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Gulf Energy

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Increasing subsea production with DRA

Subsea injection of drag reducing agents (DRA) into flowlines reduces friction and substantially increases production. For years, DRA has been widely used onshore, and in upstream transfer and export systems. Today, breakthrough advancements allow DRA to be injected into subsea production systems.

■ JOHN GILLESPIE, LiquidPower Specialty Products Inc. (LSPI); ART SCHROEDER, Safe Marine Transport, LLC (SMT); and GRAEME KINNELL, Subsea 7

Drag reducing agents (DRA) have been used successfully for over 40 years to increase the pipeline flowrate in land-based pipelines and offshore export lines. This transformative technology is now available for subsea multiphase flowlines. For decades, it has been a vision of DRA manufacturers and oil producers, alike, to use DRA subsea to increase well production by increasing the throughput of subsea flowlines.

Fig. 1. Subsea DRA storage and injection unit.

After years of testing and development, it was determined that transferring long-chain polymers through umbilicals was too great a challenge with current technology. To solve this challenge, Safe Marine Transfer, LLC (SMT) took an innovative step to patent, design and build a subsea DRA storage and injection unit. SMT's unit transformed the subsea DRA injection vision into reality, as shown in **Fig. 1.**

Over the past three years, SMT developed a fit-for-purpose subsea DRA storage and injection unit, capable of injecting DRA into subsea flowlines to increase production. This technology and supporting alliances were initially unveiled in August 2021 at the Offshore Technology Conference.[1] In October 2021, *World Oil* honored SMT for their innovative technology when independent industry judges selected SMT for the *Best Deepwater Technology Award:* "Subsea production increase via DRA," **Fig. 2.**[2]

A Cooperation Agreement was executed between SMT (www.safemarinetransfer.com), LiquidPower Specialty Products Inc. (LSPI), a Berkshire Hathaway Company (www.liquidpower.com), and Subsea 7 (www.subsea7.com), with the objective of combining the strengths of each company to increase the value of their offering to subsea production operators.

LSPI pioneered DRA development over 40 years ago and has accumulated over 70 patents related to drag reduction. LSPI has several commercial DRA products for specific applications. LSPI's strengths in this effort were the development of a subsea multiphase DRA, and the ability to evaluate and quantify potential DRA opportunities for the consideration of oil companies.

Subsea 7 has a global footprint, with a world class fleet, and a diverse and talented workforce. These strengths make Subsea 7 uniquely qualified to safely and

Fig. 2. Accepting *World Oil's* "Best Deepwater Technology Award" on Oct. 14, 2021, were Darren Wyatt (CFO, LSPI); Laura Reinosa (V.P., Finance, LSPI); and Art Schroeder (CEO, SMT). Image: *World Oil.*

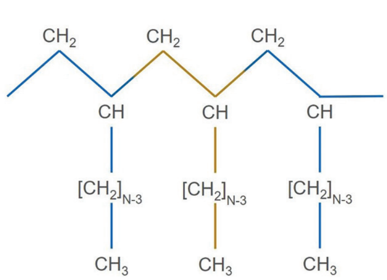
cost-effectively install, commission, recover and maintain subsea DRA storage and injection units all over the world. The installation and recovery can be accomplished independently or in conjunction with other offshore campaigns.

The combination of SMT's, LSPI's, and Subsea 7's strengths create a unique capability to provide a global, full-service subsea DRA injection solution to oil companies.

Drag Reducing Agents (DRA) are long-chain, ultra-high molecular weight polymers (poly-alpha-olefins) made only of carbon and hydrogen atoms (**Fig. 3**) and have a strong affinity to crude oil. DRA interacts with the crude oil molecules and reduce the turbulent eddy currents, which reduces the frictional pressure lost in the system.[3] A short video of how drag reduction occurs with DRA can be viewed at the following site: https://vimeo.com/lspi/howdraworks

DRA is injected in parts per million (PPM). Given that DRA is a polyolefin (hydrocarbon polymer), the DRA has no negative impacts on crude oil or refineries. In over 40 years of DRA injection into crude oil, no incompatibilities with other production chemicals or pipeline additives have been observed.

Fig. 3. DRA chemical structure.



DRA has many positive attributes and misconceptions. Several common misconceptions of DRA are listed below:

DRA *does not:*

- Coat pipeline walls
- Change the viscosity of the flowing fluid
- Change the density of the flowing fluid
- Negatively impact refineries.

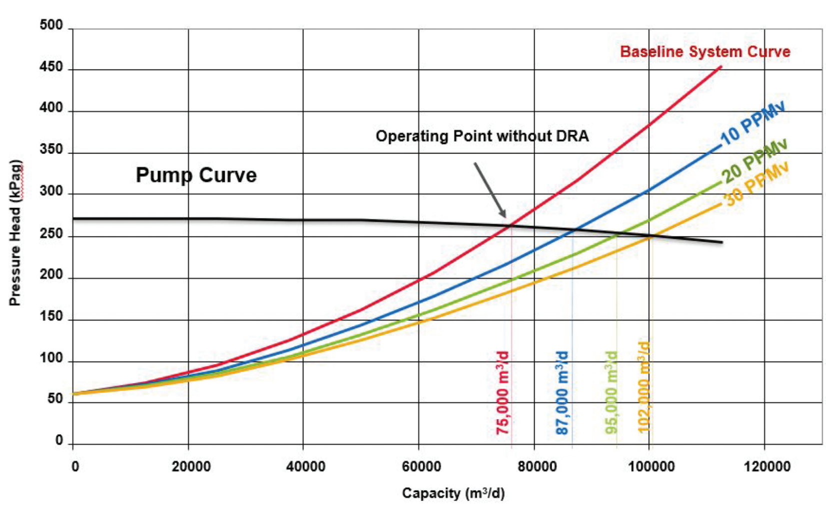
DRA *does:*

- Reduce turbulence
- Increase flowrates/production
- Reduce pipeline pressure
- Reduce the pressure loss per mile/km
- Dissolve with hydrocarbons.

DRA can reduce pressure losses, due to friction, by >80% in single-phase, light-oil applications. Water and gas reduce drag reduction performance; so even with a properly engineered DRA, a multi-phase application will typically yield lower performance than a single-phase crude application. DRA performance is dependent on the crude and multiphase characteristics. If a flowline has a 3,000-psi frictional pressure loss, and DRA provides a 33% drag reduction effectiveness, the system will gain 1,000 psi in pressure available to allow an increase in flow/production until the system reaches equilibrium.

A pump curve and various system curves (with varying DRA concentrations, in PPM) are shown in **Fig. 4.** The intersection of the red and black lines is the system operating point without DRA. As more DRA is added, and frictional pressure loss is reduced, the system curve shifts to the right to find an equilibrium or new operating point (i.e., less psi loss per mile/km). The operating points with DRA have a lower flowline pressure and achieve a higher flowrate/production.

Fig. 4. Pump curve and system curves.



DRA case studies and results. While DRA has not yet been injected subsea, it has been used in many multiphase applications since the initial successful multiphase application in 2005. DRA performance is dependent on crude properties and multiphase characteristics. The injection location (subsea or topside) is irrelevant to DRA performance. The information in **Fig. 5** originates from a platform-to-platform DRA application, but it is shown as a subsea DRA injection for illustration purposes.

The baseline conditions reflect the characteristics of the crude oil, flowline and system. The colored box shows the system characteristics while injecting 150 ppm of DRA: a 35% drag reduction and a 50% production increase. As shown by this example, DRA is a valuable tool to boost production and keep hubs full.

The results of another multiphase DRA application are included in **Fig. 6.** The information in **Fig. 6** originates from a platform-to-platform DRA application, but is shown as a subsea DRA injection for illustration purposes.

The baseline conditions reflect the characteristics of the crude oil, flowline and system. The colored box shows the system characteristics while injecting 200 ppm of DRA: a 35% drag reduction and a 30% production increase. Even though the drag reduction is the same in both case studies (35%), the percent increase in production differs (30% to 50%).

The production increase depends upon the DRA performance (35%), in addition to the well's productivity index (PI – STB/day/psi). The well's PI reflects the well's ability to convert the reduction in frictional pressure loss to a production increase. This example demonstrates the value of DRA to increase production and the variability of production increase (30% to 50%) associated with the well's specific characteristics.

DRA benefits. In addition to increasing production by debottlenecking the flowline, DRA can provide offshore operators with additional benefits and operational flexibility, including:

Short-term benefits:

- Achieving production targets
- Reducing slugging by increasing flowrates and sweeping
- Increasing flowrates during early flush oil
- Eliminating valuable topside space requirements with subsea equipment.

Longer-term benefits:

- Adding wells to an existing flowline
- Increasing tie-back distances
- Increasing flexibility, as portable units can be moved when conditions and economics change
- Complementing or substituting subsea boosting systems
- Reducing capital costs via higher production through smaller flowlines
- Retaining production while reducing flowline pressure (if a flowline's MAOP is reduced).

The DRA designed for the subsea market has characteristics conducive to subsea storage and multiphase flow: low freezing-point (14°F / -10°C), product stability, shear resistance, and excellent safety and environmental ratings (OSPAR-Yellow, and NFPA-0,0,0).

LSPI DRA has been used successfully for over 40 years at greater than 1,000 locations, by more than 100 customers (e.g., national oil companies, integrated oil companies, production companies, and pipeline companies). Now, with a successfully qualified subsea DRA storage and injection unit designed specifically for LSPI's DRA, coupled with a DRA uniquely engineered for subsea multiphase flow, customers can enjoy the benefits of subsea production improvement.

SMT's Subsea DRA Storage and Injection Unit consists of two primary components:

1) A subsea DRA storage unit, as shown in **Fig. 7**, is a steel storage unit that encases a flexible bladder that, together, provide a dual barrier to the marine environment. A leak detection system was designed, patented, fabricated, and tested to further enhance environmental protection; and 2) A subsea DRA injection unit (**Fig. 8**) fits into the end of the subsea DRA storage unit (**Fig. 7**). This unit features an all-electric operation with pumps, meter, and actuated valves

Fig. 5. Case study #1.

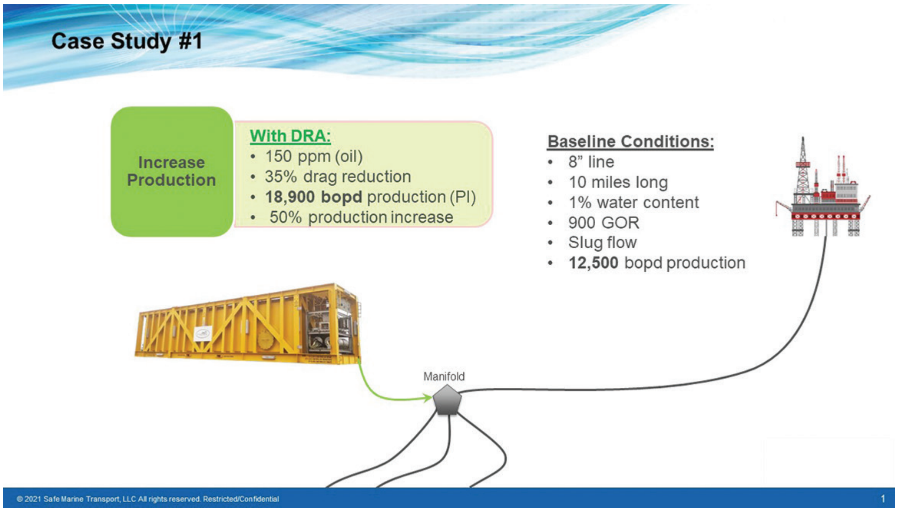


Fig. 6. Case Study #2.

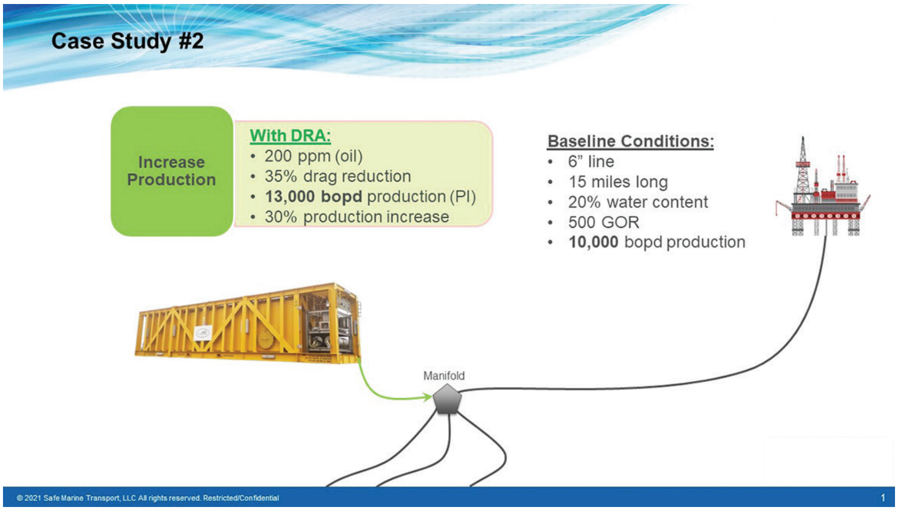


Fig. 7. Subsea DRA storage unit.

that have a fail-to-desired position and a smart battery backup, plus a variety of sensors and controls to ensure safe, reliable operation. The conjoined subsea DRA storage unit and injection unit are shown together in **Fig. 9.**

A summary of specifications for SMT's subsea DRA storage and injection unit are shown in **Table 1.**

Fig. 8. Subsea DRA injection unit.

Fig. 9. Subsea DRA storage and injection unit, together.

Subsea DRA storage and injection unit evaluation. The subsea DRA storage and injection unit has successfully completed a series of qualitative risks assessments (QRA) and Failure Mode, Effects and Criticality Analysis (FMECA), to identify risks and then to either eliminate or mitigate them risks to an acceptable level. The design and risk assessment considered the full life cycle of the unit through many operational phases:

- Pre-commissioning of controls on host facility
- Transport unit to quayside
- Quayside preparation of unit
- Transport unit to offshore site
- Prepare unit on MSV
- Install unit on seabed and complete commissioning with hand-over to host facility
- Operations (on seabed)
- Recover unit from seabed to MSV
- Transport unit to quayside
- Quayside refill/inspection/test.

Significant effort was devoted to engineering, analyzing and testing various bladder designs and manifold arrangements while considering a number of factors:

- Dual-barrier feature and overall constructability
- Material characteristics
- Inspection, maintenance and repair (IMR)
- Replacement
- Abrasion of bladder and containment
- Operational sensors/ instrumentation interfaces
- Fill/depletion manifolding requirement
- API and military recommended practices and specifications.

An inspection and test plan (ITP) was developed and implemented to manage quality control and document SMT's quality assurance program. Not surprisingly, standards, codes and cri-

Table 1. SMT's Subsea DRA storage and injection unit specifications

Component	Description	Reference/standard
Overall system	"Patent-issued dual-barrier chemical containment Qualified to 10,000 fsw / 10-year design life"	Meets IMDG requirements (non-hazardous chemical)
Frame	"40 ft x 8 ft x 8.5 ft (tall) Weight: 64,000 Kg, (tare)"	DnV 2.7-3
Storage tank	200 bbl (w/ 2- bbl reserve)	ASME, Sect VIII Div. 1
Bladder	200 bbl	Mil spec MIL-PRF-32233
Pump	"Modified triplex pump (onshore proven) 84 gpd of chemical @ DP up to 10,000 psi (with 15,000 psi still in qualification) Electric driven, variable speed-controlled"	Custom, based on API RP 14 C
Valves & actuators	Electric motor valve actuators, w/ battery back-up. Smart Batteries for fail-to-close position	Safety Integrity Level (SIL)2, per IEC 61508
Controls & sensor	Electronics; 1 Atmosphere cans (3)	API RP 17 F-compliant & various IEEE
Piping	"Various sizes, SS w/ Swagelok fittings Flexible flying leads, rated to 20 ksi "	"API RP-1111 section 2.1.7 (c) Welding: API Specification 17D "

Table 2. Partial listing of the ITP

Activity	Description	Quality-related activity	Reference document	Acceptance criteria	Verifying document
12	Post-weld NDE	Perform: MP, PT, UT, RT	NDE Procedures; Visual examination; NDE personnel qualification records	AWS D1.1; AWS D1.6; ASNT-TC-1A; ASME B31.3	NDE Test Report; NDE personnel qualification records
13	Dimensional checks	Perform dimensional checks and review of markings	Detailed drawings	Detailed drawings	Dimensional check; Form: Quality inspection report
14	Coating	Submission of coating procedure	SOS-QWI-ENG-740-02	SOS-QWI-ENG-740-02	Vendor certificate of conformance (inspection report)
15	Assembly	Assemble all equipment	Seanic drawings	Seanic drawings	Seanic drawings
16	Prototype qualification test	Perform PQT	PQT's; 14885-1355543; 14913-1296625; 16115-1387887; 16087-1405866; 16087-1413433; 16087-1447587; 16087-1447739	Approved procedure	PQT reports; 14885-1355543-1; 14913-1296625-1; 16115-1387887-1; 16087-1405866-1; 16087-1413433-1; 16087-1447587-1; 16087-1447739-1

teria, specifically for subsea storage and injection units, do not exist. Numerous existing codes and standards covering various parts, assemblies and activities in the design, engineering, manufacturing, fabrication and testing phases were used for the subsea DRA storage and injection unit. **Table 2** includes five of the 20 incorporated ITP activities.

Individual sub-assemblies were subjected to qualification tests. The sub-assemblies were then combined to create the storage unit and injection unit, which were subjected to additional qualification tests. A dry factory acceptance test (FAT) was completed, followed by a system integration test (SIT). The SIT was initially conducted on the deck, then fully submerged in a test pool. **Figure 10** shows four photos taken during the setup and administration of the submerged SIT.

Conclusion. DRA has been proven successfully in offshore and onshore applications to increase flowrates and decrease pipeline pressures. With the availability of a subsea multiphase DRA, the capability to deliver projects and services to the offshore industry, and the development of subsea DRA storage and injection units, an unprecedented full-service solution to increase subsea crude oil production is now available to subsea well operators. **WO**

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Fig. 10. System integration test.