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Crude Oil Emulsions: Everything You Wanted to Know But Were Afraid to Ask

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Saudi Aramco

Outline

- Emulsions
  - What are emulsions?
  - Types of emulsions
  - Where do they form?
  - Stability of emulsions
  - Challenges during oil production
- Reservoir and production aspects of emulsions
- Demulsification: oil-water separation
- Emulsion treatment programs
- Recommendations

Some Examples of Emulsions

Milk

Mayonnaise

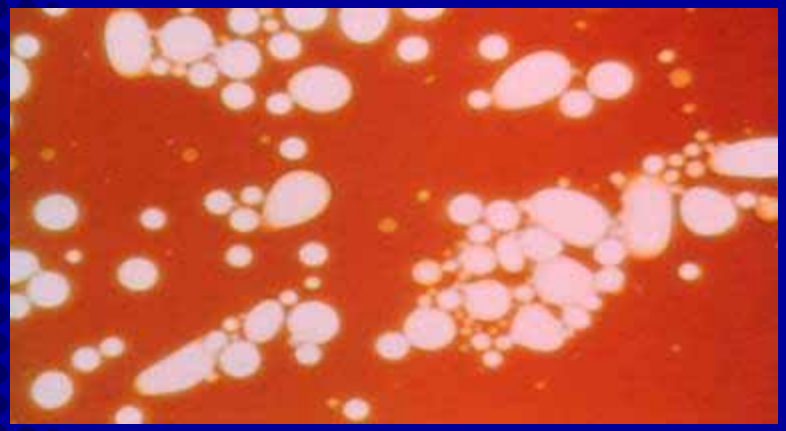
Definitions

- **Emulsion: An emulsion is a colloidal dispersion of one liquid (disperse phase) in another (continuous phase)**

- **Types of Emulsion:**
  - **Water-in-oil**
  - **Oil-in-water**
  - **Complex/multiple emulsions**

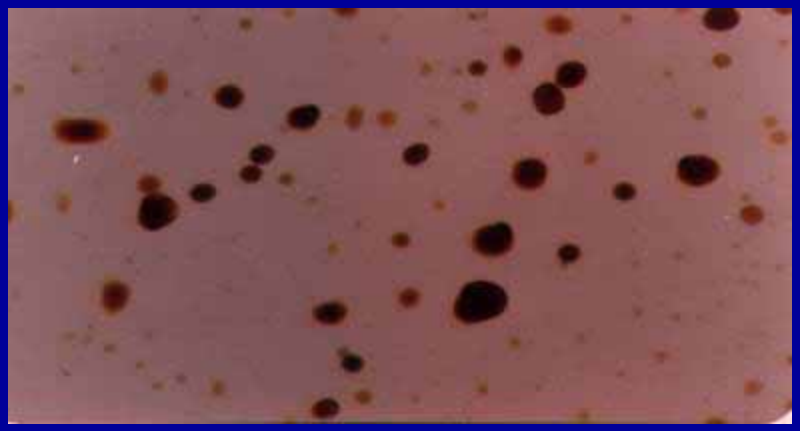
- **Macroemulsions, size > 0.1 μm**
- **Microemulsions, size < 0.1 μm**

Oil-field emulsions are water-in-oil macroemulsions

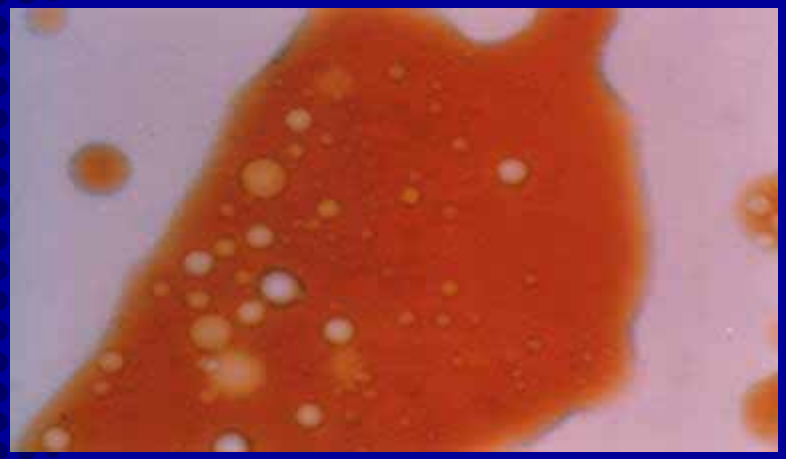


a) Water-in-oil emulsion

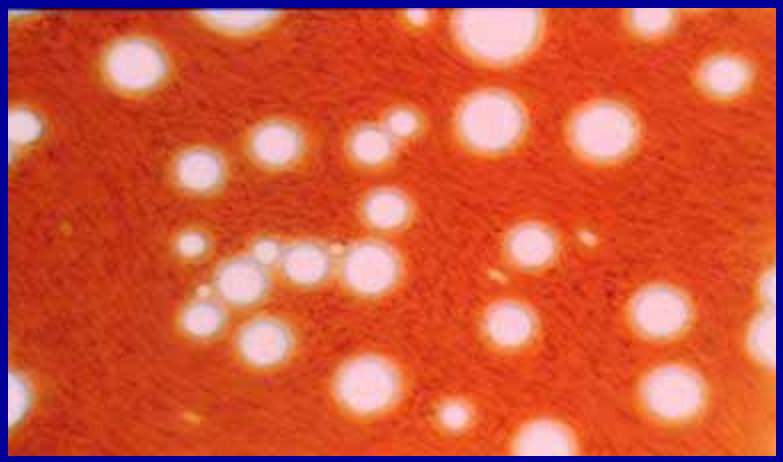
10μ



b) Oil-in-water emulsion



c) Water-in-oil-in-water emulsion

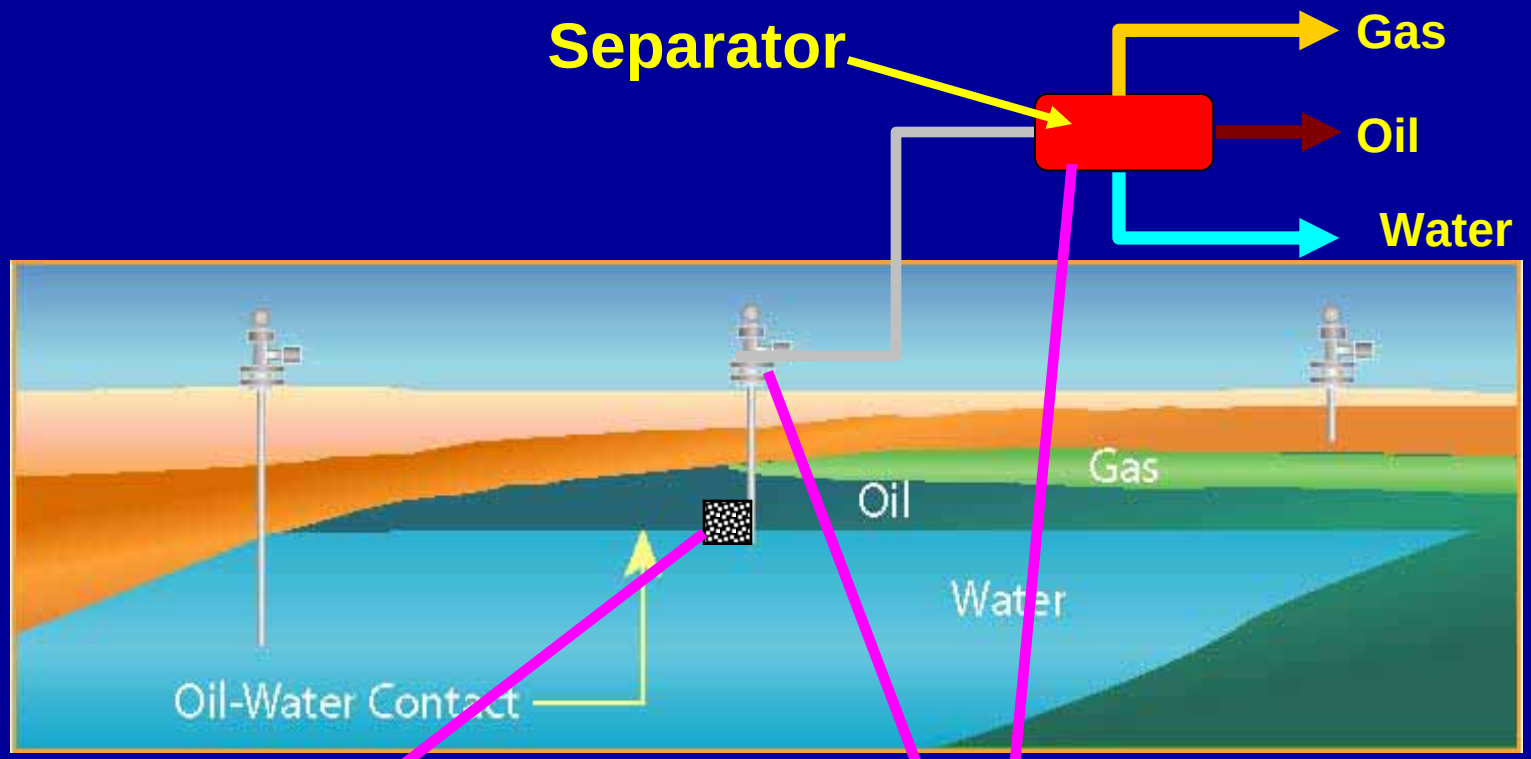


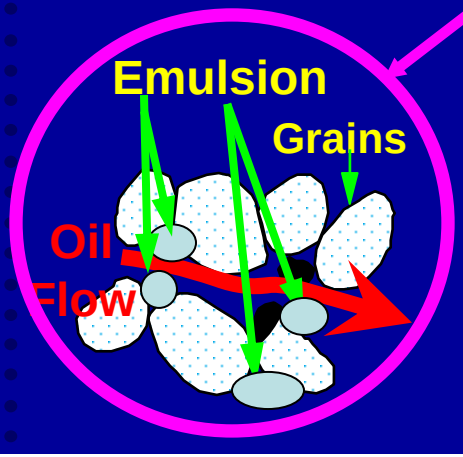
d) Presence of solids

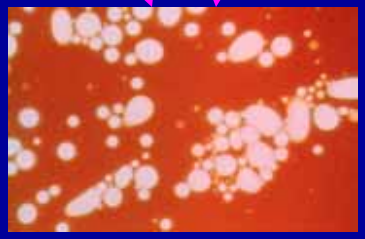
Emulsion Photomircrographs

Where do they form?

Where do we encounter emulsions?







Emulsion Stability

- Emulsions are inherently unstable
- Classified based on their kinetic stability
  - loose → few minutes
  - medium → tens of minutes
  - tight → hours, days
- Presence of emulsifying agents
- Films act as physical barriers to coalescence
- Factors Affecting Stability

Tight Emulsion

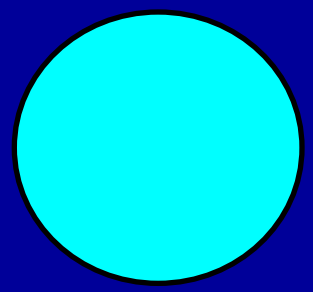
Loose Emulsion

An example of a very tight emulsion

Factors affecting stability

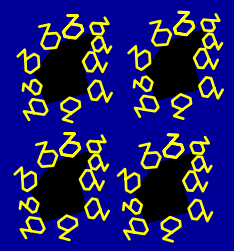
- Heavy polar material in the crude oil
- Fine solids including organics (asphaltenes, waxes) and inorganics (clays, scales, corrosion products)
- Temperature
- Droplet size and and droplet size distribution
- pH of the brine
- Brine composition

Mechanism of emulsion stabilization



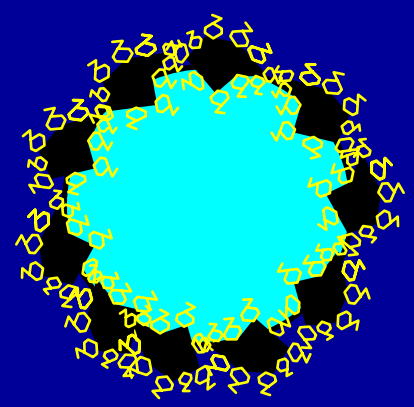
Water droplet

+

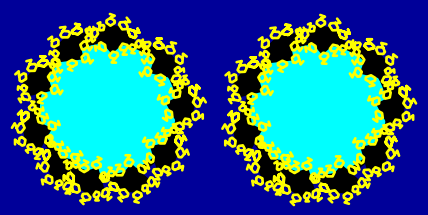


Asphaltene aggregate

→



Asphaltene Stabilized water droplet



Droplets resist coalescence due to steric/colloidal stabilization

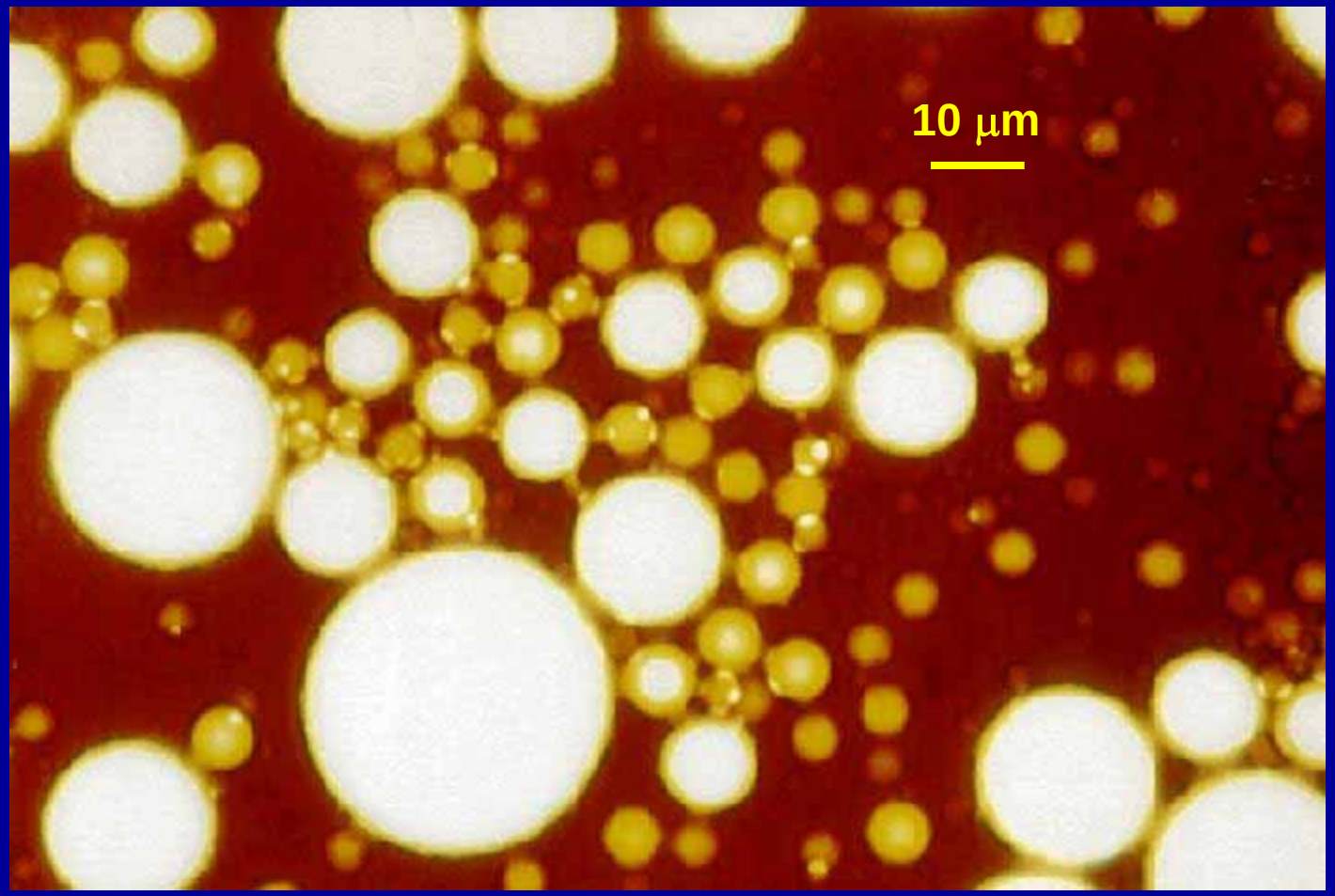


Photo-micrograph of an emulsion showing interfacial films

Measurement of stability

- Determines the ease of separation
- Most common is the bottle test
- Used for
  - water separation over time
  - water separation with demulsifier dosage
  - screening demulsifiers
- Standard ASTM method for BS&W
- Developed at Saudi Aramco: ESI or Emulsion Separation Index

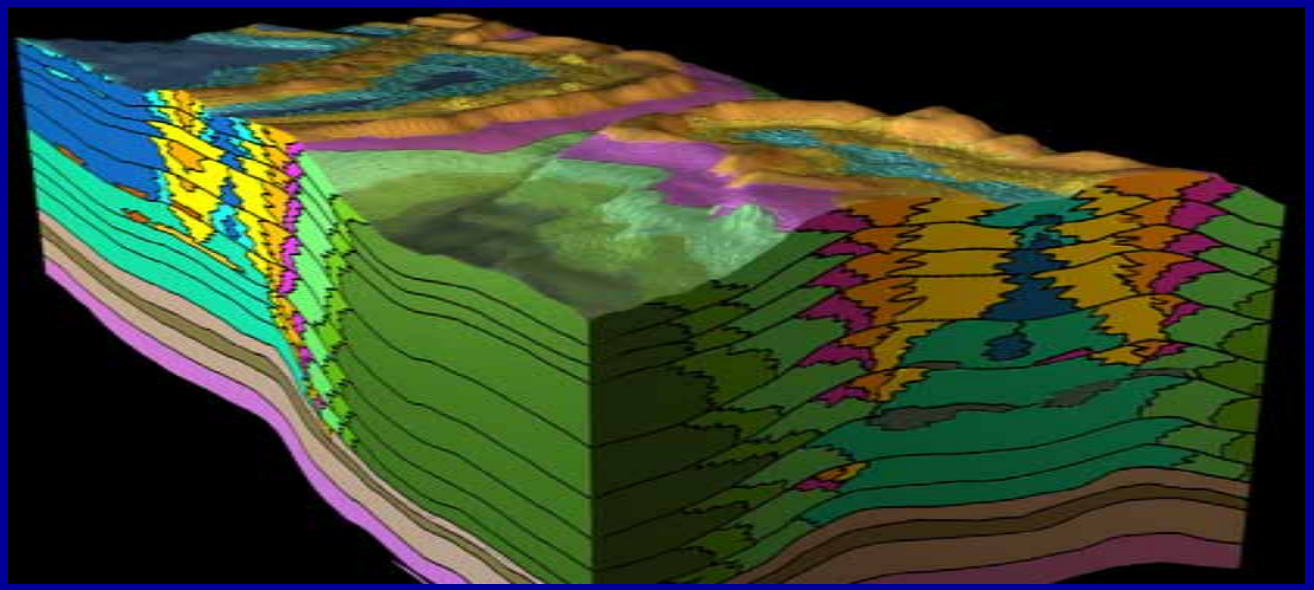
Emulsion Challenges During Oil Production

- **Negatives:**
  - Water and salt in sellable crude
  - Oil in disposal water…injectivity concerns
  - Flow assurance concerns
  - Productivity decline in wells
  - Higher demulsifier and treatment costs
  - Equipment trips and upsets
  - Higher oil production costs

- **Positives:**
  - None!

Reservoir Aspects of Emulsions

- During drilling operations
- Acidization of wells
- Well treatments
- EOR/IOR operations

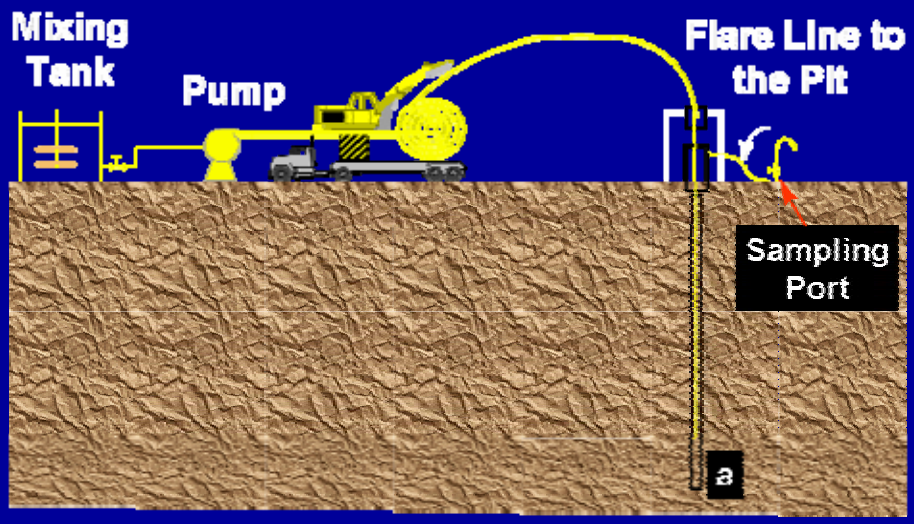


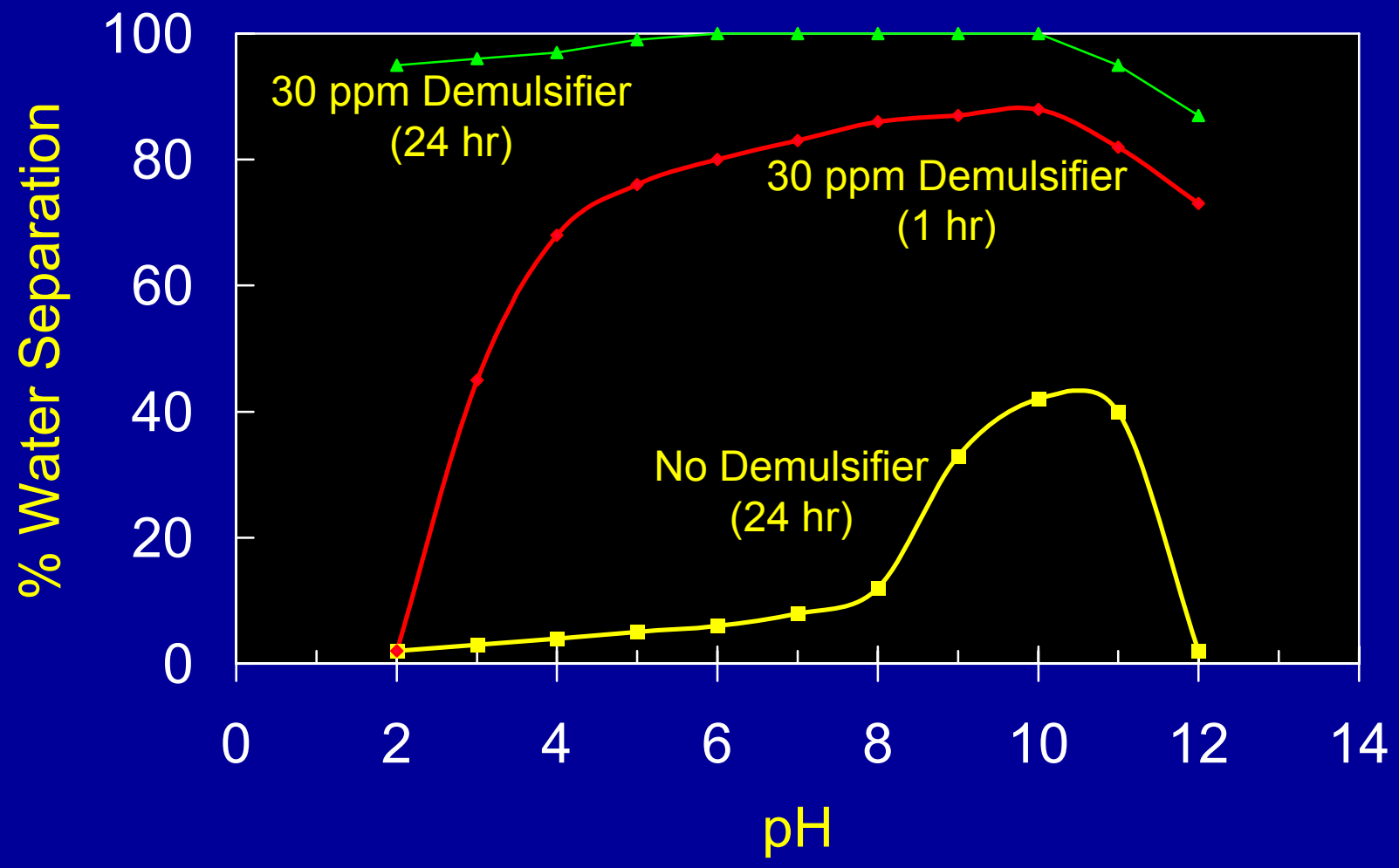
Drilling Operations

- Drilling muds can form tight emulsions
- May cause formation damage
- Incorrect estimation of reserves
- Most likely to form in reservoirs with:
  - Lower APIs (< 25º)
  - Lower temperatures (< 150ºF)
  - Poorer rock quality (low porosities and permeabilities)
  - Higher amounts of asphaltenes
- Recommend compatibility studies

Acidization Operations

- pH affects emulsion stability
- Severe emulsion upsets after acid stimulation
- Occurs due to solid precipitates mainly asphaltenes
- Form very stable and tight emulsion and can kill a well
- Proper design of acid treatment is necessary to avoid emulsion upsets



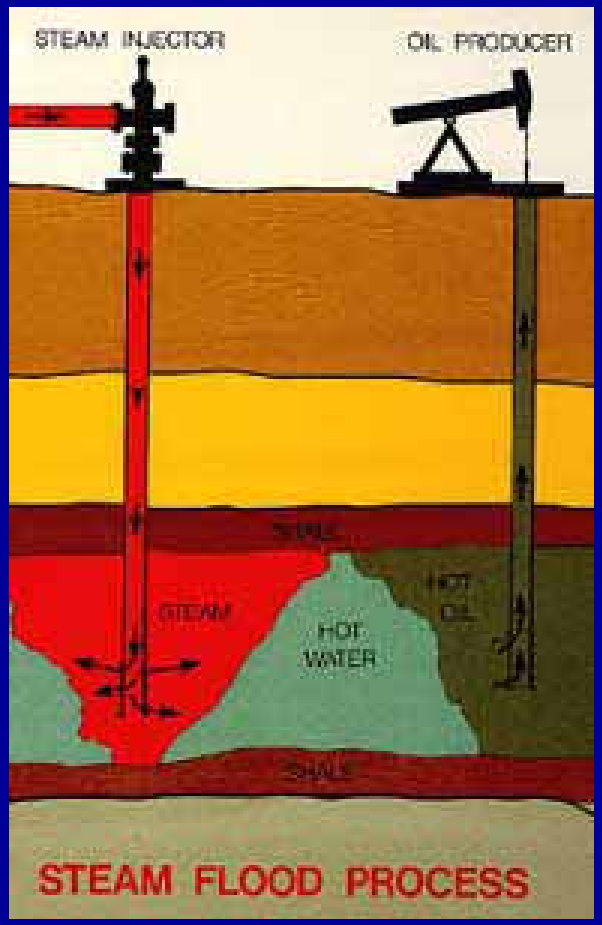


Effect of pH on emulsion stability

EOR/IOR Operations

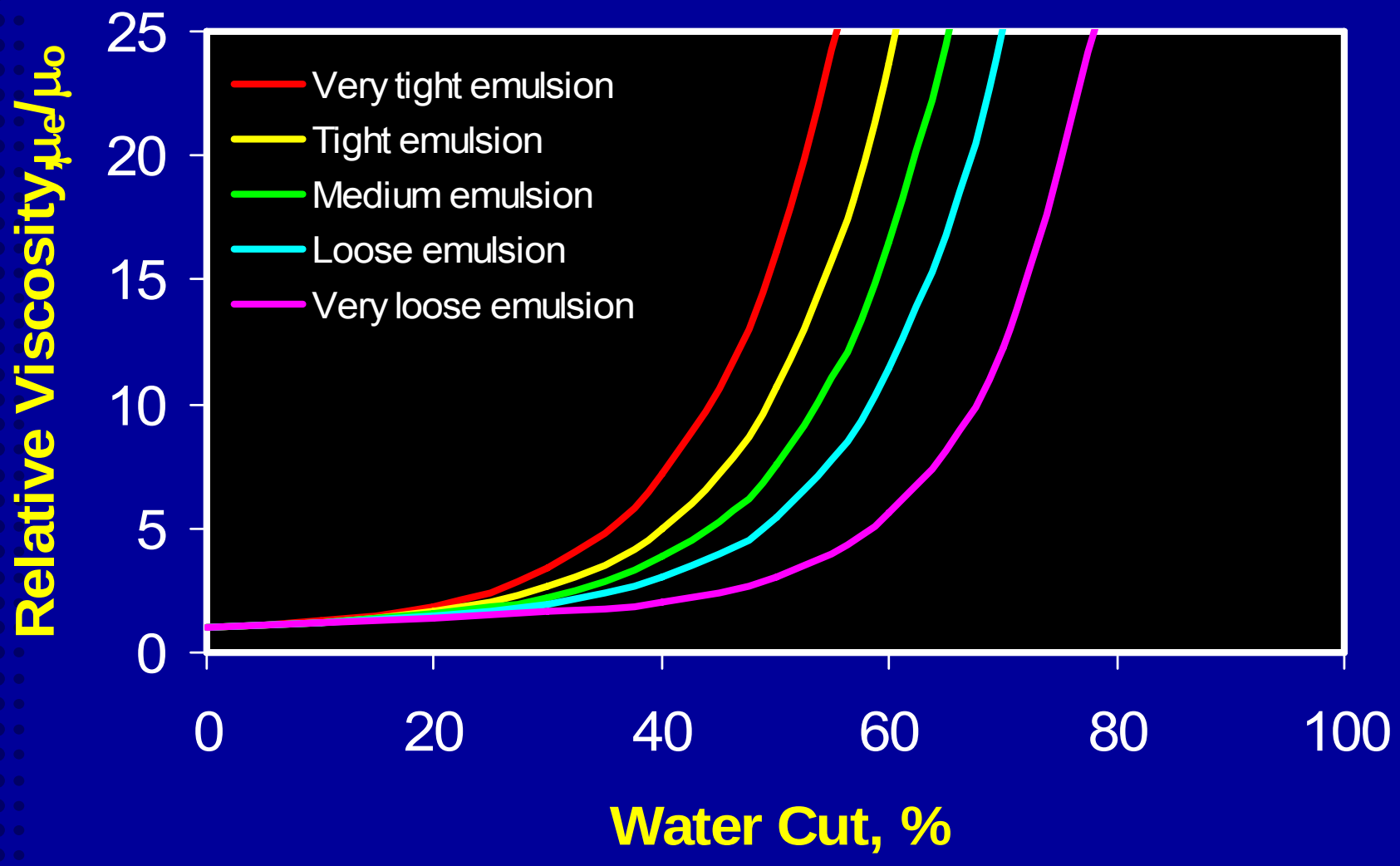
- Chemical (ASP) method prone to emulsion problems
- CO2 injection → asphaltene precipitation → tight emulsions
- Microbial → sludges
- Thermal → heavy oil → solid stabilized emulsions

- Much higher demulsifier treatment costs



Production Aspects of Emulsions

- High viscosities of emulsions → flow assurance issues
- Productivity declines
- Oil-water separation concerns
- Facilities operational concerns
- Off-spec crude and disposal water



Viscosity of emulsions

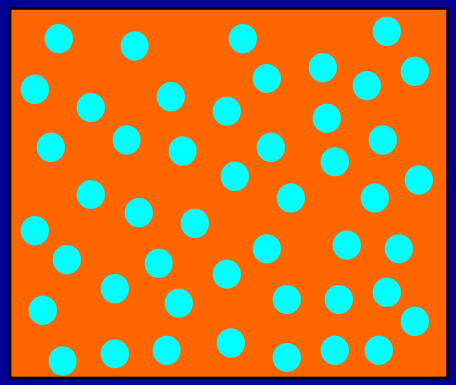
Demulsification

- Breaking of a crude oil emulsion into oil and water phases
- From a process point of view:
  - Rate or speed of separation
  - Residual water in oil
  - Residual oil in water
- Oil should not contain more that 0.2% BS&W and 10 PTB salt
- Water should contain less than 100 ppm of oil

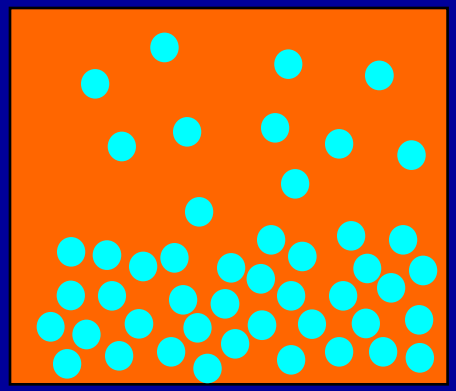
Mechanisms Involved in Demulsification

- Two step process
  - Flocculation (or aggregation, or agglomeration or coagulation)
  - Coalescence
- Either of these steps can be the rate determining step

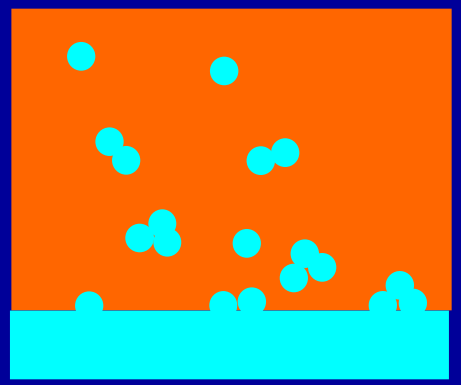
Emulsion



Flocculation



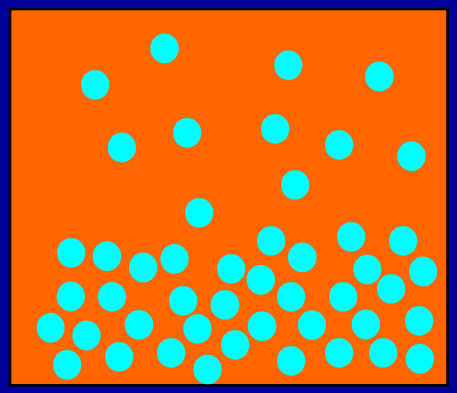
Coalescence



Flocculation

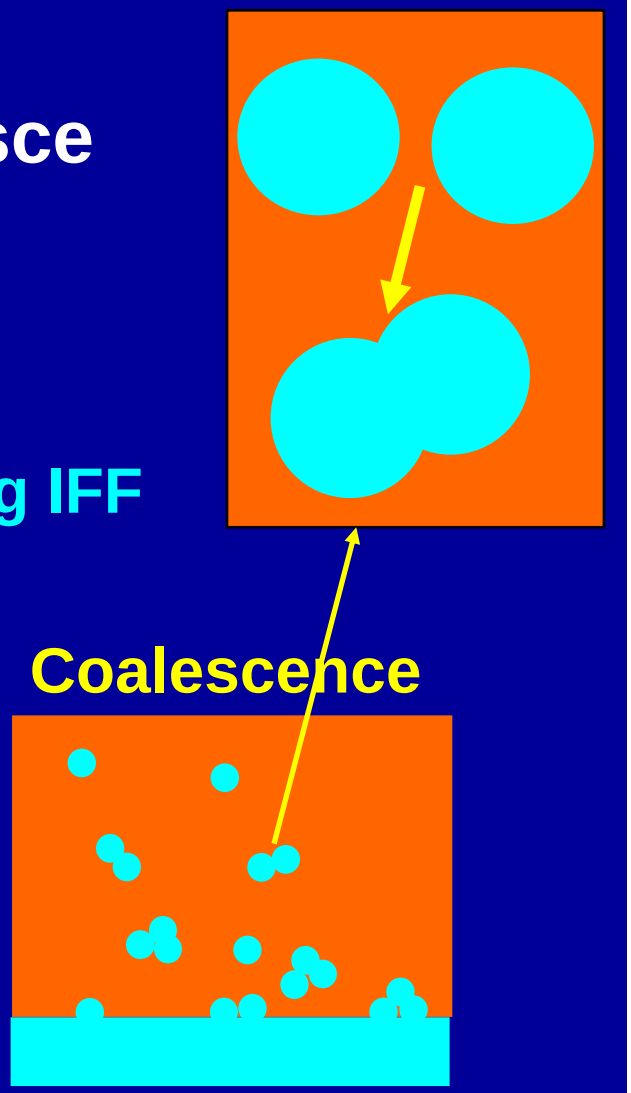
- Droplets clump together forming "floccs"
- May not lose their identity
- Rate of flocculation depends on
  - Watercut of the emulsion
  - Temperature
  - Viscosity of the oil
  - Density difference
  - Electrostatic field

Flocculation



Coalescence

- Water droplets fuse or coalesce to form a larger drop
- Coalescence is enhanced by
  - High rate of flocculation
  - Absence of mechanically strong IFF
  - High interfacial tensions
  - High watercuts
  - Low oil viscosity
  - Low interfacial viscosity
  - Chemical demulsifiers
  - Higher temperatures



Methods of Emulsion Breaking

- Any or combination of:
  - Thermal…providing heat
  - Mechanical…residence time
  - Electrical…electrostatic grids
  - Chemical…adding demulsifiers
- Demulsification methods very application specific
- Dynamic process: emulsions and conditions change with time

Emulsion Video

Emulsion Treatment Program

- Very site specific
- Experience and engineering judgment
- Data needed:
  - Laboratory studies
  - Data from nearby wells/fields
  - Field trials
- Balance between chemical, thermal, mechanical and electrical
- Optimization

Emulsion Treatment Program
Questions?

- Are we using the best demulsifier?
- What is the retention time?
- What type of emulsion?
- What is the water cut?
- System heated, or can it be?
- Range of operating conditions?
- Feed constant or changing?

Emulsion Treatment Program
Guidelines

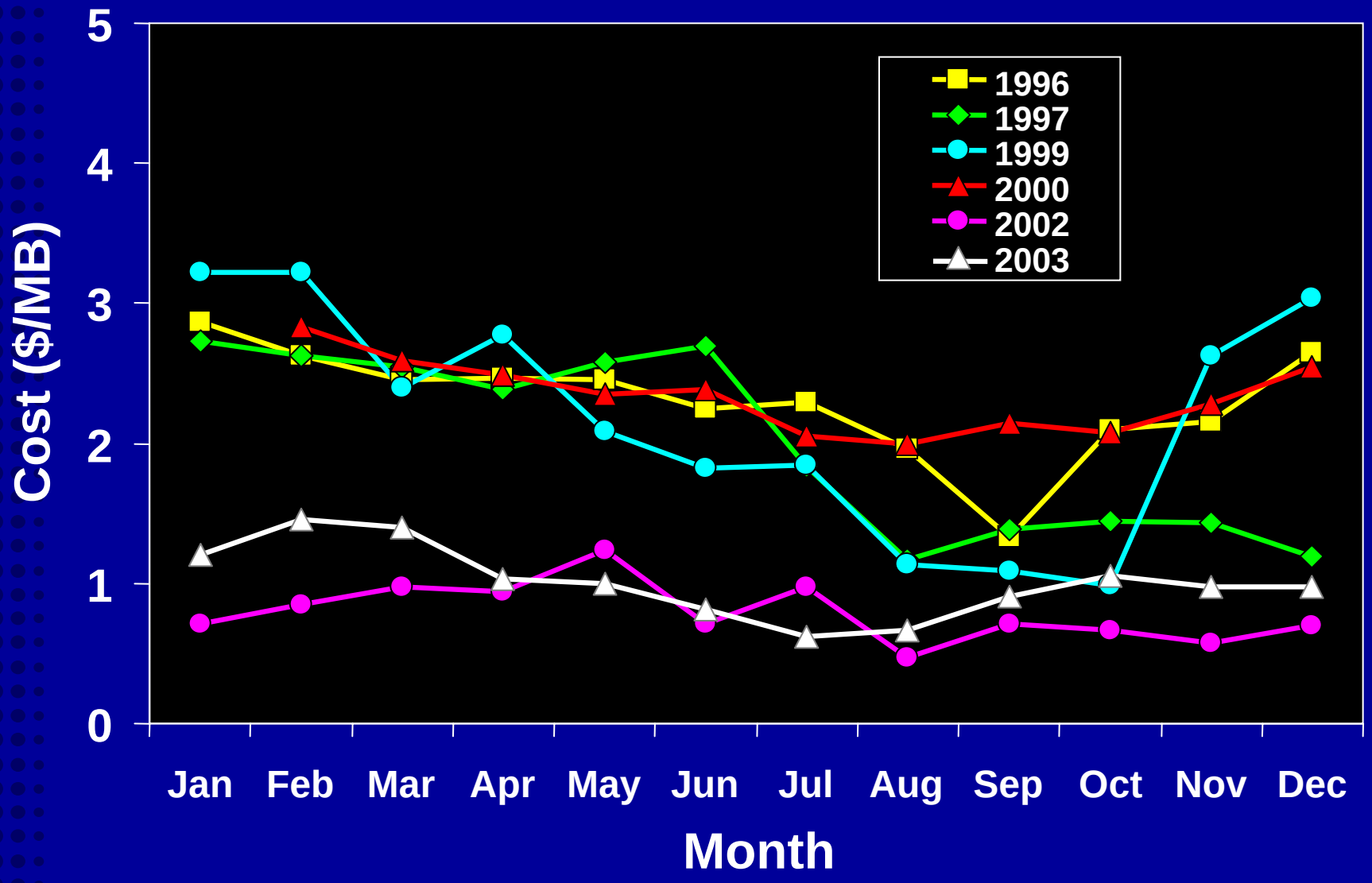
- Each production stream unique
- Laboratory tests with actual samples
- Incorporate flexibility during design
- Planning early
- Pilot and field trials
- Re-engineering and retrofitting
- Record data for diagnosis
- Review periodically

Emulsion Treatment Program
Prevention

- Fine solids management
  - Scales: Inhibit scale formation
  - Asphaltenes: management, dispersants
  - Corrosion products: inhibitors
- Acidization…review field performance
- Commingling of crudes…compatibility
- Mixing and shear…reduce, optimize
- Check compatibility of chemicals

Emulsion Treatment Program
Demulsifier Selection & Optimization

- Bottle tests…representative samples
- Field testing with promising demulsifiers
- Proper demulsifier mixing
- Demulsifier overdosing
- Understanding the causes of tightness
- Evaluating the process
- Maintaining a database
- Demulsifier usage
  - Less than 5 ppm to over 200 ppm
  - Generally between 10 to 50 ppm



Demulsifier costs at a separation plant

Recommendations

- Diagnose…your emulsions and your hardware
- Retrofit…your vessels…after economic analysis
- Perform…field trials…periodically
- Monitor…performance
- Reduce…shear and fine solids…scales, asphaltenes, clays
- Maintain…records
- Proactive…in using new technology…

One thing to remember…

Crude Oil Emulsions:

Society of Petroleum Engineers
Petroleum Engineering Handbook
Volume 1, Chapter 12

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