Appendix 5
CONDEA Vista Company:
Surface Tension Methods and Data

Contents:

1) Letter from D. Smith to J. Al-Atrash, dated October 28, 1994 (two pages).
2) Letter from D. Smith to J.E. Heinze, dated March 11, 1997 (one page).

Appendix 7
SensaDyne Instrument Division:
Dynamic Surface Tension Methods and Data

Contents:

1) Report: "Physical & Chemical Properties of Nonionic Surfactants, Surface Tension Study" - HWI# 6310-105.
2) Fax from T.C. Christensen to J. Al-Atrash, dated March 2, 1995 (three pages).
3) Fax from T.C. Christensen to J. Al-Atrash, dated March 21, 1995 (15 pages).
4) Fax from T.C. Christensen to J.E. Heinze, dated March 11, 1996 (one page).
5) Product brochure: "Surface Tensiomters" (eight pages).
6) Product brochure: "PC9000" (one page).
7) Presentation: S.M. Hosseini, "Dynamic Surface Property Measurement of Aqueous Surfactant Solutions," American Chemical Society, Northeast Regional Meeting, June 1992 (22 pages).
8) Presentation: V.P. Janule, "Three Dimensional Characterization of Active Surfactants," The Fine Particle Society, 23rd Annual Meeting, July 1992 (12 pages).

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Appendix 5

October 28, 1994

VISTA

Dr. Jenan Al-Atrash
The Soaps and Detergent Association
475 Park Avenue South
New York, NY 10016

Dear Dr. Al-Atrash:

I have completed measuring the surface tension of the eleven samples I received from Hazelton Laboratory. These samples are part of the study of "Primary Eye Irritation of Nonionic Surfactants in Rabbits (Low Volume Procedure)". The measurements were made on samples as received unless otherwise indicated. All measurements were at 25 C.

Sample	Surface Tension (dynes/cm)
Brij® 35	41.39
Lauramine Oxide pH = 10.5	32.54
Lauramine Oxide pH = 7	31.92
Neodol® 23-6.5	27.46
Neodol® 23-3	25.56
ALFONIC® 810-5	26.43
ALFONIC® 1412-7	28.29
Triton® N101	31.33
Tween® 85[1]	32.81
Cocamide DEA[1]	26.79
Glucopon 625CS [1]	28.63

[1] Because of high viscosity, these samples were diluted 1:3 with deionized water prior to measurement.

The dilution of the last three samples was done by adding 15 ml of as received sample to 45 ml of DI water. This gave a solution sufficiently fluid to measure the surface tension. This procedure is valid only if dilution does not change the surface tension (concentration remains above the cmc). To test the validity of this procedure a further dilution of 5 ml of DI water was added to each of the last three solutions and the surface

SUMMARY

SAMPLE PREPARATION

A graduated beaker was carefully filled to the 100ml mark. Surfactant was then added with a 0-0.5ml (0-500 microliter syringe graduated in 10 microliter graduations) in increments of 0.4ml (400 microliters) and mixed for a minimum of 30 seconds.

TESTING PROCEDURE

After mixing for a minimum of 30 seconds, probes were placed in the sample and a reading was recorded after the values had stabilized. The sample was then removed and re-mixed. At this time the test probes were cleaned. After the sample was re-mixed, a second reading was recorded. This procedure was repeated for each sample in increments of 0.4ml until the surface tension readings no longer changed (no further lowering of surface tension was evident.) This criteria accounts for the difference in maximum surfactant levels used.

CALIBRATION

Each of the 11 samples was tested over 4 bubble rates to generate a dynamic curve. Prior to each of the 4 testing runs the instrument was set at a predetermined bubble rate (Bubbles per Second) in water and calibrated. Calibration was done with de-ionized water and Spectrum Chemical Mfg. Corp. ET107 Ethyl Alcohol, anhydrous, 200 Proof. The calibration was then rechecked for accuracy prior to each new sample being tested at that rate. Calibration values can be found in Section 2, Sample Group 1 at the beginning of each data set.

POSSIBLE ERRORS

For all samples tested our results were repeatable on consecutive tests within 0.10 dynes/cm at the time of testing. Estimated error in adding surfactant is estimated to be within $\pm$ 5 microliters. In some of the samples tiny bubbles were evident that undoubtedly caused measurement error (ratio of bubbles to liquid is unknown).

TEMPERATURE ADJUSTMENTS

Temperature is known to effect surface tension inversely. The temperatures of the test samples varied slightly over the range of the tests. Although this variation is not believed to have a significant effect on the results of these tests the following correction factor may be used if necessary. Surface tension will increase 0.15 dynes/cm for every 1.0 °C decrease in temperature.

MEAN AND STANDARD DEVIATION

Since the repeatability of all tests was within $\pm$0.10 dynes/cm. The Mean will equal the value itself, if no change occurred during the second test.. If a difference was noted, the mean will equal the first value $\pm$0.05 dynes/cm. Based on this, Maximum Standard Deviation will also be equal to $\pm$0.05 dynes/cm. Minimum Standard Deviation is equal to $\pm$0.0 dynes/cm.

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SensaDyne Instrument Div.

Chem-Dyne Research Corp.

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Physical & Chemical Properties of Nonionic Surfactants
Surface Tension Study - HWI# 6310-105

1	SAMPLE GROUP 8
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1	SUMMARY
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8	SAMPLE GROUP 7

SURFACE AGE

Bubble interval consists of 2 time elements, Surface Age and "Dead Time". Bubble Interval is the time between bubbles. Surface Age, however, is only the time between the beginning of the bubble formation to the maximum bubble pressure point, at which the bubble releases. The difference between the two is the amount of time it takes to fill the void created by the departing bubble, before the pressure builds up from the orifice to the start of new bubble generation. As Bubble Interval decreases this "Dead Time" becomes a greater percentage of the Bubble Interval.

GENERAL COMMENTS

All tests were repeatable within 0.10 dynes/cm at the time of testing. Resulting dynamic curve and Critical Micelle Concentration (CMC) graphs appeared accurate within measurement error. 3-Dimensional Graphs depicting dynamic characteristics were run on FOXGRAPH®, This program provides an axis for bubble rate that is not to scale. Graphs related to CMC's were run on PSPLOT®.

REPORT CONTENTS

Each subsequent section of this report contains the following information on a single sample in the following order:

1. **Data Points** for:
   - Surface Tension
   - Temperature
   - Bubble Rate (Bubbles per Second - B/S)
   - Bubble Interval
   - Surface Age
2. **Equilibrium Surface Tension Values and respective Bubble Rates**
3. **Dynamic Surface Tension Characteristics Graphs** - (Surface Tension vs. Concentration vs. Bubble Rate)
4. **Single Line CMC Graph** - (Surface Tension vs. Logarithmic Concentration in Moles per 100ml H2O vs. Bubble rate in Bubbles per Second.)
5. **Multiple Line CMC Graph** - Showing the shift in CMC curves as a result of Dynamic Surface Tension.

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Foxgraph is a registered trade mark of Fox Software Inc.
®
PSPLOT is a registered trade mark of Polysoft Ltd.

SLOWEST RATE - Aproximately .10 bubbles per second

Calibration H2O - 72.7d/cm 21.5*C .10 b/s
Alc. - 22.2 d/cm 22.1*C

SAMPLE GROUP 1: HWI: 6310-105
Test Material: A 12-13 EO 6.5 (Neodol 23-6.5)

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.7	21.5	.10	10	9.90
.4ml	TEST A	35.5	21.5	.33	3.03	2.81
	TEST B	35.5	21.5	.33	3.03	2.81
.8ml	TEST A	31.0	21.5	.33	3.03	2.81
	TEST B	31.0	21.5	.33	3.03	2.81
1.2ml	TEST A	29.9	21.5	.31	3.22	3.02
	TEST B	29.8	21.6	.31	3.22	3.02
1.6ml	TEST A	29.2	21.6	.33	3.03	2.81
	TEST B	29.2	21.6	.33	3.03	2.81
2.0ml	TEST A	28.9	21.6	.33	3.03	2.81
	TEST B	28.9	21.6	.33	3.03	2.81
2.4ml	TEST A	28.8	21.7	.30	3.33	3.16
	TEST B	28.8	21.7	.31	3.22	3.02
2.8ml	TEST A	28.7	21.7	.29	3.45	3.27
	TEST B	28.7	21.7	.30	3.33	3.16
3.2ml	TEST A	28.6	21.8	.30	3.33	3.16
	TEST B	28.6	21.8	.31	3.22	3.02
3.6ml	TEST A	28.5	21.9	.30	3.33	3.16
	TEST B	28.5	21.9	.29	3.45	3.27
4.0ml	TEST A	28.4	21.9	.29	3.45	3.27
	TEST B	28.4	22.0	.29	3.45	3.27
4.4ml	TEST A	28.4	22.0	.30	3.33	3.16
	TEST B	28.4	22.0	.30	3.33	3.16
4.8ml	TEST A	28.4	22.0	.29	3.45	3.27
	TEST B	28.4	22.0	.29	3.45	3.27

SLOW BUBBLE RATE - CALIBRATION (Aproximately .24 bubbles per second)

	d/cm	*C	b/s
H2O	**72.8**	**20.1**	**.24**
Alc.	**22.3**	**20.9**	

SAMPLE GROUP 1

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml additive	TEST A	72.8	20.1	.24	4.16 sec.	3.95
.4ml additive	TEST A	37.2	21.1	.52	1.92 sec.	1.75
	TEST B	37.2	21.1	.52	1.92 sec.	1.75
.8ml additive	TEST A	32.6	21.5	.52	1.92 sec.	1.75
	TEST B	32.6	21.5	.52	1.92 sec	1.75
.12ml additive	TEST A	30.1	21.7	.53	1.88 sec.	1.71
	TEST B	30.2	21.7	.53	1.88 sec.	1.71
1.6ml Additive	TEST A	29.6	21.8	.52	1.92 sec.	1.75
	TEST B	29.6	21.8	.52	1.92 sec.	1.75
2.0ml additive	TEST A	29.2	21.8	.50	2.00 sec.	1.82
	TEST B	29.2	21.8	.50	2.00 sec	1.82
2.4ml additive	TEST A	29.0	21.9	.49	2.04 sec.	1.87
	TEST B	28.9	21.9	.49	2.04 sec.	1.87
2.8ml additive	TEST A	28.8	22.0	.49	2.04 sec.	1.87
	TEST B	28.8	22.0	.49	2.04 sec.	1.87
3.2ml additive	TEST A	28.6	22.0	.49	2.04 sec.	1.87
	TEST B	28.6	22.0	.49	2.04 sec.	1.87
3.6ml additive	TEST A	28.5	22.1	.49	2.04 sec.	1.87
	TEST B	28.5	22.1	.49	2.04 sec.	1.87
4.0ml additive	TEST A	28.4	22.2	.49	2.04 sec.	1.87
	TEST B	28.4	22.2	.49	2.04 sec.	1.87
4.4ml additive	TEST A	28.3	22.1	.49	2.04 sec.	1.87
	TEST B	28.3	22.1	.49	2.04 sec.	1.87
4.8ml additive	TEST A	28.2	22.2	.49	2.04 sec.	1.87
	TEST B	28.2	22.2	.49	2.04 sec.	1.87
5.2ml additive	TEST A	28.2	22.2	.49	2.04 sec.	1.87
	TEST B	28.2	22.2	.49	2.04 sec.	1.87

MEDIUM BUBBLE RATE - aprox 1b/s

CALIBRATION	H2O	72.7d/cm	21.1*C	1.01b/s
	Alc.	22.2	21.8*C	

SAMPLE GROUP 1 - MED RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.7	21.1	1.01	.99	.86
.4ml	TEST A	45.4	21.2	1.96	.51	.42
	TEST B	45.4	21.2	1.96	.51	.42
.8ml	TEST A	38.4	21.2	1.94	.51	.42
	TEST B	38.4	21.2	1.96	.51	.42
1.2ml	TEST A	35.7	21.2	2.04	.49	.41
	TEST B	35.7	21.2	2.05	.49	.41
1.6ml	TEST A	34.6	21.2	2.07	.48	.39
	TEST B	34.6	21.2	2.06	.48	.39
2.0ml	TEST A	33.5	21.2	2.07	.48	.39
	TEST B	33.5	21.2	2.07	.48	.39
2.4ml	TEST A	33.0	21.3	2.07	.48	.39
	TEST B	33.0	21.3	2.07	.48	.39
2.8ml	TEST A	32.7	21.3	2.15	.47	.38
	TEST B	32.7	21.3	2.11	.47	.38
3.2ml	TEST A	32.4	21.4	2.14	.47	.38
	TEST B	32.4	21.4	2.13	.47	.38
3.6ml	TEST A	32.2	21.4	2.14	.47	.38
	TEST B	32.2	21.4	2.16	.46	.37
4.0ml	TEST A	32.1	21.5	2.16	.46	.37
	TEST B	32.1	21.5	2.16	.46	.37
4.4ml	TEST A	32.0	21.5	2.17	.46	.37
	TEST B	32.0	21.5	2.16	.46	.37
4.8ml	TEST A	31.9	21.5	2.17	.46	.37
	TEST B	31.9	21.5	2.19	.46	.37
5.2ml	TEST A	31.8	21.5	2.19	.46	.37
	TEST B	31.8	21.5	2.19	.46	.37
5.6ml	TEST A	31.7	21.6	2.19	.46	.37
	TEST B	31.7	21.6	2.19	.46	.37
6.0ml	TEST A	31.6	21.6	2.22	.45	.36
	TEST B	31.6	21.6	2.19	.46	.37
6.4ml	TEST A	31.5	21.6	2.20	.45	.36
	TEST B	31.5	21.6	2.19	.46	.37
6.8ml	TEST A	31.4	21.6	2.19	.46	.37
	TEST B	31.4	21.6	2.19	.46	.37
7.2ml	TEST A	31.4	21.6	2.20	.45	.36
	TEST B	31.4	21.7	2.17	.46	.37
7.6ml	TEST A	31.3	21.7	2.19	.46	.37
	TEST B	31.3	21.7	2.17	.46	.37
8.0ml	TEST A	31.3	21.7	2.19	.46	.37
	TEST B	31.3	21.7	2.19	.46	.37
8.4ml	TEST A	31.3	21.7	2.17	.46	.37
	TEST B	31.3	21.7	2.17	.46	.37
8.8ml	TEST A	31.2	21.7	2.17	.46	.37
	TEST B	31.2	21.7	2.17	.46	.37
9.2ml	TEST A	31.2	21.7	2.19	.46	.37
	TEST B	31.2	21.7	2.19	.46	.37

FAST BUBBLE RATE Aprox. 4b/s

CALIBRATION		**H2O**	**72.7d/cm**	**21.0*C**	**4.33b/s**
	Alc	**22.3d/cm**	**21.1**		

SAMPLE GROUP 1

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.8	21.0	4.33	.23	.14
.4ml	TEST A	59.0	20.9	5.49	.18	.10
	TEST B	58.9	20.9	5.50	.18	.10
.8ml	TEST A	51.2	20.9	6.06	.17	.09
	TEST B	51.3	20.9	6.06	.17	.09
1.2ml	TEST A	47.4	21.0	6.29	.16	.08
	TEST B	47.4	21.0	6.29	.16	.08
1.6ml	TEST A	44.8	21.0	6.50	.15	.08
	TEST B	44.8	21.0	6.49	.15	.08
2.0ml	TEST A	43.0	21.1	6.75	.15	.08
	TEST B	43.0	21.1	6.75	.15	.08
2.4ml	TEST A	41.8	21.1	6.98	.14	.07
	TEST B	41.8	21.1	6.98	.14	.07
2.8ml	TEST A	40.8	21.1	6.98	.14	.07
	TEST B	40.7	21.1	6.98	.14	.07
3.2ml	TEST A	40.1	21.1	6.99	.14	.07
	TEST B	40.1	21.1	6.99	.14	.07
3.6ml	TEST A	39.5	21.2	6.98	.14	.07
	TEST B	39.5	21.2	6.99	.14	.07
4.0ml	TEST A	39.1	21.2	7.29	.14	.07
	TEST B	39.1	21.2	7.29	.14	.07
4.4ml	TEST A	38.7	21.2	7.29	.14	.07
	TEST B	38.7	21.2	7.29	.14	.07
4.8ml	TEST A	38.5	21.2	7.31	.13	.06
	TEST B	38.5	21.2	7.29	.14	.07
5.2ml	TEST A	38.4	21.2	7.29	.14	.07
	TEST B	38.3	21.2	7.29	.14	.07
5.6ml	TEST A	38.1	21.2	7.29	.14	.07
	TEST B	38.2	21.2	7.29	.14	.07
6.0ml	TEST A	38.0	21.2	7.25	.14	.07
	TEST B	37.9	21.2	7.29	.14	.07
6.4ml	TEST A	37.7	21.2	7.25	.14	.07
	TEST B	37.7	21.2	7.29	.14	.07
6.8ml	TEST A	37.5	21.2	7.29	.14	.07
	TEST B	37.5	21.2	7.29	.14	.07
7.2ml	TEST A	37.3	21.2	7.29	.14	.07
	TEST B	37.3	21.3	7.29	.14	.07
7.6ml	TEST A	37.1	21.3	7.29	.14	.07
	TEST B	37.1	21.3	7.25	.14	.07
8.0ml	TEST A	37.0	21.3	7.29	.14	.07
	TEST B	36.9	21.3	7.29	.14	.07
8.4ml	TEST A	36.8	21.3	7.29	.14	.07
	TEST B	36.9	21.3	7.25	.14	.07
8.8ml	TEST A	36.8	21.3	7.31	.15	.08
	TEST B	36.7	21.3	7.29	.14	.07
9.2ml	TEST A	36.7	21.3	7.31	.15	.08
	TEST B	36.6	21.3	7.29	.14	.07

Sample Group 1 - Fast Rate Continued

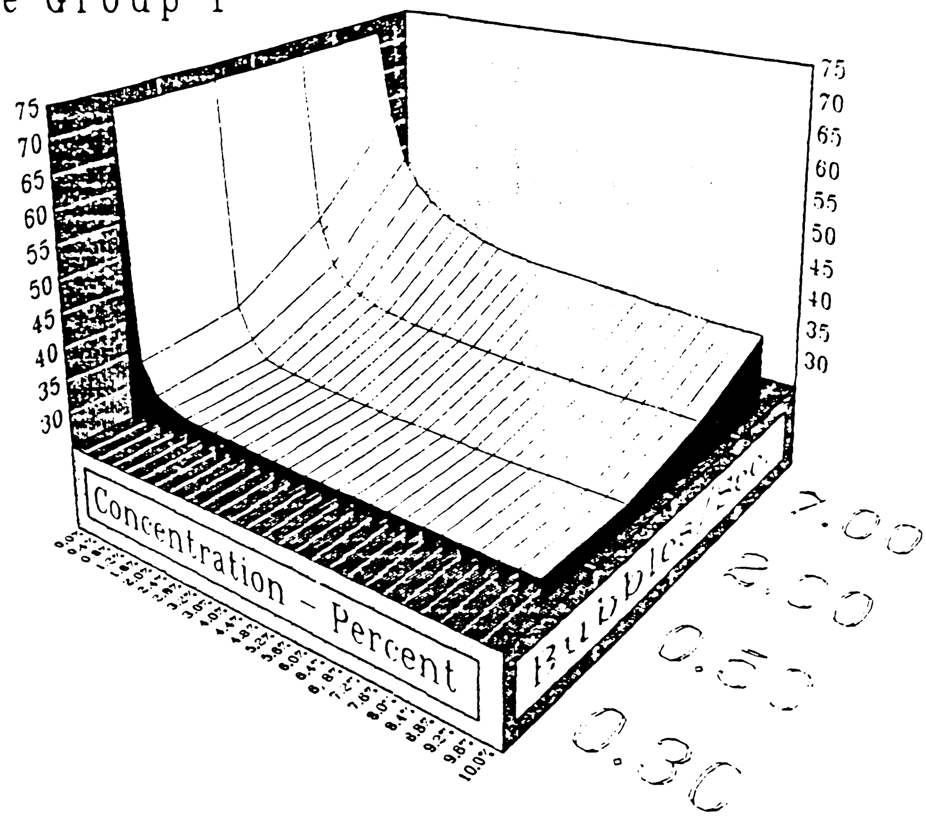
9.6ml	TEST A	36.6	21.3	7.29	.14	.07
	TEST B	36.6	21.3	7.29	.14	.07
10.0ml	TEST A	36.6	21.4	7.29	.14	.07
	TEST B	36.6	21.4	7.29	.14	.07

EQUILIBRIUM SURFACE TENSIONS

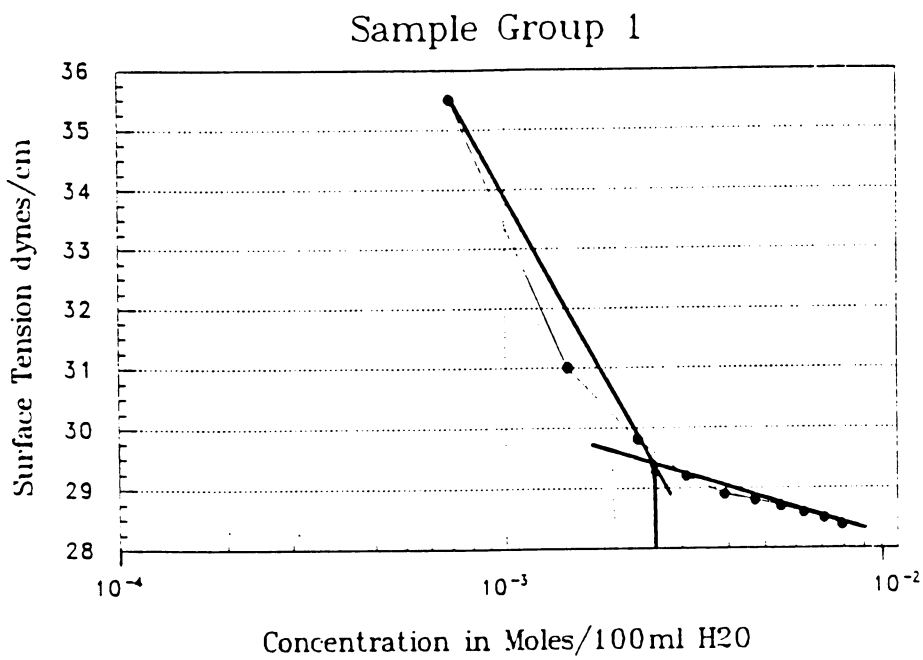
SAMPLE GROUP 1

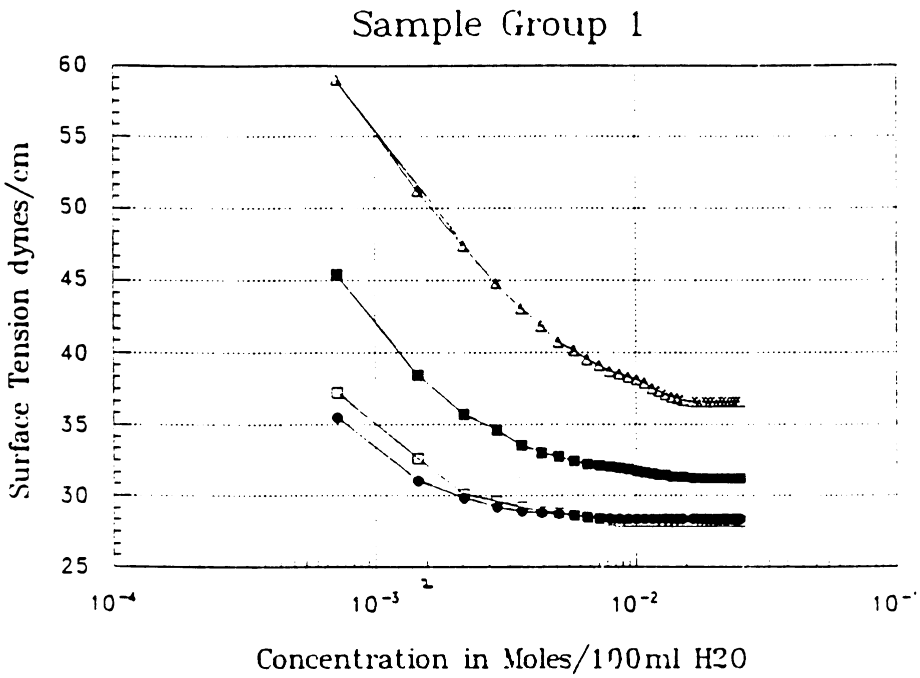
CONCEN.	SURF. TEN.	B/SEC.
.4ml	35.5 d/cm	.33
.8ml	31.0 d/cm	.33
1.2ml	29.8 d/cm	.31
1.6ml	29.2 d/cm	.33
2.0ml	28.9 d/cm	.33
2.4ml	28.8 d/cm	.33
2.8ml	28.7 d/cm	.30
3.2ml	28.6 d/cm	.30
3.6ml	28.5 d/cm	.29
4.0ml	28.4 d/xm	.29
4.4ml	28.4 d/cm	.29
4.8ml	28.4 d/cm	.29

Sample Group 1



Dynamic Surface Tension Graph


Sample Group 1
36
35
34
33
32
31
30
29
28
Surface Tension dynes/cm
10^{-4}
10^{-3}
10^{-2}
Concentration in Moles/100ml H20



Sample Group 1
Surface Tension dynes/cm
60
55
50
45
40
35
30
25
10⁻⁴
10⁻³
10⁻²
10⁻¹
Concentration in Moles/100ml H2O

SLOWEST RATE

SAMPLE GROUP 2 - HWI: 6310-105
Test Material: A12-14 EO7 (Alfonic 1412-7)

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.7	21.5	.10	10	9.90
.4ml	TEST A	35.8	21.5	.28	3.57	3.39
	TEST B	35.9	21.5	.29	3.45	3.28
.8ml	TEST A	33.2	21.6	.30	3.33	3.16
	TEST B	33.2	21.6	.30	3.33	3.16
1.2ml	TEST A	31.9	21.6	.30	3.33	3.16
	TEST B	31.9	21.7	.30	3.33	3.16
1.6ml	TEST A	31.2	21.7	.30	3.33	3.16
	TEST B	31.2	21.7	.30	3.33	3.16
2.0ml	TEST A	30.9	21.8	.30	3.33	3.16
	TEST B	31.0	21.8	.30	3.33	3.16
2.4ml	TEST A	30.5	22.0	.30	3.33	3.16
	TEST B	30.5	22.0	.30	3.33	3.16
2.8ml	TEST A	30.2	22.1	.30	3.33	3.16
	TEST B	30.2	22.1	.30	3.33	3.16
3.2ml	TEST A	30.1	22.2	.30	3.33	3.16
	TEST B	30.1	22.2	.30	3.33	3.16
3.6ml	TEST A	30.1	22.2	.30	3.33	3.16
	TEST B	30.1	22.2	.30	3.33	3.16
4.0ml	TEST A	30.1	22.2	.30	3.33	3.16
	TEST B	30.1	22.2	.30	3.33	3.16

Appendix 5
CONDEA Vista Company:
Surface Tension Methods and Data

Contents:

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October 28, 1994

VIST/

Dr. Jenan Al-Atrash
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Lauramine Oxide pH = 10.5	32.54
Lauramine Oxide pH = 7	31.92
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ALFONIC® 1412-7	28.29
Triton® N101	31.33
Tween® 85[(1)]	32.81
Cocamide DEA[(1)]	26.79
Glucopon 625CS [(1)]	28.63

[(1)] Because of high viscosity, these samples were diluted 1:3 with deionized water prior to measurement.

The dilution of the last three samples was done by adding 15 ml of as received sample to 45 ml of DI water. This gave a solution sufficiently fluid to measure the surface tension. This procedure is valid only if dilution does not change the surface tension (concentration remains above the cmc). To test the validity of this procedure a further dilution of 5 ml of DI water was added to each of the last three solutions and the surface tension remeasured. The results are in the next table:

Sample	15ml sample:45 ml water	15 ml sample:50 ml water
Tween 85	32.81	32.97
Cocoamide DEA	26.79	26.70
Glucopon 625CS	28.63	28.30

The agreement of the two values means that the solutions were above the cmc and so even though dilute, the surface tension values obtained are the same as the more concentrated "as received" samples.

Sincerely,

Dewey Smith
Sr. Research Scientist
Surfactants and Specialties Technical Service

cc: John E. Heinze

CONDEA Vista Company
12024 Vista Parke Drive
Austin, Texas 78726-4050
(512) 331-2500

CONDEA VISTA

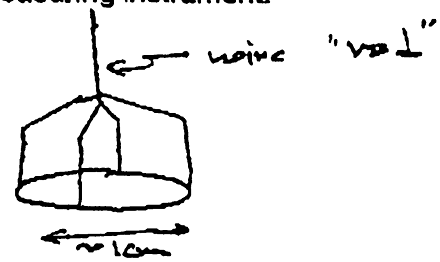
March 11, 1997

Dr. John E. Heinze
7699 Lavenham Landing
Alexandria, VA 22315

Dear John,

I do not have a written procedure other than the manual that explains the method used to measure surface tension. Since the manual is far more detailed that you probably want (which button does what). I will summarize the general method.

The method is described in the literature as the du Nuoy ring method. This is a very old method but has recently been automated. The theory is the same however. The du Nuoy ring we used is made of thin platinum wire and is approximately 1 cm in diameter. The ring is attached to a rod and the rod is used to attach the ring to the measuring instrument.



The measurement proceeds by placing the ring below the interface that is being measured. In the measurements we did for SDA this was an air-water interface so the ring was below the water. The operator then slowly raises the ring by turning a calibrated dial until the ring breaks free of the interface (manual instrument). In the automated version, the ring is automatically pulled through the interface until the maximum pull on the ring is measured. In either case, the force measured, along with the geometry of the ring and the density difference between the interfaces can be used to calculate the surface tension.

I hope this is helpful. If you would like further details, please call me at (512)-331-2447.

Sincerely,

Dewey Smith

Appendix 6
United States Testing Company:
Surface Tension, Interfacial Tension and Contact Angle Methods and Data

Contents:

United States Testing Company, Inc.
1415 Park Avenue • Hoboken, New Jersey 07030 • 201-792-2400 • Fax: 201-792-7607

REPORT OF TEST

January 12, 1995

CLIENT: Soap & Detergent Association
475 Park Avenue South
New York, NY 10016

PROJECT NO: 403518
PRELIMINARY REPORT

Attention: Dr. Jenan Al-Atrash

SUBJECT: Client supplied eleven (11) samples of "non-ionic" surfactant solution.

AUTHORIZATION: Client's letter of March 25, 1994.

PURPOSE: To determine the surface tension, interfacial tension and contact angle of the samples.

TEST DATES: December 12, 1994 to January 10, 1995.

PROCEDURE: The surface tension and interfacial tension were determined in accordance with ASTM D-1331 using a DuNouy Tensiometer. Octyl Alcohol was used for interfacial measurements. Contact angle measurement was made in accordance with ASTM D-724. Teflon (tape) was used as the substrate for making contact angle measurements.

SIGNED FOR THE COMPANY BY

db

S. Venkataraman
Preparer

Lisa Van Savage
Laboratory Manager

Joseph Kwiatkowski
Assistant Vice President

SGS Member of the SGS Group

United States Testing Company, Inc.

CLIENT: Soap & Detergent Association

PROJECT NO: 403518
DATE: 01/12/95
PRELIMINARY REPORT

RESULTS:

Group	Sample	Surface Tension (dynes/cm)	Interfacial Tension (dynes/cm)	Contact Angle (degrees
1	$A_{12-13}EO_{6-5}$ (Neodol 23	26.3 26.5	0.0 0.0	[illegible] 33.7
2	$A_{12-14}EO_{7}$ (Alfonic 1412-7)	27.2 26.6	0.0 0.0	47.0 46.
3	$A_{8-10}EO_{5}$ (Alfonic 810-5)	25.4 24.8	1.5 1.2	32.0 29.
4	$A_{12-13}EO_{3}$ (Neodol 23-3)	[illegible] 25.0	0.0 0.8	[illegible] 11.
5	$A_{12}EO_{23}$ (Brij-35)	[illegible] 38.3	0.8 2.0	87.0 88.
6	Nonylphenol - $EO_{9.5}$ (Triton N101)	[illegible] 29.5	[illegible] 0.0	[illegible] 56.
7	Sorbitan Oleate - EO_{20} (Tween 85)	[illegible] 41.5	6.16 6.2	79.0 85.
8	A_{12-16} - $Glucose_{1.6}$ (Glucopon 625CS)	[illegible] 30.0	1.3 1.1	[illegible] 74.
9	Lauramine Oxide pH 7.0	31.2 30.7	2.6 4.0	39.0 58.
10	Cocamide DEA	29.5 29.5	[illegible] 11.0	67.0 68.
11	Lauramine Oxide pH 10.5	31.4 30.1	4.1 1.6	53.0 35.

NOTE:

1. Group 7 and Group 10 are viscous as compared to the other samples.
2. Though care was taken to eliminate all air bubbles during determinations, Group 10 posed difficulties in complete elimination of air bubbles.
3. Group 2, Group 1 and Group 7 when layered with octonol, indicated formation of white colored substance at the interface.

United States Testing Company, Inc.
1415 Park Avenue • Hoboken, New Jersey 07030 • 201-792-2400 • Fax 201-792-7607

REPORT OF TEST

February 1, 1995

PROJECT NO: 403518

CLIENT: Soap & Detergent Association
475 Park Avenue South
New York, NY 10016

Attention: Dr. Jenan Al-Atrash

SUBJECT: Client supplied eleven (11) samples of "non-ionic" surfactant solution identified as:

Sample #	Sample Identification
1	$A_{12\text{-}13}EO_{6\text{-}5}$ (Neodol 23
2	$A_{12\text{-}14}EO_7$ (Alfonic 1412-7)
3	$A_{8\text{-}10}EO_5$ (Alfonic 810-5)
4	$A_{12\text{-}13}EO_3$ (Neodol 23-3)
5	$A_{12}EO_{23}$ (Brij-35)
6	Nonylphenol - $EO_{9.5}$ (Triton N101)
7	Sorbitan Oleate - EO_{20} (Tween 85)
8	$A_{12\text{-}16}$ - $Glucose_{1.6}$ (Glucopon 625CS)
9	Lauramine Oxide, pH 7.0
10	Cocamide DEA
11	Lauramine Oxide, 10.5

The samples are hereafter refered to as Sample "#1" to "#11".

AUTHORIZATION: Client's letter of March 25, 1994.

PURPOSE: To determine the surface tension, interfacial tension and contact angle of the samples.

TEST DATES: December 12, 1994 to January 10, 1995.

SIGNED FOR THE COMPANY BY

db

S. Venkataraman
Preparer

Lisa Van Savage
Laboratory Manager

Joseph Kwiatkowski
Assistant Vice President

United States Testing Company, Inc.

CLIENT: Soap & Detergent Association

PROJECT NO: 403518
DATE: 02/01/95

PROCEDURE:

The surface tension and interfacial tension were determined in accordance with ASTM D-1331 using a DuNouy Tensiometer. Octyl Alcohol was used for interfacial measurements. Contact angle measurement was made in accordance with ASTM D-724. Teflon (tape) was used as the substrate for making contact angle measurements.

Ten readings were taken for each test.

The raw data shows the apparent surface tension and the correction factor is applied to determine the true tension.

RESULTS:

Surface Tension (dynes/cm)

	1	2	3	4	5	6	7	8	9	10	11
	29.8	30.6	28.5	27.4	43.1	34.1	44.1	32.0	35.2	34.4	35.4
	29.6	30.6	28.4	27.4	43.2	34.2	43.0	32.2	35.0	33.5	35.6
	29.6	30.7	28.6	27.5	43.2	34.0	43.0	32.1	35.0	33.7	35.3
	29.6	30.6	28.6	27.4	43.2	34.1	41.5	32.2	35.0	32.0	35.3
	29.7	30.5	28.6	27.2	43.2	34.2	45.0	32.8	35.1	33.0	35.3
	29.7	30.7	28.6	27.4	43.2	34.1	44.0	33.1	35.0	33.5	35.3
	29.5	30.6	28.7	27.4	43.2	34.2	44.7	33.0	35.1	33.0	35.3
	29.6	30.7	28.6	27.5	43.1	34.2	45.0	32.3	35.0	32.1	35.2
	29.6	30.7	28.7	27.5	43.2	34.2	44.2	32.3	35.0	32.4	35.3
	29.6	30.7	28.5	27.5	43.1	34.2	44.0	32.7	35.1	33.0	35.3
Avg.	29.6	30.6	28.6	27.4	43.2	34.2	43.9	32.5	35.1	33.1	35.3
Cor*.	26.3	27.2	25.4	24.4	38.5	30.4	39.1	28.9	31.2	29.5	31.4
n	0.08	0.06	0.09	0.09	0.05	0.07	1.03	0.37	0.07	0.71	0.10
(3) n-1	0.08	0.07	0.09	0.09	0.05	0.07	1.08	0.40	0.07	0.75	0.10
(4)	0.06	0.05	0.06	0.06	0.04	0.05	0.76	0.28	0.05	0.53	0.07

* Cor = Corrected Figure.

NOTE:

1. The "Corrected Figure" is the surface tension after the correction factor is applied.
2. Sample #8 had small solid matter.
3. Standard deviation
4. 95% confidence interval value

United States Testing Company, Inc.

CLIENT: Soap & Detergent Association

PROJECT NO: 403518
DATE: 02/01/95

RESULTS:

Interfacial Tension (dynes/cm)

	1	2	3	4	5	6	7	8	9	10	11
	0.0	0.0	2.1	0.0	0.8	0.0	6.8	2.3	2.7	9.0	4.6
	0.0	0.0	1.9	0.0	0.9	0.0	7.0	2.2	2.8	9.1	4.4
	0.0	0.0	1.6	0.0	0.9	0.0	7.0	1.1	2.5	10.0	4.5
	0.0	0.0	1.6	0.0	0.9	0.0	7.1	1.0	2.6	9.2	4.7
	0.0	0.0	1.6	0.0	1.0	0.0	7.0	2.1	2.5	9.1	4.5
	0.0	0.0	1.5	0.0	0.9	0.0	6.9	1.1	2.5	9.1	4.6
	0.0	0.0	1.6	0.0	0.8	0.0	7.0	1.0	2.5	9.1	4.6
	0.0	0.0	1.6	0.0	0.9	0.0	7.2	1.2	2.6	9.0	4.6
	0.0	0.0	1.6	0.0	0.9	0.0	7.1	1.3	2.5	9.7	4.5
	0.0	0.0	1.7	0.0	0.9	0.0	7.0	1.2	2.6	9.0	4.5
Avg.	0.0	0.0	1.7	0.0	0.9	0.0	7.0	1.5	2.6	9.2	4.6
Cor*.	0.0	0.0	1.5	0.0	0.8	0.0	6.16	1.3	2.6	8.2	4.1
n	0.0	0.0	0.18	0.0	0.06	0.0	0.10	0.53	0.1	0.32	0.08
(4) n-1	0.0	0.0	0.18	0.0	0.06	0.0	0.11	0.50	0.1	0.34	0.09
(5)	0.0	0.0	0.13	0.0	0.04	0.0	0.08	0.35	0.07	0.24	0.06

* Cor = Corrected Figure.

NOTE:

1. The "Corrected Figure" is the surface tension after the correction factor is applied.
2. Sample #7 and #10 were viscous as compared to other samples.
3. Sample #1, #2, #4, #7 and #9 when layered with octono indicated formation of white colored substance at the interface.
4. Standard deviation
5. 95% confidence interval value

United States Testing Company, Inc.

CLIENT: Soap & Detergent Association

PROJECT NO: 403518
DATE: 02/01/95

RESULTS:

Contact Angle (dynes/cm)

	1	2	3	4	5	6	7	8	9	10	11
	39.0	46.0	35.0	18.0	87.0	64.0	81.0	89.0	24.0	63.0	52.0
	39.0	46.0	32.0	15.0	86.0	58.0	78.0	86.0	28.0	64.0	57.0
	43.0	48.0	39.0	27.0	84.0	50.0	78.0	89.0	38.0	78.0	58.0
	42.0	46.0	26.0	27.0	84.0	56.0	75.0	87.0	39.0	73.0	54.0
	40.0	47.0	35.0	27.0	86.0	53.0	83.0	86.0	38.0	75.0	56.0
	40.0	48.0	22.0	21.0	85.0	54.0	84.0	84.0	37.0	64.0	52.0
	33.0	47.0	42.0	25.0	90.0	49.0	84.0	84.0	44.0	63.0	46.0
	22.0	47.0	42.0	25.0	90.0	50.0	84.0	87.0	47.0	66.0	44.0
	34.0	48.0	27.0	24.0	90.0	63.0	71.0	86.0	43.0	63.0	56.0
	28.0	47.0	22.0	20.0	90.0	58.0	73.0	85.0	48.0	59.0	56.0
Avg.	36.0	47.0	32.0	23.0	87.0	56.0	79.0	86.0	39.0	67.0	53.0
n	6.39	0.77	7.26	3.9	2.44	5.03	4.61	1.68	7.32	5.93	4.48
(4) n-1	6.73	0.82	7.66	4.20	2.57	5.30	4.86	1.77	7.72	6.25	4.72
(5)	4.81	0.58	5.48	3.00	1.84	3.79	3.47	1.27	5.52	4.47	3.37

NOTE:

1. The average is corrected to whole numbers.
2. Sample #10 had numerous air bubbles and could not be eliminated.
3. Sample #7 and #10 were viscous as compared to other samples.
4. Standard deviation
5. 95% Confidence interval values

Designation: D 1331 – 89

AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race St., Philadelphia, Pa. 19103
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If not listed in the current combined index, will appear in the next edition.

Standard Test Methods for Surface and Interfacial Tension of Solutions of Surface-Active Agents[1]

This standard is issued under the fixed designation D 1331; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover the determination of surface tension and interfacial tension of solutions of surface-active agents, as defined in Definitions D 459. Two methods are covered as follows:

Method A—Surface Tension.

Method B—Interfacial Tension.

1.2 Method A is written primarily to cover aqueous solutions of surface-active agents, but is also applicable to nonaqueous solutions and mixed solvent solutions.

1.3 Method B is applicable to two-phase solutions. More than one solute component may be present, including solute components that are not in themselves surface-active.

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Material Safety Data Sheets are available for reagents and materials. Review them for hazards prior to usage.

2. Referenced Document

2.1 *ASTM Standard:*

D 459 Definitions of Terms Relating to Soaps and Other Detergents[2]

3. Apparatus

3.1 *Tensiometer*—Either the du Nouy precision tensiometer or the du Nouy interfacial tensiometer, equipped with either the 4 or the 6-cm circumference platinum ring, as furnished by the manufacturer, may be used. The tensiometer shall be placed on a sturdy support that is free from vibrations and other disturbances such as wind, sunlight, and heat. The wire of the ring shall be in one plane, free of bends or irregularities, and circular. When set in the instrument, the plane of the ring shall be horizontal, that is, parallel to the surface plane of the liquid being tested.

3.2 *Sample Container*—The vessel for holding the liquid shall be not less than 6 cm in diameter, and sufficiently large to ensure that the contact angle between the ring and the interface is zero.

4. Preparation of Apparatus

4.1 Clean all glassware thoroughly. The use of fresh chromic-sulfuric acid cleaning mixture, followed by a thorough rinsing in distilled water, is recommended.

4.2 Clean the platinum ring by rinsing thoroughly in a suitable solvent and in distilled water, before taking a set of measurements. Allow the ring to dry, and then heat to white heat in the oxidizing portion of a gas flame.

5. Calibration of Apparatus

5.1 The tensiometer is, in fact, a torsion balance, and the absolute accuracy depends on the length of the torsion arm, which is adjustable. Torsion may be applied to the wire by means of either the dial-adjusting screw (which controls the dial reading) or a rear adjusting screw. Calibration consists essentially in adjusting the length of the torsion arm so that the dial scale will read directly in dynes per centimetre. The precision tensiometer shall be calibrated in accordance with the following: 5.1.1 to 5.1.3; the interfacial tensiometer shall be calibrated in accordance with 5.1.1 to 5.1.4.

5.1.1 Level the tensiometer. A liquid level of the type employed on analytical balances may be used. Place the level on the table that holds the sample for testing, and adjust the leg screws of the tensiometer until the table is horizontal. Pull the torsion wire taut by means of the tension screw, and adjust the dial reading and the vernier to zero. Insert the platinum ring in the holder, and place a small piece of paper across the ring. This will serve as a platform to hold the calibrating weight. Turn the rear adjusting screw of the torsion wire until the index level of the arm is opposite the reference line of the mirror; this automatically compensates for the weight of the paper platform. Next, place an accurately standardized weight of between 500 and 800 mg on the paper platform and turn the dial-adjusting screw until the index level of the arm is opposite the reference line of the mirror. Record the dial reading to 0.10 divison. Call this "gamma-c."

5.1.2 Calculate what the reading "gamma-c" obtained in 5.1.1 *should be* when the tensiometer is properly adjusted, as follows (Note 1):

$$\gamma_c = (M \times g)/2L$$

where:

M = weight placed on the paper platform, g,
g = gravity constant (Note 2), cgs units, and
L = mean circumference of the ring (furnished by the manufacturer with each ring).

If the recorded dial reading "gamma-c" is greater than the calculated value, the torsion arm should be shortened. If

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[1] These test methods are under the jurisdiction of ASTM Committee D-12 on Soaps and Other Detergents and are the direct responsibility of Subcommittee D12.15 on Physical Testing.

Current edition approved May 26, 1989. Published July 1989. Originally published as D 1331 – 54 T. Last previous editions D 1331 – 56(1986).

[2] *Annual Book of ASTM Standards*, Vol 15.04

"gamma-c" is less than the calculated value, the torsion arm should be lengthened. Repeat the calibration procedure, re-adjusting the zero position after each change in the length of the torsion arm, until the dial reading agrees with the calculated value. Each unit of the scale now represents a pull on the ring of 1 dyne/cm. Note that a conversion factor, *F* (see 5.1.3), must be multiplied by the scale reading to give corrected surface tension in dynes per centimetre.

NOTE 1—*Example*—If *M* is exactly 0.600 g and *L* is 4.00 cm:

$$\gamma_c = (0.600 \times 980.3)/(2 \times 4.00) = 73.52 \text{ dynes/cm}$$

NOTE 2—The gravity constant is 980.3 at Chicago; in other localities it will differ very slightly from this value.

5.1.3 After the tensiometer has been calibrated, it is convenient to calculate the number of grams total pull on the ring that is represented by each scale division. This is done simply by dividing the scale reading into the weight used for calibration (Note 3). This value is used in the calculation of the conversion factor, *F*, mentioned in 5.1.2.

NOTE 3—In the example given in Note 1, each scale unit after calibration represents:

$$0.600/73.52 = 0.008161 \text{ g}$$

5.1.4 *Interfacial Tensiometer*—With the interfacial tensiometer, the same principle of calibrating by adjusting the length of the torsion arm also applies. This instrument has, however, in addition to the torsion arm, a torsion-arm counterbalance. Adjust the length of this counterbalance to coincide with that of the torsion arm itself, in order that the vertical members of the assembly may remain in line.

METHOD A—SURFACE TENSION

6. Procedure

6.1 After the tensiometer has been calibrated, check the level and insert the cleaned platinum ring (Note 4) that will be used in the measurement. Check the plane of the ring, and set the dial and vernier at zero. Adjust the rear adjusting screw so that the index level of the arm is opposite the reference mark on the mirror, that is, the ring system is at the zero position.

NOTE 4—Extreme care must be taken to have the sample vessel and platinum ring clean. Contamination of the liquid surface by dust or other atmospheric impurities during measurement should be avoided.

6.2 Place the solution to be tested (Note 5), contained in the thoroughly cleaned vessel (Note 4), on the sample platform. Raise the sample platform by means of its adjusting screw until the ring is just submerged.

NOTE 5—Since the surface tension of a solution is a function of the concentration, care must be taken that the concentration is adjusted and recorded within known limits. The presence of solutes other than the surface-active agent should be ascertained and reported qualitatively and quantitatively, insofar as possible. This includes hardness components in the water. Care should be taken that the solution is physically homogeneous. Measurements made near or above the cloud point or other critical solubility points can be in serious error. This is particularly true when the solute is a surface-active material.

6.3 Lower the platform slowly, at the same time applying torsion to the wire by means of the dial-adjusting screw. These simultaneous adjustments must be carefully proportioned so that the ring system remains constantly in its zero position. As the breaking point is approached, the adjustments must be made more carefully and more slowly. Record the dial reading when the ring detaches from the surface.

6.4 Make at least two measurements. Additional measurements shall be made if indicated by the over-all variation obtained, the total number of readings to be determined by the magnitude of that variation.

6.5 Record the temperature of the solution and the age of the surface at the time of testing. Since the submerging of the ring (6.2) may constitute a significant disturbance of the surface, take the age as the elapsed time between submersion and breakaway of the ring. The accuracy of this time observation may be indicated in the usual manner. In most cases an accuracy of ±5 s is reasonable, and sufficient for this test method.

7. Calculation and Report

7.1 The dial reading, obtained from a measurement carried out in the foregoing manner with a calibrated instrument, is actually the pull per linear centimetre on the ring (both inner and outer circumference being considered) at the break-point, expressed in dynes. This value, called the uncorrected surface tension, must be multiplied by a correcting factor, *F*, to give the corrected surface tension. *F* is a function of the contours of the liquid surface in the neighborhood of the ring at the instant of breakaway. It can be numerically specified in terms of *R*, the mean radius, in centimetres, of the ring; *r*, the radius, in centimetres, of the wire from which the ring is made; and *V*, the maximum volume of liquid elevated above the free surface of the liquid. For liquids of low surface tension, such as surface-active agents, *F* is, in general, appreciably less than unity. It must, therefore, be ascertained and applied. Values of *F* in terms of two compounded parameters, R^3/V and R/r have been compiled and tabulated by Harkins and Jordan.[3] In order to look up *F* in the tables, the values of these two parameters must be calculated. Values for *R* and *r* are furnished by the manufacturer with each ring. The value of *V* is calculated from the following equation:

$$V = M/(D - d)$$

where:

M = weight of liquid raised above the free surface of the liquid,
D = density of liquid, and
d = density of air saturated with vapor of the liquid.

To calculate *M*, multiply the tensiometer dial reading by the factor which converts this reading into grams pull on the ring, as calculated in 5.1.3. The factor *D* can be measured by the usual procedures, and the value *d* can be obtained from published data. The corrected surface tension in dynes per centimetre is obtained by multiplying the uncorrected surface tension value by *F*.

7.2 Unless specified, the surface tension values reported shall be corrected values. Report also the temperature at which the measurement was made. If it is desired to report the surface tension value of an aqueous solution at some

[3] Harkins, W. D., and Jordan, H. F., "A Method for Determination of Surface and Interfacial Tension from the Maximum Pull on a Ring," *Journal Am. Chemical Soc.*, Vol 52, 1930, p. 1751. These tables are also published in *Physical Methods of Organic Chemistry*, Interscience Publishers, Inc., New York, NY, Vol 1, 1945, pp. 182–184.

standard temperature, for example, 25°C, and the measurement was actually made at a temperature within about 3°C of this value (that is, 22 to 28°C), a correction factor of 0.14 dynes/cm·°C may be used. Subtract this correction factor from the surface tension when the temperature of the test is lower than the reported temperature, and add it to the surface tension when the temperature of the test is higher than the reported temperature. This value for the correction factor is not valid for nonaqueous liquids, and should be used only where the solvent is preponderantly water.

METHOD B—INTERFACIAL TENSION

8. Procedure

8.1 Determine interfacial tension as described in Section 6 for surface tension, with the following modifications:

8.1.1 Always move the ring from the aqueous side of the interface through to the nonaqueous side. With liquids lighter than water, it is accordingly possible to use the precision tensiometer as well as the interfacial tensiometer. With liquids heavier than water, where the ring must be pushed downward, the interfacial tensiometer should be used.

8.1.2 Use fresh solutions and a freshly cleaned ring for each determination.

8.1.3 When operating with a liquid heavier than the aqueous solution, place the two-layer system in the sample vessel and place the ring in the upper (aqueous) layer. Make the measurement by turning the torsion wire counter-clockwise and simultaneously keeping the ring system in the zero position, as in the measurement of surface tension, until the ring breaks through the interface.

8.1.4 When operating with a liquid (oil) lighter than the aqueous solution, first place the aqueous solution in the sample vessel and immerse the ring therein. Carefully pour the oil on top of the aqueous solution to form the two-layer system. Contact between the oil and the ring should be avoided during this operation. After allowing sufficient time for the interfacial tension to come to its equilibrium value (Note 6), make the measurement in the same manner as that used for measuring surface tension.

NOTE 6—Since the interfacial energy of a newly formed liquid-liquid interface generally requires some time to reach its equilibrium value, it is advisable to wait at least 5 min after the interface is formed before taking a measurement.

9. Calculation and Report

9.1 As in the case of surface tension, a correction factor, *F*, must be multiplied by the dial reading (pull on the ring in dynes) in order to obtain the corrected value for interfacial tension. Values for *F* have been published by Zuidema and Waters.[4] The factor *F* is, in this case, a function of the densities of the two liquids as well as of *R* and *r*, the radius of the ring and that of the wire, respectively.

9.2 Unless specified, interfacial tension values reported shall be corrected values. Report and adequately specify the nature of the nonaqueous liquid (oil) used in the determination. Also report the temperature at which the determination was made. In contrast to surface tension values, interfacial tension values cannot adequately be corrected for small temperature deviations by means of a simple formula.

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[4] Zuidema, H. H., and Waters, G. W., "A Ring Method for Determination of Interfacial Tension," *Industrial and Engineering Chemistry*, Analytical Edition, Vol 13, 1941, p. 312.

Designation: D 724 – 94

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Method for Surface Wettability of Paper (Angle-of-Contact Method)[1]

This standard is issued under the fixed designation D 724; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the quantitative determination of the resistance of paper surfaces to wetting by measuring the behavior of a drop of liquid when applied directly to the paper surface.

1.2 The procedure described in this test method involves the measurement of the angle of contact. Both the initial wettability and the rate of change of wettability may be measured.

1.3 When using a standard ink, the initial contact angle or wettability is considered to be a measure of the ruling quality of the paper. The rate of change of contact angle or wettability is considered to be a measure of the writing quality.

1.4 Other liquids, both aqueous and nonaqueous, may be used with this technique in special applications. Modification of the procedure may be required when using liquids other than the standard ink described.

1.5 Two types of apparatus for measuring the contact angle are described. Additional apparatus that can perform the test may also provide equivalent results.

1.6 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 585 Practice for Sampling and Accepting a Single Lot of Paper, Paperboard, Fiberboard, or Related Product[2]

D 685 Practice for Conditioning Paper and Paper Products for Testing[2]

E 122 Practice for Choice of Sample Size to Estimate a Measure of Quality for a Lot or Process[3]

2.2 *TAPPI Standard:*

TAPPI Test Method T 458 Surface wettability of paper (angle of contact method)[4]

3. Apparatus

3.1 *Drop Projection Instrument*—An instrument capable of projecting the image of a drop of liquid on the surface of paper onto a screen so that the angle of a line tangent with the drop at the paper surface can be measured. The general concept is shown in Fig. 1 and shall consist of the following:

NOTE 1—While the projection instrument illustrated and described is antiquated, it describes the concept of the measuring procedure. Instruments are available in a more convenient form that serve the same purpose, that is projecting the image of the drop on a screen.

3.1.1 *Angle Measuring Device*—A protractor or similar device for measurement of contact angle.

3.1.2 *Filter*, used to reduce the heat on the specimen and drop.

3.1.3 *Lamp*—A ventilated lamp house containing a light source.

3.1.4 *Microscope*—A microscope draw tube suitable for projecting the image of the drop on a screen with an enlargement of 25 to 30 times.

3.1.5 *Screen*—A frosted glass screen on which the drop is projected is required.

3.1.6 *Stage*—A horizontal stage capable of holding the test specimen, with means for vertical adjustment of the stage.

3.1.7 *Tube and Lens*—A tube capable of containing a lens to concentrate the beam of light.

3.2 *Hypodermic Syringe*—A syringe, such as a 1-mL hypodermic, equipped with a No. 27 stainless steel needle, capable of providing 150 to 200 drops, 1 mL, is suitable for use with water-like liquids. More viscous liquids may require a needle of different size.

3.3 Other instruments suitable for measuring contact angle include a device where the screen is replaced by a camera using instant developing film.

3.4 *Reflective Goniometer*—An instrument consisting of a controlled light source, stage to hold the test specimen, and a

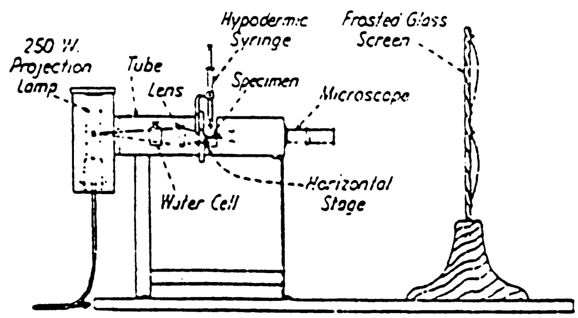

FIG. 1 Projection Apparatus

[1] This test method is under the jurisdiction of ASTM Committee D-6 on Paper and Paper Products and is the direct responsibility of Subcommittee D06.92 on Test Methods.

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[2] *Annual Book of ASTM Standards*, Vol 15.09.

[3] *Annual Book of ASTM Sindards*, Vol 14.02.

[4] Available from the Technical Association of the Pulp and Paper Industry, Technology Park/Atlanta, P.O. Box 105113, Atlanta, GA 30348.

microscope for direct viewing of the drop on the paper specimen is required. The microscope shall be fitted with an ocular graduated in degrees and adjustable so that the angle of contact between a line tangent to the drop at the paper surface can be determined.

4. Test Liquids

4.1 The liquid selected for testing purposes is a function of the characteristic to be evaluated. The standard ink (see 4.4) is used to determine writing characteristics of paper. The ink described is typical of that used in fluid ink writing instruments.

4.2 Water is used for determining wetting characteristics of that liquid when paper is expected to be exposed to water only.

4.3 Other liquids may be used using the technique described for special applications. There may be a need under those conditions to modify the test method from the standpoint of size of droplet used and the time at which contact angle is to be measured. Slow wetting liquids may be evaluated over a longer time period.

4.4 *Standard Ink*—A standard ink having the following composition shall be used for determining the writing qualities of paper:

Tannic acid, g	11.5
Gallic acid crystals, g	3.8
Ferrous sulfate 7 hydrate, g	15.0
Hydrochloric acid 1 N, mL	12.5
Phenol, g	1.0
Soluble blue dye, Color Index 42755, Acid Blue 22, g	3.5
Water, distilled or deionized to make 1000 mL at 20°C (68°F)	

All chemicals used in preparing the ink shall be of reagent grade or equivalent quality. Some blue dyes react with phenol to cause a film having a metallic appearance and such dyes shall not be used. The ink shall be prepared as follows:

4.4.1 Dissolve the tannic acid and gallic acid in about 400 mL of water at about 50°C (122°F). In a separate vessel, dissolve the ferrous sulfate in about 200 mL of water that contains the hydrochloric acid. In a third vessel dissolve the dye in about 200 mL of water. Mix the three solutions in a 1-L volumetric flask, rinse the vessels with small portions of water, and add the rinsings to the flask. Add the phenol. Dilute the water to 1 L at 20°C (68°F).

4.5 *Water*—Distilled or deionized.

4.6 *Other Liquids*—Other liquids might be either aqueous- or nonaqueous-based. Some examples would be specified inks, adhesive, oils, and coating materials.

5. Sampling

5.1 For acceptance sampling, obtain the sample in accordance with Practice D 585.

5.2 When sampling for other purposes, use Practice E 122 as an alternative.

6. Test Specimens

6.1 The test specimens shall be cut to a size appropriate for the instrument being used. They shall be cut in such a way as to be thoroughly representative of the sample. Tests shall be made on both sides of each specimen. The actual test areas tested shall not contain water marks or visible blemishes or defects and shall not be touched with the fingers or contaminated in any other way.

6.2 The test specimens shall be conditioned in accordance with Practice D 685.

7. Procedure

7.1 Test the specimens under standard atmospheric conditions in accordance with Practice D 685.

7.2 Place the test specimen in the instrument, holding it in close contact with the stage by means of small weights, clips, or whatever fixtures are associated with the instrument.

7.3 Set the tip of the hypodermic needle 3.2 mm (1/8 in.) from the surface of the specimen and deposit a drop of test liquid 1/150 to 1/200 mL in size on the specimen.

7.4 For initial wettability, used as a measure of ruling quality, make the measurement of the angle of contact after the drop has been in contact with the paper for 5 s. For rate of change of wettability, used as a measure of writing quality, make two measurements, one after 5 s and the other after 60 s have elapsed.

7.5 *Angle of Contact Measurement* (see Fig. 2):

7.5.1 *Projected Image Procedure*—Project the image of the drop enlarged on a glass screen, at the back of which shall be clamped a sheet of transparent onionskin paper. Draw a horizontal line on the transparent paper coinciding with the image of the base of the drop and as soon as the specified time of contact of the drop with the specimen has elapsed, quickly draw two tangents to the curve at the two points of contact with the base line. Measure the two interior angles between the base line and the tangents with a protractor.

7.5.2 *Reflective Goniometer Procedure*—Adjust the eye piece and the internal measuring mechanism so that the interior angle of each of the two points of contact can be determined.

7.6 Make measurements for 5 drops on each side of the specimen. The contact angle for each drop shall be the average of the angles at the two edges of the drop. If the two contact angles are significantly different, the value should be eliminated and the test repeated.

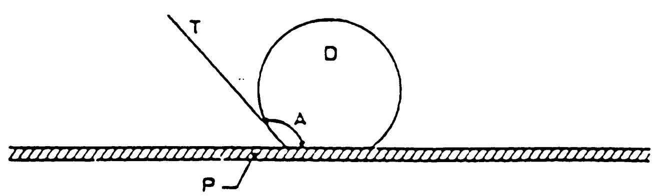
8. Calculation

8.1 *Calculation*—Calculate the rate of change in wettability as follows:

$$R = (A - a)/55$$

where:

R = rate of change in wettability, °/s,
A = average angle of contact after 5 s, and
a = average angle of contact after 60 s.



A = contact angle
D = drop of liquid
P = paper
T = tangent at paper surface

FIG. 2 Measuring Angle of Contact

9. Interpretation of Results

9.1 In considering the results of the angle-of-contact test, the following factors that all affect the results in different degrees shall be considered: (*a*) the wetting power of the test liquid used, (*b*) the wettability of the sizing agent used in sizing the paper, and (*c*) the surface texture of finish of the paper.

9.2 The standard ink will give smaller angles of contact than water, indicating that it wets the paper more readily than water. Papers surface-sized with starch will generally show smaller angles than papers of about the same finish tube-sized with glue. A machine-finished paper with a grainy surface would have a greater angle of contact than a plated or calendered paper of equal sizing. It is known that in practice, ruling results will depend on both the surface wettability and finish of the paper. Thus, the angle of contact should give a very good idea of what is to be expected. It has been found that excellent ruling will prevail when the average angle of contact with water lies between 90 and 100°; when the angle of contact is greater than 110°, breaks are likely to occur in the ruled lines; when the angle is smaller than 90°, the ruling fluid is likely to feather.

9.3 In determining the writing qualities of paper by means of the angle-of-contact method, it is necessary to take into account that medium-sized papers will at times show feathering only after the ink has partly penetrated the paper. The tendency of a writing paper to feather will be indicated by the decrease in the angle of contact between measurement after 5 and 60 s. In hard-sized papers, the angle of contact will not change perceptibly between the measurements at 5 and 60 s. If the initial wettability is less than 90°, it is quite likely the paper will feather as soon as it is written upon.

9.4 As the range in contact angle for specific conditions is small, a refined technique is required in performing the test. This is indicated by the above examples as well as by theoretical considerations.

10. Report

10.1 Report the following information:

10.1.1 *Standard Ink:*

10.1.1.1 The initial wettability or ruling quality shall be reported as the average angle of contact after 5-s exposure expressed to the nearest degree,

10.1.1.2 The rate of change of wettability or writing quality is reported as calculated in 8.1,

10.1.1.3 If possible to identify the two sides, the results shall be identified as to the wire side and the felt side. Otherwise, the size may be arbitrarily designated, as for example, *A* and *B*, and

10.1.1.4 Test results shall be expressed as maximum, minimum, and average for each side of the specimen tested, reported to two significant figures.

10.1.2 *Other Liquids*—If liquids other than the standard ink are used, the liquid used along with any modifications of the procedures shall be reported.

11. Precision and Bias

11.1 *Precision:*

11.1.1 When the procedure in this test method is applied by a single operator using the same equipment to paper whose surface characteristics impacting this test method are homogeneous, and where ten tests are run on the same side of two test specimens cut from the same sheet of paper giving a result of 90° or greater using this test method, the repeatability standard deviation is approximately 7° and the 95 % repeatability is 2° (see TAPPI T 458).

11.1.2 Using the data reported by Bristow,[5] the reproducibility standard deviation is approximately 2.5° and the 95 % reproducibility limit is approximately 7° for two different operators using the same apparatus.

11.1.3 It is not practicable to specify in greater detail the precision of the procedure for determining contact angle in this test method because of variations in equipment, variations in test liquid, and most specifically in paper coating uniformity which are encountered. It must be left to individual laboratories to determine precision estimates for specific paper grades and testing needs.

11.2 *Bias*—No statement can be made about the bias of the procedure in this test method because contact angle is defined in terms of the test method.

12. Keywords

12.1 angle-of-contact; contact angle; paper; surface wettability

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[5] Bristow, J.A., "The Reproducibility of Contact Angle Measurement," *Paperi ja Puu* 50 (4a): 171, 1968.

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FAX TRANSMITTAL

TO: John Heinze
DATE: 3/21/97
COMPANY: SDA (Consultant)
FROM: LisA Van Sav
FAX NO.: 703 924 9365
OF PAGES:
(including cover sheet)

MESSAGE/COMMENTS:

We have a Kayness Inc Model # D1060 Drop Projection Contact angle instrument

- If you need specific info about project 403513 Please have the SDA send us a letter indicating that you are working with them and authorizing us to discuss w/ you.

291 Fairfield Avenue
Fairfield, NJ 07004
Tel: 201-575-5252
800-777-8378
Fax: 201-244-1823
201-244-1694

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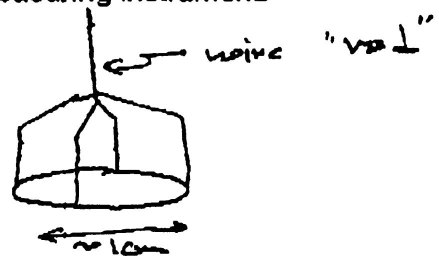
March 11, 1997

Dr. John E. Heinze
7699 Lavenham Landing
Alexandria, VA 22315

Dear John,

I do not have a written procedure other than the manual that explains the method used to measure surface tension. Since the manual is far more detailed that you probably want (which button does what). I will summarize the general method.

The method is described in the literature as the du Nuoy ring method. This is a very old method but has recently been automated. The theory is the same however. The du Nuoy ring we used is made of thin platinum wire and is approximately 1 cm in diameter. The ring is attached to a rod and the rod is used to attach the ring to the measuring instrument.



The measurement proceeds by placing the ring below the interface that is being measured. In the measurements we did for SDA this was an air-water interface so the ring was below the water. The operator then slowly raises the ring by turning a calibrated dial until the ring breaks free of the interface (manual instrument). In the automated version, the ring is automatically pulled through the interface until the maximum pull on the ring is measured. In either case, the force measured, along with the geometry of the ring and the density difference between the interfaces can be used to calculate the surface tension.

I hope this is helpful. If you would like further details, please call me at (512)-331-2447.

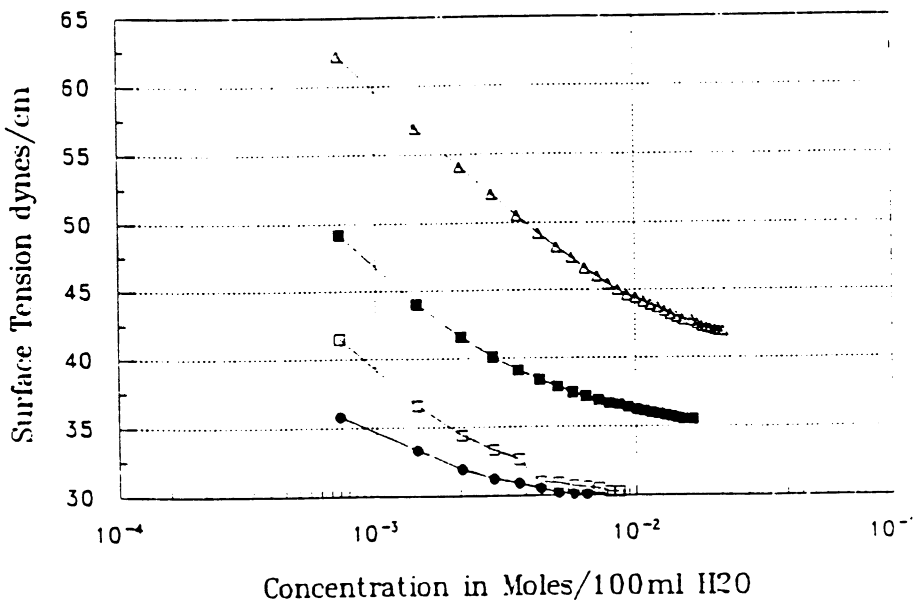
Sincerely,

Dewey Smith

"Appendix 5"

P.O. Box 200135 · Austin, Texas 78720-0135 · Fax (512) 331-2387

Sample Group 2



SAMPLE GROUP 3 - SLOWEST RATE
HWI:6310-105 Test Material: A8-10 EO5 (Alfonic 810-5)

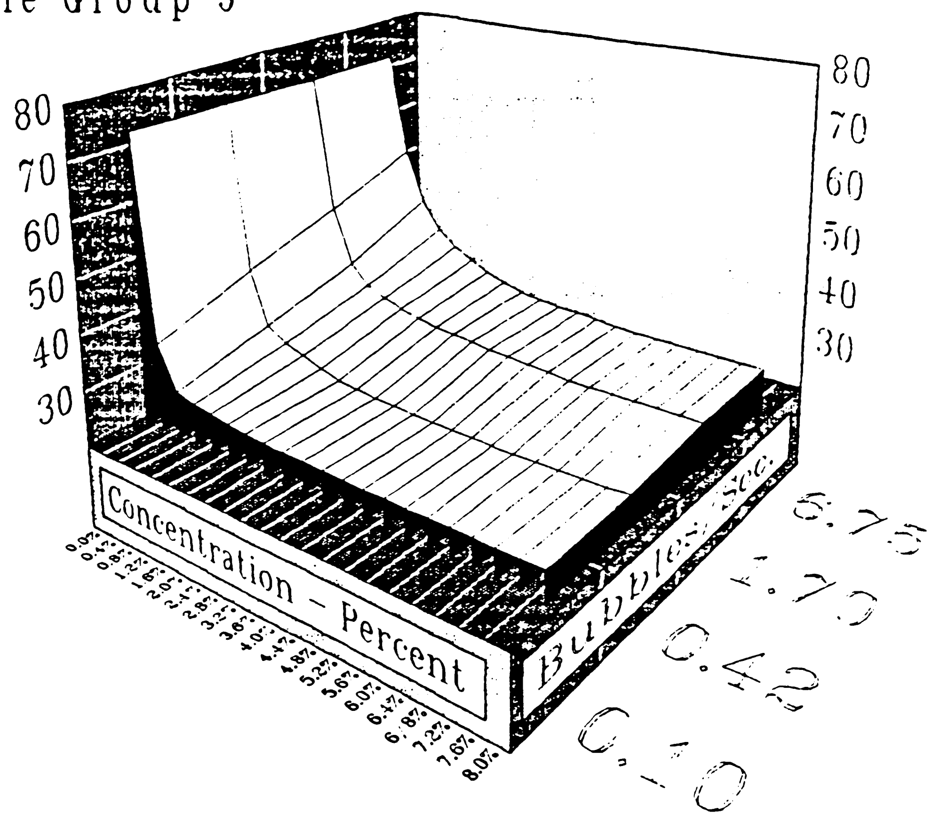
		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	73.0	19.0	.15	6.66	6.39
.4ml	TEST A	36.0	19.4	.26	3.85	3.66
	TEST B	36.0	19.4	.25	4.00	3.80
.8ml	TEST A	28.6	19.7	.33	3.03	2.81
	TEST B	28.6	19.8	.33	3.03	2.81
1.2ml	TEST A	27.5	19.9	.33	3.03	2.81
	TEST B	27.5	19.9	.33	3.03	2.81
1.6ml	TEST A	27.0	19.9	.32	3.12	2.90
	TEST B	27.0	19.9	.32	3.12	2.90
2.0ml	TEST A	26.4	20.0	.31	3.22	3.02
	TEST B	26.4	20.1	.32	3.12	2.90
2.4ml	TEST A	26.1	20.1	.33	3.03	2.81
	TEST B	26.1	20.2	.31	3.22	3.02
2.8ml	TEST A	25.8	20.3	.32	3.12	2.90
	TEST B	25.8	20.3	.32	3.12	2.90
3.2ml	TEST A	25.6	20.5	.32	3.12	2.90
	TEST B	25.6	20.6	.33	3.03	2.81
3.6ml	TEST A	25.5	20.7	.30	3.33	3.16
	TEST B	25.5	20.7	.31	3.22	3.02
4.0ml	TEST A	25.4	20.8	.31	3.22	3.02
	TEST B	25.4	20.8	.30	3.03	2.82
4.4ml	TEST A	25.3	21.0	.30	3.03	2.82
	TEST B	25.3	21.0	.30	3.03	2.82
4.8ml	TEST A	25.2	21.0	.30	3.03	2.82
	TEST B	25.2	21.0	.30	3.03	2.82
5.2ml	TEST A	25.2	21.1	.30	3.03	2.82
	TEST B	25.2	21.1	.30	3.03	2.82
5.6ml	TEST A	25.2	21.2	.30	3.03	2.82
	TEST B	25.2	21.2	.30	3.03	2.82

SAMPLE GROUP 3 - SLOW RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml additive	TEST A	72.6	22.0	.24	4.16 sec	3.95
.4ml additve	TEST A	41.8	22.9	.32	3.12 sec	2.90
	TEST B	41.8	22.9	.32	3.12 sec	2.90
.8ml additive	TEST A	32.0	22.9	.36	2.77 sec	2.58
	TEST B	32.0	22.9	.36	2.77 sec	2.58
1.2ml additive	TEST A	29.9	22.9	.41	2.43 sec	2.21
	TEST B	29.9	22.9	.41	2.43 sec	2.21
1.6ml additive	TEST A	28.7	23.0	.42	2.38 sec	2.17
	TEST B	28.8	23.0	.42	2.38 sec	2.17
2.0ml additive	TEST A	27.4	22.9	.44	2.27 sec	2.06
	TEST B	27.4	22.9	.44	2.27 sec	2.06
2.4ml additvie	TEST A	26.5	23.0	.41	2.43 sec	2.21
	TEST B	26.5	23.0	.41	2.43 sec	2.21
2.8ml additive	TEST A	26.1	23.0	.44	2.27 sec	2.06
	TEST B	26.1	23.0	.44	2.27sec	2.06
3.2ml additive	TEST A	25.7	23.0	.42	2.38 sec	2.17
	TEST B	25.7	23.0	.42	2.38 sec	2.17
3.6ml additve	TEST A	25.5	23.0	.43	2.32 sec	2.11
	TEST B	25.5	23.0	.43	2.32 sec	2.11
4.0ml additive	TEST A	25.3	23.0	.43	2.32 sec	2.11
	TEST B	25.3	23.0	.43	2.32 sec	2.11
4.4ml additive	TEST A	25.2	23.0	.50	2.00sec	1.82
	TEST B	25.1	23.0	.50	2.00 sec	1.82
4.8ml additve	TEST A	25.2	22.9	.50	2.00 sec	1.82
	TEST B	25.2	22.9	.50	2.00 sec	1.82
5.2ml additive	TEST A	25.2	22.9	.50	2.00 sec	1.82
	TEST B	25.2	22.9	.50	2.00 sec	1.82

SAMPLE GROUP 3 - MED RATE		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.7	20.8	1.00	1.00	.87
.4ml	TEST A	47.1	20.7	1.52	.66	.56
	TEST B	47.0	20.7	1.52	.66	.56
.8ml	TEST A	36.8	20.7	1.52	.66	.56
	TEST B	36.8	20.7	1.54	.65	.55
1.2ml	TEST A	33.3	20.7	2.04	.49	.40
	TEST B	33.3	20.7	2.04	.49	.40
1.6ml	TEST A	31.7	20.7	2.14	.47	.38
	TEST B	31.7	20.7	2.15	.47	.38
2.0ml	TEST A	30.6	20.7	2.16	.46	.37
	TEST B	30.7	20.7	2.16	.46	.37
2.4ml	TEST A	29.8	20.8	2.19	.46	.37
	TEST B	29.7	20.8	2.17	.46	.37
2.8ml	TEST A	29.2	20.8	2.22	.45	.36
	TEST B	29.2	20.8	2.22	.45	.36
3.2ml	TEST A	29.0	20.8	2.25	.44	.35
	TEST B	29.0	20.8	2.22	.45	.36
3.6ml	TEST A	28.7	20.9	2.22	.45	.36
	TEST B	28.7	20.9	2.22	.45	.36
4.0ml	TEST A	28.4	20.9	2.22	.45	.36
	TEST B	28.4	20.8	2.25	.44	.35
4.4ml	TEST A	28.2	20.9	2.22	.45	.36
	TEST B	28.2	20.9	2.25	.44	.35
4.8ml	TEST A	27.9	20.9	2.22	.45	.36
	TEST B	28.0	20.9	2.25	.44	.35
5.2ml	TEST A	27.8	20.9	2.25	.44	.35
	TEST B	27.7	20.9	2.22	.45	.36
5.6ml	TEST A	27.5	20.9	2.22	.45	.36
	TEST B	27.6	20.9	2.22	.45	.36
6.0ml	TEST A	27.5	20.9	2.22	.45	.36
	TEST B	27.5	20.9	2.25	.44	.35
6.4ml	TEST A	27.4	20.9	2.25	.44	.35
	TEST B	27.4	20.9	2.25	.44	.35
6.8ml	TEST A	27.4	20.9	2.22	.45	.36
	TEST B	27.4	20.9	2.25	.44	.35
7.2ml	TEST A	27.3	20.9	2.22	.45	.36
	TEST B	27.3	20.9	2.25	.44	.35
7.6ml	TEST A	27.3	20.9	2.25	.44	.35
	TEST B	27.3	20.9	2.22	.45	.36
8.0ml	TEST A	27.3	20.9	2.22	.45	.36
	TEST B	27.3	20.9	2.25	.44	.35

Sample Group 3

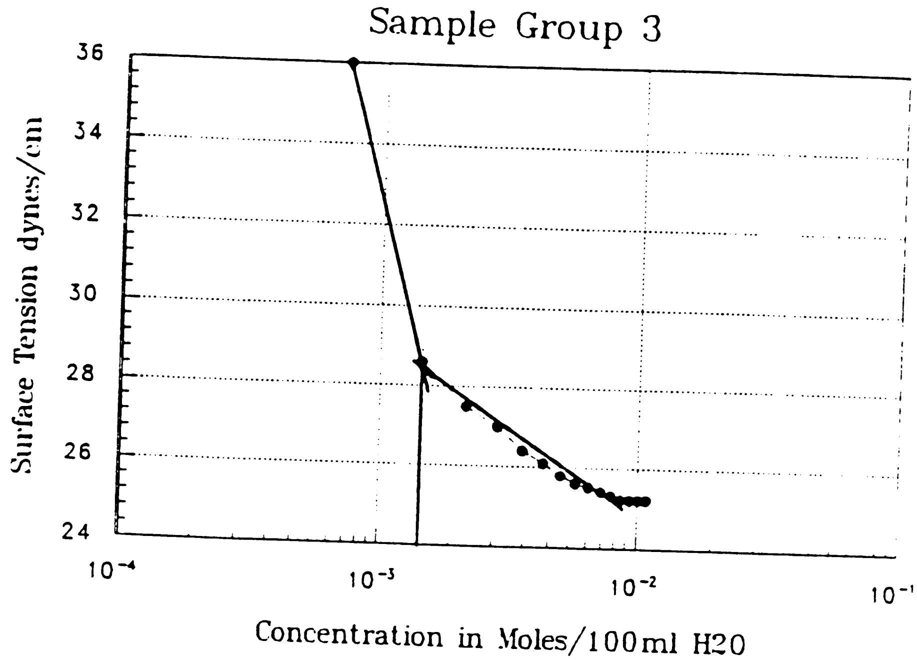


Dynamic Surface Tension Graph

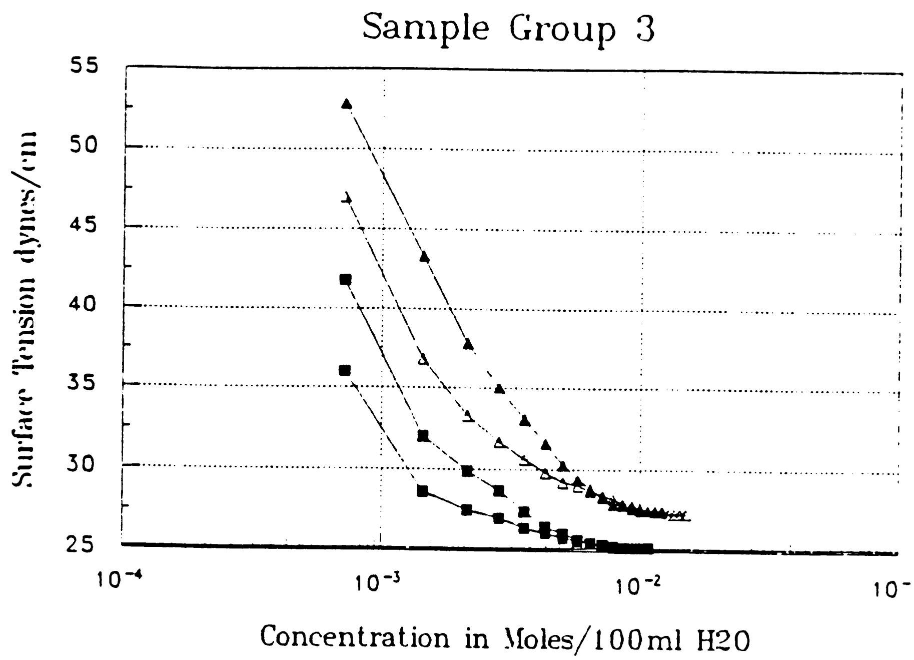
SAMPLE GROUP 3 - FAST RATE		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.6	21.8	4.25	.24	.15
.4ml	TEST A	52.8	21.7	5.89	.17	.09
	TEST B	52.8	21.7	5.89	.17	.09
.8ml	TEST A	43.3	21.7	6.77	.15	.08
	TEST B	43.3	21.7	6.77	.15	.08
1.2ml	TEST A	37.8	21.7	7.29	.14	.07
	TEST B	37.8	21.7	7.29	.14	.07
1.6ml	TEST A	35.0	21.7	7.93	.13	.06
	TEST B	35.0	21.8	7.97	.13	.06
2.0ml	TEST A	33.1	21.8	7.95	.13	.06
	TEST B	33.0	21.8	7.95	.13	.06
2.4ml	TEST A	31.6	21.7	8.28	.12	.05
	TEST B	31.6	21.7	8.28	.12	.05
2.8ml	TEST A	30.3	21.8	8.68	.12	.05
	TEST B	30.4	21.8	8.62	.12	.05
3.2ml	TEST A	29.4	21.8	8.68	.12	.05
	TEST B	29.4	21.8	8.62	.12	.05
3.6ml	TEST A	28.8	21.8	8.68	.12	.05
	TEST B	28.9	21.9	8.68	.12	.05
4.0ml	TEST A	28.3	21.9	8.68	.12	.05
	TEST B	28.3	21.9	8.68	.12	.05
4.4ml	TEST A	27.9	21.9	8.71	.11	.05
	TEST B	28.0	21.9	8.71	.11	.05
4.8ml	TEST A	27.8	21.9	8.71	.11	.05
	TEST B	27.7	21.9	8.71	.11	.05
5.2ml	TEST A	27.6	21.9	8.71	.11	.05
	TEST B	27.5	21.9	8.71	.11	.05
5.6ml	TEST A	27.5	21.9	8.71	.11	.05
	TEST B	27.5	21.9	8.71	.11	.05
6.0ml	TEST A	27.5	21.9	8.71	.11	.05
	TEST B	27.5	21.9	8.71	.11	.05
6.4ml	TEST A	27.5	21.9	8.71	.11	.05
	TEST B	27.5	21.9	8.71	.11	.05

EQUILIBRIUM SURFACE TENSION POINTS
SAMPLE GROUP 3

CONCEN.	SURF. TEN	B/SEC.
.4ml	36.0 d/cm	.26
.8ml	28.6 d/cm	.32
1.2ml	27.5 d/cm	.33
1.6ml	27.0 d/cm	.32
2.01ml	26.4 d/cm	.32
2.4ml	26.1 d/cm	.32
2.8ml	25.8 d/cm	.33
3.2ml	25.6 d/cm	.30
3.6ml	25.5 d/cm	.30
4.0ml	25.4 d/cm	.30
4.4ml	25.3 d/cm	.30
4.8ml	25.2 d/cm	.30
5.2ml	25.2 d/cm	.30
5.6ml	25.2 d/cm	.30



Sample Group 3
36
34
32
30
28
26
24
Surface Tension dynes/cm
10⁻⁴
10⁻³
10⁻²
10⁻¹
Concentration in Moles/100ml H2O


Sample Group 3
55
50
45
40
35
30
25
Surface Tension dynes/cm
10^{-4}
10^{-3}
10^{-2}
10^{-}
Concentration in Moles/100ml H20

SAMPLE GROUP 4 - SLOWEST RATE
HWI:6310-105 Test Material: A12-14 EO3 (Neodol 23-3)

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.5	22.4	.12	8.33	8.16
.4ml	TEST A	40.2	22.4	.24	4.16	3.95
	TEST B	40.2	22.4	.24	4.16	3.95
.8ml	TEST A	37.7	22.5	.27	3.70	3.52
	TEST B	37.7	22.5	.28	3.57	3.39
1.2ml	TEST A	35.8	22.6	.28	3.57	3.39
	TEST B	35.7	22.6	.28	3.57	3.39
1.6ml	TEST A	34.1	22.7	.30	3.33	3.19
	TEST B	34.2	22.7	.30	3.33	3.19
2.0ml	TEST A	33.0	22.8	.30	3.33	3.19
	TEST B	33.0	22.8	.30	3.33	3.19
2.4ml	TEST A	32.6	22.8	.30	3.33	3.19
	TEST B	32.6	22.8	.30	3.33	3.19
2.8ml	TEST A	32.0	22.9	.33	3.03	2.84
	TEST B	32.0	22.9	.32	3.12	2.96
3.2ml	TEST A	31.7	22.9	.32	3.12	2.96
	TEST B	31.7	22.9	.31	3.22	3.03
3.6ml	TEST A	31.3	23.0	.33	3.33	3.19
	TEST B	31.3	23.0	.30	3.33	3.19
4.0ml	TEST A	30.9	23.0	.33	3.03	2.84
	TEST B	31.0	23.0	.31	3.22	3.03
4.4ml	TEST A	30.7	23.2	.30	3.33	3.19
	TEST B	30.6	23.1	.32	3.12	2.96
4.8ml	TEST A	30.5	23.1	.31	3.22	3.03
	TEST B	30.4	23.1	.30	3.33	3.19
5.2ml	TEST A	30.4	23.3	.31	3.22	3.03
	TEST B	30.4	23.3	.31	3.22	3.03
5.6ml	TEST A	30.4	23.3	.31	3.22	3.03
	TEST B	30.4	23.3	.31	3.22	3.03
6.0ml	TEST A	30.4	23.3	.31	3.22	3.03
	TEST B	30.4	23.3	.31	3.22	3.03

SAMPLE GROUP 4 - SLOW RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml additive	TEST A	72.5	22.8	.24	4.16 s.	3.95
.4ml additive	TEST A	45.8	23.0	.24	4.16 s.	3.95
	TEST B	45.9	23.0	.24	4.16 s.	3.95
.8ml additive	TEST A	43.0	22.6	.28	3.57 s.	3.39
	TEST B	42.9	22.6	.28	3.57 s.	3.39
1.2ml additive	TEST A	41.0	22.9	.30	3.33 s.	3.16
	TEST B	40.9	22.9	.30	3.33 s	3.16
1.6ml additive	TEST A	38.5	22.9	.32	3.12 s	2.93
	TEST B	38.5	22.9	.32	3.12	2.93
2.0ml additive	TEST A	37.4	23.1	.36	2.77	2.58
	TEST B	37.5	23.1	.36	2.77	2.58
2.4ml additive	TEST A	36.5	22.9	.40	2.50	2.28
	TEST B	36.5	22.9	.40	2.50	2.28
2.8ml additive	TEST A	36.0	23.1	.39	2.56	2.33
	TEST B	36.0	23.1	.39	2.56	2.33
3.2ml additive	TEST A	34.9	23.0	.39	2.56	2.33
	TEST B	34.9	23.0	.39	2.56	2.33
3.6ml addditive	TEST A	33.9	23.0	.38	2.63	2.43
	TEST B	33.9	23.0	.38	2.63	2.43
4.0ml additive	TEST A	33.7	22.9	.37	2.70	2.44
	TEST B	33.7	22.9	.37	2.70	2.44
4.4ml additive	TEST A	33.2	22.9	.37	2.70	2.44
	TEST B	33.2	22.9	.37	2.70	2.44
4.8ml additive	TEST A	33.0	22.9	.37	2.70	2.44
	TEST B	33.0	22.9	.37	2.70	2.44
5.2ml additive	TEST A	32.7	22.9	.38	2.63	2.43
	TEST B	32.8	22.9	.38	2.63	2.43
5.6ml additive	TEST A	32.6	22.9	.39	2.56	2.33
	TEST B	32.6	22.9	.39	2.56	2.33
6.0ml additive	TEST A	32.3	22.8	.39	2.56	2.33
	TEST B	32.4	22.9	.39	2.56	2.33
6.4ml additive	TEST A	32.1	22.9	.39	2.56	2.33
	TEST B	32.2	22.9	.39	2.56	2.33
6.8ml additive	TEST A	31.6	22.9	.39	2.56	2.33
	TEST B	31.5	22.9	.39	2.56	2.33
7.2ml additive	TEST A	31.1	22.9	.40	2.50	2.28
	TEST B	31.2	22.9	.40	2.50	2.28
7.6ml additive	TEST A	31.1	23.0	.40	2.50	2.28
	TEST B	31.0	23.0	.40	2.50	2.28
8.0ml additive	TEST A	30.8	23.0	.40	2.50	2.28
	TEST B	30.8	23.0	.40	2.50	2.28
8.4ml additive	TEST A	30.8	23.0	.40	2.50	2.28
	TEST B	30.8	23.0	.40	2.50	2.28
8.8ml additive	TEST A	30.8	23.0	.40	2.50	2.28
	TEST B	30.8	23.0	.40	2.50	2.28

SAMPLE GROUP 4 - MED RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.8	20.9	1.01	.99	.86
.4ml	TEST A	60.0	20.9	1.04	.96	.83
	TEST B	60.0	20.9	1.05	.95	.82
.8ml	TEST A	57.1	21.0	1.12	.89	.77
	TEST B	57.1	21.0	1.10	.91	.78
1.2ml	TEST A	54.9	21.0	1.17	.85	.73
	TEST B	54.9	21.0	1.17	.85	.73
1.6ml	TEST A	52.9	21.0	1.20	.83	.71
	TEST B	52.9	21.0	1.19	.84	.72
2.0ml	TEST A	52.0	21.0	1.25	.80	.69
	TEST B	52.0	21.0	1.25	.80	.69
2.4ml	TEST A	51.0	21.0	1.30	.77	.66
	TEST B	51.0	21.0	1.30	.77	.66
2.8ml	TEST A	50.2	21.0	1.32	.76	.65
	TEST B	50.2	21.0	1.30	.77	.66
3.2ml	TEST A	49.6	21.1	1.32	.76	.65
	TEST B	49.6	21.1	1.34	.75	.64
3.6ml	TEST A	48.9	21.1	1.36	.74	.63
	TEST B	48.9	21.1	1.34	.75	.64
4.0ml	TEST A	48.1	21.1	1.38	.72	.62
	TEST B	48.1	21.1	1.39	.72	.62
4.4ml	TEST A	47.5	21.2	1.39	.72	.62
	TEST B	47.5	21.2	1.40	.71	.61
4.8ml	TEST A	47.0	21.2	1.40	.71	.61
	TEST B	47.0	21.2	1.40	.71	.61
5.2ml	TEST A	46.5	21.2	1.42	.70	.60
	TEST B	46.5	21.2	1.40	.71	.61
5.6ml	TEST A	46.0	21.2	1.42	.70	.60
	TEST B	45.9	21.2	1.42	.70	.60
6.0ml	TEST A	45.6	21.2	1.43	.70	.60
	TEST B	45.7	21.2	1.43	.70	.60
6.4ml	TEST A	45.6	21.2	1.45	.69	.59
	TEST B	45.5	21.2	1.46	.68	.58
6.8ml	TEST A	45.1	21.2	1.45	.69	.59
	TEST B	45.0	21.2	1.46	.68	.58
7.2ml	TEST A	44.6	21.3	1.48	.68	.58
	TEST B	44.5	21.3	1.48	.68	.58
7.6ml	TEST A	44.4	21.3	1.48	.68	.58
	TEST B	44.4	21.3	1.48	.68	.58
8.0ml	TEST A	44.2	21.3	1.50	.67	.57
	TEST B	44.2	21.3	1.48	.68	.58
8.4ml	TEST A	44.0	21.3	1.50	.67	.57
	TEST B	44.0	21.3	1.51	.68	.58
8.8ml	TEST A	43.7	21.3	1.54	.65	.55
	TEST B	43.7	21.3	1.56	.64	.54
9.2ml	TEST A	43.5	21.3	1.56	.64	.54
	TEST B	43.5	21.3	1.54	.65	.55
9.6ml	TEST A	43.4	21.3	1.52	.66	.56
	TEST B	43.3	21.3	1.52	.66	.56
10.0ml	TEST A	43.2	21.3	1.52	.66	.56
	TEST B	43.1	21.3	1.52	.66	.56

Sample Group 4 - Medium Rate Continued

10.4ml	TEST A	43.0	21.3	1.53	.65	.55
	TEST B	42.9	21.3	1.54	.65	.55
10.8ml	TEST A	42.9	21.3	1.56	.64	.54
	TEST B	42.9	21.3	1.56	.64	.54
11.2ml	TEST A	42.9	21.3	1.56	.64	.54
	TEST B	42.9	21.3	1.56	.64	.54

SAMPLE GROUP 2 - SLOW RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml additive	TEST A	72.8	20.1	.24	4.16 sec.	3.95
.4ml additive	TEST A	41.5	22.5	.40	2.50 sec.	2.30
	TEST B	41.5	22.5	.40	2.50 sec.	2.30
.8ml additive	TEST A	36.6	22.6	.40	2.50 sec.	2.30
	TEST B	36.6	22.6	.40	2.50 sec.	2.30
1.2ml additive	TEST A	34.5	22.8	.43	2.32 sec.	2.11
	TEST B	34.4	22.8	.43	2.32 sec.	2.11
1.6ml additive	TEST A	33.3	22.7	.43	2.32 sec.	2.11
	TEST B	33.3	22.7	.43	2.32 sec.	2.11
2.0ml additive	TEST A	32.6	23.1	.44	2.27sec.	2.06
	TEST B	32.6	23.1	.44	2.27 sec.	2.06
2.4ml additive	TEST A	31.0	23.1	.44	2.27sec.	2.06
	TEST B	30.9	23.1	.44	2.27sec.	2.06
2.8ml additive	TEST A	30.9	23.1	.44	2.27 sec.	2.06
	TEST B	30.9	23.1	.44	2.27sec.	2.06
3.2ml additive	TEST A	30.8	23.1	.43	2.32 sec.	2.11
	TEST B	30.8	23.1	.43	2.32sec.	2.11
3.6ml additive	TEST A	30.7	23.2	.42	2.38 sec.	2.17
	TEST B	30.6	23.2	.42	2.38 sec.	2.17
4.0ml additive	TEST A	30.5	23.2	.41	2.40 sec	2.18
	TEST B	30.5	23.2	.41	2.40 sec	2.18
4.4ml additive	TEST A	30.3	23.2	.44	2.27 sec	2.06
	TEST B	30.3	23.2	.44	2.27 sec	2.06
4.8ml additive	TEST A	30.3	23.2	.43	2.32 sec	2.11
	TEST B	30.3	23.2	.43	2.32 sec	2.11
5.2ml additvie	TEST A	30.3	23.2	.43	2.32 sec	2.11
	TEST B	30.3	23.3	.43	2.32 sec	2.11

SAMPLE GROUP 2 - MED. RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.7	21.2	1.01	.99	.86
.4ml	TEST A	49.2	21.2	1.53	.65	.55
	TEST B	49.2	21.2	1.54	.65	.55
.8ml	TEST A	44.0	21.2	1.68	.60	.51
	TEST B	44.0	21.2	1.65	.60	.51
1.2ml	TEST A	41.6	21.3	1.78	.56	.46
	TEST B	41.6	21.3	1.78	.56	.46
1.6ml	TEST A	40.1	21.3	1.82	.55	.46
	TEST B	40.1	21.3	1.87	.53	.44
2.0ml	TEST A	39.1	21.3	1.86	.53	.44
	TEST B	39.1	21.3	1.87	.53	.44
2.4ml	TEST A	38.4	21.3	1.92	.52	.43
	TEST B	38.4	21.3	1.94	.52	.43
2.8ml	TEST A	37.9	21.4	1.92	.52	.43
	TEST B	37.9	21.4	1.92	.52	.43
3.2ml	TEST A	37.5	21.4	1.94	.52	.43
	TEST B	37.5	21.4	1.94	.52	.43
3.6ml	TEST A	37.2	21.4	1.88	.53	.44
	TEST B	37.2	21.4	1.88	.53	.44
4.0ml	TEST A	36.9	21.4	1.94	.52	.43
	TEST B	36.9	21.4	1.94	.52	.43
4.4ml	TEST A	36.7	21.4	1.88	.53	.44
	TEST B	36.7	21.5	1.88	.53	.44
4,8ml	TEST A	36.6	21.5	1.96	.52	.43
	TEST B	36.6	21.5	1.94	.52	.43
5.2ml	TEST A	36.4	21.5	1.98	.51	.42
	TEST B	36.4	21.5	1.96	.52	.43
5.6ml	TEST A	36.2	21.5	1.92	.52	.43
	TEST B	36.2	21.5	1.94	.52	.43
6.0ml	TEST A	36.1	21.5	1.96	.52	.43
	TEST B	36.1	21.5	1.94	.52	.43
6.4ml	TEST A	36.0	21.5	1.96	.52	.43
	TEST B	36.0	21.5	1.96	.52	.43
6.8ml	TEST A	35.9	21.6	1.96	.52	.43
	TEST B	35.9	21.6	1.94	.52	.43
7.2ml	TEST A	35.8	21.6	1.94	.52	.43
	TEST B	35.8	21.6	1.96	.52	.43
7.6ml	TEST A	35.7	21.6	1.98	.51	.42
	TEST B	35.7	21.6	1.96	.52	.43
8.0ml	TEST A	35.6	21.7	2.02	.50	.41
	TEST B	35.6	21.7	1.98	.51	.42
8.4ml	TEST A	35.5	21.7	2.00	.50	.41
	TEST B	35.5	21.7	2.02	.50	.41
8.8ml	TEST A	35.5	21.7	2.00	.50	.41
	TEST B	35.5	21.7	2.00	.50	.41
9.2ml	TEST A	35.5	21.7	2.02	.50	.41
	TEST B	35.5	21.7	2.03	.49	.40
9.6ml	TEST A	35.5	21.7	1.98	.51	.42
	TEST B	35.5	21.7	2.00	.50	.41
10.0ml	TEST A	35.5	21.7	2.02	.50	.41
	TEST B	35.5	21.7	2.00	.50	.41

SAMPLE GROUP 2 -FAST RATE		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.7	21.3	4.33	.23	.14
.4ml	TEST A	62.2	21.2	5.34	.19	.11
	TEST B	62.2	21.3	5.34	.19	.11
.8ml	TEST A	56.9	21.3	5.68	.18	.10
	TEST B	56.9	21.2	5.68	.18	.10
1.2ml	TEST A	54.1	21.3	5.89	.17	.09
	TEST B	54.1	21.3	5.89	.17	.09
1.6ml	TEST A	52.1	21.3	6.10	.16	.08
	TEST B	52.1	21.3	6.10	.16	.08
2.0ml	TEST A	50.5	21.3	6.29	.16	.08
	TEST B	50.5	21.3	6.29	.16	.08
2.4ml	TEST A	49.2	21.3	6.29	.16	.08
	TEST B	49.2	21.3	6.29	.16	.08
2.8ml	TEST A	48.2	21.3	6.29	.16	.08
	TEST B	48.2	21.3	6.29	.16	.08
3.2ml	TEST A	47.4	21.3	6.29	.16	.08
	TEST B	47.4	21.3	6.30	.16	.08
3.6ml	TEST A	46.6	21.3	6.48	.15	.08
	TEST B	46.6	21.3	6.50	.15	.08
4.0ml	TEST A	46.0	21.3	6.48	.15	.08
	TEST B	46.0	21.3	6.50	.15	.08
4.4ml	TEST A	45.4	21.3	6.50	.15	.08
	TEST B	45.4	21.3	6.48	.15	.08
4.8ml	TEST A	45.0	21.3	6.50	.15	.08
	TEST B	45.0	21.3	6.50	.15	.08
5.2ml	TEST A	44.7	21.4	6.53	.15	.08
	TEST B	44.6	21.4	6.75	.15	.08
5.6ml	TEST A	44.4	21.4	6.75	.15	.08
	TEST B	44.4	21.4	6.75	.15	.08
6.0ml	TEST A	44.1	21.4	6.75	.15	.08
	TEST B	44.1	21.4	6.75	.15	.08
6.4ml	TEST A	43.9	21.4	6.75	.15	.08
	TEST B	43.9	21.4	6.75	.15	.08
6.8ml	TEST A	43.7	21.4	7.01	.14	.07
	TEST B	43.7	21.4	6.70	.15	.08
7.2ml	TEST A	43.4	21.4	6.75	.15	.08
	TEST B	43.4	21.4	6.75	.15	.08
7.6ml	TEST A	43.2	21.4	6.99	.14	.07
	TEST B	43.2	21.5	6.75	.15	.08
8.0ml	TEST A	43.0	21.5	6.99	.14	.07
	TEST B	43.0	21.5	6.75	.15	.08
8.4ml	TEST A	42.8	21.5	6.75	.15	.08
	TEST B	42.8	21.5	6.99	.14	.07
8.8ml	TEST A	42.7	21.6	6.77	.15	.08
	TEST B	42.7	21.6	6.75	.15	.08
9.2ml	TEST A	42.5	21.6	6.79	.15	.08
	TEST B	42.5	21.6	6.99	.14	.07
9.6ml	TEST A	42.3	21.6	6.99	.14	.07
	TEST B	42.4	21.6	6.99	.14	.07
10.0ml	TEST A	42.2	21.6	6.77	.15	.08
	TEST B	42.2	21.6	6.72	.15	.08

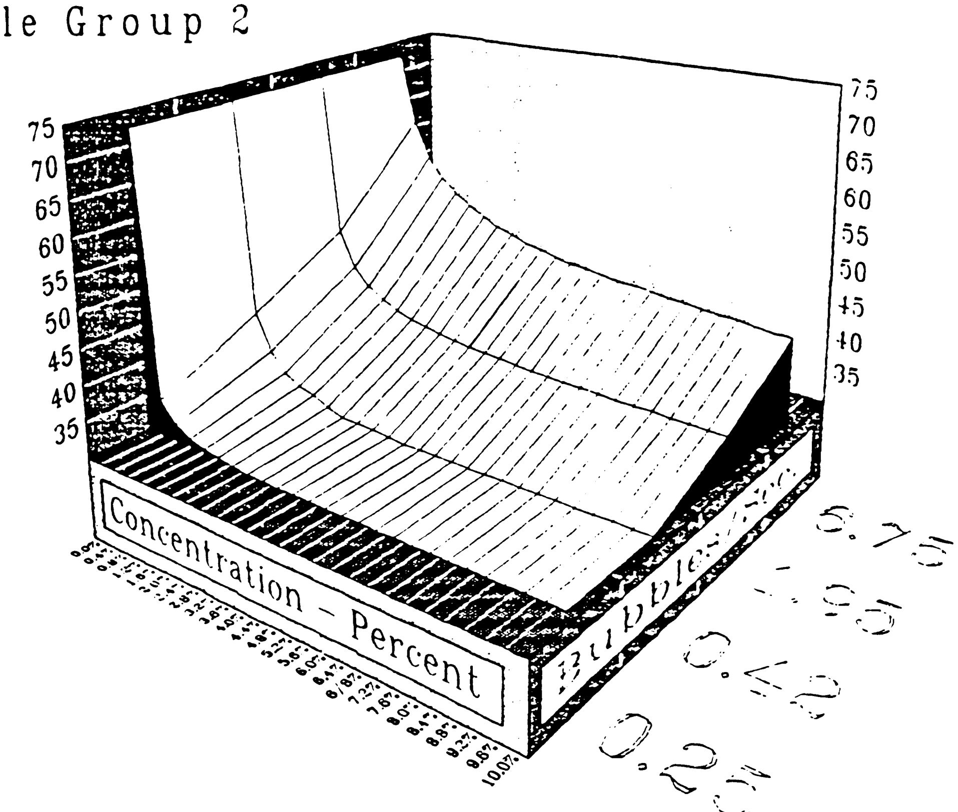
Sample Group 2 - Fast Rate Continued

10.4ml	TEST A	42.1	21.6	6.72	.15	.08
	TEST B	42.0	21.6	6.77	.15	.08
10.8ml	TEST A	41.9	21.6	6.79	.15	.08
	TEST B	41.9	21.6	6.79	.15	.08
11.2	TEST A	41.9	21.6	6.77	.15	.08
	TEST B	41.9	21.6	6.79	.15	.08
11.6ml	TEST A	41.9	21.6	6.79	.15	.08
	TEST B	41.9	21.6	6.77	.15	.08

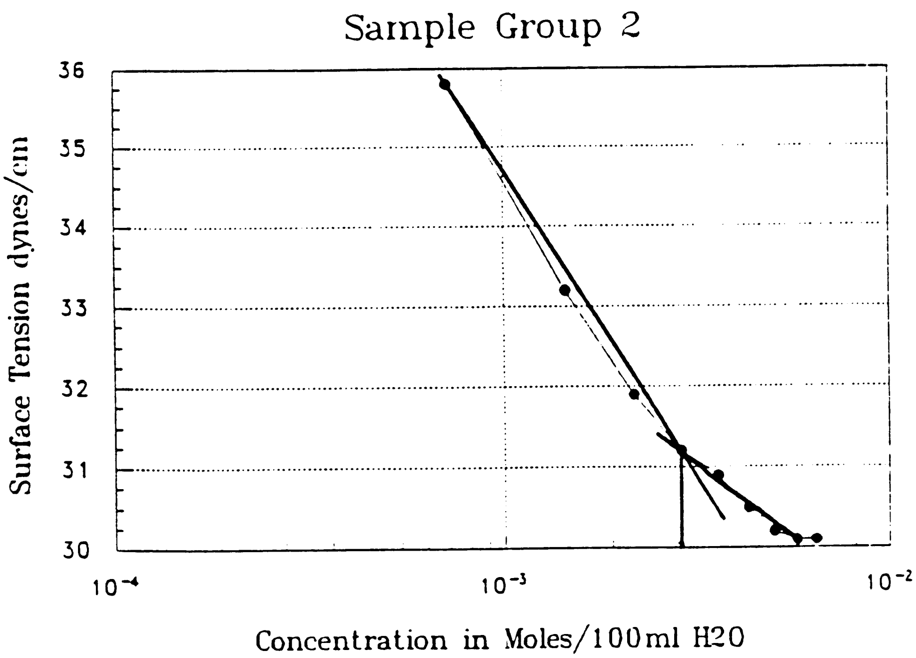
EQUILIBRIUM SURFACE TENSION POINTS
SAMPLE GROUP 2

CONCEN.	SURF. TEN	B/SEC.
.4ml	35.7 d/cm	.29
.8ml	33.1 d/cm	.30
1.2ml	31.8 d/cm	.30
1.6ml	31.2 d/cm	.30
2.0ml	30.9 d/cm	.30
2.4ml	30.5 d/cm	.30
2.8ml	30.2 d/cm	.30
3.2ml	30.1 d/cm	.30
3.6ml	30.1 d/cm	.30
4.0ml	30.1 d/cm	.30
4.4ml	30.1 d/cm	.30
4.8ml	30.1 d/cm	.30

Sample Group 2



Dynamic Surface Tension Graph


Sample Group 2
36
35
34
33
32
31
30
Surface Tension dynes/cm
10⁻⁴
10⁻³
10⁻²
Concentration in Moles/100ml H20

SAMPLE GROUP 4 - FAST RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.6	22.0	4.32	.23	.14
.4ml	TEST A	67.5	22.0	4.93	.20	.12
	TEST B	67.4	22.0	4.93	.20	.12
.8ml	TEST A	65.3	22.0	4.92	.20	.12
	TEST B	65.4	22.0	4.93	.20	.12
1.2ml	TEST A	64.1	22.0	4.92	.20	.12
	TEST B	64.1	22.1	4.92	.20	.12
1.6ml	TEST A	62.6	22.1	4.93	.20	.12
	TEST B	62.6	22.1	4.94	.20	.12
2.0ml	TEST A	61.4	22.1	4.93	.20	.12
	TEST B	61.4	22.1	4.93	.20	.12
2.4ml	TEST A	60.9	22.1	5.18	.19	.11
	TEST B	60.9	22.1	5.11	.19	.11
2.8ml	TEST A	60.2	22.2	5.21	.19	.11
	TEST B	60.2	22.2	5.21	.19	.11
3.2ml	TEST A	59.9	22.2	5.21	.19	.11
	TEST B	59.9	22.2	5.21	.19	.11
3.6ml	TEST A	59.2	22.2	5.21	.19	.11
	TEST B	59.2	22.2	5.21	.19	.11
4.0ml	TEST A	58.9	22.3	5.34	.19	.11
	TEST B	58.9	22.3	5.21	.19	.11
4.4ml	TEST A	58.2	22.3	5.20	.19	.11
	TEST B	58.2	22.3	5.21	.19	.11
4.8ml	TEST A	58.0	22.3	5.20	.19	.11
	TEST B	58.0	22.3	5.20	.19	.11
5.2ml	TEST A	57.8	22.3	5.21	.19	.11
	TEST B	57.8	22.3	5.21	.19	.11
5.6ml	TEST A	57.3	22.3	5.31	.19	.11
	TEST B	57.3	22.3	5.21	.19	.11
6.0ml	TEST A	57.0	22.3	5.34	.19	.11
	TEST B	57.0	22.3	5.37	.19	.11
6.4ml	TEST A	56.8	22.4	5.36	.19	.11
	TEST B	56.8	22.4	5.36	.19	.11
6.8ml	TEST A	56.4	22.3	5.38	.19	.11
	TEST B	56.5	22.4	5.38	.19	.11
7.2ml	TEST A	56.1	22.4	5.38	.19	.11
	TEST B	56.1	22.4	5.38	.19	.11
7.6ml	TEST A	55.9	22.4	5.53	.18	.10
	TEST B	55.9	22.4	5.53	.18	.10
8.0ml	TEST A	55.4	22.4	5.53	.18	.10
	TEST B	55.4	22.4	5.53	.18	.10
8.4ml	TEST A	55.0	22.4	5.49	.18	.10
	TEST B	55.1	22.4	5.49	.18	.10
8.8ml	TEST A	54.6	22.4	5.49	.18	.10
	TEST B	54.6	22.4	5.53	.18	.10
9.2ml	TEST A	54.5	22.4	5.53	.18	.10
	TEST B	54.4	22.4	5.53	.18	.10
9.6ml	TEST A	54.3	22.4	5.68	.17	.09
	TEST B	54.2	22.4	5.68	.17	.09
10.0ml	TEST A	54.2	22.5	5.70	.17	.09
	TEST B	54.2	22.5	5.70	.17	.09

Sample Group 4 - Fast Rate Continued

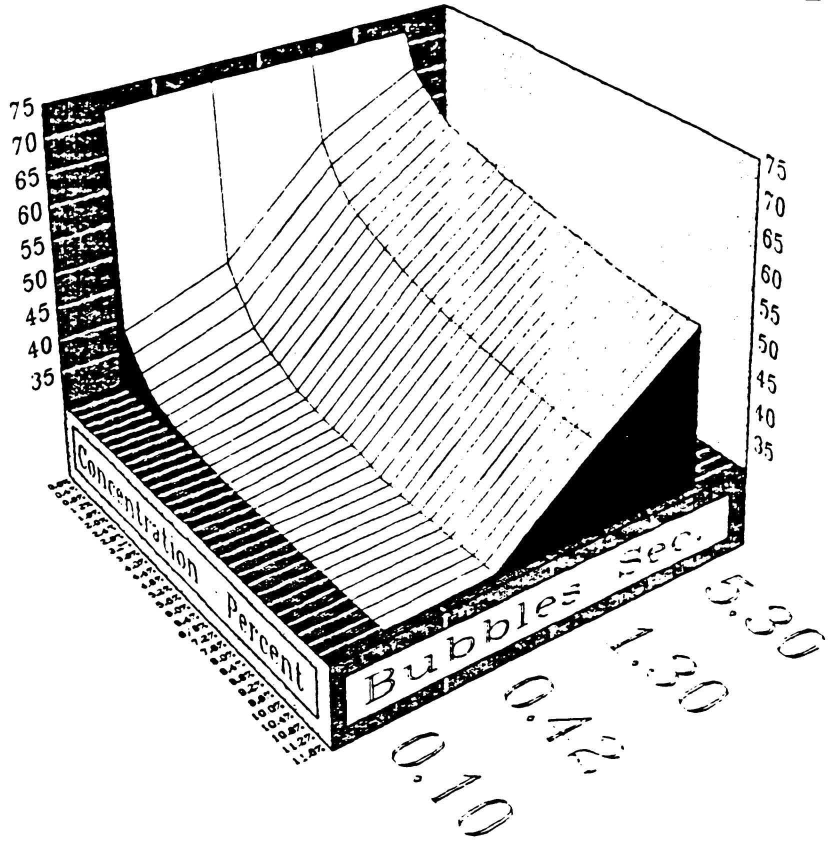
sat. conc

10.4ml	TEST A	53.9	22.5	5.69	.17	.09
	TEST B	53.9	22.5	5.69	.17	.09
10.8ml	TEST A	53.8	22.5	5.71	.17	.09
	TEST B	53.8	22.5	5.69	.17	.09
11.2ml	TEST A	53.8	22.5	5.69	.17	.09
	TEST B	53.8	22.5	5.69	.17	.09
11.6ml	TEST A	53.8	22.5	5.69	.17	.09
	TEST B	53.8	22.5	5.69	.17	.09

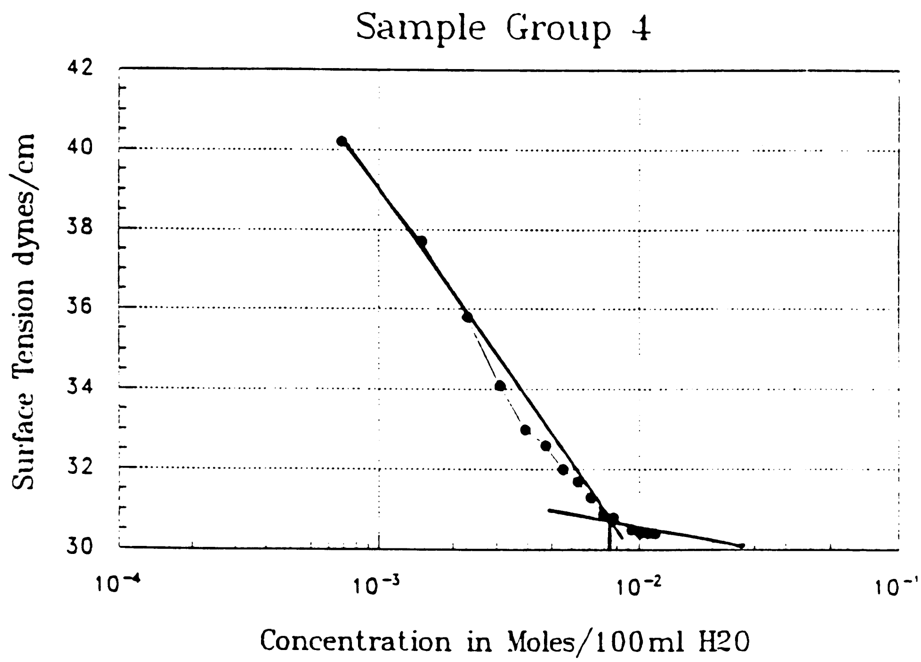
EQUILIBRIUM SURFACE TENSION POINTS
SAMPLE GROUP 4

CONC.	SURF TEN.	B/SEC.
.4ml	40.2	.24
.8ml	37.7	.27
1.2ml	35.7	.28
1.6ml	34.1	.30
2.0ml	33.0	.30
2.4ml	32.6	.32
2.8ml	32.0	.33
3.2ml	31.7	.33
3.6ml	31.3	.33
4.0ml	30.9	.33
4.4ml	30.7	.32
4.8ml	30.5	.31
5.2ml	30.4	.31
5.6ml	30.4	.31
6.0ml	30.4	.31

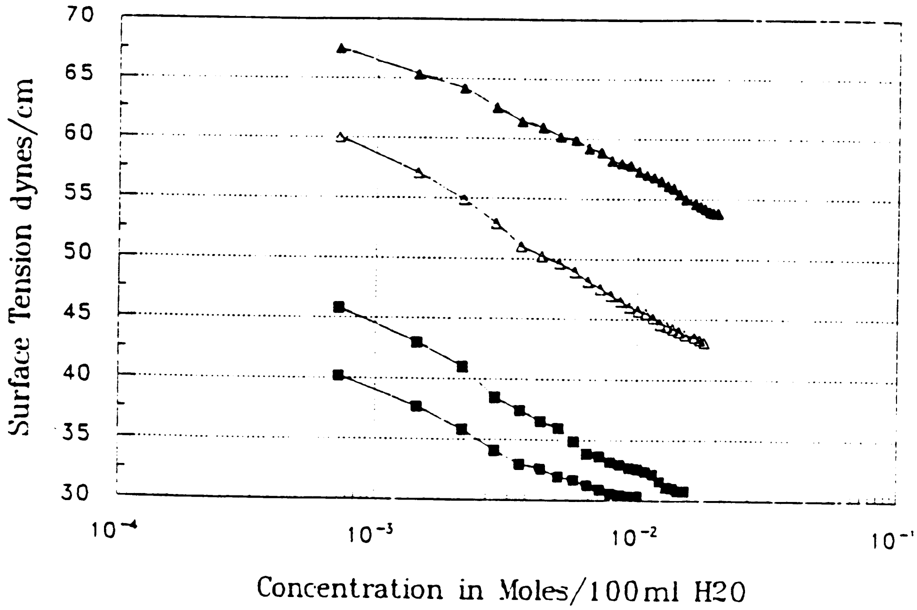
Dynamic Surface Tension Graph



Sample Group 4


Sample Group 4
Surface Tension dynes/cm
42
40
38
36
34
32
30
10⁻⁴
10⁻³
10⁻²
10⁻¹
Concentration in Moles/100ml H20

Sample Group 4



SAMPLE GROUP 5 - SLOWEST RATE
HWI: 6310-105 Test Material: A12 EO23 (Brij-35)

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.3	23.9	.15	6.66	6.39
.4ml	TEST A	47.6	23.9	.17	5.88	5.62
	TEST B	47.6	23.9	.17	5.88	5.62
.8ml	TEST A	45.2	23.9	.17	5.88	5.62
	TEST B	45.3	23.9	.17	5.88	5.62
1.2ml	TEST A	44.4	23.9	.17	5.88	5.62
	TEST B	44.4	23.9	.17	5.88	5.62
1.6ml	TEST A	44.0	23.9	.17	5.88	5.62
	TEST B	44.0	23.9	.17	5.88	5.62
2.0ml	TEST A	43.7	23.9	.17	5.88	5.62
	TEST B	43.7	23.9	.17	5.88	5.62
2.4ml	TEST A	43.5	23.9	.17	5.88	5.62
	TEST B	43.5	23.9	.17	5.88	5.62
2.8ml	TEST A	43.4	23.9	.17	5.88	5.62
	TEST B	43.4	23.9	.17	5.88	5.62
3.2ml	TEST A	43.3	23.9	.17	5.88	5.62
	TEST B	43.3	23.9	.17	5.88	5.62
3.6ml	TEST A	43.3	23.9	.17	5.88	5.62
	TEST B	43.3	23.9	.17	5.88	5.62
4.0ml	TEST A	43.3	23.9	.17	5.88	5.62
	TEST B	43.3	23.9	.17	5.88	5.62

SAMPLE GROUP 5 -- SLOW RATE		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml additive	TEST A	73.0	19.0	.24	4.16	3.95
.4ml additive	TEST A	49.0	19.6	.37	2.70	2.44
	TEST B	49.1	19.6	.37	2.70	2.44
.8ml addititve	TEST A	46.6	19.8	.37	2.70	2.44
	TEST B	46.7	19.8	.37	2.70	2.44
1.2ml additive	TEST A	46.3	20.1	.38	2.63	2.43
	TEST B	46.3	20.1	.38	2.63	2.43
1.6ml additive	TEST A	46.2	20.2	.38	2.63	2.43
	TEST B	46.1	20.2	.38	2.63	2.43
2.0ml additive	TEST A	46.1	20.3	.38	2.63	2.43
	TEST B	46.0	20.3	.38	2.63	2.43
2.4ml additive	TEST A	46.0	20.2	.38	2.63	2.43
	TEST B	46.0	20.2	.38	2.63	2.43
2.8ml additive	TEST A	45.9	20.3	.38	2.63	2.43
	TEST B	45.9	20.3	.38	2.63	2.43
3.2ml additive	TEST A	45.8	20.3	.38	2.63	2.43
	TEST B	45.8	20.3	.38	2.63	2.43
3.6ml additive	TEST A	45.8	20.3	.38	2.63	2.43
	TEST B	45.7	20.3	.38	2.63	2.43
4.0ml additive	TEST A	45.6	20.3	.38	2.63	2.43
	TEST B	45.6	20.3	.38	2.63	2.43
4.4ml additive	TEST A	45.5	20.3	.38	2.63	2.43
	TEST B	45.5	20.3	.38	2.63	2.43
4.8ml additive	TEST A	45.5	20.3	.38	2.63	2.43
	TEST B	45.4	20.3	.38	2.63	2.43
5.2ml additive	TEST A	45.4	20.3	.38	2.63	2.43
	TEST B	45.4	20.3	.38	2.63	2.43
5.6ml additive	TEST A	45.4	20.4	.38	2.63	2.43
	TEST B	45.4	20.4	.38	2.63	2.43
6.0ml additive	TEST A	45.4	20.4	.38	2.63	2.43
	TEST B	45.4	20.4	.38	2.63	2.43

SAMPLE GROUP 5 - MED RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.7	21.0	1.01	.99	.86
.4ml	TEST A	50.5	21.0	1.21	.83	.71
	TEST B	50.5	21.0	1.21	.83	.71
.8ml	TEST A	48.4	21.0	1.23	.81	.69
	TEST B	48.4	21.0	1.24	.81	.69
1.2ml	TEST A	47.6	21.0	1.24	.81	.69
	TEST B	47.6	21.0	1.26	.79	.68
1.6ml	TEST A	47.3	21.0	1.26	.79	.68
	TEST B	47.3	21.0	1.26	.79	.68
2.0ml	TEST A	47.0	21.0	1.29	.78	.67
	TEST B	47.0	21.0	1.26	.79	.68
2.4ml	TEST A	46.9	21.1	1.26	.79	.68
	TEST B	46.9	21.1	1.26	.79	.68
2.8ml	TEST A	46.8	21.2	1.26	.79	.68
	TEST B	46.8	21.2	1.26	.79	.68
3.2ml	TEST A	46.7	21.2	1.26	.79	.68
	TEST B	46.7	21.2	1.26	.79	.68
3.6ml	TEST A	46.6	21.2	1.27	.79	.68
	TEST A	46.6	21.2	1.26	.79	.68
4.0ml	TEST A	46.5	21.2	1.27	.79	.68
	TEST B	46.5	21.2	1.27	.79	.68
4.4ml	TEST A	46.5	21.2	1.27	.79	.68
	TEST B	46.5	21.2	1.27	.79	.68
4.8ml	TEST A	46.4	21.2	1.27	.79	.68
	TEST B	46.4	21.2	1.27	.79	.68
5.2ml	TEST A	46.4	21.2	1.29	.78	.67
	TEST B	46.4	21.2	1.27	.79	.68
5.6ml	TEST A	46.4	21.2	1.29	.78	.67
	TEST B	46.4	21.2	1.31	.76	.65
6.0ml	TEST A	46.4	21.2	1.29	.78	.67
	TEST B	46.4	21.2	1.29	.78	.67

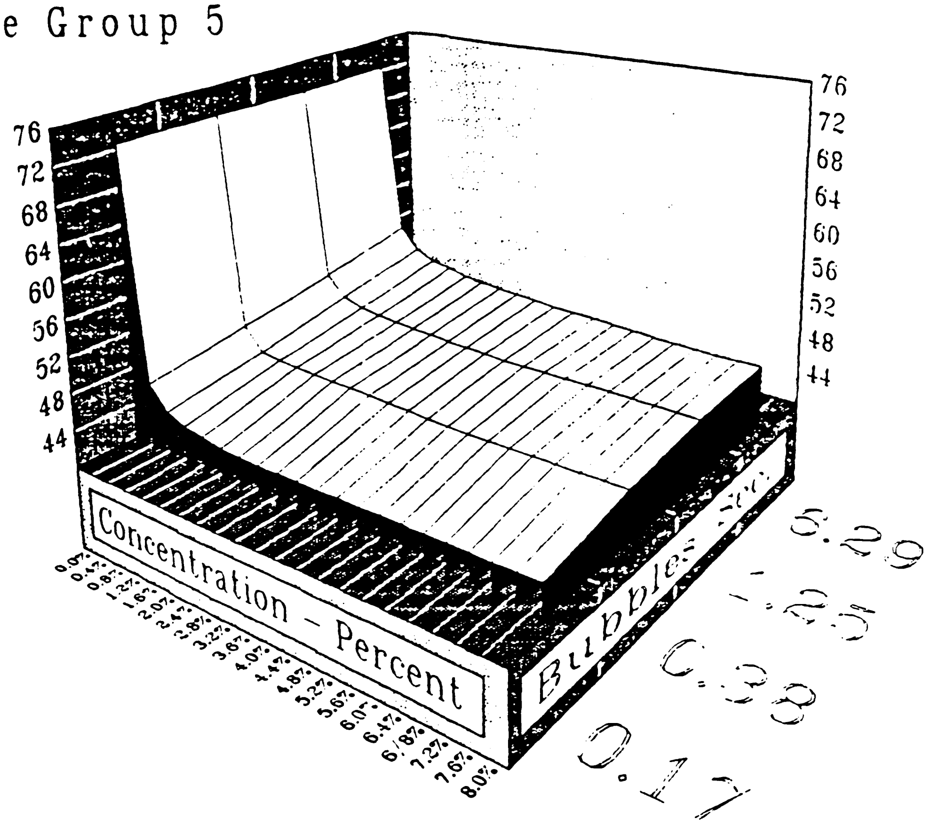
SAMPLE GROUP 5 - FAST RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.5	22.3	4.33	.23	.14
.4ml	TEST A	52.4	22.3	5.69	.18	.10
	TEST B	52.4	22.3	5.69	.18	.10
.8ml	TEST A	49.9	22.3	5.89	.17	.09
	TEST B	49.9	22.3	5.89	.17	.09
1.2ml	TEST A	49.0	22.3	5.87	.17	.09
	TEST B	49.0	22.3	5.87	.17	.09
1.6ml	TEST A	48.5	22.3	6.07	.16	.08
	TEST B	48.5	22.4	6.29	.16	.08
2.0ml	TEST A	48.1	22.4	6.29	.16	.08
	TEST B	48.1	22.4	6.29	.16	.08
2.4ml	TEST A	47.8	22.5	6.29	.16	.08
	TEST B	47.8	22.5	6.29	.16	.08
2.8ml	TEST A	47.6	22.6	6.29	.16	.08
	TEST B	47.6	22.6	6.29	.16	.08
3.2ml	TEST A	47.5	22.6	6.28	.16	.08
	TEST B	47.4	22.6	6.29	.16	.08
3.6ml	TEST A	47.3	22.6	6.29	.16	.08
	TEST B	47.2	22.6	6.29	.16	.08
4.0ml	TEST A	47.1	22.6	6.29	.16	.08
	TEST B	47.1	22.6	6.29	.16	.08
4.4ml	TEST A	47.0	22.6	6.29	.16	.08
	TEST B	47.0	22.6	6.29	.16	.08
4.8ml	TEST A	46.9	22.6	6.29	.16	.08
	TEST B	46.9	22.6	6.29	.16	.08
5.2ml	TEST A	46.8	22.6	6.29	.16	.08
	TEST B	46.8	22.6	6.29	.16	.08
5.6ml	TEST A	46.8	22.6	6.29	.16	.08
	TEST B	46.8	22.6	6.29	.16	.08
6.0ml	TEST A	46.7	22.7	6.29	.16	.08
	TEST B	46.7	22.7	6.29	.16	.08
6.4ml	TEST A	46.7	22.7	6.29	.16	.08
	TEST B	46.6	22.8	6.29	.16	.08
6.8ml	TEST A	46.6	22.8	6.29	.16	.08
	TEST B	46.5	22.8	6.29	.16	.08
7.2ml	TEST A	46.5	22.8	6.29	.16	.08
	TEST B	46.5	22.8	6.29	.16	.08
7.6ml	TEST A	46.5	22.8	6.29	.16	.08
	TEST B	46.5	22.8	6.29	.16	.08
8.0ml	TEST A	46.5	22.9	6.29	.16	.08
	TEST B	46.5	22.9	6.29	.16	.08

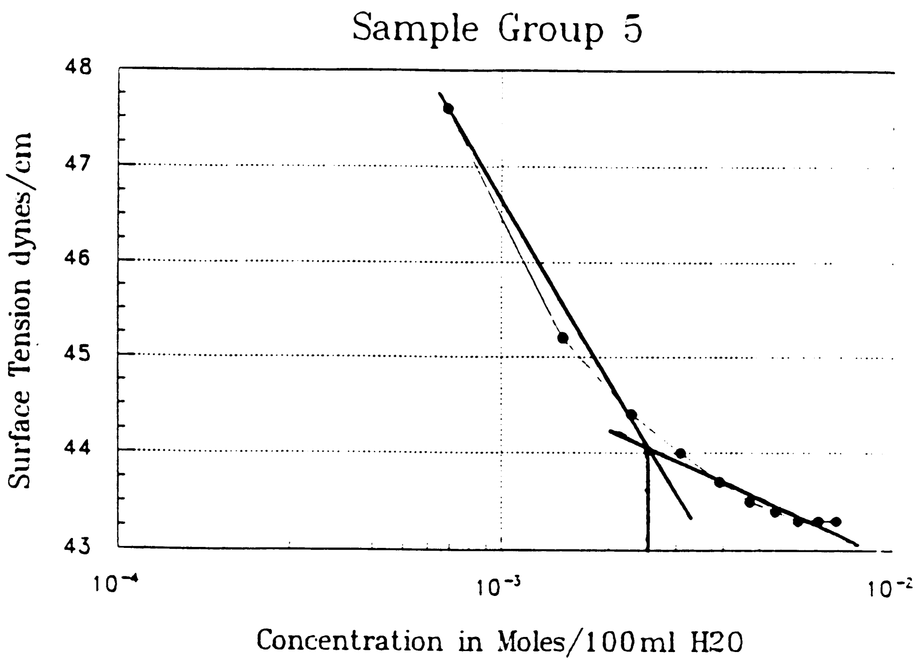
EQUILIBRIUM SURFACE TENSION POINTS
SAMPLE GROUP 5

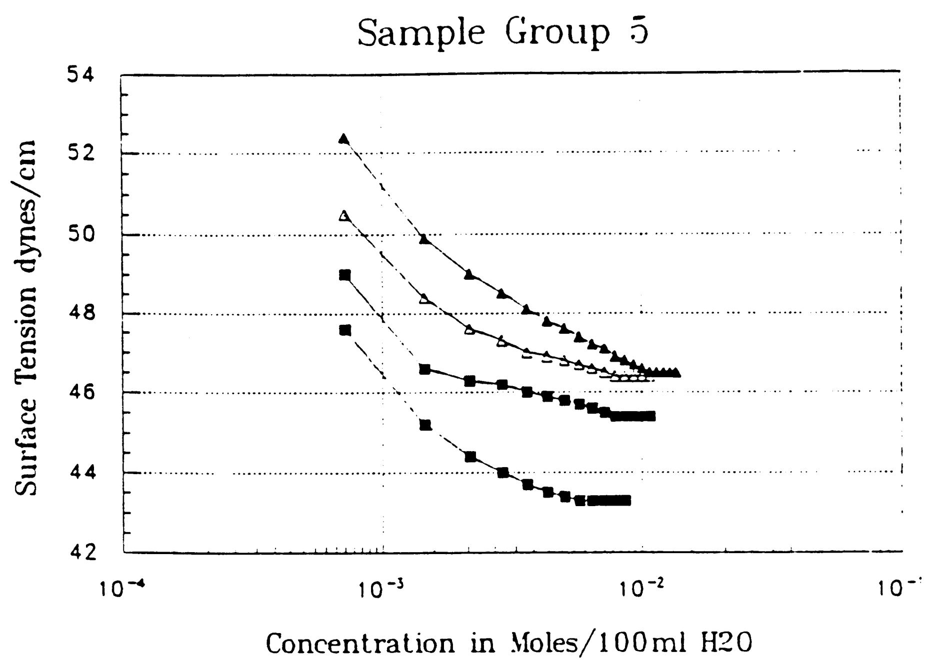
CONCEN.	SURF. TEN	B/SEC.
.4ml	47.6 d/cm	.17
.8ml	45.2 d/cm	.17
1.2ml	44.4 d/cm	.17
1.6ml	44.0 d/cm	.17
2.0ml	43.7 d/cm	.17
2.4ml	43.5 d/cm	.17
2.8ml	43.4 d/cm	.17
3.2ml	43.3 d/cm	.17
3.2ml	43.3 d/cm	.17
3.6ml	43.3 d/cm	.17
4.0ml	43.3 d/cm	.17
4.4ml	43.3 d/cm	.17
4.8ml	43.3 d/cm	.17

Sample Group 5



Dynamic Surface Tension Graph


Sample Group 5
Surface Tension dynes/cm
48
47
46
45
44
43
10⁻⁴
10⁻³
10⁻²
Concentration in Moles/100ml H20



Sample Group 5
Surface Tension dynes/cm
54
52
50
48
46
44
42
10⁻⁴
10⁻³
10⁻²
10⁻¹
Concentration in Moles/100ml H2O

SAMPLE GROUP 6 - SLOWEST RATE
HWI: 6310-105 Test Material: Nonylphenol - EO9.5 (Triton N101)

		d/cm	°C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.2	24.3	.14	7.14	6.92
.4ml	TEST A	35.9	24.3	.24	4.16	3.95
	TEST B	35.8	24.3	.24	4.16	3.95
.8ml	TEST A	33.7	24.2	.24	4.16	3.95
	TEST B	33.7	24.2	.24	4.16	3.95
1.2ml	TEST A	33.1	24.2	.23	4.34	4.12
	TEST B	33.0	24.2	.22	4.55	4.32
1.6ml	TEST A	32.8	24.1	.22	4.55	4.32
	TEST B	32.8	24.1	.22	4.55	4.32
2.0ml	TEST A	32.6	24.0	.22	4.55	4.32
	TEST B	32.6	24.0	.22	4.55	4.32
2.4ml	TEST A	32.5	24.0	.22	4.55	4.32
	TEST B	32.5	23.9	.22	4.55	4.32
2.8ml	TEST A	32.4	23.9	.22	4.55	4.32
	TEST B	32.4	23.9	.22	4.55	4.32
3.2ml	TEST A	32.4	23.9	.22	4.55	4.32
	TEST B	32.4	23.9	.22	4.55	4.32
3.6ml	TEST A	32.4	23.9	.22	4.55	4.32
	TEST B	32.4	23.9	.22	4.55	4.32
4.0ml	TEST A	32.4	23.9	.22	4.55	4.32
	TEST B	32.4	23.9	.22	4.55	4.32

SAMPLE GROUP 6 - SLOW RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml additive	TEST A	72.8	20.2	.24	4.16	3.95
.4ml additive	TEST A	37.7	20.4	.49	2.04	2.48
	TEST B	37.7	20.4	.53	1.88	1.71
.8ml additive	TEST A	35.1	20.4	.53	1.88	1.71
	TEST B	35.1	20.4	.53	1.88	1.71
1.2ml additive	TEST A	33.9	20.4	.53	1.88	1.71
	TEST B	33.9	20.4	.53	1.88	1.71
1.6ml additive	TEST A	33.4	20.4	.53	1.88	1.71
	TEST B	33.4	20.4	.53	1.88	1.71
2.0ml additive	TEST A	33.1	20.5	.53	1.88	1.71
	TEST B	33.1	20.5	.54	1.85	1.68
2.4ml additive	TEST A	32.9	20.5	.53	1.88	1.71
	TEST B	32.9	20.5	.53	1.88	1.71
2.8ml additive	TEST A	32.8	20.5	.53	1.88	1.71
	TEST B	32.8	20.5	.53	1.88	1.71
3.2ml additive	TEST A	32.7	20.5	.53	1.88	1.71
	TEST B	32.6	20.5	.54	1.85	1.68
3.6ml additive	TEST A	32.6	20.6	.53	1.88	1.71
	TEST B	32.5	20.6	.53	1.88	1.71
4.0ml additive	TEST A	32.5	20.7	.53	1.88	1.71
	TEST B	32.5	20.8	.53	1.88	1.71
4.4ml additive	TEST A	32.5	20.9	.54	1.85	1.68
	TEST B	32.5	20.9	.53	1.88	1.71
4.8ml additive	TEST A	32.5	20.9	.53	1.88	1.71
	TEST B	32.5	20.9	.54	1.85	1.68

SAMPLE GROUP 6 - MED RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.7	21.0	.97	1.03	.90
.4ml	TEST A	42.5	21.0	1.53	.65	.56
	TEST B	42.5	21.0	1.54	.65	.56
.8ml	TEST A	37.2	21.0	1.60	.63	.54
	TEST B	37.3	21.0	1.60	.63	.54
1.2ml	TEST A	35.8	21.0	1.66	.60	.51
	TEST B	35.8	21.0	1.64	.61	.52
1.6ml	TEST A	35.2	21.0	1.68	.59	.50
	TEST B	35.2	21.0	1.64	.61	.52
2.0ml	TEST A	34.9	21.1	1.68	.59	.50
	TEST B	34.9	21.1	1.68	.59	.50
2.4ml	TEST A	34.6	21.1	1.67	.60	.51
	TEST B	34.7	21.1	1.67	.60	.51
2.8ml	TEST A	34.5	21.1	1.67	.60	.51
	TEST B	34.5	21.1	1.68	.59	.50
3.2ml	TEST A	34.4	21.1	1.70	.59	.50
	TEST B	34.4	21.1	1.69	.59	.50
3.6ml	TEST A	34.3	21.2	1.69	.59	.50
	TEST B	34.3	21.2	1.70	.59	.50
4.0ml	TEST A	34.2	21.2	1.70	.59	.50
	TEST B	34.2	21.2	1.70	.59	.50
4.4ml	TEST A	34.1	21.2	1.70	.59	.50
	TEST B	34.1	21.2	1.70	.59	.50
4.8ml	TEST A	34.0	21.2	1.72	.58	.49
	TEST B	34.0	21.2	1.74	.57	.48
5.2ml	TEST A	34.0	21.2	1.74	.57	.48
	TEST B	34.0	21.2	1.74	.57	.48
5.6ml	TEST A	33.9	21.2	1.72	.58	.49
	TEST B	33.9	21.2	1.74	.57	.48
6.0ml	TEST A	33.9	21.2	1.74	.57	.48
	TEST B	33.9	21.2	1.74	.57	.48
6.4ml	TEST A	33.9	21.2	1.74	.57	.48
	TEST B	33.8	21.2	1.72	.58	.49
6.8ml	TEST A	33.8	21.2	1.72	.58	.49
	TEST B	33.8	21.2	1.72	.58	.49
7.2ml	TEST A	33.8	21.2	1.72	.58	.49
	TEST B	33.8	21.2	1.74	.57	.48
7.6ml	TEST A	33.8	21.2	1.72	.58	.49
	TEST B	33.8	21.2	1.72	.58	.49
8.0ml	TEST A	33.8	21.2	1.72	.58	.49
	TEST B	33.8	21.2	1.72	.58	.49

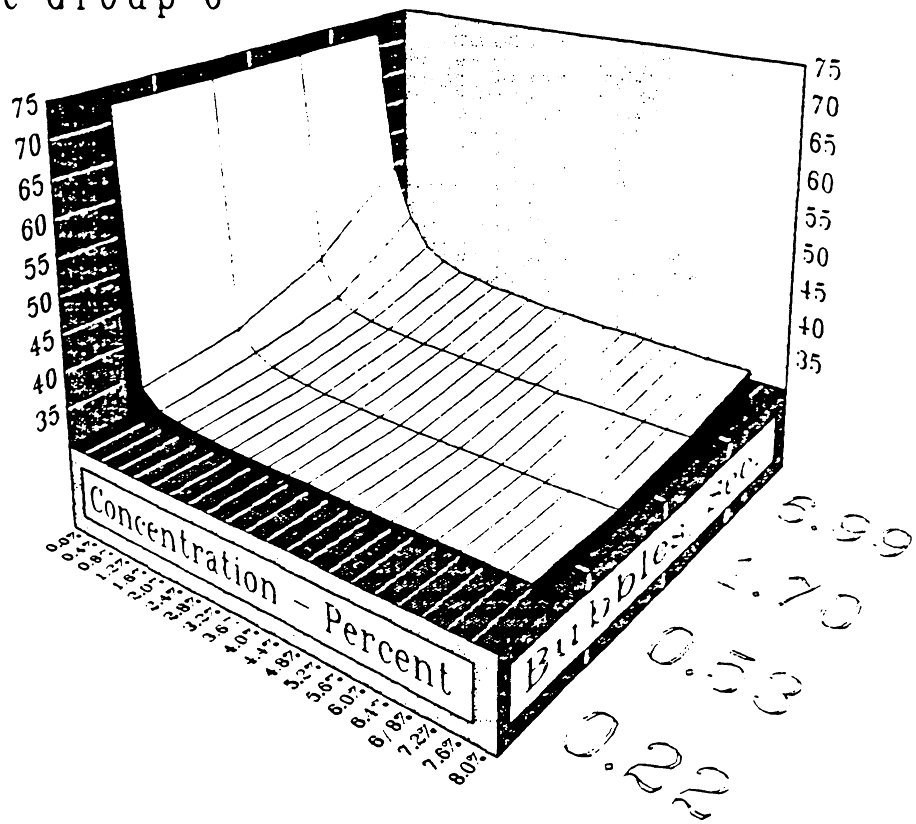
SAMPLE GROUP 6 - FAST RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.5	22.5	4.33	.23	.14
.4ml	TEST A	51.8	22.5	5.89	.17	.09
	TEST B	51.8	22.5	5.89	.17	.09
.8ml	TEST A	44.5	22.5	6.24	.16	.08
	TEST B	44.5	22.6	6.20	.16	.08
.1.2ml	TEST A	40.5	22.6	6.50	.15	.08
	TEST B	40.5	22.6	6.50	.15	.08
1.6ml	TEST A	38.8	22.6	6.75	.15	.08
	TEST B	38.8	22.6	6.77	.15	.08
2.0ml	TEST A	37.9	22.6	6.99	.14	.07
	TEST B	37.9	22.6	6.97	.14	.07
2.4ml	TEST A	37.4	22.6	6.99	.14	.07
	TEST B	37.4	22.7	6.99	.14	.07
2.8ml	TEST A	37.0	22.7	6.99	.14	.07
	TEST B	37.0	22.7	6.99	.14	.07
3.2ml	TEST A	36.8	22.7	6.99	.14	.07
	TEST B	36.8	22.7	6.99	.14	.07
3.6ml	TEST A	36.5	22.8	6.99	.14	.07
	TEST B	36.5	22.8	6.99	.14	.07
4.0ml	TEST A	36.3	22.8	6.99	.14	.07
	TEST B	36.3	22.8	6.99	.14	.07
4.4ml	TEST A	36.2	22.8	6.99	.14	.07
	TEST B	36.2	22.8	6.99	.14	.07
4.8ml	TEST A	36.0	22.8	6.99	.14	.07
	TEST B	36.0	22.8	6.99	.14	.07
5.2ml	TEST A	35.9	22.8	6.99	.14	.07
	TEST B	35.9	22.8	6.99	.14	.07
5.6ml	TEST A	35.9	22.8	6.99	.14	.07
	TEST B	35.9	22.8	6.99	.14	.07
6.0ml	TEST A	35.8	22.9	6.99	.14	.07
	TEST B	35.8	22.9	6.99	.14	.07
6.4ml	TEST A	35.8	22.9	6.99	.14	.07
	TEST B	35.7	22.9	6.99	.14	.07
6.8ml	TEST A	35.7	22.9	6.99	.14	.07
	TEST B	35.7	22.9	6.99	.14	.07
7.2ml	TEST A	35.6	22.9	6.99	.14	.07
	TEST B	35.6	22.9	6.99	.14	.07
7.6ml	TEST A	35.6	22.9	6.99	.14	.07
	TEST B	35.6	22.9	6.99	.14	.07
8.0ml	TEST A	35.6	22.9	6.99	.14	.07
	TEST B	35.6	22.9	6.99	.14	.07

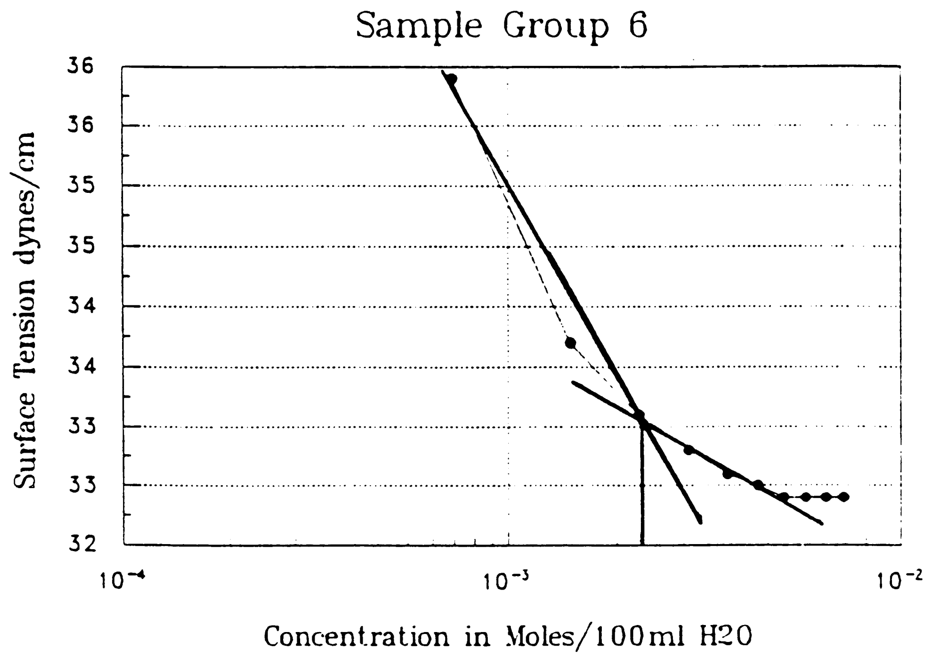
EQUILIBRIUM SURFACE TENSION POINTS
SAMPLE GROUP 6

CONCEN.	SURF. TEN	B/SEC.
.4ml	35.8 d/cm	.24
.8ml	33.7 d/cm	.24
1.2ml	33.0d/cm	.23
1.6ml	32.8 d/cm	.22
2.0ml	32.6 d/cm	.22
2.4ml	32.5 d/cm	.22
2.8ml	32.4 d/cm	.22
3.2ml	32.4 d/cm	.22
3.6ml	32.4 d/cm	.22
4.0ml	32.4 d/cm	.22
4.4ml	32.4 d/cm	.22
4.8ml	32.4 d/cm	.22

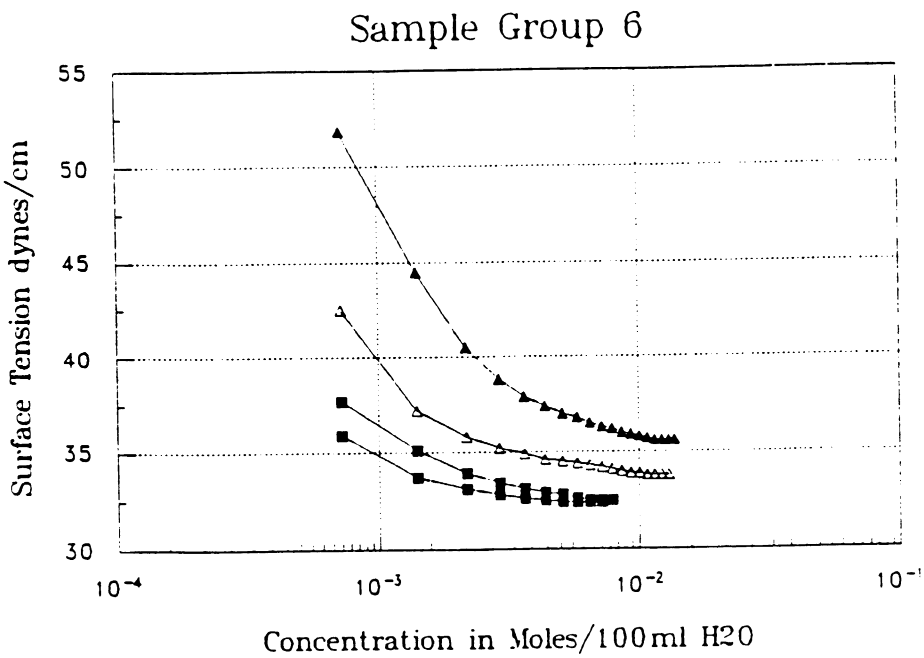
Sample Group 6



Dynamic Surface Tension Graph



Sample Group 6
Surface Tension dynes/cm
36
36
35
35
34
34
33
33
32
10⁻⁴
10⁻³
10⁻²
Concentration in Moles/100ml H20


Sample Group 6
55
50
45
40
35
30
Surface Tension dynes/cm
10^{-4}
10^{-3}
10^{-2}
10^{-1}
Concentration in Moles/100ml H20

SAMPLE GROUP 7 - SLOWEST RATE
HWI: 6310-105 Test Material: Sorbitan Oleate -E20 (Tween 85)

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	73.0	19.0	.10	10.00	9.90
.4ml	TEST A	66.8	19.5	.12	8.33	8.16
	TEST B	66.8	19.6	.12	8.33	8.16
.8ml	TEST A	65.0	19.6	.12	8.33	8.16
	TEST B	65.0	19.6	.12	8.33	8.16
1.2ml	TEST A	64.4	19.7	.13	7.69	7.46
	TEST B	64.4	19.7	.13	7.69	7.46
1.6ml	TEST A	60.6	19.7	.13	7.69	7.46
	TEST B	60.6	19.8	.14	7.14	6.93
2.0ml	TEST A	60.2	19.8	.14	7.14	6.93
	TEST B	60.2	19.8	.14	7.14	6.93
2.4ml	TEST A	61.3	19.8	.15	6.66	6.39
	TEST B	61.3	19.9	.15	6.66	6.39
2.8ml	TEST A	60.6	19.9	.15	6.66	6.39
	TEST B	60.6	19.9	.14	7.14	6.93
3.2ml	TEST A	60.2	19.9	.14	7.14	6.93
	TEST B	60.2	19.9	.14	7.14	6.93
3.6ml	TEST A	59.4	20.0	.14	7.14	6.93
	TEST B	59.4	20.0	.14	7.14	6.93
4.0ml	TEST A	59.0	20.0	.14	7.14	6.93
	TEST B	59.0	20.0	.14	7.14	6.93
4.4ml	TEST A	58.5	20.0	.14	7.14	6.93
	TEST B	58.5	20.0	.14	7.14	6.93
4.8ml	TEST A	58.1	20.0	.14	7 14	6.93
	TEST B	58.1	20.0	.14	7.14	6.93
5.2ml	TEST A	57.6	20.0	.14	7.14	6.93
	TEST B	57.6	20.0	.14	7.14	6.93
5.6ml	TEST A	57.0	20.0	.14	7.14	6.93
	TEST B	57.0	20.0	.14	7.14	6.93
6.0ml	TEST A	56.6	20.0	.14	7.14	6.93
	TEST B	56.6	20.0	.14	7.14	6.93
6.4ml	TEST A	56.1	19.9	.14	7.14	6.93
	TEST B	56.1	19.9	.14	7.14	6.93
6.8ml	TEST A	55.7	20.0	.14	7.14	6.93
	TEST B	55.7	20.0	.14	7.14	6.93
7.2ml	TEST A	55.2	20.0	.14	7.14	6.93
	TEST B	55.2	20.0	.14	7.14	6.93
7.6ml	TEST A	54.8	20.0	.14	7.14	6.93
	TEST B	54.8	20.0	.14	7.14	6.93
8.0ml	TEST A	54.4	20.0	.14	7.14	6.93
	TEST B	54.4	20.0	.14	7.14	6.93
8.4ml	TEST A	54.1	20.0	.14	7.14	6.93
	TEST B	54.1	20.0	.14	7.14	6.93
8.8ml	TEST A	53.6	20.0	.14	7.14	6.93
	TEST B	53.6	20.0	.14	7.14	6.93
9.2ml	TEST A	53.4	20.0	.14	7.14	6.93
	TEST B	53.4	20.0	.14	7 14	6.93
9.6ml	TEST A	53.0	19.9	.14	7.14	6.93
	TEST B	53.0	19.9	.14	7.14	6.93

Sample Group 7 - Slowest Rate Continued

10.0ml	TEST A	52.7	20.0	.14	7.14	6.93
	TEST B	52.7	20.0	.14	7.14	6.93
10.4ml	TEST A	52.4	20.0	.14	7.14	6.93
	TEST B	52.4	20.0	.14	7.14	6.93
10.8ml	TEST A	52.3	20.0	.14	7.14	6.93
	TEST B	52.3	20.0	.14	7.14	6.93
11.2ml	TEST A	52.2	20.0	.14	7.14	6.93
	TEST B	52.2	20.0	.14	7.14	6.93
11.6ml	TEST A	52.1	20.0	.14	7.14	6.93
	TEST B	52.1	20.0	.14	7.14	6.93
12.0ml	TEST A	52.1	20.0	.14	7.14	6.93
	TEST B	52.1	20.0	.14	7.14	6.93
12.4ml	TEST A	52.1	20.0	.14	7.14	6.93
	TEST B	52.1	20.0	.14	7.14	6.93

SAMPLE GROUP 7 - SLOW RATE

		d/cm	•C	b/s	Bubble Interval	Surface Age
0ml additive	TEST A	72.8	20.1	.24	4.16	3.95
.4ml additive	TEST A	67.5	21.3	.19	5.26	5.02
	TEST B	67.5	21.3	.19	5.26	5.02
.8ml additive	TEST A	66.0	21.3	.19	5.26	5.02
	TEST B	66.0	21.3	.19	5.26	5.02
1.2ml additive	TEST A	65.2	21.4	.19	5.26	5.02
	TEST B	65.2	21.4	.19	5.26	5.02
1.6ml additive	TEST A	64.3	21.4	.19	5.26	5.02
	TEST B	64.3	21.4	.19	5.26	5.02
2.0ml additive	TEST A	63.6	21.5	.19	5.26	5.02
	TEST B	63.6	21.5	.19	5.26	5.02
2.4ml additive	TEST A	63.0	21.5	.19	5.26	5.02
	TEST B	63.0	21.5	.19	5.26	5.02
2.8ml additive	TEST A	62.3	21.5	.19	5.26	5.02
	TEST B	62.3	21.5	.19	5.26	5.02
3.2ml additive	TEST A	61.7	21.5	.19	5.26	5.02
	TEST B	61.7	21.5	.19	5.26	5.02
3.6ml additve	TEST A	61.2	21.6	.19	5.26	5.02
	TEST B	61.2	21.6	.19	5.26	5.02
4.0ml additive	TEST A	60.6	21.6	.19	5.26	5.02
	TEST B	60.6	21.6	.19	5.26	5.02
4.4ml additive	TEST A	59.4	21.7	.19	5.26	5.02
	TEST B	59.4	21.7	.19	5.26	5.02
4.8ml additive	TEST A	59.0	21.7	.19	5.26	5.02
	TEST B	59.0	21.8	.19	5.26	5.02
5.2ml additive	TEST A	58.6	21.8	.19	5.26	5.02
	TEST B	58.6	21.8	.19	5.26	5.02
5.6ml additive	TEST A	58.0	21.8	.19	5.26	5.02
	TEST B	58.0	21.8	.19	5.26	5.02
6.0ml additive	TEST A	57.5	21.9	.19	5.26	5.02
	TEST B	57.5	21.9	.19	5.26	5.02
6.4ml additive	TEST A	57.1	22.0	.19	5.26	5.02
	TEST B	57.1	22.0	.19	5.26	5.02
6.8ml additive	TEST A	56.7	22.0	.19	5.26	5.02
	TEST B	56.7	22.0	.19	5.26	5.02
7.2ml additive	TEST A	56.3	22.0	.19	5.26	5.02
	TEST B	56.3	22.0	.19	5.26	5.02
7.6ml additive	TEST A	55.9	22.0	.19	5.26	5.02
	TEST B	55.9	22.1	.19	5.26	5.02
8.0ml additive	TEST A	55.4	22.1	.19	5.26	5.02
	TEST B	55.4	22.1	.19	5.26	5.02
8.4ml additive	TEST A	55.1	22.2	.19	5.26	5.02
	TEST B	55.1	22.2	.19	5.26	5.02
8.8ml additive	TEST A	54.8	22.2	.19	5.26	5.02
	TEST B	54.8	22.2	.19	5.26	5.02
9.2ml additive	TEST A	54.4	22.2	.19	5.26	5.02
	TEST B	54.4	22.2	.19	5.26	5.02
9.6ml additive	TEST A	54.0	22.2	.19	5.26	5.02
	TEST B	54.0	22.2	.19	5.26	5.02

Sample Group 7 - Slow Rate Continued

10.0ml additive	TEST A	53.7	22.2	.19	5.26	5.02
	TEST B	53.7	22.2	.19	5.26	5.02
10.4ml additive	TEST A	53.4	22.2	.19	5.26	5.02
	TEST B	53.4	22.2	.19	5.26	5.02
10.8ml additive	TEST A	53.2	22.2	.19	5.26	5.02
	TEST B	53.2	22.2	.19	5.26	5.02
11.2ml additive	TEST A	53.0	22.2	.19	5.26	5.02
	TEST B	53.0	22.2	.19	5.26	5.02
11.6ml additive	TEST A	52.6	22.2	.19	5.26	5.02
	TEST B	52.6	22.2	.19	5.26	5.02
12.0ml additive	TEST A	52.4	22.2	.19	5.26	5.02
	TEST B	52.4	22.2	.19	5.26	5.02
12.4ml additive	TEST A	52.3	22.2	.19	5.26	5.02
	TEST B	52.3	22.2	.19	5.26	5.02
12.8ml additive	TEST A	52.3	22.2	.19	5.26	5.02
	TEST B	52.3	22.2	.19	5.26	5.02
13.2ml additive	TEST A	52.2	22.2	.19	5.26	5.02
	TEST B	52.2	22.2	.19	5.26	5.02
13.6ml additive	TEST A	52.2	22.2	.19	5.26	5.02
	TEST B	52.2	22.2	.19	5.26	5.02
14.0ml additive	TEST A	52.2	22.2	.19	5.26	5.02
	TEST B	52.2	22.2	.19	5.26	5.02

SAMPLE GROUP 7 - MED RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.7	21.2	.83	1.20	1.06
.4ml	TEST A	71.6	21.1	.80	1.25	1.10
	TEST B	71.6	21.1	.80	1.25	1.10
.8ml	TEST A	70.6	21.2	.81	1.23	1.08
	TEST B	70.6	21.2	.81	1.23	1.08
1.2ml	TEST A	70.1	21.2	.82	1.22	1.07
	TEST B	70.1	21.2	.83	1.20	1.06
1.6ml	TEST A	69.6	21.2	.82	1.22	1.07
	TEST B	69.6	21.2	.81	1.23	1.08
2.0ml	TEST A	68.9	21.2	.83	1.20	1.06
	TEST B	68.9	21.3	.81	1.23	1.08
2.4ml	TEST A	67.8	21.3	.81	1.23	1.08
	TEST B	67.8	21.3	.81	1.23	1.08
2.8ml	TEST A	67.4	21.3	.81	1.23	1.08
	TEST B	67.4	21.3	.81	1.23	1.08
3.2ml	TEST A	67.0	21.3	.80	1.25	1.10
	TEST B	67.0	21.3	.81	1.23	1.08
3.6ml	TEST A	66.5	21.4	.82	1.22	1.07
	TEST B	66.5	21.4	.81	1.23	1.08
4.0ml	TEST A	66.2	21.4	.82	1.22	1.07
	TEST B	66.2	21.5	.82	1.22	1.07
4.4ml	TEST A	65.7	21.5	.82	1.22	1.07
	TEST B	65.7	21.5	.82	1.22	1.07
4.8ml	TEST A	65.4	21.5	.82	1.22	1.07
	TEST B	65.4	21.5	.84	1.19	1.04
5.2ml	TEST A	65.0	21.5	.84	1.19	1.04
	TEST B	65.0	21.5	.84	1.19	1.04
5.6ml	TEST A	64.7	21.5	.84	1.19	1.04
	TEST B	64.7	21.5	.83	1.20	1.06
6.0ml	TEST A	64.5	21.5	.83	1.20	1.06
	TEST B	64.5	21.5	.84	1.19	1.04
6.4ml	TEST A	64.1	21.5	.83	1.20	1.06
	TEST B	64.1	21.5	.84	1.19	1.04
6.8ml	TEST A	63.8	21.5	.84	1.19	1.04
	TEST B	63.8	21.5	.83	1.20	1.06
7.2ml	TEST A	63.4	21.5	.82	1.22	1.07
	TEST B	63.4	21.5	.84	1.19	1.04
7.6ml	TEST A	63.1	21.5	.84	1.19	1.04
	TEST B	63.1	21.5	.83	1.20	1.06
8.0ml	TEST A	62.8	21.5	.84	1.19	1.04
	TEST B	62.8	21.5	.85	1.18	1.03
8.4ml	TEST A	62.5	21.5	.85	1.18	1.03
	TEST B	62.5	21.5	.83	1.20	1.06
8.8ml	TEST A	62.3	21.5	.85	1.18	1.03
	TEST B	62.3	21.5	.85	1.18	1.03
9.2ml	TEST A	62.1	21.5	.85	1.18	1.03
	TEST B	62.1	21.5	.85	1.18	1.03
9.6ml	TEST A	61.8	21.5	.84	1.19	1.04
	TEST B	61.8	21.5	.83	1.20	1.06
10.0ml	TEST A	61.6	21.5	.85	1.18	1.03
	TEST B	61.6	21.5	.85	1.18	1.03

Sample Group 7 - Medium Rate Continued

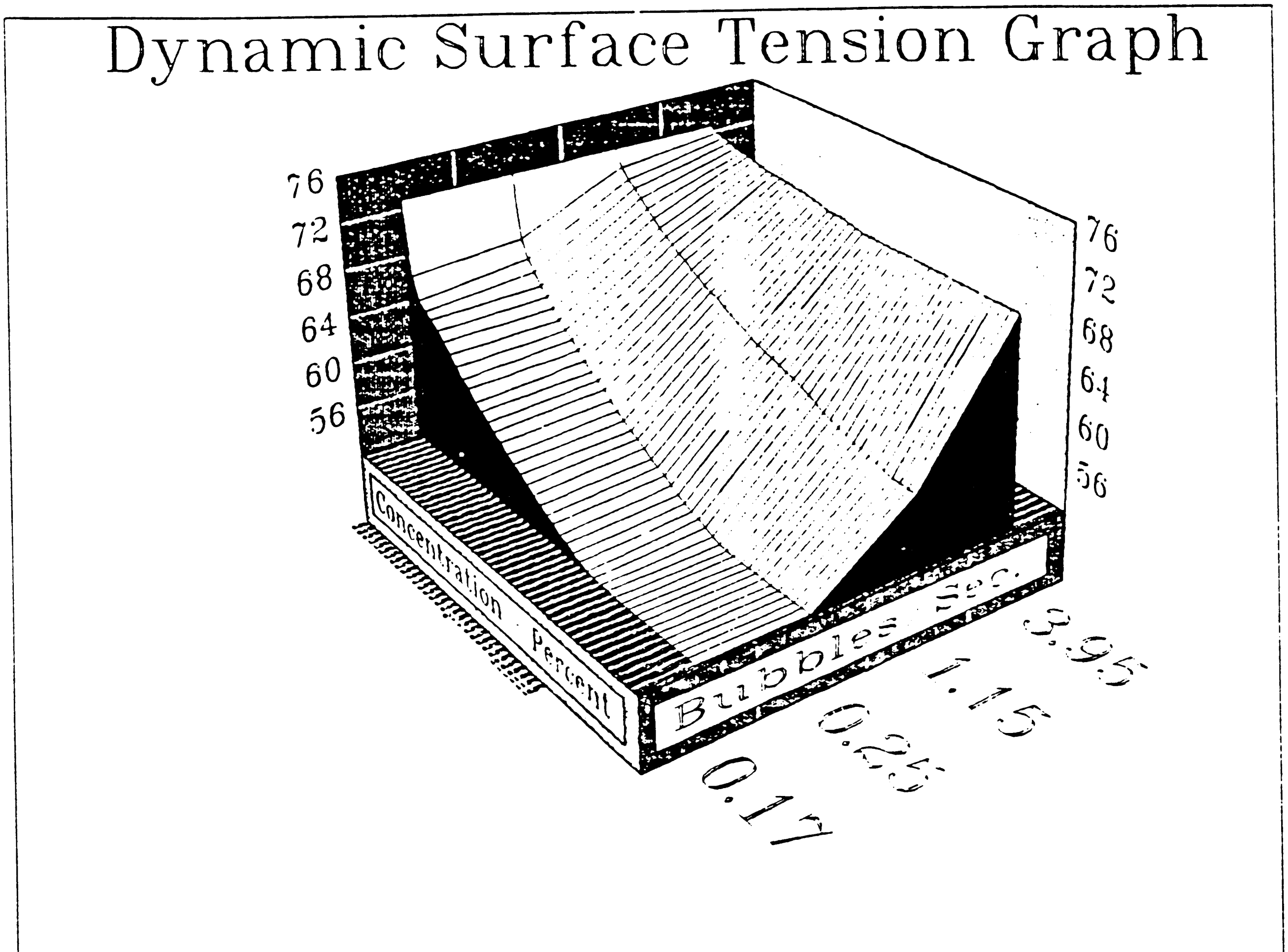
10.4ml	TEST A	61.4	21.5	.84	1.19	1.04
	TEST B	61.4	21.5	.85	1.18	1.03
10.8ml	TEST A	61.1	21.5	.85	1.18	1.03
	TEST B	61.1	21.5	.85	1.18	1.03
11.2ml	TEST A	60.8	21.5	.84	1.19	1.04
	TEST B	60.8	21.5	.85	1.18	1.03
11.6ml	TEST A	60.5	21.5	.85	1.18	1.03
	TEST B	60.5	21.5	.85	1.18	1.03
12.0ml	TEST A	60.1	21.5	.85	1.18	1.03
	TEST B	60.1	21.5	.85	1.18	1.03
12.4ml	TEST A	59.9	21.5	.85	1.18	1.03
	TEST B	59.9	21.5	.85	1.18	1.03
12.8ml	TEST A	59.7	21.5	.84	1.19	1.04
	TEST B	59.7	21.5	.85	1.18	1.03
13.2ml	TEST A	59.4	21.5	.85	1.18	1.03
	TEST B	59.4	21.5	.85	1.18	1.03
13.6ml	TEST A	59.2	21.5	.84	1.19	1.04
	TEST B	59.2	21.5	.85	1.18	1.03
14.0ml	TEST A	59.1	21.5	.85	1.18	1.03
	TEST B	59.1	21.5	.85	1.18	1.03
14.4ml	TEST A	59.0	21.5	.85	1.18	1.03
	TEST B	58.9	21.5	.85	1.18	1.03
14.8ml	TEST A	58.7	21.5	.84	1.19	1.04
	TEST B	58.7	21.5	.85	1.18	1.03
15.2ml	TEST A	58.5	21.5	.85	1.18	1.03
	TEST B	58.4	21.5	.85	1.18	1.03
15.6ml	TEST A	58.3	21.5	.84	1.19	1.04
	TEST B	58.3	21.5	.85	1.18	1.03
16.0ml	TEST A	58.3	21.5	.85	1.18	1.03
	TEST B	58.3	21.5	.85	1.18	1.03
16.4ml	TEST A	58.3	21.5	.85	1.18	1.03
	TEST B	58.3	21.5	.85	1.18	1.03

SAMPLE GROUP 7 - FAST RATE

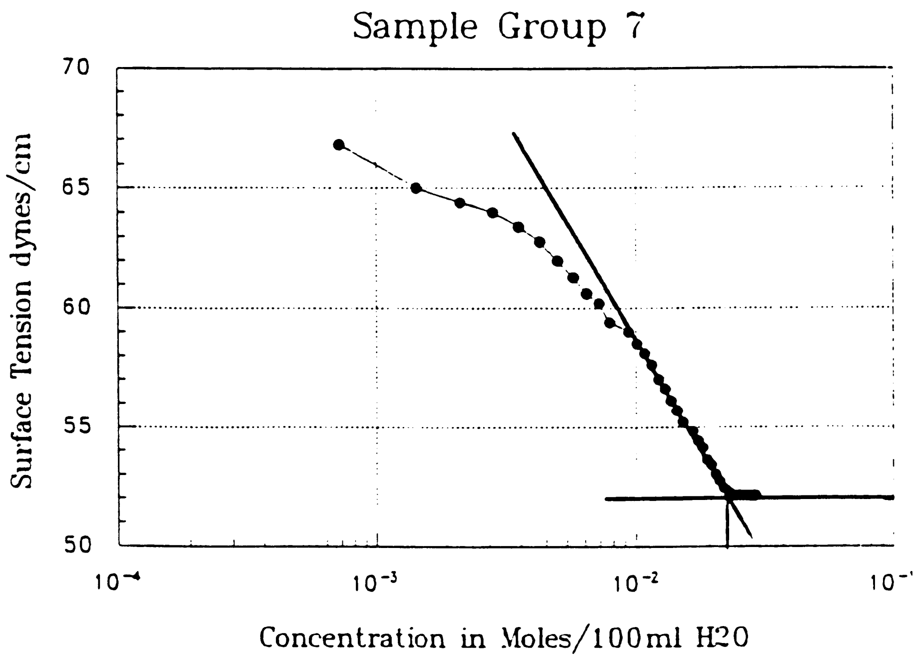
		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	73.0	19.0	3.95	.25	.16
.4ml	TEST A	72.4	19.4	3.95	.25	.16
	TEST B	72.4	19.4	3.95	.25	.16
.8ml	TEST A	72.2	19.5	3.97	.25	.16
	TEST B	72.2	19.5	3.97	.25	.16
1.2ml	TEST A	72.0	19.5	3.97	.25	.16
	TEST B	72.0	19.5	3.97	.25	.16
1.6ml	TEST A	71.8	19.7	3.95	.25	.16
	TEST A	71.8	19.7	3.95	.25	.16
2.0ml	TEST A	71.7	19.9	3.95	.25	.16
	TEST B	71.7	19.9	3.97	.25	.16
2.4ml	TEST A	71.6	20.0	3.95	.25	.16
	TEST B	71.6	20.0	3.95	.25	.16
2.8ml	TEST A	71.5	20.0	3.97	.25	.16
	TEST B	71.5	20.1	3.95	.25	.16
3.2ml	TEST A	71.3	20.1	3.95	.25	.16
	TEST B	71.3	20.2	3.95	.25	.16
3.6ml	TEST A	71.2	20.2	3.97	.25	.16
	TEST B	71.1	20.2	3.97	.25	.16
4.0ml	TEST A	71.0	20.2	3.95	.25	.16
	TEST B	71.0	20.2	3.95	.25	.16
4.4ml	TEST A	71.0	20.2	3.96	.25	.16
	TEST B	71.0	20.2	3.97	.25	.16
4.8ml	TEST A	70.9	20.3	3.95	.25	.16
	TEST B	70.8	20.3	3.97	.25	.16
5.2ml	TEST A	70.8	20.3	3.97	.25	.16
	TEST B	70.8	20.4	3.97	.25	.16
5.6ml	TEST A	70.7	20.4	3.97	.25	.16
	TEST B	70.7	20.5	3.97	.25	.16
6.0ml	TEST A	70.6	20.5	3.96	.25	.16
	TEST B	70.6	20.5	3.97	.25	.16
6.4ml	TEST A	70.5	20.6	3.95	.25	.16
	TEST B	70.4	20.6	3.95	.25	.16
6.8ml	TEST A	70.4	20.6	3.95	.25	.16
	TEST B	70.4	20.7	3.97	.25	.16
7.2ml	TEST A	70.3	20.7	3.97	.25	.16
	TEST B	70.2	20.7	3.97	.25	.16
7.6ml	TEST A	70.2	20.8	3.97	.25	.16
	TEST B	70.2	20.8	3.97	.25	.16
8.0ml	TEST A	70.2	20.8	3.96	.25	.16
	TEST B	70.1	20.8	3.97	.25	.16
8.4ml	TEST A	70.0	20.8	3.95	.25	.16
	TEST B	70.0	20.8	3.95	.25	.16
8.8ml	TEST A	69.9	20.8	3.97	.25	.16
	TEST B	69.9	20.9	3.96	.25	.16
9.2ml sat. conc.	TEST A	69.8	20.9	3.95	.25	.16
	TEST B	69.8	20.9	3.95	.25	.16
9.6ml	TEST A	69.8	20.9	3.95	.25	.16
	TEST B	69.8	20.9	3.97	.25	.16
10.0ml	TEST A	69.8	20.9	3.96	.25	.16
	TEST B	69.8	20.9	3.97	.25	.16

EQUILIBRIUM SURFACE TENSIONS
SAMPLE GROUP 7

CONCEN.	SURF. TEN.	B/SEC.
.4ml	66.8 d/cm	.12
.8ml	65.0 d/cm	.12
1.2ml	64.4 d/cm	.12
1.6ml	64.0 d/cm	.13
2.0ml	63.4 d/cm	.14
2.4ml	62.8 d/cm	.15
2.8ml	62.0 d/cm	.14
3.2ml	61.3 d/cm	.14
3.6ml	60.6 d/cm	.14
4.0ml	60.2 d/xm	.14
4.4ml	59.4 d/cm	.14
4.8ml	59.0 d/cm	.14
5.2ml	58.5 d/cm	.14
5.6ml	58.1 d/cm	.14
6.0ml	57.6 d/cm	.14
6.4ml	57.0 d/cm	.14
6.8ml	56.6 d/cm	.14
7.2ml	56.1 d/cm	.14
7.6ml	55.7 d/cm	.14
8.0ml	55.2 d/cm	.14
8.4ml	54.8 d/cm	.14
8.8ml	54.4 d/cm	.14
9.2ml	54.1 d/cm	.14
9.6ml	53.6 d/cm	.14
10.0ml	53.4 d/cm	.14
10.4ml	53.0 d/cm	.14
10.8ml	52.7 d/cm	.14
11.2ml	52.4 d/cm	.14
11.6ml	52.3 d/cm	.14
12.0ml	52.2 d/cm	.14
12.4ml	52.1 d/cm	.14
12.8ml	52.1 d/cm	.14
13.2ml	52.1 d/cm	.14

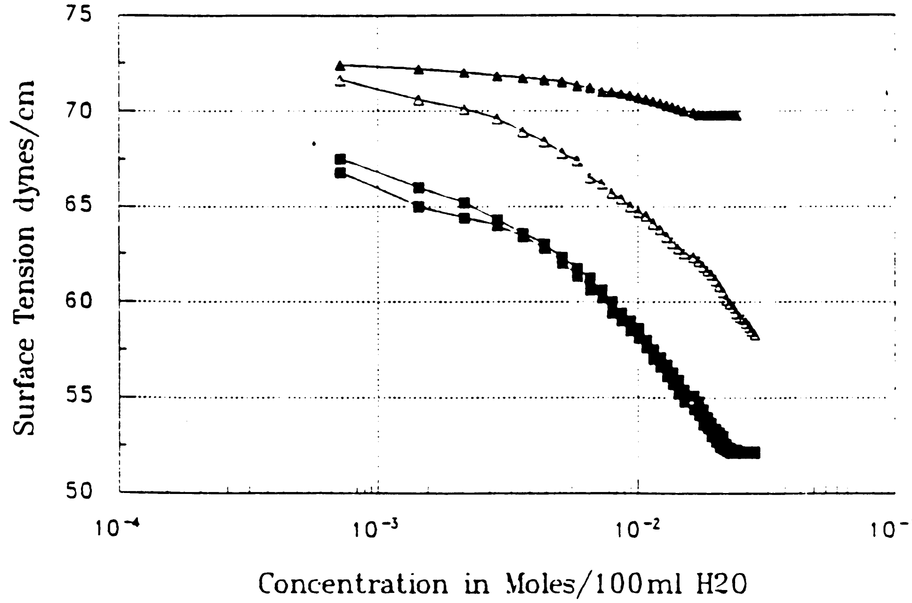


Sample Group 7



Sample Group 7
70
65
60
55
50
Surface Tension dynes/cm
10^{-4}
10^{-3}
10^{-2}
10^{-1}
Concentration in Moles/100ml H20

Sample Group 7



SAMPLE GROUP 8 - SLOWEST RATE
HWI: 6310-105 Test Material: A12-16 Glucose 1.6 (Glucopon 625CS)

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.9	20.3	.10	10.00	9.90
.4ml	TEST A	45.3	20.3	.18	5.55	5.30
	TEST B	45.2	20.3	.18	5.55	5.30
.8ml	TEST A	40.1	20.3	.22	4.55	4.32
	TEST B	40.1	20.3	.22	4.55	4.32
1.2ml	TEST A	37.7	20.3	.24	4.16	3.95
	TEST B	37.7	20.3	.24	4.16	3.95
1.6ml	TEST A	36.0	20.3	.26	3.85	3.66
	TEST B	36.0	20.3	.27	3.70	3.51
2.0ml	TEST A	34.4	20.3	.27	3.70	3.51
	TEST B	34.4	20.3	.27	3.70	3.51
2.4ml	TEST A	33.4	20.3	.27	3.70	3.51
	TEST B	33.4	20.3	.27	3.70	3.51
2.8ml	TEST A	33.1	20.4	.27	3.70	3.51
	TEST B	33.1	20.4	.27	3.70	3.51
3.2ml	TEST A	32.5	20.4	.27	3.70	3.51
	TEST B	32.5	20.4	.27	3.70	3.51
3.6ml	TEST A	32.3	20.4	.27	3.70	3.51
	TEST B	32.3	20.4	.27	3.70	3.51
4.0ml	TEST A	31.9	20.4	.27	3.70	3.51
	TEST B	31.8	20.4	.27	3.70	3.51
4.4ml	TEST A	31.6	20.4	.27	3.70	3.51
	TEST B	31.6	20.4	.27	3.70	3.51
4.8ml	TEST A	31.4	20.4	.27	3.70	3.51
	TEST B	31.4	20.4	.27	3.70	3.51
5.2ml	TEST A	31.2	20.4	.27	3.70	3.51
	TEST B	31.2	20.4	.26	3.85	3.66
5.6ml	TEST A	30.8	20.5	.26	3.85	3.66
	TEST B	30.8	20.5	.26	3.85	3.66
6.0ml	TEST A	30.8	20.5	.26	3.85	3.66
	TEST B	30.8	20.5	.26	3.85	3.66
6.4ml	TEST A	30.8	20.5	.26	3.85	3.66
	TEST B	30.8	20.5	.26	3.85	3.66
6.8ml	TEST A	30.8	20.5	.26	3.85	3.66
	TEST B	30.8	20.5	.26	3.85	3.66

SAMPLE GROUP 8 - SLOW RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml additive	TEST A	72.6	22.1	.23	4.34	4.12
.4ml additive	TEST A	54.0	22.3	.32	3.12	2.90
	TEST B	54.0	22.3	.32	3.12	2.90
.8ml additive	TEST A	49.8	22.3	.38	2.63	2.43
	TEST B	49.8	22.4	.38	2.63	2.43
1.2ml additive	TEST A	45.8	22.5	.43	2.32	2.11
	TEST B	45.8	22.5	.43	2.32	2.11
1.6ml additive	TEST A	43.0	22.5	.50	2.00	1.82
	TEST B	43.0	22.5	.50	2.00	1.82
2.0ml additive	TEST A	40.8	22.6	.52	1.92	1.75
	TEST B	40.8	22.6	.53	1.88	1.71
2.4ml additive	TEST A	39.2	22.7	.50	2.00	1.82
	TEST B	39.2	22.7	.52	1.92	1.75
2.8ml additive	TEST A	38.0	22.8	.52	1.92	1.75
	TEST B	38.0	22.8	.52	1.92	1.75
3.2ml additive	TEST A	37.1	22.8	.52	1.92	1.75
	TEST B	37.1	22.8	.52	1.92	1.75
3.6ml additive	TEST A	36.5	22.9	.52	1.92	1.75
	TEST B	36.5	22.9	.53	1.88	1.71
4.0ml additive	TEST A	35.9	22.8	.52	1.92	1.75
	TEST B	35.9	22.9	.53	1.88	1.71
4.4ml additive	TEST A	35.5	22.9	.53	1.88	1.71
	TEST B	35.5	22.9	.53	1.88	1.71
4.8ml additive	TEST A	35.2	22.9	.53	1.88	1.71
	TEST B	35.2	22.9	.53	1.88	1.71
5.2ml additive	TEST A	34.9	22.9	.53	1.88	1.71
	TEST B	34.9	22.9	.53	1.88	1.71
5.6ml addtive	TEST A	34.6	22.9	.53	1.88	1.71
	TEST B	34.6	22.9	.53	1.88	1.71
6.0ml additive	TEST A	34.4	22.9	.53	1.88	1.71
	TEST B	34.4	22.9	.53	1.88	1.71
6.4ml additive	TEST A	34.2	22.9	.53	1.88	1.71
	TEST B	34.2	22.9	.53	1.88	1.71
6.8ml	TEST A	34.1	22.9	.53	1.88	1.71
	TEST B	34.1	22.9	.53	1.88	1.71
7.2ml	TEST A	34.0	22.9	.53	1.88	1.71
	TEST B	34.0	22.9	.53	1.88	1.71
7.6ml	TEST A	33.9	22.9	.54	1.85	1.68
	TEST B	33.8	22.9	.53	1.88	1.71
8.0ml	TEST A	33.7	22.9	.54	1.85	1.68
	TEST B	33.7	22.9	.53	1.88	1.71
8.4ml	TEST A	33.7	22.9	.53	1.88	1.71
	TEST B	33.6	22.9	.53	1.88	1.71
8.8ml	TEST A	33.6	22.9	.54	1.85	1.68
	TEST B	33.5	22.9	.54	1.85	1.68
9.2ml	TEST A	33.4	22.9	.54	1.85	1.68
	TEST B	33.4	22.9	.54	1.85	1.68
9.6ml	TEST A	33.4	22.9	.54	1.85	1.68
	TEST B	33.4	22.9	.54	1.85	1.68

SAMPLE GROUP 8 - MED RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.6	21.4	.98	1.02	.89
.4ml	TEST A	62.6	21.4	.98	1.02	.89
	TEST B	62.6	21.4	.98	1.02	.89
.8ml	TEST A	58.2	21.4	1.12	.89	.77
	TEST B	58.3	21.4	1.11	.90	.77
1.2ml	TEST A	54.8	21.4	1.21	.83	.71
	TEST B	54.8	21.4	1.19	.84	.72
1.6ml	TEST A	52.0	21.5	1.30	.77	.66
	TEST B	52.0	21.5	1.30	.77	.66
2.0ml	TEST A	49.6	21.5	1.32	.76	.65
	TEST B	49.7	21.6	1.38	.72	.62
2.4ml	TEST A	47.9	21.6	1.38	.72	.62
	TEST B	47.9	21.6	1.36	.74	.64
2.8ml	TEST A	46.5	21.6	1.44	.69	.59
	TEST B	46.5	21.6	1.40	.71	.61
3.2ml	TEST A	45.2	21.6	1.46	.68	.58
	TEST B	45.2	21.6	1.48	.68	.58
3.6ml	TEST A	44.3	21.6	1.48	.68	.58
	TEST B	44.3	21.6	1.49	.67	.57
4.0ml	TEST A	43.6	21.7	1.52	.66	.56
	TEST B	43.6	21.7	1.53	.66	.56
4.4ml	TEST A	42.9	21.7	1.54	.65	.55
	TEST B	42.9	21.7	1.54	.65	.55
4.8ml	TEST A	42.4	21.7	1.54	.65	.55
	TEST B	42.4	21.7	1.56	.64	.54
5.2ml	TEST A	42.0	21.8	1.56	.64	.54
	TEST B	42.0	21.8	1.56	.64	.54
5.6ml	TEST A	41.4	21.8	1.56	.64	.54
	TEST B	41.5	21.8	1.56	.64	.54
6.0ml	TEST A	41.0	21.8	1.53	.66	.56
	TEST B	41.0	21.8	1.54	.65	.55
6.4ml	TEST A	40.8	21.8	1.56	.64	.54
	TEST B	40.8	21.9	1.54	.65	.55
6.8ml	TEST A	40.6	21.9	1.56	.64	.54
	TEST B	40.5	21.9	1.54	.65	.55
7.2ml	TEST A	40.3	21.9	1.57	.64	.54
	TEST B	40.3	21.9	1.56	.64	.54
7.6ml	TEST A	40.1	21.9	1.58	.63	.53
	TEST B	40.1	21.9	1.57	.64	.54
8.0ml	TEST A	40.0	22.0	1.56	.64	.54
	TEST B	39.9	22.0	1.56	.64	.54
8.4ml	TEST A	39.7	22.0	1.60	.63	.53
	TEST B	39.7	22.0	1.58	.63	.53
8.8ml	TEST A	39.6	22.1	1.63	.61	.51
	TEST B	39.5	22.1	1.63	.61	.51
9.2ml	TEST A	39.4	22.1	1.58	.63	.53
	TEST B	39.3	22.1	1.60	.63	.53
9.6ml	TEST A	39.2	22.1	1.58	.63	.53
	TEST B	39.2	22.1	1.64	.61	.51
10.0ml	TEST A	39.1	22.2	1.63	.61	.51
	TEST B	38.9	22.1	1.60	.63	.53

Sample Group 8 - Medium Rate Continued

10.4ml	TEST A	38.9	22.2	1.60	.63	.53
	TEST B	38.9	22.2	1.60	.63	.53
10.8ml	TEST A	38.9	22.2	1.63	.61	.51
	TEST B	38.9	22.2	1.60	.63	.53
11.2ml	TEST A	38.9	22.2	1.63	.61	.51
	TEST B	38.9	22.2	1.63	.61	.51

SAMPLE GROUP 8 - FAST RATE		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.8	20.2	3.97	.25	.16
.4ml	TEST A	69.6	20.3	3.97	.25	.16
	TEST B	69.6	20.4	3.97	.25	.16
.8ml	TEST A	65.6	20.7	4.05	.25	.16
	TEST B	65.5	20.7	4.07	.25	.16
1.2ml	TEST A	63.6	20.7	4.23	.24	.15
	TEST B	63.5	20.7	4.23	.24	.15
1.6ml	TEST A	62.1	20.7	4.32	.24	.15
	TEST B	62.1	20.7	4.32	.24	.15
2.0ml	TEST A	60.6	20.7	4.44	.23	.14
	TEST B	60.5	20.7	4.44	.23	.14
2.4ml	TEST A	59.2	20.8	4.55	.22	.13
	TEST B	59.1	20.8	4.56	.22	.13
2.8ml	TEST A	58.0	20.9	4.44	.23	.14
	TEST B	58.1	20.9	4.44	.23	.14
3.2ml	TEST A	56.9	20.9	4.65	.22	.13
	TEST B	56.8	20.9	4.65	.22	.13
3.6ml	TEST A	55.5	21.0	4.81	.21	.13
	TEST B	55.5	21.0	4.81	.21	.13
4.0ml	TEST A	54.4	21.1	4.79	.21	.13
	TEST B	54.4	21.1	4.79	.21	.13
4.4ml	TEST A	53.5	21.2	4.81	.21	.13
	TEST B	53.5	21.2	4.81	.21	.13
4.8ml	TEST A	52.7	21.2	4.92	.20	.12
	TEST B	52.7	21.2	4.92	.20	.12
5.2ml	TEST A	51.8	21.3	4.92	.20	.12
	TEST B	51.8	21.3	4.92	.20	.12
5.6ml	TEST A	51.1	21.3	4.92	.20	.12
	TEST B	51.2	21.3	4.92	.20	.12
6.0ml	TEST A	50.4	21.4	4.92	.20	.12
	TEST B	50.4	21.4	4.92	.20	.12
6.4ml	TEST A	50.0	21.4	5.06	.20	.12
	TEST B	50.0	21.4	5.07	.20	.12
6.8ml	TEST A	49.6	21.4	5.05	.20	.12
	TEST B	49.6	21.4	5.06	.20	.12
7.2ml	TEST A	49.1	21.4	5.07	.20	.12
	TEST B	49.1	21.4	5.07	.20	.12
7.6ml	TEST A	48.8	21.4	5.06	.20	.12
	TEST B	48.8	21.4	5.07	.20	.12
8.0ml	TEST A	48.5	21.5	5.05	.20	.12
	TEST B	48.5	21.5	5.05	.20	.12
8.4ml	TEST A	48.2	21.5	5.05	.20	.12
	TEST B	48.2	21.5	5.04	.20	.12
8.8ml	TEST A	48.0	21.5	5.05	.20	.12
	TEST B	48.0	21.5	5.05	.20	.12
9.2ml	TEST A	47.9	21.5	5.07	.20	.12
	TEST B	47.9	21.5	5.07	.20	.12
9.6ml	TEST A	47.6	21.5	5.07	.20	.12
	TEST B	47.6	21.5	5.07	.20	.12
10.0ml	TEST A	47.5	21.5	5.06	.20	.12
	TEST B	47.5	21.5	5.07	.20	.12

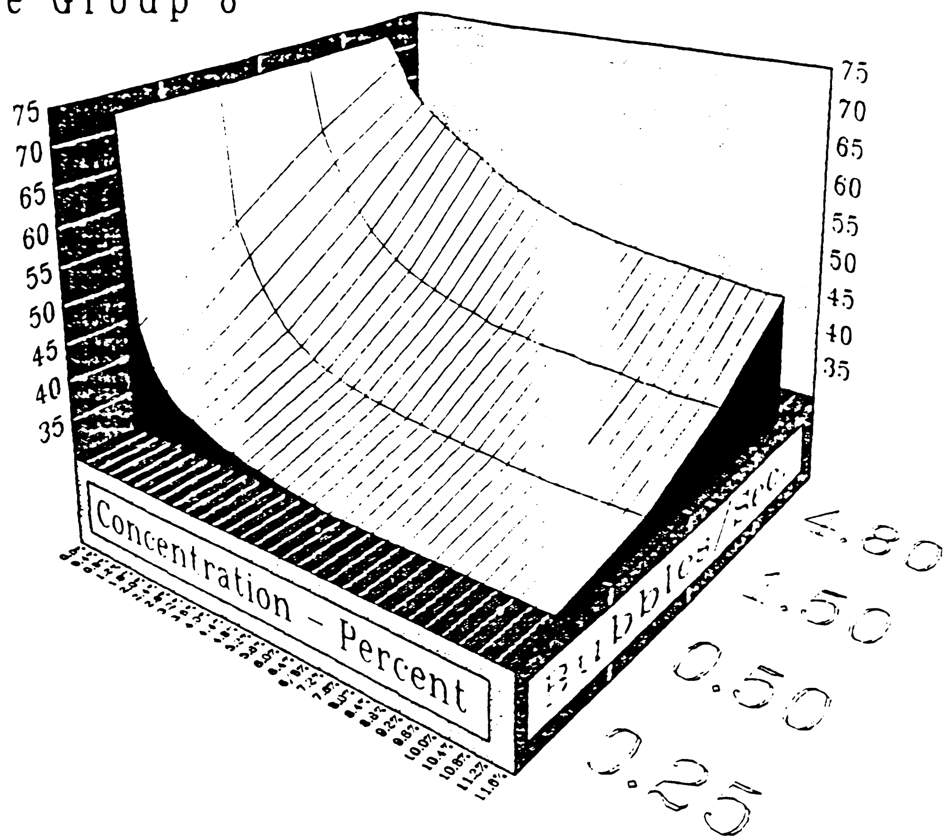
Sample Group 8 - Fast Rate Continued

10.4ml	TEST A	47.2	21.6	5.08	.20	.12
	TEST B	47.3	21.6	5.07	.20	.12
10.8ml	TEST A	47.1	21.6	5.08	.20	.12
	TEST B	47.0	21.6	5.05	.20	.12
11.2ml	TEST A	46.9	21.6	5.08	.20	.12
	TEST B	46.9	21.6	5.07	.20	.12
11.6ml	TEST A	46.9	21.6	5.05	.20	.12
	TEST B	46.9	21.6	5.05	.20	.12
12.0ml	TEST A	46.9	21.6	5.05	.20	.12
	TEST B	46.9	21.6	5.05	.20	.12

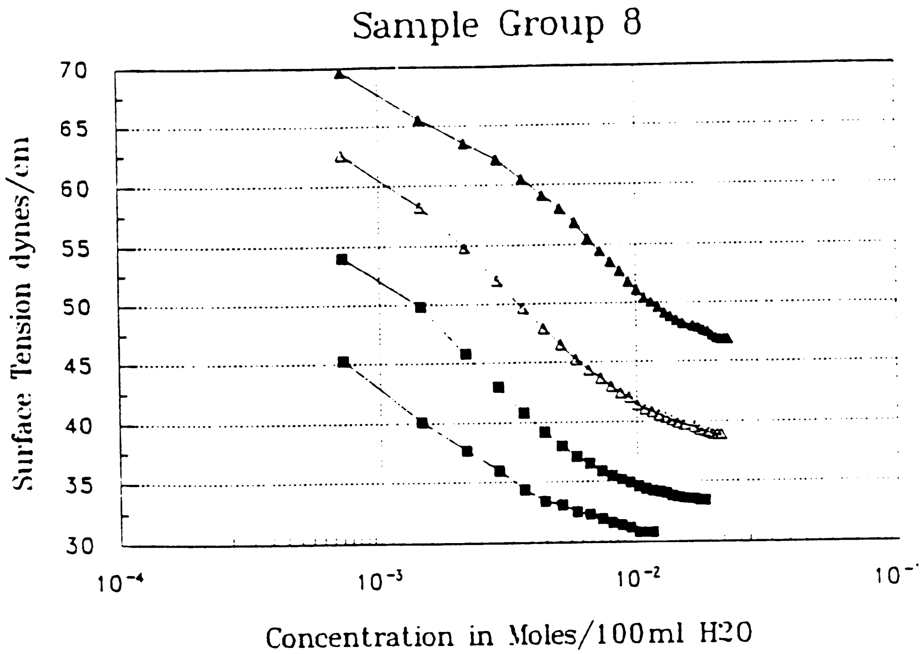
EQUILIBRIUM SURFACE TENSION POINTS
SAMPLE GROUP 8

CONCEN.	SURF. TEN.	B/SEC.
.4ml	45.1 d/cm	.18
.8ml	39.9 d/cm	.22
1.2ml	37.5 d/cm	.24
1.6ml	35.9 d/cm	.26
2.0ml	34.2 d/cm	.27
2.4ml	33.2 d/cm	.27
2.8ml	33.0 d/cm	.27
3.2ml	32.5 d/cm	.27
3.6ml	32.3 d/cm	.27
4.0ml	31.8 d/cm	.27
4.4ml	31.6 d/cm	.27
4.8ml	31.4 d/cm	.27
5.2ml	31.2 d/cm	.27
5.6lml	30.8 d/cm	.27
6.0ml	30.8 d/cm	.26
6.4ml	30.8 d/cm	.26

Sample Group 8



Dynamic Surface Tension Graph



Sample Group 8
70
65
60
55
50
45
40
35
30
Surface Tension dynes/cm
10⁻⁴
10⁻³
10⁻²
10⁻¹
Concentration in Moles/100ml H20

SAMPLE GROUP 9 - SLOWEST RATE
HWI: 6310-105 Test Material: Lauramine Oxide (Incromine Oxide L) PH aprox: 10.5

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.8	20.8	.12	8.33	8.16
.4ml	TEST A	64.0	20.8	.12	8.33	8.16
	TEST B	64.0	20.8	.12	8.33	8.16
.8ml	TEST A	55.0	20.8	.14	7.14	6.93
	TEST B	55.0	20.8	.14	7.14	6.93
1.2ml	TEST A	49.5	20.8	.15	6.66	6.39
	TEST B	49.5	20.8	.18	5.55	5.30
1.6ml	TEST A	45.1	20.8	.18	5.55	5.30
	TEST B	45.1	20.8	.19	5.26	5.02
2.0ml	TEST A	41.7	20.8	.19	5.26	5.02
	TEST B	41.7	20.8	.19	5.26	5.02
2.4ml	TEST A	36.0	20.8	.20	5.00	4.75
	TEST B	36.0	20.8	.20	5.00	4.75
2.8ml	TEST A	35.1	20.8	.20	5.00	4.75
	TEST B	35.1	20.8	.20	5.00	4.75
3.2ml	TEST A	34.1	20.8	.20	5.00	4.75
	TEST B	34.1	20.8	.20	5.00	4.75
3.6ml	TEST A	33.7	20.8	.20	5.00	4.75
	TEST B	33.7	20.8	.20	5.00	4.75
4.0ml	TEST A	33.5	20.8	.20	5.00	4.75
	TEST B	33.5	20.8	.20	5.00	4.75
4.4ml	TEST A	33.3	20.8	.20	5.00	4.75
	TEST B	33.3	20.8	.20	5.00	4.75
4.8ml	TEST A	33.3	20.8	.20	5.00	4.75
	TEST B	33.3	20.8	.20	5.00	4.75
5.2ml	TEST A	33.3	20.8	.20	5.00	4.75
	TEST B	33.3	20.8	.20	5.00	4.75
5.6ml	TEST A	33.3	20.8	.20	5.00	4.75
	TEST B	33.3	20.8	.20	5.00	4.75

SAMPLE GROUP 9 - SLOW RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.5	22.9	.22	4.55	4.32
.4ml	TEST A	65.7	22.6	.25	4.00	3.80
	TEST B	65.7	22.6	.25	4.00	3.80
.8ml	TEST A	56.5	22.6	.30	3.33	2.99
	TEST B	56.5	22.6	.30	3.33	2.99
1.2ml	TEST A	50.5	22.6	.33	3.03	2.88
	TEST B	50.5	22.6	.33	3.03	2.88
1.6ml	TEST A	46.1	22.7	.36	2.77	2.58
	TEST B	46.2	22.7	.36	2.77	2.58
2.0ml	TEST A	42.9	22.7	.39	2.56	2.33
	TEST B	42.9	22.7	.40	2.50	2.28
2.4ml	TEST A	40.1	22.7	.41	2.44	2.22
	TEST B	40.2	22.7	.41	2.44	2.22
2.8ml	TEST A	38.2	22.7	.43	2.33	2.12
	TEST B	38.2	22.7	.43	2.33	2.12
3.2ml	TEST A	37.0	22.7	.46	2.17	1.97
	TEST B	37.0	22.7	.46	2.17	1.97
3.6ml	TEST A	36.3	22.7	.46	2.17	1.97
	TEST B	36.3	22.7	.47	2.13	1.94
4.0ml	TEST A	35.8	22.8	.48	2.08	1.89
	TEST B	35.8	22.8	.48	2.08	1.89
4.4ml	TEST A	35.4	22.8	.48	2.08	1.89
	TEST B	35.4	22.8	.48	2.08	1.89
4.8ml	TEST A	35.1	22.7	.48	2.08	1.89
	TEST B	35.1	22.7	.48	2.08	1.89
5.2ml	TEST A	34.9	22.8	.49	2.04	1.86
	TEST B	34.8	22.7	.49	2.04	1.86
5.6ml	TEST A	34.6	22.8	.49	2.04	1.86
	TEST B	34.6	22.8	.49	2.04	1.86
6.0ml	TEST A	34.5	22.8	.49	2.04	1.86
	TEST B	34.5	22.8	.49	2.04	1.86
6.4ml	TEST A	34.4	22.8	.49	2.04	1.86
	TEST B	34.3	22.8	.49	2.04	1.86
6.8ml	TEST A	34.2	22.8	.49	2.04	1.86
	TEST B	34.2	22.8	.49	2.04	1.86
7.2ml	TEST A	34.2	22.8	.49	2.04	1.86
	TEST B	34.1	22.8	.49	2.04	1.86
7.6ml	TEST A	34.1	22.8	.49	2.04	1.86
	TEST B	34.1	22.8	.49	2.04	1.86
8.0ml	TEST A	34.1	22.8	.49	2.04	1.86
	TEST B	34.1	22.8	.49	2.04	1.86

SAMPLE GROUP 9 - MED RATE		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.6	21.8	.93	1.07	.93
.4ml	TEST A	67.0	21.8	.93	1.07	.93
	TEST B	67.0	21.8	.97	1.07	.93
.8ml	TEST A	59.3	21.8	1.05	.95	.82
	TEST B	59.3	21.8	1.05	.95	.82
1.2ml	TEST A	53.6	21.8	1.20	.83	.71
	TEST B	53.6	21.8	1.19	.83	.71
1.6ml	TEST A	49.2	21.8	1.29	.78	.67
	TEST B	49.3	21.8	1.29	.78	.67
2.0ml	TEST A	46.0	21.9	1.39	.72	.62
	TEST B	46.0	21.9	1.40	.71	.61
2.4ml	TEST A	43.5	21.9	1.40	.71	.61
	TEST B	43.5	21.9	1.43	.70	.60
2.8ml	TEST A	41.8	21.9	1.43	.70	.60
	TEST B	41.8	21.9	1.43	.70	.60
3.2ml	TEST A	40.3	21.9	1.49	.67	.58
	TEST B	40.2	21.9	1.49	.67	.58
3.6ml	TEST A	38.9	21.9	1.52	.66	.58
	TEST B	38.9	21.9	1.58	.63	.54
4.0ml	TEST A	38.4	21.9	1.56	.64	.55
	TEST B	38.3	21.9	1.54	.65	.55
4.4ml	TEST A	37.8	22.0	1.61	.62	.53
	TEST B	37.8	22.0	1.59	.63	.54
4.8ml	TEST A	37.3	22.0	1.58	.63	.54
	TEST B	37.3	22.0	1.58	.63	.54
5.2ml	TEST A	36.9	22.1	1.64	.61	.52
	TEST B	36.9	22.1	1.63	.61	.52
5.6ml	TEST A	36.7	22.1	1.68	.59	.48
	TEST B	36.6	22.1	1.70	.59	.48
6.0ml	TEST A	36.3	22.1	1.64	.61	.52
	TEST B	36.4	22.1	1.67	.60	.49
6.4ml	TEST A	36.2	22.2	1.67	.60	.49
	TEST B	36.1	22.2	1.67	.60	.49
6.8ml	TEST A	36.0	22.2	1.69	.59	.48
	TEST B	36.0	22.2	1.72	.58	.47
7.2ml	TEST A	36.0	22.2	1.73	.58	.47
	TEST B	35.9	22.2	1.73	.58	.47
7.6ml	TEST A	35.8	22.2	1.69	.59	.48
	TEST B	35.8	22.2	1.73	.58	.47
8.0ml	TEST A	35.7	22.2	1.67	.60	.49
	TEST B	35.7	22.2	1.67	.60	.49
8.4ml	TEST A	35.6	22.2	1.67	.60	.49
	TEST B	35.6	22.2	1.68	.60	.49
8.8ml	TEST A	35.6	22.2	1.67	.60	.49
	TEST B	35.5	22.2	1.65	.61	.52
9.2ml	TEST A	35.4	22.2	1.65	.61	.52
	TEST A	35.4	22.2	1.70	.59	.48
9.6ml	TEST A	35.4	22.2	1.72	.58	.47
	TEST B	35.4	22.2	1.74	.57	.46
10.0ml	TEST A	35.4	22.2	1.74	.57	.46
	TEST B	35.4	22.2	1.74	.57	.46

SAMPLE GROUP 9 - FAST RATE

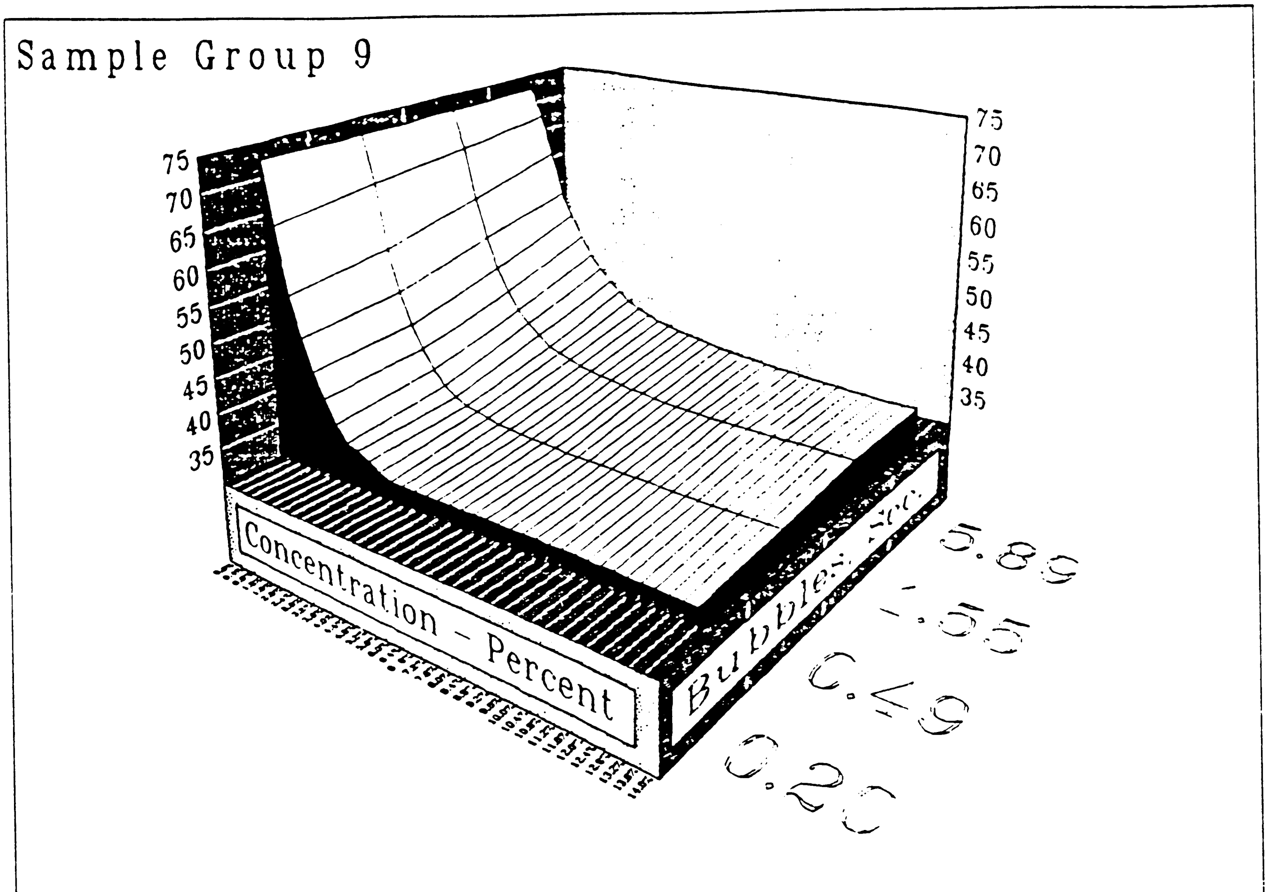
		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.7	21.3	4.05	.25	.16
.4ml	TEST A	64.5	21.3	4.35	.23	.14
	TEST B	64.5	21.3	4.32	.23	.14
.8ml	TEST A	60.0	21.4	4.32	.23	.14
	TEST B	60.1	21.4	4.35	.23	.14
1.2ml	TEST A	56.1	21.4	4.67	.21	.13
	TEST B	56.1	21.4	4.65	.21	.13
1.6ml	TEST A	52.7	21.4	4.68	.21	.13
	TEST B	52.7	21.4	4.65	.21	.13
2.0ml	TEST A	49.6	21.5	4.76	.21	.13
	TEST B	49.6	21.5	4.76	.21	.13
2.4ml	TEST A	47.0	21.6	5.07	.20	.12
	TEST B	47.1	21.6	5.07	.20	.12
2.8ml	TEST A	45.0	21.6	5.20	.19	.11
	TEST B	45.0	21.6	5.20	.19	.11
3.2ml	TEST A	43.3	21.6	5.22	.19	.11
	TEST B	43.3	21.6	5.22	.19	.11
3.6ml	TEST A	42.1	21.8	5.51	.18	.10
	TEST B	42.1	21.8	5.51	.18	.10
4.0ml	TEST A	41.0	21.8	5.60	.18	.10
	TEST B	41.0	21.8	5.60	.18	.10
4.4ml	TEST A	40.1	21.9	5.71	.18	.10
	TEST B	40.1	21.9	5.89	.17	.09
4.8ml	TEST A	39.5	21.9	5.89	.17	.09
	TEST B	39.6	21.9	5.89	.17	.09
5.2ml	TEST A	39.0	21.9	5.89	.17	.09
	TEST B	39.0	21.9	5.89	.17	.09
5.6ml	TEST A	38.5	21.9	5.89	.17	.09
	TEST B	38.5	21.9	5.89	.17	.09
6.0ml	TEST A	38.2	21.9	6.07	.16	.08
	TEST B	38.2	21.9	6.07	.16	.08
6.4ml	TEST A	37.9	22.0	6.06	.16	.08
	TEST B	37.9	22.0	6.07	.16	.08
6.8ml	TEST A	37.7	22.0	6.07	.16	.08
	TEST B	37.7	22.0	6.07	.16	.08
7..2ml	TEST A	37.4	22.0	6.07	.16	.08
	TEST B	37.4	22.0	6.05	.16	.08
7.6ml	TEST A	37.1	22.0	6.07	.16	.08
	TEST B	37.1	22.0	6.07	.16	.08
8.0ml	TEST A	37.0	22.0	6.05	.16	.08
	TEST B	36.9	22.0	6.07	.16	.08
8.4ml	TEST A	36.8	22.0	6.07	.16	.08
	TEST B	36.8	22.0	6.07	.16	.08
8.8ml	TEST A	36.6	22.1	6.07	.16	.08
	TEST B	36.6	22.1	6.07	.16	.08
9.2ml	TEST A	36.4	22.1	6.05	.16	.08
	TEST B	36.4	22.1	6.07	.16	.08
9.6ml	TEST A	36.3	22.2	6.07	.16	.08
	TEST B	36.3	22.2	6.07	.16	.08
10.0ml	TEST A	36.2	22.2	6.09	.16	.08
	TEST B	36.2	22.2	6.07	.16	.08
10.4ml	TEST A	36.1	22.2	6.07	.16	.08

Sample Group 9 - Fast Rate Continued

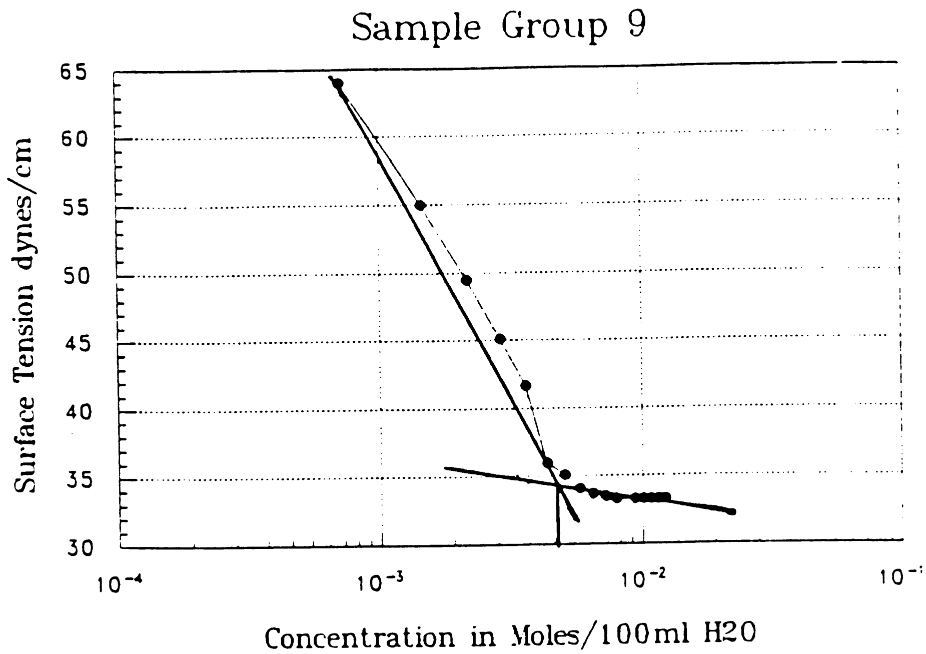
	TEST B	36.1	22.2	6.07	.16	.08
10.8ml	TEST A	36.0	22.2	6.05	.16	.08
	TEST B	36.0	22.2	6.07	.16	.08
11.2ml	TEST A	35.9	22.2	6.07	.16	.08
	TEST B	35.9	22.2	6.07	.16	.08
11.6ml	TEST A	35.8	22.2	6.07	.16	.08
	TEST B	35.8	22.2	6.07	.16	.08
12.0ml	TEST A	35.7	22.2	6.07	.16	.08
	TEST B	35.7	22.2	6.05	.16	.08
12.4ml	TEST A	35.6	22.2	6.07	.16	.08
	TEST B	35.6	22.2	6.07	.16	.08
12.8ml	TEST A	35.6	22.2	6.07	.16	.08
	TEST B	35.6	22.2	6.07	.16	.08
13.2ml	TEST A	35.6	22.2	6.07	.16	.08
	TEST B	35.6	22.2	6.07	.16	.08

EQUILIBRIUM SURFACE TENSION POINTS
SAMPLE GROUP 9

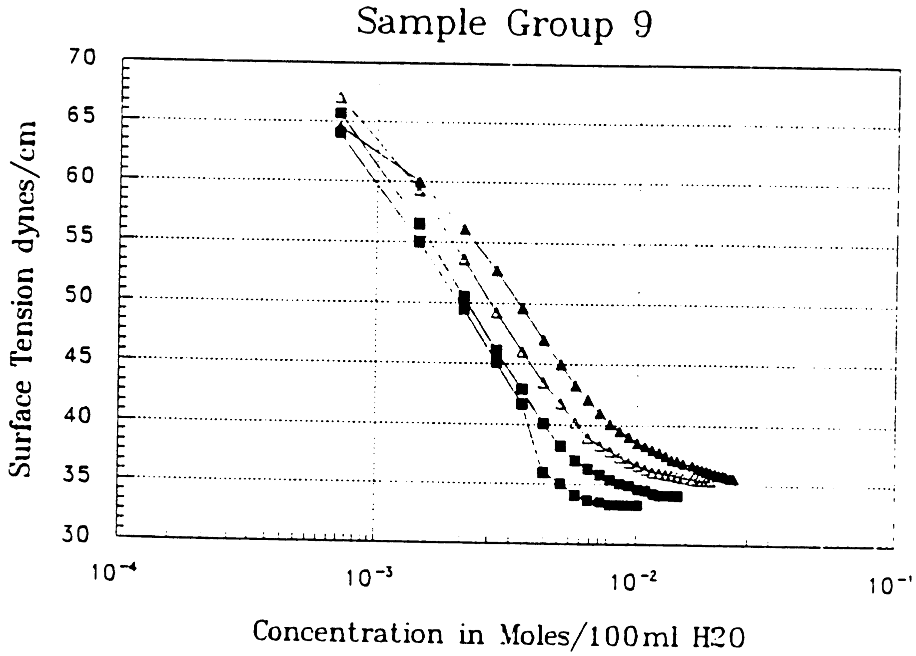
CONCEN.	SURF. TEN.	B/SEC.
.4ml	64.0 d/cm	.12
.8ml	55.0 d/cm	.14
1.2ml	49.5 d/cm	.15
1.6ml	45.1 d/cm	.18
2.0ml	41.7 d/cm	.19
2.4ml	36.0 d/cm	.19
2.8ml	35.1 d/cm	.20
3.2ml	34.1 d/cm	.20
3.6ml	33.7 d/cm	.20
4.0ml	33.5 d/cm	.20
4.4ml	33.3 d/cm	.20
4.8ml	33.3 d/cm	.20
5.2ml	33.3 d/cm	.20



Dynamic Surface Tension Graph



Sample Group 9
Surface Tension dynes/cm
65
60
55
50
45
40
35
30
10⁻⁴
10⁻³
10⁻²
Concentration in Moles/100ml H20

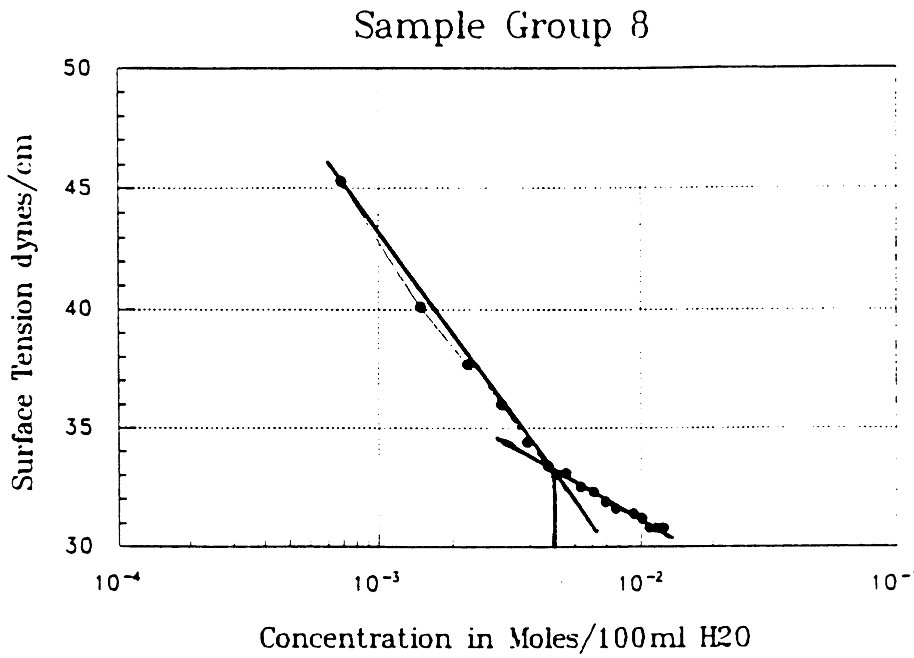

Sample Group 9
Surface Tension dynes/cm
70
65
60
55
50
45
40
35
30
10^{-4}
10^{-3}
10^{-2}
10^{-1}
Concentration in Moles/100ml H20

SAMPLE GROUP 10 - SLOWEST RATE
HWI: 6310-105 Test Material: Cocamide DEA (Standamid KD)

		d\cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.7	20.9	.20	5.00	4.75
.4ml	TEST A	44.3	20.9	.20	5.00	4.75
	TEST B	44.3	20.9	.20	5.00	4.75
.8ml	TEST A	37.3	20.9	.25	4.00	3.80
	TEST B	37.3	20.9	.25	4.00	3.80
1.2ml	TEST A	36.0	20.9	.27	3.70	3.52
	TEST B	36.0	20.9	.28	3.57	3.39
1.6ml	TEST A	34.7	20.9	.29	3.45	3.28
	TEST B	34.7	20.9	.29	3.45	3.28
2.0ml	TEST A	32.8	20.9	.28	3.57	3.39
	TEST B	32.8	20.9	.27	3.70	3.52
2.4ml	TEST A	31.5	20.9	.27	3.70	3.52
	TEST B	31.5	20.9	.26	3.85	3.66
2.8ml	TEST A	30.9	20.9	.27	3.70	3.52
	TEST B	30.9	20.9	.27	3.70	3.52
3.2ml	TEST A	30.6	20.9	.28	3.57	3.39
	TEST B	30.6	20.9	.26	3.85	3.66
3.6ml	TEST A	30.3	20.9	.26	3.85	3.66
	TEST B	30.3	20.9	.27	3.70	3.52
4.0ml	TEST A	30.0	20.9	.26	3.85	3.66
	TEST B	30.0	20.9	.26	3.85	3.66
4.4ml	TEST A	29.8	20.9	.26	3.85	3.66
	TEST B	29.8	20.9	.26	3.85	3.66
4.8ml	TEST A	29.6	20.9	.26	3.85	3.66
	TEST B	29.6	20.9	.26	3.85	3.66
5.2ml	TEST A	29.5	20.9	.26	3.85	3.66
	TEST B	29.5	20.9	.26	3.85	3.66
5.6ml	TEST A	29.4	20.9	.26	3.85	3.66
	TEST B	29.4	20.9	.26	3.85	3.66
6.0ml	TEST A	29.3	20.9	.26	3.85	3.66
	TEST B	29.3	20.9	.26	3.85	3.66
6.4ml	TEST A	29.3	20.9	.26	3.85	3.66
	TEST B	29.3	20.9	.26	3.85	3.66
6.8ml	TEST A	29.3	20.9	.26	3.85	3.66
	TEST B	29.3	20.9	.26	3.85	3.66
7.2ml	TEST A	29.3	20.9	.26	3.85	3.66
	TEST B	29.3	20.9	.26	3.85	3.66

SAMPLE GROUP 10 - SLOW RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.5	22.8	.22	4.55	4.32
.4ml	TEST A	47.7	22.8	.39	2.56	2.33
	TEST B	47.7	22.8	.39	2.56	2.33
.8ml	TEST A	44.7	22.8	.43	2.33	2.12
	TEST B	44.7	22.8	.43	2.33	2.12
1.2ml	TEST A	42.2	22.8	.45	2.22	2.02
	TEST B	42.2	22.8	.45	2.22	2.02
1.6ml	TEST A	40.5	22.8	.50	2.00	1.82
	TEST B	40.5	22.8	.50	2.00	1.82
2.0ml	TEST A	38.5	22.8	.51	1.96	1.78
	TEST B	38.5	22.8	.50	2.00	1.82
2.4ml	TEST A	37.1	22.8	.52	1.92	1.75
	TEST B	37.0	22.8	.52	1.92	1.75
2.8ml	TEST A	36.3	22.8	.53	1.88	1.71
	TEST B	36.2	22.8	.54	1.85	1.68
3.2ml	TEST A	35.1	22.8	.53	1.88	1.71
	TEST B	35.2	22.8	.53	1.88	1.71
3.6ml	TEST A	34.7	22.8	.54	1.85	1.68
	TEST B	34.8	22.8	.54	1.85	1.68
4.0ml	TEST A	34.3	22.8	.54	1.85	1.68
	TEST B	34.3	22.8	.54	1.85	1.68
4.4ml	TEST A	34.0	22.8	.54	1.85	1.68
	TEST B	34.0	22.8	.54	1.85	1.68
4.8ml	TEST A	33.6	22.8	.54	1.85	1.68
	TEST B	33.5	22.8	.53	1.88	1.71
5.2ml	TEST A	33.3	22.8	.54	1.85	1.68
	TEST B	33.2	22.8	.54	1.85	1.68
5.6ml	TEST A	33.0	22.8	.54	1.85	1.68
	TEST B	33.0	22.8	.54	1.85	1.68
6.0ml	TEST A	32.8	22.8	.54	1.85	1.68
	TEST B	32.8	22.8	.54	1.85	1.68
6.4ml	TEST A	32.7	22.8	.54	1.85	1.68
	TEST B	32.7	22.8	.54	1.85	1.68
6.8ml	TEST A	32.5	22.8	.54	1.85	1.68
	TEST B	32.6	22.8	.54	1.85	1.68
7.2ml	TEST A	32.4	22.8	.54	1.85	1.68
	TEST B	32.3	22.8	.54	1.85	1.68
7.6ml	TEST A	32.3	22.8	.54	1.85	1.68
	TEST B	32.2	22.8	.54	1.85	1.68
8.0ml	TEST A	32.2	22.8	.54	1.85	1.68
	TEST B	32.1	22.8	.54	1.85	1.68
8.4ml	TEST A	32.1	22.8	.54	1.85	1.68
	TEST B	32.0	22.8	.54	1.85	1.68
8.8ml	TEST A	31.9	22.8	.54	1.85	1.68
	TEST B	31.9	22.8	.54	1.85	1.68
9.2ml	TEST A	31.9	22.8	.54	1.85	1.68
	TEST B	31.9	22.8	.54	1.85	1.68
9.6ml	TEST A	31.8	22.8	.53	1.88	1.71
	TEST B	31.8	22.8	.54	1.85	1.68
10.0ml	TEST A	31.8	22.8	.54	1.85	1.68
	TEST B	31.8	22.8	.54	1.85	1.68



Sample Group 8
50
45
40
35
30
Surface Tension dynes/cm
10⁻⁴
10⁻³
10⁻²
10⁻¹
Concentration in Moles/100ml H20

SAMPLE GROUP 10 - MED RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.6	22.0	.97	1.03	.90
.4ml	TEST A	55.5	22.0	1.17	.85	.73
	TEST B	55.5	22.0	1.17	.85	.73
.8ml	TEST A	50.0	22.0	1.35	.74	.64
	TEST B	49.9	22.0	1.33	.75	.65
1.2ml	TEST A	46.9	22.0	1.47	.68	.58
	TEST B	46.9	22.1	1.47	.68	.58
1.6ml	TEST A	45.1	22.1	1.53	.65	.55
	TEST B	45.1	22.1	1.53	.65	.55
2.0ml	TEST A	43.7	22.1	1.56	.64	.54
	TEST B	43.6	22.1	1.56	.64	.54
2.4ml	TEST A	42.6	22.1	1.67	.60	.50
	TEST B	42.6	22.1	1.67	.60	.50
2.8ml	TEST A	41.6	22.1	1.73	.59	.50
	TEST B	41.6	22.1	1.73	.59	.50
3.2ml	TEST A	40.6	22.2	1.66	.60	.50
	TEST B	40.6	22.2	1.67	.60	.50
3.6ml	TEST A	39.9	22.1	1.61	.62	.52
	TEST B	39.9	22.2	1.67	.60	.50
4.0ml	TEST A	39.3	22.3	1.66	.60	.50
	TEST B	39.3	22.3	1.66	.60	.50
4.4ml	TEST A	38.8	22.3	1.63	.61	.51
	TEST B	38.8	22.4	1.64	.61	.51
4.8ml	TEST A	38.4	22.4	1.69	.59	.50
	TEST B	38.4	22.4	1.69	.59	.50
5.2ml	TEST A	37.9	22.4	1.64	.61	.51
	TEST B	37.9	22.4	1.67	.60	.50
5.6ml	TEST A	37.6	22.4	1.64	.61	.51
	TEST B	37.7	22.5	1.64	.61	.51
6.0ml	TEST A	37.4	22.5	1.69	.59	.50
	TEST B	37.4	22.5	1.68	.59	.50
6.4ml	TEST A	37.1	22.6	1.72	.58	.49
	TEST B	37.1	22.6	1.73	.58	.49
6.8ml	TEST A	36.8	22.6	1.72	.58	.49
	TEST B	36.9	22.6	1.72	.58	.49
7.2ml	TEST A	36.6	22.6	1.68	.59	.50
	TEST B	36.5	22.6	1.68	.59	.50
7.6ml	TEST A	36.3	22.6	1.68	.59	.50
	TEST B	36.3	22.7	1.68	.59	.50
8.0ml	TEST A	36.2	22.7	1.72	.58	.49
	TEST B	36.3	22.8	1.73	.58	.49
8.4ml	TEST A	36.1	22.8	1.67	.60	.50
	TEST B	36.0	22.8	1.68	.59	.50
8.8ml	TEST A	35.9	22.9	1.72	.58	.49
	TEST B	35.9	22.9	1.72	.58	.49
9.2ml	TEST A	35.8	22.9	1.72	.58	.49
	TEST B	35.8	22.9	1.72	.58	.49
9.6ml	TEST A	35.8	22.9	1.72	.58	.49
	TEST B	35.8	22.9	1.72	.58	.49
10.0ml	TEST A	35.8	22.9	1.72	.58	.49
	TEST B	35.8	22.9	1.72	.58	.49

SAMPLE GROUP 10 - FAST RATE

		d/cm	*C	B/S	Bubble Interval	Surface Age
0ml	TEST A	72.5	22.3	3.97	.25	.16
.4ml	TEST A	63.5	22.4	4.29	.23	.14
	TEST B	63.5	22.4	4.29	.23	.14
.8ml	TEST A	60.4	22.4	4.32	.23	.14
	TEST B	60.4	22.4	4.32	.23	.14
1.2ml	TEST A	58.3	22.5	4.56	.22	.13
	TEST B	58.3	22.5	4.56	.22	.13
1.6ml	TEST A	56.2	22.6	4.60	.22	.13
	TEST B	56.2	22.6	4.60	.22	.13
2.0ml	TEST A	54.5	22.6	4.76	.21	.13
	TEST B	54.6	22.6	4.76	.21	.13
2.4ml	TEST A	52.8	22.6	4.79	.21	.13
	TEST B	52.8	22.6	4.79	.21	.13
2.8ml	TEST A	51.3	22.7	4.79	.21	.13
	TEST B	51.3	22.7	4.79	.21	.13
3.2ml	TEST A	50.0	22.7	4.79	.21	.13
	TEST B	49.9	22.7	4.79	.21	.13
3.6ml	TEST A	48.9	22.7	4.90	.20	.12
	TEST B	48.9	22.7	4.90	.20	.12
4.0ml	TEST A	47.8	22.7	5.05	.20	.12
	TEST B	47.8	22.7	5.07	.20	.12
4.4ml	TEST A	46.7	22.8	5.18	.19	.11
	TEST B	46.8	22.8	5.19	.19	.11
4.8ml	TEST A	45.9	22.8	5.20	.19	.11
	TEST B	46.0	22.8	5.21	.19	.11
5.2ml	TEST A	45.2	22.9	5.20	.19	.11
	TEST B	45.2	22.9	5.20	.19	.11
5.6ml	TEST A	44.5	22.9	5.21	.19	.11
	TEST B	44.4	22.9	5.20	.19	.11
6.0ml	TEST A	43.8	23.0	5.21	.19	.11
	TEST B	43.8	23.0	5.21	.19	.11
6.4ml	TEST A	43.3	23.0	5.20	.19	.11
	TEST B	43.3	23.0	5.21	.19	.11
6.8ml	TEST A	42.8	23.0	5.21	.19	.11
	TEST B	42.8	23.0	5.20	.19	.11
7.2ml	TEST A	42.4	23.0	5.34	.19	.11
	TEST B	42.4	23.0	5.34	.19	.11
7.6ml	TEST A	41.8	23.0	5.37	.19	.11
	TEST B	41.8	23.0	5.37	.19	.11
8.0ml	TEST A	41.6	23.0	5.37	.19	.11
	TEST B	41.6	23.0	5.36	.19	.11
8.4ml	TEST A	41.2	23.0	5.34	.19	.11
	TEST B	41.2	23.0	5.37	.19	.11
8.8ml	TEST A	40.9	23.1	5.37	.19	.11
	TEST B	40.9	23.1	5.37	.19	.11
9.2ml	TEST A	40.6	23.1	5.53	.18	.10
	TEST B	40.5	23.1	5.53	.18	.10
9.6ml	TEST A	40.3	23.1	5.53	.18	.10
	TEST B	40.4	23.1	5.53	.18	.10
10.0ml	TEST A	40.1	23.2	5.71	.18	.10
	TEST B	40.1	23.2	5.71	.18	.10

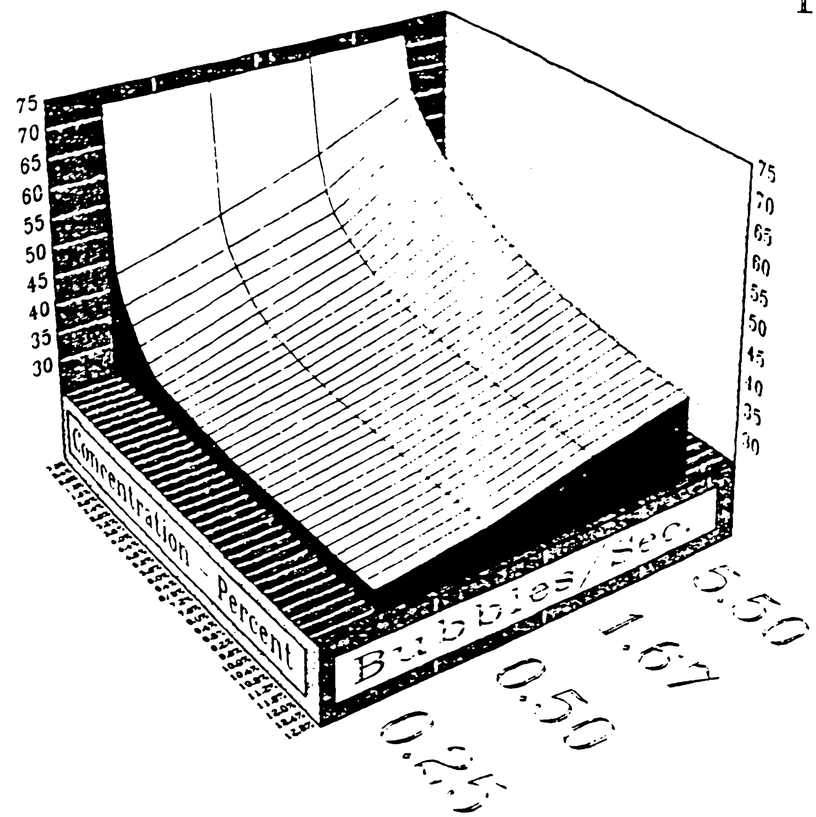
Sample Group 10 - Fast Rate Continued

10.4ml	TEST A	39.8	23.2	5.52	.18	.10
	TEST B	39.8	23.2	5.53	.18	.10
10.8ml	TEST A	39.5	23.2	5.48	.18	.10
	TEST B	39.5	23.2	5.50	.18	.10
11.2ml	TEST A	39.2	23.1	5.49	.18	.10
	TEST B	39.2	23.1	5.49	.18	.10
11.6ml	TEST A	39.2	23.1	5.49	.18	.10
	TEST B	39.2	23.1	5.49	.18	.10
12.0ml	TEST A	39.1	23.1	5.49	.18	.10
	TEST B	39.1	23.1	5.49	.18	.10
12.4ml	TEST A	39.1	23.1	5.49	.18	.10
	TEST B	39.1	23.1	5.49	.18	.10
12.8ml	TEST A	39.1	23.1	5.52	.18	.10
	TEST B	39.1	23.1	5.49	.18	.10

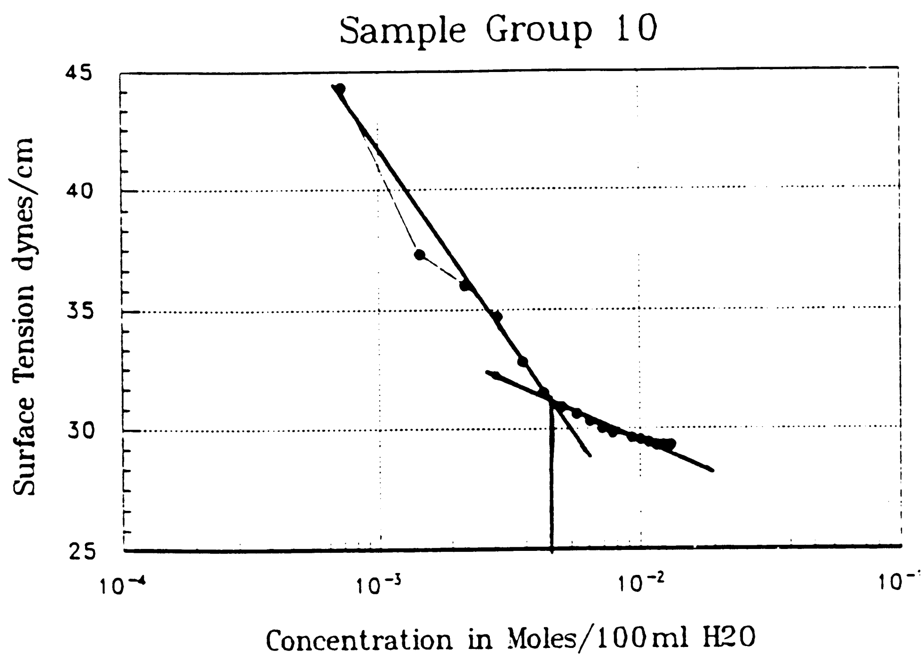
EQUILIBRIUM SURFACE TENSION POINTS
SAMPLE GROUP 10

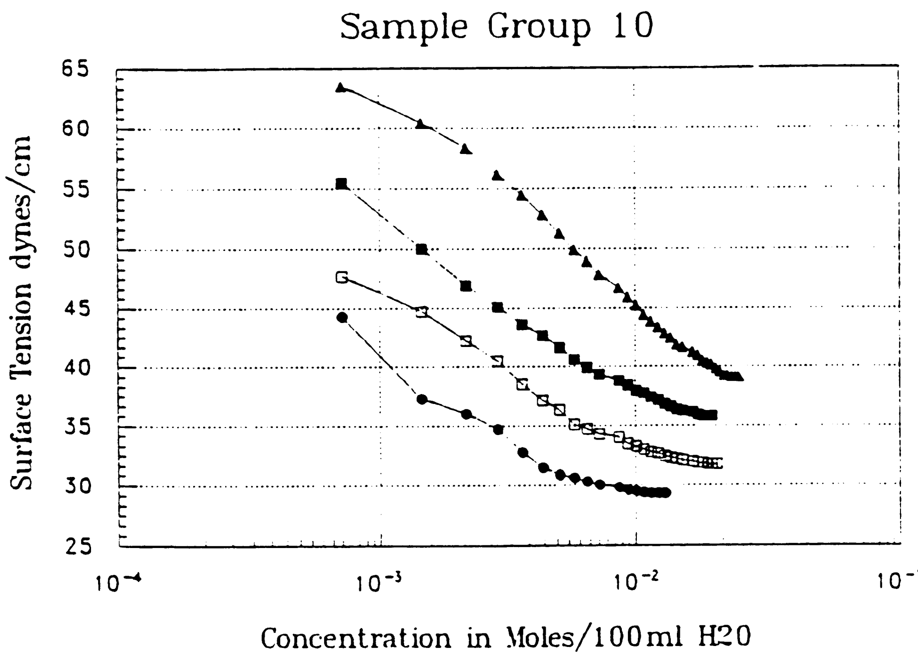
CONCEN.	SURF. TEN	B/SEC.
.4ml	44.3 d/cm	.20
.8ml	37.3 d/cm	.25
1.2ml	35.9 d/cm	.27
1.6ml	34.5 d/cm	.29
2.0ml	32.8 d/cm	.28
2.4ml	31.5 d/cm	.27
2.8ml	30.9 d/cm	.26
3.2ml	30.6 d/cm	.27
3.6ml	30.3 d/cm	.26
4.0ml	30.0 d/cm	.26
4.4ml	29.8 d/cm	.26
4.8ml	29.6 d/cm	.26
5.2ml	29.5 d/cm	.26
5.6ml	29.4 d/cm	.26

Dynamic Surface Tension Graph



Sample Group 10


Sample Group 10
Surface Tension dynes/cm
45
40
35
30
25
10⁻⁴
10⁻³
10⁻²
10⁻¹
Concentration in Moles/100ml H2O



Sample Group 10
Surface Tension dynes/cm
65
60
55
50
45
40
35
30
25
10⁻⁴
10⁻³
10⁻²
10⁻¹
Concentration in Moles/100ml H20

SAMPLE GROUP 11 - SLOWEST RATE
HWI: 6310-105 Test Material: Lauramide Oxide (Incromine Oxide L) PH aprox. 7

		d/cm	*C	b/s	Bubble Interval	Surf. Age
0ml	TEST A	72.9	19.6	.10	10.00	9.90
.4ml	TEST A	63.4	19.8	.10	10.00	9.90
	TEST B	63.4	19.8	.10	10.00	9.90
.8ml	TEST A	48.7	19.8	.13	7.69	7.46
	TEST B	48.7	19.8	.13	7.69	7.46
1.2ml	TEST A	44.2	19.8	.14	7.14	6.93
	TEST B	44.2	19.8	.14	7.14	6.93
1.6ml	TEST A	40.0	19.8	.15	6.66	6.39
	TEST B	40.1	19.8	.15	6.66	6.39
2.0ml	TEST A	38.1	19.9	.17	5.88	5.59
	TEST B	38.1	19.9	.17	5.88	5.59
2.4ml	TEST A	36.6	19.9	.19	5.26	4.99
	TEST B	36.6	19.9	.19	5.26	4.99
2.8ml	TEST A	35.7	19.9	.19	5.26	4.99
	TEST B	35.7	19.9	.19	5.26	4.99
3.2ml	TEST A	34.7	19.9	.19	5.26	4.99
	TEST B	34.7	19.9	.20	5.00	4.75
3.6ml	TEST A	34.1	20.0	.20	5.00	4.75
	TEST B	34.1	20.0	.20	5.00	4.75
4.0ml	TEST A	33.8	20.0	.20	5.00	4.75
	TEST B	33.8	20.1	.20	5.00	4.75
4.4ml	TEST A	33.7	20.1	.20	5.00	4.75
	TEST B	33.7	20.1	.20	5.00	4.75
4.8ml	TEST A	33.7	20.1	.20	5.00	4.75
	TEST B	33.7	20.1	.20	5.00	4.75
5.2ml	TEST A	33.7	20.1	.20	5.00	4.75
	TEST B	33.7	20.1	.20	5.00	4.75
5.6ml	TEST A	33.7	20.1	.20	5.00	4.75
	TEST B	33.7	20.1	.20	5.00	4.75

SAMPLE GROUP 11 - SLOW RATE		d/cm	•C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.8	20.6	.23	4.55	4.32
.4ml	TEST A	65.1	20.5	.24	4.16	3.95
	TEST B	65.1	20.5	.24	4.16	3.95
.8ml	TEST A	51.8	20.6	.30	3.33	3.16
	TEST B	51.8	20.6	.30	3.33	3.16
1.2ml	TEST A	47.5	20.7	.33	3.03	2.82
	TEST B	47.5	20.7	.33	3.03	2.82
1.6ml	TEST A	43.6	20.7	.32	3.13	2.91
	TEST B	43.6	20.7	.33	3.03	2.82
2.0ml	TEST A	40.7	20.7	.40	2.50	2.28
	TEST B	40.7	20.7	.40	2.50	2.28
2.4ml	TEST A	38.5	21.0	.42	2.38	2.17
	TEST B	38.6	21.0	.42	2.38	2.17
2.8ml	TEST A	37.6	21.0	.43	2.32	2.11
	TEST B	37.5	21.0	.43	2.32	2.11
3.2ml	TEST A	36.9	21.0	.43	2.32	2.11
	TEST B	36.9	21.0	.43	2.32	2.11
3.6ml	TEST A	36.5	21.0	.45	2.22	2.02
	TEST B	36.5	21.0	.45	2.22	2.02
4.0ml	TEST A	36.1	21.1	.45	2.22	2.02
	TEST B	36.1	21.1	.45	2.22	2.02
4.4ml	TEST A	35.8	21.1	.45	2.22	2.02
	TEST B	35.8	21.1	.45	2.22	2.02
4.8ml	TEST A	35.6	21.0	.43	2.32	2.11
	TEST B	35.6	21.0	.45	2.22	2.02
5.2ml	TEST A	35.5	21.1	.45	2.22	2.02
	TEST B	35.5	21.2	.45	2.22	2.02
5.6ml	TEST A	35.3	21.2	.44	2.27	2.07
	TEST B	35.4	21.2	.44	2.27	2.07
6.0ml	TEST A	35.3	21.2	.44	2.27	2.07
	TEST B	35.3	21.2	.44	2.27	2.07
6.4ml	TEST A	35.2	21.2	.44	2.27	2.07
	TEST B	35.2	21.2	.45	2.22	2.02
6.8ml	TEST A	35.1	21.2	.45	2.22	2.02
	TEST B	35.0	21.2	.44	2.27	2.07
7.2ml	TEST A	35.0	21.2	.45	2.22	2.02
	TEST B	35.0	21.2	.45	2.22	2.02
7.6ml	TEST A	35.0	21.2	.45	2.22	2.02
	TEST B	35.0	21.2	.45	2.22	2.02
8.0ml	TEST A	35.0	21.2	.44	2.27	2.07
	TEST B	35.0	21.2	.45	2.22	2.02

SAMPLE GROUP 11 -MED RATE

		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.7	21.1	.95	1.05	.91
.4ml	TEST A	67.2	20.8	1.04	.96	.83
	TEST B	67.2	20.8	1.04	.96	.83
.8ml	TEST A	57.2	20.8	1.20	.83	.67
	TEST B	57.3	20.8	1.20	.83	.67
1.2ml	TEST A	51.2	20.8	1.35	.74	.64
	TEST B	51.2	20.8	1.35	.74	.64
1.6ml	TEST A	47.1	20.8	1.46	.68	.58
	TEST B	47.0	20.8	1.45	.69	.59
2.0ml	TEST A	44.0	20.8	1.48	.67	.57
	TEST B	44.0	20.8	1.47	.68	.58
2.4ml	TEST A	42.1	20.8	1.54	.65	.55
	TEST B	42.1	20.8	1.54	.65	.55
2.8ml	TEST A	40.6	20.9	1.60	.63	.53
	TEST B	40.6	20.9	1.62	.62	.52
3.2ml	TEST A	39.6	20.9	1.64	.61	.51
	TEST B	39.6	20.9	1.62	.62	.52
3.6ml	TEST A	38.7	20.9	1.66	.60	.50
	TEST B	38.6	20.9	1.68	.60	.50
4.0ml	TEST A	38.1	20.9	1.70	.59	.50
	TEST B	38.1	20.9	1.72	.58	.49
4.4ml	TEST A	37.6	20.9	1.74	.57	.48
	TEST B	37.6	20.9	1.72	.58	.49
4.8ml	TEST A	37.2	20.9	1.74	.57	.48
	TEST B	37.2	20.9	1.74	.57	.48
5.2ml	TEST A	36.9	20.9	1.79	.56	.47
	TEST B	36.9	20.9	1.79	.56	.47
5.6ml	TEST A	36.6	21.0	1.79	.56	.47
	TEST B	36.7	21.0	1.78	.56	.47
6.0ml	TEST A	36.4	21.0	1.75	.57	.48
	TEST B	36.4	21.0	1.79	.56	.47
6.4ml	TEST A	36.2	21.0	1.75	.57	.48
	TEST B	36.2	21.0	1.75	.57	.48
6.8ml	TEST A	36.1	21.0	1.75	.57	.48
	TEST B	36.1	21.0	1.75	.57	.48
7.2ml	TEST A	36.0	21.0	1.75	.57	.48
	TEST B	36.0	21.0	1.75	.57	.48
7.6ml	TEST A	35.9	21.0	1.75	.57	.48
	TEST B	35.9	21.0	1.75	.57	.48
8.0ml	TEST A	35.7	21.0	1.75	.57	.48
	TEST B	35.7	21.0	1.79	.56	.47
8.4ml	TEST A	35.6	21.0	1.79	.56	.47
	TEST B	35.6	21.0	1.79	.56	.47
8.8ml	TEST A	35.6	21.0	1.79	.56	.47
	TEST B	35.6	21.0	1.77	.57	.48
9.2ml	TEST A	35.5	21.0	1.79	.56	.47
	TEST B	35.5	21.0	1.79	.56	.47
9.6ml	TEST A	35.5	21.0	1.79	.56	.47
	TEST B	35.5	21.0	1.77	.57	.48
10.0ml	TEST A	35.5	21.0	1.79	.56	.47
	TEST B	35.5	21.0	1.79	.56	.47

SAMPLE GROUP 11 - FAST RATE		d/cm	*C	b/s	Bubble Interval	Surface Age
0ml	TEST A	72.4	23.0	3.97	.25	.16
.4ml	TEST A	69.1	23.0	3.97	.25	.16
	TEST B	69.1	23.0	3.97	.25	.16
.8ml	TEST A	63.2	23.0	4.05	.25	.16
	TEST B	63.2	23.0	4.05	.25	.16
1.2ml	TEST A	57.7	23.0	4.35	.23	.14
	TEST B	57.7	23.0	4.35	.23	.14
1.6ml	TEST A	53.3	23.1	4.55	.22	.13
	TEST B	53.3	23.1	4.55	.22	.13
2.0ml	TEST A	49.9	23.1	4.79	.21	.13
	TEST B	49.9	23.1	4.79	.21	.13
2.4ml	TEST A	47.2	23.1	4.90	.20	.12
	TEST B	47.2	23.1	4.90	.20	.12
2.8ml	TEST A	44.8	23.1	5.21	.19	.11
	TEST B	44.8	23.1	5.21	.19	.11
3.2ml	TEST A	43.0	23.1	5.36	.19	.11
	TEST B	43.0	23.1	5.35	.19	.11
3.6ml	TEST A	41.5	23.1	5.49	.18	.10
	TEST B	41.5	23.1	5.53	.18	.10
4.0ml	TEST A	40.5	23.1	5.49	.18	.10
	TEST B	40.4	23.1	5.50	.18	.10
4.4ml	TEST A	39.6	23.1	5.68	.18	.10
	TEST B	39.6	23.1	5.68	.18	.10
4.8ml	TEST A	39.0	23.2	5.69	.18	.10
	TEST B	39.0	23.2	5.68	.18	.10
5.2ml	TEST A	38.4	23.2	5.69	.18	.10
	TEST B	38.4	23.2	5.69	.18	.10
5.6ml	TEST A	38.1	23.2	5.84	.17	.09
	TEST B	38.2	23.2	5.87	.17	.09
6.0ml	TEST A	37.8	23.2	5.89	.17	.09
	TEST B	37.8	23.3	5.89	.17	.09
6.4ml	TEST A	37.5	23.2	6.05	.17	.09
	TEST B	37.5	23.2	6.05	.17	.09
6.8ml	TEST A	37.2	23.2	6.05	.17	.09
	TEST B	37.2	23.2	6.07	.17	.09
7.2ml	TEST A	37.0	23.2	6.05	.17	.09
	TEST B	37.0	23.2	6.03	.17	.09
7.6ml	TEST A	36.9	23.2	5.89	.17	.09
	TEST B	36.9	23.2	5.89	.17	.09
8.0ml	TEST A	36.8	23.3	6.04	.17	.09
	TEST B	36.8	23.3	6.05	.17	.09
8.4ml	TEST A	36.6	23.3	6.10	.16	.08
	TEST B	36.6	23.3	6.10	.16	.08
8.8ml	TEST A	36.5	23.3	6.07	.17	.09
	TEST B	36.5	23.3	6.09	.16	.08
9.2ml	TEST A	36.3	23.3	6.10	.16	.08
	TEST B	36.3	23.3	6.07	.17	.09
9.6ml	TEST A	36.2	23.3	6.07	.17	.09
	TEST B	36.2	23.3	6.09	.16	.08
10.0ml	TEST A	36.0	23.3	6.11	.16	.08
	TEST B	36.0	23.3	6.10	.16	.08

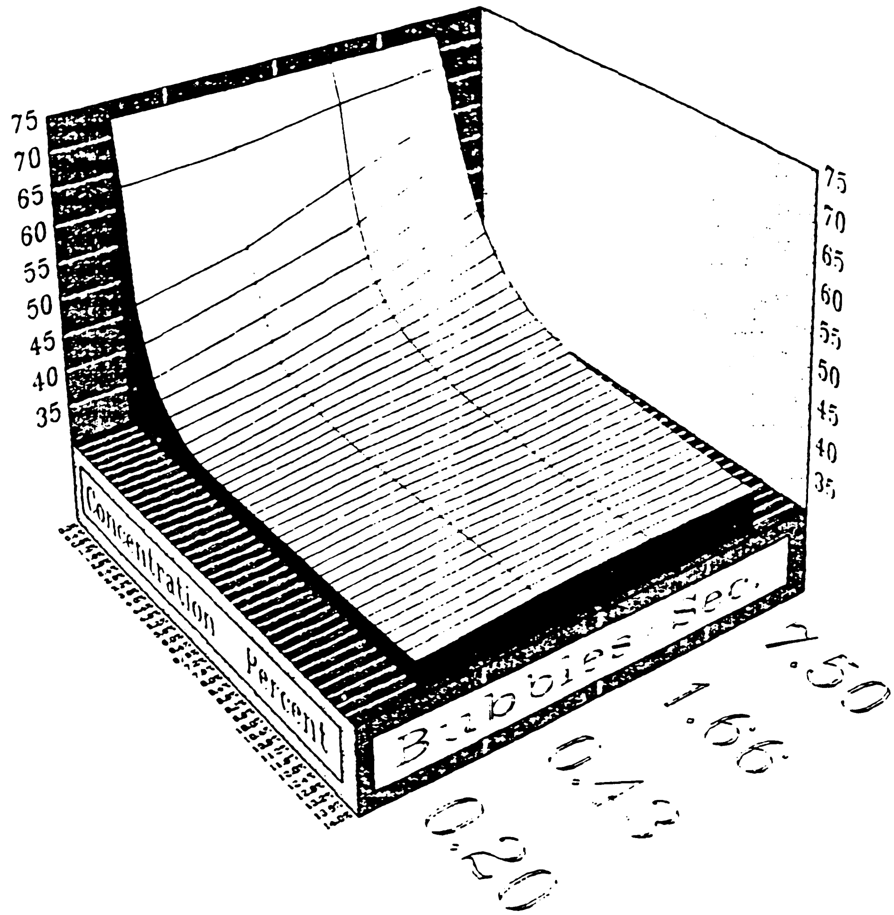
Sample Group 11 - Fast Rate Continued

10.4ml	TEST A	35.9	23.3	6.29	.16	.08
	TEST B	35.9	23.3	6.29	.16	.08
10.8ml	TEST A	35.8	23.3	6.29	.16	.08
	TEST B	35.8	23.3	6.26	.16	.08
11.2ml	TEST A	35.7	23.3	6.29	.16	.08
	TEST B	35.7	23.3	6.29	.16	.08
11.6ml	TEST A	35.6	23.3	6.29	.16	.08
	TEST B	35.6	23.3	6.29	.16	.08
12.0	TEST A	35.6	23.3	6.29	.16	.08
	TEST B	35.5	23.3	6.29	.16	.08
12.4ml	TEST A	35.4	23.3	6.29	.16	.08
	TEST B	35.4	23.3	6.29	.16	.08
12.8ml	TEST A	35.3	23.3	6.29	.16	.08
	TEST B	35.3	23.3	6.29	.16	.08
13.2ml	TEST A	35.3	23.3	6.29	.16	.08
	TEST B	35.3	23.3	6.29	.16	.08
13.6ml	TEST A	35.3	23.3	6.29	.16	.08
	TEST B	35.3	23.3	6.29	.16	.08

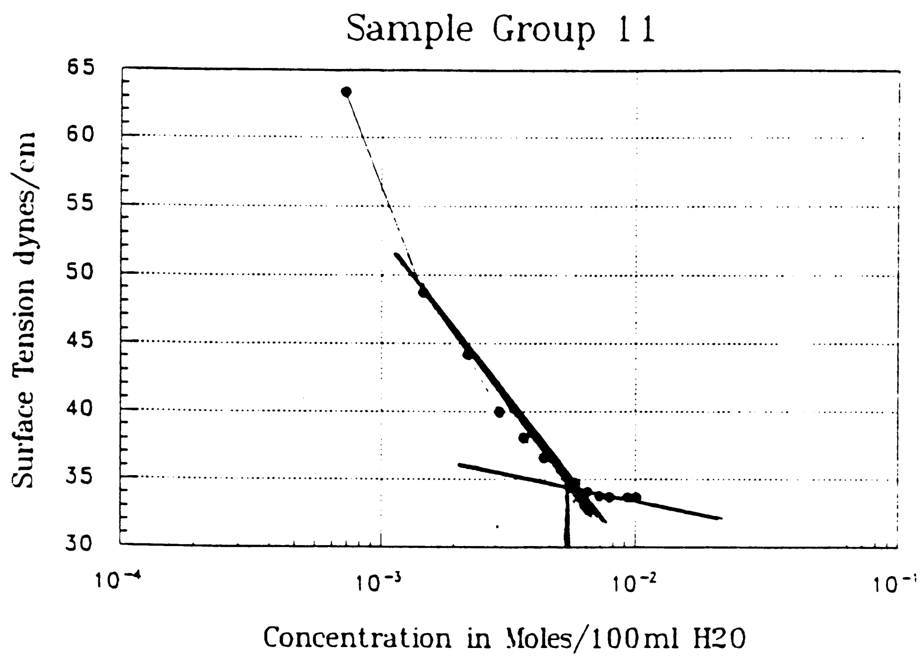
EQUILIBRIUM SURFACE TENSION POINTS
SAMPLE GROUP 11

CONCEN.	SURF. TEN.	B/SEC.
.4ml	63.4 d/cm	.10
.8ml	48.7 d/cm	.13
1.2ml	44.2 d/cm	.14
1.6ml	40.1 d/cm	.15
2.0ml	38.1 d/cm	.17
2.4ml	36.6 d/cm	.19
2.8ml	35.7 d/cm	.19
3.2ml	34.7 d/cm	.20
3.6ml	34.1 d/cm	.20
4.0ml	33.8 d/cm	.20
4.4ml	33.7 d/cm	.20
4.8ml	33.7 d/cm	.20
5.2ml	33.7 d/cm	.20

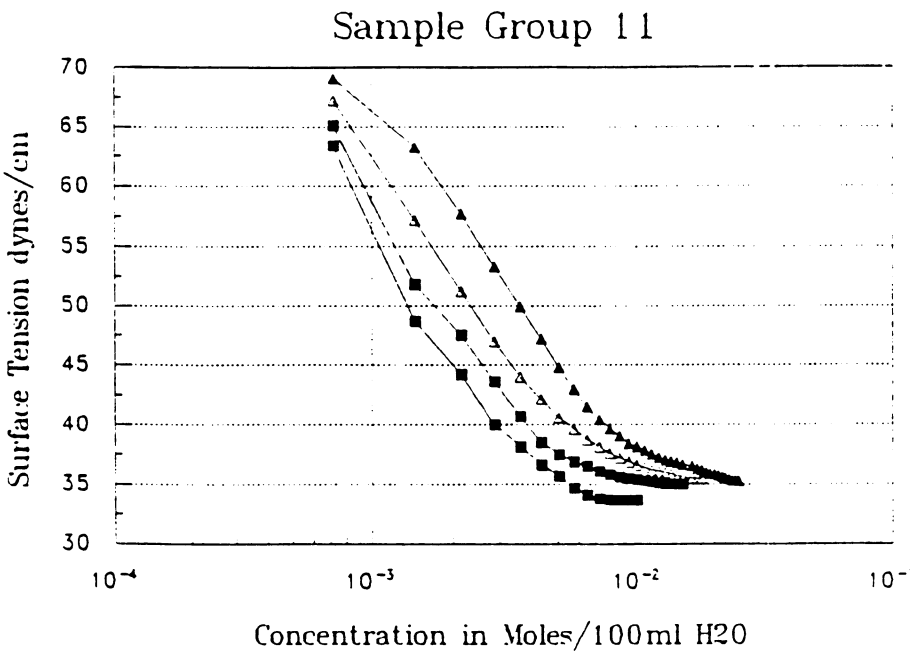
Dynamic Surface Tension Graph



Sample Group 11



Sample Group 11
65
60
55
50
45
40
35
30
Surface Tension dynes/cm
10⁻⁴
10⁻³
10⁻²
10⁻¹
Concentration in Moles/100ml H20


Sample Group 11
Surface Tension dynes/cm
70
65
60
55
50
45
40
35
30
10^{-4}
10^{-3}
10^{-2}
10^{-1}
Concentration in Moles/100ml H2O

JA

SensaDyne *Instrument Div.*
Chem-Dyne Research Corp.
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TEL: (602) 924-1744 FAX: (602) 924-1754

FAX MESSAGE, March 21, 1995 Page 1 of 15

To: ***Dr. Jenan Al-Atrash***
Company: ***SDA • Soap & Detergent Assoc.***
Fax: ***212-213-0685***
Subject: ***Surface Tension Study***

Dear Dr. Al-Atrash:

Enclosed are the CMC points and the Saturation points that you requested. Please keep in mind that saturation points are not equivalent to equilibrium surface tension. Equilibrium surface tension is only equal to saturation at the slowest bubble rate. If you have any questions about this please call me.

The graphs enclosed are enlarged for better view. We also noticed that the prior graphs sent were not on a proper log scale. (we have been having trouble with this graphing program) However the new graphs are correct and have been marked and labeled with all four CMC's for each sample.

If we can be of further assistance please let us know. I am sending the originals with a copy of our technical papers listing under separate cover. To avoid confusion the original graphes being sent to you are in full color.

Regards,

Tanya

Tanya C. Christensen

DYNAMIC SURFACE TENSION SATURATION POINTS

	Saturation Concentration	Surface Tension at Saturation
Sample 1		
.24 bubbles/sec.	4.8ml additive	28.2 dynes/cm
1 bubble/sec.	8.8ml additive	31.2 dynes/cm
4 bubbles/sec.	9.6ml additive	36.6 dynes/cm
Sample 2		
.24 bubbles/sec.	4.4ml additive	30.3 dynes/cm
1 bubble/sec.	8.4ml additive	35.5 dynes/cm
4 bubbles/sec.	10.8ml additive	41.9 dynes/cm
Sample 3		
.24 bubbles/sec.	4.4ml additive	25.2 dynes/cm
1 bubble/sec.	7.2ml additive	27.3 dynes/cm
4 bubbles/sec.	5.2ml additive	27.5 dynes/cm
Sample 4		
.24 bubbles/sec.	8.0ml additive	30.8 dynes/cm
1 bubble/sec.	10.4ml additive	42.9 dynes/cm
4 bubbles/sec.	10.8ml additive	53.8 dynes/cm
Sample 5		
.24 bubbles/sec.	4.8ml additive	45.4 dynes/cm
1 bubble/sec.	4.8ml additive	46.4 dynes/cm
4 bubbles/sec.	6.8ml additive	46.5 dynes/cm
Sample 6		
.24 bubbles/sec.	3.6ml additive	32.5 dynes/cm
1 bubble/sec.	6.4ml additive	33.8 dynes/cm
4 bubbles/sec.	7.2ml additive	35.6 dynes/cm
Sample 7		
.24 bubbles/sec.	13.2ml additive	52.2 dynes/cm
1 bubble/sec.	16.6ml additive	58.3 dynes/cm
4 bubbles/sec.	9.2ml additive	69.8 dynes/cm
Sample 8		
.24 bubbles/sec.	9.2ml additive	33.4 dynes/cm
1 bubble/sec.	10.4ml additive	38.9 dynes/cm
4 bubbles/sec.	11.2ml additive	46.9 dynes/cm
Sample 9		
.24 bubbles/sec.	7.2ml additive	34.1 dynes/cm
1 bubble/sec.	9.2ml additive	35.4 dynes/cm
4 bubbles/sec.	12.4ml additive	35.6 dynes/cm
Sample 10		
.24 bubbles/sec.	9.6ml additive	31.8 dynes/cm
1 bubble/sec.	9.2ml additive	35.8 dynes/cm
4 bubbles/sec.	12.0ml additive	39.1 dynes/cm
Sample 11		
.24 bubbles/sec.	6.8ml additive	35.0 dynes/cm
1 bubble/sec.	9.2ml additive	35.5 dynes/cm
4 bubbles/sec.	12.8ml additive	35.3 dynes/cm

CRITICAL MICELLE CONCENTRATIONS

Sample 1	CMC Point
.10 bubbles/sec.	.0025 moles/100 ml H2O
.24 bubbles/sec.	.0028 moles/100 ml H2O
1 bubble/sec.	.0040 moles/100 ml H2O
4 bubbles/sec.	.0057 moles/100 ml H2O

Sample 2	CMC Point
.10 bubbles/sec.	.0029 moles/100 ml H2O
.24 bubbles/sec.	.0038moles/100 ml H2O
1 bubble/sec.	.0052 moles/100 ml H2O
4 bubbles/sec.	.0079 moles/100 ml H2O

Sample 3	CMC Point
.10 bubbles/sec.	.0015 moles/100 ml H2O
.24 bubbles/sec.	.0018 moles/100 ml H2O
1 bubble/sec.	.0024 moles/100 ml H2O
4 bubbles/sec.	.0030 moles/100 ml H2O

Sample 4	CMC Point
.10 bubbles/sec.	.0031 moles/100 ml H2O
.24 bubbles/sec.	.0037 moles/100 ml H2O
1 bubble/sec.	.0043 moles/100 ml H2O
4 bubbles/sec.	.0050 moles/100 ml H2O

Sample 5	CMC Point
.10 bubbles/sec.	.0026 moles/100 ml H2O
.24 bubbles/sec.	.0029 moles/100 ml H2O
1 bubble/sec.	.0033 moles/100 ml H2O
4 bubbles/sec.	.0038 moles/100 ml H2O

Sample 6	CMC Point
.10 bubbles/sec.	.0023 moles/100 ml H2O
.24 bubbles/sec.	.0025 moles/100 ml H2O
1 bubble/sec.	.0027 moles/100 ml H2O
4 bubbles/sec.	.0031 moles/100 ml H2O

Sample 7	CMC Point
.10 bubbles/sec.	.022 moles/100 ml H2O
.24 bubbles/sec.	.025 moles/100 ml H2O
1 bubble/sec.	.030 moles/100 ml H2O
4 bubbles/sec.	.019 moles/100 ml H2O

Sample 8	CMC Point
.10 bubbles/sec.	.0043 moles/100 ml H2O
.24 bubbles/sec.	.0052 moles/100 ml H2O
1 bubble/sec.	.0077 moles/100 ml H2O
4 bubbles/sec.	.013 moles/100 ml H2O

= 25 mM vs.

$\frac{4\ ml \times .2\ M}{104\ ml} = 7.7\ mM$

.0025 moles/4 ml = .625 M

vs .2 M nominal

.0029 moles/3.2 ml = .906 M

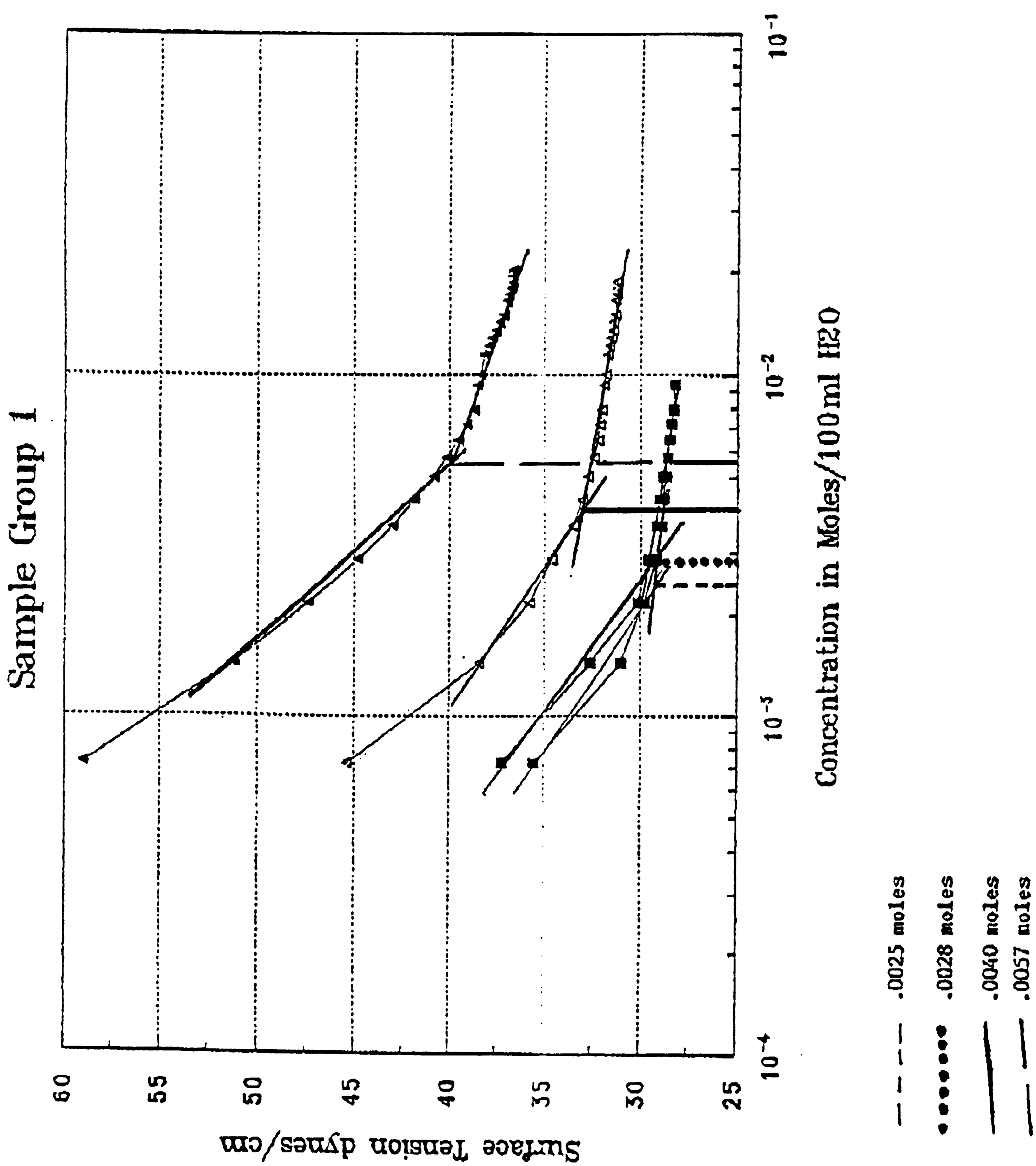
.0015 moles/4.8 ml = 0.312 M

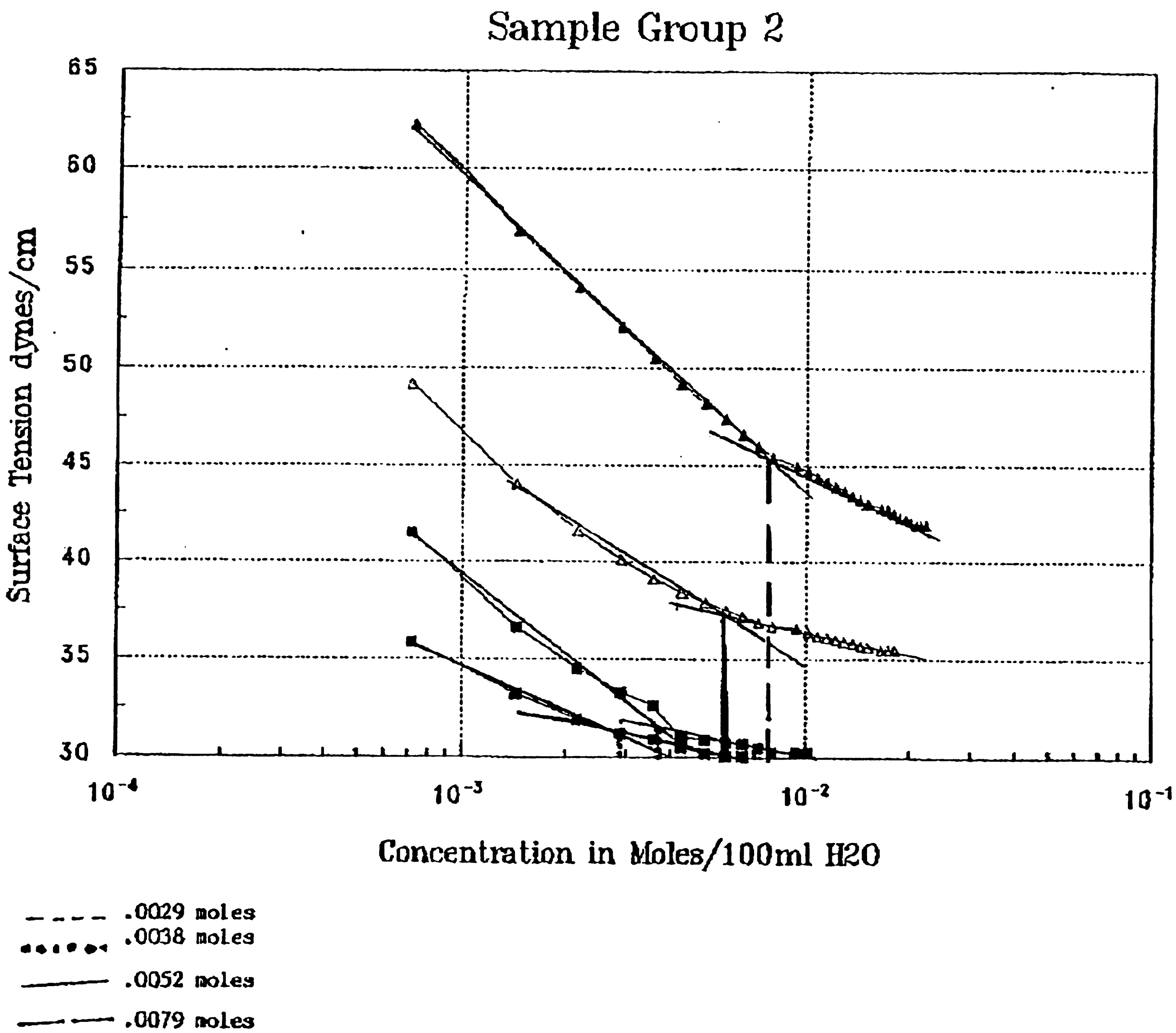
CRITICAL MICELLE CONCENTRATIONS Cont.

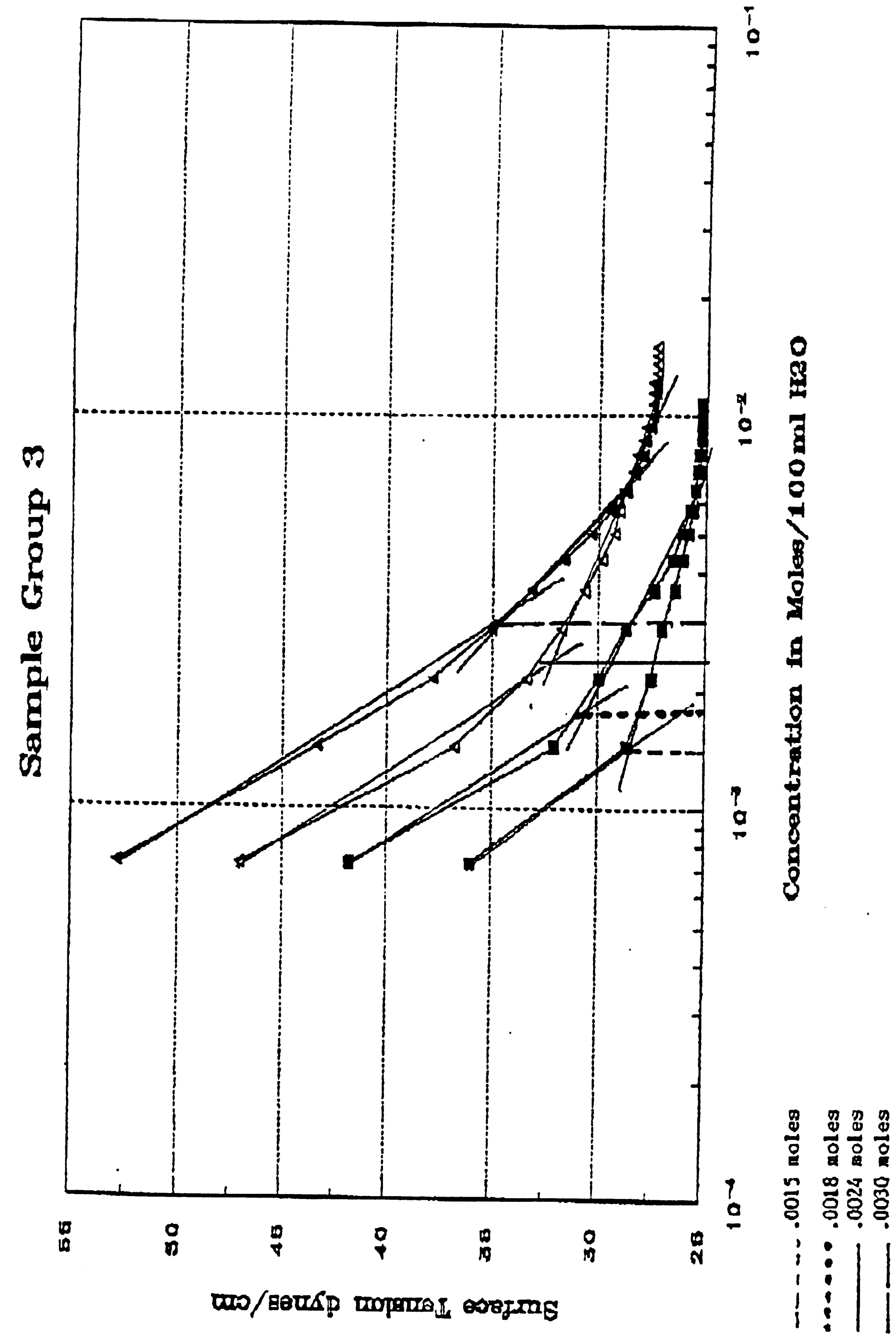
Sample 9	CMC Point
.10 bubbles/sec.	.0045 moles/100 ml H2O
.24 bubbles/sec.	.0052 moles/100 ml H2O
1 bubble/sec.	.0063 moles/100 ml H2O
4 bubbles/sec.	.0074 moles/100 ml H2O

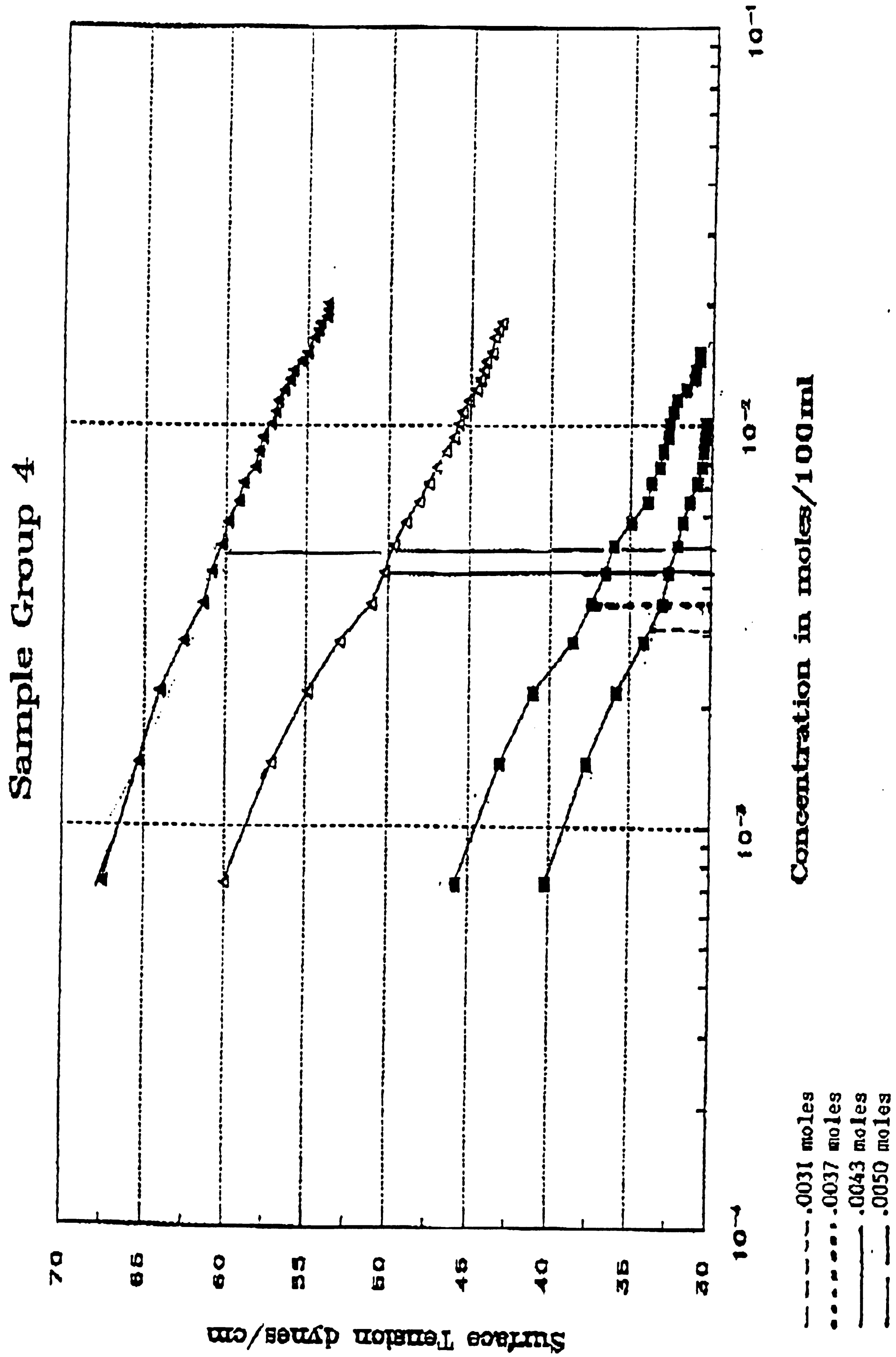
Sample 10	CMC Point
.10 bubbles/sec.	.0041 moles/100 ml H2O
.24 bubbles/sec.	.0055 moles/100 ml H2O
1 bubble/sec.	.0075 moles/100 ml H2O
4 bubbles/sec.	.011 moles/100 ml H2O

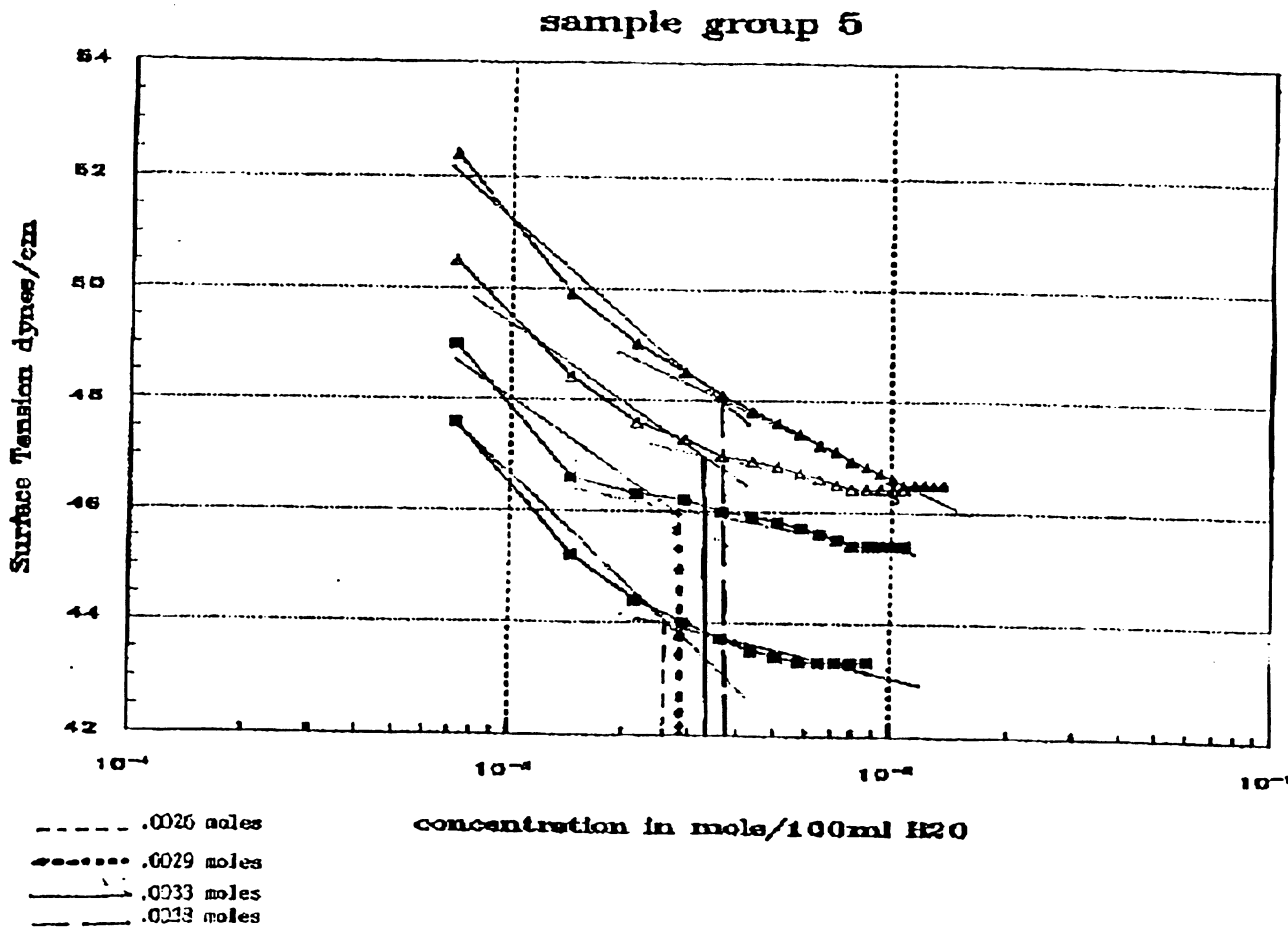
Sample	CMC Point
.10 bubbles/sec.	.0052 moles/100 ml H2O
.24 bubbles/sec.	.0076 moles/100 ml H2O
1 bubble/sec.	.0090 moles/100 ml H2O
4 bubbles/sec.	.012 moles/100 ml H2O


Sample Group 1
Surface Tension dynes/cm
60
55
50
45
40
35
30
25
Concentration in Moles/100ml H2O
10^{-4}
10^{-3}
10^{-2}
10^{-1}
.0025 moles
.0028 moles
.0040 moles
.0057 moles

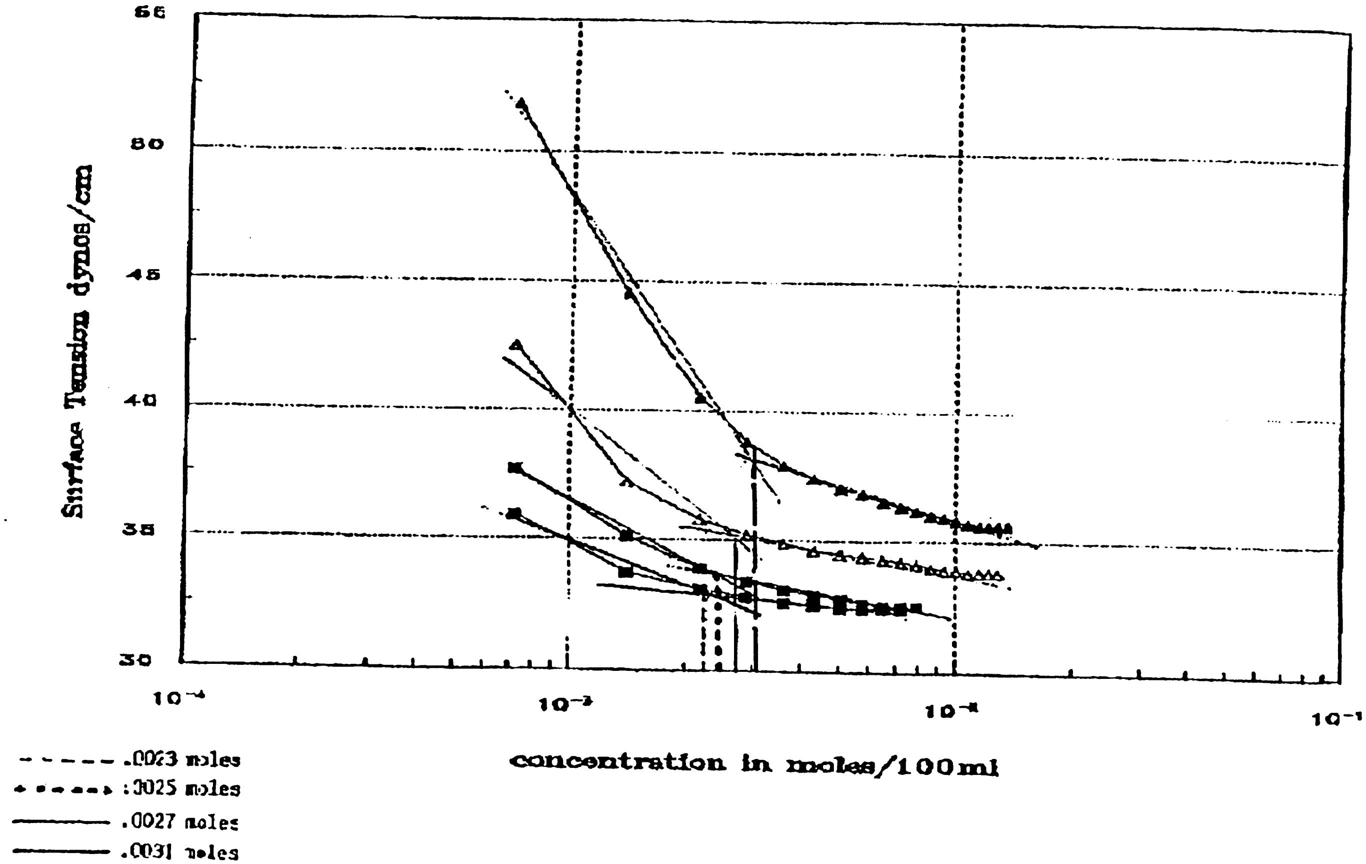

Sample Group 2
Surface Tension dynes/cm
65
60
55
50
45
40
35
30
10⁻⁴
10⁻³
10⁻²
10⁻¹
Concentration in Moles/100ml H2O
.0029 moles
.0038 moles
.0052 moles
.0079 moles

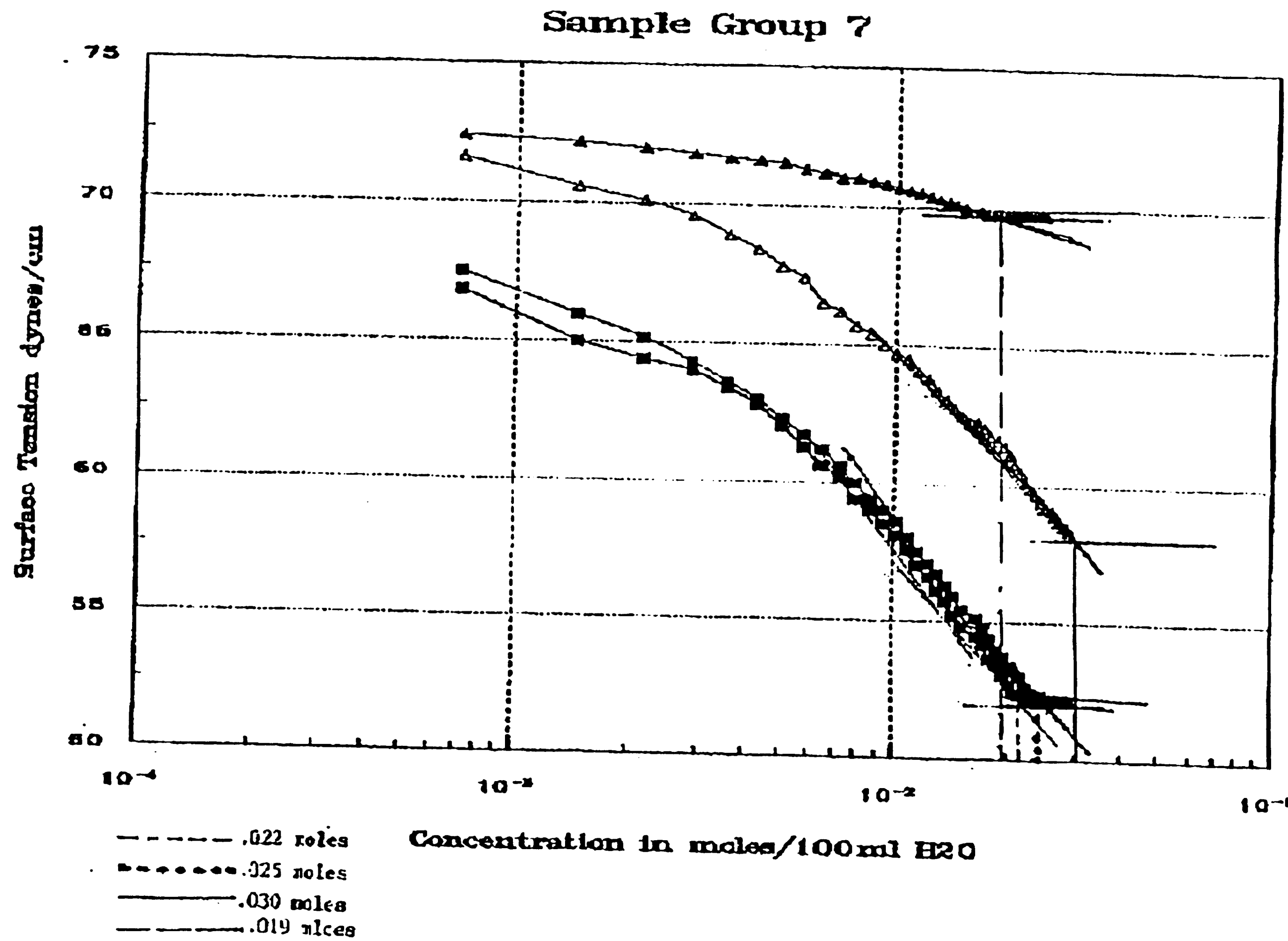

Sample Group 3
Surface Tension dynes/cm
55
50
45
40
35
30
25
Concentration in Moles/100ml H2O
10^{-4}
10^{-3}
10^{-2}
10^{-1}
.0015 moles
.0018 moles
.0024 moles
.0030 moles


Sample Group 4
Surface Tension dynes/cm
70
65
60
55
50
45
40
35
30
Concentration in moles/100ml
.0031 moles
.0037 moles
.0043 moles
.0050 moles

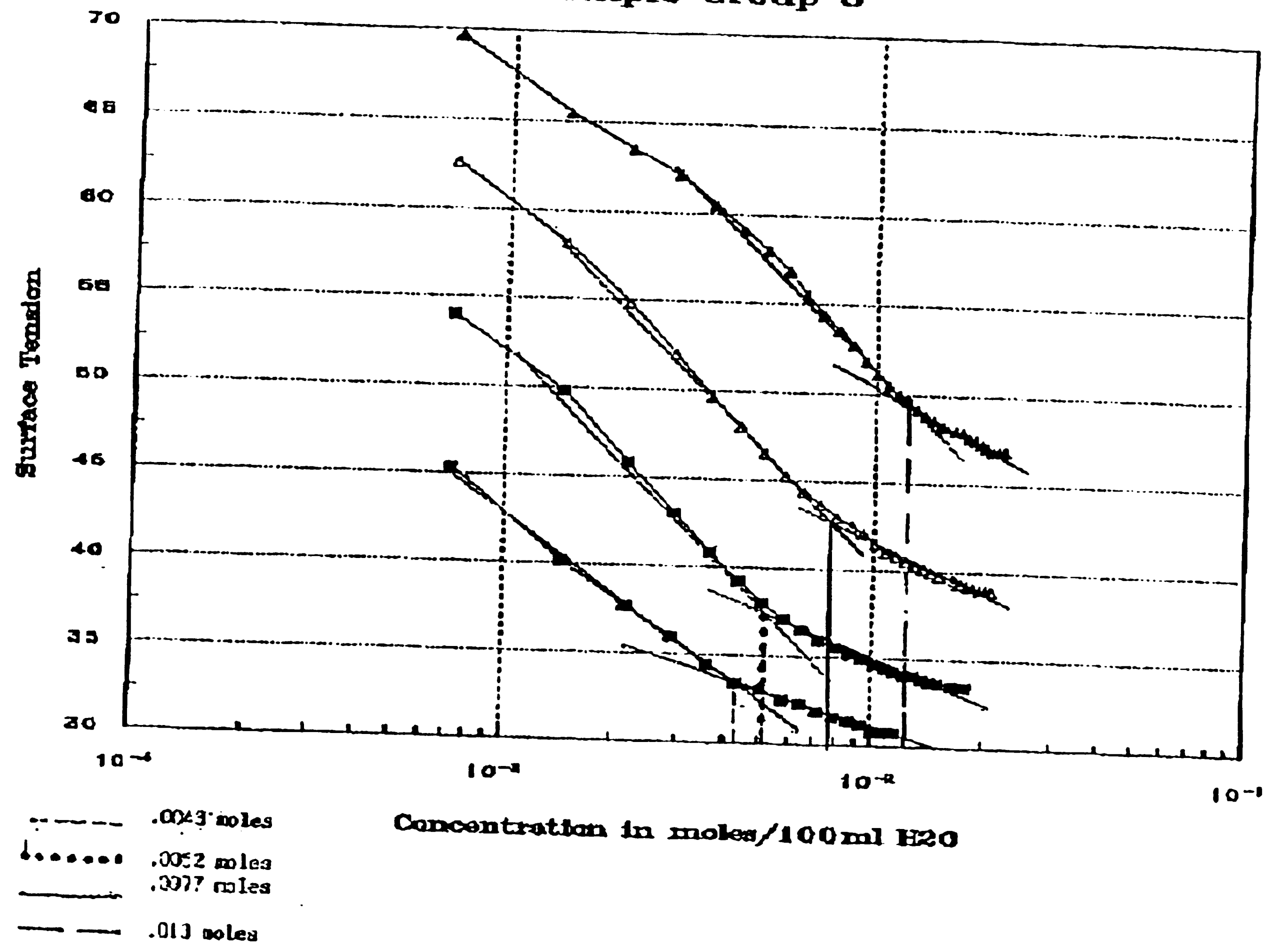

sample group 5
Surface Tension dynes/cm
54
52
50
48
46
44
42
concentration in mols/100ml H20
.0026 moles
.0029 moles
.0033 moles
moles

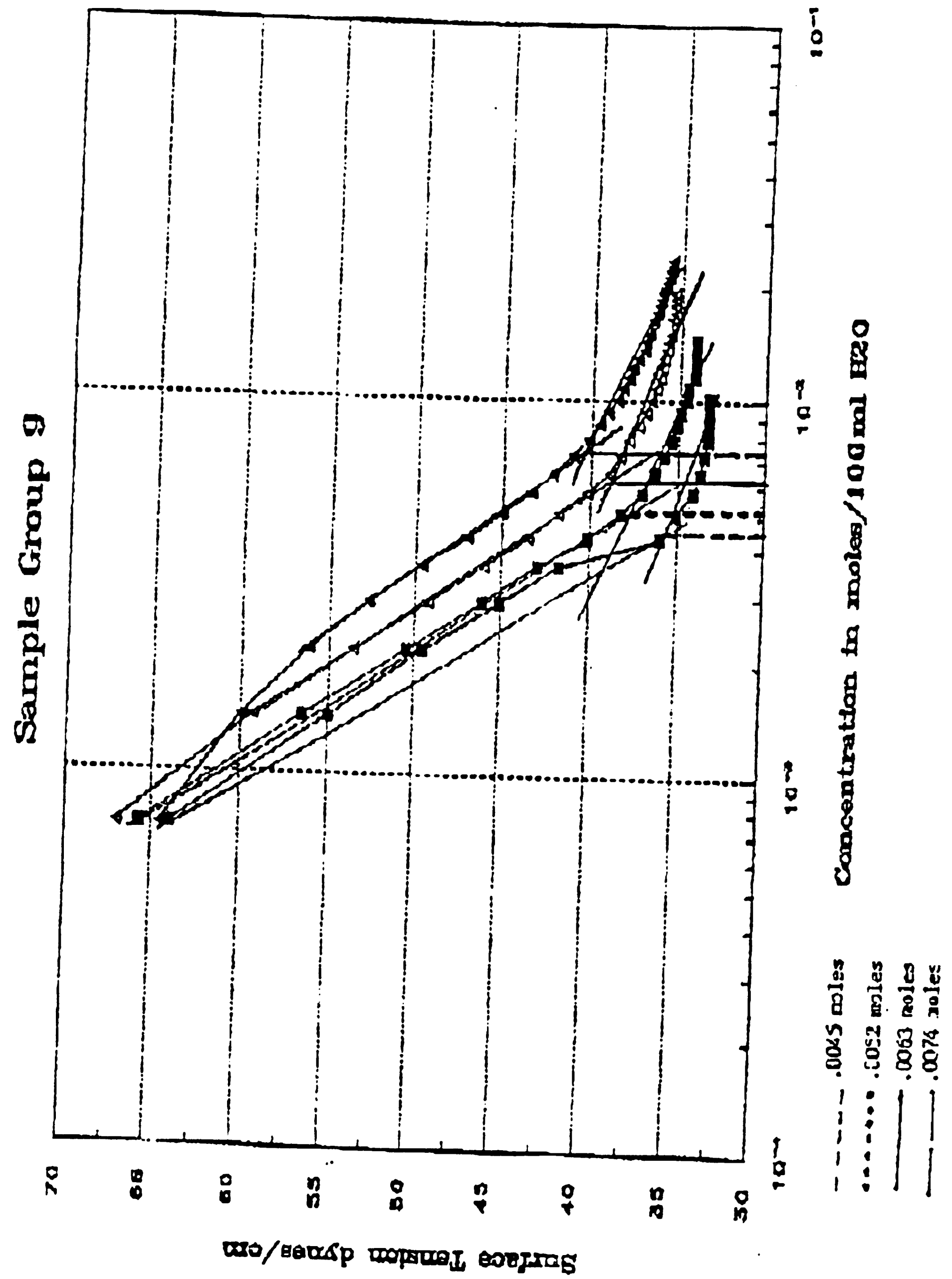
Sample Group 6

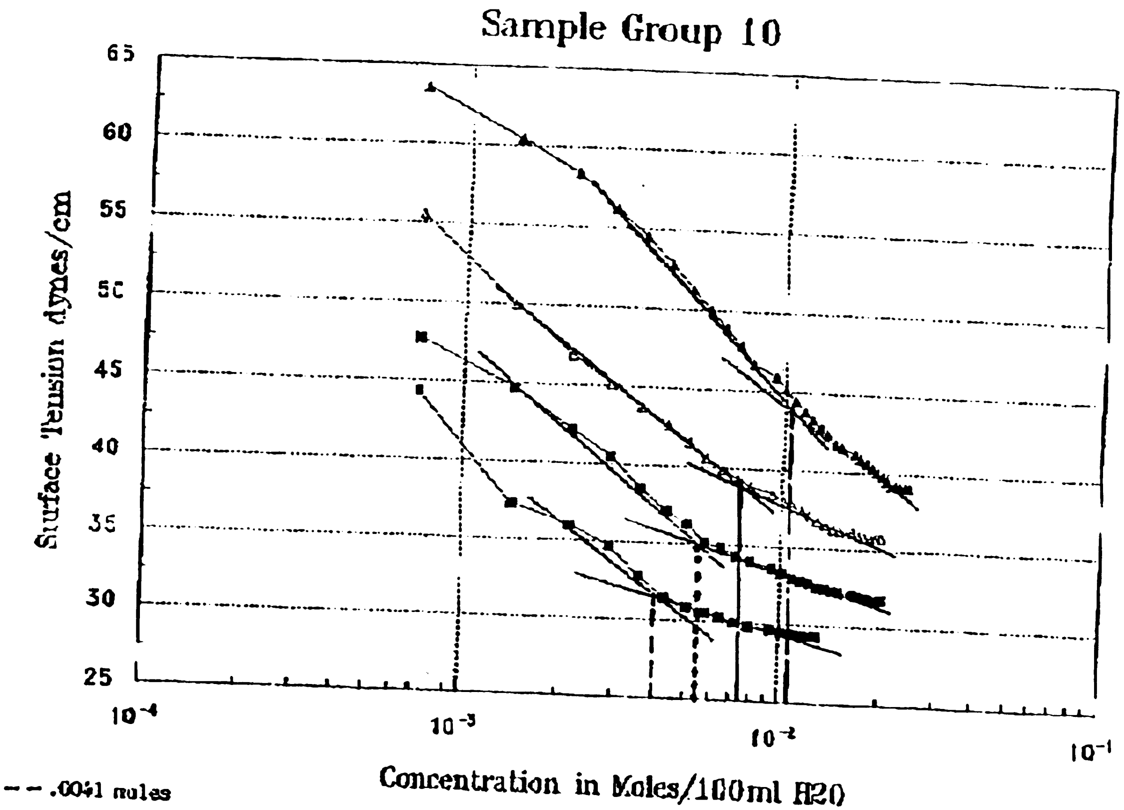



Sample Group 7
Surface Tension dynes/cm
75
70
65
60
55
50
10⁻⁴
10⁻³
10⁻²
10⁻¹
Concentration in moles/100ml H2O
.022 moles
.025 moles
.030 moles
.019 moles

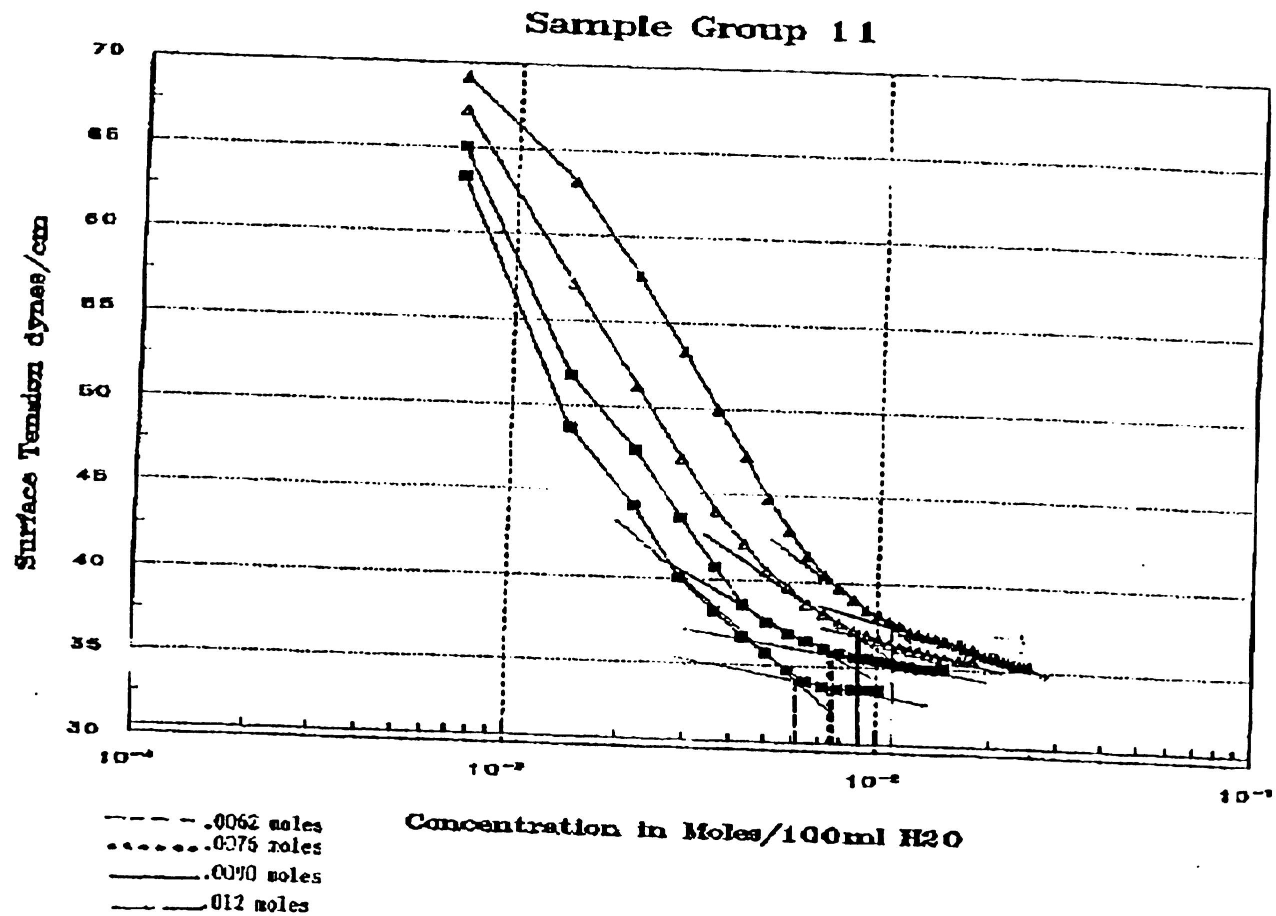
Sample Group 8




Sample Group 9
Surface Tension dynes/cm
70
65
60
55
50
45
40
35
30
Concentration in moles/100ml H20
10^{-4}
10^{-3}
10^{-2}
10^{-1}
.0045 moles
.0052 moles
.0063 moles
.0074 moles



- - - - - - .0041 moles
• • • • • • .0055 moles
———— .0075 moles
—— —— .011 moles


Sample Group 11
Surface Tension dynes/cm
70
65
60
55
50
45
40
35
30
10⁻⁴
10⁻³
10⁻²
10⁻¹
Concentration in Moles/100ml H20
.0062 moles
.0075 moles
.0090 moles
.012 moles

SensaDyne Instrument Div.
Chem-Dyne Research Corp.
P.O. Box 30430 Mesa AZ 85275-0430 U.S.A.
TEL: (602) 924-1744 FAX: (602) 924-1754

FAX MESSAGE, March 2, 1995 Page 1 of 3

To: ***Dr. Jenan Al-Atrash***
Company: ***The Soap & Detergent Association***
Fax: ***1-212-213-0685***
Subject: ***HWI# 6310-105 - Surface Tension Studies***

Dear Dr. Al-Atrash:

Enclosed is an additional summary of the surface tension test results. We hope that this additional information, when combined with the information we sent earlier, will allow you to better interpret the data. If you have any further questions regarding what we have sent, please call us.

Regards,

Tanya Christensen

Tanya C. Christensen

SUMMARY - Appendix 1

EQUILIBRIUM SURFACE TENSIONS

When an air/fluid interface is formed the surfactant molecules react by diffusing to the interface. It is only at this air/fluid interface that the surfactant molecules line up with their hydrophobic ends pointed at the interface, and surface tension is lowered. The concentration and the strength of the surfactant determines by how much the surface tension is reduced. The speed of diffusion is also a function of the size and nature of the surfactant molecule

The equilibrium surface tension points shown for each sample are points at which all available surfactant molecules, for the particular concentration indicated, have fully diffused to the interface. At a specific concentration we reach the lowest possible surface tension (equilibrium) for a particular surfactant. Any surfactant added above this concentration will not lower the surface tension any further. At this point there is an overabundance of surfactant molecules still in solution.

	Saturation Concentration	Lowest Achievable Surface Tension
Sample 1	4.0 ml concentration	28.4 dynes/cm
Sample 2	3.2 ml concentration	30.1 dynes/cm
Sample 3	4.8 ml concentration	25.2 dynes/cm
Sample 4	5.2 ml concentration	30.4 dynes/cm
Sample 5	3.2 ml concentration	43.3 dynes/cm
Sample 6	2.8 ml concentration	32.4 dynes/cm
Sample 7	12.4 ml concentration	52.1 dynes/cm
Sample 8	5.6 ml concentration	30.8 dynes/cm
Sample 9	4.4 ml concentration	33.3 dynes/cm
Sample 10	6.0 ml concentration	29.3 dynes/cm
Sample 11	4.4 ml concentration	33.7 dynes/cm

DYNAMIC SURFACE TENSION

The dynamic surface tension graphs plot all of the raw data in terms of Surface Tension vs. Concentration at different bubble rates, to achieve a three-dimensional characterization of the sample.

CRITICAL MICELLE CONCENTRATIONS (CMC's)

Classical belief is that many surface tension - related properties such as detergency, foaming and wetting. either maximize or minimize at the surfactant critical micelle concentration (CMC). These relationships, however are based on classical measurements limited to equilibrium surface tension conditions, when equilibrium has been established between the surface layer and the bulk solution. Dynamic surface tension measurements of active surfactants indicate a shift in the CMC, as shown on the included graphs. These show multiple CMC curves under dynamic conditions (different allowable diffusion times.)

On the information submitted we have marked the equilibrium CMC for the various samples (The "knee" of the equilibrium curve for each individual sample group).
We have also plotted the shift in the CMC curves (although each wasn't specifically marked) as the surface age is reduced and we progress form equilibrium conditions to dynamic conditions The shift is always towards increasing concentration & higher surface tension. The higher surface tension values are due to shorter surface age times where fewer surfactant molecules are able to migrate to the interface. At these shorter surface ages the "dynamic" CMC point occurs at higher surfactant concentrations.

Mean CMC values
for equilibrium +
dynamic surface
[illegible] plots

SensaDyne Instrument Div.

Chem-Dyne Research Corp.

P.O. Box 30430 Mesa AZ 85275-0430 U.S.A.

(602) 924-1744 FAX: (602) 924-1754

Message - March 11, 1997

To:	***Dr. John E. Heinze***
Company:	***Technical Consultant***
Fax	***703 924 9365***
Subject:	***SDA Surface Tension Tests***

Dear Dr. Heinze

Thank you for your fax. Enclosed please find the information you requested on the instrument description. The instrument used was the PC9000, which replaced the old 6000 as our production model in late 1994. The instruments are functionally the same, except that the PC9000 has upgraded flow controllers for better accuracy & precision.

Also enclosed, please find a listing of our technical papers and application notes. If any of these would be helpful to you, please mark them and we will make a second mailing.

If you have any further questions after reviewing this information, please do not hesitate to contact us.

Best Regards,

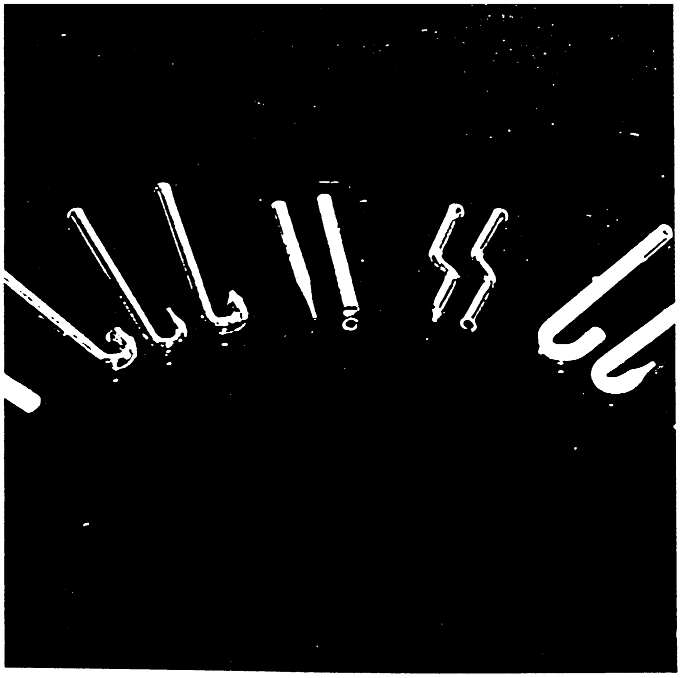
T. Christensen

Tanya C. Christensen

SensaDyne Instrument Div

The Experts in Dynamic Surface Tension

SURFACE TENSION



Surface Tension Simplified

The surface tension of a fluid is the tendency of the fluid to "stick" to itself when there is a surface between the liquid and the vapor phase (known as an interface). A good example is a drop of water falling in air. The drop assumes a spherical shape due to surface tension forces. that minimize its surface given the volume.

Molecules at the surface of a liquid exert strong attractive forces on other molecules within their vicinity. The resultant force acting perpendicular to a line of unit length in the surface is known as surface tension. usually measured in Dynes/Centimeter.

In the maximum bubble pressure method. bubbles are formed at the ends of two immersed tubes of different orifice diameters. The difference in the maximum pressures required to generate bubbles in the fluid is directly proportional to the fluid surface tension.

In processes where new liquid surfaces are created or terminated. the classical methods used to measure surface tension. such as the Du Noüy ring or the Wilhelmy Plate are inadequate. The Maximum Bubble Pressure method is required to detect changes in "active" surfactant containing systems. Varying the rate of bubble formation allows the study of active surfactants at various surfactant molecule diffusion times resulting in "Dynamic" Surface Tension Measurement.

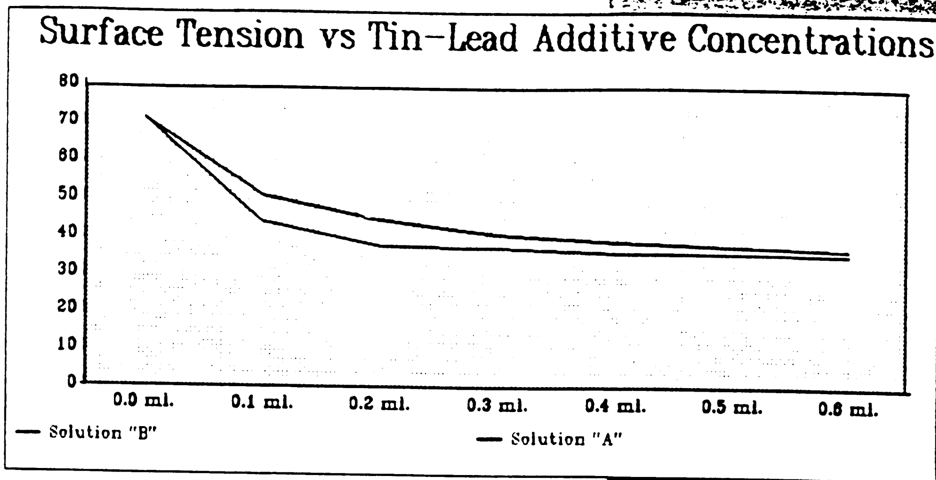
Dynamic Measurement

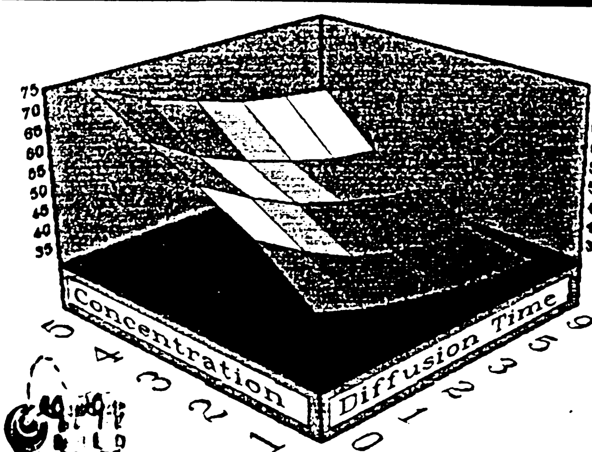
Active surfactants are known to have dynamic characteristics. Higher surface tension results as the interface development time (Surface Age) is reduced. limiting the time that surfactant molecules migrate to the interface. This allows characterization of fluids in two dimensions: Dynamic Surface Tension versus Surface Age (diffusion time).

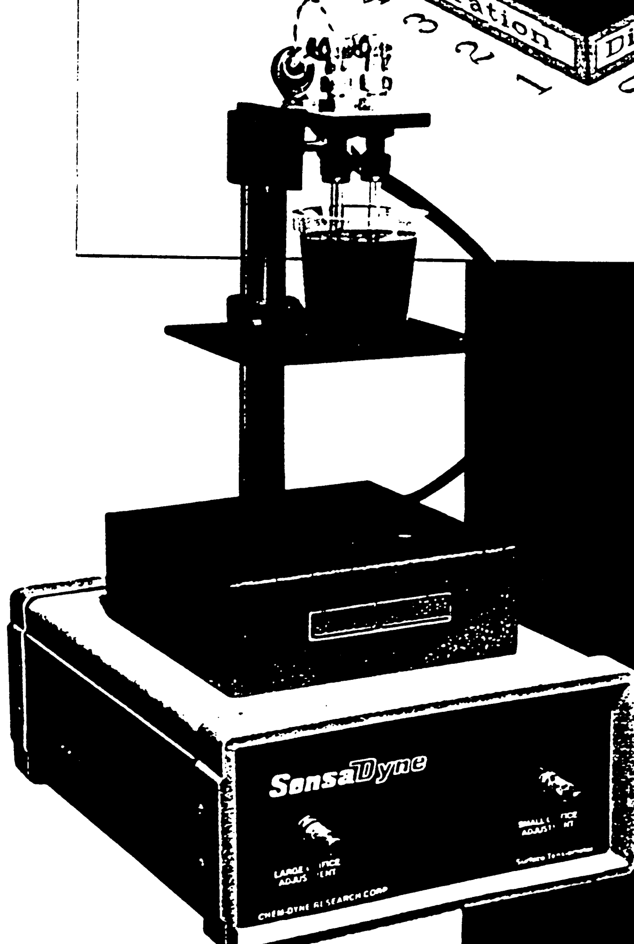
The characteristics of a surfactant can also be shown in three dimensions. when the surface tension is also measured as a function of Surfactant Concentration. as well as Dynamic Surface Tension and Surface Age.

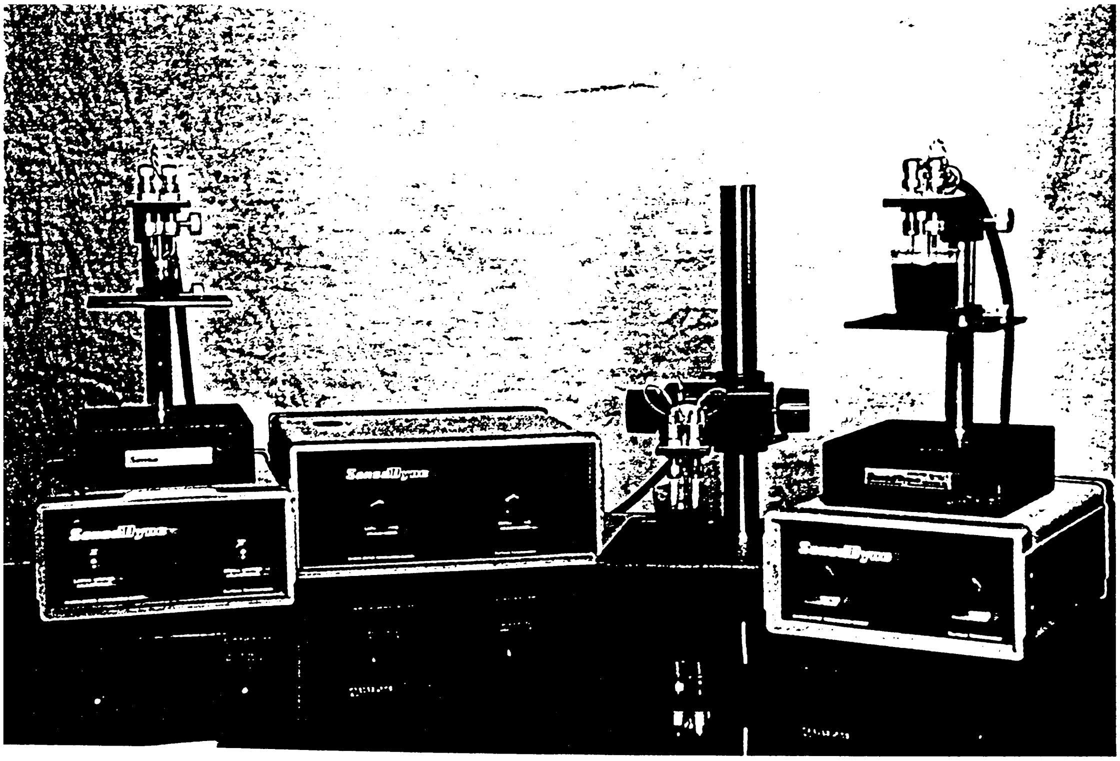
The SensaDyne tensiometer allows both intermittent and continuous measurements at any point on the dynamic curve of an active surfactant containing formulation. Continuous measurement capability also facilitates process control applications where surface tension is the controlling parameter.

At slow bubble rates the surface age is approximately equal to the bubble rate. As the bubble rate increases the surface age becomes a decreasing percentage of the bubble rate. If the bubble rate is increased too much, then bubbles begin to link together in an oscillating jet mode. An oscilloscope software program is available to verify bubble separation and to very accurately read bubble rate as well as surface age at very fast bubble rates.









The SensaDyne Surface Tensiometers

SensaDyne Tensiometers are the most advanced. computerized. instruments now available for measuring both static and dynamic fluid surface tension.

Classical methods such as the Du Noüy ring, Capillary Height. and others. require a clear surface without contaminants in order to obtain accurate measurements. These methods cannot be used where surface foaming occurs. or surface debris is present.

SensaDyne instruments can continuously monitor surface tension within fluid sample streams. using a flow - through cell arrangement. The measurement is taken within the body of the fluid and is unaffected by any surface contaminants.

SensaDyne Tensiometers use a patented technology that is a refinement of the Maximum Bubble Pressure Method. This method was first suggested by Simon in 1851 and later developed by Jäeger in 1917. The first viable commercial instrument was introduced by SensaDyne in 1982. and a subsequent design was interfaced with a computer several years later. allowing use of software tools that make even complex three dimensional studies relatively straight forward.

The maximum bubble pressure method avoids error-causing effects by measuring surface tension within the body of the fluid. It is the "Simplest Accurate Method" for measuring surface tension. A comprehensive mathematical analysis of the maximum bubble pressure method can be found in U.S. Patent No. 4.416.148 (covering the SensaDyne technology.)

Two probes having orifices of different diameters are positioned below the surface of the liquid. A pressurized process gas source forms bubbles in the liquid. and the differential pressure of the bubbles is measured and equated to the surface tension of the measured liquid.

Unlike other maximum bubble pressure methods. The SensaDyne's patented double probe method allows complete independence of immersion depth. for accurate repeatable results. The Tensiometer's pneumatic system provides constant volumetric gas flow. making the flow independent of down-stream pressure. Flow rate to each orifice is adjustable through external valves. This allows interface formation time (bubble rate) selection from up to forty or more bubbles per second to one bubble every thirty or more seconds. Bubble rate. fluid temperature and fluid surface tension are displayed on the computer's video terminal.

SensaDyne Tensiometers are the only commercially available instruments that replicate ASTM test method D3825-90 Standard Test Method "Dynamic Surface Tension by the Fast-Bubble Technique"

Temperature

The surface tension of a liquid generally increases as the temperature decreases, and vice versa. In the SensaDyne, a temperature probe is immersed in the fluid at orifice level to always provide a temperature reading with a resolution of 0.1 degrees C.

Computer Interface and Operation

SensaDyne Tensiometers interface to a personal computer using a plug-in computer interface board. The Software program allows display, storage and collection of data, redisplay of stored files, and graphing of surface tension related data.

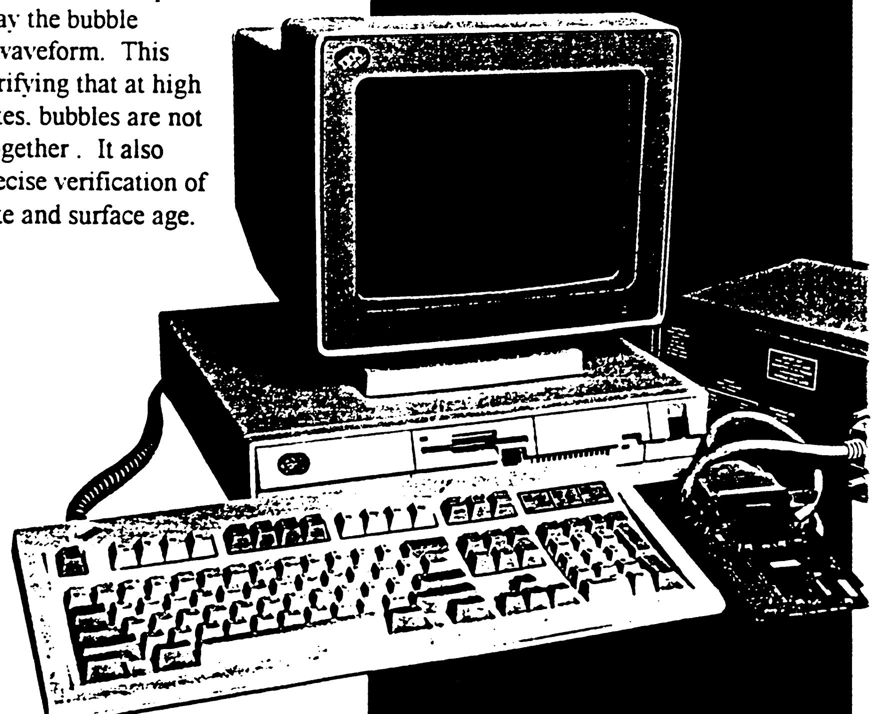
The SensaDyne unit functions as a computerized sensor with the ability to store real-time surface tension values, and provide visual displays of the monitored parameters. Each time a bubble is generated at the orifice, the SensaDyne makes a discrete surface tension measurement. This is output as a moving average surface tension value. If the process changes, the tensiometer readings will track the change. The SensaDyne instrument can be used for simple, quality control measurements or integrated into the most complex closed-loop process control system.

Calibration

The SensaDyne does not require a skilled, experienced technician for operation. Calibration is entirely a function of two known standard fluids and the surface tension values of each. The computer program calculates and stores the required calibration curve. Each step of the calibration procedure is displayed and operator-prompted on the computer terminal in a step-by-step sequence.

Surface Age Determination Software Program

UNKELSCOPE ® SOFTWARE PACKAGE
Unkelscope software is used to emulate an oscilloscope and display the bubble pressure waveform. This allows verifying that at high bubble rates, bubbles are not linking together . It also allows precise verification of bubble rate and surface age.



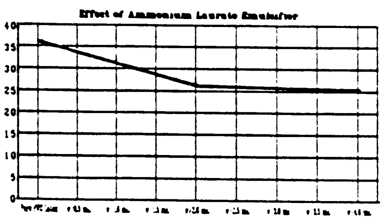
APPLICATIONS

PROCESS CONTROL

On-line measurement and process analysis and control, using surface tension can achieve increased product uniformity and decrease waste, and over-all product cost.

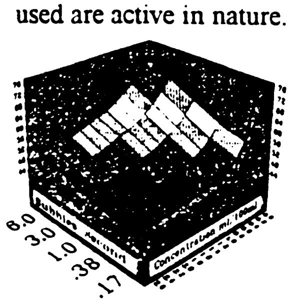
CRITICAL MICELLE CONCENTRATIONS

CMC's can be quickly determined by plotting Surfactant concentration versus surface tension.



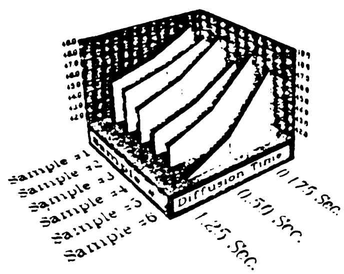
DETERGENTS

Detergent formulations require surface tension studies to understand and optimize performance, since many surfactants commonly used are active in nature.



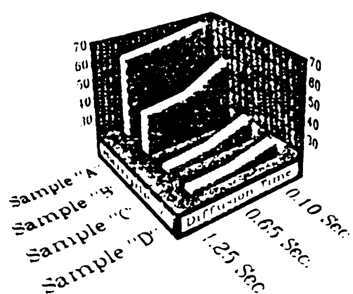
INKS & FOUNTAIN SOLUTIONS

Formulations can be compared and press performance more accurately predicted at higher speeds. Many coating products contain active surfactants that directly influence quality during the application process.



AEROSOLS & COSMETICS

Comparison of spray formulations that are aerosol applied are subject to time-limited surfactant diffusion rates.



SURFACTANT DIFFUSION RATE STUDIES

The SensaDyne instrument's analog outputs include the differential pressure transducer signal. When used with the Unkelscope® program, this allows precise measurement of surface age; of the time available for surfactant molecules to migrate from the surrounding fluid to the air/liquid interface.

WAXERS, STRIPPERS & DEGREASERS

Formulations and the effects of different surfactant additives can be compared.

ACTIVE SURFACTANTS

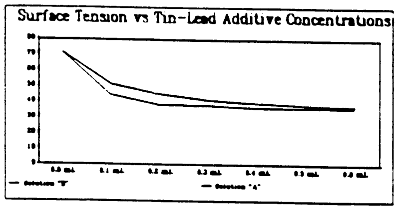
Problems can be defined and mitigated by testing formulations and obtaining a three dimensional characteristics plot.

SEMICONDUCTOR PLATING BATHS

Concentration and usage of additives can accurately be determined by measuring surface tension.

DETERMINING THE CONCENTRATION OF ADDITIVES

The concentration of additives can be determined, as illustrated by this example. Concentrations can be mixed and measured and reference curves generated .



FLUID CONTAMINATION DETECTION

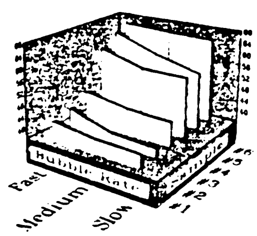
Detection of unacceptable contamination in fluids is a critical application for the SensaDyne Tensiometer.

PHARMACEUTICALS

Surface tension measurements can be utilized in pharmaceutical applications in diverse areas such as pharmaceutics absorption rates, additive (solid) dissolution rates, the influence of salts on the dynamic surface tension of colloids, and critical micelle concentration studies. Surface tension measurements can determine the quality of additives prior to their use, as well as being used as a quality check.

COATINGS , PAINTS & VARNISHES

Many coating products contain active surfactants that directly influence quality during the application process.



SensaDyne Users U.S.A.

(Partial Listing)
3M Company
ARCO Oil & Gas Co.
Air Products & Chemicals Inc.
Allied-Signal Inc.
Aluminum Co. of America
American Cynamid Co.
Amkor Electronics. Inc.
Analog Devices Semiconductor
Anchor/Lithkemko
Appleton Papers
Aristech Chemical Corp.
Avery International
BASF Corporation
Betz PaperChem
Boehringer Ingelheim Ltd.
Boise Cascade Paper Group
Bristol-Meyers Squibb Co.
Burns & Roe Pacific Co.
CPS Chemical Process & Supply
Celanese Fibers Operations
Chicago Magnet Wire Corp.
Clorox Company
Colgate-Palmolive Company
Combustion Engineering, Inc.
Conoco, Inc.
Danbury Printing & Litho
Desoto, Inc.
Delco Electronics Corp.
Dexter Corporation
DiversyWyandotte Corp.
Domino Amjet, Inc.
Dow Chemical U.S.A.
Dow Corning Corporation
Dubois Chemical
E.I. Dupont de Nemours & Co.
Eastman Kodak Company
Ecolab Inc.
Ecotec
Exxon Chemical Company
Faber-Castell Corporation
Flint Ink Corporation
Fujitsu Microelectronics, Inc.
G.E. Chemicals, Inc.
Garden State Paper Co.
General Electric
George A. Goulston Co.
Glidden Company
Helene Curtis
Henkel
Hewlett Packard
International Blending Corp.
Itausa Export North America
James River Corporation
Johnson-Matthey
KTI Chemicals
Kimberly-Clark
Kiwi Brands, Inc.
Kraft General Foods
L&F Products (Minwax)
M-I Drilling Fluids Co.
Manville Sales Corp.
Mead Imaging
Miller Brewing Company
Mississippi Chemical
Monsanto Company
Morton Thiokol Int'l., Inc.
Motorola, Inc.
Nashua Corporation
Naval Air Propulsion Center
Olin Corporation
Olin Hunt
Owens-Corning Fiberglas Corp.
Pitney Bowes
Polaroid Corporation
Printing Developments, Inc.
Proctor & Gamble
Reichhold Chemicals, Inc.
Reynolds Metals Company
Rhone-Poulenc A.G. Co.
Rochester Film Company
Rockwell International
Rohm & Haas Company
Rycoline Products, Inc.
S.C. Johnson Wax
Sandoz Pharmaceuticals
Sauder Woodworking Co.
Shell Development Company
Sherwin-Williams Company
Smith Kline & French Labs
Standard Oil Co.
Stepan Comapny
Sun Chemical
Technic Inc.
Texaco Inc.
Texas Instruments
Upjohn Company
U.S. Department of Energy
U.S. Department of Agriculture
Union Camp Corporation
Union Carbide Corporation
University o f Arizona
University Of Illinois
University of Missouri
University of Oklahoma
University of Washington

International Users

(Partial Listing)
3M Company - Belgium
Abitibi-Price, Inc. - Canada
Agfa-Gevaert N.V. - Belgium
Akzo Fibers bv. - The Netherlands
Alberta Research Council - Canada
Ankor/Anam Pilipinas Inc. - Philippines
Baglini Inchiostri S.P.A. - Italy
Bayer AG - Germany
Casco Nobel Inks Ltd. - Denmark
Colgate Palmolive Inc. - Belgium
DaiNippon Inks - Japan
Dawson College - Canada
Diversey Wyandotte, Inc. - Canada
Dow Chemical Inc. - Canada
Dow Corning Co., Ltd. - Japan
Druckerel-Service GmbH - Germany
Electro-Nite International N.V. - Belgium
Exxon Chemical Ltd. - United Kingdom
F.T. Wimble & Co. Ltd. - Australia
Government of the Republic of Korea
H.S. Manufacturing Co., Inc. - Korea
Horsell Graphic Ind. Ltd. - United Kingdom
IBM Canada Ltd. - Canada
ICI Fibers - United Kingdom
Industries Resistol S.A. - Mexico
Inst. Columbiano del Petroleo - Columbia
Itaucom - Brasil
L'Oreal - France
Lester Graphics & Systems Ltd. - Canada
Liri Industriale SRL - Italy
Mitsubishi Heavy Industries - Japan
Motorola Electronics - Taiwan
Nissin Chemical Industry Co. - Japan
Philips Semiconductors - Thailand
PolyChrome Ltd. - United Kingdom
Potash Corp. of Saskatchewan - Canada
Rhone-Poulenc - France
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Syncrude Canada Ltd. - Canada
Toyo Ink Manufacturing - Japan
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Unilever Nederland - The Netherlands
Union Carbide S.A. - Switzerland
University de Bologna - Italy
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Thermo Instrument Systems
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Hong Kong, Indonesia, Malaysia, Philippines, Singapore, Taiwan, R.O.C., Thailand (Semiconductor Applications) -
Technic Electroplating & Eng. Pty., Ltd.
TEL: 284-0900 / 284-0984

Malaysia-
Meridien-Point SDN. BHD.
TEL: (603) 495-8262

Hong Kong / China-
Guyline Technologies Ltd.
TEL: (852) 2856 0606

PC9000 *High Performance Surface Tensiometer*

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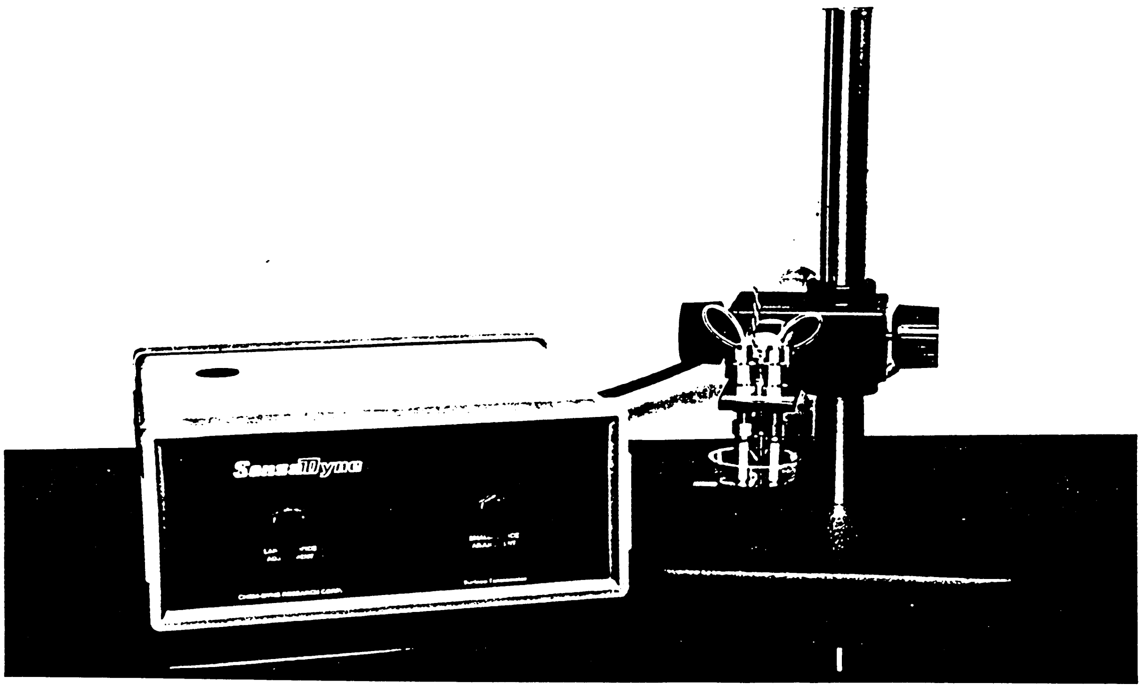


PC9000 FEATURES:

* Adjustable Bubble Rate:
  Max: ***40+ Bubbles/Second***
  Min: ***1 Bubble Every 30+ Second***
* Operates with External Regulated Dry Air, Nitrogen, or Inert Process Gas Supply.
* Very Simple Operation.
* Simple Menu-Driven Calibration for Surface Tension and Temperature.
* Independent Large and Small Orifice Flow Controllers.
* Heavy-Duty Probe Assembly Stand with 7.5" (19 cm.) Vertical and 9" (22.8 cm.) Horizontal Adjustment.
* Precise Active Surfactant Diffusion Rate (Surface Age) Determination.
* Comprehensive, Optional Process Control Package.
* Optional Stainless Steel Fittings, Components, and Teflon® Tubing.
* Hardware and Software Peak-Detection Options: Accuracy within ***+/- 0.05 Dynes/Cm.***

APPLICATIONS:

* **Laboratory Uses:**
  - Research & Development.
  - Quality Control.
  - Surfactant Research.
  - Formulation Optimization.
  - Contamination Testing.
  - Active Surfactant Diffusion Rate (Surface Age) Studies.
  - Measuring Viscous Fluids.
  - Fast CMC Determination.
  - 3D Characterization of Active Surfactants/Formulations.
* Continuous and Intermittent Testing Capabilities.
* Continuous Flow-Through and Process Control Configurations.

ALL SENSADYNE MODELS:

* Measure Both Dynamic and Static (Equilibrium) Surface Tension.
* Allow Accurate, Continuous Real-Time Measurements.
* Interface with PS/2 and Standard IBM or Compatible Computers.
* Provide Computerized Data Collection & Graphing.

PC9000 ADVANTAGES:

* Most Accurate, Advanced Surface Tension Instrument on the International Market.
* No Expensive and Fragile Platinum Rings or Plates, Lenard Frames, or Syringes.
* No Ring Deformation.
* No Special Training Required.
* Simple Set-Up and Operation.
* Uses the Modified Maximum Bubble Pressure Method for Simplicity, Precise Accuracy, and Repeatability.
* Independent of Probe Depth.
* Unaffected by Foaming or Surface Contamination.
* Capable Of Measuring Very Viscous Fluids, and Fluids with High Solids Content.
* Two (2) Variable, Constant Differential Flow Controllers Provide Accurate, Consistent Bubble Rates, with Maximum Adjustment Flexibility.
* Unkelscope® Jr. Software Included for Diffusion Rate (Surface Age) Determination.

DYNAMIC SURFACE PROPERTY MEASUREMENT OF AQUEOUS SURFACTANT SOLUTIONS

BY

SAEED M. HOSSEINI, Ph.D.

PRESENTED AT

NORTHEAST REGIONAL MEETING XXI
AMERICAN CHEMICAL SOCIETY
UNIVERSITY OF MASSACHUSETTS, AMHERST
JUNE 23-26, 1991

ABSTRACT

Many surface related properties such as detergency, foaming and wetting are believed to either maximize or minimize at CMC. However, these foundations are traditionally based on the CMC determined at equilibrium state by static methods. We will show that dynamic property measurement can reveal the most effective concentration of surfactant which is not necessarily related to the equilibrium CMC value. These properties consist of surface and interfacial tensions, surface viscosity, wetting and foam stability. Time factor inclusion in dynamic property measurements generates a non-equilibrium state which is indeed the practical state for surfactant consumption in many industrial applications, including spray cleaning, oil recovery agricultural sprays, emulsion polymerizations etc. Results correlating dynamic surface tension with end use application will be presented.

Introduction:

Surfactants are known for their performances at low critical micelles concentration (CMC). Many surface related properties are believed to either maximize or minimize around the CMC. These foundations are traditionally based on the CMC determined at equilibrium state by static surface tension (SST) measurements using DuNouy ring or Wilhelmy plate methods. Since surfactants face severe conditions of non-equilibrium state (Dynamic processes) in any industrial application, therefore dynamic surface tension (DST) measured at NON-EQUILIBRIUM state may be preferred over SST EQUILIBRIUM state data.

We have used the Sensadyne 6000 instrument to measure the DST by means of air bubble formation inside liquid solution. This instrument allows you to select the rate of the bubble formation, control it, and regulate it so that the surfactant behavior at the gas/fluid interface can be studied. DST measurement is corrolated to the surfactant migration to the bubble surface which is closely monitored by dynamic environment variation or bubble formation rate variation. DST in contrast to SST is able to determine the optimum concentration at which surfactant effectiveness is at its highest and very essential to its industrial application. Other studies also essential to industry such as; water hardness effect, temperature effect, salt (electrolyte) effect and their correlation with dynamic surface tension are easily adoptable here as well. We will show the effect of two electrolytes; sodium metasilicate and NaOH on DST values of C9-40P surfactant.

Discussions:

Laplace equation $P-P_o = 2\gamma/r + \rho hg$ is used to determine the dynamic surface tension γ by measuring the maximum air pressure P necessary in capillary tube to form a bubble in solution. The effect of liquid density ρ, capillary depth h, gravity g and atmospheric pressure Po on γ are eliminated by placing the second capillary tube in solution. Measuring the pressure difference ΔP between two tubes allows cancellation of all constants ρ, h, g and Po and direct γ measurement.

- Figure 1 shows the plot of DST vs. bubble frequency for 0.01% 2A-1L. Notic the large difference between DST and SST values as well as the wide range o DST distribution (24 dynes/cm) which indicates that the effectiveness of this specific surfactant concentration could easily change depending on the type o the dynamic process present.

- Figure 2 plots the DST and SST vs. POLY-TERGENT ® C9-40P concentrations. This figure shows:
  a. Surface tension is dependent upon dynamic processes.
  b. Large difference between DST and SST for concentrations lower than 0.5%
  c. Static CMC break (equilibrium) shifted to higher concentrations for dynamic measurements (non-equilibrium).
  d. The optimum concentration with the highest effectiveness is expected to be at 0.5% or slightly higher.

- Figures 3-4 show that low surfactant concentrations below the dynamic CMC are dynamic dependent (even at static CMC). However, as soon as dynamic CMC is reached surfactant concentrations become dynamic independent.

- Figure 5 shows the electrolyte effect on surface tension of C9-40P surfactant. DuNouy ring method is used here to measure the static surface tension (SST). Although, the figure shows slight decrease in CMC. However, the SST method fails to recognize any significant change caused by electrolyte. Next, we will show how precisely the DST method realizes the changes reflected by electrolyte.

- Figures 6-8 show the major electrolyte effect on improving the diffusibility or better migration of surfactant to bubble surface in bulk solution. Better surfactant migration to surface generates more populated surface leading to lower surface tension which is exactly what DST observed while SST failed. Electrolytes are expected to affect the surfactant property such as diffusibility. Our dynamic surface tension studies (Figure 6-8) show that the same effect which are distinct CMC lowering and surface tension lowering for concentrations below CMC.

- Figures 6-8 show that 0.3% electrolyte lowered both CMC value and surface tension of concentrations lower than CMC.

- Table 1 lists interesting results for pure water consisting electrolyte. SST measurements show significant electrolyte effect on water while DST method observed no effect at all. This indicates that in bulk solution, electrolytes do not change the diffusibility or migration of water molecules to the bubble surface therefore, DST does not change. In contrast to bulk solution at air/liquid surface, water diffusibility is affected when exposed to aeroso.

- Wetting time measurements shown in Table 2 and Figs. 9-12 appear to be closely related to the dynamic CMC break rather than the static CMC. Wetting time results show that both surfactants are better wetting agents at higher concentrations closer to the dynamic CMC break (0.5%). They become bad wetting agents as concentrations are lowered toward the static CMC break (0.05%).

- Table 3 illustrates the correlation between hard surface cleaning and Dynamic Surface Tension (DST). Three C-Series surfactants with C_{10}, C_{13}, C_{16} hydrophobe chains were examined. As hydrophobicity increased DST values increased, indicating a decrease in surface penetration rate by longer chain surfactants. In another world DST values predict lower cleaning performance for longer hydrophobe surfactant which is in complete agreements with hard surface spray cleaning results shown in Table 3 "The longer the hydrophobe, the higher the DST value therefore, the lower cleaning performance".

- Table 4 shows slight increase in sequestering, but larger increase in DST meausrements for longer hydrophobe surfactants. Sequestering property of C-Series is perhaps due to carboxyl groups in hydrophilic heads and not related to hydrophobicity. However, since the DST changes are in the same sequence as sequestering variations, it indicates that there could exist a possible relation between DST and sequestering property which we do not understand it at this time to draw any conclusions.

- Table 3-4 show less surface activities (higher surface tensions) for C-Series with longer hydrophobe chain tail while theoretical prediction is totally the opposite "The longer the hydrophobe the higher the surface activities". This theory is based on static measurements, normally using DuNouy ring method which examines very aged surfaces that have reached equilibrium state. Figures 13-15 attempt to explain why the traditional theory based on static measurements (equilibrium state) is not always true in contrary the dynamic (non-equilibrium state) results are more logical and scientifically acceptable.

1. Static Equilibrium State: Static methods such as DuNouy ring ignores the time factor while measures surface tensions. Time elimination provides unlimited time (more than 1 minute) for any surfactant with either short or long hydrophobe tail to diffuse and migrate to the air/liquid surface. Therefore, the gravity effect which partially determines the movement or diffusibility of the surfactant becomes meaningless, since both surfactants populate the surface until saturation well before the ring detachment takes place.

   Two surfactants with the same size and type polar heads but different size hydrophobic tails will most likely have the same population number of molecules on the surface. Since their hydrophobe tails are sticking out in the air, of course the one with longer chain tail reflects higher surface activities (lower surface tension) on the ring. These measurements (by ring or Wilhelmy plate) would have been true surface tensions only if equilibrium is reached every time surfactant is used in any practical application. However, in real life it is near impossible to achieve such an equilibrium since anything we do is mechanically or dynamically oriented. For example, in laundry machines cycling creates non-equilibrium state for surfactant or in oil recovery, surfactant faces severe pressures which causes non-equilibrium. Therefore, it is logical and more practical if a dynamic environment is created (non-equilibrium) during the surface tension measurements.

2. Dynamic Non-Equilibrium State: Bubbling air in solution and controlling the bubble formation rate generates a non-equilibrium state dynamically, and provides a certain limited time for surfactants to diffuse and migrate to the bubble surface. At the fast rates between 0.5-3 bubbles/second, surfactants are given a short time period to migrate and those with longer chain tails are heavier and diffuse to the surface much slower than the shorter chain ones. As a result, less number of heavier molecules can reach the bubble surface compared to lighter molecules (short chain tails), therefore higher surface tension would be expected as shown in Tables 3-4.

In contrary if slow bubble formation rate is used to form about 1 bub per minute then the unlimited time (equilibrium) is given to surfactant migrate to the surface and results approaches the static methods. In conclusion one may examine the hydrophobicity effect and measure opposite results depending on the applied method. "Static methods (equilibrium) measure low surface tension for long chains while dynar method (non-equilibrium) reports the opposite".

- In the past decade, dynamic surface tension studies has gained attention ar shown in tables 5-7 a great number of industrial facilities both in states an abroad are now interested in dynamic measurements. We hope to evaluate surface properties of our surfactants dynamically and provide more technica useful data for our customers.

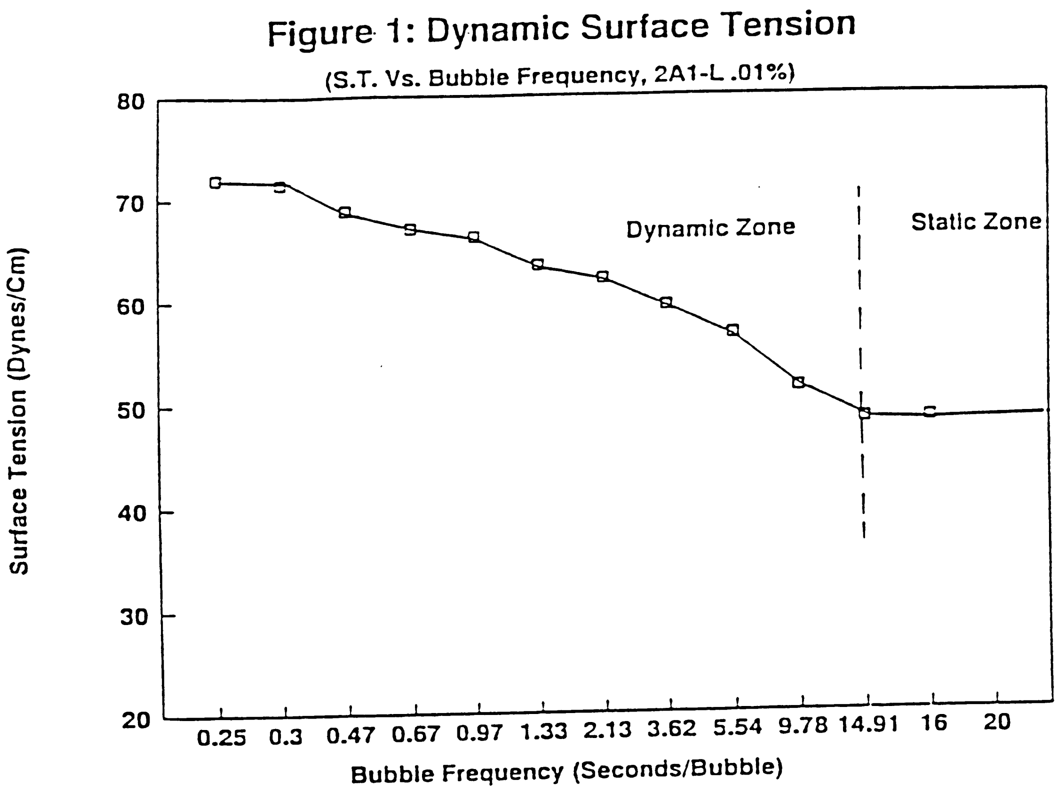


Figure 1

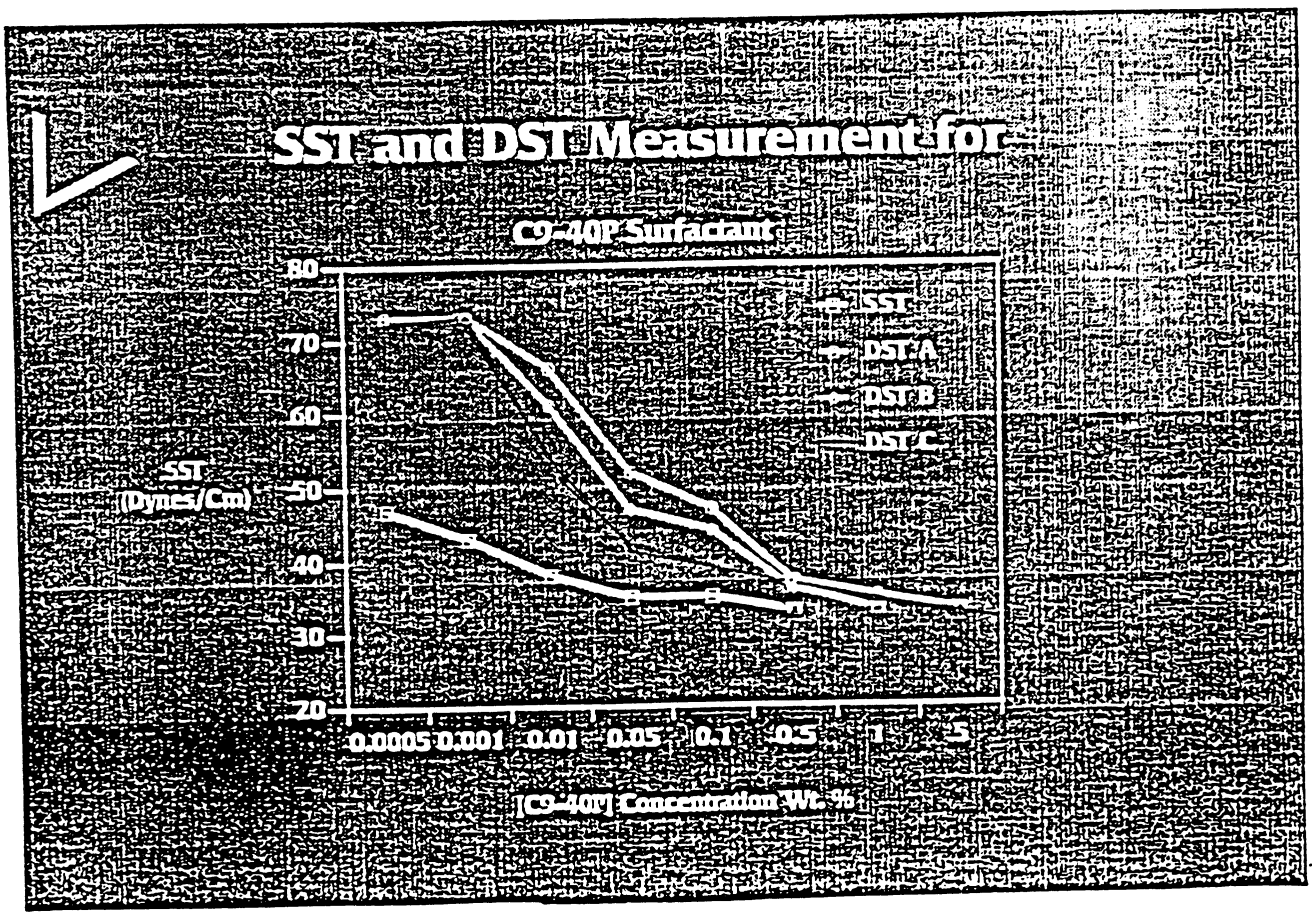


Figure 2

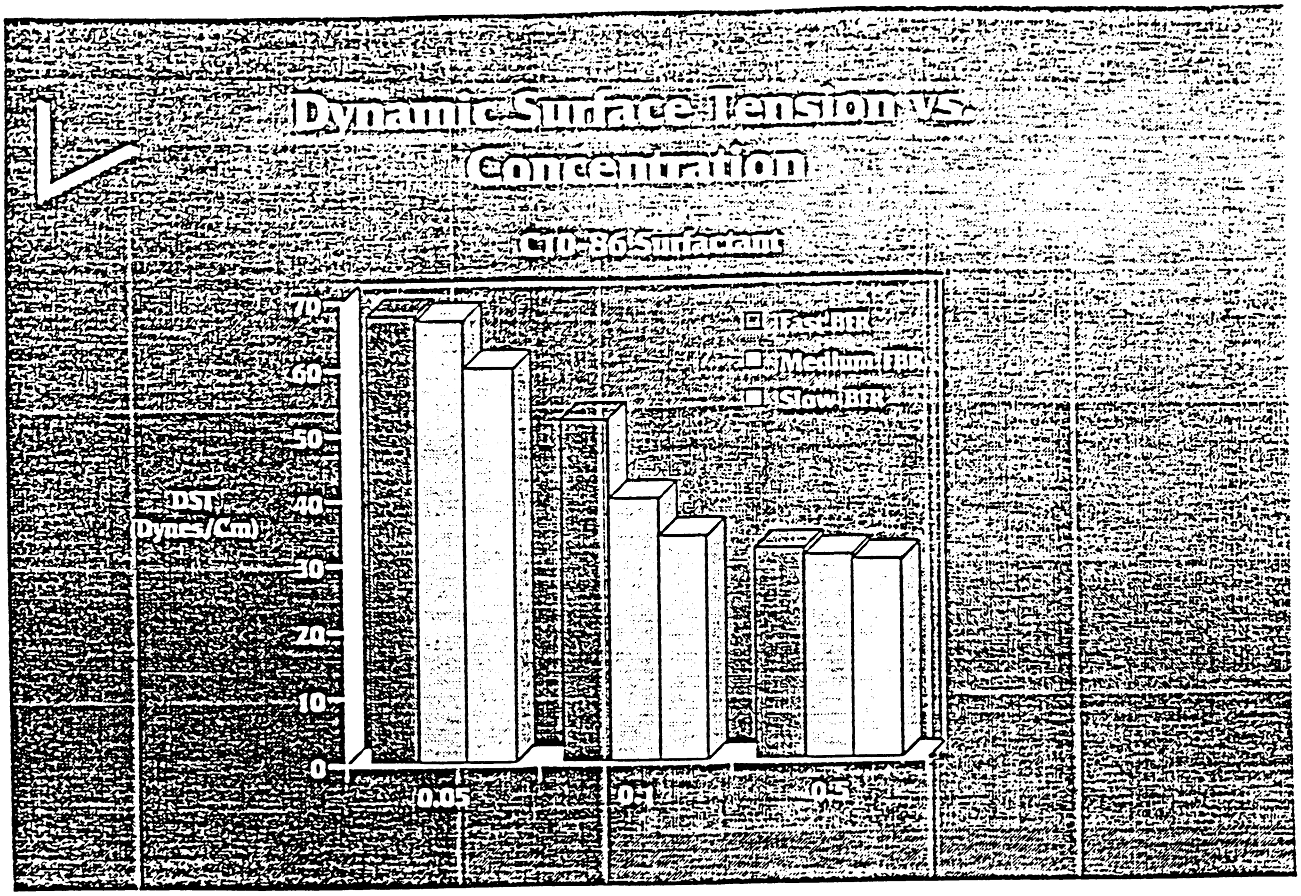


Figure 3

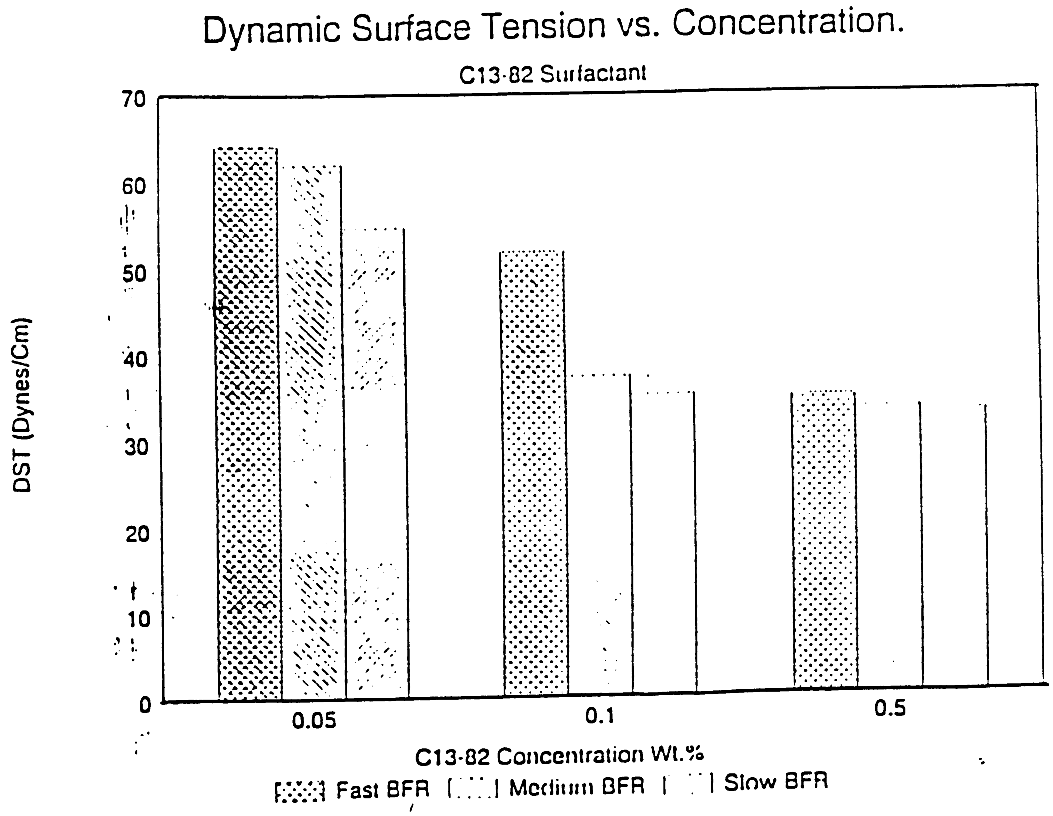


Figure 4

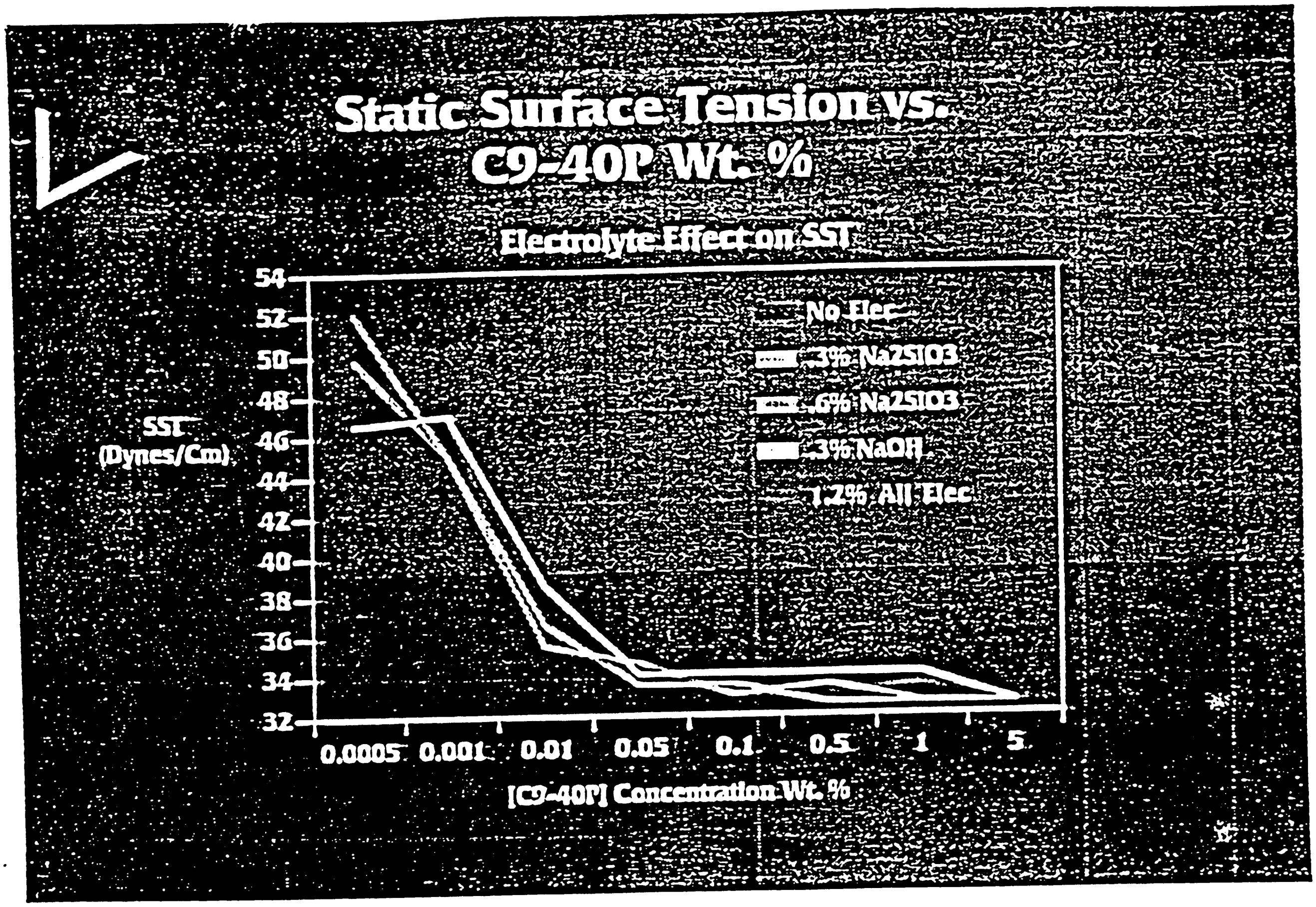


Figure 5

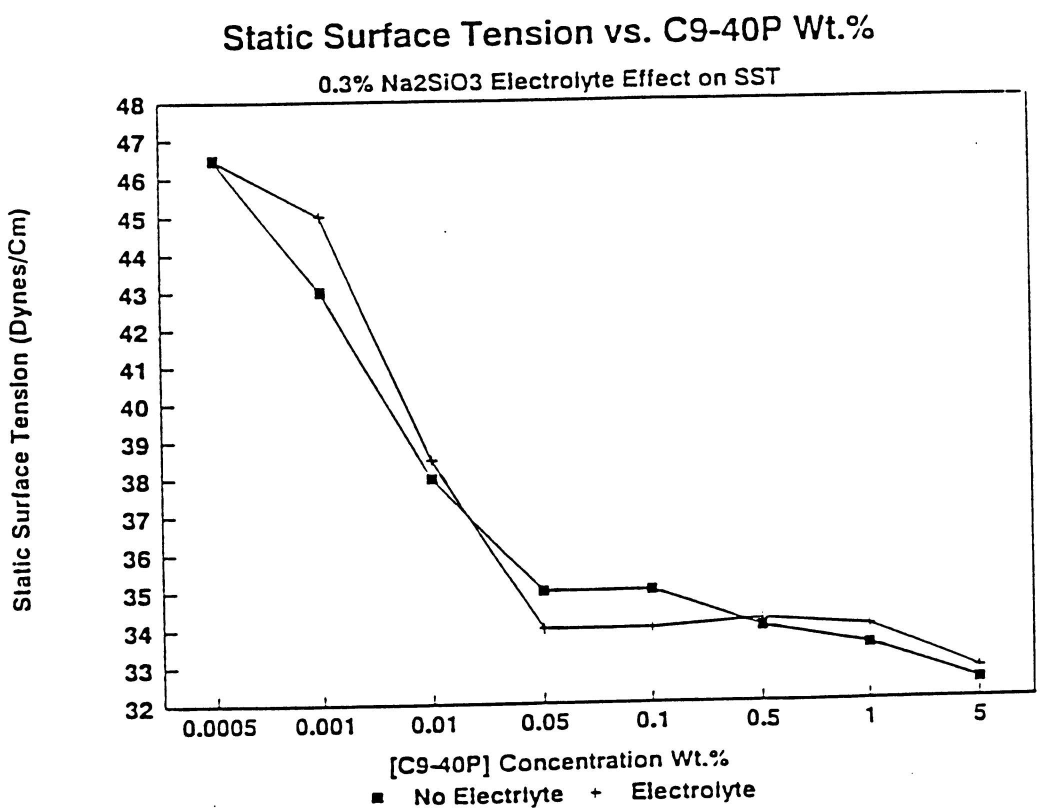


Figure 6

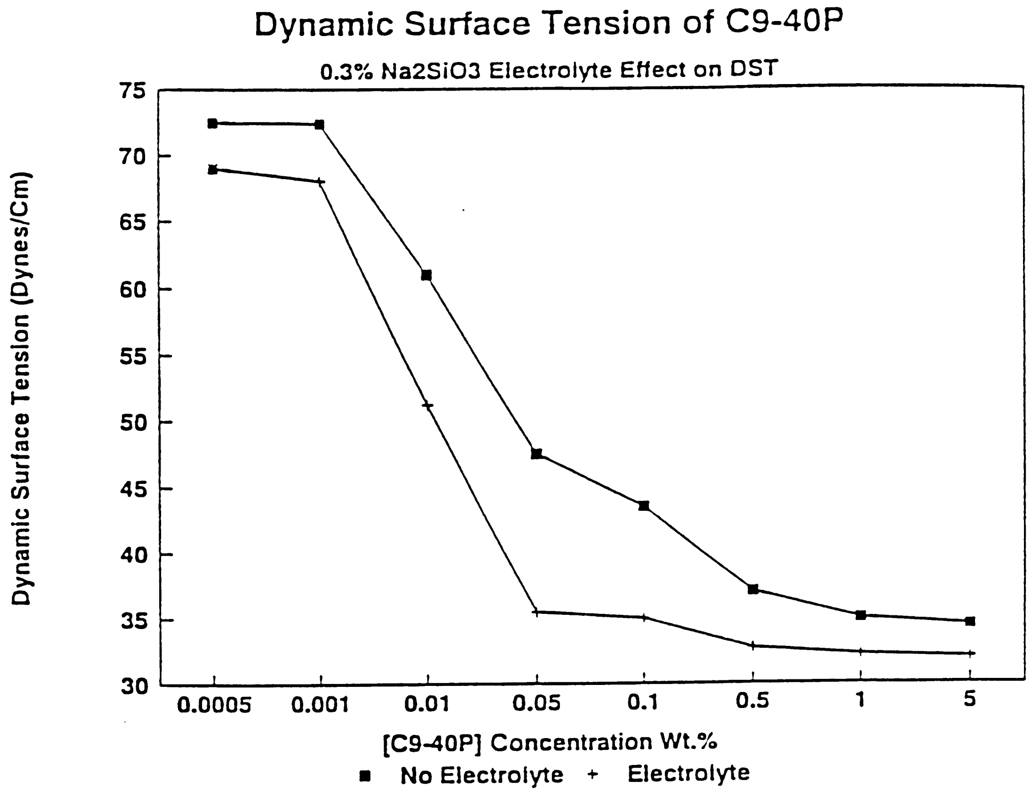


Figure 7

TABLE 1

SST AND DST MEASUREMENTS FOR PURE WATER
AND WATER PLUS ELECTROLYTES

SURFACE TENSION (DYNES/CM)

	STATIC	DYNAMIC
NO ELECT	72	72.9
Na2SiO3 0.6%	52.5	72.7
Na2Si3 0.3%	51	72.5
NaOH 0.3%	53	72.6

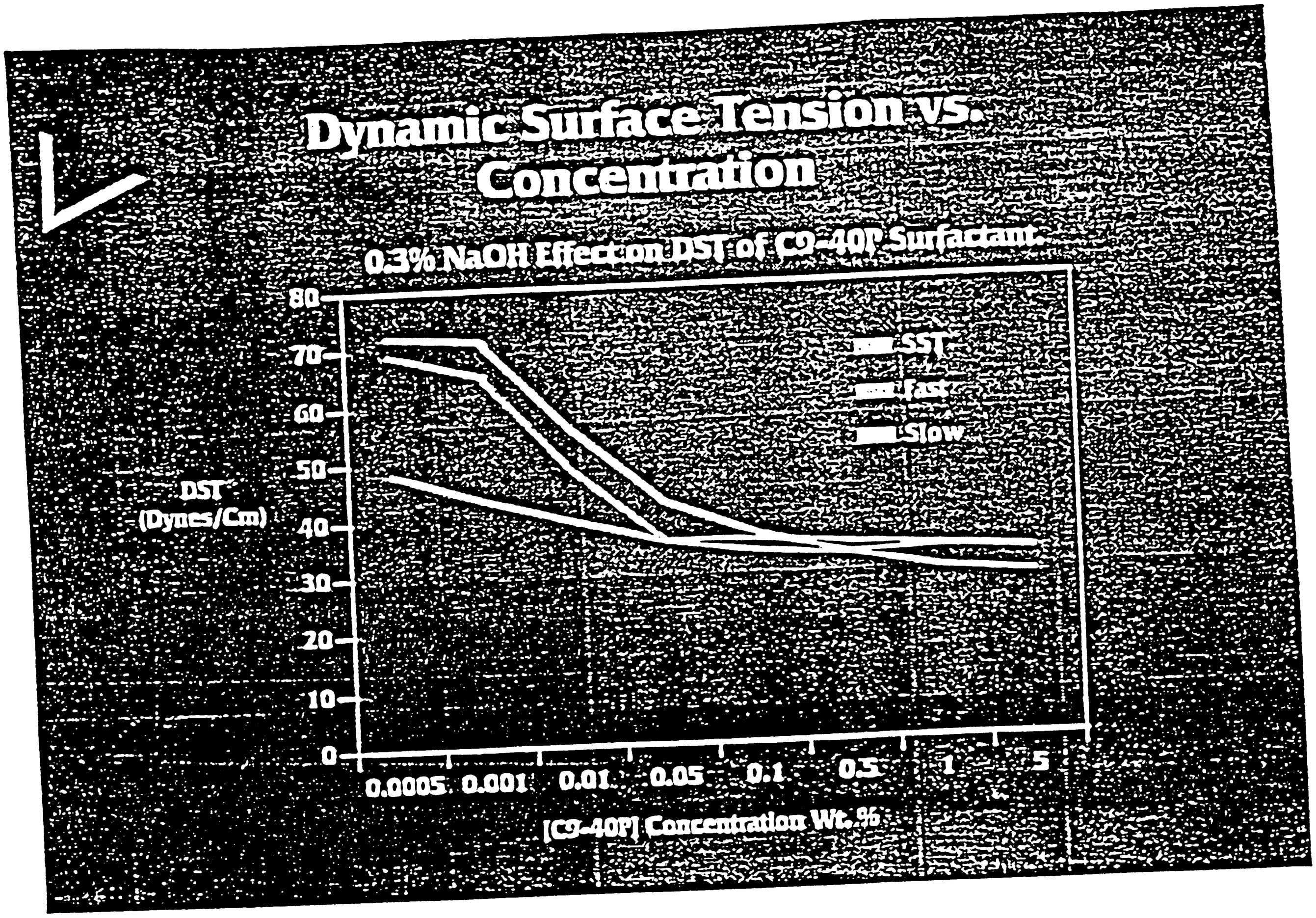


Figure 8

TABLE 2 WETTING TIME MEAUSUREMENTS (SECONDS)

SURFACTANTS WT%	3%	1%	0.5%	0.25%	0.1%	0.05%	0.0 25%
C9-51P	2	4	15	52	363	TL	TL
ALKOXYLATED LINEAR ALCOHOL	0	0	0	4	20	104	667

TL: TOO LONG TO MEASURE

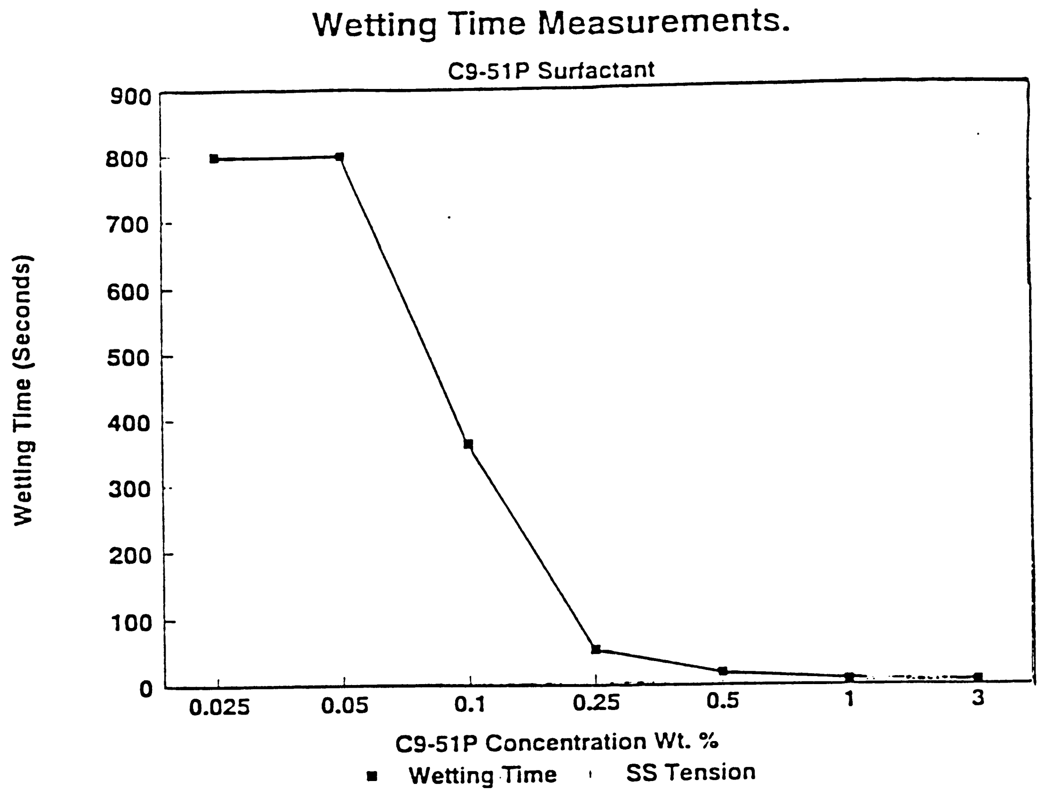


Figure 9

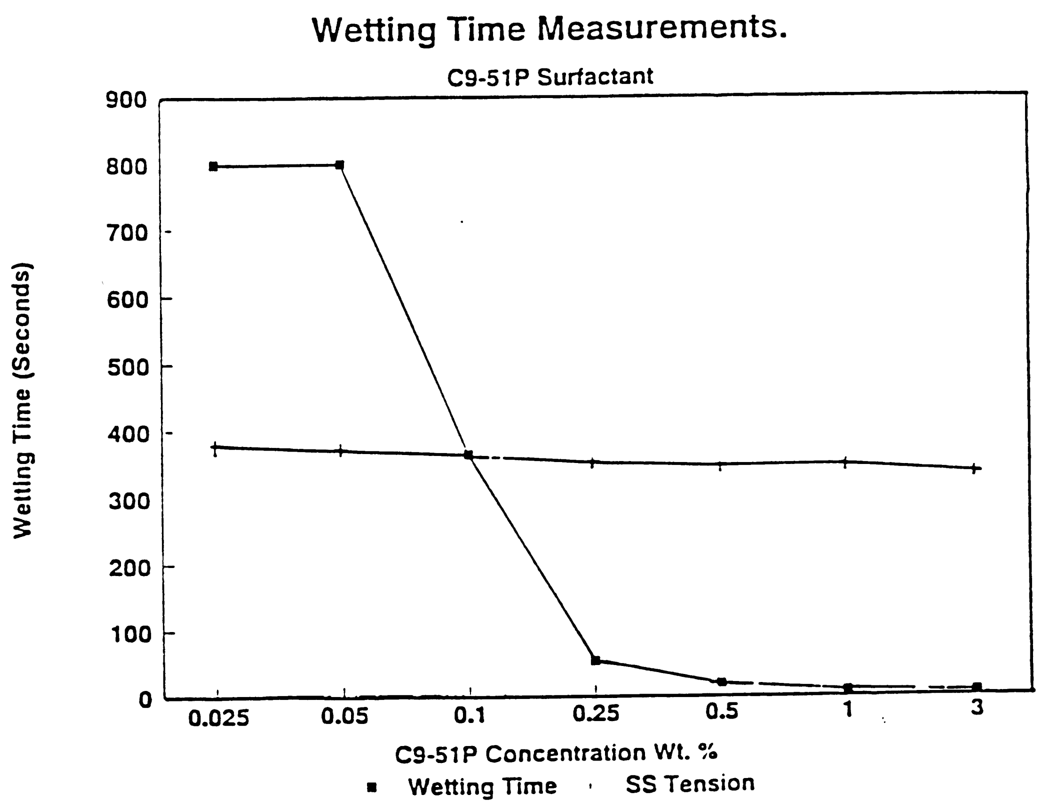


Figure 10

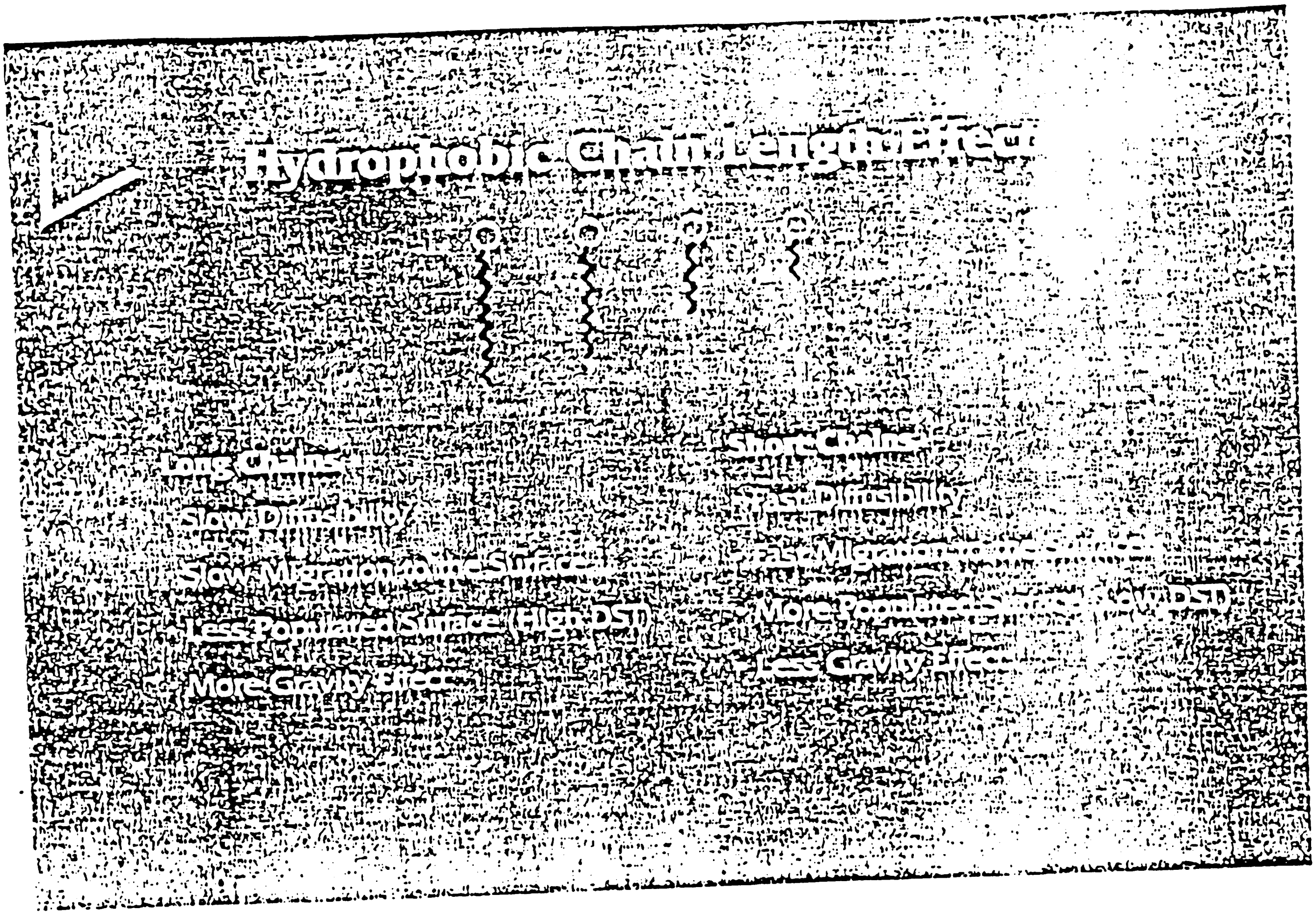


Figure 15

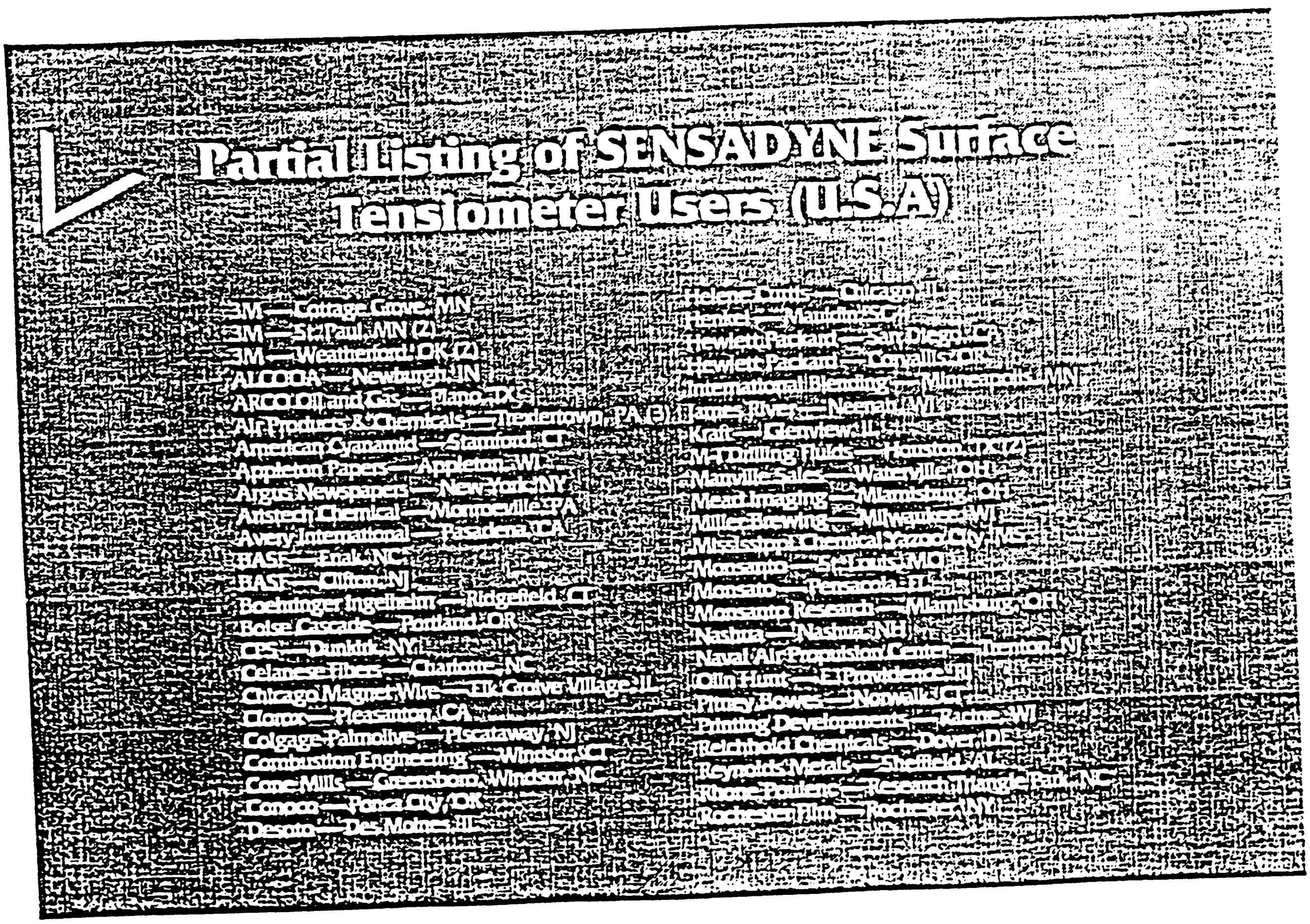


Table 5

TABLE 3

DYNAMIC SURFACE PROPERTY MEASUREMENT OF
AQUEOUS SURFACTANT SOLUTIONS

SURFACTANT 0.1% by wt.	HARD SURFACE		DST (DYNES/CM)
	oily spray 137°F/124°F	particulate soil 137°F/124°F	
C10-86	96/90	88/44	41
C13-88	77/68	31/21	52
C16-82	28/10	25/18	58

TABLE 4

DYNAMIC SURFACE PROPERTY MEASUREMENT OF
AQUEOUS SURFACTANT SOLUTIONS

SEQUESTERING PROPERTY

SURFACTANT 0.1% by wt.	CALCIUM SEQUESTERING (in mg. Ca/g. Surfactant)		DST (DYNES/CM)
	pH11	pH12.5	
C10-86	13	24	41
C13-88	17	26	52
C16-82	19	29	58

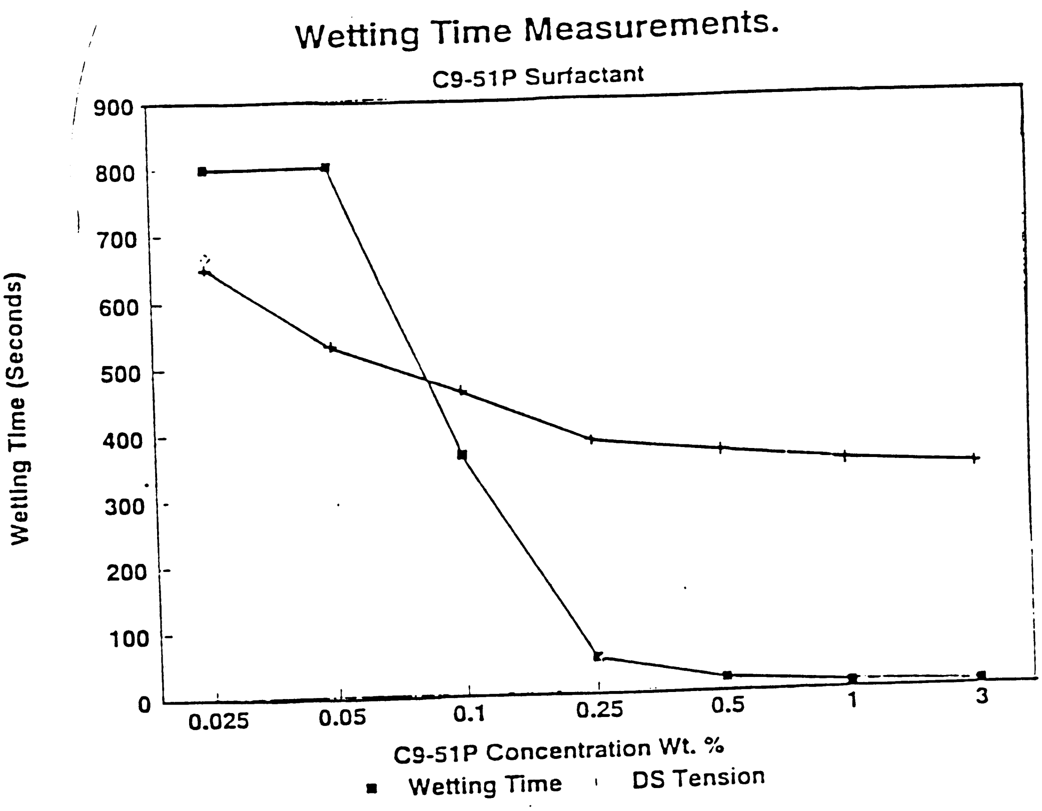


Figure 11

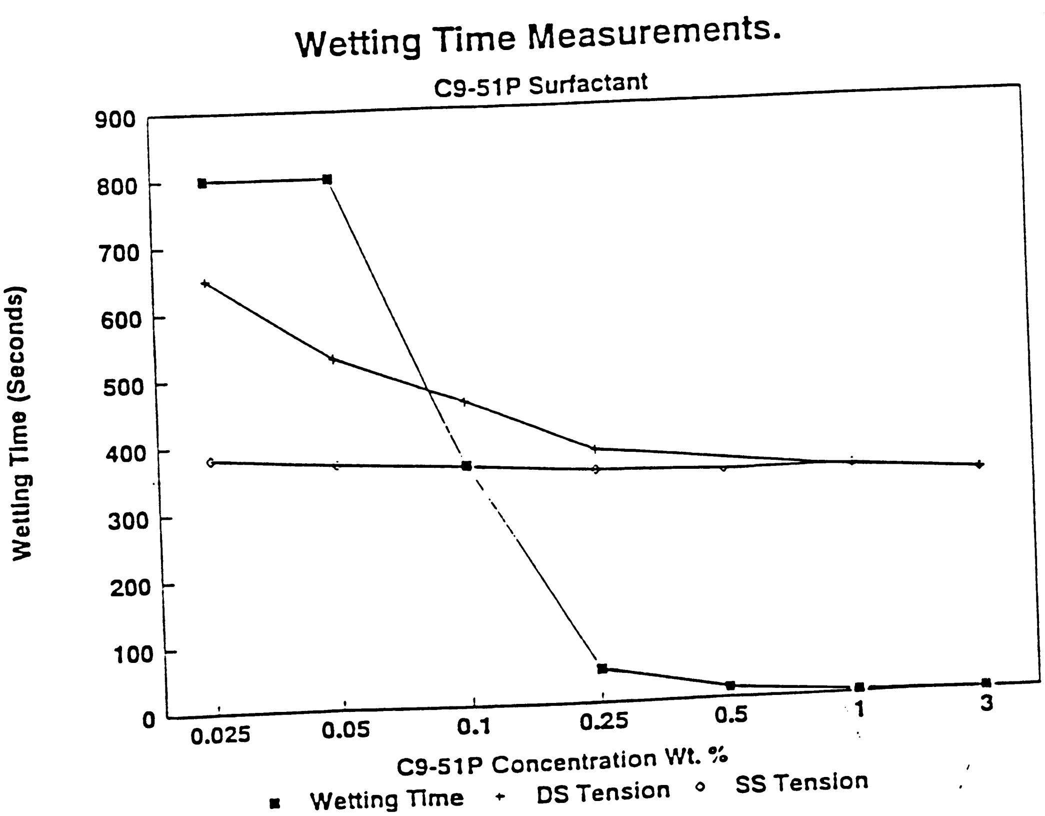


Figure 12

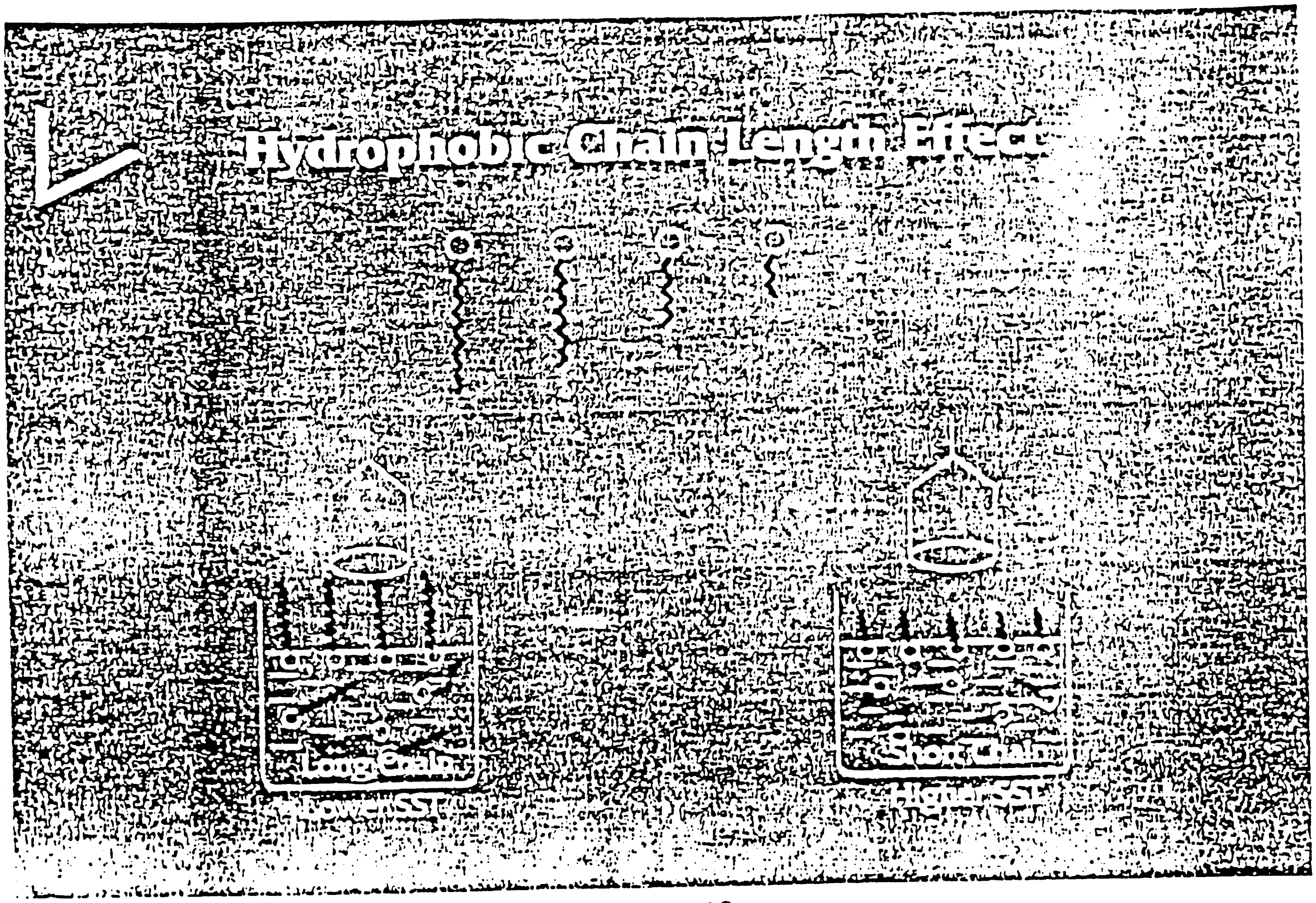
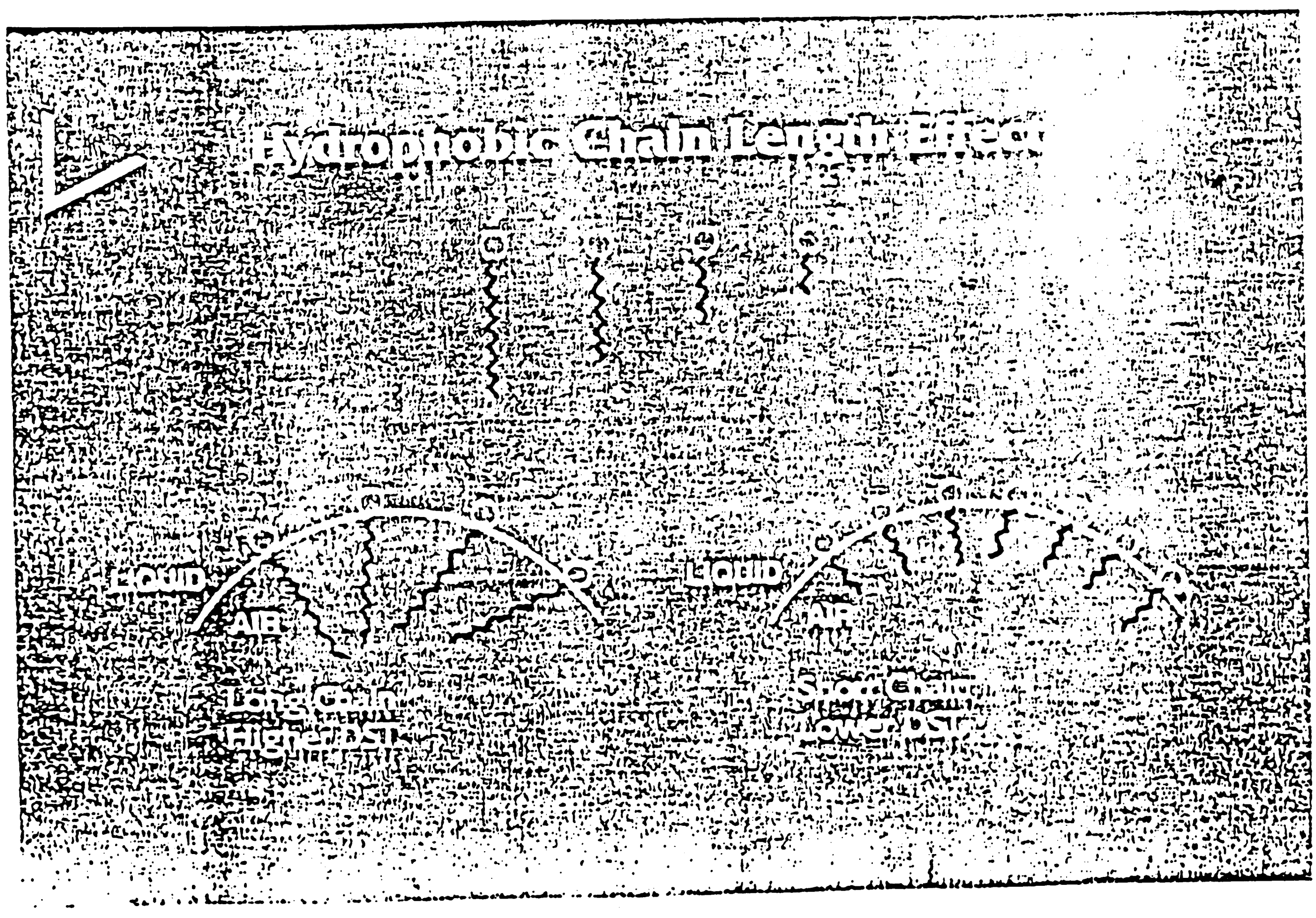
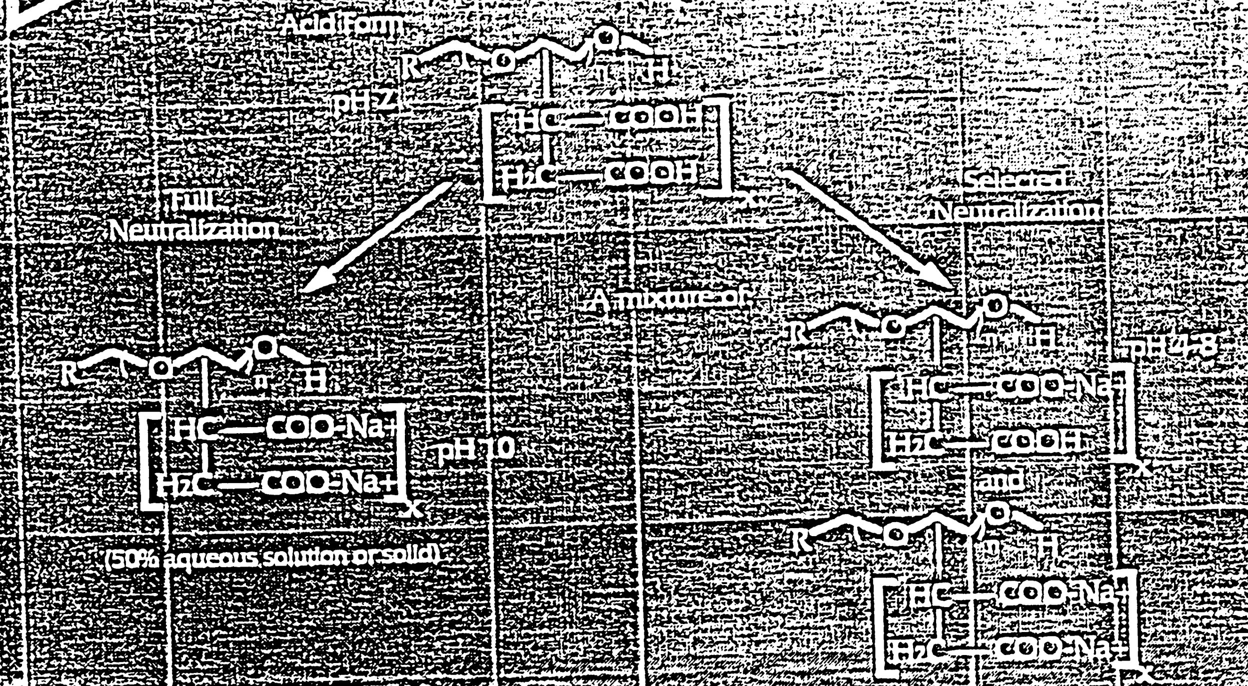

Hydrophobic Chain Length Effect
Long Chain
Lower SST
Short Chain
Higher SST

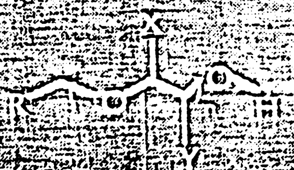
Figure 13


Hydrophobic Chain Length Effect
LIQUID
AIR
Long Chain
Higher DST
LIQUID
AIR
Short Chain
Lower DST

Polycarboxylated Surfactants

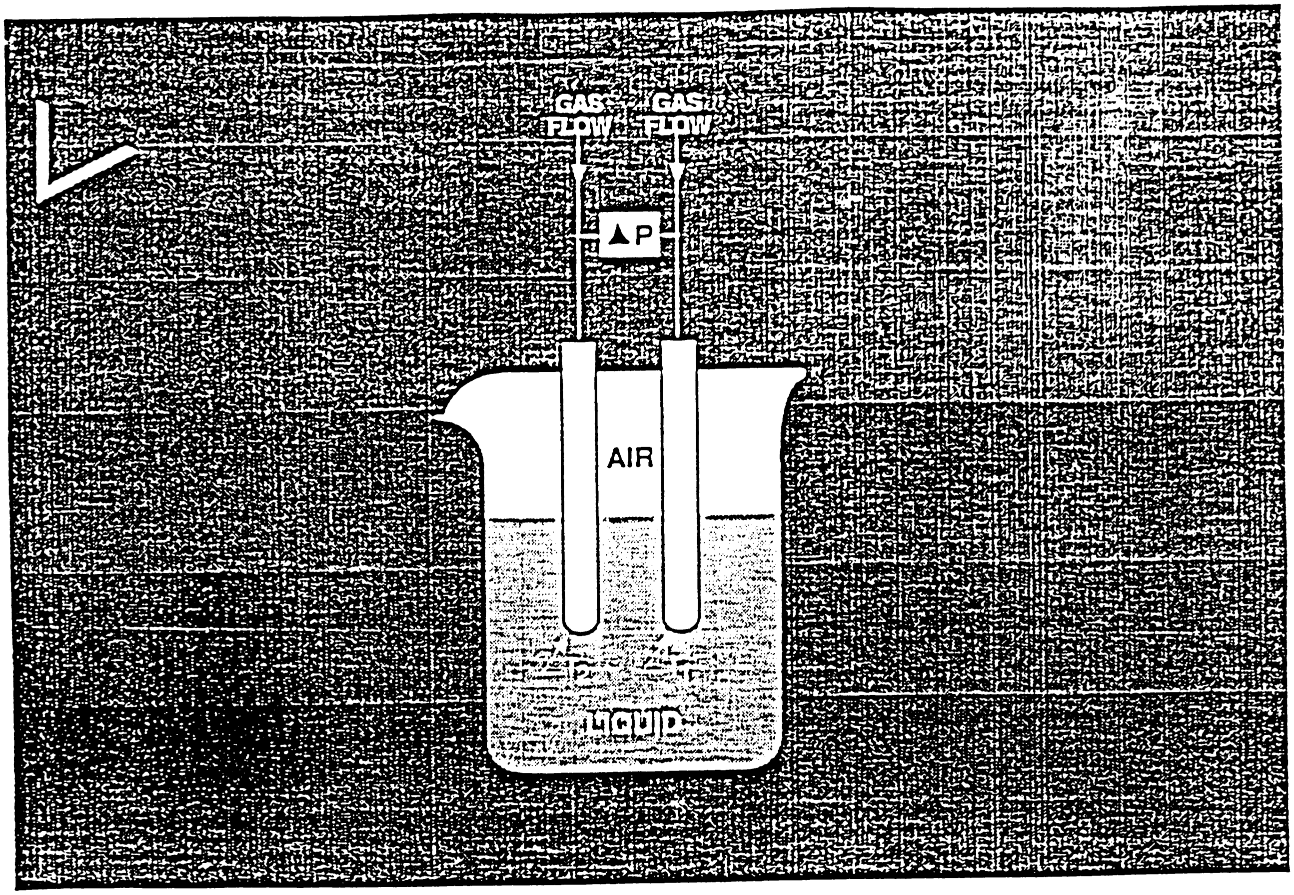


Polycarboxylated Poly-Tergent "C" Series



Polycarboxylated Surfactant	Hydrophobe Length (average C#)	Hydrophile (% by weight)
Poly-Tergent CS-1 (C9-51P)	C9	51%
Poly-Tergent C 9-40P	C9	40%
Poly-Tergent C 9-62P	C9	62%
Poly-Tergent C 9-74P	C9	74%
Poly-Tergent C 10-86	C10	86%
Poly-Tergent C 13-65	C13	65%
Poly-Tergent C 13-82	C13	82%
Poly-Tergent C 13-88	C13	88%
Poly-Tergent C 16-82	C16	82%

Note—"P" denotes that the surfactant contains a degree of PO.



Two Capillaries:

$$\Delta P = P_1 - P_2$$

$$\Delta P = \left(Po + \rho gh + \frac{2\delta}{r_1}\right) - \left(Po + \rho gh + \frac{2\delta}{r_2}\right)$$

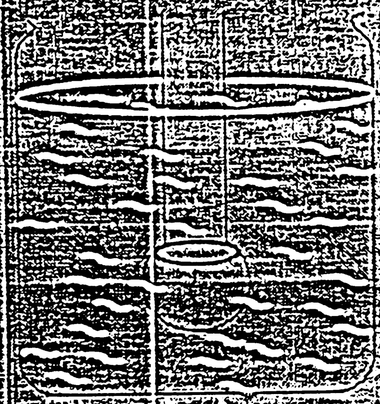
$$\Delta P = \left(\frac{2\delta}{r_1} - \frac{2\delta}{r_2}\right)$$

$$\Delta P = \delta\left(\frac{2}{r_1} - \frac{2}{r_2}\right)$$

$$\boxed{\Delta P = \propto \delta}$$

ΔP = Differential Pressure

Dynamic Surface Tension is the surface tension of a ***freshly*** created surface measured at a given time and represents a ***non-equilibrium*** state.



One Capillary:

$$P - Po = \frac{2\delta}{r} + \rho g h$$

P = Capillary Pressure (bubble pressure)

Po = Atmospheric Pressure

δ = Surface Tension

r = Capillary Radius

ρ = Liquid Density

g = Gravity

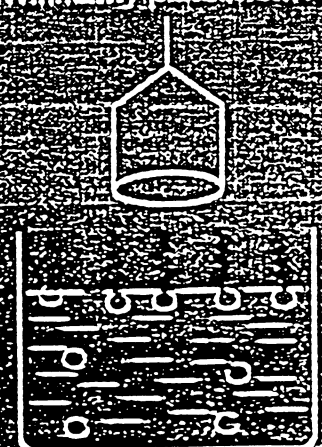
h = Height of Capillary Tip from Solution Surface

Dynamic Surface Property Measurement of Aqueous Surfactant Solutions

- Comparison between Dynamic Surface Tension (DST) and Static Surface Tension (SST)
- Which results are more applicable to industry?
- What is the advantage of DST to SST method?

Dynamic Surface Property Measurement of Aqueous Surfactant Solutions

Static Surface Tension corresponds to a state where an equilibrium has been established between surface layer and bulk solution (aged surface) e.g. DuNouy ring, Capillary height and Wihhelmy plate methods.



Partial Listing of SENSADYNE Surface Tensiometer Users (U.S.A)

Deleet Merchandising — Newark, NJ
Diversey Wyandotte — Wyandotte, MI
Domino Amjet — Appleton, WI
Dorsey Laboratories — Lincoln, NE
Dow Chemical U.S.A. — Midland, MI
Dow Consumer Products — Greenville, SC
Dow Corning — Midland, MI
DuBois Chemical — Sharonville, OH
E.I. Dupont — Towanda, PA
E.I. Dupont — Louisville, KY
E.I. DuPont — Kinston, NC
E.I. DuPont — Deepwater, NJ
E.I. Dupont — Brevard, NC
Eastman Kodak — Rochester, NY (2)
Ecolab — St. Paul, MN
Ecotec — Cincinnati, OH
Exxon — Amandale, NJ
Faber-Castell — Lewisburg, TN
Flint Ink — Ann Arbor, MI
Fujitsu Microelectronics — San Diego, CA
G.E. Chemicals — Washington, WV
Garden State Paper — Garfield, NJ
General Electric Plastics — Selkirk, NJ
George A. Grouiston — Monroe, NC
Rohm & Haas — Spring House, PA
Rohm & Haas Delaware Valley — Bristol, PA
Rycoline Products — Chicago, IL
S.C. Johnson & Sons — Racine, WI
Sandoz Crop Protection — Des Plaines, IL
Sauder Wood Working — Archbold, OH
Shell Development — Houston, TX (2)
Smith & Nephew Medical — Massillon, OH
Stepan — Northfield, IL
Sun Chemical — Carlstadt, NJ (3)
Sun Chemical — Cincinnati, OH
Technic — Cranston, RI
Tennessee Eastman — Kingsport, TN
Texas Instruments — Sherman, TX
Glidden — Strongville, OH
Standard Oil — Cleveland, OH
Upjohn — Kalamazoo, MI
U.S. Department of Energy — Pittsburgh, PA
Union Carbide — Tarrytown, NY
Union Carbide — S. Charleston, WV
University of Illinois-Chicago — Chicago, IL
University of Missouri-Rolla — Rolla, MO
Videojet Systems — Elk Grove Village, IL
Weyerhauser — Kent, WA

Table 6

Partial Listing of SENSADYNE Surface Tensiometer Users (International)

Abitibi-Price — Canada
Agfa-Gevaert — Belgium
Alberta Research Council — Canada
Baglini Inchiostri — Italy
Colgate Palmolive R&D — Belgium
Diversey Wyandotte — Canada
Dow Chemical — Canada (2)
Dow Corning — United Kingdom
Druckerei Service GMBH — West Germany
Electro-Nite International — Belgium
Energy, Mines & Resources — Canada
Energy Research Foundation — The Netherlands
Enka Research — The Netherlands
F.T. Wimble & Co. — Australia
Huels AG — West Germany
ICI Fibers — United Kingdom
Industrias Resistol — Mexico
L'Oreal — France
Lester Graphics & Systems — Canada
Postash Corp. of Saskatchewan — Canada
Sandoz AG — Switzerland
Shinhan Scientific — Korea
Syncrude Research — Canada (3)
Xerox Research Centre — Canada

Table 7

Conclusions

- Surface Tension and CMC are Dynamic Dependent
- Concentrations below the CMC (determined by DST) are more dynamic dependent than those above the CMC.
- Bubble-formation rate variation can determine the dynamic dependency.
- DST can rapidly determine the CMC of the surfactant which is free of aerosol contamination
- DST can be used as alternative to Du Nuoy ring or Wilhelmy plate.
- The most effective concentration of a surfactant lies around the CMC best determined by DST.
- DST measurements for cleaning application.

THREE-DIMENSIONAL CHARACTERIZATION OF ACTIVE SURFACTANTS

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The Fine Particle Society

July 15, 1992 Las Vegas, Nevada

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ABSTRACT

Active surfactants are known to have dynamic characteristics when surface tension is determined as a function of interface development time. Higher surface tensions result as interface development times are reduced. This allows the characterization of a fluid in two dimensions, surface tension versus interface development time, which includes both the static (or equilibrium) and dynamic zones. When a fluid's surface tension is further measured as a function of surfactant concentration, then the action of the surfactant can be characterized in three dimensions: concentration, surface tension, and interface development time.

The method presented can be applied readily to active surfactants added to coatings, aqueous solutions, fountain solutions/ink emulsions, and other chemicals or formulations for which surface tension can be measured using the modified maximum bubble pressure method. In the example presented, the SensaDyne Tensiometer was used with several auxiliary software programs, one for accurate determination of interface development times, and a second program for three-dimensional graphing of the data.

INTRODUCTION

The SensaDyne Tensiometer uses a patented technology that is a refinement of the maximum bubble pressure method. This method was first suggested by Simon in 1851 and later developed by Jaeger in 1917. The first viable commercial instrument was introduced in 1982, and a subsequent design interfaced to the personal computer several years later, allowing us now to use software tools that make three dimensional studies relatively straight forward.

This modified maximum bubble pressure method is illustrated in Figure 1, showing a descriptive diagram of two capillaries of different radii immersed beneath a fluid surface. Process gas, bubbled through these tubes produces a differential pressure signal, the value of which is used to calculate fluid surface tension. The resulting differential pressure equation includes effects of fluid head (h), density of the liquid (ρ), and gravitational constant (g). These are effectively cancelled if the orifices are oriented to allow the bubbles to release at the same height. This normal probe arrangement can be modified to use inverted probes to mitigate problems of bubble distortion that can result in viscous coatings or fluids with a high solids content. These inverted probes allow unobstructed upward release of the bubbles in the fluid.

The rate of gas flow to the orifices is a user-controlled feature of the SensaDyne Tensiometer, allowing the bubble rate to be varied, and consequently the interface development time. The amount of time it takes the bubble to form and release from the orifice is also the amount of time available for the surfactant to migrate to the interface where it can lower the surface tension.

By measuring surface tension at different bubble rates in a fluid or coating that has an active surfactant, a dynamic surface tension graph can be plotted similar to the one shown in Figure 2. In this example, the dynamic curves of two different fluids are plotted. The curve results when the values obtained at different bubble rates are connected. The transition from the dynamic to the static zone occurs where the curves level off horizontally.

The instrument operates by generating a sawtooth wave from the electronic output of a differential pressure transducer, as illustrated in Figure 3. This is an accurate representation of the pressure waveform that occurs at the small orifice. The electronics track each bubble as it forms until a peak is reached [the maximum differential bubble pressure]. This peak value is captured and then updated with each subsequent peak value. The resultant steady state output is an effective "moving average" of discrete surface tension measurements that accurately tracks the surface tension of the test fluid or coating.

This technology allows the instrument to be used for intermittent or continuous measurements at any point on the dynamic curve where an active surfactant is present. The continuous measurement capability enables process control using an enhanced version of the same software program [UnkelScope®] that is used for interface development time verification.

At slow bubble rates, the interface development time is approximately equal to the bubble rate [peak to peak value] that is displayed on the computer screen. If desired, this can also be stored on disk in a data file along with surface tension values and fluid temperature. As the bubble rate is increased, as illustrated in Figure 4, it becomes increasingly difficult to verify the bubble formation time from the computer software's normal strip chart program option.

Verification becomes increasingly important as the bubble rate increases because the interface development time becomes a decreasing percentage of the peak to peak time [bubble rate]. A second problem occurs because a specific-sized orifice will only generate a limited number of discrete bubbles per second as the flow rate is increased before the bubbles are forced out so fast that they begin to link together. For example, a 0.5 MM. orifice can support approximately ten to twelve discrete bubbles per second while a 0.25 MM. orifice can go as high as twenty to twenty-five bubbles per second.

To address these problems, a supplemental software program is used to turn the computer into an oscilloscope, with the screen allowing a display such as is illustrated in Figure 5. This display covers a one second time frame, showing a frequency of four bubbles per second. An auxiliary feature of this software allows any display to be captured in memory. It can be brought back to the screen and then a pair of cursors can be moved along the waveform. One is positioned at the start of bubble formation and the second at the peak value (as illustrated). The time between cursors is automatically calculated and displayed in the left side data column (not shown) allowing the accurate determination of bubble formation time and consequently the maximum allowable surfactant migration time.

Figure 6 illustrates a condition that approaches an oscillating jet; the flow is too great for the orifice size and bubbles have started to link together. In this particular example each large peak represents a single discrete bubble. Each small peak represents a pair of bubbles that are linked together.

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The progression from Figures 5 to 6 would be an increasing number of large peaks until a single small peak would result as the first pair of bubbles link together. As the flow rate increases the number of small peaks would increase, until eventually the large peaks disappear and no single bubbles emerge from the orifice. Because the instrument cannot distinguish between a valid peak (maximum bubble pressure) and a small (false) peak, it will average the waveform, causing an invalid, and often fluctuating, surface tension output reading.

At fast bubble rates, it is important to set the instrument up to generate valid data, by generating a series of individual (non-linked) bubbles from the worst case fluid to be used. Otherwise there is a risk that the instrument will be calibrated and used, and the resultant data may not be valid. The worst case is the the waveform and bubble rate that results in the lowest surface tension fluid to be measured, either for testing or calibration. Typically, the worst case is when alcohol is used as the lower surface tension calibration standard.

If alcohol is the only low surface tension calibration fluid available, this problem can be mitigated by calibrating the instrument with water and alcohol, formulating and accurately measuring a "new" water/alcohol mixture (for example, in the 40 to 50 dynes/cm. range), and using this mixture as the "new" low surface tension standard. This moves the worst case lower limit from the 20 dynes/cm. range into the 40 to 50 dynes/cm. range.

EXPERIMENTAL

Materials

Regain NF is a heavy duty liquid stripper/degreaser that exhibits known dynamic characteristics due to an active surfactant. It has been tested at various times to generate dynamic curves. Solubility in water is complete, and is stable under normal handling conditions. It's overall characteristics are representative of water-based coatings, inks, fountain solutions, and most fluids that contain active surfactants. The dynamic curves for Regain NF are similar to the examples shown in Figure #2, for Fluids A and B. Regain NF is composed of the chemicals listed in Table 6.

Deionized water [surface tension of 72.9 dynes/cm. @ 20 degrees C.] and ethyl alcohol [surface tension of 22.4 dynes/cm, @ 20 degrees C.] were used as calibration standards.

Procedure for Dynamic Surface Tension Determination

In this method, the titration of the Regain NF was carried out in aqueous solution and monitored by using the SensaDyne Model 6000 surface tensiometer. A series of five different bubble rates were selected and the SensaDyne instrument was calibrated at each bubble rate, prior to data collection.

The cell was placed on a laboratory stirrer, and the Regain NF was introduced into a 100ml aqueous base in increments of 0.2 ml. After each incremental addition, a stirrer was turned on to mix the solution and then turned off to allow the solution to stabilize. When the surface tension reading stabilized after stirring, the data was captured and sent to a user-named ASCII file [R-1.TXT, etc.] by pushing a function key (F2) on the computer keyboard.

In addition to the file name, the user enters an alphabetical label [A to Z] and up to a thirty character comment. The resultant data is shown in Tables 1 through 5.

RESULTS AND DISCUSSION

Each of the five sets of data generated by the titrations can be plotted in two dimensions, similar to Figure 2, as a function of surface tension versus concentration. Figure 7 shows two-dimensional test plots at the five bubble rate settings. The resultant two-dimensional graph shows a nest of five curves with the higher curve having the fastest bubble rates. The higher surface tensions over the same concentrations are the result of reduced dynamic surfactant migration times. These same curves can be better shown in a three-dimensional context by re-plotting them, as in Figure 8. Here, each two-dimensional curve is taken from Figure 7 and re-plotted along a third axis at corresponding bubble frequencies [bubbles/second].

The data sets in Tables 1 through 5 can be further manipulated to form a series of two-dimensional plots of surface tension versus bubble frequency, with each plot at a different concentration, by plotting the data in all the "A' rows, "B" rows, etc. These plots are shown in Figure 9, in a three-dimensional context for clarity purposes.

The data in Tables 1 through 5 are in ASCII format and can readily be imported into various spreadsheet or word processing programs for consolidation, and to develop the three-dimensional data matrix needed for a graphing program. Entering the data for surface tension, concentration, and bubble freqency into a three-dimensional graphing program results in the graph shown in Figure 10. This particular graph was done using "Foxgraph" by Fox Software, although any similar three-dimensional plotting program can provide similar suitable results.

Figure 10 shows the effects on surface tension when concentration and bubble rates are varied. These results can be correlated to any time-dependent coating, spray, or dynamic fluid application process where a dynamic surfactant has a time constraint placed upon it due to the speed of the process. By testing the fluid or coating and obtaining the three-dimensional characteristics, operational and quality control problems can be more readily defined and mitigated.

The data can further be revised to reflect accurate interface development times instead of peak to peak bubble rates, as done here. More accurate interface development times would influence the data in Figures 8 through 10 such that the slopes at higher bubble rates would not be quite as pronounced as those shown. The overall three-dimensional graphs would be quite similar.

CONCLUSIONS

The surface tension data acquisition and three-dimensional graphic display method presented here has several advantages over other surfactant analysis techniques. By using a titration method, as described, a maximum amount of data can be accurately obtained in a minimum amount of time. The five data sets in Tables 1 through 5 were collected over a period of less than four hours. This data represents the complete three-dimensional characterization of Regain NF. The method is kept quite simple by continuously monitoring surface tension during a single phase titration, and capturing only the values needed at points after each new solution was thoroughly mixed and stable.

Some limitations of this method can appear where coatings or other fluids are very viscous or have high solids percentages. Very high bubble rates may not be always achievable. Past work done with some very difficult polymers indicate that maximum rates of four or five bubbles per second are the best that can be obtained due to the much slower flow of the fluid. Bubble rate, to some degree depends on the ability and speed of the fluid to flow back into the void created by the bubble departing from the orifice. In some cases, the more limited amount of three-dimensional data obtainable may have to be further extrapolated into the area of interest.

The advantage of the method is very evident when data in Tables 1 through 5 is compared with the single three-dimensional graph in Figure 10. The method can be applied, in general, to any fluid or coating that contains an active surfactant.

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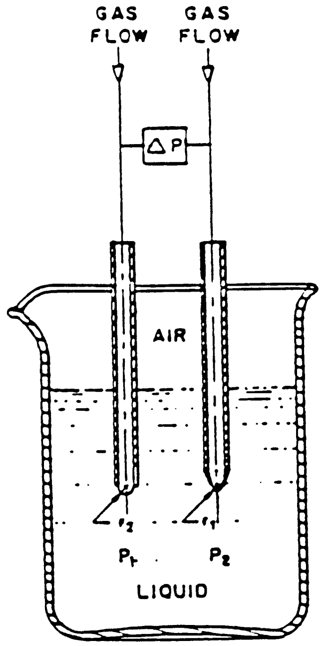
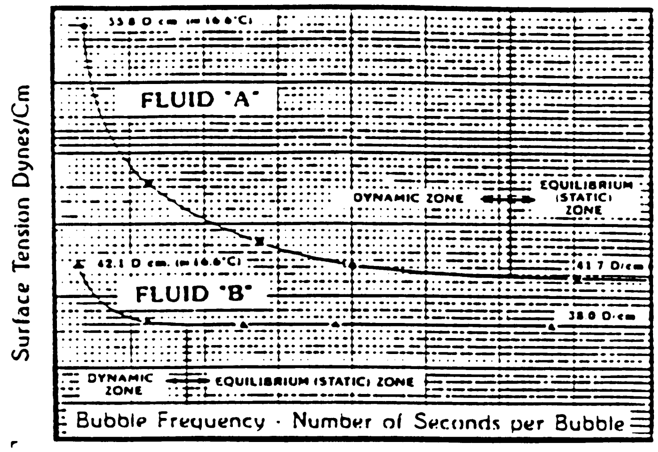


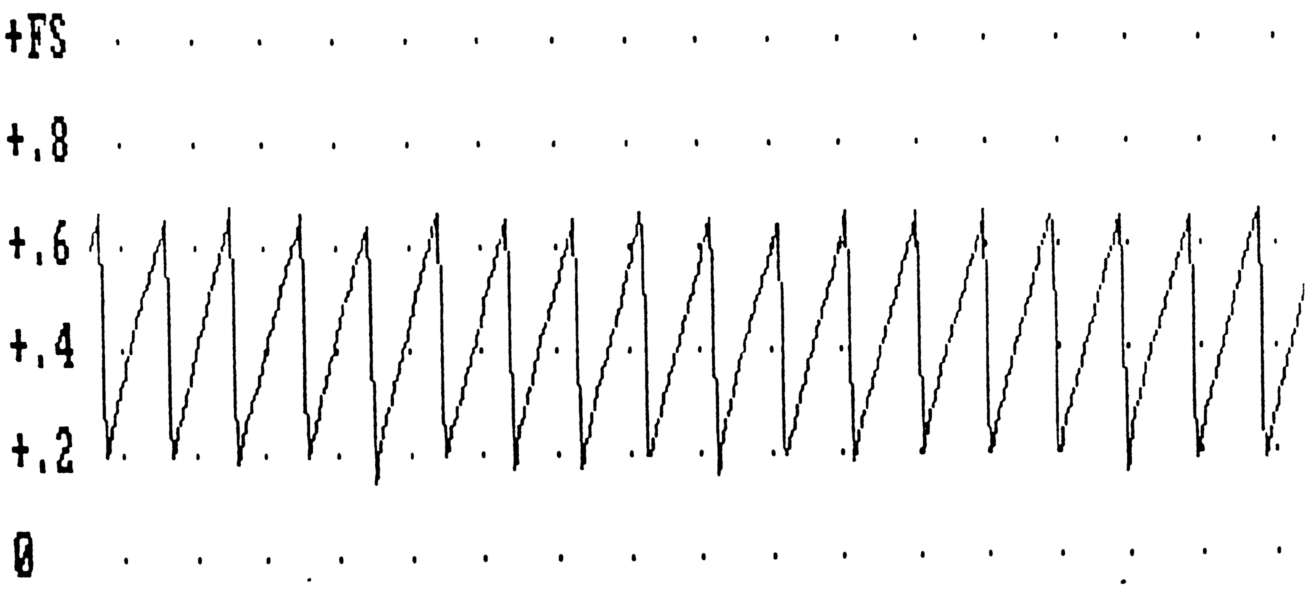
BUBBLE METHOD-DESCRIPTIVE DIAGRAM

Figure 1



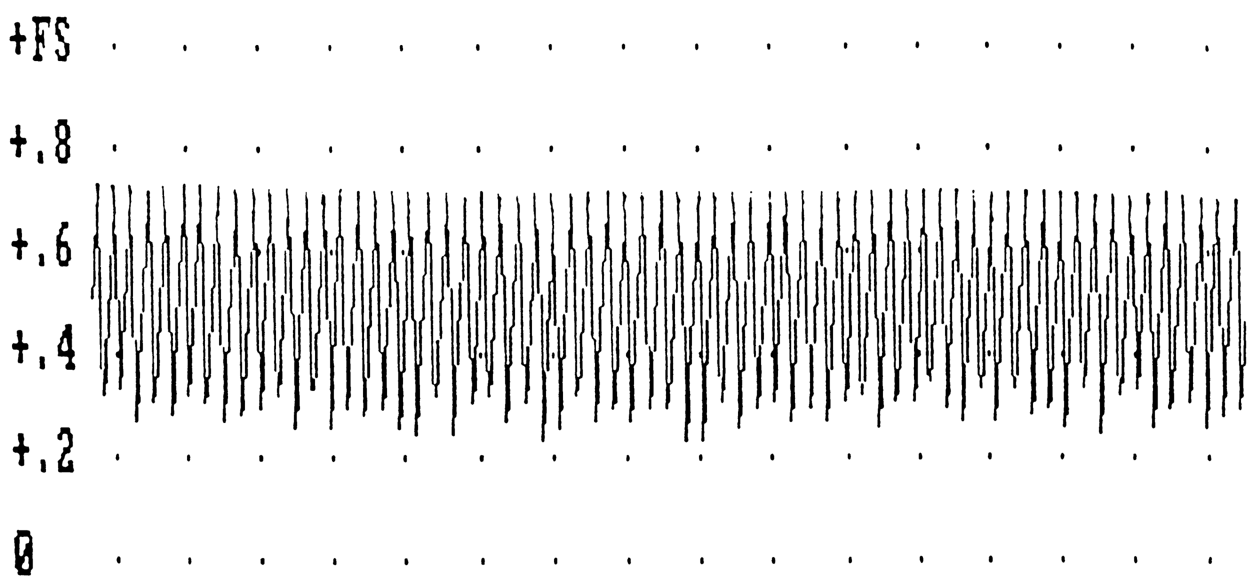
Dynamic Surface Tension Graph

Figure 2



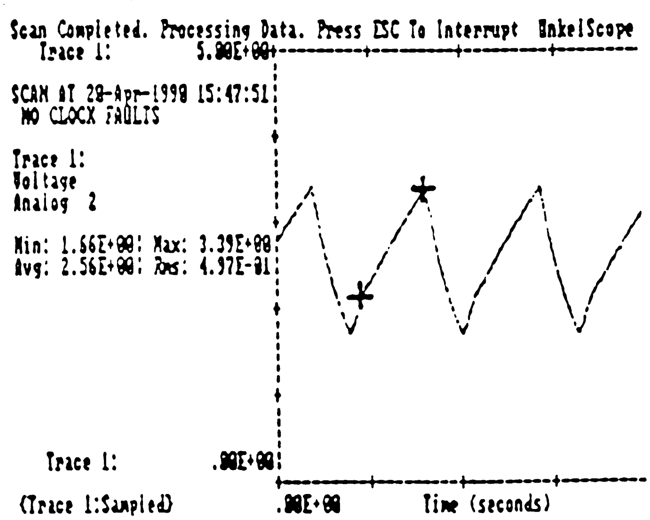
Differential Pressure Transducer Output

Figure 3



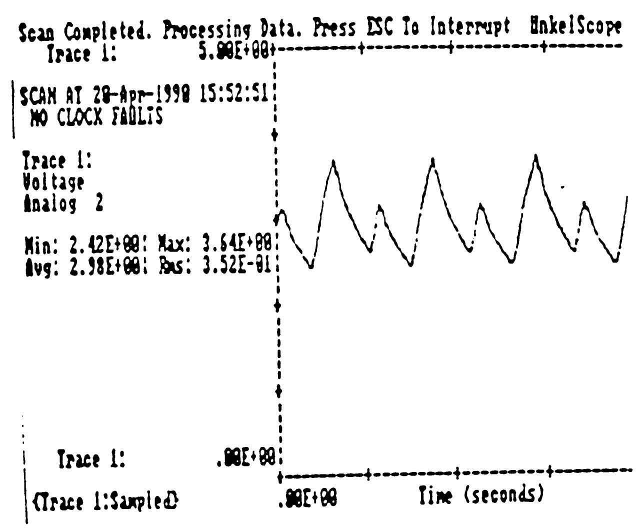
Transducer Output - Fast Bubble Rate

Figure 4



Oscilloscope Program
Valid Bubble Rate Setting

Figure 5



Oscilloscope Program
Invalid Bubble Rate Setting

Figure 6

R-1.TXT

Date	Time	#	Temp	B/s.	S.T.	Comments
06-25-1992	10:15:33	A	22.3	0.17	55.7	0.2 ml concentration
06-25-1992	10:25:44	B	22.3	0.19	51.3	0.4 ml concentration
06-25-1992	10:30:54	C	22.3	0.20	48.3	0.6 ml concentration
06-25-1992	10:34:05	D	22.3	0.22	47.7	0.8 ml concentration
06-25-1992	10:40:41	E	22.3	0.23	46.5	1.0 ml concentration
06-25-1992	10:45:00	F	22.4	0.25	45.8	1.2 ml concentration
06-25-1992	10:48:13	G	22.5	0.26	45.5	1.4 ml concentration
06-25-1992	10:50:41	H	22.5	0.27	45.3	1.6 ml concentration
06-25-1992	10:54:04	I	22.6	0.27	44.5	1.8 ml concentration
06-25-1992	10:58:43	J	22.6	0.29	44.4	2.0 ml concentration
06-25-1992	11:04:07	K	22.7	0.30	44.3	2.2 ml concentration
06-25-1992	11:10:29	L	22.7	0.31	44.1	2.4 ml concentration
06-25-1992	11:14:13	M	22.7	0.33	43.8	2.6 ml concentration

Table 1

R-2.TXT

Date	Time	#	Temp	B/s.	S.T.	Comments
06-25-1992	12:08:07	A	23.1	0.38	58.4	0.2 ml concentration
06-25-1992	12:14:00	B	23.1	0.42	54.3	0.4 ml concentration
06-25-1992	12:16:52	C	23.1	0.45	51.5	0.6 ml concentration
06-25-1992	12:21:19	D	23.1	0.47	49.8	0.8 ml concentration
06-25-1992	12:26:04	E	23.2	0.48	48.5	1.0 ml concentration
06-25-1992	12:30:03	F	23.2	0.49	47.5	1.2 ml concentration
06-25-1992	12:33:12	G	23.2	0.50	47.1	1.4 ml concentration
06-25-1992	12:36:44	H	23.3	0.51	46.8	1.6 ml concentration
06-25-1992	12:43:09	I	23.3	0.52	46.2	1.8 ml concentration
06-25-1992	12:44:55	J	23.3	0.52	45.5	2.0 ml concentration
06-25-1992	12:46:41	K	23.4	0.53	45.2	2.2 ml concentration
06-25-1992	12:50:55	L	23.4	0.54	45.0	2.4 ml concentration
06-25-1992	12:55:23	M	23.4	0.55	44.7	2.6 ml concentration

Table 2

R-3.TXT

Date	Time	#	Temp	B/s.	S.T.	Comments
06-25-1992	13:54:46	A	23.4	0.98	63.0	0.2 ml concentration
06-25-1992	13:57:01	B	23.4	1.07	59.0	0.4 ml concentration
06-25-1992	14:00:27	C	23.5	1.14	55.9	0.6 ml concentration
06-25-1992	14:03:11	D	23.5	1.20	53.8	0.8 ml concentration
06-25-1992	14:05:58	E	23.5	1.24	52.1	1.0 ml concentration
06-25-1992	14:09:48	F	23.5	1.28	50.7	1.2 ml concentration
06-25-1992	14:13:14	G	23.6	1.31	49.8	1.4 ml concentration
06-25-1992	14:16:49	H	23.6	1.33	48.8	1.6 ml concentration
06-25-1992	14:19:32	I	23.6	1.35	47.7	1.8 ml concentration
06-25-1992	14:21:19	J	23.6	1.38	47.5	2.0 ml concentration
06-25-1992	14:25:48	K	23.7	1.39	47.2	2.2 ml concentration
06-25-1992	14:28:36	L	23.7	1.40	46.8	2.4 ml concentration
06-25-1992	14:30:36	M	23.7	1.43	46.3	2.6 ml concentration

Table 3

R-4.TXT

Date	Time	#	Temp	B/s.	S.T.	Comments
06-26-1992	09:51:32	A	21.4	2.97	67.8	0.2 ml concentratio
06-26-1992	09:55:36	B	21.4	3.02	63.8	0.4 ml concentratio
06-26-1992	10:03:14	C	21.4	3.34	60.3	0.6 ml concentratio
06-26-1992	10:05:32	D	21.4	3.43	57.9	0.8 ml concentratio
06-26-1992	10:09:37	E	21.4	3.55	56.0	1.0 ml concentratio
06-26-1992	10:13:52	F	21.4	3.63	54.4	1.2 ml concentratio
06-26-1992	10:16:29	G	21.4	3.63	53.5	1.4 ml concentratio
06-26-1992	10:18:37	H	21.4	3.76	52.3	1.6 ml concentratio
06-26-1992	10:21:33	I	21.5	3.80	51.0	1.8 ml concentratio
06-26-1992	10:24:42	J	21.5	3.92	50.5	2.0 ml concentratio
06-26-1992	10:27:18	K	21.5	4.08	50.1	2.2 ml concentratio
06-26-1992	10:29:07	L	21.5	4.14	49.5	2.4 ml concentratio
06-26-1992	10:30:52	M	21.5	4.24	49.2	2.6 ml concentratio

Table 4

R-5.TXT

Date	Time	#	Temp	B/s.	S.T.	Comments
06-26-1992	11:05:39	A	21.5	6.05	71.8	0.2 ml concentratio
06-26-1992	11:07:21	B	21.5	6.12	68.1	0.4 ml concentratio
06-26-1992	11:11:03	C	21.5	6.24	64.2	0.6 ml concentratio
06-26-1992	11:14:46	D	21.6	6.43	61.6	0.8 ml concentratio
06-26-1992	11:16:12	E	21.6	6.52	59.5	1.0 ml concentratio
06-26-1992	11:19:56	F	21.6	6.65	57.7	1.2 ml concentratio
06-26-1992	11:22:31	G	21.6	6.76	56.5	1.4 ml concentratio
06-26-1992	11:26:08	H	21.7	6.83	55.5	1.6 ml concentratio
06-26-1992	11:28:57	I	21.7	6.90	54.4	1.8 ml concentratio
06-26-1992	11:31:17	J	21.7	7.12	53.3	2.0 ml concentration
06-26-1992	11:34:33	K	21.8	7.38	52.8	2.2 ml concentration
06-26-1992	11:38:44	L	21.8	7.66	52.5	2.4 ml concentration
06-26-1992	11:42:40	M	21.8	7.94	52.0	2.6 ml concentratio

Table 5

Water, Zeolite Softened
Sodium Silicate
Monoethanolamine
Butoxyethanol
Polyethoxylated Alcohol
Tetrasodium EDTA

Composition of Regain NF

Table 6

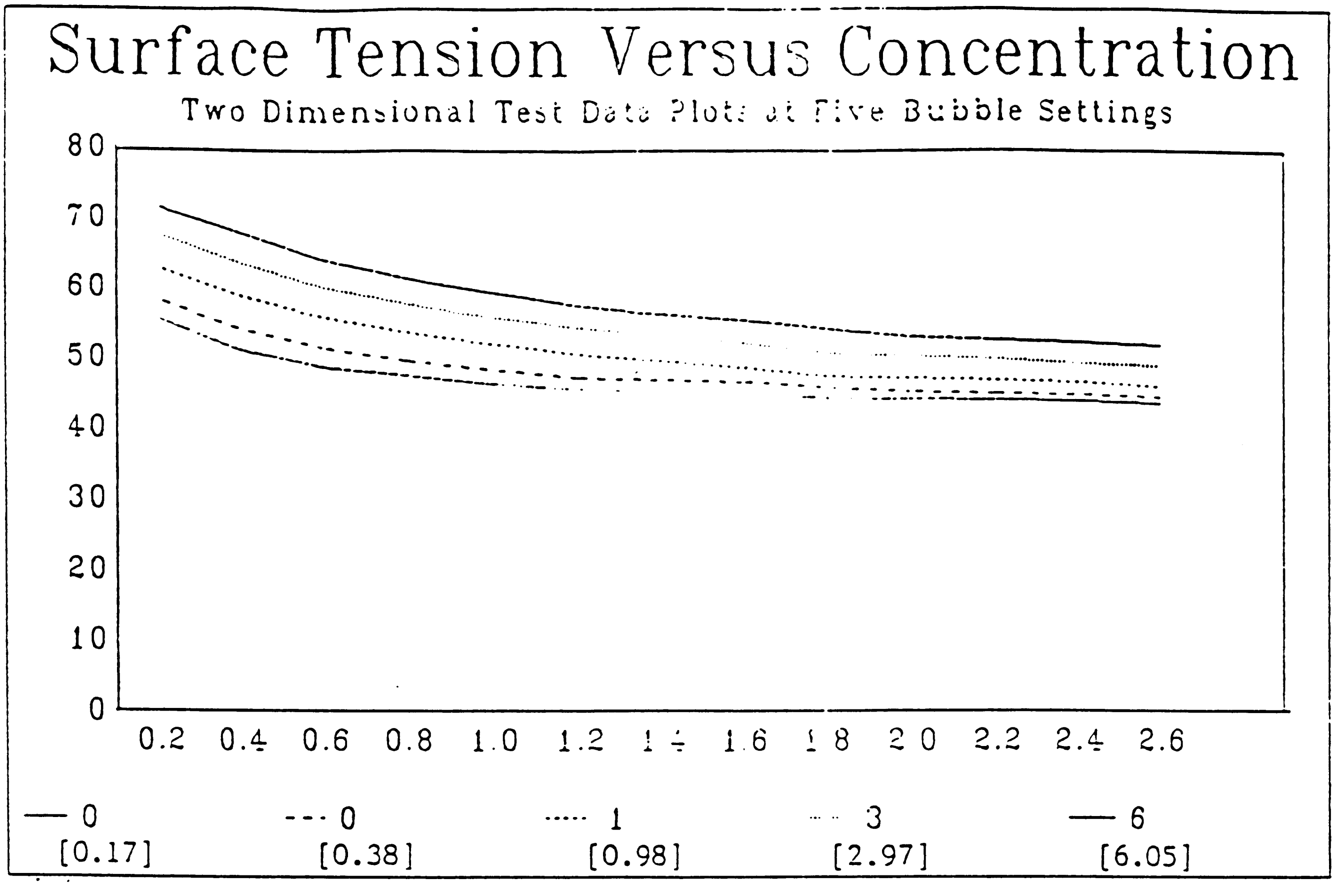


Figure 7

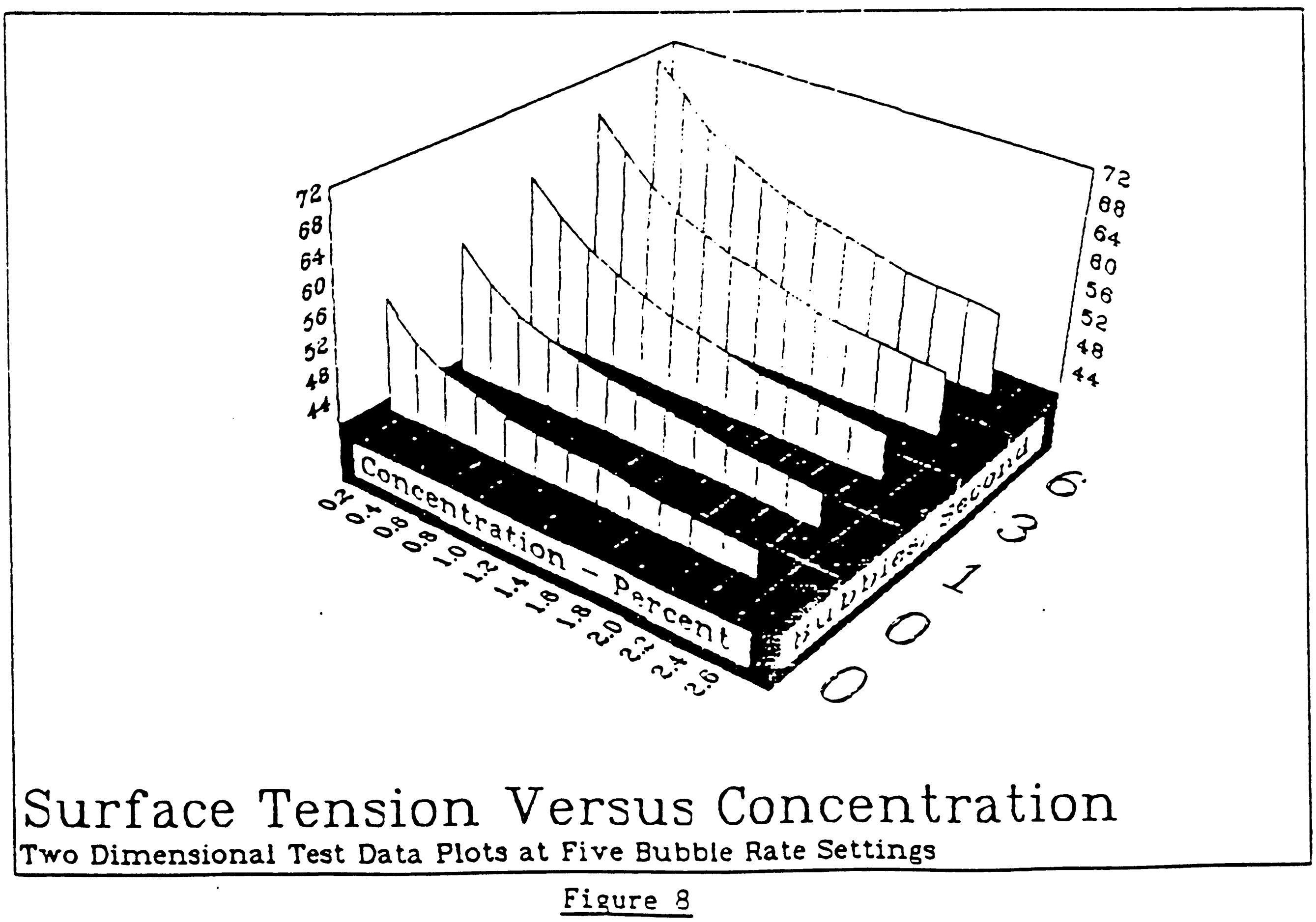
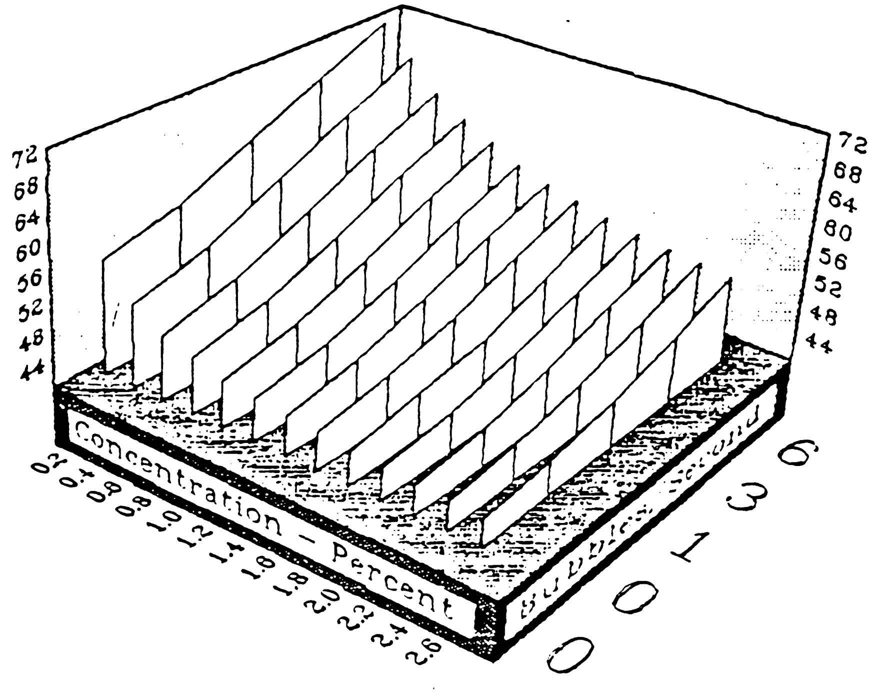


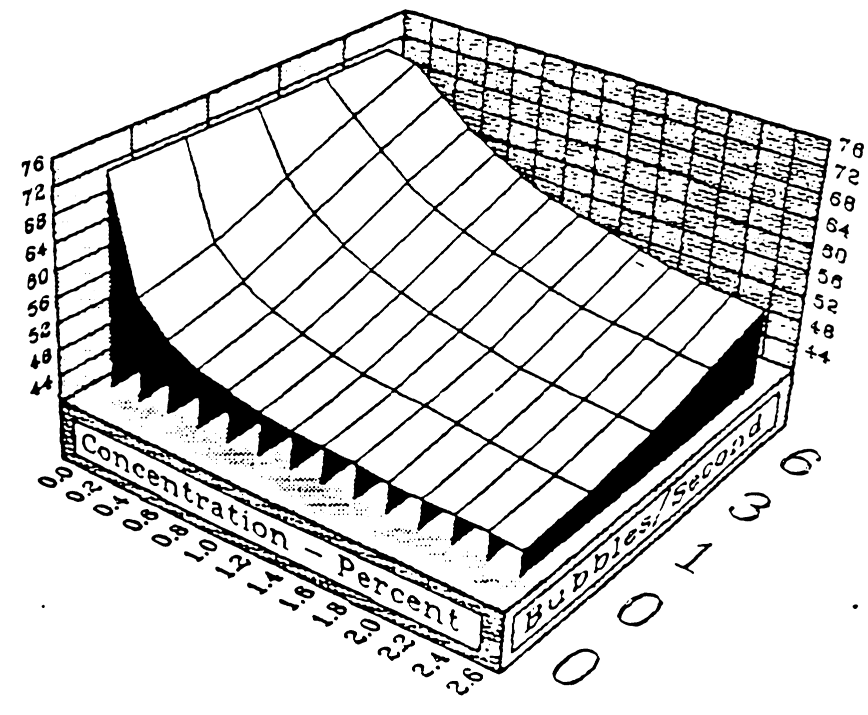
Figure 8



Surface Tension Versus Bubble Rate

Two Dimensional Test Data Plots at Various Concentrations

Figure 9



Dynamic Surface Tension Graph

Three Dimensional Characteristics

Figure 10

Appendix 8
Statistical Analysis

Contents:

1) Letter from K. A. Booman to R. Sedlak, dated November 3, 1994 (five pages).
2) Fax from J. Heinze to J. Al-Atrash, dated March 16, 1995 (four pages).
3) Fax from J. Al-Atrash to Nonionic Surfactant Task Force, dated October 25, 1995 (11 pages).
4) Computer print out: "Stat-Packets Statistical Analysis Package: Analysis of Variance" (four pages).

172 Mountain Avenue
North Plainfield, NJ 07060-4405
November 3, 1994

Mr. Richard Sedlak
Technical Director
The Soap and Detergent Association
475 Park Avenue South
New York, New York 10016

Dear Rich:

Here is a short summary of insights I have been able to develop on the variability of Draize data. I will be out of town until November 14, so this is all I can do before mid-November.

Figure 1 shows the impressive correlation between the 90% confidence interval for average scores observed at 1 and 24 hours. Most of the maximum average scores were observed at these observation times. This figure means that the standard deviation calculated for six-animal data can be converted into a 90% confidence interval (the 95% limit minus the 5% limit) for the maximum average score by multiplying the standard deviation by 1.23. If the data were normally distributed, the factor would be 2.015 x 2 / 6^.5 = 1.65 (For a tail area probability of 0.05 and five degrees of freedom, t = 2.015). As I have noted before, the Draize data distribution is somewhat narrower than the normal distribution.

Figures 2 and 3 show the dependence of standard deviation of the Draize average scores at 1 and 24 hours. 90% confidence intervals for both variables are shown on the graphs. These were calculated by a bootstrap method. The curves shown on the graphs are based on a smoothing operation that uses a robust linear least squares fit to the 2/3 of the data closest to a point to estimate a smoothed value for that point. These figures strongly suggest that variability, as measured by standard deviation, is generally higher at 24 hours than at 1 hour. Put differently, variability appears to depend on time after dosing as well as on irritancy.

Figures 2 and 3 also suggests that variability may depend on class of chemical as well as on time and irritancy. That suggestion is inferred by the observation that a smooth curve cannot be drawn through either graph that intercepts every error bar (or, more realistically, 90% of them). The clump of four points in figure 2 below the curve, and between average scores of 13 and 17, are examples. The vertical error bars for these points miss or barely touch the smooth curve that has been fit to the data. The points represent glycerine, dodecylamine, NaOH (0.2 meq/g) and the powdered cleaner. Other examples are apparent in both figures. Do these materials actually exhibit less (or more) variability in irritancy caused by them than is "normal?" Put the other way around, why should all classes of test materials have the same relationship between variability and level of irritancy (and observation time)?

Why should we care? A raw material for consumer products might be more desirable if the variability of its irritancy was low. A material that had acceptable irritancy on average might be unacceptable if the irritancy was highly variable, if the material caused irritancy on occasion that was too high.

With the data in hand, variability of Draize data appears to depend on more factors than level of irritancy and elapsed time after dosing. At the same time, the standard deviation of Draize data is a good measure of variability. The standard deviation is easily converted into confidence limits that allow a decision to be made as to whether or not an observed difference in the irritancy of two materials is due to experimental error or to a real difference in irritancy.

Sincerely,

Keith A. Booman

Keith A. Booman, Ph.D.

Figure 1. Standard Deviation Predicts 90% Confidence Interval for Average Draize Scores

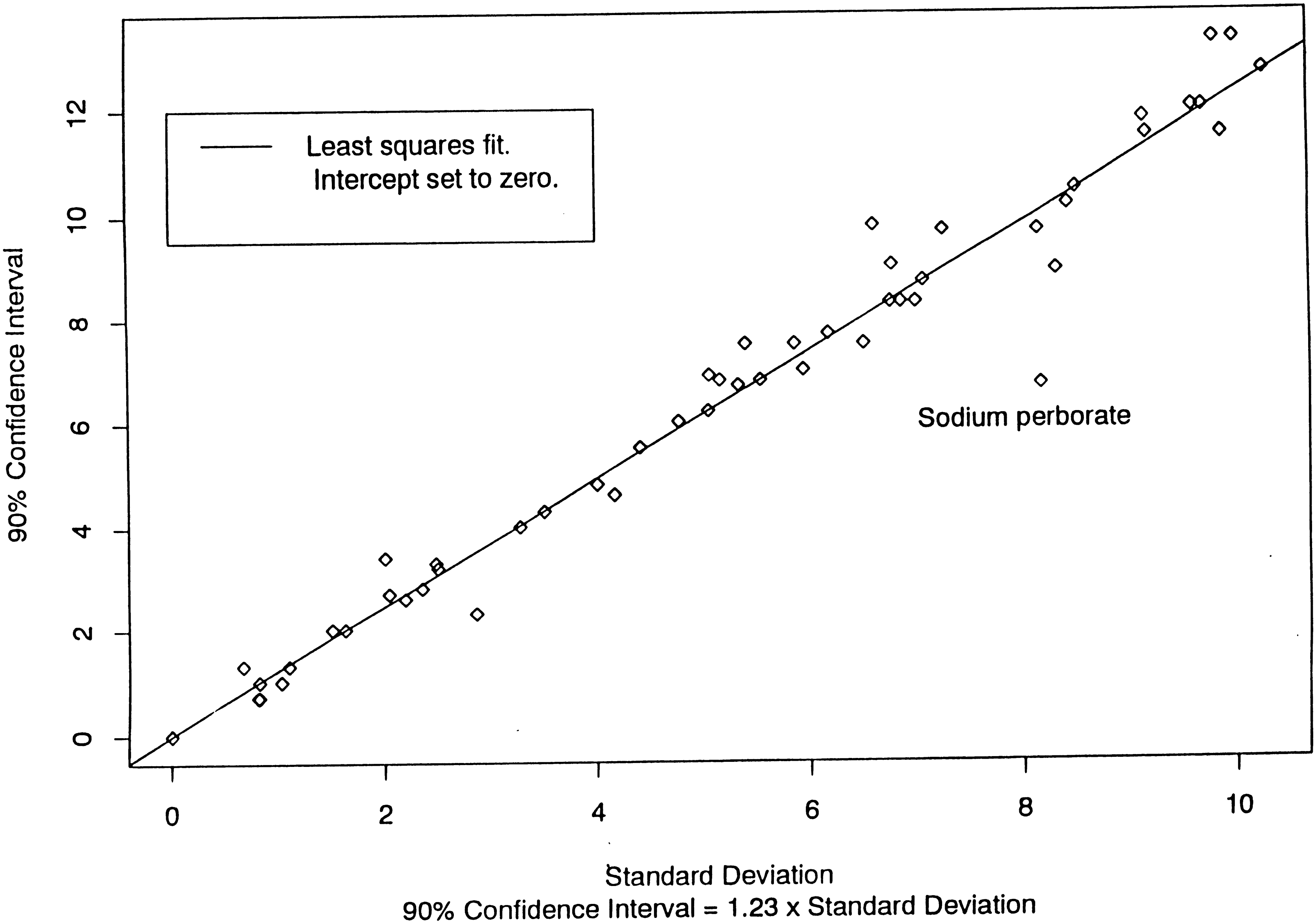
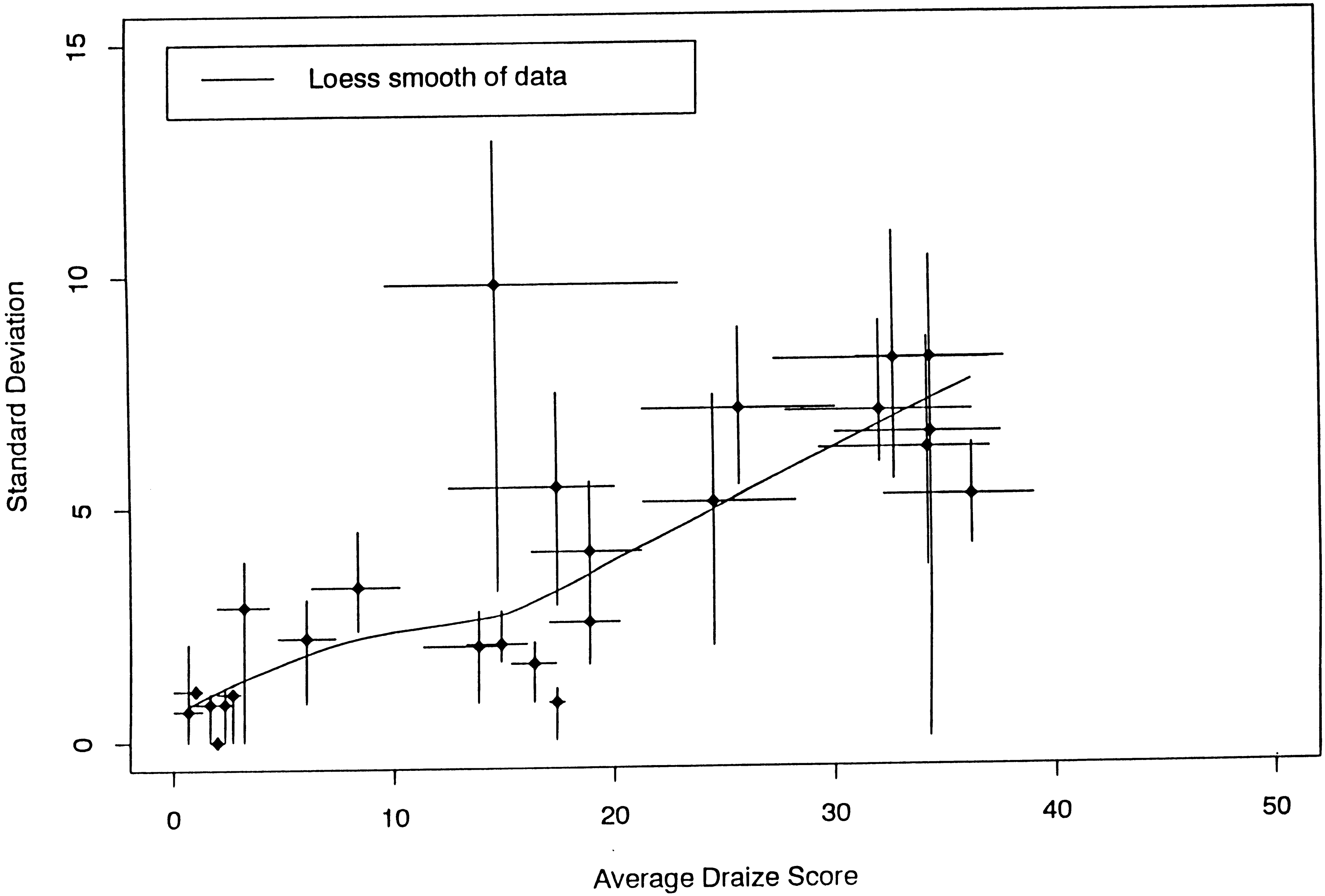
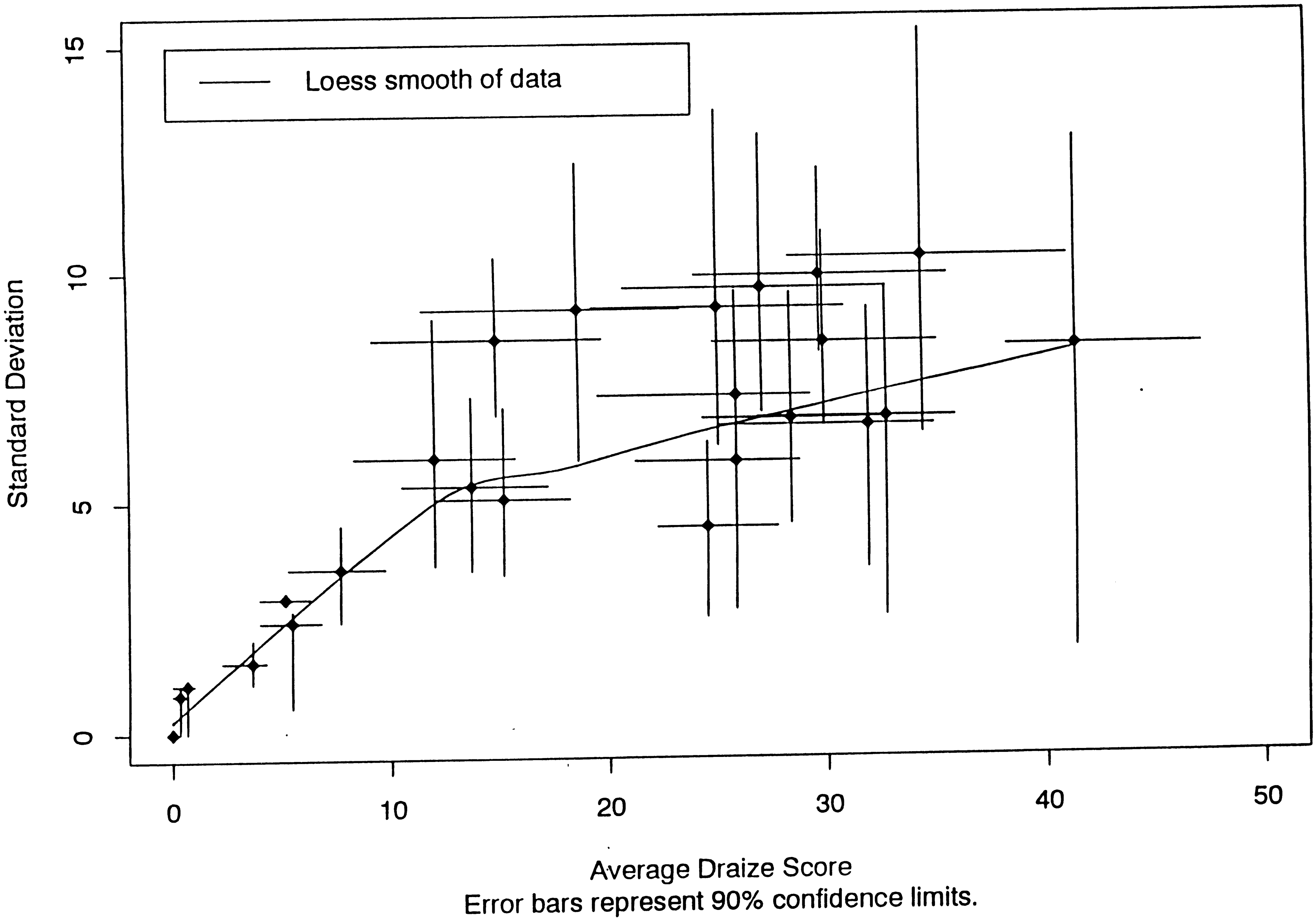


Figure 2. Variability of Draize Scores (one hour data)



Error bars represent 90% confidence limits.

Figure 3. Variability of Draize Scores (24 hour data)



Vista Chemical Company
12024 Vista Parke Drive
Austin, Texas 78726-4050
(512) 331-2500
P.O. Box 200135
Austin, Texas 78720-0135
Fax (512) 331-2387

Via Courier

VISTA

To: Jenan Al-Atrash
Human Health & Safety Director
Soap and Detergent Association
475 Park Ave. South
New York, NY 10016

From: John Heinze, Corp. R&D
Date: March 16, 1995

Subject: **Statistical Analysis**

Attached is the statistical analysis of the MAS scores on the nonionic surfactants recently tested by Hazleton.

The table shows the 1-hour Draize scores for each animal, taken from the raw data sent to you by Hazleton on March 3, 1995. Also shown are the standard deviation and confidence intervals for each mean MAS. The confidence intervals were calculated using the value of 1.23 times the standard deviation, as suggested by Keith Booman's analysis of Draize scores from our Phase III testing (see his letter to Rich Sedlak, dated November 3, 1994).

Figure I shows a graph of the confidence intervals from which the mean scores are placed into groups that do not differ significantly, i.e. their 95% confidence intervals overlap. There are six such groups, "a" through "f". The groups are shown in the table and in Figure 2.

This is a rather more complicated pattern of statistical differences that I had hoped to see. However, the analysis can be simplified by observing that the three nonionics giving the lowest MAS scores (A1213-EO3, sorbitan trioleate-EO20 & A12-EO23) comprise a group which is significantly different from the group of four nonionics which give the highest MAS scores (A810-EO5, lauramine oxide, pH=7.0, lauramine oxide, pH=10.5, & nonylphenol-EO9). The remaining four nonionics (A1214-EO7, A1213-EO6.5, cocamide DEA & A1216-glucose1.6) comprise a group with intermediate MAS scores and confidence intervals which overlap the low and high MAS groups.

Please fax this statistical analysis to the other members of the Non-animal Testing Subcommittee so that any questions or comments can be raised at the March 23 conference call.

John

John Heinze

cc: Dave Penney, SHE, Houston

NONIONIC SURFACTANTS:
MAS Results--Statistical Analysis

Test Material*	MAS	Animal # 1	2	3	Mean	Std. Dev.	90% C.I.	Lower C.I.	Upper C.I.	Sig. Dif.
A1213-EO3	0	0	0	0	0.00	0.00	0.00	0.00	0.00	a
Sorbitan trioleate-EO20	0.7	2	0	0	0.67	1.15	1.42	-0.75	2.09	a,b
A12-EO23	1.3	0	2	2	1.33	1.15	1.42	-0.09	2.75	a,b,c
A1214-EO7	4.7	4	8	2	4.67	3.06	3.76	0.91	8.42	b,c,d
A1213-EO6.5	7	6	4	11	7.00	3.61	4.43	2.57	11.43	b,c,d,e
Cocamide DEA	7.3	11	2	9	7.33	4.73	5.81	1.52	13.15	b,c,d,e,f
A1216-glucose1.6	8.7	13	2	11	8.67	5.86	7.21	1.46	15.87	b,c,d,e,f
A810-EO5	11.3	17	8	9	11.33	4.93	6.07	5.27	17.40	b,c,d,e,f
Lauramine oxide (pH=7.0)	11.7	13	13	9	11.67	2.31	2.84	8.83	14.51	c,d,e.f
Lauramine oxide (pH=10.5)	13	13	13	13	13.00	0.00	0.00	13.00	13.00	d,e,f
Nonylphenol-EO9.5	13.3	21	8	11	13.33	6.81	8.37	4.96	21.71	c,d,e,f

* "A" = alcohol (number is carbon chain length)
"EO" = ethylene oxide units (number is moles)

Std. Dev. = sample standard deviation.
90% C.I. = 90% confidence interval = 1.23 X Std. Dev. (K. Booman)
Lower C.I. = lower 95% confidence interval = mean - 90% C.I.
Upper C.I. = upper 95% confidence interval = mean+90% C.I.
Sig. Dif. = values with the same letter are NOT significantly different: the 95% confidence intervals of their mean values overlap.

Figure 1

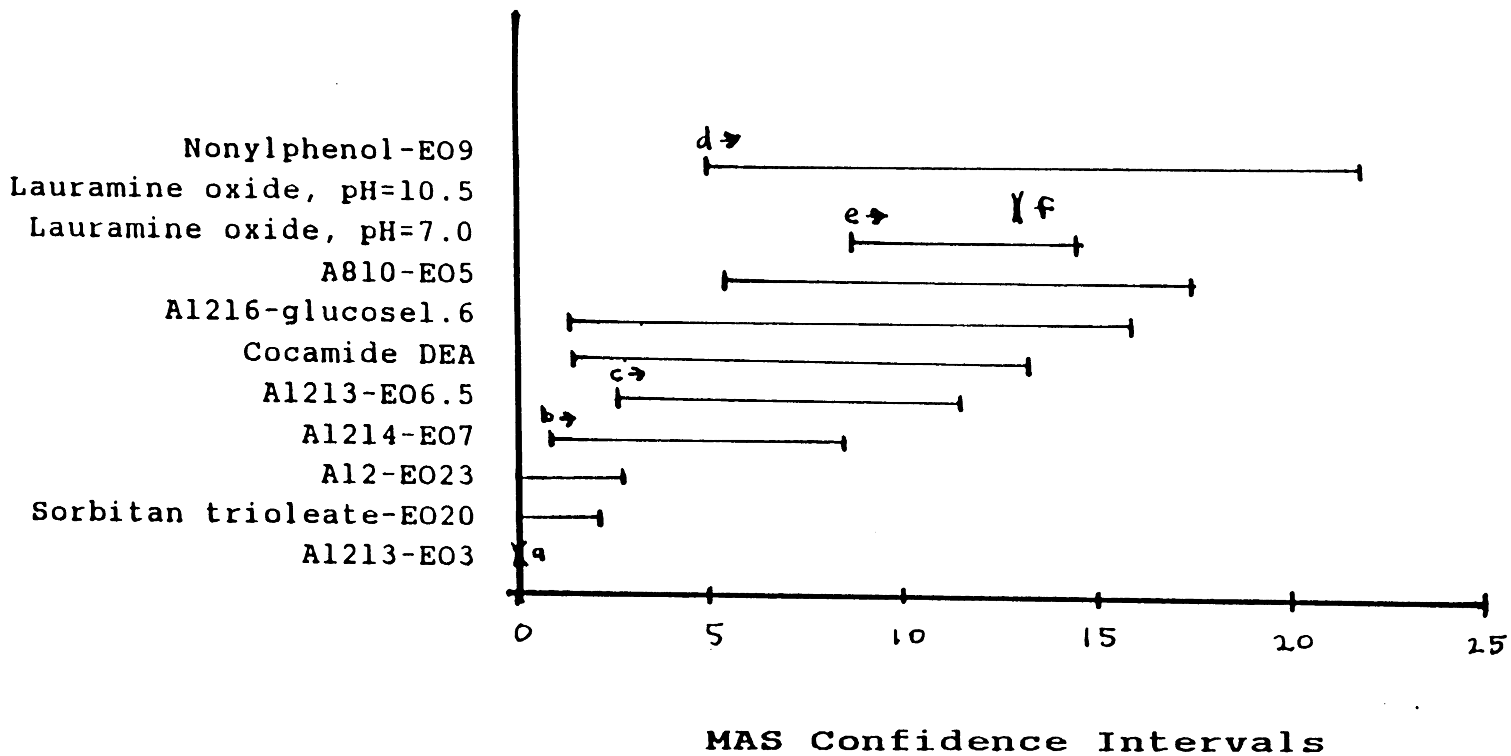
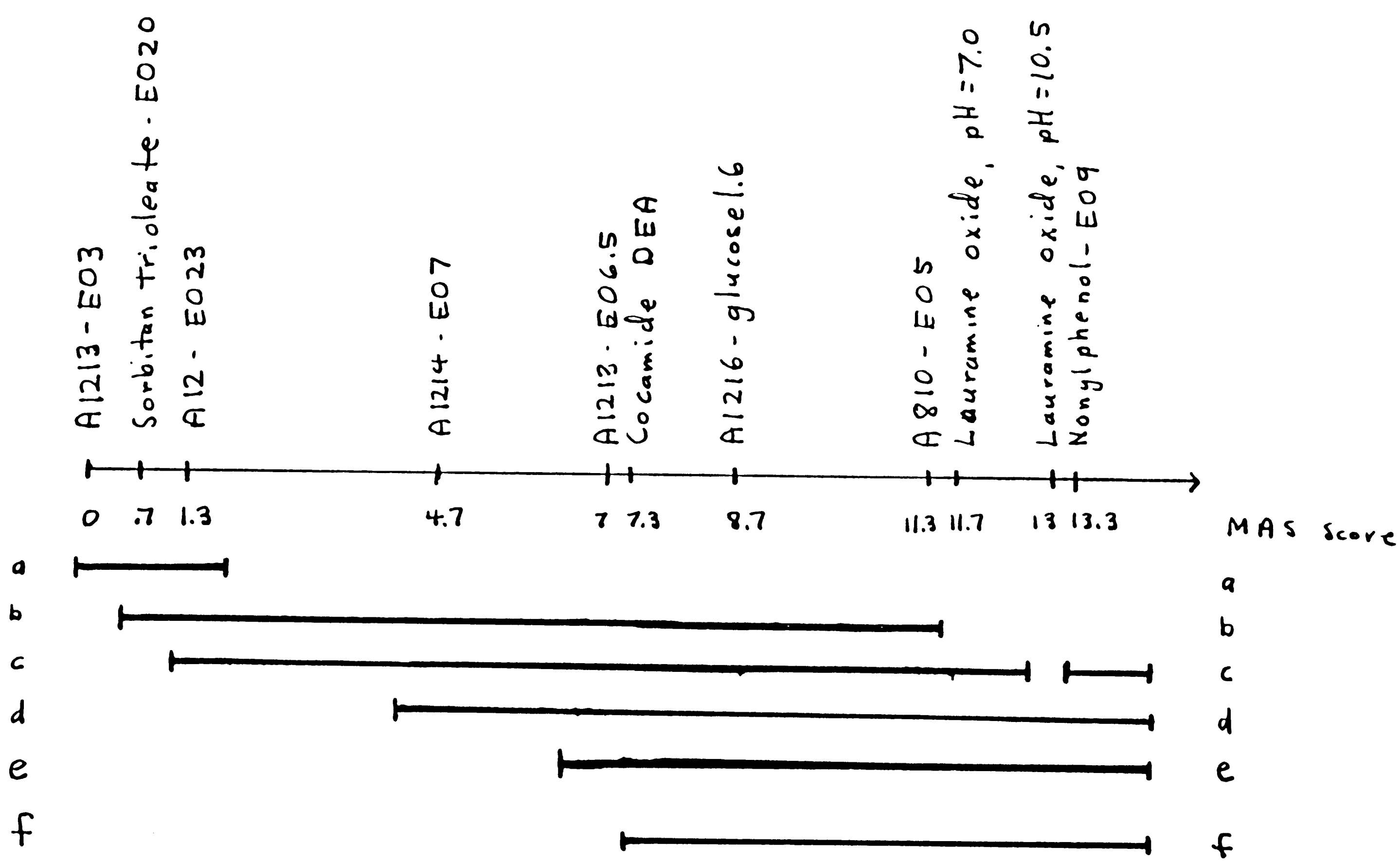

Nonylphenol-EO9
Lauramine oxide, pH=10.5
Lauramine oxide, pH=7.0
A810-EO5
A1216-glucose1.6
Cocamide DEA
A1213-EO6.5
A1214-EO7
A12-EO23
Sorbitan trioleate-EO20
A1213-EO3
a
b
c
d
e
f
0
5
10
15
20
25
MAS Confidence Intervals

Figure 2

Significant Groups (a-f):

Each line indicates a group of values which are NOT significantly different from each other.



SDA The Soap and Detergent Association

FOR YOUR IMMEDIATE RESPONSE
COMMENTS DUE NOVEMBER 15, 1995

October 25, 1995]

TO: NONIONIC SURFACTANT TASK FORCE

Philip Casterton	-	Amway Corporation
Ed Carmines	-	The Dial Corp
Toni Fedoroski	-	Reckitt & Colman Inc.

FROM: Jenan Al-Atrash, Dr. PH, Human Health & Safety Director

RE: Nonionic Surfactant Eye Irritation Study

As you recall, because of poor historical animal eye irritation data for nonionics, the Non-Animal Testing Subcommittee undertook a study to determine if chemical structure or physical properties influence eye irritation results. Eleven nonionics were tested *in vivo* and the resulting animal data were compared to several physical parameters: alkyl chain length, EO chain length, hydrophilic/lipophilic balance, surface tension and pH.

Attached for your review and comments is Fred Heitfeld's summary of this data. Original data should be in your files. Attached are the following:

1. A graph of physical data versus the maximum, average Draize score and the maximum number of days for all ocular irritation to clear.

2. Physical parameters evaluated: pH (Hazelton), surface tension (Vista and U.S. Testing), interfacial tension and central angle (U.S. Testing).

3. A comparison of the effect on irritancy of alkyl chain length and the degree of ethoxylation for the straight chain nonionics.

Fred's conclusions are:

1. No clear relationship between the physical parameters measured and ocular irritation were found.

475 Park Avenue South, New York, N.Y. 10016 • (212) 725-1262 • Fax (212) 213-0685

2. The droplet contact angle gives the best apparent "correlation" with ocular irritancy.

3. With the Neodol 23-3 data the correlation is 0.16 for the maximum average Draize and 0.35 for days to clear. Without 23-3, the correlations improve to 0.6 and 0.55 respectively. No correlation coefficients were calculated for other parameters as the data appear random.

Also, I am enclosing a draft final report to Hazelton which was sent to the Subcommittee on June 21 for comments. No comments were received. Please review this draft report once more, in order to finalize this project.

Comments on Fred Heitfeld's summary and Hazelton's final report are due by November 15.

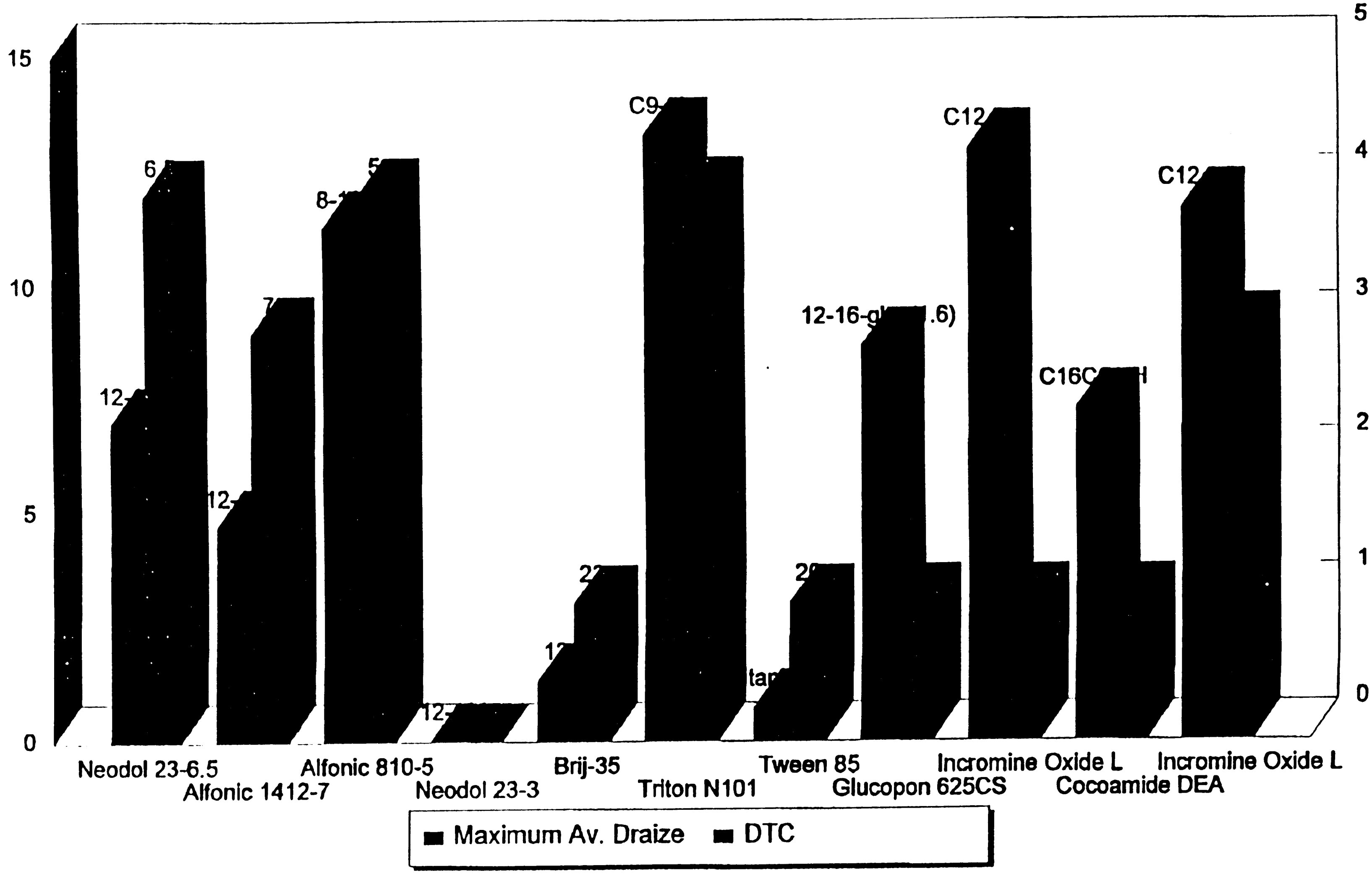
If you have any questions, please give me a call.

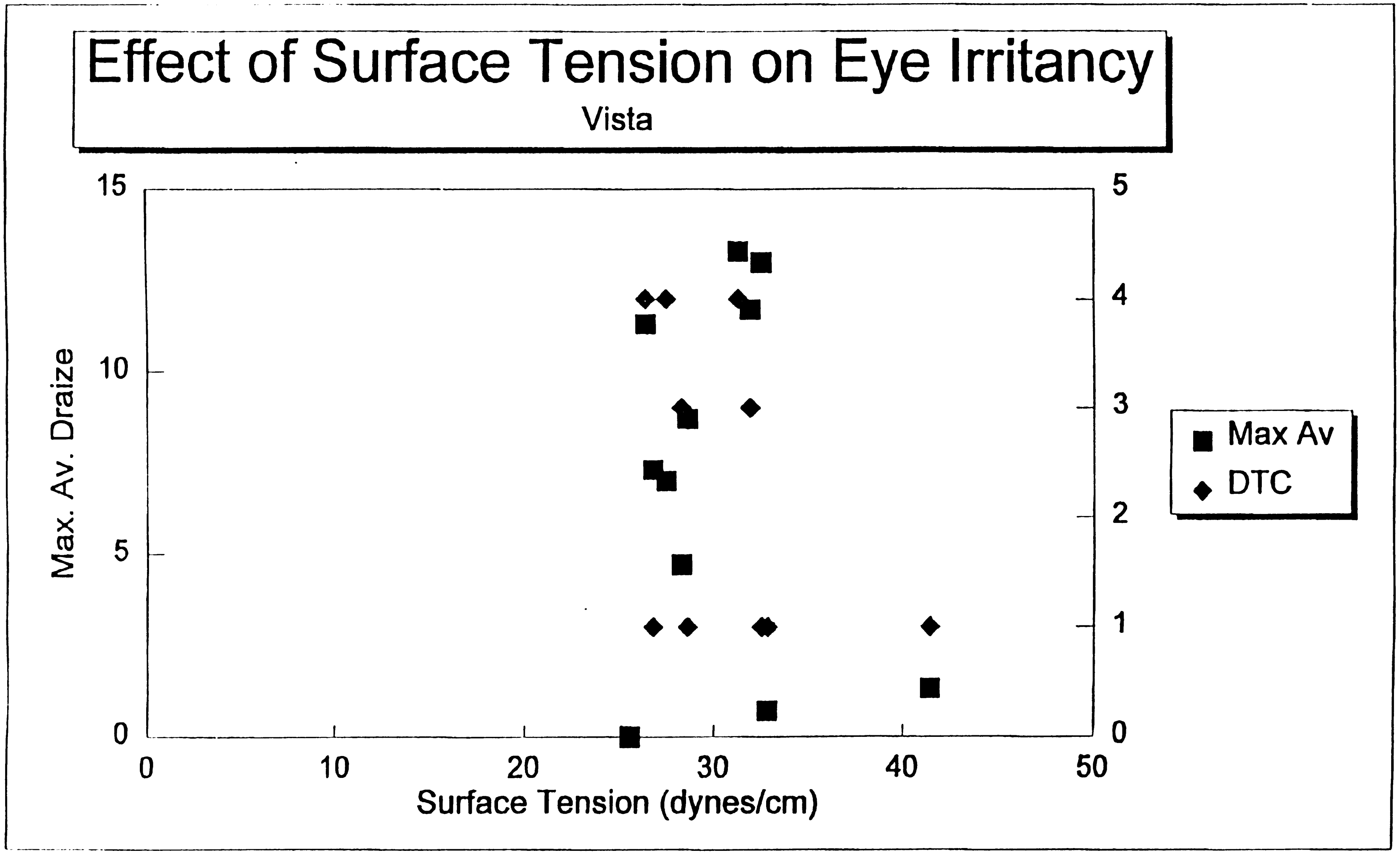
cc: R. Sedlak

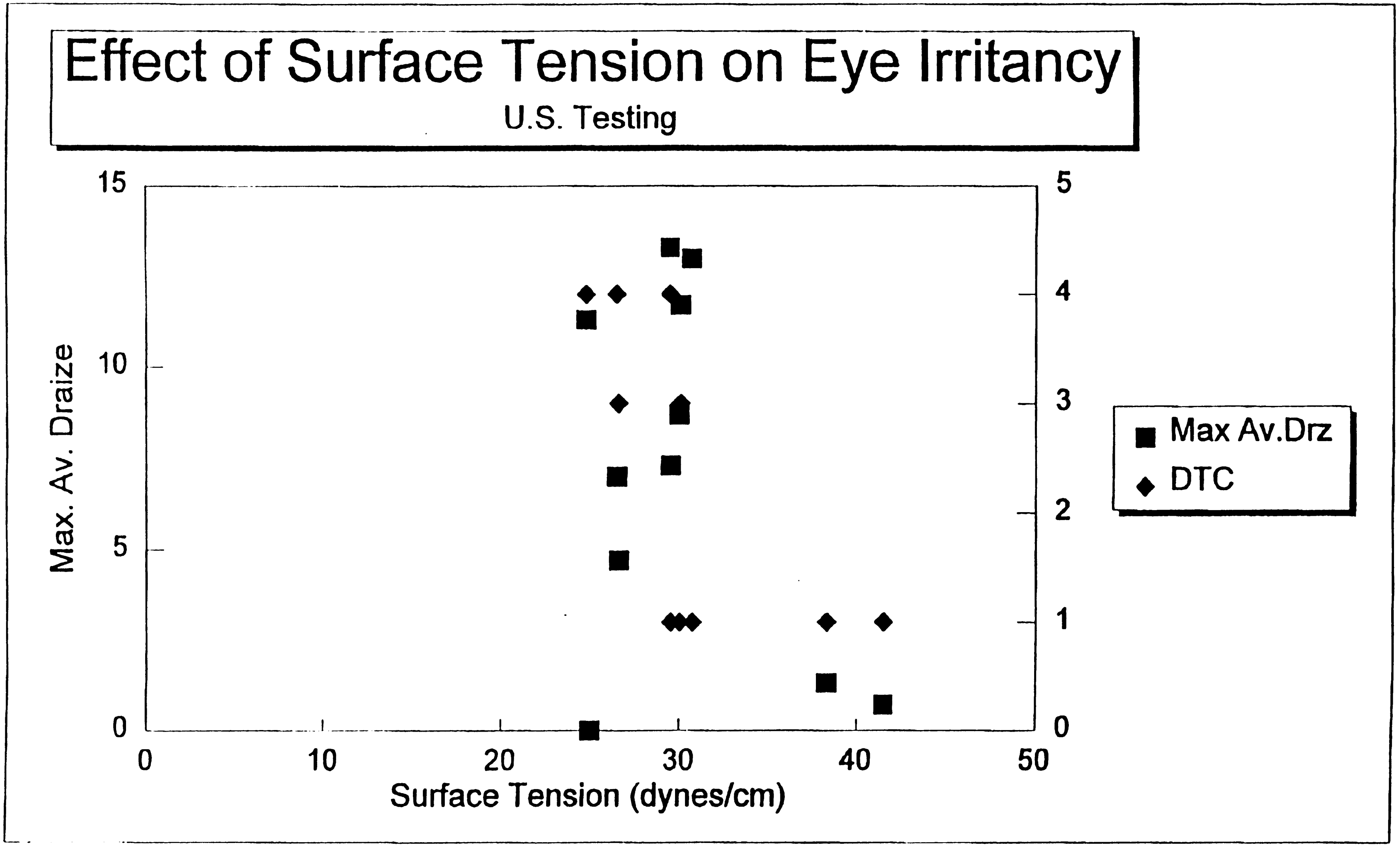
\em

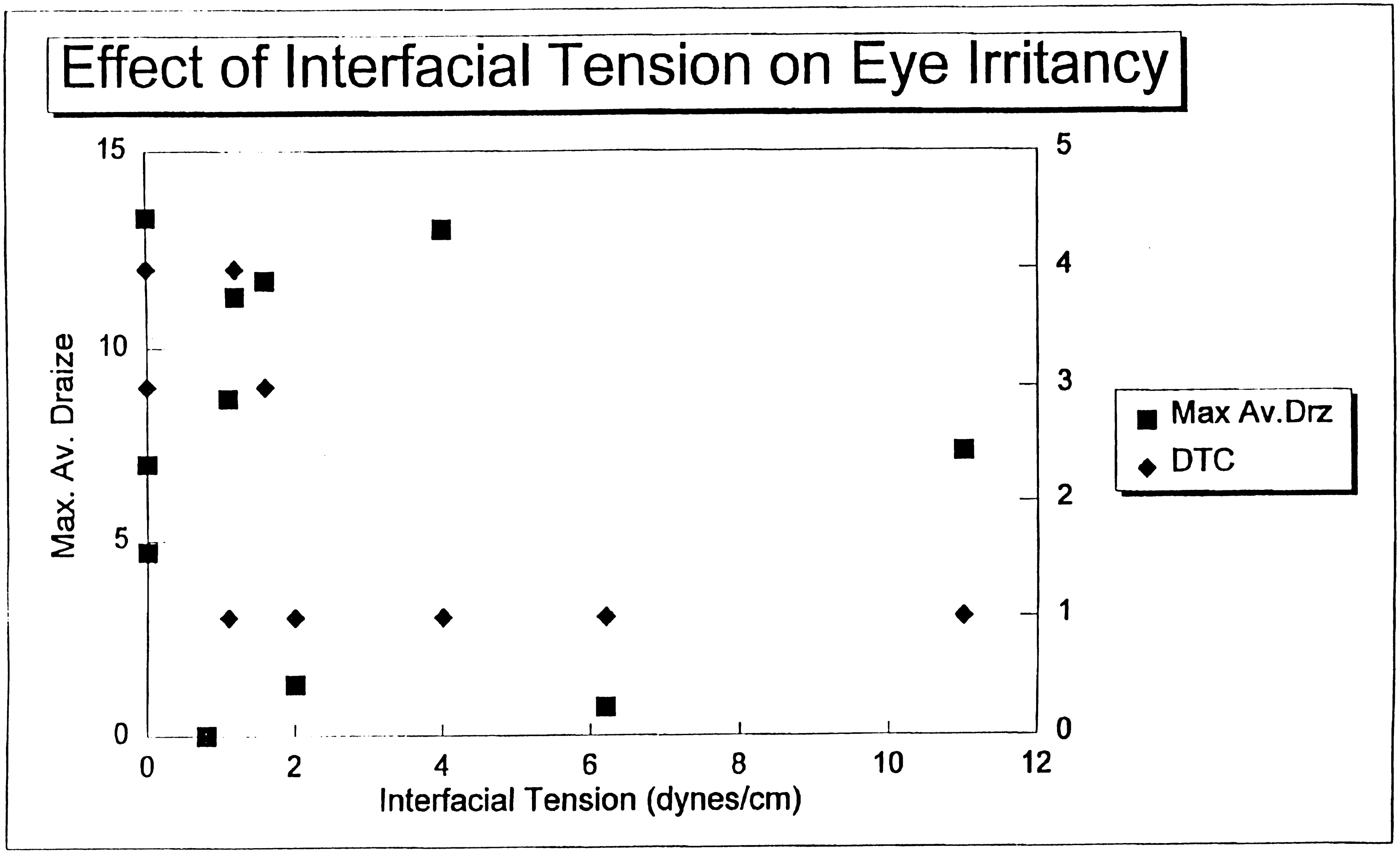
Alkyl Lngth	EO	Name	Max Av.Drz	DTC	pH	Surface Tension Vista	US Test	Interfcl Ten	Contct Ang.
12-13	6.5	Neodol 23-6.5	7	4	5.4	27.5	26.5	0	33.7
12-14	7	Alfonic 1412-7	4.7	3	5.8	28.3	26.6	0	46.7
8-10	5	Alfonic 810-5	11.3	4	6	26.4	24.8	1.2	29.3
12-13	3	Neodol 23-3	0	0	5.1	25.6	25	0.8	11.7
12	23	Brij-35	1.3	1	3.1	41.4	38.3	2	88.3
C9-ph	9.5	Triton N101	13.3	4	6.1	31.3	29.5	0	56
Sorbitan oleate	20	Tween 85	0.7	1	7.4	32.8	41.5	6.2	85
12-16-gluc(1.6)		Glucopon 625CS	8.7	1	9	28.6	30	1.1	74.3
C12 AO		Incromine Oxide L	13	1	10.5	32.5	30.7	4	58
C16CONH		Cocoamide DEA	7.3	1	10	26.8	29.5	11	68.3
C12 AO		Incromine Oxide L	11.7	3	7	31.9	30.1	1.6	35
						(DYNES/CM)	(DYNES/CM)	(DYNES/CM)	(Degrees)

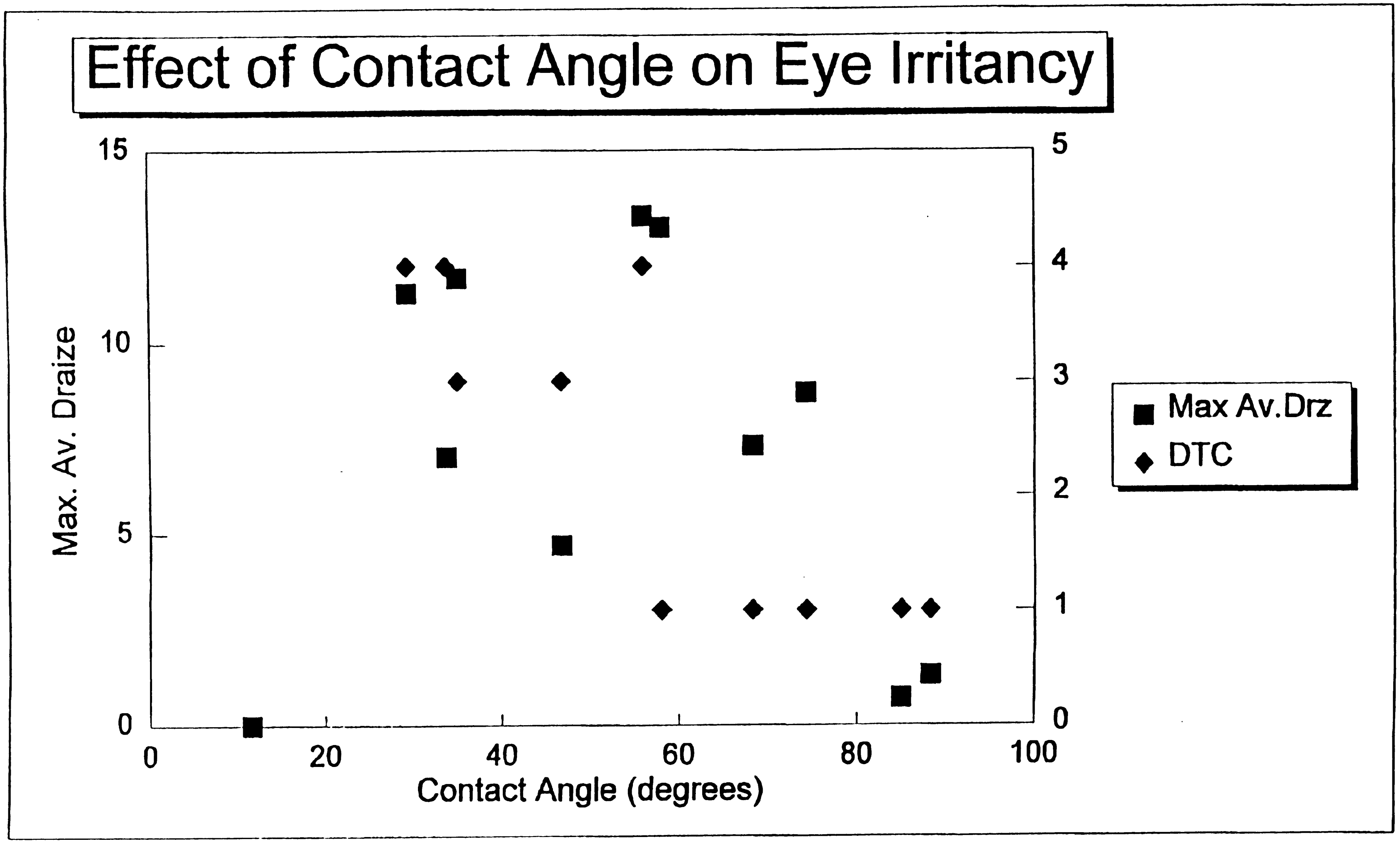
Effect of Alkyl Chain Length on Ocular Toxicity

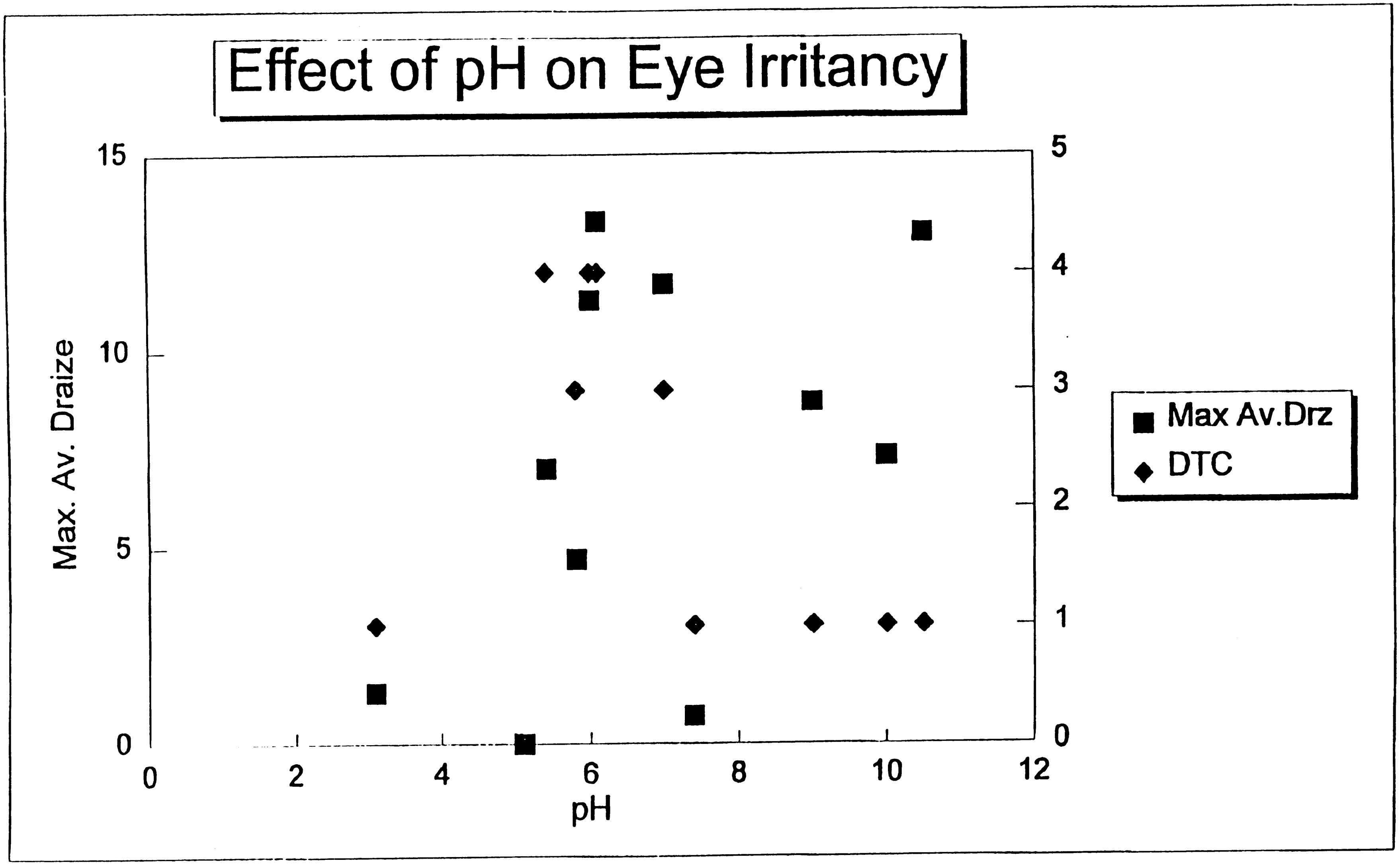


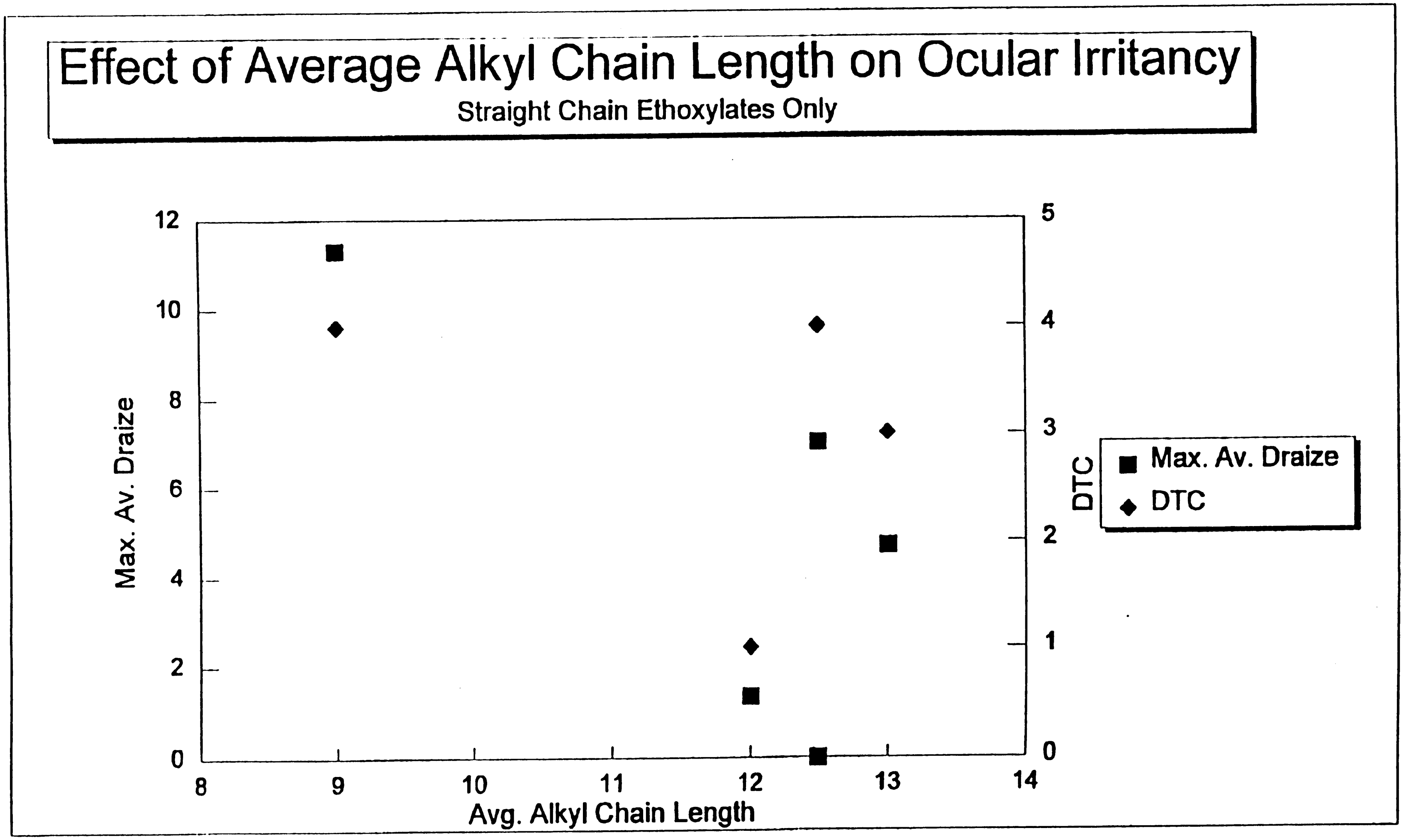

Effect of Surface Tension on Eye Irritancy
Vista
Max. Av. Draize
Surface Tension (dynes/cm)
0
5
10
15
0
1
2
3
4
5
0
10
20
30
40
50
Max Av
DTC

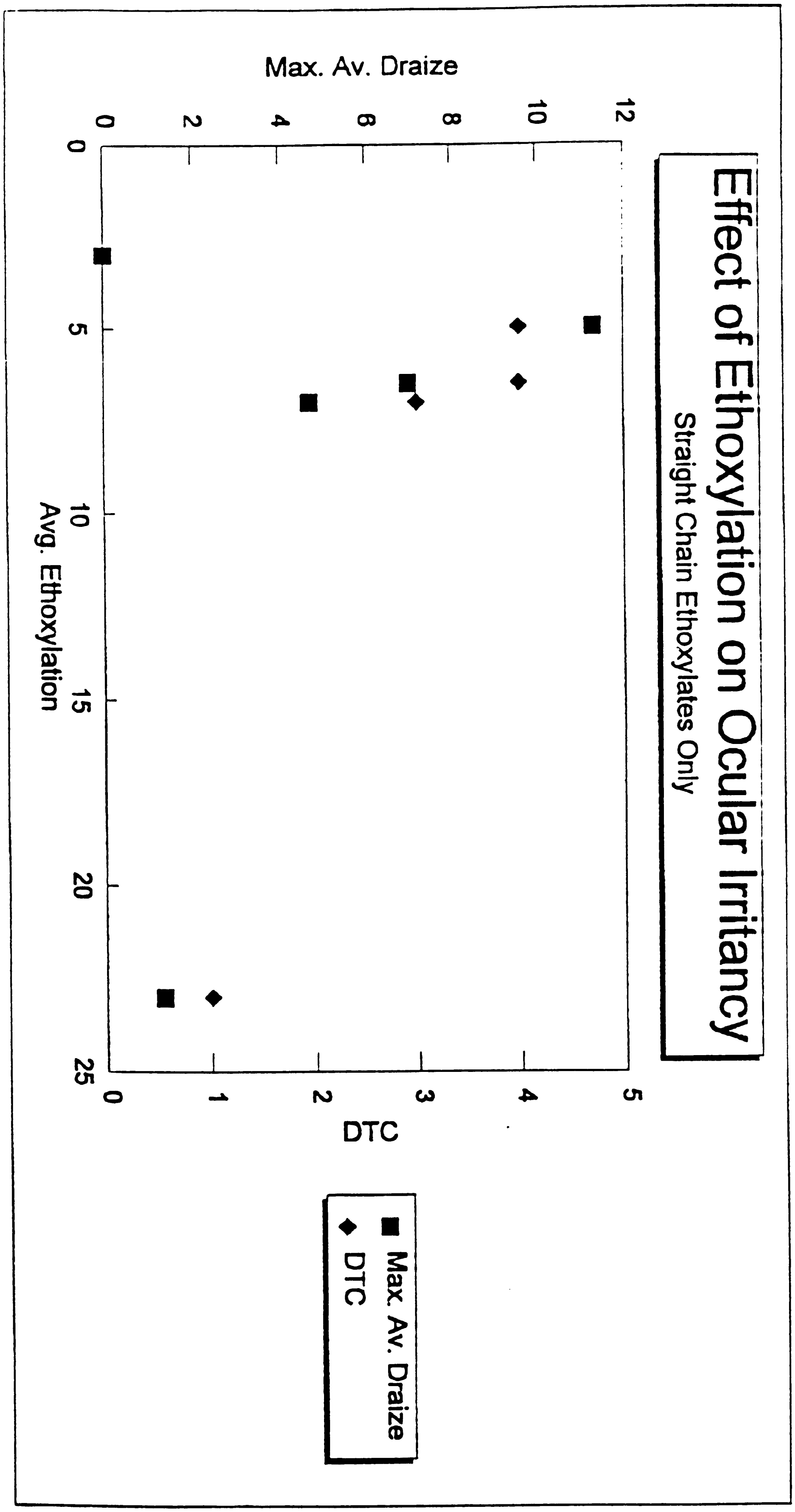

Effect of Surface Tension on Eye Irritancy
U.S. Testing
15
10
5
0
Max. Av. Draize
5
4
3
2
1
0
0
10
20
30
40
50
Surface Tension (dynes/cm)
Max Av.Drz
DTC


Effect of Interfacial Tension on Eye Irritancy
Max. Av. Draize
15
10
5
0
5
4
3
2
1
0
0
2
4
6
8
10
12
Interfacial Tension (dynes/cm)
Max Av.Drz
DTC


Effect of Contact Angle on Eye Irritancy
Max. Av. Draize
15
10
5
0
5
4
3
2
1
0
0
20
40
60
80
100
Contact Angle (degrees)
Max Av.Drz
DTC


Effect of pH on Eye Irritancy
Max. Av. Draize
pH
0
5
10
15
0
2
4
6
8
10
12
0
1
2
3
4
5
Max Av.Drz
DTC


Effect of Average Alkyl Chain Length on Ocular Irritancy
Straight Chain Ethoxylates Only
Max. Av. Draize
DTC
Avg. Alkyl Chain Length
0
2
4
6
8
10
12
0
1
2
3
4
5
8
9
10
11
12
13
14
Max. Av. Draize
DTC


Effect of Ethoxylation on Ocular Irritancy
Straight Chain Ethoxylates Only
Max. Av. Draize
0
2
4
6
8
10
12
Avg. Ethoxylation
0
5
10
15
20
25
DTC
0
1
2
3
4
5
Max. Av. Draize
DTC

Stat-Packets Statistical Analysis Package

Analysis of Variance [Data set: "Nonionic.wk1; range 1: b2..b34; range 2: a2..a34]

Design: One Factor Completely Randomized Design

Factor A (Fixed) - Col A
Level 1 -- 1
Level 2 -- 2
Level 3 -- 3
Level 4 -- 4
Level 5 -- 5
Level 6 -- 6
Level 7 -- 7
Level 8 -- 8
Level 9 -- 9
Level 10 -- 10
Level 11 -- 11

Descriptive Statistics for: Col B

Factor A: Col A

Cell Definition	N	Mean	SD
(A) Level 1	3	7.0000	3.6056
(A) Level 2	3	4.6667	3.0551
(A) Level 3	3	11.3333	4.932[illegible]
(A) Level 4	3	0.0000	0.000
(A) Level 5	3	1.3333	1.154
(A) Level 6	3	13.3333	6.806
(A) Level 7	3	0.6667	1.154
(A) Level 8	3	8.6667	5.859
(A) Level 9	3	11.6667	2.309
(A) Level 10	3	13.0000	0.000
(A) Level 11	3	7.3333	4.725

Anova Summary Table

Source of Variation	DF	Sum of Squares	Mean Squares	F	Significan Level
A	10	737.5758	73.7576	5.1459	0.0007
Error	22	315.3333	14.3333		
Total	32	1052.9091			

Stat-Packets Statistical Analysis Package

Analysis of Variance (Continued)

T-Test Between Cell Means - (Values of p are for a two-tailed test.)
Note: Statistics are only printed if p is less than or equal to .050

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t = 2.2645 Factor (A) Level 1
p = .0337 Factor (A) Level 4

t = 2.1567 Factor (A) Level 2
p = .0422 Factor (A) Level 3

t = 2.8037 Factor (A) Level 2
p = .0103 Factor (A) Level 6

t = 2.2645 Factor (A) Level 2
p = .0337 Factor (A) Level 9

t = 2.6958 Factor (A) Level 2
p = .0132 Factor (A) Level 10

t = 3.6663 Factor (A) Level 3
p = .0014 Factor (A) Level 4

t = 3.2350 Factor (A) Level 3
p = .0038 Factor (A) Level 5

t = 3.4506 Factor (A) Level 3
p = .0023 Factor (A) Level 7

t = 4.3133 Factor (A) Level 4
p = .0003 Factor (A) Level 6

t = 2.8037 Factor (A) Level 4
p = .0103 Factor (A) Level 8

t = 3.7741 Factor (A) Level 4
p = .0010 Factor (A) Level 9

t = 4.2055 Factor (A) Level 4
p = .0004 Factor (A) Level 10

t = 2.3723 Factor (A) Level 4
p = .0268 Factor (A) Level 11

t = 3.8820 Factor (A) Level 5
p = .0008 Factor (A) Level 6

t = 2.3723 Factor (A) Level 5
p = .0268 Factor (A) Level 8

t = 3.3428	Factor (A) Level 5
p = .0029	Factor (A) Level 9
t = 3.7741	Factor (A) Level 5
p = .0010	Factor (A) Level 10

Stat-Packets Statistical Analysis Package

Analysis of Variance (Continued)

t = 4.0976	Factor (A) Level 6
p = .0005	Factor (A) Level 7
t = 2.5880	Factor (A) Level 7
p = .0168	Factor (A) Level 8
t = 3.5585	Factor (A) Level 7
p = .0018	Factor (A) Level 9
t = 3.9898	Factor (A) Level 7
p = .0006	Factor (A) Level 10
t = 2.1567	Factor (A) Level 7
p = .0422	Factor (A) Level 11

Surf. #	MAS	MDTC
1	4	3
1	6	4
1	11	4
2	2	3
2	4	3
2	8	3
3	8	2
3	9	2
3	17	3
4	0	0
4	0	0
4	0	0
5	0	0
5	2	1
5	2	1
6	8	4
6	11	4
6	21	4
7	0	0
7	0	0
7	2	1
8	2	1
8	11	1
8	13	1
9	9	2
9	13	2
9	13	3
10	13	1
10	13	1
10	13	1
11	2	1
11	9	1
11	11	1

"Nonionic.wk1"

(Quattro Pro File)