Oil Water Separation By Centrifugal Force

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ABSTRACT

An oil spill is the release of a liquid petroleum hydrocarbon into the environment, especially marine areas, due to human activity, and is a form of pollution. The term is usually applied to marine oil spills, where oil is released into the ocean or coastal waters, but spills may also occur on land. Oil spills may be due to releases of crude oil from tankers, offshore platforms, drilling rigs and wells, as well as spills of refined petroleum products (such as gasoline, diesel) and their by-products, heavier fuels used by large ships such as bunker fuel, or the spill of any oily refuse or waste oil.

This paper deals with the problem of recovery of spilled crude oil. It has been observed that the separation efficiency is greater for high range of viscosity and oil water ratios. Separation efficiency data on tests of water versus diesel, crude oil, and IS0 460 gear oil will be presented for two sizes of separators.

Oil spills can have disastrous consequences for society; both economically and environmentally. As a result of these consequences oil spill accidents can initiate intense media attention and political uproar. Despite substantial national and international policy improvements on preventing oil spills adopted in recent decades, large oil spills keep occurring.

1. INTRODUCTION

Ocean spills of crude oil and refined petroleum products are a continuing environmental concern. Regulations are being implemented in hopes of reducing the number and size of petroleum spills. Double hulled tankers, tanker escorts, and numerous operational rules have been implemented.

However, as long as oil products are transported by tanker or pipeline across open waters, the potential for spills exist. Therefore, better methods of spill recovery must be developed.

The average recovery rate of spilled crude oil ranges from 10% to 30%, but recovery of refined fuels and solvents is even lower. This is due to the rapid evaporation rate of such products, and the fact that they leave little or no residue once vaporized. There are many factors which complicate the recovery of spilled oil. The size of the spill, the nature of the spilled oil, response time, location, weather, personnel and equipment readiness, and regulations all impact effective spill recovery.

Several unified response organizations were formed to select and stage equipment, provide and coordinate teams for large spill response, and train commercial fishermen and boatmen for additional manpower. Contracts with the general marine industry were established to help clarify and streamline response to large spills.

Heightened awareness has inspired efforts to improve oil spill recovery equipment. The search for a high volume, efficient oil-water separator has been an important outcome of this process.

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No "single technology" approach will solve the problems of recovery of every possible petroleum spill. Viscosities can range from that of water (- 1 centipoise) to that of crude oils, tars, and asphalts (- 2000 centipoise). Weather and time constantly change the nature of spilled crude oil, making equipment which worked well on fresh oil ineffective within a few days. The evaporation rate of the more volatile components of crude oil directly affects its viscosity Formation of emulsions causes additional problems arising from increasing viscosity, substantially hindering recovery operations such as pumping and skimming. Emulsions also contain large quantities of water which greatly increases the storage requirements for the collected liquid. Wave motion also serves to enhance emulsion formation. For these reasons, rapid response time is a crucial factor in recovery of petroleum spills.

As previously noted, liquid storage capacity is another major consideration which can directly limit spill response. Since most high volume skimmers are at best 20% efficient, much more water is recovered than oil even in the best of conditions. Without real time oil-water separators employed during the skimming process, the volume of liquid which must be stored is at least five times that of the actual spill. As the slick thins over time the amount of water skimmed becomes even greater. In large spills, recovery often stops prematurely because all available storage is full. On-line separation is therefore an important requirement for successful oil spill recovery. Separator tanks employing gravity alone ($1g=9.81m/sec^2$), even when combined with coalescers, are limited by the natural separation rates of the oil-water mixture. For this reason, 1 g separators which can process hundreds of gallons per minute are quite large and weigh many tons when full. Centrifugal separators, which employ g-forces in the hundreds or thousands, are much more attractive candidates for oil spill recovery in marine applications. However, none of the existing liquid-liquid centrifuge designs have been successfully employed in oil spill recovery.

2. A NEW CENTRIFUGAL OIL-WATER SEPARATOR DESIGN

The new separator design presented is the result of a patented technology transfer from the Department of Energy The initial goals were to scale up and commercially produce separators with capacities from 2 to 400 gallons per minute (gpm). The separator is a liquid-liquid centrifuge, which includes a mixing annulus in the area between the rotor and the rotor housing. A schematic of the device in operation is shown in *Figure 1*. Two liquid phases, either pre-mixed or separate, are pumped into the annulus between the housing and the rotor. The spinning rotor mixes the two phases to form a uniform dispersion. The dispersed mixture then flows downward to the bottom plate where it is directed toward the center of the rotor by radial vanes. The dispersion enters the rotor and is rapidly accelerated to rotor speed. Baffles within the rotor prevent re-mixing and allow separation to occur under the influence of 200-300 g's. The denser phase migrates toward the periphery of the rotor and displaces the lighter phase toward the rotor center. Weirs control the rate of escape for each phase and are thus used to set the desired interface position between phases. The separate phases leave the rotor and are collected in two regions of the upper housing which lead to exit ports as shown in *Figure 1*. This design provides an efficient method for the continuous separation of two immiscible liquids such as water and oil. The rotor functions as a pump and fills when rotating. This is an important feature which allows equilibrium to be maintained during changes of ratios and flow, or even in cases of complete flow interruption. Startup equilibrium is achieved within 30 seconds. Large changes in phase ratio are tolerated due to the dispersion formed in the mixing annulus. Air pumped from skimmer operations to the separator does not affect equilibrium as it bypasses the rotor and exits through the liquid outlets. Shipboard wave motion is also tolerated due to an efficient design and the centrifugal form within the rotor. Static testing at a

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35" tilt showed no change in performance. Tests conducted on a large prototype operating at 135 gpm were successful in four foot ocean swells.

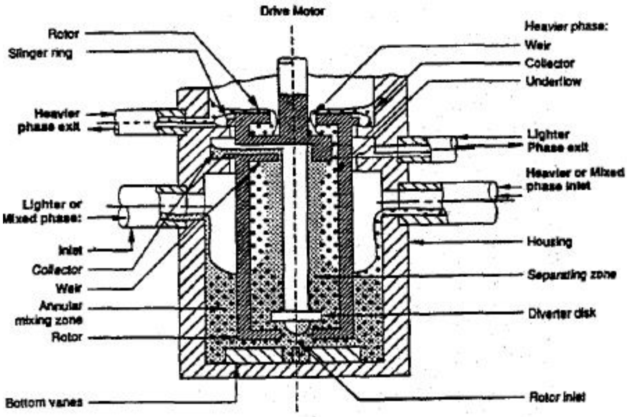

Fig.1: Centrifugal Oil-Water Separator

3. EXPERIMENTAL DATA

Separator tests were conducted using various oils, and fresh water which was adjusted to 1500 ± 100 ppm total dissolved solids by adding solid $NaHCO_3$. Diesel was tested to categorize separation behavior toward fuel and solvent spill cleanup. IS0 460 gear oil, having a viscosity of 1800 centipoise at 21^{0}C, was used to study heavier oil separation from water.

Separated effluents were sampled for analysis by an outside contract laboratory. Standard methods of analysis were used; water by EPA 413.l (oil and grease) and oils by ASTM D-96 (bottom sediment and water). Two sizes of separators were tested: the ten to thirty gpm V-10, and the eighty to two hundred gpm V-20. In each separator model, the number following the V designation is the outside diameter of the rotor in inches. The height of the separating zone for each model is 2.4 times the diameter. (This data have been taken from a research paper)

3.1 V-10 Tests

The next larger separator, the V-10, was also tested during prototype development. The results of tests in which diesel were skimmed from an 8’x30’ test tank are given in *Table* 1. The rotor speed for these studies was 1300 ± 20 rpm which again provides 200 g’s of force. Separation quality is comparable to the results obtained from V-5 testing for recovered oil. The water quality, while still very good, contained approximately twice the oil content of samples from the V-5 separator. This is most likely due to the added mixing in the annulus with increased rotor diameter and shear forces on the liquids. The V-10 rotor at 1300 rpm has a 1.5 times higher linear speed than that of the V-5 at 1700 rpm. The dispersion thus created is more difficult to separate once inside the rotor both oil and water effluent qualities are still at reasonable levels.

Table - 1 : V-10 Separator Test DATA Diesel - Water

Input Oil Concentration	Input Flow Rate (gpm)	Effluent Result
66%	20	Water: 1200 ppm oil Oil: 0.07%water
33%	20	Water: 2200 ppm oil Oil: 0.14%water
9%	20	Water: 1300ppm oil Oil: 0.06% water
5%	20	Water: 1200 ppm oil Oil: 0.06% water
2.4%	20	Water: 11 00 ppm oil Oil: 0.05%water
25%	30	Water: 1200ppm oil Oil: 0.07%water
33%	35	Water: 6200ppm oil Oil: 0.01%water

3.2 V-20 Tests

Testing of the V-20 separator at flow rates above 100 gpm provided unique challenges. The test tank volume of 2500 gallons is rapidly circulated (about three times per hour of testing), and output flow ratios are difficult to measure accurately while sampling with present equipment. For these reasons, no effort was made to measure the input oil concentration while skimming at these flow rates. Instead, 50 to 100 gallon spills of the test oil were processed and sampled chronologically to demonstrate typical effluent characteristics. The data taken from tests of diesel, ISA 460. Gear oil, are given in *Table 2.* Again, an increase in the oil content of effluent water is observed as additional mixing in the annulus occurs. The V-20 rotor speed tested was 850 rpm, but the linear rate is 1.3 times that of the V-10 separator. Again, this rotor speed provides 200 g's of force for separation. Still, very favorable separation results were obtained even at flow rates of 125 gpm and a wide viscosity range of test oils.

Table - 2 : V-20 Separator Test DATA Various Oil – Water

Input Oil Concentration	Input Flow Rate (gpm)	Separator Effluent Analytical Result
As Skimmed-Test #1	125	Water: 3800 ppm oil Oil: 0.1% water
As Skimmed-Test #2	125	Water: 9300 ppm oil Oil: 0.05% water
As Skimmed-Test #3	125	Water: 8600 ppm oil Oil: 0.05% water
As Skimmed-Test #4	125	Water: 5000 ppm oil Oil: 4.0% water
As Skimmed-Test #5	125	Water: 9600 ppm oil Oil: 2.3% water
As Skimmed-Test #6	125	Water: 12,000 ppm oil Oil: 1.0% water
As Skimmed-Test #7	125	Water: 4800 ppm oil Oil: 3.4% water
As Skimmed-Test #8	125	Water: 2200 ppm oil Oil: 3.0% water

4. CONCLUSION

Development of a new high volume centrifugal separator with application in spill recovery has occurred. The design is elegant in simplicity employing only one moving part. Results are favorable when employed as an emergency cleanup device for primary oil-water separation. Even the V-20 is compact and lightweight enough for airlift delivery to remote locations. It is easily deployed on modest sized boats and simple to operate. Plans for continued testing of this separator in actual oil spill recovery events are being finalized. Modifications to the design aimed at lowering the mixing of water and oil within the annulus are in progress. Further scale up to a V-30 with an expected throughput of greater than 400 gpm has been completed. Fabrication and testing of this first prototype will occur in the near future.

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