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Sunken Oil Recovery System Recommendations

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ABSTRACT 299936:

The Coast Guard R&D Center (RDC) has just completed a multi-year project to develop a complete approach for recovery of spills of submerged oils, specifically for sunken oil. Three companies spent one year in designing and one year in developing prototypes to identify and recover oil that attempt to address some of the shortfalls of relying on divers. This paper briefly describes the technologies and results from prototype testing at the Ohmsett test facility in the United States and some field tests. Based on this research, proposed guidance for responders to heavy oil is provided to identify all of the issues that need to be addressed when working with sunken oil.

BACKGROUND:

Even though heavy (sinking) oils have historically accounted for a small percentage of spills, environmental and economic consequences resulting from a spill can be high. Heavy oils can sink and destroy shellfish and other marine life populations in addition to causing closure of water intakes at industrial facilities and power plants. The underwater environment poses major problems, including: poor visibility, difficulty in tracking oil spill movement, colder temperatures, inadequate containment methods and technologies, and problems with the equipments' interaction with water. The National Academy of Science recognized these issues and developed a report that provided a baseline for responders (NRC 1999). Since that report, some progress has been made to identify successes and performance gaps (CRRC 2007, Michel 2008, Usher 2008, Rymell 2009, Elliott 2003, 2005, 2008, 2012). In addition a guideline for assessment and removal techniques is being developed by the International Maritime Organization (IMO). (Chapman 2014). For the purpose of this paper and following CRRC 2007 and Chapman 2014, "submerged oil" describes any oil that is not floating at or near the surface. "Sunken oil" describes the accumulation of bulk oil on the seafloor.

The CG Research and Development Center started a project in 2008 to address the issues involved with sunken oil. Interim reports have described the details (Hansen et.al. 2009, 2011 and 2012) and a final report has been compiled (Fitzpatrick, et. al. 2013) that provides a summary of the technologies. The final report also contains a job aid for use by CG responders. This paper will briefly summarize the final report.

RECOVERY SYSTEM DEVELOPMENT:

Three companies spent 1 year designing and then an additional year building prototype systems.

REMOTELY OPERATED VEHICLES (ROV) SYSTEM:

A design concept called SEA HORSE (SEagoing Adaptable Heavy Oil Recovery SystEm) was designed and developed using Remotely Operated Vehicles (ROVs) by Alion. In developing a system that fills the niche of a lightweight approach, the three major aspects considered to be crucial were: mobility, flexibility, and low cost. The original recovery system consists of two Sea Lion II ROVs, a Lamor GTA 20 pump (capacity of 20 cubic meters/hour (m^3/hr)) with an aluminum nozzle and an aluminum framework with an option to mount a multi-beam sonar. A major effort was to develop a multiple ROV control system and this worked well, keeping both ROVs working together. Only a limited amount of oil was recovered during an oil recovery test at the Bureau of Safety and Environmental Enforcement (BSEE) Ohmsett test tank mostly because the sled was underpowered and could not keep the face of the nozzle in the correct flat orientation to contact the oil. A large amount of water was recovered. (Hansen et.al. 2012) A limited number of sonar runs were performed to help determine the best individual sonar and settings needed to detect the oil. A field test was performed in 2012 to address issues that were not evaluated at Ohmsett as part of the system designed for the searching task. The sonar system was able to detect targets that were not oil, mark them and then direct the ROV operator back to the anomalies. (Fitzpatrick et. al. 2013) This is a crucial stem to ensure that the recovery system can be directed to the oil. The final configuration for the recovery system (See Figure 1) consists of the three-ROV-powered sled, the pump, the nozzle, and the hoses. The additional ROV appears to address the lack of power in the system.

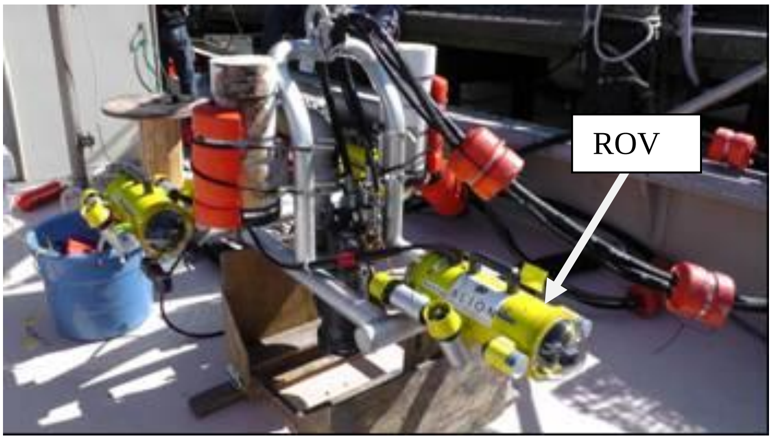

Figure 1. Alion SEA HORSE.

SUNKEN OIL RECOVERY USING A MANNED SUBMERSIBLE:

Marine Pollution Control (MPC) has developed a system composed of a manned submersible teamed with a recovery capability and additional sensors including sonar and laser fluorometer. Since the Ohmsett tank was too shallow to deploy the submersible, a test rig (Figure 2) was configured to represent the operational recovery parts of the submersible configuration including a heated nozzle, a robotic arm, sonar, two laser fluorosensors and multiple video cameras and lights. **(**Hansen et.al. 2012)

Figure 2. Back view of Rig

The submersible from SEAmagine associated with this system has been exhibited at multiple oil spill conferences in the past. A specially designed pumping apparatus system was installed in the system including a transfer pump, a vortexenhancer/debris chamber and the skimmer head recovery nozzle. This kept a large amount of silt from going into pump and the collection tank.

The system easily picked up the oil and a large amount of sand and water. These amounts were reduced as the nozzle opening and the power of the pump was reduced as the testing progressed. The oil separator system worked well permitting water to be re-introduced into the Ohmsett tank after decanting and running through a sorbent filter system.

SUBMERSIBLE DREDGE

The Sub-Dredge is a remote-controlled pumping vehicle designed by Tornado Motion Technologies (TMT) with a patented “Eddy” pump mounted at the end of an articulated arm. It relies on an external detection system for initial detection, but utilizes underwater cameras mounted on the pump for recovery. This system was also too big to place in the Ohmsett tank, so the pump was mounted on an excavator and the mounted camera system used for control with a closed-circuit monitor installed in the excavator cab. A full oil separation system was deployed that also utilized a settling tank, mesh filter cloths and two surface skimmers. Initially, this system also recovered oil with a large amount of water, but refinements and increased operator experience resulted in better output later in the testing period. The oil separation system functioned well, being similar to the MPC approach. (Hansen et. al. 2012) A field test was completed in 2012 using a more compact system called the Ninja, (Figure 3) that uses the same pumping system but greatly reduces the size of the vehicle. (Fitzpatrick et. al. 2013)

The original vehicle was 19 feet long and weighed 29,000 pounds while the Ninja is 9 feet long and weighs about 3200 pounds. This smaller system **may** be useful in the surf zone but still may get stuck in soft bottoms.

Figure 3 Ninja Crawler

EQUIPMENT SUMMARY:

Three unique systems have been designed and tested that meet the required specifications for detection and recovery of sunken oil. All three systems rely on video cameras to permit the operator to control the nozzle location. Permitting the person controlling the pump to also see the picture could reduce any lag time and should also reduce the amount of water and bottom material collected. This test did not gather enough information to determine how fast and how much one of these systems can gather oil during an actual spill. The use of multiple steps for separating oil is needed, especially since any sand sticking to the oil may not separate during pumping operations. All of the vendors indicated that larger and possibly multiple collection tanks would be need for a large spill. The size of the filter systems varied from 10 to 200 microns and this will probably need to be adjusted for each spill, depending upon the bottom type. The development of these systems may not preclude the use of divers in some situations but may be an alternative if the oil is deep (use manned submersible), in a surf zone (use crawler system) or if placing divers into the water is unsafe (use ROV).

SUNKEN OIL RESPONSE GUIDANCE:

As part of this project, proposed language that could be useful for Federal On-Scene Commanders (FOSC) has been developed that specifically addresses sunken oil. Oil suspended in the water column is not addressed. The summary of oil behavior developed by the National Research Council (NRC) is still an excellent guidance (see Figure 4). This was utilized in decisions made both in the Deepwater Horizon and the Kalamazoo River spill in 2010. Decision trees from NRC that can serve as job aids were modified in the IMO document (Chapman 2014) and further modified below. Additional options have been added for detection (Figure 5) including new guidance for water depths for various and some newer sensors. For recovery options (Figure 6), a further listing of diver depth capabilities and some new technologies were added (manned submersible and the crawler). Some of the initial tradeoffs for the use in recovery as a function of potential impact on habitat are given in a table format (Table 1).

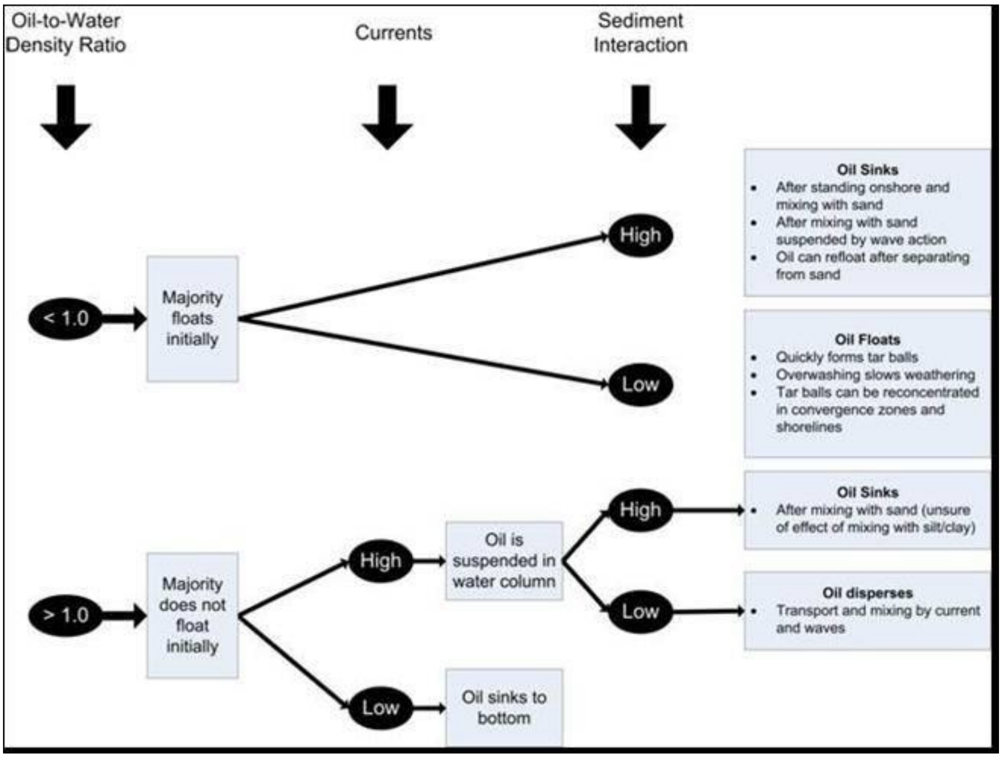

Figure 4. Summary of oil behavior of submerged or sunken oil. (NRC 1999)

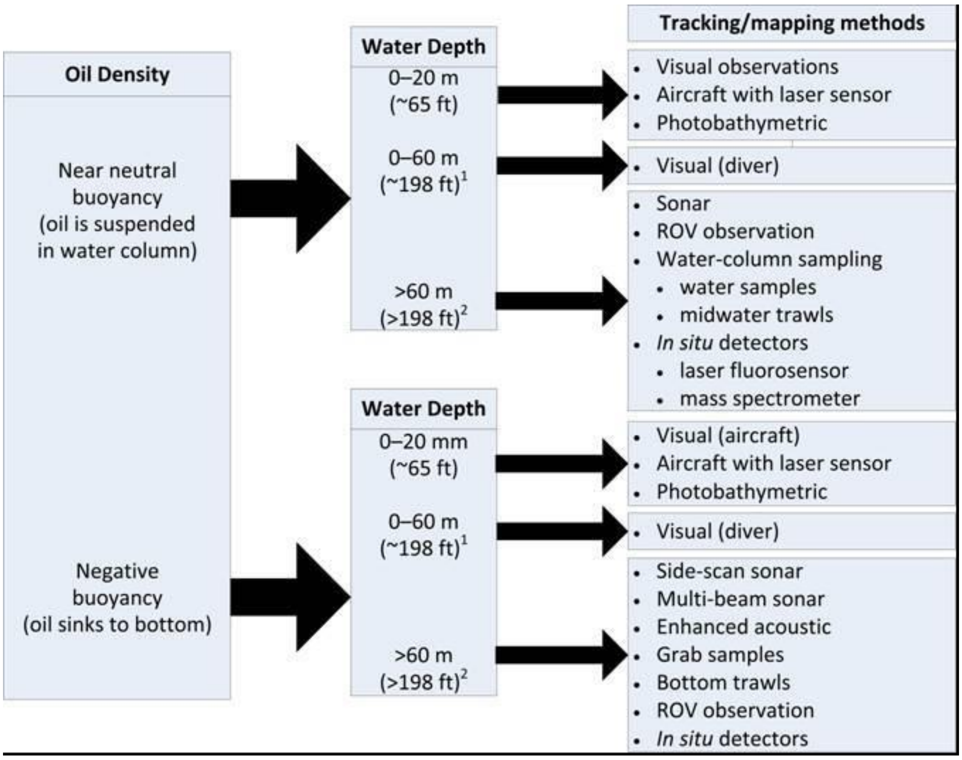

Figure 5. Detection decision tree (modified from IMO 2014)

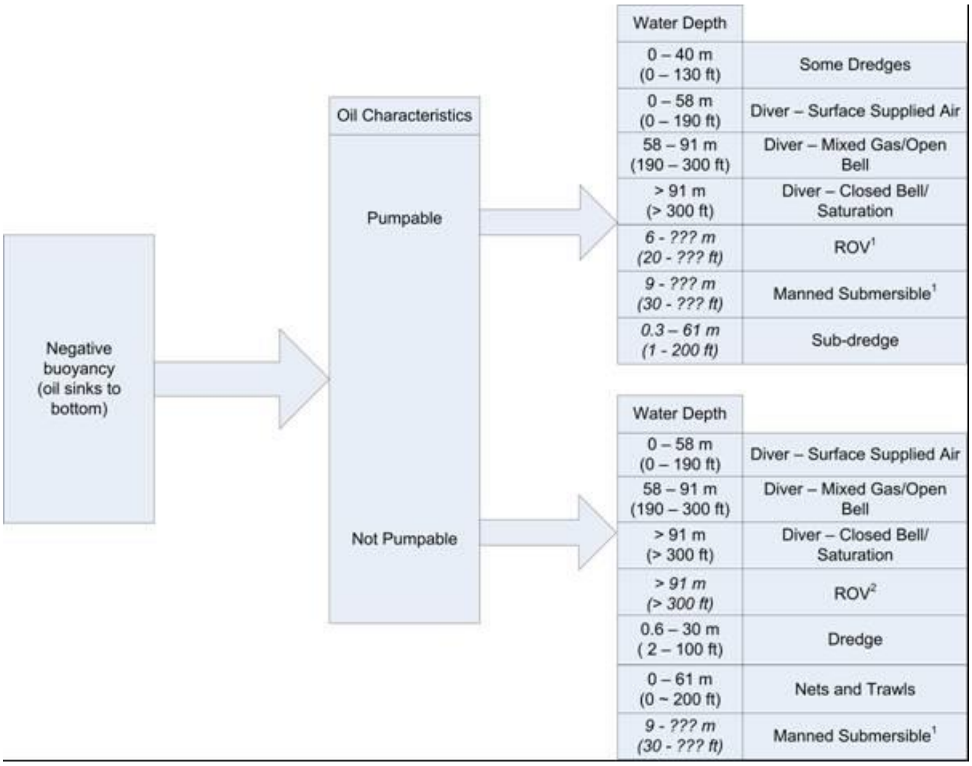

Figure 6. Decision tree for recovery options for sunken oil. (modified from NRC 1999)

Table 1. Removal Impact Recommendations Matrix

	Manual Removal	Directed Vacuuming	Bottom Net/Trawl	Dredging	Capping
Coral Reef	Recommended	Provisional	Not Recommended	Not Recommended	Not Recommended
Sea Grass Beds	Recommended	Recommended	Provisional	Not Recommended	Not Recommended
Kelp Forest	Recommended	Recommended	Provisional	Provisional	Not Recommended
Rocky Bottom	Recommended	Recommended	Recommended	Provisional	Provisional
Sand	Recommended	Recommended	Recommended	Recommended	Provisional
Mud	Recommended	Recommended	Recommended	Recommended	Recommended

Recommended
Provisional
Not Recommended

When deploying personnel and equipment on or near the bottom, there are other issues and safety hazards not encountered on the surface that must be considered. The use of a net environmental benefit analysis (NEBA) is described, because of additional potential for disturbing wildlife habitat and archeological areas on the bottom that are not normally a major issue for surface spills. Potential safety issues include buried electrical cables, pipelines, unexploded ordinance and sites of previous contamination. Each of these considerations is discussed below:

- Ecological Sensitivity – Bottom types will range from the most ecologically sensitive and important such as essential fish habitat, coral reefs, sea grass and eelgrass beds, and kelp forests to the less important, such as rocky substrate, sand, and mud. Probably the least sensitive bottom types are sand and mud bottoms in areas that already suffer from pollution such as industrial areas. Note that the NOAA ESI maps will generally delineate sensitive bottom habitats that are in shallower water adjacent to the shoreline and those impacts to Essential Fish Habitat may need to be considered. The NOAA Scientific Support Coordinator (SSC) and state resource trustees (e.g., Department of Natural Resources (DNR) and Department of Environmental Protection (DEP)) can provide information on bottom resources. In coastal areas, local fishermen are often familiar with bottom substrate type and marine resources.

- Persistence of Sunken Oil – The persistence of sunken depends on the permeability/porosity of substrate, the oil's density (buoyancy), and the adhesion properties of the oil. Persistence is also a function of bottom turbulence and currents. Persistence can either warrant or preclude rapid cleanup actions. If the oil is in an ecologically sensitive area, the persistence of the oil warrants more timely removal action.

- Proximity of Sensitive Resources – As with surface spills, it is important to consider the current location of the oil and environmental sensitivity, but also the sensitivity of locations where the oil might be transported. Such areas include ecologically sensitive shorelines (salt marshes and mangrove areas), recreational beaches, municipal water intakes, essential fish habitats and valuable infrastructure.

- Threatened and Endangered Species – Threatened and endangered species that are located in the area under consideration are usually identified on the ESI maps. As most of the threatened and endangered species of concern in an oil spill are marine mammals and birds, they are not likely to be directly disturbed by removal of oil from the bottom. However, they may be injured or disturbed by response vessels and equipment, and contaminated if oil is re-suspended in the water column.

- Historic/Archeological Resources – Archeological and historic resources are sometimes known (but not always) and are identified on the ESI maps. However, there may be historic and archeological resources below the water which have not been located and charted, which may be uncovered and disturbed by cleanup operations. The State Historic Preservation Officer (SHPO) and local officials should be consulted before dredging or other intrusive cleanup operations are undertaken on the bottom in areas of historic interest, or if wrecks or other artifacts are encountered during the operation.

- Safety Hazards – Safety hazards such as electrical cables, underwater pipelines, and unexploded ordnance should be indicated on navigation charts but are sometimes not known. Port Authorities, the U.S. Army Corps of Engineers (USACE), and local utility companies can provide more detailed information on infrastructure on the bottom. Some areas of the bottom (e.g., Superfund sites) may have toxic contaminants present in the sediments which would best be left undisturbed. The U.S.

Environmental Protection Agency (EPA) and state and local environmental agencies should be consulted regarding the presence of these sites.

When taking into account the issues above, information for several broad categories of approaches is provided in a table below that can assist decision –makers in selecting an appropriate response.

DECANTING:

One of the other major issues is handling the potential large amount of water and silt that can be collected with the oil. Due to the relatively high pressures needed to move heavy and usually viscous oil through a pump, most systems will collect a large amount of silt and water with vacuum and dredge options. An efficient method is needed to separate out all of the water and sediment from the oil. The separated oil may sink or it may float so the process needs to be in stages. While this has been done before in previous spills, it was sometimes done ad-hoc so this report lays out a recommended configuration that could be considered. In Figure 7, the multiple stages are needed to handle the solids (Stages 1 and 2) whether the oil floats or sinks upon recovery. A skimmer may be needed on the tank surfaces as well as sediment traps on the bottom of the tanks. Then the oil (Stage 3), water (stages 4 and 5) and sediment (Stage 6) all need to follow separate waste streams for reuse or disposal. Multiple tanks will most likely be needed and the selection of skimmers and filters may need to be adjusted depending on the spill situation.

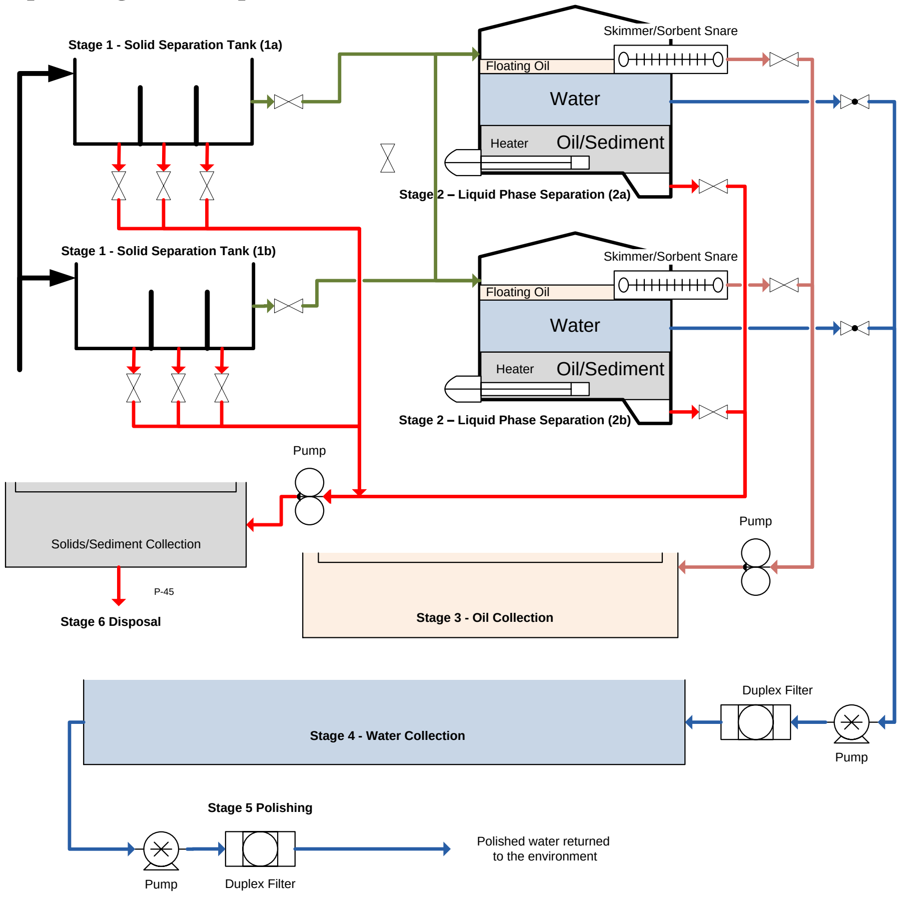

Figure 7. Recommended Decanting System

SUMMARY:

While many answers for the recovery of sunken were found, all of the possible combinations of oil and bottom types could not be addressed. (Hansen 2014) The project advanced three systems as alternatives to divers for recovery of oil. The level of funding and the complexity did not permit a full operational evaluation of these systems in on offshore setting. Additional detailed work is needed as well as trade-offs for costs during a spill response:

- Developing detailed and easily implemented alternatives for processing the data collected by the detection sensors and how this data is used during evaluation in real-world environments. Additional guidance for the sensor use is also needed.
- Detailed development of recovery systems from the size and shape of the nozzles to moving the oil through the hose utilizing annular injection since the effect of a large amount of water and sediment is not known. Tradeoffs between pump requirements and use of water injection still need to be addressed.
- Characterizing the system capabilities needed under multiple conditions and oils.
- Cost benefit analysis of these techniques need to be performed during a spill taking into account the environment and the amount of potential oil recovered.

NON-ATTRIBUTION POLICY:

Opinions or assertions expressed in this paper are solely those of the author and do not necessarily represent the views of the U.S. Government. The use of manufacturer names and product names are included for descriptive purposes only and do not reflect endorsement by the author or the U. S. Coast Guard of any manufacturer or product.

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