The Role of Microorganisms on The Phase Variation For Crude Oil -Nutrient Solution System

By M.Khairy *, M.H.Sayyouh *, A.Mahmoud *, A.Osman*, and G.A.EL Morsy**

* Petroleum Engineering Department, Cairo University, Egypt.
**Plant Pathology Insititute,ARC.Giza, Egypt

ABSTRACT

The main objective of this study was to investigate the effect of bacteria , originally present in the crude oil , and their metabolic products on phase variation of crude oil - aqueous phase system .

It was found that , the phase variation was affected by the salinity , temperature , and nutrient type and concentration .These findings are new and will establish the interpretations of increasing oil recovery by microorganisms.

INTRODUCTION

The limited chance for the discovery of new high quality oil reservoirs has focused attention on processes which may contribute to improved petroleum recovery from existing wells. These processes are designed primary to overcome the capillary forces which trap oil in the reservoir rock and to improve the volume of the oil - bearing formation swept by natural or introduced fluids and gases.

The petroleum industry is continuing to develop oil recovery and enhanced oil recovery technology. The cost of these processes produces marginal or negative economics . Unfortunately , the cost of the compounds used in enhanced oil recovery (EOR) is related directly to the cost of petroleum . In these processes financial returns by definition must remain marginal . This problem can be solved if the compounds used in EOR is produced in situ by just nutriting indigenous bacteria present in the crude oil. Further , the in situ produced metabolites may be avoided from losses due to

1-Production of solvents, such as alcohols and ketones that may dissolve more residual oil and stabilize the formed emulsion.
2-Production of gases such as H_2,N_2,CO_2 and CH_4 that could improve oil recovery through increasing reservoir pressure and reducing viscosity of the residual oil left behind the primary and/or secondary production mechanisms.
3-Production of bioploymers and extracellular slimes that may plug the high permeability zones of the rock (channeling) so that a successive water-flood will be inverted into the smaller pores resulting in reduced fingering and increasing areal sweep efficiency.
4-Production of organic acids that can dissolve the carbonaceaus rock and accordingly increase reservoir permeability.
5-Production of biosurfactants that may reduce the oil water interfacial tension (IFT) and cause emulsification.The biosurfactant, on the other hand, might alter the relative permeability of the rock to oil by changing the wettability of the reservoir rock and thus, improves the oil recovery.
6-Generation of high pressure by bacterial growth in the pores of the rock close to the wellbore, that may be used as a clean-out process by blowing after a shut-in period.

The main objectives of this work are to isolate and identify the indigenous bacteria associated with two different crude oil samples (A and B) and to study the effect of the metabolic products of these bacteria on the reservoir fluid properties.

MATERIALS AND METHODS

Crude Oils:

Two crude oil samples (A and B) obtained from two different Egyptian reservoirs were used. Characteristics of the crude oil samples are given in tables 1 and 2.

Table 1: Reservoir Characteristics of Crude Oil A

Property	Value
Initial Reservoir Pressure.	2660 PSI
Bubble Point Pressure.	1960 PSI
Reservoir Temperature.	170°F
Oil Gravity(API)	30
GOR	460 SCF/STB
Oil Viscosity	3.3 cP

Table 2: Reservoir Characteristics of Crude Oil B

Properties	Value
Intial Reservoir Pressure.	5632 PSI
Bubble Point Pressure.	1198 PSI
Reservoir Temperature.	255°F
Oil Gravity(API)	24
GOR	312 SCF/STB
Oil Viscosity	3.2 cP

Isolation and Purification of Associated Bacteria:

Nutrient Agar (NA) meduim was prepared in 250 ml flasks and autoclaved. The meduim was cooled up to 50 °C. One gram from each oil sample was added to the cooled NA flask and distributed by agitation. The seeded meduim was poured in Petri dishes before getting solidified. Petri dishes were incubated at 30 °C for 7 days before examination. Suspected aerobic colonies were purified on NA plates and transferred on NA slants, whereas anaerobic isolates were kept in nutrient broth (NB) tubes under sterile paraffin wax.

Identification of Associated Bacteria:

Identification was based on colony characters, cell morphology and physiology, gram reaction, KOH-solubility test, heat test of spores, endospore observation, acid and gas production from glucose, anaerobic growth and catalase reaction (Buchanon et al., 1974).

Effect of Metabolic Products of the Isolated Bacteria on Fluid Properties:

Equal volumes of oil and dextrose solutions was put in test tubes. The aqueous and oleic samples were separated using a syringe after they had shaken for 3 minutes and left to equilibrate for a certain time at the required temperature. The surface and interfacial tension were measured by using the ring method at 70°C. The pH value of the dextrose solutions was measured at 35°C.

RESULTS AND DISCUSSION

1-Isolation and Identification of the Indigenous Bacteria:

Isolation made from oil samples resulted in different types of bacterial colonies. Some of the colonies were grown on the surface of the medium (aerobic) and

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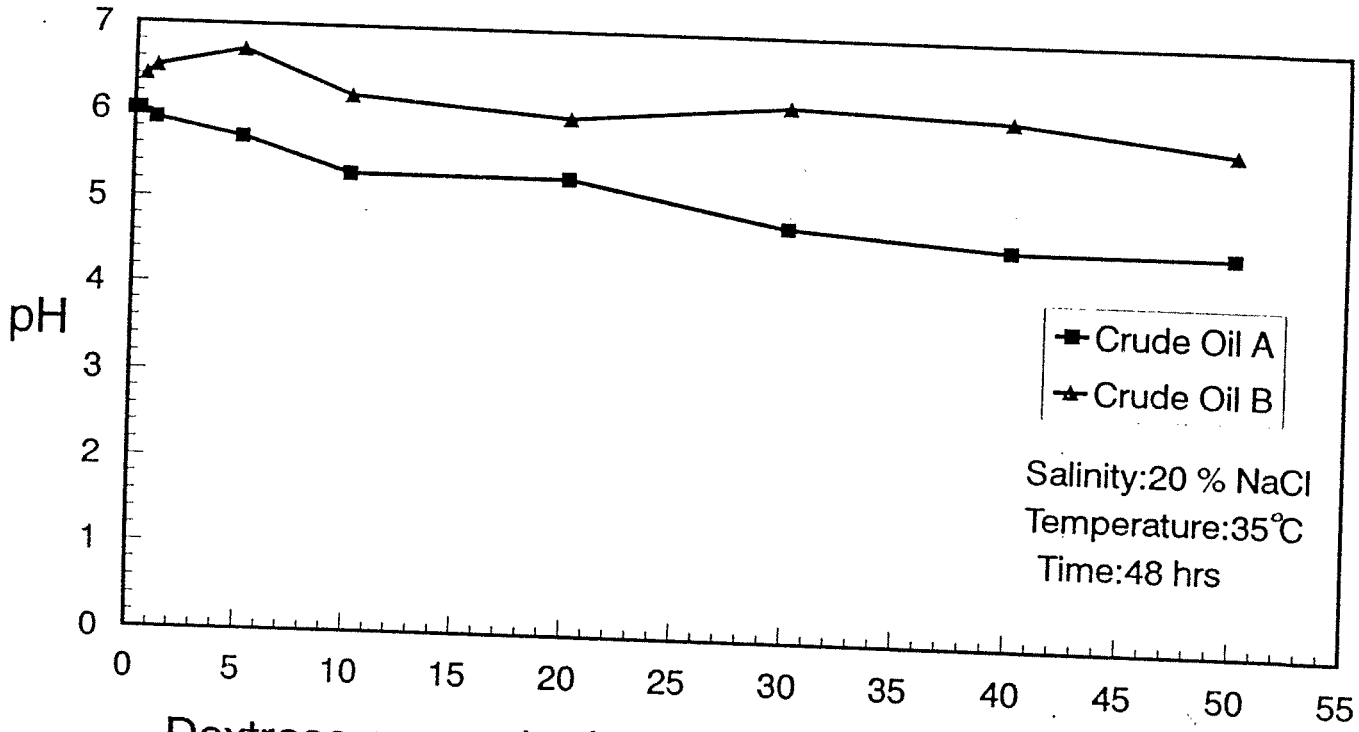

Fig.1:Effect of dextrose concentration on pH of the nutrient solutions with crudes oil A and B using 20% NaCl salinity at 35°C.

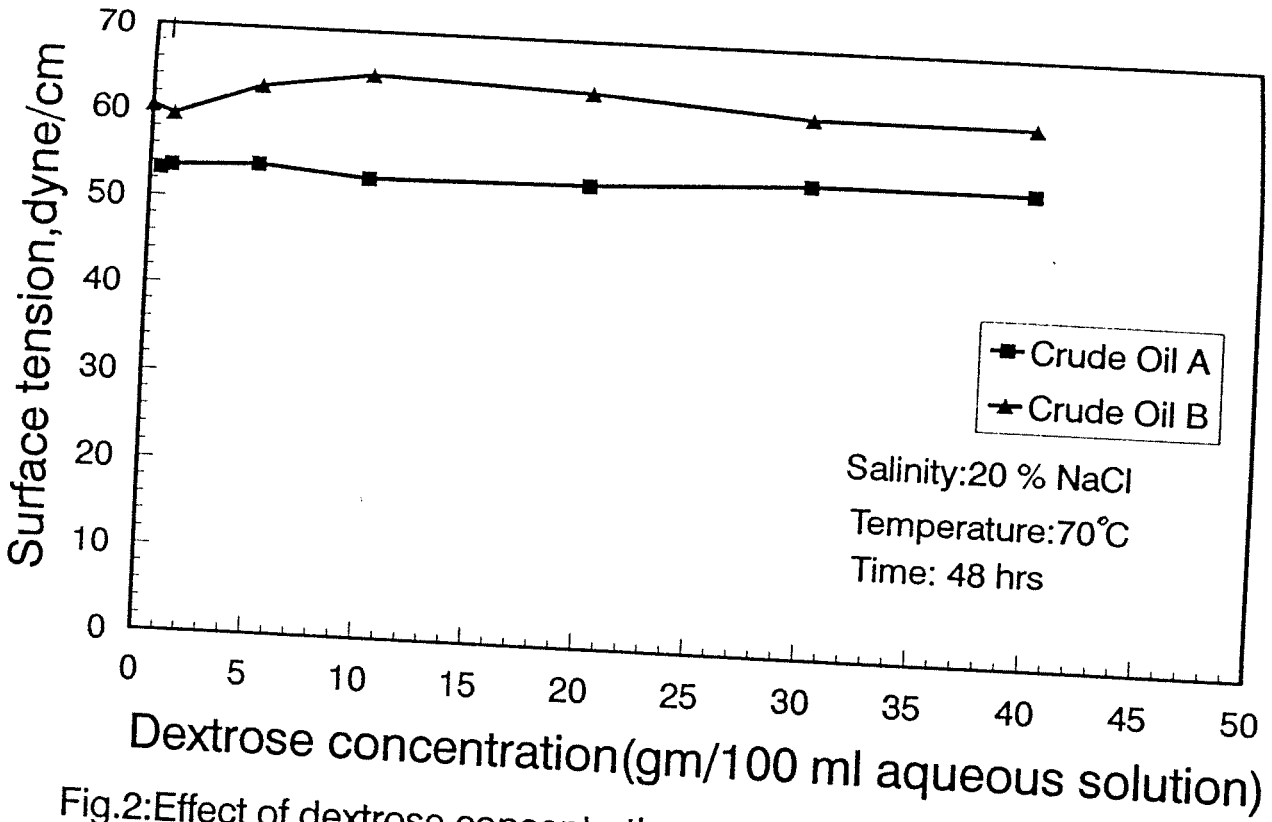

Fig.2:Effect of dextrose concentration on surface tension of dextrose solutions with crudes oil A and B using 20% NaCl salinity at 70°C.

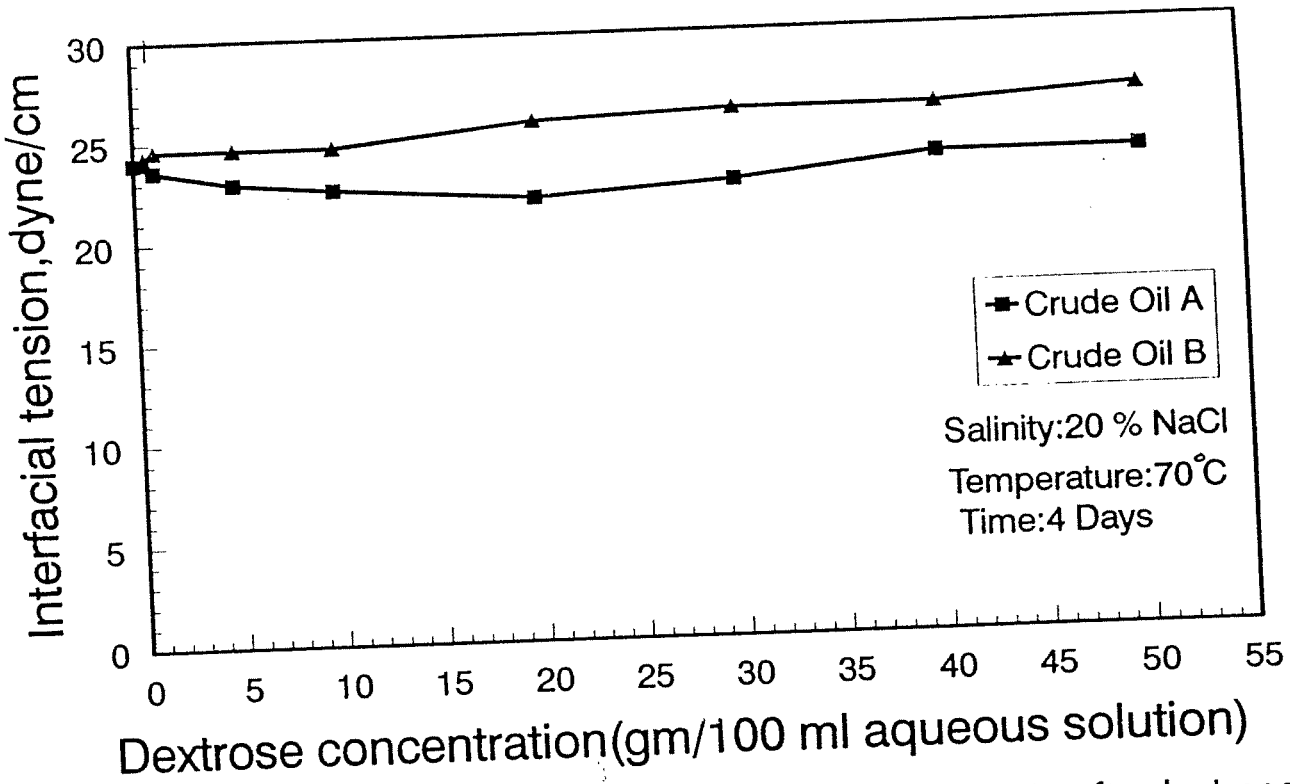

Fig.3:Effect of dextrose concentration on interfacial tension for dextrose solutions and crude oils A and B using 20% NaCl salinity at 70°C.

adsorption to rock surfaces and other losses due to physical and chemical conditions of the reservoir .

In some applications ,it is desirable to emulsify produced crude oil and water . The most obvious applications are sludge cleanup and viscosity reduction prior to pipelining[1]. It is well known that microbial growth and the metabolic products have an effect on the chemical and physical properties of reservoir fluids . As a result , the heavy oil viscosity may be reduced [2,3] and oil -in -water emulsion can be created [4]. Emulsification , an important property of microorganisms capable of assimilating hydrocarbons , is a recognized mechanism for improving oil recovery [5] . The formed emulsion will therefore be more easily produced .

An emulsion is a heterogeneous liquid consisting of two immiscible liquids with one of liquids intimately dispersed in the from of droplets in the second liquid in the presence of an emulsifier . This dispersion can be reflected on phase volume changes (or phase behavior) . The main objective of this study was to investigate the effect of bacteria , originally present in the crude oil , and their metabolic products on phase behavior of crude oil - aqueous system as a function of nutrient type , salinity and temperature . Two crude oils , containing two different bacteria from two different Egyptian reservoirs , were used .

EXPERIMENTAL WORK

A nutrient solution is a brine (gm NaCl/100 ml distilled water) containing a certain nutrient concentration (gm/100 ml brine). Equal volumes of oil and nutrient solutions were put in graduated test tubes. The tubes then were shaked for 3 minutes to get adequate contact between aqueous nutrient solution and crude oil in each tube . The tubes then were put in an oven at the required temperature for2 days. After that , the aqueous and oleic phases volumes were recorded.

Two crude oils were used through out this study. One of them (Crude G) contains *clostridium* bacteria and the other (Crude S) contains *bacillus* bacteria .

RESULTS AND DISCUSSION

In an effort to understand the microbial enhanced oil recovery (MEOR) technology , the mechanisms involved must be obvious. The study of the ability of bacteria and bacterial metabolic products to emulsify crude oil and aqueous phase should be carried out .

Effect of Nutrient Type

Figs 1 and 2 show the effect of the concentration of the three nutrient types (molasses , sucrose and dextrose) on the aqueous phase volume to the total (aqueous + oleic) volume at 35 ° C using 20% NaCl after 48 hr. equilibrium time with crude G and crude S respectively. Fig. 1 shows that the best phase volume changes (i.e., minimum aqueous phase volume) can be obtained when using 10% dextrose (optimum concentration). In addition sucrose ,in the studied concentrations range, and dextrose

at concentrations less than 15% give aqueous phase volumes lower than that of molasses.

The stability of the emulsion against coalescence depends on the conditions in thin region between tow approaching droplets. A tendency of three components , aqueous phase ; oleic phase ; and the emulsifier (metabolic products + cells of bacteria) to form a layered structure (liquid crystalline) will give stability against coalescence . The formation of micelles has the opposite effect [6] . Therefore, the low aqueous phase volume ratio, at low dextrose concentration as well as with sucrose at all concentrations, may be due to the formation of liquid crystalline phase at an emulsifier concentration lower than the critical micelle concentration (CMC). The charged surface of the bacterial cells[7] and the produced metabolic products (emulsifiers) lead to the formation of this liquid crystalline interfacial film . On the other hand , the increase in the aqueous phase volume ratio at high dextrose concentration and at all molasses concentrations may be attributed to the formation of micelles in the region between the droplets. The micelles formation may be due to the increase in the production of biomass and metabolic surface active materials . The increase of emulsifier concentration can give rise to micelle formation in the region between the droplets. When the emulsifier can form micelles in both the aqueous and oil phases of the emulsion the stability will be very poor[6]. It is worth - while to mention her that the maximum biomass was produced when the nutrient was molasses [8] . Fig.2 shows that the minimum aqueous phase volume have been obtained when molasses was used. Dextrose and sucrose gave almost the same aqueous phase volume which are higher than that of molasses solutions . The difference between the results in Figs .1 and 2 is attributed to the difference in both types of crude oils and types of bacteria present in each crude .

Effect of Salinity

It is well known that the bacterial cells have charged - surfaces and produce metabolic , interfacially active products . These charged cells (can be imagined as a charged solid particles) and surface active substances lead to the formation of an interfacial film . The stability of this film depends on the interface free energy of the three face boundaries of oil, water , and cells (i.e., the wettability of bacterial cells surfaces) , and on the long range electrical forces collected at the interface . Figs . 3 and 4 plot the aqueous phase volume to the total volume ratio versus molasses concentration after 48 hrs. equilibrium time with G and S crudes at 50 °C using 10 and 20 % NaCl . Fig .3 shows that as NaCl concentration increased from 10 to 20 % , the aqueous phase volume decreased .At molasses concentrations from 3 to 25%, the increase in salt concentration have shown minimum in aqueous value . This result is very important for fluid applications where high salinities are present in the oil reservoirs. Therefore , for high salinity reservoirs , about 20% molasses concentration is recommended to be used. This behavior may be due to the effect of NaCl on the solubility of the surface active metabolic products in the aqueous phase ,oil phase ,and interfacial film . Also, the NaCl affect the ionic strength of the aqueous phase and in turn the wettability of the bacterial cells . Increasing salinity increases the solubility of the surface active material in the interfacial film and may lead the bacterial cells to become more water

wetting . This may increase both the stability of the interfacial film and the volume of the aqueous phase enveloped by the film .

Fig .4 shows that there is no effect of salinity on the aqueous phase separated after equilibrium with crude S which contains bacillus bacteria .

Effect of Temperature

The effect of temperature on the ratio of the aqueous phase to the total liquid (aqueous phase + oleic) volume versus the molasses concentration after 48 hrs. incubation time at 20% NaCl, for crudes G and S, is shown in Figs . 5 and 6 .The two figures indicate that the effect of temperature is more pronounced with crude G. On the other hand, the effect of temperature on phase volume variation is very low with crude S . This means that the effect of temperature on phase variation depends basically on the type of crude oil used as well as the type of bacteria present in the crude. However, the aqueous phase volumes increased with temperature in both cases. This may be attributed to the increase in the segregation effect due to the increase in the density differences of the aqueous and oleic phases that facilitate their separation[9]. Also , increasing the temperature reduces the viscosity of the oil (suspending medium) ; and changes the partitioning of the metabolic surface active products between the aqueous phase ,the oil phase , and the interfacial film. Further , the added heat increases the motion (kinetic energy)of the particles , as well as the potential energy of the particles (work done against attractive forces)[10].The formed emulsions can be completely separated into their original oil and water volumes as the temperature increased to 70 °C .

CONCLUSIONS

At the studied conditions, the following conclusions can be obtained:

1- The minimum aqueous phase volume with crude G (which contains *clostridium*) at 50 °C and 20 % NaCl was obtained when dextrose was used . However , molasses gave the minimum aqueous phase volume with crude S (which contains *bacillus*) at the same conditions.

2- The minimum aqueous phase volume with crude G at 50 °C was at 20 % NaCl . For crude S, there is no effect of salinity at the same conditions .

3- For both types of crudes , the aqueous phase volume increased as the temperature increased .

4-The formed emulsions are unstable at 70 °C , therefore they do not need further treatment for separation.

ACKNOWLEDGMENT

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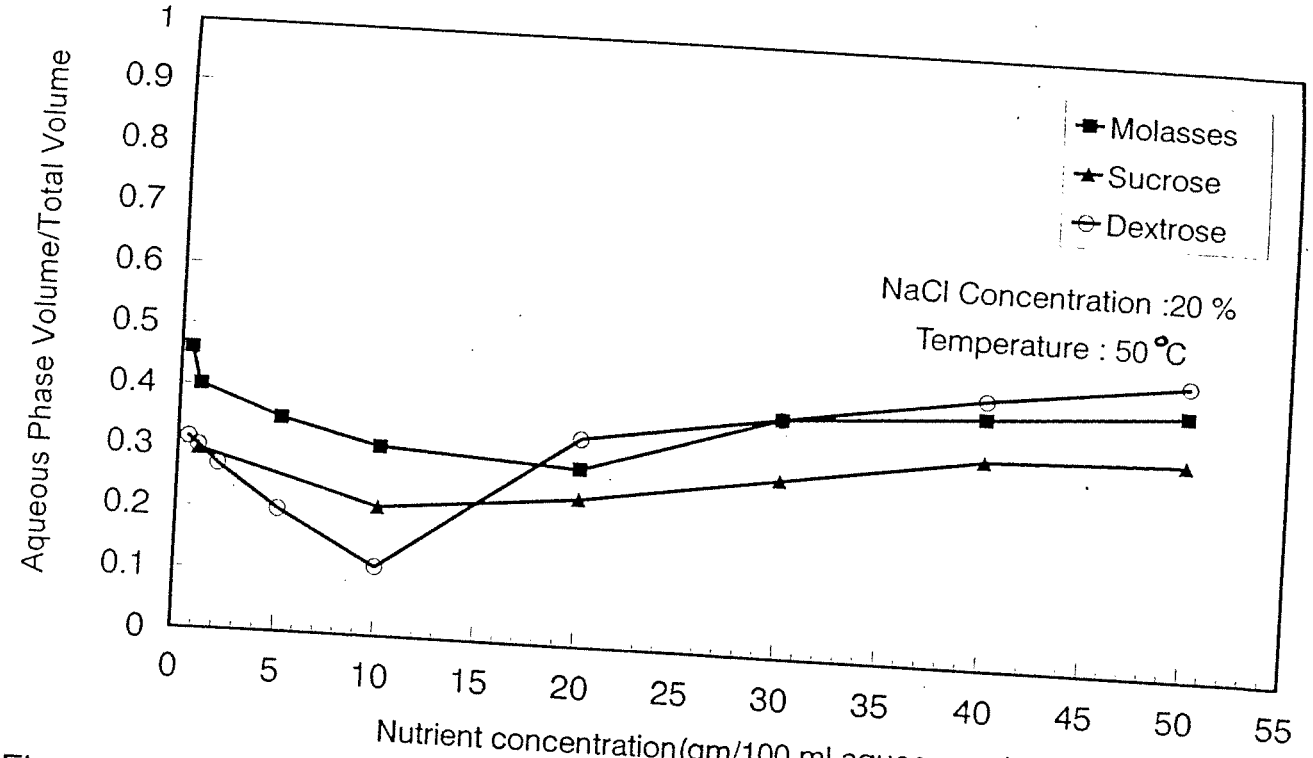

Fig.1- Effect of nutrient type and concentration on phase volume with crude oil G using 20% NaCl at 50°C.

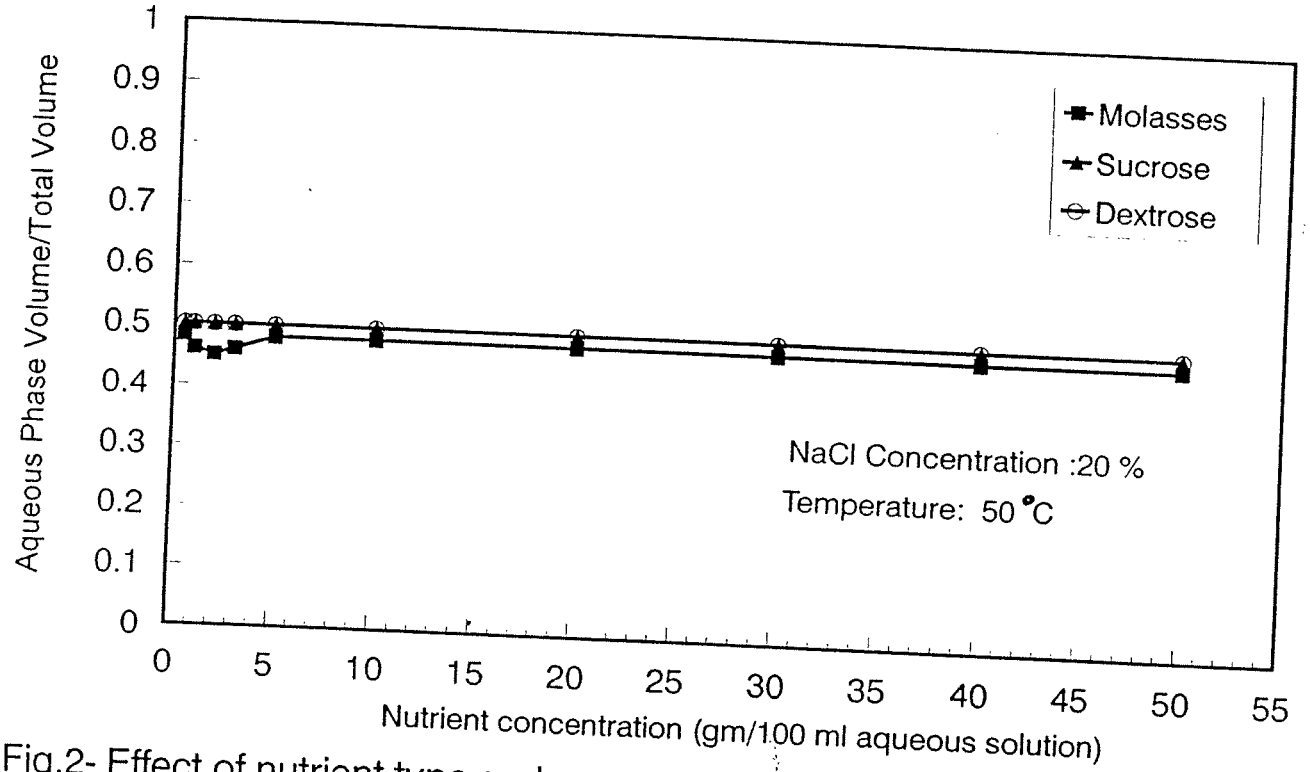

Fig.2- Effect of nutrient type and concentration on phase volume wih curde oil S using 20% NaCl at 50°C.

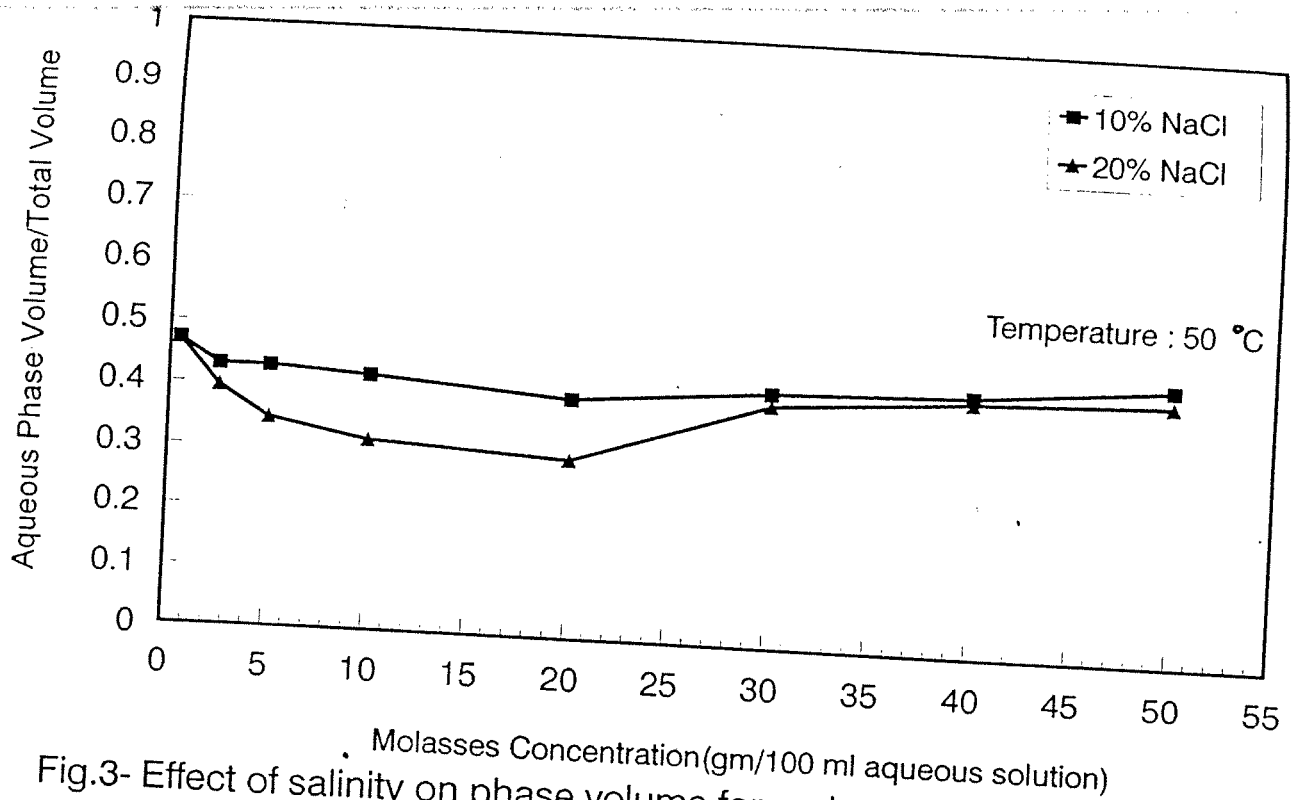

Fig.3- Effect of salinity on phase volume for molasses solution and crude G at 50 °C

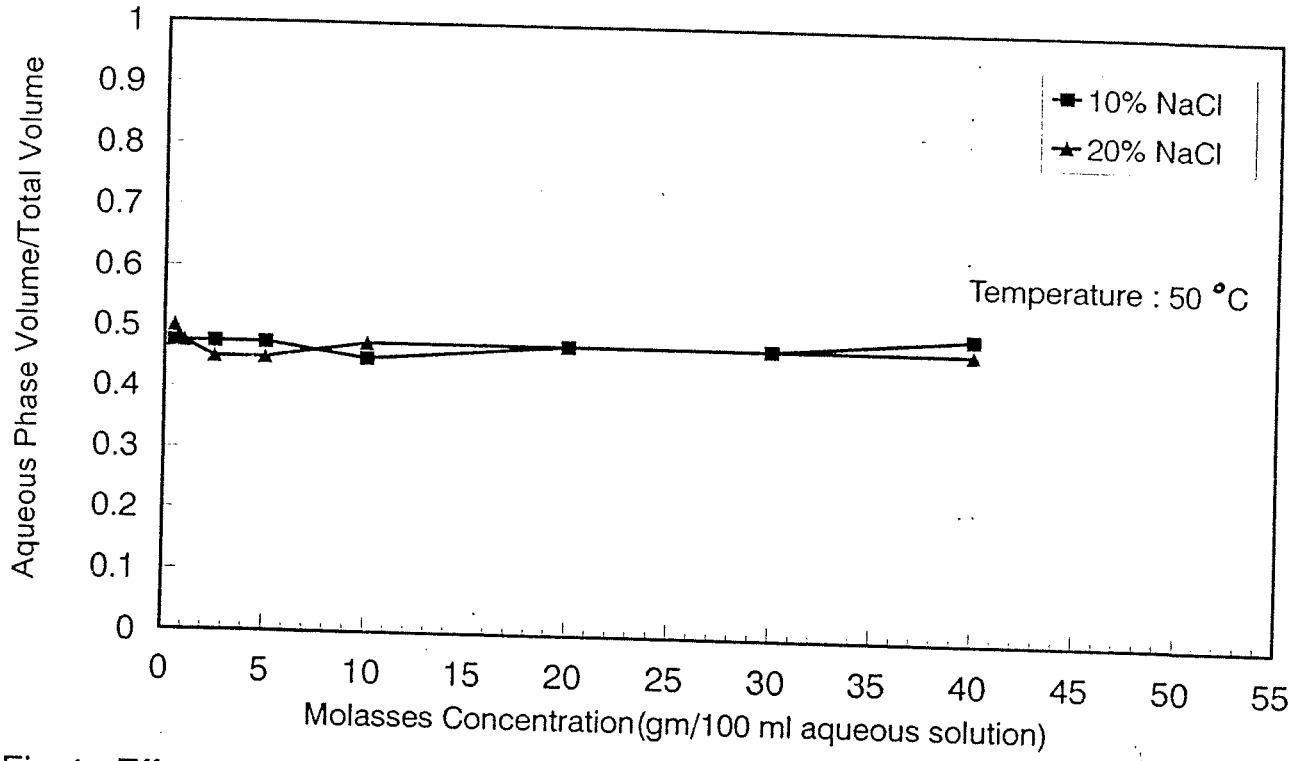

Fig.4- Effect of salinity on phase volume for molasses solution and crude oil S at 50 °C

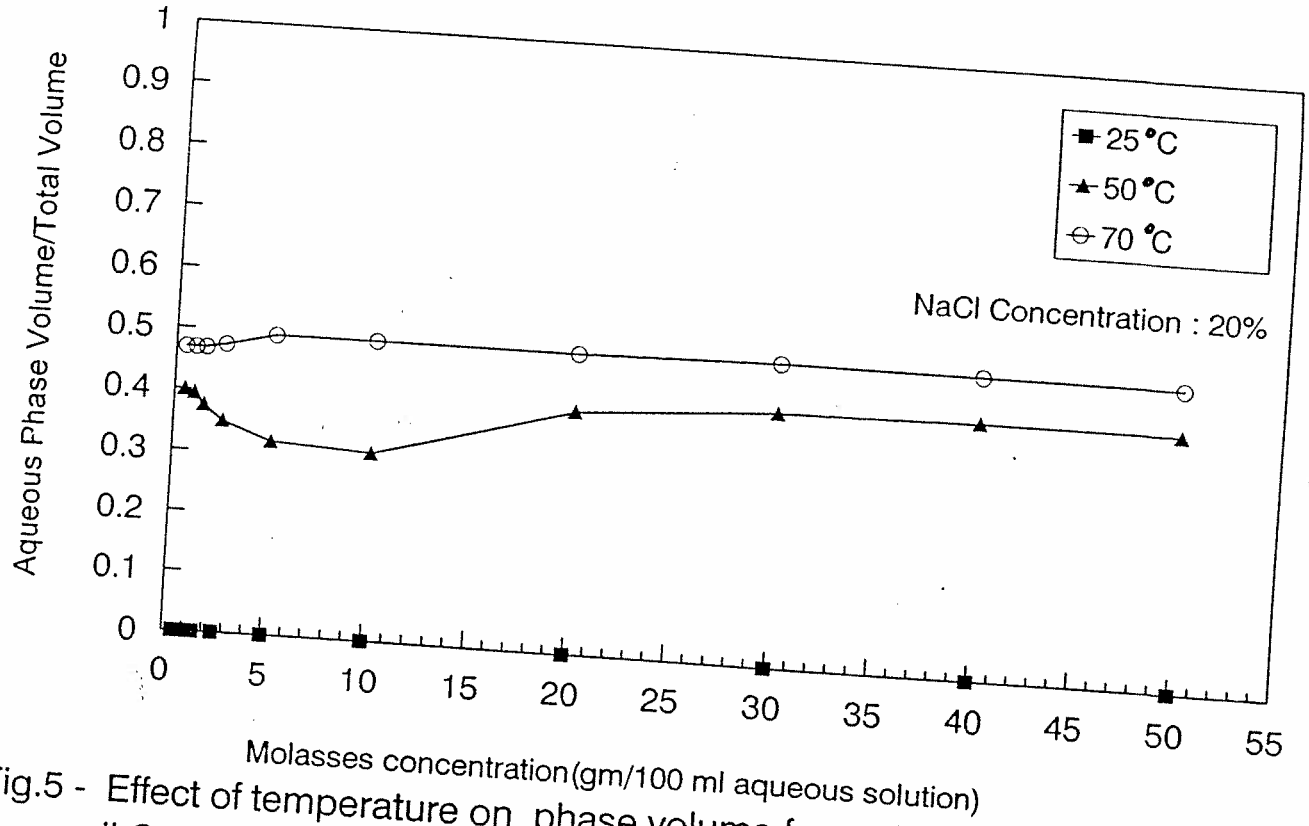

Fig.5 - Effect of temperature on phase volume for molasses solution and crude oil G using 20% NaCl

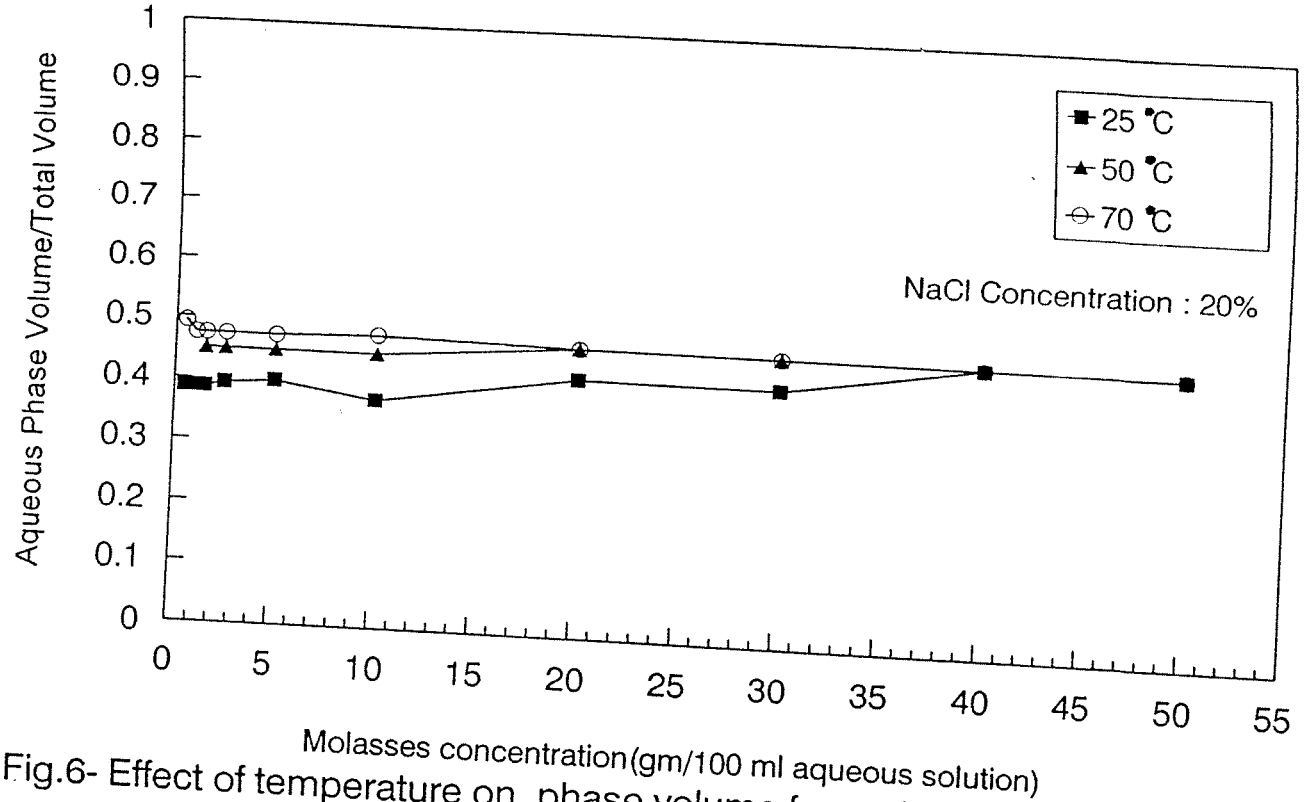

Fig.6- Effect of temperature on phase volume for molasses solution and crude oil S using 20% NaCl