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Drag Reducing Agents: Expanding the Use of A Proven Technology to Increase Subsea Production

LiquidPower Specialty Products Inc
A Berkshire Hathaway Company
Dr. Yung Lee

Society of Petroleum Engineers
November 17, 2022

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LSPI
A Berkshire Hathaway Company

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Agenda

Introduction to Author	5	Minutes
Hydraulics and Drag Reduction	15	Minutes
Drag Reduction in Multiphase	5	Minutes
Subsea DRA Storage & Injection Unit	3	Minutes
Multiphase Case Studies	12	Minutes
Value Proposition	5	Minutes
Questions	15	Minutes
Total	60	Minutes

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Biography

Dr. Yung Lee
Fellow Emeritus
LiquidPower Specialty Products Inc. (LSPI)

Dr. Yung Lee is the former Director of Engineering & Technical Services for LiquidPower Specialty Products Inc. (LSPI). He currently is the Fellow Emeritus on Drag Reduction for LSPI. He has been involved in the development and evolution of drag reducing agents (DRA) technology for over 30 years and has played an instrumental role in LSPI's 40-year track record of global DRA technology leadership. Launched under Conoco, the business merged into ConocoPhillips, and spun off to Phillips 66, prior to the acquisition by Berkshire Hathaway in 2014.

Dr. Lee has been granted 5 patents around the development of new DRA products for the pipeline industry and has written and presented numerous papers focused on fluid flow and DRA applications.

Dr. Lee holds a B.S. in Chemical Engineering from Washington University in St. Louis, a M.S. in Chemical Engineering from Texas A&M University, and a Ph.D. in Chemical Engineering from Oklahoma State University. Prior to joining the business in 1988 he held a variety of positions within research and engineering organizations for several different organizations.

Dr. Lee currently lives in Houston, TX and enjoys traveling and spending time with his family including his grandchildren. He enjoys teaching others about the science of drag reduction and applications of the technology for improving pipeline operations and business results.

Flow Regimes

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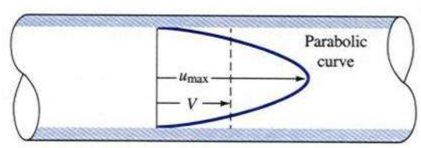
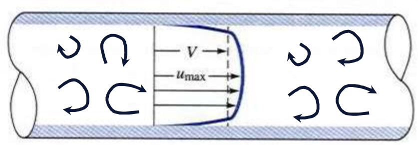
Laminar Flow
- Smooth
- Undirectional
- Efficient

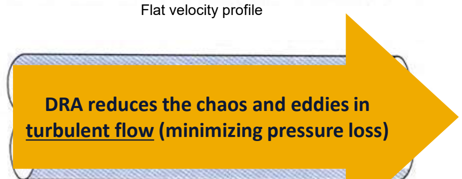


Parabolic velocity profile

Turbulent Flow
- Chaotic
- Swirling (eddies)
- Inefficient



Flat velocity profile



Flat velocity profile

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Drag Reduction - How Does DRA Work?

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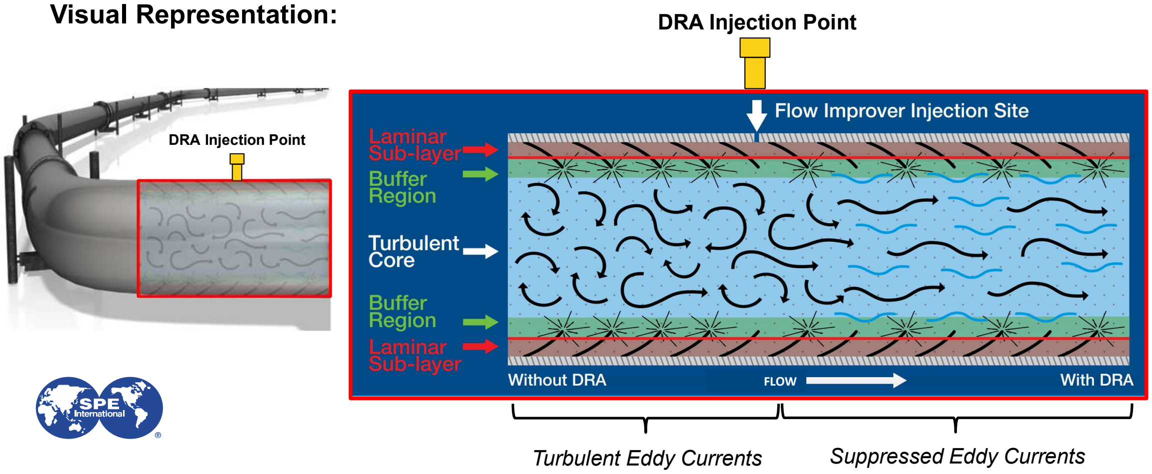
Technical Description: Drag reducing agents suppress the energy dissipation of turbulent eddy currents near the pipe wall during turbulent flow

Visual Representation:



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Drag Reduction - Suppression of Turbulent Eddies (Video)

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High Turbulence

Less Turbulence

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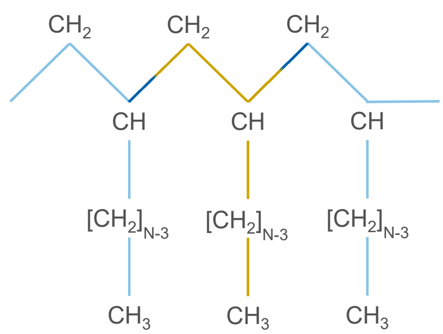
Drag Reduction – Poly-Alpha-Olefin

DRA is a high molecular weight, long chain polymer designed to reduce frictional pressure loss.

The polymer is a poly-alpha-olefin made of hydrogen-carbon chains. As such, the polymer fully dissolves in hydrocarbons and has no negative refinery impact.

DRA is injected in parts per million (ppm) and used extensively onshore and in offshore export pipelines and multiphase systems to increase flowrate or reduce pressure.

Poly-Alpha-Olefin



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Drag Reduction - DRA Polymer

Question: If an oil molecule is the size of a grape and a DRA molecule is a rope, about how long is the rope?

a) ~20 ft

b) ~100 ft

c) ~2,000 ft

d) ~1 mile

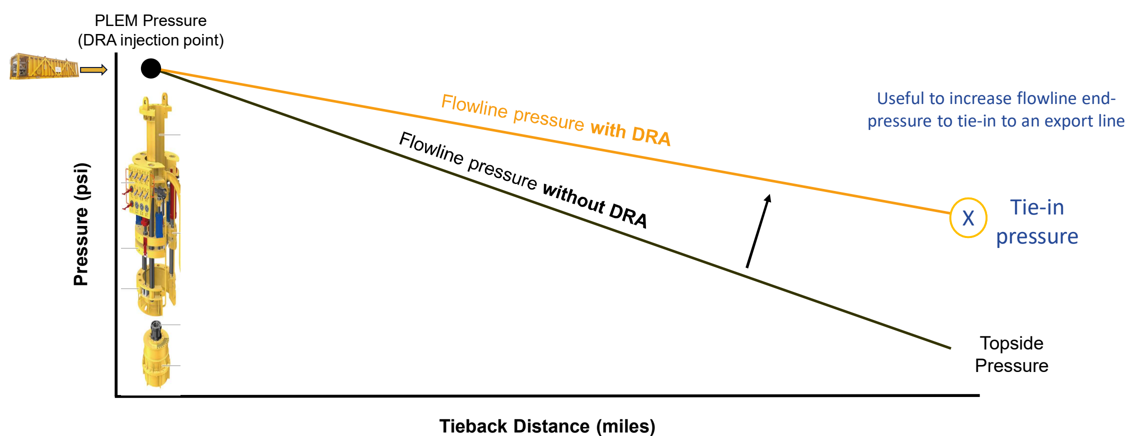
Oil Molecule

DRA Polymer

DRA contains the longest man-made polymer in the world!

Drag Reduction – Hydraulic Gradient

Question: How will DRA change your hydraulic gradient when flow & PLEM pressure are constant?



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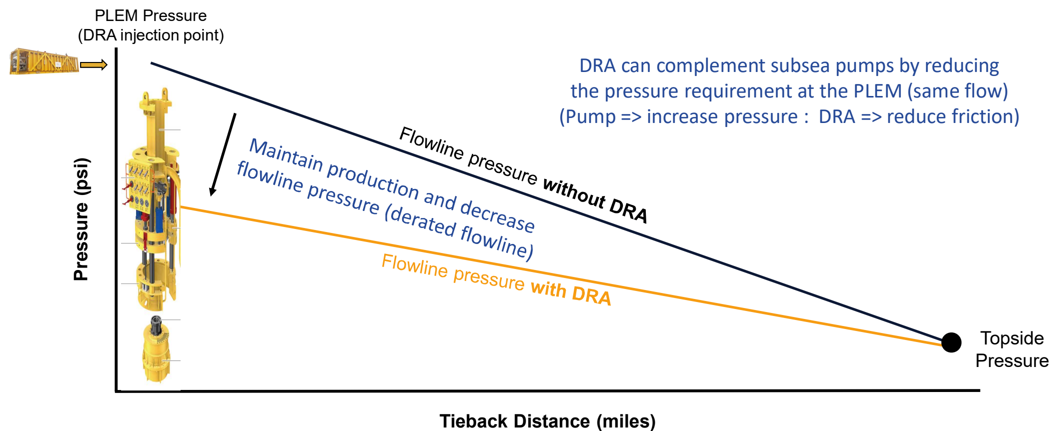
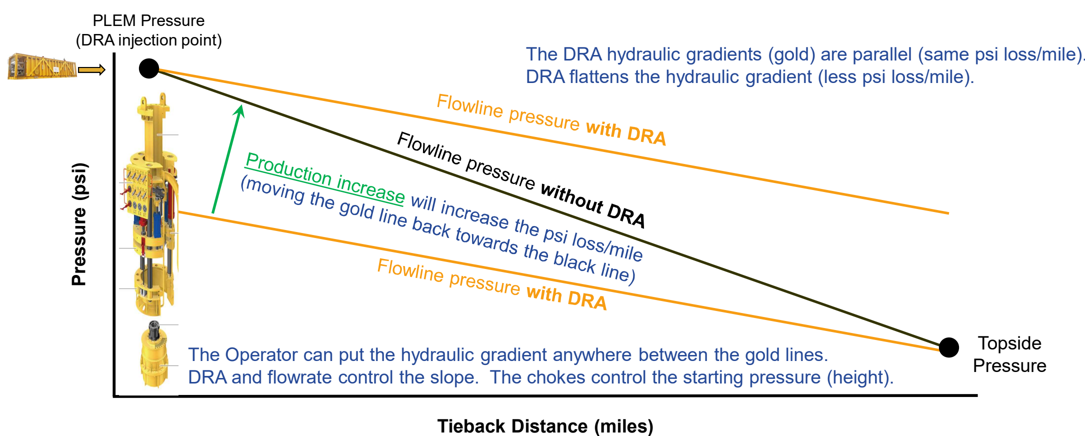
Drag Reduction – Hydraulic Gradient

Question: How will DRA change your hydraulic gradient when flow & topside pressure are constant?



Drag Reduction – Hydraulic Gradient

Question: What is the difference between the hydraulic gradients we just looked at?



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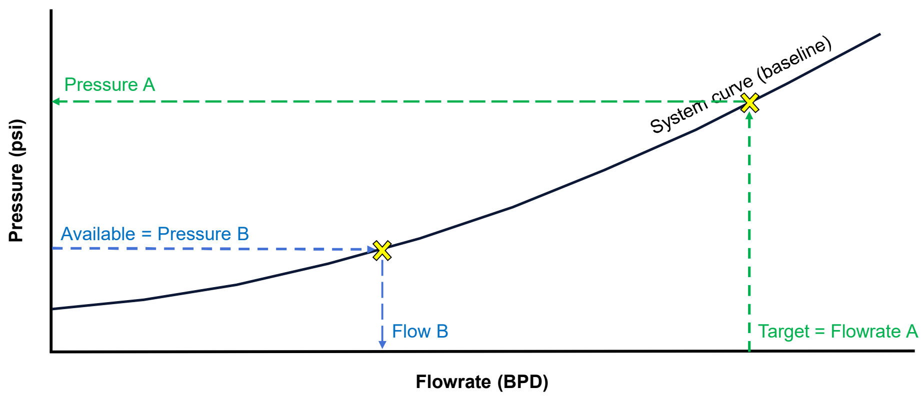
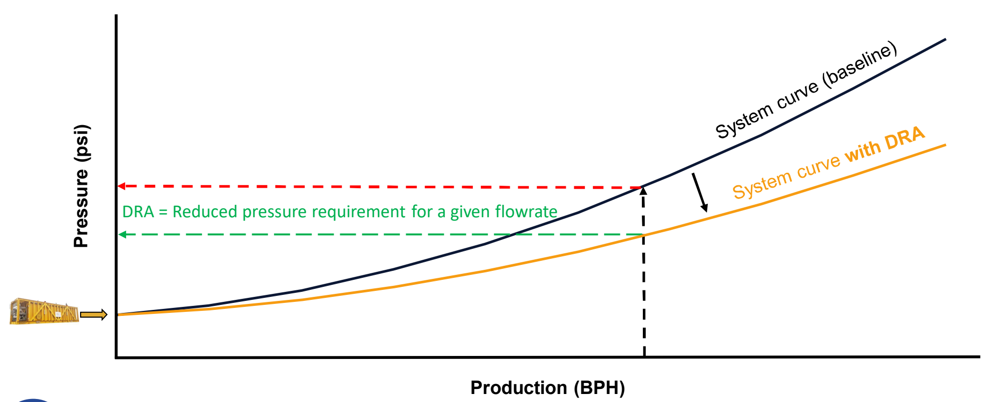
System Curve

For a single fluid flowing in a single segment, the Darcy-Weisbach equation can be used to generate a plot of the pressure required to achieve any flowrate.



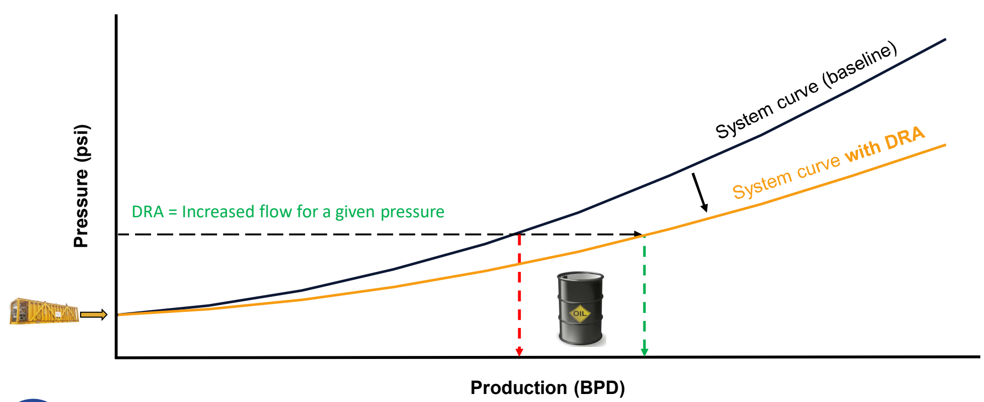
Drag Reduction – System Curve

Question: How will DRA change your flowline system curve when the flowrate is the same?



Drag Reduction – System Curve

Question: How will DRA change your flowline system curve, assuming PLEM and topside pressure are the same?



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Drag Reduction – Production Increase

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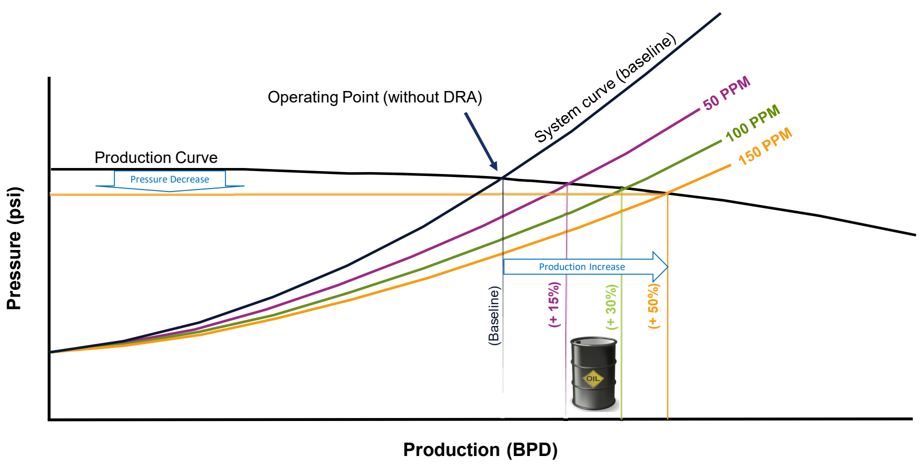

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Drag Reduction – Measuring DRA Performance

%DR = Percent Drag Reduction

- Primary measure of DRA performance
- Fraction of the frictional pressure drop eliminated by injecting DRA

$$\%\boldsymbol{DR} = \frac{\Delta \boldsymbol{P}_{\boldsymbol{f},\boldsymbol{Baseline}} - \Delta \boldsymbol{P}_{\boldsymbol{f},\boldsymbol{With\ DRA\ Injected}}}{\Delta \boldsymbol{P}_{\boldsymbol{f},\boldsymbol{Baseline}}}$$

Example: DRA is used to reduce a 4000 psi frictional pressure loss to 2600 psi:

$$\%\boldsymbol{DR} = \frac{\mathbf{4000}\ \boldsymbol{psi} - \mathbf{2600}\ \boldsymbol{psi}}{\mathbf{4000}\ \boldsymbol{psi}} = \mathbf{35}\%\ \boldsymbol{DR}$$

Note: Over 80% DR is achievable with single-phase light crudes (4000 psi friction loss to < 800 psi).
35% DR is a reasonable target for multiphase

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Drag Reduction

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DRA is a long chain polymer designed to reduce frictional pressure loss and injected in parts per million (ppm). DRA is used extensively onshore and in offshore export pipelines and multiphase systems to increase flowrate and reduce pressure

DRAs do:

- Fully dissolve in hydrocarbons
- Reduce turbulence
- Reduce the pressure loss per mile/km
- Reduce flowline pressure
- Increase production/flowrate

DRAs do not:

- Change crude characteristics (viscosity/density)
- Coat pipeline walls
- Negatively impact refineries

Common DRA Applications

- Constraint removal/debottlenecking
  - Production/flow increase
  - Pressure reduction
- Delay/decrease capital investment
- Energy savings
- CO_2 reduction

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Drag Reduction – Life Cycle of DRA Polymer

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Neat Product $\xrightarrow[\text{Dissolution}]{\text{Injection}}$ Active Product $\xrightarrow[\text{in Pipeline}]{\text{Degradation}}$ Inactive Product

Packaged Polymer in Product Form | Extended Polymer | Sheared Polymer at Low Mol. Weight

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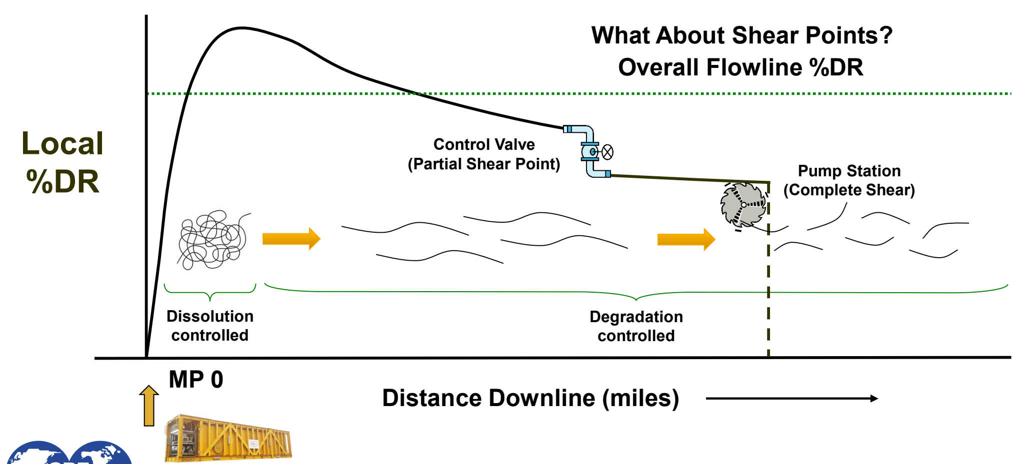
Drag Reduction – Performance Profile



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Drag Reduction – Variables Affecting Performance

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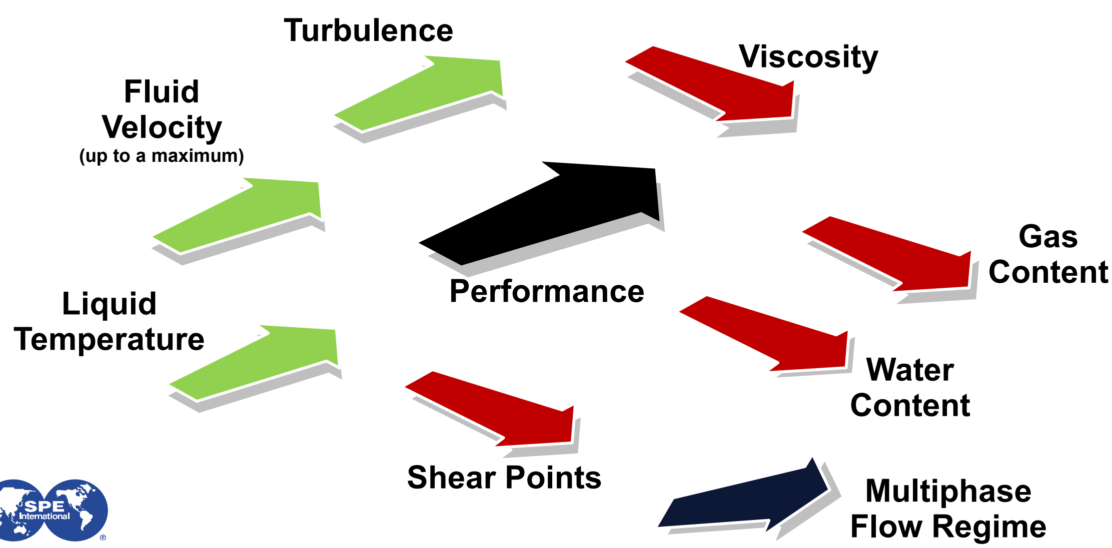

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Multiphase – DRA Effects (IFE)*

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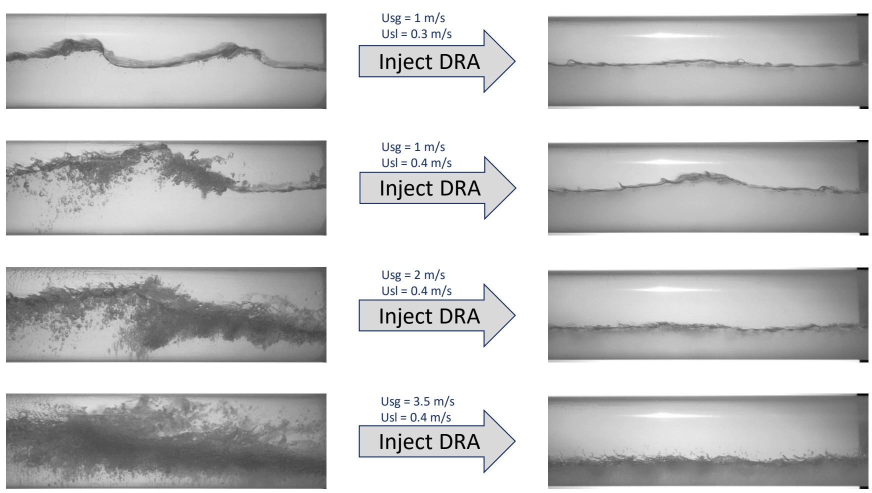
Slug flow



Wavy flow

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****IFE: Institute for Energy Technology, 2004***

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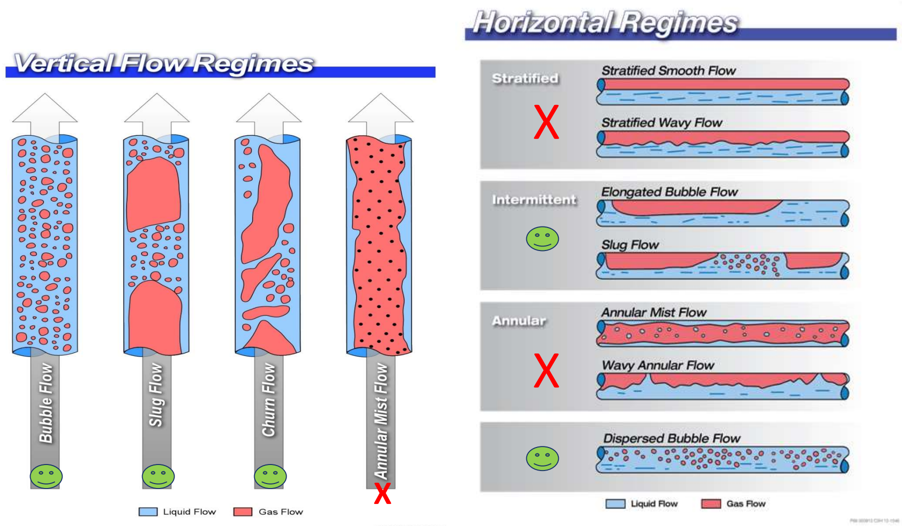
Multiphase – Drag Reduction in Flow Regimes



Good regimes for drag reduction

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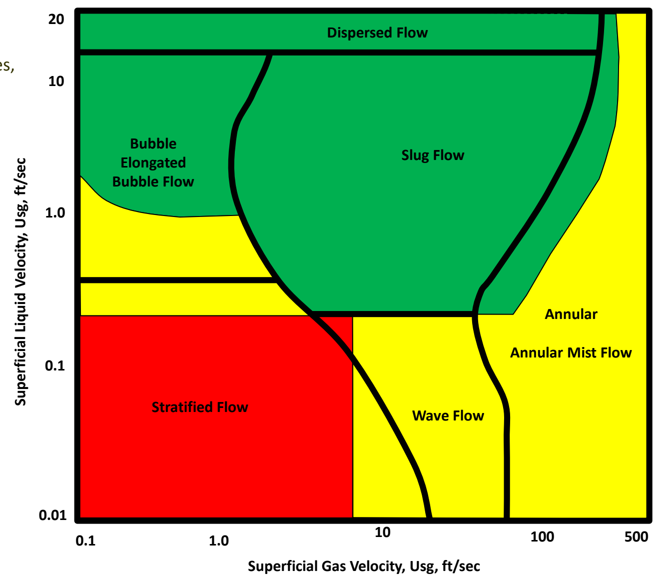
Multiphase – Flow Pattern Map* and DRA

Map is a function of fluid properties, pipe diameter, and pipe angle.



High DR potential
Low DR potential
No DR potential

Stratified flow is the prevailing flow regime in wet gas production.

Slug flow is the prevailing flow regime in oil production.

AND

The sweet spot for drag reduction

*Mandhane map for predicting flow regime in horizontal flow (1974).

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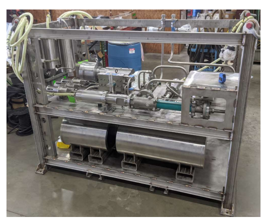
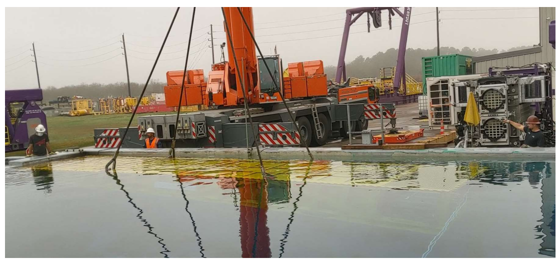
Subsea DRA Storage and Injection Unit

200 bbl DRA Storage

DRA Injection Module



System Integration Testing (SIT)



Multiphase - Case Studies

#1 Flowline - Baseline:

- 6" line
- 15 miles long
- 20% water content
- 500 GOR
- **10,000** bopd production

#1 Flowline - with DRA:

- 200 ppm (oil)
- 35% drag reduction
- 13,000 bopd production (PI)
- **30%** production increase

Best Candidates:

Light oil	Slug flow (reduce slugging)
Low water content	Bubble flow
Low GOR	Churn flow
High productivity index	Plateau / peak production

Manifold

#2 Flowline - Baseline:

- 8" line
- 10 miles long
- 1% water content
- 900 GOR
- Slug flow
- **12,500** bopd production

#2 Flowline - with DRA:

- 150 ppm (oil)
- 35% drag reduction
- 18,900 bopd production (PI)
- **50%** production increase

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Multiphase - Case Studies

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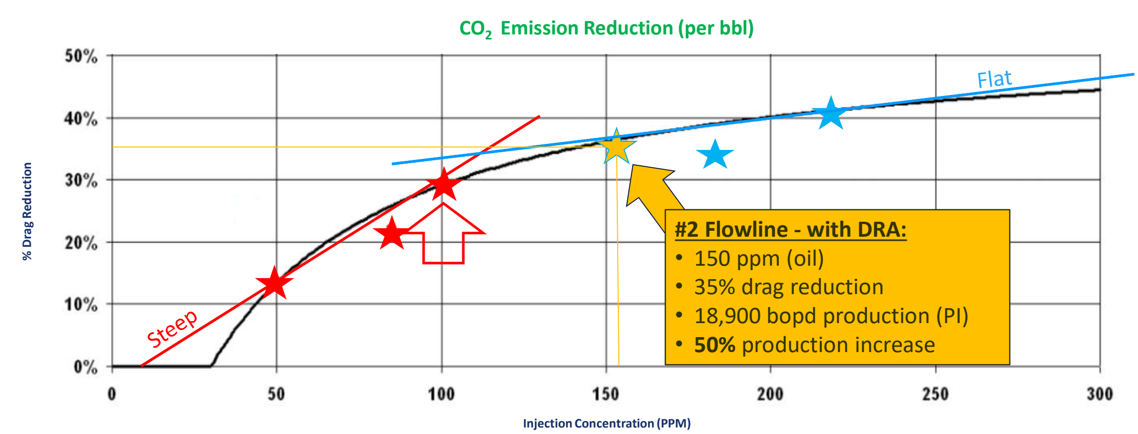

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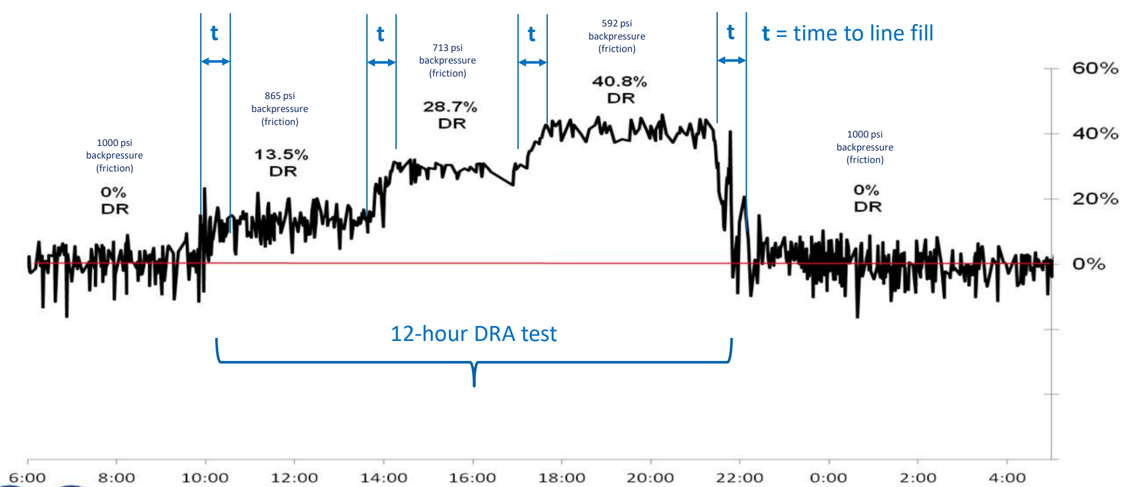
Multiphase – Slug Flow Case Study



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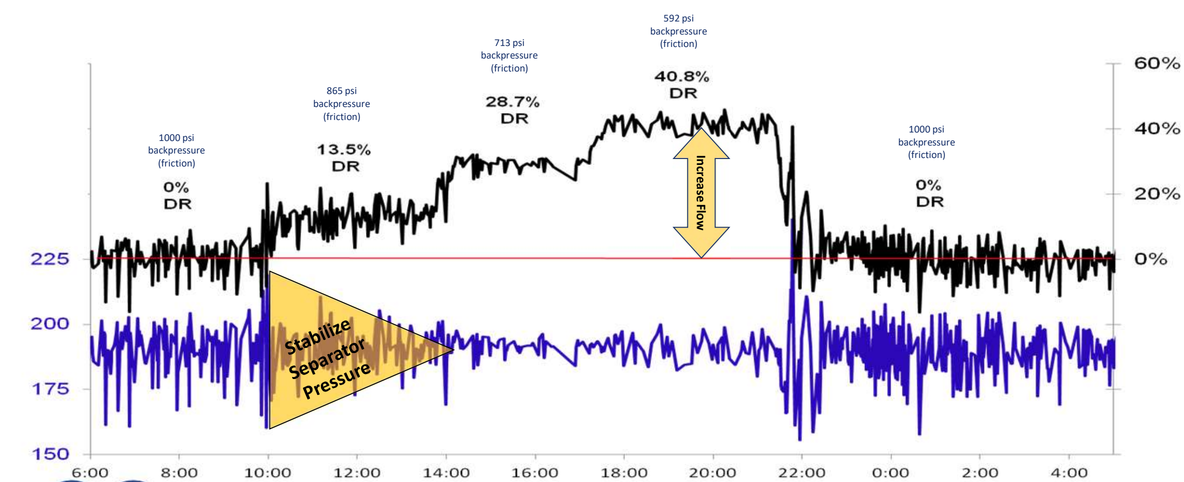
Multiphase – Slug Flow Case Study



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Value Proposition

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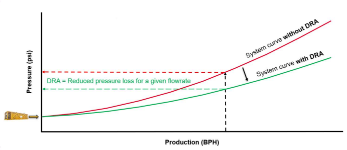
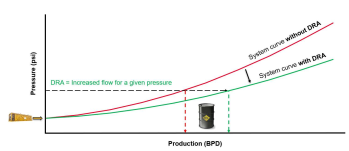
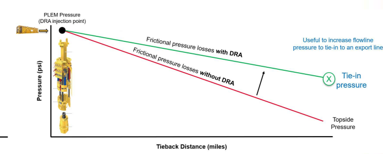
Decrease flowline pressure
Retain production in a derated flowline



Reduce backpressure
Increase production
Reduce CO_2 emissions (per bbl)



Increase end-line pressure
Achieve required tie-in pressure



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Value Proposition

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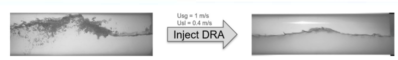
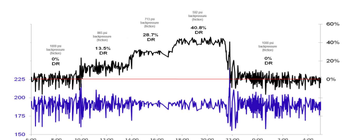
Other values:
- Reduce slugging
- Increase tie-back distances
- Reduced flowline size (less capital cost)
- Add wells to an existing flowline
- Complement subsea boosting systems





Values for all applications
- Portable units
- No topside space required
- Independent of host platform
- Remote chemical storage

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