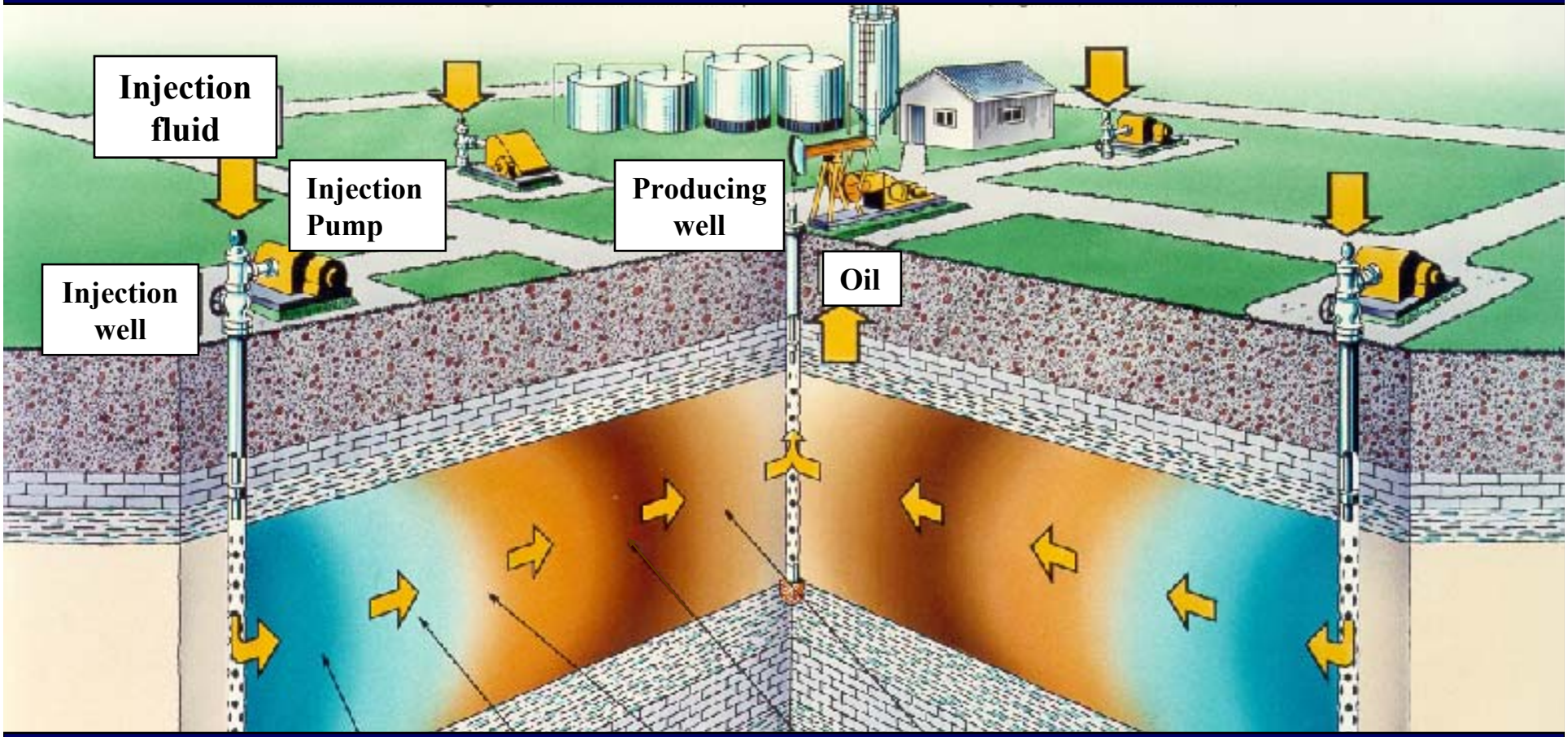
SURFACTANT INJECTION PROJECTS - FIELD CASES

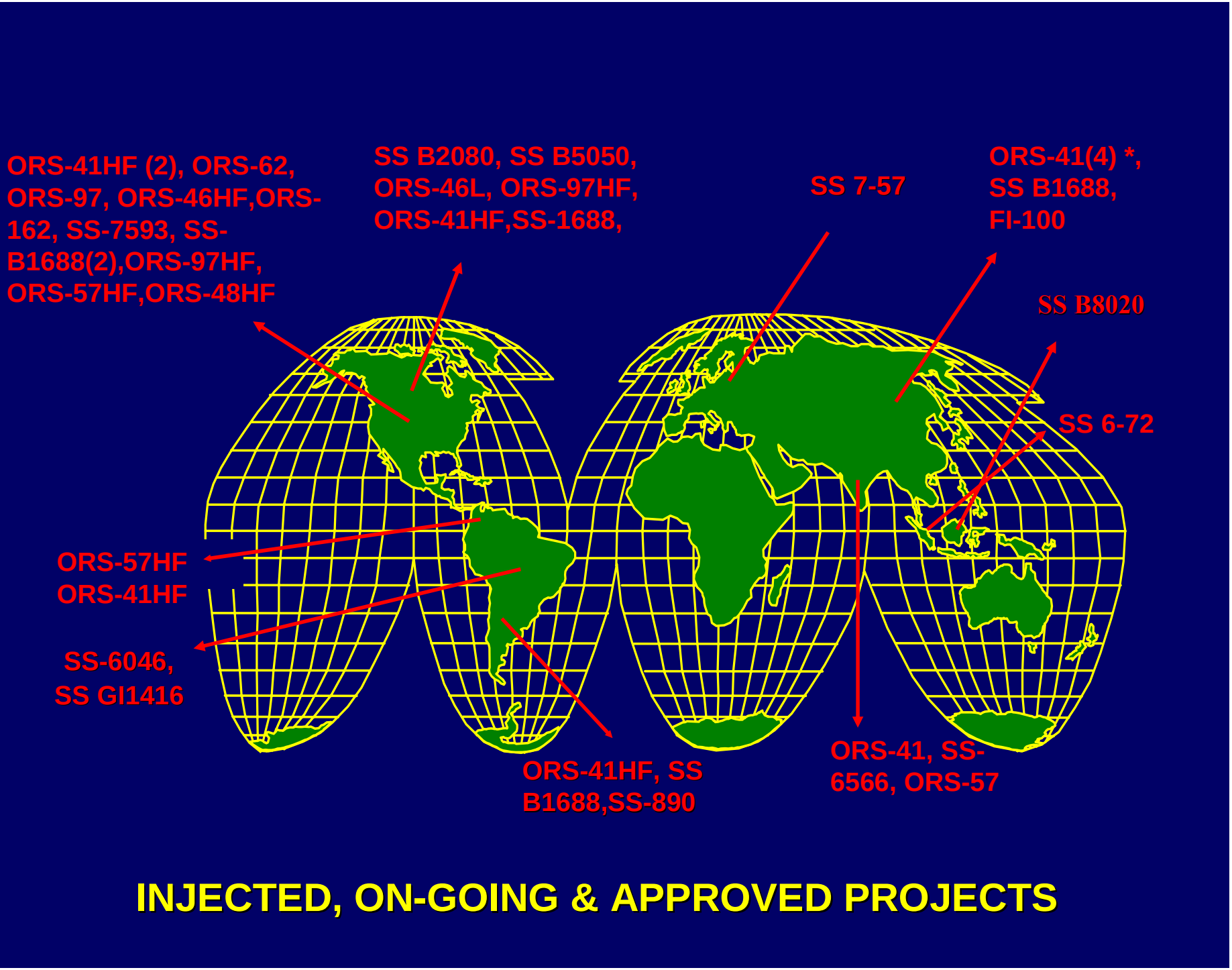
Christie Lee / Paul Berger
Oil Chem Technologies, Inc.

OIL CHEM TECHNOLOGIES

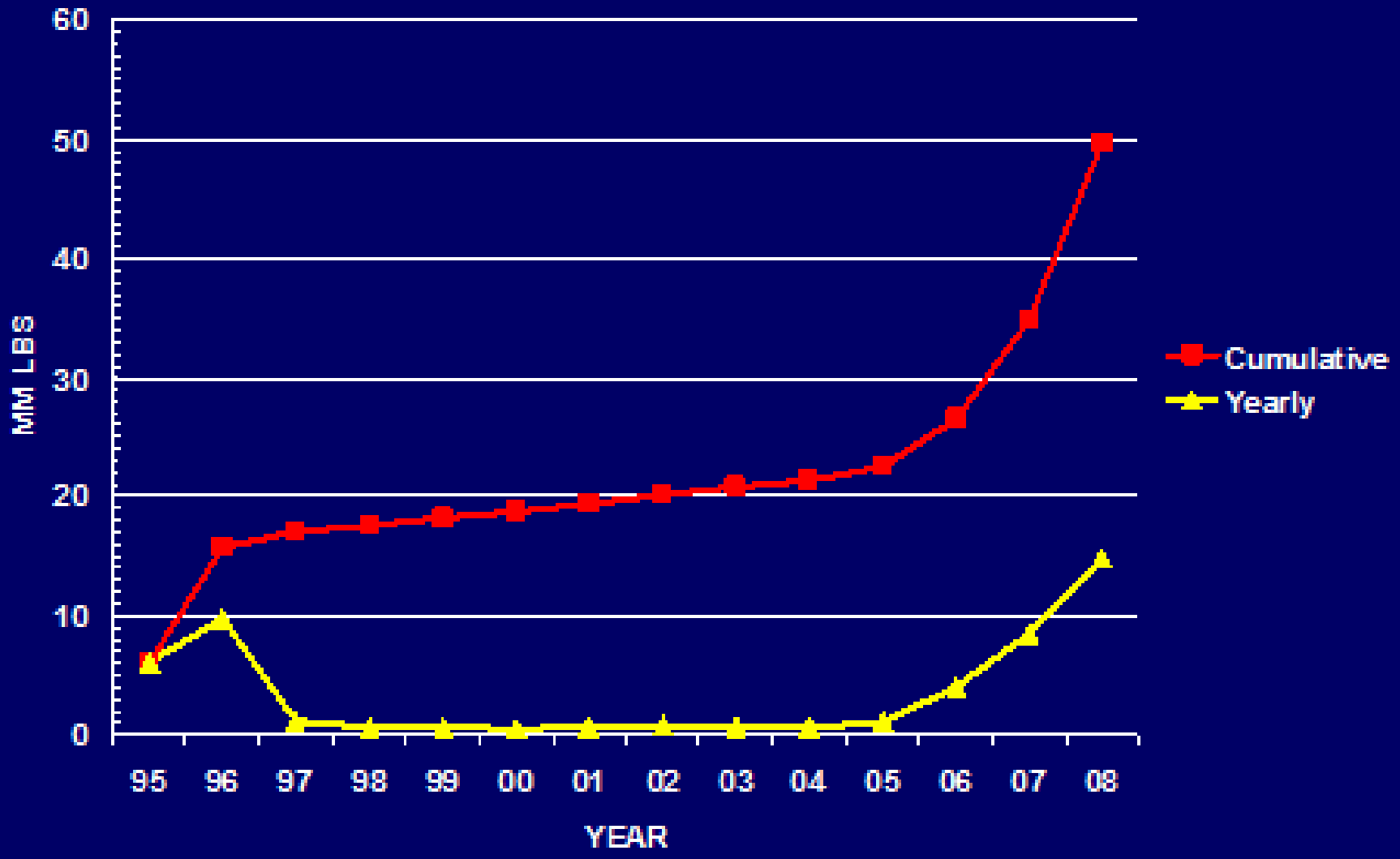
- Research and develop surfactants exclusively for EOR since 1995
- Worked closely with the operators to custom design and optimize surfactants/processes based on the need of each project
- Field proven products and processes – more than 50 million pounds of surfactants successfully injected all over the world.
- Continuously improve and develop products / processes based on field results and aimed for the future
- No. 6 fastest growing company in energy in USA

ARE THERE CHEMICAL EOR PROJECTS?




ORS-41HF (2), ORS-62, ORS-97, ORS-46HF,ORS-162, SS-7593, SS-B1688(2),ORS-97HF, ORS-57HF,ORS-48HF
SS B2080, SS B5050, ORS-46L, ORS-97HF, ORS-41HF,SS-1688,
SS 7-57
ORS-41(4) *, SS B1688, FI-100
SS B8020
SS 6-72
ORS-57HF
ORS-41HF
SS-6046, SS GI1416
ORS-41HF, SS B1688,SS-890
ORS-41, SS-6566, ORS-57
INJECTED, ON-GOING & APPROVED PROJECTS

EOR SURFACTANTS SALES



PRESENTATION OUTLINE

- Chemical EOR – Past
- Chemical EOR – Present
  - Oil Chem field experience to share
- Chemical EOR – Problems/solution
- Conclusions

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EOR IN EARLY 1980's

Field	Loudon	Big Muddy	Robinson
Company	Exxon, 1983	Conoco, 1981	Marathon, 1983
Surfactant Conc.	2 surfactants 2.3%	3%	10%
Pore Volume	0.3	0.1	0.3
Co-solvent	- - -	5% iso-butanol	0.6% hexanol
Salt	96% connate salinity	0.6%	2.5%
Polymer	0.1% xanthan	0.22% polyacrylamide	None
Recovery	68% RIOP	15% RIOP	19-21% ROIP

EOR BY CHEMICAL FLOOD

Never <u>really</u> took off in the past - Reasons?

- Sensitivity to oil price
- Large up-front investment
- Unpredictable return on investment
- High surfactant concentration
- Salinity optimization required
- Optimum salinity shift in the formation
- Potential emulsion block
- Economic feasibility

However,

- **Extensive lab evaluations support the feasibility of chemical flooding**
- **Field data proves chemical flooding is an effective way to recover residual oil**
- **New chemicals and processes open the door for new opportunities**

COST OF CHEMICALS

	1980 Micellar	2008 (Oil Chem's surfactant /process)
Polymer	$3-4/lb	$1 – $1.8/lb
Surfactant[1]	$0.40-$0.60/lb	$0.80-$1.5/lb
Alkali[2]	$0.12/lb	$0.30 – $0.60/lb
Crude Oil	~ $12/bbl	$60-$140/bbl
Incr. Cost/bbl	$8 - > $15	$2 - $10

[1] Surfactant concentration has been reduced by 10 times as compared to 1980's

[2] Alkali has been reduced or in some cases is not needed at all

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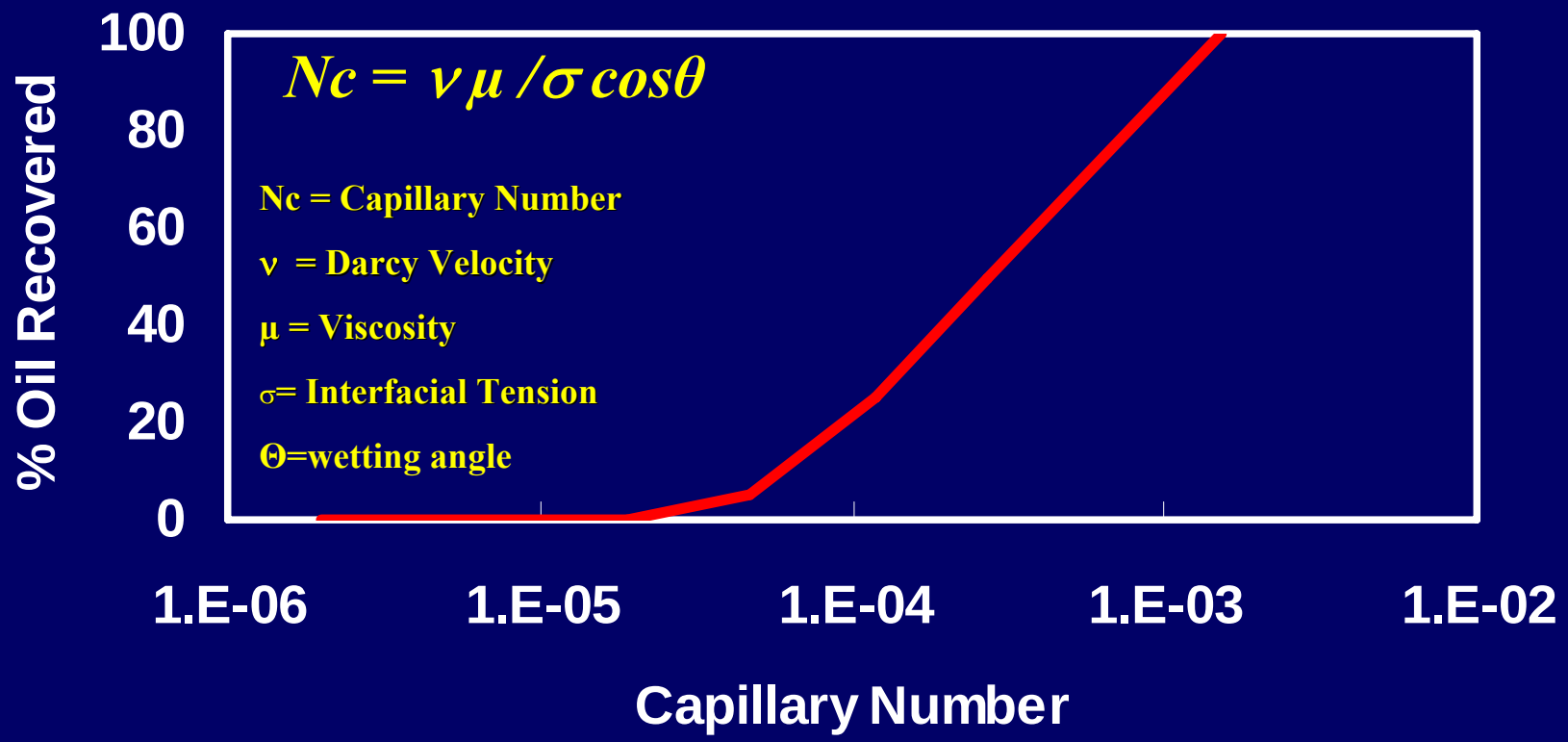
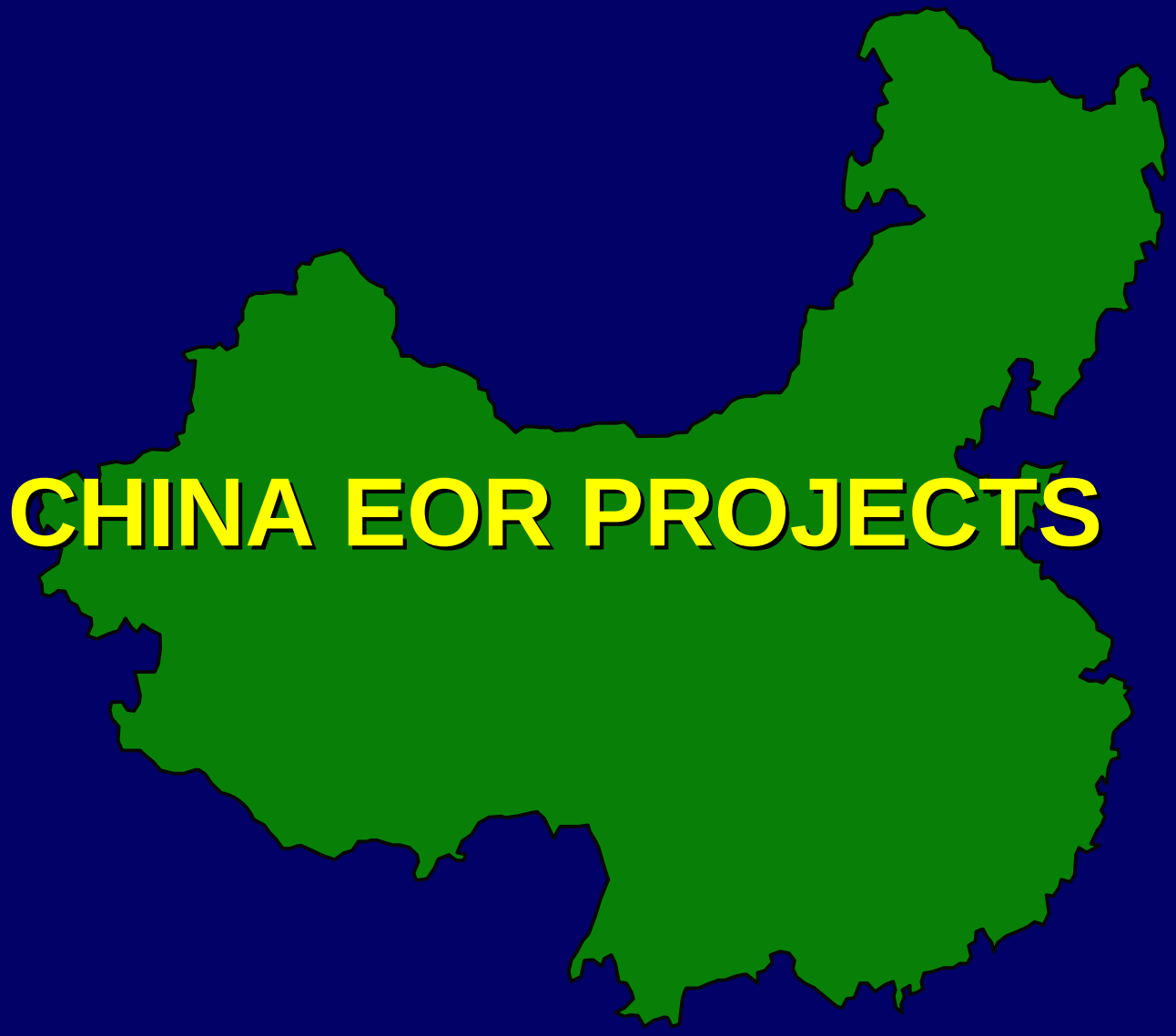
RELATIONSHIP BETWEEN CAPILLARY NUMBER AND OIL RECOVERY



Chatzis and Morrow, SPEJ, (1994) 561.

CHINA EOR PROJECTS



DAQING ASP PROJECT

Over 100 surfactants were evaluated in the lab during 1992-94 including:

- ORS-41
- Petroleum Sulfonates
- Carboxylates
- Lignin Sulfonate/Petroleum Sulfonates
- Microbiological

1995 - INITIAL FIELD EVALUATION

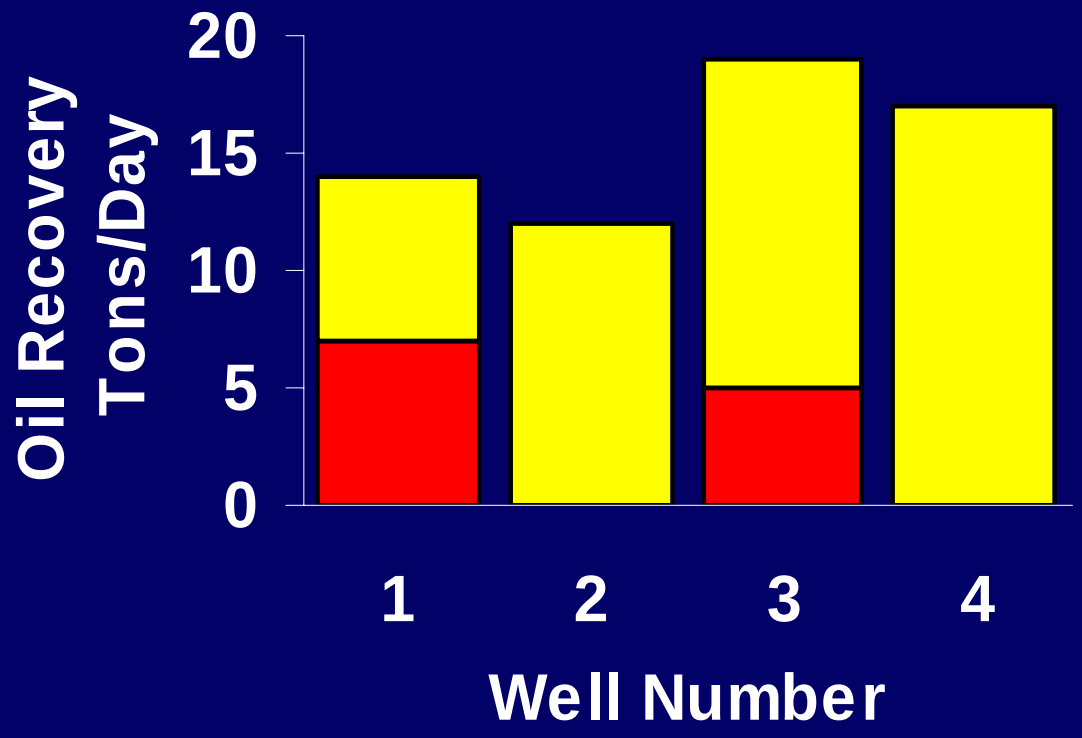
- Daqing No.4 Field - Oil Chem Technologies' ORS-41
- Daqing No.1 Field – another US company's Petroleum Sulfonate

1996-1998: ENLARGED FIELD EVALUATION

ORS-41 was chosen as the only surfactant for enlarged field flood. More than 7000 MT of the ORS-41 was injected in several field blocks and this confirmed the viability of the ASP process. Cost was $3.74/bbl of incremental oil

SPE 36748, 57288, 71061, 71491, 71492

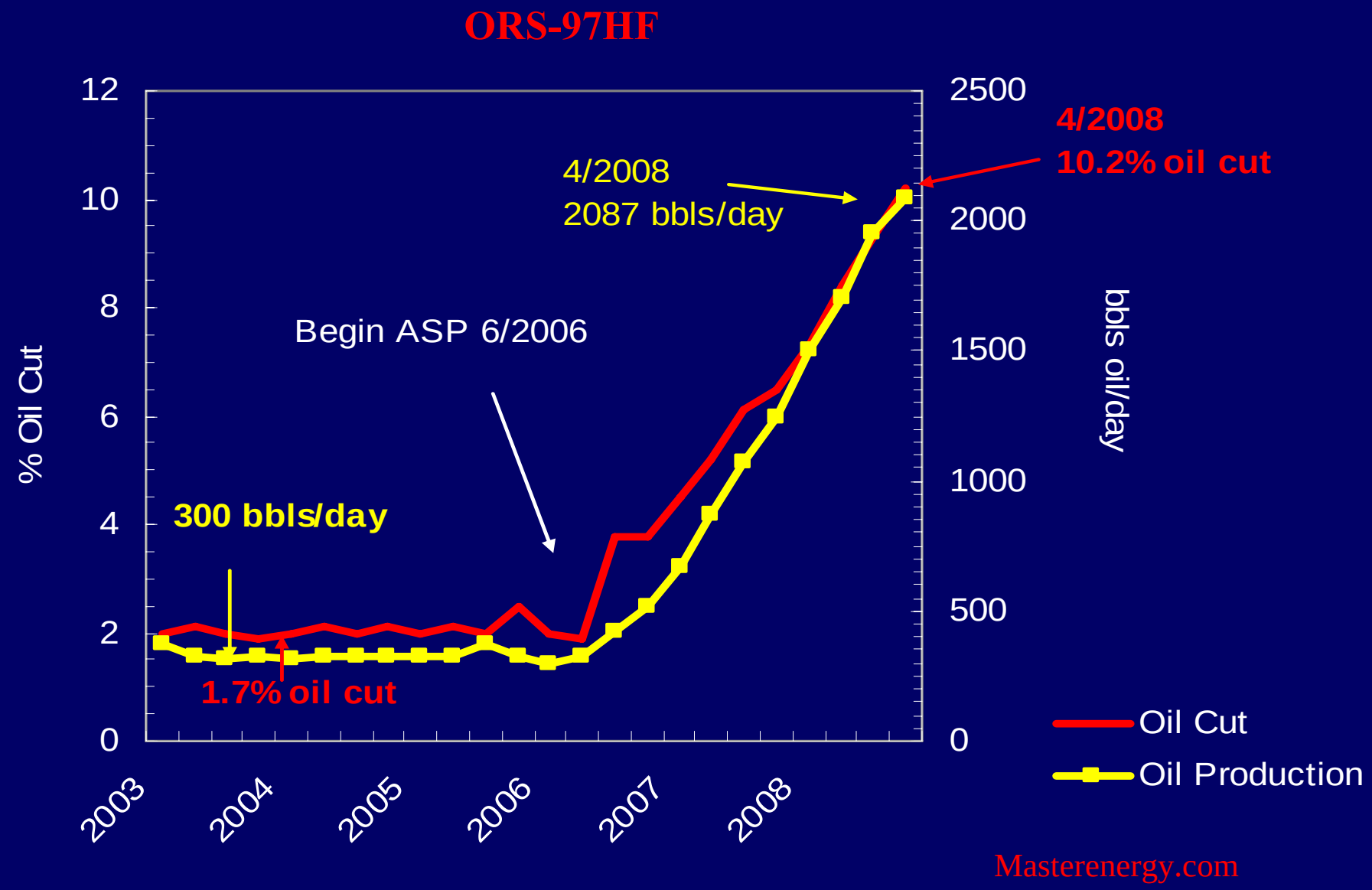
ASP PROJECT USING ORS-41™ IN DAQING, CHINA



SPE 36748 (1996)

CANADA EOR PROJECTS

HUSKY TABER ASP PROJECT



Masterenergy.com

CANADA SP PROJECT

- Heavy oil field
- Under polymer flood
- Added 0.1% surfactant with polymer in November, 2006
- ~ 3 months later, the water cut reduced from 97% to 58%


USA EOR PROJECTS

REX ENERGY ASP PROJECTS

- The Lawrence Field - estimated one billion barrels of original oil-in-place
- The Cypress (Mississippian) and the Bridgeport (Pennsylvanian) sandstones are the major producing horizons in the field.
- Produced more than 400 million barrels (40%) of oil since its discovery in 1906.

REX ENERGY ASP PROJECT

- During 2007, core floods resulted in an oil recovery rate of 21% OOIP for Cypress, and 24% OOIP for Bridgeport
- In 2006 and 2007, 18 wells drilled in two pilot areas
- 2008- pilot ASP injection started
- Bridgeport Sandstone is demonstrating an initial response to the ASP chemical injection as indicated by an increase in the oil cut ratio in the pilot wells

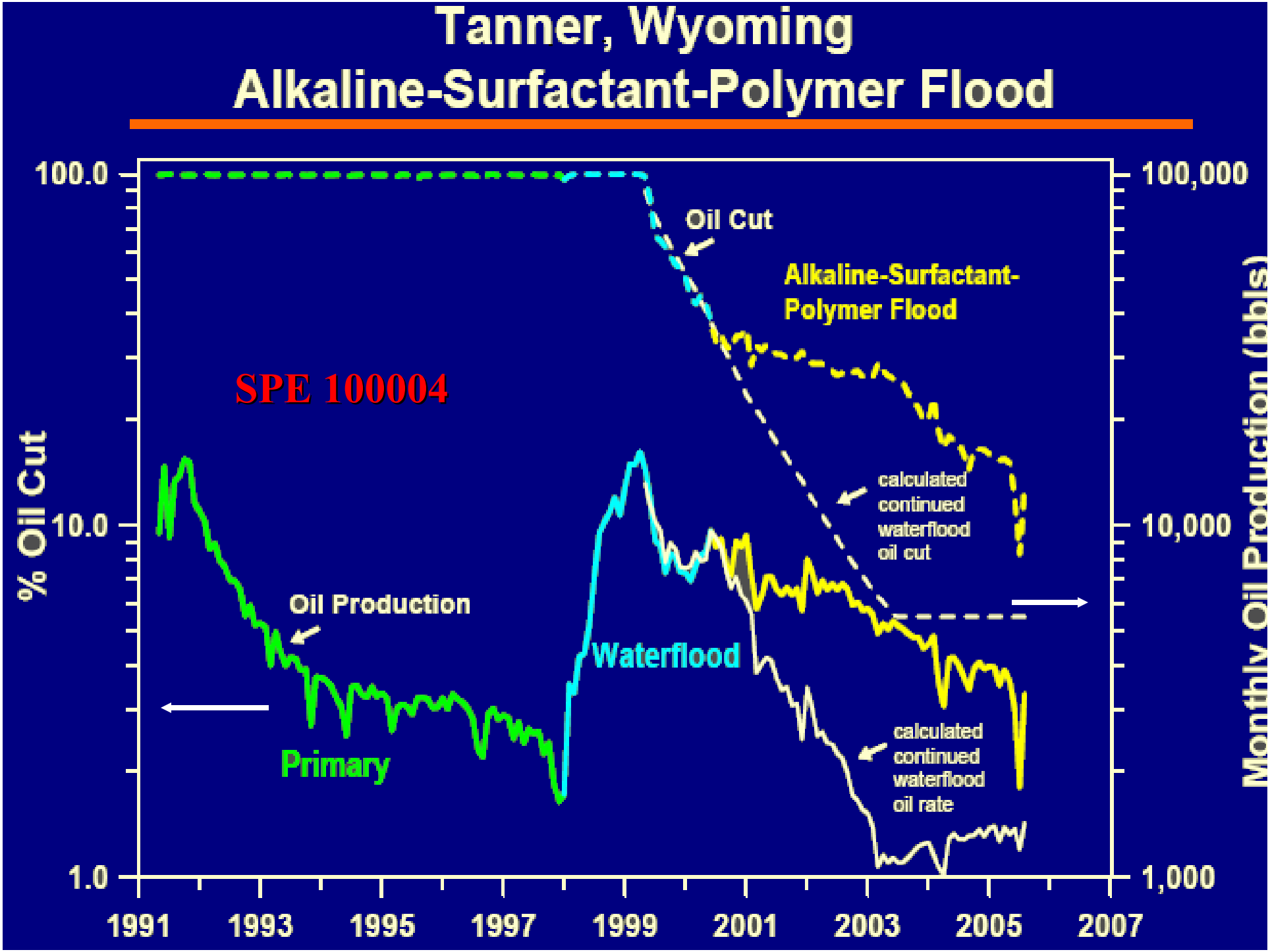
REX ENERGY ASP PROJECTS

- Cypress Sandstone ASP pilot is continuing to demonstrate a response to the ASP chemical injection
- Plans to implement a broad ASP flood program within the 13,500 net acres of the field commencing in 2009 based on successful pilot runs in either field.

TANNER FIELD, WYOMING ASP PROJECT

- Crude oil : 21^{o} API
- Bottom Hole Temperature: 175^{o}F
- Depth: 8915 ft
- Thickness: 25 ft
- Porosity: 20%
- Permeability: 200 mD

SPE 100004


Tanner, Wyoming
Alkaline-Surfactant-Polymer Flood
SPE 100004
100.0
10.0
1.0
% Oil Cut
100,000
10,000
1,000
Monthly Oil Production (bbls)
1991
1993
1995
1997
1999
2001
2003
2005
2007
Oil Cut
Alkaline-Surfactant-Polymer Flood
calculated continued waterflood oil cut
Oil Production
Waterflood
Primary
calculated continued waterflood oil rate

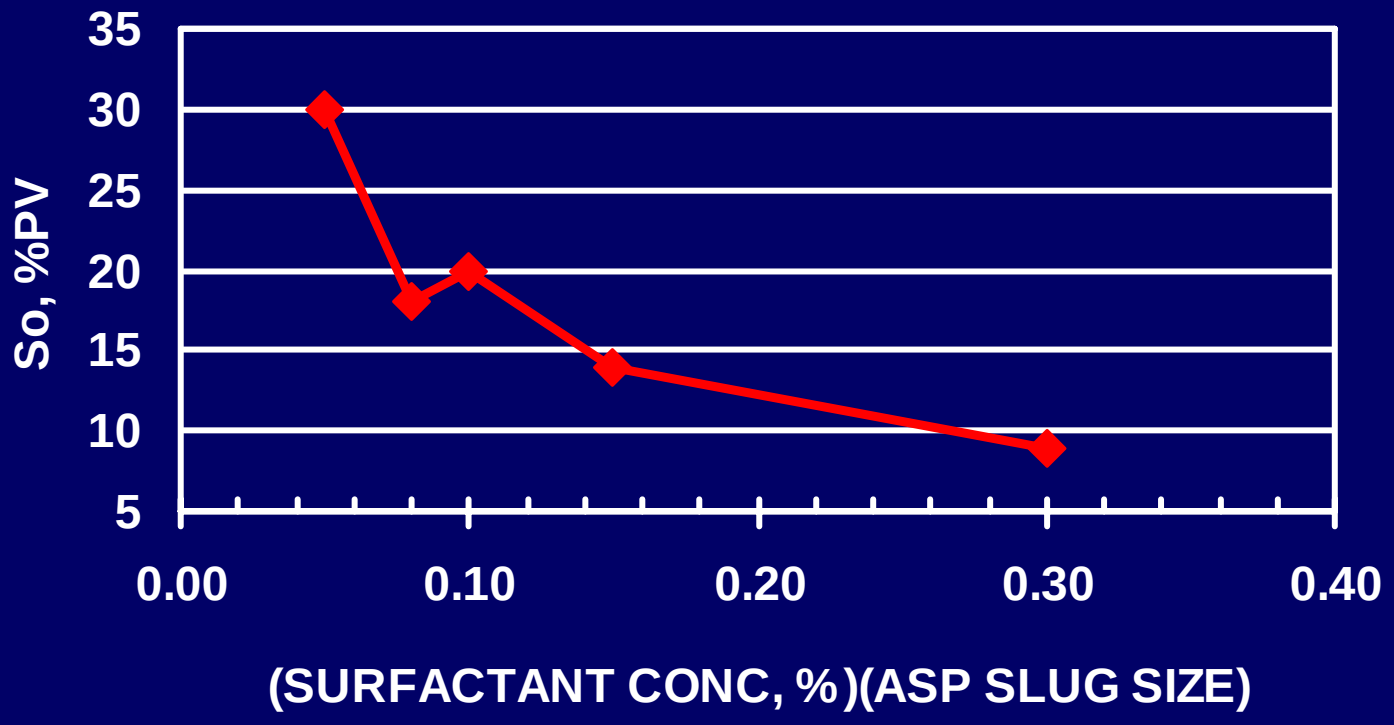
SHO-VEL-TUM FIELD
ASP PROJECT

- On production > 40 yrs, extensive water flood, produced 4 bbl/day
- ASP started on 2/98, using Na_2CO_3 and ORS-62
- Total incremental oil > 10,444 bbl in 1.3 years

  (A 500% increase in production)

SPE 84904

OIL SATURATION AFTER ASP INJECTION



SPE 84904

BIG SINKING FIELD, KY

Surfactant Assisted Water Flood

- 100 Million barrels oil-in-place
- Depth 1150 feet
- BHT 30°C
- Thickness 25 feet
- Permeability 45 mD
- High water cuts and very low injectivity

SPE 89384

BIG SINKING, KENTUCKY

Surfactant Assisted Water Flood

Chemical injected:

0.8% NaOH + 0.1% ORS-162HF

Problems overcome:

- **IFT lowered from 23.6 to 0.001 mN/m**
- **Poor water injectivity**
- **High water cuts**
- **220% increase in injectivity**
- **Large field trial scheduled to begin in 12/2007**

SPE 89384

SOUTH AMERICA PROJECTS

ARGENTINA SP PROJECT

- SP injection using SS-1688, injection started in September, 2007
- Initial surfactant Injection – 1000 ppm, tapered down to 250 ppm after 6 months
- No alkali, no salinity optimization, no co-solvent is used
- Oil production Increased ~50% and ~80% after 4 months for 2 blocks

SOUTHEAST ASIA

OFFSHORE ALKALINE SURFACTANT (AS) PROJECT

- Sea water is softened on the platform
- Single well test successfully performed using SS 6-72LV injected with NaOH
- Pilot project will proceed

SPE 100943, 109033


Phnom Penh
Ho Chi Minh City
Long Xuyen
Gulf of Thailand
Sea
SPRATLY ISLANDS
ANGSI FIELD
Phuket
Songkhla
George Town
Ipoh
Bandar Seri Begawan
BRUNEI
Kota Kina
Medan
Kuala Lumpur
KEPULAUAN NATUNA
MALAYSIA
Melaka
Kuching
Borneo
Singapore
SINGAPORE
Pontianak
Samarinda
Padang
Sumatra
PEGUNUNGAN BARISAN
KEPULAUAN MENTAWAI
Palembang
Banjarmasin
Tanjungkarang
Java Sea
Makass

SPE 109033

PROJECTS SUMMARY

- Only selected, published data has been presented to maintain the confidentiality of the producers
- More than 50 million pounds of Oil Chem's surfactants have been successfully injected
- Equivalent to ~ 143 million bbl of the injection fluid at 0.1% surfactant
- Processes included ASP, SP, S and heavy oil recovery

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EXPERIENCE GATHERED FROM THE FIELD PROJECTS

- Success
- Problems encountered
- Solutions
- Improvement

S. M. Faroug Ali, Univ. Of Calgary:

WHY EOR HAS NOT LIVED UP TO EXPECTION?

- Some of the oil recovery methods suffer from limitations not easily understood from unscaled lab experiments – field failures were the only way to understand them
- In many cases, reservoir description /heterogeneity is the problem
- Economics are the key to large scale application of even tested processes

CONDITIONS ENCOUNTERED AND SOLUTIONS

	Conditions	Solution
Handling & Logistics	high viscosity, multiple chemicals, extra surface equipment, shipping, storage, tax	
Salinity optimization	cost, poor polymer performance, corrosion	
Corrosion & Scale	alkali, NaCl, $CaCO_3$, $MgCO_3$, $NaSiO_4$	
Water quality	TDS, hardness	
Emulsion	emulsion block, water quality	
Adsorption	poor propagation	

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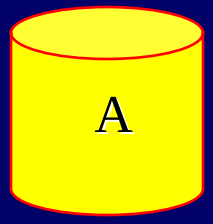
PROCESS COMPARISONS

Typical ASP vs Oil Chem ASP

Typical ASP Flood



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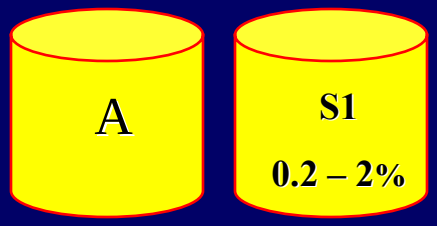

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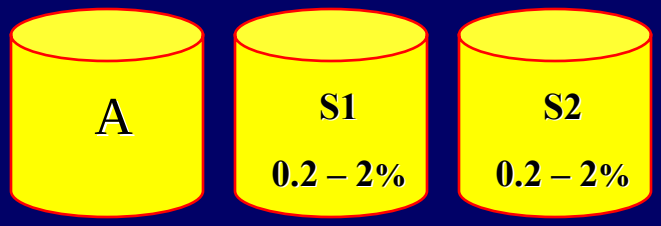

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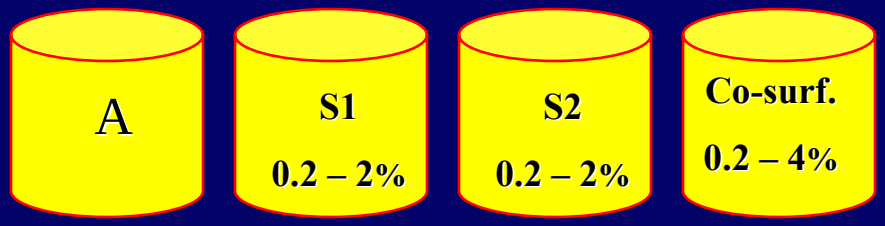

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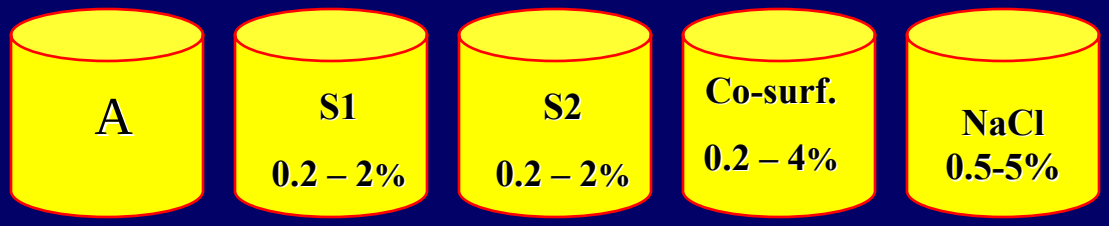

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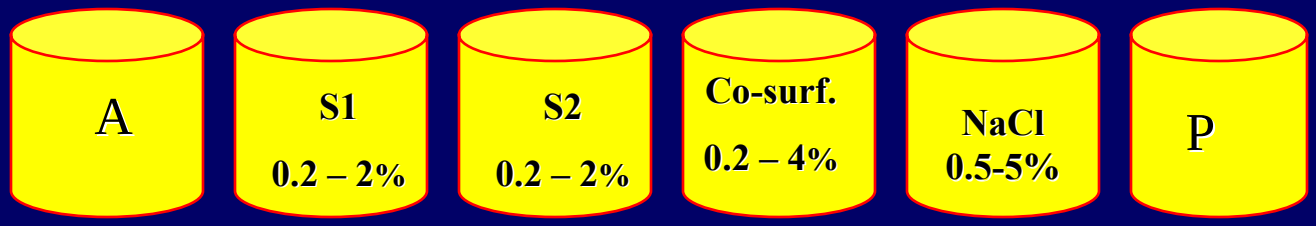

~ $10 - $30/bbl Incremental Oil

PROCESS COMPARISONS

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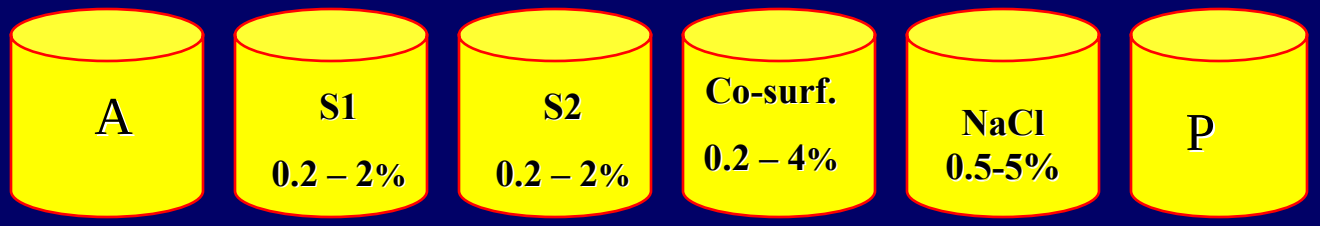
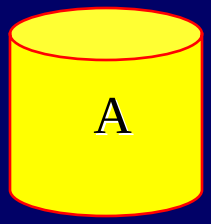
Typical ASP Flood



~ $8-20/bbl Incremental Oil

Oil Chem Typical ASP Flood



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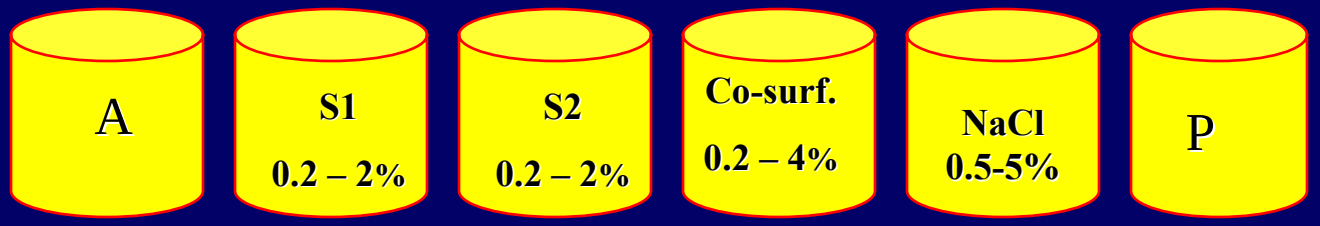

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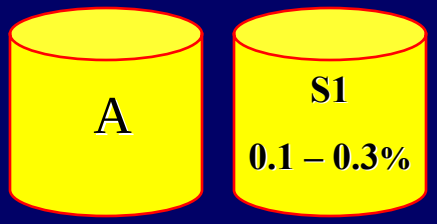

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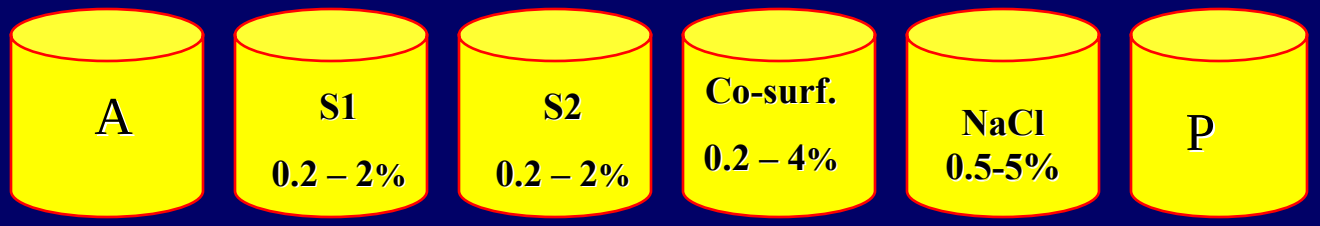

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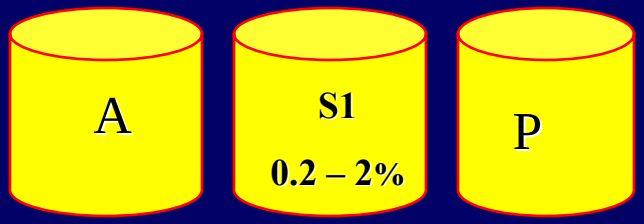

~ $4 - $10/bbl Incremental Oil

CONDITIONS ENCOUNTERED AND SOLUTIONS

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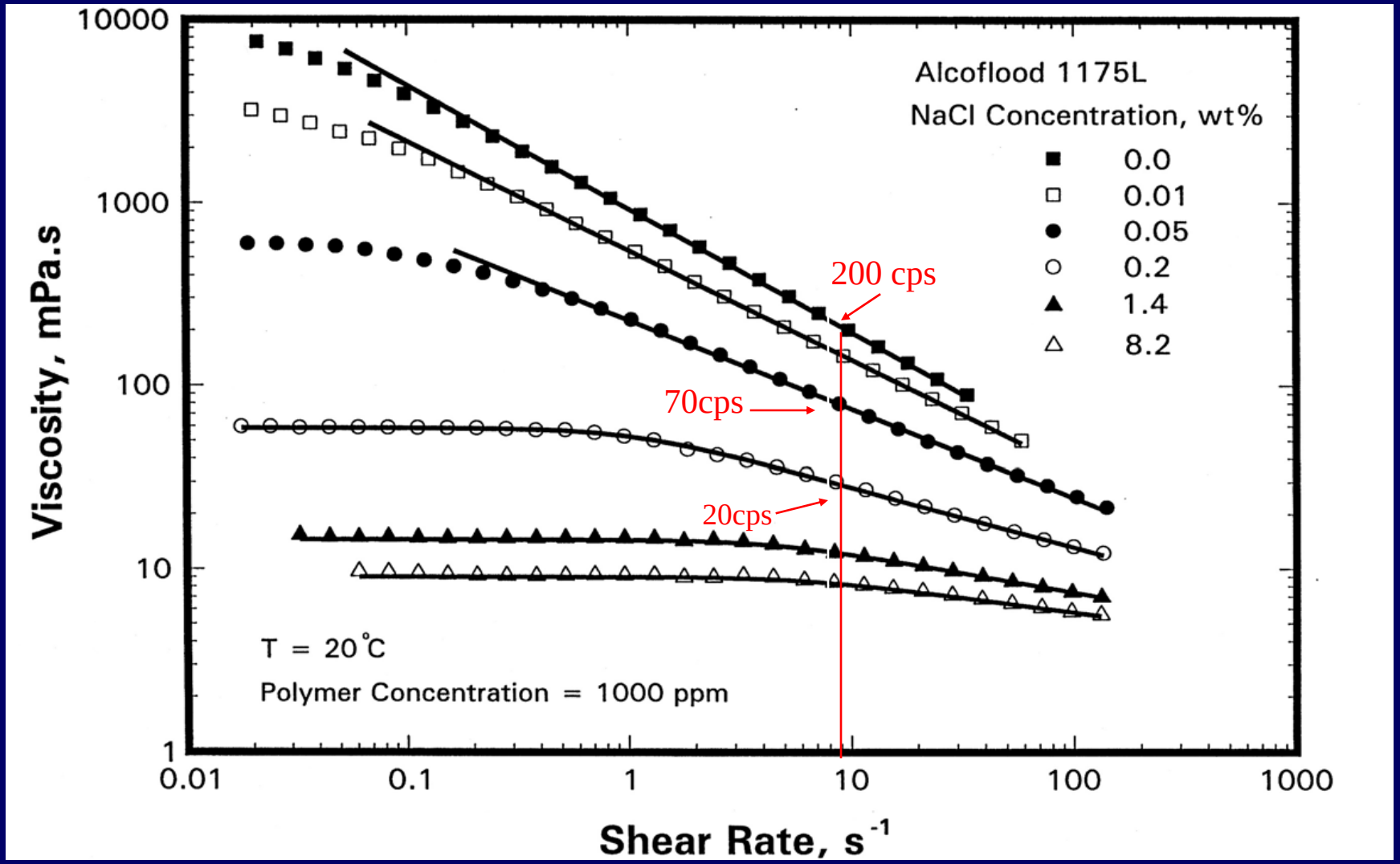
Handling & Logistics	high viscosity, multiple chemicals, extra surface equipment, shipping, storage, tax	proper formulation, minimize number of components, local manufacturing
Salinity optimization	Cost, poor polymer performance, corrosion	surfactants do not require salinity optimization
Corrosion & Scale	alkali, NaCl, $CaCO_3$, $MgCO_3$, $NaSiO_4$	
Water quality	TDS, hardness	
Emulsion	emulsion block, water quality	
Adsorption	poor propagation	

EFFECT OF SALT ON VISCOSITY



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Sample No.1
Na_2CO_3 in
Un-Softened Brine
Sample No. 2
Na_2CO_3 in
Softened Brine
Sample No. 3
Organic alkali in
Un-Softened Brine
Samples No. 4
Organic alkali in
Softened Brine

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Adsorption	poor propagation	low adsorption surfactant

SP FLOODS – ADVANTAGES / PROBLEMS

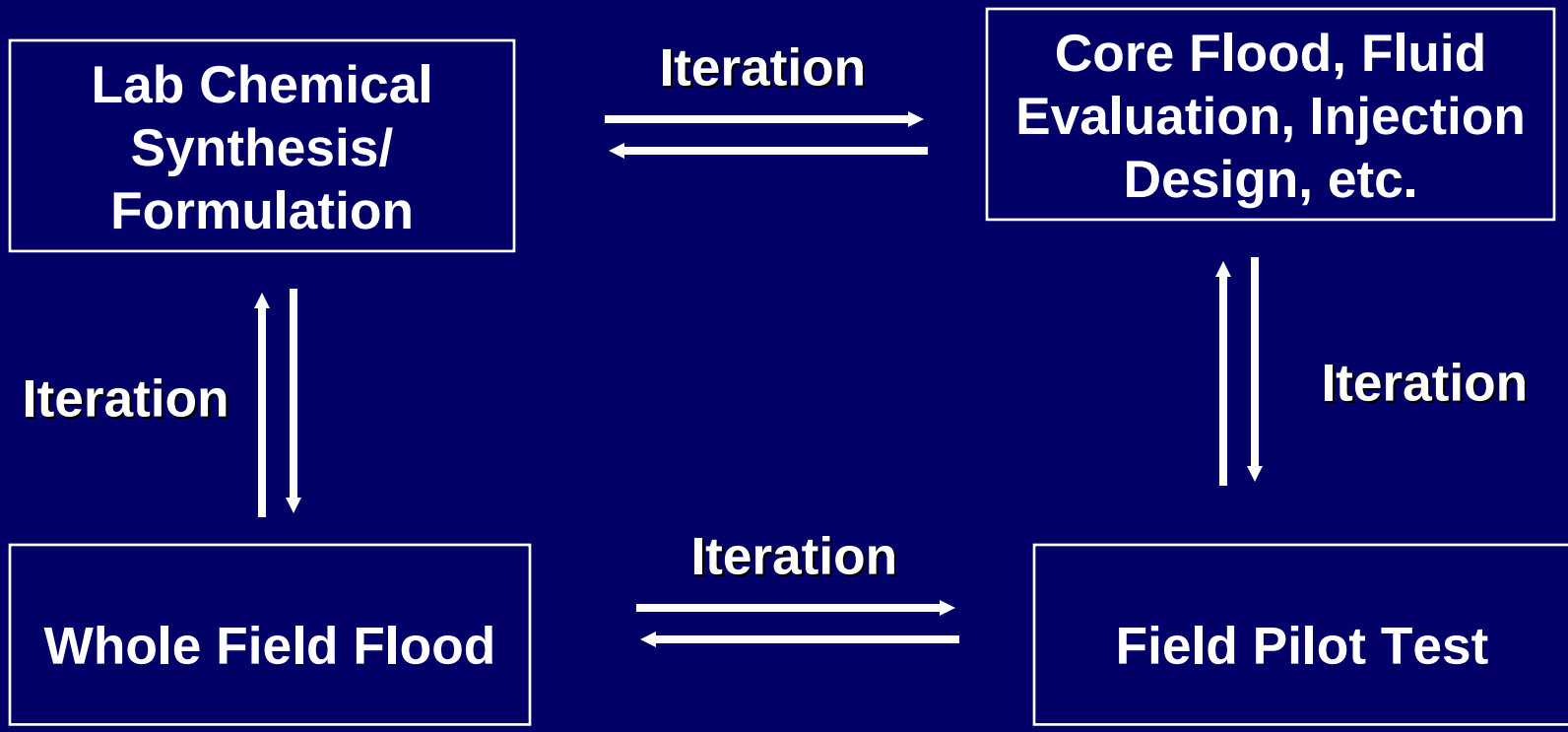
- Advantages
  - No alkali
  - No water softening
  - No salinity optimization
  - Better polymer performance
- Problems
  - High adsorption

LOW ADSORPTION SURFACTANTS (Patent Pending)

	Carbonates Avg., mg/g	Sandstone Avg., mg/g
Anionic Surfactants	1.0	1.0
Amphoteric Surfactants	1.0	> 3
New Low Adsorption Surfactants	0.1 – 0.8	0.1 – 0.8

No Salinity Optimization Is Required!

FIELD PROVEN CHEMICALS - ITERATION PROCESS



HEAVY OIL RECOVERY

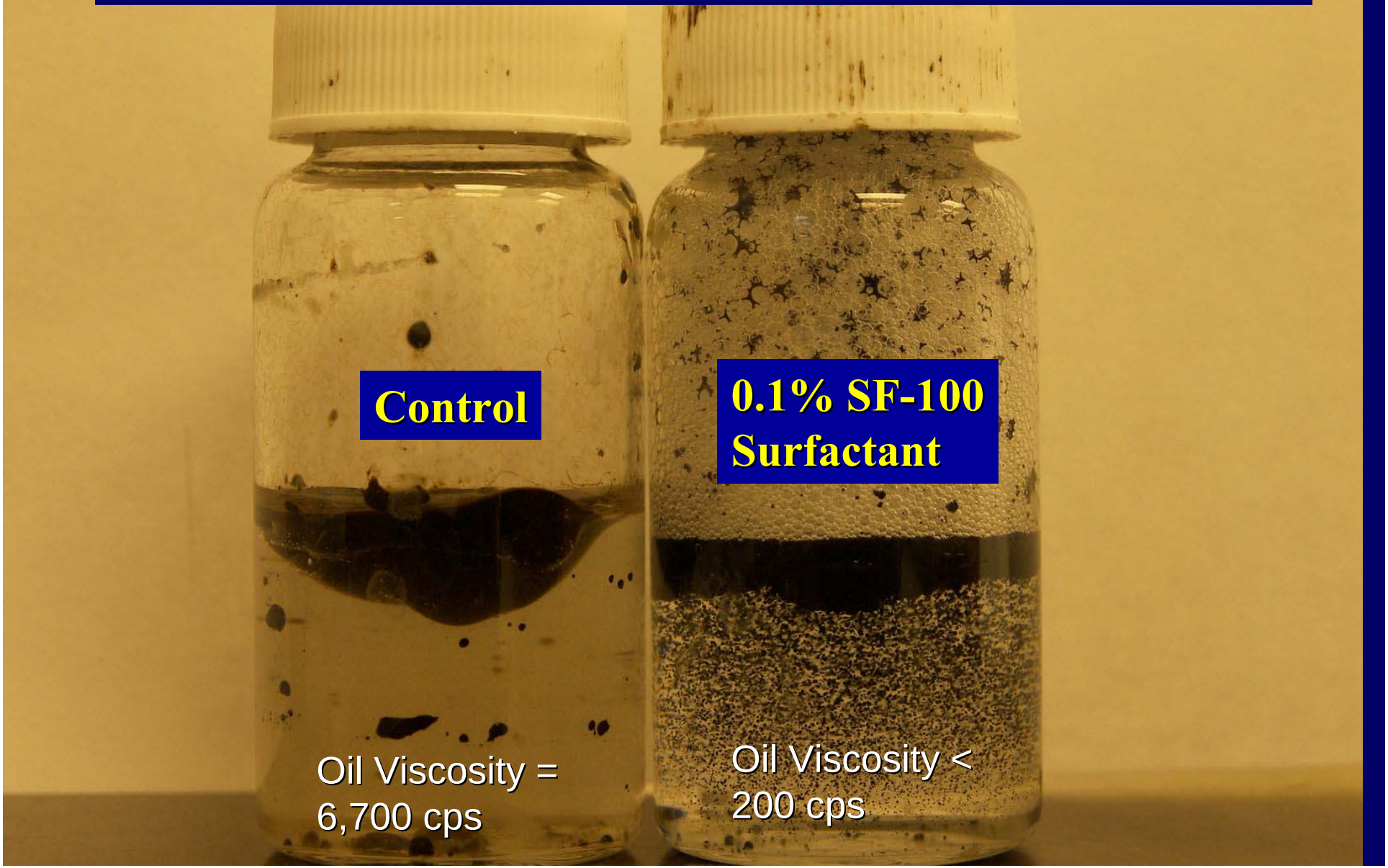
HEAVY OIL RECOVERY

- CO_2
- Steam
- SAGD

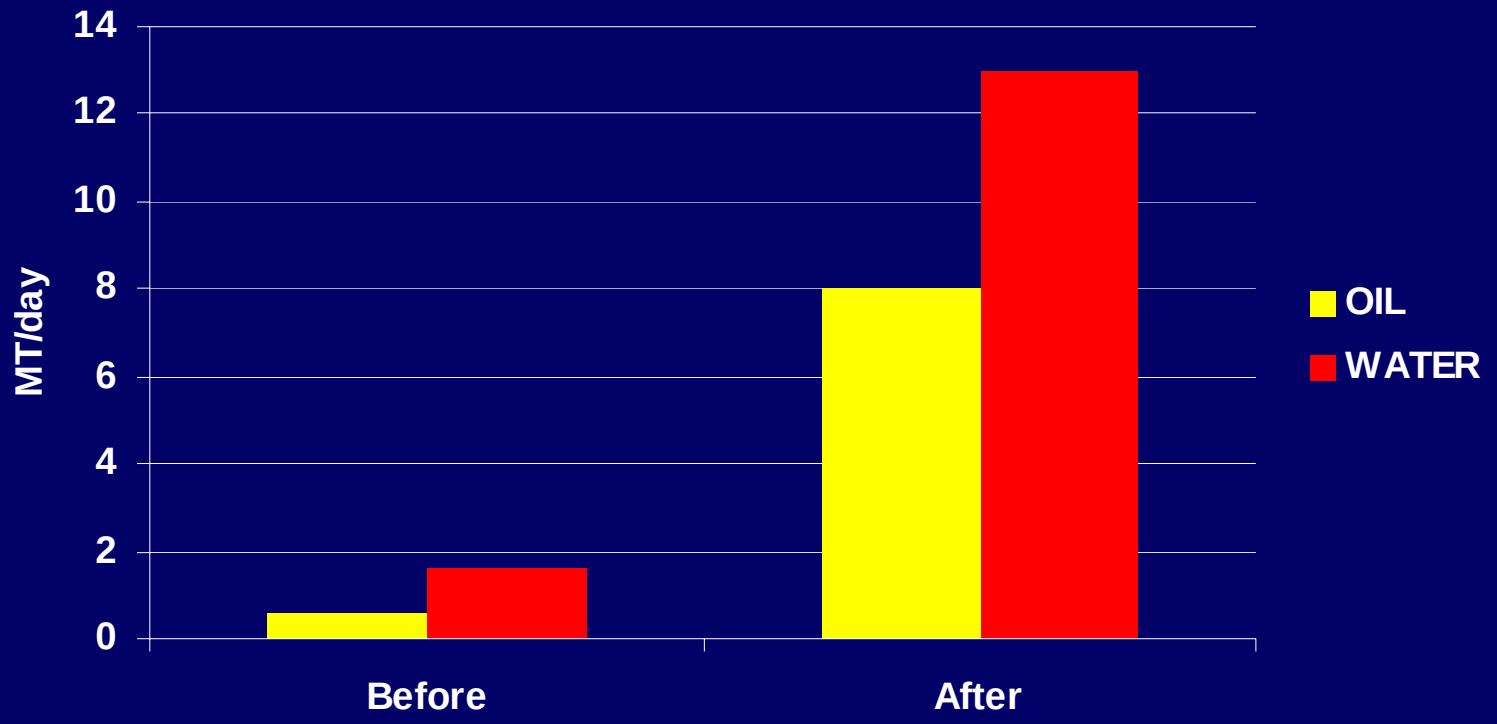
HEAVY OIL RECOVERY - NEW DEVELOPMENT

- Reduce heavy oil viscosity by creating water external pseudo-emulsion
- Reduce the polymer viscosity required by reducing the crude oil viscosity
- Reduce the energy provided by steam to mobilize the oil

HEAVY OIL PSEUDO-EMULSION



HEAVY OIL PROJECT (70ºC, 12 API)



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CONCLUSIONS

- Worldwide “un-recoverable” oil ~ two trillion bbl oil
- Mostly in depleted reservoirs or those nearing depletion
- Oil reserves and reservoir characteristics have already been confirmed
- Conventional Oil Recover Factor <33%
- Today’s demand for oil makes chemical EOR an effective and economic means of increasing the oil supply

CONCLUSIONS

- Recent successes in the field have confirmed that chemical EOR is a viable technique
- New chemicals and processes have been developed to increase the effectiveness and the economics of EOR, including some extreme reservoir conditions

CONCLUSIONS

How To Choose Chemicals On Your EOR Projects? Be Aware of:

- State of the art products/process available
- Field proven chemicals
- Field proven process
- Work with experts in each area based on their expertise and field experiences, field success
- Team work, direct involvement

THANK YOU !

Oil Chem Technologies, Inc.
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www.oil-chem.com