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SOLUBLE SURFACTANT EFFECTS
ON GAS ABSORPTION OF ORGANIC COMPOUNDS

BY

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ABSTRACT

A literature search dating back to the beginning of this century turned up no previous work similar to ours. We discuss several methods and experiments involving the scrubbing of air streams.

The objective of this work was the determination of surfactant affects on the solubility of certain organic compunds of varying solubility in water. A means of simulating a packed tower was devised to allow for bench scale evaluation and thus enabled a greater number of organic compounds to be examined with a greater variety of surfactants.

Curves were plotted based on organic vapor concentration, surfactant concentration, organic type, surfactant type, and the initial organic in water concentration. Vapor pressure data was determined through use of gas chromatography techniques.

Data was analyzed with respect to surfactant type and considerations were given to surfactant critical micelle concentration and its effects on each organic compound. Trends in solubility differentials as a result of surfactant concentrations were observed and noted.

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INTRODUCTION

The removal of gaseous pollutants from an air stream is mandatory, both for health reasons and law requirements. A gas absorption process, sometimes accompanied by a chemical reaction, is usually used for the removal of noxious gases such as hydrogen, fluoride, hydrogen sulfide, hydrogen chloride, and chlorine from an air stream. This method involves the removal of the contaminant gases from the gas stream into a liquid in which it is soluble or partly soluble. The two basic factors controlling this gas absorption process are (1) the degree of solubility of the gas to be removed in the liquid used for scrubbing, and (2) the means of obtaining intimate contact between the gas and liquid streams to bring about the quickest absorption rate possible.[1] In processes which use gases that are less soluble in the liquid media, caustics or salts are introduced to react chemically with these contaminants. An example of this would be the use of sodium hydroxide as a scrubbing liquid to react with chlorine to produce relatively harmless sodium hypochlorite.

Those organic compounds which are normally immiscible or partly miscible in water can be gas contaminants also and their subsequent removal from a gas stream by a liquid medium is dependent on their solubility in that medium. Water, the most economical liquid scrubbing medium by far, must be examined for possible use.

Immiscibility and therefore the solubility of one compound in another is a function of the physical properties of the solute-solvent interface. Bonilla and Baron[2] studied the absorption of ethylene oxide in a packed column with variours aqueous and non-aqueous solvents. They varied the gas temperature and concentration in the air stream passing through the column and concluded that the liquid-film resistance is the controlling factor for absorption.

Othmer and Scheibel[3] in doing work with acetone in a semicommercial packed tower; varied the range of concentration of acetone in the air and in the washing solutions. They found the rate of acetone absorption by the water was dependent on both the liquid and gas films. Interfacial resistance seems to be the governing factor determining mass transfer and mass transfer rates. Emmert and Pigford[4] found that in falling liquid films, mass transfer rates were greater when rippling occurred as the gas (i.e. they examined CO_2) passed through it rater than when there were no ripples. The addition of surface active agents eliminated the rippling of the liquid. In some part greater transfer rates can be attributed to there being less surface area on a straight sheet than on a liquid sheet with a rippling motion. Shou[5] found this to be true in devising apparatus for absorbing gases and vapors. He immersed a member of great surface area into the liquid and withdrew it, thereby subjecting the gas to be absorbed to a large surface of film of absorbing liquid. Thousands of patents were issued over the years for just the above type of process. The absorption of gases in liquids has inspired many a researcher and some of their works will be discussed.

In discussing the principles of gas absorption Lewis and Whitman[6] tell us that when a liquid and gas come in contact, there are film layers between them. On the gas side as well as the liquid side of the interface there is a film layer in which motion by convection is slight. Therefore, the transfer of solute through the films is by slow diffusion and they are the controlling parameters of absorption. They devised the following equation pertaining to absorption:

$$\text{Rate of absorption} = \frac{dw}{Ad\theta} = Kg(Pg - Pi)$$
$$- Ki(Ci - Cl)$$

w---weight of solute (grams)

θ---time (hours)

P---concentration of solute in gas (atmosphere)

g---outside gas film

i---interface

l---inside liquid film

Lewis and Whitman further explain that mixing increases the interfacial area between the gas and liquid and from this standpoint alone absorption increases.

Confirming this work, Donnan and Masson[7] in formulating their theory of gas scrubbing towers with internal packing, have come up with the following criteria for higher absorption efficiency:

a) The interfacial area between the gas and washing liquid must be large.

b) There must be a high relative motion between gas and liquid.

c) There must be a degree of turbulent motion in one or both phases.

d) There must be a sufficient rate of flooding to obtain the maximum drip effect.

Mixing obviously accomplishes the first three criteria and should increase absorption.

Free turbulence and the diffusional processes developed under its influence was analyzed by Kafarov and Troimov.[10] They studied the absorption of HH_3, SO_2, Me_2CO, EtOH, and CO_2 from air streams by water in a packed tower. The packed volume varied from 0.25 liters to 9.15 liters and the gas rate, G, from 2.3 to 31 cubic meters/hour and the liquor rate, L, from 5 to 160 liters/hour.

They also varied packing types, thus free space of the tower. From their data they found that only turbulent mass transfer is controlling when diffusion is concerned.

However, as was seen previously, absorption is controlled by the physical properties of the media involved, and in order to have an absorption rate to influence, one must first have absorption. V. Koran[8] studied the action of vapors of some organic liquids on the surface tension of water. Saturated vapors of CCl_4, C_6H_6, PlMe, benzine, $CHCl_3$, Et_3N, and Et_2O were passed through water and the surface tension was measured. The surface tension varied over the range or organics used, but it was found that the surface activity of these vapors and their effect on water parallel the interfacial activity of the corresponding organic liquid phases upon water.

Schwartz and Perry[9] explain that most organic compounds which are soluble in water lower its surface tension, however a brief explanation of surface tension seems necessary.

Van der waal's forces occur between one molecule and another in a liquid. For the molecule surrounded by other molecules, i.e. one at the liquid interior, the resultant force is zero, however, the molecule at the liquid surface is subjected only to forces which tend to pull it inward. The liquid, as a result, takes the form with the least surface area per unit volume. Thus we note drops are spherical. This tendency for contraction and the forces associated with it is considered free energy, and this free energy per unit area is called the surface tension.

E. Filippi[11] did some work with other absorption in certain liquids. He measured the surface tension of various colloidal solutions. Emulsions formed when the differences in surface tensions of the two compounds was not very large. Emulsions did not form when surface tensions were large. Emulsions are the dispersion of one liquid in another liquid, the two being immiscible or partly miscible. Obviously absorption of a gas from a stream of air is dependent on the properties of the surfaces of gases and liquids that come in contact.

Dubinin[12] discusses absorption as a function of surface layers of absorbent and absorbate. During the time the gas first comes in contact with the scrubbing liquid and it is detectable in the liquid, the absorbent may be divided into three regions: (1) a layer next to the entering surface saturated with gas, (2) an operating layer in which gas is being absorbed, (3) a layer not yet reached by the gas. As the above layers form or fail to form, absorption is effected and their formation is affected by gas velocity, cross sectional area of scrubbing device, maximum concentration of absorbed gas per unit volume of absorbent, vapor pressure of the gas. Brown's[13] fundamental principle governing the process of gas washing for the recovery or removal of a gas or vapor component is that the scrubbing liquid can absorb the gas or vapor until the vapor pressure of the latter in solution is equal to the partial pressure of the gas or vapor in the gases entering the washing unit.

Summarizing the previous work cited on absorption, and our main interest in absorption of gases in packed towers, we find that Baker[14] has defined the absorption of a gas from a gas mixture by a liquid in a packed tower as a product of five factors:

1) The theoretical absorption--- the vapor pressure of a gas in a liquid phase equals the partial pressure of the gas in the gaseous phase. The liquid will be saturated with gas when the absorbed gas exerts no pressure.
2) The difference in these partial and vapor pressures---This difference is the force which determines rate of absorption and will not equal zero in commercial work.
3) The intimacy of contact of gas and liquid phases.

4) Contact time of gas and liquid phases.
5) A proportionality constant that depends on the units in which the other factors are expressed.

Our main concern, however, is the removal of specific cases, namely organic vapors, from a gas mixture or air stream. Several methods have been investigated and the following are included:

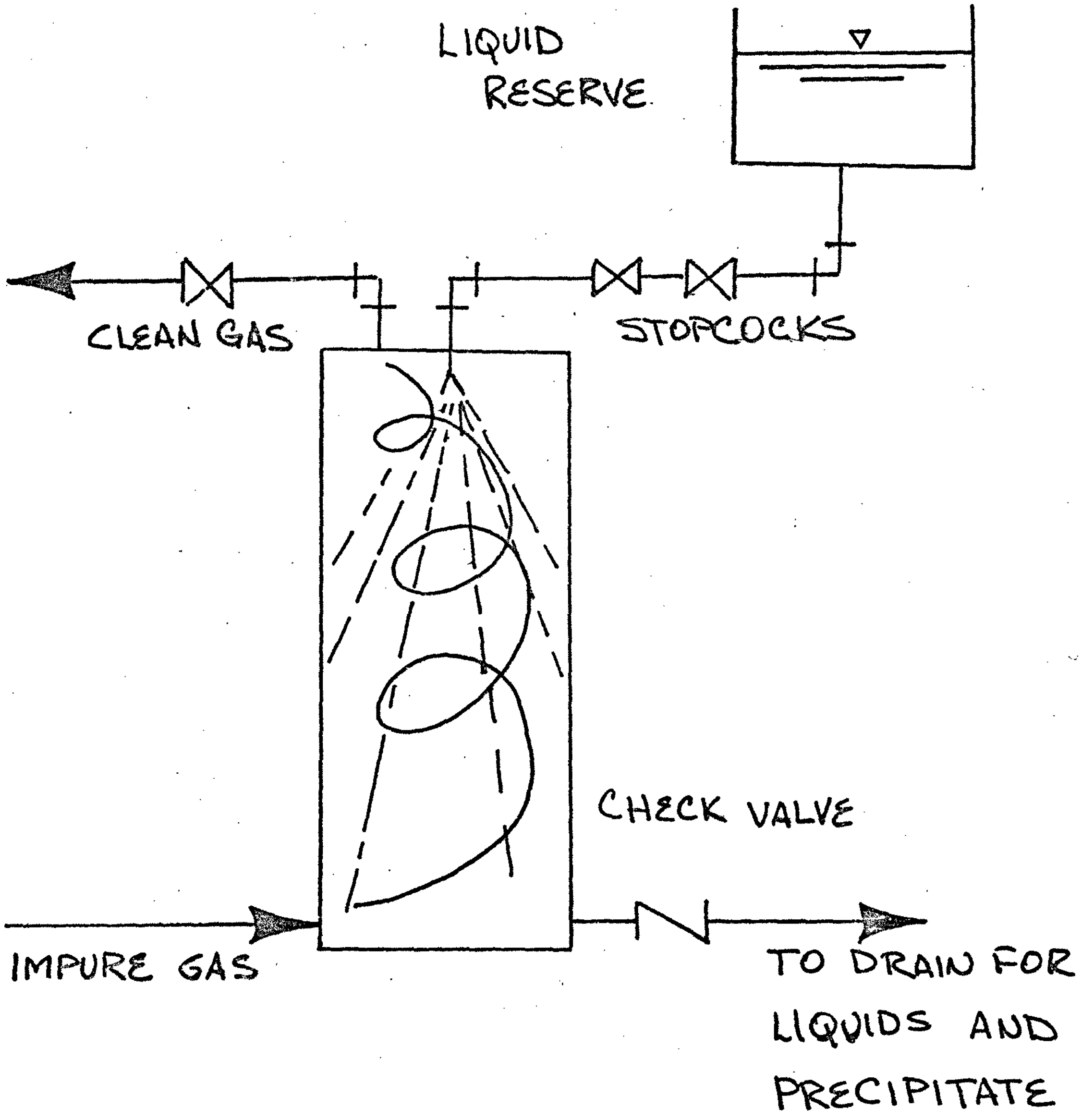
1) Carbon adsorption of the organic vapor.
2) Atmospheric combustion of the organic vapor.
3) Catalytic combusion of the organic vapor.
4) Condensation of the organic vapor by cooling the gas stream.

Original Methods of Gas Stream Scrubbing

Literally thousands upon thousands of patents and papers have been issued and presented on the subject of gas removal from a gas mixture by a scrubbing liquid. Before discussing some of the methods for organic vapor removal from a gas stream, we will discuss some of the early methods and apparatus for gas in liquid removal.

S. Kohn[15] back in 1907 wrote of a more efficient means of utilizing absorption towers. He passed a dilute gas through a series of absorbing towers under uniform conditions and calculated the amount of gas unabsorbed. The quantity of gas absorbed in proportion to the total quantity of gas passing through the tower was defined as P/Q, and by solving simultaneous equations he found the gas lost to average around 8.3% for all towers. P/Q varies with tower size, water quantity, and manner of distribution, and rate of gas flow. Billy[16] describes an absorption column to be for continuous use and he concurred that using them in series removed a high percentage of impurities. Using absorption towers in series effects the removal of two or more impurities with two or more liquids. Billy's column permitted the purification of any gas by absorption of impurities in any liquid necessary. A long tube 40 mm in diameter is packed with glass, porcelain, and pumice for a large surface area for the liquid to wet, and because these substances are not readily corrosive. Figure 1 shows a schematic of the column.

Over the years different packings for towers have been devised. Probably the earliest packing consisted of bricks, tiles, earthenware, terra cotta, etc.[17] .. arranged so liquid from one layer drips onto the next layer, thus splitting the liquid drop further and exposing more surface area. Rashig later invented a packing for absorption or reaction towers consisting of small cylinders irregularly arranged.[18] They are dropped in the tower at random. How-



ABSORPTION COLUMN

FIGURE 1

ever, the latest packing entities are Tellerettes, which have the greatest surface area per unit volume along with a lower pressure drop as the gas passes over them. They also have thousands more interstitial holdup points where the gas is absorbed more readily.

Another type of apparatus allows a tower to be divided into chambers provided with two or more spraying devices mounted upon separate drive shafts. The gas to be cleansed rises through the sprays of liquid discharged by centrifugal action.[19] One could write a book on all the different processes devised, such as a horizontal cylinder with rotating disks mounted axially in the liquid chamber. Gases pass across the disks that are wetted and absorb impurities. Disks are coated with earthenware, enamel, cement, or asbestos for protection.[20] Other columns used plates superimposed upon one another,[21] activated charcoal, silica gel.[22] Other methods include the bringing of vapors of volatile liquids into contact with cold walls and causing condensation,[23] and the idea of bubbling the impure gas through the absorbing liquid by having the bubbles follow the path of a spiraling tube through the liquid.[24]

Methods of Organic Vapor Removal

Our concern is with the removal of organic vapors from an air stream and because of activated carbon's affinity for organics, its use in water and air pollution is widespread. However its use is limited in low concentrations and because of the necessity for constant regeneration and high initial costs, installations are held down. Some of the earlier applications will be discussed. R. Kattwinkel[25] used a metal cylincer 410x65 mm with 100 grams of activated carbon packing. A measured amount of gases with organic vapors, such as benzine or benzene, were introduced to the cylinder and the benzine or benzene was adsorbed by the activated carbon. The organic vapors were recovered in a condenser and then a receiver when steam at 300°F was passed through the cylinder to drive out the adsorbed gases. Berl and Andreas[26] did similar work with activated carbon. They recovered vapors of organic materials from mixtures of air and water vapor on the carbon. Vapors of organic compounds, such as Et_2O, MeOH ErOH, C_6H_6, CCl_4, acetone with high molecular weights and high boiling points can be recovered, and it was noted that repeated use of carbon reduced its efficiency.

One of the earliest patents issued for separating organic vapors was to Bayer & Co. in 1916. The found the separation of organic gases or vaporized organic substances from their mixtures with air or other not absorbable gases, such as hydrogen, is effected by treatment of the mixtures with porous carbon. The extraction of the organic substances from the carbon was with steam.[27,28] Englehardt[28] adsorbed ether from an air stream on activated charcoal. 1 kg. of highly activated charcoal may adsorb as much as 200 gms of ether. Further work was done in the area of Kattwinkel,[29] and Esons and Wheaton,[30] until the present where highly sophisticated control systems, regeneration methods, and chemical extraction processes are applied, but the simplicity of activated carbon remains the same.

Absorption of organic gases has been effected on rubber and rubberized fabric,[31] tar oils,[32] silica gel,[29] etc. Apparatus[33,34] and methods[35,36,37,38] for their removal and recovery become redundant.

Many of the methods cited and available are not practical on the commercial scale and those that are applicable, are possible only with a relatively high capital investment and/ or a high operating cost.

Absorption of Organic Compounds

It is generally considered impractical to collect water immiscible organic compounds from the vapor phase in water with a high degree of efficiency. One of the principal reasons has been the organic compound vapor pressure or partial pressure contribution to the gas phase of the system once equilibrium has been reached. This partial pressure at equilibrium conditions reduces the driving force of collection by water, restricting it to a condensation rather than one of adsorption. Condensation is limited because packed tower operation is usually carried out at elevated or at best ambient conditions. Water scrubbing of organic vapors is limited, however some of the previous works on the subject will be discussed.

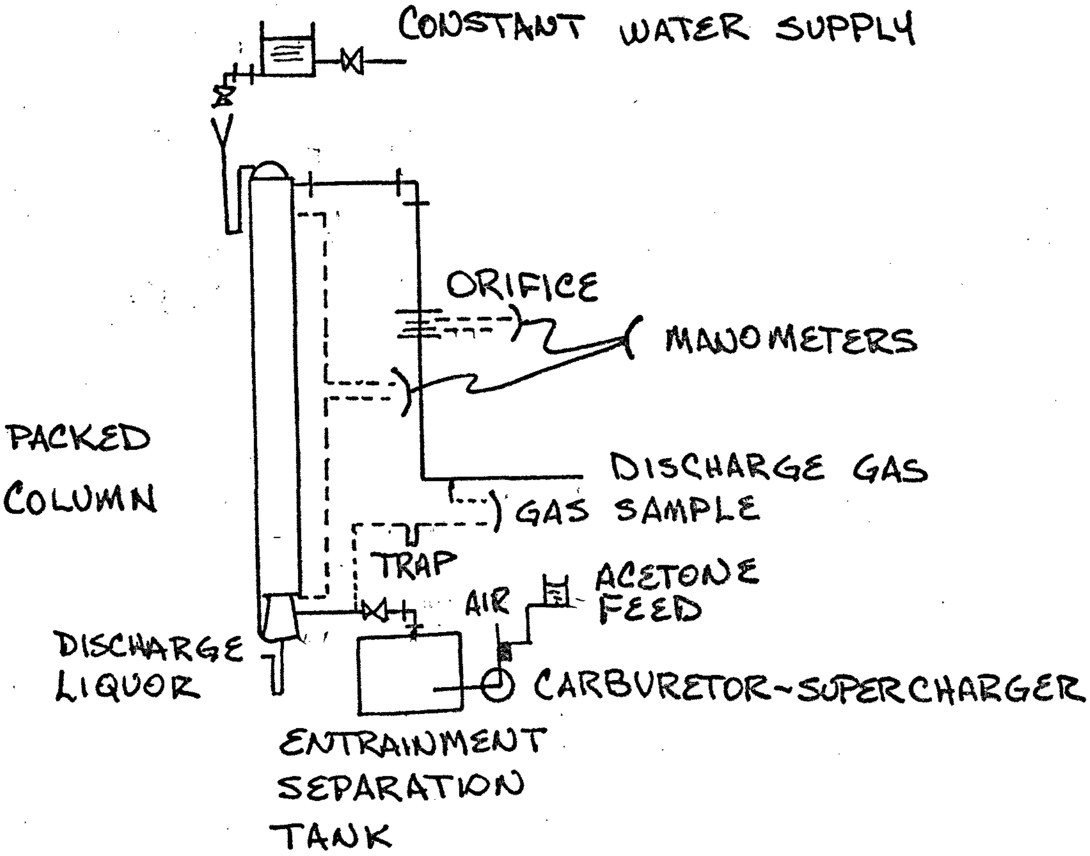
Sunkov, Kuznetsova and Gorinov[38] followed the absorption of phenol vapors from waste gases in a water scrubber. The absorber was 1: 1 meter diameter by 2.2 meters high with perforated plates for a free space of 16.7%. Gas flow was 6000 meters 3/hour which contained 1 gram phenol/meters^3 gas and the water rate in the absorber was 1-1.5 meters^3/meters^2-hour. They did not draw any serious conclusions. However the absorption of acetone by water in a sieve plate absorber was investigated by Drozdov, Kisarova, and Sidel'nikova.[39] Acetate concentration in the gas stream was 101.1 mg/l and the liquid to gas volume was 2.36 liters/meters^3. The coefficient of absorption increased from 2940 to 22,700 (kg-mole/hr)/ (m kg-mole/kg-mole) as the gas velocity increases from .2 to 2 meters/sec. During this same period the efficiency dropped from 93% to 63% thus leaving one to suspect that the absorption is dependent on the time the gas and liquid are in contact, or possibly the size of the sieve plate which would allow more gas to comein contact with more liquid. This is what Garbarenko and Stabmikov[40] confirmed as they calculated absorption coefficients of packed columns for absorbing alcohol vapors by water scrubbing. The absorption coefficient was determined experimentally in a packed tower for different velocities of the EtOH-air phase and different flooding velocities of water used for scrubbing. The coefficient was dependent on the gas and water velocities as well as the column dimensions.

Gas film coefficients of methanol, ethanol, and acetone, when absorbed by water from an air stream, were computed. Houston and Walker[41] examined the influence of molecular diffusivity on gas film coefficients in a 12 inch diameter column packed 2 feet deep with 1inch carbon Raschig rings. Gas rates varied from 100 to 600 $lb/hr\text{-}ft^2$ and water rates from 500 to 2000 $lb/hr\text{-}ft^2$ and it was found that the gas film coefficients were proportional to 2/3 of the gas phase diffusivity.

Absorption of acetylene by water from a gas mixture of 20% acetylene and 80% hydrogen was studied and the packed tower's, packed with Raschig rings, absorbability coefficient was obtained. Sanka[42] concluded that absorption was a case of interphase transfer with the liquid film controlling the mass transfer. This seems to be verified by Konochuk and Stabinkov[43] who experimented with alcohol vapors being absorbed by water. They used columns with parallel or zig-zag packing angles of 120° or 90°. Mass transfer increased with decreasing zig-zag angle and the zig-zag angle of 90° had the highest efficiency. At the smaller angles the liquid film is broken up to a greater extent as the interstitial hold up points increase allowing greater surface area to be available to the vapors.

This attraction to use water, by researchers, is with good reason, water is plentiful and cheap---the cheapest form of any scrubbing liquid available---therefore when it comes down to applying laboratory work to field installations, the costs versus practicallity curve is brought out and the 100% efficient system is discarded for the most practical system.

Othmer and Scheibel[44] used water to absorb acetone from an air stream flowing through a semi-commercial packed tower. Figure 2 shows a schematic of the equipment assembly. The column was 9-7/8" internal diameter, 10" I.P.S., and 19' overall height. The packing consisted of Stoneware Raschig rings that had 1" diameter, 1" length with 1/8" walls. There were 1350 pieces per cubic foot, 73% free space, 58 ft^2 exposed area per cubic foot and 80 ft^2 absorption surface per cubic foot of free gas space for a total of 195½" packing. City water was used for scrubbing and the flow



ACETONE ABSORPTION BY WATER

FIGURE 2

rate was less than 85 gallons of water per hour per square foot of column cross section. Gas velocities through the column were varied from .6 to 1.8 feet per second and gas concentrations used 1 to 4% of the air stream by volume.

The pressure drop across the column varied with the gas rate. The pressure differential was directly proportional to increased gas flow. At a gas flow of 481 lbs. air/ft^2/hr. P was .1236 while at a gas rate of 86 lbs. air/ft^2/hr. and P=.0058 in. H_2O foot/packing. The pressure drop seemed unaffected by liquid flow rate. Recovery efficiency of acetone from the air stream was mostly in the 90-99% range with one down to 60%. However, efficiency over a given set of conditions is a function of column length: the pressure differential, and the gas pumping costs depend on this differential. Therefore the efficiency of acetone removal is dependent on allowable costs for operating the gas fan.

Othmer and Scheibell[44] found the overall gas absorption coefficient KgA to vary with the liquor rate, L, and the gas rate, G, by the following equation.

$$KgA = \frac{1}{\dfrac{23}{L^{.95}} + \dfrac{30}{G^{0.8}}}$$

And since heat affected the above equation, the mass transfer also depends on the rate the water could be cooled as a result of a heat exchanger. Acetone condensation would cause the water to heat. Thus many factors must be considered when scrubbing a gas with a liquid, and these factors vary with the gas to be absorbed.

Other organics such as ethanol and ethyl acetate are not so easily removed. In fact laboratory tests[45] have concluded that water scrubbing of air streams containing ethanol and ethyl acetate in a 1:2 weight ratio and in total concentrations from 0.01 lb./Mft^3 to 1 lb./Mft^3 is impractical. Ethanol and ethyl acetate aqueous solutions were prepared containing the desired percent of each by weight. Twenty ml of each solution were placed in flasks which has a head space of 39 ml after they were closed with a rubber serum cap. After standing 18 hours at room temperature (22^0), one ml of laboratory air was injected into each flask, immediately withdrawn and injected into a gas chromatograph. A Perkin-Elmer 900 Gas Chromatograph, equipped with flame ionization detectors, was used with nitrogen gas as the carrier.

The laboratory tells us the model developed has both mathematical and physical validity, that it describes conditions at equilibrium accurately for the stated temperature. It also explains that the scrubbing out of solvent vapors from an air stream depends on the equilibrium concentrations of the solvent in the gases and the liquid phase.

Their results showed the minimum amount of water required to reduce by 90% the concentration of ethanol in a 1000 cft air stream was 7.7 gallons, while 288 gallons of water was necessary to reduce the ethyl acetate concentration by 90%. This latter figure is absolutely impractical from the standpoint of equipment size and operational costs. The laboratory also points out that recycling the water to increase the solvent concentration in it and thus reducing costs to make recovery by distillation possible, would not be feasible; because of concentrations in the liquid being too high, not enough or no scrubbing of the air would take place. They also feel further work along the water scrubbing design concept is not warranted and support this with their results.

The scrubbing of organic insoluble vapors in water seems impractical. Further work in the area was done by Cutting and Jones[46], who studied the effect on the surface tension of water of various vapor pressures up to saturation of benzene, toluene, p-xylene, n-C_5H_{12}, and other immiscible organics. They found that in all cases at low vapor pressures the surface tension decreases almost linearly with increasing vapor pressure, whereas at higher vapor pressures the change in surface tension with respect to the change in vapor pressure increases continuously with pressure. We therefore realize the surface tension of water can be affected by organics to some extent to allow for greater absorption, however the adsorbed films are in the gaseous state even when multilayers are formed. And although the life of the adsorbed molecule on the bare surface or in a mono-layer or multilayer may be affected by interaction with other adsorbate molecules, they eventually escape back to the gas stream they were traveling in.

Therefore we must change the physical properties of the water by some greater degree that would allow the organics' vapors to be absorbed by the water composition. Surface active agents change the properties of water. They are organic compounds, and like most organic compounds which are soluble in water as we have stated previously, lower its surface tension, and surface active agents do this to the extreme.[9]

A liquid by its tendency towards contraction is actually striving to a state of equilibrium. The function of a surface active agent is to alter this equilibrium status;[47] and its ability to alter the equilibrium state for the desired effect is the basis of a good surfactant.

In a solution of two liquids, the Van der waal's as well as other attractive forces are not equal for each molecule of solute and solvent. The attractive forces of the solvent will be greater than those of the solute, thus the solvent molecules will be pulled away from the surface faster than the solute molecules. Therefore there is a concentration of solute molecules with weaker attractive forces at the surface, resulting in the lowering of the free energy, i.e. the surface tension.

The concentration at the phase boundary of one component of a solution is called adsorption.[9] Surface active agents exhibit the tendency to be adsorbed at the phase boundary. The surface active agent molecule is composed of one or more groups which show an affinity for the substance they are dissolved in, called hydrophilic groups; and one or more groups which tend to be expelled by the substance, called hydrophobic groups. Surfactant molecules adsorbed at the water surface will have a majority of their hydrophilic groups towards the aqueous phase and a majority of the hydrophobic groups turned away from the water.[47]

Figure 3 shows a plot of a common surfactant (sodium lauryl sulfate) concentration versus several physical properties as a result of micelle formation. A micelle, or group of molecules and/or ions form at the solution interior. Since there is no surface for adsorption to occur and the hydrophobic and water molecules do exhibit repulsive actions to one another, an aggregate of molecules forms. The hydrophobic links of the surfactant molecule are at the center, while the outside of the micelle is hydrophilic links. Figure 3 notes the sharp changes in solution properties as

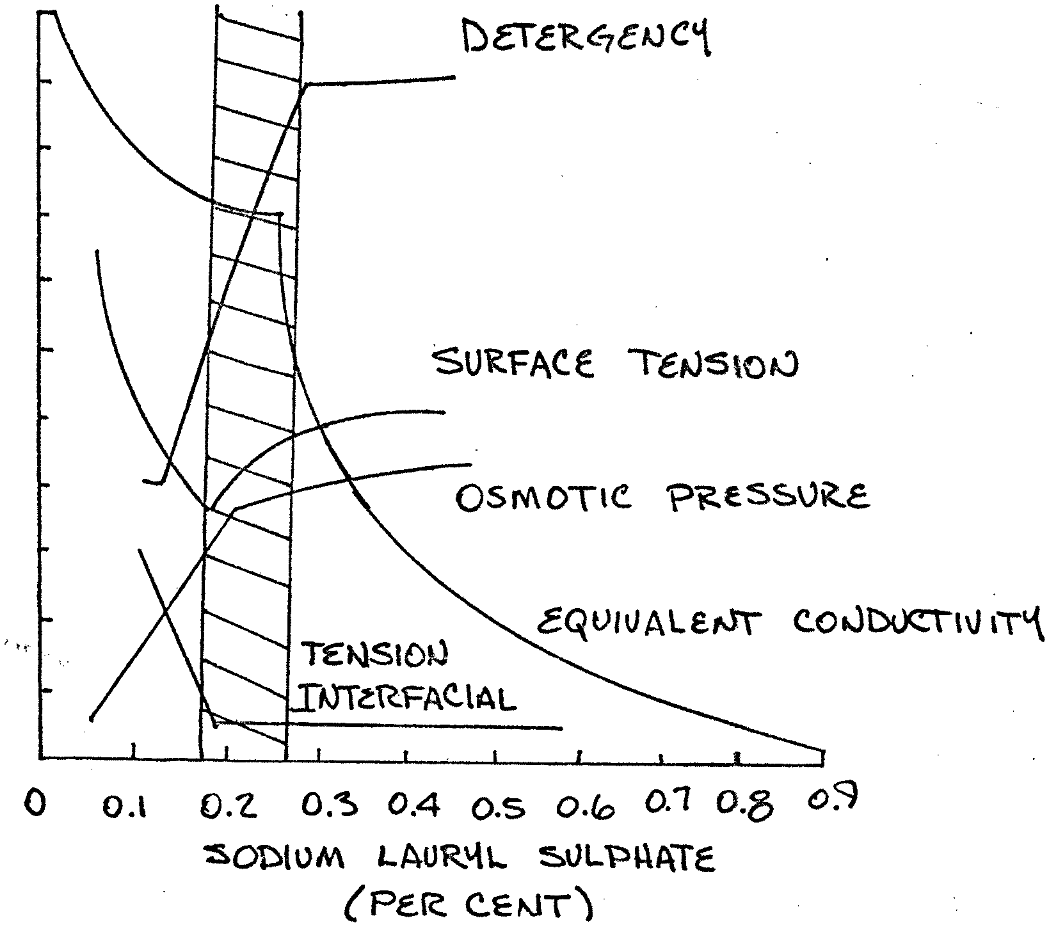

DETERGENCY
SURFACE TENSION
OSMOTIC PRESSURE
EQUIVALENT CONDUCTIVITY
TENSION
INTERFACIAL
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
SODIUM LAURYL SULPHATE
(PER CENT)

FIGURE 3

the range in concentration of surfactant varies. The surface tension decreases sharply at low concentrations for surfactant and as the cmc range (critical micelle concentration---concentration where large numbers of micelles form) is approached, a sharp increase occurs and then a leveling off because of increased concentrations. As a result of these phenomena, surface active agents can affect the physical properties of water greatly, and thus the absorption properties.

Early work done in this area was by H. L. Barthelemy[48] whose patent named the adding of substances such as AmOH, saponin, egg albumin, and preferably the addition of soaps ---K stearate, NH_4 oleate---to the scrubbing water to effect absorption of acetone. The acetone is distributed in the form of a foam in the absorption column and scrubbing may take place continuously.

J. R. Pound[49] studied the interstitial tensions between organic liquids and water, and took measurements of the surface tension and of the diffusion of the mutually saturated liquid layers at 30° C. Impurities lessen the tension as a function of time and depending on whether the impurity is an acid or alkali the time period varies. Impurities such as reactive solutes added to water increase the absorption of insoluble or partly soluble gases. Nash[50] recommends this method for the transport of toxic gases across the air-water interface.

Very early in the twentieth century it was found that in manufacturing emulsifiable solutions of organic substances, the property of suloricinate and alkali so soaps to dissolve certain organic compounds was increased by using a castor oil soap (the castor oil soap was later changed to an alkali sulfide).[51] The castor oil effected the sulorianate's physical properties enough to cause the rise in dissolving power.

A. Dobry-Duclaux[52] investigated the lytopic series of salts. These salts increased and decreased the solubility of organic compounds in water. Salts that increase aqueous solubility, lower the vapor pressure of the water-organic compound system. Those that decrease the aqueous solubility, raise the vapor pressure of the system. The salts had their greatest effect on volatile organic compounds and decreased in the order as follows: acetone, esters, alcs., nitriles, ethers, saturated and chlorinated hydrocarbons--where the salts had negligible effects on the latter three. The salts were arrayed in series with each organic compound and the measure of lyotropic behavior was obtained. $ZnCl_2Be(ClO_4)_2$, $Cd(TiBr_4)_2$ had the strongest solubilizing action.

The solubility of difficulty soluble compounds to obtain aqueous solutions of organic compounds is further confirmed by I. G. Farbenind.[53] He was issued a French patent for his work in this field. Aqueous solutions of phenylethylbarbitaric acid, cyclohexenyl-ethylbarbituric acid, or camphor can be obtained by adding monoalkylamides of lower fatty acids to water and through the use of methylacetamide as an intermediary solvent. Similar work was done by the addition of a hydrogenate phenolic compound such as hexahydrophenol or hexahydrocresol to the absorbing liquid to remove vapors from gaseous mixtures.[54]

Surface active agents therefore may work to allow or increase absorption. The decrease, minimization and subsequent increase in the rate of mass transfer through the liquid gas interfaces with increasing bulk concentrations of surface active agents can be attributed to hydrodynamic changes in the layers adjacent to the interface. The mobility of the interface is determined by the tangential forces which arise from the surface tension gradient, and by the properties of the adsorbed film of the surface active agent itself.[55]

Mirev, Elenkov, and Balarev[56,57] have done much work with absorption and surfactants. The surfactants they worked with were Nekal VKh and OP-10, and it was found in one series of experiments in horizontal columns that they did not affect the rate of absorption of C_2H_2in water. In the same series of experiments in verticle columns, with the same two compounds, a minimum occurs in the curve of surface active agent concentration versus rate of absorption. Thus we find there is a point where adding more surfactant actually hinders absorption. The depth of this minimum varies with the thickness of the liquid, making the column packing an important factor to absorption. It is the packing which disperses the water drops across their surface area.

In subsequent studies the preceding is confirmed---similar work and compounds showed that the hydrodynamics of absorption affect the character of the minimum of the stated curve. As the liquid velocity increases and exceeds a certain value the minimum disappears because there is greater liquid surface area for the gases to be absorbed. The horizontal column in these studies showed a minimum for the rate of absorption for the gases to be absorbed. The horizontal column in these studies showed a minimum for the rate of absorption to be sharper than other columns and shifted towards the lower concentration of surface active substances. The authors attribute the rate of absorption to the chemical structure of the surface active substances and to the hydro--dynamic conditions of absorption.

Elenkov and Bozhov[58] varied the concentrations of two surfactants---Nekal BX and OP-10 in distilled water. Absorption rates of C_2H_2, CO, & CO_2 were determined as a function of stirring. The surfactants increased the absorption rates, but at a high level of agitation, the surfactant has no effect. This is due to a removal of the surfactant from the surface of the water to its interior as agitation increases. Thus the hydrodynamics of the water flow is almost as important as the surface active agent.

Further proof of this is stated by Elenkov and Bozhov[59] where the absorption rate of C_2H_2 in water depends not on the rate of C_2H_2flow, but entirely on the absorption rate of the water, which can be affected by such things as stirring and/or surface active agents.

A study of the effects of soluble surfactants on gas absorption using liquid laminar jets.[60] The liquid laminar jet was used as the gas absorption contactor since it offers the major advantage of being able to measure interfacial resistances at short contact times when the resistances of the bulk of the liquid phase is very small in comparison. Four soluble surfactants were chosen for study. Dodecyltrimethylammonium chloride, hexadecyltrimethylammonium chloride, dodecyl sodium sulfate and hexadecyl sodium sulfate. A schematic diagram is shown in figure 4 of the laminar jet apparatus.

Pure CO_2 was absorbed into deionized water at different jet rates and with different surfactants present in the water. It was found that the interfacial resistance to gas absorption increased with increasing hydrophobic chain and for a given hydrophobic chain length, the resistance was

GAS PURGING SYSTEM

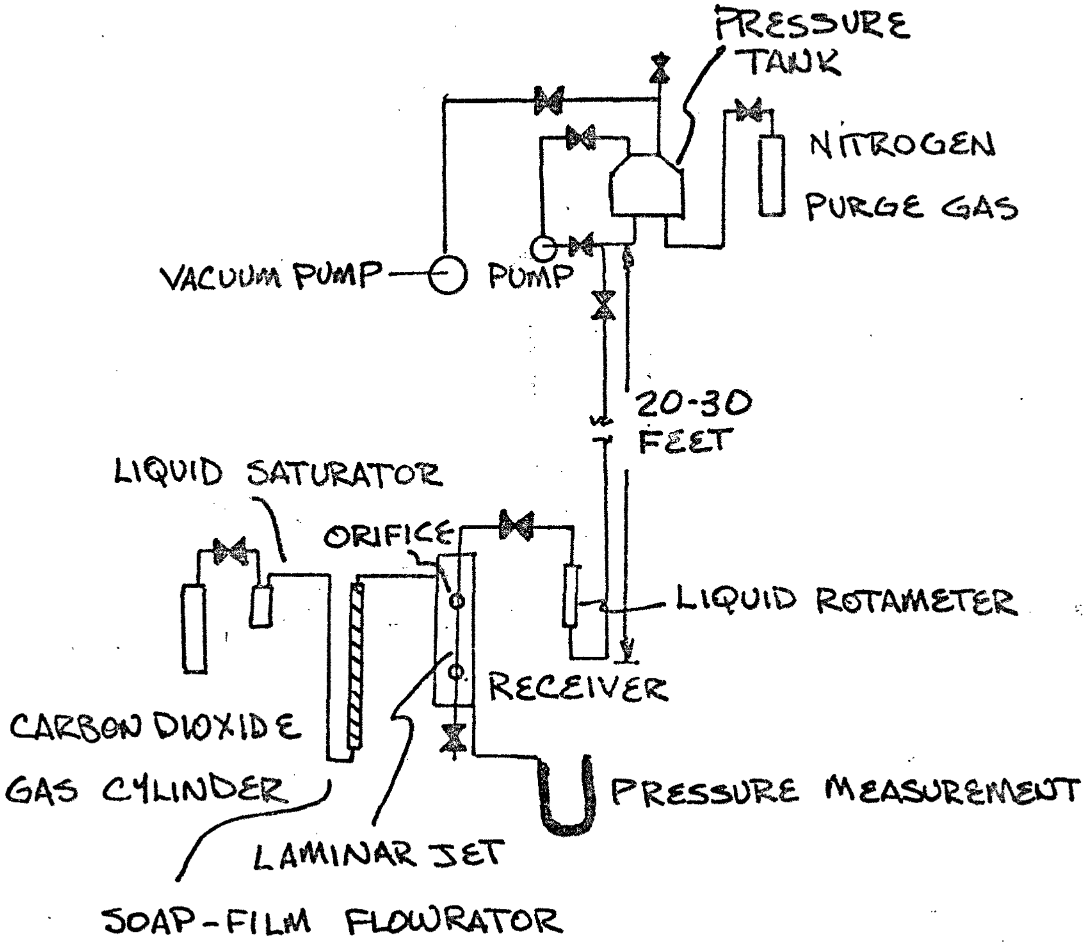


FIGURE 4

higher for the surfactant with the lower molecular mass of the hydrophilic portion of the molecule.

From this previous work ~~we must conclude~~ indications are that immiscible organic compounds ~~can~~ might be recovered from an air stream by the use of surfactants or wetting agents modifying the solubility and other variables of the water towards these compounds.

DISCUSSION OF RESULTS

The scrubbing of organics normally considered immiscible or partly miscible from an air stream was considered. The scrubbing liquid was water with small concentrations of surfactant. The investigation followed similar experimental techniques where the investigators[45] determined the scrubbing of ethanol and ethyl acetate with water to be impractical. The introduction of a surfactant to the water has extreme effects on the properties of the water and our experiments try to prove these effects beneficial to increasing the solubility of certain organics in water.

In our experiment we used 50 ml erlenmeyer flasks with rubber serum caps. Various concentrations of water, organic compound, and surfactant were added to the flasks. The water quantity was either 19 ml or 19.5 ml and was added to 1ml or 0.5 ml of organic compound, respectively. Thus a total of 20 ml of the organic compound-water system filled the flask with approximately 40 ml of headspace. After the addition of from 0.5 to 4.0 grams of surfactant, the rubber serum cap was fitted into place and the solutions were shakened vigorously and allowed to stand and reach the equilibrium state. To reach this equilibrium state each flask stood at room temperature (24°C) for 24 hours or more.

A sample of the vapor in the flask (i.e. the head-space) was taken by syringe and immediately injected into a gas chromatograph to determine the organic compound concentration in the vapor. Sample size was in the magnitude of 5.0 ml or 10.0 ml, depending on the organic compound's reaction with the gas chromatograph.

The gas chromatograph used was a Beckman/GC-2 model with a general purpose silicone packing. The following are the conditions set on the gas chromatograph and held constant throughout our tests:

Bridge current---200ma

Gas flowrate---63.4 ml/min

Column temperature---160°C

Recorder chart speed---½ inch/min

Chart span---1.0 mv

Room temperature---24°C

Gas type---Helium

Attenuator---setting depended on organic compound's individual reaction with the gas chromatograph and the sample size. For each organic compound tested, the sample size coupled with the attentuator setting which provided the optimum results was used.

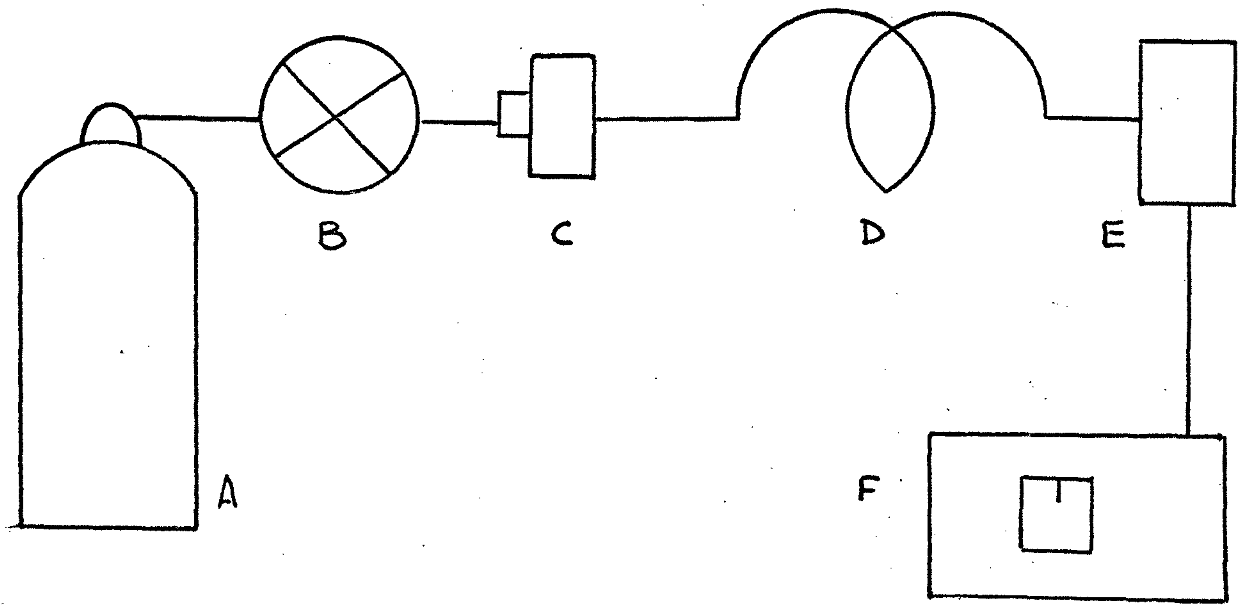
Sample size---see attentuator

Retention time---see individual organic charts in appendix.

Figures 5 and 6 are schematic diagrams of the gas chromatograph and the gas flow system. The gas chromatograph was calibrated with 1 ul of liquid organic compound.

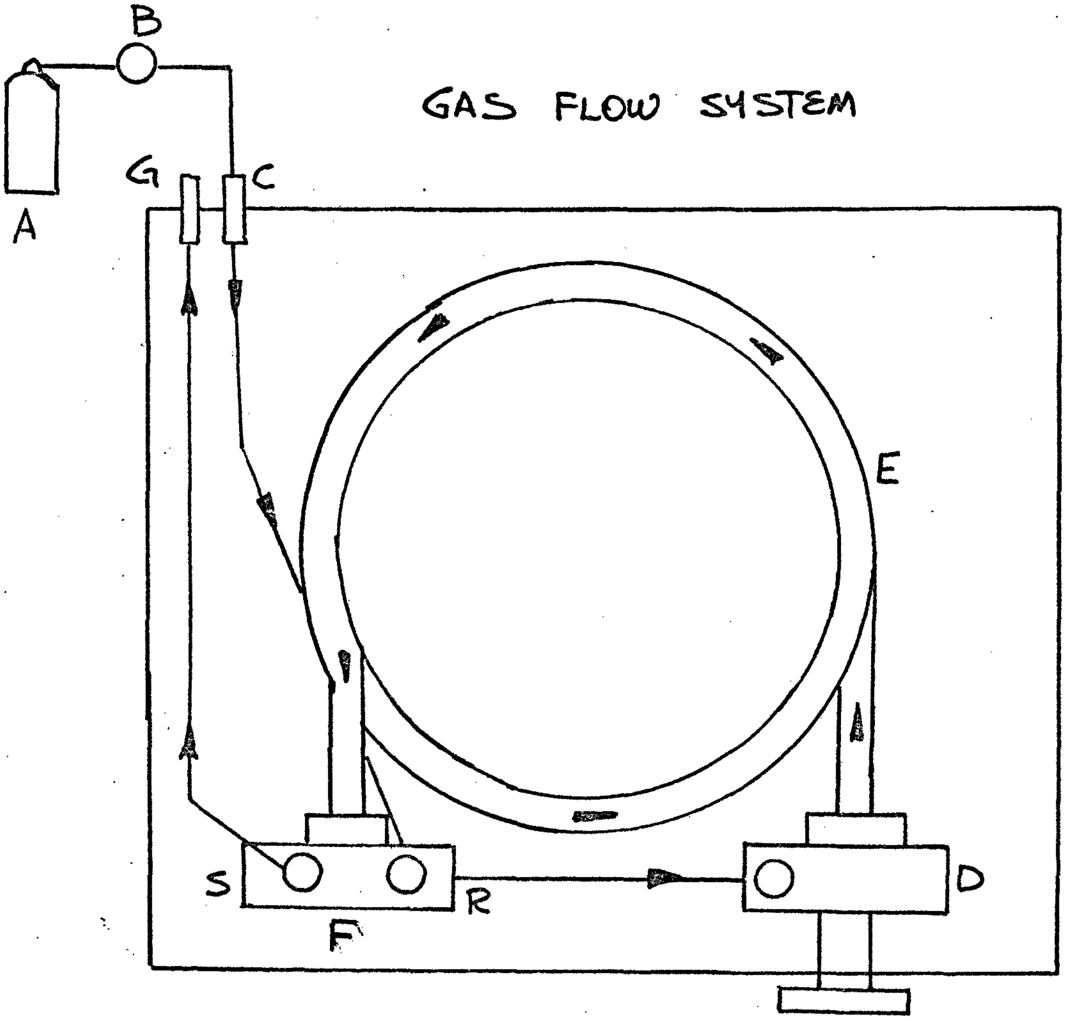
Each solution was made in triplicate to avoid gross experimental error; an obviously erroneous result was set aside. Controls were made for each organic and each surfactant providing a solution of just water and organic compound. We then noted the difference in the concentration of the organic compound in the vapor state between the organic compound-water system and the organic compound-water-surfactant system. The concentration of each organic compound in the vapor headspace of each flask was plotted against the surfactant concentration of each solution, and the series of curves in the appendix were developed.

As was previously noted, the vapor pressure of a gas in a liquid phase equals the partial pressure of the gas in the gaseous phase upon saturation of the liquid. The partial pressure of the gas decreases as the vapor pressure increases until equilibrium is achieved in a closes system. The closed system is our 50 ml erlenmeyer flask and we note this reduction in partial pressure to be a reduction in concentration of the organic compound in the vapor headspace, thereby increasing its vapor pressure in the water-surfactant mixture or increasing the amount of organic absorbed and the solubility of the organic in the system. The converse is



A. CARRIER GAS (HELIUM)
B. REGULATOR
C. INJECTION PORT
D. COLUMN
E. DETECTOR
F. RECORDER

FIGURE 5



A. HELIUM TANK
B. PRESSURE REGULATOR
C. INLET
D. INJECTION PORT
E. COLUMN
F. DETECTOR
  R. REFERENCE
  S. SAMPLE
G. OUTLET

FIGURE 6

also true, an increase in organic concentration in the vapor state would mean an increase in partial pressure and thus a reduction of the vapor pressure of the organic in the water-surfactant system, thereby reducing the amount of organic absorbed and denoting a reduction of solubility of the organic in the vapor, the lesser amounts of organic entered into solution with the water. Or the lower the concentrations of organic compound in the vapor state, the greater amounts of organic entered into solution with the water. By comparing the original concentration of the organic in the vapor state of the control sample to the concentrations of organic in the vapor state of each sample containing an increasing amount of surfactant, we determined the differences in solubility of the organic compound in the water-surfactant solution.

Our curves exhibit these differences in solubility quite readily and the following discussion will try to develop the patterns and trends of the various organics' when effected by the different surfactant types used. Tables of the data obtained are included in the appendix.

The following immiscible or partly miscible organics in water were examined to determine whether surfactants could affect this immiscibility.

1. Xylene
2. Toluene
3. Carbon Tetrachloride
4. Ethyl Acetate
5. Iso-propyl Alcohol

We used a reagent grade of organic compound and city water in the experiment. The practicality of a process depends on its feasibility on the commercial scale; and the large amounts of water necessary to operate any scrubber compounded by the need to keep costs as low as possible, makes it imperative for us to keep down the requirements of the scrubbing liquid, hence city water.

The above organics were "scrubbed" (i.e. meaning being acted upon by our experimental procedures) with varying concentrations of the following surfactant types:

Anionic -- ethylene oxide based
Anionic -- ethylene oxide based-linear
Anionic -- sulfonate
Anionic -- hydrotrope

This limited surfactant range was used to determine the trends of the surfactant affects on the solubility of the organics in water.

We then proceeded to examine xylene's immiscibility with a wider range of surfactants under the same experimental conditions. These surfactants included:

A. Various alkyl sulfates
    1. Fatty Alcohol
    2. Fatty Ether

B. Various sulfonates
   1. Dodecylbenzene
   2. Alkyl Benzene
   3. Alkyl Carboxy

C. An Alkylolamide
   1. Fatty Acids

D. A Hydrotrope
   1. Xylene based

E. An Anionic-Nonionic

After much discussion, we analyzed the the data obtained in accordance with the above surfactant groupings.
We found, generally, the surfactants to have an effect on the organic-water system. Therefore, to determine if these effects are common to all organics or all surfactants, or certain organics, or certain surfactants, or to just certain organic-surfactant systems, we felt this method of analization to be most appropriate.

Surfactant concentration for such a simple varied from 0% for the control cample to over 16%. Thus we feel we explored the possible ranges of surfactant concentrations that would be feasible in an actual scrubbing situation. That is, at greater surfactant concentrations, the amount of water would make the process impractical.

Ethylene oxide based surfactant

This surfactant is Sandopan DTC Gel Paste 6400-0-100, manufactured by Sandoz. This surfactant's effects on the solubilities of the above organic compounds can be seen in Figures 100, 104, 108, 112 and 116. Charts 100, 104, 108, 112, and 116 express percent changes of solubility for each organic in water at specific surfactant concentrations.

From Figure 100, the xylene vapor concentration for the xylene liquid to water concentration of 1ml to 19ml decreases, then increases and then decreases as the surfactant quantities are increased. When the xylene concentration was more than halved to 0.5ml xylene to 19.5ml water a gradual decrease in xylene vapor concentration was followed by a minimum at 4.8% surfactant. The solubility of xylene was increased about 18% at this point. A comparable increase in solubility at the lower xylene concentration of 17% occurred at 9.2% surfactant. This surfactant. This surfactant increased the solubility of xylene in water at nearly all concentrations.

A nearly identical course is set by isopropyl alcohol, Figure 116. The higher isopropyl alcohol in water concentration's vapor concentration decreases, shows an increase and then a decrease. The solubility is increased about 18% at 9.2% surfactant. The lower isopropyl alcohol concentration curve has two minima, increasing the solubility of isopropyl alcohol nearly 88% at 4.8% surfactant and 87% at 16.8% surfactant. This surfactant effected a large increase in the solubility of isopropyl alcohol in water after a slight variation increase at first. Large increases such as these warrant further investigation on a larger scale.

Carbon tetrachloride, Figure 104, exhibited similar results as xylene and iso-propyl alcohol at the concentration of 1ml organic and 19ml water. The same basic curve was developed: an initial increase followed by a decrease in solubility. However, although the decrease varies with surfactant concentration, the surfactant is generally a great hindrance to the solubility of carbon tetrachloride in water. A 57% decrease in solubility occurs at 8.8% surfactant concentration for the high CCl_4 to water system, and at the same surfactant concentration the low CCl_4 - water concentration system exhibited a decrease in solubility of 92%.

Initially this surfactant was a hindrance to the absorption of ethyl acetate and to toluene of higher concentrations as the surfactant concentration increased to about 4.8%. However, at this concentration a dramatic increase in the solubility of these organic compounds can be noted, see Figures 112 and 108. The ethyl acetate increase in solubility in water is 55% at a surfactant concentration of 9.6% for the low ethyl acetate concentration system; and 23% for the high ethyl acetate concentration system at the same surfactant concentration. From Figure 112 we note a minimum at this 9.6% surfactant concentration and then both ethyl acetate concentrations show greater surfactant concentrations in water inhibiting further solubility of the ethyl acetate.

Toluene also shows a minimum at about 9.2% surfactant concentration. This increase in solubility is 39% for the high toluene concentration system and 18% when the toluene concentration was halved. At the low toluene concentration a gradual increase in solubility is accompanied by greater increases as the surfactant concentration increases.

Certain aspects of all the curves seem to be comparable to other aspects of the curves. Close examination shows that except for one or two points, the xylene, toluene, and iso-propyl alcohol curves are quite similar, exhibiting the same trends (i.e. increasing or decreasing solubility) at similar surfactant concentrations. All the organics tested, with the exception of carbon tetrachloride, had their solubilities in water increased to some extent through the use of this surfactant.

Also all the curves (see figures noted) of organic compound vapor concentrations versus surfactant concentration had a dramatic maximum or minimum occur between 4.8% and 9.2% surfactant concentration. This phenomena could be explained as the critical micelle concentration occurring around the concentration. Figure 3 identifies the critical micelle concentration as the point where surfactant effects on water properties is drastically altered. The critical micelle concentration is the concentration where the maximum change in water properties occurs, thus it is logical for the greatest amount of absorption to occur at this point. If the properties of the water were changed to the extent that they are a hindrance to absorption or an aid to desorption, it is only proper that a maximum occur at the critical micelle concentration. The abrupt changes in solubility experienced by our data at a predictable concentration leads us to believe this theory true.

Water properties agreeable to ethyl acetate desorption seem to be effected by small amounts of surfactant increased and reached what we consider the critical micelle concentration at a point between 4.8 and 9.2%, the water properties are changed such that the absorption of the ethyl acetate occurs quite readily.

Examining the flasks and their contents gives no impression at this surfactant concentration of the critical micelle concentration, or other physical characteristics that may develop into a pattern. The xylene solutions are hazy at first and then clear up upon high surfactant concentrations (see Tables). The toluene solutions had similar physical characteristics as the xylene solutions: a light haze that got denser followed by a clearing of the solution with added quantities of surfactant.

The carbon tetrachloride solution, upon the addition of 0.5 grams of surfactant was cloudy with a white residue on the bottom of the flask (possibly denoting supersaturation of the solution with surfactant or a reaction between the surfactant and the carbon tetrachloride forming a precipitate). Increasing the surfactant concentration changed the solution's appearance to a slight haze.

We could speculate that since all the above solutions were white hazy in appearance around the surfactant concentration range 4.8 - 9.2%, this must be the critical micelle concentration. At the critical micelle concentration the large number of micelles, or aggregate of moleculse, produce a translucent solution because of the reflection and refraction of light waves by these micelles.

However, we cannot conclude this to be true because of the ethyl acetate and iso-propyl alcohol solutions. These solutions produced a solution of one clear layer, even for the control, which was two clear layers for the other organic compounds; suggesting some solubility of these two organics before the tests began. Another reason for not stressing the physical appearance to explain our results or to find the critical micelle concentration is published data from the manufacturer, Sandoz[61] notes the differences in solution appearances for a variety of compounds and Sandopan DTC Gel Paste concentrations. The appearance range from a haze for xylene in a 10% surfactant range (which does clear upon increased surfactant bearing out our findings), to clear for a solution of 5% NaOH and 1% surfactant, to a phase separation for a solution of mineral spirits and 5% surfactant. Obviously, for this surfactant, physical appearance has little meaning for the interpretation of the results.

Ethylene oxide based -- linear surfactant

This surfactant is Sandopan DTC Linear Gel 7445-121-5 manufactured by Sandoz. We must address ourselves to the fact that by solving an air pollution problem, we might be creating a water pollution problem. Besides the obvious, removing the organic emulsions formed from the water, the surfactant-water solution might create undesirable situations in the event water volumes for this scrubbing process are large.

This linear surfactant tested is more readily biodegradeable than its non-linear counterpart. Depending on the test method, the linear surfactant proved to be biodegradeable in excess of 90%. Using the river water die-away test after 15 days this surfactant was degraded 94% compared to a 48% degradation of the previously discussed surfactant.

Concentrations of organics in the vapor state decreased greatly in nearly all cases, thus, solubility was increased for nearly all tests with the specified organics except for CCl_4 which showed a decrease in solubility. Note figures 103, 107, 111, 115 and 119 for the following discussion:

Xylene's solubility in water was increased dramatically. For the higher xylene in water concentration (1ml xylene:19ml water) the solubility increase was 32% at 2.5% surfactant. This increase became smaller as the surfactant concentration increased to about 14% at 9.2% surfactant concentration. The low xylene to water ratio 0.15: 19.5 had similar characteristics but at different surfactant concentrations. Its curve had a minimum at a concentration of 4.8% surfactant concentration with the net result of 39% increase in solubility.

Ethyl acetate was absorbed more readily in water as the surfactant concentration increased. There is a direct proportionality involved between ethyl acetate solubility and surfactant concentration. For both ethyl acetate water system concentrations the increase in solubility continues as the surfactant concentration increases, such that at 16.7% surfactant concentration we note an 18% and 46% solubility increase for the high and low ethyl acetate to water ratios respectively. (see Figure 115).

Isopropyl alcohol, see Figure 119, exhibits diverse characteristics of solubility in water-surfactant solutions. For all concentrations of surfactant tested with the 1.0ml isopropyl alcohol : 19.0ml water ratio, the isopropyl alcohol's solubility was increased. Initially at 2.5% surfactant the solubility increased to 48%. The addition of greater amounts of surfactant proved to lessen this large increase in solubility. However at 9.2% surfactant the solubility increase is still 33%. At this same surfactant concentration for the 0.5ml isopropyl alcohol: 19.5 ml water ratio the increase in solubility was 50%. The lower water to isopropyl alcohol ratio at first shows a slight decrease in the amount of organic absorbed, followed by a sharp increase and finally decreasing by as much as 42% at 16.8% surfactant. Surfactant concentration greatly affects the solubility of isopropyl alcohol in water. We note that even slight changes in concentration produces large changes in the solubility of this organic in water. A 2.3% differential in surfactant concentration produced a 41% differential in solubility.

This characteristic of large differences in solubility with increasing surfactant concentration is also exhibited by toluene. Initially the lower and higher toluene concentrations exhibit different characteristics. This surfactactant proved to increase the solubility of toluene for the higher toluene concentration, but aided desorption for the lower toluene concentration. See Figure 111. Surfactant concentrations up to over 5% aided desorption of the toluene from the water at a toluene concentration of 0.5:19.5. After 4.8% surfactant concentration, the two toluene concentrations showed sharp increases in solubility with added surfactant: nearly 43% and 21% increase at 9.2% surfactant for high and low toluene concentrations, respectively. Water requires larger amounts of this surfactant to improve toluene solubility in it than the other organics tested.

This surfactant was a hindrance to the solubility of carbon tetrachloride in water. The carbon tetrachloride left us no reason to believe this surfactant might aid its solubility. All tests showed an increase in CCl_4 concentration in the vapor state thus denoting desorption of carbon tetrachloride from the water. The water properties were changed by the surfactant to cause an initial sharp rise in CCl vapor in the vapor state, followed by a gradual decrease as the surfactant concentration increased further. See Figure 107.

Again we noted the physical characteristics of each solution and tried to develop a connection between solubility changes, linear ethylene oxide surfactant concentration changes, and physical appearance.

The xylene solutions are slightly hazy at first followed by a denser haze and clearing of the solution. The toluene solutions had similar appearances. Ethyl acetate solutions of surfactant and water were clear: one clear layer for all surfactant concentrations. Iso-propyl alcohol solutions were also one clear layer for all concentrations. The carbon tetrachloride solutions exhibited a phase separation as a white residue settled on the bottom of all flasks with a quantity of surfactant.

There does not appear to be any dependence of solubility on physical appearance. The same physical appearances are not present for all organics or all surfactant concentrations. Therefore, determination of the critical micelle concentration of some other concentration where solubility increases are more apparent, is not feasible through physical characteristics of a solution of this surfactant.

Solubility effects do not occur more readily in a water-Sandopan DTC Linear gel surfactant concentration range of just under 5% through 10%. Nearly all minimum and maximums of the curves plotted fall within this surfactant range. This surfactant must affect the water properties to the utmost in this concentration range although from their physical appearance this coult not be ascertained.

Neither ethylene oxide based surfactant could change the properties of water to the extent needed to make carbon tetrachloride more soluble in it. Both proved to be a hindrance to CCl_4 solubility and an aid to its desorption.

Inspection of the curves, Figures 104 & 107, leave no reason for fuether investigation of these surfactants and carbon tetrachloride.

On the other hand xylene's solubility was improved by both linear and nonlinear ethylene oxide based surfactants-in water. The linear surfactant increased solubility to a greater extent over the nonlinear surfactant; 39% to 18% at comparable surfactant concentrations. Ethyl acetate, toluene, and iso-propyl alcohol also showed a general increase in solubility with the addition of the ethylene oxide based surfactants. And basically the solubility increases were no greater for the linear ethylene oxide than for the nonlinear surfactant.

Further examination of these graphs reveals to us a general similarity between curves for each organic tested. The high and low concentrations of each organic compound exhibited similar characteristics upon examination with water and the ethylene oxide surfactants. There is no reason to believe organic concentration greatly affects the effects of a solution of surfactant and water and organic. The solubility changes resulting from the surfactants' addition to water are not dependent on organic concentration in the system.

In nearly all instances outside of the carbon tetrachloride the trend of each curve for these two ethylene-oxide based surfactants is for increased solubility. In some cases we note a gradual change in solubility as surfactant concentration increases and in others a slight change in surfactant quantity produces differences in solubility.

The ethylene oxide based surfactants have influenced the properties of water to effect the solubility of some organics in water to some extent. Our investigation continues with a variety of differently based surfactants as we search for optimum as well as conclusive results.

Sulfonates

The sulfonate surfactant tested with all the previously tested organic compounds was Ultrawet 1565 (45.D5,) manufactured by Arco Chemical Company. It is an anionic surfactant whose basic composition is sodium dodecylbenzene sulfonate. The effects of the other sulfonates were examined as they pertain to xylene. These are Ninate 401, another dodecylbenzene sulfonate, only instead of sodium being the cation, Ninate 401 has a calcium cation; Stepantex DA-52 which has an alkyl benezene organic base with an amine cation; and Stepantex WB-42, a sodium alkyl carboxy sulfonate 70% active. These three surfactants are manufactured by Stephan Chemical Company. These final three surfactants along with the Ultrawet 1565 offer a wide range of sulfonates with their various bases and cation combinations. Thus the latter examination of xylene with this scope of sulfonates gives us a clearer picture as to possible surfactant effects on immiscible organic compounds' solubility in water.

The effects of Ultrawet 1565 on the solubilities of the organic compounds tested in water willbe discussed first.

Carbon tetrachloride's solubility is affected by this surfactant. See Figure 105. The CCl_4 concentration in the vapor state decreased greatly at the initial surfactant concentration of 2.5%. Thus we note (see table 105) a solubility increase of 66% for the CCl_4 in water concentration of 1:9 and 30% increase for the low CCl_4 concentration. The solubility of CCl_4 in water is improved at larger surfactant concentrations, although to a lesser degree, until surfactant concentrations reach around 10%. After this point the surfactant causes a desorption of CCl_4 from water providing a greater obstruction to the absorption of CCl_4 by this water-surfactant solution than just plain water. From the curves it is seen that a change in CCl_4 concentration does not greatly affect the effects of a surfactant-water solution on the solubility of CCl_4 in it. The curve of the two CCl_4 concentrations are nearly identical to one another denoting this conception. There is, however, a greater increase in solubility for the higher CCl_4 concentration.

Isopropyl-alcohol has an initial increase of solubility in water with a surfactant concentration of 2.5%. See Figure 117. The isopropyl-alcohol concentration in the vapor state decreased for both concentrations of isopropyl alcohol and water. At the higher organic in water concentration the solubility increase is 12% and 50% for the lower concentration at the initial quantity of surfactant. The solubility of isopropyl alcohol at the low concentration is improved but to a lesser degree as surfactant concentration increases until a concentration of 9.2% surfactant is reached. For the higher organic in water concentration, the solubility decreases after about 3.5% surfactant and continues decreasing to a minimum of 15% at 9.2%. After a 9.2% surfactant concentration the solubility of iso-propyl-alcohol increases and improves by as much as 40% at 16.8% surfactant for the 0.5:19.5 ratio of isopropyl alcohol to water.

Again we note, see Figure 117, the patterns of the effects of this surfactant on both concentrations of isopropyl-alcohol. Except for the size of the change, there appears to be no apparent difference in the effects of this surfactant on isopropyl-alcohol concentration.

This surfactant has similar effects on ethyl acetate's solubility in water as it does on isopropyl alcohol and carbon tetrachloride. After an initial large increase in solubility at low surfactant concentrations, the improvement decreases and then is effected to a greater degree after a surfactant concentration of 9.2%.

Ethyl acetate in the vapor state is decreased by 23% for an organic to water ratio of 1:19 and 11% for an organic to water ratio of 0.5:19.5 at a surfactant concentration of 2.5%. Further increase in surfactant produces an even greater effect on the solubility of the higher ethyl acetate concentration up to 4.8%. The solubility at the lower concentration is unaffected by a surfactant range of 4.8 to 9.6%. The greatest change in solubility occurs at a surfactant concentration of over 40% for both ethyl acetate concentrations. See Figure 113. Similar characteristics of the curves of both ethyl acetate concentrations causes us to believe that surfactant effects on solubility are not dependent on the quantity of ethyl acetate in water.

Examining the curves for isopropyl alcohol and ethyl acetate. Figures 113 & 117, we note the similar characteristics this surfactant produces on both organic compounds. The same general properties are held by CCl_4 (Figure 105) for this surfactant as the previously mentioned organics except for at high surfactant concentrations.

Toluene at its lower concentration of 0.5:19.5 in water is relatively unaffected by this surfactant. The largest change in solubility is only 5% at a surfactant concentration of a 4.8%, this decreases such that the toluene-water system's miscibility is unchanged. The most rapid change and increase in solubility occurs after 2.5%. This is also true for the higher toluene in water concentration where after the 2.5% surfactant concentration the greatest increase in toluene concentration in the vapor headspace occurs. Furthermore, this surfactant is an aid for desorption of toluene from the water-toluene mixture at the high toluene concentration, and this desorption increases as surfactant concentration increases.

With the above surfactant, xylene also showed no appreciable change in solubility. The lower xylene concentration system had its solubility (see Figure 101 and Table 101) increased 5% at 2.5% surfactant. This was the maximum value obtained as further increase in surfactant had lesser effects on the properties of the xylene-water mixture, until no effects could be determined. The higher concentration xylene system peaked at a 26% decrease in solubility at 4.8% surfactant and then declined as further increases in surfactant concentration proved to be less of a hindrance to solubility. This Ultrawet 1565 surfactant is a sodium dodecylbenzene sulfonate and the results obtained we believe are comparable to Ninate 401, another dedecylbenzene organic based sulfonate only with a calcium cation instead of sodium. See Figure 126. The effects of both surfactants on xylene are similar except Ninate 401 produces much more drastic results. The lower concentration of xylene in water had its solubility changed for the better by 21% at 4.8% surfactant. At other surfactant concentrations the increase in solubility was not as great. The higher xylene in water concentration produced the opposite results with this surfactant as it did with the previous surfactant. There is a steady rise in xylene concentration in the vapor state, denoting desorption, until it reaches a 47% increase at 9.1% surfactant. The drop in surfactant effects that follows is dramatic; in fact, for both dodecylbenzene surfactants, the effects on water properties to influence absorption of xylene is diminished at higher concentrations. This is true for both concentrations of xylene in water as at high dodecylbenzene surfactant concentrations there is relatively no change in solubility.

The affects of other sulfonated surfactants on xylene solubility in water was explored. Stepantex WB-42 the soldium alkyl carboxy sulfonate (see Figure 123) influenced a greater absorption of xylene by water. For both xylene concentrations there is an initial increase in solubility followed by a decline in the size of this increase as larger amounts of surfactant are added to the system. The lower xylene concentration curve shows two minima for xylene concentrations in the vapor state. A 31% increase in solubility at 2.5% surfactant and 49% increase at 16.7%. The higher xylene concentration also varies dramatically with surfactant concentration.

This is true for the various concentrations of Stepantex DA-52 tested. Although the higher concentration of xylene in water proved this surfactant to have adverse effects on xylene solubility, after an initial decrease of 59% at 2.5% surfactant, these decreases were relatively small at greater surfactant concentrations. The lower concentration of xylene in water system shows xylene solubility to be unaffected by this surfactant until the surfactant concentration surpasses 2.5%. Xylene solubility in water is then improved by as much as 18% as the surfactant concentration increases.

We note from these surfactants that the initial xylene concentration in water is a factor when determining surfactant effects on the solubility of xylene in water. Figures 101 & 126 exhibit this fact. From Figure 123 we might suspect the same, however, both xylene solubility and the concentration of this surfactant could be more significant than previously tested surfactants. It seems from these results that the type of surfactant is just as important as surfactant concentration when trying to influence the properties of the xylene-water system. Whereas, over 80% of all tests of xylene with sulfonate surfactants resulted in improved solubility, the variables are considerable and seem to be quite specific. That is, a certain xylene concentration might need a specific concentration of a specific sulfonate surfactant in order to effect the required results.

We examined the appearance of these samples and found no evidence of physical appearances affecting specific results. Ethyl acetate and isopropyl alcohol exhibit similar physical characteristics of a clear solution for all organic and surfactant concentrations. Carbon tetrachloride had a phase separation--a clear solution with a white residue on the bottom. Toluene and xylene for the Ultrawet 1565 produced hazy solutions for the surfactant ranges tested.

Xylene, water, and Stepantex WB-42 initially appeared as a grayish milky white solution and gradually changed with increased surfactant concentration. Its appearance went from milky white to a light off yellow solution. Stepantex DA-52, xylene, and water solutions were at first milky white at a 2.5% surfactant and the solution's appearance became off white with additional surfactant. The solution was transformed into an amber gel at a surfactant concentration of about 16.8%. Ninate 401, xylene and water effected a phase separation. Initially we noted a hazy solution with a white and yellow residue on top. With increased surfactant this residue turned more yellow, then into a hazy yellow gel, and then a clear solution surrounding a yellow gel with a white solid residue on top.

The physical characteristics were unaffected by organic concentration. From Tables in the Appendix we see the slight differences that did appear.

In nearly all cases the solubility results were not dependent on organic concentration, however, we note the irregularities that occured with the latter surfactants discussed and xylene concentration.

Most activity for the Ultrawet 1565 surfactant occurred in a concentration range of 2.5-4.8%. Within this range we note an increased number of minima and maxima on our curves denoting drastic changes in water properties affecting solubility. Whether this is the range in which the cmc falls we have not determined. As noted physical characteristics of the different organic solutions exhibited no similarities to suggest a developing trend that might allow us to make such an assumption.

For all the surfactants tested there was a general influence on the physical properties of water to allow for a greater organic solubility in water.

Hydrotropes

All the previously mentioned organics were examined with surfactant 40SX as manufactured by the Arco Chemical Company. Xylene was further examined for solubility effects by Stepanate AM as manufactured by Stepan Chemical Company. Surfactant 40SX is a sulfonate hydrotrope with xylene as the organic base and sodium the cation. Stepanate AM is a similar hydrotrope with a sodium cation and xylene organic base.

The 40SX surfactant decreased the solubility of xylene in water at all times. At the higher xylene concentration we note the decrease in solubility is directly proportioned to the increase in surfactant concentration. Our graph (Figure 102) showing a maximum 42% decrease at 9.2% surfactant. The lower xylene concentration fared better, in that after a large initial decrease of 28% solubility at 2.5% surfactant, the decreasing diminished and leveled off at a decrease in xylene solubility approximately 15%.

A similar decrease in xylene solubility resulted with the lower xylene in water concentration system and Stepanate AM. A sharp decrease of 23% at 2.5% surfactant is followed by results showing practically no surfactant effects at 4.8% surfactant. Variations in solubility of xylene continue with increased surfactant concentrations, however these variations are rather small. The higher xylene concentration system (1ml:19ml) improved in the amount of xylene absorbed in the water. Variations are sharp as a slight increase in this surfactant produced a wide difference in xylene solubility.

Except for the higher xylene concentration and Stepanate AM system, we noted a decrease in xylene solubility for these surfactants. Since these are xylene based surfactants the results could have been affected by a xylene concentration already in the water. In the control flasks without the surfactant, we determined the xylene concentration, and then with the surfactant we did the same. Obviously in those flasks with xylene, water, and surfactant there is more xylene than in those without a surfactant. As a result of partial pressures differences, xylene from the surfactant solutions might be forced out of solution to add to the xylene concentration in the vapor state. Thus when passing a sample through the gas chromatograph a larger xylene concentration is recorded for surfactant samples. The possibility also exists that these surfactants are just detrimental to xylene solubility in water, that they change the water's properties to effect the immiscibility of xylene in water.

The other organics were only tested with surfactant 40SX and the results, while mixed, showed a general trend towards improvement of solubility in water.

Carbon tetrachloride showed a gradual increase in solubility over the surfactant concentrations used. The higher carbon tetrachloride system's solubility was relatively unaffected by the surfactant until a concentration over 2.5% is reached. After this point, increases in CCl_4 solubility are directly proportional to surfactant increases reaching a maximum of 21% improvement at 16.2% surfactant. The lower CCl_4 concentration system initially increases in solubility by about 19% at 2.4% surfactant. The solubility of CCl_4 is improved with further surfactant increases, but this improvement varies without any consistency. Both concentrations of CCl_4 show solubility improvements in the same order of magnitude and there is a relationship between CCl_4 concentration, surfactant concentration, and the size of the solubility improvement.

For the high isopropyl alcohol concentration system, the solubility as well as magnitude of solubility increases are dependent on surfactant concentration increases. At 2.5% surfactant concentration the isopropyl alcohol solubility improvement is 24%. This improvement varies unpredicably with further surfactant increases, as declines and increases in solubility improvement magnitudes are noted (see Figure 118). When the isopropyl alcohol concentrations was halved, the solubility was unaffected by small amounts of surfactant. In fact the solubility of isopropyl alcohol in water is generally unchanged at the lower concentration until a surfactant concentration of around 9% is reached. At this concentration the amount of isopropyl alcohol in the vapor state is nearly doubled denoting the affects of the surfactant as a hindrance to solubility.

Toluene's solubility in water at the lower concentration of toluene to water 0.5:19.5 improved by 34% at a 2.5% surfactant concentration. A decline in improvement occurs at 4.8% and then increases to 22% at 9.2% surfactant. Thus the magnitude of solubility improvement is highly dependent on the surfactant concentration. This is also true for the higher toluene concentration system (see Figure 110). Although there is a decrease in solubility, the magnitude of this change is also dependent on surfactant concentration with large variations accompanying slight changes in surfactant quantities.

Similar results were obtained by the ethyl acetate system. The high ethyl acetate to water ratio system showed ethyl acetate's solubility decrease by 29% at 2.5% surfactant. The size of this decrease remained stable with increased surfactant until 9.6% surfactant concentration.

However, with a surfactant concentration of 16.7% surfactant affects on water properties to effect absorption are diminished. This is not apparent for the lower ethyl acetate concentration. In these tests the ethyl acdtate's solubility was improved by 32% at 2.5% surfactant and continued to improve, although slightly, with increased surfactant concentration.

We note for both toluene and ethyl acetate the high organic in water ratio is affected by the surfactant in such a manner that there is more organic in the vapor state, suggesting the surfactant to be a hindrance to solubility at higher concentrations. There is a solubility improvement for the organics when the surfactant is added to the water of the lower organic to water ratio tested.

We note for the surfactant 40-SX that the concentration range between 2.5 and 4.8% produces the most radical differences in water-organic absorption properties. We might suggest this concentration to be the critical micelle concentration, since in order for these radical differences to occur the water must be effected to a maximum and at this point the critical micelle concentration occurs.

Appearances of the solutions do not suggest any trends and/or critical micelle concentration. All the physical characteristics of the original five organics tested--xylene, toluene, ethyl acetate, carbon tetrachloride and isopropyl alcohol -- were the same for surfactant 40 SX as for Ultrawet 1565 and the ethylene oxide compounds. Please see tables. Stepanate AM surfactant produced unusual characteristics for the xylene water surfactant solution (see Table 127,) however there does not seem to be any connection between solubility, water and organic properties, and solution physical appearances. Physical characteristics in some cases--xylene, toluene, CCl_4--are dependent on surfactant concentration. Ethyl acetate and isopropyl alcohol show no such dependencies.

We cannot make the general statement that solubility effects produced by a surfactant are independent or organic concentration. These surfactants effected solubility changes which were dependent on organic concentrations and surfactant concentrations, thus making predictability of an optimum system difficult and nearly impossible. Such a dual dependency for optimal results would make water scrubbing or organic gases impossible since gas concentrations will change quite readily, and to constantly monitor the gas concentration to effect a surfactant concentration change would be unfeasible both on the technical as well as economic levels.

Alkyl Sulfates

The following surfactants tested are manufactured by Stepan Chemical Company. Stepanol WAT has a fatty alcohol organic base and TEA cation. Steol KS-460 has a fatty ether organic base and sodium cation. Xylene was the only organic tested with these surfactants. The general characteristics of the affects on the solubility of xylene are identical for each surfactant, see Figures 120 and 121. There is the initial increase of xylene concentration in the vapor state, (i.e. denoting a reduction in solubility,) followed by a decline in xylene vapor concentration and to finally increase with increasing surfactant concentration.

Stepanol WAT effects an initial 70% decrease in xylene solubility at 2.5% surfactant for the high 1:19 xylene to water ratio. With further addition of surfactant to a 4.8% concentration, the decrease in solubility declines to about 45%. At this point a minimum is reached and additional surfactant concentrations further decrease the solubility of xylene in water. The low xylene to water concentration 0.5 to 19.5 exhibited not so drastic effects by the surfactant. Although the trends were similar, there is merely a 7% decrease in solubility at 2.5% surfactant. The increase in xylene absorption by water that follows reaches a minimum at 4.8% surfactant and results in a 15% increase in xylene solubility. However, after this surfactant concentration, solubility of xylene is indirectly proportional to surfactant concentration. That is, an increase in surfactant concentration produces a decrease in solubility attaining a maximum decrease of 31% at 16.7% surfactant.

Steol KS-460, although effecting various results, did not cause an increase in xylene solubility. For the 1:19 xylene to water ratio, a peak of 69% increase in xylene vapor concentration is attained at 2.5% surfactant. The vapor concentration is increased by all surfactant concentrations tested, although the magnitude of these increases varied. Solubility is decreased by only 22% at 4.8% surfactant, but again decreases with increased surfactant after this point. Xylene in water at a concentration of 0.5:19.5 exhibit similar effects by this surfactant. The maximum reduction in solubility of 87% occurs at 4.8% surfactant concentration. A drop off in this reduction is effected at 9.1% surfactant and continues as the solubility decreases with further surfactant increases.

By observing the data produced, xylene concentration is not a factor in an alkyl sulfate's ability to effect solubility. Both concentrations of both surfactants tested have highly similar characteristics. Xylene to water concentrations are different only with respect to magnitude of the solubility change, rather than the change itself. Both surfactants effect drastic changes in solubility at a surfactant concentration range between 2.5-4.8% denoting large water property changes and possibly marking the critical micelle concentration.

Other physical characteristics of these solutions did not exhibit any properties which would lead us to suspect an increase in surfactant past the critical micelle concentration (about 2.5-4.8%) would effect further solubility changes. The Steol KS-460 surfactant-water-xylene system produced milkly white solutions for all surfactant concentrations until it turned clear upon the addition of 16.7% of the surfactant. We note the Steol KS-460 solutions were predominately milkly white through the concentration range where a variation in surfactant to a slight degree, produced large changes in xylene absorption by water.

This result is duplicated by Stepanol WAT. For the concentration range of 2.5 to 4.2% we observe a hazy solution with a white residue on top, thus possibly denoting the cmc, and at these concentrations our most serious changes occurred. Further increasing the surfactant concentration turned the solution clear and reduced the amount of white residue on top until there was a clear solution at 16.7% surfactant. From these surfactants we can suggest the interrelationship of solution physical appearance and its characteristics (i.e. the cmc) to effect miscibility of xylene.

As much as these alkyl sulfates do affect water properties to effect changes in xylene solubility, they do not result in increased xylene solubility in water. In fact they prove to be a hindrance to the absorption of xylene by water and prove to further aid the immiscibility of xylene to water.

Alkylolamides

The alkylolamide tested with xylene was manufactured by the Stepan Chemical Company. Ninol 1281 has an organic base of fatty acids.

Solubility of xylene in water was initially decreased by around 8% for the higher xylene in water concentration. The solubility of xylene in the water-surfactant solution begins to increase after a 4.8% surfactant concentration is reached and continues until a 14% increase is attained at 9.2%. Further surfactant increases decrease the solubility of xylene. The lower xylene to water ratio follows suit. The initial decrease in solubility is followed by an increasing insolubility to about 5% at a 4.8% surfactant concentration. Again solubility deceases with further increases in surfactant.

The properties exhibited by these water-xylene-surfactant systems seem to be pretty much universal -- there is a surfactant concentration in water, possibly the cmc, which is favorable to the absorption of xylene by water to a greater extent than just xylene in water.

This alkylolamide produced hazy solutions with white residues for surfactant concentrations up to about 5%. After which the solutions turned yellowish and then into gels.

As in all previous cases the organic concentration had very little affect on the physical appearances of the solutions. And in this instance both xylene in water concentrations were dependent on surfactant concentration to the same degree.

Emulsifiers

The emulsifier used with xylene was Toximul R as manufactured by Stepan Chemical Company. It is an anionic-nonioic emulsifier and produced some interesting results.

For both xylene in water concentrations there are very small affects produced by nearly all surfactant concentrations. The high concentration of xylene at first exhibits a reduction in xylene concentration in the vapor headspace, therefore an increase in solubility by 7%. This figure decreases with increasing surfactant until no distinguished at 9.1% (see Table 124). Following this point, surfactant effects increase and we note a 36% xylene solubility increase at 16.7% surfactant.

The lower xylene-water concentration system initially decreases in solubility by about 10% and remains unaffected by further surfactant increases up through 9.1% surfactant. As with the previously discussed xylene concentration, after this point solubility increases and reaches a maximum improvement of 2% at 16.7%. Although this improvement is small in comparison with the improvement noted for the higher xylene concentration, we must acknowledge the trends developing for this surfactant and make note of the increased solubility at a relatively high concentration of 16.7%.

This 16,7% concentration could be the critical micelle concentration for this surfactant. Regretably we did not foresee this development to examine higher surfactant concentrations which would have given us more data. Physical appearances do not prove to be of any significance. Solutions of xylene, water and Toximul R are milkly white until 4.8% surfactant is reached, then a yellow tinge develops to the milky white solution and finally we have a translucent solution with a yellow tinge. Since after the development of the yellow tinge the beginning of the solubility increases occurs, we suggest this yellow tinge is the formation of the micelles resulting in the cmc at 16.7%.

What we are suggesting is that if the cmc is known, and if this is where the solubility increases are effected, then the problem of scrubbing organics from an air stream with a water-surfactant solution is reduced to producing a scrubbing liquid of proportionate amounts of water and surfactant.

Therefore, if the minimums on our graphs (denoting increases in solubility) are in actuallity the critical micelle concentration of the surfactant we have proved our theory of surfactants affecting water properties to effect the solubility of certain immiscible or partly miscible organics. If these minima are not the individual cmc of each surfactant tested, we have still proved our theory of immiscibility correct, but further investigation at higher surfactant concentrations may provide the cmc of that solution and the optimum xylene in water solubility should result.

CONCLUSION

It is clear from our results that the solubilities of certain immiscible and partly immiscible organics in water can be affected by surfactants. Depending on the surfactant type, surfactant concentration, and in some instances the organic concentration, the solubility of these organics in water can be increased dramatically. Therefore the scrubbing of an air stream including organics with a water-surfactant solution is ~~highly~~ possible. However it is also evident that for each particular organic a specific surfactant and a specific surfactant-in-water concentration is necessary to obtain optimum results.

For each surfactant there is a concentration, the critical micelle concentration, where water properties are affected to the greatest degree and evidence of this is exhibited by our results. There is a surfactant concentration, whether favorable or unfavorable, where the surfactant-water system affects the solubility of the organics to the utmost. Our curves show these points with minima and maxima.

The activity that occurs at these points should be explored to a greater extent. By finding the surfactant concentration which effects the greatest absorption of a particular organic by water, we can seed the scrubbing water with the surfactant to the required concentration and thus "clean" an air stream polluted with organic vapors.

Warranting further examination is the possibility or recirculating the scrubbing water-surfactant-organic solution. Because wet scrubbers may require vast amounts of scrubbing liquid, the scrubbing liquid is usually recirculated to reduce costs. However the efficiency of scrubbing declines to a point where recirculation becomes impractical. In our investigations we did not explore the absorption of organics by an organic-water-surfactant solution, which we feel possibly would become more efficient as the organic absorbed is increased. Since these surface active agents are organic compounds, and they do affect water properties such as surface tension and interfacial tension, the absorption of an organic pollutant would cause further effects, preferably to induce the absorption of more organic compound.

In most of our experiments the organic to water concentration was relatively unimportant. That is, the effects of a particular surfactant and surfactant concentration are not dependent on the initial organic concentration. Although the organic absorbed differentials are varied, the relative magnitude of organic absorbed by the water and therefore surfactant effects are similar for different organic concentrations.

The solubility of each organic---xylene, toluene, carbon tetrachloride, ethyl acetate, and isopropyl alcohol---

in water can be improved by the addition of a surfactant. Not all surfactants are useful with all organics. Some organics' solubilities are decreased, some are unaffected, and others are increased with the addition of certain surfactants. Different surfactant's effect different organics to different extents. All the organics examined showed a solubility improvement with one or more of the surfactants tested.

We believe our experiments justify further examination under actual operating conditions, i.e. a wet scrubber. We have effected solubility in water changes for the organics tested, but only with a packed tower will we be able to predict further feasibility.

REFERENCES

1. Air Pollution Control Equipment, Ceilcote Company, Inc., Berea, Ohio.
2. C. F. Bonilla and S. Baron, A.I.CH.E. Journal, 1, 49-54, (1955).
3. D.F. Othmer and E.G. Scheibel, Trans. Am. Inst. Chem. Engr., 37, 211-236, (1941).
4. R. E. Emmert and R.L. Pigford, Chem. Eng. Prop., 50, 87-93, (1954).
5. P. Shou, British Patent 1,628, Jan. 21, 1911.
6. W. K. Lewis and W.G. Whitman, Ind. Eng. Chem., 1215-1220, (1924).
7. F. C. Donnan and I. Masson, J. Soc. Chem. Ind., 39, 236-241T, (1920).
8. V. Koran, Rec. Trav. Chem., 44, 466-475, (1925).
9. A.M. Schwartz and J.M. Perry, Surface Active Agents, (New York, Interscience Publishers, Inc., 1945).
10. V. V. Kafarov and V.I. Trofimov, Zhur, Briklad, Khim., 31, 1809-1816, (1958)
11. E. Filippi, Lo. Sper., 1908, nos. 1,2, & 3 thru Biochem. Cantr., 8, 317-318.
12. M. M. Dubinin, J. Russ, Phys. Chem. Soc., 62, 683-692, (1930).
13. J. Brown, J. Soc. Chem. Ind., 44, 410-412T, (1925).
14. E. M. Baker, Chem. Met. Eng., 22, 122-124, (1920).
15. S. Kohn, Chem.-Ztg., 31, 758, (1907).
16. M. Billy, Bull. Soc. Chim., 7, 579-583, (1911).

17. W. Green and Huncoat Plastic Brick and Terra Cotta Co., British Patent 28,004, Dec. 2, 1910.

18. F. Rashig, British Patent 6,288, March 12, 1914.

19. Kirkham, Hulett, Chadler and Hersey, British Patent 104 261, April 28, 1916.

20. A. B. Clemworth, British Patent 115,521, June 8, 1917.

21. L. Gay, British Patent 144,374, March 7, 1919.

22. G. A. Burrell, G.G. Oberfell, C.L. Voress, U.S. Patent 1,402,340, Jan. 3, 1922.

23. H. Diamanti and C. Lambert, British Patent 5,019, March 1, 1907.

24. E. S. Stintson and J. W. Shive, Science, 59, 193-194, (1924).

25. R. Kattwinkle, Brennstoff-Chem., 4, 179-180, (1923).

26. E. Berl and K. Andress, Z. Angew Chem., 34, Aufsatzeil, 369-371, 377-382, (1921).

27. Bayer & Co., German Patent 310,092, Nov. 4, 1916.

28. A. Englehardt, Kunststoffe, 10, 194-195 (1920).

29. R. Kattwinkle, Brennstoff-Chem., 5, 102, (1924).

30. J. Crosfield & Sons and H. J. Wheaton, British Patent 196,646, Nov. 29, 1021.

31. T. M. Rector, Ind. Eng. Chem., 15, 1132-1134, (1923).

32. U.S. Patent 1,440,108, Dec. 26, 1923.

33. W. Thumm and F.Volk, German Patent 1,091,536, Oct. 27, 1950.

34. P. Andreizv, Chem. Fabrik, 147-149, (1929).

35. W.E. Lummus, U.S. Patent 1,336,360, April 6, 1920.

36. E. Berl and L. Ranis, Z. Angew, Chem. 43, 600-603, (1930).

37. I. Masson and T. L. McEwan, J. Soc. Chem. Ind., 40, 32-38T, (1921).

38. E. I. Sunkov, A.G. Kunznetsova, and P.V. Gorinov, Tr. Mosk. Khim-Teckhnol. Inst., no.33, 48-51, (1961).

39. N.P. Drozdov, L.I. Kisarova and G.I. Sidel'nikova, Zhur Priclad. Khim., 33, 2609-2612, (1960).

40. V.G. Garbarenko and V.N. Stabnikov, Tr. Kievsk. Tekhnol. Inst. Pishchevoi. Prom., no. 24, 145-151, (1961).

41. R. W. Houston and C.A. Walker, Ind. Eng. Chem., 42, 1105-1112, (1950).

42. S. Sanka, J. Soc. Chem. Ind. Japan, 45, 425-428, (1942).

43. A. A/ Konochuk and V. N. Stabinkov, Izu. Vyssh Ucheb. Zaved., Pishch, Tekhnol, 3, 188-189, (1972).

44. D.F. Othmer and E.G. Scheibel, Trans. Am. Inst. Chem., Engr., 37, 211-236, (1941).

45. General Laboratories, Foster D. Snell, Inc., Florham Park, New Jersey, (1973)

46. C. L. Cutting and D. C. Jones, J. Chem. Soc., 4067-4075, (1955).

47. J. L. Moilliet, B. Collie, and W. Black, Surface Activity, (New York, Interscience Publishers, Inc., 1949).

48. H. L. Barthelemy, British Patent 282, 792, Dec. 28, 1926.

49. J. R. Pound, J. Phys. Chem., 30, 791-817, (1926)

50. T. Nash, Am. Occup. Hyg., 13(4), 213-217, (1970).

51. R. Vidal, French Patent 445,053, Sept. 23, 1911.

52. A. Dobry-Duclaux, Chem. Ztg., 76, 805-809, (1952).

53. I. G. Farbenind, French Patent 677,597, June 28, 1924.

54. J. H. Bregeat, U.S. Patent 1,558,336, Oct. 20, 1926.

55. L. Boyadjiev, Compt. Rend. Acad. Bulgare Sc., 16(2), 145-148, (1963).

56. D. Mirev, D. Elenkov, and Khr. Balarev, Isv. Inst. Obsheha Neorg. Khim., Org. Khim., Bulgar Akad. Nauk, 8, 73-81, (1961).

57. D. Mirev, D. Elenkov, and Kh. Balarev, Compt. Rend. Acad. Bulgare Sci., 14, 349-352, (1961).

58. I. Bozhov and D. Elenkov., Compt. Rend. Acad. Bulgare Sci., 16(3), 277-280, (1963).

59. D. Elenkov and I. Bozhov., Compt. Rend. Acad. Bulgare Sci,,10, 25-28, (1957).

60. J. A. Caskey and W.B. Barlage, J. Colloid and Interface Sci., 41(1), (1972).

61. Sandoz Colors & Chemicals, East Hanover, New Jersey, Sandopan DTC: Surfactant for Specialty Industries. Publication 7-166.

APPENDIX

RETENTION TIMES

Organic Compound	Time in gas chromatograph before recording
Xylene	7.4 minutes
Toluene	4.2 minutes
Carbon Tetrachloride	2.3 minutes
Ethyl Acetate	2.1 minutes
Iso-propyl Alcohol	1.6 minutes

KEY TO FLASK NUMBERING SYSTEM

First Diget	Organic type
Second Diget or Letter	Surfactant type
Third Diget	Surfactant concentration
Fourth Diget	Flask differences for surfactant concentrations

ORGANIC NUMBERING SYSTEM

ZERO	Xylene
ONE	Toluene
TWO	Carbon Tetrachloride
THREE	Ethyl Acetate
FOUR	Iso-propyl Alcohol

SURFACTANT NUMBERING SYSTEM

1	Sandopan DTC Gel Paste*
2	Ultrawet 1565 (45.DS)**
3	40 SX-Lot #5212**
4	Sandopan DWC Linear Gel*
A	Stepanol WAT***
B	Steol KS-460***
C	Ninol 1281***
D	Stepantex WB-42***
E	Toximal R***
F	Stepantex DA-52***
G	Ninate 401***
H	Stepanate AM***

*Manufactured by Sandoz

**Manufactured by Arco Chemical Company

***Manufactured by Stephan Chemical Company

TABLES OF RESULTS

TABLE 100

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)
011A	19	1	0	clear with	2.174 X 10^{-5}
011B	19	1	0	two	2.20 X 10^{-5}
011C	19	1	0	layers	1.91 X 10^{-5}
Wetting Agent Concentration		0.0000		Average	2.187 X 10^{-5}
012A	19	1	0.5		1.933 X 10^{-5}
012B	19	1	0.5	hazy	2.356 X 10^{-5}
012C	19	1	0.5		1.958 X 10^{-5}
Wetting Agent Concentration		0.0246		Average	1.946 X 10^{-5}
013A	19	1	1.0	denser	2.635 X 10^{-5}
013B	19	1	1.0	haze	1.678 X 10^{-5}
013C	19	1	1.0		2.176 X 10^{-5}
Wetting Agent Concentration		0.0479		Average	2.406 X 10^{-5}
014A	19	1	2.0	still	1.874 X 10^{-5}
014B	19	1	2.0	denser	1.74 X 10^{-5}
014C	19	1	2.0	haze	1.51 X 10^{-5}
Wetting Agent Concentration		0.0914		Average	1.807 X 10^{-5}

*Sandopan DTC Gel Paste 6400-0100
**Xylene

TABLE 100

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)
015A	19.5	0.5	0	clear with	2.54 X 10^{-5}
015B	19.5	0.5	0	two	1.752 X 10^{-5}
015C	19.5	0.5	0	layers	2.176 X 10^{-5}
Wetting Agent Concentration		0.0000		Average	2.353 X 10^{-5}
016A	19.5	0.5	0.5		1.813 X 10^{-5}
016B	19.5	0.5	0.5	hazy	2.272 X 10^{-5}
016C	19.5	0.5	0.5		2.78 X 10^{-5}
Wetting Agent Concentration		0.0244		Average	2.288 X 10^{-5}
017A	19.5	0.5	1.0	denser	2.082 X 10^{-5}
017B	19.5	0.5	1.0	haze	1.813 X 10^{-5}
017C	19.5	0.5	1.0		1.933 X 10^{-5}
Wetting Agent Concentration		0.0478		Average	1.943 X 10^{-5}
018A	19.5	0.5	2.0	still	2.015 X 10^{-5}
018B	19.5	0.5	2.0	denser	2.12 X 10^{-5}
018C	19.5	0.5	2.0	haze	1.474 X 10^{-5}
Wetting Agent Concentration		0.0913		Average	2.067 X 10^{-5}

*Sandopan DTC Gel Paste 6400-0-100
**Xylene

TABLE 101

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)
021A	19	1	0	clear with	1.752 X 10^{-5}
021B	19	1	0	two	2.455 X 10^{-5}
021C	19	1	0	layers	2.056 X 10^{-5}
Wetting Agent Concentration		0.0000		Average	2.088 X 10^{-5}
022A	19	1	0.5		2.205 X 10^{-5}
022B	19	1	0.5	haze	2.239 X 10^{-5}
022C	19	1	0.5		2.470 X 10^{-5}
Wetting Agent Concentration		0.0246		Average	2.222 X 10^{-5}
023A	19	1	1.0	denser	2.119 X 10^{-5}
023B	19	1	1.0	hase	2.648 X 10^{-5}
023C	19	1	1.0		2.66 X 10^{-5}
Wetting Agent Concentration		0.0479		Average	2.654 X 10^{-5}
024A	19	1	2.0	still	2.356 X 10^{-5}
024B	19	1	2.0	denser	1.715 X 10^{-5}
024C	19	1	2.0	hase	2.119 X 10^{-5}
Wetting Agent Concentration		0.0914		Average	2.238 X 10^{-5}

*Ultrawet 1565 (45.DS)
**Xylene

TABLE 101

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)
025A	19.5	0.5	0	clear with two layers	2.445×10^{-5}
025B	19.5	0.5	0		2.60×10^{-5}
025C	19.5	0.5	0		2.345×10^{-5}
Wetting Agent Concentration		0.0000		Average	2.463×10^{-5}
026A	19.5	0.5	0.5	haze	1.994×10^{-5}
026B	19.5	0.5	0.5		2.385×10^{-5}
026C	19.5	0.5	0.5		2.300×10^{-5}
Wetting Agent Concentration		0.0244		Average	2.342×10^{-5}
027A	19.5	0.5	1.0	still denser haze	2.356×10^{-5}
027B	19.5	0.5	1.0		2.965×10^{-5}
027C	19.5	0.5	1.0		2.42×10^{-5}
Wetting Agent Concentration		0.0478		Average	2.388×10^{-5}
028A	19.5	0.5	2.0	still denser haze	-----
028B	19.5	0.5	2.0		2.575×10^{-5}
028C	19.5	0.5	2.0		2.43×10^{-5}
Wetting Agent Concentration		0.0914		Average	2.502×10^{-5}

*Ultrawet 1565 (45.DS)
**Xylene

TABLE 102

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)
031A	19	1	0	clear with	1.97×10^{-5}
031B	19	1	0	two	1.45×10^{-5}
031C	19	1	0	layers	0.918×10^{-5}
Wetting Agent Concentration		0.0000		Average	1.710×10^{-5}
032A	19	1	0.5	haze	1.91×10^{-5}
032B	19	1	0.5		2.345×10^{-5}
032C	19	1	0.5		1.765×10^{-5}
Wetting Agent Concentration		0.0246		Average	1.837×10^{-5}
033A	19	1	1.0	denser	2.235×10^{-5}
033B	19	1	1.0		2.345×10^{-5}
033C	19	1	1.0	haze	1.427×10^{-5}
Wetting Agent Concentration		0.0478		Average	2.290×10^{-5}
034A	19	1	2.0	still	1.933×10^{-5}
034B	19	1	2.0	denser	2.331×10^{-5}
034C	19	1	2.0	haze	2.540×10^{-5}
Wetting Agent Concentration		0.0913		Average	2.435×10^{-5}

*40SX--Lot#5212

**Xylene

TABLE 102

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)
035A	19.5	0.5	0	clear with two layers	2.49×10^{-5}
035B	19.5	0.5	0		2.187×10^{-5}
035C	19.5	0.5	0		2.065×10^{-5}
Wetting Agent Concentration		0.0000		Average	2.126×10^{-5}
036A	19.5	0.5	0.5	haze	2.660×10^{-5}
036B	19.5	0.5	0.5		2.780×10^{-5}
036C	19.5	0.5	0.5		1.812×10^{-5}
Wetting Agent Concentration		0.0244		Average	2.72×10^{-5}
037A	19.5	0.5	1.0	denser haze	2.50×10^{-5}
037B	19.5	0.5	1.0		2.477×10^{-5}
037C	19.5	0.5	1.0		2.356×10^{-5}
Wetting Agent Concentration		0.0478		Average	2.444×10^{-5}
038A	19.5	0.5	2.0	still denser haze	1.994×10^{-5}
038B	19.5	0.5	2.0		2.356×10^{-5}
038C	19.5	0.5	2.0		2.518×10^{-5}
Wetting Agent Concentration		0.0913		Average	2.437×10^{-5}

*40SX--Lot#5212

**Xylene

TABLE 103

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-5}
041A	19	1	0	clear with two layers	2.065
041B	19	1	0		1.330
041C	19	1	0		2.633
Wetting Agent Concentration		0.0000		Average	2.351
042A	19	1	0.5	haze	1.50
042B	19	1	0.5		2.540
042C	19	1	0.5		1.691
Wetting Agent Concentration		0.0246		Average	1.595
043A	19	1	1.0	denser haze	1.50
043B	19	1	1.0		1.933
043C	19	1	1.0		1.933
Wetting Agent Concentration		0.0479		Average	1.933
044A	19	1	2.0	still denser haze	1.209
044B	19	1	2.0		1.875
044C	19	1	2.0		2.285
Wetting Agent Concentration		0.0914		Average	2.030

*Sandopan DTC Linear Gel 6445-121-5
**Xylene

TABLE 103

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-5}
045A	19.5	0.5	0	clear with	3.240
045B	19.5	0.5	0	two	3.190
045C	19.5	0.5	0	layers	2.730
Wetting Agent Concentration		0.0000		Average	3.215
046A	19.5	0.5	0.5	haze	2.610
046B	19.5	0.5	0.5		2.961
046C	19.5	0.5	0.5		3.165
Wetting Agent Concentration		0.0246		Average	3.063
047A	19.5	0.5	1.0	denser	2.260
047B	19.5	0.5	1.0	haze	3.240
047C	19.5	0.5	1.0		1.631
Wetting Agent Concentration		0.0479		Average	1.945
048A	19.5	0.5	2.0	still	2.720
048B	19.5	0.5	2.0	denser	3.625
048C	19.5	0.5	2.0	haze	2.720
Wetting Agent Concentration		0.0914		Average	2.720

*Sandopan DTC Linear Gel 6445-121-5
**Xylene

TABLE 104

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-4}
210A	19	1	0	Clear with	1.70
210B	19	1	0	two	----
210C	19	1	0	layers	1.82
Wetting Agent Concentration		0.0000		Average	1.76
211A	19	1	0.5	cloudy white	1.63
211B	19	1	0.5	with white	1.61
211C	19	1	0.5	residue on bottom	1.72
Wetting Agent Concentration		0.0237		Average	1.65
212A	19	1	1.0	less cloudy	2.54
212B	19	1	1.0	white	2.31
212C	19	1	1.0	residue on bottom	2.24
Wetting Agent Concentration		0.0462		Average	2.36
213A	19	1	2.0	hazy--trace	2.96
213B	19	1	2.0	of white	2.68
213C	19	1	2.0	residue on bottom	2.64
Wetting Agent Concentration		0.0884		Average	2.76
214A	19	1	4.0	hazy--trace	----
214B	19	1	4.0	of white	2.41
214C	19	1	4.0	residue on bottom	2.36
Wetting Agent Concentration		0.1624		Average	2.38

*Sandopan DTC Gel Paste
**CCl_4

TABLE 104

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-4}
215A	19.5	0.5	0	clear with	1.33
215B	19.5	0.5	0	two	1.28
215C	19.5	0.5	0	layers	1.20
Wetting Agent Concentration		0.0000		Average	1.27
216A	19.5	0.5	0.5	cloudy white	----
216B	19.5	0.5	0.5	with white	2.04
216C	19.5	0.5	0.5	residue on bottom	2.15
Wetting Agent Concentration		0.0240		Average	2.09
217A	19.5	0.5	1.0	one clear	2.07
217B	19.5	0.5	1.0	layer with	----
217C	19.5	0.5	1.0	white residue on bottom	2.17
Wetting Agent Concentration		0.0469		Average	2.12
218A	19.5	0.5	2.0	one clear	----
218B	19.5	0.5	2.0	layer-trace	2.60
218C	19.5	0.5	2.0	of residue on bottom	2.27
Wetting Agent Concentration		0.0896		Average	2.44
219A	19.5	0.5	4.0	one clear	1.76
219B	19.5	0.5	4.0	layer	2.08
219C	19.5	0.5	4.0	no residue	----
Wetting Agent Concentration		0.1645		Average	1.92

*Sandopan DTC Gel Paste

** CCl_4

TABLE 105

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-4}
220A	19	1	0	two clear layers	2.16
220B	19	1	0		----
220C	19	1	0		2.04
Wetting Agent Concentration		0.0000		Average	2.10
221A	19	1	0.5	one clear layer-white residue on bottom	----
221B	19	1	0.5		0.833
221C	19	1	0.5		1.03
Wetting Agent Concentration		0.0237		Average	0.93
222A	19	1	1.0	same as 221	----
222B	19	1	1.0		1.81
222C	19	1	1.0		1.42
Wetting Agent Concentration		0.0462		Average	1.62
223A	19	1	2.0	same as 221	----
223B	19	1	2.0		1.67
223C	19	1	2.0		1.74
Wetting Agent Concentration		0.0884		Average	1.71
224A	19	1	4.0	same as 221	2.54
224B	19	1	4.0		2.09
224C	19	1	4.0		----
WettingAgent Concentration		0.1624		Average	2.32

*Ultrawet 1565 (45.DS)

**CCl_4

TABLE 105

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-4}
225A	19.5	0.5	0	two clear layers	1.46
225B	19.5	0.5	0		----
225C	19.5	0.5	0		1.64
Wetting Agent Concentration		0.0000		Average	1.55
226A	19.5	0.5	0.5	one clear layer/white residue on bottom	0.925
226B	19.5	0.5	0.5		1.26
226C	19.5	0.5	0.5		----
Wetting Agent Concentration		0.0240		Average	1.09
227A	19.5	0.5	1.0	same as 226	----
227B	19.5	0.5	1.0		1.48
227C	19.5	0.5	1.0		1.39
Wetting Agent Concentration		0.0469		Average	1.44
228A	19.5	0.5	2.0	same as 226	----
228B	19.5	0.5	2.0		1.62
228C	19.5	0.5	2.0		1.57
Wetting Agent Comcentration		0.0896		Average	1.60
229A	19.5	0.5	4.0	same as 226	2.68
229B	19.5	0.5	4.0		1.99
229C	19.5	0.5	4.0		1.02
Wetting Agent Concentration		0.1645		Average	1.89

*Ultrawet 1565 (45.DS)
**CCl_4

TABLE 106

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X10^{-4}
230A	19	1	0	two clear layers	----
230B	19	1	0		1.57
230C	19	1	0		2.16
Wetting Agent Concentration		0.0000		Average	1.87
231A	19	1	0.5	two clear layers/white residue on bottom	1.79
231B	19	1	0.5		1.99
231C	19	1	0.5		----
Wetting Agent Concentration		0.0237		Average	1.89
232A	19	1	1.0	same as 231	1.70
232B	19	1	1.0		----
232C	19	1	1.0		1.81
Wetting Agent Concentration		0.0462		Average	1.76
233A	19	1	2.0	same as 231	1.32
233B	19	1	2.0		1.57
233C	19	1	2.0		1.89
Wetting Agent Concentration		0.0884		Average	1.57
234A	19	1	4.0	two clear layers	1.63
234B	19	1	4.0		1.48
234C	19	1	4.0		1.33
Wetting Agent Concentration		0.1624		Average	1.48

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**CCl_4

TABLE 106

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-4}
235A	19.5	0.5	0	two clear	1.76
235B	19.5	0.5	0	layers	----
235C	19.5	0.5	0		1.71
Wetting Agent Concentration		0.0000		Average	1.74
236A	19.5	0.5	0.5	two clear	1.07
236B	19.5	0.5	0.5	layers/white	1.74
236C	19.5	0.5	0.5	residue on bottom	1.39
Wetting Agent Concentration		0.0240		Average	1.40
237A	19.5	0.5	1.0	same as	1.46
237B	19.5	0.5	1.0	236	----
237C	19.5	0.5	1.0		1.50
Wetting Agent Concentration		0.0469		Average	1.48
238A	19.5	0.5	2.0	two clear	0.944
238B	19.5	0.5	2.0	layers	1.67
238C	19.5	0.5	2.0		1.33
Wetting Agent Concentration		0.0896		Average	1.31
239A	19.5	0.5	4.0	same as	1.63
239B	19.5	0.5	4.0	238	1.54
239C	19.5	0.5	4.0		1.46
Wetting Agent Concentration		0.1645		Average	1.54

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**CCl_4

TABLE 107

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-4}
240A	19	1	0	two clear layers	1.85
240B	19	1	0		1.94
240C	19	1	0		2.13
Wetting Agent Concentration		0.0000		Average	1.97
241A	19	1	0.5	white cloudy w/white residue on bottom	2.71
241B	19	1	0.5		2.64
241C	19	1	0.5		----
Wetting Agent Concentration		0.0237		Average	2.67
242A	19	1	1.0	less cloudy w/ white residue on bottom	3.24
242B	19	1	1.0		3.05
242C	19	1	1.0		3.19
Wetting Agent Concentration		0.0462		Average	3.16
243A	19	1	2.0	solution hazy-trace whiteresidue on bottom	2.97
243B	19	1	2.0		3.15
243C	19	1	2.0		----
Wetting Agent Concentration		0.0884		Average	3.06
244A	19	1	4.0	same as 243	2.45
244B	19	1	4.0		2.93
244C	19	1	4.0		----
Wetting Agent Concentration		0.1624		Average	2.69

*Sandopan DTC Linear Gel

**CCl_4

TABLE 107

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-4}
245A	19.5	0.5	0	two clear layers	2.27
245B	19.5	0.5	0		----
245C	19.5	0.5	0		2.37
Wetting Agent Concentration		0.0000		Average	2.32
246A	19.5	0.5	0.5	cloudy white-white residue on bottom	----
246B	19.5	0.5	0.5		2.64
246C	19.5	0.5	0.5		2.51
Wetting Agent Concentration		0.0240		Average	2.57
247A	19.5	0.5	1.0	one clear layer-white residue on bottom	----
247B	19.5	0.5	1.0		2.60
247C	19.5	0.5	1.0		2.66
Wetting Agent Concentration		0.0469		Average	2.63
248A	19.5	0.5	2.0	one clear layer-trace white residue on bottom	2.71
248B	19.5	0.5	2.0		2.62
248C	19.5	0.5	2.0		2.76
Wetting Agent Concentration		0.0896		Average	2.69
249A	19.5	0.5	4.0	one clear layer-- no residue	2.31
249B	19.5	0.5	4.0		2.40
249C	19.5	0.5	4.0		2.52
Wetting Agent Concentration		0.1645		Average	2.41

*Sandopan DTC Linear Gel

**CCl_4

TABLE 108

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-}
111A	19	1	0	two clear layers	----
111B	19	1	0		6.56
111C	19	1	0		6.25
Wetting Agent Concentration		0.0000		Average	6.40
112A	19	1	0.5	hazy solution	----
112B	19	1	0.5		6.61
112C	19	1	0.5		7.04
Wetting Agent Concentration		0.0246		Average	6.83
113A	19	1	1.0	hazy solution	6.68
113B	19	1	1.0		6.68
113C	19	1	1.0		----
Wetting Agent Concentration		0.0479		Average	6.68
114A	19	1	2.0	denser haze	5.26
114B	19	1	2.0		3.76
114C	19	1	2.0		2.61
Wetting Agent Concentration		0.0915		Average	3.88

*Sandopan DTC Gel Paste
**Toluene

TABLE 108

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-5}
115A	19.5	0.5	0	two clear	6.35
115B	19.5	0.5	0	layers	----
115C	19.5	0.5	0		5.22
Wetting Agent Concentration		0.0000		Average	5.78
116A	19.5	0.5	0.5	hazy	6.01
116B	19.5	0.5	0.5	solution	5.41
116C	19.5	0.5	0.5		----
Wetting Agent Concentration		0.0244		Average	5.71
117A	19.5	0.5	1.0	hazy	----
117B	19.5	0.5	1.0	solution	4.79
117C	19.5	0.5	1.0		5.38
Wetting Agent Concentration		0.0486		Average	5.09
118A	19.5	0.5	2.0	denser	----
118B	19.5	0.5	2.0	haze	4.91
118C	19.5	0.5	2.0		4.60
Wetting Agent Concentration		0.0912		Average	4.75

*Sandopan DTC Gel Paste
**Toluene

TABLE 109

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-5}
121A	19	1	0	two clear layers	7.77
121B	19	1	0		8.14
121C	19	1	0		8.14
Wetting Agent Concentration		0.0000		Average	8.02
122A	19	1	0.5	hazy solution	8.11
122B	19	1	0.5		8.25
122C	19	1	0.5		8.25
Wetting Agent Concentration		0.0246		Average	8.20
123A	19	1	1.0	hazy solution	8.86
123B	19	1	1.0		----
123C	19	1	1.0		9.09
Wetting Agent Concentration		0.0479		Average	8.98
124A	19	1	2.0	denser haze	9.24
124B	19	1	2.0		----
124C	19	1	2,0		9.69
Wetting Agent Concentration		0.0915		Average	9.47

*Ultrawet 1565 (45.DS)
**Toluene

TABLE 109

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-5}
125A	19.5	0.5	0	two clear layers	9.20
125B	19.5	0.5	0		9.37
125C	19.5	0.5	0		8.95
Wetting Agent Concentration		0.0000		Average	9.17
126A	19.5	0.5	0.5	hazy solution	----
126B	19.5	0.5	0.5		9.15
126C	19.5	0.5	0.5		9.58
Wetting Agent Concentration		0.0244		Average	9.37
127A	19.5	0.5	1.0	hazy solution	8.86
127B	19.5	0.5	1.0		----
127C	19.5	0.5	1.0		8.76
Wetting Agent Concentration		0.0486		Average	8.81
128A	19.5	0.5	2.0	hazy solution	----
128B	19.5	0.5	2.0		9.15
128C	19.5	0.5	2.0		9.21
Wetting Agent Concentration		0.0912		Average	9.18

*Ultrawet 1565 (45.DS)

**Toluene

TABLE 110

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-5}
131A	19	1	0	two clear layers	5.65
131B	19	1	0		5.38
131C	19	1	0		----
Wetting Agent Concentration		0.0000		Average	5.52
132A	19	1	0.5	hazy solution	----
132B	19	1	0.5		6.72
132C	19	1	0.5		6.82
Wetting Agent Concentration		0.0246		Average	6.77
133A	19	1	1.0	hazy solution	6.12
133B	19	1	1.0		----
133C	19	1	1.0		6.04
Wetting Agent Concentration		0.0479		Average	6.08
134A	19	1	2.0	denser haze	5.60
134B	19	1	2.0		6.10
134C	19	1	2.0		----
Wetting Agent Concentration		0.0915		Average	5.85

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**Toluene

TABLE 110

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)x10^{-5}
135A	19.5	0.5	0	two clear	5.26
135B	19.5	0.5	0	layers	5.38
135C	19.5	0.5	0		----
Wetting Agent Concentration		0.0000		Average	5.32
136A	19.5	0.5	0.5	hazy	----
136B	19.5	0.5	0.5	solution	3.35
136C	19.5	0.5	0.5		3.64
Wetting Agent Concentration		0.0244		Average	3.50
137A	19.5	0.5	1.0	hazy	4.69
137B	19.5	0.5	1.0	solution	5.69
137C	19.5	0.5	1.0		----
Wetting Agent Concentration		0.0486		Average	5.19
138A	19.5	0.5	2.0	denser	4.11
138B	19.5	0.5	2.0	haze	4.19
138C	19.5	0.5	2.0		----
Wetting Agent Concentration		0.0912		Average	4.15

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**Toluene

TABLE 111

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-5}
141A	19	1	0	two clear layers	----
141B	19	1	0		6.10
141C	19	1	0		6.10
Wetting Agent Concentration		0.0000		Average	6.10
142A	19	1	0.5	hazy solution	3.88
142B	19	1	0.5		5.29
142C	19	1	0.5		6.82
Wetting Agent Concentration		0.0246		Average	5.33
143A	19	1	1.0	hazy solution	6.49
143B	19	1	1.0		----
143C	19	1	1.0		7.40
Wetting Agent Concentration		0.0479		Average	6.95
144A	19	1	2.0	denser haze	3.26
144B	19	1	2.0		3.71
144C	19	1	2.0		----
Wetting Agent Concentration		0.0915		Average	3.49

*Sandopan DTC Linear Gel
**Toluene

TABLE 111

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-5}
145A	19.5	0.5	0	two clear	----
145B	19.5	0.5	0	layers	6.27
145C	19.5	0.5	0		6.25
Wetting Agent Concentration		0.0000		Average	6.26
146A	19.5	0.5	0.5	hazy	7.04
146B	19.5	0.5	0.5	solution	7.11
146C	19.5	0.5	0.5		----
Wetting Agent Concentration		0.0244		Average	7.08
147A	19.5	0.5	1.0	hazy	7.04
147B	19.5	0.5	1.0	solution	----
147C	19.5	0.5	1.0		7.04
Wetting Agent Concentration		0.0486		Average	7.04
148A	19.5	0.5	2.0	hazy	2.80
148B	19.5	0.5	2.0	(denser)	4.59
148C	19.5	0.5	2.0	solution	6.51
Wetting Agent Concentration		0.0912		Average	4.97

*Sandopan DTC Linear Gel
**Toluene

TABLE 112

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-4}
310A	19	1	0	one clear layer	5.88
310B	19	1	0		5.94
310C	19	1	0		----
Wetting Agent Concentration		0.0000		Average	5.91
311A	19	1	0.5	one clear layer	6.17
311B	19	1	0.5		----
311C	19	1	0.5		6.74
Wetting Agent Concentration		0.0245		Average	6.74
312A	19	1	1.0	one clear layer	7.03
312B	19	1	1.0		----
312C	19	1	1.0		7.16
Wetting Agent Concentration		0.0478		Average	7.10
313A	19	1	2.0	one clear layer	2.01
313B	19	1	2.0		----
313C	19	1	2.0		3.73
Wetting Agent Concentration		0.0959		Average	2.67
314A	19	1	4.0	one clear layer	----
314B	19	1	4.0		4.76
314C	19	1	4.0		4.74
Wetting Agent Concentration		0.1674		Average	4.75

*Sandopan DTC Gel Paste
**Ethyl Acetate

TABLE 112

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-4}
315A	19.5	0.5	0	one clear layer	3.44
315B	19.5	0.5	0		2.44
315C	19.5	0.5	0		4.71
Wetting Agent Concentration		0.0000		Average	3.53
316A	19.5	0.5	0.5	one clear layer	5.68
316B	19.5	0.5	0.5		4.65
316C	19.5	0.5	0.5		4.04
Wetting Agent Concentration		0.0244		Average	4.34
317A	19.5	0.5	1.0	one clear layer	----
317B	19.5	0.5	1.0		5.02
317C	19.5	0.5	1.0		4.91
Wetting Agent Concentration		0.0477		Average	4.97
318A	19.5	0.5	2.0	one clear layer	2.72
318B	19.5	0.5	2.0		----
318C	19.5	0.5	2.0		----
Wetting Agent Concentration		0.0911		Average	2.72
319A	19.5	0.5	4.0	one clear layer	5.85
319B	19.5	0.5	4.0		----
319C	19.5	0.5	4.0		4.39
Wetting Agent Concentration		0.1670		Average	5.12

*Sandopan DTC Gel Paste
**Ethyl Acetate

TABLE 113

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-4}
320A	19	1	0	one clear layer	12.6
320B	19	1	0		12.2
320C	19	1	0		----
Wetting Agent Concentration		0.0000		Average	12.4
321A	19	1	0.5	one clear layer	9.45
321B	19	1	0.5		9.76
321C	19	1	0.5		----
Wetting Agent Concentration		0.0245		Average	9.60
322A	19	1	1.0	one clear layer	8.22
322B	19	1	1.0		7.02
322C	19	1	1.0		----
Wetting Agent Concentration		0.0478		Average	7.62
323A	19	1	2.0	one clear layer	8.45
323B	19	1	2.0		8.05
323C	19	1	2.0		----
Wetting Agent Concentration		0.0959		Average	8.25
324A	19	1	4.0	one clear layer	-----
324B	19	1	4.0		7.02
324C	19	1	4.0		7.16
Wetting Agent Concentration		0.1674		Average	7.09

*Ultrawet 1565 (45.DS)
**Ethyl Acetate

TABLE 113

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-4}
325A	19.5	0.5	0	one	----
325B	19.5	0.5	0	clear	5.01
325C	19.5	0.5	0	layer	5.33
Wetting Agent Concentration		0.0000		Average	5.17
326A	19.5	0.5	0.5	one	4.47
326B	19.5	0.5	0.5	clear	----
326C	19.5	0.5	0.5	layer	4.76
Wetting Agent Concentration		0.0244		Average	4.62
327A	19.5	0.5	1.0	one	5.16
327B	19.5	0.5	1.0	clear	----
327C	19.5	0.5	1.0	layer	5.30
Wetting Agent Concentration		0.0477		Average	5.23
328A	19.5	0.5	2.0	one	5.12
328B	19.5	0.5	2.0	clear	4.73
328C	19.5	0.5	2.0	layer	5.44
Wetting Agent Concentration		0.0911		Average	5.10
329A	19.5	0.5	4.0	one	2.44
329B	19.5	0.5	4.0	clear	----
329C	19.5	0.5	4.0	layer	3.29
Wetting Agent Concentration		0.1670		Average	2.86

*Ultrawet 1565 (45.DS)
**Ethyl Acetate

TABLE 114

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-4}
330A	19	1	0	one	10.1
330B	19	1	0	clear	----
330C	19	1	0	layer	10.3
Wetting Agent Concentration		0.0000		Average	10.2
331A	19	1	0.5	one	12.8
331B	19	1	0.5	clear	13.1
331C	19	1	0.5	layer	13.8
Wetting Agent Concentration		0.0245		Average	13.2
332A	19	1	1.0	one	----
332B	19	1	1.0	clear	12.1
332C	19	1	1.0	layer	12.9
Wetting Agent Concentration		0.0478		Average	12.5
333A	19	1	2.0	one	----
333B	19	1	2.0	clear	12.8
333C	19	1	2.0	layer	12.6
Wetting Agent Concentration		0.0959		Average	12.7
334A	19	1	4.0	one	----
334B	19	1	4.0	clear	10.4
334C	19	1	4.0	layer	9.85
Wetting Agent Concentration		0.1674		Average	10.1

*40SX-Lot#5212
**Ethyl Acetate

TABLE 114

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-4}
335A	19.5	0.5	0	one	7.80
335B	19.5	0.5	0	clear	----
335C	19.5	0.5	0	layer	7.34
Wetting Agent Concentration		0.0000		Average	7.57
336A	19.5	0.5	0.5	one	5.17
336B	19.5	0.5	0.5	clear	5.14
336C	19.5	0.5	0.5	layer	----
Wetting Agent Concentration		0.0244		Average	5.16
337A	19.5	0.5	1.0	one	----
337B	19.5	0.5	1.0	clear	6.05
337C	19.5	0.5	1.0	layer	5.44
Wetting Agent Concentration		0.0477		Average	5.74
338A	19.5	0.5	2.0	one	5.44
338B	19.5	0.5	2.0	clear	----
338C	19.5	0.5	2.0	layer	4.70
Wetting Agent		0.0911		Average	5.07
339A	19.5	0.5	4.0	one	----
339B	19.5	0.5	4.0	clear	4.47
339C	19.5	0.5	4.0	layer	4.56
Wetting Agent Concentration		0.1670		Average	4.52

*40SX-Lot#5212
**Ethyl Acetate

TABLE 115

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-4}
340A	19	1	0	one	11.9
340B	19	1	0	clear	11.5
340C	19	1	0	layer	----
Wetting Agent Concentration		0.0000		Average	11.7
341A	19	1	0.5	one	11.9
341B	19	1	0.5	clear	11.2
341C	19	1	0.5	layer	10.9
Wetting Agent Concentration		0.0245		Average	11.4
342A	19	1	1.0	one	10.4
342B	19	1	1.0	clear	----
342C	19	1	1.0	layer	9.80
Wetting Agent Concentration		0.0478		Average	10.1
343A	19	1	2.0	one	9.74
343B	19	1	2.0	clear	9.74
343C	19	1	2.0	layer	----
Wetting Agent Concentration		0.0959		Average	9.74
344A	19	1	4.0	one	----
344B	19	1	4.0	clear	9.91
344C	19	1	4.0	layer	9.31
Wetting Agent Concentration		0.1674		Average	9.61

*Sandopan DTC Linear Gel
**Ethyl Acetate

TABLE 115

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-4}
345A	19.5	0.5	0	one	6.76
345B	19.5	0.5	0	clear	6.67
345C	19.5	0.5	0	layer	----
Wetting Agent Concentration		0.0000		Average	6.62
346A	19.5	0.5	0.5	one	4.44
346B	19.5	0.5	0.5	clear	6.19
346C	19.5	0.5	0.5	layer	5.27
Wetting Agent Concentration		0.0244		Average	5.30
347A	19.5	0.5	1.0	one	5.36
347B	19.5	0.5	1.0	clear	5.16
347C	19.5	0.5	1.0	layer	5.16
Wetting Agent Concentration		0.0477		Average	5.23
348A	19.5	0.5	2.0	one	5.74
348B	19.5	0.5	2.0	clear	----
348C	19.5	0.5	2.0	layer	5.54
Wetting Agent Concentration		0.0911		Average	5.64
349A	19.5	0.5	4.0	one	3.58
349B	19.5	0.5	4.0	clear	3.58
349C	19.5	0.5	4.0	layer	----
Wetting Agent Concentration		0.1670		Average	3.58

*Sandopan DTC Linear Gel
**Ethyl Acetate

TABLE 116

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-6}
410A	19	1	0	one	----
410B	19	1	0	clear	3.01
410C	19	1	0	layer	2.90
Wetting Agent Concentration		0.0000		Average	2.95
411A	19	1	0.5	one	2.53
411B	19	1	0.5	clear	2.48
411C	19	1	0.5	layer	----
Wetting Agent Concentration		0.0246		Average	2.50
412A	19	1	1.0	one	3.01
412B	19	1	1.0	clear	----
412C	19	1	1.0	layer	3.03
Wetting Agent Concentration		0.0481		Average	3.02
413A	19	1	2.0	one	1.91
413B	19	1	2.0	clear	2.88
413C	19	1	2.0	layer	2.43
Wetting Agent Concentration		0.0918		Average	2.41
414A	19	1	4.0	one	----
414B	19	1	4.0	clear	2.69
414C	19	1	4.0	layer	2.93
Wetting Agent Concentration		0.1681		Average	2.81

*Sandopan DTC Gel Paste
**Isopropyl Alcohol

TABLE 116

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-6}
415A	19.5	0.5	0	one	----
415B	19.5	0.5	0	clear	2.67
415C	19.5	0.5	0	layer	4.13
Wetting Agent Concentration		0.0000		Average	3.23
416A	19.5	0.5	0.5	one	----
416B	19.5	0.5	0.5	clear	2.30
416C	19.5	0.5	0.5	layer	4.03
Wetting Agent Concentration		0.0245		Average	3.16
417A	19.5	0.5	1.0	one	-----
417B	19.5	0.5	1.0	clear	0.392
417C	19.5	0.5	1.0	layer	0.392
Wetting Agent Concentration		0.0479		Average	0.392
418A	19.5	0.5	2.0	one	1.52
418B	19.5	0.5	2.0	clear	1.52
418C	19.5	0.5	2.0	layer	----
Wetting Agent Concentration		0.0914		Average	1.52
419A	19.5	0.5	4.0	one	0.549
419B	19.5	0.5	4.0	clear	-----
419C	19.5	0.5	4.0	layer	0.392
Wetting Agent Concentration		0.1676		Average	0.471

*Sandopan DTC Gel Paste
**Isopropyl Alcohol

TABLE 117

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-6}
420A	19	1	0	one	2.56
420B	19	1	0	clear	----
420C	19	1	0	layer	3.14
Wetting Agent Concentration		0.0000		Average	2.85
421A	19	1	0.5	one	2.82
421B	19	1	0.5	clear	----
421C	19	1	0.5	layer	2.20
Wetting Agent Concentration		0.0246		Average	2.51
422A	19	1	1.0	one	3.03
422B	19	1	1.0	clear	3.06
422C	19	1	1.0	layer	3.24
Wetting Agent Concentration		0.0481		Average	3.11
423A	19	1	2.0	one	3.40
423B	19	1	2.0	clear	----
423C	19	1	2.0	layer	3.14
Wetting Agent Concentration		0.0918		Average	3.27
424A	19	1	4.0	one	2.80
424B	19	1	4.0	clear	2.56
424C	19	1	4.0	layer	2.51
Wetting Agent Concentration		0.1681		Average	2.63

*Ultrawet 1565 (45.DS)
**Isopropyl Alcohol

TABLE 117

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-6}
425A	19.5	0.5	0	one	----
425B	19.5	0.5	0	clear	1.25
425C	19.5	0.5	0	layer	1.96
Wetting Agent Concentration		0.0000		Average	1.60
426A	19.5	0.5	0.5	one	0.968
426B	19.5	0.5	0.5	clear	-----
426C	19.5	0.5	0.5	layer	0.628
Wetting Agent Concentration		0.0245		Average	0.798
427A	19.5	0.5	1.0	one	----
427B	19.5	0.5	1.0	clear	1.25
427C	19.5	0.5	1.0	layer	1.10
Wetting Agent Concentration		0.0479		Average	1.17
428A	19.5	0.5	2.0	one	1.20
428B	19.5	0.5	2.0	clear	1.57
428C	19.5	0.5	2.0	layer	----
Wetting Agent Concentration		0.0914		Average	1.39
429A	19.5	0.5	4.0	one	0.870
429B	19.5	0.5	4.0	clear	0.870
429C	19.5	0.5	4.0	layer	-----
Wetting Agent Concentration		0.1676		Average	0.870

*Ultrawet 1565 (45.DS)
**Isopropyl Alcohol

TABLE 118

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-6}
435A	19.5	0.5	0	one	0.392
435B	19.5	0.5	0	clear	0.601
435C	19.5	0.5	0	layer	-----
Wetting Agent Concentration		0.0000		Average	0.497
436A	19.5	0.5	0.5	one	0.471
436B	19.5	0.5	0.5	clear	-----
436C	19.5	0.5	0.5	layer	0.523
Wetting Agent Concentration		0.0245		Average	0.497
437A	19.5	0.5	1.0	one	-----
437B	19.5	0.5	1.0	clear	-----
437C	19.5	0.5	1.0	layer	-----
Wetting Agent Concentration		0.0479		Average	-----
438A	19.5	0.5	2.0	one	-----
438B	19.5	0.5	2.0	clear	1.10
438C	19.5	0.5	2.0	layer	0.836
Wetting Agent Concentration		0.0914		Average	0.936
439A	19.5	0.5	4.0	one	0.942
439B	19.5	0.5	4.0	clear	-----
439C	19.5	0.5	4.0	layer	-----
Wetting Agent Concentration		0.1676		Average	0.942

*40SX-Lot#5212
**Isopropyl Alcohol

TABLE 118

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-6}
430A	19	1	0	one	----
430B	19	1	0	clear	3.01
430C	19	1	0	layer	3.40
Wetting Agent Concentration		0.0000		Average	3.20
431A	19	1	0.5	one	2.48
431B	19	1	0.5	clear	----
431C	19	1	0.5	layer	2.40
Wetting Agent Concentration		0.0246		Average	2.44
432A	19	1	1.0	one	----
432B	19	1	1.0	clear	3.27
432C	19	1	1.0	layer	2.75
Wetting Agent Concentration		0.0481		Average	3.01
433A	19	1	2.0	one	2.43
433B	19	1	2.0	clear	2.48
433C	19	1	2.0	layer	----
Wetting Agent Concentration		0.0918		Average	2.45
434A	19	1	4.0	one	----
434B	19	1	4.0	clear	2.75
434C	19	1	4.0	layer	2.88
Wetting Agent Concentration		0.1681		Average	2.82

*40SX-Lot#5212
**Isopropyl Alcohol

TABLE 119

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-}
440A	19	1	0	one	3.35
440B	19	1	0	clear	2.67
440C	19	1	0	layer	----
Wetting Agent Concentration		0.0000		Average	3.01
441A	19	1	0.5	one	1.44
441B	19	1	0.5	clear	2.33
441C	19	1	0.5	layer	0.916
Wetting Agent Concentration		0.0246		Average	1.56
442A	19	1	1.0	one	2.69
442B	19	1	1.0	clear	1.44
442C	19	1	1.0	layer	4.29
Wetting Agent Concentration		0.0481		Average	2.81
443A	19	1	2.0	one	1.83
443B	19	1	2.0	clear	2.17
443C	19	1	2.0	layer	----
Wetting Agent Concentration		0.0918		Average	2.00
444A	19	1	4.0	one	----
444B	19	1	4.0	clear	3.92
444C	19	1	4.0	layer	1.20
Wetting Agent Concentration		0.1681		Average	2.56

*Sandopan DTC Linear Gel
**Isopropyl Alcohol

TABLE 119

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-6}
445A	19.5	0.5	0	one	1.88
445B	19.5	0.5	0	clear	2.04
445C	19.5	0.5	0	layer	1.83
Wetting Agent Concentration		0.0000		Average	1.92
446A	19.5	0.5	0.5	one	----
446B	19.5	0.5	0.5	clear	2.20
446C	19.5	0.5	0.5	layer	2.20
Wetting Agent Concentration		0.0245		Average	2.20
447A	19.5	0.5	1.0	one	----
447B	19.5	0.5	1.0	clear	----
447C	19.5	0.5	1.0	layer	1.83
Wetting Agent Concentration		0.0479		Average	1.83
448A	19.5	0.5	2.0	one	0.968
448B	19.5	0.5	2.0	clear	0.942
448C	19.5	0.5	2.0	layer	-----
Wetting Agent Concentration		0.0914		Average	0.955
449A	19.5	0.5	4.0	one	2.77
449B	19.5	0.5	4.0	clear	----
449C	19.5	0.5	4.0	layer	2.67
Wetting Agent Concentration		0.1676		Average	2.72

*Sandopan DTC Linear Gel
**Isopropyl Alcohol

TABLE 120

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-6}
OA0A	19	1	0	clear with small xylene bubbles	----
OA0B	19	1	0		6.83
OA0C	19	1	0		7.90
Wetting Agent Concentration		0.0000		Average	7.37
OA1A	19	1	0.5	hazy with white residue on top	10.7
OA1B	19	1	0.5		14.4
OA1C	19	1	0.5		----
Wetting Agent Concentration		0.0245		Average	12.6
OA2A	19	1	1.0	hazy with white residue on top	----
OA2B	19	1	1.0		11.1
OA2C	19	1	1.0		10.3
Wetting Agent Concentration		0.0478		Average	10.7
OA3A	19	1	2.0	clear sol. w/ white residue on top	10.8
OA3B	19	1	2.0		10.7
OA3C	19	1	2.0		11.5
Wetting Agent Concentration		0.0913		Average	11.0
OA4A	19	1	4.0	clear sol. yellowish trace white residue	10.7
OA4B	19	1	4.0		13.6
OA4C	19	1	4.0		----
Wetting Agent Concentration		0.1673		Average	12.2

*Stepanol WAT
**Xylene

TABLE 120

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-6}
OA5A	19.5	0.5	0	clear sol.	11.8
OA5B	19.5	0.5	0	w/ xylene	12.6
OA5C	19.5	0.5	0	bubbles	----
Wetting Agent Concentration		0.0000		Average	12.2
OA6A	19.5	0.5	0.5	clear sol.	13.5
OA6B	19.5	0.5	0.5	traces white	----
OA6C	19.5	0.5	0.5	residue on top	12.6
Wetting Agent Concemtration		0.0244		Average	13.1
OA7A	19.5	0.5	1.0	clear sol.	11.5
OA7B	19.5	0.5	1.0	less residue	9.05
OA7C	19.5	0.5	1.0	than OA6	-----
Wetting Agent Concentration		0.0477		Average	10.3
OA8A	19.5	0.5	2.0	clear sol.	13.4
OA8B	19.5	0.5	2.0	see OA7	----
OA8C	19.5	0.5	2.0		14.2
Wetting Agent Concemtration		0.0911		Average	13.8
OA9A	19.5	0.5	4.0	yellowish	11.9
OA9B	19.5	0.5	4.0	clear sol.	----
OA9C	19.5	0.5	4.0	white residue on top	14.5
Wetting Agent Concentration		0.1670		Average	12.9

*Stepanol WAT
**Xylene

TABLE 121

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-6}
OB0A	19	1	0	clear	4.28
OB0B	19	1	0	solution	----
OB0C	19	1	0		4.53
Wetting Agent Concentration		0.0000		Average	4.40
OB1A	19	1	0.5	milky	----
OB1B	19	1	0.5	white	8.06
OB1C	19	1	0.5	solution	6.83
Wetting Agent Concentration		0.0245		Average	7.44
OB2A	19	1	1.0	milky	4.28
OB2B	19	1	1.0	white	----
OB2C	19	1	1.0	solution	6.09
Wetting Agent Concentration		0.0478		Average	5.18
OB3A	19	1	2.0	milky	----
OB3B	19	1	2.0	white	6.91
OB3C	19	1	2.0	solution	4.94
Wetting Agent Concentration		0.0913		Average	5.92
OB4A	19	1	4.0	milky	3.87
OB4B	19	1	4.0	white	8.81
OB4C	19	1	4.0	solution	5.76
Wetting Agent Concentration		0.1673		Average	6.14

*Steol KS-460
**Xylene

TABLE 121

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-6}
OB5A	19.5	0.5	0	clear	6.17
OB5B	19.5	0.5	0	solution	----
OB5C	19.5	0.5	0		5.51
Wetting Agent Concentration		0.0000		Average	5.84
OB6A	19.5	0.5	0.5	milky	7.32
OB6B	19.5	0.5	0.5	white	----
OB6C	19.5	0.5	0.5	solution	6.42
Wetting Agent Concentration		0.0244		Average	6.87
OB7A	19.5	0.5	1.0	milky	----
OB7B	19.5	0.5	1.0	white	11.8
OB7C	19.5	0.5	1.0		10.0
Wetting Agent Concentration		0.0477		Average	10.9
OB8A	19.5	0.5	2.0	milky	8.81
OB8B	19.5	0.5	2.0	white	7.74
OB8C	19.5	0.5	2.0		----
Wetting Agent Concentration		0.0911		Average	8.27
OB9A	19.5	0.5	4.0	clear	10.7
OB9B	19.5	0.5	4.0	solution	9.14
OB9C	19.5	0.5	4.0		11.5
Wetting Agent Concentration		0.1670		Average	10.4

*Steol KS-460
**Xylene

TABLE 122

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-6}
OCOA	19	1	0	clear sol.	8.31
OCOB	19	1	0	w/ xylene	10.6
OCOC	19	1	0	bubbles	9.21
Wetting Agent Concentration		0.0000		Average	9.37
OC1A	19	1	0.5	hazy sol.	9.87
OC1B	19	1	0.5	w/ white	8.64
OC1C	19	1	0.5	residue	11.8
Wetting Agent Concentration		0.0245		Average	10.1
OC2A	19	1	1.0	hazy sol.	9.87
OC2B	19	1	1.0	w/ white	8.64
OC2C	19	1	1.0	residue	11.5
Wetting Agent Concentration		0.0478		Average	10.0
OC3A	19	1	2.0	milky	9.13
OC3B	19	1	2.0	yellow	12.6
OC3C	19	1	2.0	solution	7.07
Wetting Agent Concentration		0.0913		Average	8.10
OC4A	19	1	4.0	thick	----
OC4B	19	1	4.0	yellow	10.5
OC4C	19	1	4.0	gel	10.2
Wetting Agent Concentration		0.1673		Average	10.4

*Ninol 1281
**Xylene

TABLE 122

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-6}
OC5A	19.5	0.5	0	clear sol.	8.64
OC5B	19.5	0.5	0	w/ xylene	5.59
OC5C	19.5	0.5	0	bubbles	10.3
Wetting Agent Concentration		0.0000		Average	7.11
OC6A	19.5	0.5	0.5	hazy sol.	7.57
OC6B	19.5	0.5	0.5	w/ white	7.81
OC6C	19.5	0.5	0.5	residue	7.90
Wetting Agent Concentration		0.0244		Average	7.76
OC7A	19.5	0.5	1.0	hazy sol.	----
OC7B	19.5	0.5	1.0	w/ yellow	6.66
OC7C	19.5	0.5	1.0	tinge	6.83
Wetting Agent Concentration		0.0477		Average	6.74
OC8A	19.5	0.5	2.0	milky	----
OC8B	19.5	0.5	2.0	yellow	8.23
OC8C	19.5	0.5	2.0	solution	8.23
Wetting Agent Concentration		0.0911		Average	8.23
OC9A	19.5	0.5	4.0	thick	7.24
OC9B	19.5	0.5	4.0	yellow	9.05
OC9C	19.5	0.5	4.0	gel	8.23
Wetting Agent Concentration		0.1670		Average	8.17

*Ninol 1281
**Xylene

TABLE 123

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-6}
OD0A	19	1	0	clear sol. w/ xylene bubbles	----
OD0B	19	1	0		8.23
OD0C	19	1	0		12.0
Wetting Agent Concentration		0.0000		Average	10.7
OD1A	19	1	0.5	milky light-gray	----
OD1B	19	1	0.5		10.6
OD1C	19	1	0.5		11.4
Wetting Agent Concentration		0.0245		Average	11.0
OD2A	19	1	1.0	milky white	9.46
OD2B	19	1	1.0		6.74
OD2C	19	1	1.0		----
Wetting Agent Concentration		0.0478		Average	8.10
OD3A	19	1	2.0	off-white	8.23
OD3B	19	1	2.0		9.46
OD3C	19	1	2.0		----
Wetting Agent Concentration		0.0913		Average	8.84
OD4A	19	1	4.0	off-yellow	----
OD4B	19	1	4.0		10.4
OD4C	19	1	4.0		10.4
Wetting Agent Concentration		0.1673		Average	10.4

*Stepantex WB42
**Xylene

TABLE 123

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-6}
OD5A	19.5	0.5	0	clear sol. w/ xylene bubbles	----
OD5B	19.5	0.5	0		12.4
OD5C	19.5	0.5	0		13.2
Wetting Agent Concentration		0.0000		Average	12.8
OD6A	19.5	0.5	0.5	milky light gray	----
OD6B	19.5	0.5	0.5		8.64
OD6C	19.5	0.5	0.5		8.97
Wetting Agent Concentration		0.0244		Average	8.80
OD7A	19.5	0.5	1.0	milky white	10.6
OD7B	19.5	0.5	1.0		11.6
OD7C	19.5	0.5	1.0		10.9
Wetting Agent Concentration		0.0477		Average	11.0
OD8A	19.5	0.5	2.0	hazy grayish	10.0
OD8B	19.5	0.5	2.0		11.0
OD8C	19.5	0.5	2.0		8.72
Wetting Agent Concentration		0.0911		Average	9.90
OD9A	19.5	0.5	4.0	off-yellow transparent	7.16
OD9B	19.5	0.5	4.0		----
OD9C	19.5	0.5	4.0		5.84
Wetting Agent Concentration		0.1670		Average	6.50

*Stepantex WB42
**Xylene

TABLE 124

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-6}
OE0A	19	1	0	clear sol.	----
OE0B	19	1	0	w/ xylene	9.38
OE0C	19	1	0	bubbles	10.2
Wetting Agent Concentration		0.0000		Average	9.79
OE1A	19	1	0.5	milky	8.64
OE1B	19	1	0.5	white	9.54
OE1C	19	1	0.5		----
Wetting Agent Concentration		0.0245		Average	9.09
OE2A	19	1	1.0	milky	9.71
OE2B	19	1	1.0	white	8.64
OE2C	19	1	1.0		----
Wetting Agent Concentration		0.0478		Average	9.17
OE3A	19	1	2.0	milky-white	9.79
OE3B	19	1	2.0	yellow	----
OE3C	19	1	2.0	tinge	9.71
Wetting Agent Concentration		0.0913		Average	9.75
OE4A	19	1	4.0	light	5.67
OE4B	19	1	4.0	yellow	----
OE4C	19	1	4.0	translucent solution	6.91
Wetting Agent Concentration		0.1673		Average	6.29

*Toximul R

**Xylene

TABLE 124

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-6}
OE5A	19.5	0.5	0	clear sol,	8.23
OE5B	19.5	0.5	0	w/ xylene	8.64
OE5C	19.5	0.5	0	bubbles	8.39
Wetting Agent Concentration		0.0000		Average	8.42
OE6A	19.5	0.5	0.5	milky	9.79
OE6B	19.5	0.5	0.5	white	8.97
OE6C	19.5	0.5	0.5	solution	----
Wetting Agent Concentration		0.0244		Average	9.38
OE7A	19.5	0.5	1.0	milky	----
OE7B	19.5	0.5	1.0	white	9.05
OE7C	19.5	0.5	1.0	solution	9.71
Wetting Agent Concentration		0.0477		Average	9.38
OE8A	19.5	0.5	2.0	hazy	----
OE8B	19.5	0.5	2.0	grayish	9.05
OE8C	19.5	0.5	2.0	solution	9.62
Wetting Agent Concentration		0.0911		Average	9.33
OE9A	19.5	0.5	4.0	clear	7.81
OE9B	19.5	0.5	4.0	yellowish	8.64
OE9C	19.5	0.5	4.0	solution	----
Wetting Agent Concentration		0.1670		Average	8.22

*Toximul R
**Xylene

TABLE 125

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-6}
OF0A	19	1	0	clear sol.	7.81
OF0B	19	1	0	w/ xylene	----
OF0C	19	1	0	bubbles	6.66
Wetting Agent Concentration		0.0000		Average	7.23
OF1A	19	1	0.5	milky	----
OF1B	19	1	0.5	white	12.9
OF1C	19	1	0.5		10.1
Wetting Agent Concentration		0.0245		Average	11.5
OF2A	19	1	1.0	milky	6.83
OF2B	19	1	1.0	white	10.4
OF2C	19	1	1.0		8.64
Wetting Agent Concentration		0.0478		Average	8.62
OF3A	19	1	2.0	grayish	----
OF3B	19	1	2.0	white	7.07
OF3C	19	1	2.0		8.23
Wetting Agent Concentration		0.0913		Average	7.65
OF4A	19	1	4.0	amber	8.23
OF4B	19	1	4.0	gel	8.88
OF4C	19	1	4.0		----
Wetting Agent Concentration		0.1673		Average	8.55

*Stepantex DA-52
**Xylene

TABLE 125

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-6}
OF5A	19.5	0.5	0	clear sol.	10.0
OF5B	19.5	0.5	0	w/ xylene	9.54
OF5C	19.5	0.5	0	bubbles	----
Wetting Agent Concentration		0.0000		Average	9.77
OF6A	19.5	0.5	0.5	milky	10.4
OF6B	19.5	0.5	0.5	white	9.46
OF6C	19.5	0.5	0.5		9.38
Wetting Agent Concentration		0.0244		Average	9.74
OF7A	19.5	0.5	1.0	milky	----
OF7B	19.5	0.5	1.0	white	7.81
OF7C	19.5	0.5	1.0		8.97
Wetting Agent Concentration		0.0477		Average	8.39
OF8A	19.5	0.5	2.0	grayish	8.23
OF8B	19.5	0.5	2.0	white	9.05
OF8C	19.5	0.5	2.0		6.91
Wetting Agent Concentration		0.0911		Average	8.06
OF9A	19.5	0.5	4.0	amber	9.71
OF9B	19.5	0.5	4.0	gel	----
OF9C	19.5	0.5	4.0		8.55
Wetting Agent Concentration		0.1670		Average	9.13

*Stepantex DA-52
**Xylene

TABLE 126

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc) X 10^{-6}
OG0A	19	1	0	clear sol.	6.74
OG0B	19	1	0	w/ xylene	6.25
OG0C	19	1	0	bubbles	----
Wetting Agent Concentration		0.0000		Average	6.49
OG1A	19	1	0.5	hazy-white	8.64
OG1B	19	1	0.5	&yellow	6.83
OG1C	19	1	0.5	residue	----
				on top	
Wetting Agent Concentration		0.0245		Average	7.73
OG2A	19	1	1.0	hazy-white	6.41
OG2B	19	1	1.0	&(more)yellow	9.46
OG2C	19	1	1.0	residue	----
				on top	
Wetting Agent Concentration		0.0478		Average	7.93
OG3A	19	1	2.0	hazy	----
OG3B	19	1	2.0	yellow	9.05
OG3C	19	1	2.0	gel	10.0
Wetting Agent Concentration		0.0913		Average	9.52
OG4A	19	1	4.0	clear sol.	6.00
OG4B	19	1	4.0	surrounding	6.83
OG4C	19	1	4.0	yellow gel	----
				white residue	
				on top	
Wetting Agent Concentration		0.1673		Average	6.41

*Ninate 401
**Xylene

TABLE 126

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-6}
OG5A	19.5	0.5	0	clear sol. w/ xylene bubbles	----
OG5B	19.5	0.5	0		9.46
OG5C	19.5	0.5	0		8.72
Wetting Agent Concentration		0.0000		Average	9.09
OG6A	19.5	0.5	0.5	hazy-white & yellow residues on top	7.48
OG6B	19.5	0.5	0.5		8.31
OG6C	19.5	0.5	0.5		----
Wetting Agent Concentration		0.0244		Average	7.89
OG7A	19.5	0.5	1.0	white hazy sol--yellow residue on bottom	6.74
OG7B	19.5	0.5	1.0		7.07
OG7C	19.5	0.5	1.0		7.73
Wetting Agent Concentration		0.0477		Average	7.18
OG8A	19.5	0.5	2.0	hazy sol. surrounding a yellow gel	7.81
OG8B	19.5	0.5	2.0		8.64
OG8C	19.5	0.5	2.0		----
Wetting Agent Concentration		0.0911		Average	8.22
OG9A	19.5	0.5	4.0	clear sol. surrounding a yellow gel w/ suspended white residue	----
OG9B	19.5	0.5	4.0		8.88
OG9C	19.5	0.5	4.0		8.64
Wetting Agent Concentration		0.1670		Average	8.76

*Ninate 401
**Xylene

TABLE 127

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-6}
OH0A	19	1	0	clear	----
OH0B	19	1	0	w/ xylene	12.7
OH0C	19	1	0	bubbles	12.9
Wetting Agent Concentration		0.0000		Average	12.8
OH1A	19	1	0.5	milky	8.23
OH1B	19	1	0.5	white	----
OH1C	19	1	0.5		9.54
Wetting Agent Concentration		0.0245		Average	8.88
OH2A	19	1	1.0	milky	11.8
OH2B	19	1	1.0	white	11.0
OH2C	19	1	1.0		11.7
Wetting Agent Concentration		0.0478		Average	11.5
OH3A	19	1	2.0		9.46
OH3B	19	1	2.0	hazy	7.48
OH3C	19	1	2.0		11.4
Wetting Agent Concentration		0.0913		Average	9.44
OH4A	19	1	4.0		10.2
OH4B	19	1	4.0	hazy	13.2
OH4C	19	1	4.0		11.7
Wetting Agent Concentration		0.1673		Average	11.7

*Stepanate AM
**Xylene

TABLE 127

Bottle Number	Water (ml)	Organic** (ml)	Wetting Agent* (grams)	Appearance	Organic Vapor Concentration (grams/cc)X 10^{-6}
OH5A	19.5	0.5	0	clear	11.1
OH5B	19.5	0.5	0	W/ xylene	----
OH5C	19.5	0.5	0	bubbles	9.87
Wetting Agent Concentration		0.0000		Average	10.5
OH6A	19.5	0.5	0.5	milky	12.6
OH6B	19.5	0.5	0.5	white	13.2
OH6C	19.5	0.5	0.5		----
Wetting Agent Concentration		0.0244		Average	12.9
OH7A	19.5	0.5	1.0	milky	10.9
OH7B	19.5	0.5	1.0	white	10.5
OH7C	19.5	0.5	1.0		----
Wetting Agent Concentration		0.0477		Average	10.7
OH8A	19.5	0.5	2.0		11.7
OH8B	19.5	0.5	2.0	hazy	----
OH8C	19.5	0.5	2.0		11.7
Wetting Agent Concentration		0.0911		Average	11.7
OH9A	19.5	0.5	4.0		11.8
OH9B	19.5	0.5	4.0	hazy	10.7
OH9C	19.5	0.5	4.0		10.8
Wetting Agent Concentration		0.1670		Average	11.1

*Stepanate AM
**Xylene

FIGURES OF ORGANIC VAPOR CONCENTRATION
VS. SURFACTANT CONCENTRATION

FIGURE 100

SURFACTANT - SANDOPAN DTC GEL PASTE

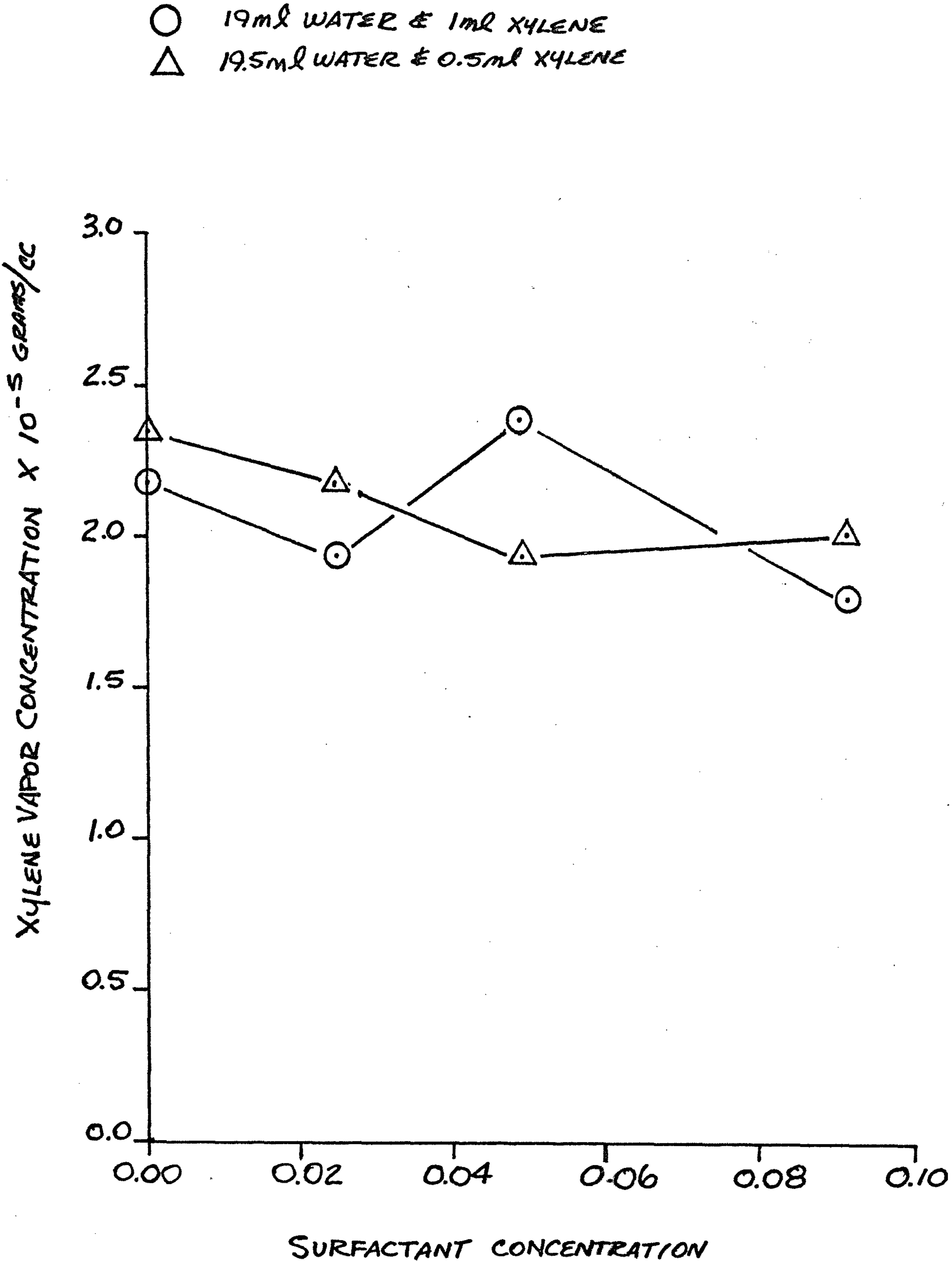


FIGURE 101

SURFACTANT ULTRAWET 1565 (15.DS)

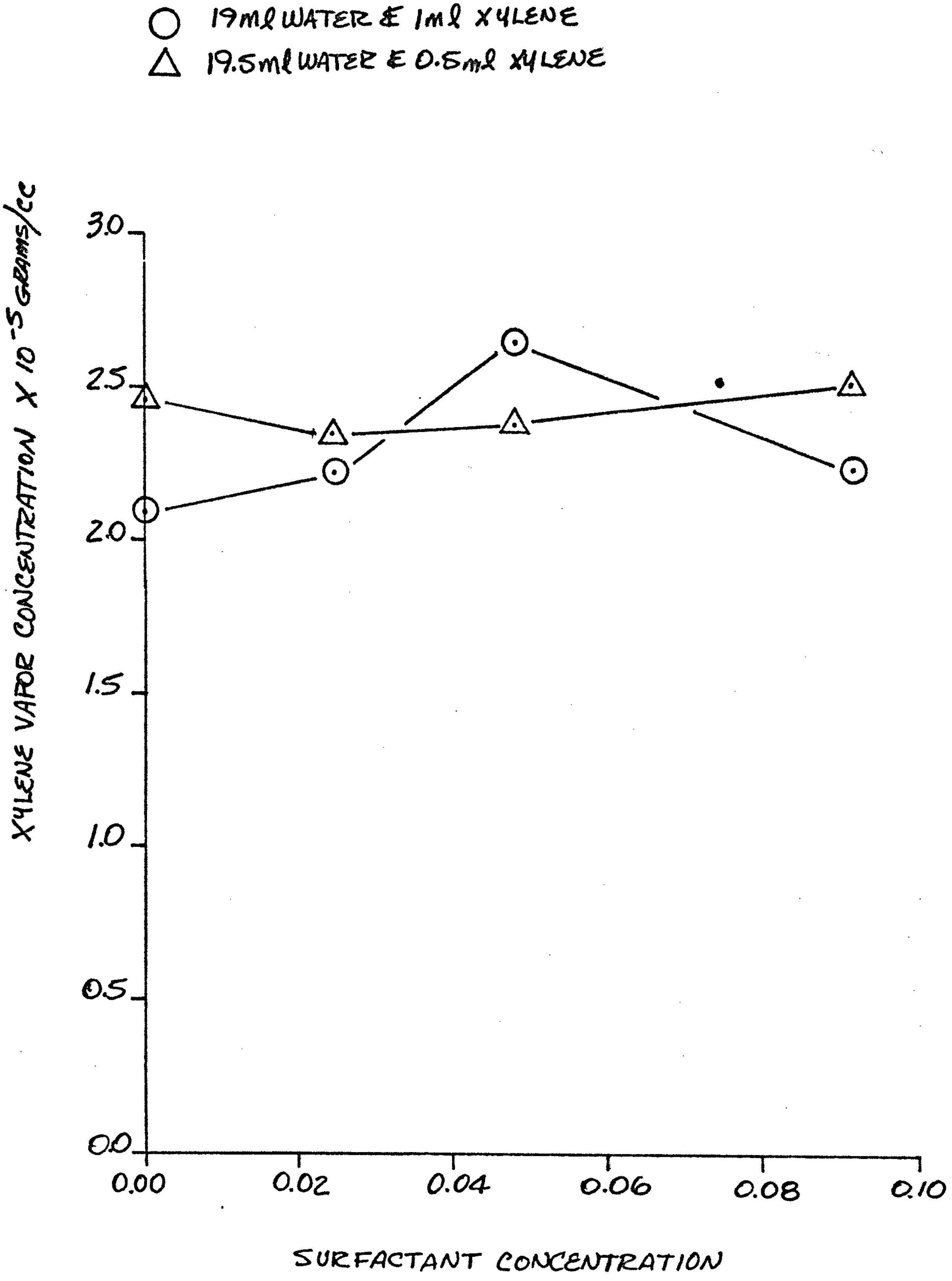


FIGURE 102

SURFACTANT 405X - LOT # 5212

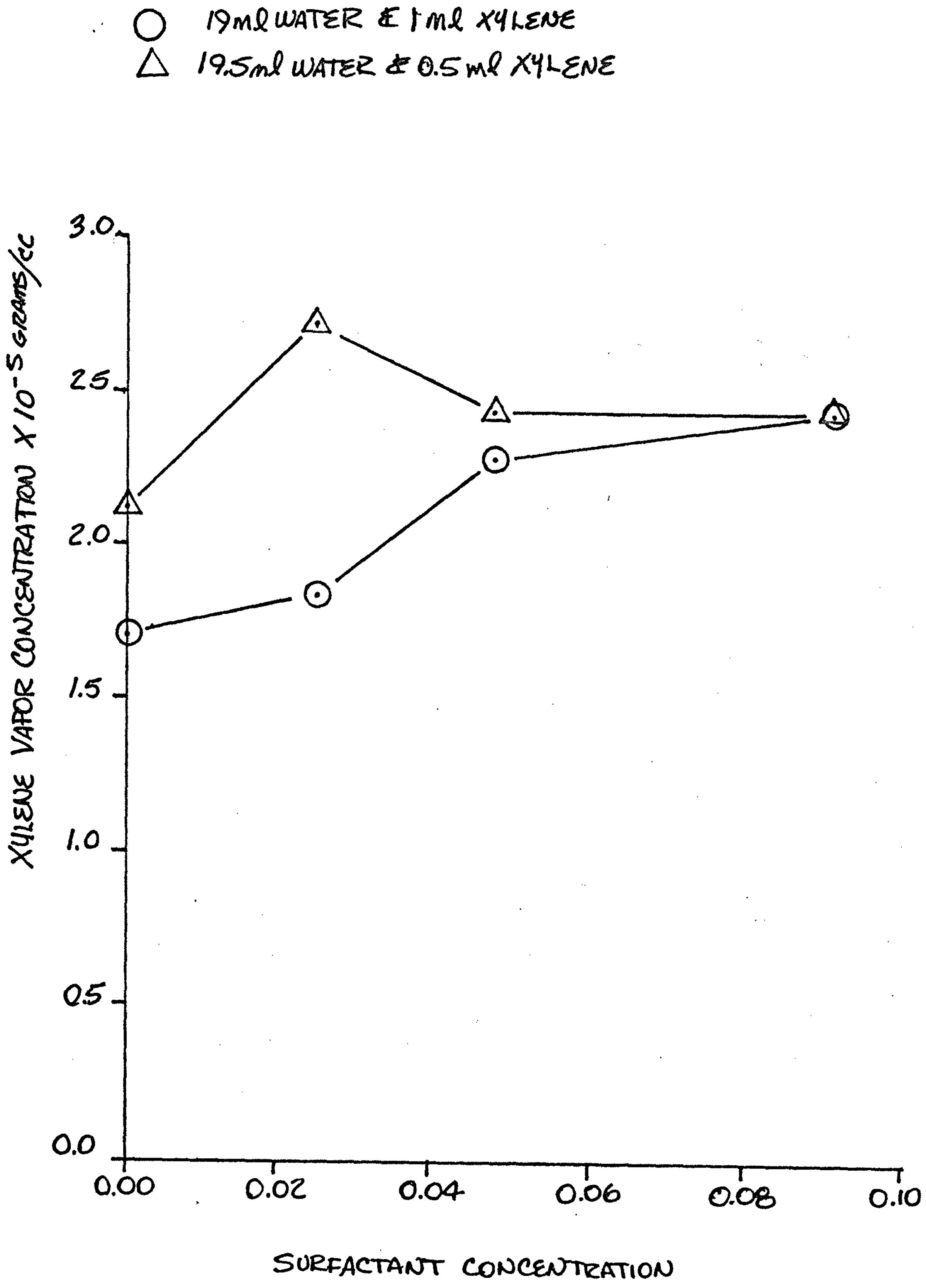


FIGURE 103

SURFACTANT SANDOPAN DTC LINEAR GEL

○ 9ml WATER & 1ml XYLENE

△ 19.5ml WATER & 0.5ml XYLENE

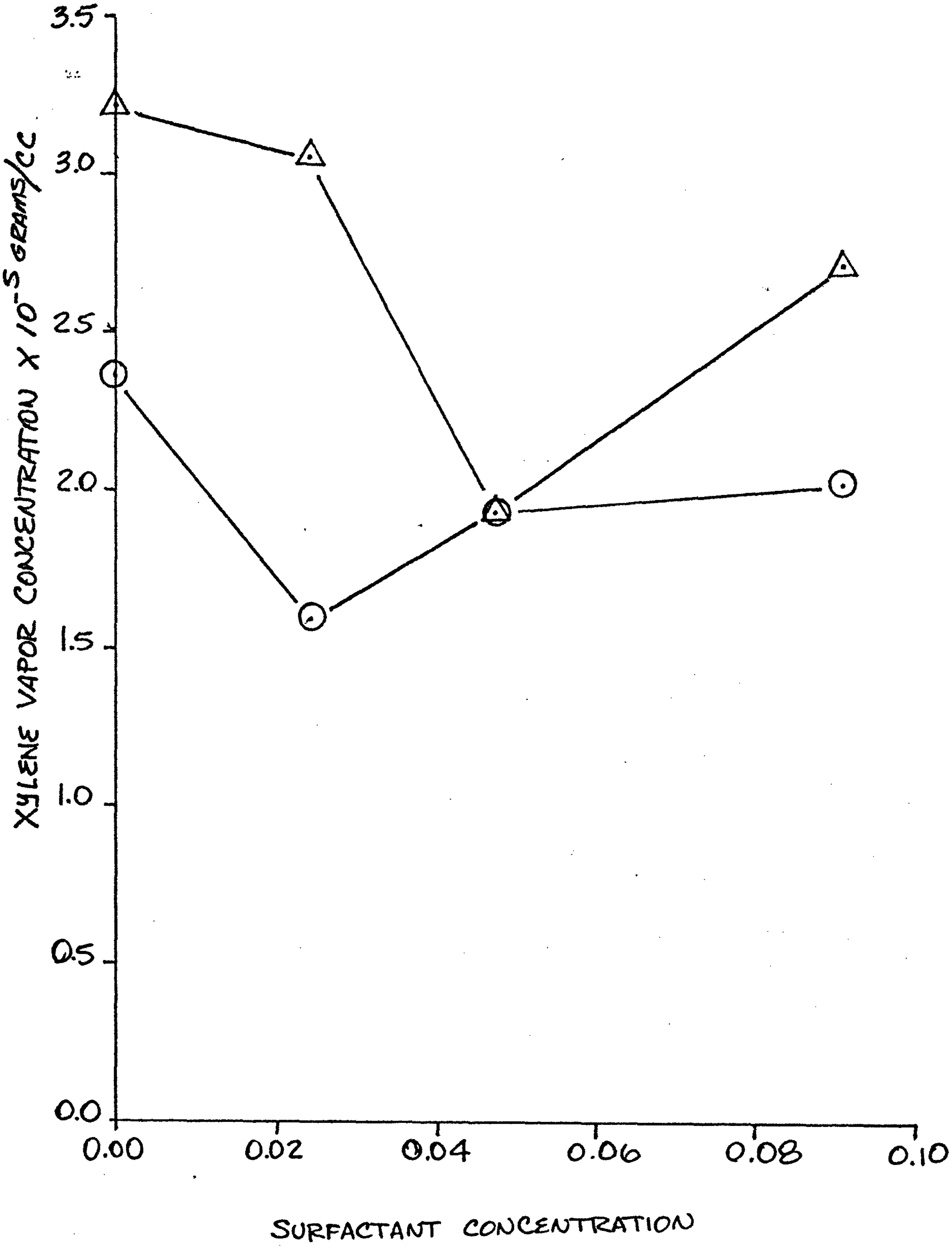


FIGURE 104

SURFACTANT SANDOPAN DTC GEL PASTE

○ 19ml WATER & 1ml CCl_4

△ 19.5ml WATER & 0.5ml CCl_4

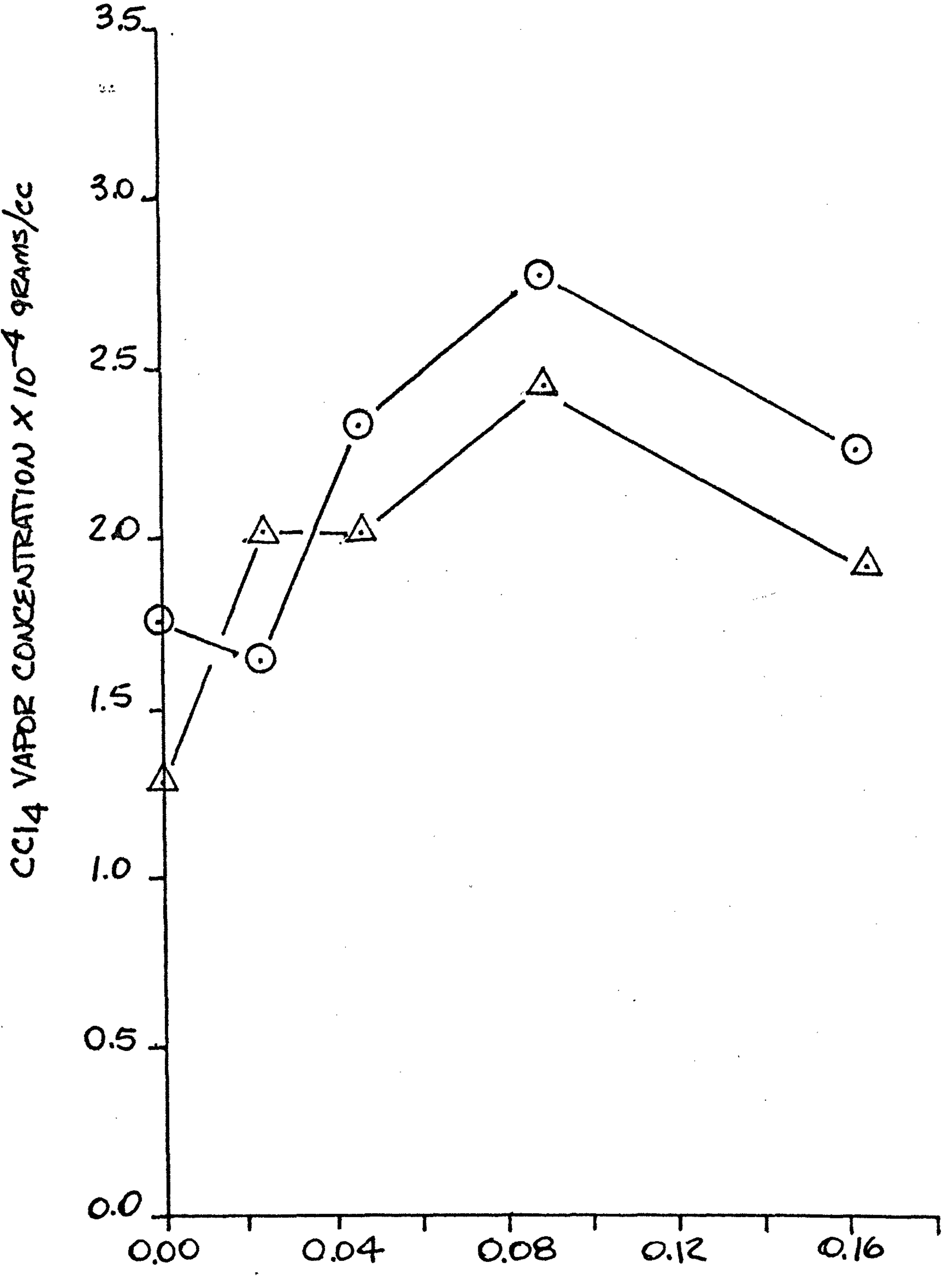


FIGURE 105
SURFACTANT ULTRAWET 1565 (45.DS)

○ 19ml WATER & 1 ml CCl_4
△ 19.5ml WATER & 0.5 ml CCl_4

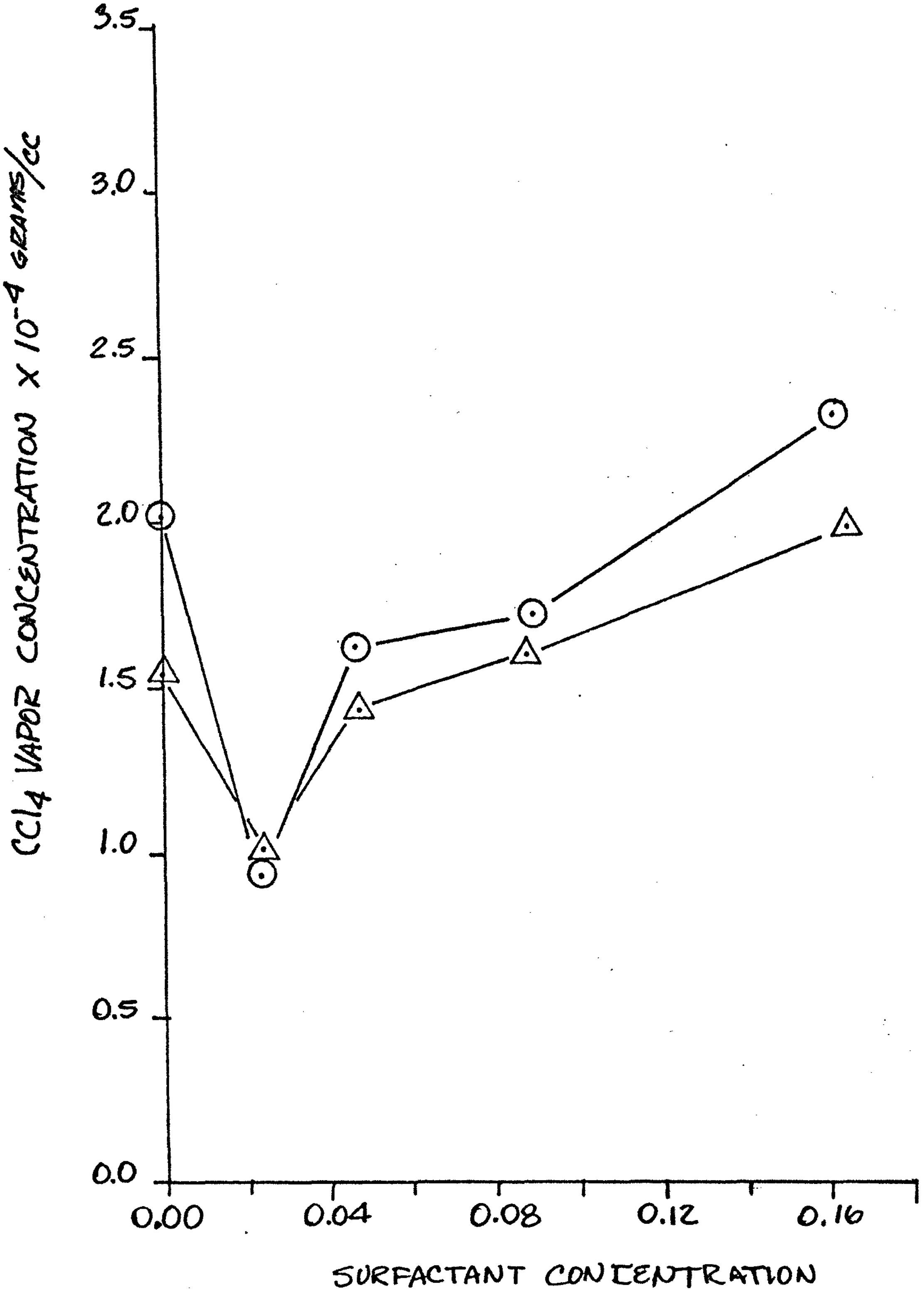


FIGURE 106
SURFACTANT 40SX-LOT# 5212

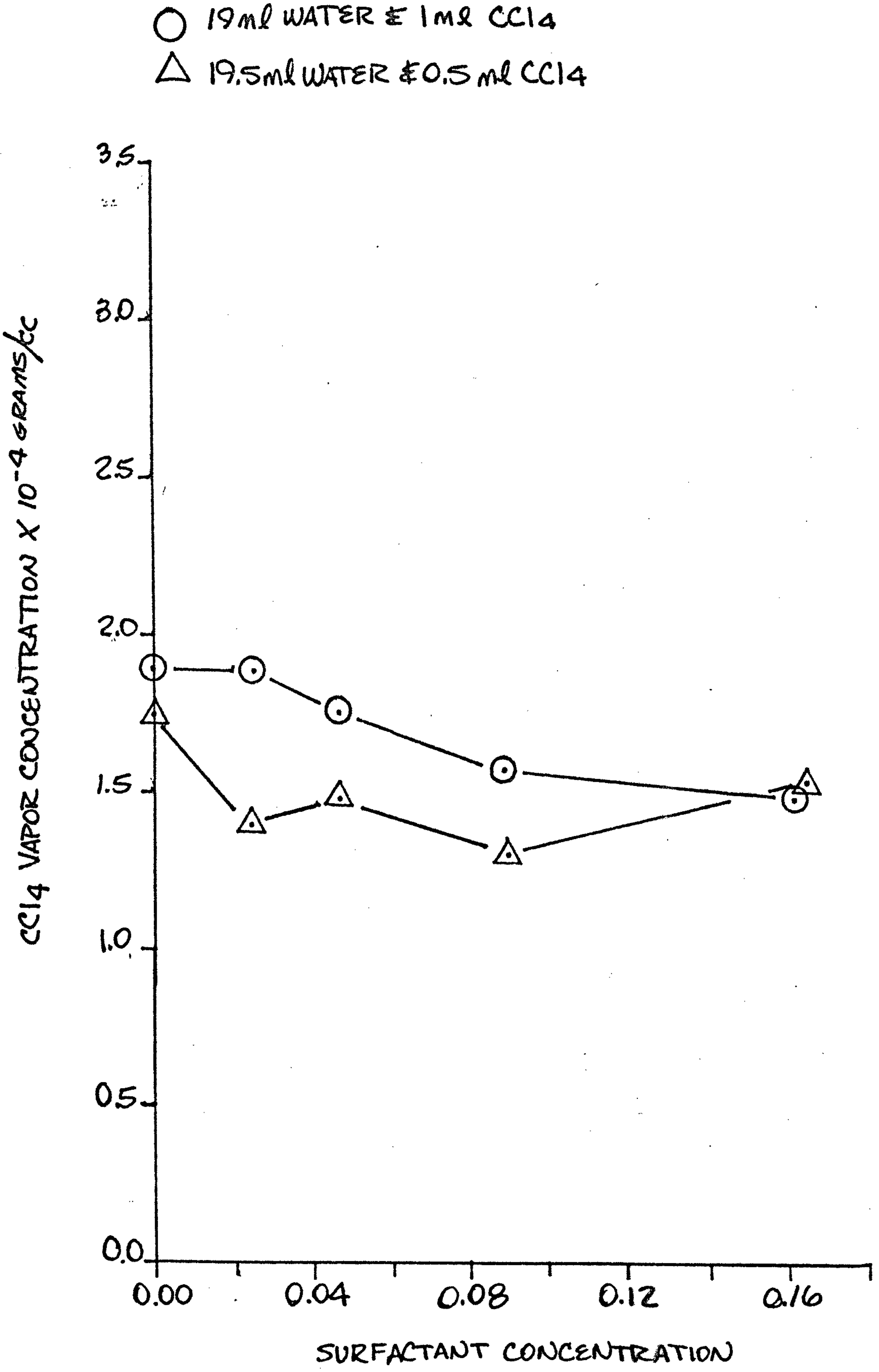


FIGURE 107

SURFACTANT SANDOPAN DTC LINEAR GEL

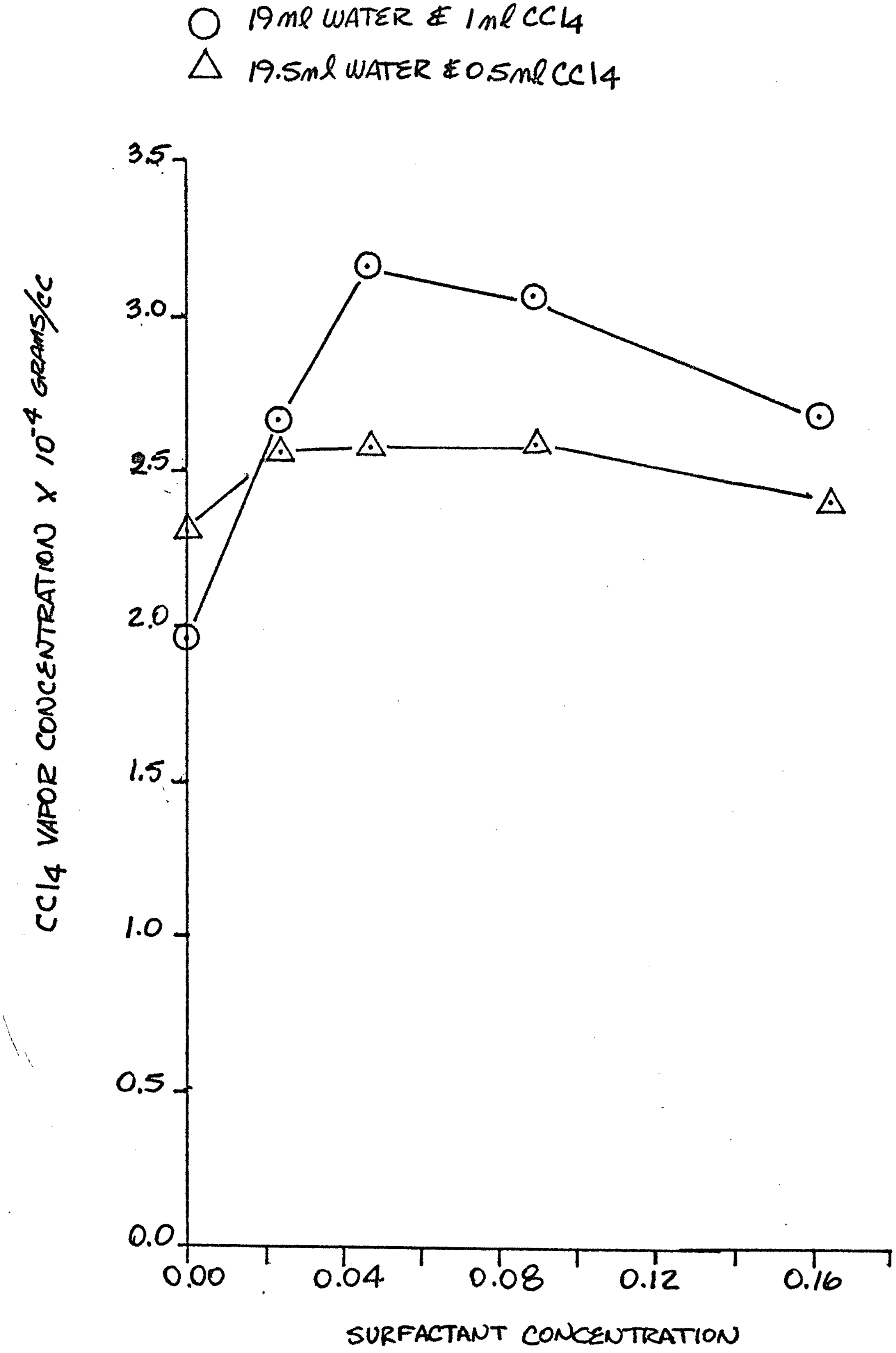


FIGURE 108

SURFACTANT SANDOPAN DTC GEL PASTE

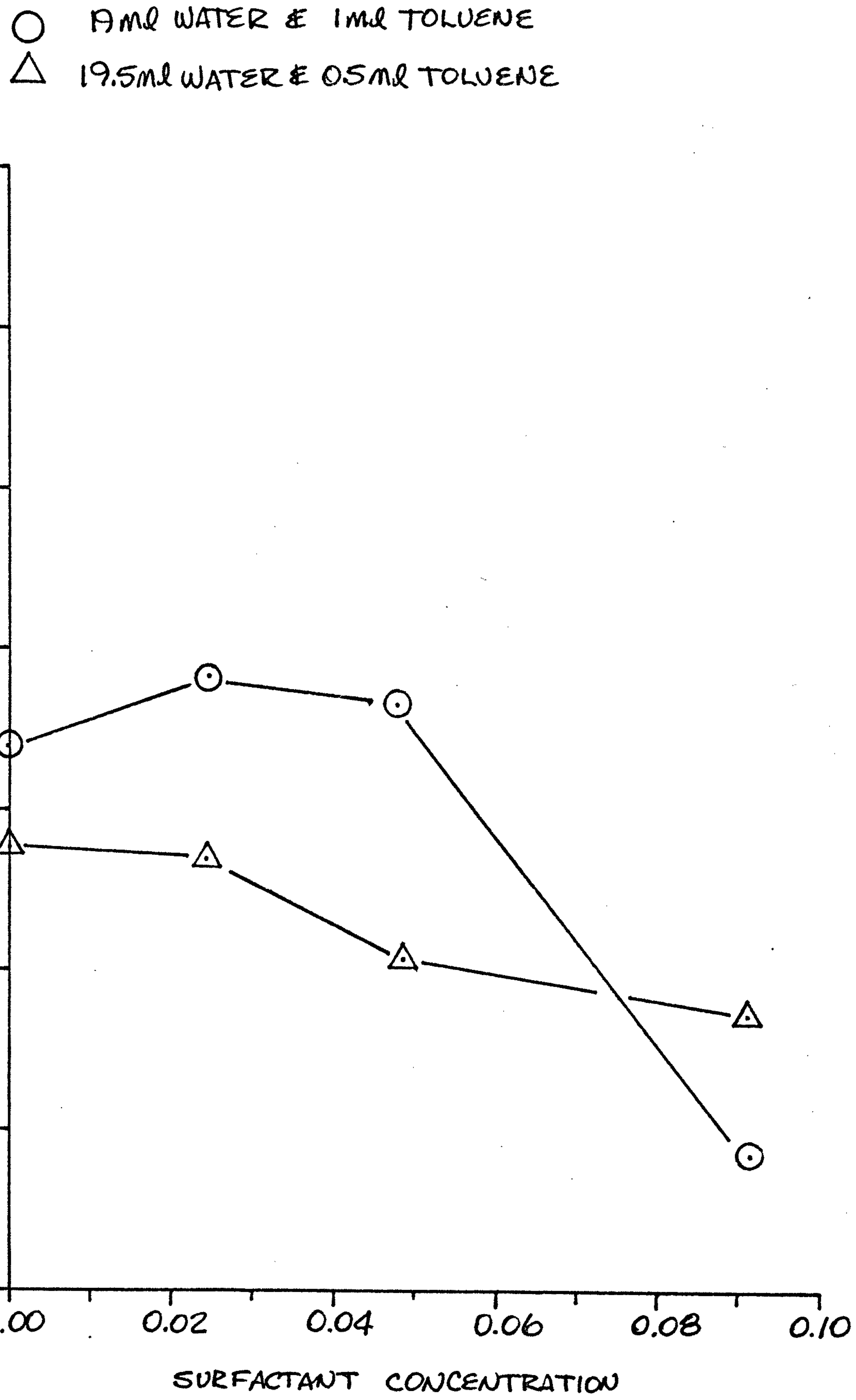


FIGURE 109

SURFACTANT ULTRAWET 1565 (45.DS)

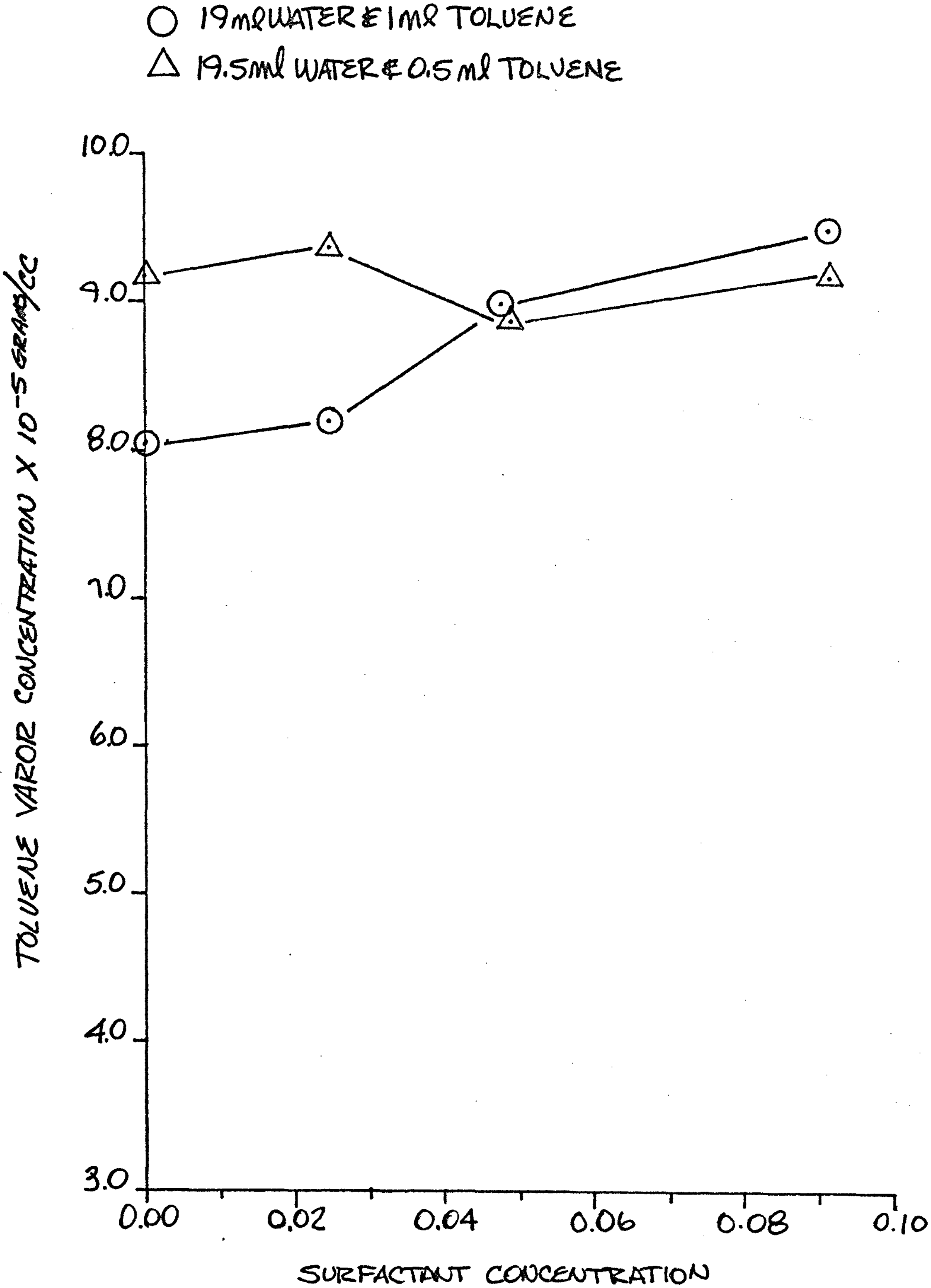


FIGURE 110

SURFACTANT 40SX-LOT#5212

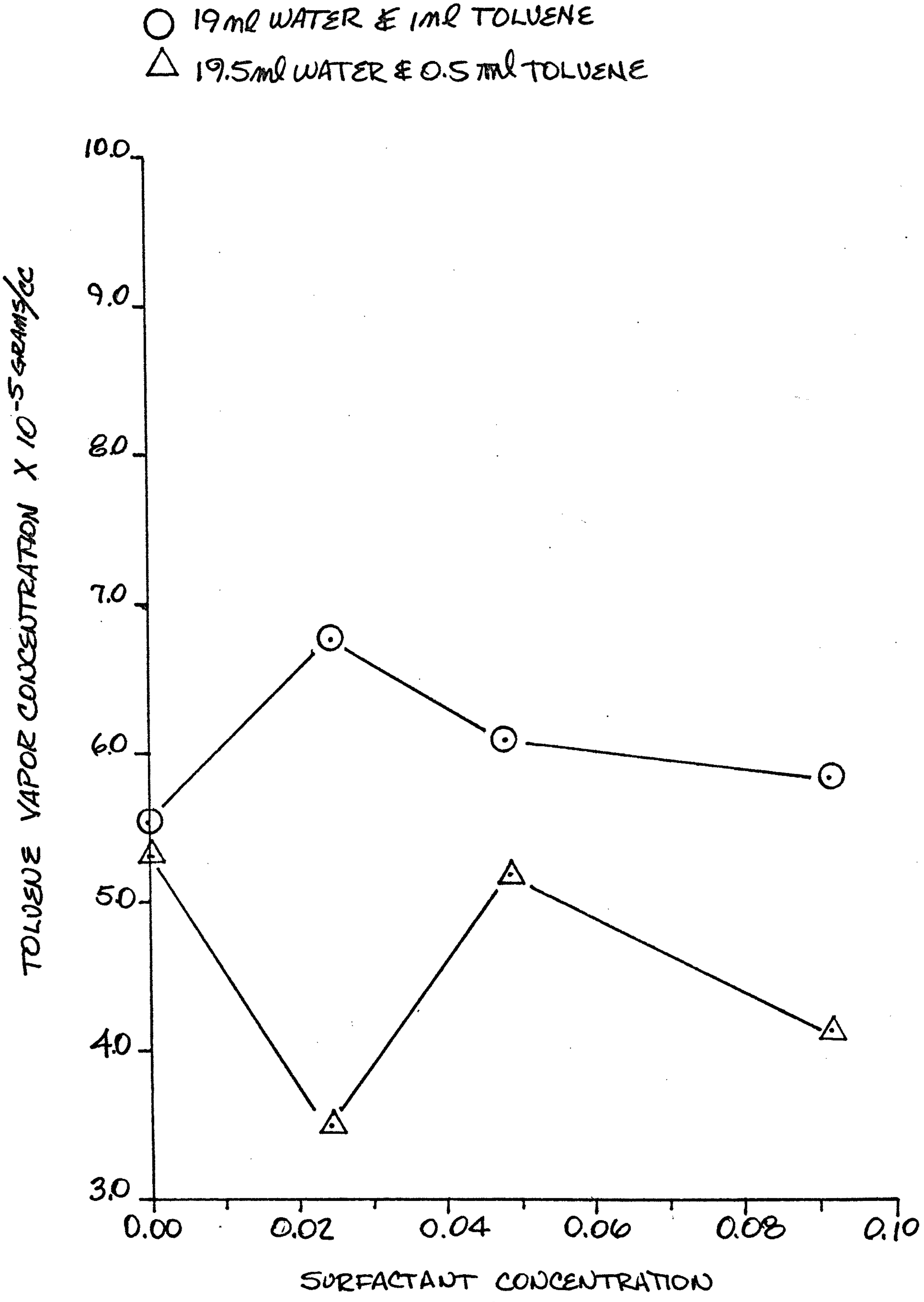


FIGURE III
SURFACTANT SANDOPAN DTC LINEAR GEL

○ 19ml WATER & 1ml TOLUENE
△ 19.5ml WATER & 0.5ml TOLUENE

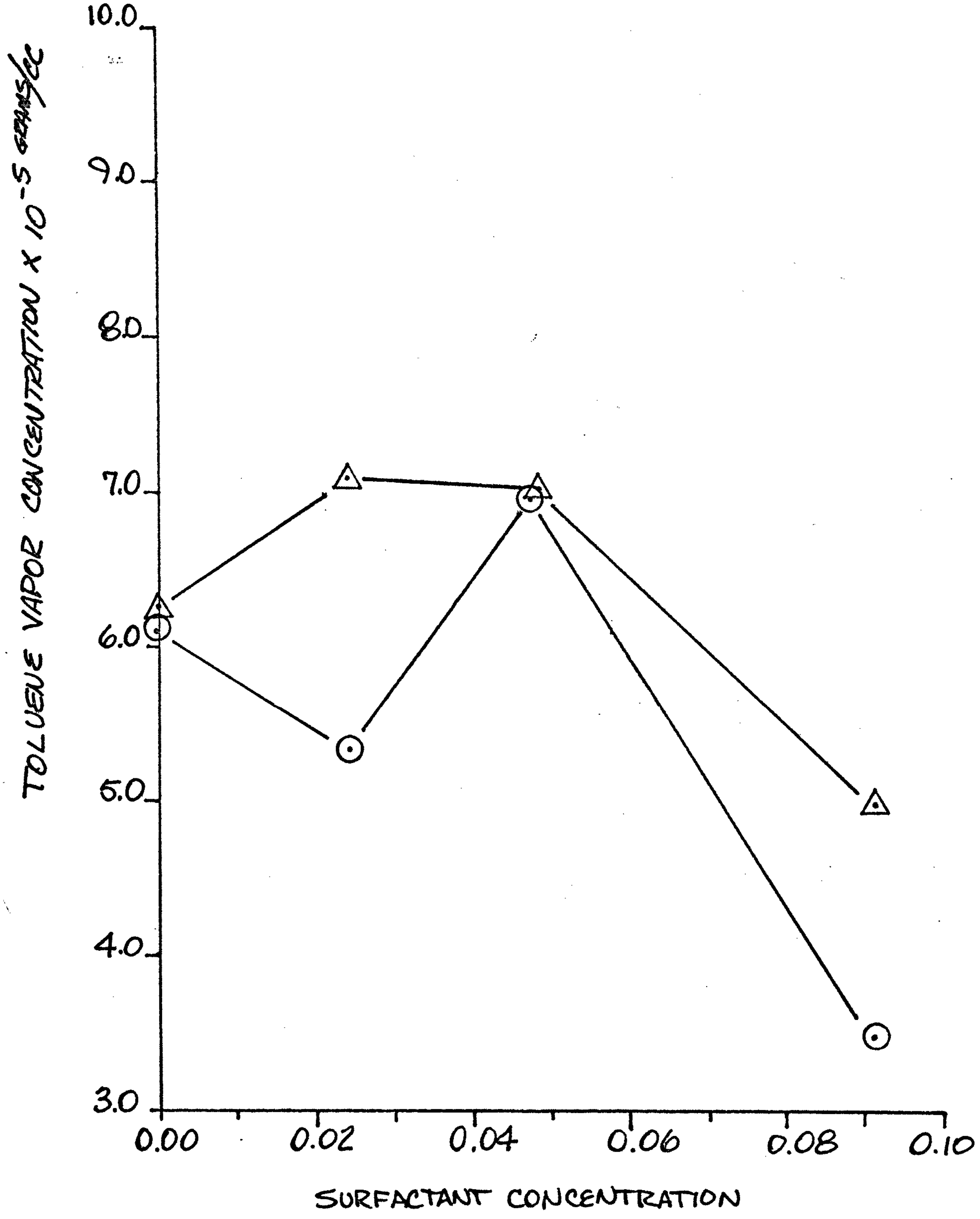


FIGURE 112

SURFACTANT SANDOPAN DTC GEL PASTE

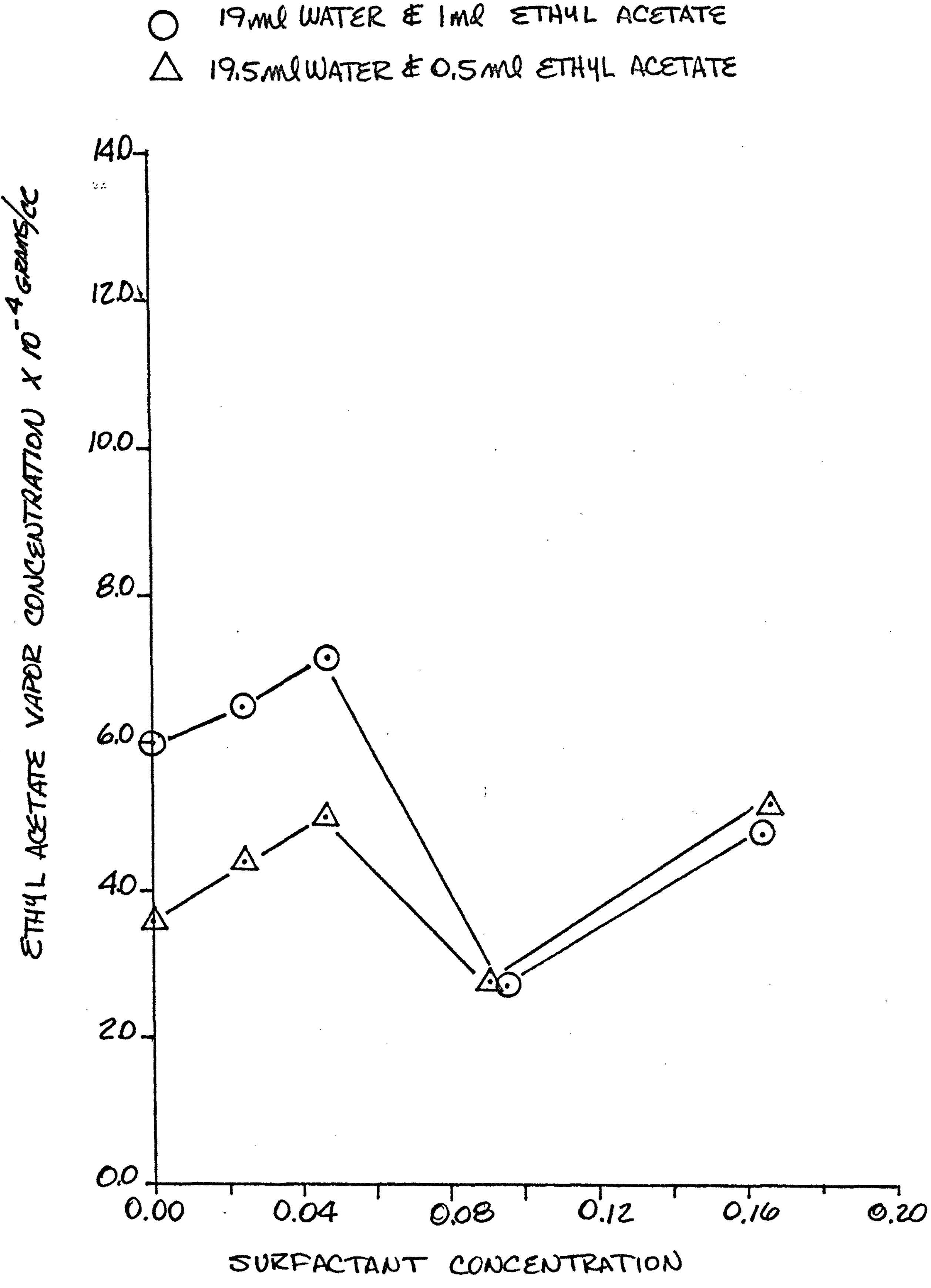


FIGURE 113
SURFACTANT ULTRAWET 1565 (45.DS)

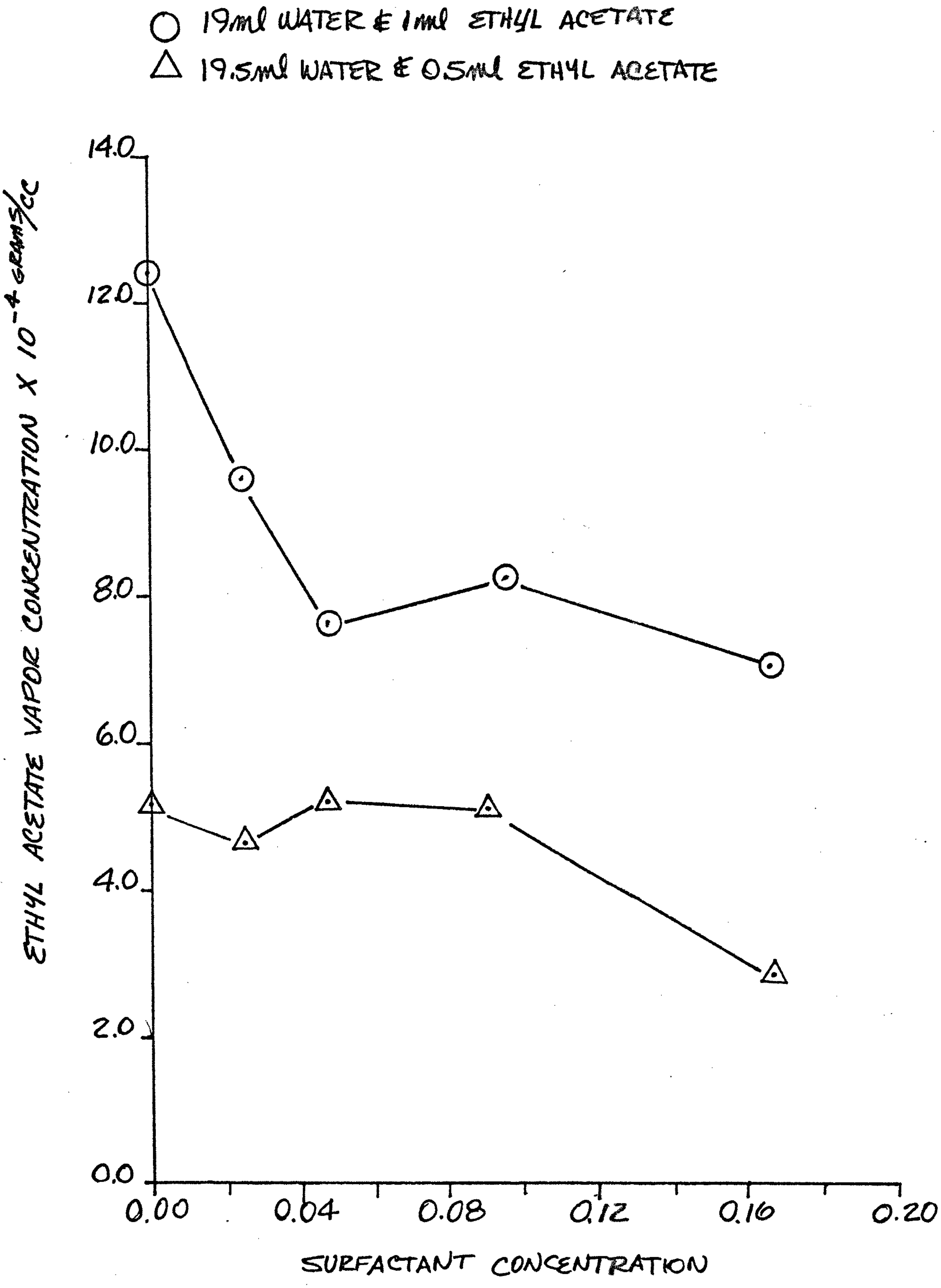


FIGURE 114

SURFACTANT 40SX-LOT #5212

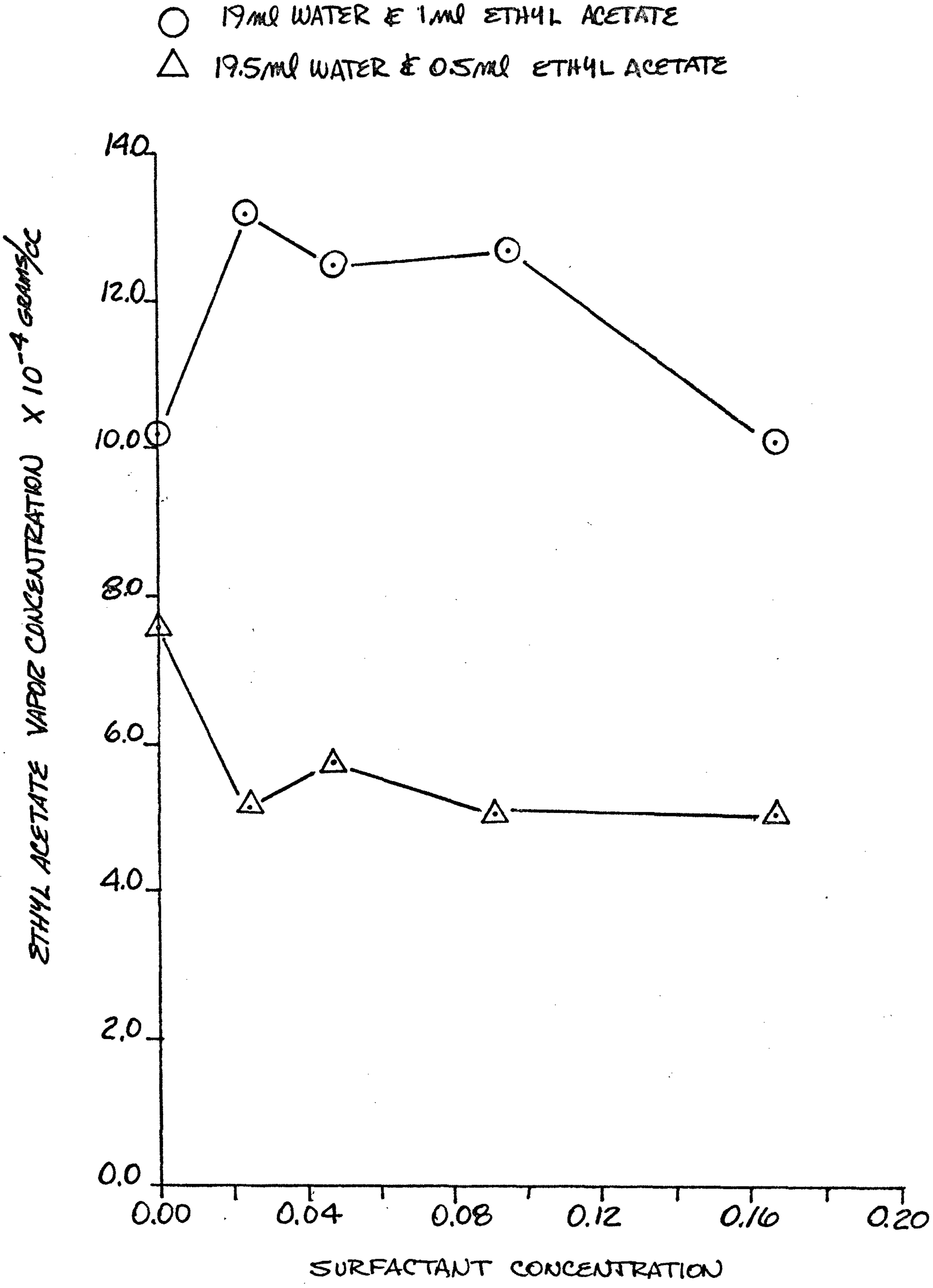


FIGURE 115
SURFACTANT SANDOPAN DTC LINEAR GEL

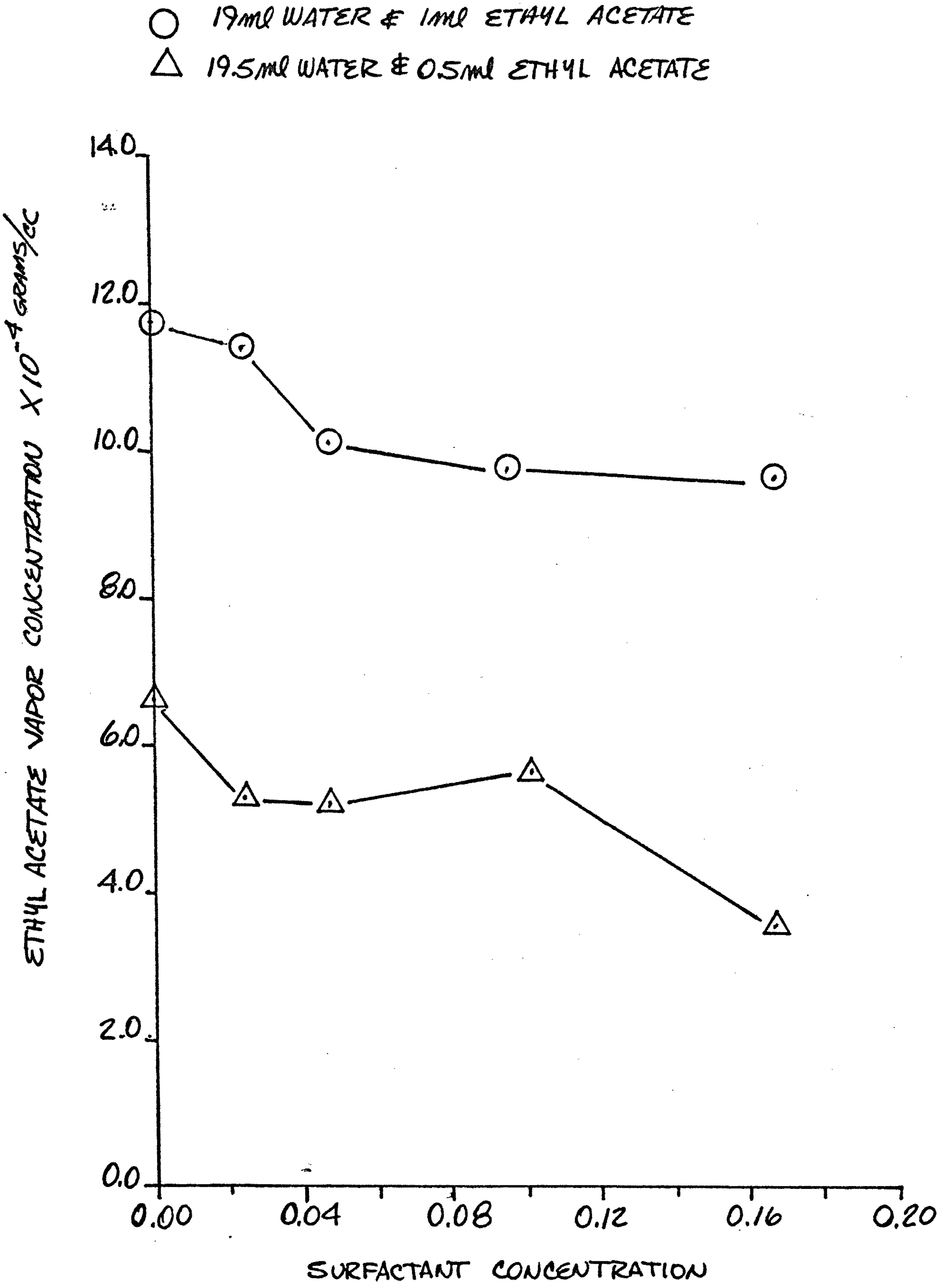


FIGURE 116

SURFACTANT SANDOPAN DTC GEL PASTE

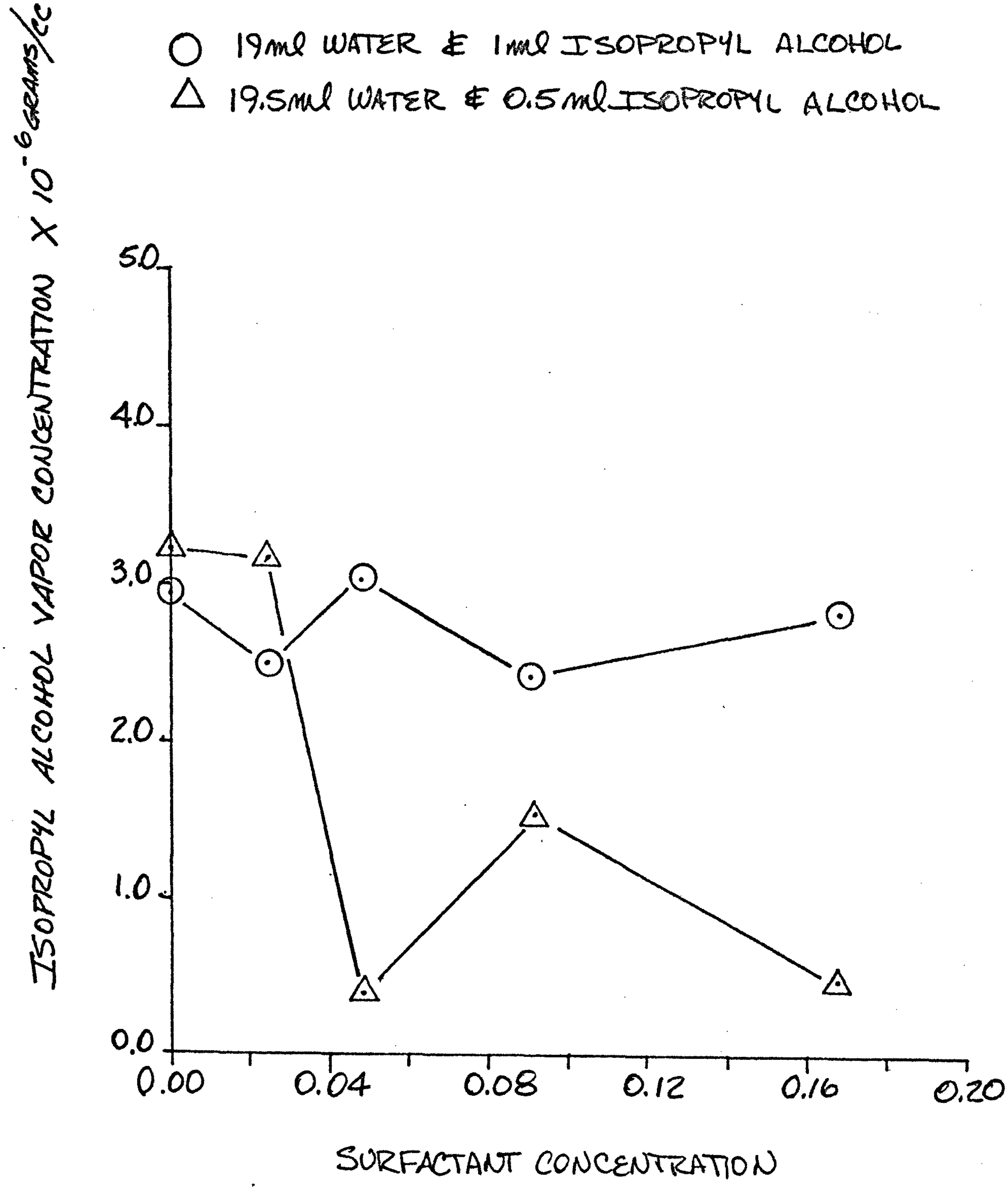


FIGURE 117

SURFACTANT ULTRAWET 1565 (45.DS)

○ 19ml WATER & 1ml ISOPROPYL ALCOHOL

△ 19.5ml WATER & 0.5ml ISOPROPYL ALCOHOL

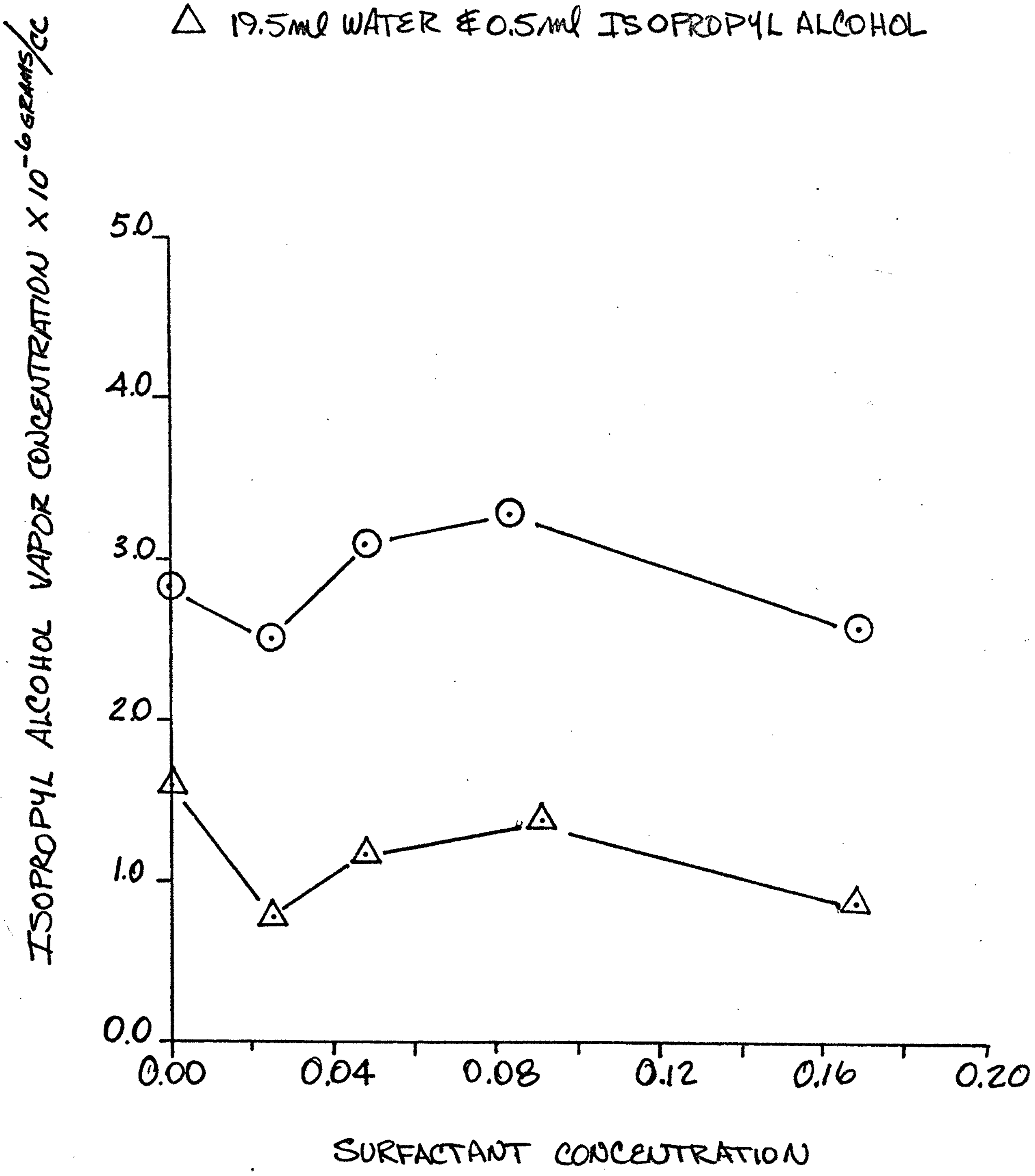


FIGURE 118

SURFACTANT 40SX-LOT#5212

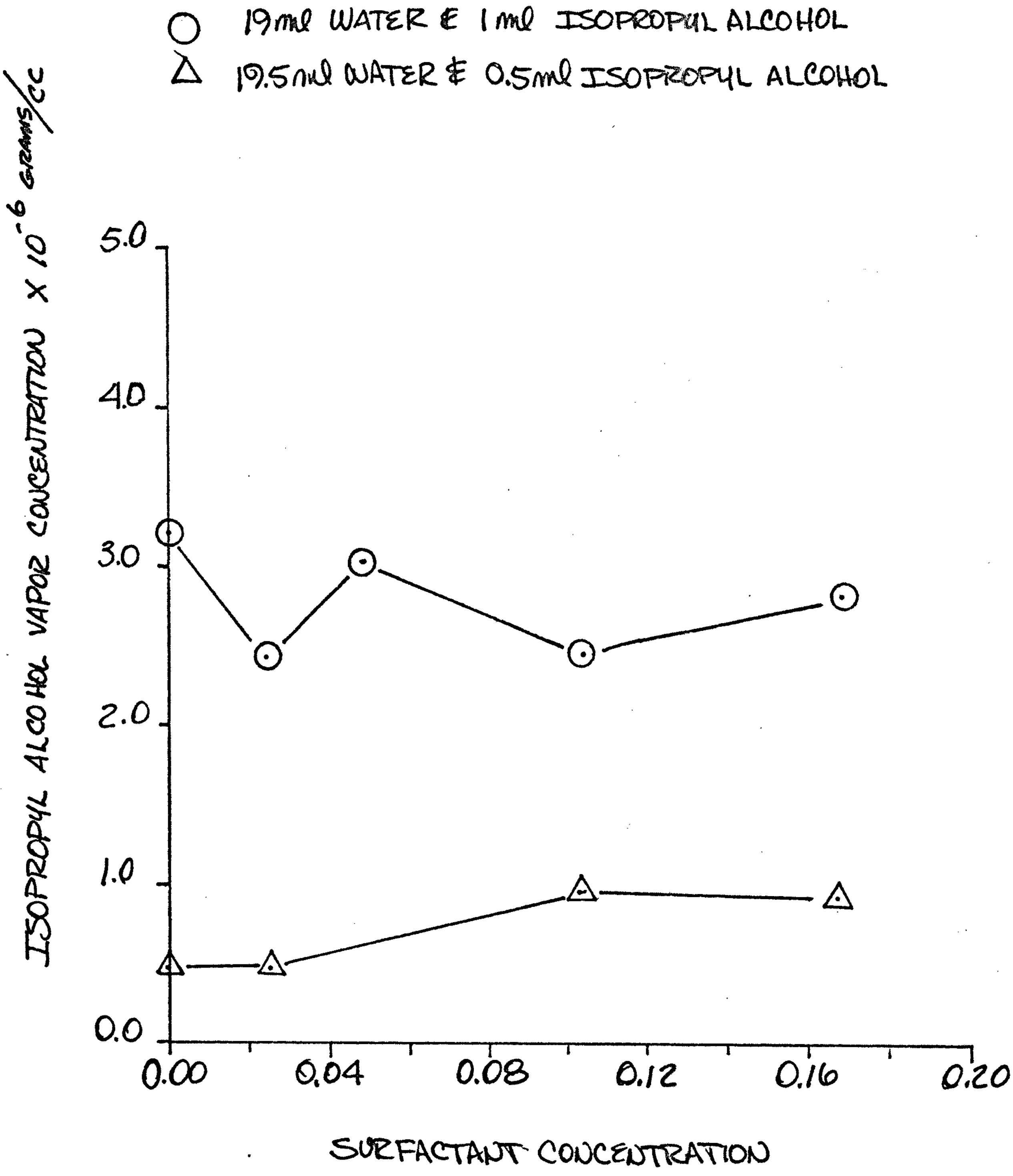


FIGURE 19

SURFACTANT SANDOPAN DTC LINEAR GEL

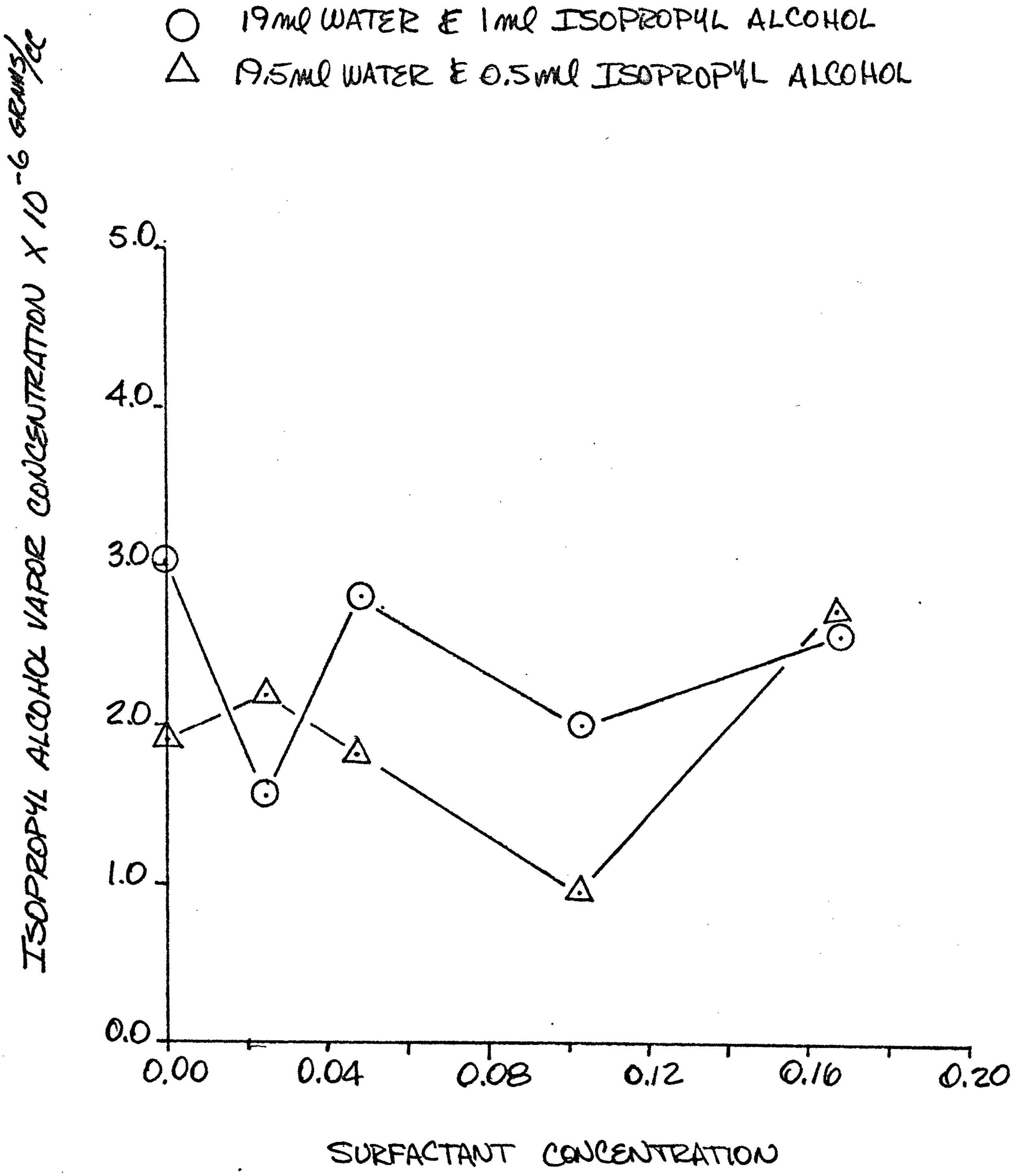


FIGURE 120

SURFACTANT STEPANOL WAT

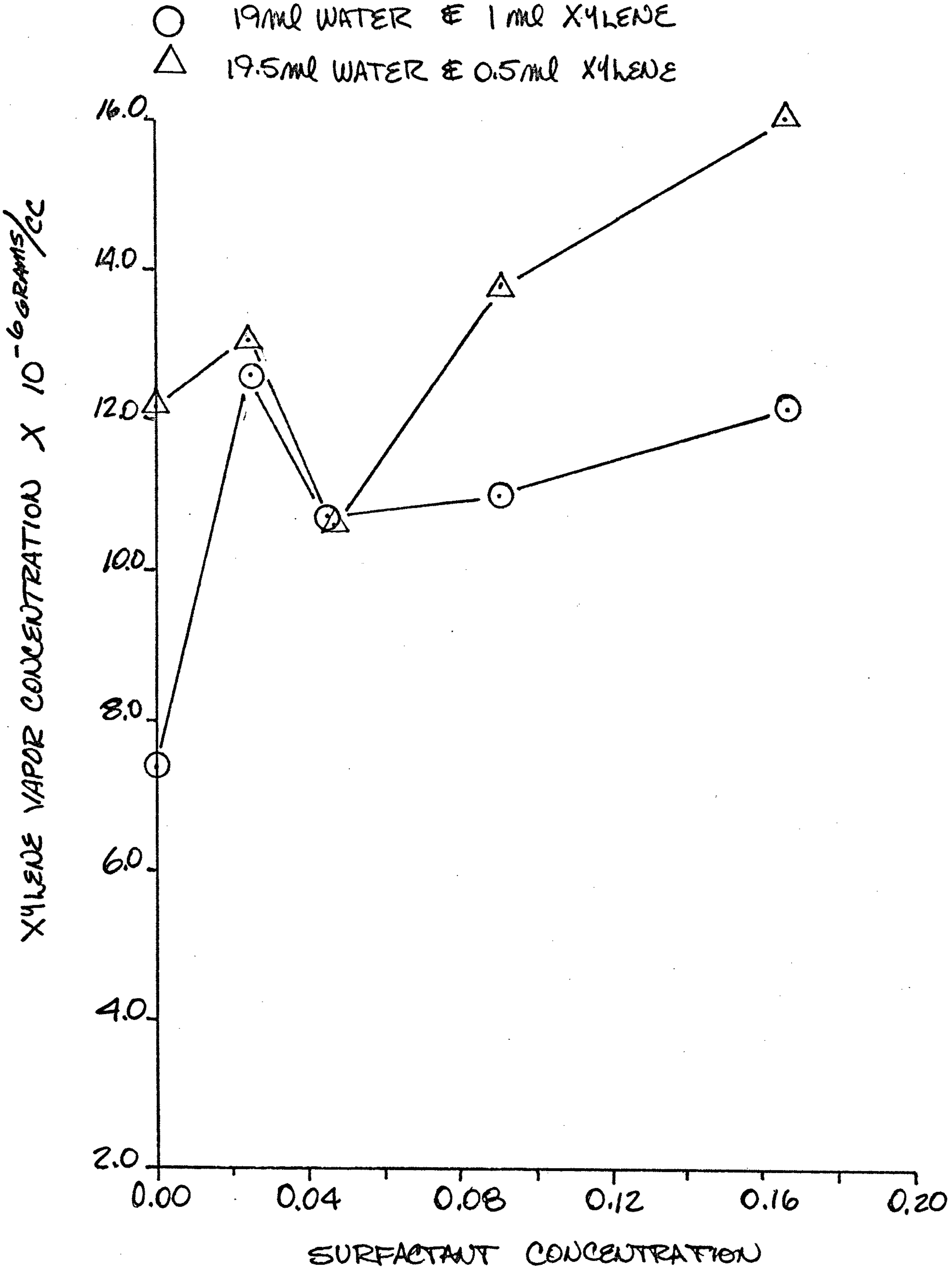


FIGURE 121
SURFACTANT STEOL KS 460

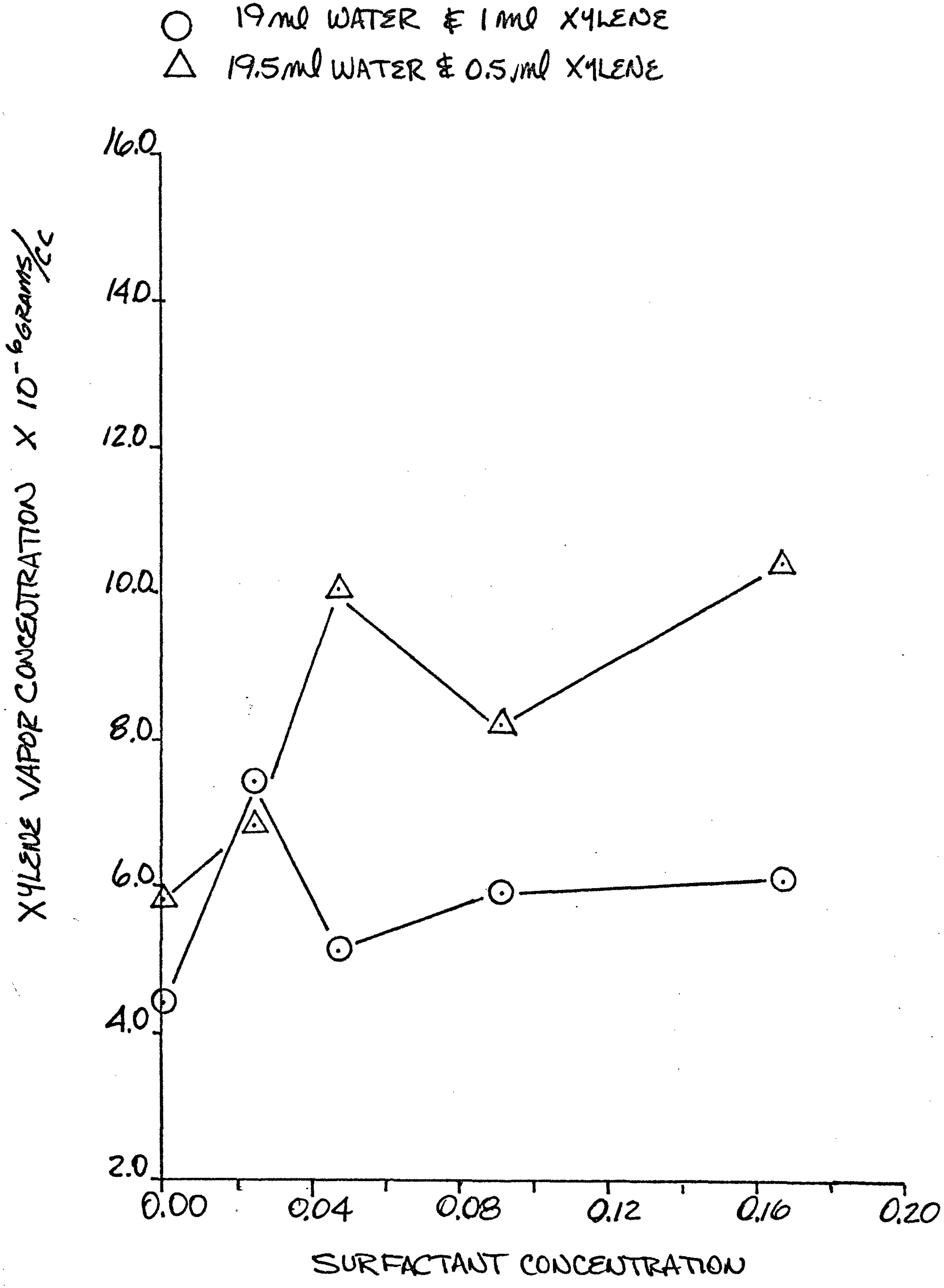


FIGURE 122
SURFACTANT NINOL 1281

○ 19 ml WATER & 1 ml XYLENE
△ 19.5 ml WATER & 0.5 ml XYLENE

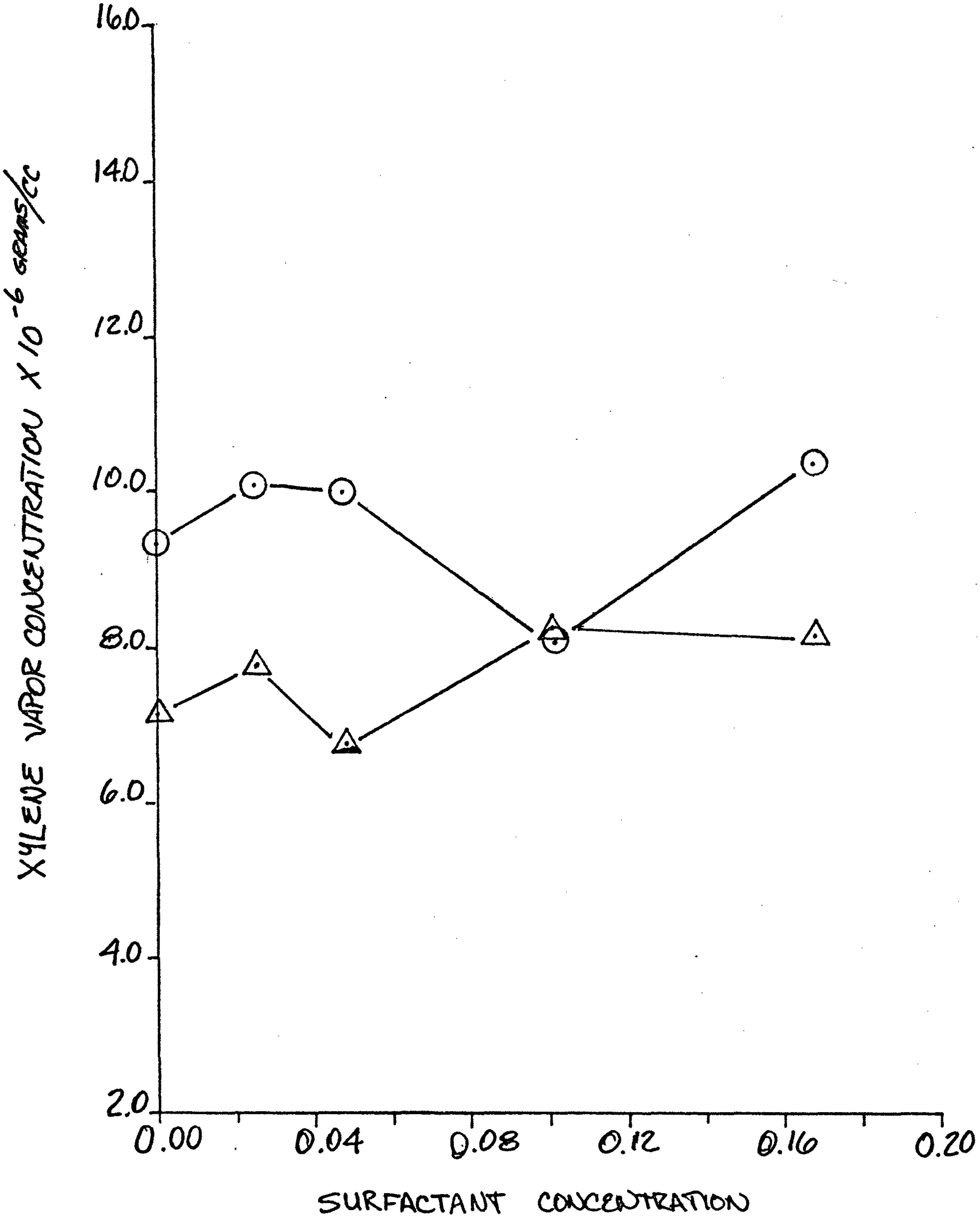


FIGURE 123

SURFACTANT STEPANTEX WB-42

○ 19ml WATER & 1ml XYLENE

△ 19.5ml WATER & 0.5ml XYLENE

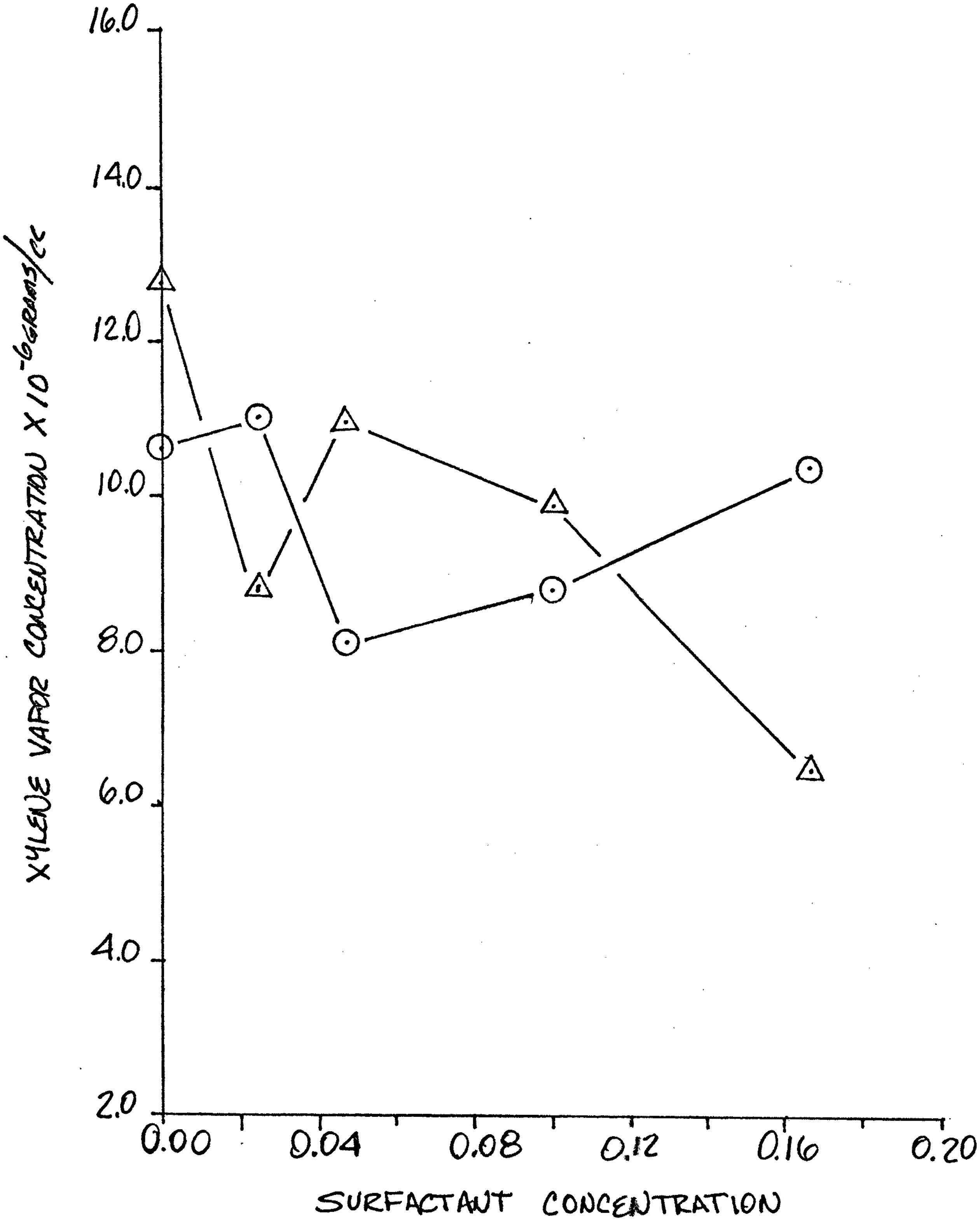


FIGURE 124

SURFACTANT TOXIMUL R

○ 19ml WATER & 1ml XYLENE
△ 195ml WATER & 0.5ml XYLENE

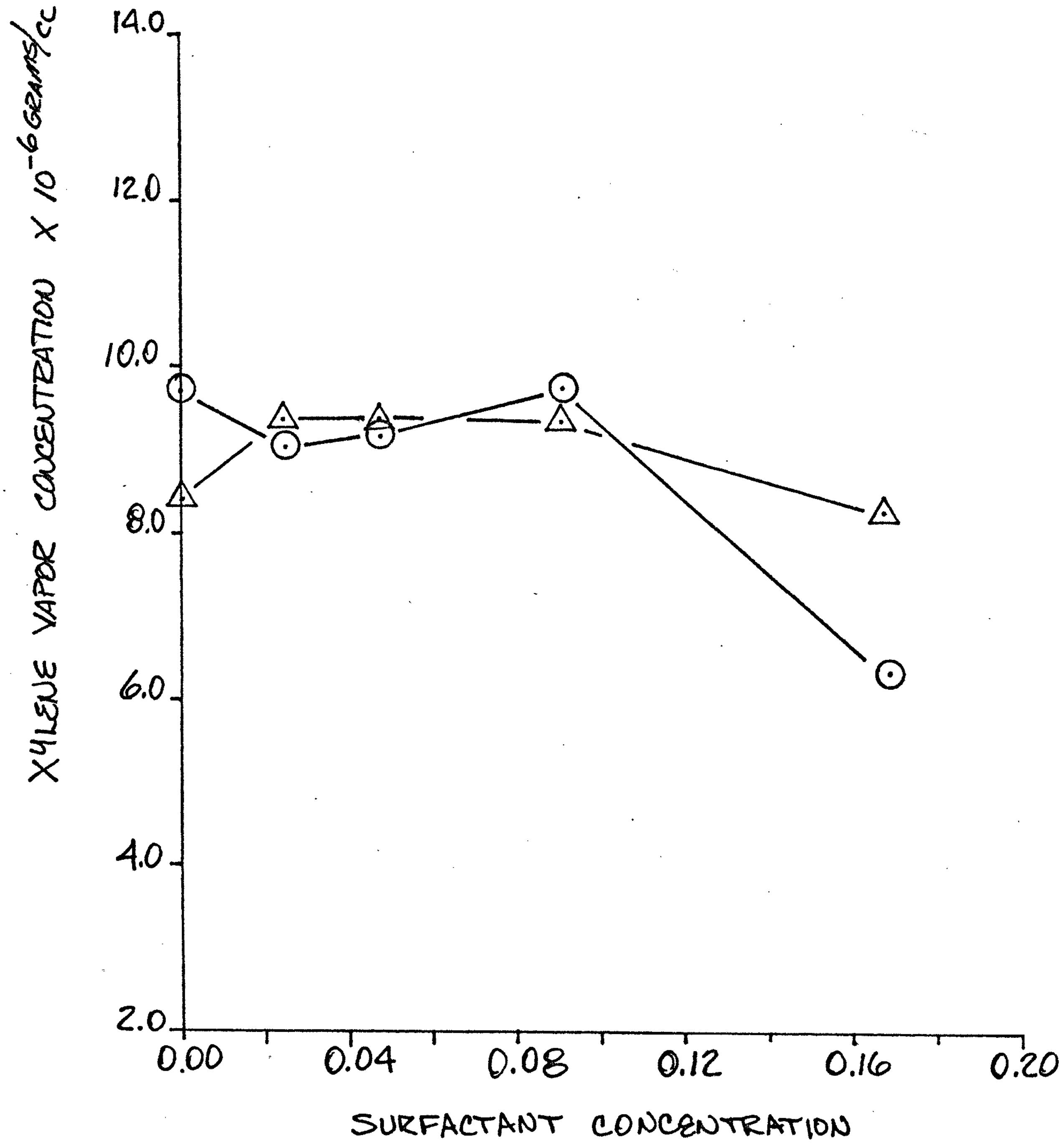


FIGURE 125

SURFACTANT STEPANTEX DA-52

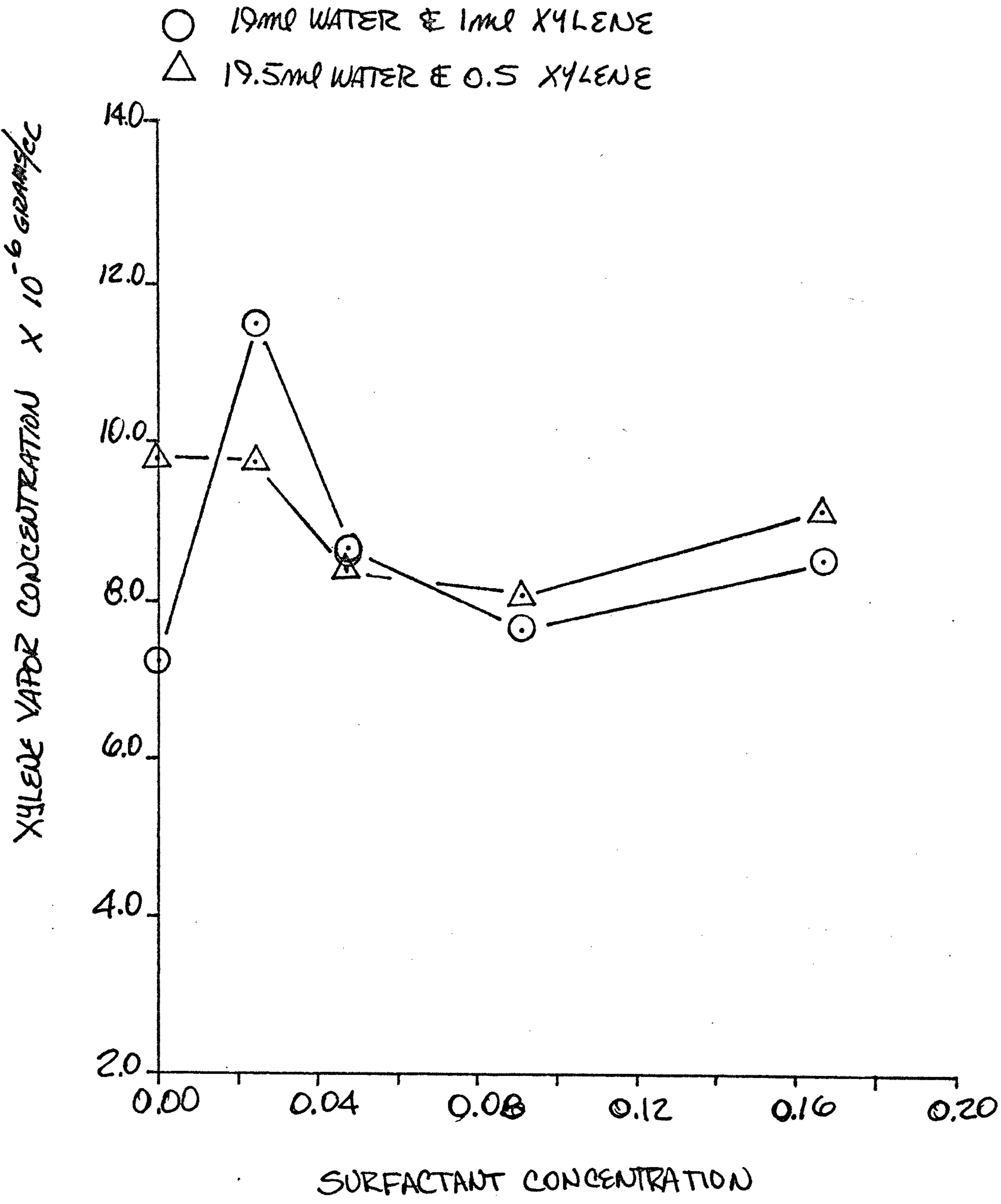


FIGURE 126

SURFACTANT NINATE 401

○ 19ml WATER & 1ml XYLENE

△ 19.5ml WATER & 0.5ml XYLENE

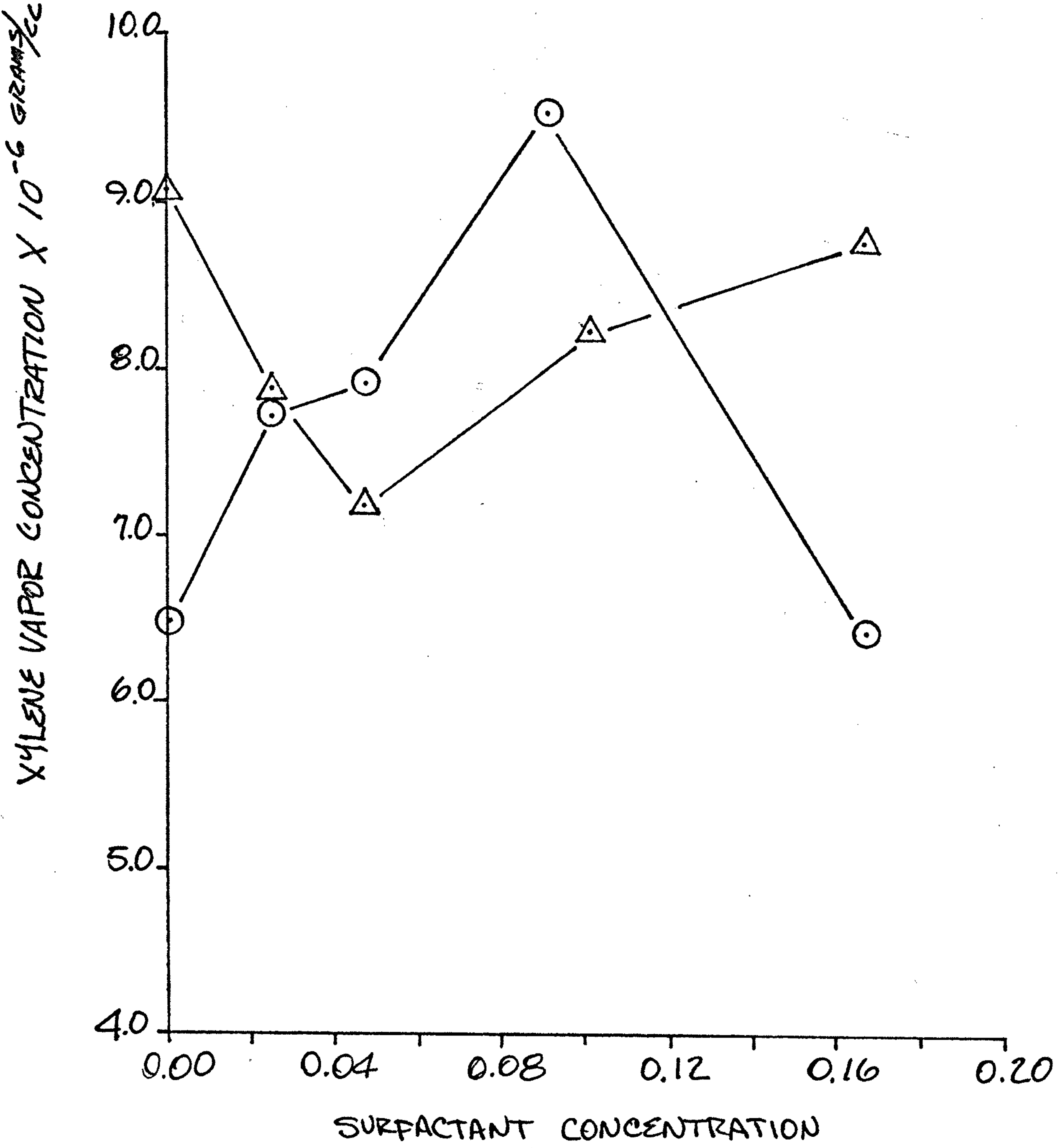
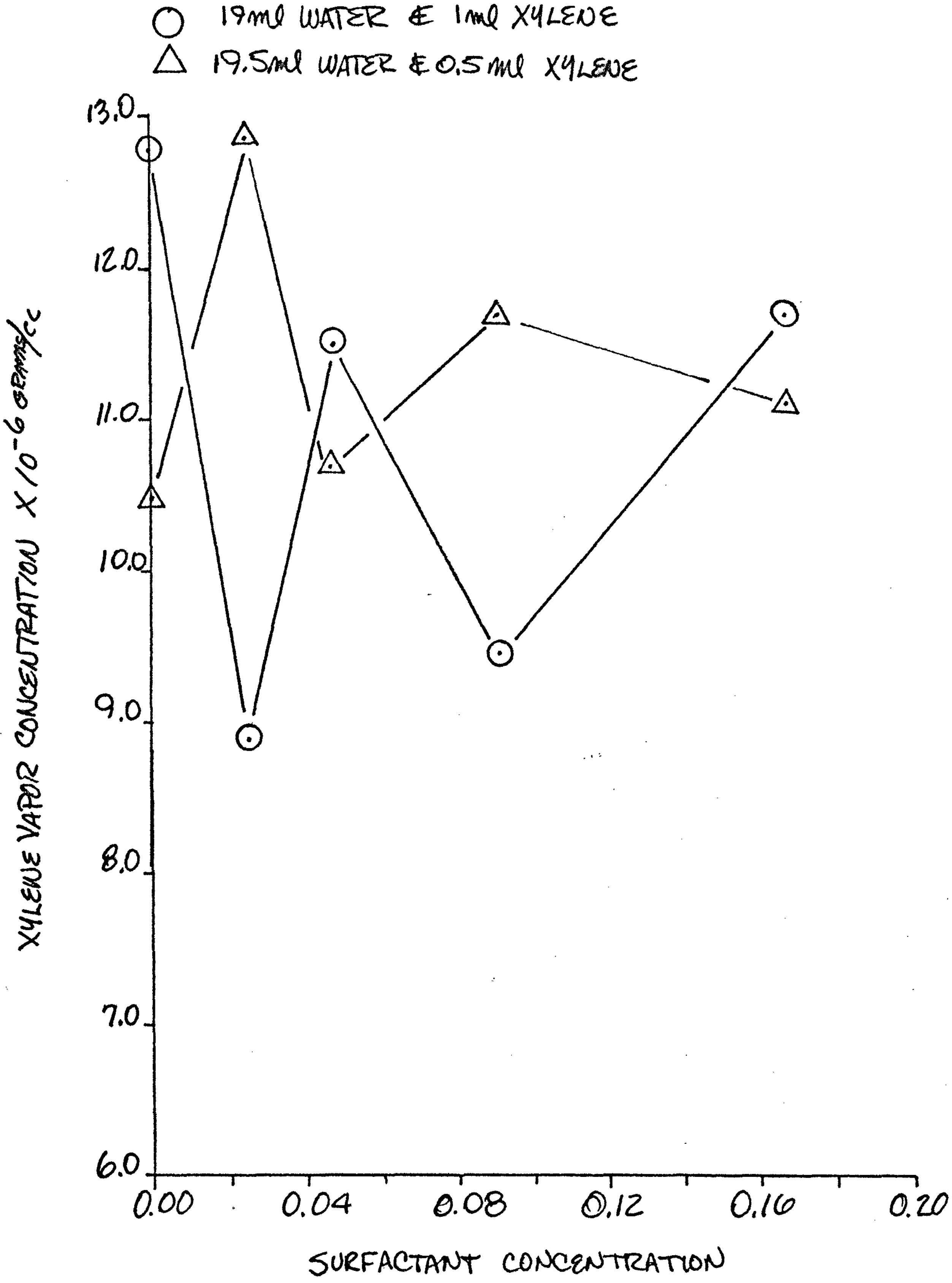


FIGURE 127

SURFACTANT STEPANATE AM



CHARTS OF ORGANIC RESULTANT SOLUBILITY DIFFERENTIAL

*CHART 100

19.0 ml water--1.0 ml organic**

% surfactant	solubility change (per cent)
2.5	11
4.8	-10
9.2	17

19.5 ml water--0.5 ml organic**

% surfactant	
2.5	3
4.8	18
9.2	12

---

*For further data refer to Table or Figure with corresponding number

**Xylene

*CHART 101

19.0 ml water--1.0 ml organic**	solubility change (per cent)
% surfactant	
2.5	-6
4.8	-26
9.2	-7

19.5 ml water--0.5 ml organic**	
% surfactant	
2.5	6
4.8	4
9.2	-1.5

*For further data refer to Table or Figure with corresponding number

**Xylene

*CHART 102

19.0 ml water--1.0 ml organic**	solubility change (per cent)
% surfactant	
2.5	-11.5
4.8	-34
9.2	-42

19.5 ml water--0.5 ml organic**	
% surfactant	
2.5	-28
4.8	-15
9.2	-15

*For further data refer to Table or Figure with corresponding number

**Xylene

*CHART 103

19.0 ml water--1.0 ml organic** % surfactant	solubility change (per cent)
2.5	32
4.8	18
9.2	14

19.5 ml water--0.5 ml organic** % surfactant	
2.5	5
4.8	39
9.2	15

*For further data refer to Table or Figure with corresponding number

**Xylene

*CHART 104

19.0 ml water--1.0 ml organic**

% surfactant	solubility change (per cent)
2.4	6
4.6	-38
8.8	-57
16.2	-38

19.5 ml water--0.5 ml organic**

% surfactant	
2.4	-64
4.6	-67
8.8	-92
16.2	-51

---

*For further data refer to Table or Figure with corresponding number

**CCl_4

*CHART 105

19.0 ml water--1.0 ml organic**	solubility change (per cent)
% surfactant	
2.4	66
4.6	23
8.8	19
16.2	-11

19.5 ml water--0.5 ml organic**	
% surfactant	
2.4	30
4.6	7
8.8	- 3
16.2	-22

*For further data refer to Table or Figure with corresponding number

**CCl_4

*CHART 106

19.0 ml water--1.0 ml organic** % surfactant	solubility change (per cent)
2.4	- 1
4.6	6
8.8	16
16.2	21

19.5 ml water--0.5 ml organic** % surfactant	
2.4	19
4.6	15
8.8	25
16.2	11

*For further data refer to Table or Figure with corresponding number

**CCl_4

*CHART 107

19.0 ml water--1.0 ml organic**	solubility change (per cent)
% surfactant	
2.4	-35
4.6	-60
8.8	-55
16.2	-37

19.5 ml water--0.5 ml organic**	
% surfactant	
2.4	-11
4.6	-13
8.8	-16
16.2	- 4

*For further data refer to Table or Figure with corresponding number

**CCl_4

*CHART 108

<u>19.0 ml water--1.0 ml organic</u>**	solubility change (per cent)
% surfactant	
2.5	- 7
4.8	- 4
9.2	39

<u>19.5 ml water--0.5 ml organic</u>**	
% surfactant	
2.5	1
4.8	12
9.2	18

*For further data refer to Table or Figure with corresponding number

**Toluene

*CHART 109

<u>19.0 ml water--1.0 ml organic</u>** % surfactant	solubility change (per cent)
2.5	- 2
4.8	-12
9.2	-18

<u>19.5 ml water--0.5 ml organic</u>** % surfactant	
2.5	- 2
4.8	4
9.2	0

*For further data refer to Table or Figure with corresponding number

**Toluene

*CHART 110

19.0 ml water--1.0 ml organic**	solubility change (per cent)
% surfactant	
2.5	-23
4.8	-10
9.2	- 6

19.5 ml water--0.5 ml organic**	
% surfactant	
2.5	34
4.8	2
9.2	22

*For further data refer to Table or Figure with corresponding number

**Toluene

*CHART 111

19.0 ml water--1.0 ml organic** % surfactant	solubility change (per cent)
2.5	13
4.8	-14
9.2	43

19.5 ml water--0.5 ml organic** % surfactant	
2.5	-13
4.8	-13
9.2	21

*For further data refer to Table or Figure with corresponding number

**Toluene

*CHART 112

<u>19.0 ml water--1.0 ml organic</u>** % surfactant	solubility change (per cent)
2.5	- 9
4.8	-20
9.6	55
16.7	20

<u>19.5 ml water--0.5 ml organic</u>** % surfactant	
2.5	-22
4.8	-41
9.6	23
16.7	-55

*For further data refer to Table or Figure with corresponding number

**Ethyl Acetate

*CHART 113

19.0 ml water--1.0 ml organic** % surfactant	solubility change (per cent)
2.5	23
4.8	39
9.6	34
16.7	43

19.5 ml water--0.5 ml organic** % surfactant	
2.5	11
4.8	- 1
9.6	1
16.7	45

*For further data refer to Table or Figure with corresponding number

** Ethyl Acetate

*CHART 114

19.0 ml water--1.0 ml organic**

% surfactant	solubility change (per cent)
2.5	-29
4.8	-23
9.6	-24
16.7	1

19.5 ml water--0.5 ml organic**

% surfactant	
2.5	32
4.8	24
9.6	33
16.7	40

---

*For further data refer to Table or Figure with corresponding number

**Ethyl Acetate

*CHART 115

<u>19.0 ml water--1.0 ml organic</u>** % surfactant	solubility change (per cent)
2.5	3
4.8	14
9.6	17
16.7	18

<u>19.5 ml water--0.5 ml organic</u>** % surfactant	
2.5	20
4.8	21
9.6	15
16.7	46

---

*For further data refer to Table or Figure with corresponding number

**Ethyl Acetate

*CHART 116

19.0 ml water--1.0 ml organic** % surfactant	solubility change (per cent)
2.5	15
4.8	- 2
9.2	18
16.8	5

19.5 ml water--0.5 ml organic** % surfactant	
2.5	2
4.8	88
9.2	53
16.8	87

*For further data refer to Table or Figure with corresponding number

**Isopropyl Alcohol

*CHART 117

19.0 ml water--1.0 ml organic** % surfactant	solubility change (per cent)
2.5	12
4.8	- 9
9.2	-15
16.8	8

19.5 ml water--0.5 ml organic** % surfactant	
2.5	50
4.8	27
9.2	13
16.8	46

*For further data refer to Table or Figure with corresponding number

**Isopropyl Alcohol

*CHART 118

19.0 ml water--1.0 ml organic** % surfactant	solubility change (per cent)
2.5	24
4.8	6
9.2	25
16.8	12

19.5 ml water--0.5 ml organic** % surfactant	
2.5	0
4.8	-
9.2	-95
16.8	-90

*For further data refer to Table or Figure with corresponding number

**Isopropyl Alcohol

*CHART 119

19.0 ml water--1.0 ml organic**

% surfactant	solubility change (per cent)
2.5	48
4,8	7
9.2	33
16.8	15

19.5 ml water--0.5 ml organic**

% surfactant	
2.5	-15
4.8	5
9.2	50
16.8	-42

*For further data refer to Table or Figure with corresponding number

**Isopropyl Alcohol

*CHART 120

19.0 ml water--1.0 ml organic** % surfactant	solubility change (per cent)
2.5	-70
4.8	-45
9.1	-49
16.7	-65

19.5 ml water--0.5 ml organic** % surfactant	
2.5	- 7
4.8	16
9.1	-13
16.7	-31

*For further data refer to Table or Figure with corresponding number

**Xylene

*CHART 121

<u>19.0 ml water--1.0 ml organic</u>**	solubility change (per cent)
% surfactant	
2.5	-69
4.8	-22
9.1	-35
16.7	-40

<u>19.5 ml water--0.5 ml organic</u>**	
% surfactant	
2.5	-18
4.8	-87
9.1	-42
16.7	-79

*For further data refer to Table or Figure with corresponding number

**Xylene

*CHART 122

19.0 ml water--1.0 ml organic** % surfactant	solubility change (per cent)
2.5	- 8
4.8	- 7
9.2	14
16.7	-11

19.5 ml water--0.5 ml organic** % surfactant	
2.5	- 9
4.8	5
9.1	-16
16.7	-15

*For further data refer to Table or Figure with corresponding number

**Xylene

*CHART 123

19.0 ml water--1.0 ml organic**	solubility change (per cent)
% surfactant	
2.5	- 3
4.8	24
9.1	17
16.7	2
19.5 ml water--0.5 ml organic**	
% surfactant	
2.5	31
4.8	14
9.1	23
16.7	49

*For further data refer to Table or Figure with corresponding number

**Xylene

*CHART 124

19.0 ml water--1.0 ml organic**

% surfactant	solubility change (per cent)
2.5	7
4.8	6
9.1	0
16.7	36

19.5 ml water--0.5 ml organic**

% surfactant	
2.5	-11
4.8	-11
9.1	-10
16.7	2

*For further data refer to Table or Figure with corresponding number

**Xylene

*CHART 125

19.0 ml water--1.0 ml organic** % surfactant	solubility change (per cent)
2.5	-59
4.8	-19
9.1	- 6
16.7	-18

19.5 ml water--0.5 ml organic** % surfactant	
2.5	0
4.8	14
9.1	18
16.7	7

*For further data refer to Table or Figure with corresponding number

**Xylene

*CHART 126

<u>19.0 ml water--1.0 ml organic</u>** % surfactant	solubility change (per cent)
2.5	-19
4.8	-22
9.1	-47
16.7	1

<u>19.5 ml water--0.5 ml organic</u>** % surfactant	
2.5	13
4.8	21
9.1	10
16.7	4

*For further data refer to Table or Figure with corresponding number

**Xylene

*CHART 127

19.0 ml water--1.0 ml organic**

% surfactant	solubility change (per cent)
2.5	31
4.8	10
9.1	26
16.7	9

19.5 ml water--0.5 ml organic**

% surfactant	
2.5	-23
4.8	- 2
9.1	-11
16.7	- 6

*For further data refer to Table or Figure with corresponding number

**Xylene