# FULL-SCALE TESTS OF A GRAVITY-TYPE SEPARATOR

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**ABSTRACT:** *From September 30 to October 4, 1991, CEDRE carried out a series of tests on a gravity-type separator (SEPCON) to assess the possibility of its use downstream from a skimming barrier. The apparatus was supplied for these tests by its constructor, the German company JAFO Technology, and is entirely self-contained and designed to accept an input of 80 $m^3/h$. This equipment was particularly adapted for conditions likely to be met during an accidental pollution off the Norwegian shore, where it had previously undergone tests.*

*The tests carried out at CEDRE involved two petroleum products: marine fuel 50/50 (50 cs at 50° C) and heavy fuel (bunker C). A maximum output was required with a level of hydrocarbons in the mixture varying from about 15 to 50 percent.*

*Due to the inability of the 50/50 fuel to settle naturally in water, some problems arose, which caused mediocre results. A modification of the internal position of the interface detectors could improve performance. Bunker C tests had better results, although the oil's high viscosity resulted in more water in the oil output. In general, the results obtained for the coil content in the water output are satisfactory (almost always less than 1 percent) although performance needs to be improved for the water content in the oil output (more than 30 percent, and sometimes even 50 percent). Simple modifications, particularly in the interface detectors, are all that seem to be necessary to reduce the water content of the oil output.*

The French Navy requested that CEDRE evaluate the SEPCON separator, built by JAFO Technology of Germany, with a view to assessing the possibility of using such an apparatus to settle the effluent from a skimming barrier, such as the SIRENE 20 used in France. This request was made as a follow-up to a series of tests carried out by CEDRE in June 1990, again at the request of the French Navy, on a cyclone-type separator (CYCLOIL DEOILER) built by the French company MAPE, an affiliate of ELF.

In the early 1980s, taking into account the constraints related to the oil recovery operations at sea (using Navy vessels), CEDRE cooperated with IFREMER (French Research Institute for the Exploitation of the Sea) to improve a separator of this type, which was designed for other purposes.[2] The Navy's interest in the technique of separation made it possible for CEDRE to collaborate in such studies. Unfortunately, despite the encouraging results obtained at the time at CEDRE's experimental site, the study was stopped before it resulted in the development of an industrial product designed for the needs of the French Navy:

- Flow input, 60 to 200 or even 400 $m^3/h$
- Oil content in the input, 5 to 75 percent
- Water content in the oil output noticeably lower than in the flow input
- Water output hydrocarbon levels less than 1 percent (5 percent in certain difficult cases)
- Possibility of treating skimmer effluents containing a range of hydrocarbons from light to heavy as well as water/oil inverse emulsions, all at seawater temperatures
- Minimal weight, because the separator will be used on a ship.

CEDRE's suspension of work on the subject for a few years was due solely to the lack of interest of an industrial partner and is in no way related to a lack of need. This is all the more true today, when ships designed exclusively for antipollution activities, and therefore equipped with such a separator, are contemplated.

This situation explains the interest shown by CEDRE and the French Navy for the equipment built in 1989 by the MAPE company and tested by CEDRE in 1990.

The CYCLOIL DEOILER is composed of cyclone devices mounted in parallel. The number of these cyclone devices is a function of the volume of effluent to be treated, because a basic cyclone can handle an input on the order of 10 $m^3/h$. The tests were carried out on a basic element to determine the maximum oil content acceptable in the effluent while still attaining the required levels at the oil output and, more importantly, the water output. The oil contents usually envisaged for the CYCLOIL input vary between 10 and 12,000 ppm, which are, at best, around 50 times less than what could be expected in the case of use downstream of a SIRENE 20 skimming barrier. However, the levels of hydrocarbons at the water outlet of a CYCLOIL separator are, during normal functioning, no more than 200 ppm, and therefore about 50 times less than what could be permissible during a major oil spill intervention at sea.

During the tests carried out at CEDRE's experimental zone, it was not possible to reach an overall input greater than 6.5$m^3/h$, due to a corresponding counterpressure, and the oil content in the input was never more than 25 percent (due to the material available for experimentation).

These tests revealed that it is not practical to use such a separator downstream of a skimmer due to the counterpressure that it creates. Also, for satisfactory functioning of the machine, it is necessary either to continually modify the settings to take into account the fluctuations of the levels of hydrocarbons or to set the apparatus for the highest level of hydrocarbon content in the entering mixture. From these tests, one can conclude that the CYCLOIL is not adaptable to the needs identified. This result in turn explains the interest shown in the SEPCON separator, which was conceived for the type of use envisaged by CEDRE and the French Navy.

## The SEPCON separator

**The SEPCON concept.** Designed specifically by a German company, JAFO Technology, for pollution response, the SEPCON is a containerized version of the ORAS separators, designed by the same company, which are already incorporated in various antipollution vessels. These ORAS separators are found in several German vessels: the supply types *Scharhorn*, *Mellum*, and *MS Kiel*, and the scissors-type ships *Bottsand*, *Eversand*, or *Ecopemex*, used in Mexico.[1]

The system consists of gravity-type separators allowing the continual separation of the water/oil mixture at an output able to reach several tens of cubic meters per hour (630 $m^3/h$ for the *Mellum* and the *Scharhorn*). The ISO 20-ft containerized version allows an output of between 60 and 100 $m^3/h$, while the 40-ft model can reach 220 $m^3/h$.

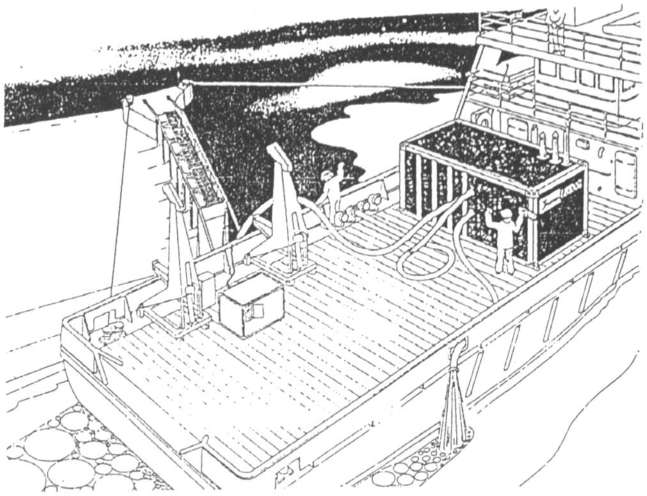

Figure 1. The use of the SEPCON separator at sea

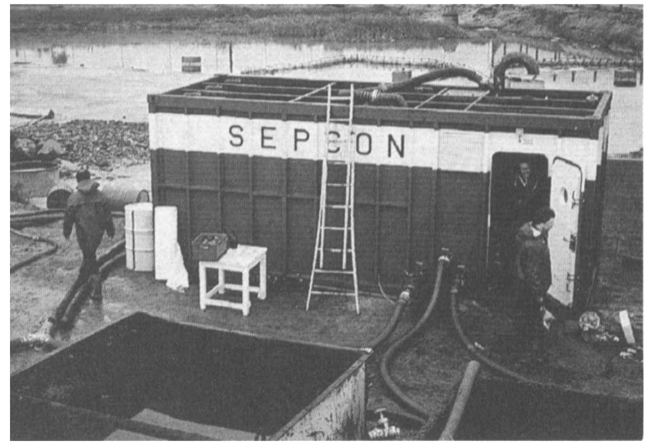

Figure 2. The SEPCON separator under test conditions

The ISO containerized version includes the settling tanks, the hydraulic and pumping circuits, and even the command and control equipment, as well as the diesel motor. The weight and dimensions of the SEPCON as well as its design permit good mobility, quick transportation to the pollution site (on sea or on land), rapid installation, and ease of use, thanks to its automatic functioning.

These separators are designed to be used downstream of a collection unit (Figure 1). They are supposed to separate practically any type of oil-water mixture and to obtain levels below 5 percent water in the oil output and 0.01 percent (100 ppm) oil in the water output.

**The tested separator.** The separator supplied for the tests (Figure 2) is a SEPCON 20′-80/14-GA (automatic model) designed to work continually at low pressure (some tens of bars), as opposed to the version fitted with a water pump to keep the internal pressure low.

The working principle is illustrated by Figures 3 and 4. The entering liquid follows a route across a labyrinth equipped with coalescers (Figure 3), which induce the gravity separation of the oil and water before the end of the circuit, where the water is continually pumped back at an output equal to that of the input, as long as not too much oil is being accumulated at the front of the oil tank.

When enough oil has accumulated (detected by detector D1, Figure 4), the valve V giving access to the oil tank opens and the water valve V, at the water outlet, closes so the oil tank begins to fill. Once the detector at level N2 is reached inside the oil tank, the oil pump starts to pump out the oil so long as the level remains above N1. When the detector D2 detects water in the main tank, valve V closes back and the

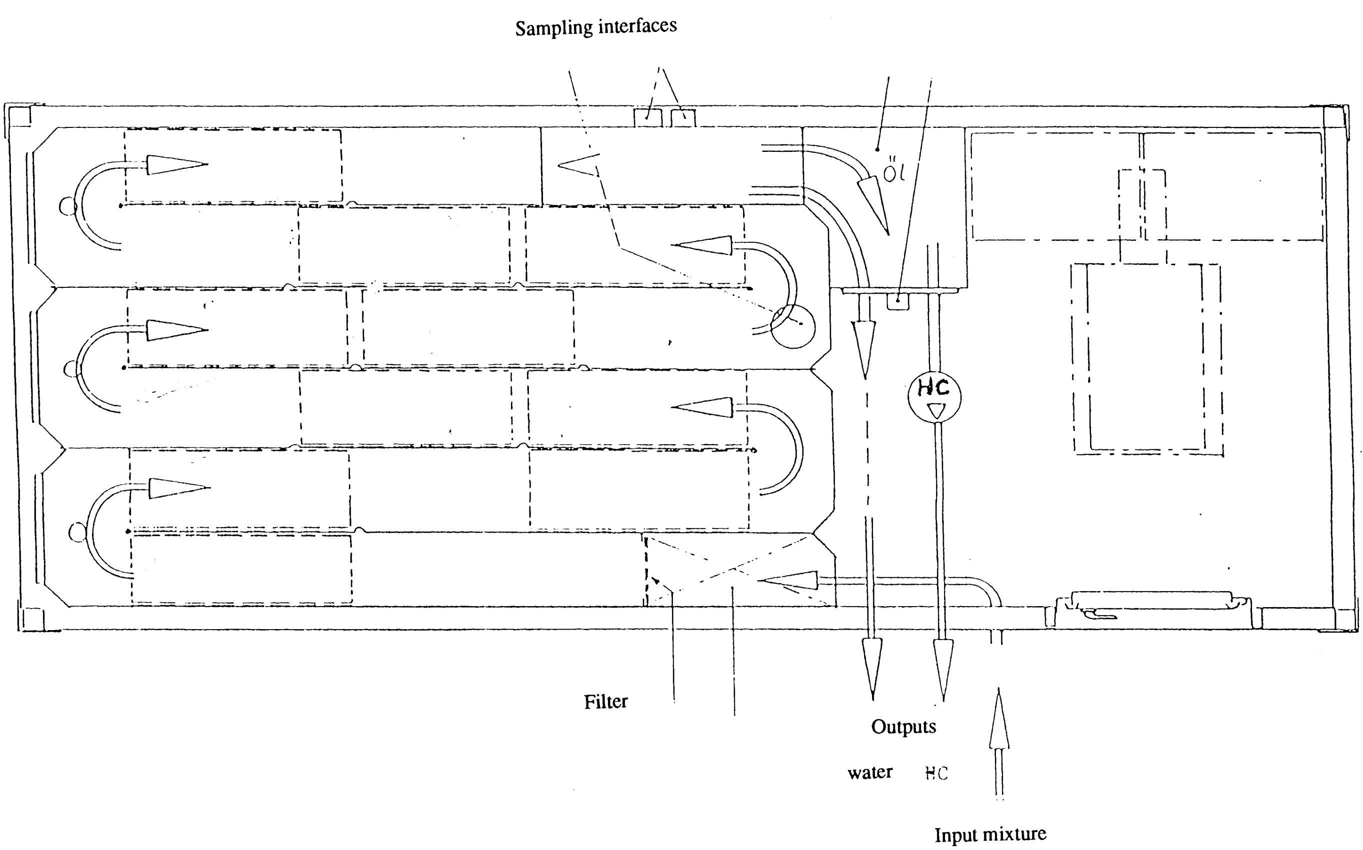


Figure 3. Fluid circulation inside SEPCON (view from above)

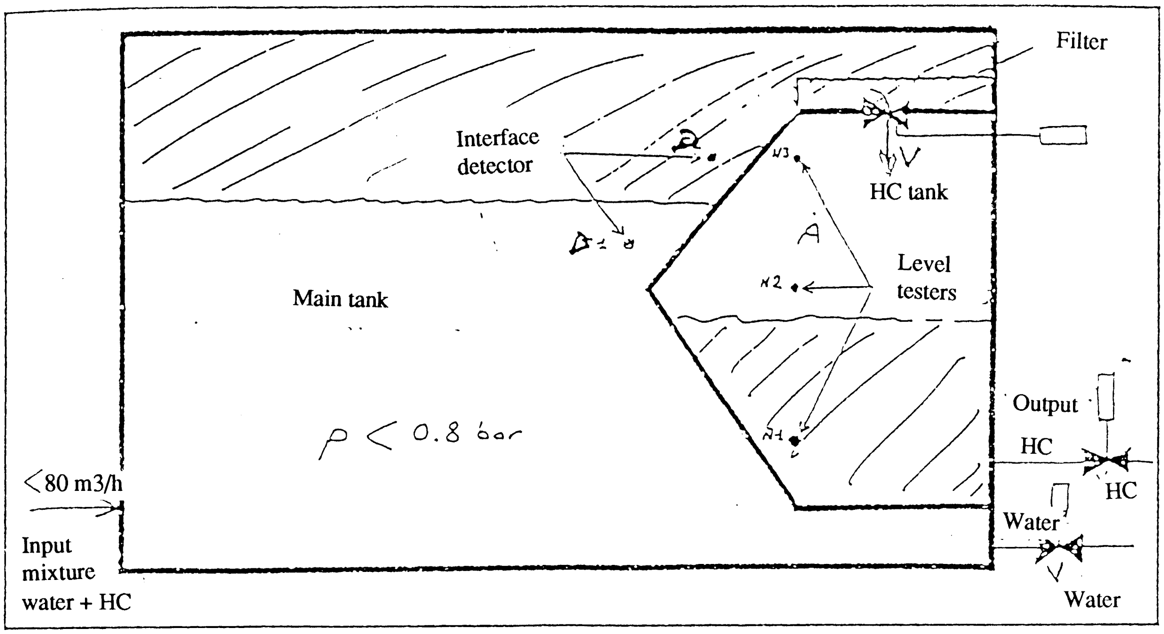


Figure 4. The operating principle of the SEPCON (side view)

water valve reopens just until the point at which detector D1 again detects oil and the process repeats itself.

If, due to malfunction, level N3 is reached, an alarm signal is sounded, informing the operators to stop the input into the separator. This risk is a minor one, because the oil pump has a capacity greater than the normal input of the separator. The oil pump is a self-priming volumetric pump adapted to pump viscous liquids, and has a maximum input of 160 $m^3$/h in water, or a maximum service pressure of 10 bars.

The volume of the main tank is about 17 $m^3$, which represents a resting time of about 13 min for an input of 80 $m^3$/h. The useful volume of the oil tank is around 1 $m^3$.

Two filters of expanded metal are incorporated in the system, one at the entrance of the main tank (see Figure 3) and the other in front of valve V (see Figure 4). At the top of the entrance chamber there is a calibrated valve (to about 0.8 bar), to prevent the pressure from becoming too high in the main tank. It gives access to the oil tank or even to the free air above the roof of the container.

The separator can also be operated manually. This can be helpful when testing inside the oil tank for the level of oil present, and the position of the detectors D1 and D2 in relation to the oil (inside or out).

At the rear of the SEPCON, samplers can be found, allowing visual control of the levels of the liquids (Figure 5).

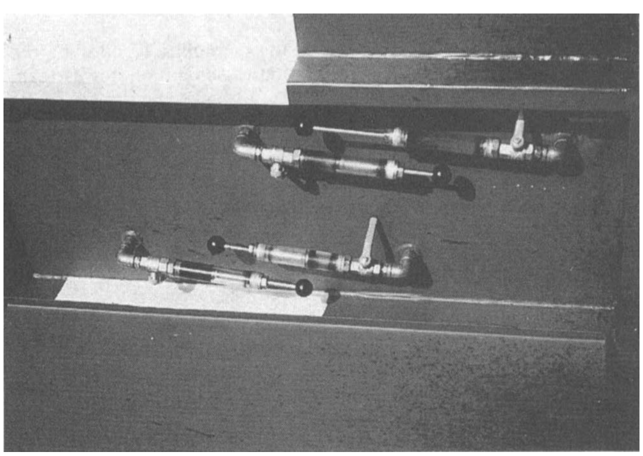

Figure 5. At rear of SEPCON, samplers at different levels in the separating tank

## Testing procedures

**Material.** The experimental material included the following (Figure 6).

- Upstream of the SEPCON, there was (a) a lagoon for storing sea water and a tank for each of the petroleum products used, and (b) two volumetric pumps with variable output (endless screw types), one for drawing water, driven by a diesel motor, and the other for the hydrocarbons, connected to the gears of an agricultural tractor (Figure 7).
- Downstream of the SEPCON, there were two tanks for collecting the oil output and a tank for measuring the water output, while the rest of the exiting water was directed toward the lagoon of the experimental area.

The instrumentation used during the tests, in addition to those on the separator itself, included two volumetric counters (water entering, water leaving). The output of oil was measured by checking the level variations in the tank. This was also the case for the water output and for the input of bunker C. Samples were taken to determine the respective contents of water and oil at the SEPCON's entrance and exits.

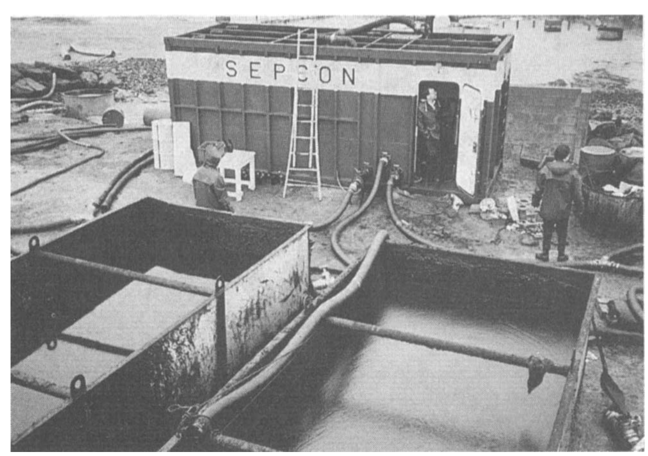

Figure 6. View of experimental equipment

Figure 7. Volumetric pumps used at SEPCON input—in foreground, oil pump connected to tractor gears; in background, water pump driven by a diesel engine

Two petroleum products were used for the tests:

- A 50/50 (50 cs at 50° C) fuel with a viscosity of 800 cs at test temperature and a density of 0.92.
- A heavy fuel (bunker C) with a viscosity of about 25,000 cs at test temperature and a density of 0.95.

**Tests.** Six tests were carried out under the conditions shown in Table 1. The better accuracy of the bunker C test conditions is due to the possibility of directly measuring the volume of injected oil from the level in the storage tank. This was less possible when testing with the 50/50 fuel.

Additionally, a trial run brought to light a fault of the separator, which was that the output valve remained blocked in the open position by solid wastes (in this case, a dead bird).

**Analysis of the results.** Results of the tests are summarized in Table 2. An input of 80 $m^3/h$ is close to the limits of a correct functioning of the SEPCON, to avoid excessive pressure in the separator.

It was never possible to obtain the quality of output promised, no matter what the total input and its oil content were.

It was not possible to show the influence of the input mixture or its oil content on the qualities of oil and water output.

On the other hand, the nature of the entering product had a certain influence. Also, the water output was less polluted in the case of the heavy fuel (less than 0.6 percent oil) than in the case of the 50/50 (up to 1.5 percent oil). This is explained by a greater tendency of the heavy fuel to settle naturally. On the contrary, the level of water at the oil output was lower in the case of the 50/50. This result may be explained by the heavy oil's high viscosity, which would encourage a preferential water flow toward the oil tank at the opening of valve V. However, high viscosity does not pose any problem for the SEPCON when pumping out.

In general, the quality of the effluent at the water output is satisfactory for the requirements foreseen. It also satisfies the requirements stated previously, if the 50/50 fuel is considered as being a difficult case. However, the water content at the oil output is excessive: 10 to 30 percent with the 50/50 and 25 to 67 percent with the bunker C. Note also that the nonaveraged values obtained from the samples taken (Table 3) are even higher, but these measurements are not significant, because when pumping out at the oil output, there will first be a water output before progressively obtaining a product which is practically water-free. In this case, the particular sample taken is not a good representation of the average output (about 1.5 $m^3$). In the same way, the individual samples taken at the input have a limited value, particularly in the case of the bunker C, where the heterogeneity of the mixture is very noticeable.

The quality of the oil output could be improved by the use of other types of testing interfaces, which are less sensitive to the presence of oil-in-water emulsions. It should also be remembered that the equipment supplied by JAFO Technology was a version specifically designed for use by NOFO in Norway to work on light, nonviscous crudes with high demands for the quality of water output.

Overall, the separator proved to be easy to use and relatively reliable. Two problems are apparent however, one with the hydraulic filter, which was twice the cause of a small oil spill, and the other with the discharge valve in the main tank. The first problem is not related to the SEPCON, but the second justifies a review of the valve's position.

**Table 1. Test conditions**

| Test | Type of oil | Input conditions: Total input ($m^3/h$) | Oil content (%) |
|---|---|---|---|
| A | Fuel 50/50 | 67 | 50–65 |
| B | Fuel 50/50 | 63 | 35–40 |
| C | Fuel 50/50 | 80 | 15–20 |
| D | Bunker C | 55 | 17 |
| E | Bunker C | 72 | 13 |
| F | Bunker C | 80 | 45 |

## Conclusion

The tests carried out have shown that the SEPCON separator allows the separation of an oil-water mixture at an input rate of 80 $m^3/h$. Thus, this equipment is a viable option for use downstream of a skimming barrier. Also, as a general rule, it can reject 70 percent of the water which has entered directly back to the sea, with a concentration of hydrocarbons less than 1 percent.

Also, it would seem to be possible to slightly modify the SEPCON to further improve the quality of separation in terms of the water content in the oil output without any significant reduction in the quality of the water output.

The tests have therefore confirmed the possibility of fulfilling the objectives which were defined in relation to separation downstream from an offshore skimmer, since aspects of weight and design are no longer as important as they once were.

**Table 2. Overall results of tests**

| Test | Duration: Total (min) | Injection (min) | Volume: Oil injected ($m^3$) | Recuperated at output ($m^3$) | Average water output ($m^3/h$) | Volume of entering water (L) |
|---|---|---|---|---|---|---|
| A | 7 | 6 | 4 | 5.1 | 90 | 71 |
| B | 26 | 9 | 4.4 | 4.9 | 115 | 79 |
| C | 17 | 15 | 6 | 8.2 | n.m. | 51 |
| D | 70 | 37 | 5.7 | 9.4 | 115 | 93 |
| E | 28 | 20 | 3.1 | 9 | 130 | 81 |
| F | 22 | 18 | 10.8 | 14 | 130 | 83 |

**Table 3. Levels of oil and water in the samples taken at time t (in relation to the beginning of testing)**

| | Input | | | Water Output | | Oil Output | | |
|---|---|---|---|---|---|---|---|---|
| Test | t (h:min) | Clean water (%) | Water in oil emulsion (%) | t (h:min) | Hydrocarbons (%) | t (h:min) | Clean water (%) | Water in emulsion (%) |
| A | 2:30 | 34.3 | 0.6 | 2:40 | 0 | 3:30 | 28.2 | 29.2 |
| | 4:50 | 47.4 | 0.8 | 6:10 | 0.3 | 5:00 | 35.2 | 13.8 |
| B | 1:10 | 62.1 | 0.3 | 11:2 | 0.2 | 10:30 | 0 | 18.4 |
| | | | | 18:10 | 1.1 | | | |
| C | 9:10 | 82.8 | 27.2 | 9:10 | 1.5 | 11:15 | 32.1 | 16.2 |
| | 14:00 | 79.6 | 18.3 | | 1.0 | 14:30 | 84.9 | 15.7 |
| D | 2:50 | 95.8 | 0 | 17:00 | 0.3 | 27:10 | 0 | 39.2 |
| | 9:30 | 97.9 | 0 | 28:20 | 0.3 | 45:00 | 47.8 | 10.3 |
| | | | | | | 56:20 | 94.7 | |
| E | 2:50 | 95.2 | 0 | 10:20 | 0.6 | 12:00 | 85.4 | 22.8 |
| | 15:00 | 97.4 | 0 | 16:35 | 0.6 | 17:30 | 87.9 | 15.9 |
| F | 3:00 | 78.4 | 30.4 | 8:00 | 0 | 6:20 | 76.4 | 23.8 |
| | 8:30 | 95.0 | 0 | | | 10:00 | 86.2 | 24.9 |
| | | | | | | 15:20 | 36.6 | 28.5 |

In this context, the new possibilities opened up by the use of supply-type vessels (chartered by the French Navy) justify a review of the constraints, as defined in 1985, on the types of separator which can be placed aboard the ships. Any changes should be put into print, so that all manufactures will know the specifications to which they must comply should they be interested in building such a separator for the Navy. Any testing required on new separators could be carried out at CEDRE's experimental site in the same manner as those which were made on the SEPCON separator.

## References


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2. Le Guen, Peigne, Bonazzi, and Lemaitre, 1987. Development of a great rate oily water separating system. *Proceedings of the 1987 Oil Spill Conference*, American Petroleum Institute, Washington, D.C., p620.