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A Collaborative Effort to Define the Application, Approval, and Monitoring Process for Subsea Dispersant Use

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ABSTRACT 300070:

Since the *Deepwater Horizon* (DWH) well control incident in 2010, oil and gas operators have worked diligently with Federal and State government officials and source control management organizations to develop equipment, operating procedures, monitoring plans and new technologies to support subsea dispersant operations. Many drilling permits in the U.S. Gulf of Mexico include a subsea dispersant injection capability in their oil spill response contingency plans. These contingency plans are frequently tested during command post or functional exercises to demonstrate preparedness.

A critical step in this type of well control event is requesting governmental approval for subsea dispersant use. Although several years have elapsed since the DWH incident, the use of subsea dispersants has not been formally approved during an exercise despite industry demonstrating the capability of implementing subsea dispersant operations. The API D3 Joint Industry Task Force (JITF) Subsea Dispersant project has worked with Clean Gulf Associates, Marine Well Containment Company (MWCC), Helix Well Control Group (HWCG) and both Gulf Regional Response Teams to develop and improve the API recommended model subsea dispersant monitoring plan, and standardized documents that can be used for requesting RRT concurrence for subsea dispersant use. As these documents have evolved in response to lessons

learned from industry led exercises over the last three years, the API D3 JITF has also worked to identify and test emerging monitoring technologies available to support subsea dispersant use. Recent advancements include the new LISST-DEEP instrument for *in situ* droplet size analysis at depth and pressure, and improvements to optical dissolved oxygen probe technology.

The Region VI Regional Response Team (RRT) has also begun a process to improve clarity on approval request procedures, and has tasked its Industry Work Group (IWG) with developing standardized forms and documents that could be used to request RRT concurrence with subsea dispersant use decisions. The IWG will coordinate with the API D3 JITF in developing those products. This paper will discuss the results of those efforts and present a recommended RRT concurrence request submittal package, which will include the API recommended model subsea dispersant monitoring plan, monitoring equipment recommendations, and operational plans with injection equipment recommendations.

INTRODUCTION:

Subsea dispersant injection was first used as a response method during the 2010 Deepwater Horizon (DWH) well blowout, primarily to improve safety for crews involved in response actions near the well head and prevent oil from reaching the surface and affecting sensitive areas along the Gulf of Mexico coastline. Although subsea dispersant injection was seen as effective, lessons learned indicated that it would be helpful to establish standard subsea dispersant injection procedures and environmental monitoring protocols, and identify appropriate monitoring technologies.

To further the state of the knowledge regarding subsea dispersant use, the American Petroleum Institute (API) established a Subsea Dispersant Injection (D3) Joint Industry Task Force (JITF) that has implemented focused research on subsea dispersant effectiveness, fate and effects, modeling, and monitoring. In particular, the API D3 Monitoring team has concentrated on addressing some of the lessons learned from the subsea dispersant injection operations during DWH. This team's efforts include the development of recommended monitoring practices in the event that dispersants are used to respond to an uncontrolled subsea oil release; the evaluation of existing and emerging technologies for subsea dispersant monitoring; and, in conjunction with Regional Response Teams IV and VI, the initial development of procedures for obtaining authorization to use subsea dispersant injection as a response tool.

INDUSTRY RECOMMENDED SUBSEA DISPERSANT MONITORING PLAN:

One of the goals of subsea dispersant injection is to reduce the size of oil droplets rising from an uncontrolled subsea release. Research has shown that oil droplets smaller than 100 microns should become suspended in the water column where they can be degraded by naturally occurring microbes (Johansen et al., 2003) and other processes. This may prevent or reduce the amount of oil reaching the surface, thereby reducing the amount of potentially hazardous volatile organic compounds (VOCs) in the area where emergency responders are working to control the source. Additionally, this action may reduce the environmental effects of spilled oil, by preventing or reducing the amount of oil that reaches the surface and washes ashore on sensitive shorelines (Lewis & Aurand, 1997). Certain types of monitoring equipment may assist responders in determining oil droplet size distribution of both undispersed and dispersed oil, thereby enabling the determination of dispersant effectiveness.

Monitoring may also inform operational decision-making. Responders employing a wide array of devices may be able to characterize a deep water dispersed oil plume, allowing an initial assessment of potential ecological effects. With this information, the benefits and consequences of subsea dispersant injection may be weighed against other response options, enabling an optimized approach to spill response. Other types of monitoring exist and include those designed to assess long-term ecological effects of dispersed oil in the environment. However, those monitoring activities are beyond the scope of this paper.

In 2013, two documents were released outlining procedures that could be used to develop operational monitoring plans. In May, the National Response Team (NRT) published *Environmental Monitoring for Atypical Dispersant Operations*, which addressed monitoring guidance for both "atypical" surface and subsea dispersant use. In September, API detailed its guidance in its *Industry Recommended Subsea Dispersant Monitoring Plan Version 1.0*. Although there are some differences between the NRT and API documents, both provide recommendations that may be used to develop a subsea monitoring plan tailored to the spill event. API and NRT continue to coordinate their activities and achieve congruence between the recommended monitoring approaches.

Recommended monitoring approach

Monitoring plans must be adjusted to the magnitude, location and complexity of the response. Therefore, API recommends the use of an adaptive, scientifically-based approach that is designed to meet incident-specific response requirements. The purpose of sampling and monitoring as described in this document are to a) determine dispersant efficacy; b) characterize the nature and extent of subsea, dispersed oil plumes; and c) provide an initial assessment of potential ecological effects as they relate to operational response decision-making. To enable the use of the widest array of response options, the API guidance outlines a phased approach to allow rapidly-deployable monitoring systems to be put into place to provide initial dispersant efficacy information to operational decision makers. This preliminary deployment may be supplemented by more comprehensive monitoring tools and analytical procedures as they become available.

API guidance format

The guidance is organized into three phases. The first stage evaluates dispersant effectiveness near the discharge point and assesses VOC levels at the surface. The second phase characterizes dispersed oil concentrations in the water column. Finally, the third segment details the hydrocarbon content in water samples. These phases are listed in order of increasing complexity, and for most responses, in chronological order of implementation. Each section contains a description of operations to be conducted, outlines recommended methods, and lists required equipment. Additional sections provide recommendations for data communication, quality assurance, ecological toxicity assessment, and the establishment of action levels.

Confirmation of dispersant effectiveness

Efficacy monitoring may be conducted in three ways and includes visual assessments using Remotely Operated Vehicles (ROVs) equipped with underwater video cameras; aerial imaging and analysis of the oil's surface expression; and analytically monitoring air at the surface for VOCs and percent of the lower explosive limit (LEL). Visual monitoring is based on detecting color or appearance changes of an oil plume when dispersant is added. Air monitoring, which is also important for ensuring worker safety, is based on the premise that VOCs at the surface can be reduced by dispersing oil into the water column. During the DWH event, visual observations and VOC and LEL measurements supported conclusions that subsea dispersant use was effective. It must be noted that these methods yield primarily qualitative measures of dispersant effectiveness.

Characterization of dispersed oil concentrations at depths in the water column.

Water column monitoring seeks to determine the location, extent, and characteristics of the dispersed oil plume at depth. This may be accomplished from a research vessel equipped with a Conductivity Temperature Depth (CTD) instrument outfitted with a fluorometer and a dissolved oxygen (DO) sensor. Additionally, oil droplet size may be determined with a Laser In-Situ Scanning Transmissometer (LISST) particle size analyzer, either deployed just above the subsea dispersant application location by an ROV, or by shipboard analysis of collected water samples. Furthermore, CTD results should be evaluated to determine station and depth locations for water sample collection for subsequent chemical analysis. Sample analysis should be conducted aboard the research vessel, if practical, using Gas Chromatography-Mass Spectroscopy (GC-MS) with flame ionization detector capability to determine total petroleum hydrocarbons (TPHs).

Detailed chemical characterization of water samples.

Detailed chemical analysis seeks to fully characterize all water samples using shipboard GC-MS, when possible, and a certified and accredited laboratory capable of processing large volumes of samples, using state-of-the-art laboratory analytical techniques for petroleum analytes and dispersant marker analysis. Laboratory analysis may be time consuming in that it can frequently require 7 to 10 days to process and analyze the samples, perform data analysis, and then communicate the data to response decision-makers.

Additional recommendations.

As previously discussed, additional sections of the API guidance address the areas of data communication, quality assurance, ecological toxicity assessment, and action levels. The data communication section outlines a variety of topics such as data standards, digital data management, data flow through the response structure, and data reporting schedules. During a large spill, a number of organizations may be involved in monitoring activities, and early establishment of data standards and reporting methods is essential to ensure that all data generated are usable and support the monitoring objectives. The Quality Assurance Project Plan (QAPP) ensures that data quality is known and is sufficient to support intended objectives. To support this aim, adoption of the U.S. Environmental Protection Agency's (EPA) QAPPs 4 and 5 should be considered.

An ecological toxicity assessment plan should be developed, in consultation with the Unified Command (UC). This plan should be based on a comparison of water quality data generated through implementation of the subsea dispersant monitoring plan to science-based ecotoxicity benchmarks (EB) centered on species sensitivity distributions.

Action levels should also be established through consultation with the UC. Action levels may be based on water quality data (e.g., DO value below 2.0 mg/L), analytical data such as dispersant marker compounds, or EBs. It is important to note that attainment of an action level should not indicate that dispersant operations should cease. Instead, it should signal members of the response management structure to review current dispersant operations, consider net environmental benefits of dispersant effectiveness compared to other response tools being implemented at the spill event, and recommend changes to the response strategy, if appropriate.

REQUESTING AUTHORIZATION FOR SUBSEA DISPERSANT USE:

Dispersant use in the U.S. is governed by Subpart J of the National Contingency Plan (NCP), which is found in 40 CFR Section 300.910, *Authorization of use*. The legal framework for subsea application of dispersants is the same as for surface dispersant application. The NCP establishes the roles of its major components related to dispersant use, which include the NRT, the RRT, On-Scene Coordinator (OSC), and the UC structure for managing response events. The role of each in authorizing dispersant use, and a recommended process for requesting subsea dispersant use authorization, is described in this section.

The NRT, chaired and co-chaired by the EPA and U.S. Coast Guard, respectively, is composed of 15 Federal agencies and is responsible for response planning and coordination. Ordinarily, the NRT does not become involved in response operations, but supports emergency preparedness by publishing guidance, coordinating planning activities, sponsoring training, and supporting the RRTs. The NRT's most significant role in supporting subsea dispersant use is the publication of guidance documents for OSCs, RRTs, and responsible parties on factors to be considered in planning for subsea dispersant use, and in conducting environmental monitoring in support of subsea dispersant injection operations.

According to 40 CFR 300.910, the RRTs have specific roles with regard to dispersant use. These duties include evaluating the desirability of dispersant use for specific areas and circumstances; developing pre-authorization plans, where appropriate; and responding to incident-specific OSC requests for dispersant authorization. If regional pre-authorization plans are proposed, they must be accepted by the RRT representatives from EPA, the affected state(s), the Department of Commerce (DOC), and the Department of Interior (DOI). OSCs may authorize the use of approved dispersants in response to a specific incident not covered by a pre-authorization plan, per 40 CFR 300.910(c). However, they must seek the concurrence of the RRT representatives from the EPA, and the affected state(s), in consultation with the representatives from DOC and DOI. Most RRTs have approved pre-authorization plans for surface dispersant use in selected areas, but at this time, none have approved pre-authorization plans for subsea dispersant use.

The OSC is responsible for establishing the UC for an incident and for approving, or denying, dispersant use. The OSC may allow dispersant use without RRT involvement if, in his or her judgment, its use is necessary to protect or "substantially reduce a hazard to human life." Currently, subsea dispersant use may be authorized by an OSC, using his or her authority to mitigate hazards to human life, or must receive concurrence from the NCP-mandated RRT representatives using the process previously described.

The UC consists (at a minimum) of the OSC, a representative of the potentially affected State(s), and a representative from the responsible party, known as the Qualified Individual /Incident Commander (QI/IC). The QI/IC typically initiates the process of seeking dispersant use authorization by reporting the incident to the National Response Center and the OSC. The QI/IC is responsible for providing the OSC with information necessary to support the decision to authorize subsea dispersant injection. Most RRTs have developed forms and checklists that may be used by QI/ICs and OSCs to facilitate the decision process. However, these forms and checklists have been designed to request surface dispersant authorization. To address this shortfall, RRT VI, in collaboration with API D3 JITF, is developing an “RRT Concurrence Package,” including forms and checklists, to support the process of requesting RRT concurrence for subsea dispersant use. The package includes a signature page for the OSC, state representative, and the responsible party QI/IC; an Incident Data Sheet (IDS); a high level summary of the proposed subsea dispersant operations plan; and the subsea dispersant monitoring plan. These documents address information requirements identified in the NRT's *Environmental Monitoring for Atypical Dispersant Operations*, API’s *Industry Recommended Subsea Dispersant Monitoring Plan Version 1.0,* and the EPA requirements developed during the DWH response.

A recommended subsea dispersant authorization request process

The high level dispersant operations plan and subsea dispersant monitoring plan that compose part of the authorization request package were previously outlined. The IDS includes information not contained in these documents. Specifically, it includes the name(s) of the responsible party or parties, the incident location and description, bathymetry, oil characterization, spill description, proposed dispersant use (name, quantity, injection rate, volume, and estimated duration), weather conditions, oceanographic data, subsurface plume modeling, resources at risk, and key elements from the monitoring plan.

There should be an option for a responsible party to rapidly commence a request for subsea dispersant authorization by sending the request to the OSC and providing the information required on the IDS, to the extent possible. The OSC should consult with the UC and determine whether or not dispersant use is appropriate, based on incident-specific considerations. If the OSC decides to authorize subsea dispersant injection, he/she then may choose to seek concurrence on the deployment plan from the relevant RRT. This is typically accomplished through a conference call consultation scheduled by the RRT co-chair from the USCG.

Information needed to support the conference call is provided to RRT members by the USCG RRT Coordinator and includes the RRT Concurrence Package.

During the conference call, members of the UC should provide an overview of the information in the concurrence package, whereas the QI/IC would typically summarize the incident. The RRT will then either concur with the plan, or raise questions about it, or request modifications to the plan. After consulting with the RRT, the OSC retains his or her authority to decide whether dispersant use is appropriate for a particular oil spill response. If dispersants will be used, the use plan should establish and include data reporting procedures and additional coordination requirements.

SUBSEA DISPERSANTS MONITORING KIT AND CAPABILITY:

The purpose and benefits of assembling a subsea dispersant operations monitoring kit include the ability to provide response decision-makers with reliable, consistent, and science-based information; enable rapid deployment to the operational theater; deliver a 2-week response capability to support initial response operations; allow integration with oil spill response (OSR) exercises; and assist response personnel with the characterization of the sub-surface water column, including oil droplet size and concentration and information to support plume trajectory modeling efforts.

Functional requirements and core elements

Due to the operational nature of the potential deployment, the monitoring kit is designed to meet clear functional requirements. These include equipment and sensors with depth ratings of 2000 meters or more; delivery of data designed to complement the information captured at the surface (e.g., SMART protocols); and delivery of near real-time data for rapid decision-making. The monitoring capability is comprised of four core elements that include a fit-for-purpose marine science vessel; a rapidly deployable suite of sensors for *in situ* data acquisition; an industry standard sampling and analysis protocol; and a competent science team to deploy and operate the monitoring kit. This scientific team must have the ability to rapidly interpret and synthesize shipboard data, in the context of dispersed oil science, to help define the context of dispersant effectiveness into the overall net environmental benefit analysis for the response. Table 1 outlines a sample monitoring kit.

The fit-for-purpose sampling vessel will serve as the primary platform from which monitoring activities will occur. The vessel will host not only the monitoring kit, but the science team complement, and maintain sufficient range to sustain and support a two-week deployment. In addition, the vessel must be capable of safely hosting the deep-sea winches and frames required to deploy and retrieve the monitoring sensor packages, and provide room for the shipping container used to house the monitoring kit. Standard wet and dry laboratory space is also requisite onboard the vessel.

Given the potential need to provide sustained monitoring operations in support of source control activities, the kit includes some redundancy of key sensors and materials to reduce the risk of information gaps due to equipment fouling or failure while underway. The equipment and sensors will be accompanied by requisite laboratory materials, health and safety equipment for science personnel, and deployment protocols. During a real deployment, the protocols would be subject to modification by the ICs, as dictated by safety considerations and operational priorities.

The monitoring kit will be deployed by a trained science staff, responsible for delivering timely and accurate scientific information to support of response decision-making. The science complement will be trained in the Incident Command System and execute the mission guidance provided by the Incident Command staff. In addition, designated science team members will provide shore-side support for communications, relay and transport of physical and digital samples, and synthesis of data to provide ICs with a clear and consistent characterization of sub-surface hydrocarbons and dispersant efficacy. For this reason, it is essential that the scientific personnel have a deep understanding of dispersant strategies and dispersed oil science to present information in context with other ongoing response strategies.

During storage, the monitoring kit will be maintained through a set of formal practices. This maintenance plan will include a certified inventory and inspection of the equipment, sensors, and materials; a rotation of materials, as warranted; periodic calibration of instruments, per manufacturer specification; and the ability to inspect the storage facility. Similarly, following any deployment, the monitoring kit will be restored to its pre-deployment status. This may include refurbishment, replacement, and replenishment of equipment, sensors, and materials.

Future developments

As sampling technology continues to evolve, science will mature, and new operational mandates and practices will emerge. To help meet these changes, while still maintaining core response capability, the API D3 JITF proposes the adoption of several pragmatic steps. These steps include:

- A bi-annual review of monitoring kit composition and protocols to ensure the adoption of current technology and alignment with any changes in regulations;
- The creation of a multi-sector operational science panel (including industry, academic, and regulatory representatives) to oversee the review;
- A dedicated program to review future sub-sea monitoring technologies; and
- Continued public awareness and education through a formalized communications plan.

BASIC SUBSEA DISPERSANT OPERATIONS EQUIPMENT AND METHOD:

Although specific subsea dispersant monitoring packages may vary slightly in configuration and outfitting, some fundamental, high-level operational methods exist for operating this equipment. These procedures are described in Figure 1.

Figure 1. Operational Overview of Subsea Dispersant Injection

- Mobilize the equipment to the location;
- Connect surface hose to dispersant supply tanks;
- Take VOC and LEL readings on site;
- Integrate the dispersant vessel into the incident's SIMOPS command*;
- Position the vessel as instructed by OSC;
- Deploy acoustic frequency management system;
- Deploy clump weight with coiled tubing;
- Deploy manifold;
- ROV connects hot stab connection to clump weight on the manifold;
- ROV connects chemical hose to the manifold;
- ROV connects chemical hose with applicator to the manifold. If a "Top Hat" is deployed, hot stab the chemical injection hose into the Top Hat;
- ROV #1 takes an "overview" position to assist ROV #2 in positioning the applicator into the plume;
- Commence dispersant pumping from the dispersant vessel;
- ROV #2 inserts applicator into the plume;
- Adjust injection operations to maximize dispersant effectiveness, as indicated by *in situ* monitoring; and
- Record volumes, pressures, and visual observations at intervals in accordance with approved monitoring plan.

** the dispersant vessel is different from the marine science vessel described previously*

Subsea dispersant injection equipment

Subsea dispersant injection operations, regardless of the provider, follow some fundamental principles (Figures 2 and 3). The dispersants must be pumped from a surface dispersant vessel to the first component in the system. Depending on the depth of the water, this is typically accomplished with coiled tubing, a pump and injection head. The coiled tubing can vary from 1.25 inches inner diameter to 2 inches. Due to the weight of the tubing and limited reel sizes, deeper depths required smaller diameter tubing.

The hose or coiled tubing attaches to either a suspended, free-standing manifold, coiled tubing connector attached to an umbilical or chemical hose with a clump weight; or to a distribution panel on the mud line. Either chemical hoses or umbilical are used as a conduit between the coiled tubing and the distribution panel or manifold. A minimum of 300 meters is required to allow the vessel supporting subsea dispersant injection operations to offset from the well flow at the surface to avoid air hazards such as VOCs, hydrogen sulfide (H_2S), or LELs that create hazardous work conditions for crew members. Once the dispersants are injected into the well flow, the air hazards should diminish within a few hours, depending on water depth, flow rate, and gas-to-oil ratio of the open flow.

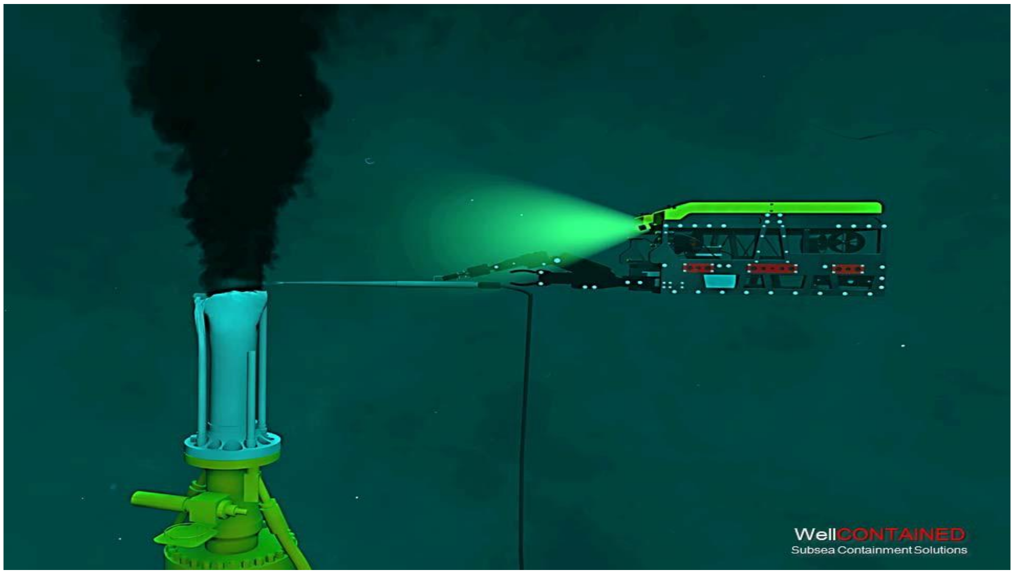

Figure 2. Notional view of subsea dispersant injection into broken riser (Source: WWC)

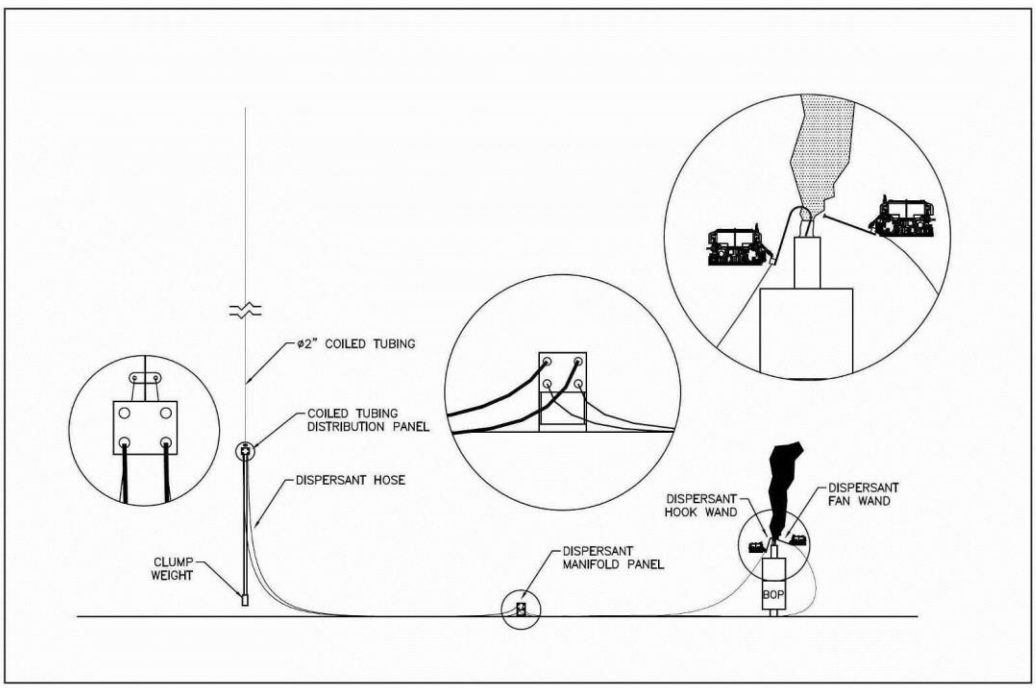

Figure 3. Schematic of subsea dispersant equipment (Source: MWCC)

The open flow can come from single or multiple sources such as a ruptured riser, blowout preventer connection, or flange. Depending on source, one of two arrays may be attached to and extend from the distribution panel or manifold to enable dispersant injection into the rising oil plume. These arrays include 17H hot stabs that attach to the capping stack or Top Hat dispersant injection ports, or Joint Industry Council (JIC) fittings attached to dispersant spray wands to inject dispersants directly into the open flow.

Supporting Equipment

In addition to the coiled tubing equipment, additional support equipment is required. Dispersants are typically stored in 3000 to 5000 gallon ISO tanks which are transported to the work vessels and stored on the deck. Typically, these main supply tanks are connected to a smaller, 100 to 500 barrel storage tank via a manifold, associated plumbing, and a pump. The small storage tank is then connected to the coiled tubing and would include a flow meter on the discharge side of the pump to enable an accurate measure of dispersant flow rate.

Subsea Injection Vessel

Depending on the water depth, a multi-purpose vessel or offshore construction vessel at least 90m Length Overall with the following specifications is recommended as the primary work platform:

- **Dynamic positioning capability -** A DP2 rating is preferred, depending on consideration of factors such as geographic location, water depth, and met-ocean data.
- **Deck load capability -** Coiled tubing equipment packages can weigh up to 50 tons, depending on the size of the coiled tubing. Deck loading capacities and structural support beam locations must be known to ensure that supporting vessel and equipment are compatible.
- **Deck area -** Available deck space is determined by the actual scope of equipment and supplies on the vessel. As a guide, 500 to 1000 square meters should be used.
- **Crane capacity -** The crane should be fitted with Active Heave Compensation and capable of lifting 150 tons to allow loading/unloading of equipment and dispersant supplies.
- **ROV -** Two pressure-rated, work class ROV's are required (note that these are separate from the ROV previously described for monitoring activities).
- **Gas detection -** Gas detectors for H_2S, VOCs, and LELs are required.
- **Service requirements -** Deck supply of water; clean, dry air; and electricity (110 V, 220 V and 440 V depending on equipment specifications) are required.

In addition to the subsea dispersant injection vessel, dedicated supply vessels to transport dispersant tanks between the logistics base and the offshore vessel are recommended. Transit distances and dispersant usage should be used to determine the number of vessels required.

Staffing

In addition to the equipment and personnel required to operate subsea dispersant monitoring operations, subsea dispersant injection operations requires the assembly of specialized equipment and qualified personnel. ROVs are the primary underwater platform used to conduct subsea dispersant injection operations. In addition, shipboard operators trained to handle coiled tubing winches and dispersant pumps from the stern of a vessel are necessary. Careful coordination between dispersant injection and dispersant monitoring teams is essential in ensuring optimal dispersant injection rates. As a result, personnel needed to staff a subsea dispersant injection operation include shipboard dispersant equipment specialists, flow engineer, ROV operations specialists, dispersant manufacturer representative, and dispersant use specialist.

CONCLUSIONS:

Subsea dispersant operational methods, environmental monitoring protocols, monitoring technologies, and procedures for regulatory engagement in dispersant decision making have all improved in the four years since the Deepwater Horizon incident in the Gulf of Mexico. Advancements in preparedness to employ subsea dispersant injection as a primary response method should continue as a result of targeted research and active participation of operators, regulators, and response organizations in realistic drills and exercises. The API D3 JITF can facilitate further improvement in response capacity by continuing to evaluate emerging technologies, sharing lessons learned and industry best practices arising from these activities, and continuing its engagement with the NRT and RRTs on response policy issues.

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Table 1. List of primary sampling equipment and sensors with description of purpose.

Equipment		
Item (Count)	**Description**	**Purpose/Notes**
DNV-Rated 20-ft Container - Storage (1)	Customized for kit storage, with lift and tie points. Must lock and be configured to store all specified equipment and materials.	Storage and transport container for contents.
DNV-Rated 20-ft Container - Lab (1)	Customized as mobile lab, with lift and tie points, filtered ventilation, lighting, bench space, electrical power outlets, and standard wet lab HSSE features.	Serves as a mobile lab on sampling vessel (as necessary).
-80degC Chest Freezer (1)	Stand-alone deep-freezer unit, capable of holding 100, 1L sample bottles.	For preservation of samples.
32 Carousel Water Sampler Rosette with 12-Bottle (Niskin) Array with Autofire Mechanism (1)	Rosette-style sampling platform for sampling bottles and instrumentation array.	For capturing and securing water samples at depth.
Niskin Bottles (Min. 4L Volume) (20)	Remotely-triggered sampling containers for use at depth in ocean environment.	For capturing and securing water samples at depth.
DNV-Rated Tie-down Straps (multiple)	Industry standard ratchet or tie-down straps for use in interior of containers, and sufficient to secure all travel cases for instruments and materials.	To secure contents of storage containers during transit.
Instruments		
Item (Count)	**Description**	**Purpose/Notes**
LISST-Deep and accompanying data/power cable. (2)	Deep-sea (rated to 3000m) laser-based particle analyzer. Primary and spare.	For in-column water sampling of oil particle size and estimation of concentration. Type-C LISST (2.5-500µm).
LISST-100x and accompanying data/power cable. (2)	Laser-based particle analyzer. Must include accessories for bench use. Primary and spare.	One for shallow water use and one for bench-based verification of oil particle size. Type-C LISST (2.5-500µm).
Deep-sea CDOM Fluorometer (2)	CDOM fluorometer for indirectly detecting hydrocarbons (processed or raw) in solution.	Helps track and characterize oil at depth.
Ship-Mountable ADCP (1)	Mobile Acoustic Doppler Current Profiler to serve as primary ADCP (or augment in-hull ADCP).	To help determine current profiles in immediate vicinity of sampling location.

CTD, Depth-Rated real time data readout (2)	Measures conductivity (a proxy for salinity) and temperature at depth, plus pressure. Primary and spare. Includes SBE-11Plus V2 deck unit.	Delivers data on critical oceanographic parameters, to enhance modeling and understanding of oil fate and transport.
"Deck Unit" (1)	Integration point for submerged equipment and sensor array. Spare for integrated CTD module.	Provides requisite connections for receiving data from deployed sensor array.
Depth-rated Dissolved Oxygen Sensor (2)	Measures dissolved oxygen at depth. Primary and spare.	Delivers data on potential impactful levels of oxygen depletion.
Depth-rated Altimeter (2)	Measures depth in water column, allowing accurate documentation of sample location	Provides important real-time depth information to protect equipment and ensure consistent measurements.
Ultra-Short Baseline (USBL) Underwater Acoustic System (1)	Provides accurate positioning information to be associated with in-column instruments.	Helps maintain integrity of data acquisition by verifying position within water column.
Depth-rated, underwater still/video camera(s) with light source (2)	Depth-rated still/video camera with light source adequate for in-column imaging. To include required power cabling or on-board power source.	Helps maintain integrity of data acquisition by providing visual representation of site.
Deep-tow system (1)	Serves as in-column platform for a range of sensors, and designed to be towed while vessel is underway.	Provides science team with stable, versatile alternative to CTD rosette as an in-column sensor host platform.
Benzene Monitor (3)	Handheld instantaneous benzene monitoring device.	Ship-based personnel safety. Two deployed and one spare.
VOC Monitor (3)	Handheld instantaneous VOC monitoring device.	Ship-based personnel safety. Two deployed and one spare.
Permissible Exposure Level (PEL) Badge (15)	Monitors exposure and provides alerts to personnel.	PELs for ship-based science team members. Ten for use, plus 5 spares.
Mobile GC/MS Analyzer (1)	Mobile, gas chromatograph/mass spectrometer.	Used to perform rapid, shipboard analysis of water samples and constituents.