



JBF
ENVIRONMENTAL TECHNOLOGY

OIL SPILL RESPONSE

BASIC GUIDE

Oil Recovery Strategies

And

The Dynamic Inclined Plane Skimming System

CONTENTS

1. INTRODUCTION
2. GENERAL
 - A. DIP CONCEPT
 - B. BOOM FAILURE
3. ENCOUNTER RATE
 - A. ESTIMATION OF ENCOUNTER RATE
 - B. ESTIMATION OF THICKNESS OF OIL
 - C. AMOUNT SPILLED
 - D. RECOVERY TIME ISSUES
4. SPILL CONDITIONS
 - A. SEA CONDITIONS
 - B. WIND
 - C. CURRENT
 - D. AREA/LOCATION
5. SKIMMING EFFICIENCIES
 - A. OIL RECOVERY EFFICIENCY
 - B. THROUGHPUT EFFICIENCY
6. SKIMMING OPERATIONS
 - A. OPERATIONAL GOALS
 - B. OPERATIONAL CHECKPOINTS
7. ADVANCING OPERATIONS
8. STATIONARY OPERATIONS
9. MISCELLANEOUS ISSUES

1. INTRODUCTION

The success of a response to an oil spill depend heavily both on the performance and capability of the equipment used and on the training of the responder. Even equipped with good equipment, an untrained or unknowledgeable responder will have a difficult time in having a successful spill response. The responder must learn how to read the spill, and its particular conditions to develop the best plan for response to a spill. Further, the responder must thoroughly know the capabilities of the skimming equipment, which they will be using to be able to recover the most oil, and in the least amount time.

All types of factors will affect the success of the skimmer operations. These include skimmer type, sea conditions, oil type, time, and many other factors. One thing has been proven over the last 30-35 years, "No two spills are alike."

2. GENERAL

The technical aspects of the JBF Dynamic Inclined Plane oil skimmer play a major role in the performance and operation of the JBF skimmers and oil recovery vessels. It is important to fully understand the oil recovery system to obtain maximum performance results.

A. Dynamic Inclined Plane Concept of Oil Recovery and Collection

The Dynamic Inclined Plane (DIP) takes advantage of the laws of physics to collect oil from the surface of water. A key benefit of the DIP skimmer is the combination of oil collection and separation into a single step. This fully maximizes the use of both pumping capacity and available storage, by allowing the transfer of only pure oil from the collection well to storage.

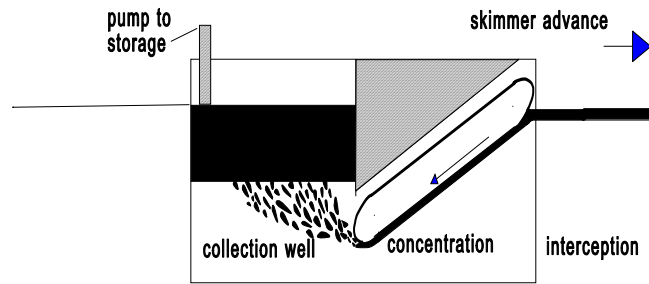
As shown in Figure b, the oil on the surface of the water is intercepted by the moving plane at the same relative velocity as that of the combined net velocity of the current and skimming vessel, (either integrated or VOSS.) Thus, the oil, the moving plane, and the adjacent water velocity all move at the same relative velocity so that the oil is not subjected to any turbulence that could cause it to mix with the water. The oil layer is simply redirected down the moving plane. When the oil reaches the bottom of the belt, it floats to the top of the collection well with a minimum of mixing action forming a deep oil layer at the top of the well. This thick oil layer is then pumped, water free, to storage tanks. Extensive testing and experience in actual spills show that less than 1% water is collected in the recovery oil.

Because there is no relative velocity between the oil, the moving plane, and the hydrodynamic streamlines, the oil layer moves down the plane, undisturbed.

This is important in order to minimize emulsification of the oil. Further

development and testing in the 1970s found a practical

upper limit of 3 knots, while still maintaining near 100% throughput efficiency, was achieved at a belt angle of 23 degrees. More recent testing in 1997-98 conducted by the US Coast Guard has proven expansion of the operational range of the DIP skimmer to 5 knots.



The oil/water layer is redirected down the moving plane assembly to

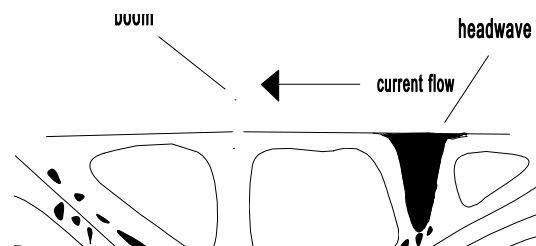
Since the oil is pumped from the collection well only from the top 5-10 cm, it has been proven that the DIP skimmer can maintain a 90-99% Oil Recovery Efficiency regardless of speed, or wave height.

B. Containment Boom Failure

In addition to the DIP skimming system, the operator must also fully understand the concept of containment boom failure or entrainment. Figure (a) below is a schematic of the cross section of a typical containment boom during entrainment.

Regardless of the geometry or the strength of the boom, it has been proven both in circulating tanks and under actual conditions that, in only 0.75 knots of current, oil will escape beneath the boom.

In studying this fact, it was determined, as the current increases, a large teardrop shaped oil mass is formed at a



predetermined, perpendicular distance upstream from the face of the barrier. This formation is called a head wave. At these higher current speeds, oil from the head wave shears off, becomes entrained in the hydraulic streamlines and flows under the boom. This condition is found to always occur when there is any attempt to slow down the flow of oil and water in front of a boom or barrier. The only effect of increasing the depth of the boom or barrier was to form the head wave at a greater distance upstream from the boom. The oil continued to entrain under the boom. As a practical matter, increasing the boom draft will raise the boom drag when towed in a traditional "U" boom configuration. In actual practice, the substantial pulling power required for boom of 1-2 meters draft, from the towing vessels, becomes impractical or simply unavailable.

3. ENCOUNTER RATE

1. Estimation of Encounter Rate

Every skimming system will have a maximum recovery rate associated with its operation. The point at which the oil skimmer is overwhelmed by oil and can no longer recover additional oil determines the maximum rate. The maximum rate of recovery is usually determined in a laboratory or test tank. In many cases, the manufacturer will simply use the maximum pump rate of the pump used in the skimmer, regardless of the skimming technology used. However, a skimmer's maximum recovery rate must not be confused with the recovery rate obtained during an actual spill recovery operation. In an actual spill situation, the skimmer recovery rate will be limited to the rate oil that the skimmer encounters. In simple terms, you will not be able to pickup more oil than is present on the water in the first place. This may seem to be common sense, but it can be easily forgotten at the time of an actual spill.

Take the example, of a skimmer with a maximum rate of 70 m³/hour such as the JBF DIP402 VOSS. In a spill situation with a side sweep width of 8.5 meters, a skimming speed of 1 knot (0.5 m/sec) and a continuous oil layer thickness of 2 mm, you would have an "encounter rate" of 31 m³/hour. (8.5 x 0.002 x 0.5 x 60 x 60= 31) "If" you had this situation in an actual spill, you could pump oil from the collection well at a maximum rate of only 31 m³/hour, and NOT ever reach the 70 m³/hour rated capacity. The tendency is for the operator to "try" to collect more oil by simply increasing the pumping rate from the collection well. This is very common mistake with skimmers where a large pump is matched to a small capacity or low performance skimmer. This will NOT work, since you cannot possibly pump more oil than you have presented to the skimmer, in the first place. Increasing the pump rate beyond the encounter rate will only cause you to pump water with the oil recovered. By pumping excess water with the oil, you will cause your oil recovery efficiency (oil/water ratio) to drop. Since your goal is to maintain as pure as possible the oil you pump to your storage tank, you must not pump excess water.

RULE TO REMEMBER: ENCOUNTER RATE

1.9 tons/hour (31 liters/min) = 1mm of oil at 1 knot with a sweep width of 1 meter.

Example: for a spill of 2 mm of oil and using a skimmer with a V-sweep of 3 meters and moving a 2 knots through the spill you would have: (2 x 3 x 2 x 1.9) or 22.8 tons/hour (372 liters/min) encounter rate.
Trying to collect anything more than 22.8 tons will only result in recovery of water, and cause the ORE to decrease.

B. Thickness of Oil

You will know your sweep width and your speed, but you must estimate the thickness of the oil layer on the water. First, realize that there is a very strong tendency for the untrained person to always overestimate the amount of oil in a spill. Without actually measuring the oil thickness, the following estimation guide can be used:

Sheen (silver-gray)	=	0.000025 mm
Iridescent (rainbow)	=	0.00025 to 0.0025 mm
Dull (translucent w/ Partial dark or rainbow)	=	0.0025 to 0.025 mm
Blue-Black (aged/wind- Blown oil or fresh oil on Warm water)	=	0.025 to 0.25 mm
Blue-Black (fresh oil on Cold water)	=	2.5 mm
Emulsion (brown-orange /red)	=	2.5 mm of oil (seen as 5-10 mm oil/water)

Of course this guide must take into account the viscosity of the oil spilled. Heavier oil will be able to maintain thicker layers, while light oil, as in #2 diesel, will always spread to very thin sheens. This guide is for free spilled oil. If containment boom is used to “trap” the oil and there is no entrainment, you can obtain higher thicknesses of oil. The ideal textbook situation of 25-50 mm of oil is rarely obtained in actual spill conditions. Let alone the 1-2 cm that is required for a large number of skimmer types to operate properly. Also note that at thickness more than 5 mm, it will be very difficult to accurately determine the thickness, since 5 mm of oil and 20 mm of oil will look the same to the operator, looking down from a boat.

3. Spilled Amount (Area & Thickness)

An extremely common mistake made at an oil spill is the over-estimation of the total amount spilled. Over-estimation is a result of the inability of untrained and even trained persons and the high state of emotions and chaos at the early stages of oil spill scene. Even if the total loss of oil from a barge or tank is accurately known, it will still be extremely difficult to judge how much oil is contained over a specific area, such as within a boomed area. You must also consider that the media, elected government officials, the general public and other untrained people are only seeing the large surface area of a spill and will easily over-estimate the amount of oil present.

A skimmer operator should familiarize themselves with simple measurements and amounts of oil. Consider some examples, one barrel of oil spilled over an area 10 x 10 meters results in 1.5 mm of oil. One cubic meter of oil spilled over an area of 50 x 50 meters results in 0.4 mm of oil. A spill of 1000 cubic meters of over one square kilometer will still result in only a thickness of only 1 mm!!!! And these examples assume that the oil is ideally contained within a boom. If unconstrained, the oil will continually spread out to sheen, (<0.0001 mm).

4. The Effect of Time on Spill thickness

As a general guide, in an unconstrained spill of oil, the area of the spilled oil will double every 2 hours in the first 12 hours and double again every 12 hours after that. This is, of course, dependent on many factors including total amount spilled, viscosity of oil, sea conditions, and current.

Along with spreading, another factor of time is the evaporation of the oil. In lighter oils, evaporation will cause the oil layer on the water to decrease with time. In spills of mixed oils (release of both cargo of #2 oil and fuel of bunker C) and in spills of crude oils, evaporation has a slightly different result. As evaporation progresses of the lighter fractions, the oil thickness will decrease. However, as the lighter product is lost, the remaining oil will increase in viscosity. The increase in viscosity will tend to slow down the spreading of the oil, and could cause the remaining oil layer to actually be thicker.

4. Spill Conditions

A. Sea Conditions

One of the biggest factors that will affect an oil recovery operation is the sea state or wave condition that the skimmer is operating in. Almost all skimmer types will perform rather well in a calm water condition. It is the fact the real world environment is rarely totally flat and calm that will truly test a skimmer's performance ability. A common question, may be, "How big a wave can the DIP skimmer (or any other skimmer) work in?" Or "What wave height is the skimmer rated at?" But these questions are much too vague. The more appropriate question is "How do different size waves, from zero to 2-3 meters, affect the performance of the skimmer?" The result is that you will try to develop a performance versus wave height relationship or curve. This is not a case where the answer is a clear black & white, wave height, but rather a decreasing curve. When comparing two different types of skimmers, you will want to know what happens to the performance of the skimmer (as claimed or tested in calm conditions) as the wave height increases. The waves referred to here are waves that of a length that will affect a skimmer. Wavelengths of 8-10 times the size of the skimmer will have little effect on most skimmers. A long wave will appear to the skimmer locally as a calm condition. This is true of course only if the skimmer is able to freely follow the wave's surface.

The two characteristics that are typically affected by waves are ORE and TE. As the

waves become larger, these two numbers will decrease. Some skimmers, such as weirs, will decrease their ORE even in the smallest waves. In larger waves, the ORE will drop so close to zero as to make them useless in oil recovery. In some cases, the performance of a skimmer will decrease as the wave height increases, but in a more gradual curve. In the case the DIP skimmer, this curve will remain higher for a longer period. The DIP skimmer operation will be discussed in greater detail in a later section.

Another, issue to consider in waves, is simply the seaworthiness of the skimmer, physically. You would never consider taking a small 1-meter long skimmer into the open ocean, off shore environment. If the skimmer is physically unstable, then the performance issue does not need to be considered. If the skimmer is integrated into the hull of a vessel, then the vessel's sea keeping characteristics will be key factor in the skimmer's performance. In examining, a VOSS or "over-the-side" type skimmer, it will be the skimmer's sea keeping characteristics to consider. This assumes that the VOSS is fully independent from the vessel and can react to the waves fully independently from the vessel.

B. Wind

Wind can also affect the recover performance of a skimmer. More specifically it is the wind waves caused by the wind that will affect the skimmer. The small, harbor chop, like waves will tend to have much more of an effect on a skimmer, than the large, rolling swells.

Wind can also effect the operation of the skimmer, if the skimmer has a large surface area exposed that can act like a sail. This will cause physical problems with the maneuvering of the skimmer. A skimmer that can be moved easily in the wind will have little chance of oil recovery.

5. SKIMMING EFFICIENCIES

1. Oil Recovery Efficiency

Oil recovery efficiency (ORE) is defined as the percent oil in the total volume recovered by the skimmer. A primary advantage of the DIP skimming system is its ability to maintain high oil/water ratios in spill recovery operations. In many skimmers, most specifically the weir type skimmers, the ORE are very, very low, usually less than 10-20%. In cases of thin sheens, or waves, the ORE can easily drop to 1%!

The reasons that high oil recovery efficiencies are important are:

1. **INCREASED COSTS.** All water collected is of no value. Once water is collected along with the oil, you must now be prepared to handle the additional volume, and to process the water, for proper disposal. The additional handling, treating, and disposal results in higher costs.
2. **LIMITED STORAGE.** Assuming that you do not have unlimited storage for the oil recovered from a spill, any water volume collected will occupy storage space, that could otherwise be used for oil.

Let's look at some practical examples. Consider a small spill, of 1000 liters (1 m³) of oil, in which you are able to successfully pick up all of the oil, but with only 10% oil recovery efficiency. You now would have 10 m³ of oily water, to store, transport, treat and dispose of. As a first estimate, you will be paying 10 times the disposal costs as compared to if you had collected only the 1 m³ of pure oil. Now, in this small spill example, the excess cost may be small enough to absorb by the spiller. But now consider a spill of 100 m³ of oil, with the same 10% ORE. You now have a situation where you will now have an additional 900 m³ of water, which you will have to dispose of. If the cost to handle, treat, and dispose of the water is only US\$1000 per m³, you will have an additional spill cleanup cost of US\$900,000!!

In the case of large spills, ORE and storage space are extremely important. You must always consider the available storage that is or will be available for the recovered product. Take the case of the 100-m³ spills above. As you begin recovery you find that you only have two 100 m³ barges available. This means that any ORE under 50% will mean a problem, since you will have no place to put the recovered oil.

Even in a small spill, you must strive to keep the ORE very near 90-100%. Take the example above of the 1 m³ spill again. You respond to the spill with a JBF DIP400/420. With an ORE of >90% you could recover this spill in a single trip. However, with improper operation of the DIP skimmer or when using a low performance skimmer, such as the weir, what happens with an ORE of only 10%? Since the JBF420 has an on-board storage tank of 5 m³, after recovery of 0.5 m³ of oil and 4.5 m³ of water, you will be forced to return to off load your tanks. In the meantime, the remaining 0.5 m³ of oil left on the water will have time to spread further, damage shoreline, etc.

During recovery operations, a practical method to determine when the collection well is full is to look for the appearance of oil behind the skimmer. This will be a sign that the well is full of oil and oil is escaping from well through the aft exit.

B. Throughput Efficiency

Throughput Efficiency (TE) is the percent oil recovered by a skimmer as compared to the amount of oil encountered.

6. SKIMMING OPERATIONS

1. PRINCIPLE

The belt speed of the DIP skimmer should approximately equal the speed of the advance of the skimmer. This is a relative speed only. For example, a belt speed of 1 meter per second or 2 knots would be fully adequate for skimming at 1 to 3 knots.

The key problems to avoid, for the operator, are a very slow belt, less than 0.5 meters per second, or a very fast belt speed of more than 2 meters per second. Operation of the belt at speeds outside this range can cause a 10% to 20% loss in skimmer efficiency.

2. OPERATIONAL GOALS

1. Maintain a 99%/1% oil/water ratio in collected product
2. Maintain maximum throughput efficiency to minimize 2nd and 3rd sweeps over same area.
3. Maintain optimum speed vs. throughput efficiency

C. Operational Checkpoints for the DIP skimming system

1. Belt should operate at approximately the same speed as the current or as the advancing speed of the skimmer. (Within +/- 1 knot is fine.)
2. Pump only when the collection well is full of oil. Stop pumping when the well contains only water.
3. Maintain pumping rate (pump cycles) at or below the oil encounter rate. (See chart in section 6)
4. DIP skimmer is insensitive to oil viscosity and thickness.

D. Belt Speed

During operation, the belt speed can be calculated by a simple measurement of the number of seconds per revolution. A DIP belt will have one section of contrasting color material to serve as a point of reference.

For example, on the JBF DIP402 VOSS, the belt is 6.5 meters in length (or twice the length of the belt box assembly.) To obtain a belt speed of 2 knots or 1 m/sec, you would adjust the hydraulic flow to the drive motor to obtain 6-7 seconds per revolution.

5. Skimming Speed

Skimming speed will be determined by the conditions of the spill, such as oil type, viscosity, thickness, waves and weather conditions. A good starting point for skimming is a speed of 1-2 knots. Remember that this is relative speed of the skimmer, so any current present must be factored in. For example, in a tidal current of 1 knot and a skimmer speed of 1 knot into the current, you have a resulting 2 knots skimming speed.

In currents of 3-5 knots or more, where large amounts of oil are being lost behind the skimmer, it is suggested that the skimmer move astern at 1-3 knots when facing into the current. Alternatively, the skimmer can “chase” the oil by moving 5 knots down current. This allows you to maintain a 2-knot relative speed at the skimmer.

Other considerations include:

- In heavy or higher viscosity oils, skimming speed may have to be increased to avoid oil “building up” at the mouth of the skimmer.

- As waves become larger, the skimming speed should be reduced.

- The size of the skimmer and the vessel will play a major role in the recovery performance. Larger JBF DIP skimmers, such as the large vessels, will be able to handle higher speeds and larger waves more easily, than the smaller skimmers.

7. STATIONARY RECOVERY OPERATIONS

In operation as a stationary skimmer, you use the natural current (whether from tide or river flow) to assist in directing the oil to you. This is in contrast to chasing after the oil in advancing skimming. The operator should try to position the skimmer in a location that is already a natural collection point for the oil. The skimmer can be moored at a dock, anchored, or even held steady by the vessel's engines.

The fronts of all JBF skimmers utilize universal C type boom connectors. This enables the operator to directly attach containment boom, (ASTM or C) to the JBF skimmer.

In addition to onboard storage tanks, if the skimmer position is near the shoreline, you can consider the use of a land-based storage tank, such as portable tanks, trucks or trailers. Place deflection boom chevrons at angles of 30 degrees or less to current flow.

Boom length should be based on the location and practical considerations. Remember that the boom is for diversion or deflection of the oil, not collection or containment.

Several smaller sections of boom are generally better than trying to place a single large section. Each section of deflection boom is placed to overlap the section behind it. At the point the oil contacts the skimmer, the oil is NOT required to pool up first. Rather the DIP skimmer immediately collects the oil into the collection well. Contrast this system with the typical U boom arrangement. In a U boom system, the oil must be allowed to pool up to a thick layer before skimming can occur. And in a U boom system, the current at the apex of the boom must be less than 3/4 knot or entrainment of the oil will occur. With the JBF DIP skimmer, entrainment is not an issue, so you are able to operate in currents up to 2-3 knots.

