterline. The oil-water mixture enters the tanks by gravitation alone, which limits the formation of emulsion and allows rapid settling and immediate extraction of water. It is therefore inaccurate to consider the selectivity of this system as the ratio of oil to water in the mixture flowing down the weir to the tank of the ship insofar as water entering is more or less immediately extracted from the tanks and discharged to the sea. The system may thus permit the recovery of very viscous pollutants by a carrying effect.

A deflecting boom enlarges the swath of the skimmer head so that the total sweeping width of the recovery device is 12 m and can be 20 m using a longer jib. For these tests the boom was a 14.5-m-long Iroise boom, developed, like the jib, by the French Petroleum Institute. It consists of beam floats and a vertical screen made up of a semirigid plastic skirt and fastened to the top and bottom of a vertical frame. The skimmer itself is a catamaran 3 m wide and 4 m long made of painted steel. The semiflexible hose is 400 mm in diameter and equipped with a connecting flange. Projecting slides on the hull guide the flange down to its position in front of the opening in the hull, in this case, 1.5 m under the waterline. Watertightness is obtained by eccentric clamps operated from the deck, so that the device can be completely worked from the deck without underwater operation. The opening in the hull is obturated by a valve in the contiguous tank operated from the deck. In the present model, the recovered mixture flows directly into a tank, but in future ones an entrance lock will be provided.

The ESCA offshore skimmer has been developed by the ESCA Company with the help of different French agencies, CNEXO, and PAM, owner of the support ship. Preliminary tests with little spilled oil were promising enough to consider evaluating the skimmer's real capacity to collect a significant amount of spilled oil in an Ecumoire test.

STOPOL 3P. The STOPOL 3P was developed and refined through the association of the French Institute of Petroleum and the two French oil companies Compagnie Française des Pétroles TOTAL and Société Nationale Elf Aquitaine. The system is designed to be towed alongside a ship, generally a supply ship as it was initially designed, to recover oil spills occurring during oil exploitation. Because there is little storage capacity onboard these ships, a selective skimmer is used so that the recovered product contains a small amount of free water. This makes it unnecessary to separate the water onboard and reduces the required pumping and storage capacities.

The skimmer used is a drum-type oleophilic skimmer. The whole system comprises a CAROL skimmer, consisting of two contrarotating oil drums on a catamaran-shaped floating frame and its power pack, a deflecting boom, and a jib (Figure 3). The boom and jib are the same as those in the ESCA offshore skimmer described above.

The two drums consist of a cylinder covered with an oleophilic skim. Cylinder diameter is 60 cm, and length 1.20 m. The drums rest on a frame of four floats held still by cross-members. This floating frame holds the hydraulic motors and supports, the double-screw volumetric. The transfer pump (EGMO W 100) is located on one side of the parallel paired floats. Its maximum capacity is 50 m^3/h of oil. The CAROL skimmer is 3.9 m long and 2.3 m wide and weighs 950 kg. The 12-m-long jib is fitted at both ends with articulated braces, with stainless steel connections for pullies and hawsers and with a stainless steel bracket to be fixed on the bulwark of the ship. The jib weighs around 110 kg.

Test conditions using oil

Test location and environmental conditions. Considering the risks of spills along with the possible losses of spread oil, we decided to operate far from the coastline so that time allowed treating unrecovered oil and favored its natural dispersion before it could reach the coast. The zone chosen was 30 nm south of Toulon. The Mediter-

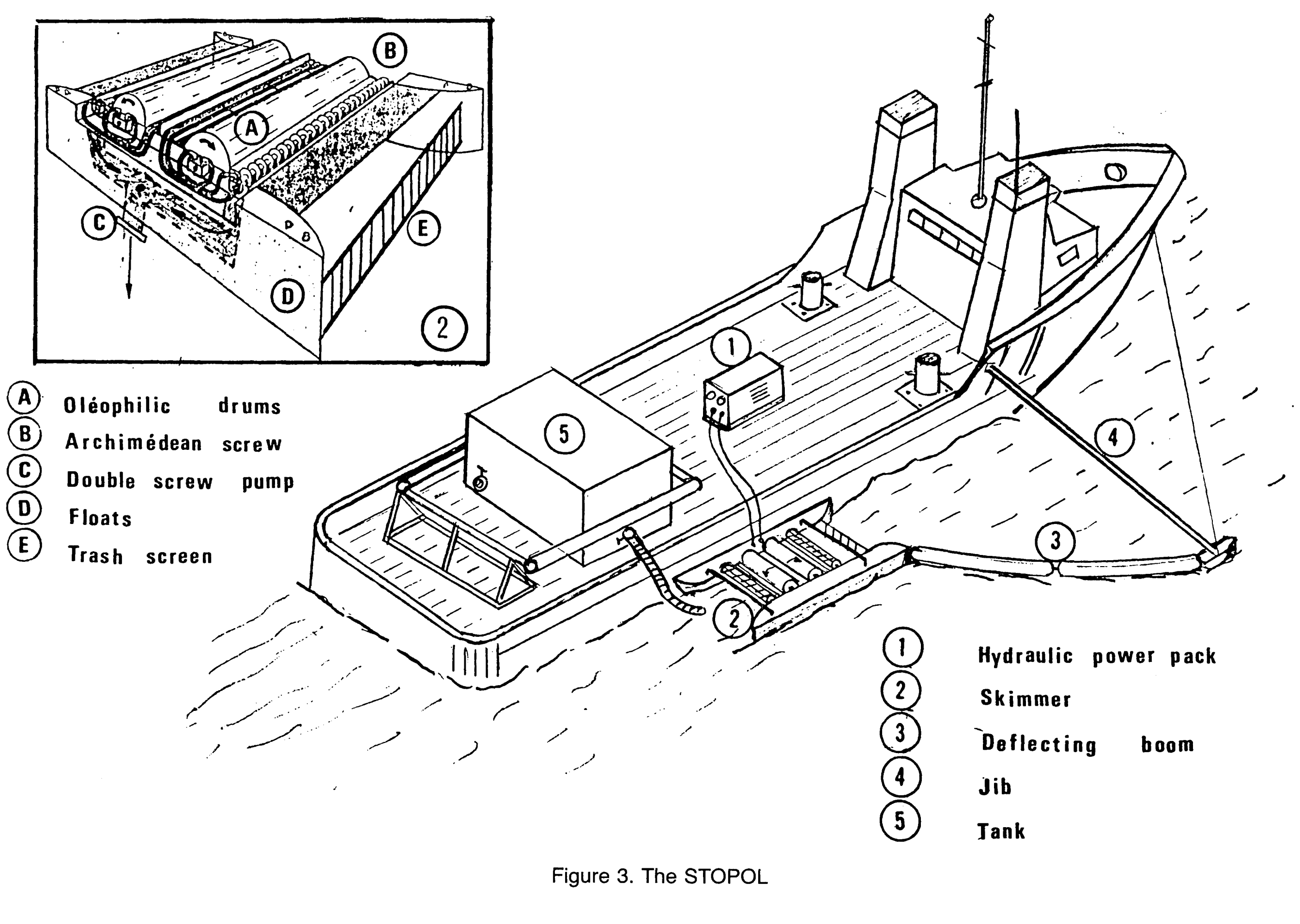

Figure 3. The STOPOL

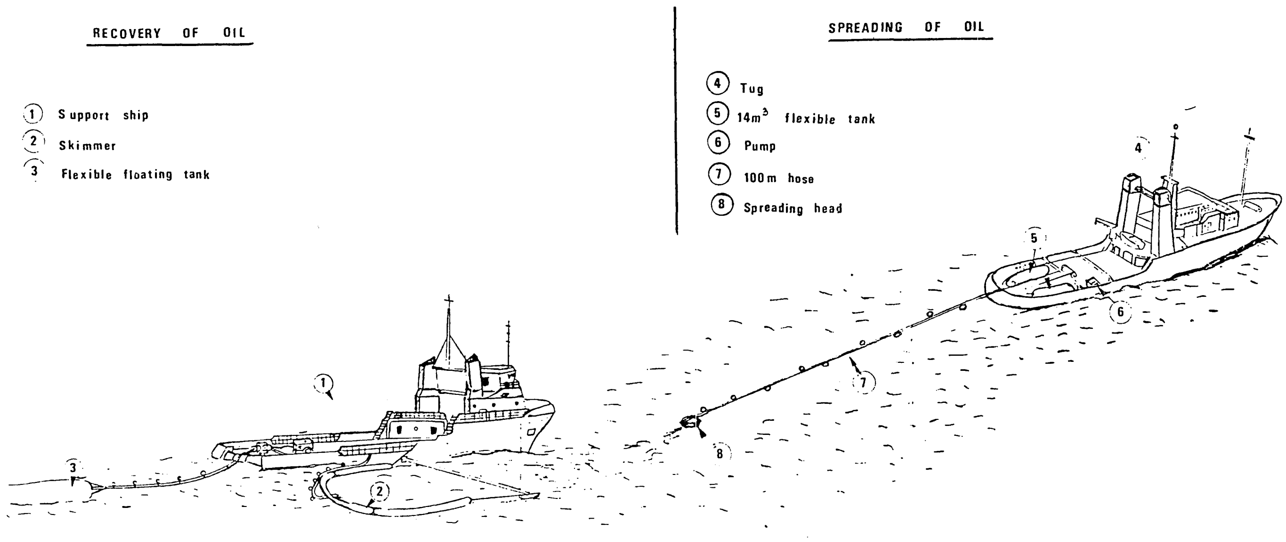

Figure 4. The test equipment

ranean Sea was chosen over the Atlantic Ocean or the English Channel because in these seas prevailing winds and currents favor faster moving of the slicks toward shore. Furthermore, in March the sea state is generally too bad in these seas to operate offshore skimmers, which are limited to force 5. For the test, wave conditions were hoped to be force 4 (2-m waves). These conditions were met in the tests of SIRENE and ESCA; but for the STOPOL, the state of the sea was no more than force 2 (5-cm waves).

Test facility and procedures. For each test involving oil, two vessels were used, one to spread the oil and the other to support the recovery device (Figure 4). The 16,000-hps ocean-going tug *Abeille Normandie* supported the spreading device. It had on its deck two flexible tanks, each with a capacity of 14 cm^3, and a pumping unit. A spreading head is towed 100 m abaft and connected to the pumps by a discharge hose. This head was designed to allow a gentle spreading of the oil on the surface, thus avoiding the oil's initial mixing into the water column. The oil emerges on the top of the circular float and runs over the sides into the water. The spreading pump was not that initially designed but an air-driven double-acting diaphragm pump unit from a SIRENE skimmer.

Discharge rates were predetermined to simulate a 1-mm-thick slick swept by the devices. Rates depended on the characteristics, swath, and speed of each skimmer: 54 m^3/h for the SIRENE advancing at 1.5 knots, 44 m^3/h for the ESCA at 2 knots, and 22 m^3/h for the STOPOL at 1 knot. Unfortunately, due to limited air production the intended rate was reached only for the STOPOL; for the SIRENE actual rate was no more than 25 m^3/h, 17 m^3/h for the ESCA. The pump was calibrated prior to spreading the oil with an electromagnetic flowmeter and measured time of spreading confirmed expected values of flow rates.

Figure 5. The ESCA skimmer under test with oil

A medium oil was chosen for the test since the aim was to ensure skimmers could recover some types of oils and not to evaluate skimmers' maximum capacity for very viscous oils, which are the most difficult to pump. There were two main reasons for this choice. First, we knew that the SIRENE would have problems skimming very viscous products and that these problems could be overcome by using another type of pump, set on the water just behind the skimmer itself. Second, since we were not sure of collecting all the spilled oil, we preferred to use an oil fluid enough to be dispersible. The oil chosen was a fuel oil with a viscosity of 50 centistoke (cs) at 50° C and of 800 cs at 14° C, which was the average temperature during the tests. The release period was chosen so that there was time to get stable conditions in the systems and still have 10 to 15 min of stable conditions for measurements. This condition was reached in principle, but due to wave motion dynamic conditions were observed during the entire test period. These variations cannot be avoided and will also be present in an operational system. The quantity of released oil was predetermined to be 14 m^3 for each test so that each skimmer would work at least 15 min. In fact, as the spreading rate was half the time intended, the release period was more than 30 min for the SIRENE. For the STOPOL two spreadings of 7 m^3 were made, the first in 20 min, mainly at a rate of 21 m^3/h, the second in 40 min, with a main rate of 10 m^3/h. For the ESCA only 7 m^3 of oil were released in 25 min, with a main rate of 17 m^3/h.

The oil was to be released so that all the oil arrived within the entrance of the devices (Figure 5). This was done to be sure of the real quantity of oil encountered by the skimmers and also to limit the volume of unrecovered oil. This aim was well achieved for the SIRENE and STOPOL tests since they were activated by a very maneuverable vessel.

But the small tanker carrying the ESCA offshore skimmer could not maneuver to keep the spreading head just in front of the jib at the entrance of the device. This is why only 7 m^3 of oil were eventually spread, after oil losses appeared on the sides of the device.

The navy vessel *Chevreuil* was used as support for the SIRENE and STOPOL skimmers. This supply ship is 52 m long and has a beam width of 7.5 m, a draft of 3.2 m, and light displacement of 400 tons. Ship power includes two 1,000-hp diesel engines and an 80-hp bow thruster. Equipment onboard includes a 6-ton crane telescoping to 12 m and aft a 50-ton hoisting gantry, and is designed for coastal towage and oil spill control. Since this ship has no real capacity for storing the recovered oil, a Dracone flexible floating tank was towed to the ship as would be be done in a real operation. The Dracone used belongs to the navy. Its capacity is 160 m^3, its length 50 m, and its empty weight 2.2 tons.

The *Chasse Marée* is a 640-dwt tanker. It is 51 m long and has a

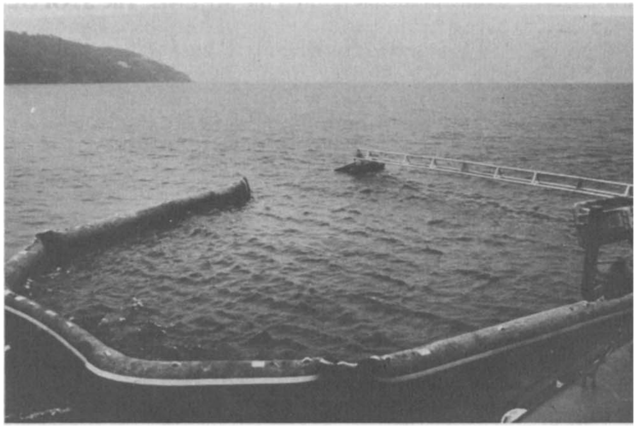

Figure 6. The SIRENE 20 under test without oil

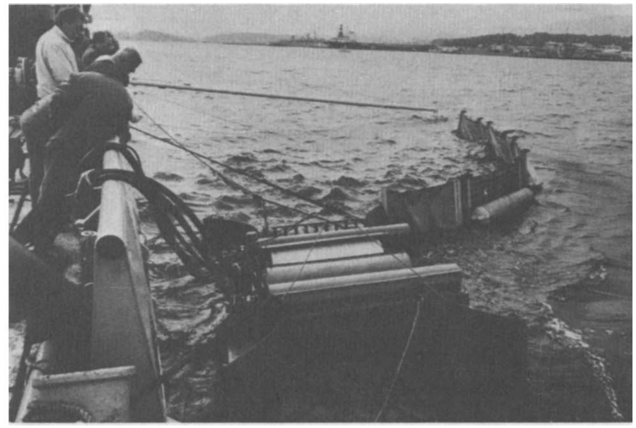

Figure 7. The STOPOL under test without oil

beam width of 8 m and a draft of 2.8 m. It is powered by two 160-hp diesel engines and has a fixed-blade propeller. Despite its poor maneuverability, it was used as support for the ESCA offshore skimming device since it was the only appropriately equipped ship available. Since ship power was insufficient to propel the ship as well as drive the inboard pumps, a vortex self-priming pump was used continuously to discharge the water collected with the oil when the mixture settled.

Figure 4 shows how the test ship and equipment were arranged. Test procedures were very detailed to accommodate regulations and backup measurements. The basic design was to deploy the skimmer at sea, deploy the oil slick generator, dump the oil on the sea, operate the skimmer to collect the oil, and measure the skimmer's performance. For each test, the following independent parameters were specified: forward surface speed, oil spreading rate, and skimmer pumping speed. The selected speeds corresponded to optimal values observed during previous tests in test tanks.

Oil spreading rate was supposed to represent a real spill. Following seas were preferred to limit surface agitation in front of the skimming devices, but due to difficulties in maneuvering the *Chasse Marée,* the end of the ESCA test was done head-on sea.

Data on the following were collected:

- sea state
- relative velocity between skimmer and sea
- samples of released oil
- samples of recovered product with short intervals during each test
- total volume of collected product
- total volume of collected oil (after settling) or of emulsion

Three quantities were defined to characterize the performance of the skimmer. Throughput efficiency (TE) is the percentage of oil collected divided by the oil encountered. The oil encountered is equal to the oil released, except for the ESCA device, due to losses not attributable to the skimmer. Recovery efficiency (RE) is the percentage of oil in the skimmer-collected mixture. Oil recovery rate (ORR) is the calculated flow of oil collected by the skimmer, exclusive of seawater.

During the first day at sea the SIRENE and ESCA offshore skimmers were tested with oil (during morning and afternoon respectively). The second day was dedicated to emptying the Dracone to evaluate the total volumes of oil and water collected by the SIRENE and to test the STOPOL without oil. During the third day, after testing the possibility of operating two SIRENE 20 from the *Chasse Marée,* which was first self-propelled and then towed, the STOPOL 3P was tested with oil.

Test results

Results of tests without oil. No problem was encountered when the self-propelled *Chasse Marée* towed two SIRENE 20, one on each side (Figure 6). The little tanker maneuvered at speeds from 1.5 to 3 knots. The only limit to using this ship as a support is its lack of crane to establish the skimmers and their jibs. This can easily be done with the help of a small ship, a coast tug for example. When towed by a supply vessel, sistership of the *Chevreuil,* the *Chasse-Marée* was inclined to luff, and the tug could not force the tanker to sweep a precise place. Thus, the operation of SIRENE from a towed barge is not advisable when controlling scattered small slicks but only when working on a large slick. These two observations confirm the interest of an oil recovery device including two skimmers like the SIRENE 20 activated by a small tanker. The tanker would preferably be 2,000 to 3,000 dwt and equipped with a controllable pitch propeller and a bow thruster.

The preliminary test of STOPOL without oil proved very useful since it allowed the adjusting of connections between the skimmer and the support ship (Figure 7). Indeed, bad connections cause the skimmer to list and be in bad trim. Launching and installing the skimmer was quick and easy owing to the hydraulic crane of the *Chevreuil.*

Results of tests with oil. Results of the skimmer's performances at sea with oil are presented in Table 1. The first four column headings represent independent variables and the last three dependent performance variables.

Table 1. Skimmer performance test results

Device tested	Forward speed (knots)	Sea state (force)	Oil released: Volume (m^3)	Oil released: Distribution rate (m^3/h)	Oil slick thickness (mm)	Oil encountered (m^3)	Performance[1] (percent): TE	RE	ORR
SIRENE 20	2	3–4	14	22	0.3	14	72	40	10
ESCA	2	3–4	7	17	0.4	6	50	99	8.5
STOPOL									
(1)	1	1–2	7	21	0.4	7	75	75	9
(2)	1	1–2	7	10	0.2	7	80	80	6

1. TE = throughput efficiency, RE = recovery efficiency, ORR = oil recovery rate

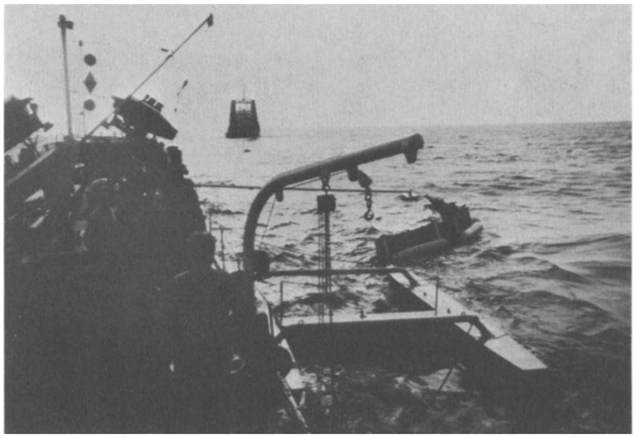

Figure 8. The catamaran-supported weir of the ESCA skimmer

Average thickness of the slick is the ratio between the rate of oil encountered and the products of the swath by the speed of advance. In fact, the real thickness of the slick encountered was two to three times this ratio since the width of the slick was two to three times less than the swath of the skimmers.

Recovery efficiency is the average value of samples taken during the stable conditions in the systems, except for the ESCA. The value indicated for the ESCA reflects the absence of water in the samples taken in the tank after continuous settling and discharge of water during recovery. This settling is part of the skimmer's normal working conditions. The percentage of oil in the product flowing into the tank was more than 20 times less, but is of no consequence except for the tank capacity required for settling.

For the STOPOL two different values of distribution rate were examined corresponding to two different settlings of the CAROL skimmer. If the rate is low, it is possible to work more quickly, lowering a central barrier between the two drums. In this case the first drum is the main recovery device and the second only recovers oil losses. Alternatively, if the rate is high, speed has to be reduced and the barrier is placed aft the two drums, which then work in parallel and play the same role.

It is impossible and even dishonest to establish a final comparison of the three skimmers according to the test results. Test conditions were neither the same nor equally propitious for the three devices, which moreover were not designed for the same purpose. For example, the low viscosity of the oil favored the SIRENE. The STOPOL is expected to have a better performance with very viscous products and the ESCA is unaffected by viscosity. The low flow rate was unfavorable for the ESCA, whereas the STOPOL was limited by the recovering capacity of its drums and the SIRENE by its pumping capacity. Also, the sea was calm for the STOPOL and agitated for the others. The poor maneuverability of the *Chasse Marée* prevented the ESCA from operating in good conditions (Figure 8).

In other respects the RE and ORR values shown in Table 1 have limited precision, mainly due to the difficulties encountered when emptying the flexible floating tank.

However, these tests showed some of the advantages and drawbacks of each device.

The SIRENE 20 is the least affected by waves and would work in seas to force 4. Its recovery efficiency is good enough to consider working with flexible floating tanks. On a given thickness of oil its encounter rate is higher than that of the two other devices. On the other hand, it is actually limited to less viscous products due to its suction length.

The ESCA is certainly the most rustic and robust. It is also the least affected by variations in the viscosity and thickness of oil encountered. Since it recovers large amounts of water with the oil, however, it is necessarily associated with a vessel or barge with large storage capacity.

The STOPOL is the more selective and can be recommended for recovering small spills using vessels without storage capacity. Its oil recovery rate is low but is expected to increase with increasing viscosity of the oil, as generally seen in real spills. It is certainly the most sophisticated.

Conclusions

The test program was considered a success for many reasons. The aim of the trials, to evaluate the ability of devices to recover oil effectively under real operating conditions, was realized. Moreover, some qualities and limits of each skimmer were identified. The trials did not permit comparing the performances of the three devices absolutely, but this was not the test objective since the skimmers were not designed for the same purpose. Following the trials the STOPOL was modified: the CAROL was disconnected from the support ship by using a second length of boom to tow the skimmer at the apex of a "U"-shaped boom. This new configuration would allow the STOPOL to be affected less by waves, a prediction confirmed by new tests. The French Navy has acquired some SIRENE 20 skimmers to equip its vessels and concluded an agreement with one company to equip small tankers with ESCA offshore recovery devices.