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Recent Developments on Herder Commercialization

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ABSTRACT

Herders (also known as surface collecting agents) are made of surface active compounds (surfactants). They reduce the surface tension of water and thereby change the spreading behavior of immiscible liquids, such as an oil slick, floating on the surface. Oil slicks that have spread too thin to burn can be re-thickened if herders are sprayed on the water surface around a slick. Once the slick is thickened, it is amenable to *in situ* burning without the need for fire-resistant boom. Herders are listed as surface collecting agents on the National Contingency Product Schedule administered by the US Environmental Protection Agency (USEPA, 2019) for use in US waters. Herders are commercially available and oil spill response organizations have the capability to utilize herders.

A new joint industry / government agency project was recently initiated to develop a novel herder delivery and ignition system. The initial plan is to develop a remotely operated surface vehicle (RSV) that will deliver herder from an onboard reservoir and a system to ignite herded slicks. The RSV we are developing has 10 -12 hours of operation time, a range of 500 miles and can travel at speeds of up to 65 miles/hour. The RSV can be deployed from a helicopter that has a cargo hook, a boat, and potentially a fixed-wing aircraft that has an appropriately sized hatch. The vision is rapid deployed to a remote spill location using a helicopter (or a fixed-wing aircraft) and operated from this platform until a response vessel

arrives on the scene. The response vessel can then take over RSV control freeing the aircraft for other duties.

This paper will describe the planned development and testing of the RSV and other progress toward herder commercialization.

INTRODUCTION

Herders (also known as surface collecting agents) are surfactants (surface active compounds) similar to those used in shampoos and soaps. They reduce the surface tension of water to change how an insoluble, buoyant liquid like crude oil behaves. Slicks that have spread very thin will rapidly (within a few minutes) thicken after herder application to become burnable (Buist & Nedwed, 2011). Only a small amount of herder is used because only a mono-molecular layer is needed. If the same size oil slick was treated with dispersant, at least 100 times more surfactant would be needed.

Herders are applied directly to the water surface surrounding an oil slick. When the resulting surfactant layer spreads to the edge of a thin oil slick, the interfacial forces acting on the slick change causing the slick to contract in area and thicken. Herders work in open water because they do not require a border to “push” against. A conceptual drawing of the herding process is shown in Figure 1.

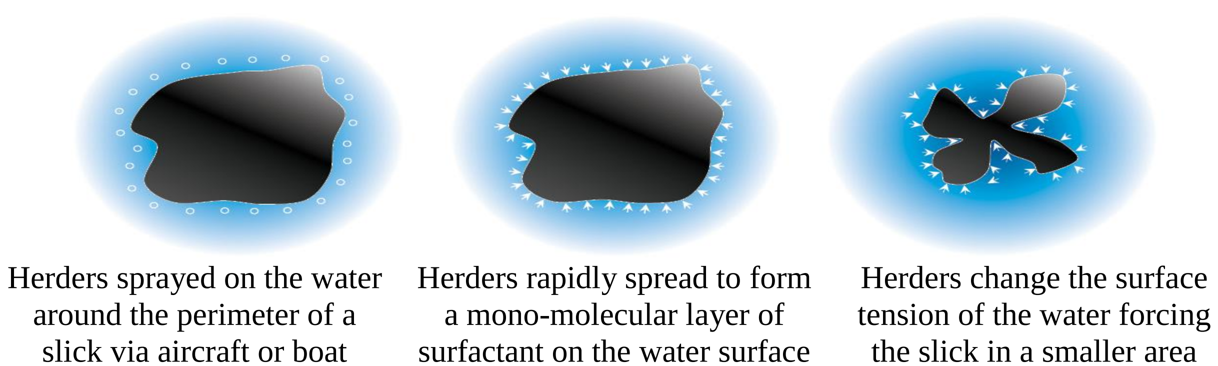

Figure 1. Conceptual drawing depicting the herding process to thicken an oil slick.

The use of herding surfactants was first reported during World War II to push burning oil away from tankers (Zisman, 1942). Herding agents were used in harbors in Hawaii on diesel spills (Walker et al., 1993), and they were tested during the 1980 *Texaco Connecticut* oil spill in the Panama Canal (Chong et al., 1983). Also, herders were used to protect a marsh in 1993 (Walker et al., 1993).

Garrett and Barger (1972) were the first to consider herders to enhance oil spill recovery and conducted in-depth evaluations for the US Naval Research Laboratory in the late 1960s / early 1970s. They evaluated 47 surfactants to determine their effectiveness as herding agents. They also conducted open water tests and found that No. 6 fuel oil was herded for 2 ½ hours in 6 foot seas with numerous white caps.

Most of the Garret and Barger (1972) research was conducted under temperate conditions including multiple field demonstrations. Since then, herders have undergone many years of research and development primarily under temperate conditions (Buist et al., 2104). In fact, most of the research on herders has been conducted under temperate conditions so it is not just a technique for oil spills in ice (Buist et al., 2014).

Two herders are commercially available (Desmi, 2019) and listed on the USEPA National Product Schedule making them available for oil spill response in waters of the United States. One of the herders (Thickslick™ 6535) is a formula developed by Garret and Barger (1972). This product has toxicity nearly an order of magnitude less than most dispersants and No. 6 fuel oil (USEPA, 2019). The other herder (OP-40) is a silicone based surfactant.

The herder Thickslick™ consists of a surfactant (derived by combining a fatty acid (lauric acid) and a simple sugar alcohol (sorbitol)) and an alcohol based solvent. Both components are plant based and are rapidly biodegraded in fresh and marine waters. The surfactant in Thickslick™ is also used as an emulsifying agent in vaccines, creams and ointments for cosmetics and pharmaceuticals, and in food products (Sorbitan Monolaurate 20, 2019). The rapid biodegradation of Thickslick™ means it cannot bioaccumulate in the food chain.

Thickslick™ meets the USEPA definition of being practically non-toxic (as defined by the USEPA aquatic toxicity ranking system – see http://www.epa.gov/espp/litstatus/effects/redleg- frog/ naled/appendix-i.pdf). The expected concentrations of Thickslick™ when properly applied in the field are at least three orders of magnitude lower than measured concentrations that cause acute toxicity to marine organisms (USEPA, 2019). This is based on an application rate of 0.05 gal/acre (100 times lower than a common dispersant application rate) and an assumed mixing into the top 1 m of the water column.

Herder research in the 60s and 70s was focused on enhancing skimming of oil slicks. This application was not fully accepted by the oil spill response community for a couple reasons. First, herders do not eliminate the logistical issues associated with mechanical recovery. Boats are still required to store collected oil and transfer it to shore. Second, skimming herded but free-floating oil slicks is inherently less efficient than those contained by booms. Skimmers have to be continuously repositioned in free-floating oil slicks whereas they remain in a fixed position at the apex of a boom when skimming with a boom. Also, skimmers were developed for thick oil that is generated at the apex of a boom. Herders can thicken oil slicks to roughly 5 mm. Skimmers that are placed at the apex of a boom are designed to recover oil that is several centimeters thick. The ASTM method for determining skimmer recovery rates requires slicks to be between 5 – 7.5 cm thick (ASTM F2709-18). Skimming 5 mm thick oil is well below the thickness for efficient skimming operations (McKinney et al., 2017).

To date, ISB enabled by herders has not been an operational oil spill response tool during a real spill event. It has, however, undergone many lab-scale test and several field / large basin demonstrations. The first demonstration was during the 2008 Oil in Ice joint industry project near Svalbard, Norway. In this demonstration, 630 liters of a Norwegian crude oil was successfully herded and ignited using boat-based systems (Buist, 2010). In 2015, a large test basin outside of Fairbanks, Alaska was used to demonstrate a helicopter delivery and ignition system (Potter et al., 2017). A successful open water test of ISB enabled by herders was carried out in 2016 (Cooper et al., 2017)

The key to oil spill response is speed, and herders combined with *in situ* burning (ISB) allow response at the speed of aircraft. In addition, burning with herders can remove over 90% of the oil (Buist, 2010) eliminating most of the logistical issues related to mechanical recovery. By eliminating most of the on-water operations required for skimming, herders are protective of personnel by reducing the need for responders on the water.

A concern with burning of free-floating oil slicks is risk to nearby infrastructure. This risk can be managed with proper burn protocols. Free-floating oil slicks burn and then extinguish very quickly because they are not fed fresh oil. Fire booms can be towed to collect fresh oil to allow extended burn times. Oil slick burn rates can approach 2.5 mm of slick thickness/min under ideal conditions (IPIECA/IOGP, 2016). Burns of slicks thickened using herders were conducted in 2008 (Buist, 2010). The largest burn involved 0.7 m^3 of oil that was consumed in two burns that lasted a total of 15 minutes. Much of that time was due to the time necessary for the slick to become fully engulfed. Understanding burn rates and how thick herded oil slicks can become while fully engulfed in flame allows responders to plan burns with no risk to nearby infrastructure. Herded slicks might be 3 – 5 mm thick but they can thicken to 10 mm or slightly more because of wind herding during a burn (Buist, 2010). For example, it might take a few minutes for an entire oil slick to become fully engulfed in the burn. Then the burn will continue until the slick is approximately 1 mm thick. If we assume a burn rate well below the maximum (say 1 mm/min), then <10 minutes are required before a 10 mm slick self-extinguishes. This means an individual slick is unlikely to burn for 30 minutes. Assuming a slick is traveling at 2 knots, a burning slick would only travel 2 nautical miles if it burned 1 hour. Knowledge of burn rates and ambient conditions allows for the development of burn protocols that eliminate the potential for secondary fires to offshore infrastructure.

To understand why herders are needed for enabling burning of marine oil slicks *in situ*, it is important to understand the logistical challenges of burning oil slicks with fire-resistant booms. Most spills are short-duration releases and the resulting oil slicks weather, emulsify, and break apart too fast for deploying fire-resistant booms. Fire-resistant booms are large bulky pieces of equipment that require cranes to transfer from storage locations to ground transportation and then transfer by cranes to vessels at the port. Oil spill responders estimate that this requires 3 – 4 hours, best case depending on location of storage relative to vessel port. Load out on deployment vessels requires sea fastening and transit to location of the spills. Estimates are that this could be 1 – 2 hours or more depending on distance from port to spill location. Once at the spill site, deploying boom, connecting towing vessels, moving to position, and collecting oil at best requires another 1 – 2 hours. Under best-case assumptions, fire-resistant boom requires 6 – 8 hours for deployment based on math describe above. ISB with booms has only been an operational response option for one offshore spill – Deepwater Horizon (BSEE, 2015) – because of these challenges. Deployment of herders by aircraft requires a small fraction of this time thereby allowing burning as soon as possible after a spill.

The use of herders to enable burning of offshore oil slicks has important advantages compared to other response options assuming the oil is burnable and burning is accepted by stakeholders. Because of this, industry has been working to develop an aerial herder delivery system that is also capable of igniting herded slicks to allow implementation of the entire burn process from a single platform. This effort led to development of a helicopter-based herder delivery system (Figure 2) that was tested at a large test tank located near Fairbanks, AK in 2015 (Potter et al., 2017). The system consisted of a tank to hold herder, a pump, and a hose reel capable of dropping a nozzle 150' below the helicopter to avoid impact of the herder spray by the prop wash from the helicopter. It performed well and was capable of delivering herder to the test slicks. These tests slicks were subsequently ignited using a Helitorch™. The testing, however, identified a significant shortcoming of this setup. The Helitorch™ and the herder delivery system could not be flown in a single helicopter during one flight because you can't fly with two slung loads. The operation required spraying the test slicks with herder, retracting the herder hose reel into the helicopter, landing the helicopter, picking up the slung-load Helitorch™, and then igniting the herded slick with gelled gasoline/diesel mix. Recommendations from this work were to develop a combined aerial herder delivery and ignition system.

Figure 2. Photos of the prototype helicopter herder delivery system in the cabin of a helicopter (left image) and deploying the 150' hose and nozzle assembly during flight.

A new joint-industry / government project was initiated to continue development of the herder delivery / ignition system. The Prince William Sound Oil Spill Recovery Institute (OSRI) in Cordova, Alaska is leading this effort. Participants in the project include OSRI, ExxonMobil, and the U.S. Bureau of Safety and Environmental Enforcement. The project team has contracted with a vendor that primarily develops equipment for the U.S. Department of Defense, Tactical Electronics, to evaluate the existing technologies and recommend potential improvements or new approaches. This paper describes efforts by the project team to develop an aircraft-deployable system capable of delivering and applying herder to surface slicks and then igniting a herded slick.

DISCUSSION

Based on the recommendations from the 2015 testing in Fairbanks, work to develop a combined herder delivery / slick ignition system capable of being flown in a single helicopter began in 2016. The result was a slung load igniter system (Figure 3) that was connected to a reservoir of herder located in the cabin of a helicopter (DESMI Ro-Clean, 2017). A nozzle was located on the ignitor body to allow spraying herder. Developers found a couple of issues with the system during testing. First, the slung load positioning kept the helicopter from reaching maximum speed. This limits both response speed and range. Another issue was that the individual ignitor design of the system did not balance the amount of herder. That is, much more oil could be herded than could be ignited. Issues with the combination slung-load ignitor / herder delivery system led to it being scrapped, and the effort to develop a completely new system began.

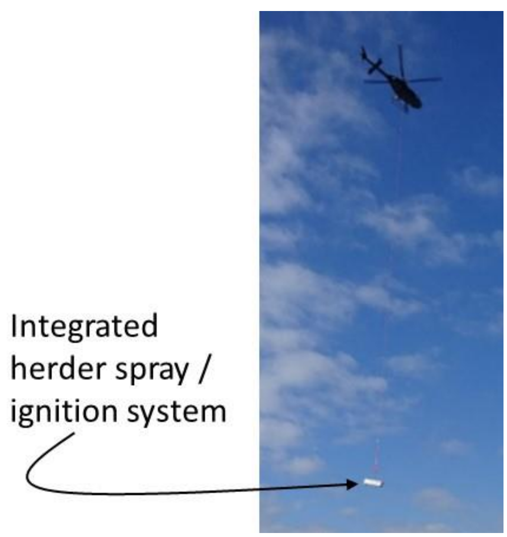

Figure 3. Combined herder spray and ignitor system slung from a helicopter.

Remotely Operated Surface Vehicle

Development of a new herder delivery / slick ignition system capable of aerial transport is the objective of the OSRI-led joint industry / government project. The goal of the project is to identify approaches that make significant advancements compared to existing technology. A long-term goal of aerial herder systems is delivery via fixed-wing aircraft – the fastest delivery possible for remote spill locations. This was expected to require an extended development period to get regulatory approval to install herder delivery booms, nozzles, and ignitors on an airplane. Because of this, a staged development plan was considered – first a helicopter delivery system and then a fixed-wing aircraft delivery system.

Tactical Electronics personnel, however, envisioned a remotely operated surface-vehicle (RSV) concept to both deliver herder and ignite herded slicks. The RSV removes many of the regulatory issues of installing equipment outside the fuselage of aircraft. The aircraft is simply a method of transporting the RSV to / near a spill location where it is dropped to the surface. Once on scene at a spill site, the RSV is remotely operated to spray herder and ignite herded slicks. As a standalone system, the RSV has the flexibility of delivery via any platform including a boat. Figure 4 shows conceptual drawings off all three delivery methods.

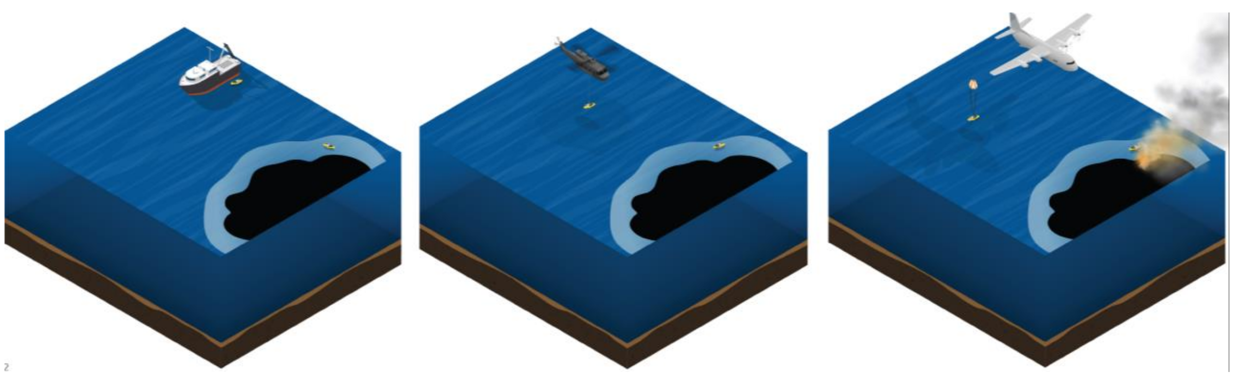

Figure 4. Conceptual drawing depicting the herding process using the RSV to thicken an oil slick.

A prototype system was built using a commercial jet-ski platform. This platform provides a durable injection molded hull that resists cracking inherent in fiberglass hulls. It is powered by an energy efficient engine capable of 12+ hours of operation, 500 mile range, and speeds over 65 miles/hour. The body of the platform is a “clam shell” design. This allows the topsides to be removed and replaced with a custom-made topsides with the capabilities needed for our application. Figure 5 shows a conceptual drawing of the RSV.

Figure 5. Conceptual drawing the unmanned surface vehicle (120"x46"x24" height; approximately 400 lbs).

The RSV is capable of autonomous operation or remote operation by a "virtual reality" operator. This allows an expert on herding and ISB to operate the system from any remote location. It has four surface, two underwater, and one 360º cameras. It has lighting above and below water, a global positioning system, and multiple communication methods.

To ensure accurate placement of herder and ignition of herded slicks, the RSV has a tethered unmanned aerial vehicle (UAV) that sits within an onboard hangar when not in use. A tethered UAV eliminates safety concerns with free-flying UAVs and allows flight times equal to the operation time of the RSV (12 hours) because the battery to operate the UAV is located on the RSV and wiring between the two transfers power. The tethered UAV gives the operator an aerial view (up to 200' – 300') of the oil slick to ensure that herder is placed around the perimeter and then ensure that ignitors are placed appropriately on the herded slick.

The system is capable of holding 350 lbs of equipment. If half of this capacity is used to carry herder (~80 liters) and herder is delivered at 5 L/km of slick perimeter (Buist and Nedwed, 2011), then 16 km of oil slick perimeter can be treated. Assuming the 16 km of slick perimeter is divided into ten equal size slicks of 1.6 km circumference and each slick is 0.5 mm thick on average before herding, then a RSV is capable of treating ~600 bbls (~10 m^3) of oil. If the RSV treated five equal size slicks, then using the same assumptions the 80 liters of herder could treat ~2,500 bbls of oil.

The initial prototype will use gelled gasoline as the ignition system. Pre-ignited gelled gasoline will be ejected from a nozzle to provide a closely spaced line of ignitors onto the slick. Gelled gasoline has undergone many years of testing for oil slick ignition and was the primary method of igniting slicks during the Deepwater Horizon spill.

The initial prototype will focus on herder delivery and slick ignition capabilities. We envision, however, that future development may allow the RSV with tethered UAV to perform SMART ISB (Special Monitoring for Applied Response Technologies; NOAA, 2006) monitoring of the smoke plume to ensure that particulate levels are not impacting sensitive areas. SMART ISB defines protocols for measuring particulates in smoke plumes to evaluate possible effects on the general public downwind. Particulate analyzers could be placed both on the UAV and on the RSV for this purpose.

Herder Commercialization

As mentioned, there are two herder formulations listed on the USEPA's National Contingency Plan Subpart J Product Schedule (USEPA, 2019). Listing on the product schedule allows these products to be considered for oil spill response on waters of the United States, however, use during actual spills requires approval by the appropriate authorities.

Several oil spill response organizations (Marine Spill Response Corp., Clean Gulf Associates, and Oil Spill Response Limited) have or intend to have stockpiles of herders, boat-based delivery systems, and ignitors. This will allow their use during a real spill event if the appropriate conditions exist and decision authority is granted.

SUMMARY & CONCLUSIONS

ISB of free floating oil slicks produced by herders has undergone many years of development and is ready for a trial during a real spill event. Most of the research on herders has been conducted under temperate conditions so it is not just a technique for oil spills in ice. Burning of free-floating oil slicks can be made safe by accounting for the burn time and potential for the fire to drift. That is, slicks burn at a rate of approximately 2.5 mm of thickness / min. Herded oil slicks are unlikely to be more than 10 mm thick. So, burns can't burn for more than a few minutes to a few tens of minutes. Conducting burns an appropriate distance away from infrastructure will ensure they are conducted safely.

A joint industry / government agency project was formed to develop a novel herder delivery and ignition system to allow ISB. The system is built on a commercial jet-ski capable of 12 hours of operation, 500 mile range, and 65+ mph. This system can be delivered to a spill location by airplane, helicopter, or boat to be a very flexible, rapid response tool. We believe that this system will allow ISB to become an important oil spill response option. The goal is to make this technology widely available to the spill response community.

FUTURE PLANS

Plans for 2020 are to build at least two prototypes of the RSV. They will undergo testing at a large test basin in Poker Flats outside of Fairbanks, AK. Plans beyond 2020 are to demonstrate the RSV during potential field trials if potential opportunities materialize. If the Poker Flats basin tests are successful, however, we intend to make the system available to oil spill response organizations for evaluation. Thus, we believe the system could be available for commercial use by 2021.

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