TECHNOLOGY WEEK

Understanding the technology behind optimizing drag reducing agents (DRA) and the operational benefits

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SAFER, SMARTER, GREENER

Shock Absorbers

- Have you ever had to replace a car shock absorber?

howstuffworks.com

- DRA act like little shock absorbers

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Content

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04 Impacts of DRA

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09 DRA in Design

10 Software – Modeling DRA

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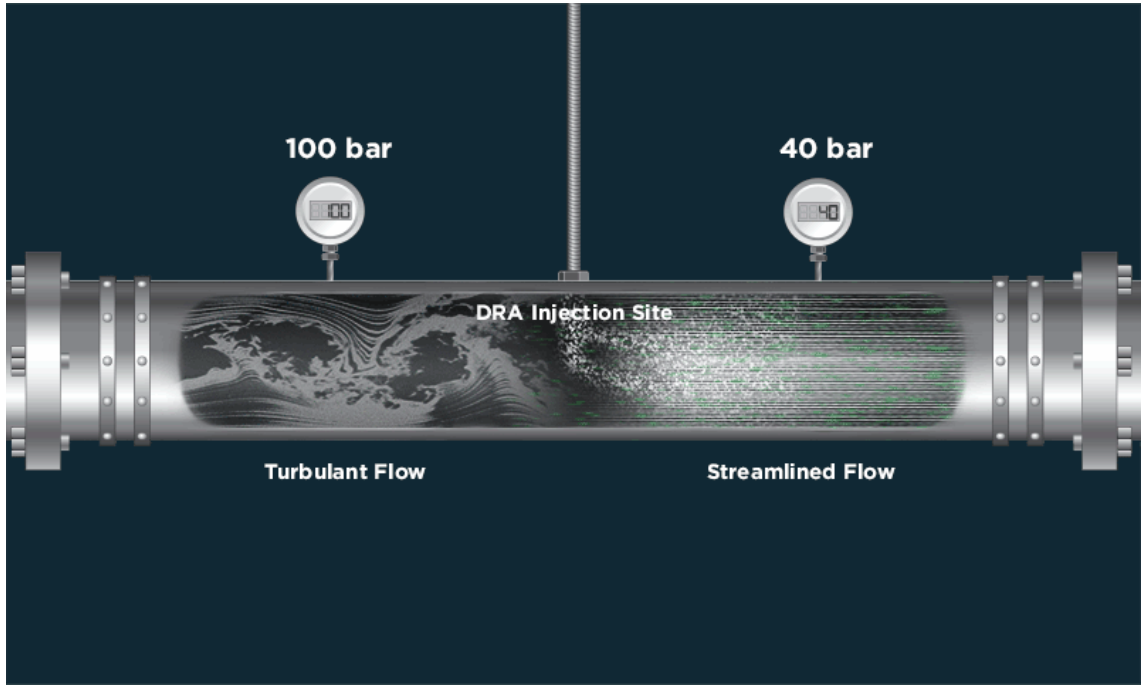
What is DRA

- Drag Reducing Agent
- Chemicals injected during flow in pipes
- Primarily used for increasing pipeline capacity
- Reduces turbulence in the system



© Flowchem website
http://www.flowchem-dra.com/index.php/how-turboflo-works.html

What is DRA

- DRA– high molecular-wt polymer

$$\left(CH_2 - \underset{\underset{R}{|}}{CH} - CH_2 -\right)_N$$

- R = carbon chains of various lengths
- N = repetitions of chain (can be as high as 100,000)
- Molecular weight can be 100s of millions!

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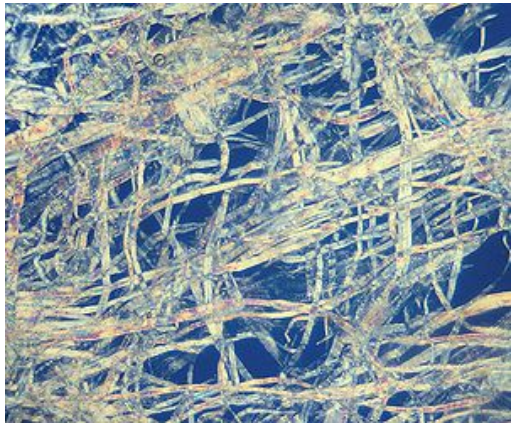
Origins of DRA

- Reduced pressure drop during turbulent pipe flow first observed in 1930's during paper pulp transport
  - Suspended solution of cellulose fiber in water

Pulp fibers structure →



Wikipedia

- Toms (1948) first to recognize:
  - Wall shear stress reduction
  - Caused by addition of linear macromolecules to flowing liquid
- Extensive ~30-year study was followed on Drag Reduction with polymer additives
- Conoco Inc (1979) introduced CDR
  - First Commercial Drag Reducer
  - Extremely successful and demand grew
  - Now LiquidPower Specialty Products (LSPI)

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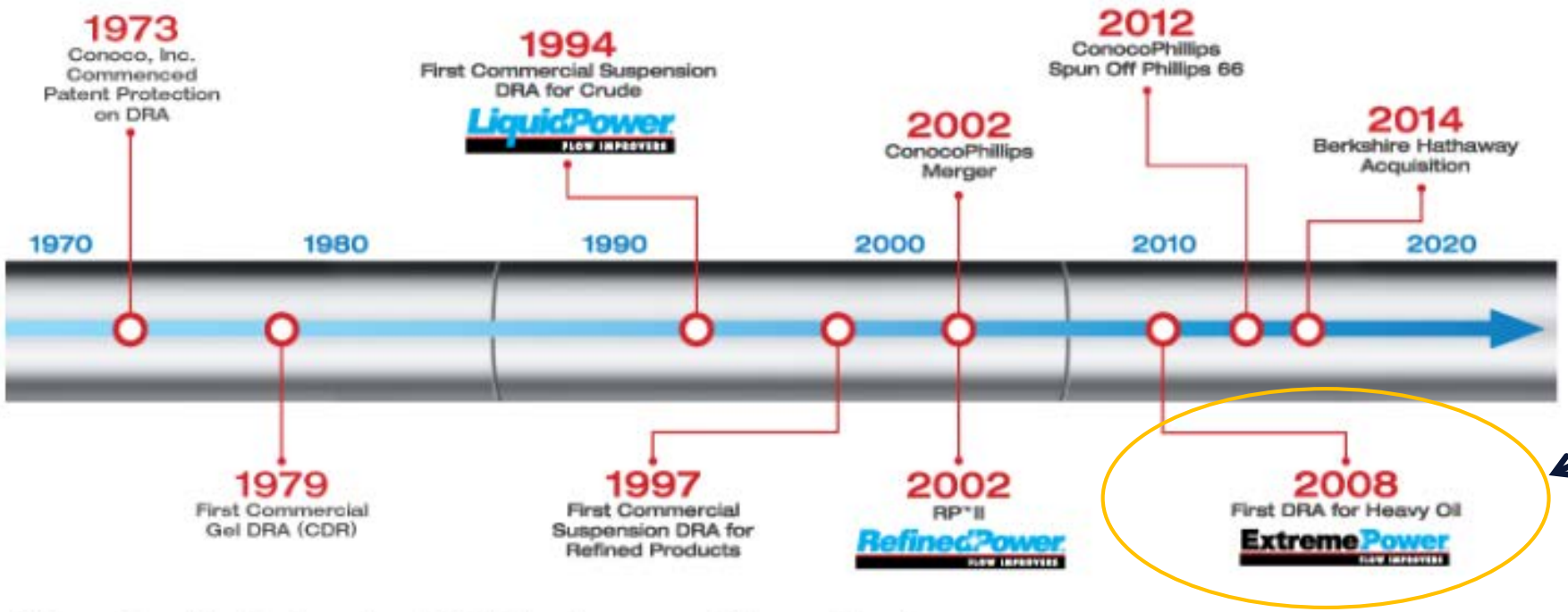
Origins of DRA

- History of DRA on LSPI website



First for Heavy Oil In 2008

LiquidPower Specialty Products Inc. (LSPI) Flow Improvers – History – Timeline

© LSPI website
https://www.liquidpower.com/about-lspi/history/

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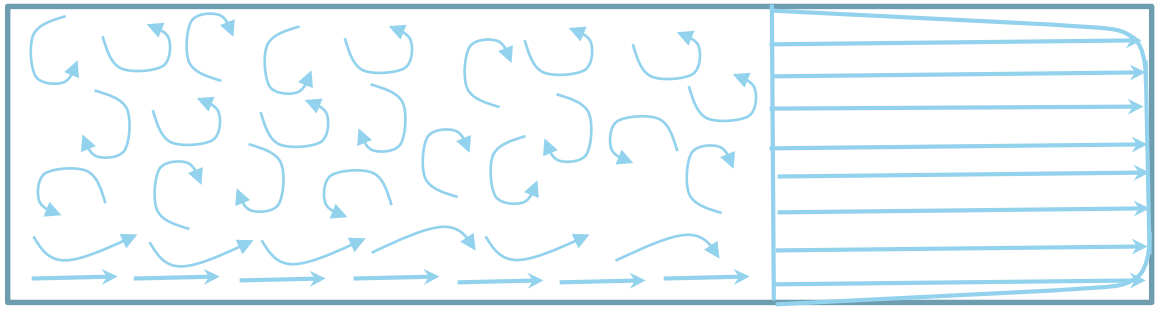
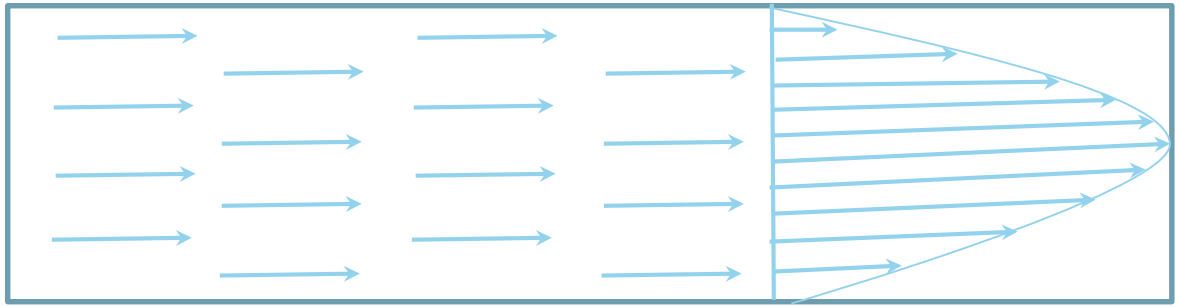
How Does DRA work?

- Pipeline Flow Types/Zones



Fully Turbulent Flow
Re > 4000



Laminar Flow
Re < 2100

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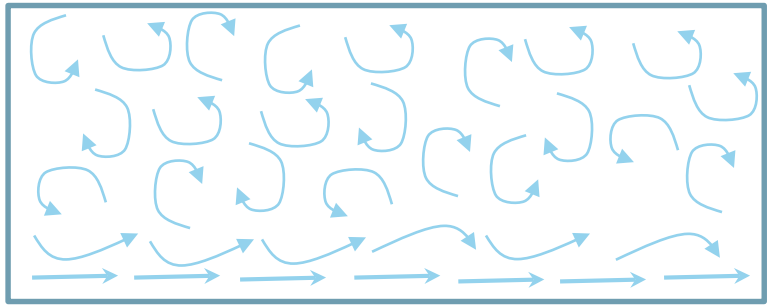
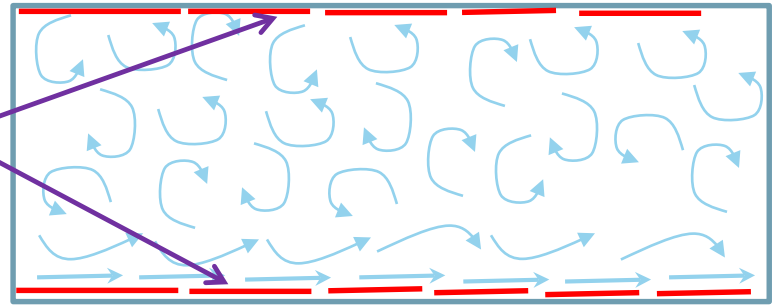
How Does DRA work?



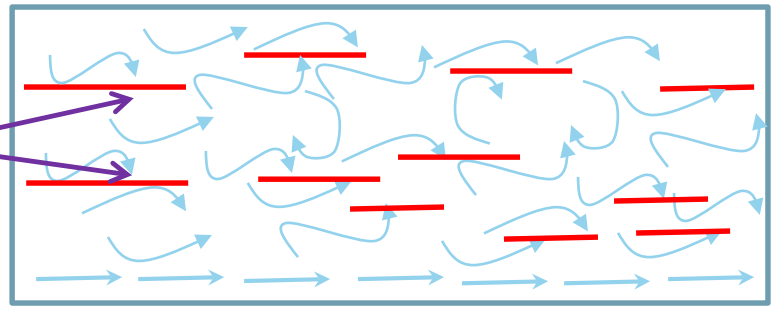
Fully Turbulent Flow

A.
DRA strips



Is the Injected DRA on the Pipe Wall?

B.
DRA strips



Is the Injected DRA suspended in Flow?

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How does DRA work?

- Long polymer strips of DRA interact with flowing fluid
- DRA reduces (or “breaks up”) the fluid molecules turbulence
- Dampens the rotational flow
- Turbulence shock absorber/dissipator
- Less eddy currents leads to less energy dissipation
- Specifically for Turbulent Flow
  - Re > 4000 (preferably higher)

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Impacts of DRA

- **DRA is NOT:**
  - Coating for pipe
    - Does not stick on pipe walls!
  - Fluid density modifier
  - Fluid viscosity modifier
  - Usable at all flows
    - Not for laminar flow
  - Usable for all fluids
  - Reusable
    - Degrades in pipe

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Impacts of DRA

- Operational Benefits
  - Increases pipe flow rate
  - Reduces operating pressure
  - Reduces power consumption

- DRA in Pipe Design Reduces Required:
  - Pipe size
  - Pipe wall thickness/Design Pressure
  - # of pump stations
  - Max transient pressures for same flow rate

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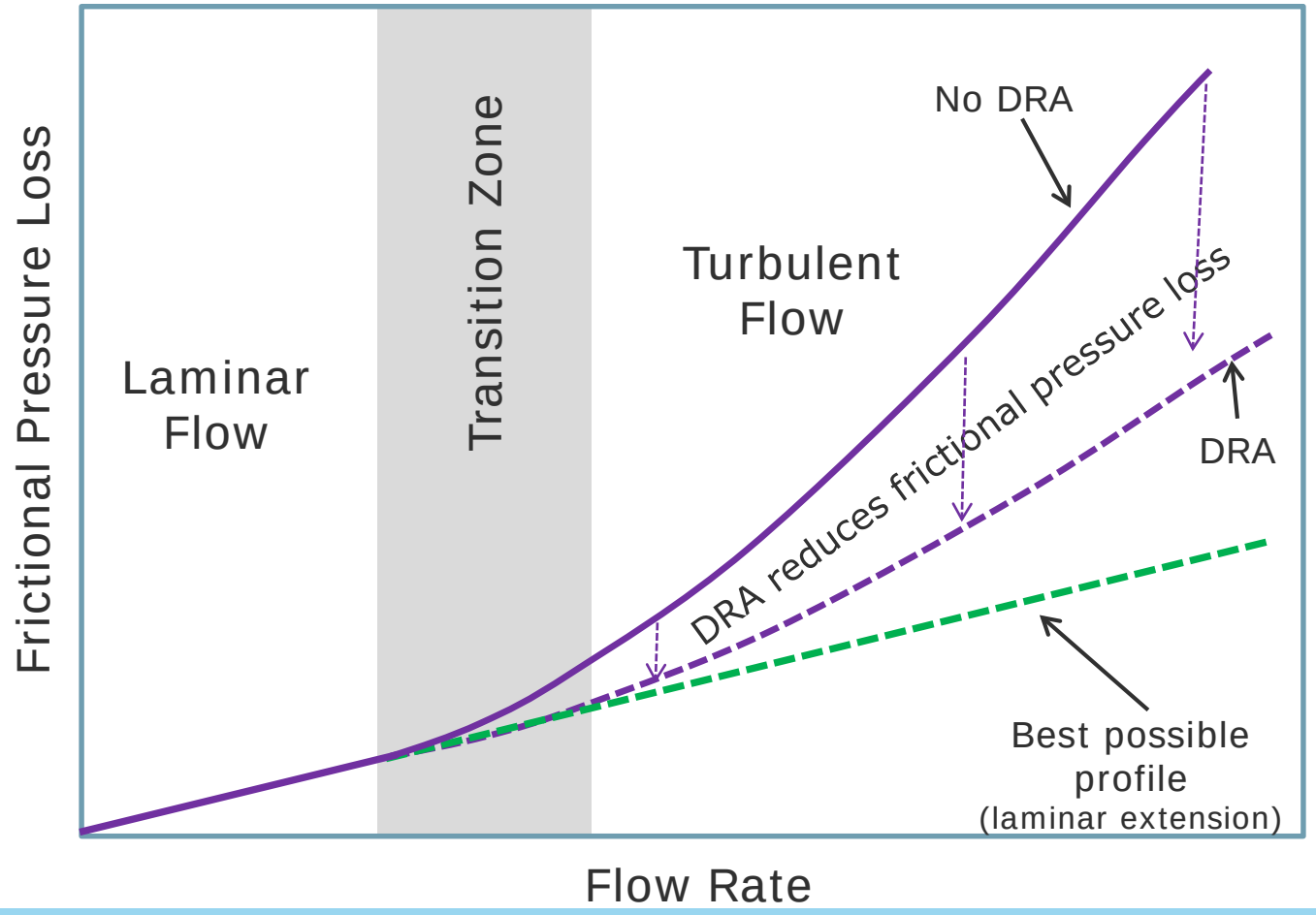
Impacts of DRA

- DRA reduces turbulence



- No impact on Laminar
- Other regions tend to Laminar
- Can't go lower

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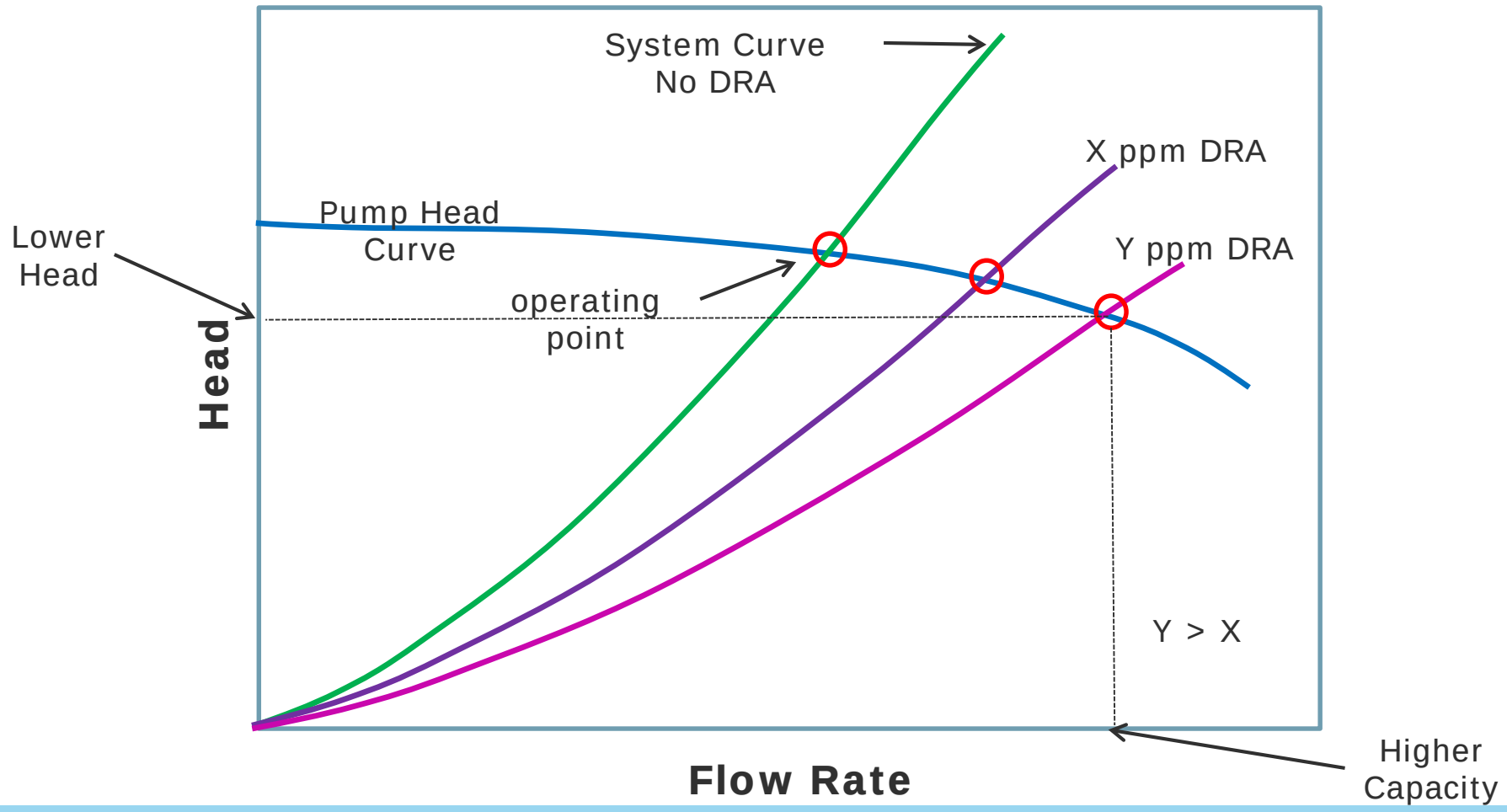
Impacts of DRA

- Effect on Pump Operation



How is DRA Applied?

- DRA produced as:
  - long polymer strips
  - coiled up
  - suspended in non-solvent fluid (slurry)

- DRA is Injected
  - In parts per million (ppm)
  - after pump discharge
  - at each pump station
  - or after certain distance for long pipeline

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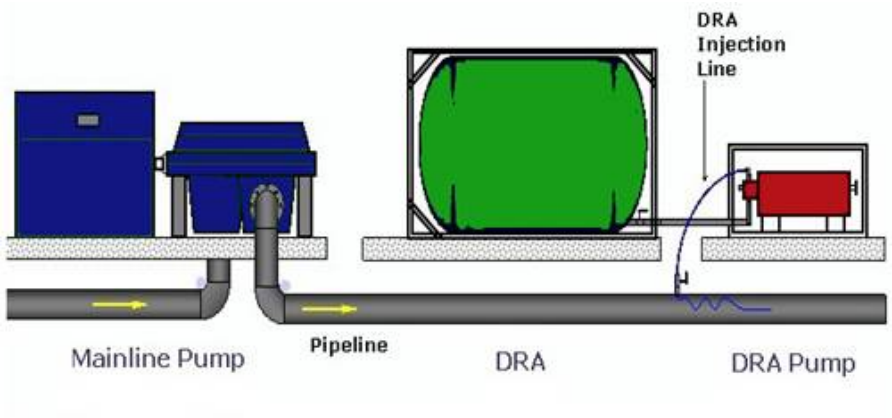
How is DRA Applied?

- DRA injection nozzle design is important
- Improper DRA injection results in:
  - DRA not dissolving well
  - DRA particle lumps
  - Lower performance
  - Deposits on filters
- DRA vendor can design skid



From www.pipers.com

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DRA Calculations

- How is the “effectiveness” of DRA application determined?
- What is the required DRA ppm?
- How much volume of DRA is to be injected?

  - Percent Drag Reduction (%DR)
    - Ratio of frictional pressure drop before and after DRA injection
    - At same flow rate

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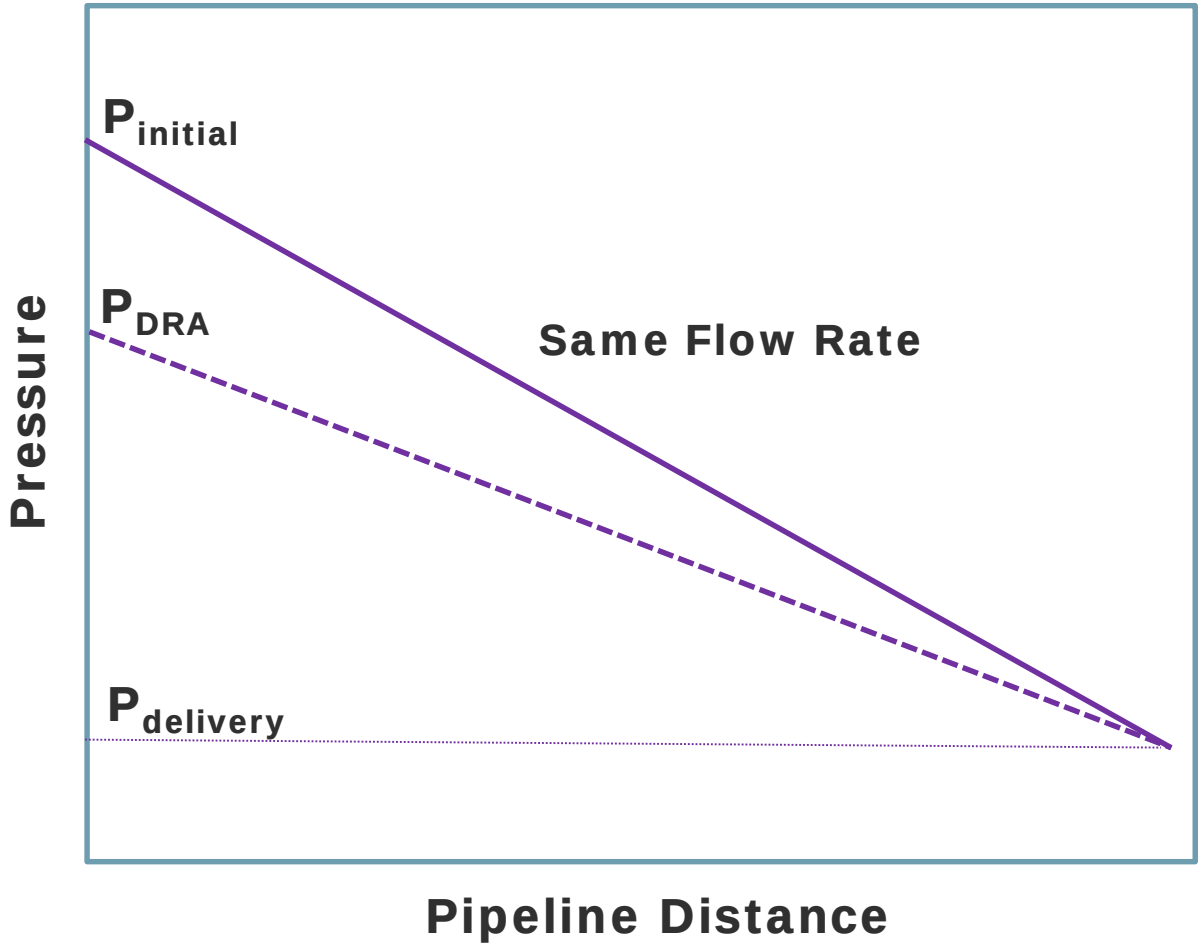
DRA Calculations

- Calculating % Drag Reduction (%DR)



$$\Delta P = P_{initial} - P_{delivery}$$

$$\Delta P_{DRA} = P_{DRA} - P_{delivery}$$

Determines %DR

$$\%DR = 100 \times \frac{\Delta P - \Delta P_{DRA}}{\Delta P}$$

$P_{initial}$ also referred to as baseline conditions

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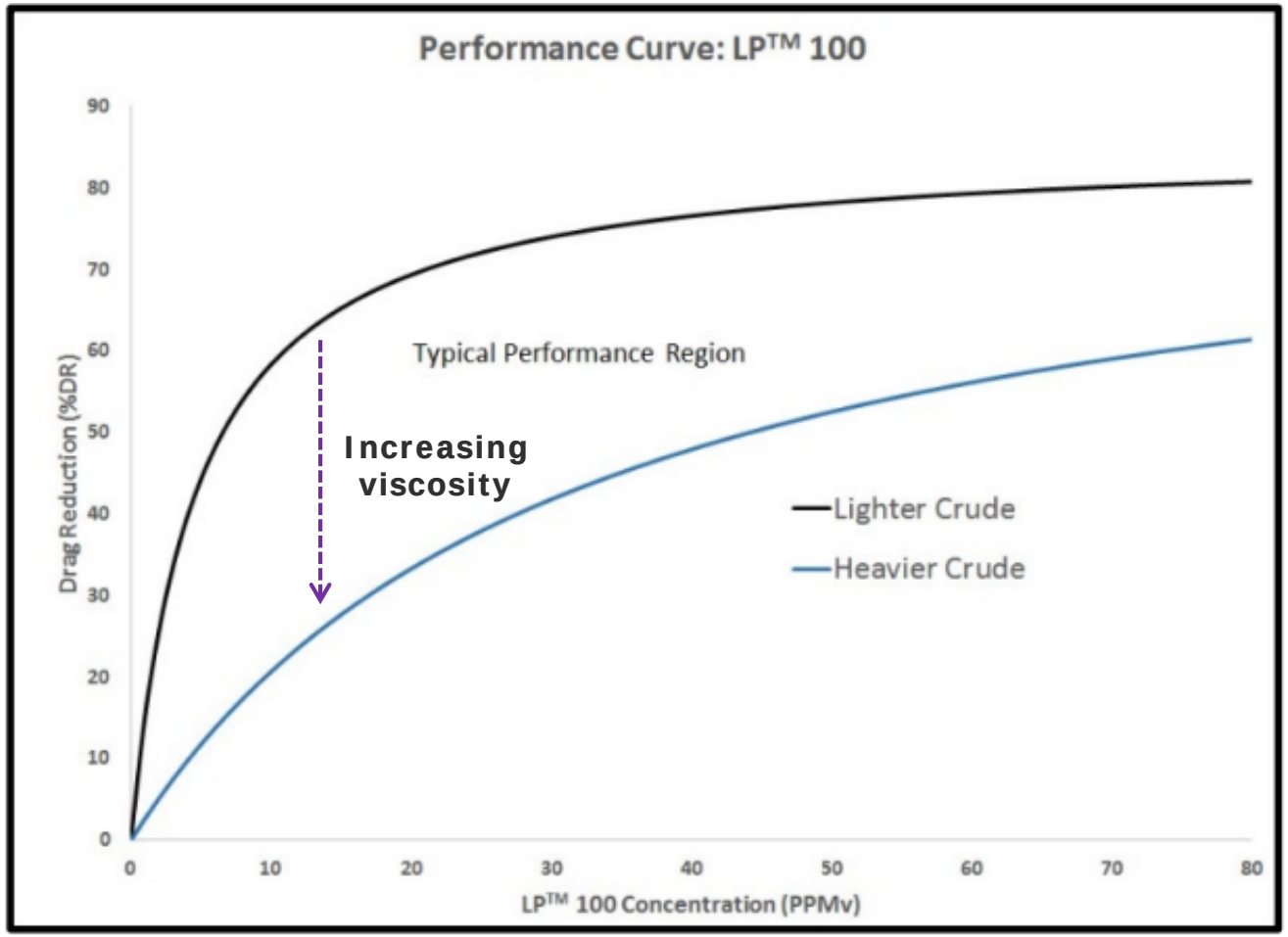
Sample DRA Performance Curve

- Liquid Power, LP100 Performance Curve



From LSPI website

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DRA Calculations

- Determining DRA injection volume (GPD)

$$GPD_{DR} = \frac{bpd_{oil} \times ppm_v \times 42 gal/bbl}{1{,}000{,}000}$$

GPD = gallons per day
bpd = barrels per day
gal = gallons
bbl = barrels
ppm_v = DRA parts per million (volume basis)
ppm_w = DRA parts per million (weight basis)
SG = specific gravity

In terms of weight:

$$ppm_w = ppm_v \times \left[\frac{SG_{DRA}}{SG_{oil}}\right]$$

$$GPD_{DR} = \frac{bpd_{oil} \times ppm_w \times \left[\frac{SG_{oil}}{SG_{DRA}}\right] \times 42 gal/bbl}{1{,}000{,}000}$$

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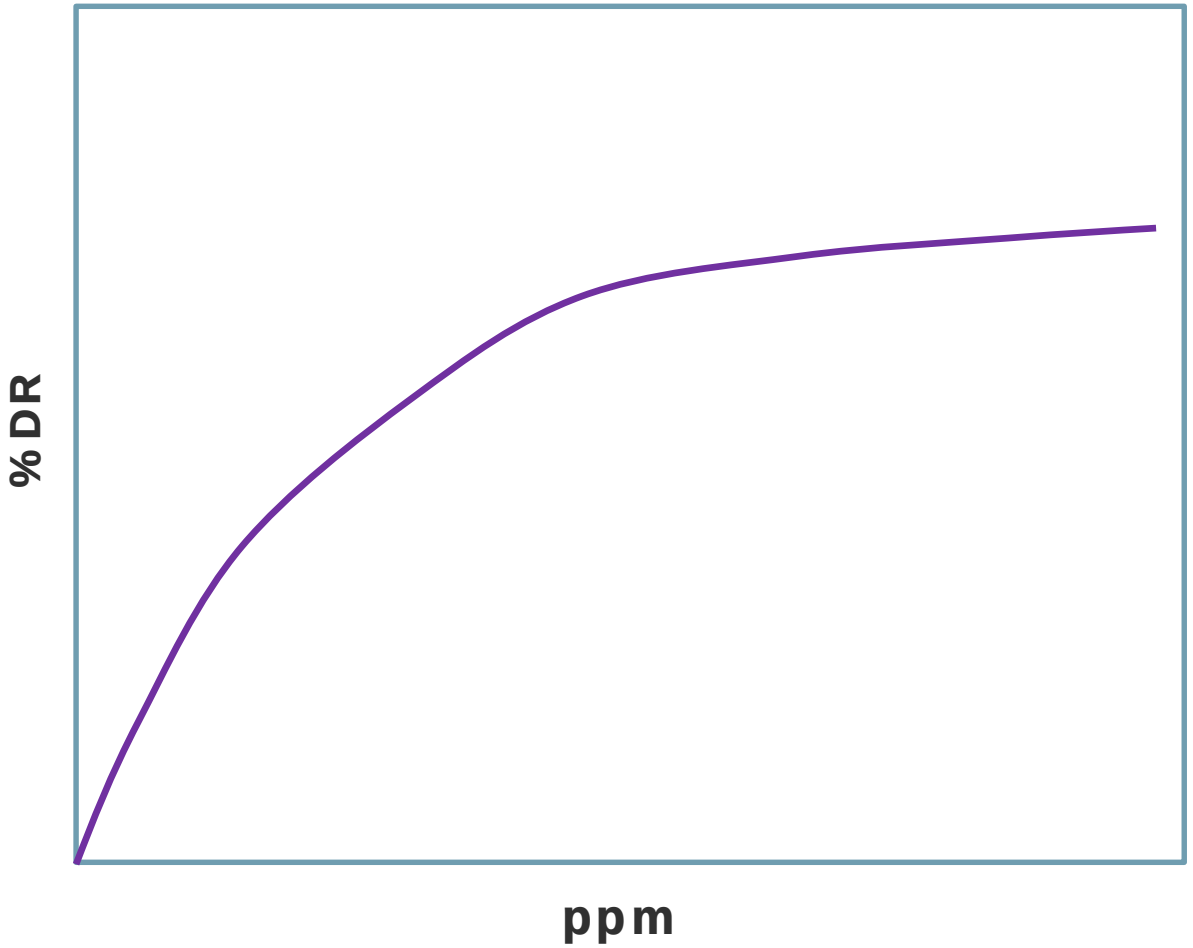
DRA Calculations

- DRA Performance Curve



$$\%\mathrm{DR} = \frac{ppm}{\mathrm{m} + \mathrm{b} \times \mathrm{ppm}}$$

$$\frac{1}{\%\mathrm{DR}} = \frac{m}{\mathrm{ppm}} + b$$

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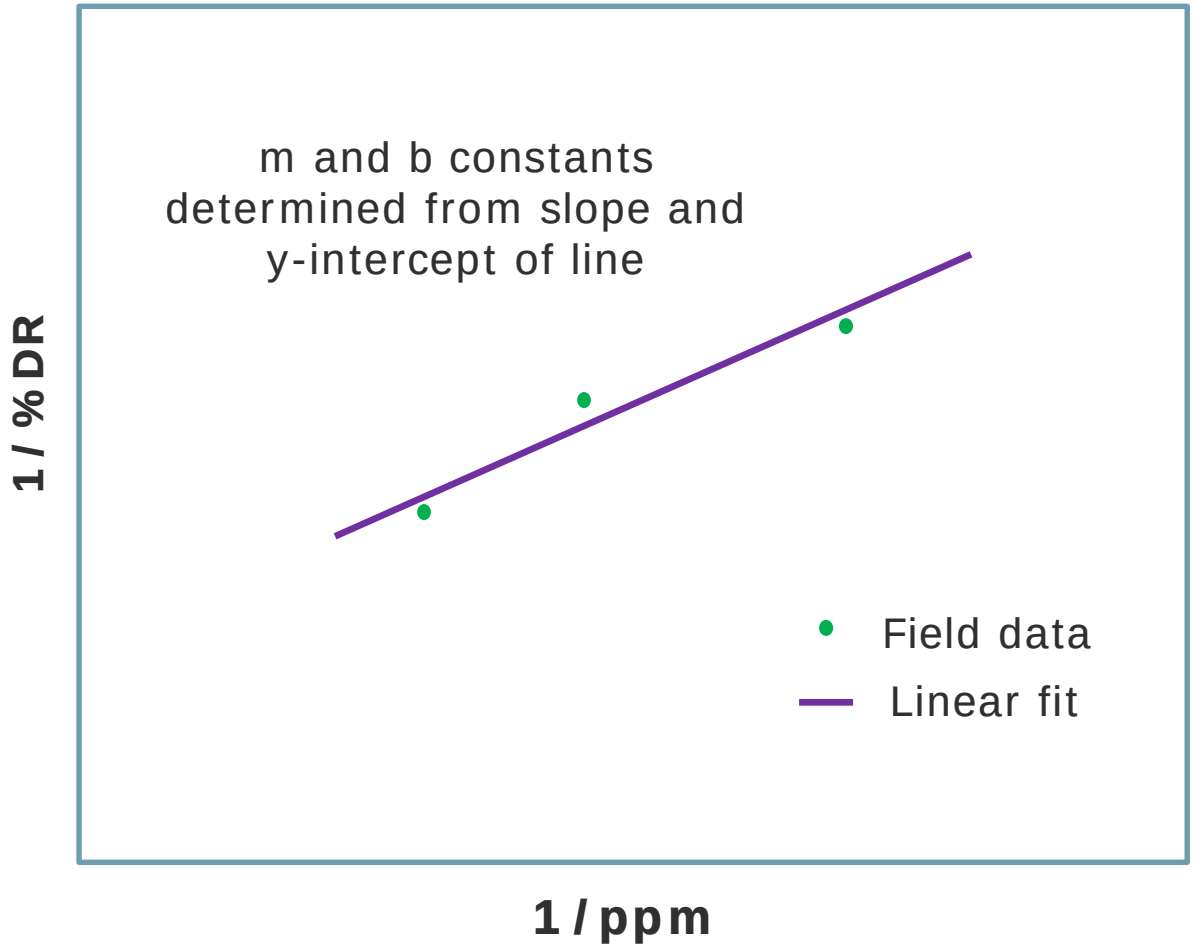
DRA Calculations

- DRA Performance Curve



$$\frac{1}{\%\mathrm{DR}} = \frac{m}{\mathrm{ppm}} + b$$

m and b constants differ with fluid for same DRA

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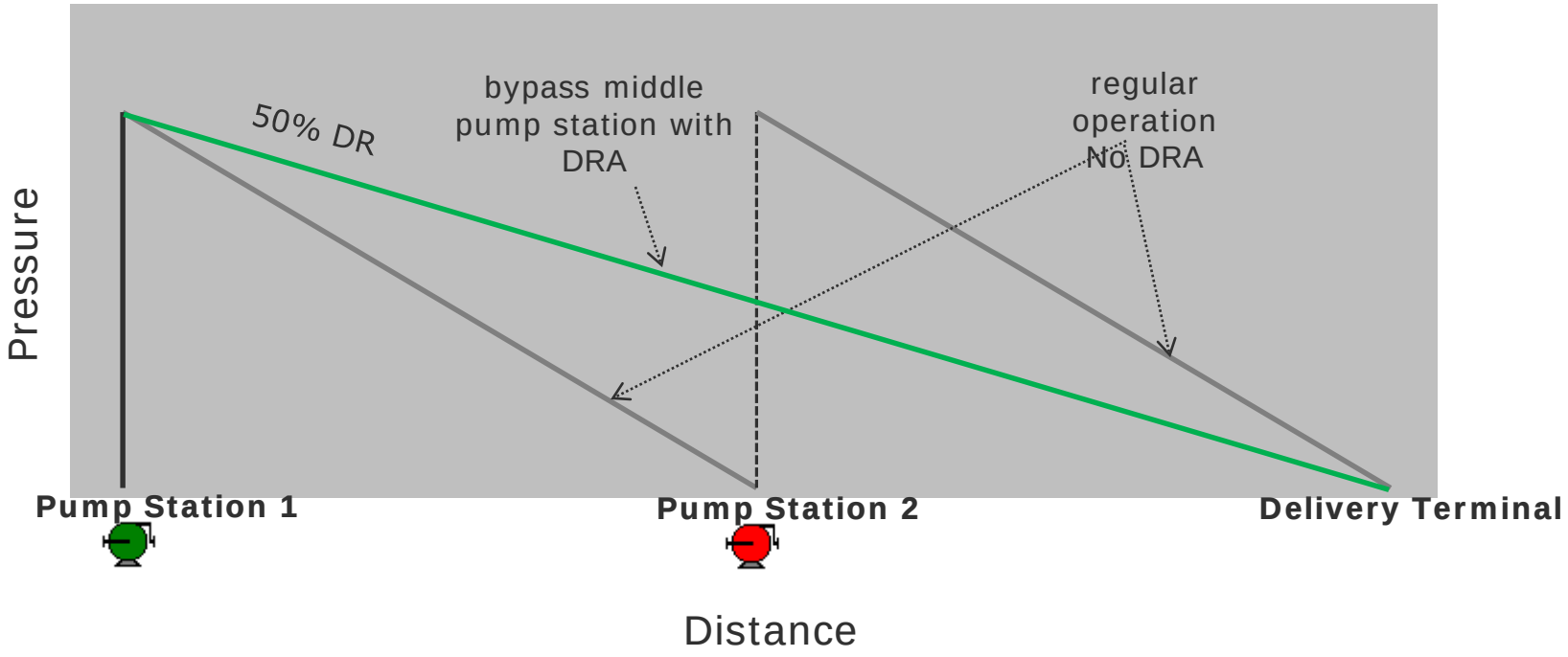
DRA Performance

- Power Cost Savings
  - Can reduce the # of pump stations required



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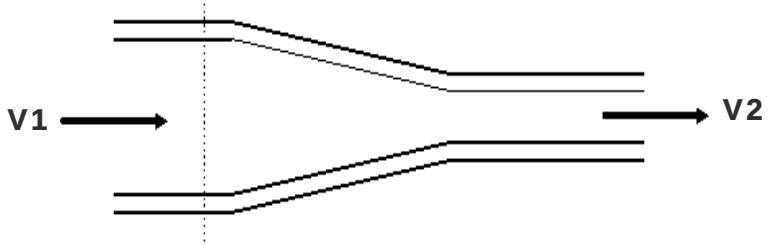
DRA Performance

- Degradation
  - Longer polymer strips have better performance
  - Breaks with shear
    - Pump
    - Throttling
    - Flow change to smaller pipe
    - Flow across long distance
    - Think of airplane going through turbulence



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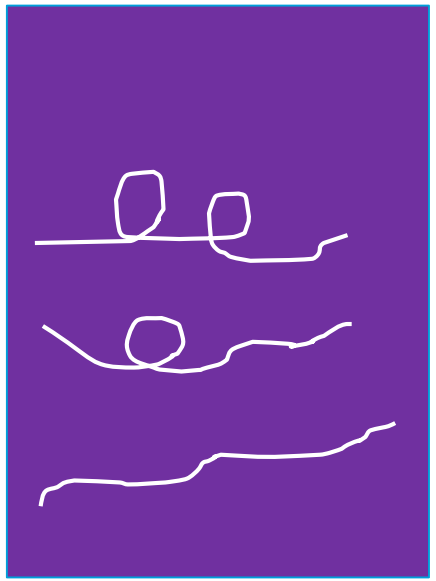
DRA Performance

- From product to injection to degradation

DRA in Product form

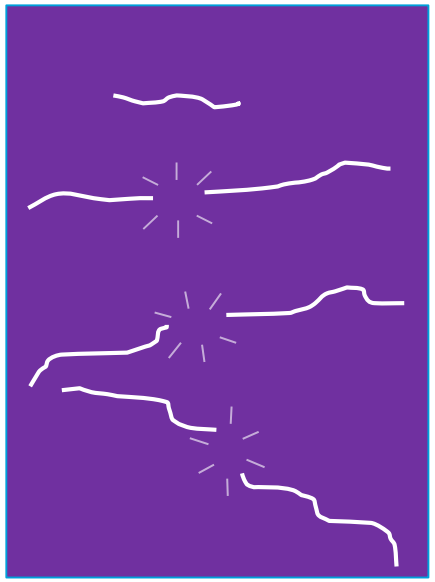
- Initial product neatly packed in coils and rolled up
- Protects polymer from being sheared

After Injection of DRA



- Injected after pump discharge
- Polymers stretch out upon dissolving in pipe fluid

Degradation in pipeline



- Stretched polymer becomes susceptible to shear

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DRA Performance in Gases???

- DRA can **NOT** be used in Gases
- How can we improve flow performance?
- Pipe Wall Absolute Roughness Value
  - Lower is better
  - Typical roughness of new pipe is lower 1800 micro-inch
  - Apply pipeline coating

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Factors Affecting DRA Performance

Improves Performance

- Turbulence
- Fluid Velocity
  (up to a max.)
- Liquid Temperature
- Lighter Oil

Reduces Performance

- Fluid Viscosity
- Shear Points
- Length of Pipeline
- Water Content
  (for multiphase)
- DRA Injection nozzle
- Wax content

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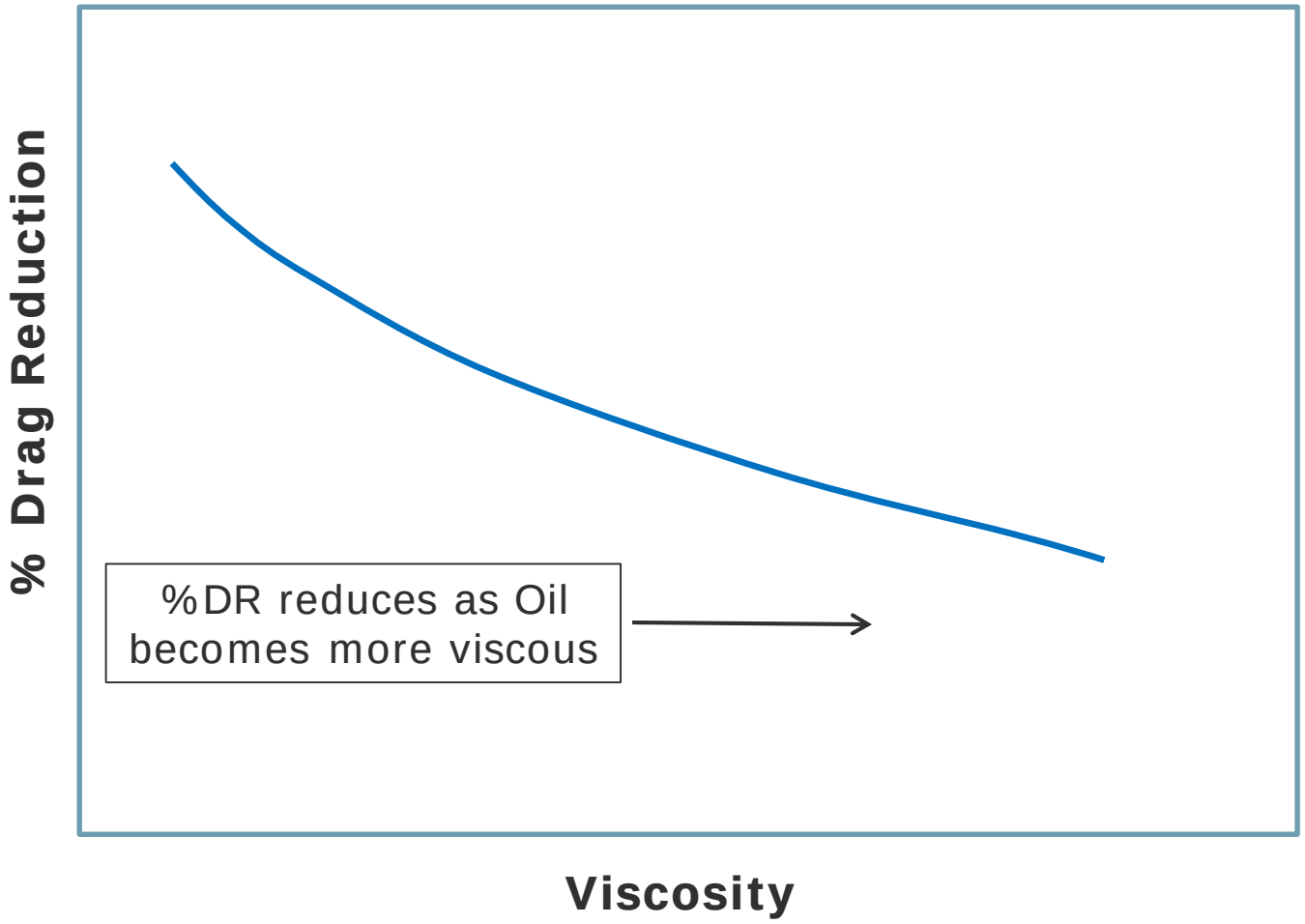
Effect of Oil Viscosity



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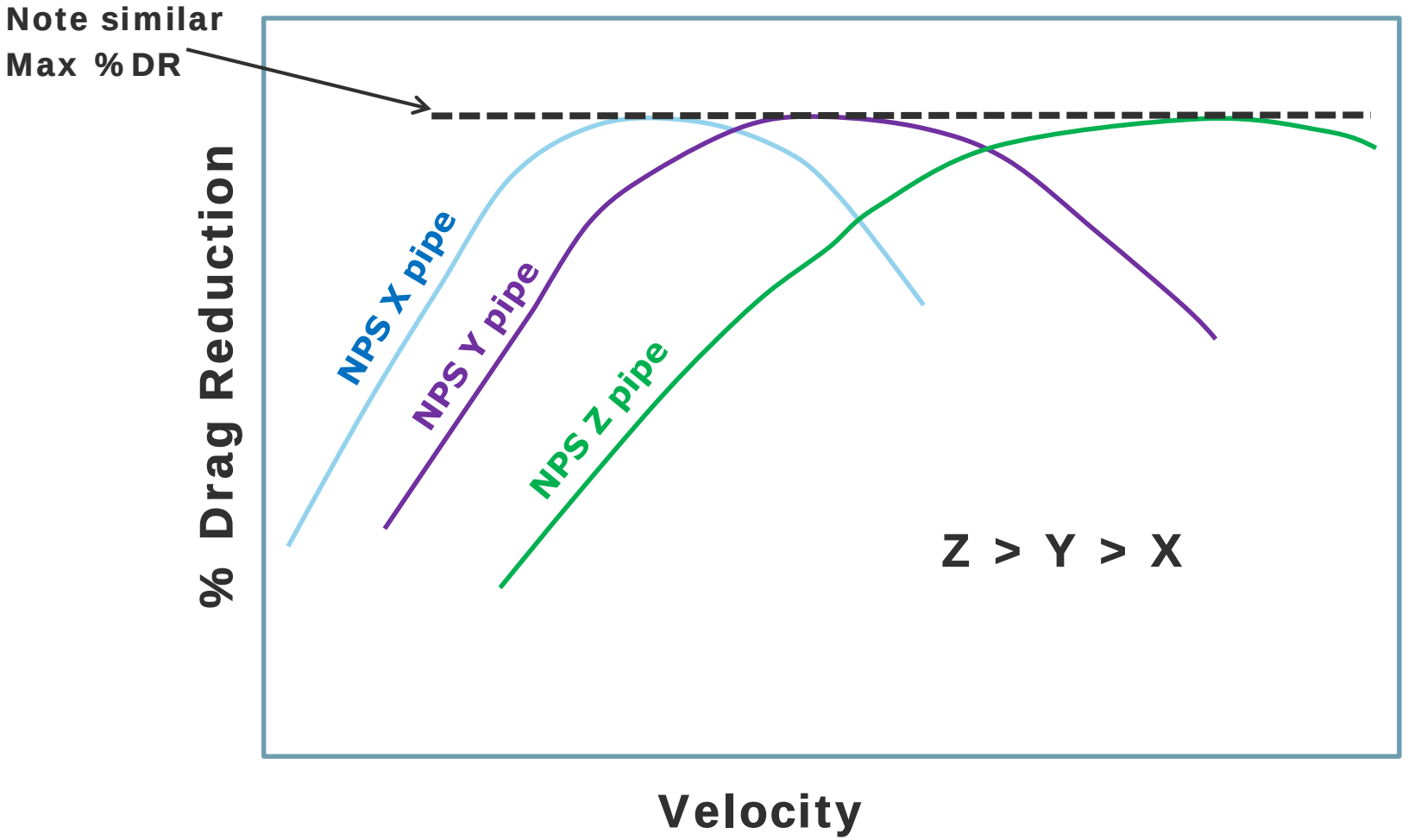
Effect of Velocity & Pipe Diameter



- Increases with velocity to max
- Decreases after velocity reaches max
- Higher max velocity in bigger pipes

- Data from one supplier for a particular fluid
  - NPS 30
    - 5 – 8 ft/s Max
  - NPS 20
    - 4 – 7 ft/s Max

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Effects of Turbulence, Temperature & Oil

- Turbulence
  - Performance improves with turbulence
- Oil
  - Lighter oil has lower viscosity & higher turbulence
- Temperature
  - Higher temperature improves:
    - turbulence
    - viscosity
    - DRA dissolution (clusters together at low T)
    - but degrades faster at higher T
    - Destroyed at extreme T

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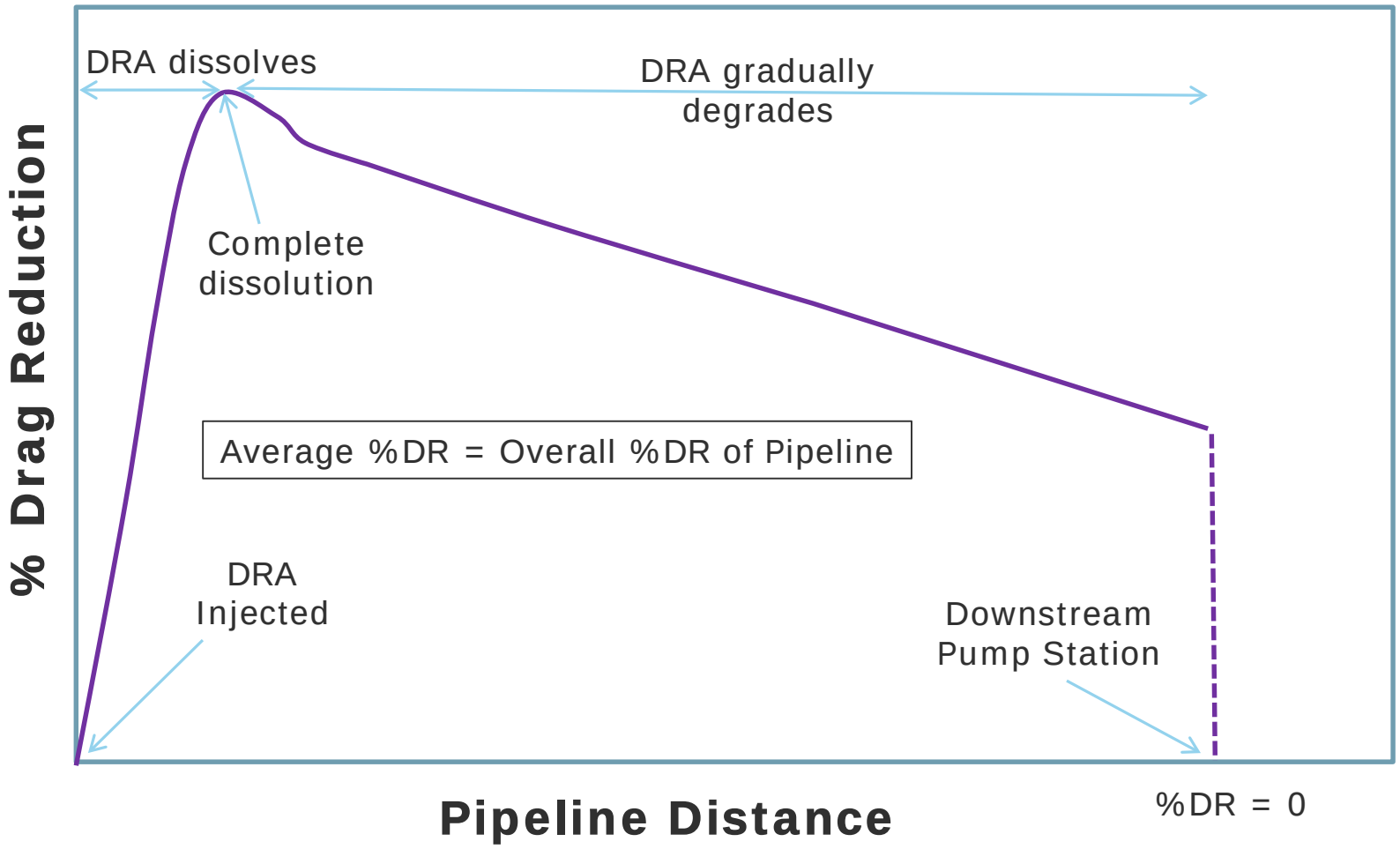
Effect of Pipeline Length



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Effects of Shear Points

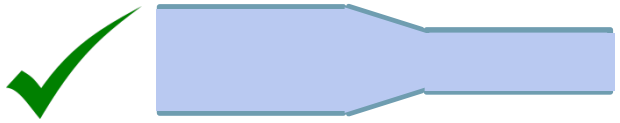
- Impact of shear points or velocity changes on DRA particles

Degrades DRA particles

- Sharp changes in flow velocity/direction
- Diameter changes
- Flow through T diversion
- Partially closed valve
- In-line Orifice

Minimal effect on DRA particles

- Gradual/smooth changes in flow velocity/direction
- Gradual reduction
- Bell reducer
- Side stream injection
- Velocity decrease



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DRA in Design

- Determine what is required
  - Increased capacity
  - Reduced pressure requirements
  - Reduced power requirements
  - Reduced # of pump stations
- Ensure flow is in turbulent region
- Calculate required drag reduction
- Contact DRA vendor

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DRA in Design

- Information required by vendor
  - Oil properties
  - Pipeline capacity
  - Pipeline size
  - Pipeline length
  - Fittings along pipeline length
  - # of Pump stations
- Vendor can determine
  - Drag reduction coefficients
  - Degradation due to shear points
  - Degradation due to pipe length

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DRA in Design

- Design Rules of Thumb
  - Maximum %DR for modeling / calculations
    - ~30% for heavy oil
    - ~50 – 60% for light oil
  - Maximum Length
    - ~50 miles

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Software – Modeling DRA

- DRA can be modeled in Hydraulics Software
- Steady State and Transient software
- DNV GL's Synergi Pipeline Simulator (SPS aka "Stoner")
- Modeled using:
  - DRA coefficients m & b (A and B in SPS)
  - %DR (span in SPS)

DRA DEMO IN SPS

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Additional DRA Info

- Not traditionally used for terminal/plant or refinery
  - Shear points
  - Short pipe lengths
  - DRA dissolution
  - Some vendors claim their product can be used – fast dissolving
- Research for use in transition flow zone
- Used in refined products – not approved for Jet fuel
- Reduced mass transfer rate at wall causes:
  - Reduced Heat Transfer
  - Lower heat transfer coefficient
  - Reduced Wax Deposition
  - Corrosion
- Chemicals such as Aluminum can be added at low temperatures to reduce cluster (lowers polymer cohesion)
- Surge analysis highly recommended for DRA-induced increased capacity

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Understanding the technology behind optimizing drag reducing agents (DRA) and the operational benefits

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