HALLIBURTON

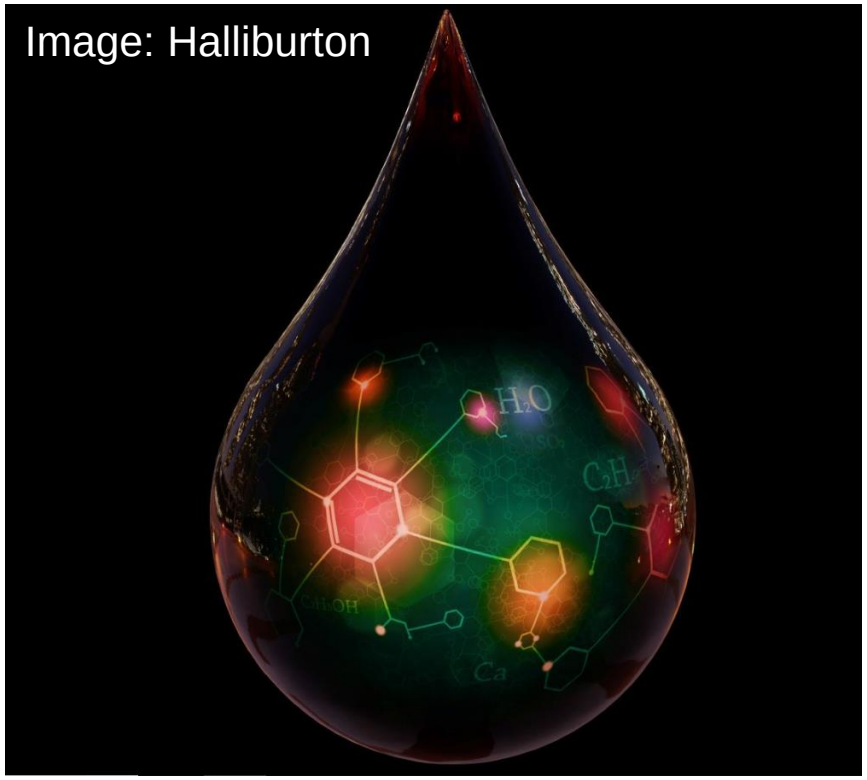
Base Fluids

JJ Miller, Sr. Product Manager

© 2019 Halliburton. All rights reserved.

Topics

- Base Fluid Primer
  - Use in Oil-Based/Synthetic-Based Fluids
  - Global perspective
  - History of development
  - Chemistry
- Classifications
- Important Properties
- Selecting a Base Oil



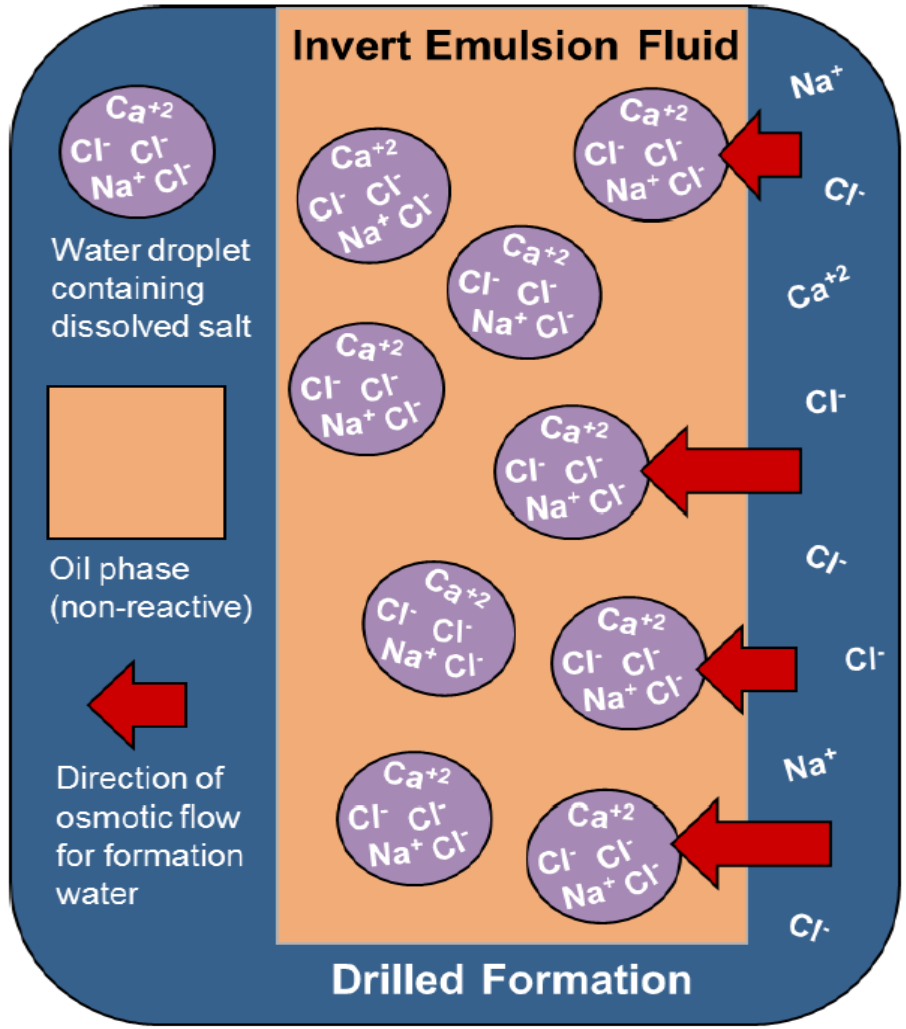
© 2017 Halliburton. All rights reserved.

HALLIBURTON

Base Fluid - Function

- Primary liquid phase of drilling fluids
  - Like water for other types
  - ***But…not like water***
  - Two types of oil-based fluids:
    - »'All-oil'
    - »Invert emulsions (water-in-oil)

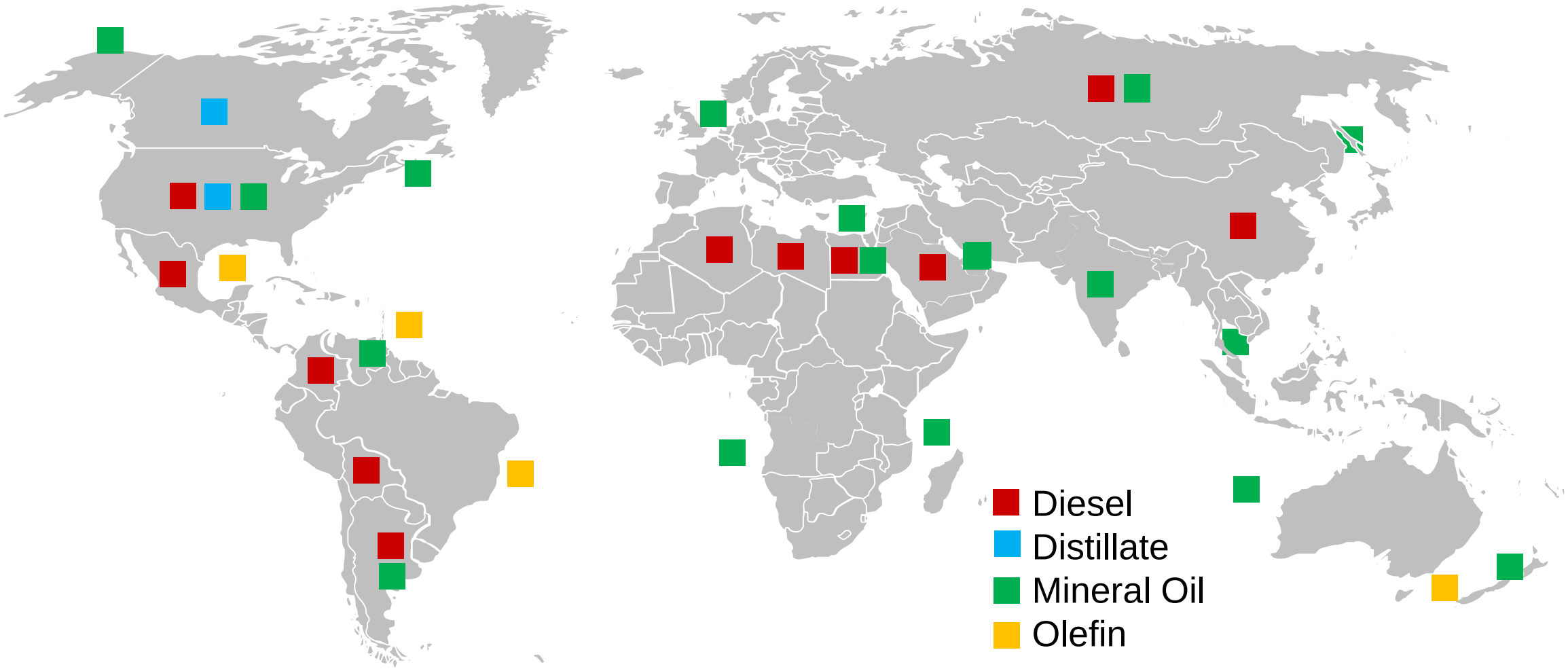
- Primary cost component
  - **But there are other aspects to consider**



© 2017 Halliburton. All rights reserved.

HALLIBURTON

Base Fluids in Use Worldwide (partial)

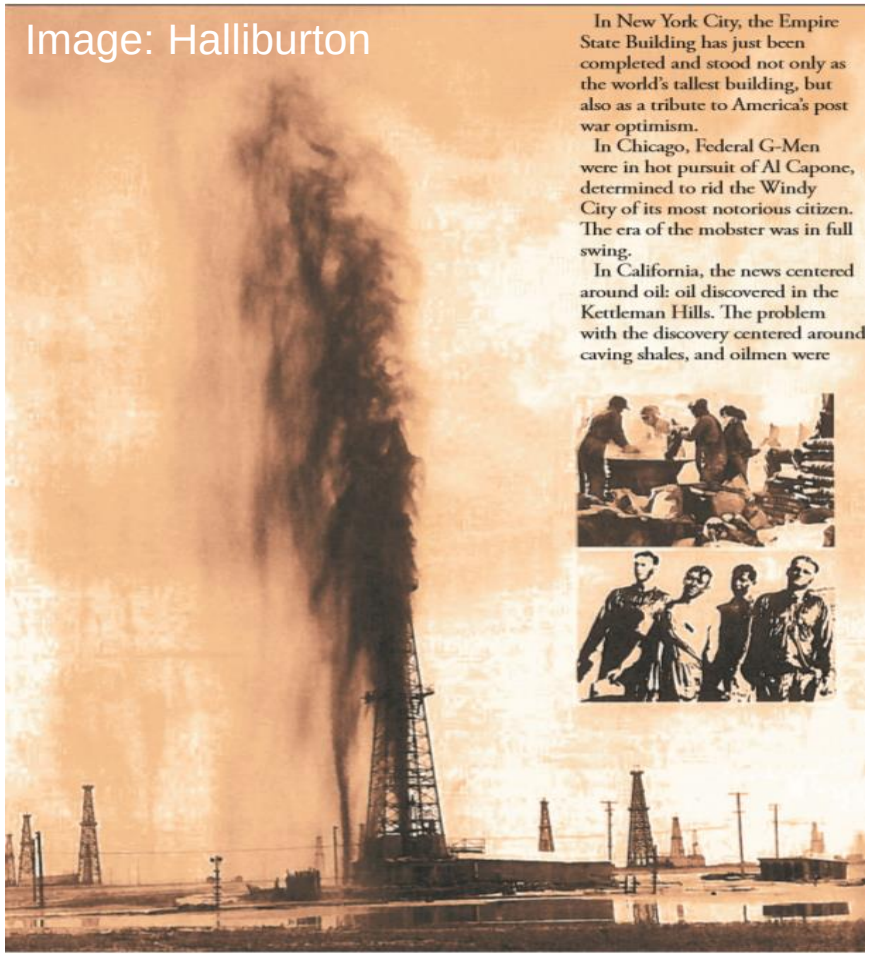


© 2017 Halliburton. All rights reserved.

HALLIBURTON

History of Development

- Crude oil was first (early 1900s)
  - Low flash point
  - Range of materials used for filtration control
- Diesel-based systems debuted around 1940 (low water content)
- Invert emulsions with diesel were applied in the early 1960s
  - Protection from risks of ignition
  - Salinity helped tame reactive clays
- Low-aromatic mineral oil systems came into favor in the 1980s
- Synthetics followed, and 100% ester systems once had a large footprint



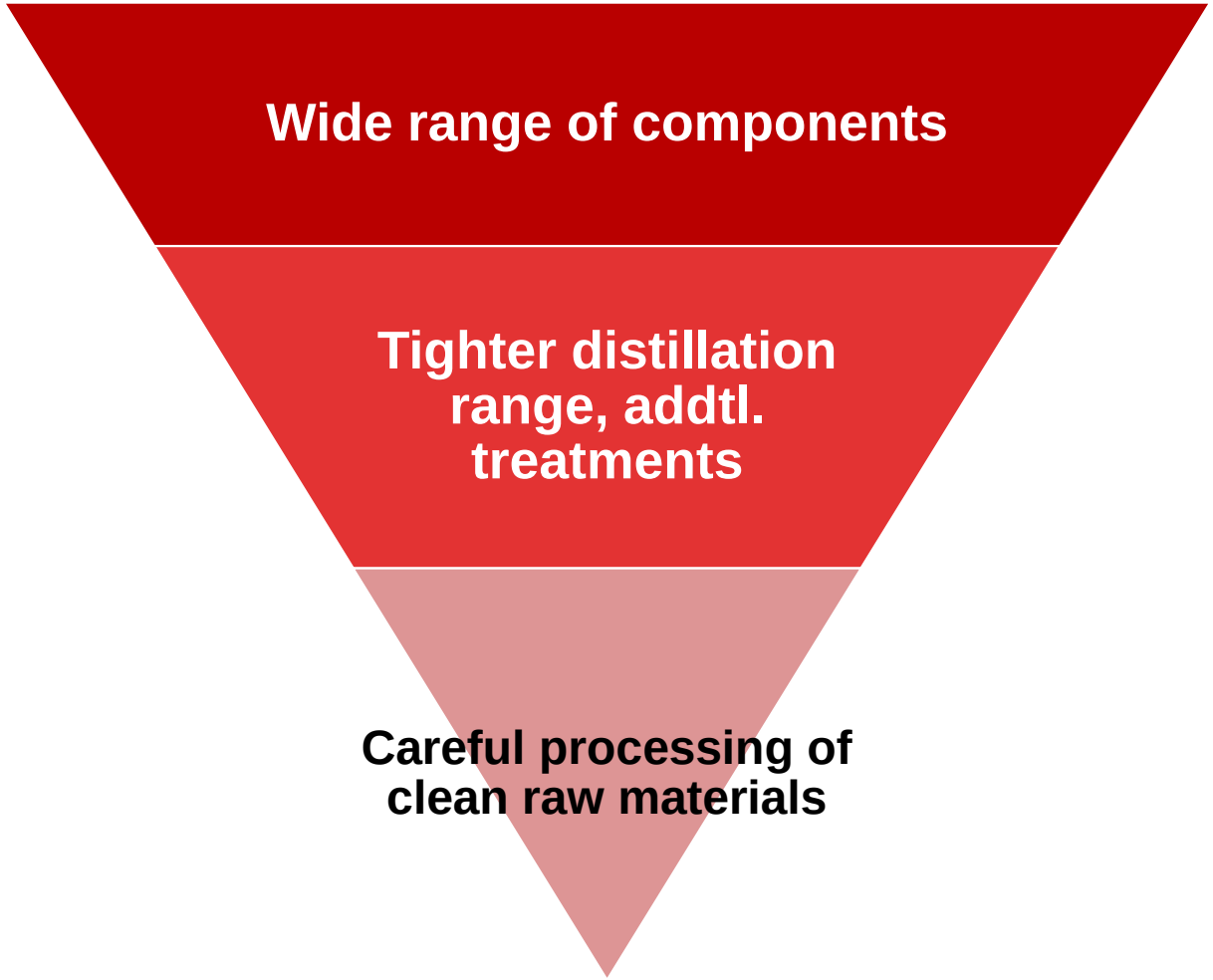
Darley, H. and Gray, G. (1988). *Composition and Properties of Drilling and Completion Fluids.* 5th Ed. Houston, Texas: Gulf Publishing Company.

© 2017 Halliburton. All rights reserved.

HALLIBURTON

Base Oil Chemistry

- Refined Crude Hydrocarbons
  - #2 Off-road Diesel
  - Distillates
- Low-Aromatic Mineral Oils
  - n-Paraffin or Alkane (straight)
  - iso-Paraffin (branched)
  - Cyclic Paraffin or naphthenic
  - Mixtures of the above
- Synthetic (Reacted Products)
  - Gas-To-Liquid paraffins
  - Fatty Acid Esters
  - Internal Olefins
  - Linear Alpha Olefins
  - Poly Alpha Olefins
  - Ethers



© 2017 Halliburton. All rights reserved.

HALLIBURTON

Oil and Gas Producers (OGP) - Base Oil Classifications

Non-Aqueous (Oil) Category	Examples	Aromatic Content
Group I	Crude Oil, Diesel, Conventional Mineral Oil	5 – 35% (High Content)
Group II	Low-Toxicity Mineral Oil	0.5% - 5% (Medium Aromatic Content)
Group III	Ester, LAO, IO, PAO, Linear Paraffin, Highly Processed Mineral Oil	<0.5% and PAH Lower than .001%

- Polycyclic Aromatic Hydrocarbon = PAH

© 2017 Halliburton. All rights reserved.

Baroid - Base Oil Classifications

Non-Aqueous (Oil) Category	Examples	Aromatic Content
Group I	Crude Oil, Diesel, Conventional Mineral Oil	5 – 35% (High Content)
Group II	Low-Toxicity Mineral Oil	0.5% - 5% (Medium Aromatic Content)
Group IIIA	Linear Paraffin, Highly Processed Mineral Oil	<0.5% and PAH Lower than .001%
Group IIIB	Ester, LAO, IO, PAO	0%

Group III was split out to further distinguish between fluid types and aromatics content

© 2017 Halliburton. All rights reserved.

Important Base Oil Properties

- **Non-toxic** Base Oil required in some areas
  - Low Aromatic content (UV, %) <0.01%
  - Aquatic toxicity and biodegradation
  - Offshore OOC limits and discharge permits

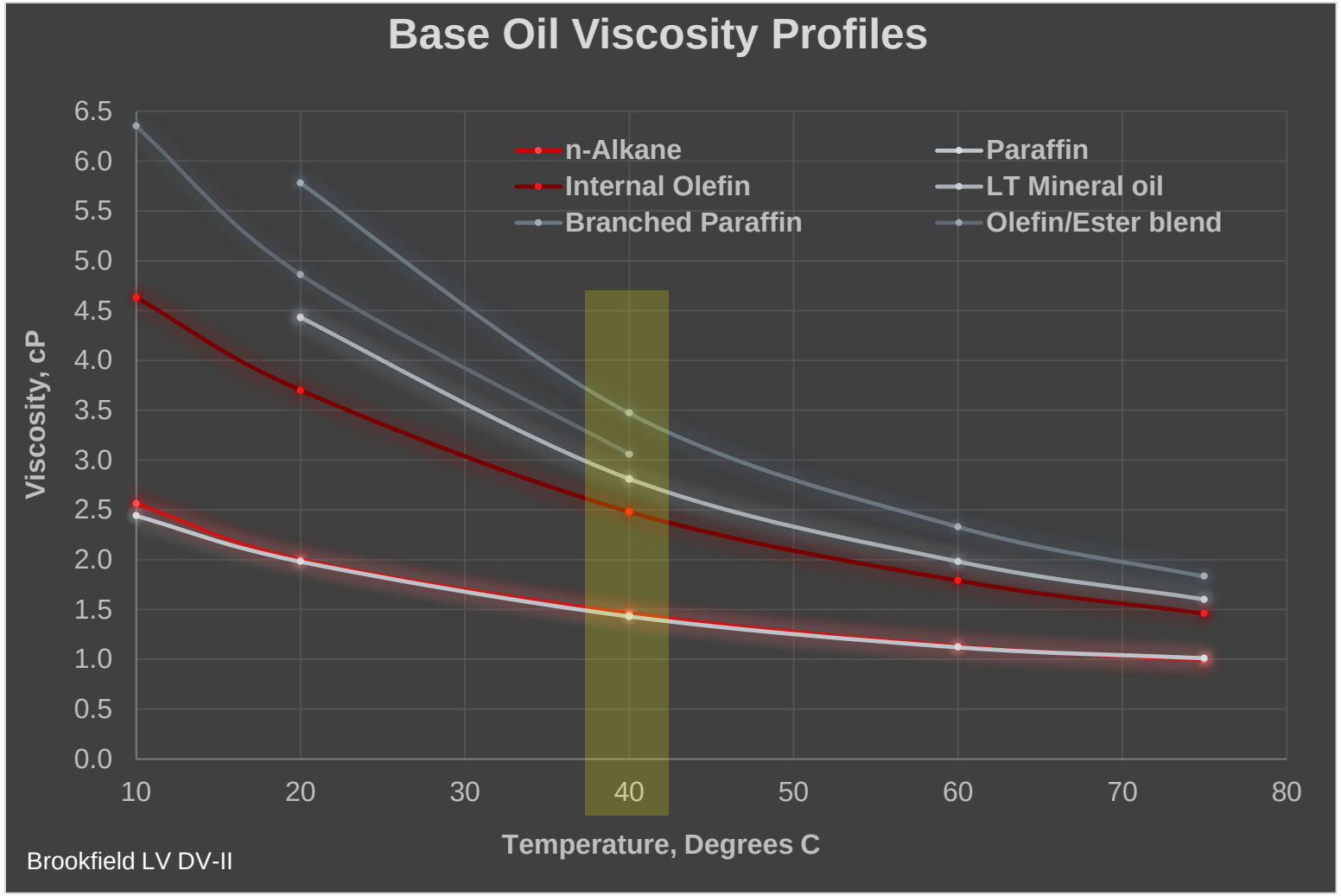
- Lower **Kinematic Viscosity** helps manage fluid viscosity:
  - Full Range = 1.6 to > 5 centiStokes (cSt)
  - Typical Viscosity at 40°C (104°F) ≤ 3.5 cSt
  - Other examples:
    - » honey ~74
    - » olive oil ~44
    - » distilled water = 1.00 (at 68°F)


Image: Halliburton

© 2017 Halliburton. All rights reserved.

HALLIBURTON

Important Base Oil Properties

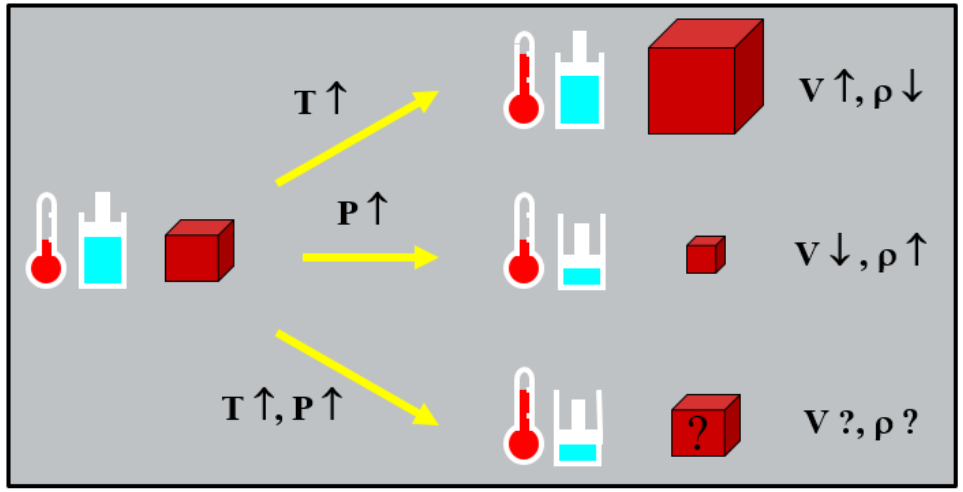


© 2017 Halliburton. All rights reserved.

HALLIBURTON

Important Base Oil Properties

- **Flash Point** – temperature for vapors to ignite
  - *Range of 75-140ºC (167-284ºF) for non-diesel*
- **Physical Analysis** for well temperature & pressure
  - Required for accurate density in deep/hot wells
  - Responsible for changing surface density
  - Influences hydraulics predictions
- **Aniline Point** (higher extends elastomer life)
  - > 75ºC (167ºF) for most Group III oils
- **Pour Point** in arctic applications



© 2017 Halliburton. All rights reserved.

HALLIBURTON

Total Cost and Supply Continuity

- Ancillary expenses with Invert Emulsions
  - Drilling Waste treatment and disposal
  - Transportation (fluids and waste)
  - Storage and processing to extend the run life of used drilling fluids
    - » Service company Liquid Mud Plants (LMPs)
  - Bulk base fluid storage (suppliers / service companies)
- Supply Chain Roles
  - Consistency
  - Security of supply
- Transition pains
  - Large inventories


Image: Halliburton.com

© 2017 Halliburton. All rights reserved.

HALLIBURTON

Selecting a Base Fluid



Total Cost and Supply Continuity

- Environmental permitting
- Mixing, storage and waste handling
- Consistent composition and properties



Logistics

- Lead times and inventory
- Delivery timelines
- Contingency stock



Cost per unit volume

- Consider alternatives in similar Classifications
- Map to market indices
- Potential for reclamation



Technical Aspects

- Compatibility with product ranges
- Stable performance over planned temperature and density range
- Suitable pour point for cold climates

© 2017 Halliburton. All rights reserved.

THANK YOU