
Heavy Oil Flow Assurance Challenges

Lewis Norman, Ph.D.

Heavy Crude Oil

Heavy Crude Oil or **Extra Heavy Oil** is any type of crude oil which does not flow easily. It is a relative term, compared to light crude oil, but relates to specific technical issues of its own on production, transportation, and refining. Physical properties that distinguish heavy crudes from lighter ones include higher viscosity and specific gravity, as well as heavier molecular composition. Extra heavy oil from the area north of the Orinoco river in Venezuela, which has by far the largest volume of the 30 or more countries with known reserves, has a viscosity of over 10,000 centipoise and 10° API specific gravity. Generally a diluent is added at regular distances in a pipeline carrying heavy crude to facilitate its flow.

Some petroleum geologists categorize bitumen from tar sands as extra heavy oil although bitumen does not flow at ambient conditions.

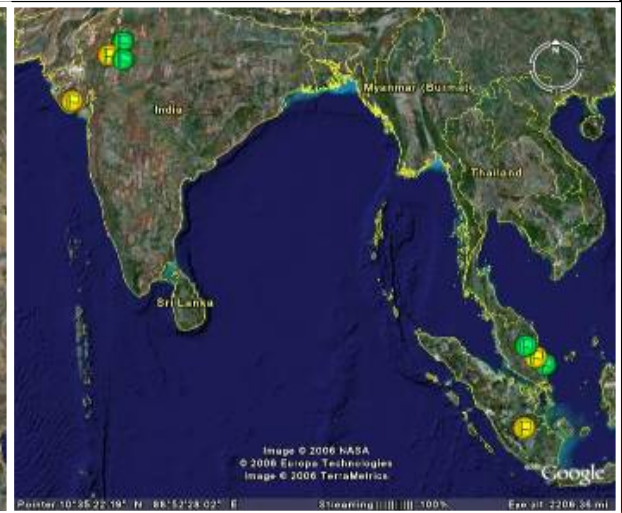
Heavy Oil: Big Picture

INCLUDES

- Production
- Transportation
- Refining

Global Reserves

- 0-10 API
- 11-15 API
- 16-20 API
- 21-26 API



“Large resource, but contribution to supply so far has been modest”

Alberta's Oil Sands

“In short, it is an enterprise of epic proportions, akin to the building of the pyramids or China’s Great Wall. Only bigger.” Prime Minister Harper to the Canada-UK Chamber of Commerce, July 2006

The oil sands at a glance

Proved reserves: 174bn barrels
Production (2005): 1.1m b/d
Production forecast (2020): 4m b/d
Investment (1996-2005): C\$44bn
Investment forecast (to 2020): C\$100bn
Oil-sands lease agreements: 2,700
Land not yet leased: 70%
Total oil-sands area: 140,800 square km
Gravity of oil-sands bitumen: around 8°API
Gravity of upgraded syncrude: 31-33°API

Sources: CAPP, Alberta Energy, Canadian Energy Research Institute



Pictures: Suncor, Petro-Canada Map: CAPP

Source: The oil sands at a glance, Petroleum Economist



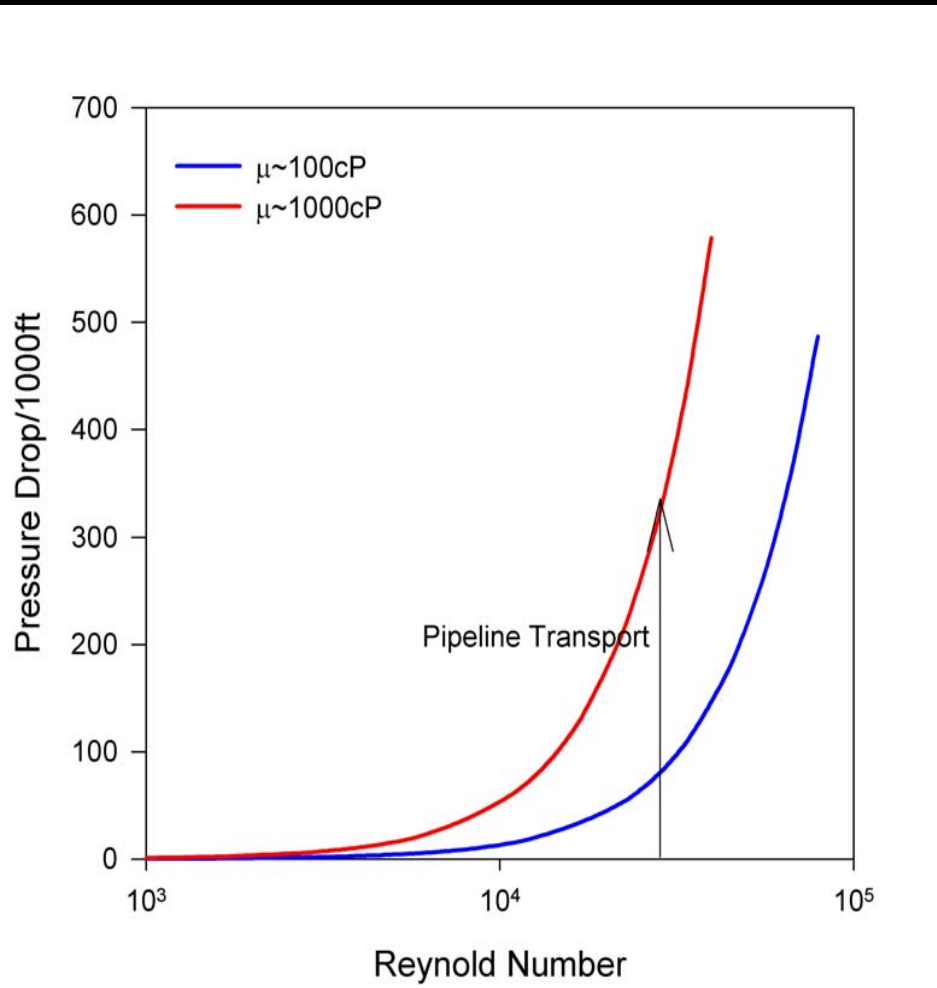
Heavy Oil – Flow Assurance



Pipeline flow from subsea well head to processing facility.



The Viscosity Problem



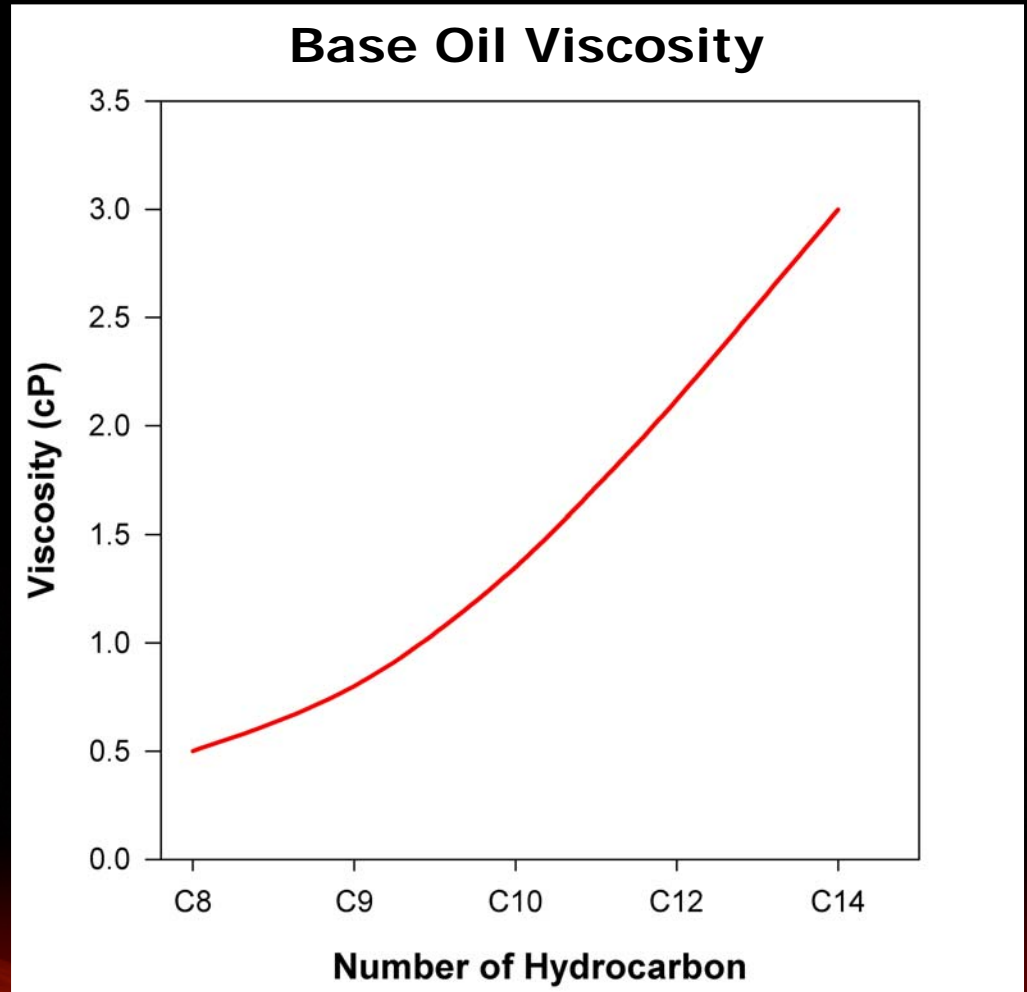
$$Re = \frac{\rho v D}{\mu}$$

Given Conditions:

- Pipe ID = 8"
- Density of fluid 1.0 g/cc
- Flow rate ~ 6.5 ft/sec
- Maximum pressure 800 psig
- Steel pipe, smooth wall

Heavy Oil Contains

1. Base Fluid
2. Insoluble Materials
3. High Molecular Weight- polymer like materials

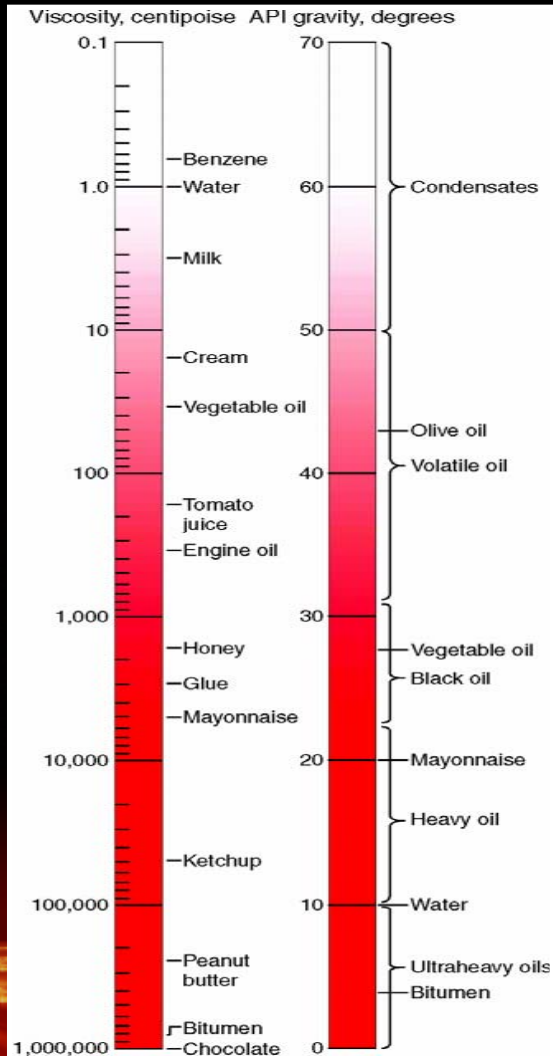


Relationship between viscosity and number of hydrocarbon

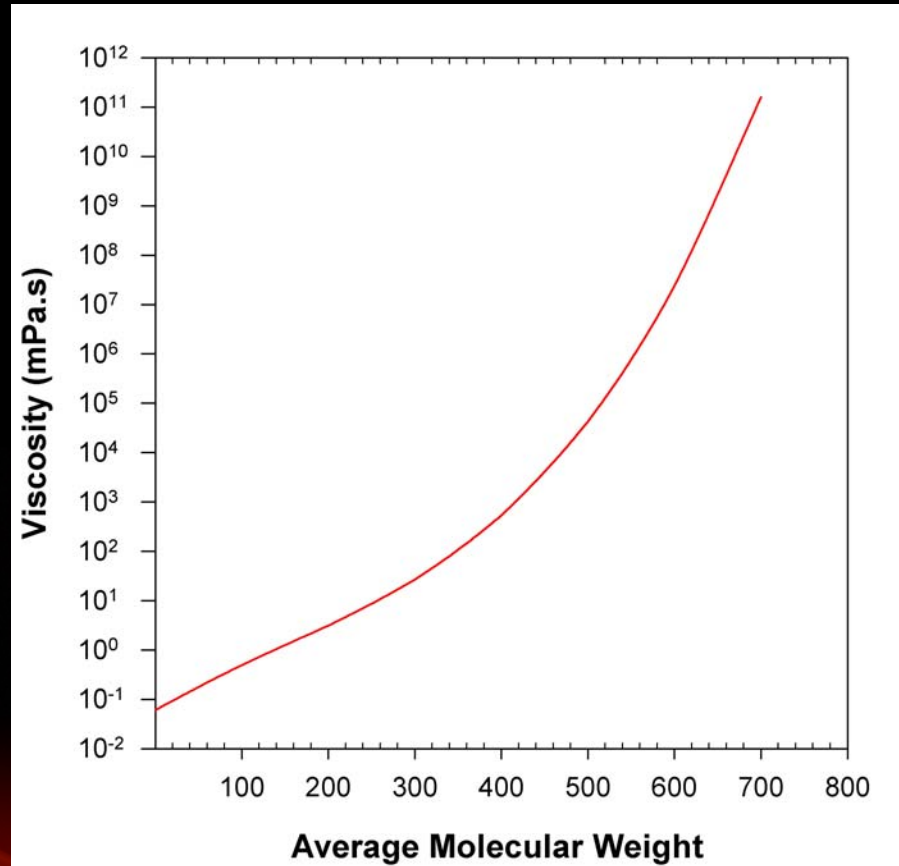
@25°C*

Heavy Oil Characteristics

Viscosity and API gravity¹



Viscosity as a function of molecular weight²

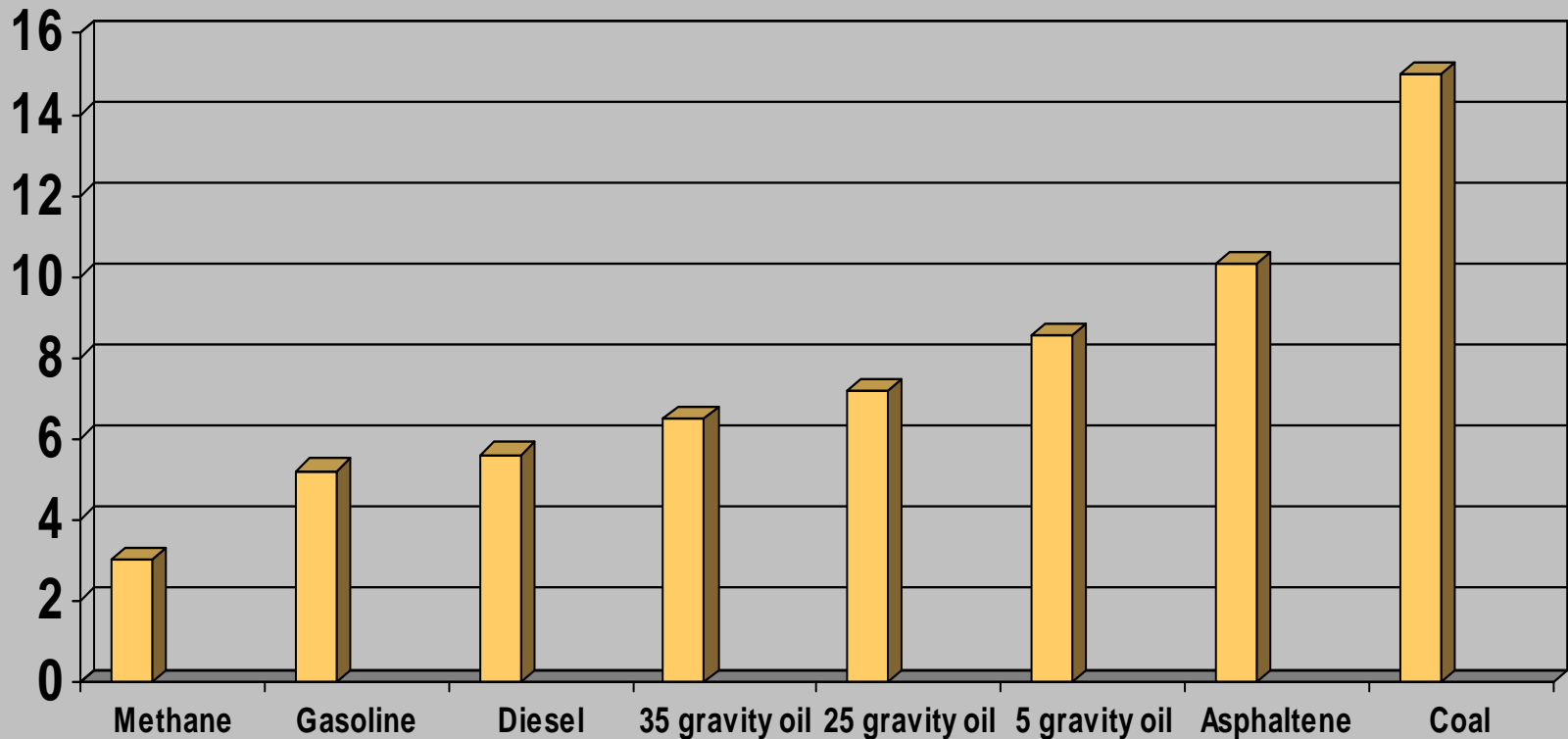


¹ Reprinted from Oilfield Review, Autumn 2002, pp 31

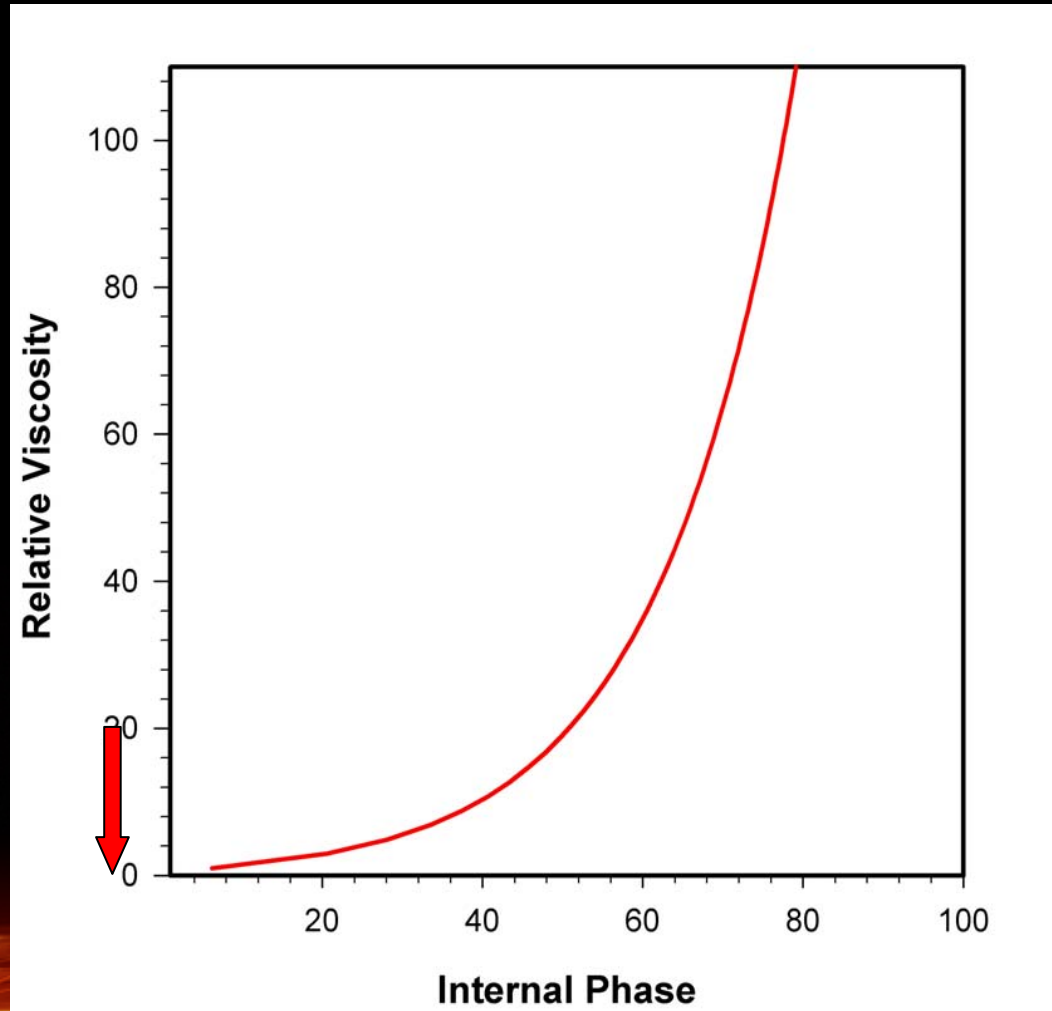
² Duplicated from P.J. Closmann & R.D. Seba JCPT, July-August, 1990 vol.29, No 4 pp115

Carbon to Hydrogen Ratios

Carbon to Hydrogen Ratios

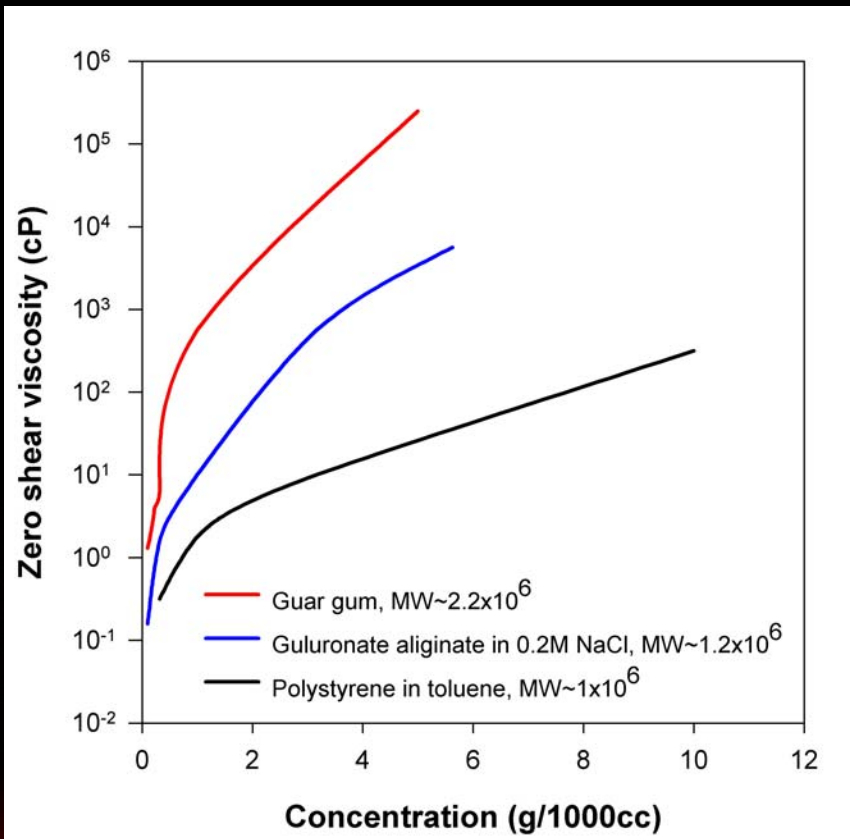


Insoluble Materials

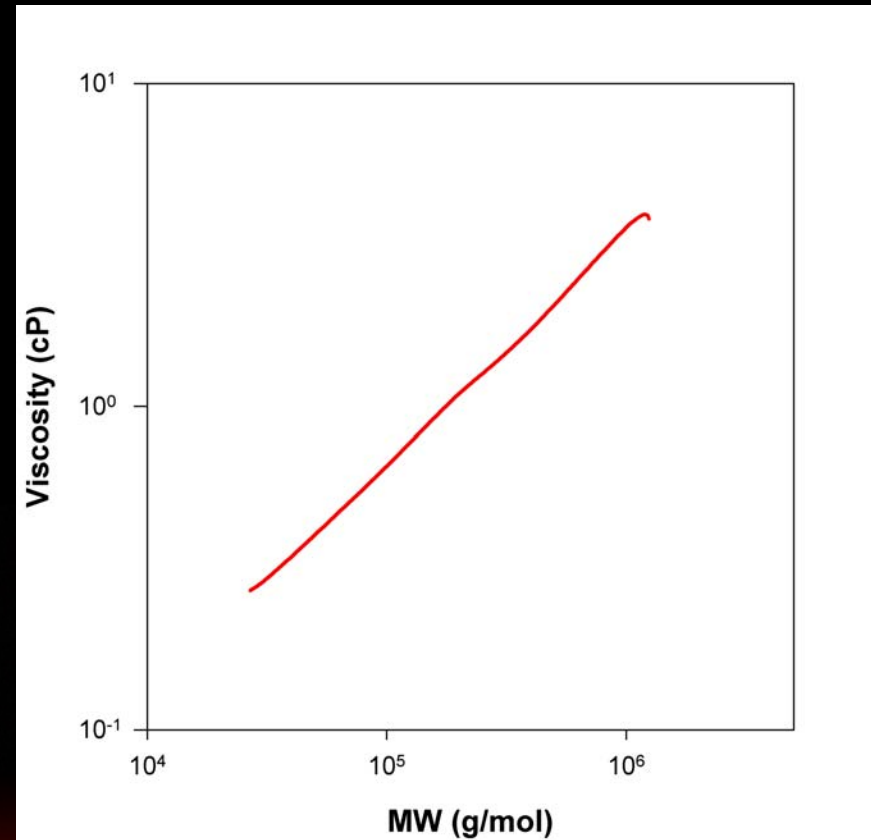


Relationship between viscosity and internal phase @ 25°C*

High Molecular Weight



Relationship between viscosity and polymer concentration*



Relationship between viscosity and polymer Molecular weight for PAM in 0.2M Na₂SO₄ at 25°C**

*E.R. Morris, A.N. Cutler, Carbohydr. Polymers, 1981, 1, p5

**R.S. Harland, R.K. Prud'homme, Polyelectrolyte Gels ACS Symposium Series 480, 1990, p59

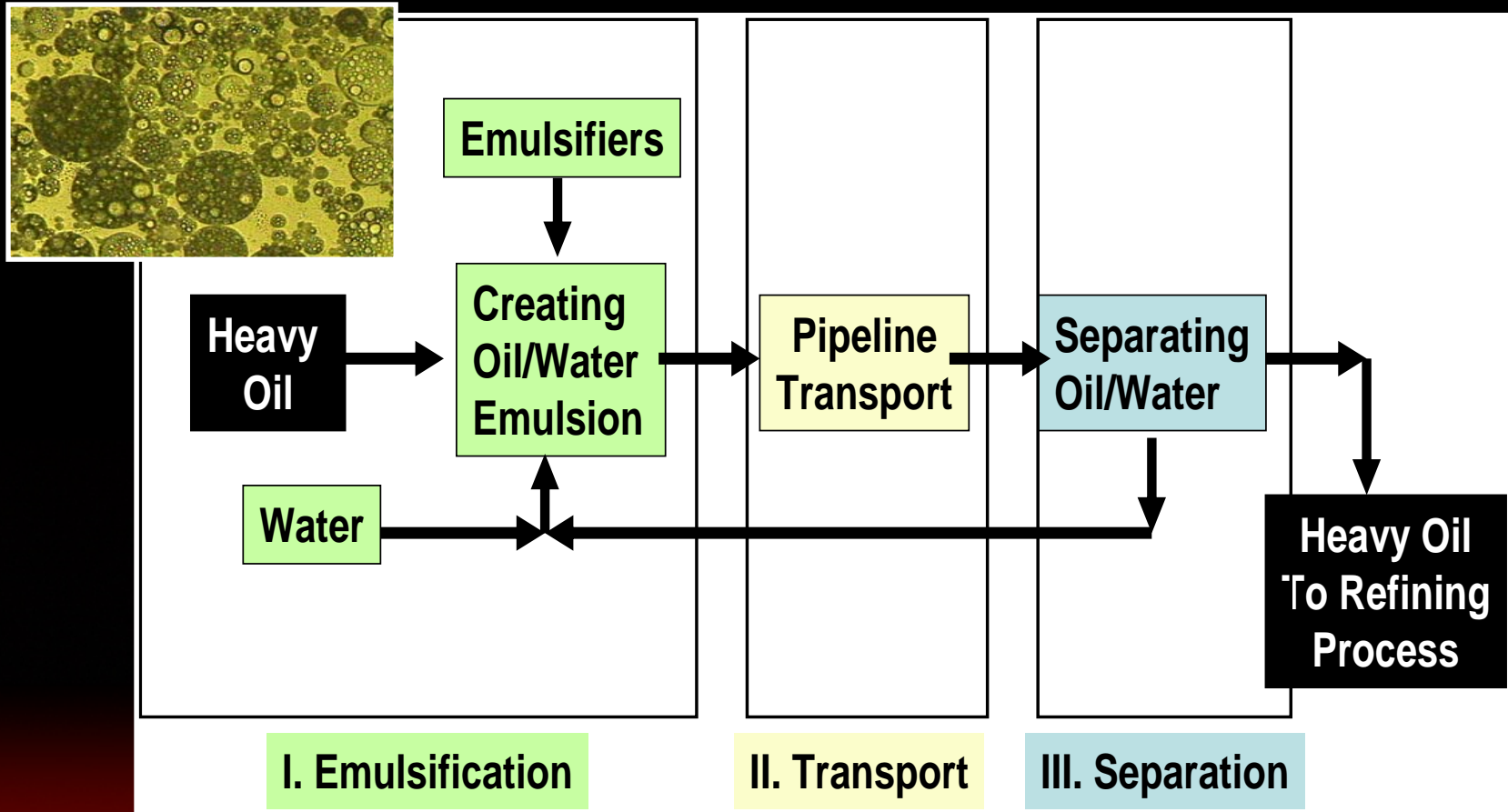
How to Reduce Heavy Oil Viscosity

Approaches:

- Thermal Thinning *(16 refs*)*
- Inhibitors *(281 refs*)*
- Solvent Dilution *(161 refs*)*
- Emulsions *(14 refs*)*
- Cracking *(33 refs*)*

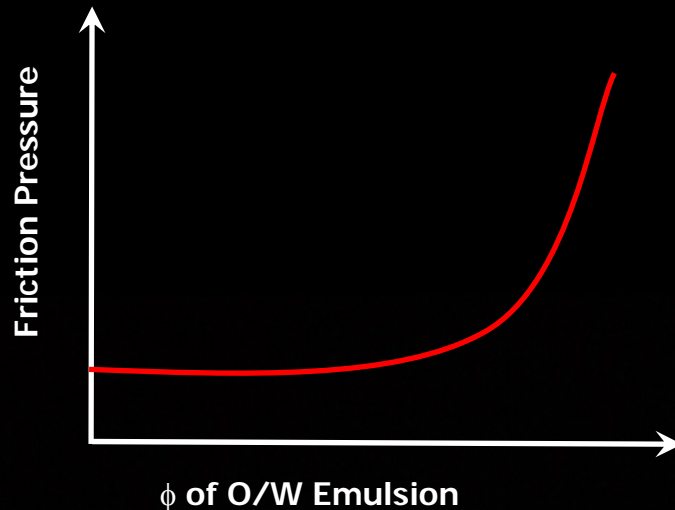
Emulsion for Heavy Oil Transport

Graphic of W/O Emulsions*



Emulsion

- Cost **↑** in some cases
- Significant friction pressure remains as [\$oil] **↑**



- Chemical/Equipment and H₂O recycle can be problematic

Thermal & Piping Methods



“Minimize heat loss during heating process of a heavy oil to reduce η ”

- Electronic heating
- Pipe-in-pipe system

Advantages:

- Uniform heat transfer

Drawbacks:

- Cost!!!
- Insulation issues especially on the sea bed pipeline

Graphic of Pipeline Insulation (Pipe-in-pipe systems)

**Courtesy of StatOil Corp.*

Some Technical Opportunities

- Cracking / Catalyst
- Inhibitors / Thinners
- Mechanical Systems
- New Ideas.....

WHAT?