EOR Screening Criteria Revisited- Part 1: Introduction to Screening Criteria and Enhanced Recovery Field Projects

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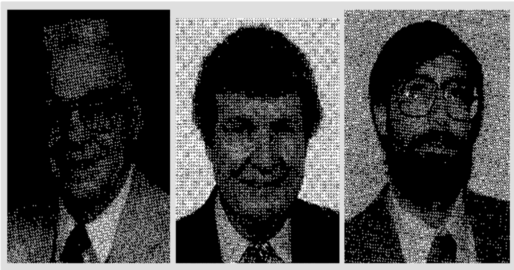

Summary

all Screening criteria have been proposed for enhanced oil recovery (EOR) methods. Data from EOR projects around the world have been examined and the optimum characteristics for successful projects have been noted. Steam flooding is still the dominant EOR method. All chemical flooding has been declining, but polymers and gels are being used successfully for sweep improvement and water shutoff. Only C02 flooding activity has increased continuously.

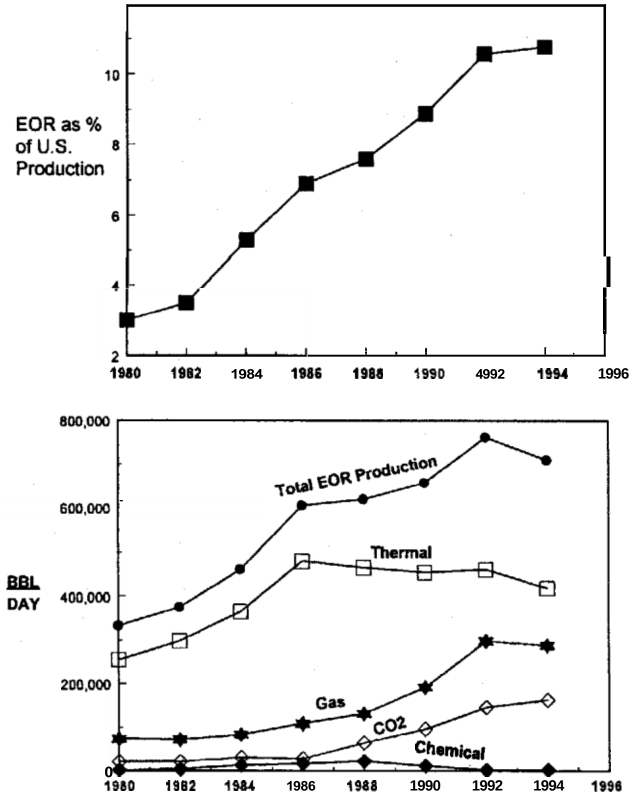

Fig. 1-EOR production in the U.S. (data from Ref. 25).

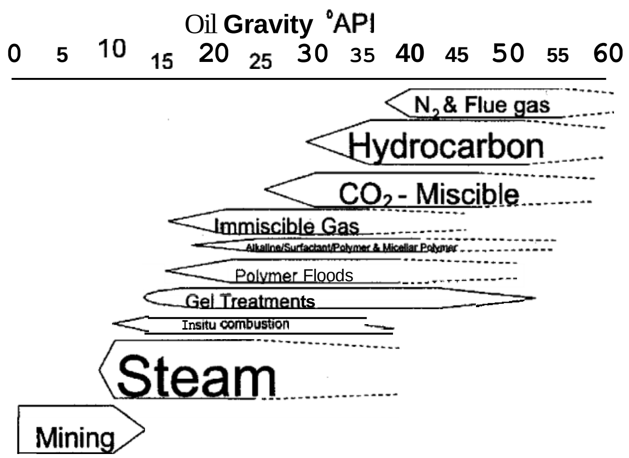

Fig. 2—Oil gravity range of oil that is most effective for EOR methods. Relative production (BID) is shown by size of type.

TABLE 1—CURRENT AND PAST EOR METHODS

Method	Table Number (in Ref. 16)
Gas (and Hydrocarbon Solvent) Methods	
"Inert" gas injection	
Nitrogen injection	1
Flue-gas injection	1
Hydrocarbon-gas (and liquid) injection	2
High-pressure gasdrive	
Enriched-gasdrive	
Miscible solvent (LPG or propane) flooding	
CO_2 flooding	3
Improved Waterflooding Methods	
Alcohol-miscible solvent flooding	
Micellar/polymer (surfactant) flooding	4
Low IFT waterflooding	
Alkaline flooding	4
ASP flooding	4
Polymer flooding	5
Gels for water shutoff	
Microbial injection	
Thermal Methods	
In-situ combustion	6
Standard forward combustion	
Wet combustion	
02-enriched combustion	
Reverse combustion	
Steam and hot-water injection	7
Hot-waterflooding	
Steam stimulation	
Steamflooding	
Surface mining and extraction	

TABLE 2-CLASSIFICATION OF CURRENT ENHANCED RECOVERY METHODS*

Solvent extraction and/or "miscible-type" processes
Nitrogen and flue gas
Hydrocarbon-miscible methods
CO_2 flooding
"Solvent" extraction of mined, oil-bearing ore
IFT reduction processes
Micellar/polymer flooding (sometimes included in miscible-type flooding above)
ASP flooding
Viscosity reduction (of oil) or viscosity increase (of driving fluid) processes plus pressure
Steamflooding
Fireflooding
Polymer flooding
Enhanced gravity drainage by gas or steam injection

'Classified by the main mechanism of oil displacement (excluding gel treatments).

TABLE 3-SUMMARY OF SCREENING CRITERIA FOR EOR METHODS

		Oil Properties			Reservoir Characteristics					
Detail Table in Ref. 16	EOR Method	Gravity (°API)	Viscosity (cp)	Composition	Oil Saturation (% PV)	Formation Type	Net Thickness (ft)	Average Permeability (md)	Depth (ft)	Temperature (°F)
				Gas Injection Methods (Miscible)						
1	Nitrogen and flue gas	>35 ↗ 48 ↗	<0.4 ↘ 0.2 ↘	High percent of C_1 to C_7	>40 ↗ 75 ↗	Sandstone or carbonate	Thin unless dipping	NC	>6,000	NC
2	Hydrocarbon	>23 ↗ 41 ↗	<3 ↘ 0.5 ↘	High percent of C_2 to C_7	>30 ↗ 80 ↗	Sandstone or carbonate	Thin unless dipping	NC	>4,000	NC
3	CO_2	>22 ↗ 36 ↗ [a]	<10 ↘ 1.5 ↘	High percent of C_5 to C_{12}	>20 ↗ 55 ↗	Sandstone or carbonate	Wide range	NC	>2,500[a]	NC
1–3	Immiscible gases	>12	<600	NC	>35 ↗ 70 ↗	NC	NC if dipping and/or good vertical permeability	NC	>1,800	NC
				(Enhanced) Waterflooding						
4	Micellar/Polymer, ASP, and Alkaline Flooding	>20 ↗ 35 ↗	<35 ↘ 13 ↘	Light, intermediate, some organic acids for alkaline floods	>35 ↗ 53 ↗	Sandstone preferred	NC	>10 ↗ 450 ↗	>9,000 ↘ 3,250	>200 ↘ 80
5	Polymer Flooding	>15	<150, >10	NC	>50 ↗ 80 ↗	Sandstone preferred	NC	>10 ↗ 800 ↗ [b]	<9,000	>200 ↘ 140
				Thermal/Mechanical						
6	Combustion	>10 ↗ 16 →?	<5,000 ↓ 1,200	Some asphaltic components	>50 ↗ 72 ↗	High-porosity sand/sandstone	>10	>50[c]	<11,500 ↘ 3,500	>100 ↗ 135
7	Steam	>8 to 13.5 →?	<200,000 ↓ 4,700	NC	>40 ↗ 66 ↗	High-porosity sand/sandstone	>20	>200 ↗ 2,540 ↗ [d]	<4,500 ↘ 1,500	NC
—	Surface mining	7 to 11	Zero cold flow	NC	>8 wt% sand	Mineable tar sand	>10[e]	NC	>3:1 overburden to sand ratio	NC

NC = not critical.
Underlined values represent the approximate mean or average for current field projects.
[a] See Table 3 of Ref. 16.
[b] >3 md from some carbonate reservoirs if the intent is to sweep only the fracture system.
[c] Transmissibility >20 md-ft/cp
[d] Transmissibility >50 md-ft/cp
[e] See depth.

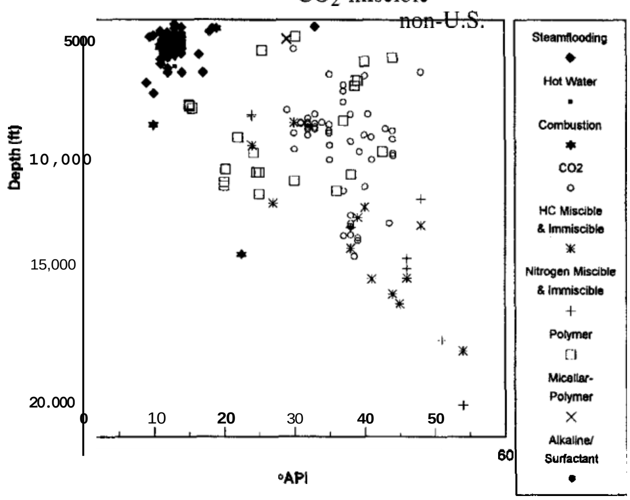

Fig. 3—Depth and oil gravity of producing EOR projects in the U.S. (data from Ref. 25).

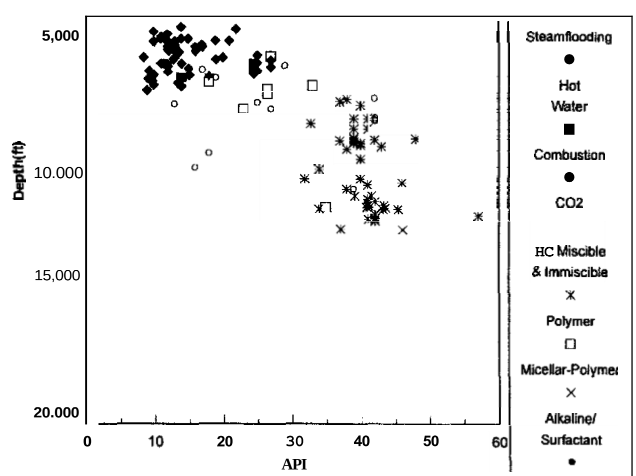

Fig. 4—Depth and oil gravity of producing EOR projects outside the U.S. (data from Ref. 25).

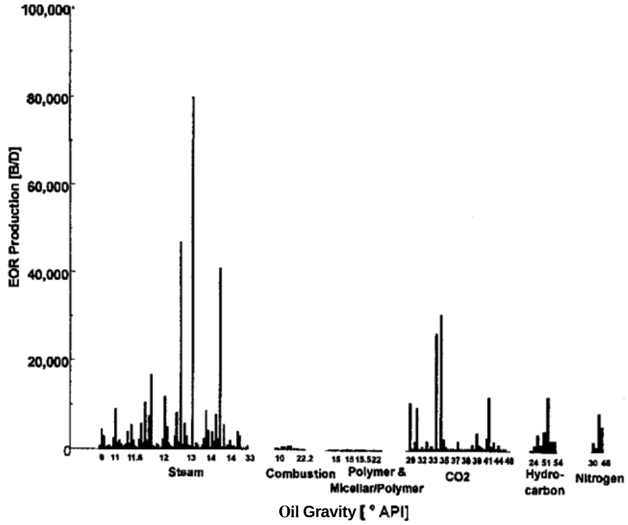

Fig. 5—EOR production vs. oil gravity in the U.S. (data from Ref. 24).

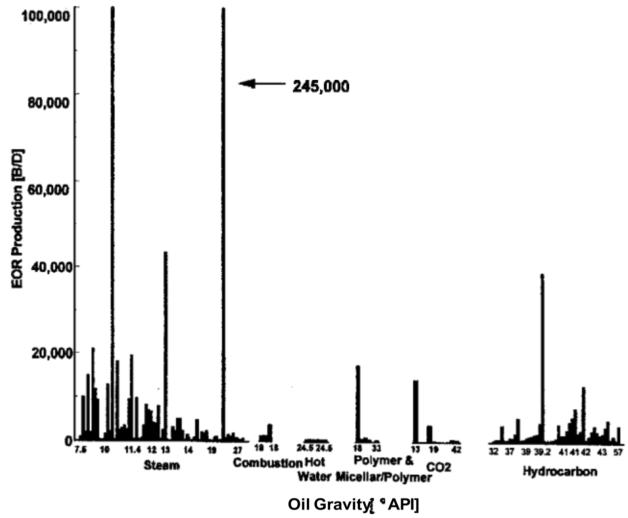

Fig. 6—EOR production vs. oil gravity outside the U.S. (data from Ref. 25).

floods, >35 ↗ 48 ↗ means that the process should work with oils
35°API

ed. They are considered together because the pressures required (MMP) for good displacement are similar,[26] and it appears that they

TABLE 4—ADDITIONAL CONVERSION FACTORS USEFUL FOR READING CO_2-FLOODING LITERATURE

1 bbl = 42 U.S. gallons = 0.159 m^3
1 ft^3 = 0.0283 m^3
1,000 ft^3 (Mscf or Mcf) = 28.3 m^3
Standard conditions in U.S. oil industry (may vary in some states) = 1 atm and 60°F (1.013 bar, 14.7 psia)
CO_2 density at standard conditions = 0.001868 g/cm^3 or 1.87 kg/m^3 = 0.1166 lbm/ft^3
17,150 ft^3 of CO_2 at 60°F (1 atm) = (weighs) 1 ton U.S. (2,000 lbm)
1 ton U.S. = 2,000 lbm = 907 kg (1 kg = 2.2 lbm)
1 ton US. = 0.907 metric ton or tonne
1 tonne CO_2 = 18,904 scf at 60°F and 1 atm
1 Gt (gigatonne) = 1 billion metric tons
1 bbl oil (35°API) = 0.16982 ton U.S. = 0.16895 tonne
1 Mscf/bbl = 0.31324 tonne CO_2/tonne oil (35°API)

Some factors are rounded for convenience and quick estimates.
Crude oil density typically ranges from 0.8 to 0.95 g/cm^3 or 800 to 950 kg/m^3.