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MICELLAR FLOODING OF BONNIE GLEN CRUDE

by

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A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE
IN
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Supervisor

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D.S. Montgomery
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Date April 19, 1984

ABSTRACT

Phase behaviour studies were conducted to determine micellar slug compositions miscible with Bonnie Glen Crude and brine. Berea sandstone cores 61/122 cm in length were saturated with oil and waterflooded to residual oil saturation. Micellar polymer floods were then initiated to evaluate the effectiveness of the various slugs in recovering tertiary oil. Effluent samples were collected and analyzed to determine sulfonate recovery.

Tertiary oil recovery for all micellar slugs evaluated was greater than 65% of the oil in place. Core floods were conducted at various frontal velocities to determine its effect on tertiary oil recovery. Oil recovery increased with increasing velocity up to a point then decreased with increasing velocity. This decrease in oil recovery was largely due to fingering of the polymer solution through the micellar slug.

Surfactant loss was found to be dependent on the micellar slug composition and the mineralogical composition of the sandstone. Cosurfactants such as n-Butyl alcohol and iso-propyl alcohol reduced sulfonate losses significantly. X-ray analysis of the Berea cores revealed the presence of illite, chlorite and kaolinite. Although the clay mineral content of the cores was only 1-3% of the matrix , because of the large surface area and high reactivity, they were partly responsible for the deactivation of the micellar slug.

In order to reduce sulfonate losses, various preflush solutions were injected prior to injection of the micellar slug. Preflushes consisting of 1% by weight sodium carbonate and 1% by weight ethylenediaminetetracetic acid (EDTA) were found to be the most effective. Sodium carbonate preflushes increased tertiary oil recovery by reducing oil/water interfacial tension and sulfonate losses. EDTA preflushes protected the micellar slug by forming metallic complexes with the multivalent cations.For a given size EDTA preflush, adjusting the pH to 11.4 resulted in a further increase in tertiary oil recovery. Lignosulfonate solutions were found to be ineffective preflushes; while aqueous solutions of Petrostep 465 plugged the cores.

For the system under study, displacement was initially miscible but as the micellar slug moved through the cores, mixing and sulfonate loss resulted in the displacement reverting to immiscible type displacement.

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1. INTRODUCTION

For every barrel of oil produced at least two barrels are left behind in the reservoir. With the ever increasing drilling cost and the realization that the world's petroleum resources are finite, it is becoming more and more important to find ways of economically producing residual oil.

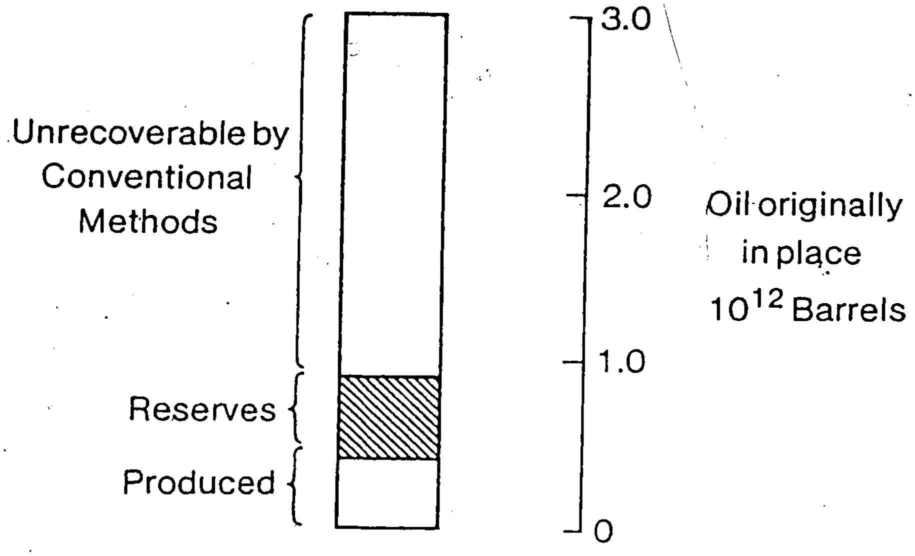

Fig. 1. Known World Petroleum Resources of Light and Medium Oil as of January 1, 1980. (adapted from reference 1).

From the above diagram it can be clearly seen that a large percentage of the oil originally in place is unrecoverable by conventional means. Quite often light oil is trapped by capillary forces, so methods of enhanced oil recovery (EOR) which lower oil/water interfacial tension are required.

Surfactant flooding by lowering interfacial tension is the obvious method. [illegible] approaches to surfactant flooding have evolved in practice. The first approach involves the injection of relatively large pore volumes of low concentration surfactant solution which mobilize oil by reduction of interfacial tension to about 10^{-3} dynes/cm. The second approach involves the injection of small volumes (0.05 to 0.15 pore volumes (PV)) of high concentration surfactant solution. These solutions are miscible to some extent with the formation water and/or crude oil. Miscibility between the surfactant slug and the resident fluids together with low interfacial tensions contribute to the displacement efficiency.

Micellar solutions generally include a combination of surfactant, water, salt, cosolvent and hydrocarbon. An effective micellar solution should be capable of producing very low oil/water interfacial tensions, should be relatively nonadsorbent on the rock surface and should be inexpensive, stable and soluble in reservoir fluids at reservoir temperatures. Most often the surfactant used is petroleum sulfonate. Proper design of surfactant floods are very difficult, one reason is that interfacial tension must be of the order of 0.01 dynes/cm and this must be maintained for a period of years as the surfactant slug moves through the reservoir .

Defining or determining the optimum conditions for a surfactant flooding process is very difficult. In addition to the compositional variables of the micellar slug many other parameters such as mobilities of the surfactant slug and polymer solution, surfactant slug size, type and concentration of polymer, composition, size and pH of the preflush, salinities of preflush, surfactant and polymer buffer must be considered. In addition the lithology, minerology, pore size distributions and wettability of the reservoir rock must be considered before commencing a surfactant flood. Considering the large number of variables, defining the optimal condition for any surfactant flood is very difficult.

Presently surfactant flooding is not economical,the approximate cost per barrel of oil(58) is between $35-50 U.S. Considerable research is therefore being done with a view to solving the technical and economic problems facing surfactant flooding, thus the future looks bright. It is predicted that by 1990's when solutions are found for the many unanswered questions, surfactant flooding might contribute about 10-20% of the total oil production.

Although Bonnie Glen Crude comes from a carbonate reservoir, core floods were conducted in Berea sandstone cores since all efforts were directed to micellar/polymer flooding of sandstone reservoirs. The primary objective of this study was to develop a micellar solution capable of effectively displacing Bonnie Glen Crude. Numerous core floods were conducted with a view to understanding recovery mechanisms and optimizing recovery through the use of various preflushes.

2. LITERATURE REVIEW

Enhanced oil recovery schemes involving surfactants date back to 1927 when Atkinson(2) proposed the use of aqueous soap solutions. Since then numerous researchers have investigated surfactant flooding. Because of the large number of publications,this review is limited to selected works.

2.1 PHASE BEHAVIOUR OF MICELLAR FLUIDS

Gogarty and Tosch(3) proposed and described micellar flooding. They studied the effect of composition on the phase behaviour of micellar solutions. Healy et al.(4,5) suggested the use of pseudo-ternary diagrams to represent the phase behaviour of micellar solutions. The compositions are considered as consisting of three components :water or brine,oil and surfactant. Various types of surfactant flooding can be depicted using a pseudo-ternary diagram. Point A on Figure 2 represents the composition of dilute surfactant in water. Systems with the composition S are soluble oil systems. Systems with the composition M will initially displace oil miscibly. One important point to note is that a smaller multiphase area under the binodal curve indicates longer periods of miscible diplacement. Injection of solutions with compositions I which are near or on the binodal curve, displace oil and water immiscibly. The dotted line represents an economic sulfonate concentration .

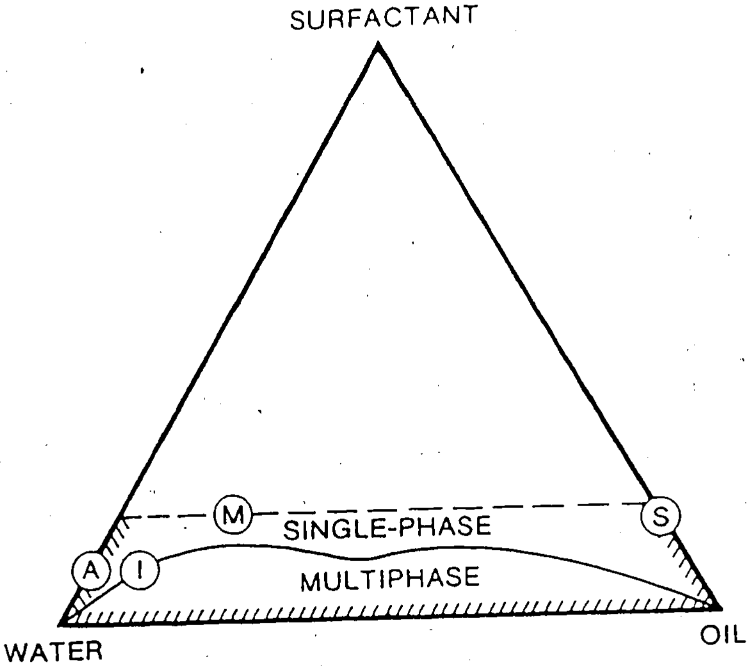

Fig.2 Pseudo-Ternary of Water, Oil and Surfactant System.

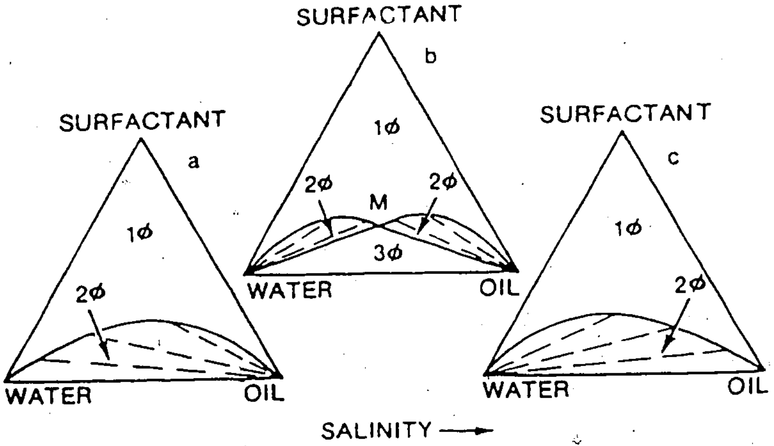

Fig.3 Simplified Versions of Phase Diagrams for a Microemulsion System.

Nelson and Pope(6) described different types of microemulsion systems. These are shown in Figure 3,Figure 3a is a Type II⁻ system. In this system, the microemulsion on the binodal curve is in equilibrium with an upper oil phase. Figure 3c is a Type II⁺ system where the microemulsion on the binodal curve is in equilibrium with a lower water rich phase. Type II⁺ has the capacity to take up additional oil and thus displace oil miscibly. In Type III systems three phases can exist in equilibrium, microemulsion, water rich phase and a oil rich phase. Type III Systems have areas that exist in II⁻ and II⁺ systems.

Each component of a microemulsion has an influence on phase behaviour. The component that has the greatest impact on a microemulsion's oil or water solubilizing capacity is the surfactant. So far petroleum sulfonates have been the surfactants of choice. A few generalizations can be made about the effect of petroleum sulfonate structure on phase behaviour(7). With sulfonates of similar structure the affinity towards oil increases with increasing equivalent weight.[1] Molecules containing two or more sulfonate groups have a much greater preference of water than similar monosulfonates. Also two sulfonates of widely differing properties can be blended with resulting properties that are linear interpolation between the properties of the individual sulfonates(8,9,10).

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[1] Equivalent weight of the sulfonate is the molecular weight divided by its valence

Salt has a marked effect on the phase behaviour(3,11) of a microemulsion prepared with a petroleum sulfonate. By altering the electrolyte concentration the single phase and multiphase regions of the pseudo ternary diagram are significantly changed. Healy et al(3,11) examined the effect of salinity on the multiphase region. They found that when salt was added to a lower phase microemulsion in equilibrium with excess hydrocarbon, a brine phase and a middle phase microemulsion appeared. Further addition of salt led to an upper phase microemulsion in equilibrium with a brine phase.

Healy et al.(11) found that the microemulsion/oil interfacial tension decreased while microemulsion/water interfacial tension increased with increasing salinity. They also found that the volume of oil and water solubilized increases as interfacial tension decreases. They concluded that there existed an optimal salinty for interfacial tension and solubilization.

The effect of a cosurfactant on phase behaviour has been discussed in a number of papers(13,14,15,16). In general water soluble alcohols make the microemulsion more compatible with reservoir brine whereas the oil soluble alcohols have the opposite effect i.e. they increase the compatibility of microemulsions with hydrocarbons. Also, higher viscosities are obtained with water-insoluble alcohols while the more water soluble alcohols lower microemulsion viscosities. Jones and Dreher(6) investigated the influence of alcohols as cosurfactants. They found that alcohols modify phase behaviour and control the amount of brine or hydrocarbon that a microemulsion can solubilize. They concluded that the relative amounts of oil and water that a microemulsion can solubilize was controlled partially by cosolvent type and concentration and not by the external phase.

Bae(20) et al. compared the performance of oil external microemulsions, water external microemulsions and aqueous surfactant systems using the same concentration of cosolvent and sulfonate for each type of system. They concluded that the aqueous system would give better overall performance. Although the literature contains conflicting reports on the merits of oil external and water external micellar solutions, it is generally believed that the nature of the external phase is unimportant. The effectiveness of a micellar solution is measured by its ability to solubilize oil and water. Most researchers strive to design a micellar solution capable of solubilizing equal amounts of oil and water.

Kremesec(21) et al. observed increased recovery with increased polymer concentration in the micellar or surfactant slug. This increase in recovery was attributed to the effect of mobility control and the higher capillary number. Kellerhals(22) like Kremesec(21) et al. and Hill et al.(23) found that polymer present in a micellar slug improved the displacement performance. Kellerhals(22) found that for surfactant concentration above some critical value, polymer concentration was more important than surfactant concentration.

Pope et al.(24) studied the effect of various polymers on the phase behaviour of various surfactant formulations. They found that all combinations of surfactant and polymers had regions of composition that were compatible and some that were not. In aqueous systems they found that there was a well defined critical electrolyte concentration (CEC) where a separate polymer rich phase formed. This CEC was the same for all polymers and a given surfactant. The CEC was dependent on temperature and alcohol concentration.

2.2 MOBILITY CONTROL

The success of any flooding procedure depends on the attainment of good mobility control. Unfavourable mobility control results in fingering, low sweep efficiency and poor performance. Good mobility control improves sweep efficiency and conformance,thus minimizing the size of micellar and polymer slug necessary for maximum oil recovery.

Gogarty et al.(17) described the conditions necessary for obtaining mobility control with miscible type waterfloods using micellar solutions. They found that for stability the mobility of the buffer has to be less than or equal to that of the surfactant slug which must be less than or equal to the mobility of oil/water bank ahead. Gogarty and Davis(18) studied the effect of mobility control on oil recovery. Their results showed that additional oil is recovered with mobility buffers greater than 50% PV, and below 50% PV favourable mobility control is more critical in two dimensional slabs than in linear flooding. They concluded that larger pore volumes of mobility buffer are needed in actual reservoirs where geometries are more complex.

Generally high molecular weight water soluble polymers have been used for mobility control. Most often solutions of polyacrylamides or polysaccharides have been used as mobility buffers. They improve mobility control by increasing the viscosity of water/reducing the permeability of reservoir rock to water. Table 1 summarizes the properties of current commercial EOR polymers. Even if other drawbacks can be overcome, thermal stability will be a limiting factor.

TABLE 1

ENHANCED OIL RECOVERY POLYMERS

	POLYACRYLAMIDES	XANTHAN
Thermal stability	Questionable	Poor
Salinity Tolerance	Poor	Good
Shear stability	Poor	Good
Bacterial Degradation	?	Yes
Injectivity Problems	Occasional	Frequent
Availability Outlook	Excellent	Good

2.3 MECHANISMS OF MICELLAR FLOODING

Davis and Jones(48) were the first researchers to investigate the mechanisms of micellar flooding. For their system, they found oil was displaced miscibly while interstitial water was displaced immiscibly .

Trushenski(19) et al. examined the mechanisms of micellar flooding and the interactions between the different fluid banks. Long core tests revealed the existence of a high mobility oil-water bank and a low mobility oil-micellar mixing zone. A possible explanation for the phenomena was the formation of an emulsion.

Healy(5) et al. conducted experiments wherein microemulsions of various compositions and slug sizes were injected at rates from 0.1 to 6 ft/d into Berea sandstone cores containing brine and residual oil corresponding to the components of the microemulsion ternary diagram. They found that most of the displacement was under immiscible conditions. Healy et al.(5) concluded that microemulsion flooding is a locally miscible process until slug breakdown thereafter the displacement is immiscible, also the immiscible aspect introduces a rate dependence thus making it essential to conduct laboratory floods at reservoir pressure gradients and frontal velocities if results are to have any significance.

Willhite et al.(25) studied displacement mechanisms by detailed analysis of produced effluents. In the system studied the principal displacing fluid was a finely dispersed macroemulsion which consisted of two or three fluid regions when allowed to stand for sufficient time. This macroemulsion was produced by the mixing of the injected microemulsion with resident fluids as it was displaced through the core.

Although considerable work has been done and is continuing, the mechanisms of micellar flooding are not fully understood.Quite often recoveries from pilot projects are significantly different from that predicted after extensive laboratory evaluation.

2.4 EFFECT OF SALINITY ON RECOVERY

Several researchers have investigated the effects of various salinities for each step i.e. preflush, micellar slug and polymer drive of a micellar/polymer flood. Paul and Froning(26) found that maximum recovery was obtained when the preflush/micellar/polymer salinity sequence was saline/less saline/fresh. Hurd(27) found that surfactant transport and oil recovery were improved by using freshwater behind the surfactant slug. Shah et al.(28) found that a saline polymer drive produced a higher oil recovery than a fresh water drive. Kellerhals(22) observed that a low salinity polymer drive enhance oil recovery but the optimal salinity for the polymer drive was a variable subject to the rock and fluid properties of the system.

It is now believed that one of the essential keys to successful oil recovery is the establishment of a salinity gradient. The highest salt concentration should reside in the oil bank near the leading edge of the micellar slug in order to attain low microemulsion/oil interfacial tension. If a microemulsion containing a high concentration of fresh water encounters saline water, fresh water is expelled. This action results in increased surfactant concentration. The polymer solution following the microemulsion must contain low salt concentrations to minimize polymer/microemulsion interfacial tension .

This type of salinity gradient is achieved by injecting a microemulsion with a salt concentration lower than that of the resident fluids. The polymer solution should be of an even lower salt concentration.

2.5 EFFECTS OF PREFLUSH ON RECOVERY

Numerous researchers(29, 30, 31, 32, 33, 34) have investigated the effect of preflush on oil recovery. In general it has been shown that higher oil recoveries are obtained with brine preflushes and that various sacrificial agents reduce adsorption loss.

Holm and Robertson(30) investigated various preflush solutions for use in micellar/polymer flooding. They found that oil recovery in laboratory core floods was improved by the use of high pH silicate preflush. They concluded that high pH silicate solutions were more efficient than sodium chloride as a preflush since it has a higher critical electrolyte concentration.[2] Dabbous and Elkins(35) found that preinjection of polymers in advance of a micellar slug improved volumetric sweep efficiency of oil recovery.

Holm et al.(49) found that chelating agents present in small amounts in the micellar slug or as a preflush improved oil recovery. This was due to the ability of the chelating agents to form soluble complexes with divalent ions ,thus reducing adsorption losses on the reservoir rock.

Recent studies(50,51) undertaken by the Chemical Engineering Department at the University of Ottawa indicate that the addition of lignosulfonates to petroleum sulfonates causes a reduction of interfacial tension over that obtained with the petroleum sulfonates alone. They found that lignosulfonates possess highly favourable surfactant and emulsion stabilizing properties. Lignosulfonates are wood based chemicals made from the sulfite liquor generated during the wood pulping process. Lignosulfonates are water soluble anionic surface active derivatives of lignin with molecular weights between 1,000-20,000. Thus incorporating lignosulfonates in the micellar slug or as a preflush should improve oil recovery by reducing adsorption on the resevoir rock of the more expensive petroleum sulfonates by being pre-adsorbed, and/or acting with the surfactant at liquid /liquid interface to reduce interfacial tension between oil and brine.

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[2] Critical electrolyte concentration is the salinity at which precipitation of the surfactant in the aqueous phase occurs

2.6 RATE EFFECTS OF MICELLAR FLOODING

Water flood rates in low permeability formations are frequently less than 1.0 ft/d . Studies have been undertaken to determine the effect of flow rate on recovery. Taber et al.(36) observed that at both higher and lower rates the displacement by alcohol was efficient. Healy et al.(5) found that before slug breakdown microemulsion flooding was a miscible process and thereafter an immiscible process. They observed an increase in displacement efficiency at high rates. They concluded that the immiscible aspect introduced a rate dependence into the overall process. Holm(33) like Healy et al.(5) found that after slug breakdown, the displacement was rate sensitive and more oil was recovered at high flow rates. Sayyouh et al.(37)investigated the effect of flood advance rate on micellar/polymer displacement. They found that oil recovery decreased with increasing injection rate up to a point then increased with increasing rate.

A review of the literature reveal that researchers have used frontal velocities varying from 0.5 to 80.0 ft/d, for this study injection rates were comparable to field injection rates.

2.7 EFFECT OF SLUG SIZE ON RECOVERY

Numerous researchers(3,22,23,37) have investigated the effect of chemical slug size on recovery. In general they found that oil recovery increased with slug size up to a point, further increases in slug size resulted in insignificant volumes of additional oil. Some researchers(5,34) by using a continual flooding process studied the effect of surfactant concentration on recovery. They found that increasing surfactant concentration up to a limit increased recovery. Further increases improved oil recovery insignificantly but reduced pore volumes of surfactant needed.

2.8 SURFACTANT LOSSES

Sulfonate loss is one of the single most important factors in determining the economic success or failure of a surfactant flooding process. In a typical surfactant flood, sulfonate costs are frequently half or more of the total cost. As a result numerous studies have been done in this area. It is generally accepted that four mechanisms contribute to surfactant losses: 1) adsorption, 2) surfactant precipitation, 3) an immobile surfactant-rich phase and, 4) surfactant dissipation. The literature contains many conflicting reports on the effects of reservoir parameters on surfactant loss. Some of the variables(39) affecting the adsorption and retention of petroleum sulfonates are:

a) Equivalent weight and equivalent weight distribution
b) Minerology and surface area
c) Salinity and divalent cation content of the
   reservoir fluids and micellar formulation

d) Concentration of the petroleum sulfonate

e) Physical characteristics of the formulation

f) Wettability of the rock and residual oil saturation.

Published results claim that surfactant loss from high oil content microemulsions is both greater(20) and less(40,41) than the loss from high water content microemulsions. Still others(3,43) claim that if both oil and water are present surfactant loss can be reduced. Published results have led to the conclusions that the presence of residual oil decreases(39) or increases(44) and has no effect on surfactant loss. Meyers and Salter(40) found that for a given surfactant/alcohol/oil/brine system, structural and compositional differences among fluids with the same active surfactant concentrations have no effect on the amount of surfactant adsorbed by reservoir rock. They concluded that surfactant retention is independent of brine/oil mass ratio.

Somasundaran and Hanna(46) found that surfactant adsorption could be reduced by the introduction of alkaline chemicals such as sodium silicate, phosphate and carbonate; sodium silicate was shown to be the most effective additive.

It has been found that an increase in salt concentration increases the adsorption of petroleum sulfonates(27,29) on the rock surfaces.The adsorption of petroleum sulfonate was found to be a function of its equivalent weight, Hurd(29) found a sharp increase in adsorption at a petroleum sulfonate equivalent weight of 450. Foster(27) and Hill et al(23) found that certain organic salts decreased the adsorption of petroleum sulfonates. Bae and Petrick(45) found adsorption to be dependent on flow rate.

Although there are numerous conflicting reports a few generalizations can be made,

a) Maximum adsorption occurs near the critical micelle concentration,

b) Maxima in adsorption isotherms occur with mixtures of petroleum sulfonates,

c) Adsorption increases with increasing eqivalent weight of the sulfonate ,

d) Electrolyte influences adsorption of sulfonate ,

e) Cosurfactants tend to decrease sulfonate adsorption.

3. STATEMENT OF THE PROBLEM

The main objectives of this study were,

1) To develop a micellar solution capable of effectively recovering Bonnie Glen Crude.

2) To evaluate the performance of the micellar solution by conducting micellar/polymer floods using Berea sandstone cores.

3) To evaluate the effectiveness and mechanisms by which preflush chemicals reduce sulfonate losses.

4) To determine the mineralogical composition of the sandstone cores and its effect on surfactant loss.

4. EXPERIMENTAL EQUIPMENT, MATERIALS AND PROCEDURE

4.1 EXPERIMENTAL EQUIPMENT

A schematic diagram of the experimental apparatus is shown in Figure 4. The displacement pump was a constant injection rate Ruska pump with mercury as the displacing fluid. The pumps, charged with mercury displaced the fluid of interest from 1.0 litre stainless steel cylinders into the core holder. All injected fluids were filtered using a millipore filter. All lines were of high-pressure stainless steel tubing.

A Heise pressure gauge was used to measure the pressure drop across the core. A pressure transducer connected to a chart recorder provided the pressure history for each run.

An automatic sampler with a timer capable of providing 24 samples per cycle was used to collect effluent samples.

A vacuum pump was used to evacuate the core and connections prior to each run.

4.2 POROUS MEDIA

4.2.1 Berea Cores

Berea sandstone cores 61 cm or 121 cm in length and 5 cm in diameter were used as received in all core displacements. The properties of the cores are listed in Table 2.

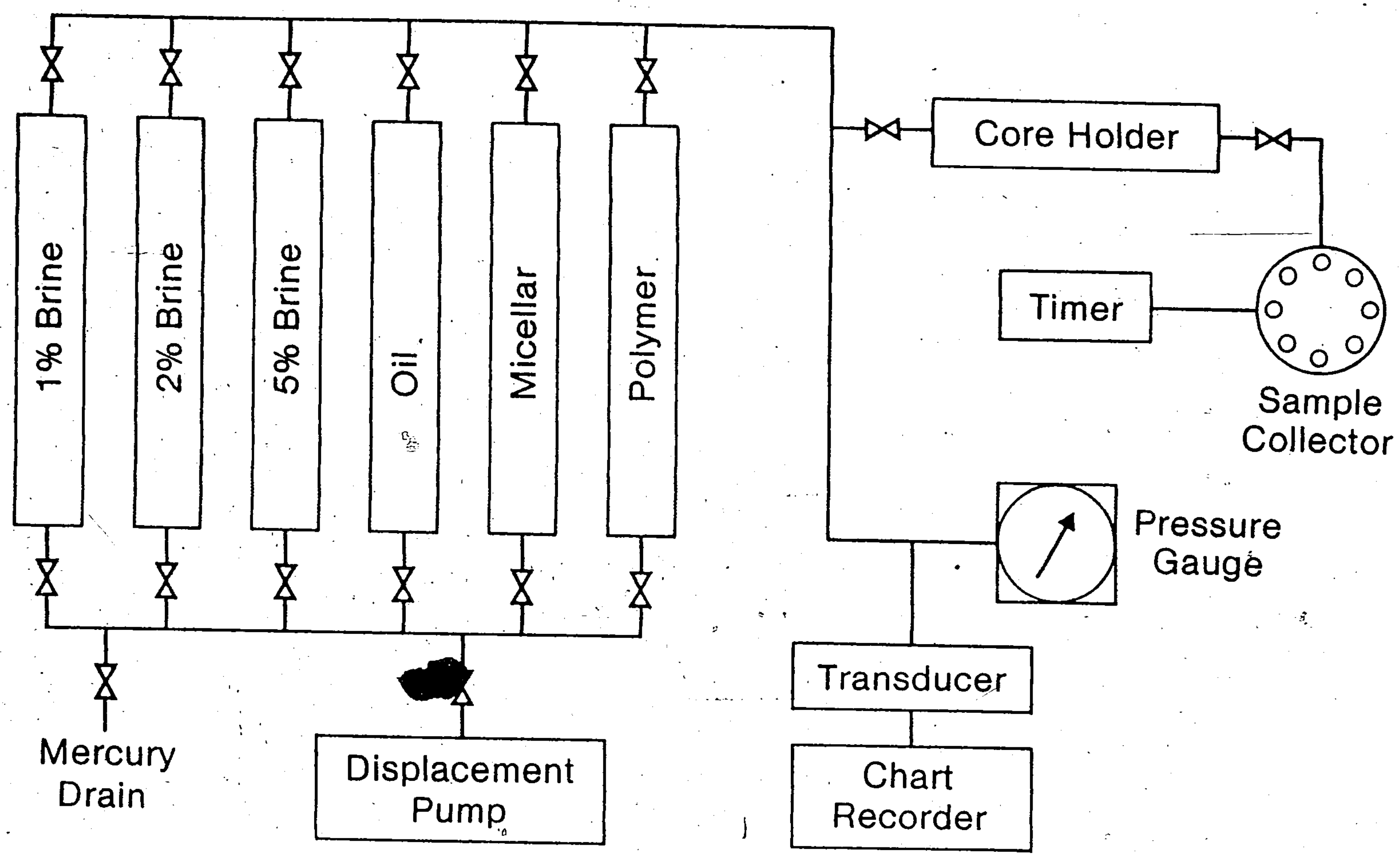


Fig.4 Schematic of Core Flooding Apparatus

TABLE : 2

PROPERTIES OF CORES

CORE NO	LENGTH (Cm)	POROSITY (%)	PERMEABILITY (µm²)	OIL SAT. BEFORE WATER FLOOD % PV	OIL SAT. AFTER WATER FLOOD % PV
1	61	25.3	0.693	64.85	29.54
2	61	24.2	0.650	66.52	34.24
3	61	25.0	0.667	60.00	29.30
4	61	23.8	0.656	63.51	31.00
5	61	24.3	0.748	58.76	26.80
6	61	23.4	0.713	62.50	29.60
7	61	20.9	0.656	63.60	27.20
8	61	22.0	0.567	64.64	42.9
9	61	23.1	0.706	63.54	38.85
10	61	22.3	0.676	55.50	27.20
11	61	23.5	0.759	67.61	37.36
12	61	23.1	0.681	63.05	31.53
13	121	24.3	0.716	62.35	32.20
14	61	23.8	0.757	68.42	34.74
15	61	22.5	0.546	69.62	35.55

TABLE : 2 (CONTINUED)

PROPERTIES OF CORES

CORE NO	LENGTH (Cm)	POROSITY (%)	PERMEABILITY (μm^2)	OIL SAT. BEFORE WATER FLOOD % PV	OIL SAT. AFTER WATER FLOOD % PV
16	61	23.0	0.739	68.52	29.82
17	61	22.6	0.716	65.55	31.85
18	61	21.9	0.684	66.32	34.69
19	61	24.5	0.679	65.27	37.78
20	61	23.5	0.667	64.06	37.72
21	61	21.1	0.639	67.19	43.51
22	61	23.4	0.739	64.64	33.93
23	61	21.3	0.722	66.67	34.90
24	61	22.1	0.714	64.15	32.83
25	61	22.6	0.673	65.68	31.73
26	61	21.9	0.814	69.84	35.88
27	61	23.4	0.831	71.42	34.64
28	61	23.0	0.815	69.09	34.90
29	122	23.2	0.799	61.26	30.45
30	61	23.2	0.830	68.90	23.60

4.2.2 Coreholders

The cores were housed in stainless steel coreholders having an internal diameter of 5.04 cm and lengths of 61 cm or 122 cm.

4.2.3 Casting the Core

The cores were painted with Phenoline 300 Epoxy Resin and allowed to dry at room temperature. Phenoline 300 Epoxy was prepared by mixing Phenoline 300 Part A and Phenoline Part B in the ratio 6:1. A teaspoon of Mica Filler was added to 250 mls of the mixture. The mixture was thinned with Phenoline thinner to a consistency which can be painted easily with a paint brush. The core was then baked in an oven at 100° F for two hours. After cooling to room temperature a second coat of paint was applied and dried similarly.

Each of the cores were then placed in a coreholder and positioned with a three pin recessed disc at one end. The other end was centered using three pieces of rope placed between the core and the coreholder. Molten Cerrobend alloy which has a melting point of 158°F was poured into each coreholder. The cores were allowed to cool to room temperature. The ends of the core were machined flush to the coreholder and flanges fitted.

4.3 FLUIDS

The following fluids were used throughout the experiments. The physical properties of the fluids are given in Table 3. Density of the various fluids were measured using a Paar Digital Density Meter. The Brookfield LV Digital Viscometer with UL Adaptor was used to determine all viscosities.Dow Corning calibration fluids were used to calibrate the viscometer prior to all measurements.Interfacial tension measurements were made using a Du Nuoy Tensiometer.

4.3.1 Brine

Reagent grade sodium chloride was used to prepare brine of various compositions.

4.3.2 Oil

Bonnie Glen Oil was used as received in all core floods. The water content was less than 0.5%.

4.3.3 Preflush

Reagent grade anhydrous sodium carbonate was used to prepare a 1% by weight sodium carbonate preflush. The lignosulfonate preflush was prepared using Marasperse C-21 manufactured by the American Can Company. (See Table 4)
The sodium salt of ethylenediaminetetraacetic acid was used to prepare the EDTA preflush. A 1% by weight sodium orthsilicate preflush was prepared using Metso

200($Na_2O/SiO_2=2.0$).

4.3.4 Polymer

The polymer used for all core floods was partially hydrolyzed polyacrylamide marketed under the trade name Dow Pusher 700 supplied by Dowell Chemical Company.

TABLE : 3

PHYSICAL PROPERTIES OF FLUIDS AT 24°c

	Density (gm/cc)	Viscosity (mPa.s)	pH
Distilled Water	0.997	1.03	6.8
1% (w) Brine	1.003	1.07	
Bonnie Glen Crude	0.836	3.5	
1% (w) Sodium Carbonate	1.005	1.08	11.8
1% (w) Sodium Orthosilicate	1.006	1.09	12.8
3% (w) Lignosulfonate	1.007	1.12	7.04
Micellar Slug B_1	0.960	294.0	
Micellar Slug B_2	0.946	88.0	
Micellar slug B_3	0.947	35.2	
250 ppm Polymer	-	9.3	
550 ppm Polymer	-	13.5	
1% w Na_4EDTA	-	1.07	5.0

TABLE : 4

ANALYSIS OF MARASPERSE C - 21

Total Sulfur 5%	6.8
Sulfate Sulphur as S, %	0.3
Sulfite Sulphur as S, %	0.09
CaO, %	5.2
mgO, %	0.3
Na_2O, %	6.1
Reducing Sugars, %	1.5
OCH_3, %	7.9

4.3.5 Micellar

The surfactant used in preparing the micellar solutions was Petrostep 465 supplied by Stepan Chemical Company. The composition of this surfactant is given in Table 5. The compositions of the micellar solutions investigated in this study are shown in Table 6. The rheological behaviour of the various micellar solutions is shown in Figure 5. All micellar slugs exhibited Newtonian type behaviour.

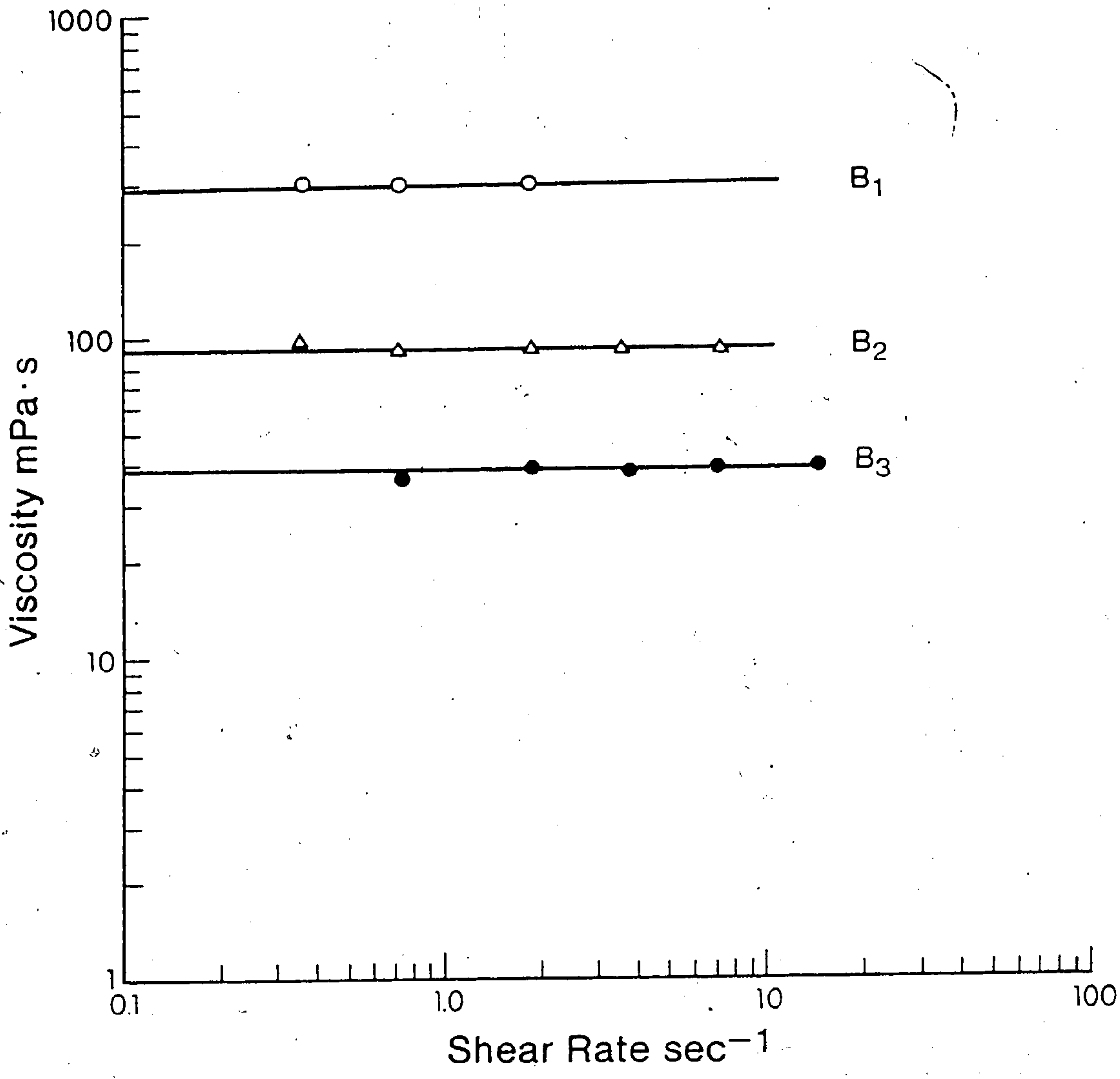


Fig. 5 Rheological behaviour of Micellar Solutions.

TABLE : 5

COMPOSITION OF PETROSTEP 465

Actives	58.7%
Free Oil	14.9%
Water	22.2%
Inorganic Salt	2.2%

TABLE : 6

COMPOSITION OF MICELLAR SLUGS

	B_1	B_2	B_3
Bonnie Glen Oil	55.0%	55.0%	45.0%
Distilled Water	15.0%	15.0%	37.5%
Petrostep 465	30.0%	30.0%	15.0%
Iso Propyl Alcohol	0	0	1.5%
N-Butyl Alcohol	0	*	1.0%

* MICELLAR SLUG B_2 WAS PREPARED BY ADDING 3%(V) N-BUTYL ALCOHOL TO MICELLAR SLUG B_1.

4.4 PREPARATION OF THE POLYMER

Because polyacrylamides are susceptible to shear degradation the following procedure was used in the preparation of the polymer. Dow Pusher 700 was added to distilled water in a beaker and stirred slowly. The mixture was then allowed to hydrate overnight at slow stirrer speeds. The polymer solution was then made up to the desired concentration and filtered using medium fast Whatman #1 filter paper to remove any unhydrated polymer molecules or large agglomerates.Because the rate of filtration was slow, air pressure of 5.0 psi was applied. The rheological behaviour of the filtered polymer is shown in Figure 6.

4.5 CORE PROPERTY DETERMINATION

4.5.1 Determination of Porosity

The core was evacuated for at least 24 hours and then allowed to suck 0.5% by weight brine. The volume of brine sucked into the pore space was assumed to be the pore volume of the core.

The pore volume as determined by the above procedure was checked by miscible displacement of the 0.5% brine by 2% by weight brine. Effluent samples were collected and their refractive index measured using an Abbe Refractometer.With the use of Figure 7 a plot of the percent displacing fluid in the effluent versus cumalative volume produced was made (See Figure 8). The areas above and below the S-shaped curve

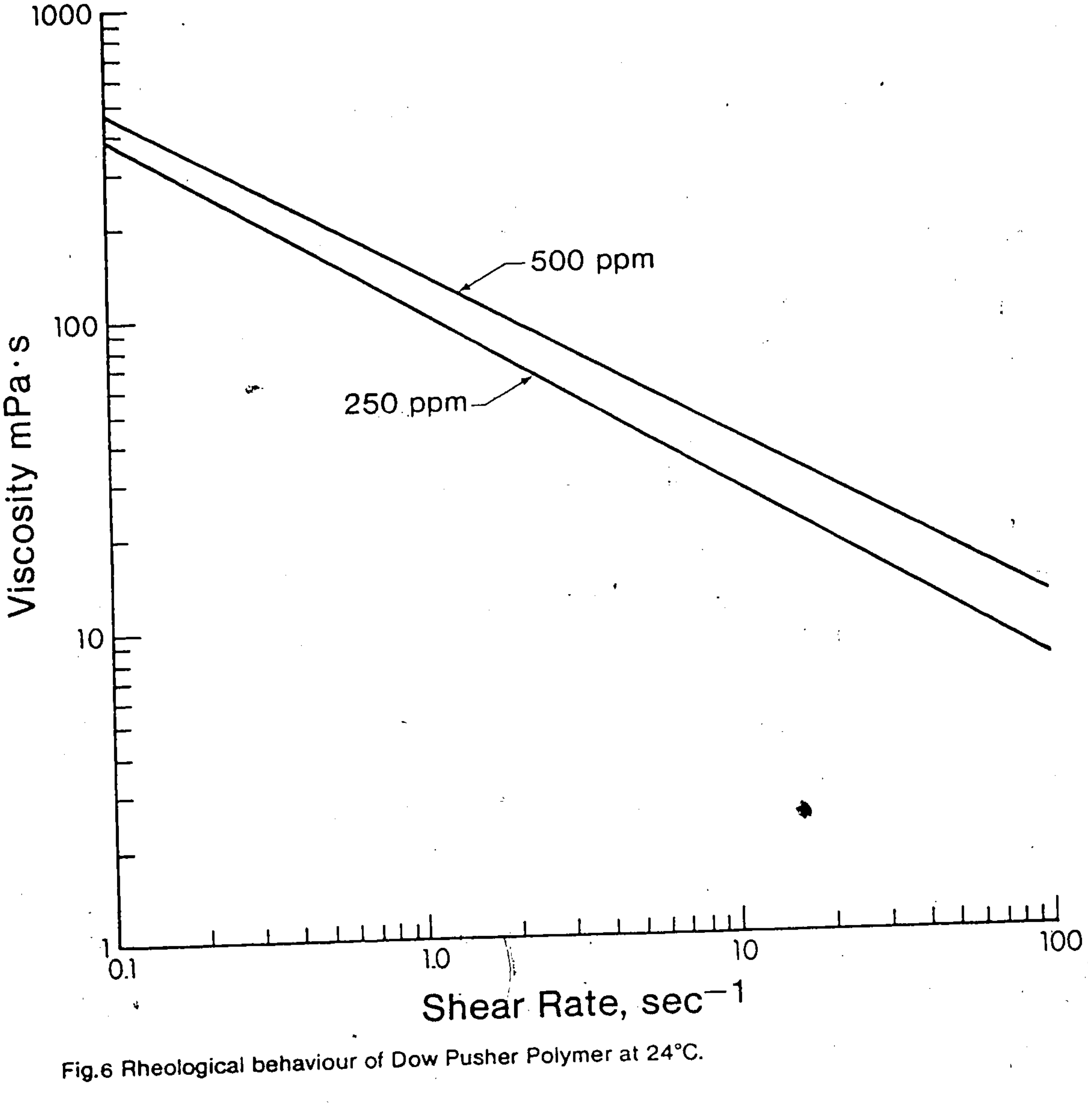


Fig.6 Rheological behaviour of Dow Pusher Polymer at 24°C.

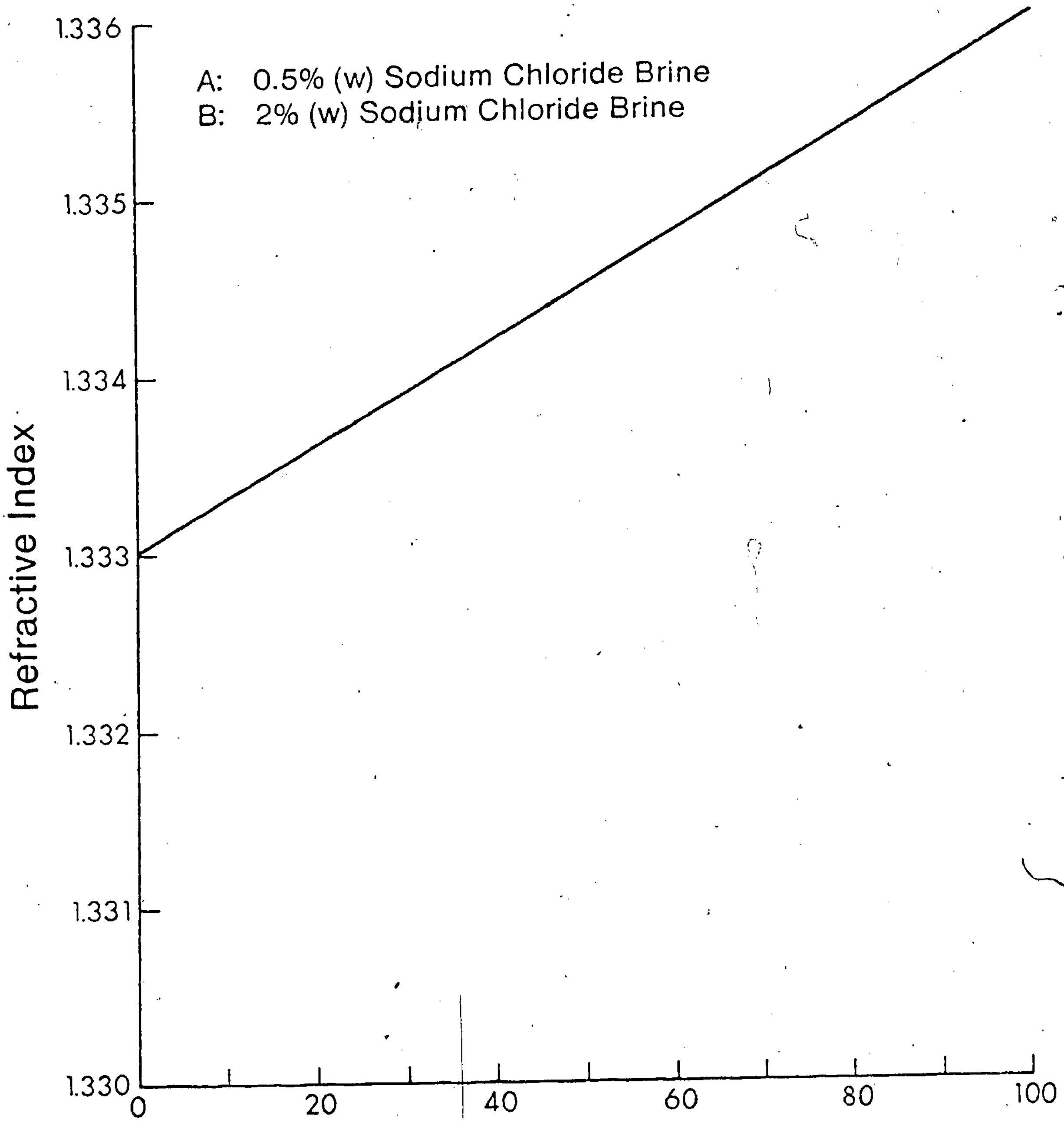
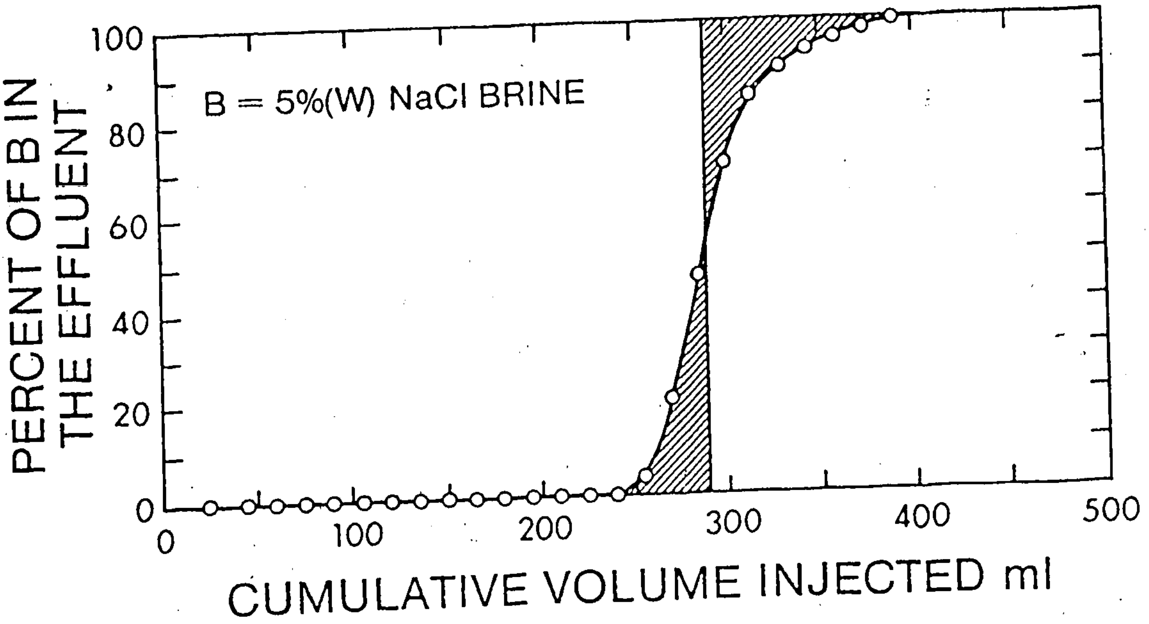


Fig. 7 Change in Refractive Index due to change in Brine Concentration.



DETERMINATION OF PORE VOLUME BY MISCIBLE DISPLACEMENT CORE#2

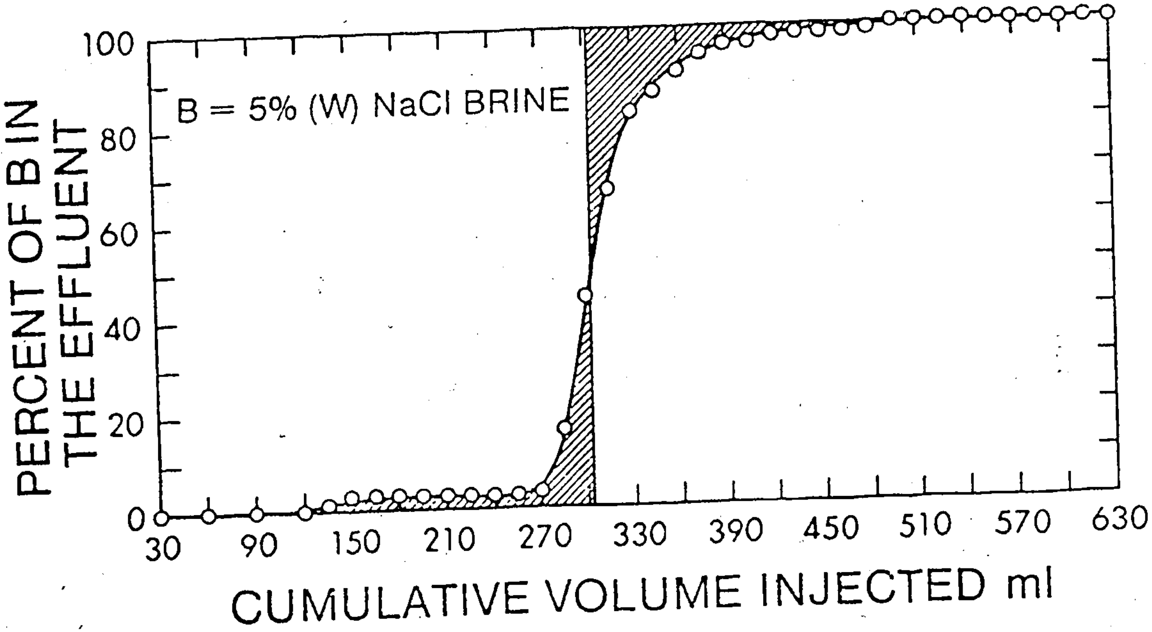


Fig. 8 DETERMINATION OF PORE VOLUME BY MISCIBLE DISPLACEMENT CORE#1

were balanced using a planimeter and the pore volume determined. Having found the bulk volume by measuring the dimensions of the core, the porosity was calculated.

4.5.2 Determination of Permeability

The absolute permeability of the core was obtained by flowing 2.0% by weight brine at various rates and noting the pressure drop at each particular flow rate. Darcy's linear flow equation was then used to calculate the absolute permeability. (See Table 2)

4.6 DISPLACEMENT PROCEDURE

The properties of the core were measured as outlined earlier. The cores were then flooded with Bonnie Glen Crude at 200 cc/hr until the connate water saturation was established. This generally required 5-7 pore volumes of oil. Next, the cores were water flooded with 2% by weight brine to obtain the residual oil saturation.

The micellar/polymer floods were started at this point or after the specified preflush solution was first injected into the porous media. The micellar slug was first injected followed by the polymer slug. One percent by weight brine was used in all core floods to displace the polymer and micellar slugs. Effluent samples were collected and analyzed.

All injected fluids were filtered using a millipore filter. All experimental work was conducted at room temperature.

4.7 ANALYSIS OF EFFLUENT SAMPLES

The effluent samples collected were analyzed to determine the sulfonate content using a Perkin Elmer Infrared Spectrophotometer.A known volume of the oleic phase was dewatered using 50% by weight calcium chloride solution, the volume of the dewatered oleic phase was noted. A small volume of the sample was injected into a barium fluoride cell an analyzed by infrared spectrophotometry. The amount of sulfonate in the sample was then determined from the calibration curve shown in Figure 9 which relate absorbance to the percent of sulphonate in a sample. Petrostep 465 absorbed infrared radiation at 1176 cm^{-1} and 1056 cm^{-1}.Based on Lambert-Beer's law the following relationships were obtained.

$$\text{Absorbance} = A = \log_{10} 1/T$$

where T = Transmittance

$A = acl$

where a = absorbtivity coefficient of the sulphonate

l = path length in the cell.

c = concentration (g/l).

Thus,

$$c = A/(ba).$$

Determination of the sulfonate content in the aqueous phase was similar to that outlined above, except 1-2 mls of toluene was added and Figure 11 rather than Figure 9 was used. Appendix A contains detailed calculations.

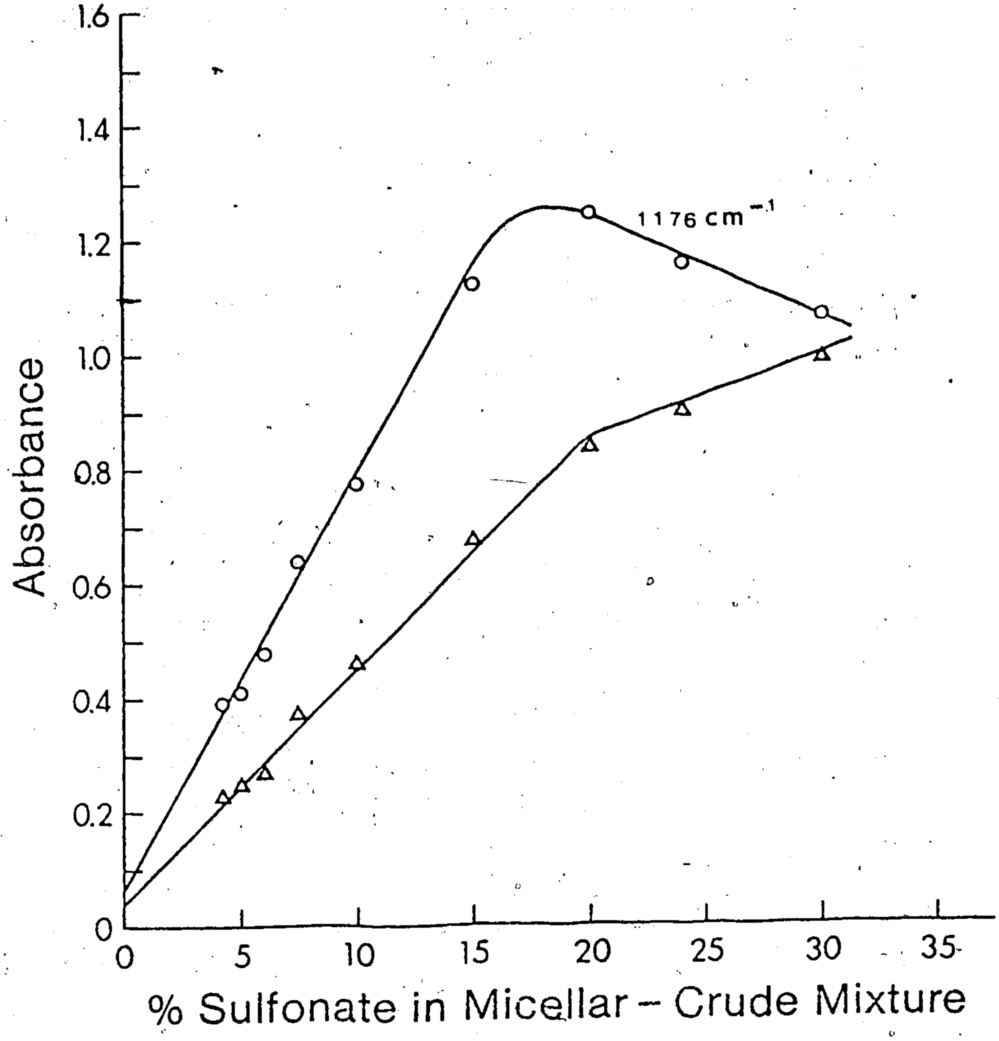


Figure .9
Calibration curve for the mixture of micellar solution B_1 and Bonnie Glen crude oil.

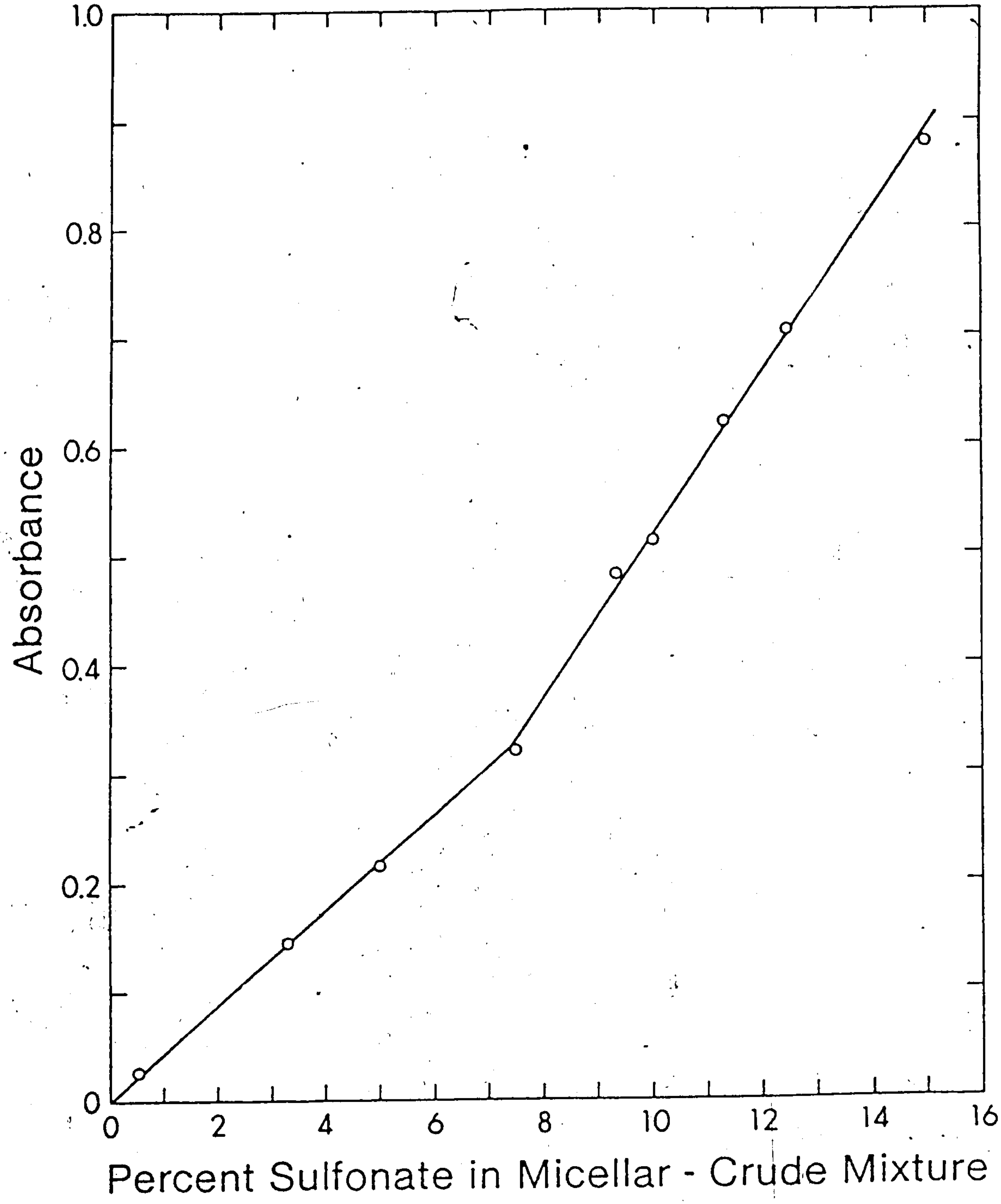


Fig.10 Calibration Curve for Petrostep 465 in B_3 - Bonnie Glen Crude Mixtures

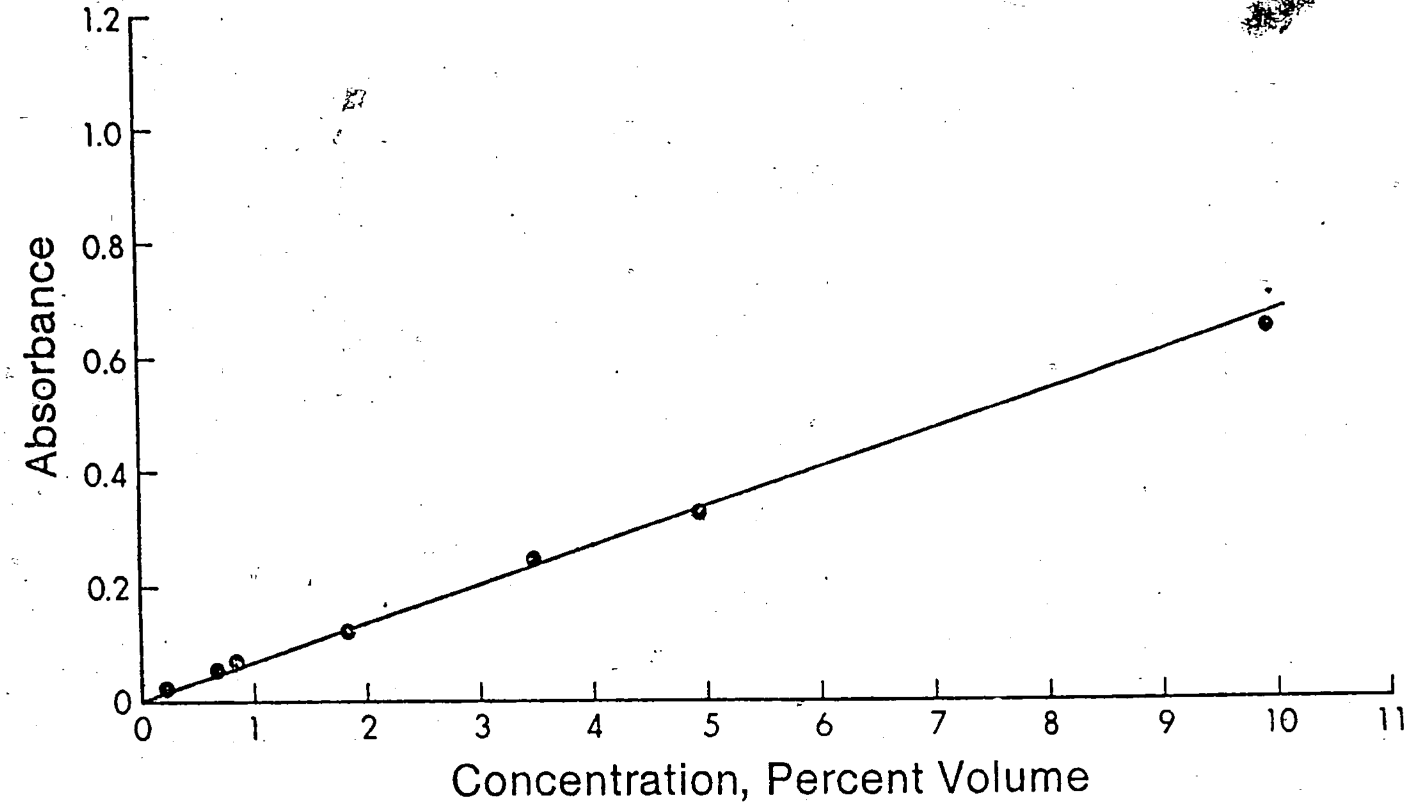


Figure 11 Calibration curve for petrostep 465 in toluene.

5. DISCUSSION OF RESULTS

5.1 GENERAL

Thirty core floods were conducted with three different micellar slugs. The results of the core floods are listed in Table 7.

Twelve core floods(#1-12) were conducted employing micellar slug B_1. (See page 26 for properties of this slug). Frontal velocity ranged from 0.53 m/d - 10 m/d, buffer size varied between 25 - 50% PV, tertiary oil recovery averaged around 78% of the oil in place. Sulfonate recovery for these core floods was low,generally less then 10% of that injected. Run# 3 was conducted to evaluate the ability of micellar slug B_1 to displace Bonnie Glen crude in a simulated reservoir enviroment. B_1 was injected continuously until all the oil in place was recovered.The recovery behaviour shown in Figure 23 (See page 122) indicates a highly efficient microemulsion.The micellar slug displaced all the oil but left some residual water as can be seen by extrapolating the straight line portion of the curve.The residual water saturation (Swrc) was about 10% so that surfactant loss through the retention of a residual microemulsion phase was not significant.

Micellar slug B_2 had a composition similar to B_1 except 3% n-Butyl Alcohol was added to reduce its viscosity. This resulted in better mobility control and consequently was more effective than B_1.Two runs #13 and 14 were conducted

TABLE 7

SUMMARY OF COREFLOOD RESULTS

CORE FLOOD NO	LENGTH (cm)	Ka (um²)	INITIAL OIL SAT. %P.V	TYPE OF PREFLUSH	PREFLUSH VOLUME %P.V	MICELLAR SLUG %P.V	BUFFER SIZE %P.V	BUFFER CONC. P.P.M	FRONTAL VELOCITY M/DAY	TERTIARY OIL RECOVERED %O.I.P	SULFONATE RECOVERED %INJECTED
1	61	0.693	29.5	-	-	5.0 B_1	50.0	250	7.73	76.5	5.2
2	61	0.650	34.2	-	-	20.0 B_1	50.0	250	8.08	71.0	6.4
3	61	0.667	29.3	-	-	100.0 B_1	-	-	9.98	100.0	
4	61	0.656	31.0	-	-	5.2 B_1	50.0	250	5.14	70.7	0.6
5	61	0.748	26.8	-	-	5.0 B_1	25.0	250	4.02	95.4	4.3
6	61	0.713	29.6	-	-	5.0 B_1	25.0	250	1.31	79.5	6.2
7	61	0.656	27.2	-	-	5.0 B_1	25.0	250	2.92	76.8	5.3
8	61	0.567	42.9	-	-	10.0$_1$	50.0	250	6.94	64.8	3.2
9	61	0.706	38.9	-	-	5.0 B_1	25.0	250	0.53	64.9	16.5
10	61	0.676	27.2	1%(w)Na_2CO_3	25.0	5.0 B_1	25.0	250	2.73	84.6	0.0
11	61	0.759	37.4	-	-	10.0 B_1	25.0	250	2.60	80.4	6.9
12	61	0.681	31.5	1%(w)Na_2CO_3	50.0	5.0 B_1	25.0	250	2.64	76.0	0.0
13	122	0.716	32.2	-	-	6.8 B_2	27.2	500	2.51	69.1	25.7
14	61	0.757	34.7	-	-	5.3 B_2	50.0	500	1.28	95.7	36.3
15	61	0.546	35.6	-	-	5.0 B_3	50.0	500	1.35	67.8	33.6

TABLE 7(CONTINUED)

SUMMARY OF COREFLOOD RESULTS

CORE FLOOD NO	LENGTH (cm)	Ka (um^2)	INITIAL OIL SAT. % P.V	TYPE OF PREFLUSH	PREFLUSH VOLUME % P.V	MICELLAR SLUG %P.V	BUFFER SIZE %P.V	BUFFER CONC. P.P.M	FRONTAL VELOCITY M/DAY	TERTIARY OIL RECOVERED %O.I.P	SULFONATE RECOVERED %INJECTED
16	61	0.739	29.8	1%(w)Na_4SiO_4	25.0	5.1 B_3	50.0	500	1.33	29.6	4.1
17	61	0.716	31.9	1%(w)Na_2CO_3	25.0	5.0 B_3	50.0	500	1.35	72.9	48.0
18	61	0.679	34.7	1%(w)Na_2CO_3	25.0	5.0 B_3	50.0	500	1.24	71.4	47.8
19	61	0.684	37.8	3%(w)L.S	25.0	5.0 B_3	50.0	500	1.39	36.9	10.1
20	61	0.667	37.7	3%(w)L.S	5.0	5.0 B_3	50.0	500	1.30	49.0	9.5
21	61	0.639	43.5	3%L.S+Brine	20/100	5.0 B_3	50.0	500	1.44	22.0	5.7
22	61	0.735	33.9	1%(w)P465	25.0	5.0 B_3	50.0	500	1.31	28.6	12.1
23	61	0.723	34.9	1%(w)P465	25.0	5.0 B_3	12.6	500	1.44	31.7	4.6
24	61	0.715	32.8	1%(w)Na_2CO_3	50.0	6.1 B_3	50.0	500	1.38	98.9	78.6
25	61	0.673	31.7	1%(w)EDTA	50.0	5.0 B_3	50.0	500	1.35	82.0	38.3
26	61	0.814	35.9	1%(w)EDTA	25.0	5.0 B_3	50.0	500	1.40	90.8	61.4
27	61	0.831	34.6	1%(w)EDTA	5.0	5.0 B_3	50.0	500	1.30	83.9	31.7
28	61	0.815	34.9	1%(w)EDTA	50.0	5.0 B_3	50.0	500	1.33	83.3	39.3
29	122	0.799	30.5	1%(w)EDTA	51.0	5.0 B_3	50.0	500	1.31	87.6	23.9
30	61	0.830	34.3	1%(w)EDTA	5.0	5.0 B_3	50.0	500	1.29	88.4	23.6

with slug B_2.

Because of the high costs of sulfonate it was decided to investigate the effectiveness of a micellar slug with a much lower sulfonate concentration. Based on phase behavior studies micellar slug B_3 was chosen. The properties and composition of this slug are given in Tables 3 and 6. Fifteen core floods(#16-30) were conducted in an effort to evaluate the performance of this slug. Various preflushes were used in order to reduce sulfonate loss and hence improve oil recovery. Runs #16,17,18 and 24 were conducted to evaluate the performance of high pH chemicals as preflushes. Runs #19 to 23 evaluated the performance of aqueous sulfonate solutions as sacrificial adsorbates .

Comparison of the results of the core floods reveals that B_3 was the most efficient slug based on percent tertiary recovery per gram of sulfonate injected.(See Figure 12).The effect of the various parameters on tertiary oil recovery and sulfonate losses will be discussed in the following sections.

5.2 PHASE BEHAVIOUR

Phase behaviour studies were conducted using Petrostep 465, Bonnie Glen Crude and distilled water with a view to selecting a micellar solution miscible with Bonnie Glen Crude and brine. The phase behaviour of the system studied is shown in Figure 13. The system was a Type III using the nomenclature discussed in chapter 2. Examination of Figure

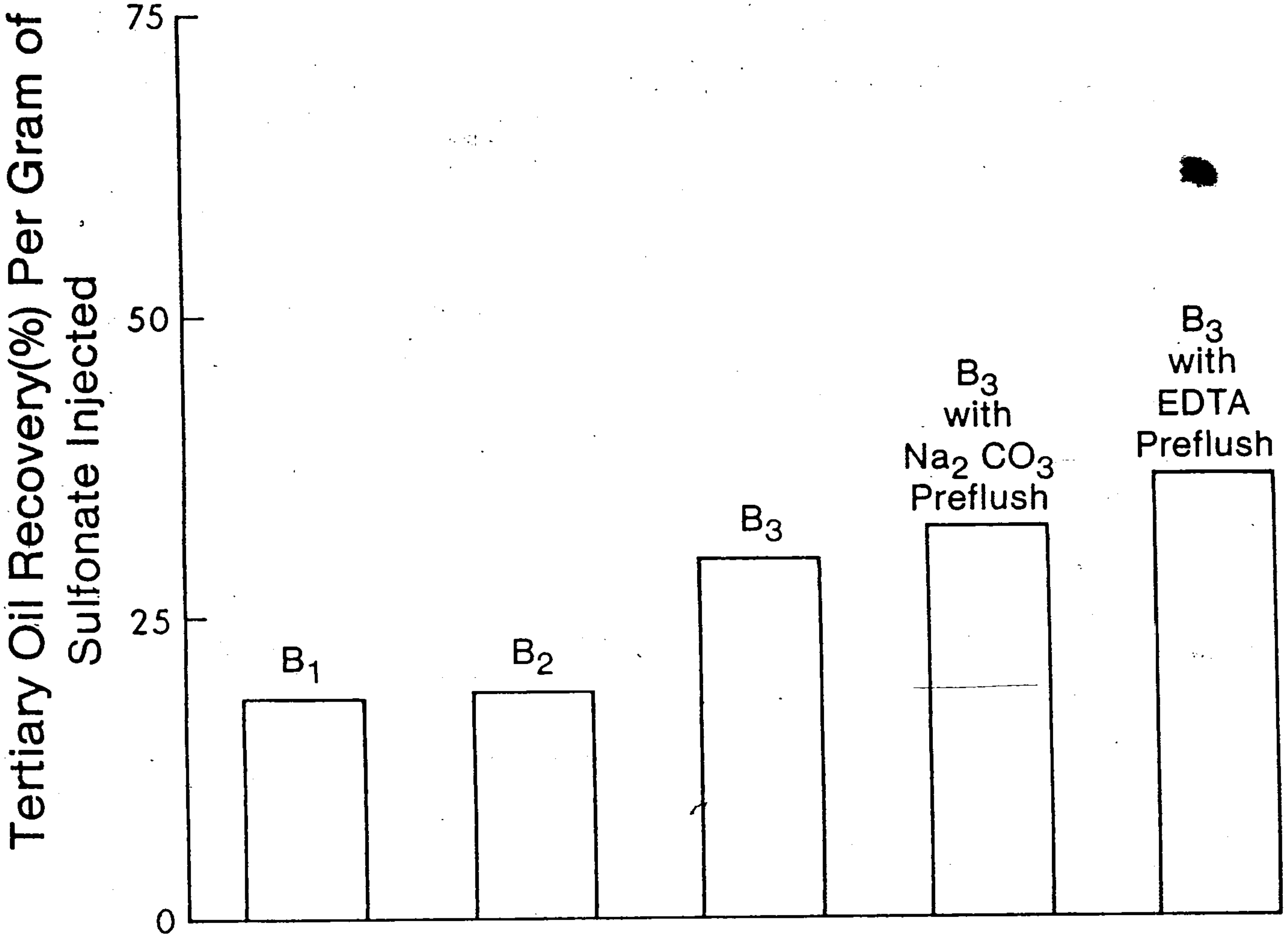


Fig. 2 Recovery Efficiency of the Various Micellar Slugs.

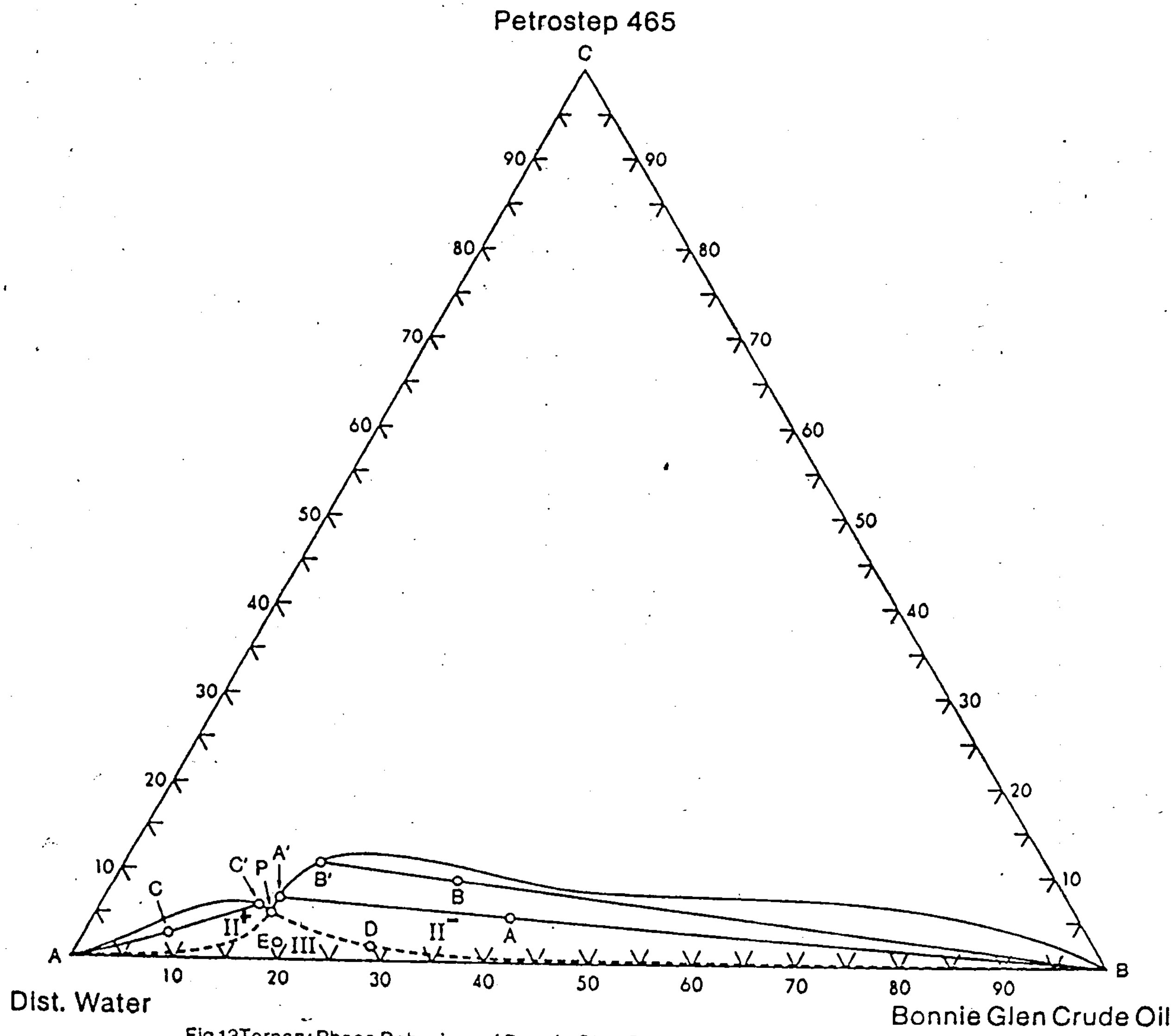


Fig.13Ternary Phase Behaviour of Bonnie Glen Crude, Petrostep 465, Distilled Water.

13 reveals the presence of three distinct regions II^-, II^+ and III. Consider a formulation of composition A, A was found to be a two-phase system with an upper phase microemulsion of composition A' and a lower oleic phase. Similarly composition B was made up of an upper phase microemulsion B' and a lower oleic phase. The tie lines in the II^+ region are also shown in Figure 13. Region III represented compositions where three phases were in equilibrium, microemulsion, a water rich phase and a oil rich phase. Various micellar formulations were screened to determine their ability to solubilize oil and water.Based on these studies micellar slug B_1 was chosen.The composition and properties of this slug are given in Tables 3 & 6.Core floods were then conducted to determine its effectiveness.

In order to obtain better mobility control of the micellar/polymer process the viscosity of slug B_1 was reduced from 294 mPa.S to 88 mPa.S using 3% by weight n-Butyl alcohol. (See Figure 14).This alcohol concentration was chosen since it did not significantly affect the slug's ability to solubilize oil and water.Corefloods #13 and #14 were undertaken to evaluate the performance of this slug.

Because of the high sulfonate content of micellar slugs B_1 and B_2, it was decided to evaluate the effectiveness of slugs with a lower sulfonate concentration. Using the phase diagram as a starting point, various composition micellar slugs were evaluated. The composition of these slugs are given in Table 8.

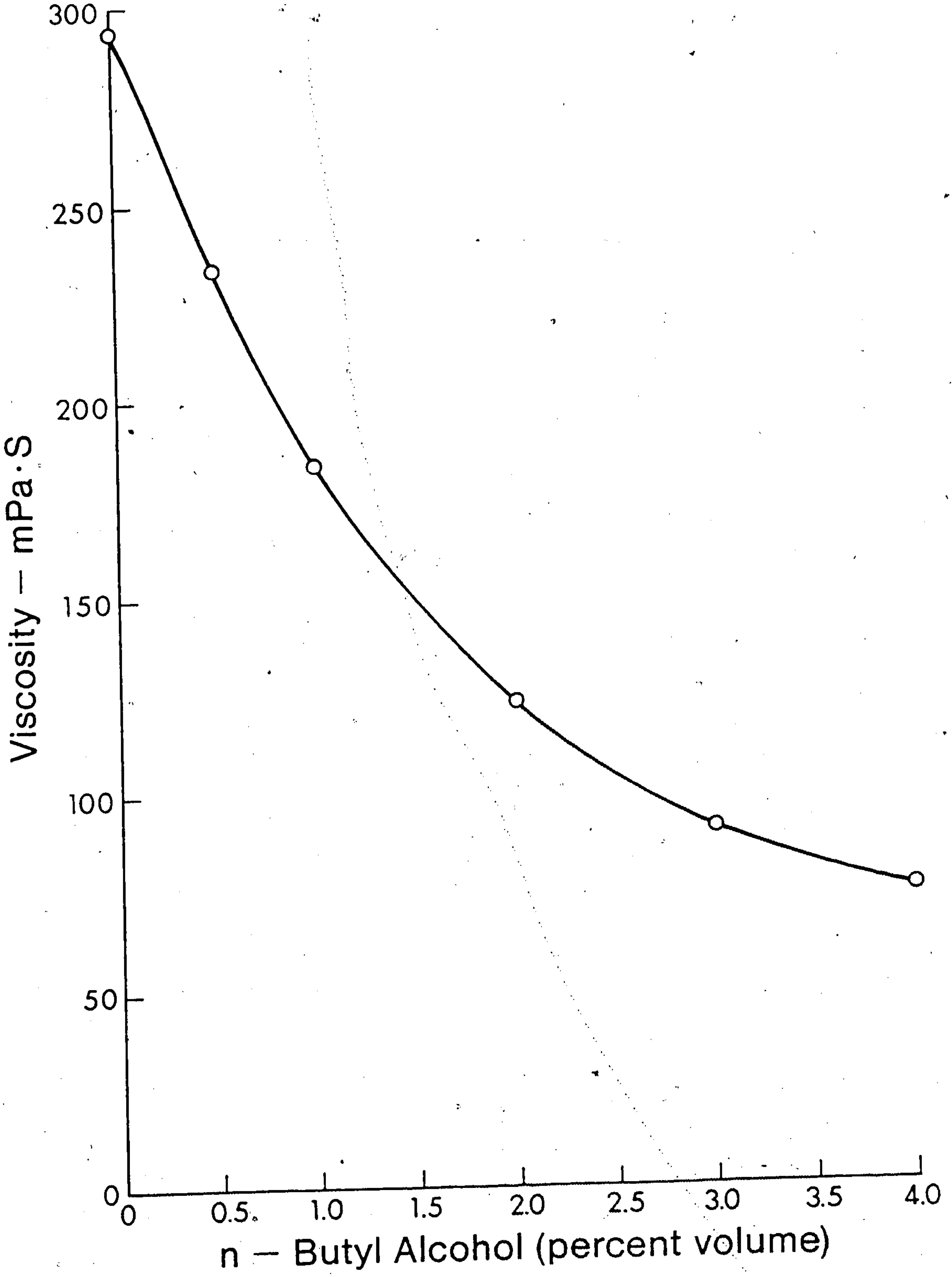


Fig.14 Effect of n — Butyl Alcohol on Viscosity of Micellar Slug B_1.

TABLE : 8

Composition and Properties of Various Micellar Slugs

Slug #	Distilled Water %	Petrostep 465 %	Bonnie Glen Crude %	Iso Propyl Alcohol %	N-Butyl Alcohol %	Ability to Solubilize Oil/H_2O	Viscosity mPa.S
1	79.5	14.9	5.6	[illegible]	0.0	Poor^{1}	
2	76.6	14.9	5.5	[illegible]	3.0	Good^{3}	2.0
3	30.0	10.0	60.0	[illegible]	0.0	Okay^{2}	
4	27.0	10.0	60.0	0.0	3.0	Poor	
5	27.0	10.0	60.0	3.0	0.0	Poor	
6	73.5	15.0	10.0	0.0	1.5	Poor	
7	40.0	15.0	45.0	0.0	0.0	Poor	
8	38.5	15.0	45.0	1.5	0.0	Good	61.0
9	37.5	15.0	45.0	1.5	1.0%	Good	35.2

1 - Poor - After addition of 5 mls or less of oil and H_2O. Phase Separation occured.

2 - okay - After addition of between 5 to 10 mls of both oil and H_2O, phase separation occured.

3 - Good - After addition of 15 mls of both oil and H_2O. Solution was single phase.

Micellar slugs 3,8 and 9 showed the greatest ability to solubilize oil and water, based on mobility considerations slug #9 was chosen. (Referred to as B_3).

Analysis of the effluent samples revealed that sulfonate recovery of micellar slugs B_2 and B_3 were significantly greater than that of B_1. (See Figure 15). This increase in sulfonate recovery was partly due to the effect of alcohol as a cosurfactant.

5.3 PROPERTIES OF BEREA CORES USED

The properties of the sandstone cores are listed in Table 2. (See page 22). Examination of this table reveals that core properties were uniform except that the permeabilities of cores #26 to 30 were significantly higher than the rest. This difference in permeability was noticed when a new batch of cores was employed, commencing at run #26. The average values of porosity and permeability together with standard deviations are listed in Table 9.

TABLE 9

AVERAGE PROPERTIES OF CORES

	AVERAGE POROSITY	STANDARD DEVIATION	AVERAGE PERMEABILITY	STANDARD DEVIATION
CORES 1-25	23.1%	1.176	0.6865 μm^2	0.052 μm^2
CORES 26-30	23.0%	0.67	0.8178 μm^2	0.013 μm^2

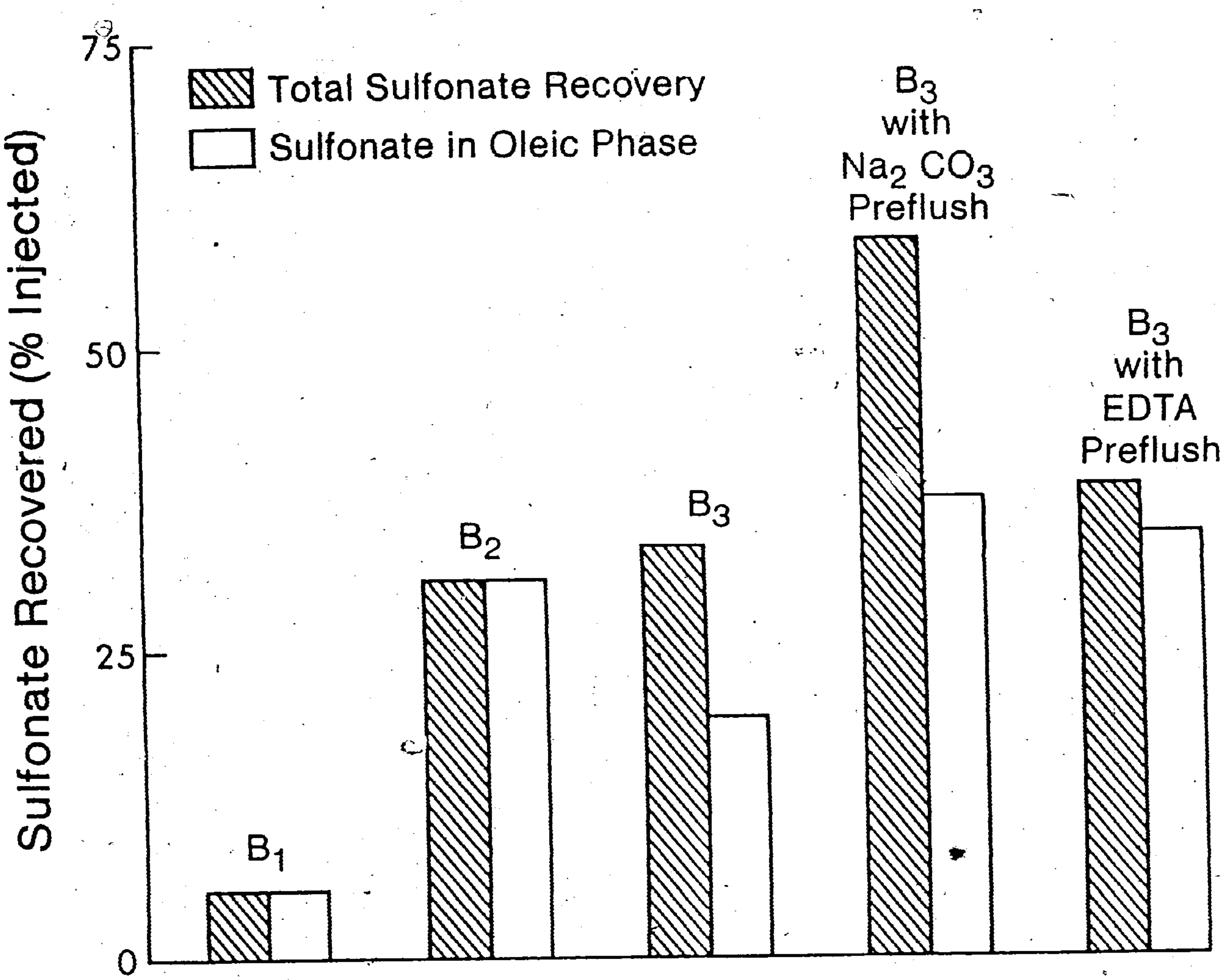


Fig.15 Average Sulfonate Recovery for the Various Micellar Slugs.

Samples of the cores were analysed by X-ray analysis to determine clay content. The clay mineral content of the core was found to be a small percentage (1 - 3%) of the total matrix. Table 10 reveals that kaolinite and illite were the major constituents of the <20 um portions of the sample. Traces of chlorite were detected in the < 2 um sample.

TABLE : 10

MINERALOGY OF THE BEREA CORES

–	Q	P	F	C	K	I	CH
5-20um	M	m	m	m	90	10	0
2-5um	M	m+	m	nM	85	15	0
<2um	M	m	m	M	60	35	5

K=kaolinite. I=Illite. CH=Chlorite.
Q=Quartz. P=Plagioclase. F=Feldspar. C=Clay. (% Abundance)
M=Major. nM=Moderate. m=minor. mt=minor-trace.

Although the clay mineral content of the core was a small percentage of the total matrix, because of the large surface area and the high reactivity, the response of the sandstone core to the micellar/polymer process was probably significantly influenced by the reactions of the clays. Surfactants and polymer adsorb readily on clay surfaces; this combined with the ion exchange capacity of the clay minerals had a detrimental effect on the micellar/polymer process. Exchange of divalent ions between clay minerals and the micellar solution results in surfactant precipitation, loss of ultralow interfacial tension and eventually leads to deactivation of the micellar slug.

The polymer buffer was also influenced by the mineralogy and clay content of the sandstone core. Divalent ions reduce the viscosity of the polymer. This together with the adsorption of the anionic polyacrylamide on clay minerals leads to an increase polymer mobility and can eventually result in a loss of mobility control.

The results of the core floods indicate that conditioning of the Berea cores through the use of Na_2CO_3 and EDTA preflushes improved tertiary oil recovery. One factor which contributed to this increase in recovery was the removal of divalent cations present within the clays by the preflush solution,thus the micellar solution was protected from the harmful divalent ions.The mechanisms by which these preflushes reduce sulfonate losses and improve tertiary oil recovery will be discussed in subsequent sections.

5.4 GENERAL CHARACTERISTICS OF PRODUCTION HISTORY

The production histories of the core floods have some common features which can be described as follows.

1) Initially only brine was produced. During this time the oil/water bank was formed.

2) At bank breakthrough, both oil and water were

produced simultaneously with an oil cut generally between 40 and 60%. The fluctuations in oil cut were due to differences in phase behaviour of the fluid system, viscosity of fluids, flood advance rate,and properties of the porous media. The oil cut was at first more or less constant, then decreased gradually.

3) During the injection of the micellar and polymer slugs, there was a gradual increase of inlet pressures followed by a gradual decrease commencing at the injection of the drive water.

4) Most of the sulfonate recovered was in the oleic phase. This was due to the much higher solubility of Petrostep 465 in the oleic phase as compared to the aqueous phase.

5.5 EFFECT OF FRONTAL VELOCITY ON RECOVERY

Based on the results of core floods #4 to 9, a plot of recovery versus frontal velocity was made.(See Figure 16) Tertiary oil recovery increased up to a point then decreased with increasing velocity. This is in conflict with the results of other investigators but can be explained by considering the mobilities of the different fluids.

The mobility of the polymer buffer was estimated to be of the order 0.01 to 0.07$(mPa.S)^{-1}$ using equations derived by Christopher and Middleman (54).(See Appendix B).Assuming that the relative permeability of the micellar slug is one, then the mobility of the slug is the reciprocal of the

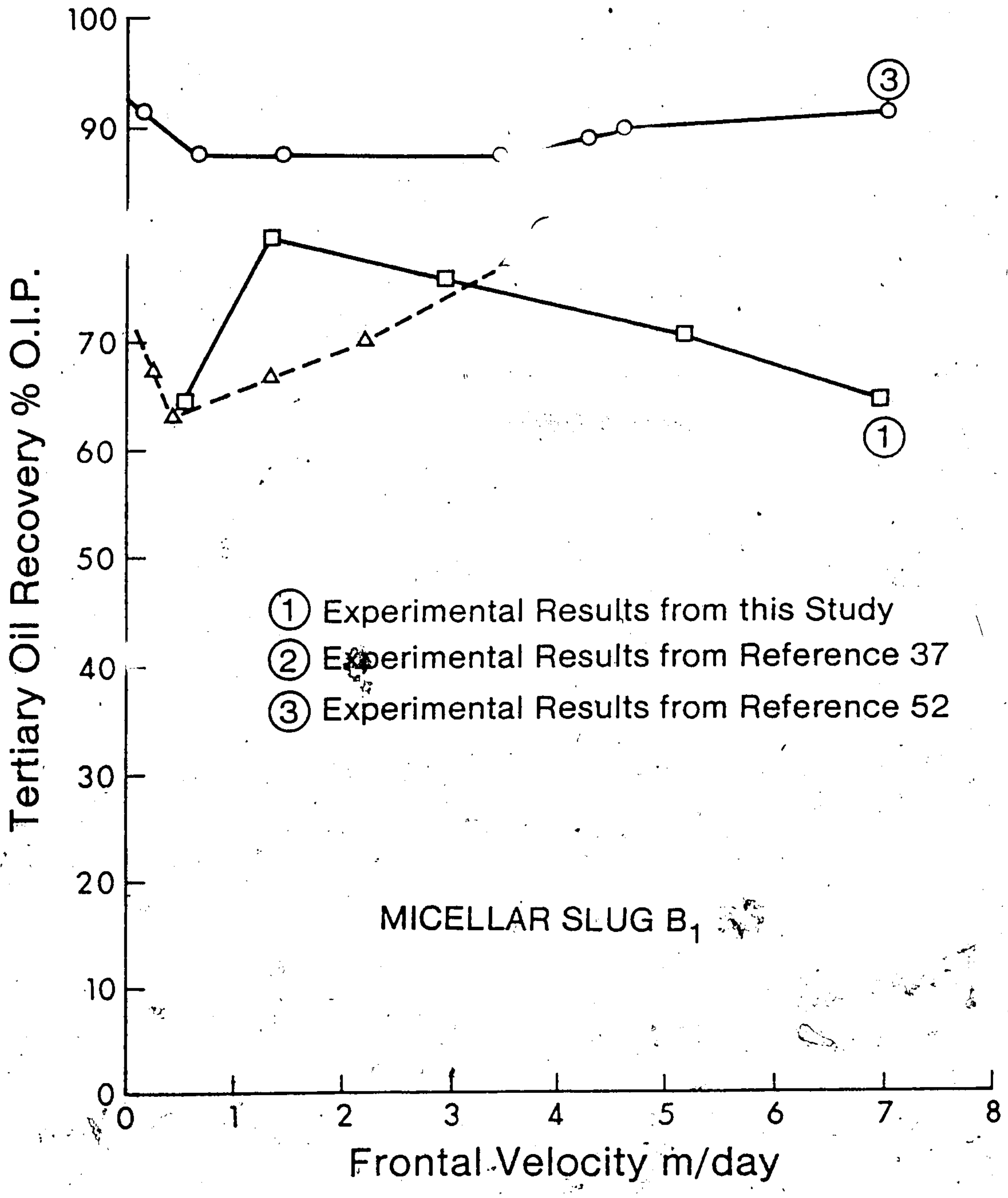


Fig.16 Tertiary Oil Recovery Versus Frontal Velocity

viscosity or 0.003 (mPa.S)$^{-1}$. Thus the mobility of the polymer buffer was greater than that of the micellar slug. This resulted in the polymer solution fingering through the micellar slug.

Another factor which contributed to this unfavourable mobility ratio is related to the size of polymer molecules. Quite often polymer molecules are larger than the diameter of the pores so that the accessible pore volume to the polymer buffer is less than that for the micellar slug. This results in the polymer solution propagating through the core faster than the micellar slug. This problem was compounded by the fact that the polymer for the first twelve core floods was not filtered, so that any unhydrated polymer molecules or large aggregates could well have plugged pore throats within the core.

The following steps were taken to improve mobility control;

1) Viscosity of the micellar slug was reduced.

2) The size and concentration of the polymer buffer were increased from 25% PV, 250 PPM to 50% PV a[illegible] a concentration of 500 PPM.

3) All polymer solutions were filtered using Whatman #1 filter paper. Because of the slow filtration rate of the polymer, air pressure of 5 - 8 psi was applied. The filtration pressure was chosen so that the rheological behaviour of the polymer before and after filtration were similar.

4) Frontal velocities were reduced to values comparable to field injection rates.

5.6 EFFECT OF MICELLAR SLUG SIZE ON RECOVERY

Based on core floods #7 and 11 exclusive of core flood #8, increasing micellar slug size from 5.0 to 10.0% pore volume increased oil recovery from 76.8 to 80.4% of the oil in place. This is to be expected since the larger slug has more sulfonate, and as a result it can solubilize more oil and water before it phase separates and can travel greater distances within the core before slug deactivation takes place. This is in agreement with the results of other investigators(3,22,23,27).

5.7 EFFECT OF 1% BY WEIGHT SODIUM CARBONATE PREFLUSH ON RECOVERY

Five core floods were conducted with a view to evaluating the effectiveness of sodium carbonate as a preflush. Coreflood #15 was conducted using micellar slug B_3 without a preflush; recovery was 67.8% of the oil in place, whereas 25% and 50% pore volume of 1% by weight sodium carbonate resulted in recoveries of 72.9% and 98.9% of the oil in place, respectively. Analysis of the effluent samples revealed that sulfonate recovery increased with preflush size, 81% of the sulfonate injected was recovered using a 50% pore volume preflush. Thus sodium carbonate was an effective preflush. (See Figure 17)

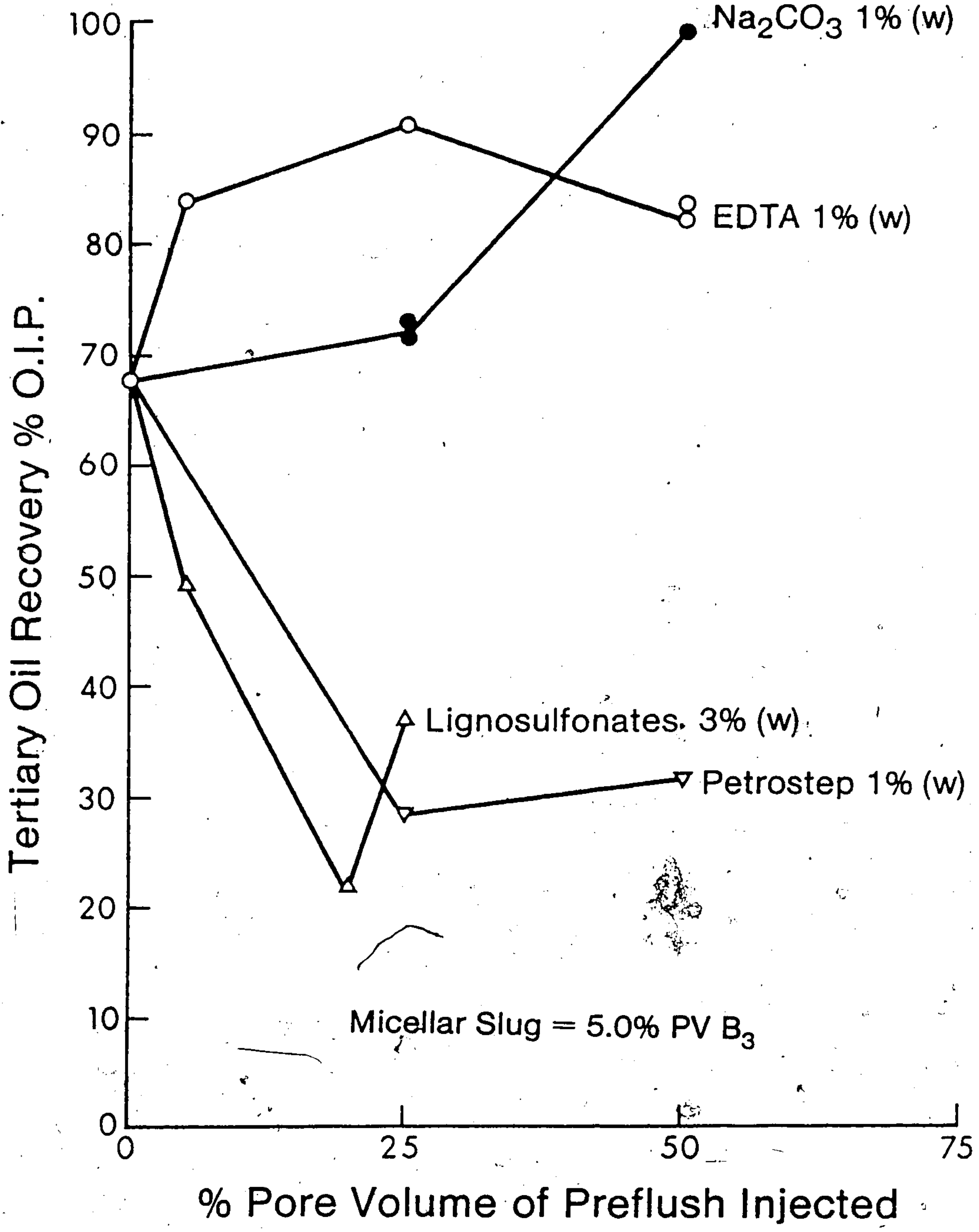


Fig.17 Effect of various Preflushes on Tertiary Oil Recovery.

High pH chemicals when injected as preflushes affect various rock and fluid parameters, such as interfacial tension, microemulsion stability, rock wettability, hardness ion reduction, surfactant adsorption and ion exchange capacity. For the particular system under study the two most important mechanisms by which sodium carbonate improved recovery were reduction of the interfacial tension between oil and water and the removal of divalent ions.

Another factor that might be responsible for the improved recovery is related to the attractive forces between the anionic surfactant and the porous media. Adsorption is due to the electrostatic attraction between the charged mineral surfaces and the charged surfactant species. The generation of a surface charge on the mineral particles is thought to be due to hydrolysis of surface species followed by pH dependent dissociation of surface hydroxyl groups. The following equation represents these reactions,

$$-M(H_2O)^+_{surface} \underset{H^+}{\rightleftharpoons} -MOH_{surface} \overset{OH^-}{\rightleftharpoons} -MO^-_{surface} + H_2O$$

From the above equation it can be seen that increasing the pH causes the mineral surface to be more negatively charged, thus adsorption between the anionic surfactant and the mineral surfaces is reduced. Somasundaran and Hanna(56) measured the effect of pH on adsorption of dodecylsulfonate on kaolinite. They observed a decrease in adsorption with increasing pH as shown in Figure 18 .

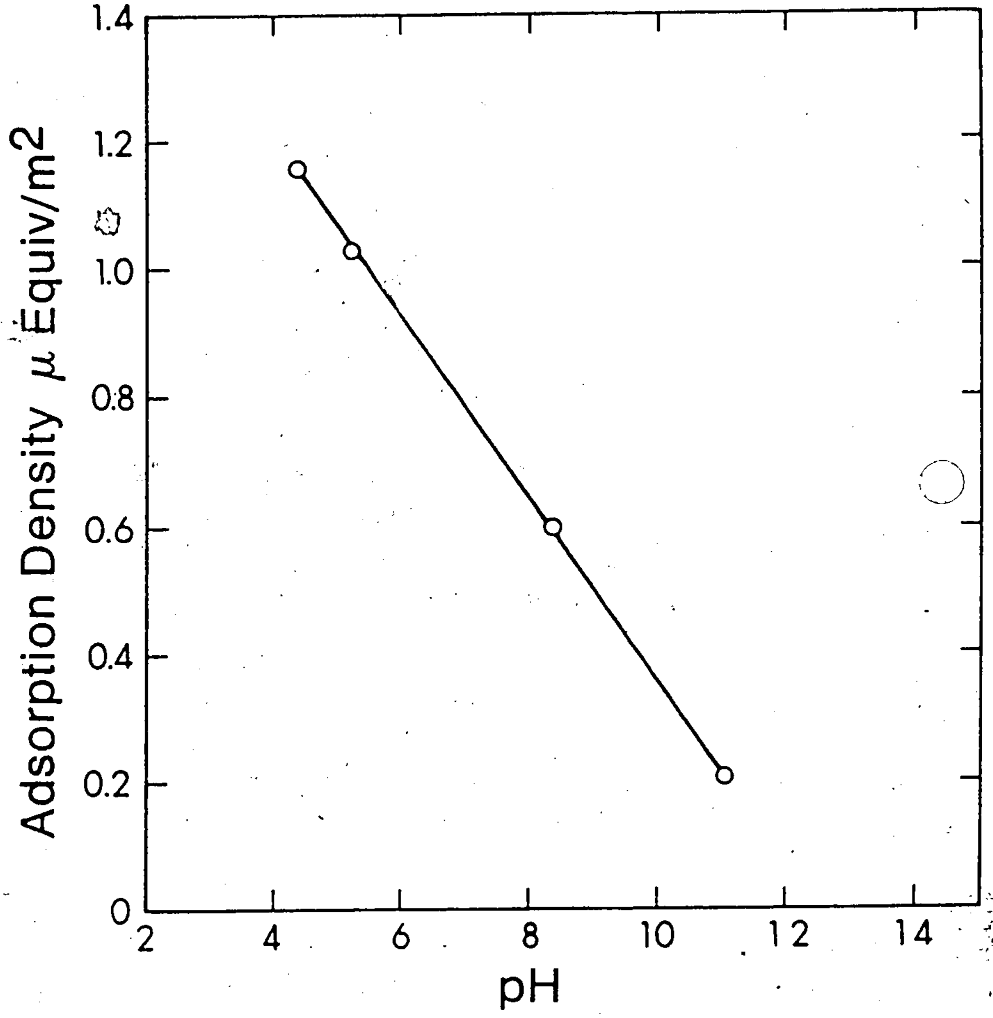


Fig.18 Effect of pH on the adsorption of Dodecylsulfonate in 10^{-2} M KNO_3 on Kaolinite (adapted from reference 56).

Although there are various mechanisms by which surfactants are lost as described in section 2.8, for the purposes of this study all surfactant losses are attributed to adsorption and surfactant precipitation since it is impossible to distinguish between these mechanisms.

5.8 EFFECT OF 1% BY WEIGHT METSO 200 PREFLUSH ON RECOVERY

Coreflood #16 was conducted using a 1%(w), 25% pore volume Metso 200 ($Na_2O/SiO_2=2.0$) preflush. It is, generally believed that the effectiveness of alkaline chemical in conditioning reservoirs can be ranked as phosphates > silicates > hydroxide > carbonate. Coreflood #16 was conducted with a view to comparing the effectiveness of sodium carbonate and sodium orthosilicate preflushes.

Recovery from this run was only 25.6% of the oil in place. Inlet presssures increased to about 700 psi indicating severe plugging. This plugged condition was probably due to the formation of precipitates by the reactions between the divalent ions and the silicate ions. Another possibility was the formation of highly complex silicate structures. These structure can then crosslink and form gels resulting in a plugged core. The hydrolysis of the monosilicate anion in water to form more complex species is shown by the following equations.

$SiO_4^{-4} + 2H_2O = SiO_2(OH)_2^{-2} + 2OH^-$

$2SiO_2(OH)_2^{-2} + H_2O = Si_2O_3(OH)_4^{-2} + 2OH^-$

$Si_2O_3(OH)_4^{-2} + SiO_2(OH)_2^{-2} + H_2O = Si_3O_4(OH)_6^{-2} + 2OH^-$

$2Si_2O_3(OH)_4^{-2} = Si_4O_6(OH)_6^{-2} + 2OH^-$

In the published literature reviewed, no investigator encountered plugging problems through the use of silicate solutions, but Holm et el (49) found that silicate solutions reduced permeability 65% to 75% of the original permeability.

5.9 EFFECT OF LIGNOSULFONATE PREFLUSH ON RECOVERY

Interfacial tension between Bonnie Glen Crude and various concentration lignosulfonate solutions was measured using a Du Nuoy Tensiometer. Figure 19 shows interfacial tension decreasing with increasing lignosulfonate concentration. Further increases in concentration result in increasing interfacial tension. Minimum interfacial tension was observed between 2 and 3.5% by weight lignosulfonate concentration. Based on the above, it was decided to evaluate the effectiveness of a 3% by weight lignosulfonate solution as a preflush.

Three core floods were conducted to evaluate the performance of lignosulfonate as a preflush. Corefloods #19 and 20 were conducted with 25% PV and 5% PV 3% by weight lignosulfonate solutions respectively. Recovery for the 5% PV slug was 49% of the oil on place while that for the 25% PV slug was only 22% of the oil place. Sulfonate recovery for both floods was only about 10% of that injected. The results of these two floods suggest that some mechanism other than sacrificial adsorption of the lignosulfonate was

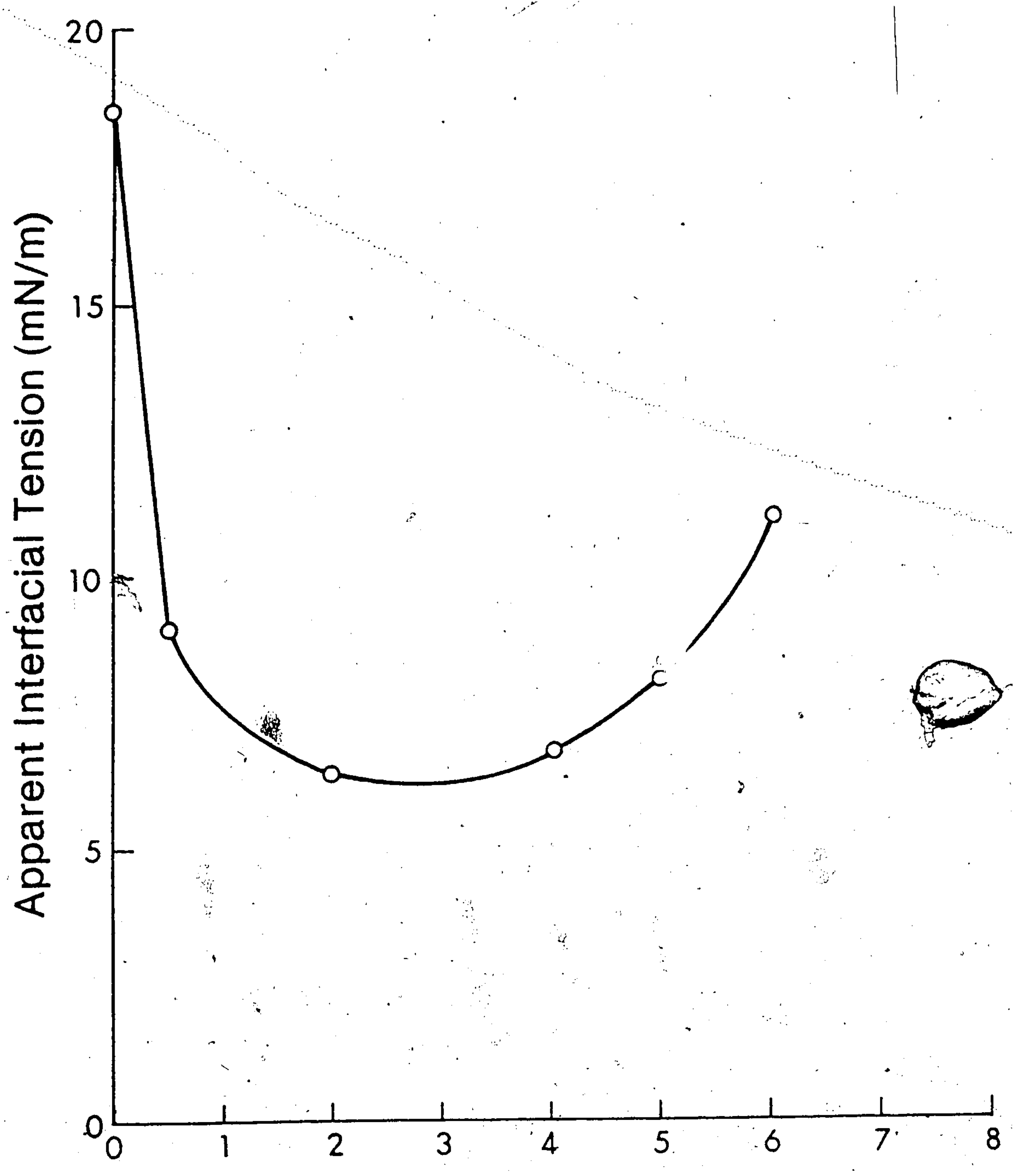


Fig.19 Apparent Interfacial Tension Between Bonnie Glen Crude and Various Concentrations Lignosulfonate Solution.

dominant. Coreflood #21 was designed to minimize micellar/preflush interaction: 20% PV of 3% by weight lignosulfonate solution was injected followed by 2% by weight brine until no lignosulfonate was in the effluent. At this stage the only lignosulfonate in the core was that adsorbed irreversibly on the porous medium. The micellar flood was then started,tertiary oil recovery was only 22% of the oil in place as compared to 67.8% from run #15 where no preflush was used.

A possible explanation for the decrease in recovery with lignosulfonate preflushes is a change in wettability(water-wet to oil-wet). Novasad et al (53) in a recent publication found that lignosulfonate preflushes decreased oil recovery although surfactant retention decreased. In this study both tertiary oil recovery and surfactant recovery decreased.

5.10 EFFECT OF 1% BY WEIGHT PETROSTEP 465 PREFLUSH ON RECOVERY

Corefloods #22 and 23 were conducted with a view to evaluating the performance of an aqueous solution containing 1% by weight Petrostep 465 as a preflush. Tertiary oil recovery was only 28.6% and 31.7% of the oil in place, respectively. Inlet pressures were three to four times higher than normal indicating a plugging problem. The results of these two runs indicate that aqueous solutions of the surfactant were not effective preflushes and can often lead to plugged cores.

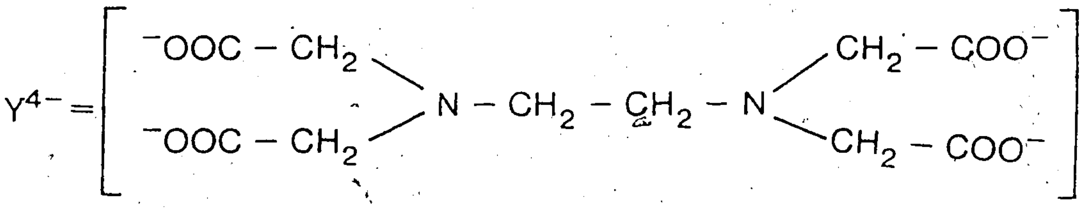
The high inlet pressures observed in runs #22 and 23 were first thought to be due to the formation of insoluble precipitates as a result of micellar/preflush interaction. Various proportions of the two fluids were mixed to explore the formation of precipitates but surprisingly this was not observed. An unused core was then evacuated and saturated with the preflush. While flowing the preflush through the core, inlet pressures rose rapidly to 650 psi. At this stage the only fluid in the core was the aqueous solution of the sulfonate , since no swelling clays were present, it was concluded that precipitation of the sulfonate from the aqueous preflush plugged the core. Further investigations revealed that the divalent ions within the core precipitated the sulfonate. Meister et al (55) found that the calcium ion tolerance of petroleum sulfonate decreased logarithmically as the average equivalent weight of the sulfonate increased. Thus Petrostep 465 with its fairly high equivalent weight of 465 has a low tolerance to multivalent cations.

5.11 EFFECT OF 1% BY WEIGHT EDTA PREFLUSH ON RECOVERY

Corefloods #25 to 30 were conducted with a view to evaluating the performance of chelating agents such as the sodium salt of ethylenediamineteraacetic acid (EDTA) as a preflush.

Corefloods #25 to 29 were conducted using a 1% by weight EDTA preflush having a pH of 5.0. Recoveries for these four runs ranged from 82% to 90% of the oil in place as compared to 67.8% where no preflush was used. Figure 17 reveals the existence of an optimum preflush size.

Chelating agents improve oil recovery by forming stable complexes with the multivalent cations present within the porous media . The equilibrium constant for the formation of EDTA/metal ion complexes are about 10^4 times greater than that for the formation of metal ions/sulfonate complexes. The formation of complexes with metal ions is shown by the following equations.



Metal Cations = m^{n+}

$$Y^{4-} + m^{2+} = MY^{2-}$$
$$Y^{4-} + m^{3+} = MY^{-}$$
$$Y^{4-} + m^{4+} = MY$$

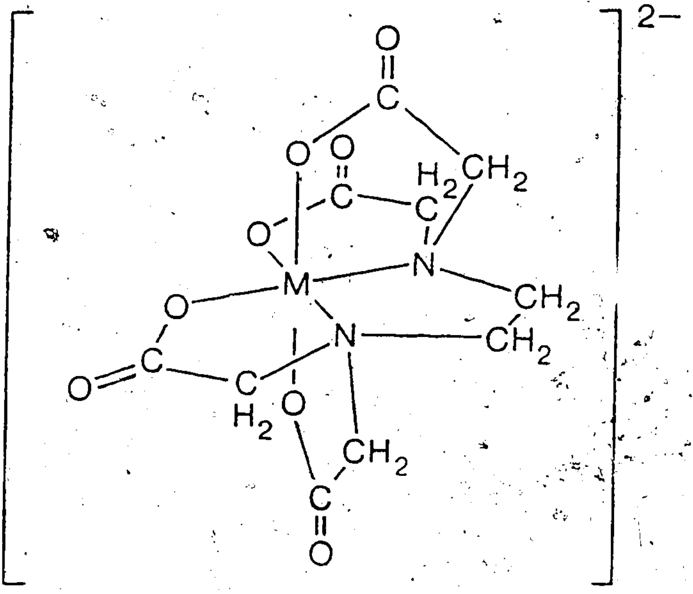


Fig.20Structure of Metal-EDTA Complex

All cations with the exception of the alkali metals react with EDTA to form stable complexes. The stability of the complexes is due to complexing groups within the molecule surrounding, and isolating the cation as shown in Figure 20.

Although tertiary oil recovery was significantly greater for floods #25 to 30 as compared to core flood #15, total sulfonate recovery was not significantly greater except for core flood #26. This inconsitency in results is thought to be due to inaccuracies in determining sulfonate content of the aqueous phase.By ignoring the sulfonate content of the aqueous phase , it was found that sulfonate recovery in the oleic phase increased with tertiary oil recovery and in all cases was greater than that recovered where no preflush was used. (See Figure 15). The ratio of tertiary oil recovery (PV) to sulfonate injected was of the order of 36 for micellar slug B_3 with an EDTA preflush, as compared to 29 without a preflush, 17.6 for slug B_2 and 16.6 for micellar slug B_1.

The pH of the EDTA preflush used in core flood #30 was adjusted to 11.3 using sodium hydroxide. Comparison of the results of core floods #27 and 30 reveal that high pH EDTA preflushes were more effective. The main reason for the increase in recovery with pH is that the extent of complex formation is dependent upon the pH of the enviroment, with high pH favouring the formation of complexes. Other mechanisms which contributed to this increase in recovery with pH are described in Section 5.6 . Holm et al.(49) also found that adjusting the pH of the EDTA preflush improved tertiary oil recovery.

5 EFFECT OF CORE LENGTH ON RECOVERY

Comparison of the results of core floods #27 and 29 reveal that tertiary oil recovery increased with an increase in core length. Coreflood #29 was identical to core flood #27 except a longer core was used, differences in recovery was about 4%. This difference can be related to the differences in length of the transition zone and was not believed to be due to experimental error.

In the case of miscible displacement it can be shown theoretically that the length of the transition zone increases as the square root of the core length i.e. the pore volume of the transition zone in terms of total pore volume for a long core is less than that of a short core. Thus, this observed increase in recovery with length may be due to the displacement being initially miscible. Farouq Ali et al.(57) observed increased recovery with increased system length for alcohol flooding.They concluded that the decrease in length of the the transition zone was due to viscous fingers being dissipated or suppressed in longer cores as result of diffusion and microscopic dispersion. Another factor which may have been responsible for this increase in recovery was contact times.Longer contact times between the resident fluids and the micellar solution enabled greater mixing of the fluids,hence an increased likelihood of compositional equilibrium being reached.

In the literature reviewed several researchers(5,48) have found micellar displacement to be initially miscible but as the slug propagates through the reservoir, mixing and surfactant losses cause slug breakdown, hence displacement reverts to immiscible type displacement.

5.13 REPRODUCIBILITY OF EXPERIMENTAL RESULTS

Pore volumes of cores #3 to 7 were measured by three different methods as described in section 4.5.(See page 29).The results show that the pore volume as measured by the different methods were within 4%. Pore volumes of cores #8 to 30 were measured by the vacuum method and double checked by miscible displacement if necessary.

TABLE : 9

COMPARISON OF PORE VOLUME MEASUREMENTS

CORE NO	PORE VOL. SUCTION (mls)	PORE VOL. FAV. MISC. (mls) DISP.	PORE VOL. UNF. MISC. (mls) DISP.
3	295	300	300
4	285	285	287
5	282	291	288
6	276	280	284
7	262	250	250

All fluid properties were accurate with in ± 1%. Reproducibility of the core floods was good within ±3% as indicated by Table 10.

TABLE : 10

REPEATABILITY OF COREFLOODS

CORE NO	RECOVERY % OIP	% SULFONATE RECOVERED	REMARKS
17	72.9	48.0	17 and 18 conducted under identical conditions
18	71.4	47.8	
25	82.0	38.3	25 and 28 conducted under identical conditions
28	83.3	39.3	

6. CONCLUSIONS

Based on the experimental work completed the following conclusions can be drawn.

1. All micellar slugs evaluated were capable of recovering at least 65% of the tertiary oil in place. Micellar slug B_3 (Petrostep 465-15%, Oil-45%, D. Water-37.5%, IPA-1.5%, NBA-1.0%) was the most efficient slug in terms of tertiary oil recovery per gram of sulfonate injected.

2. Increasing micellar slug size increased tertiary oil recovery over the range investigated.

3. The presence of cosurfactants such as n-butyl alcohol and iso propyl alcohol in the micellar slug reduced sulfonate loss.

4. One percent by weight sodium carbonate solutions were effective preflushes. Tertiary oil recovery increased with increasing preflush size. Increased oil recovery was due to the decrease in oil/water interfacial tension and a reduction of sulfonate losses .

5. Solutions of ethylenediaminetetracetic acid(EDTA) were effective preflushes. In small pore volumes EDTA was found to be the most effective preflush. For a given size preflush, adjusting the pH to 11.3 resulted in a further increase in oil recovery.

6. Aqueous solutions of Petrostep 465 were poor preflushes and resulted in plugged cores.

7. Lignosulfonate preflushes decreased tertiary oil recovery. The exact mechanism or mechanisms which resulted

in this decrease in tertiary oil recovery was not determined but it has been postulated that it was due to changes in wettability of the Berea cores.

8. For the system studied, micellar displacement was initially miscible, but as the slug propagated through the core, mixing and surfactant loss resulted in the process reverting to immiscible type displacement.

7. RECOMMENDATIONS

1. Alternate micellar slug compositions should be evaluated with a view of comparing the effectiveness of low concentration surfactant slugs.

2. Phase behaviour studies should be conducted incorporating preflush chemicals such as sodium carbonate and EDTA in the micellar slug. Based on these studies, micellar slugs should be chosen and evaluated by conducting core floods. The results should then be compared to the results of this study.

[illegible] accurate techniques such as liquid chromatography [illegible] be used to determine sulfonate content of the effluent samples.

4. Floods should be conducted at reservoir temperatures to determine the influence of increased temperature on phase behaviour, adsorption and tertiary oil recovery.

5. Floods should be conducted using scaled models so that the micellar/polymer process is more representative of that occuring within the reservoir.

8. NOMENCLATURE

EDTA - Sodium Salt of ethylenediaminetetracetic acid

K - absolute permeability μm^2

n - power law index

OIP - oil in place

P - pressure kPa

PV - pore volume

So - initial oil saturation %

Sor - residual oil saturation %

V - frontal velocity m/d or ft/d

ϕ - porosity %

$\dot{\gamma}$ - shear rate Sec^{-1}

μ - viscosity mPa.s

λ - mobility of buffer

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APPENDIX A : Determination of Sulfonate Content in effluent Samples

DETERMINATION OF SUlFONATE CONTENT IN EFFLUENT SAMPLES

Determination of Calibration Curve

a) A calibration curve was prepared by mixing -several solutions with known volumes of Bonnie Glen Crude and the micellar solution.

b) An equal volume of 50% by weight calcium chloride was added to each of the samples.

c) Approximately 1ml of the dewatered oleic phase was withdrawn and analysed using the Perkin Elmer 683 Infrared Spectrophotometer. Petrostep 465 absorbed infrared radiation at 1176 Cm^{-1} and at 1056 Cm^{-1}.

d) The absorbance of each of the samples was measured.

e) The calibration curve was obtained by plotting absorbance versus concentration of sulfonate in the sample.(See Figures 9 & 11)

The calibration curve for Petrostep 465 in toluene was prepared in a similar manner as outlined above, except sulfonate solutions of different concentrations in toluene were used.(See Figure 11).

Analysis of Effluent Samples

The volume of the aqueous and oleic phases for all effluent samples collected during the core floods were recorded. Each of the samples were analysed using infrared spectroscopy as described in section 4.7 (See page 35)

Sample Calculation

Coreflood # 29

Sample # 15

Aqueous Phase Volume = 20.0 mls

Oleic phase Volume = 11.5 mls

Oleic phase pipetted = 2.0 mls

Volume of dewatered oleic phase = 1.9

Infrared absorbance as measured = 33/3 x 1/100 = 0.11

From Figure 10, %Sulfonate in dewatered phase = 2.5

Volume of Sulfonate in dewatered phase = 0.0475 mls

Percent sulfonate in oleic phase pipetted = 2.375%

Volume of Sulfonate in oleic phase = 0.273

Percent Sulfonate in effluent = 0.87%

APPENDIX B : CALCULATION OF RESERVOIR SHEAR RATES

Christopher and Midelleman (53) developed equations for predicting the mobility of polymer buffers from viscosity measurements. They assumed parallel capillary geometry for the porous media so that values obtained are only approximate. The "capillery model" was used to develop a modified Blake-Kozeny equation applicable to laminar flow of non-newtonian fluids through porous media. They also assumed that the power law represents the rheological behaviour of the fluid.

Reservoir Shear Rate

$$\gamma = [\ 3V(3+1/n)\ ]\ /\ [\ (150k\phi)^{0.5}\ ]\ .....(1)$$

$$\mu = k\gamma^{n-1}..............................(2)$$

where n = Power law index

k = Constant

ϕ = Porosity

V = Frontal Velocity,ft/d

γ = Reservoir Shear Rate,Sec^{-1}

μ = Viscosity,mPa.S

Mobility of 250 PPM Buffer

$$\lambda = K/k\ [\ \{3V(3+1/n)\}/\{150k\phi\}^{0.5}]^{1-n}\ .....(3)$$

where K = Average Permeability,md

λ = Mobility of Polymer

Substituting into equation (3)

n = 0.45 from Figure 6

k = 110 from Figure 6

K = 0.68 md from Table 9

ϕ = 0.23 from Table 9

$$\lambda = (0.68/110)[\ \{3V(3+1/0.45)\}/\{(150x110x0.23\}^{0.5}\ ]^{1-0.45}$$

$$\lambda = 0.00618\ x\ (0.2516)^{0.55}\ x\ V\ ......(4)$$

Thus the mobility of the buffer at any frontal velocity can be estimated.

APPENDIX C : Production History of the Core Floods

Tables Describing the Production History of Core Floods are Detailed in this Appendix

TABLE : 13
PRODUCTION HISTORY OF COREFLOOD # 1

LENGTH ------------------ 61cm

CROSS SECTIONAL AREA ---19.635 cm^2

POROSITY --------------- 25.3%

PERMEABILITY ----------- 684 md/0.693 UM^2

INITIAL OIL SATURATION -- 29.5%

% SULFONATE RECOVERED -- 5.2 %

PREFLUSH -----------25.0% P.V, 0.5% (w) BRINE

MICELLAR SLUG -------- 5.0% P.V B_1

BUFFER -------------- 50% P.V 250 P.P.M

FRONTAL VELOCITY --- 7.73M/DAY

TERTIARY OIL RECOVERY -76.5% OIP

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	50	48	2.0	-	2.0	4.0	2.0	2.2	0.17
2	50	28	22.0	-	22.0	44.0	24.0	26.78	0.33
3	50	31	19.0	-	19.0	62.0	43.0	48.01	0.46
4	50	38	12.0	-	12.0	24.0	55.0	61.42	0.66
5	50	43	7.0	-	7.0	14.0	62.0	69.24	0.83
6	50	47	3.0	-	3.0	6.0	65.0	72.59	0.99
7	50	48	2.0	-	2.0	4.0	66.5	74.82	1.16
8	50	48.5	1.5	-	1.5	3.0	66.5	76.5	1.32
9	30	30	0.0	-	0.0	0.0	66.5	76.5	1.42

TABLE 14
PRODUCTION HISTORY OF COREFLOOD # 2

LENGTH ------------------ 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 23.0 %

PERMEABILITY ------------ 642 md/0.650 UM^2

INITIAL OIL SATURATION -- 34.2% P.V

PREFLUSH ---- ---------- 25.0% P.V. 0.5%(w)

BRINE

MICELLAR SLUG ---------- 20.0% P.V B$_1$

BUFFER -------------- 50% P.V 250 P.P.M

FRONTAL VELOCITY ------- 8.08 M/DAY

TERTIARY OIL RECOVERY -- 71.0% OIP

% SULFONATE RECOVERED -- 6.4%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	15	15.0	0.0	-	0.0	0.0	0.0	0.0	0.03
2	15	15.0	0.0	-	0.0	0.0	0.0	0.0	0.07
3	15	15.0	0.0	-	0.0	0.0	0.0	0.0	0.13
4	15	15.0	0.0	-	0.0	0.0	0.0	0.0	0.18
5	15	15.0	0.0	-	0.0	0.0	0.0	0.0	0.23
6	15	15.0	0.0	-	0.0	0.0	0.0	0.0	0.28
7	15	10.5	4.5	-	4.5	30.0	4.5	4.53	0.33
8	15	6.0	9.0	-	9.0	60.0	13.5	13.59	0.38
9	15	6.5	8.5	-	8.5	56.67	22.0	22.15	0.44
10	15	6.5	8.5	-	8.5	56.67	30.5	30.71	0.49
11	15	7.5	7.5	-	7.5	56.00	38.0	38.26	0.54
12	15	11.0	7.0	-	7.0	46.67	45.0	45.31	0.66
13	16	9.0	7.0	-	7.0	43.75	52.0	52.36	0.60
14	21	15.0	6.0	-	6.0	28.57	58.0	58.40	0.73
15	15	12.0	3.0	-	3.0	20.00	61.0	61.42	0.78
16	15	12.0	3.0	-	3.0	20.00	64.0	64.44	0.83

TABLE 15
PRODUCTION HISTORY OF COREFLOOD # 3

LENGTH ----------------- 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 25.0%

PERMEABILITY ------------ 676 md/0.667 um^2

INITIAL OIL SATURATION -- 29.3% P.V

PREFLUSH ---- ---------- NONE

MICELLAR SLUG ---------- 100% P.V (CONTINUOUS)

BUFFER ------ ---------- NONE

FRONTAL VELOCITY ------- 9.98M/DAY

TERTIARY OIL RECOVERY -- 100% OIP

% SULFONATE RECOVERED -- NOT MEASURED

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	20.0	20.0	0.0	-	0.0	0.0	0.0	0.0	0.17
2	21.0	21.0	0.0	-	0.0	0.0	0.0	0.0	0.24
3	32.0	32.0	0.0	-	0.0	0.0	0.0	0.0	0.30
4	21.0	11.0	10.0	-	10.0	47.6	10.0	11.4	0.42
5	20.0	11.0	9.0	-	9.0	42.9	19.0	21.6	0.46
6	22.0	10.0	12.0	-	12.0	54.5	31.0	35.2	0.53
7	20.0	12.0	10.0	-	10.0	50.0	41.0	46.6	0.60
8	20.0	10.0	10.0	-	10.0	50.0	51.0	58.0	0.65
9	20.0	10.0	10.0	-	10.0	50.0	61.0	69.3	0.73
10	20.0	10.0	10.0	-	10.0	50.0	71.0	80.7	0.79
11	20.0	10.0	10.0	-	10.0	50.0	81.0	92.0	0.87
12	20.0	10.0	10.0	-	7.0	50.0	88.0	100.0	0.94
13	20.0	10.0	M.S	0.0	0.0	0.0	88.0	100.0	1.01

TABLE 16
PRODUCTION HISTORY OF COREFLOOD # 4

LENGTH ------------------ 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 23.8%

PERMEABILITY ------------ 665 md/0.656 um^2

INITIAL OIL SATURATION -- 31.0% P.V

PREFLUSH ---- ---------- NONE

MICELLAR SLUG ---------- 5.2% P.V B_3

BUFFER ------ ---------- 50% P.V 250 P.P.M

FRONTAL VELOCITY ------- 5.14 M/DAY

TERTIARY OIL RECOVERY -- 70.7% OIP

% SULFONATE RECOVERED -- 0.6%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	20.0	20.0	0	-	0.0	0.0	0.0	0.0	0.07
2	20.0	20.0	0	-	0.0	0.0	0.0	0.0	0.14
3	21.0	21.0	0	-	0.0	0.0	0.0	0.0	0.21
4	20.0	16.8	3.2	-	3.2	16.0	3.2	3.3	0.28
5	20.0	11.7	8.3	-	8.3	41.5	11.5	11.8	0.35
6	21.0	12.0	9.0	-	9.0	45.0	20.5	21.1	0.42
7	7.8	3.3	4.5	-	4.5	58.0	25.0	25.7	0.45
8	20.0	12.0	8.0	-	8.0	40.0	33.0	33.9	0.52
9	21.0	14.5	6.5	-	6.5	31.0	39.5	40.7	0.60
10	20.0	13.2	6.8	-	6.8	34.0	46.3	47.6	0.67
11	20.0	15.2	4.8	-	4.8	24.0	51.1	52.6	0.74
12	20.0	16.2	3.8	-	3.8	19.0	54.9	56.5	0.81
13	21.0	18.0	3.0	-	3.0	15.0	57.9	59.6	0.89
14	20.0	17.9	2.1	-	2.1	10.5	60.0	61.7	0.96
15	22.0	20.2	1.8	-	1.8	8.2	61.8	63.6	1.03
16	20.0	18.2	1.8	-	1.8	8.2	63.6	65.4	1.10
17	20.0	18.7	1.3	-	1.3	6.5	64.9	66.8	1.17
18	25.0	23.2	1.8	-	1.8	7.2	66.7	68.6	1.26
19	20.0	19.0	1.0	-	1.0	5.0	67.7	69.6	1.33
20	21.0	20.0	1.0	-	1.0	5.0	68.7	70.7	1.40
21	30.0	30.0	0.0	-	0.0	0.0	68.7	70.7	1.51

TABLE 17
PRODUCTION HISTORY OF COREFLOOD # 5

LENGTH ------------------- 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm²

POROSITY ---------------- 24.3%

PERMEABILITY ------------ 758 md/0.748 um²

INITIAL OIL SATURATION -- 26.8% P.V

PREFLUSH ---- ---------- NONE

MICELLAR SLUG ---------- 5.0% P.V B₁

BUFFER ------ ---------- 25% P.V 250 P.P.M

FRONTAL VELOCITY ------- 4.02 M/DAY

TERTIARY OIL RECOVERY -- 95.4% OIP

% SULFONATE RECOVERED -- 4.3%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	40.0	40.0	0.0	-	0.0	0.0	0.0	0.0	0.14
2	29.0	29.0	0.0	-	0.0	0.0	0.0	0.0	0.24
3	16.2	11.7	4.5	-	4.5	27.8	4.5	5.2	0.29
4	22.7	12.8	9.9	-	9.9	43.6	14.4	16.7	0.37
5	30.0	16.9	13.1	-	13.1	42.7	27.5	32.0	0.47
6	33.8	19.3	14.5	-	14.5	42.9	42.0	48.8	0.59
7	34.0	11.5	12.5	-	12.5	36.8	54.5	63.4	0.71
8	33.0	23.0	10.0	-	10.0	30.3	64.5	75.0	0.82
9	33.0	26.1	6.9	-	6.9	20.9	71.4	83.0	0.93
10	32.5	27.8	4.7	-	4.7	14.5	76.1	88.5	1.04
11	32.0	29.5	2.5	-	2.5	7.8	78.6	91.4	1.15
12	32.0	29.5	2.5	-	2.5	7.6	81.1	94.3	1.27
13	33.0	32.5	0.5	-	0.5	3.1	82.1	95.4	1.38
14	20.0	20.0	0.0	-	0.0	0.0	82.1	95.4	1.44

TABLE 18
PRODUCTION HISTORY OF COREFLOOD # 6

LENGTH ------------------ 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 23.4%

PERMEABILITY ------------ 723 md/0.713 um^2

INITIAL OIL SATURATION -- 29.6% P.V

PREFLUSH ---- ---------- NONE

MICELLAR SLUG ---------- 5.0% P.V B,

BUFFER ------ ---------- 25% P.V 250 P.P.M

FRONTAL VELOCITY ------- 1.31 M/DAY

TERTIARY OIL RECOVERY -- 79.5% OIP

% SULFONATE RECOVERED -- 6.2%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	12.0	12.0	0.0	-	0.0	0.0	0.0	0.0	0.04
2	29.0	29.0	0.0	-	0.0	0.0	0.0	0.0	0.15
3	23.0	23.0	0.0	-	0.0	0.0	0.0	0.0	0.23
4	26.8	21.0	5.8	-	5.8	21.6	5.8	6.4	0.32
5	35.0	21.0	14.0	-	14.0	40.0	19.8	21.8	0.45
6	35.0	21.4	13.6	-	13.6	38.8	33.4	36.8	0.57
7	35.5	23.0	12.5	-	12.5	37.3	45.9	50.6	0.69
8	33.5	26.0	7.5	-	7.5	22.3	53.4	58.9	0.81
9	34.0	28.0	6.0	-	6.0	17.6	59.4	65.5	0.94
10	34.1	31.0	3.1	-	3.1	9.1	62.5	68.9	1.06
11	33.0	30.8	2.2	-	2.2	6.7	64.7	71.3	1.17
12	34.9	32.4	2.5	-	2.5	7.2	67.2	74.1	1.30
13	33.0	31.2	1.8	-	1.8	5.5	69.0	76.1	1.42
14	34.0	32.4	1.6	-	1.6	4.7	70.6	77.8	1.54
15	33.5	32.0	1.5	-	1.5	4.5	72.1	79.5	1.66
16	34.0	34.0	0.0	-	0.0	0.0	72.1	79.5	1.76

TABLE 19
PRODUCTION HISTORY OF COREFLOOD # 7

LENGTH ------------------ 61 cm
CROSS SECTIONAL AREA ---- 19.635 cm²
POROSITY ---------------- 20.9%
PERMEABILITY ------------ 665 md/0.656 um²
INITIAL OIL SATURATION -- 27.2% P.V

PREFLUSH ---- ---------- NONE
MICELLAR SLUG ---------- 5.0% P.V B_1
BUFFER ------ --------- 25% P.V 250 P.P.M
FRONTAL VELOCITY ------- 2.92 M/DAY
TERTIARY OIL RECOVERY -- 76.8% OIP
% SULFONATE RECOVERED -- 5.3%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	24.0	24.0	0.0	-	0.0	0.0	0.0	0.0	0.10
2	27.0	27.0	0.0	-	0.0	0.0	0.0	0.0	0.20
3	30.8	25.0	5.8	-	5.8	18.8	5.8	7.7	0.33
4	32.0	19.0	13.0	-	13.0	40.6	18.8	25.1	0.45
5	34.0	21.0	13.0	-	13.0	38.2	31.8	42.5	0.59
6	30.1	21.0	9.1	-	9.1	30.3	40.9	54.6	0.71
7	30.5	22.0	8.5	-	8.5	27.0	49.4	66.0	0.84
8	35.0	24.7	5.3	-	5.3	15.1	54.7	73.0	0.97
9	33.0	30.2	2.8	-	2.8	8.5	57.5	76.8	1.10
10	26.0	26.0	0.0	-	0.0	0.0	57.5	76.8	1.20

TABLE 20
PRODUCTION HISTORY OF COREFLOOD # 8

LENGTH ------------------ 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 21.7%

PERMEABILITY ------------ 575 md/0.567 um^2

INITIAL OIL SATURATION -- 64.6% P.V

PREFLUSH ---- ---------- NONE

MICELLAR SLUG ---------- 10.0% P.V B_1

BUFFER ------ ------- 50% P.V 250 P.P.M

FRONTAL VELOCITY ------- 6.94 M/DAY

TERTIARY OIL RECOVERY -- 64.8% OIP

% SULFONATE RECOVERED -- 3.2%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	35.0	35.0	0.0	-	0.0	0.0	0.0	0.0	0.13
2	36.9	21.5	15.4	-	15.4	41.7	15.4	12.1	0.27
3	48.5	24.0	24.5	-	24.5	50.5	39.9	31.3	0.46
4	32.8	16.8	16.0	-	16.0	48.8	55.9	43.2	0.58
5	40.4	29.3	11.1	-	11.1	27.5	67.0	52.5	0.73
6	40.1	31.1	9.0	-	9.0	22.4	76.0	59.6	0.89
7	44.0	38.3	5.7	-	5.7	13.0	81.7	64.1	1.05
8	45.0	44.0	1.0	-	1.0	2.2	82.7	64.9	1.22
9	42.0	42.0	0.0	-	0.0	0.0	82.7	64.9	1.38
10	42.0	42.0	0.0	-	0.0	0.0	82.7	64.9	1.54
11	20.0	19.0	1.0	-	1.0	2.4	83.7	65.6	1.62
12	33.0	33.0	0.0	-	0.0	0.0	83.7	65.6	1.75
13	26.0	26.0	0.0	-	0.0	0.0	83.7	65.6	1.95

TABLE 21
PRODUCTION HISTORY OF COREFLOOD # 9

LENGTH ----------------- 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY --------------- 23.12%

PERMEABILITY ----------- 697.1 md/0.706 um^2

INITIAL OIL SATURATION -- 32.85%

PREFLUSH----------------NONE

MICELLAR SLUG ---------- 50% P.V B$_1$

BUFFER ------ ---------- 25.0% P.V 250 P.P.M

FRONTAL VELOCITY -------0.53 M/DAY

TERTIARY OIL RECOVERY -- 64.9% OIP

%SULFONATE RECOVERED --16.5%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	20.0	20.0	0.0	0.00	0.00	0.00	0.00	0.00	0.07
2	20.0	20.0	0.0	0.00	0.00	0.00	0.00	0.00	0.14
3	22.0	22.0	0.0	0.00	0.0	0.00	0.00	0.00	0.22
4	16.5	16.5	0.0	0.00	0.0	0.00	0.00	0.00	0.28
5	16.0	8.9	6.1	0.00	6.1	38.13	6.1	6.18	0.34
6	20.0	11.9	8.1	0.00	8.1	40.50	14.2	14.40	0.41
7	20.7	13.0	7.7	0.01	7.7	37.20	21.9	22.20	0.49
8	21.0	12.7	8.3	0.01	8.3	39.52	30.2	30.62	0.56
9	21.0	12.6	8.4	0.03	8.4	40.00	38.6	39.14	0.64
10	20.1	13.1	7.0	0.02	7.0	34.83	45.6	46.23	0.71
11	21.0	15.0	6.0	0.04	6.0	28.57	51.6	52.32	0.79
12	21.0	16.8	4.2	0.03	4.2	20.00	55.8	56.58	0.86
13	20.9	17.4	3.5	0.06	3.5	16.75	59.3	60.13	0.94
14	22.0	19.7	2.3	0.31	2.3	10.45	61.6	62.46	1.02
15	21.0	19.6	1.4	0.00	1.4	6.67	63.0	63.88	1.09
16	21.0	20.5	0.5	0.10	6.5	2.38	63.5	64.39	1.17
17	21.0	20.0	0.5	0.00	0.5	2.38	64.0	64.89	1.25
18	21.0	21.0	0.0	0.00	0.0	0.00	64.0	64.89	1.32

TABLE 22
PRODUCTION HISTORY OF COREFLOOD # 10

LENGTH ----------------- 61.0 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 22.37%

PERMEABILITY ------------ 667.7 md/0.676 um^2)

INITIAL OIL SATURATION -- 55.5%

PREFLUSH ---- ---------- 25.0% P.V 1%(w)Na$_2$CO$_3$

MICELLAR SLUG ---------- 5.0% P.V B$_1$

BUFFER ------ ---------- 25.0% P.V 250 P.P.M

FRONTAL VELOCITY ------- 2.73 M/DAY

TERTIARY OIL RECOVERY -- 84.6% OIP

% SULFONATE RECOVERED --0

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	16.0	16.0	0.0	-	0.0	0.0	0.0	0.0	0.06
2	24.0	24.0	0.0	-	0.0	0.0	0.0	0.0	0.15
3	30.0	30.0	0.0	-	0.0	0.0	0.0	0.0	0.26
4	5.0	5.0	0.0	-	0.0	0.0	0.0	0.0	0.28
5	0.5	0.5	0.0	-	0.0	0.0	0.0	0.0	0.28
6	21.0	21.0	0.0	-	0.0	0.0	0.0	0.0	0.36
7	28.0	28.0	0.0	-	0.0	0.0	0.0	0.0	0.46
8	13.0	9.3	3.7	-	3.7	28.5	3.7	4.6	0.51
9	15.0	7.8	7.2	-	7.2	48.0	10.9	13.6	0.57
10	29.1	14.9	14.2	-	14.2	48.8	25.1	31.2	0.68
11	28.7	16.5	12.2	-	12.2	42.5	37.3	46.4	0.79
12	28.1	18.1	10.0	-	10.0	35.6	47.3	58.8	0.90
13	28.9	20.8	8.1	-	8.1	28.0	55.4	68.9	1.00
14	28.0	24.0	4.0	-	4.0	14.3	59.4	73.9	1.11
15	28.0	6.2	2.2	-	2.2	7.9	61.6	76.6	1.21
16	28.4	26.8	1.6	-	1.6	5.6	63.2	78.6	1.32
17	28.5	26.8	1.7	-	1.7	6.0	64.9	80.8	1.43
18	29.1	28.0	1.1	-	1.1	3.8	66.0	82.1	1.53
19	27.8	27.3	0.5	-	0.5	1.8	66.5	82.7	1.64
20	28.4	27.9	0.5	-	0.5	1.8	67.0	83.4	1.74
21	28.8	28.3	0.5	-	0.5	1.7	67.5	84.0	1.85
22	28.9	28.4	0.5	-	0.5	1.7	68.0	84.6	1.96
23	28.1	28.1	0.0	-	0.0	0.0	68.0	84.6	2.07
24	28.0	28.0	0.0	-	0.0	0.0	68.0	84.6	2.17

TABLE 11
PRODUCTION HISTORY OF COREFLOOD # 11

LENGTH ------------------ 61cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 23.46%

PERMEABILITY ------------ 748.8 md/0.7587 um^2

INITIAL OIL SATURATION -- 67.61%

PREFLUSH -------------- NONE

MICELLAR SLUG ---------- 10.0% P.V B_1

BUFFER ------ ---------- 25.0% P.V 250 P.P.M

FRONTAL VELOCITY ------- 2.60 M/DAY

TERTIARY OIL RECOVERY -- 80.4% OIP

% SULFONATE RECOVERED -- 6.88%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	7.5	7.5	0.0	-	0.0	0.0	0.0	0.0	0.03
2	6.5	6.5	0.0	-	0.0	0.0	0.0	0.0	0.05
3	20.0	21.0	0.0	-	0.0	0.0	0.0	0.0	0.12
4	34.0	34.0	0.0	-	0.0	0.0	0.0	0.0	0.24
5	6.7	6.7	3.6	-	3.6	53.7	3.6	3.0	0.27
6	29.2	10.5	17.7	-	17.7	60.6	21.3	17.7	0.37
7	35.2	17.0	18.2	-	18.2	51.7	39.5	32.8	0.49
8	33.6	14.0	19.6	0.20	19.6	58.3	59.1	49.0	0.61
9	33.0	21.4	11.6	0.20	11.6	35.2	70.7	58.7	0.73
10	33.0	23.5	9.5	0.24	9.5	28.8	80.2	66.6	0.85
11	33.0	25.5	7.5	0.30	7.5	22.7	87.7	72.8	0.97
12	32.0	27.0	5.0	0.36	5.0	15.6	92.7	76.9	1.08
13	33.0	30.0	3.0	0.34	3.0	9.10	95.7	79.4	1.20
14	33.0	31.9	1.1	0.09	1.1	3.4	96.8	80.4	1.32
15	33.0	33.0	0.0	0.00	0.0	0.0	96.8	80.4	1.43
16	32.0	32.0	0.0	0.0	0.0	0.0	96.8	80.4	1.55
17	32.0	32.0	0.0	0.0	0.0	0.0	96.8	80.4	1.66

TABLE 24
PRODUCTION HISTORY OF COREFLOOD # 12

LENGTH ------------------ 61.0 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 23.13 %

PERMEABILITY ------------ 671.9/0.6808 um^2

INITIAL OIL SATURATION -- 63.05%

PREFLUSH ---- ---------- 50% P.V 1% Na_2CO_3

MICELLAR SLUG ---------- 5.0% P.V B_1

BUFFER ------ ---------- 25.0% P.V 250 P.P.M

FRONTAL VELOCITY ------- 2.64 M/DAY

TERTIARY OIL RECOVERY -- 76.0% OIP

% SULFONATE RECOVERED -- 0

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	24.0	24.0	0.0	-	0.0	0.0	0.0	0.0	0.08
2	33.0	33.0	0.0	-	0.0	0.0	0.0	0.0	0.19
3	33.0	33.0	0.0	-	0.0	0.0	0.0	0.0	0.30
4	33.0	33.0	0.0	-	0.0	0.0	0.0	0.0	0.42
5	23.0	23.0	0.0	-	0.0	0.0	0.0	0.0	0.49
6	5	5	0.0	-	0.0	0.0	0.0	0.0	0.51
7	16	16	0.0	-	0.0	0.0	0.0	0.0	0.57
8	31	31	0.0	-	0.0	0.0	0.0	0.0	0.67
9	18	18	0.0	-	0.0	0.0	0.0	0.0	0.73
10	21.9	12.4	9.5	0.00	9.5	43.37	9.5	9.39	0.81
11	33.9	17.5	16.4	0.00	16.4	48.37	25.9	25.61	0.92
12	34.9	19.1	15.8	0.00	15.8	45.27	41.7	41.24	1.04
13	34.9	22.6	12.3	0.00	12.3	35.24	54.0	53.41	1.16
14	34.1	28.1	6.8	0.07	6.8	19.48	60.8	60.13	1.28
15	34.0	29.2	4.8	0.05	4.8	14.11	65.6	64.50	1.39
16	33.0	30.0	3.0	0.00	3.0	10.0	68.6	67.44	1.50
17	33.5	30.8	2.7	0.00	2.7	8.76	71.3	70.10	1.62
18	33.9	32.0	1.9	0.00	1.9	5.93	73.2	71.96	1.73
19	33.9	32.2	1.7	0.00	1.7	5.28	74.9	73.64	1.85
20	33.8	33.3	0.5	0.00	0.5	1.50	75.4	74.13	1.96
21	32.2	31.8	0.5	0.00	0.5	1.56	75.9	74.62	2.07
22	33.0	32.0	1.0	0.00	1.0	3.10	76.9	75.61	2.17
23	12.0	12.0	0.0	-	0.0	0.0	76.9	75.61	2.22
24	1.0	1.0	0.0	-	0.0	0.0	76.9	75.61	2.22

TABLE 25
PRODUCTION HISTORY OF COREFLOOD # 13

LENGTH ----------------- 122.0 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY --------------- 24.34 %

PERMEABILITY ----------- 706.3 md/0.716 um^2

INITIAL OIL SATURATION -- 62.35%

PREFLUSH ---- ---------- NONE

MICELLAR SLUG ---------- 6.8% P.V

BUFFER ------ ---------- 27.2% P.V 500 P.P.M

FRONTAL VELOCITY ------- 2.51 M/DAY

TERTIARY OIL RECOVERY -- 68.4% OIP

% SULFONATE RECOVERED -- 25.66%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	11.0	11.0	-	0.00	0.0	0.0	0.0	0.0	0.02
2	11.0	11.0	-	0.00	0.0	0.0	0.0	0.0	0.04
3	13.0	13.0	-	0.00	0.0	0.0	0.0	0.0	0.06
4	38.0	38.0	-	0.00	0.0	0.0	0.0	0.0	0.12
5	39.0	39.0	-	0.00	0.0	0.0	0.0	0.0	0.19
6	39.8	38.0	1.8	0.00	1.8	4.5	1.8	0.80	0.26
7	17.0	9.0	8.0	0.00	8.0	47.0	9.8	4.6	0.29
8	30.1	16.6	13.5	0.0	13.5	44.8	23.3	11.0	0.34
9	40.1	22.5	17.6	0.0	17.6	43.9	40.9	19.4	0.41
10	40.0	21.5	18.5	0.00	18.5	46.3	59.4	28.2	0.47
11	39.5	23.0	16.5	0.30	16.5	41.8	75.9	36.0	0.54
12	39.8	25.8	14.0	0.25	14.0	35.2	89.9	42.6	0.61
13	39.2	28.0	11.2	0.23	11.2	28.6	101.1	47.9	0.68
14	26.0	19.8	5.2	0.38	5.2	20.0	106.3	50.4	0.72
15	37.2	30.2	7.0	0.10	7.0	18.8	113.3	53.7	0.77
16	39.1	34.1	4.2	0.26	4.1	10.00	117.4	55.6	0.83
17	39.1	36.8	2.4	0.28	2.3	5.9	119.7	56.7	0.90
18	39.9	37.9	2.0	0.30	1.9	4.8	121.6	57.6	0.97
19	39.1	37.8	1.3	0.08	1.3	3.3	122.9	58.2	1.03
20	39.8	37.9	1.1	0.10	1.1	2.8	124.0	58.7	1.10
21	39.9	37.6	2.3	0.45	2.1	5.3	126.1	59.8	1.17
22	39.9	36.2	3.7	0.58	3.5	8.8	129.6	61.4	1.26
23	39.9	34.0	5.9	0.70	5.6	14.0	135.2	61.1	1.32
24	41.8	36.0	5.8	0.89	5.5	13.2	140.7	66.6	1.40
25	47.0	43.2	3.8	0.53	3.6	7.6	144.3	68.4	1.48
26	25.0	25.0	0.0	0.0	0.0	144.3	0.0	68.4	1.52

TABLE 26
PRODUCTION HISTORY OF COREFLOOD # 14

LENGTH ----------------- 61 cm
CROSS SECTIONAL AREA ---- 19.635 cm^2
POROSITY --------------- 23.79%
PERMEABILITY ------------ 747.4 md/0.757 um^2
INITIAL OIL SATURATION -- 68.42 %

PREFLUSH----------NONE
MICELLAR SLUG ---------- 5% P.V B_2
BUFFER (500 P.P.M)------ 50% P.V 500 P.P.M
FRONTAL VELOCITY ------- 1.28 M/DAY
TERTIARY OIL RECOVERY -- 94.5% OIP
% SULFONATE RECOVERED -- 36.3%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	29.0	29.0	0.0	0.00	0.0	0.0	0.0	0.0	0.10
2	20.0	20.0	0.0	0.00	0.0	0.0	0.0	0.0	0.17
3	26.0	20.0	0.0	0.00	0.0	0.0	0.0	0.0	0.26
4	25.1	10.5	14.6	0.00	14.6	58.2	14.6	13.6	0.35
5	25.2	13.0	12.5	0.06	12.5	49.6	27.1	25.3	0.44
6	25.4	14.5	10.9	0.16	10.9	42.9	38.0	35.4	0.53
7	14.6	8.6	6.0	0.14	6.0	41.1	44.0	41.0	0.57
8	3.1	1.5	1.6	0.26	1.6	51.6	45.6	42.5	0.59
9	28.1	15.8	12.3	0.26	12.2	43.4	57.8	53.9	0.69
10	27.0	15.3	11.7	0.53	11.6	43.0	69.4	64.4	0.78
11	26.4	16.8	14.6	1.60	14.2	54.0	83.6	77.9	0.88
12	26.9	17.0	9.9	2.59	9.2	34.2	92.8	86.5	0.97
13	26.7	20.1	6.6	0.97	6.3	23.6	99.1	92.4	1.06
14	27.0	24.8	2.2	0.00	2.2	8.1	101.3	94.5	1.15

TABLE 27
PRODUCTION HISTORY OF COREFLOOD # 15

LENGTH ----------------- 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 22.5%

PERMEABILITY ------------ 538.9 md/0.546 um^2

INITIAL OIL SATURATION -- 35.55%

PREFLUSH ---- ---------- NONE

MICELLAR SLUG ---------- 5.0% P.V B,

BUFFER ----- ---------- 50.0% P.V 500 P.P.M

FRONTAL VELOCITY ------- 1.35 M/DAY

TERTIARY OIL RECOVERY -- 67.79% OIP

% SULFONATE RECOVERED -- 33.63%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	10.0	9.5	0.0	0.00	0.0	0.00	0.00	0.00	0.04
2	12.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0.08
3	28.0	28.0	0.0	0.0	0.0	0.0	0.0	0.0	0.18
4	26.0	26.0	0.0	0.0	0.0	0.0	0.0	0.0	0.28
5	27.0	13.0	14.0	0.0	14.0	51.85	14.0	13.71	0.38
6	27.0	14.0	13.0	0.12	13.0	48.15	27.0	26.45	0.48
7	10.0	6.5	3.5	0.19	3.5	35.0	30.5	29.88	0.52
8	29.0	18.4	10.6	0.22	10.6	36.55	41.1	40.26	0.63
9	27.2	18.0	9.2	0.16	9.2	33.83	50.3	49.28	0.73
10	26.4	18.0	8.4	0.27	8.4	31.82	58.7	57.51	0.83
11	26.0	19.3	6.7	0.28	6.7	27.02	65.4	64.07	0.92
12	24.8	22.0	2.8	0.38	2.8	11.29	68.2	66.81	1.02
13	27.0	26.0	1.0	0.49	1.0	3.7	69.2	67.79	1.12
14	27.0	27.0	0.0	1.11	0.0	0.0	69.2	67.79	1.22
15	27.0	27.0	0.0	0.97	0.0	0.0	69.2	67.79	1.32
16	27.0	27.0	0.0	0.0	0.0	0.0	69.2	67.79	1.42

TABLE 28
COREFLOOD # 16

LENGTH ----------- ------ 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm'

POROSITY ---------------- 22.96%

PERMEABILITY ------------ 729.0 md/0.739 um'

INITIAL OIL SATURATION -- 29.82%

PREFLUSH ---- ----------- 1%(w) METSO 200

25%P.V.

MICELLAR SLUG ---------- 5.0% P.V B,

BUFFER ------ ---------- 34.2% P.V 500 P.P.M

FRONTAL VELOCITY ------- 1.33 M/DAY

TERTIARY OIL RECOVERY -- 29.6% OIP (Plugged)

% SULFONATE RECOVERED -- 4.10

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	21.0	21.0	0.0	-	-	-	-	-	0.08
2	21.0	21.0	0.0	-	-	-	-	-	0.15
3	26.0	26.0	0.0	-	-	-	-	-	0.25
4	4.0	4.0	0.0	-	-	-	-	-	0.26
5	16.0	16.0	0.0	-	-	0.00	0.00	0.00	0.32
6	31.3	30.0	1.3	0.03	-	4.15	1.3	1.5	0.43
7	29.0	23.0	6.0	0.06	-	20.7	7.3	8.3	0.54
8	27.0	23.8	3.2	0.05	-	12.9	10.5	11.9	0.64
9	29.0	26.8	2.2	0.02	-	7.6	12.7	14.4	0.74
10	33.2	31.6	1.6	0.02	-	4.8	14.3	16.2	0.86
11	33.9	32.3	1.6	0.02	-	4.7	15.9	18.0	0.99
12	33.9	32.0	1.9	0.02	-	5.6	17.8	20.2	1.11
13	33.9	32.3	1.6	0.01	-	4.7	19.4	22.0	1.23
14	33.4	32.0	1.4	0.01	-	4.2	20.8	23.6	1.35
15	34.0	32.0	1.1	0.01	-	3.2	21.9	24.8	1.48
16	34.0	32.7	1.3	0.00	-	3.8	23.2	26.3	1.60
17	34.0	33.0	1.0	0.00	-	2.9	24.2	27.4	1.72
18	34.0	33.0	1.0	0.00	-	2.9	25.2	28.5	1.84
19	34.0	33.1	0.9	0.00	-	2.9	26.1	29.6	1.96
20	34.0	34.0	0.0	0.00	-	0.0	26.1	29.6	2.09
21	34.0	34.9	0.0	0.00	-	0.0	26.1	29.6	2.21

TABLE 29
PRODUCTION HISTORY OF COREFLOOD # 17

LENGTH ------------------ 61 cm
CROSS SECTIONAL AREA ---- 19.635 cm^2
POROSITY ---------------- 22.6%
PERMEABILITY ------------ 707.0 md/0.716 um^2
INITIAL OIL SATURATION -- 31.85%

PREFLUSH ---- ---------- 25% P.V 1% (w) Na$_2$CO$_3$
MICELLAR SLUG ---------- 5.0% P.V B,
BUFFER ------ ---------- 50.0% P.V 500 P.P.M
FRONTAL VELOCITY ------- 1.35 M/DAY
TERTIARY OIL RECOVERY -- 72.9% OIP
% SULFONATE RECOVERED -- 48.0%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	68.0	68.0	0.0	0.00	0.0	0.0	0.0	0.0	0.25
2	18.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.32
3	31.0	31.0	0.0	0.06	0.0	0.0	0.0	0.0	0.43
4	32.1	27.0	5.1	0.18	5.1	15.9	5.1	5.5	0.55
5	32.1	11.7	20.4	0.26	20.4	63.6	25.5	27.7	0.67
6	26.5	13.0	13.5	0.78	13.5	50.9	39.0	42.2	0.77
7	32.0	20.4	11.7	0.63	11.7	36.6	50.7	55.0	0.89
8	28.1	21.0	7.1	0.71	7.1	25.3	57.8	62.8	0.99
9	27.8	23.5	4.3	0.36	4.3	15.5	62.1	67.4	1.09
10	26.7	23.7	3.0	0.05	3.0	11.2	65.1	70.7	1.19
11	26.8	25.8	1.0	0.00	1.0	3.7	66.1	71.8	1.29
12	28.0	28.0	0.0	0.00	0.0	0.0	66.1	71.8	1.39
13	28.2	27.2	1.0	0.00	1.0	3.5	67.1	72.9	1.50
14	29.0	29.0	0.0	0.00	0.0	0.0	67.1	72.9	1.60
15	29.0	29.0	0.0	0.00	0.0	0.0	67.1	72.9	1.70
16	29.0	29.0	0.0	0.00	0.0	0.0	67.1	72.9	1.81

TABLE 30
PRODUCTION HISTORY OF COREFLOOD # 18

LENGTH ----------------- 61 cm
CROSS SECTIONAL AREA ---- 19.635 cm^2
POROSITY ---------------- 24.55%
PERMEABILITY ------------ 669.9 md/0.6788 um^2
INITIAL OIL SATURATION -- 34.69%

PREFLUSH ---- ---------- 25% P.V 1%(w) Na_2CO_3
MICELLAR SLUG ---------- 5.0% P.V B$_1$
BUFFER ------ ---------- 50.0% P.V 500 P.P.M
FRONTAL VELOCITY ------- 1.24M/DAY
TERTIARY OIL RECOVERY -- 71.44% OIP
% SULFONATE RECOVERED -- 47.8%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	68.0	28.0	0.0	0.00	0.0	0.0	0.0	0.0	0.23
2	44.0	44.0	0.0	0.00	0.0	0.0	0.0	0.0	0.38
3	42.0	15.8	26.2	0.40	26.2	62.4	26.2	24.1	0.52
4	39.4	20.0	19.4	0.46	19.4	49.2	45.6	42.0	0.66
5	10.2	7.0	3.2	0.67	3.2	31.4	48.8	44.9	0.69
6	27.0	18.0	9.0	0.77	9.0	33.3	57.8	53.2	0.78
7	29.8	21.0	8.8	0.89	8.8	29.5	66.6	61.3	0.89
8	27.0	23.9	5.0	0.35	5.0	18.5	71.6	65.9	0.97
9	27.0	23.9	4.1	0.02	4.1	15.2	75.7	69.7	1.06
10	26.0	24.8	1.2	0.24	1.2	4.6	76.9	70.8	1.15
11	27.0	26.75	0.25	-	0.25	0.9	77.2	71.0	1.24
12	27.0	26.75	0.25	-	0.25	0.9	77.4	71.3	1.33
13	27.0	26.80	0.2	-	0.2	0.7	77.6	71.4	1.43
14	27.0	27.0	0.0	-	0.0	0.0	77.6	71.4	1.52
15	27.0	27.0	0.0	-	0.0	0.0	77.6	71.4	1.61
16	27.0	27.0	0.0	-	0.0	0.0	77.6	71.4	1.70

TABLE 31
PRODUCTION HISTORY OF COREFLOOD # 19

LENGTH ------------------ 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 21.87%

PERMEABILITY ------------ 675 md/0.684 um^2

INITIAL OIL SATURATION -- 37.78 %

PREFLUSH ---- ---------- 25% P.V 3%(w) L.S

MICELLAR SLUG ---------- 5.0% P.V B_1

BUFFER (500 ppm)-------- 50.0% P.V 500 P.P.M

FRONTAL VELOCITY ------- 1.39 M/DAY

TERTIARY OIL RECOVERY -- 36.9% OIP

% SULFONATE RECOVERED -- 10.1%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	59.0	59.0	0.0	-	0.0	0.0	0.0	0.0	0.23
2	15.0	15.0	0.0	-	0.0	0.0	0.0	0.0	0.28
3	27.0	27.0	0.0	0.00	0.0	0.0	0.0	0.0	0.38
4	26.0	19.0	7.0	0.22	7.0	26.9	7.0	6.7	0.48
5	26.5	19.0	7.5	0.24	7.5	28.3	14.5	13.8	0.59
6	26.5	19.0	7.5	0.23	7.5	28.3	22.0	20.9	0.69
7	9.0	5.7	3.3	0.01	3.3	36.7	25.3	24.1	0.72
8	24.0	19.0	5.0	0.01	5.0	26.8	30.3	28.9	0.81
9	26.1	22.5	3.6	0.00	3.6	13.8	33.9	32.3	0.91
10	21.2	18.4	2.8	-	2.8	13.2	36.7	35.0	0.99
11	24.0	22.0	2.0	-	2.0	8.3	38.7	36.9	1.08
12	26.0	26.0	0.0	-	0.0	0.0	38.7	36.9	1.18
13	26.0	26.0	0.0	-	0.0	0.0	38.7	36.9	1.28
14	26.0	26.0	0.0	-	0.0	0.0	38.9	36.9	1.38

TABLE 32
PRODUCTION HISTORY OF COREFLOOD # 20

LENGTH ------------------ 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 23.5%

PERMEABILITY ------------ 658 md/0.669 um^2

INITIAL OIL SATURATION -- 37.72%

PREFLUSH ---- ---------- 5.0% P.V 3% (w) L.S

MICELLAR SLUG ---------- 5.0% P.V B_1

BUFFER ------ ---------- 50.0% P.V 500 P.P.M

FRONTAL VELOCITY ------- 1.30 M/DAY

TERTIARY OIL RECOVERY -- 49.0% OIP

% SULFONATE RECOVERED -- 9.5%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	23.0	23.0	0.0	-	0.0	0.0	0.0	0.0	0.08
2	32.0	32.0	0.0	-	0.0	0.0	0.0	0.0	0.20
3	31.1	18.9	12.2	-	12.2	39.4	12.2	10.8	0.31
4	30.0	19.0	11.0	No Sulfonate Detected	11.0	37.7	23.2	20.6	0.41
5	29.0	19.8	9.2		9.2	31.7	32.4	28.8	0.52
6	21.5	16.3	5.2		5.2	24.2	37.6	33.4	0.59
7	31.0	22.0	9.0		9.0	29.0	46.6	41.4	0.70
8	30.0	25.0	5.0		5.0	16.7	51.6	45.9	0.81
9	32.0	29.0	3.0	-	3.0	9.4	54.6	48.5	0.92
10	32.0	31.5	0.5	-	0.5	1.6	55.1	49.0	1.04
11	32.0	32.0	0.0	-	0.0	0.0	55.1	49.0	1.15
12	32.0	32.0	0.0	-	0.0	0.0	55.1	49.0	1.26
13	32.0	32.0	0.0	-	0.0	0.0	55.1	49.0	1.38
14	32.0	32.0	0.0	-	0.0	0.0	55.1	49.0	1.49

TABLE 33
PRODUCTION HISTORY OF COREFLOOD # 21

LENGTH ------------------ 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 21.12%

PERMEABILITY ------------ 0.639 md/0.647 um^2

INITIAL OIL SATURATION -- 43.5%

PREFLUSH ---- ---------- 20.0% P.V 3%(w) L.S +
1.0 P.V 2%(w) BRINE

MICELLAR SLUG ---------- 5.0% P.V B,

BUFFER ------ ---------- 50.0% P.V 500 P.P.M

FRONTAL VELOCITY ------- 1.44 M/DAY

TERTIARY OIL RECOVERY -- 21.95% OIP

% SULFONATE RECOVERED -- 5.7%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	2.0	2.0	0.0	-	0.0	0.0	0.0	0.0	0.00
2	26.0	26.0	0.0	-	0.0	0.0	0.0	0.0	0.11
3	34.0	34.0	0.0	-	0.0	0.0	0.0	0.0	0.25
4	34.0	31.0	3.0	-	3.0	8.82	3.0	2.6	0.38
5	22.0	12.5	3.5	-	3.5	15.91	6.5	5.6	0.51
6	22.0	16.7	5.3	0.07	5.3	24.09	11.8	10.2	0.60
7	35.0	26.8	8.2	0.10	8.2	23.42	20.0	17.3	0.74
8	33.1	28.0	5.1	0.06	5.1	15.41	25.1	21.7	0.87
9	33.0	33.0	0.0	-	0.0	0.0	0.0	21.7	1.00
10	33.0	33.0	0.0	-	0.0	0.0	0.0	21.7	1.13
11	33.0	33.0	0.0	-	0.0	0.0	0.0	21.7	1.26
12	33.0	33.0	0.0	-	0.0	0.0	0.0	21.7	1.39
13	33.0	33.0	0.0	-	0.0	0.0	0.0	21.7	1.52
14	33.0	33.0	0.0	-	0.0	0.0	0.0	21.7	1.65
15	33.0	33.0	0.0	-	0.0	0.0	0.0	21.7	1.78

TABLE 34
PRODUCTION HISTORY OF COREFLOOD # 22

LENGTH ----------------- 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 23.38 %

PERMEABILITY ------------ 726 md/0.7354 um^2

INITIAL OIL SATURATION -- 33.93%

PREFLUSH ---- ---------- 25% P.V 1%(w)PETROSTEP 465

MICELLAR SLUG ---------- 5.0% P.V B,

BUFFER ------ ---------- 50.0% P.V 500 P.P.M

FRONTAL VELOCITY ------- 1.31 M/DAY

TERTIARY OIL RECOVERY -- 28.62% OIP (Plugged)

% SULFONATE RECOVERED -- 4.1%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	83.0	83.0	0.0	0.00	0.0	0.0	0.0	0.0	0.30
2	30.0	30.0	0.0	0.00	0.0	0.0	0.0	0.0	0.44
3	34.0	30.0	4.0	0.35	4.0	11.8	4.0	3.9	0.56
4	34.0	28.0	6.0	0.60	6.0	17.6	10.0	9.8	0.68
5	25.2	22.2	3.0	0.00	3.0	11.9	13.0	12.8	0.77
6	34.0	28.0	6.0	0.60	6.0	17.6	19.0	18.8	0.89
7	38.0	32.0	6.0	0.60	6.0	15.8	25.0	24.7	1.03
8	36.0	34.0	2.0	0.30	2.0	5.5	27.0	26.7	1.16
9	33.0	33.0	0.0	0.00	0.0	0.0	27.0	26.7	1.27
10	33.0	33.0	0.0	0.00	0.0	0.0	27.0	26.7	1.39
11	33.0	33.0	0.0	0.00	0.0	0.0	27.0	26.7	1.51
12	33.0	33.0	2.0	0.00	2.0	6.06	29.0	28.7	1.63
13	33.0	33.0	0.0	0.00	0.0	0.00	29.0	28.7	1.75
14	33.0	33.0	0.0	0.00	0.0	0.00	29.0	28.7	1.87

TABLE 23
PRODUCTION HISTORY OF COREFLOOD # 23

LENGTH ------------------ 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 21.29 %

PERMEABILITY ------------ 712.4 md/0.7218 um^2

INITIAL OIL SATURATION -- 34.90%

PREFLUSH ---- ---------- 50% P.V 1%(w)PETROSTEP 465

MICELLAR SLUG ---------- 5.0% P.V B$_3$

BUFFER ------ ---------- 12.6% P.V 500 P.P.M

FRONTAL VELOCITY ------- 1.44 M/DAY

TERTIARY OIL RECOVERY -- 31.7% OIP (Plugged)

% SULFONATE RECOVERED -- 4.6%

SAMPLE NO	TOTAL SAMPLE VOL.cc	AQUEOUS PHASE VOL.cc	OLEIC PHASE VOL.cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	88.0	88.0	0.0	-	0.0	0.0	0.0	0.0	0.35
2	12.0	11.5	0.5	-	0.5	4.2	0.5	0.5	0.39
3	9.0	8.5	0.5	-	0.0	0.0	0.0	0.5	0.43
4	27.0	27.0	0.0	-	0.0	0.0	0.0	0.5	0.53
5	43.0	38.8	4.2	-	4.2	9.8	4.7	4.9	0.70
6	35.0	30.0	5.0	0.06	5.0	16.7	9.7	10.2	0.84
7	37.0	34.0	3.0	0.08	3.0	8.1	12.7	13.4	0.98
8	37.1	35.2	1.9	0.03	1.9	5.1	14.6	15.4	1.13
9	36.8	35.0	1.8	0.02	1.8	4.9	16.4	17.3	1.27
10	35.9	34.0	1.9	0.02	1.9	5.3	18.3	19.3	1.41
11	37.0	35.1	1.9	0.02	1.9	5.1	20.2	21.3	1.56
12	37.0	35.1	1.9	0.02	1.9	5.4	22.1	23.3	1.70
13	36.9	35.1	1.8	-	1.8	4.9	23.9	25.2	1.84
14	37.0	35.8	1.2	-	1.2	3.2	25.1	26.5	1.99
15	36.0	35.0	1.0	-	1.0	2.8	26.1	27.5	2.14
16	37.0	36.0	1.0	-	1.0	2.7	27.1	28.6	2.28
17	38.0	37.0	1.0	-	1.0	2.6	28.1	29.6	2.42
18	38.0	37.0	1.0	-	1.0	2.6	29.1	30.7	2.56
19	38.0	37.0	1.0	-	1.0	2.6	30.1	31.7	2.70
20	38.0	38.0	0.0	-	0.0	0.0	30.1	31.7	2.84

TABLE 36
PRODUCTION HISTORY OF COREFLOOD # 24

LENGTH ------------------ 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 22.12%

PERMEABILITY ------------ 705.0 md/0.7146 um^2

INITIAL OIL SATURATION -- 32.83%

PREFLUSH ---- ---------- 50.0% P.V 1%(w) Na$_2$CO$_3$

MICELLAR SLUG ---------- 6.1% P.V B$_3$

BUFFER ------ ---------- 50.0% P.V 500 P.P.M

FRONTAL VELOCITY ------- 1.38 M/DAY

TERTIARY OIL RECOVERY -- 98.9% OIP

% SULFONATE RECOVERED -- 78.6%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	175.0	175.0	0.0	0.00	0.0	0.0	0.0	0.0	0.66
2	27.0	27.0	0.0	0.00	0.0	0.0	0.0	0.0	0.76
3	33.0	20.0	13.0	0.16	13.0	39.0	13.0	13.8	0.89
4	34.0	13.1	20.9	0.25	20.9	61.5	33.9	35.9	1.01
5	31.0	15.6	15.4	0.60	15.4	49.7	49.3	52.3	1.13
6	25.0	14.8	10.2	0.78	10.2	32.9	59.5	63.1	1.23
7	38.0	23.0	15.0	1.20	15.0	39.5	74.5	78.9	1.37
8	29.0	20.8	8.1	1.20	8.1	27.9	82.6	87.6	1.48
9	29.0	24.0	5.0	0.82	5.0	17.2	87.6	92.9	1.59
10	29.0	25.9	3.1	0.59	3.1	10.7	90.7	96.2	1.70
11	29.8	27.2	2.6	0.37	2.6	8.7	93.3	98.9	1.81
12	30.0	30.0	0.0	0.4	0.0	0.0	93.3	98.9	1.92
13	30.0	30.0	0.0	0.00	0.0	0.0	93.3	98.9	2.04
14	30.0	30.0	0.0	0.00	0.0	0.0	93.3	98.9	2.15

TABLE 37
PRODUCTION HISTORY OF COREFLOOD # 25

LENGTH ------------------ 61.0 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 22.6%

PERMEABILITY ------------ 665 md/0.673 um^2

INITIAL OIL SATURATION -- 31.73%

PREFLUSH ---- ---------- 50% P.V 1%(w) EDTA

MICELLAR SLUG ---------- 5.0% P.V B,

BUFFER ------ ---------- 50.0% P.V 500 P.P.M

FRONTAL VELOCITY ------- 1.35 M/DAY

TERTIARY OIL RECOVERY -- 82.0% OIP

% SULFONATE RECOVERED -- 38.3%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	144.0	144.0	0.0	0.00	0.0	0.0	0.0	0.0	0.53
2	14.0	14.0	0.0	0.00	0.0	0.0	0.0	0.0	0.58
3	28.0	28.0	0.0	0.00	0.0	0.0	0.0	0.0	0.69
4	31.1	20.2	10.9	0.12	10.9	35.0	10.9	11.8	0.80
5	31.8	16.8	15.0	0.21	15.0	47.2	25.9	28.1	0.92
6	33.0	18.4	14.6	0.45	14.6	44.2	40.5	43.9	1.04
7	20.1	12.6	8.1	0.62	8.1	40.3	48.6	52.6	1.11
8	34.7	23.0	11.7	0.57	11.7	33.7	60.3	65.3	1.24
9	34.8	25.0	9.8	0.46	9.8	28.2	70.1	75.9	1.37
10	34.8	30.8	4.0	0.12	4.0	11.5	74.1	80.3	1.50
11	34.1	33.0	1.1	0.01	1.1	3.2	75.2	81.5	1.62
12	34.0	33.5	0.5	0.00	0.5	1.5	75.7	82.0	1.75
13	34.0	34.0	0.0	0.00	0.0	0.0	75.7	82.0	1.87

TABLE 38
PRODUCTION HISTORY OF COREFLOOD # 26

LENGTH ------------------ 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 21.9%

PERMEABILITY ------------ 803.5 md/0.8141 um^2

INITIAL OIL SATURATION -- 35.9%

PREFLUSH ---- ---------- 25% P.V 1%(w) EDTA

MICELLAR SLUG ---------- 5.0% P.V B_1

BUFFER ------ ---------- 50.0% P.V 500 P.P.M

FRONTAL VELOCITY ------- 1.40 M/DAY

TERTIARY OIL RECOVERY -- 90.8% OIP

% SULFONATE RECOVERED -- 61.54%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	88.0	88.0	0.0	0.00	0.0	0.0	0.0	0.0	0.34
2	18.0	18.0	0.0	0.00	0.0	0.0	0.0	0.0	0.40
3	30.0	30.0	0.0	0.00	0.0	0.0	0.0	0.0	0.52
4	31.0	11.0	20.0	0.24	20.0	64.5	20.0	20.0	0.64
5	32.0	14.0	18.0	0.22	18.0	56.3	38.0	38.0	0.76
6	24.1	12.0	12.1	0.34	12.1	50.2	50.1	50.1	0.85
7	31.0	17.0	14.0	0.58	14.0	45.2	64.1	64.1	0.97
8	33.0	20.3	12.7	0.85	12.7	38.5	76.8	76.8	1.10
9	33.0	25.0	8.0	0.69	8.0	24.2	84.8	84.8	1.22
10	23.0	20.4	2.6	0.50	2.6	11.3	87.4	87.4	1.31
11	31.0	28.5	2.5	0.21	2.5	8.1	89.9	89.9	1.43
12	32.0	32.0	1.0	0.10	0.0	3.1	90.9	90.9	1.55
13	32.0	32.0	0.0	0.10	0.0	0.0	90.9	90.9	1.68
14	32.0	32.0	0.0	0.00	0.0	0.0	90.9	90.9	1.80

TABLE 40
PRODUCTION HISTORY OF COREFLOOD # 27

LENGTH ------------------ 61 cm
CROSS SECTIONAL AREA ---- 19.635 cm^2
POROSITY ---------------- 23.4%
PERMEABILITY ------------ 820 md/0.8309 um^2
INITIAL OIL SATURATION -- 34.64%

PREFLUSH ---- ---------- 5% P.V 1%(w)EDTA
MICELLAR SLUG ---------- 5.0% P.V B$_1$
BUFFER ------ ---------- 50.0% P.V 500 P.P.M
FRONTAL VELOCITY ------- 1.30 M/DAY
TERTIARY OIL RECOVERY -- 83.9% OIP
% SULFONATE RECOVERED -- 31.7%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	30.0	30.0	0.0	0.00	0.0	0.0	0.0	0.0	0.11
2	23.0	23.0	0.0	0.00	0.0	0.0	0.0	0.0	0.19
3	27.0	27.0	0.0	0.00	0.0	0.0	0.0	0.0	0.28
4	29.0	22.0	7.0	0.00	7.0	24.1	7.0	6.8	0.38
5	29.1	12.4	16.7	0.0	16.7	57.4	23.7	22.9	0.48
6	29.2	15.8	13.4	0.08	13.4	45.9	37.1	35.9	0.59
7	19.0	10.8	8.2	0.14	8.2	43.2	45.3	43.9	0.66
8	31.9	17.5	14.4	0.39	14.4	45.1	59.7	57.8	0.77
9	30.8	18.2	12.6	0.27	12.6	40.9	72.3	70.0	0.88
10	30.0	21.8	8.2	0.66	8.2	27.3	80.5	77.9	0.99
11	28.8	24.4	4.4	0.51	4.4	15.3	84.9	82.2	1.09
12	29.1	27.3	1.8	0.26	1.8	6.2	86.7	83.9	1.19
13	29.0	29.0	0.0	0.20	0.0	0.0	86.7	83.9	1.30
14	29.0	29.0	0.0	0.00	0.0	0.0	86.7	83.9	1.40
15	29.0	29.0	0.0	0.00	0.0	0.0	86.7	83.9	1.50

TABLE 39
PRODUCTION HISTORY OF COREFLOOD # 28

LENGTH ------------------ 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 23.0%

PERMEABILITY ------------ 807 md/0.815 um^2

INITIAL OIL SATURATION -- 34.9%

PREFLUSH ---- ----------50% P.V 1%(w) EDTA

MICELLAR SLUG ---------- 5.0% P.V

BUFFER ----------------- 50.0% P.V 500 P.P.M

FRONTAL VELOCITY ------- 1.33 M/DAY

TERTIARY OIL RECOVERY -- 83.3% OIP

% SULFONATE RECOVERED -- 39.29%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	172.0	172.0	0.0	0.00	0.0	0.0	0.0	0.0	0.60
2	25.0	25.0	0.0	0.00	0.0	0.0	0.0	0.0	0.72
3	27.0	17.5	9.5	0.03	9.5	35.2	9.5	9.3	0.81
4	27.5	13.7	13.8	0.0	13.8	50.2	23.3	22.8	0.91
5	28.0	15.2	12.8	0.10	12.8	45.7	36.1	35.3	1.02
6	22.0	12.5	11.5	0.20	11.5	52.3	47.6	46.6	1.09
7	22.0	12.8	11.2	0.39	11.2	50.9	58.8	57.5	1.18
8	29.5	18.5	11.0	0.80	11.0	37.3	69.8	68.3	1.28
9	28.9	21.0	7.9	0.67	7.9	27.3	77.7	76.0	1.39
10	30.0	25.0	5.0	0.31	5.0	16.7	82.7	80.9	1.50
11	30.0	25.0	5.0	0.42	1.9	6.3	84.6	82.7	1.61
12	29.0	28.5	0.5	0.00	0.5	1.7	85.1	83.3	1.71
13	29.0	29.0	0.0	0.00	0.0	0.0	85.1	83.3	1.81
14	29.0	29.0	0.0	0.00	0.0	0.0	85.1	83.3	1.91
15	29.0	29.0	0.0	0.00	0.0	0.0	85.1	83.3	2.01
16	29.0	29.0	0.0	0.00	0.0	0.0	85.1	83.3	2.11

TABLE 41
PRODUCTION HISTORY OF COREFLOOD # 29

LENGTH ----------------- 122 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY --------------- 23.2%

PERMEABILITY ----------- 788 md/0.7986 um^2

INITIAL OIL SATURATION -- 30.5% P.V

PREFLUSH ---- ---------- 51% P.V 1% EDTA

MICELLAR SLUG ---------- 5.0% P.V

BUFFER ------ ---------- 50.0% P.V 500 P.P.M

FRONTAL VELOCITY ------- 1.31 M/DAY

TERTIARY OIL RECOVERY -- 87.6% OIP

% SULFONATE RECOVERED -- 23.94%

SAMPLE NO	TOTAL SAMPLE VOL,CC	AQUEOUS PHASE VOL,CC	OLEIC PHASE VOL,CC	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY CC	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	312.0	310.5	1.5	0.00	1.5	0.5	1.5	0.8	0.56
2	24.0	24.0	0.0	0.00	0.0	0.0	1.5	0.8	0.60
3	33.0	33.0	0.0	0.00	0.0	0.0	1.5	0.8	0.66
4	34.0	34.0	0.0	0.00	0.0	0.0	1.5	0.8	0.73
5	32.0	16.0	16.0	0.00	16.0	50.0	17.5	9.6	0.78
6	33.2	17.0	16.2	0.00	16.2	48.8	33.7	18.5	0.84
7	33.0	17.1	15.9	0.00	15.9	48.2	49.6	27.2	0.90
8	33.0	19.6	13.4	0.00	13.4	40.6	63.0	34.5	0.96
9	32.3	18.5	13.8	0.08	13.8	42.7	76.8	42.1	1.02
10	29.2	17.0	11.2	0.11	11.2	38.4	88.0	48.2	1.07
11	23.0	14.0	9.0	0.18	9.0	39.1	97.0	53.2	1.11
12	31.5	18.5	13.0	0.19	13.0	41.3	110.0	60.3	1.17
13	31.5	18.8	12.7	0.20	12.7	40.3	122.7	67.2	1.23
14	31.5	19.2	12.3	0.31	12.3	39.0	135.0	74.0	1.28
15	31.5	20.0	11.5	0.87	11.5	36.5	146.5	80.3	1.34
16	30.8	23.0	7.8	0.69	7.8	25.3	154.3	84.5	1.40
17	31.0	27.5	3.5	0.42	3.5	11.3	157.8	86.5	1.45
18	30.5	28.5	2.0	0.19	2.0	6.6	159.8	87.6	1.51
19	32.0	31.5	0.0	0.00	0.0	0.0	159.8	87.6	1.57
20	32.0	32.0	0.0	0.00	0.0	0.0	159.8	87.6	1.62
21	32.0	32.0	0.0	0.00	0.0	0.0	159.8	87.6	1.68

TABLE : 43

PRODUCTION HISTORY OF COREFLOOD # 30

LENGTH ------------------ 61 cm

CROSS SECTIONAL AREA ---- 19.635 cm^2

POROSITY ---------------- 23.63%

PERMEABILITY ------------ 819 md/0.830 um^2

INITIAL OIL SATURATION -- 34.3%

PREFLUSH ---- ---------- 5% P.V 1%(w)EDTA pH=11.3

MICELLAR SLUG ---------- 5.0% P.V B,

BUFFER ------ ---------- 50% P.V 500 P.P.M

FRONTAL VELOCITY ------- 1.29 M/DAY

TERTIARY OIL RECOVERY -- 88.4% OIP

% SULFONATE RECOVERED -- 23.6%

SAMPLE NO	TOTAL SAMPLE VOL,cc	AQUEOUS PHASE VOL,cc	OLEIC PHASE VOL,cc	% SULFONATE IN SAMPLE	VOLUME OF OIL IN SAMPLE	% OIL IN SAMPLE	CUM OIL RECOVERY cc	CUM OIL RECOVERY % OIP	CUM PORE VOLUMES PRODUCED
1	33.0	33.0	0.0	0.00	0.0	0.0	0.0	0.0	0.12
2	29.0	29.0	0.0	0.00	0.0	0.0	0.0	0.0	0.22
3	33.4	30.0	3.4	0.00	3.4	10.2	3.4	3.3	0.34
4	34.6	14.2	20.4	0.08	20.4	59.0	23.8	23.0	0.46
5	34.1	18.0	16.1	0.10	16.1	47.2	39.9	38.6	0.58
6	23.0	12.0	11.0	0.15	11.0	47.8	50.9	49.3	0.66
7	39.3	20.0	19.3	0.25	19.3	49.1	70.2	68.0	0.80
8	29.0	17.5	11.5	0.36	11.5	39.6	81.7	79.1	0.90
9	29.0	22.7	6.3	0.48	6.3	21.7	88.0	85.2	1.00
10	29.3	27.0	2.3	0.20	2.3	7.8	90.3	87.4	1.10
11	28.0	27.5	0.5	0.00	0.5	1.8	90.8	87.9	1.21
12	29.0	28.5	0.5	0.00	0.5	1.7	91.3	88.4	1.31
13	29.5	29.5	0.0	0.00	0.0	0.0	91.3	88.4	1.41
14	29.5	29.5	0.0	0.00	0.0	0.0	91.3	88.4	1.52
15	29.5	29.5	0.0	0.00	0.0	0.0	91.3	88.4	1.62
16	29.5	29.5	0.0	0.00	0.0	0.0	91.3	88.4	1.73

APPENDIX D : Graphical Results of the Core Floods

Production History of all the Floods

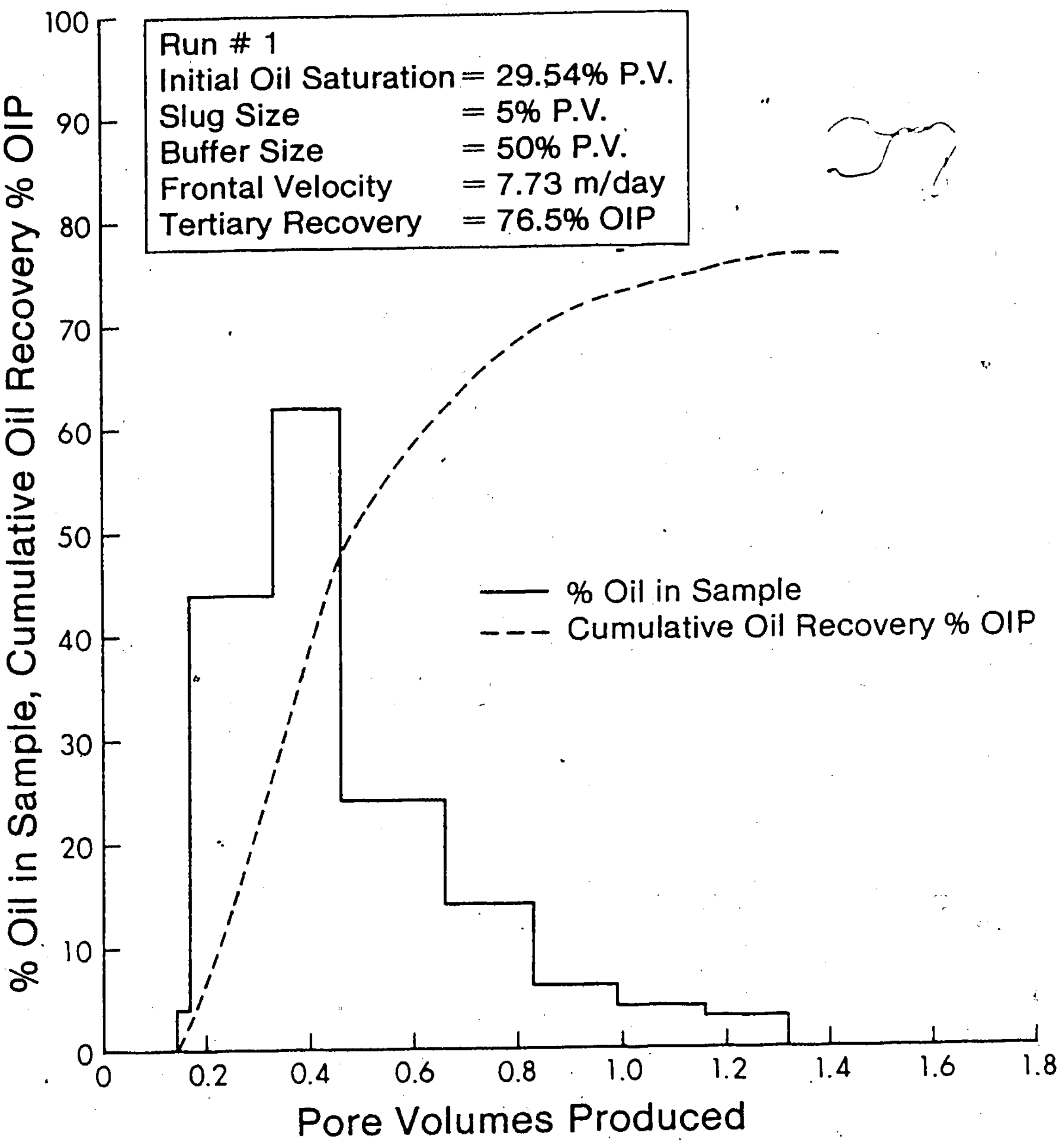


Fig. 21 Production history for 5% P.V. Micellar Slug B_1 and 50% P.V. Dow Pusher Buffer injected at 7.73 m/day.

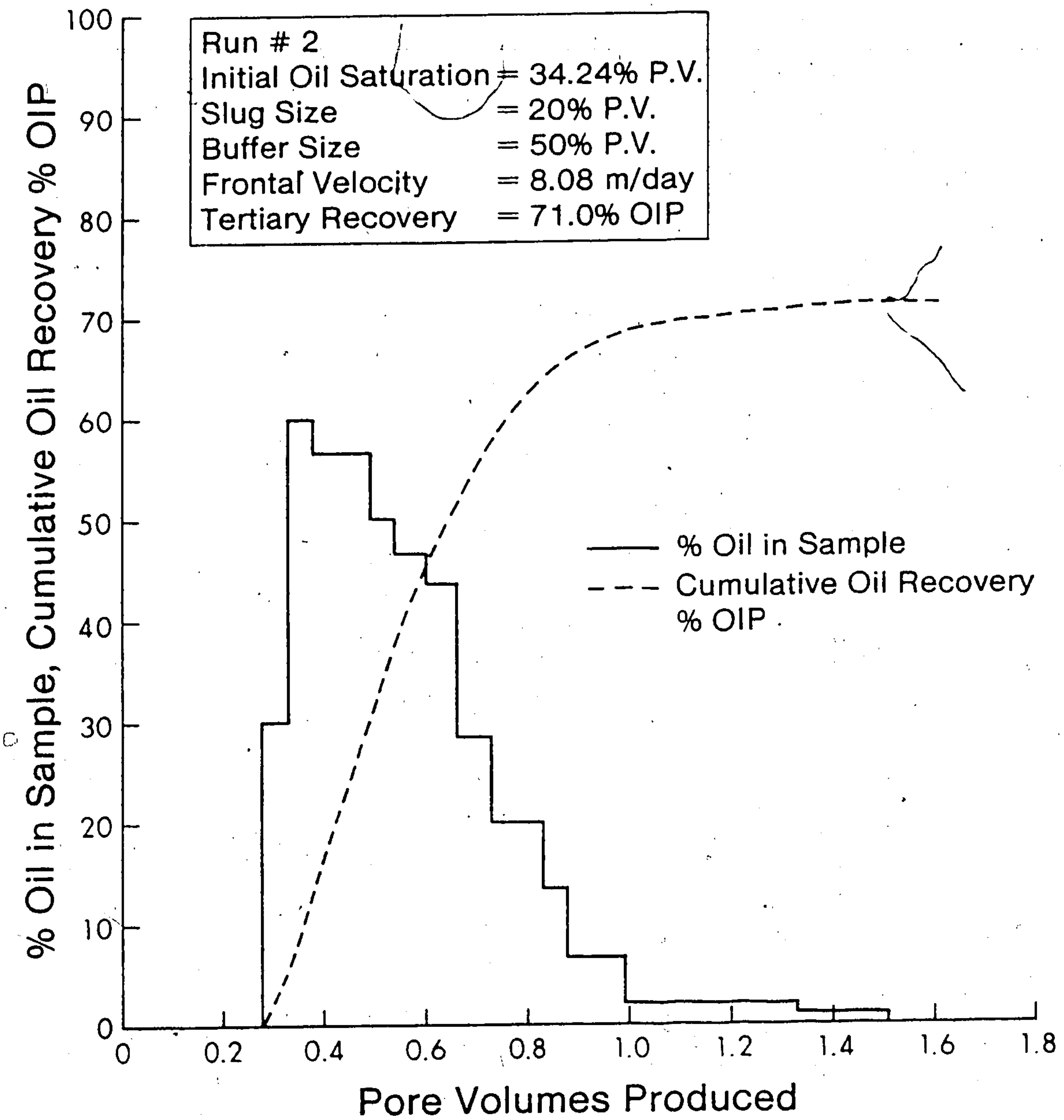
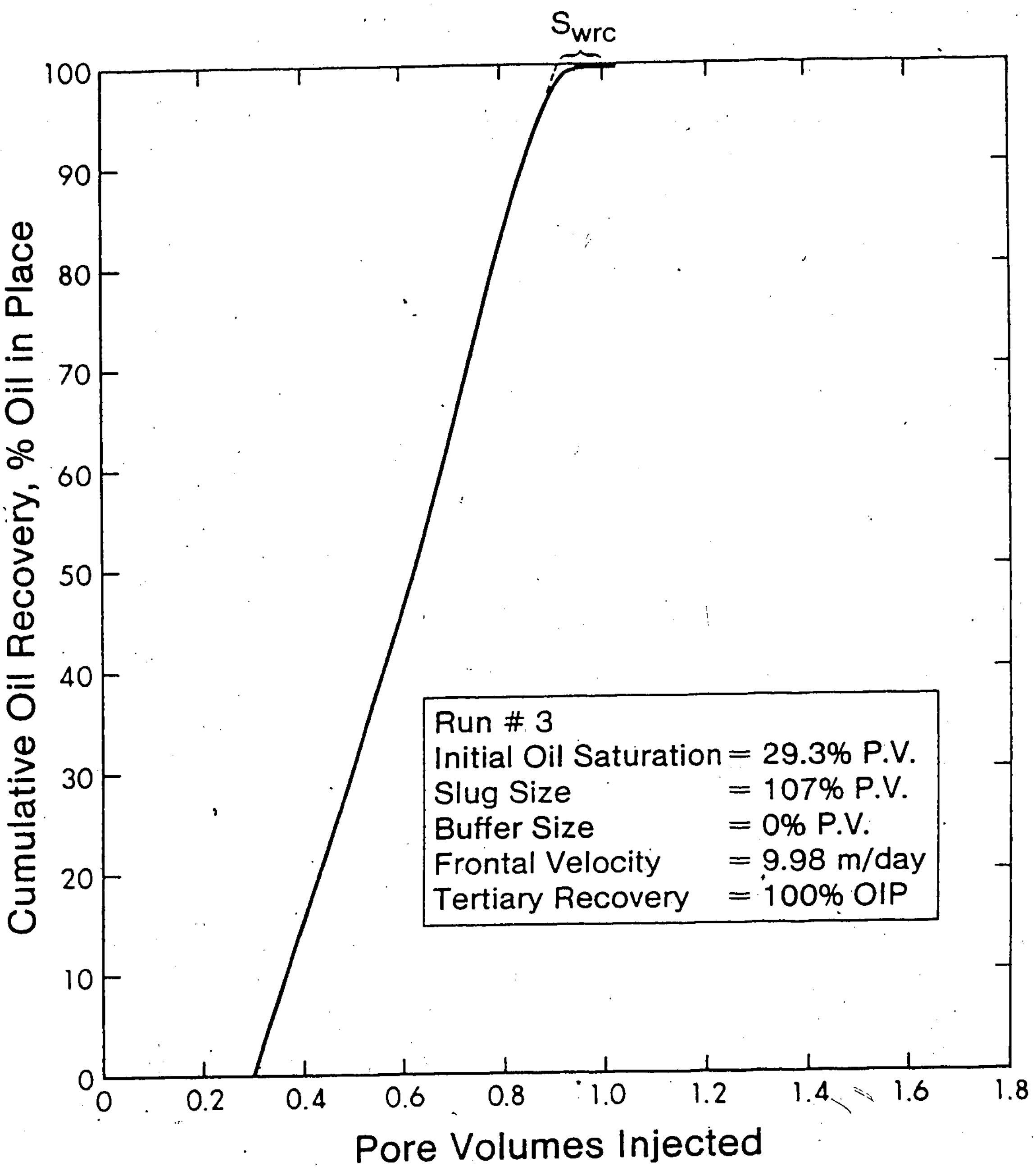


Fig. 22 Production history for 25% P.V. Micellar Slug B_1 and 50% P.V. Dow Pusher Buffer injected at 8.08 m/day.



Run # 3
Initial Oil Saturation = 29.3% P.V.
Slug Size = 107% P.V.
Buffer Size = 0% P.V.
Frontal Velocity = 9.98 m/day
Tertiary Recovery = 100% OIP

Fig.23Cumulative Oil Recovery VS Pore Volumes of Micellar Soln B_1 Injected.

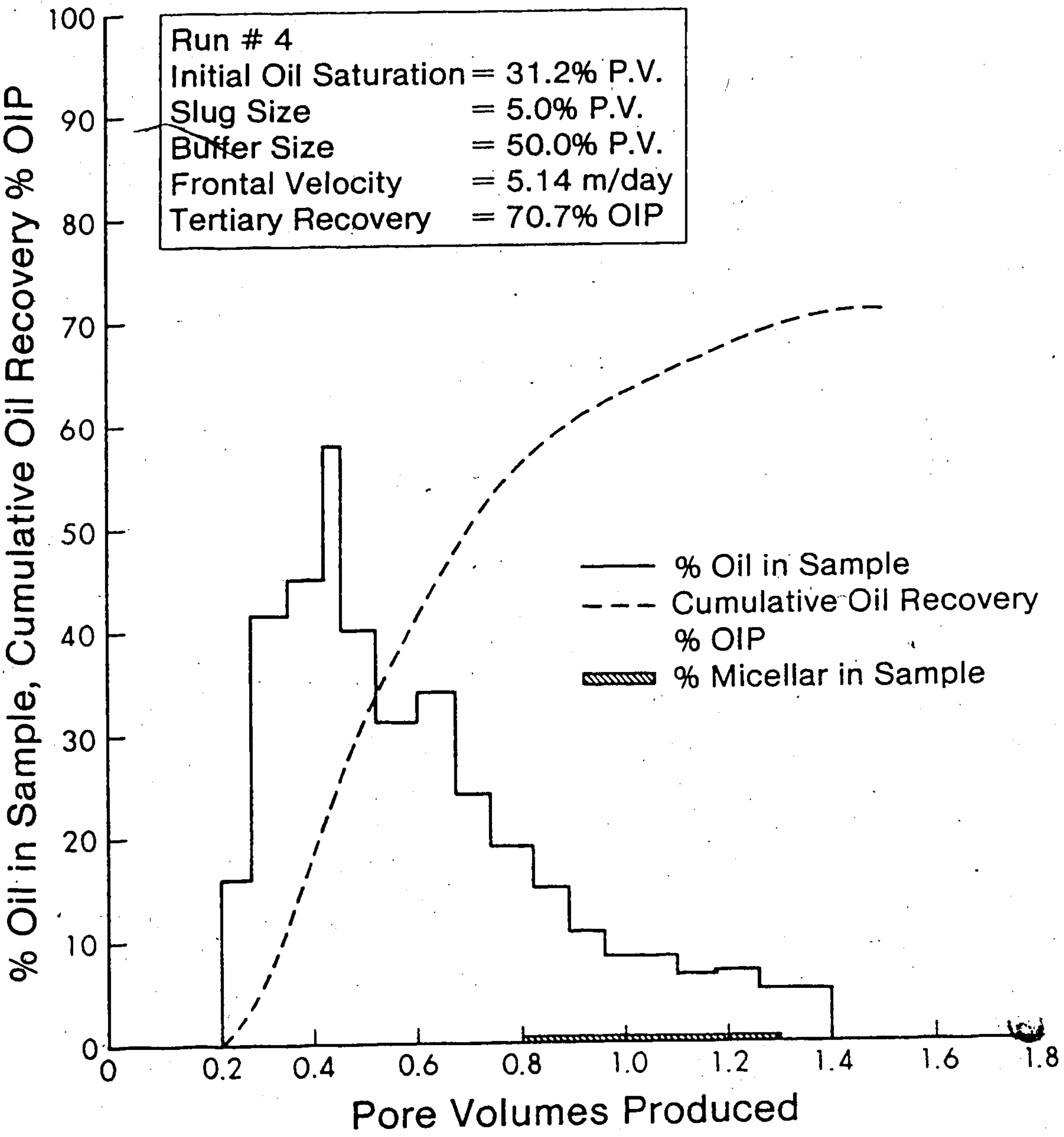


Fig24Production history for 5% P.V. Micellar Slug B_1 and 50% P.V. Dow Pusher Buffer injected at 5.14m/day.

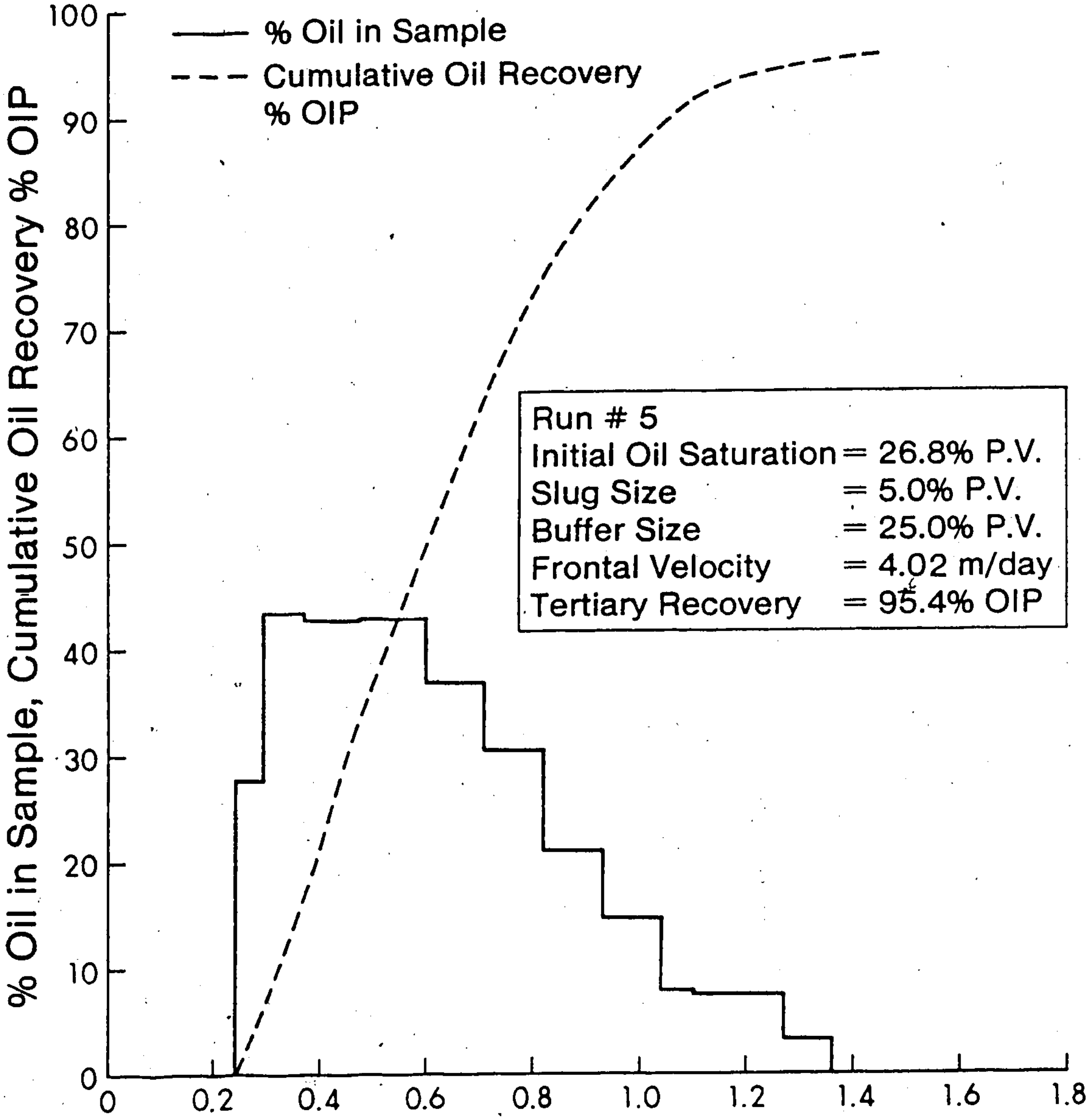


Fig. 25 Production history for 5.0% P.V. Micellar Slug B_1 and 25.0% P.V. Dow Pusher Buffer injected at 4.02 m/day.

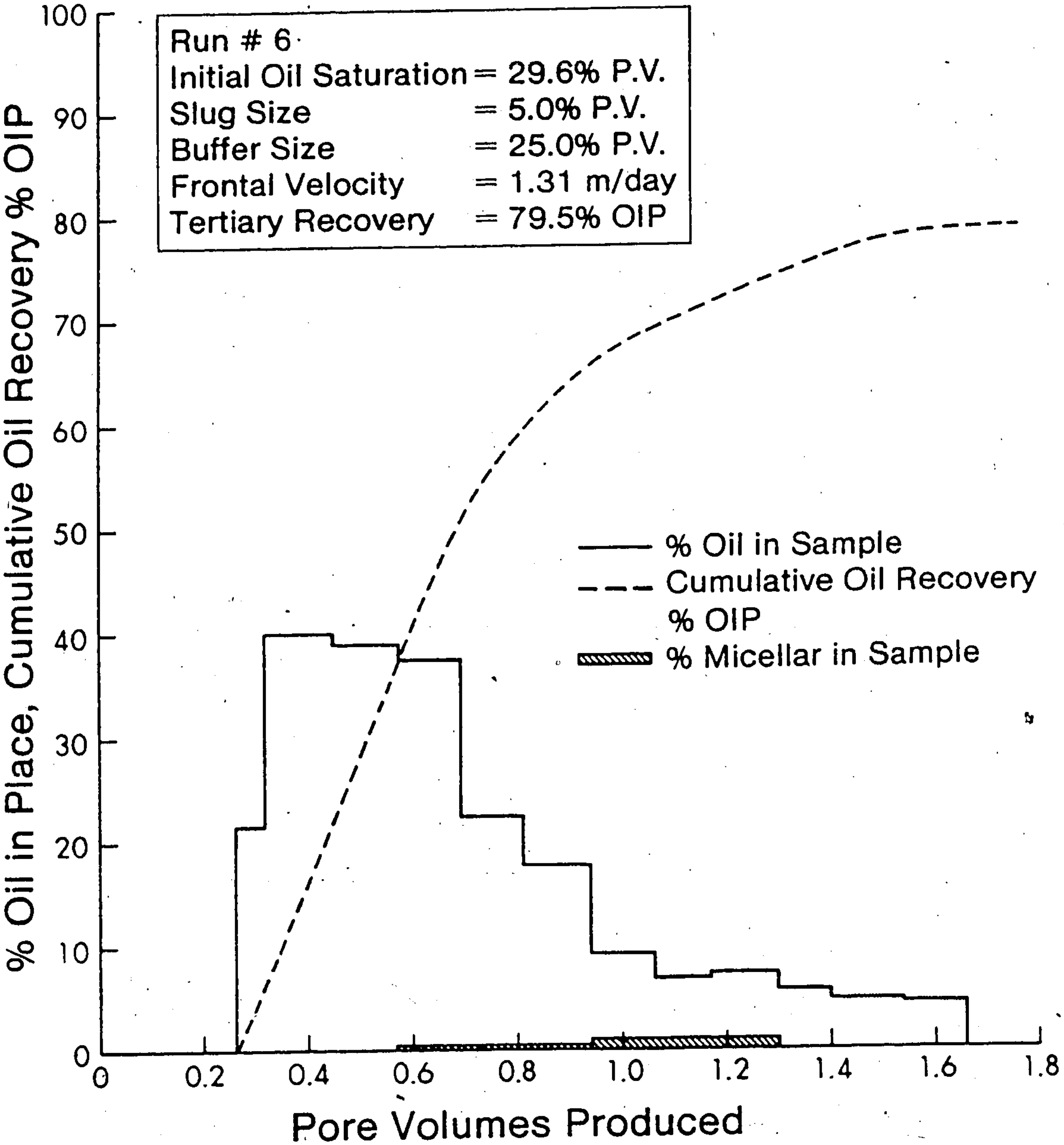


Fig. 26 Production history for 5% P.V. Micellar Slug B_1 and 25% P.V. Dow Pusher Buffer injected at 1.31 m/day.

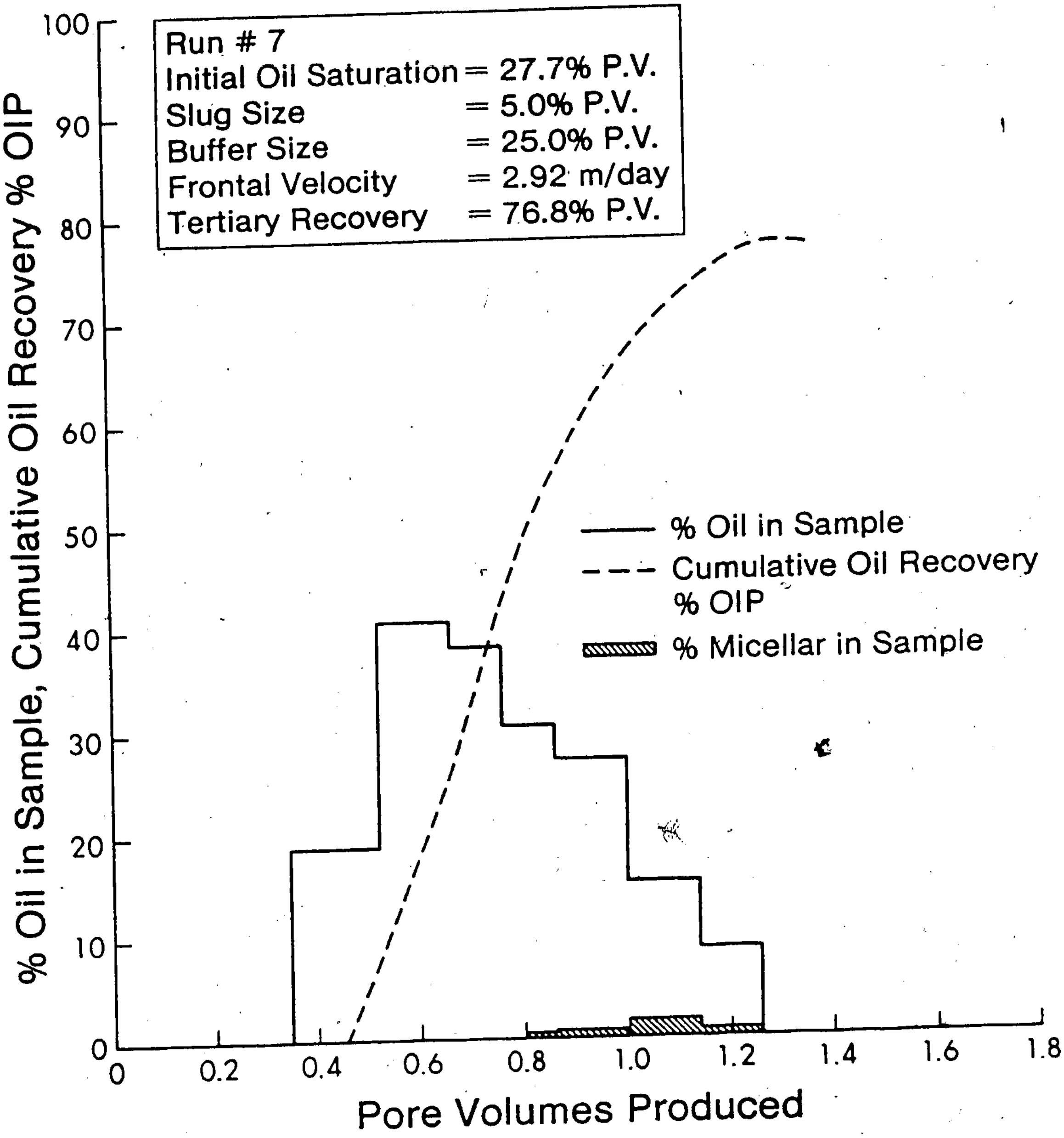


Fig. 27 Production history for 5% Micellar Slug and 25% Dow Pusher Buffer injected at 2.92 m/day.

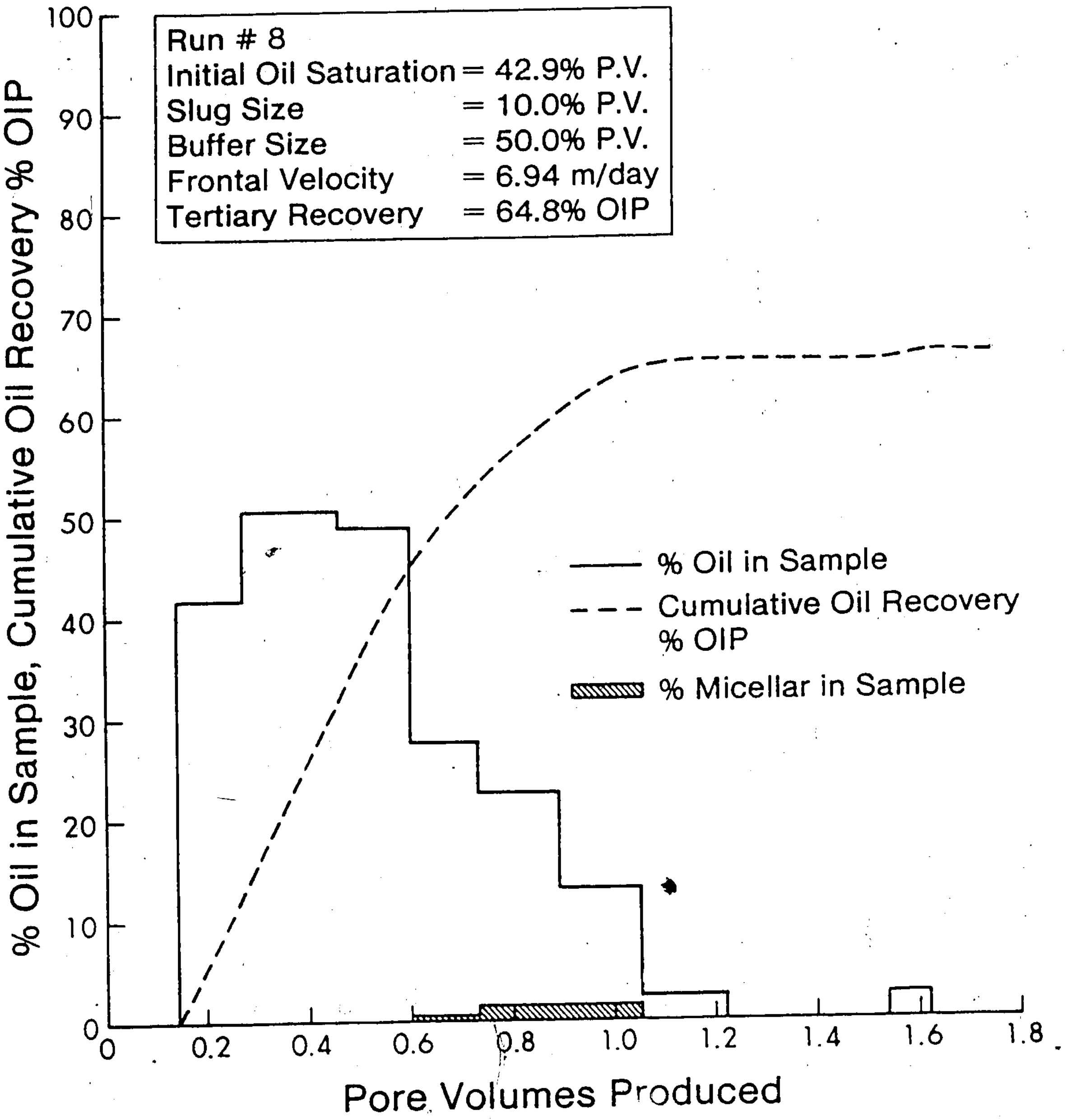


Fig. 28 Production history for 10% P.V. Micellar Slug B_1 and 50% P.V. Dow Pusher Buffer injected at 6.94 m/day.

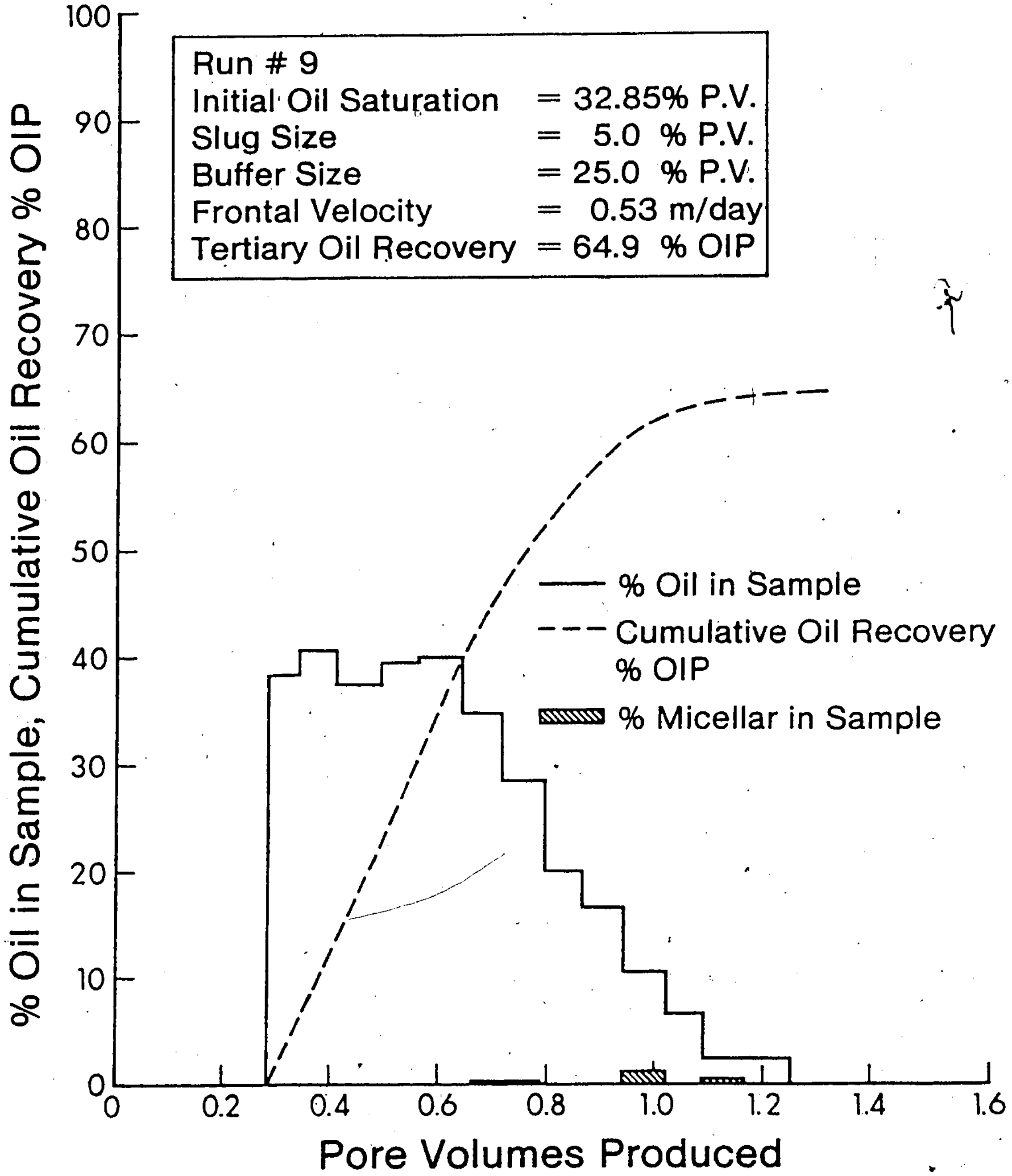


Fig. 29 Production history for 5% P.V. Micellar Slug B_1 and 25% P.V. Dow Pusher Buffer injected at 0.53 m/day.

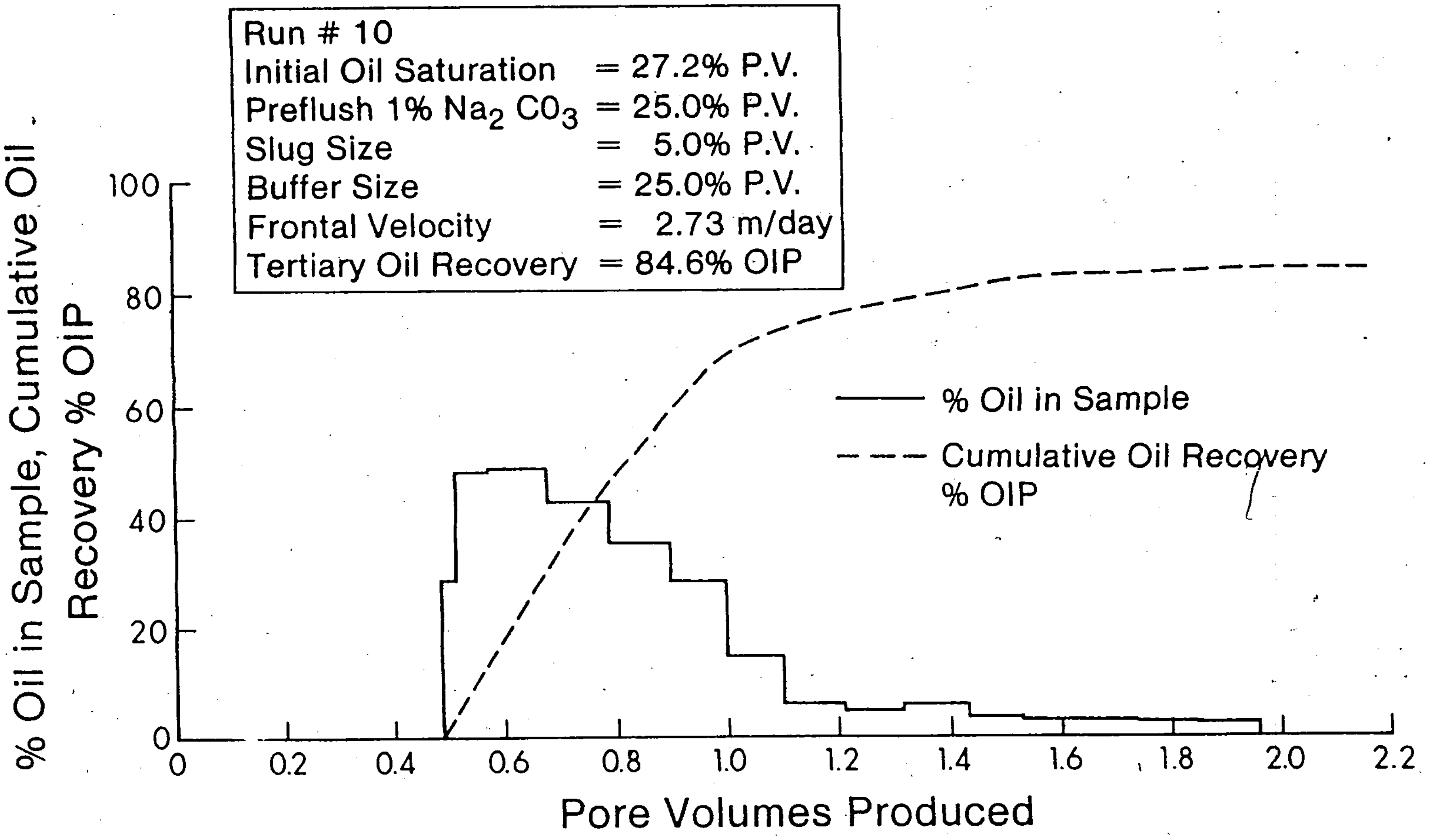


Fig.30 Prodution History for 5% P.V. Micellar Slug B_1 and 25.0% P.V. Dow Pusher Buffer injected at 2.73 m/day with Sodium Carbonate Preflush.

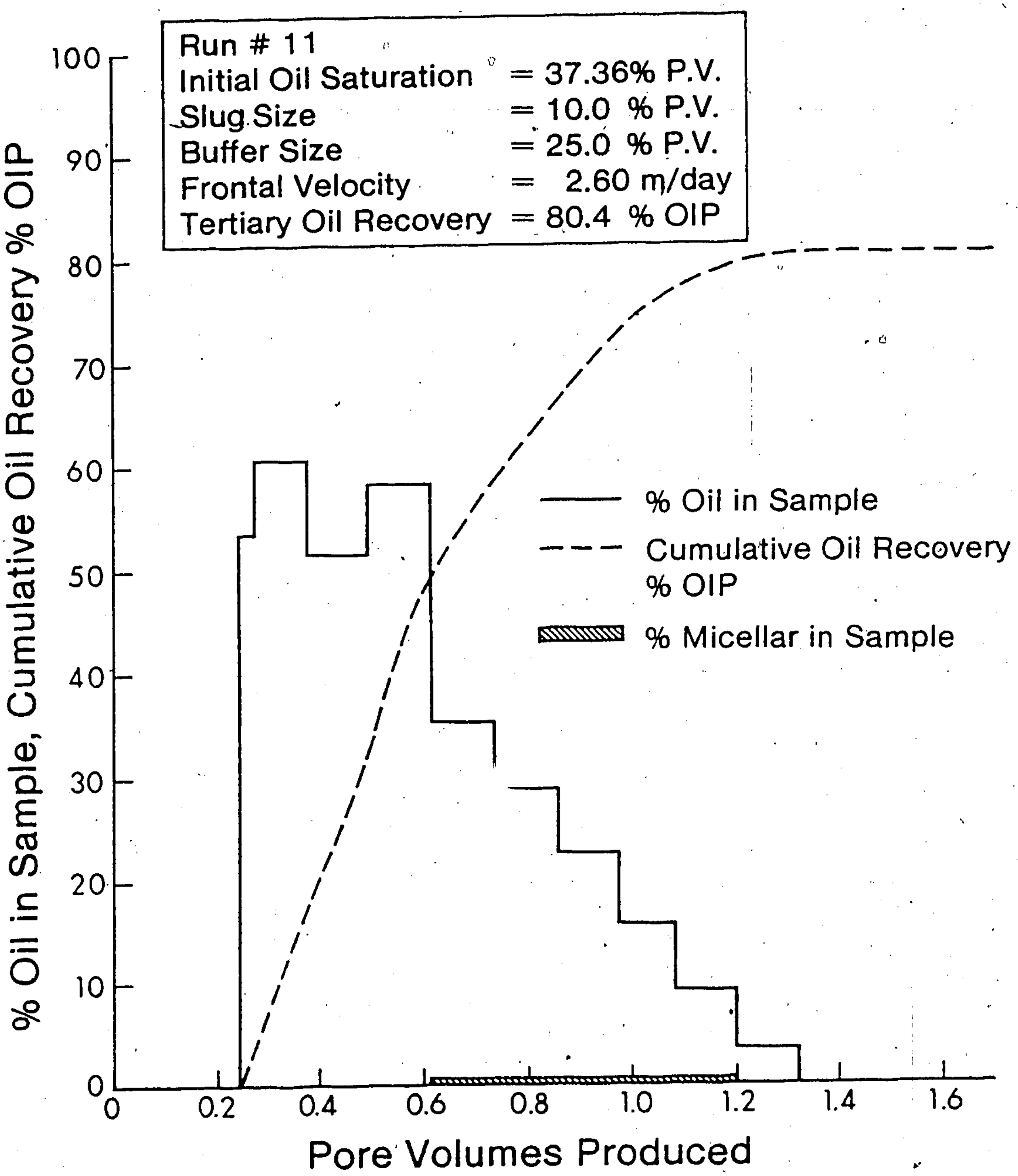


Fig31Production history for 10% P.V. Micellar Slug B_1 and 25% P.V. Dow Pusher Buffer injected at 2.60 m/day.

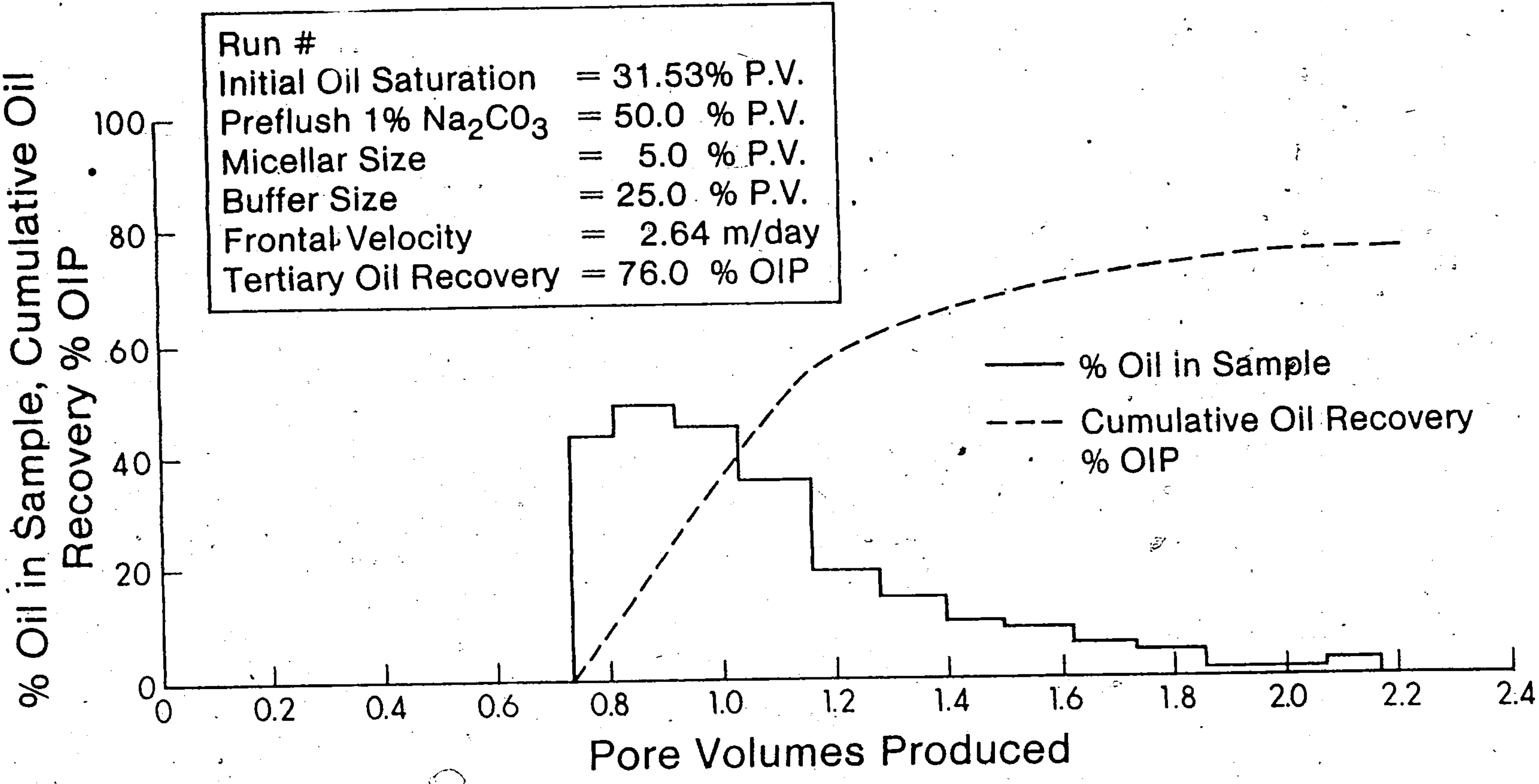


Fig.32 Production history for 5% P.V. Micellar Slug B_1 and 25% P.V. Dow Pusher Buffer injected at 2.64 m/day with Sodium Carbonate Preflush.

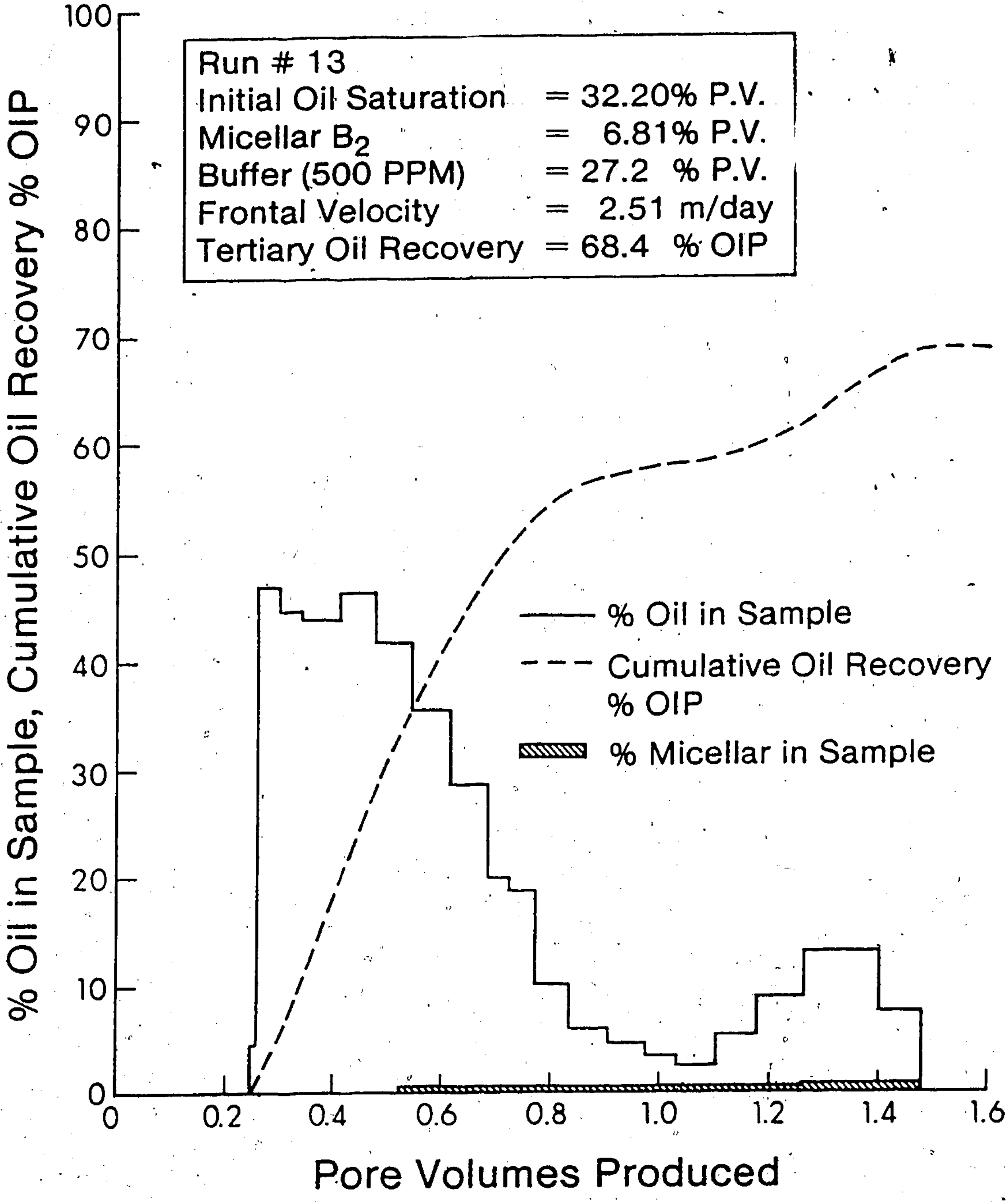


Fig33 Production history for 6.81% P.V. Micellar Slug B_2 and 27.2% P.V. Dow Pusher Buffer injected at 2.51 m/day.

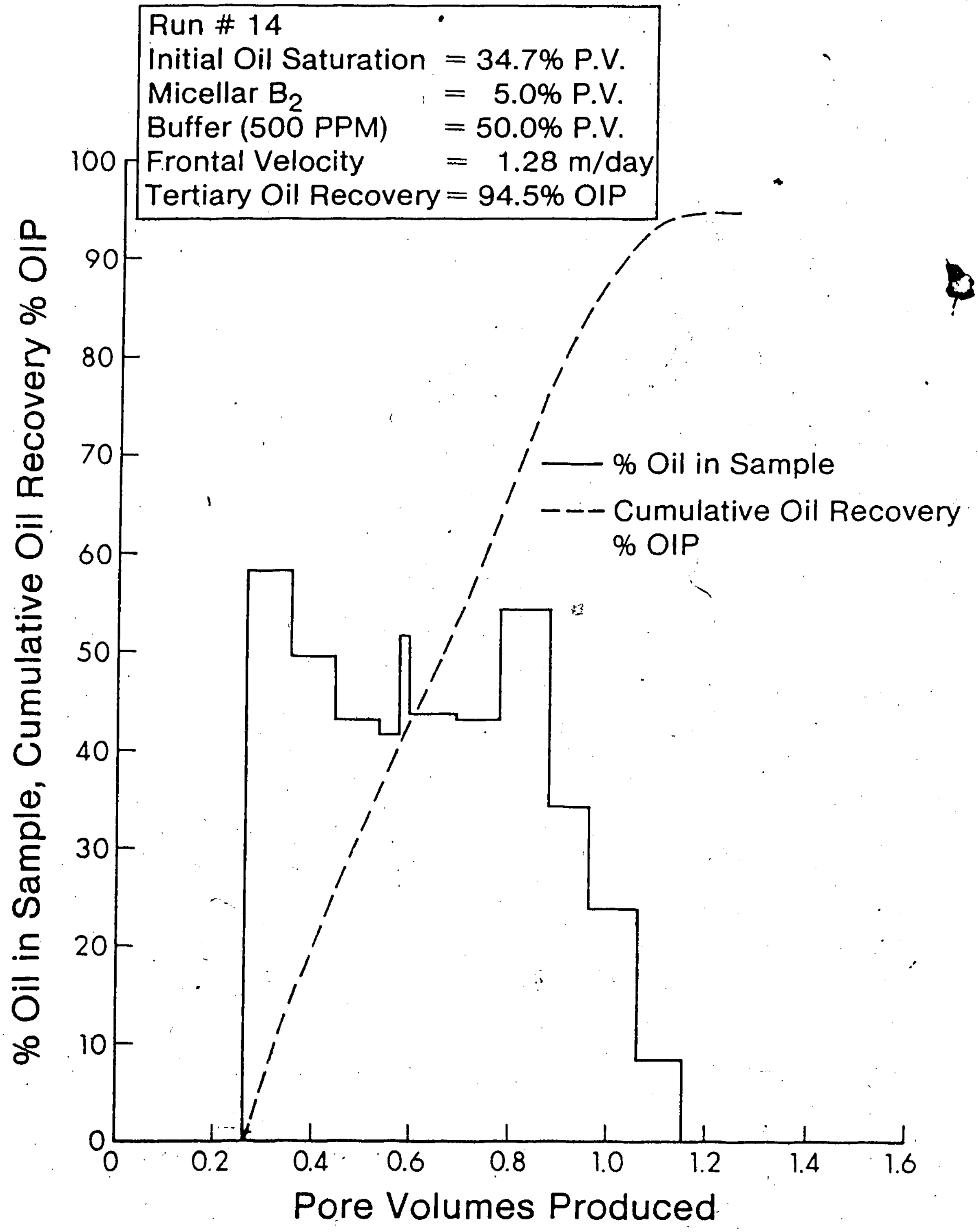


Fig.34 Production history for 5.0% P.V. Micellar Slug B_2 and 25.0% P.V. Dow Pusher Buffer injected at 1.28 m/day.

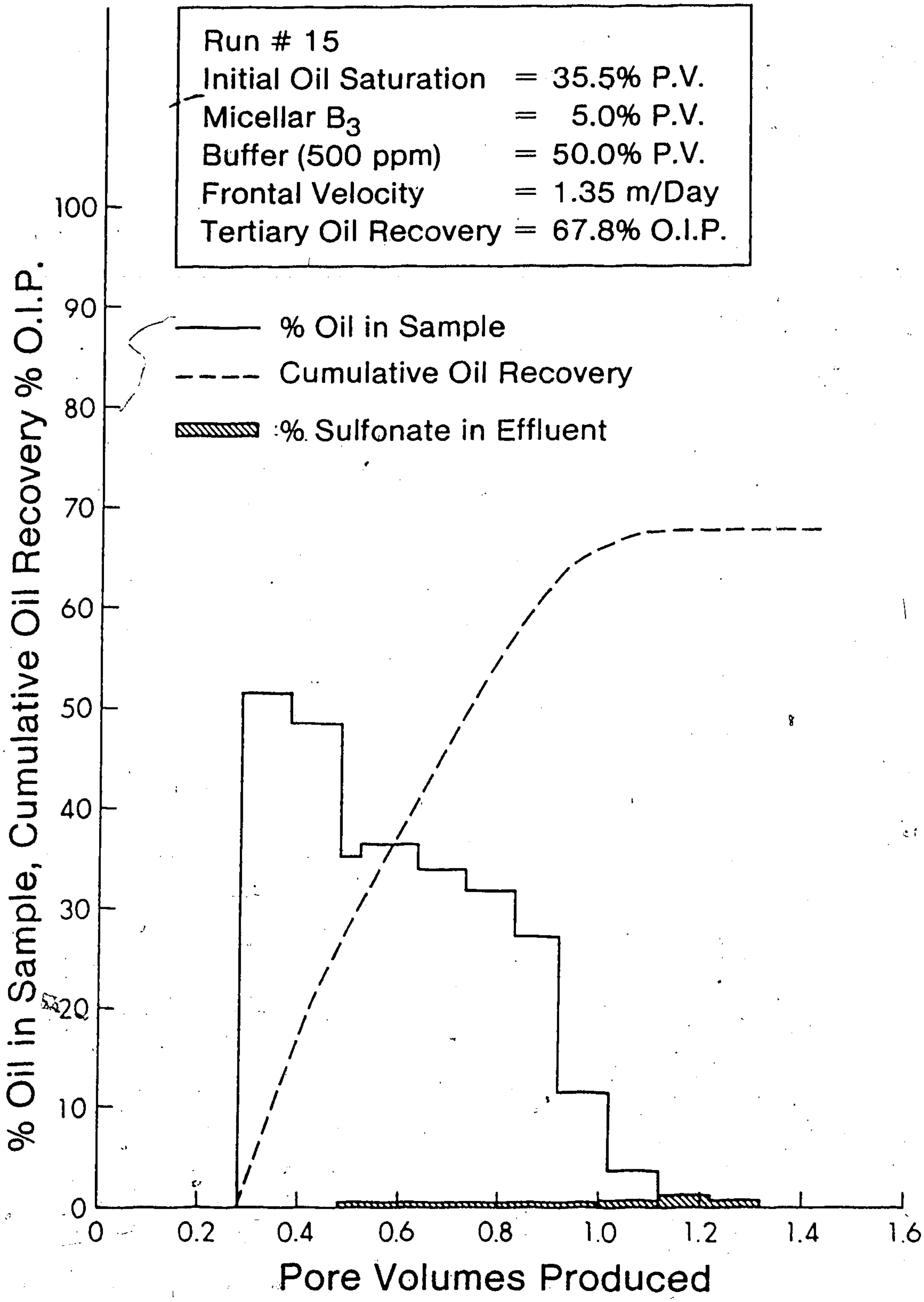


Fig. 35 Production History for 5.0% P.V. Micellar Slug B_3 and 50.0% P.V. Dow Pusher Buffer Injected at 1.35 m/Day.

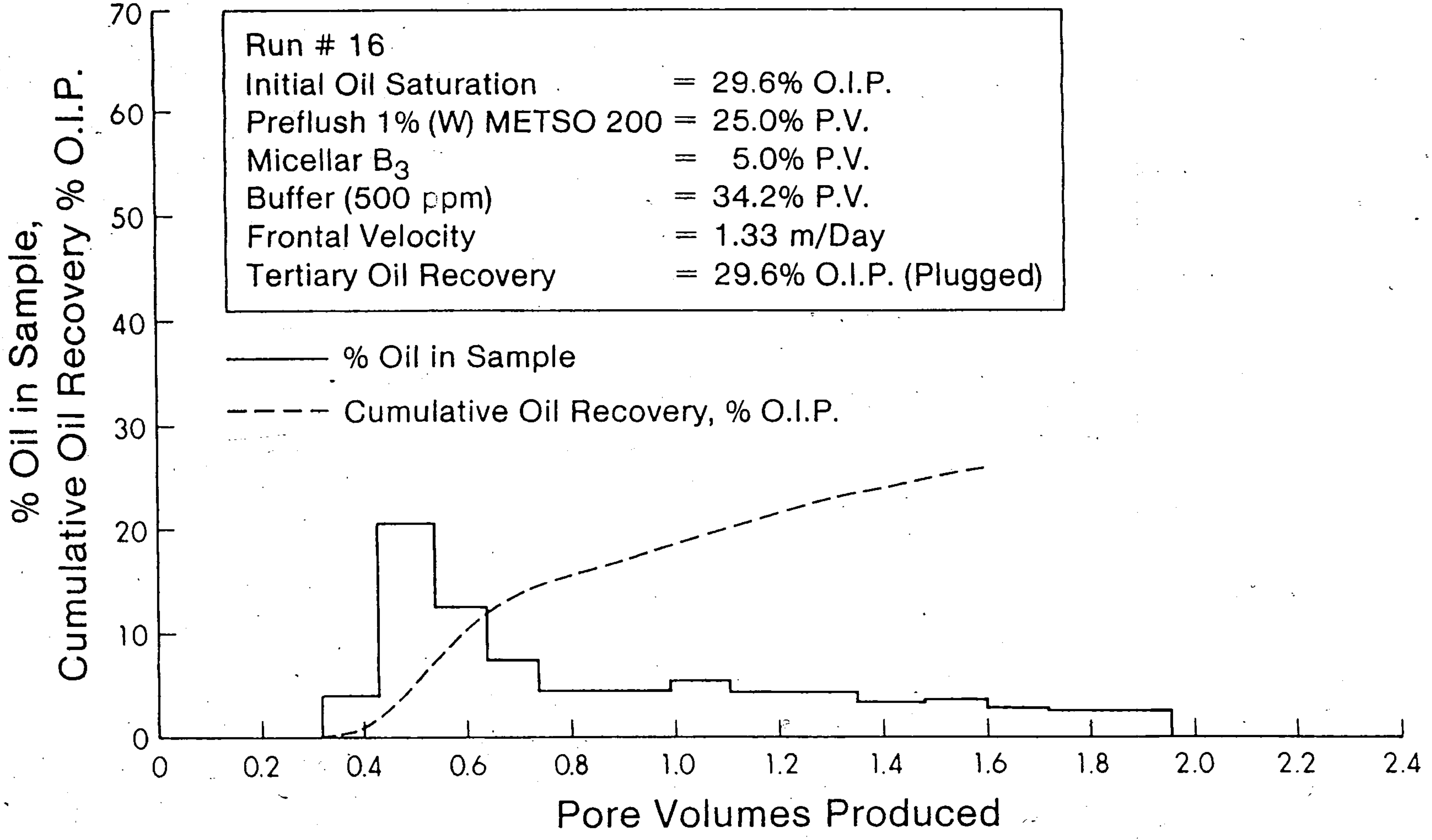


Fig.3 6 Production History for 5.0% P.V. Micellar Slug B_3 and 34.2% P.V. Dow Pusher Buffer Injected at 1.33 m/Day with 25% P.V. 1% (W) Sodium Orthosilicate Preflush.

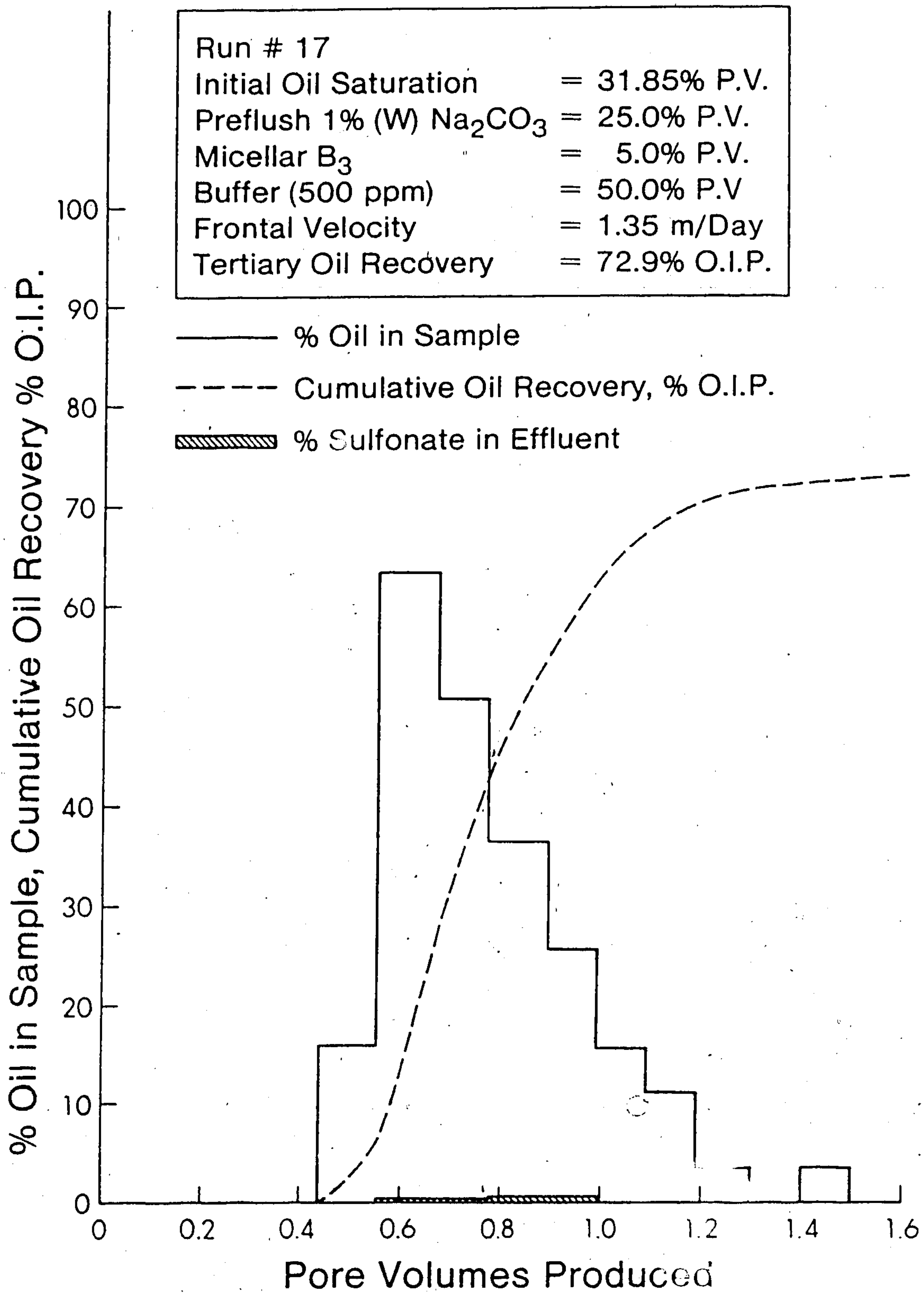


Fig.3 7 Production History for 5.0% P.V. Micellar Slug B_3 and 50.0% P.V. Dow Pusher Buffer Injected at 1.35 m/Day with 25% P.V. 1% (W) Na_2CO_3 Preflush.

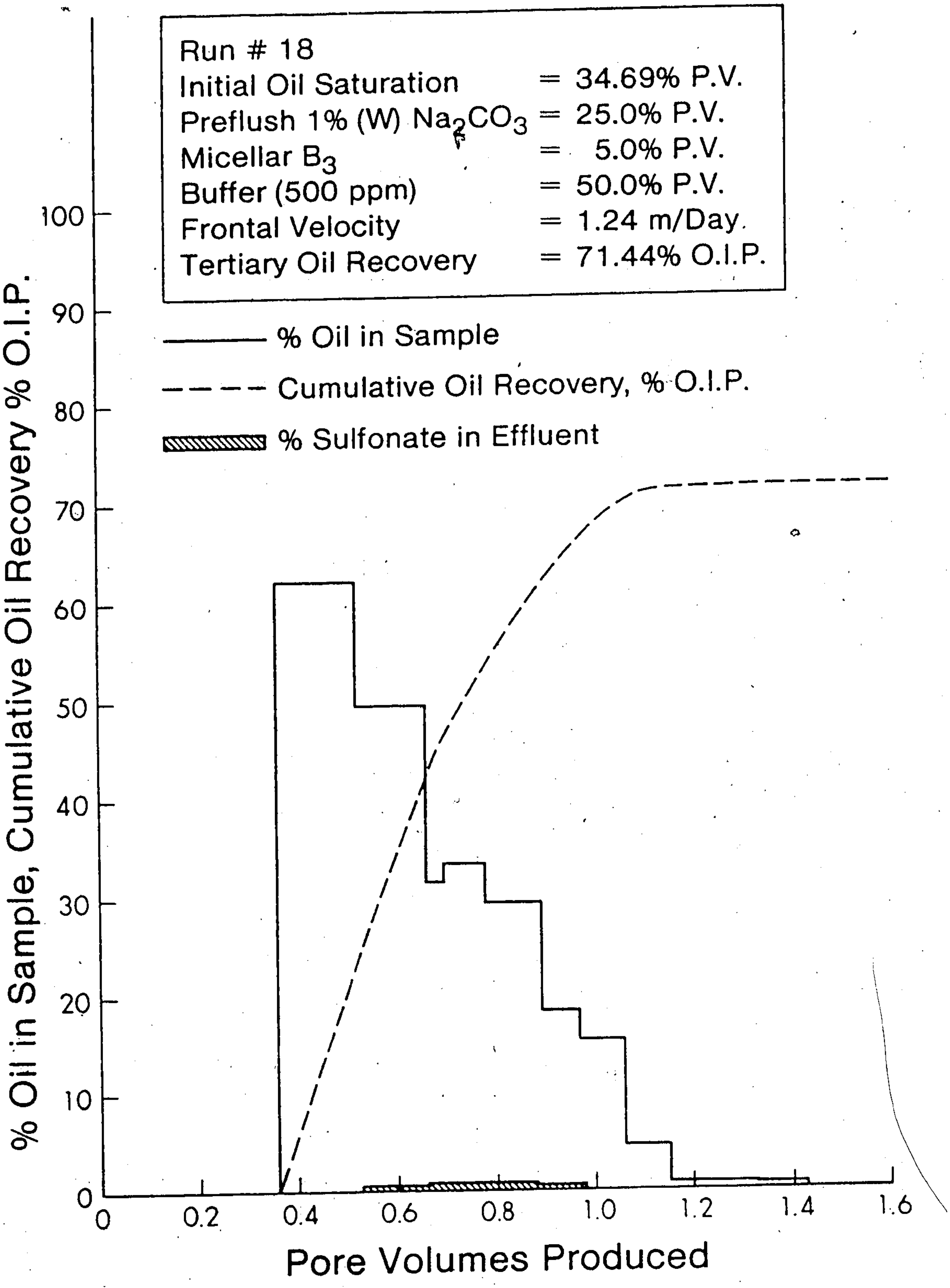


Fig. 38 Production History for 5.0% P.V. Micellar Slug B_3 and 50.0% P.V. Dow Pusher Buffer Injected at 1.24 m/Day with 25% P.V. 1% (W) Na_2CO_3 Preflush.

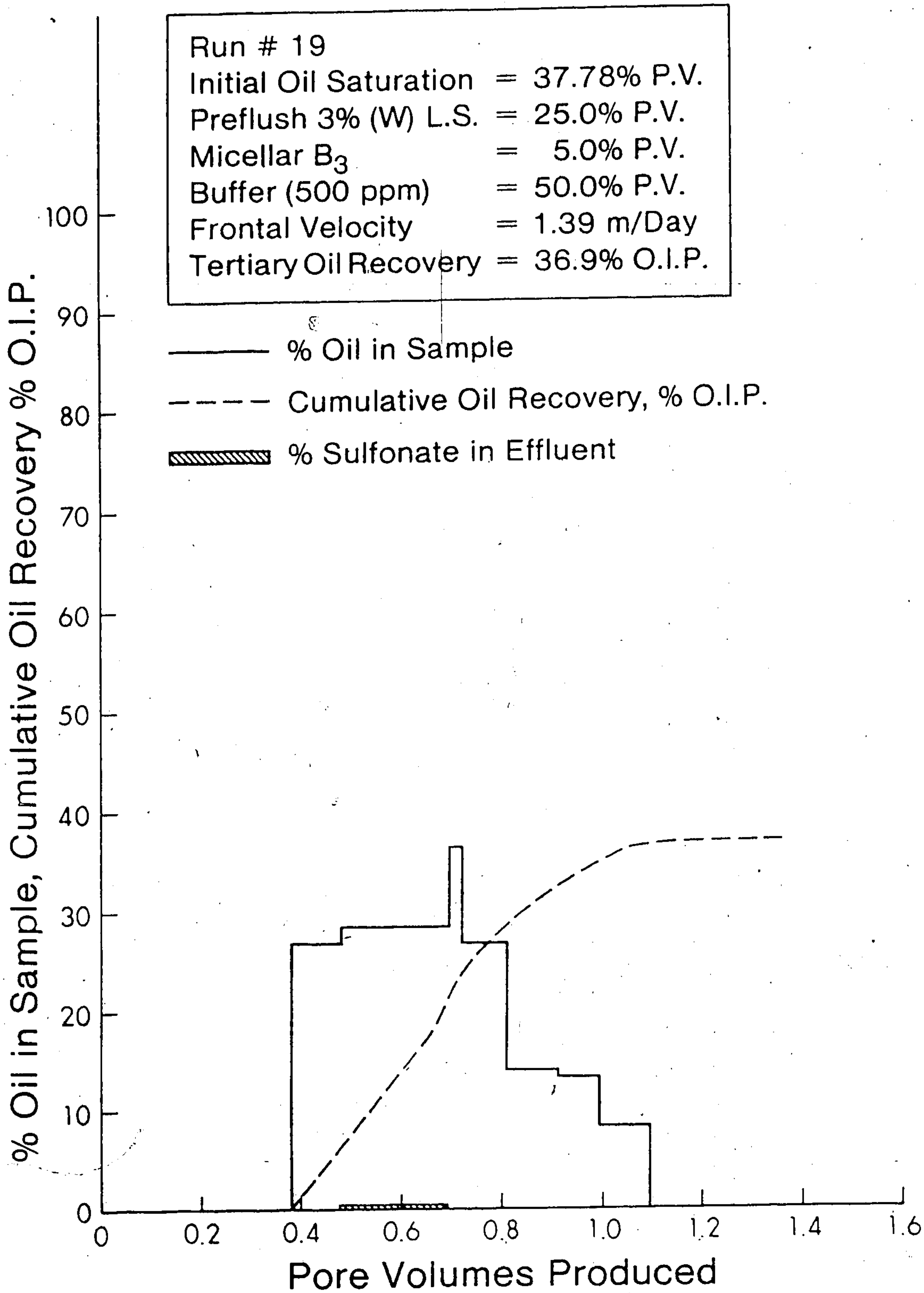


Fig. 39 Production History for 5.0% P.V. Micellar Slug B_3 and 50.0% P.V. Dow Pusher Buffer Injected at 1.39 m/Day with 25% P.V. 3% (W) Lignosulfonate Preflush.

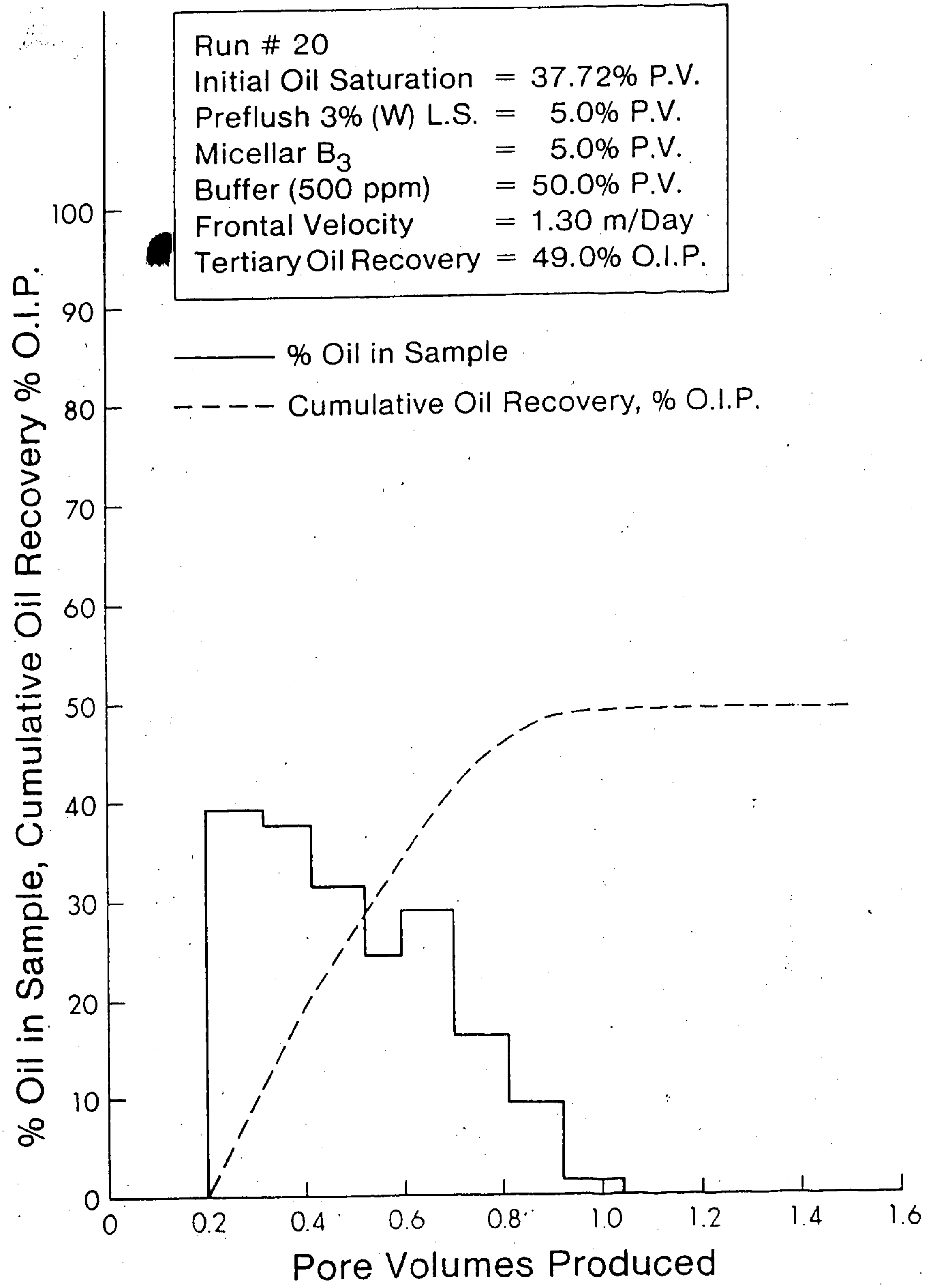


Fig.40 Production History for 5.0% P.V. Micellar Slug B_3 and 50.0% P.V. Dow Pusher Buffer Injected at 1.30 m/Day with 5% P.V. 3% (W) Lignosulfonate Preflush.

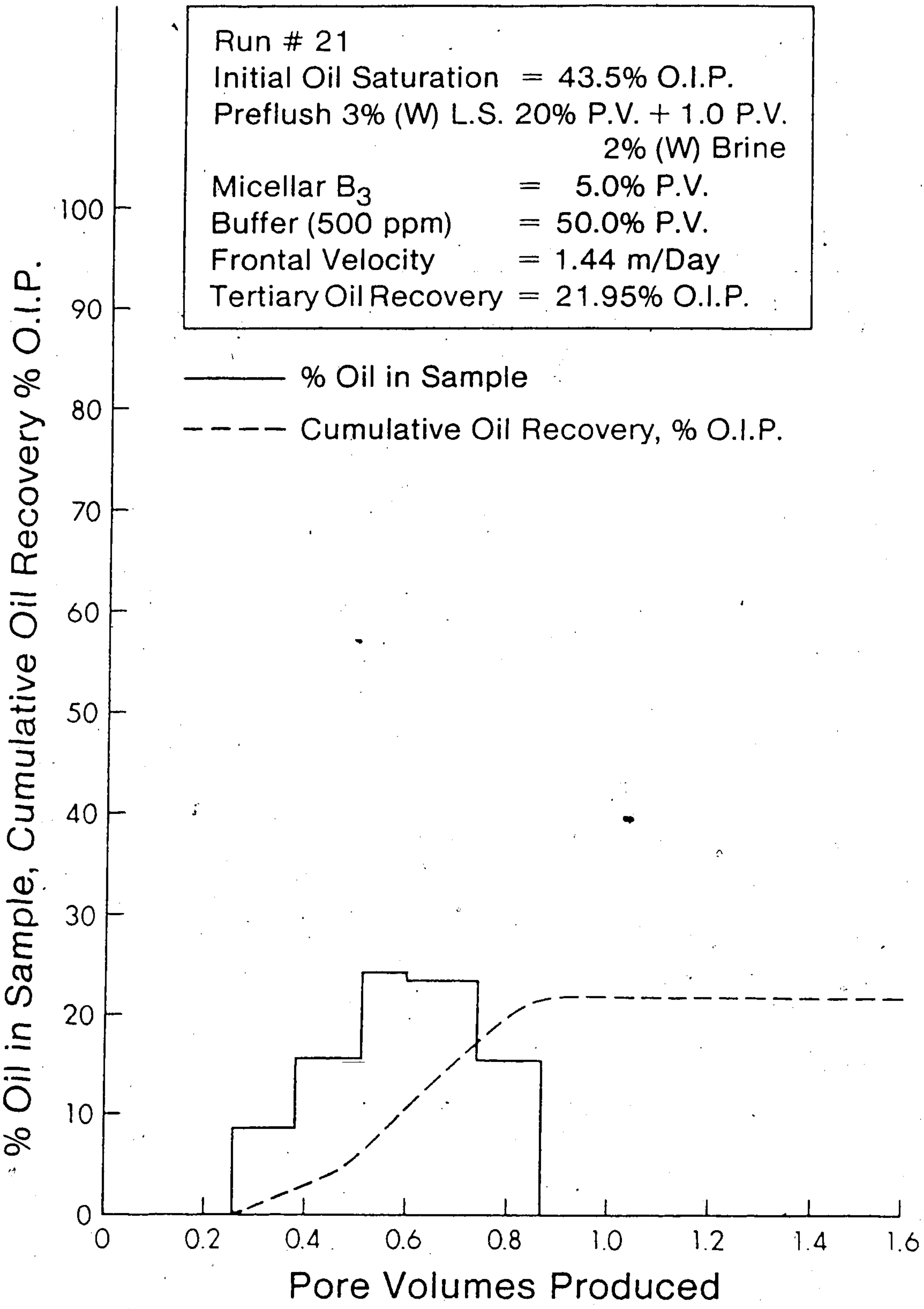


Fig.41 Production History for 5.0% P.V. Micellar Slug B_3 and 50.0% P.V. Dow Pusher Buffer Injected at 1.44 m/Day with a 3% (W) Lignosulfonate Preflush.

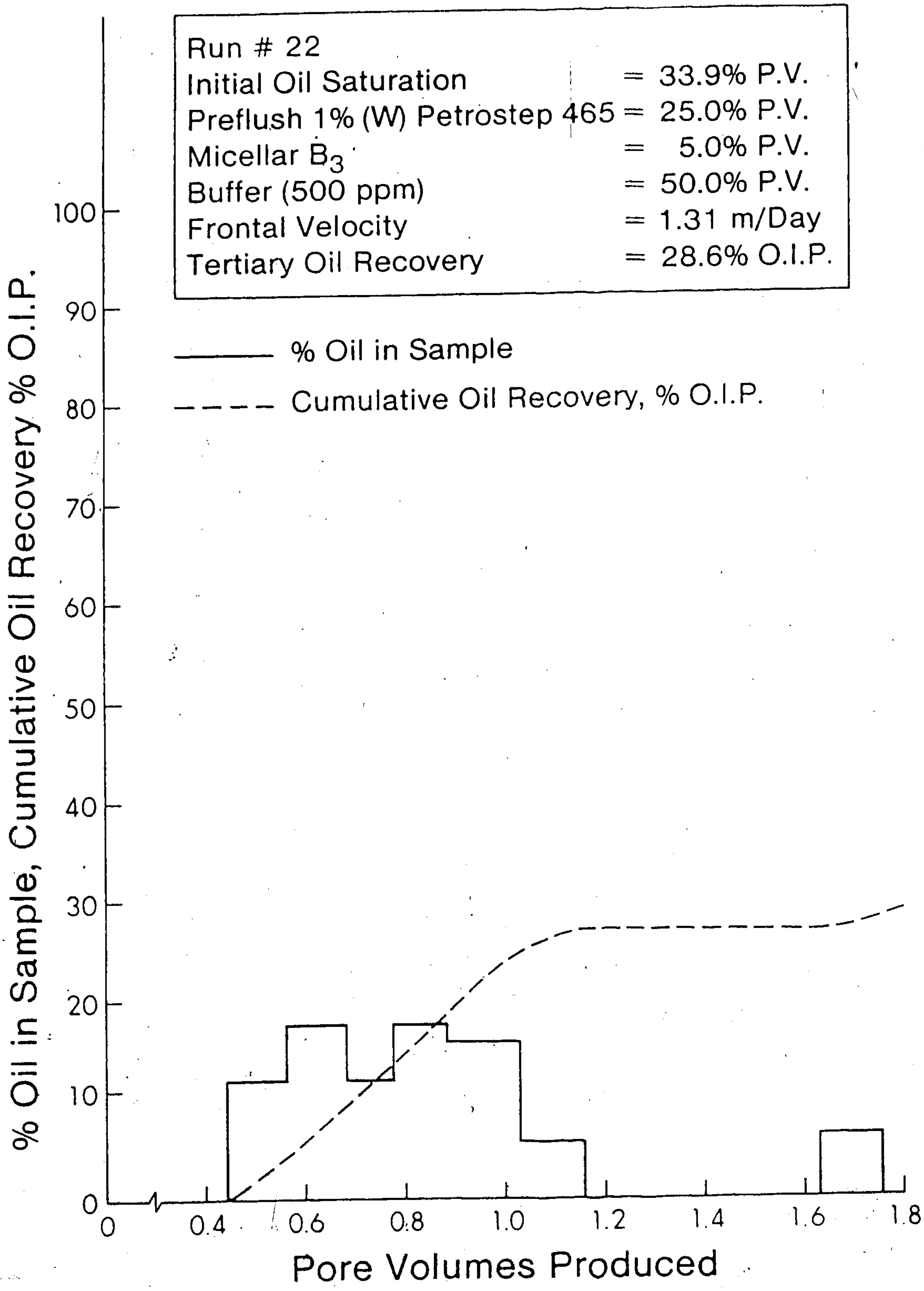


Fig.4 2 Production History for 5.0% P.V. Micellar Slug B_3 and 50.0% P.V. Dow Pusher Buffer Injected at 1.31 m/Day with 25% P.V. 1% (W) Petrostep Preflush.

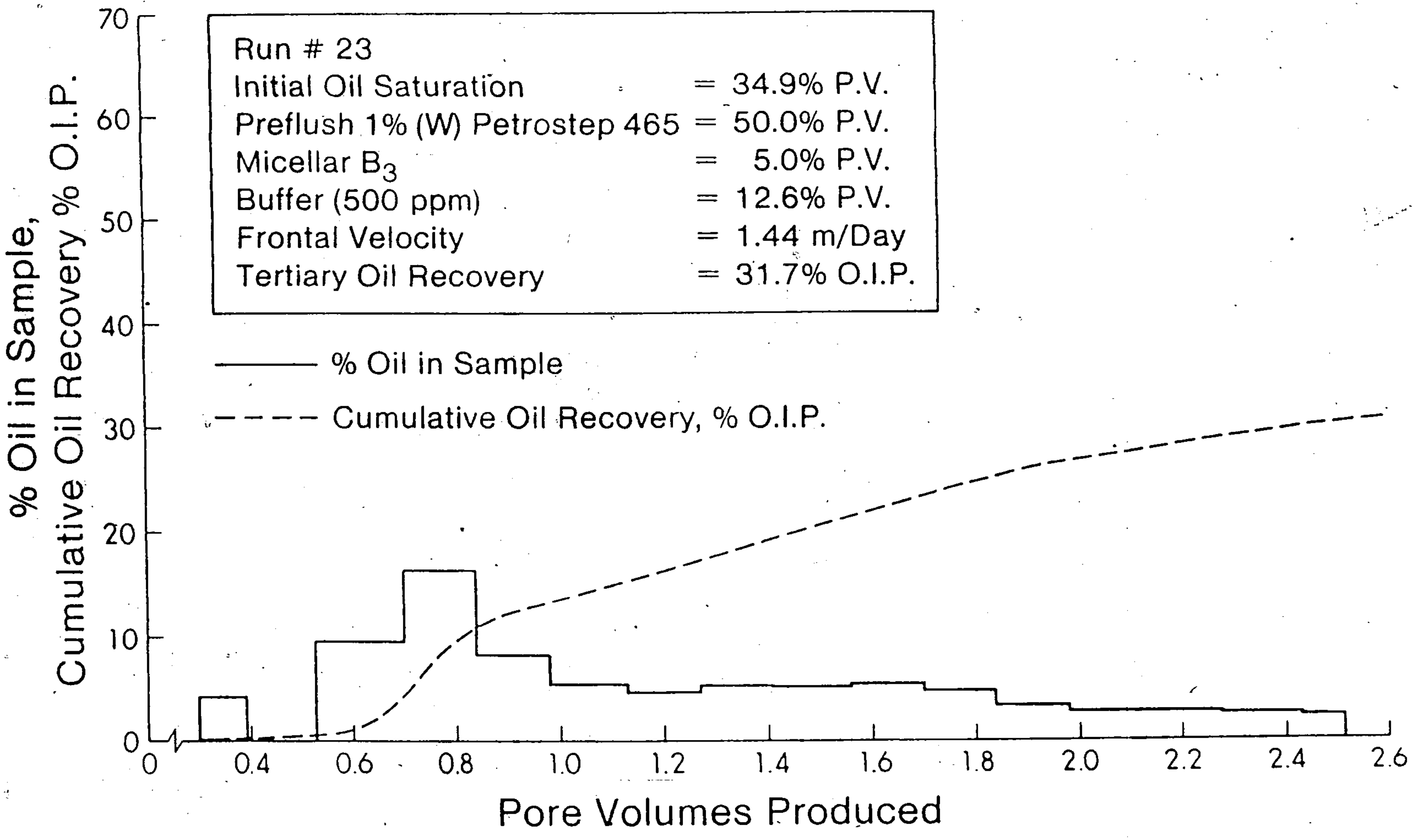


Fig.43 Production History for 5.0% P.V. Micellar Slug B_3 and 12.6% P.V. Dow Pusher Buffer Injected at 1.44 m/Day with 50.0% P.V. 1% (W) Petrostep Preflush.

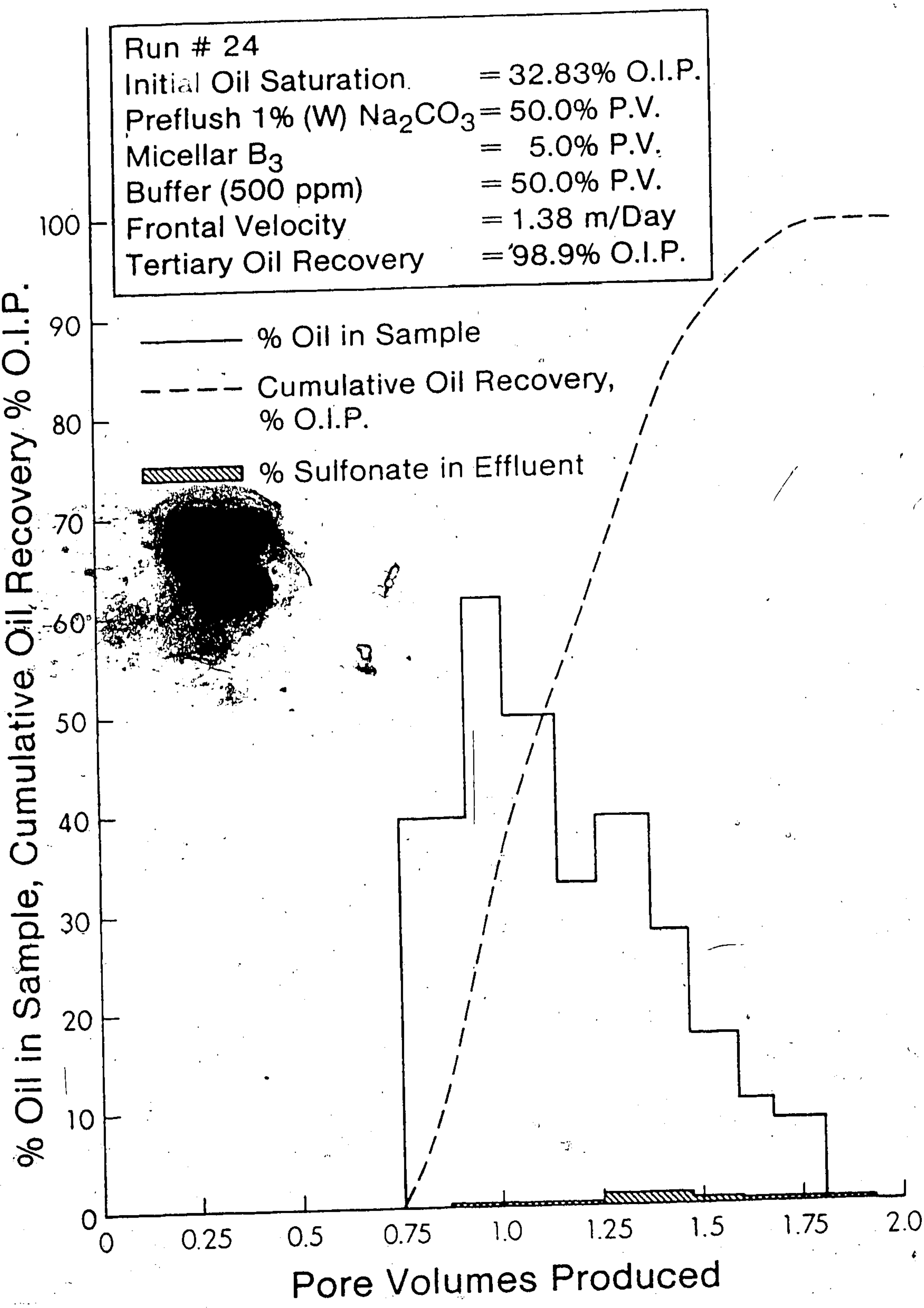


Fig.44 Production History for 5.0% P.V. Micellar Slug B_3 and 50.0% P.V. Dow Pusher Buffer Injected at 1.38 m/Day with a 50.0% P.V. 1% (W) Na_2CO_3 Preflush.

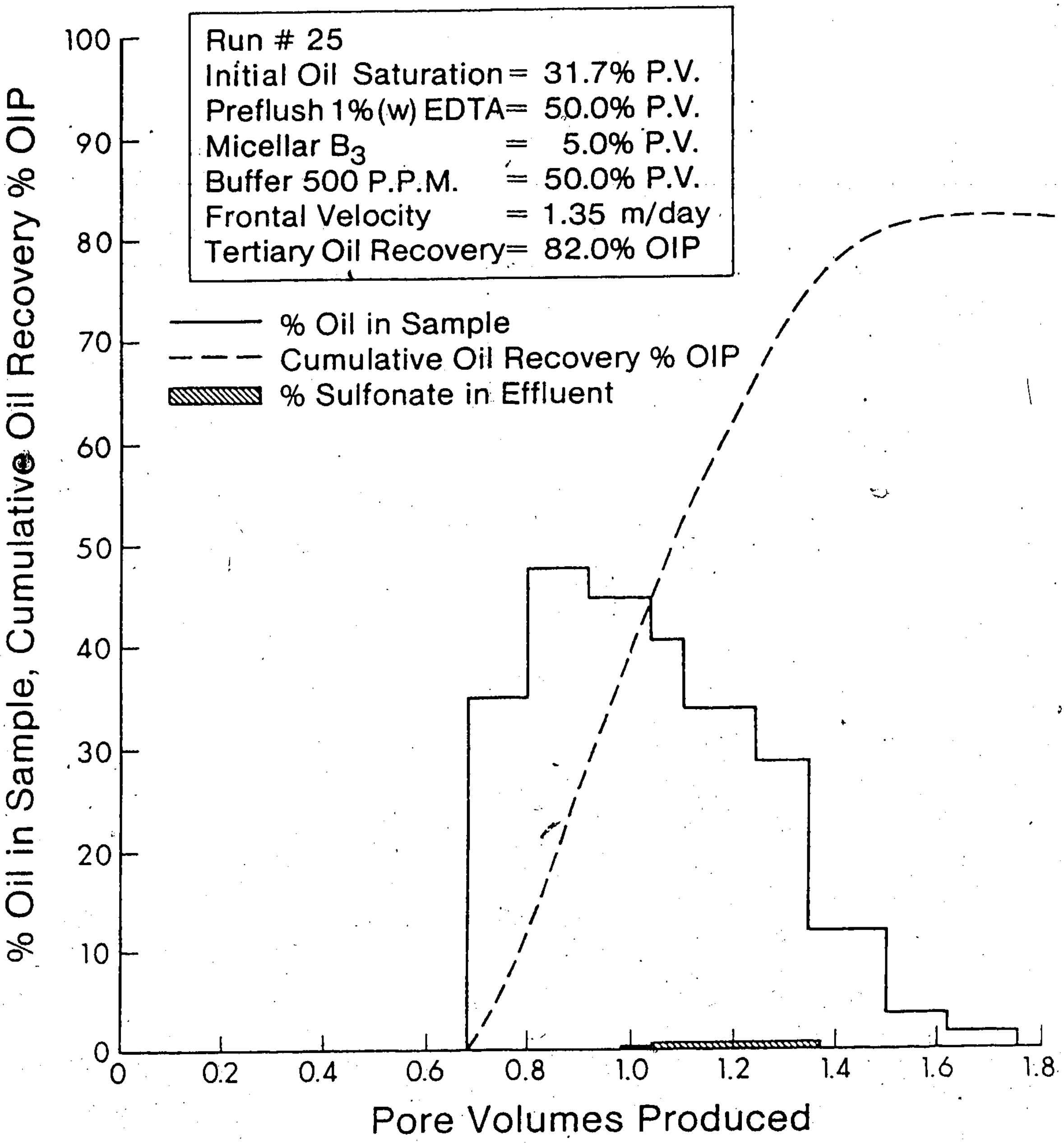


Fig45 Production history for 5.0 P.V. Micellar Slug B_3 and 50.0% P.V. Dow Pusher Buffer injected at 1.35 m/day with 50.0% P.V. EDTA Preflush.

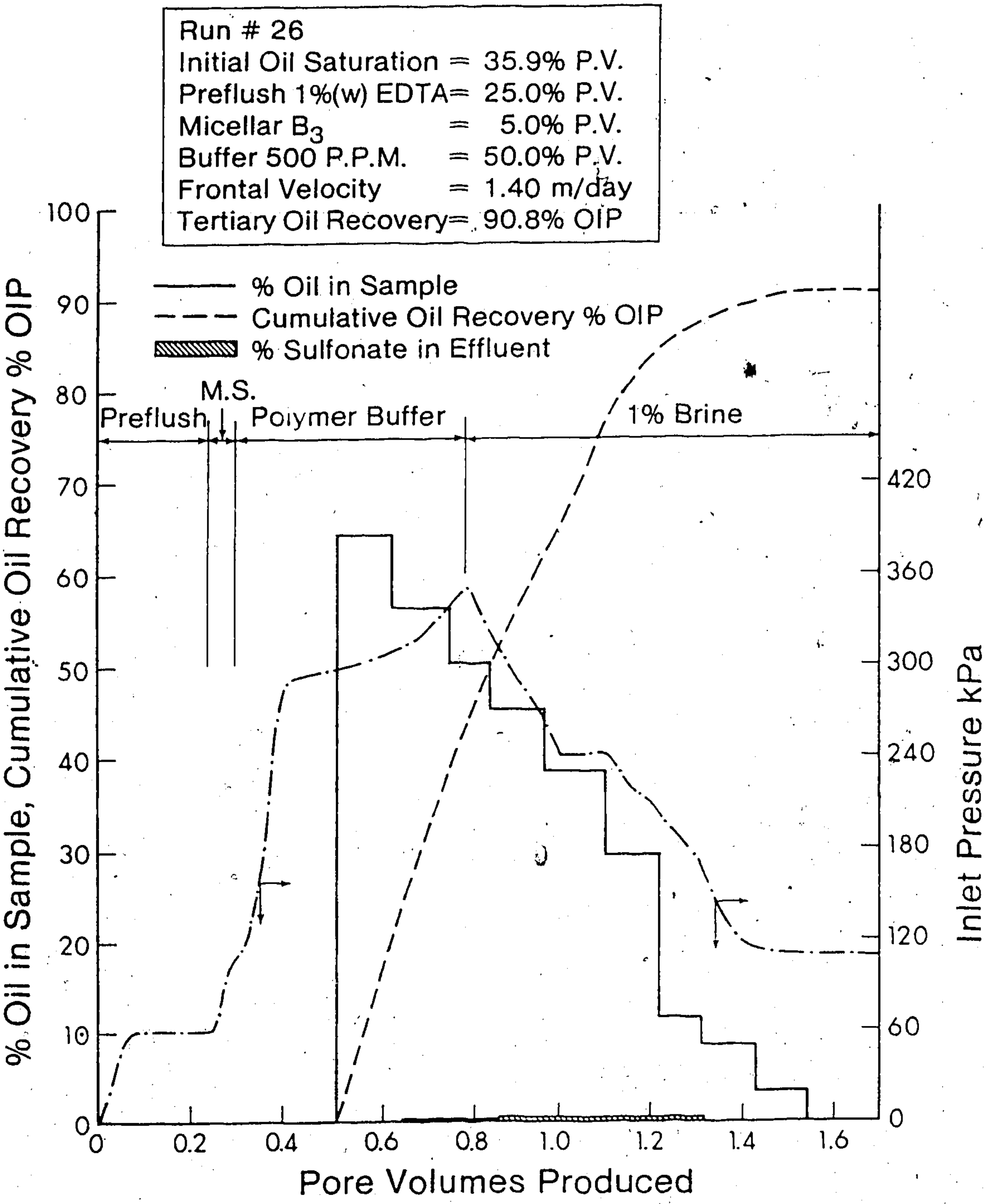


Fig.46Production history for 5.0 P.V. Micellar Slug B_3 and 50.0% P.V. Dow Pusher Buffer injected at 1.40 m/day with 25% P.V. 1%(w) EDTA Preflush.

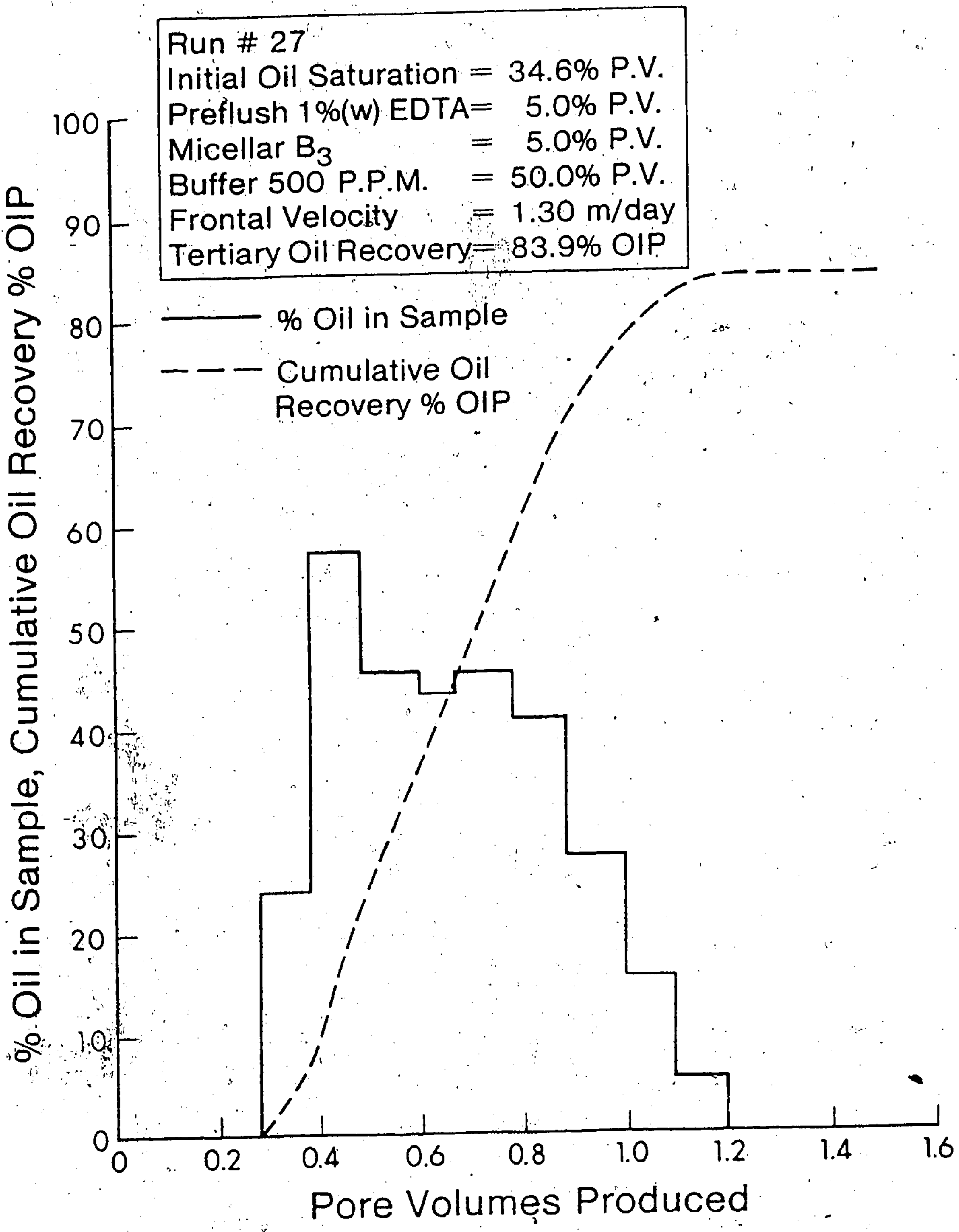


Fig.47 Production history for 5.0 P.V. Micellar Slug B_3 and 50.0% P.V. Dow Pusher Buffer injected at 1.30 m/day with a 5.0% P.V. EDTA Preflush.

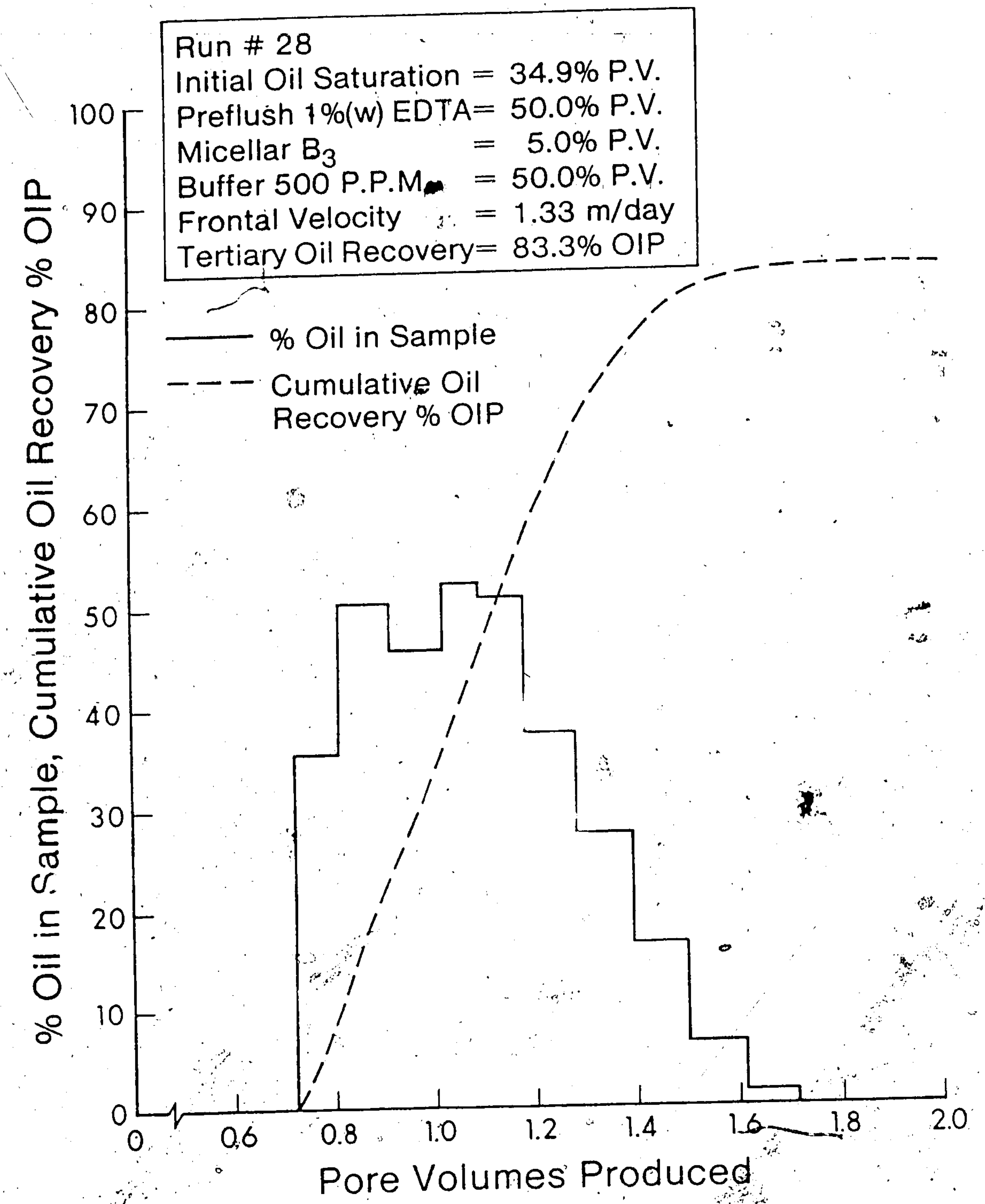


Fig.48 Production history for 5.0 P.V. Micellar Slug B_3 and 50.0% P.V. Dow Pusher Buffer injected at 1.33 m/day with 50.0% P.V. EDTA Preflush.

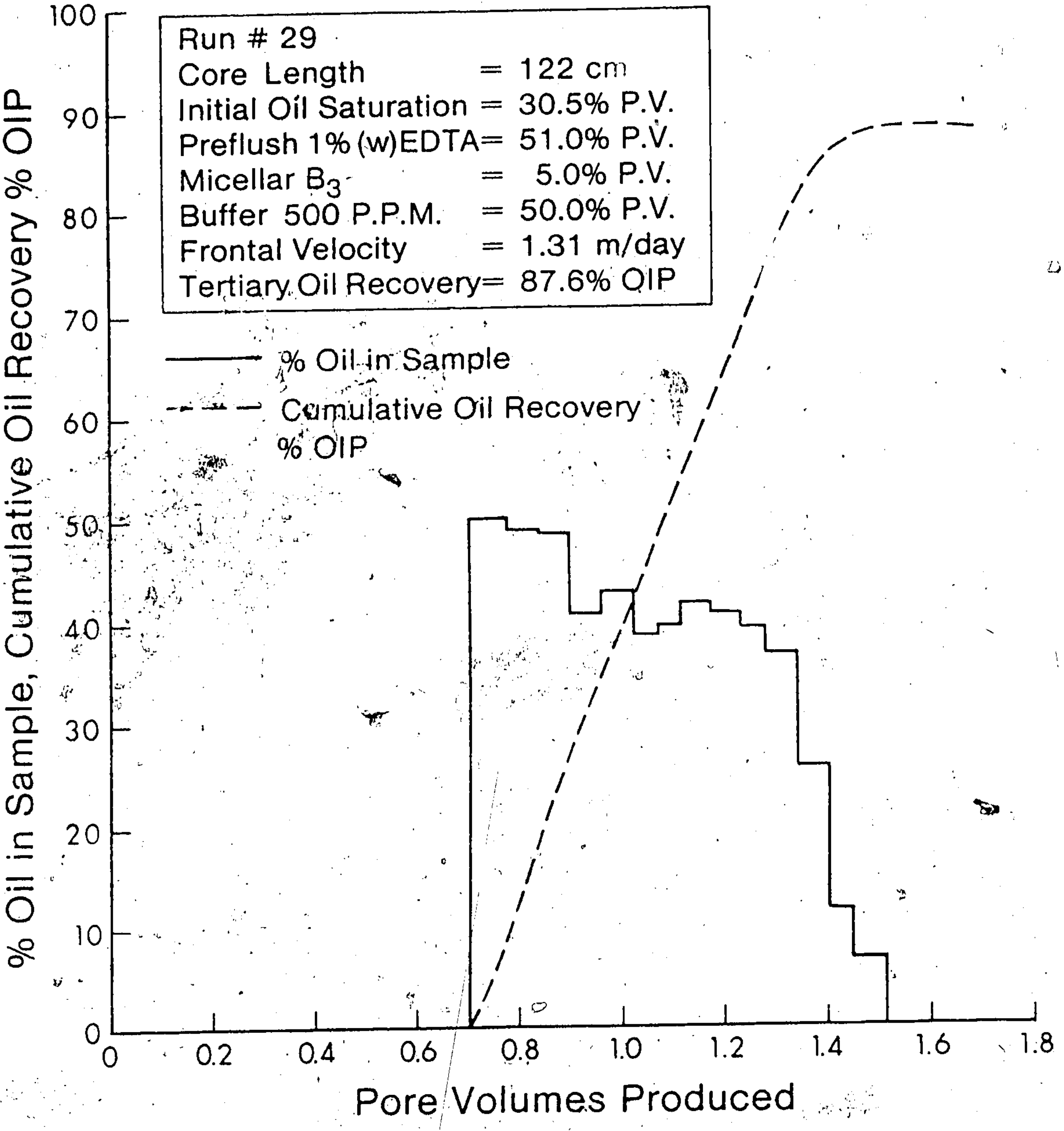


Fig49 Production history for 5.0% P.V. Micellar Slug B_3 and 50.0% P.V. Dow Pusher Buffer injected at 1.31 m/day with 51% P.V. 1%(w) EDTA Preflush.

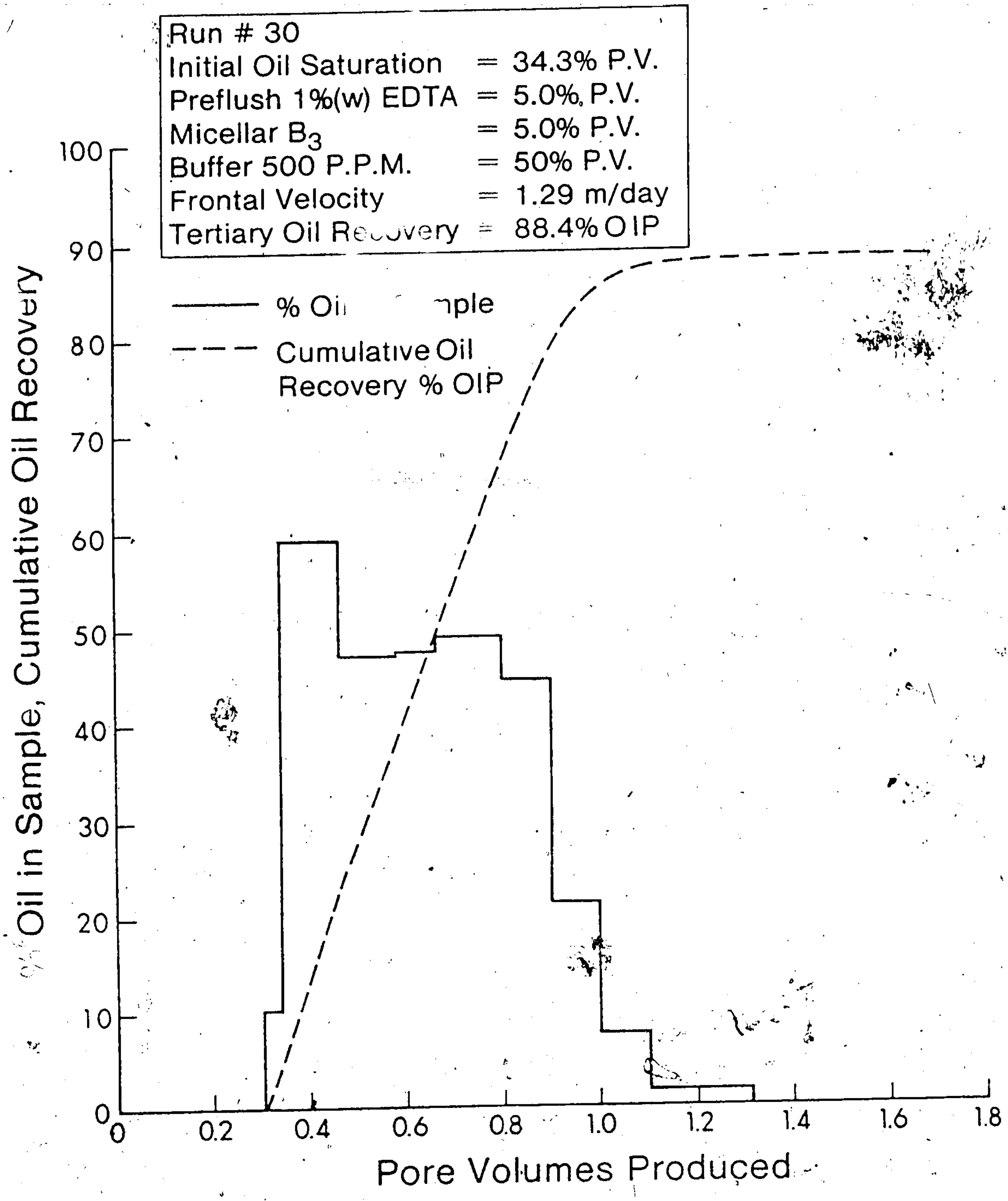


Fig.50 Production history for 5.0 P.V. Micellar Slug B_3 and 50% P.V. Dow Pusher Buffer injected at 1.29 m/day with 5.0% P.V. 1%(w) EDTA Preflush.