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APPENDIX

APPENDIX A

STANDARD TEST METHOD

A - 1

Standard Test Method for

Foaming Characteristics of Lubricating Oils

ASTM D 892

1. Scope

1.1 This test method covers determination of foaming characteristics of lubricating oils at specified temperatures. Means of empirically rating the foaming tendency and the stability of the foam are described.

1.2 The values stated in acceptable SI units are to be regarded as the standard.

1.3 This standard does not purport to address all of the safety problems, if any, 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. For specific hazard statements.

2. Apparatus

2.1 *Foaming Test Apparatus*, shown in Fig. 1, consisting of a 1000 ml. graduated cylinder fitted with a lead ring to overcome the buoyancy, and air inlet tube, to the bottom of which is fastened a gas diffuser. The gas diffuser can be either a 25.4 mm. (1 in.) diameter spherical gas diffuser cone made of fused crystalline alumina grain, or a cylindrical metal diffuser made of sintered five micron porous stainless steel. The cylinder shall have a diameter such that the distance from the inside bottom to the 1000 ml. graduation mark is 360 ± 25

mm. It shall be circular at the top and shall be fitted with a rubber stopper having one hole at the center for the air-inlet tube and a second hole off-center for an air-outlet tube. The air-inlet tube shall be adjusted so that, when the rubber stopper is fitted tightly into the cylinder, the gas diffuser just touches the bottom the cylinder and is approximately at the center of the circular cross section.

2.2 *Test Baths*, large enough to permit the immersion of the cylinder at least to the 900 ml. mark and capable of being maintained at the temperatures constant to 0.5°C (1°F) at 24°C (75°F) and 93.5°C (200°F), respectively. Both bath and bath liquid shall be clear enough to permit observation of the graduations on the cylinder.

2.3 *Air Supply*, from a source capable of maintaining and air flow rate of 94 ± 5 ml/min. through the gas diffuser. The air shall be passed through a drying tower 300 mm. in height packed as follows: just above the constriction place a 20-mm. layer of cotton, then a 110-mm. layer of desiccant, a 40-mm. layer of indicating desiccant, a 30-mm. layer of desiccant and a 20-mm. layer of the cotton. The cotton serves to hold the desiccant in place. Refill the tower when the indicating desiccant begins to show presence of moisture. A flow meter sensitive to the required tolerances to be used to measure the air flow.

2.3.1 The total volume of air leaving the foaming test apparatus shall be measured by a volume measuring device capable of accurately measuring gas volumes of about 470 ml. The air shall be passed through at least one loop of copper tubing placed around the inside circumference of the cold bath so that the volume measurement is made at approximately 24 °C (75°F). Precaution are to be taken to avoid leaks at any point in the system.

2.4 *Timer*, graduated and accurate to 1 second or better.

2.5 Thermometer, having a range as shown in table A-1.1 and conforming to requirements as prescribed in specification IP thermometer.

Table A-1.1 Thermometer range

Temperature range	*Thermometer, ASTM*	*No.,IP*
-5 to 215°F	12F	64F
-20 to 102°C	12C	64C

3. Reagent and Materials

3.1 *Petroleum Distillate*

3.2 *Toluene*, nitration, or equivalent.

3.3 *Acetone*, ACS reagent grade, or equivalent.

3.4 *Petroleum Spirit*, 60/80 conforming to the IP specification.

4. Procedure

4.1 *Sequence I-Without*, mechanical shaking or stirring decant approximately 200 ml. of sample into a beaker. Heat to 49 ± 3°C (120 ± 5°F) and allow to cool to 24 + 3°C (75 ± 5°F) See option A for stored sample. Each step of procedure descried in 4.2 and 4.4,respectively,shall be carried out within 3 hrs. after completion of the previous step. In 4.3, the test shall be carried out as soon as compatible with the temperature specification and not more than 3 hrs. after immersion in the cylinder in the 93.5°C (200°F) bath.

4.2 Pour the sample into the 1000 ml. cylinder until the liquid level is at the 190 ml. mark. Immerse the cylinder at least to the 900 ml. mark in the bath maintained at the 24 ± 0.5 °C (75 ± 1°F). When the oil has reached the bath temperature, insert the gas diffuser and the air inlet tube with the air source disconnected,and permit the gas diffuser in soak for about 5 min. Connect the air outlet tube to the air volume measuring device. At the end of 5 min, connect to the air source,adjust the air flow rate to 94 ± 5 ml/min and force clean

dry air through the gas diffuser for 5 min + 3 sec. timed from the first appearance of air bubbles rising from the gas diffuser. At the end of this period, shut off the air flow in disconnecting the hose from the flow meter immediate record the volume of foam; the volume between the oil level and the top of foam. The total air volume when has passed through the system shall be 470 + 25 ml. Allow the cylinder to stand for 10 min ± 10 sec. and again record the volume of foam.

4.3 *Sequence II*-Pour a second portion of sample into a cleaned 1000 ml. cylinder until the liquid level is at the 180 ml. mark. Immerse the cylinder at least to the 900 ml. mark in the bath maintained at 93.5 ± 0.5°C (200 ± 1°F). When the oil has reached a temperature of 93 ± 1°C (199 ± 2°F), insert a gas diffuser and air inlet tube and proceed as described in 4.2, recording the volume of foam at the end of the blowing and settling periods.

4.4 *Sequence III*- Collapse any foam remaining after the test at 93.5°C (200°F), by steering. Cool the sample to a temperature below 43.5°C (110°F) by allowing the test cylinder to stand in air at room temperature, then place the cylinder in the bath maintained at 24 ± 0.5°C (75 ± 1°F). After the oil has reached bath temperature, insert a cleaned air inlet tube and gas diffuser and proceed as described in 4.2,recording the foam value at the end of the blowing and setting periods.

4.5 Some lubricants with modern additives can pass their foam requirements when blended (with the antifoam properly dispersed in small particle sizes) but fail to meet the same requirement after two or more weeks' storage. (It appears that the polar dispersant additives have the potency to attract and hold antifoam particles, such that the apparent increased antifoam size results in decreased effectiveness to control foam in D 892) However, If the same stored oil inmerely decanted and poured into engines, transmissions, or gear boxes and those units operated for the few minutes, the oil again meets its

foam targets. Similarly, *decanting* the stored oil into the blender, followed by agitation as described for Option A (see 4.5.1), redisperses the antifoam held in suspension and the oil again will good foam control in D 892. For such oils, Option A can be used. On the other hand, if the antifoam is not dispersed into sufficiently small particles when the oil is blended, the oil cannot meet its foam requirements. If this freshly blended oil were vigorously stirred according to Option A. it is very possible that the oil would then meet its foam targets whereas the plant blend would never do so. Therefore, it is inappropriate and misleading to apply Option A for quality control of freshly blends.

4.5.1 *Option A*-Clean the container of a 1-L. (1-qt), high speed blender. Place 500 ml. of sample measured from 18 to 32°C into the container, cover, and stir at maximum speed for 1 min. Because it is normal for considerable air to the entranced during this agitation, allow to stand until entranced bubbles have dispersed and the temperature of the oil has reached 24 ± 3°C. Within 3 hrs. following the agitation, start with testing as specified in 4.2.

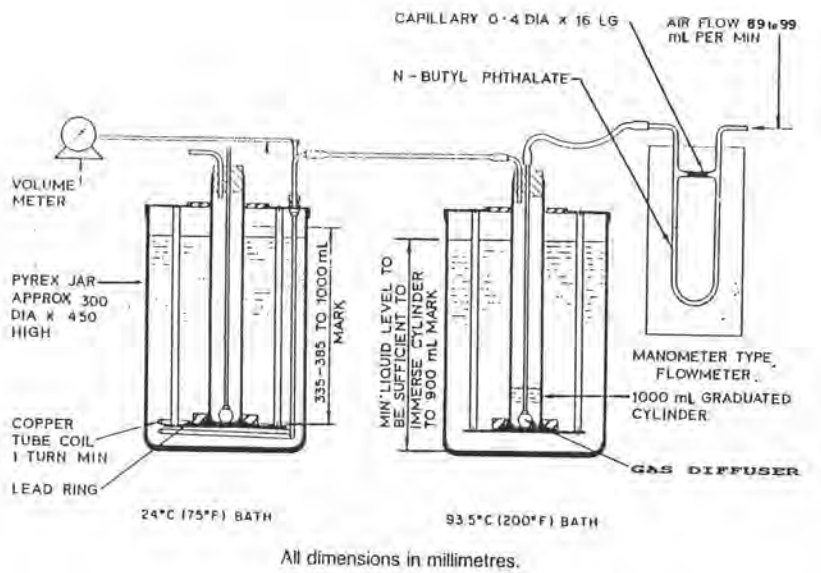


Figure A-1 Foaming test apparatus

A-2

Standard Test Method for

Kinematics Viscosity of Transparent and Opaque Liquid

ASTM D 445

1. Scope

1.1 This test method covers the determination of the kinematics viscosity of liquid petroleum products, both transparent and opaque, by measuring the time for a volume of liquid to flow under gravity through a calibrated glass capillary viscometer. The dynamic viscosity can be obtained by multiplying the measured kinematics viscosity by the density of liquid.

1.2 This test method intended primarily for application to liquids for which the shear stress and shear rates are proportional.

1.3 This test method depends on the behavior of the sample, and ideally the coefficient of viscosity should be independent of the rate of shear (this is commonly called Newtonian flow behavior). If, however, the coefficient of viscosity varies significantly with the rate of shear, different results may be obtained from viscometers of different capillary diameters.

2. Apparatus

2.1 *Viscometers* of the glass capillary type, calibrated and capable of measuring kinematics viscosity within the limit of precision. Viscometer list in table A-2.1 meet these requirements.

2.2 *Viscometer Holders* to enable the viscometer to be suspended in a similar position as when calibrated. The proper alignment of vertical parts may be confirmed by using a plumb line.

2.3 *Viscometer Thermostat and Bath* - Any transparent liquid or vapor

bath may be used, provided that it is of sufficient depth that at no time during the measurement will any portion of the sample in the viscometer be less than 20 mm below the surface of the bath liquid or less than 20 mm above the bottom of the bath.

2.3.1 The temperature control must be such that for the range from 15 - 100 °C (60-212 °F) the temperature of the bath medium does not vary by more than 0.01 °C (0.02 °F) over the range of the viscometers, or between the position of each viscometer, or at the location of the thermometer. For temperature outside this range, the variation must not exceed 0.03 °C (0.05 °F)

Table A-2.1 Viscometer Type

Viscometer Identification	Range, cSt (mm^2/s)[A]
1. Oswald type for Transparent liquids :	
1. Cannon Fenske routine[C]	0.5[B] - 20000
2. Zeitfuchs[C]	0.6 - 3000
3. SIL[C]	0.6 - 10000
4. Cannon-manning Semi-micro[C]	0.4 - 20000
5. BS/IP U-Tube[D]	0.9[B] - 10000
6. BS/IP U-tube Miniature[D]	0.2 - 100
7. Pinkevitch	0.6[B] - 17000
2. Suspended-Level Types for Transparent Liquids :	
1. Ubbelohde[C]	0.3[B] - 100000
2. FitzSimons[C]	0.6 - 1200
3. Atlantic[C]	0.75[B] - 5000
4. Cannon-Ubbelohde,Cannon-Ubbelohde dilution[C]	0.5[B] - 100000
5. Cannon-Ubbelohde semi-micro[C]	0.4 - 20000
6. BS/IP- Suspended Level[D]	3.5[B] - 100000
7. BS/IP- Suspended Level, Shortened Form[D]	1.05[B] - 10000
8. BS/IP Miniature Suspended Level[D]	0.6 - 3000
3. Reverse-flow Types for Transparent and Opaque Liquids:	
1. Zeitfuches Cross-Arm[C]	0.6 - 100000
2. Cannon-Fenske Opaque[C]	0.4 - 20000
3. Lantz-Zeitfuchs[C]	60 - 100000
4. BS/IP U-tube Reverse flow[D]	0.6 - 300000

[A] Each range quoted requires a series of viscometers. To avoid the necessity of making a kinetic energy correction, these

viscometers are designed for a flow time in excess of 200 sec. except where noted in Table 3.

[B] In each of these series, the minimum flow time for the viscometers with the lowest constant exceeds 200 sec.

[C] Specifications and operating instructions for these viscometers have been assembled in Specifications and Operating

instructions D 446.

[D] Specifications for these are given in appendixes to IP 71.

2.4 *Temperature-Measuring Device* - Standardized liquid in glass temperatures (Table A-2.2) of an accuracy after correction of 0.02 °C (0.04 °F) can be used, or any other thermometric device of equal or better accuracy. If standardized liquid in glass thermometers are used, it is recommended (but not required) that two thermometers be used, They must agree within 0.04 °C (0.07 °F)

Table A-2.2 Kinematics Viscosity Test Thermometer [A]

Test Temperature[B]	Scale Error[B]	Thermometer	Number
°F	°C	ASTM[C]	IP[D]
-65	-53.9	74F, C+	69F, C
-60 to -35	-51 to -35	43F	65F, C
-40	-40	73F, C	68F, C
-15	-26.1	126F, C	71F, C
	-20	127C	99C
0	-17.8	72F, C+	67F, C
32	0	128F, C	33F, C
68 and 70	20 and 21.1	44F, C	29F, C
77	25	45F, C	30F, C
86	30	118F, C	
100	37.8	28F, C	31F, C
	40	120C	92C
122	50	46F, C	66F, C
130	54.4	29F, C+	34F, C
140	60	47F, C	35F, C
	80		100C
180	82.2	48F, C	90F, C
200	93.3	129F, C	36F, C
210 and 212	98.9 and 100	30F	32F, C
	100	121C	
275	135	110F, C	

[A] The smallest graduation of the Fahrenheit thermometers is 0.1 °F and for the Celsius thermometers is 0.05 °C except for ASTM 43F and 65F for which it is 0.2 °F.

[B] Scale error for the Fahrenheit thermometers is not to exceed ± 0.2 °F (except for ASTM 110F which is ± 0.3 °F)

C Complete construction detail is given in Specification E 1.

D Complete construction detail is given in Part 1 of IP Standards for Petroleum and its Products.

+ Editorially corrected.

2.5 *Timing Device*- Any timing device may be used provided that the readings can be taken with a discrimination of 0.2 sec. or better, and that it has an accuracy within + 0.07 % when tested over intervals of 15 min.

2.5.1 Electrical timing devices may be used if the current frequency is controlled to an accuracy of 0.05 % or better. Alternating currents, as provided by some public power systems, are intermittently rather than continuously controlled. When used to actuate electrical timing devices, such control can cause large errors in viscosity flow measurements.

3. General procedure for Kinematics Viscosity

3.1 The specific de tails of operation vary for the different types of viscometers list in Table A-1.1. The operating in conditions for the different types of viscometers are given in Specification D 446.

3.2 Maintain the bath at the test temperature within limits given in 2.3.1 taking account of the precaution of the correction supplied on certifications of calibration.

3.2.1 In order to obtain the most reliable temperature measurement, it is recommended that two thermometer with valid calibration certificates be used. The thermometer should be held in an upright position under the condition of immersion as when calibrated. They should be used with a lens assembly giving about five times magnification and with should be arranged eliminate paralaxation.

3.3 Select a clean dry, calibrated viscometer having a covering the estimated kinematics viscosity (that is, a capillary for a very viscous liquid and a narrower for a more fluid liquid). The flow time should not less than 200 sec., or as noted in Table A-2.3.

Table A-2.3. Minimum flow times

Note- All sizes of all viscometers listed in Specification D 446 are designed for a flow time in excess off 200 sec., except as listed below. The minimum flow times for the six "BS/IP" viscometers listed in Table 1 are given in the appendices to IP 71.

Viscometer Identification	ASTM Size	Minimum flow time, sec.
Cannon-Fenske routine	25	250
Ubbelohde	0	300
Atlantic	0C	250
Cannon-Ubblohde, Cannon-Ubblohde dilution	25	250

3.3.1 When the test temperature is below the dew point, is loosely packed drying tubes to the open ends of the viscometer. The drying tubes must fit the design of the viscometer and not restrict the flow of the sample by ensures created in the instrument. Carefully flush the moisten near from the viscometer by applying vacuum to one of drying tubes. Finally, before placing the viscometer in the draw up the sample into the working capillary and drying bulb and allow to drain back as an additional against moisture condensing or freezing on the tubes.

3.3.2 Viscometers used for silicone fluids, fluoro-carbons, the other liquids which are difficult to remove by the use of cleaning agent, should be reserved for the exclusive use of the fluids except when calibrating. Such viscometers should be subjected to calibration checks at frequent inter. The solvent washings from these viscometers should not used for the cleaning of other viscometers.

4. Cleaning of Viscometer

4.1 Between successive determinations, clean the viscometer thoroughly by several rinsings with an appropriate solvent completely miscible with the sample, followed by a completely volatile solvent. Dry the tube by passing the slow stream of filtered dry air through the viscometer for 2 min. or until the last trace of solvent is removed.

4.2 Periodically clean the viscometer with chromic acid cleaning solution for at least twelve hours to remove residual traces of organic deposits, nonchromium-containing, strongly oxidizing acid cleaning solutions may be substituted so as to avoid disposal problems of chromium-containing solutions. Rinse thoroughly with distilled water followed by acetone, and dry with clean , dry air. Inorganic deposits may be removed by hydrochloric acid treatment before use of cleaning acid, particularly if barium salts are suspected. The use of alkaline cleaning solutions is not recommended as this can enlarge the working capillary and necessitate recalibration.

Standard Test Method for

Determination of Additive Elements in Lubricating Oils by

Inductively Coupled Plasma Optical Emission Spectrometry(ICP-OES)

ASTM D 4951

1. Scope

1.1 This method describes a procedure for the determination of calcium, magnesium, zinc , barium in unused lubricating oils by ICP-OES. The ranges of metal contents that can be analyzed by the method are given below.

Calcium	0.05-0.5 % m/m
Zinc	0.05-0.3 % m/m
Magnesium	0.05-0.3 % m/m
Phosphorus	0.05-0.3 % m/m
Barium	0.1-1.0 % m/m

1.2 The method can be extended to concentrations below these ranges by increasing the sample mass. In this case it is essential that base oil is added to the calibration standard solutions, to match the oil content of the sample solution.

1.3 The method can be extended to concentrations above these ranges by diluting into the appropriate range using a base oil.

1.4 The method can be used to measure a single element or up to 5 elements in the lubricating oil.

2. Apparatus

2.1 *ICP-OES Spectrometer System*, either simultaneous or sequential type.

2.2 *Analytical balance.*

2.3 *Polythene/plastic bottles*, 125 ml. capacity with screw caps. Alternatively a suitable glass vessel e.g. stoppered flask, can be used.

2.4 *Peristaltic pump*, with pumping capacity of 0.5 to 3 ml/min., fitted with pump tubing which can withstand at least 6 hr. exposure to the solvent used.

3. Reagents and Materials

3.1 *Organic solvent*, boiling range 160-200 ^{o}C, aromatics content 25 % V., max, flash point above 40 ^{o}C, filtered through a membrane not greater than one μm pore size. Suitable solvents include white spirit, kerosene, Shellsol D40 and Shellsol D60.

3.2 *Base oil*, with a kinematics viscosity of about 4 mm^2/s (cSt) at 100 ^{o}C and free of contamination from calcium, zinc, phosphorus, magnesium and barium.

3.3 *Organometallic Standards*, single element containing 5000 mg/kg of calcium or zinc or phosphorus or magnesium or barium.

3.4 *Multielement calibration standards*, concentrations as given in section 4, are prepared by combining, diluting and mixing single element organometallic standards.

4. Preparation of Calibration Standards

4.1 Before using this method for the first time, check the linear range of the instrument for each element by running the standard concentrations of 0,5,10 and 25 mg/kg. If the range is linear then a two point calibration using 0 and 25 mg/kg. is satisfactory. If not then at least one additional standard, of concentration between the blank and 25 mg/kg standard is required.

4.2 Prepare a 25 mg/kg standard solution of the elements of interest as follows: Weight accurately (to 0.1 mg) into a suitable container (2.3) 0.5 g of each of required single element calibration standard (3.3). If the number of single element calibration standards used is less than 5, make the total mass in the container equal to 2.5 g by the addition of base oil (3.2). Add solvent (3.1), weighing accurately (to 0.1 mg) to make the total mass in the container equal to 100 g. Cap/stopper the container and shake thoroughly to homogenize. Calculate the exact concentration Z, of each element in the solution from the equation;

$$Z = \frac{5000 \times m}{M}$$

Where, m = mass of single element standard, g.

M = total mass (i.e. standard + base + solvent), g.

4.3 Prepare a zero mg/kg standard (i.e.) a blank) by weighing 2.5 g of base oil (3.2) into a suitable container, add a solvent to make the total mass equal to 100 g and homogenize.

5. Preparation of Sample Solutions

5.1 The required mass of oil sample is calculated from the highest element concentration in the sample, using the equation:

$$\text{Sample mass} = 0.25 / C_{max}$$

Where, C_{max} = expected highest element concentration in the sample (e.g. for an oil containing 0.5 % m/m Ca, 0.1 % m/m Zn and 0.05 % m/m Mg then $C_{max} = 0.5$)

then a separate solution shall be prepared for the phosphorus determination, using an increased mass of sample, up to a maximum of 2.5 g.

5.2 Weigh accurately (to 0.1 mg) into a suitable container the required mass of oil sample; do not exceed 2.5 g. Add base oil, If necessary, to make the total mass equal to 2.5 g. Add solvent to make the total mass equal to 100 g. Cap/stopper the sample container and homogenize the solution.

5.3 Prepare the sample solution in duplicate.

6. Procedure

6.1 Consult the manufacturer's instructions for details of the RF power, plasma gas flow rates and solution uptake rate for operating with organic solvents. Only general instructions are given for setting up the spectrometer because of basic design differences of ICP generators and optical systems.

6.2 Check the peristaltic pump tubing daily for signs of wear (splitting, flattening, hardening, softening etc.). Replace if necessary.

6.3 Ignite the plasma and adjust the RF power, gas flow rates and solution uptake rate to the settings recommended by the manufacturer for organic solvent introduction.

6.4 Perform any procedures recommended by manufacturer to ensure the instrument is working correctly e.g. wavelength calibration, sensitivity check.

6.5 Select a suitable wavelength for each element which is free from interference caused by other elements. Ideally, a sequence or program shall be created to allow the measurement of all the wavelength of interest. (table A-3.1)

Table A-3.1 Suitable Atomic Emission Wavelengths

Elements	**Wavelengths, nm**
Barium	233.527,455.4,493.409,413.006,293.654
Calcium	396.847,317,933,422.673
Magnesium	279.55,285.213,279.806,279.079
Zinc	213.856,202.548,206.200
Phosphorus	213.618,214.914,253.565

6.6 Enter the exact concentrations of the calibration standards into the computer.

6.7 Calibrate the instrument by aspirating the zero standard and then aspirating the 25 mg/kg standard.

6.8 Check the calibration by analyzing a reference sample i.e. a sample of know concentration. Alternatively the 25 mg/kg standard can be used.

6.9 Aspirate the sample solution and initiate the data collection.

6.10 Allow a rise time between each sample and/or calibration standard. This shall be no less than 60 seconds. It is acceptable to use the sample solution for the rinsing period.

6.11 Analyze up to four sample solutions between calibration checks. If the calibration check is not satisfactory then the last group of samples shall be re-analyzed.

A - 4

Standard Test Method for

Pour Point of Petroleum Products

ASTM D 97

1. Scope

1.1 This test method is intended for use on any petroleum product. A procedure suitable for black specimens, cylinder stock, and nondistillate fuel oil.

1.2 This standard does not purport to address all of the safety problems, 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. Apparatus

2.1 *Test jar*, cylindrical, of clear glass, flat bottom, 33.2 to 34.8 mm. outside diameter, and 115 to 125 mm. in height. The inside diameter of the jar can range from 30.0 to 32.4 mm, within the constraint that the wall thickness be no greater than 1.6 mm. The jar shall have a line to indicate a sample height 54 ± 3 mm. above the inside bottom.

2.2 *Thermometers*, having ranges shown below and conforming to the requirements prescribed for thermometers:-

Table A-4.1 Specification of thermometer for ASTM D 97

Thermometer	Temperature rang	Thermometer Number	
		ASTM	IP
High cloud and pour	-38 to + 50 ° C	5C	1C
Low cloud and pour	-80 to + 20 ° C	6C	2C
Melting point	+32 to + 127 ° C	61C	63C

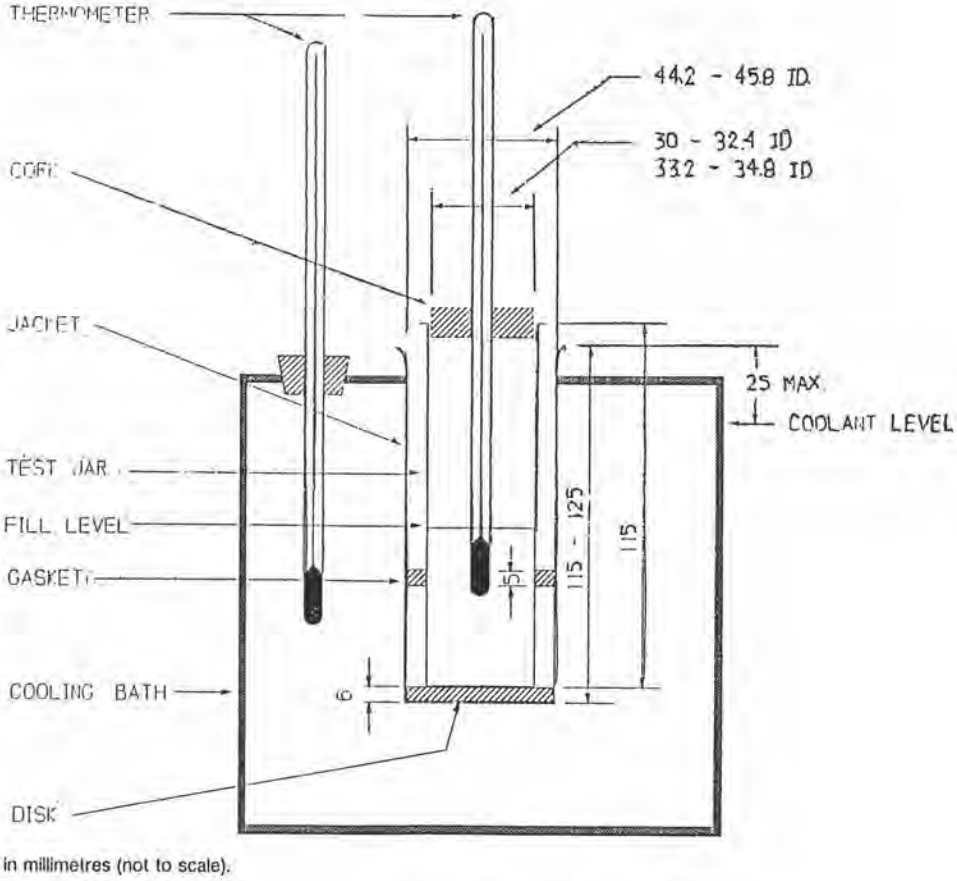
2.3 *Cork*, to fit the test jar, bored centrally for the test thermometer.

2.4 *Jacket*, water tight, cylindrical, metal, flat bottomed, 115 + 3 mm. depth, with inside diameter of 44.2 to 45.8 mm. It shall be supported in a vertical position in the cooling bath, so that not more than 25 mm. projects out of the cooling medium, and shall be capable of being cleaned.

2.5 *Disk*, cork or felt, 6 mm. thick to fit loosely inside the jacket.

2.6 *Gasket*, to fit snugly around the outside of the test jar and loosely inside the jacket. The gasket may be made of rubber, leather, or other material that is elastic enough to cling to the test jar and hard enough to hold its shape. Its purpose is to prevent the test jar from touching the jacket.

2.7 *Bath or Baths*, maintained at prescribed temperatures with a firm support to hold the jacket vertical. The required bath temperatures may be obtained by refrigeration if available, otherwise by suitable freezing mixtures.



NOTE—Dimensions are in millimetres (not to scale).

Figure A-4.1 Apparatus for Pour Point test.

3. Reagents and Materials

The technical grade are appropriate for low-temperature bath media.

3.1 *Acetone*

3.2 *Alcohol, Ethanol*

3.3 *Alcohol, Methanol*

3.4 *Petroleum Naphtha*

3.5 *Solid Carbon Dioxide*

4. Procedure

4.1 Pour the oil into the test jar to the level mark. When necessary, heat the oil in a water bath until it is just sufficiently fluid to pour into the test jar.

4.2 Close the test jar with the cork carrying the high-pour thermometer. Adjust the position of the cork and thermometer so the cork fits tightly, the thermometer and the jar are coaxial, and the thermometer bulb is immersed so the beginning of the capillary is 3 mm. below the surface of the oil.

4.3 See that the disk, gasket, and the inside of the jacket are clean and dry. Place the disk in the bottom of the jacket. Place the gasket around the test jar, 25 mm. from the bottom. Insert the test jar in the jacket. Never place a jar directly into the cooling medium.

4.4 After the oil has cooled to allow the formation of paraffin wax crystals, take great care not to disturb the mass of oil nor permit the thermometer to shift in the oil; any disturbance of the spongy network of wax crystals will lead to low and erroneous results.

4.5 Pour points are expressed in integers that are positive or negative multiples of 3 °C. Begin to examine the appearance of the oil when the temperature of the oil is 9 °C above the expected pour point. At each test thermometer reading that is a multiple of 3 °C below the starting temperature,

remove the test jar from the jacket. To remove condensed moisture that limits visibility wipe the surface with a clean cloth moistened in alcohol (Ethanol or Methanol).

4.6 Continue in this manner until a point is reached as which the oil shows no movement when the test jar is held in a horizontal position for 5 second. Record the observed reading of the test thermometer.

A-5

Standard Test method for

Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer method

ASTM D 1298

1. Scope

This practice covers the laboratory determination, using a glass hydrometer, of the density, relative density (specific gravity), or API gravity of crude petroleum, petroleum products, or mixtures of petroleum and nonpetroleum products normally handled as liquids, and having a Reid vapor pressure of (179 kPa) 26 lb or less. Values are measured on a hydrometer at convenient temperatures, readings of density being reduced to 15 °C, and readings of relative density and API gravity to 60 °F, by means of international standard tables. By means of these same tables, values determined in any one of the three systems of measurement are convertible to equivalent values in either of the other two so that measurements may be made in the units of local convenience.

2. Apparatus

2.1 *Hydrometers*, glass, graduated in units of density, relative density, or API gravity as required, determining to ASTM specification or specification of IP standards

2.2 *Thermometers*, having ranges shown in table 2 and determining to specifications of the American Society for Testing and Material or the Institute of Petroleum.

2.3 *Hydrometer cylinder*, clear glass, plastic, or other for convenience in pouring, the cylinder may have a rim. The inside diameter of the cylinder shall be at 25 mm. greater than the outside diameter of the hydrometer used in it. The

height of the cylinder shall be such appropriate hydrometer floats in the sample with at 25 mm. clearance between the bottom of the hydrometer and the bottom of the cylinder.

2.4 *Constant-temperature bath*, for use when the nature of the sample requires a test temperature much above or below room temperature.

3. Procedure

3.1 Adjust the temperature of sample, bring the hydrometer cylinder and thermometer to approximately the same temperature as the sample to be tested.

3.2 Transfer the sample to a clean hydrometer cylinder without spashing, to avoid the formation of air bubbles, and to reduce to a minimum evaporation of the lower boiling constituents of more volatile samples. Transfer highly volatile samples to the cylinder by water displacement. Remove any air bubbles formed, after they have collected on the surface of sample, by touching them with a piece of clean filter paper before inserting the hydrometer.

3.3 Place the cylinder containing the sample in a vertical position in a location free from air currents. Ensure that the temperature of the sample does not change appreciably during the time necessary to complete the test; during this period, the temperature of the surrounding medium should not change more than 2°C (5°F). When testing at temperatures much above or below room temperature, a constant temperature bath may be necessary to avoid excessive temperature changes.

3.4 Lower the hydrometer gently into the sample. Take care to avoid wetting the stem above the level to which it will be immersed in the liquid. Continuously stir the sample with the thermometer, Taking care that the mercury thread is kept fully immersed and that the stem of the hydrometer is not wetted above the immersion level. As soon as a steady reading is obtained,

record the temperature of the sample to nearest 0.25°C (0.5°F) and then remove the temperature.

3.5 Depress the hydrometer about two scale divisions into the liquid, and then release it. The remainder of the stem of the hydrometer, which is above the level of the liquid, must be kept dry since unnecessary liquid on stem affects the reading obtained. With samples of low viscosity, impart a slight spin to the hydrometer on releasing to assist in bringing it to rest, floating freely away from the walls of the cylinder. Allow sufficient time for the hydrometer to come to rest, and for all air bubbles to come to the surface. This is particularly necessary in the case of more viscous samples.

3.6 When the hydrometer has come to rest, floating freely away from the walls of the cylinder, estimate the hydrometer scale reading to the nearest 0.0001 relative density (specific gravity) or density or 0.05°API. The correction hydrometer reading is that point on the hydrometer scale which the principle surface of the liquid cuts the scale. Determine this point by placing the eye slightly below as seen as a distorted ellipse, appears to become a straight cutting the hydrometer scale. (see figure A-5.1.)

3.7 With an opaque liquid take a reading by observed with the eye slightly above the plane of the surface of liquid, the point on the hydrometer scale to which sample rises. This reading, at the top of the minimize requires correction since hydrometers are calibrated to read at the principal surface of the liquid. The correction of the particular hydrometer in use may be determined observing the maximum height above the principal surface of the liquid to which oil rises on the hydrometer scale. The hydrometer in question is immersed in a transparent having a surface tension similar to that of the sample to test. (see figure A-5.2)

3.8 Immediately after observing the hydrometer value, again cautiously stir the sample with the thermometer keeping the mercury thread fully immersed. Recorded temperature of the sample to the nearest 0.2°C (0.5°F).

Should this temperature differ from the previous reading by more than 0.5°C (1°F), repeat the hydrometer test then thermometer observations until the temperature comes stable within 0.5°C (1°F).

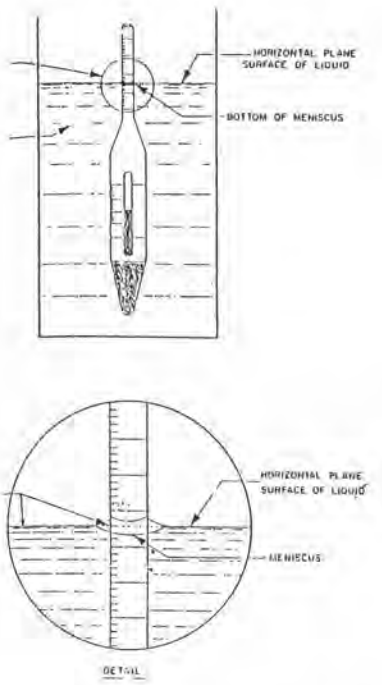


Figure A-5.1 Hydrometer scale reading for Transparent liquids

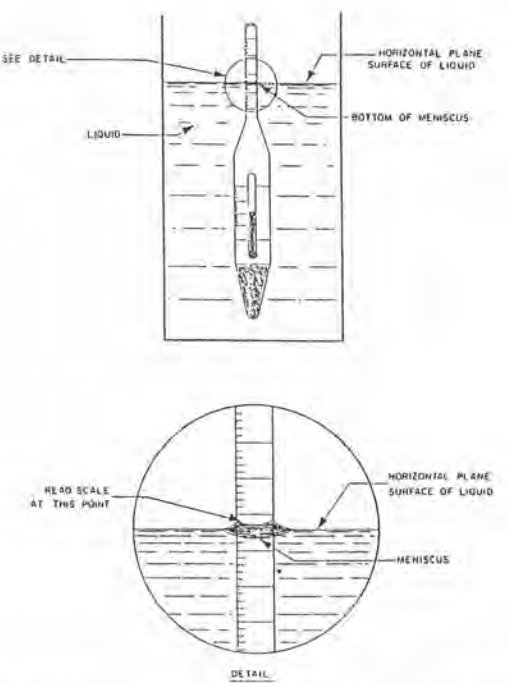


Figure A-5.2 Hydrometer scale reading for Opaque fluids.

APPENDIX B

BASIC OIL SPECIFICATION

Product : BASIC OIL-1

Table B-1 Specification of BASIC OIL-1

Properties	Unit	Method	Results
Appearance	-	Visual	Cl. & Br.
Density @ 15 Deg C	kg/l.	ASTM D 1298	0.885-0.895
Color, ASTM	-	ASTM D 1500	3.5 Max
Flash point, PMcc	Deg. C	ASTM D 93	228 Min
Viscosity @ 40 Deg C	cSt.	ASTM D 445	90-110
Viscosity @ 100 Deg C	cSt.	ASTM D 445	10.7-11.8
Viscosity index	-	ASTM D 2270	95 Min
Crackle test	-	-	pass
Pour point	Deg. C	ASTM D 97	-9 Max

BASIC OIL-1 is a paraffinic base oil refined from crude oil for use as a blending component of lubricating and greases.

Product : BASIC OIL-2

Table B-2 Specification of BASIC OIL-2

Properties	Unit	Method	Results
Appearance	-	Visual	Cl. & Br.
Density @ 15 Deg C	kg/l.	ASTM D 1298	0.896-0.920
Color, ASTM	-	ASTM D 1500	5.5 Max
Flash point, PMcc	Deg. C	ASTM D 93	267 Min
Viscosity @ 40 Deg C	cSt.	ASTM D 445	440-550
Viscosity @ 100 Deg C	cSt.	ASTM D 445	30.5-33.5
Viscosity index	-	ASTM D 2270	95 Min
Crackle test	-	-	pass
Pour point	Deg. C	ASTM D 97	-9 Max

BASIC OIL-2 is a paraffinic base oil refined from crude oil for use as a blending component of lubricating and greases.

Product : BASIC OIL-3

Table B-3 Specification of BASIC OIL-3

Properties	Unit	Method	Results
Appearance	-	Visual	Cl. & Br.
Density @ 15 Deg C	kg/l.	ASTM D 1298	0.86-0.88
Color, ASTM	-	ASTM D 1500	1.5 Max
Flash point, PMcc	Deg. C	ASTM D 93	200 Min
Viscosity @ 40 Deg C	cSt.	ASTM D 445	22-27
Viscosity @ 100 Deg C	cSt.	ASTM D 445	4.4-4.9
Viscosity index	-	ASTM D 2270	95 Min
Crackle test	-	-	pass
Pour point	Deg. C	ASTM D 97	-15 Max

BASIC OIL-3 is a paraffinic base oil refined from crude oil for use as a blending component of lubricating and greases.

Product : BASIC OIL-4

Table B-4 Specification of BASIC OIL-4

Properties	Unit	Method	Results
Appearance	-	Visual	Cl. & Br.
Density @ 15 Deg C	kg/l.	ASTM D 1298	0.89-0.92
Color, ASTM	-	ASTM D 1500	1.5 Max
Flash point, PMcc	Deg. C	ASTM D 93	153 Min
Viscosity @ 40 Deg C	cSt.	ASTM D 445	18.7-21.0
Viscosity @ 100 Deg C	cSt.	ASTM D 445	-
Viscosity index	-	ASTM D 2270	-
Crackle test	-	-	pass
Pour point	Deg. C	ASTM D 97	-33 Max

BASIC OIL-4 is a paraffinic base oil refined from crude oil for use as a blending component of lubricating and greases.

Product : BASIC OIL-5

Table B-5 Specification of BASIC OIL-5

Properties	Unit	Method	Result
Appearance	-	Visual	Clear
Density @ 15 Deg C	kg/l.	ASTM D 1298	0.970 Min
Flash point, PMcc	Deg. C	ASTM D 93	230 Min
Viscosity @ 40 Deg C	cSt.	ASTM D 445	Report
Viscosity @ 100 Deg C	cSt.	ASTM D 445	50 Min
Viscosity index	-	ASTM D 2270	Report
Ash content	% Wt.	ASTM D 482	0.02 Max
Total Acid Number, TAN	mg KOH/g.	ASTM D 974	0.1 Max
Pour point	Deg. C	ASTM D 97	38 max

APPENDIX C

ADDITIVE SPECIFICATION

Table C-1 Specification of lubricant additive (1)

Properties	Unit	Method	Result
Appearance	-	Visual	Clear
Density @ 20 Deg C	kg/l.	ASTM D 1298	0.99 (Typical)
Color, ASTM	-	ASTM D 1500	2.0 Max
Flash point, PMcc	Deg. C	ASTM D 93	145 Min
Viscosity @ 40 Deg C	cSt.	ASTM D 445	180 (typical)
Viscosity @ 100 Deg C	cSt.	ASTM D 445	18-30
Viscosity index	-	ASTM D 2270	report
Crackle test	-	-	pass
Pour point	Deg. C	ASTM D 97	-24 (typical)

Application : Lubricant Additive

Function : Detergent, corrosion, anti-oxidant

Description : Over-based calcium alkyl salicylate

Table C-2 Specification of lubricant additive (2)

Properties	Unit	Method	Result
Appearance	-	Visual	Clear
Density @ 20 Deg C	kg/l.	ASTM D 1298	0.87 (typical)
Color, ASTM	-	ASTM D 1500	3.0 Max
Flash point, COC	Deg. C	ASTM D 92	150 Min
Viscosity @ 40 Deg C	cSt.	ASTM D 445	3000-5000
Viscosity @ 100 Deg C	cSt.	ASTM D 445	250-400
Viscosity index	-	ASTM D 2270	report
Crackle test	-	-	pass
Pour point	Deg. C	ASTM D 97	-18 (typical)

Application : Lubricant Additive

Function : Pour point depressant

Description : Polyalkyl methacrylate

Table C-3 Specification of lubricant additive (3)

Properties	Unit	Method	Result
Appearance	-	Visual	Clear
Density @ 15 Deg C	kg/l.	ASTM D 1298	1.06 (typical)
Color, ASTM	-	ASTM D 1500	report
Flash point, PMcc	Deg. C	ASTM D 93	200 Min
Viscosity @ 40 Deg C	cSt.	ASTM D 445	99 (typical)
Viscosity @ 100 Deg C	cSt.	ASTM D 445	report
Viscosity index	-	ASTM D 2270	report
Crackle test	-	-	pass
Pour point	Deg. C	ASTM D 97	report

Application : Lubricant Additive

Function : Anti-rust demulsifier

Description : Nonylphenol ethoxylate

Table C-4 Specification of lubricant additive (4)

Properties	Unit	Method	Result
Appearance	-	Visual	Clear
Density @ 15 Deg C	kg/l.	ASTM D 1298	1.110 (typical)
Color, ASTM	-	ASTM D 1500	Dark blown
Flash point, PMcc	Deg. C	ASTM D 93	150 Min
Viscosity @ 40 Deg C	cSt.	ASTM D 445	17,000 (typical)
Viscosity @ 100 Deg C	cSt.	ASTM D 445	210-320
Viscosity index	-	ASTM D 2270	report
Crackle test	-	-	pass
Pour point	Deg. C	ASTM D 97	10 (typical)

Application : Lubricant Additive

Function : Detergent Additive

Description : Chemical long chain alkyl sulpho-phenate

Table C-5 Specification of lubricant additive (5)

Properties	Unit	Method	Result
Appearance	-	Visual	Clear
Density @ 15 Deg C	kg/l.	ASTM D 1298	0.98 (typical)
Color, ASTM	-	ASTM D 1500	report
Flash point, PMcc	Deg. C	ASTM D 93	165 (typical)
Viscosity @ 40 Deg C	cSt.	ASTM D 445	1850 (typical)
Viscosity @ 100 Deg C	cSt.	ASTM D 445	80 (typical)
Viscosity index	-	ASTM D 2270	report
Crackle test	-	-	pass

Application : Lubricant Additive

Function : Multi-functional detergent inhibitor package

Description : A mixture including zinc dithiophosphates, calcium sulphonates and ashless dispersants

Table C-6 Specification of lubricant additive (6)

Properties	Unit	Method	Result
Appearance	-	Visual	Clear
Density @ 15 Deg C	kg/l.	ASTM D 1298	1.165-1.195
Color, ASTM	-	ASTM D 1500	4 (typical)
Flash point, PMcc	Deg. C	ASTM D 93	120 (typical)
Viscosity @ 40 Deg C	cSt.	ASTM D 445	320 (typical)
Viscosity @ 100 Deg C	cSt.	ASTM D 445	14 (typical)
Viscosity index	-	ASTM D 2270	report
Crackle test	-	-	pass
Pour point	Deg. C	ASTM D 97	-12 (typical)

Application : Lubricant Additive

Function : Anti-oxidant and Anti-wear

Description : A Zinc di-alkyl ditrhiophosphate

Table C-7 Specification of lubricant additive (7)

Properties	Unit	Method	Result
Appearance	-	Visual	Clear
Density @ 15 Deg C	kg/l.	ASTM D 1298	0.6-1.1

Application : Lubricant Additive

Function : Anti-Foam

Description : Methyl Silicone

APPENDIX D

VISCOSITY AND DENSITY OF LUBRICATING OILS

Table D-1 Viscosity of lubricating oil at various temperature

Temperature (^{o}C)	Viscosity of Lubricating Oils , Poise		
	@ 100 ^{o}C = 12 cSt	@ 100 ^{o}C = 14 cSt	@ 100 ^{o}C = 19 cSt
40	98.357	133.697	220.871
50	58.913	76.525	139.231
60	45.872	50.451	91.153
70	26.311	33.204	58.152
80	18.204	21.879	33.754
90	13.372	15.914	23.418
100	10.238	12.013	16.657
110	7.959	9.109	12.872
120	6.284	7.227	10.133

Table D-2 Density of lubricating oil at various temperature

Temperature (^{o}C)	Density of Lubricating Oils , g / cm^{3}		
	@ 100 ^{o}C = 12 cSt	@ 100 ^{o}C = 14 cSt	@ 100 ^{o}C = 19 cSt
40	0.8861	0.8985	0.9180
50	0.8793	0.8919	0.9112
60	0.8724	0.8851	0.9043
70	0.8655	0.8784	0.8974
80	0.8587	0.8717	0.8906
90	0.8517	0.8649	0.8837
100	0.8448	0.8581	0.8767
110	0.8378	0.8513	0.8697
120	0.8268	0.8404	0.8587

APPENDIX E

LOCATION OF SAMPLING POINT

E.1 Location of sampling point

The preliminary experiments were carried out in 12 cm. diameter of tank, 300 rpm., and viscosity @ 100 Deg C = 12 cSt. to determine the location of sampling. Three positions of location of sampling, top, middle, and bottom of tank were studied. The results is shown in figure E-1.

From this graph, all of location of sampling point gave the same required mixing time, t_m, and for convenience experimental, the top level was selected for location of sampling point.

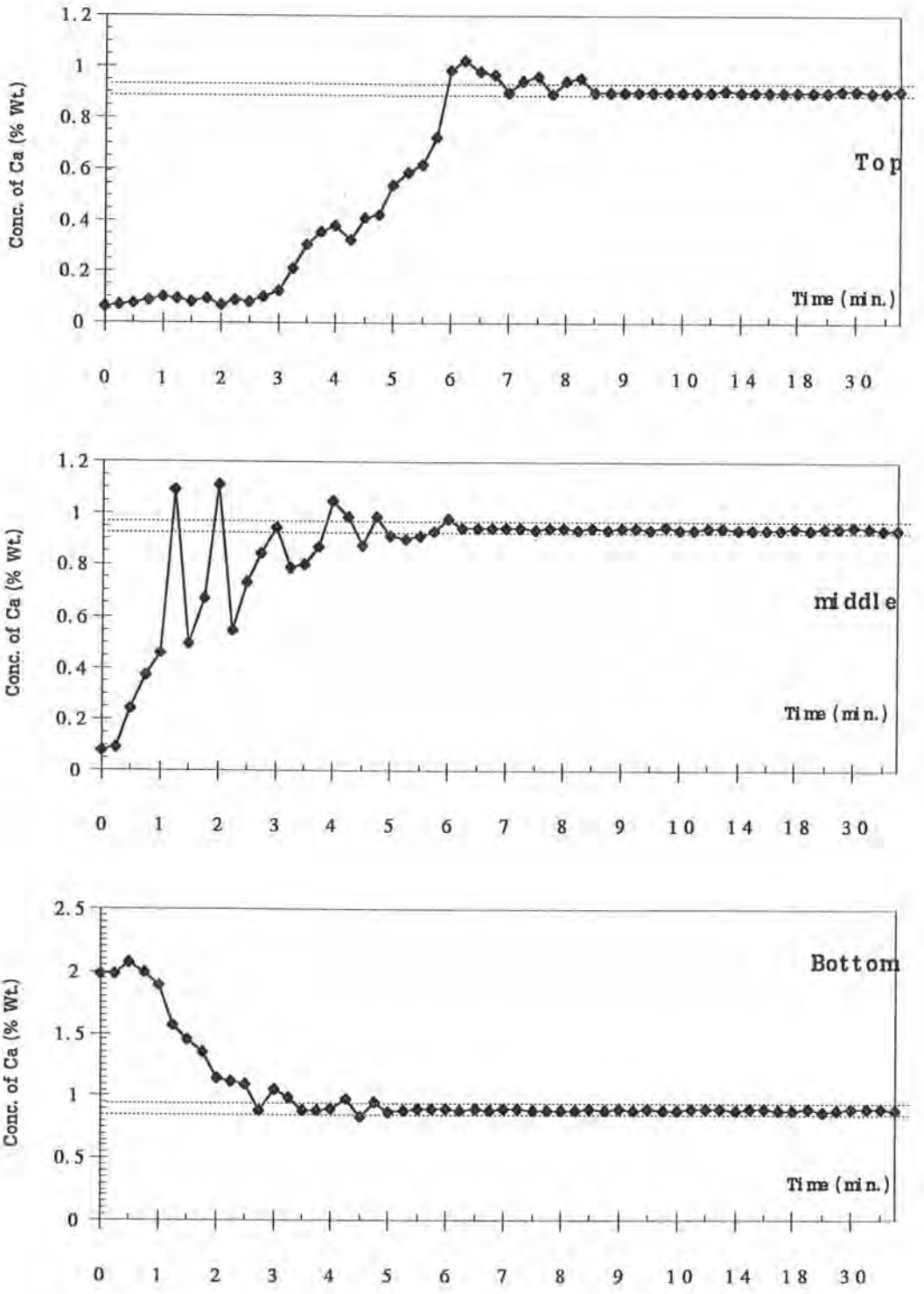


Figure E-1 Mixing time curve at top, middle and bottom positions

APPENDIX F

SAMPLES OF CALCULATION

In this part, the method of processing the data obtained from condition's experiment and standard configuration of tank.

F.1 Sample calculation for Renold number, R_e

The following is a condition for experiment.

- Diameter of impeller : 4 cm.
- Viscosity of lubricating oil @ 60 °C : 50.451 Poise .....(Appendix D)
- Density of lubricating oil @ 60 °C : 0.8851 g/cm^3 .....(Appendix D)
- Speed of impeller : 300 rpm.
- Temperature : 60 °C

$$R_e = (D_i^2 \rho N) / \mu$$

When

D_i = 4 cm.

N = 300 rpm.

ρ = 0.8851 g/cm^3

μ = 50.451 Poise

$$R_e = (4^2 \times 300 \times 0.8851) / (0.50451 \times 60)$$

$$= 140.35$$

F.2 Sample calculation to find required mixing time

For batch experiment, data were prepared for finding required mixing time as follows:-

F.2.1 The average and standard deviation of a set of experiment (VK =12 cSt, 12 cm diameter tank, 300 rpm) was evaluated to set upper and lower limits.

F.2.2 All data were normalized by dividing with the average.

F.2.3 The upper limit, its mean plus 3 times of standard deviation, and the lower limit, its mean minus 3 times of standard deviation were calculated.

F.2.4 The shortest time that counts at that time and after was not exceed these limits was verified.

For another method of determining, the followings step had been done.

F.2.5 The standard deviation of a set of experiment was calculated by moving average method (Hald, 1952)

F.2.6 The shortest time that the standard deviation at that time and after was fairly constant was verified.

Some of data for analyzed data to find required mixing time are shown below:- (for VK. @ 100 Deg C =12 cSt., 12 cm diameter of tank, 300 rpm.)

Table F-1 Analyzed data to find required mixing time

No.	Time (Min)	Conc. of Ca (% Wt.)	STD.	No.	Time (Min)	Conc. of Ca (% Wt.)	STD.
1	0	0.0647	0.3346	38	9.25	0.9021	0.0037
2	0.25	0.0692	0.3759	39	9.5	0.9018	0.0037
3	0.5	0.0734	0.3739	40	9.75	0.9015	0.0037
4	0.75	0.0845	0.3714	41	10	0.9015	0.0038
5	1	0.1018	0.3684	42	10.25	0.9055	0.0038
6	1.25	0.0925	0.3651	43	10.5	0.9078	0.0039
7	1.5	0.0808	0.3618	44	10.75	0.9105	0.0039
8	1.75	0.092	0.3571	45	11	0.9018	0.0039
9	2	0.0698	0.3506	46	11.25	0.9011	0.0038
10	2.25	0.0872	0.3433	47	11.5	0.8925	0.0038
11	2.5	0.0785	0.3328	48	11.75	0.9088	0.0039
12	2.75	0.1025	0.321	49	12	0.9031	0.0032
13	3	0.1241	0.3055	50	12.25	0.9049	0.0032
14	3.25	0.2145	0.2879	51	12.5	0.9106	0.0032
15	3.5	0.3034	0.2672	52	12.75	0.9088	0.0033
16	3.75	0.3523	0.2495	53	13	0.9101	0.003
17	4	0.4789	0.2354	54	13.25	0.9088	0.0029
18	4.25	0.3246	0.2217	55	13.5	0.9038	0.0025
19	4.5	0.4131	0.2156	56	13.75	0.8991	0.0022
20	4.75	0.4253	0.189	57	14	0.9011	0.0023
21	5	0.5426	0.1647	58	14.25	0.9033	0.0021
22	5.25	0.8261	0.1298	59	14.5	0.9019	0.0022
23	5.5	0.6231	0.1005	60	14.75	0.8979	0.0022
24	5.75	0.7251	0.1022	61	15	0.9033	0.0023
25	6	0.9861	0.0697	62	16	0.9015	0.0018
26	6.25	1.025	0.0425	63	17	0.9014	0.0019
27	6.5	0.9845	0.0416	64	18	0.9011	0.0019
28	6.75	0.9726	0.0311	65	19	0.9045	0.0018
29	7	0.9125	0.025	66	20	0.9035	0.0016
30	7.25	0.9458	0.0169	67	25	0.9048	0.0017
31	7.5	0.9321	0.0181	68	30	0.9047	0.0018
32	7.75	0.8952	0.0126	69	35	0.9045	0.0019
33	8	0.9142	0.0063	70	40	0.9028	0.0021
34	8.25	0.9012	0.0057	71	45	0.9012	0.0023
35	8.5	0.9014	0.0004	72	50	0.9046	0.0026
36	8.75	0.9019	0.0004	73	55	0.9044	0.0017
37	9	0.9011	0.0006	74	60	0.9075	0.0022
Mean =			**0.9036**				
Standard deviation =			**0.0036**				
Upper limit =			**0.9144**				
lower limit =			**0.8927**				

APPENDIX G

DATA FROM EXPERIMENTS

Data were obtained by using Inductively Coupled Plasma Optical Emission Spectroscopy. (ICP-OES) Data are shown the value between sampling times & concentration of Ca and plotted sampling times versus concentration of Ca.

All of data are shown as follows:-

Table G-1 (a) Data from experiments

Time	Concentration of Ca (% Wt.)								
	1*	2*	3*	4*	5*	6*	7*	8*	9*
0	0.0647	0.0826	0.0756	0.0685	0.0725	0.0826	0.0693	0.0578	0.0543
0.25	0.0692	0.0943	0.0643	0.0725	0.0856	0.0943	0.0725	0.0692	0.0745
0.5	0.0734	0.1085	0.1463	0.0623	0.0942	0.1082	0.0826	0.0734	0.0987
0.75	0.0845	0.0952	0.2853	0.0924	0.1152	0.0952	0.1081	0.0845	0.0951
1	0.1018	0.1231	0.3421	0.1052	0.0999	0.1234	0.0764	0.0685	0.0675
1.25	0.0925	0.2364	0.3954	0.1254	0.2451	0.2364	0.0875	0.0925	0.0989
1.5	0.0808	0.3081	0.4542	0.2014	0.3462	0.3085	0.0926	0.0808	0.1095
1.75	0.092	0.4082	0.5862	0.2451	0.4213	0.4085	0.0984	0.0921	0.1645
2	0.0698	0.4861	0.6432	0.3568	0.3985	0.4866	0.1025	0.0698	0.1742
2.25	0.0872	0.5452	0.7654	0.2965	0.5213	0.5456	0.1256	0.0872	0.2174
2.5	0.0785	0.7324	0.8832	0.3021	0.5671	0.7321	0.1564	0.0785	0.2945
2.75	0.1025	0.8453	0.8952	0.2985	0.5984	0.8452	0.1231	0.1025	0.2854
3	0.1241	0.9468	1.056	0.4021	0.6012	0.9462	0.1897	0.1241	0.3274
3.25	0.2145	0.7874	0.9912	0.4231	0.5874	0.9675	0.3024	0.2145	0.3551
3.5	0.3034	0.8041	0.8342	0.5984	0.6548	0.9875	0.2458	0.3034	0.4035
3.75	0.3523	0.8725	0.8865	0.4456	0.7432	1.009	0.3865	0.3523	0.4558
4	0.4789	1.048	0.8976	0.4692	0.7021	1.048	0.3954	0.4789	0.5647
4.25	0.3246	0.986	0.9123	0.5281	0.8321	0.9385	0.4261	0.3246	0.4965
4.5	0.4131	0.8754	0.9011	0.5864	0.8879	0.8974	0.4568	0.4132	0.6421
4.75	0.4253	0.9875	0.8976	0.5982	0.9452	0.8567	0.5194	0.4251	0.7135
5	0.5426	0.9125	0.8933	0.5397	0.9976	0.8439	0.5562	0.5432	0.8641
5.25	0.8261	0.9015	0.8888	0.6241	1.009	0.8904	0.6124	0.6348	0.9532
5.5	0.6231	0.9245	0.8999	0.6984	1.1005	0.9453	0.7364	0.6232	0.9881

Table G-1 (a) Data from experiments (continued)

Time	Concentration of Ca (% Wt.)								
	1*	2*	3*	4*	5*	6*	7*	8*	9*
5.75	0.7251	0.9345	0.8973	0.7134	0.9678	0.8873	0.7851	0.7258	0.9673
6	0.9861	0.9425	0.8977	0.7451	0.8873	0.8832	0.6351	0.8359	0.9321
6.25	1.025	0.9478	0.8911	0.8543	0.9342	0.8965	0.8325	1.0251	0.8943
6.5	0.9845	0.9421	0.8967	0.9231	0.9861	0.9321	0.8795	0.9976	0.9245
6.75	0.9726	0.9432	0.8955	1.067	0.9765	0.8569	0.7954	0.9726	0.9041
7	0.9125	0.9422	0.8999	0.8362	0.9456	0.8843	0.8865	0.9543	0.9086
7.25	0.9458	0.9422	0.9001	0.8457	0.9497	0.8964	0.9052	0.9321	0.9143
7.5	0.9321	0.9359	0.8941	0.8765	0.9585	0.8785	0.9324	0.9431	0.9042
7.75	0.8952	0.9444	0.8945	0.9583	0.9401	0.8985	0.9538	0.9648	0.9158
8	0.9142	0.9421	0.8944	0.9851	0.9462	0.9032	1.0051	0.9432	0.9109
8.25	0.9012	0.9401	0.8912	0.8678	0.9563	0.8999	0.9821	0.9426	0.9002
8.5	0.9014	0.9422	0.8967	0.8456	0.9471	0.8853	0.9452	0.9502	0.8945
8.75	0.9019	0.9403	0.8943	0.8765	0.9453	0.8821	0.8971	0.9504	0.9045
9	0.9011	0.9452	0.8999	0.8976	0.9421	0.8786	0.8543	0.9436	0.9106
9.25	0.9021	0.9444	0.8901	0.8789	0.9584	0.8888	0.8843	0.9458	0.9004
9.5	0.9018	0.9411	0.8977	0.8732	0.9475	0.8971	0.8941	0.9422	0.9058
9.75	0.9015	0.9521	0.8902	0.8699	0.9482	0.8845	0.9045	0.9601	0.899
10	0.9015	0.9401	0.8943	0.8888	0.9452	0.8754	0.8843	0.9502	0.9103
10.25	0.9055	0.9444	0.8957	0.8901	0.9582	0.8721	0.8675	0.9551	0.9016
10.5	0.9078	0.9478	0.9008	0.8777	0.9462	0.8713	0.8975	0.9413	0.9018
10.75	0.9105	0.9431	0.9005	0.8675	0.9411	0.8789	0.8845	0.9487	0.9058
11	0.9018	0.94	0.9002	0.8678	0.9433	0.8912	0.8802	0.9466	0.9088
11.25	0.9011	0.9475	0.9004	0.8765	0.9552	0.8874	0.8749	0.9503	0.9099
11.5	0.8925	0.9489	0.9018	0.8871	0.9499	0.8762	0.8648	0.9411	0.9028
11.75	0.9088	0.9501	0.8975	0.8812	0.9447	0.8742	0.8888	0.9423	0.8988
12	0.9031	0.9452	0.8966	0.888	0.9462	0.8721	0.8901	0.9444	0.8836
12.25	0.9049	0.9457	0.9103	0.8909	0.9456	0.8847	0.9012	0.9478	0.9106
12.5	0.9106	0.9512	0.8963	0.8876	0.9441	0.8775	0.8856	0.9403	0.9201
12.75	0.9088	0.9511	0.9046	0.8972	0.9421	0.8869	0.8469	0.9399	0.9036
13	0.9101	0.9458	0.9002	0.8782	0.9474	0.8772	0.8759	0.9387	0.9089
13.25	0.9088	0.9455	0.9037	0.8899	0.9485	0.8764	0.8645	0.9406	0.9048
13.5	0.9038	0.9489	0.8977	0.8903	0.9492	0.8685	0.8548	0.9448	0.9045
13.75	0.8991	0.9501	0.9011	0.8761	0.9523	0.8691	0.8847	0.9449	0.9047
14	0.9011	0.9411	0.8888	0.8769	0.9421	0.8775	0.8899	0.9508	0.9089
14.25	0.9033	0.9503	0.8847	0.8905	0.9421	0.8897	0.8867	0.9478	0.9099
14.5	0.9019	0.9478	0.8698	0.876	0.9475	0.8974	0.8876	0.9406	0.9016
14.75	0.8979	0.9455	0.8902	0.8846	0.9455	0.8749	0.8859	0.9408	0.8999
15	0.9033	0.9411	0.8977	0.8902	0.9492	0.8755	0.8854	0.9456	0.9059

Table G-1 (a) Data from experiments (continued)

Time	Concentration of Ca (% Wt.)								
	1*	2*	3*	4*	5*	6*	7*	8*	9*
16	0.9015	0.9401	0.9003	0.8904	0.9451	0.8688	0.8874	0.9487	0.9106
17	0.9014	0.9402	0.89	0.8888	0.9435	0.8755	0.8569	0.9499	0.9011
18	0.9011	0.9429	0.8923	0.8897	0.9582	0.8864	0.8975	0.9501	0.9111
19	0.9045	0.9403	0.8979	0.8456	0.9488	0.8887	0.8756	0.9389	0.9135
20	0.9035	0.9455	0.8799	0.8901	0.9496	0.8865	0.8846	0.9503	0.9112
25	0.9048	0.9422	0.8949	0.8703	0.9501	0.8824	0.8891	0.9409	0.9016
30	0.9047	0.9488	0.8999	0.8894	0.9491	0.8812	0.8965	0.9444	0.9089
35	0.9045	0.9455	0.8881	0.8852	0.9495	0.8777	0.8754	0.9489	0.9077
40	0.9028	0.9421	0.9001	0.8882	0.9421	0.8877	0.8821	0.9508	0.9083
45	0.9012	0.9501	0.9012	0.8783	0.9355	0.8834	0.8901	0.9399	0.9078
50	0.9046	0.9411	0.8971	0.8884	0.9339	0.8701	0.8877	0.9487	0.9025
55	0.9044	0.9477	0.8678	0.8854	0.9337	0.8655	0.8955	0.9488	0.9054
60	0.9075	0.9412	0.8933	0.8891	0.9491	0.8875	0.8821	0.9409	0.9135

VK. @ 100 Deg.C.= 12 cSt., 12 cm diameter of tank, 300 rpm.

VK. @ 100 Deg.C.= 12 cSt., 12 cm diameter of tank, 400 rpm.

VK. @ 100 Deg.C.= 12 cSt., 12 cm diameter of tank, 500 rpm.

VK. @ 100 Deg.C.= 12 cSt., 25 cm diameter of tank, 300 rpm.

VK. @ 100 Deg.C.= 12 cSt., 25 cm diameter of tank, 400 rpm.

VK. @ 100 Deg.C.= 12 cSt., 25 cm diameter of tank, 500 rpm.

VK. @ 100 Deg.C.= 12 cSt., 36 cm diameter of tank, 300 rpm.

VK. @ 100 Deg.C.= 12 cSt., 36 cm diameter of tank, 400 rpm.

VK. @ 100 Deg.C.= 12 cSt., 36 cm diameter of tank, 500 rpm.

Table G-1 (b) Data from experiments

Time	Concentration of Ca (% Wt.)								
	1*	2*	3*	4*	5*	6*	7*	8*	9*
0	0.0451	0.0546	0.0768	0.0589	0.0578	0.0756	0.0642	0.0512	0.0528
0.25	0.0761	0.0654	0.0897	0.0725	0.0692	0.0842	0.0842	0.0641	0.0897
0.5	0.0911	0.0678	0.0888	0.0826	0.0734	0.1052	0.0652	0.0746	0.0888
0.75	0.0942	0.0856	0.0989	0.1035	0.0924	0.0999	0.0942	0.0856	0.0989
1	0.1041	0.0987	0.1482	0.0756	0.0998	0.2451	0.1041	0.0987	0.1482
1.25	0.0986	0.0923	0.2158	0.0875	0.1254	0.3456	0.1112	0.0923	0.2158
1.5	0.0998	0.0876	0.2671	0.0926	0.1958	0.4215	0.0998	0.0876	0.2671
1.75	0.0876	0.0765	0.3975	0.0982	0.2456	0.3984	0.1024	0.0765	0.3975
2	0.0999	0.0899	0.5124	0.1024	0.3564	0.5124	0.0999	0.0899	0.4687
2.25	0.1152	0.0876	0.5894	0.1256	0.3214	0.5673	0.1152	0.0876	0.5894
2.5	0.1192	0.0799	0.7772	0.1564	0.3698	0.5984	0.1192	0.0799	0.7772
2.75	0.1452	0.1098	0.8531	0.1234	0.4126	0.6012	0.1542	0.1098	0.8847
3	0.1792	0.1123	0.9112	0.1947	0.3589	0.5879	0.2145	0.1123	0.9954
3.25	0.2165	0.2345	0.9857	0.3021	0.4231	0.6541	0.2847	0.2345	0.9857
3.5	0.2921	0.3421	1.0952	0.2456	0.5984	0.7421	0.3945	0.4124	1.0952
3.75	0.3694	0.3762	1.1462	0.3865	0.6215	0.7071	0.4214	0.3762	0.1234
4	0.4253	0.4375	1.1752	0.3954	0.6589	0.7539	0.4875	0.3245	1.1462
4.25	0.4384	0.4581	1.1587	0.4261	0.7215	0.7895	0.4384	0.4581	1.1478
4.5	0.4112	0.4312	1.1142	0.4562	0.7652	0.8324	0.4256	0.4312	1.0854
4.75	0.4962	0.5471	1.0571	0.5194	0.8235	0.8864	0.4962	0.6421	1.0571
5	0.5231	0.5551	1.1458	0.5562	0.8956	0.9054	0.5874	0.5551	1.1458
5.25	0.5874	0.6891	1.1523	0.6125	0.7856	0.9845	0.6214	0.6891	1.1654
5.5	0.6264	0.8761	1.1452	0.7365	0.8952	0.9945	0.7456	0.8546	1.1452
5.75	0.7562	0.8772	1.1524	0.7851	0.9235	1.1452	0.7423	0.8523	1.1524
6	0.7982	0.8984	1.1354	0.6351	0.9862	1.1562	0.8547	0.9954	1.1102
6.25	0.8956	0.9976	1.1542	0.8321	0.9986	1.1235	0.7542	1.0564	1.1245
6.5	0.7498	1.0258	1.1254	0.8793	1.0523	0.9985	0.8854	1.0258	1.1547
6.75	0.9432	1.067	1.1458	0.7954	1.1635	0.9458	0.9432	1.0765	1.1458
7	0.9987	1.0752	1.1456	0.8864	1.1897	0.9895	0.9987	1.0854	1.1456
7.25	1.0587	1.1254	1.1632	0.9051	1.1987	1.1526	1.0587	1.0542	1.1632
7.5	1.1125	1.0658	1.1547	0.9872	1.1658	1.0752	1.1125	1.0985	1.1547
7.75	1.025	1.0752	1.1542	1.0254	1.0569	1.0564	1.0546	1.1025	1.1542
8	1.086	1.0658	1.1365	1.1321	0.9985	1.0365	1.1054	1.1254	1.1365
8.25	1.098	1.0875	1.1521	1.1568	1.1562	1.0758	1.0156	1.0875	1.1521
8.5	1.0687	1.0523	1.1524	1.1952	1.1652	1.0546	1.1025	1.0523	1.1524
8.75	1.0785	1.0564	1.1414	0.9856	1.1453	1.0564	1.1954	1.0564	1.1563
9	1.0879	1.0658	1.1523	1.0253	1.1698	1.0325	1.0354	1.0658	1.1523
9.25	1.0985	1.0756	1.1352	1.1342	1.1685	1.0548	1.0542	1.0756	1.1352

Table G-1 (b) Data from experiments (continued)

Time	Concentration of Ca (% Wt.)								
	1*	2*	3*	4*	5*	6*	7*	8*	9*
9.5	1.0759	1.0546	1.1524	1.1258	1.1523	1.046	1.0759	1.0546	1.1524
9.75	1.0875	1.0642	1.1453	1.1563	1.1456	1.0789	1.0945	1.0642	1.1453
10	1.0985	1.0856	1.1852	1.1458	1.1852	1.0568	1.1025	1.0856	1.1624
10.25	1.0752	1.1756	1.1844	1.0029	1.1365	1.0689	1.0658	1.1756	1.1458
10.5	1.0854	1.0633	1.1999	1.1365	1.1654	1.0701	1.0854	1.0633	1.1999
10.75	1.0952	1.0548	1.1458	1.1456	1.1689	1.0568	1.0875	1.0548	1.1458
11	1.0874	1.0564	1.1754	1.1258	1.1599	1.0756	1.0874	1.0564	1.1754
11.25	1.0864	1.1647	1.1985	1.1354	1.1616	1.0658	1.0864	1.1647	1.1513
11.5	1.0654	1.0566	1.1845	1.1489	1.1548	1.0458	1.0654	1.0566	1.1845
11.75	1.0897	1.0568	1.1744	1.1203	1.1601	1.0752	1.0897	1.0568	1.1465
12	1.0578	1.0789	1.1625	1.1589	1.1499	1.0547	1.0578	1.0789	1.1458
12.25	1.0658	1.0744	1.1462	1.1352	1.1652	1.0785	1.0658	1.0744	1.1462
12.5	1.0985	1.0685	1.1477	1.1458	1.1523	1.0801	1.0845	1.0685	1.1477
12.75	1.0548	1.0986	1.1458	1.1458	1.1506	1.0752	1.0756	1.0986	1.1458
13	1.0879	1.0586	1.1424	1.1023	1.1608	1.0589	1.0746	1.0586	1.1542
13.25	1.0758	1.0623	1.1457	1.1329	1.1602	1.0803	1.0845	1.0623	1.1457
13.5	1.0759	1.0752	1.1458	1.1587	1.1549	1.0861	1.0759	1.0752	1.1458
13.75	1.0589	1.0841	1.1865	1.1024	1.1825	1.0751	1.0589	1.0841	1.1741
14	1.0985	1.0845	1.1842	1.1329	1.1452	1.0687	1.0985	1.0845	1.1678
14.25	1.0875	1.0865	1.1685	1.1452	1.1239	1.0684	1.0875	1.0865	1.1685
14.5	1.0899	1.0326	1.1235	1.1212	1.1549	1.0654	1.0899	1.0766	1.1235
14.75	1.0999	1.0857	1.1455	1.1325	1.1458	1.0725	1.0999	1.0857	1.1455
15	1.0879	1.0852	1.1436	1.1584	1.1649	1.0732	1.0879	1.0852	1.1436
16	1.0869	1.0958	1.1523	1.1352	1.1678	1.0689	1.0869	1.0958	1.1523
17	1.0964	1.0985	1.1752	1.1321	1.1699	1.0587	1.0964	1.0985	1.1752
18	1.0796	1.0568	1.1456	1.1952	1.1702	1.0548	1.0796	1.0658	1.1456
19	1.0985	1.0874	1.1438	1.1587	1.1506	1.082	1.0985	1.0874	1.1438
20	1.0965	1.0875	1.1523	1.1324	1.1709	1.0245	1.0965	1.0875	1.1523
25	1.0854	1.0863	1.1521	1.132	1.1701	1.0652	1.0854	1.0863	1.1423
30	1.0486	1.0486	1.1515	1.1365	1.1598	1.0703	1.0486	1.0754	1.1515
35	1.0589	1.0587	1.1645	1.1523	1.1602	1.0706	1.0589	1.0587	1.1645
40	1.0874	1.0879	1.1425	1.1325	1.1516	1.0699	1.0874	1.0879	1.1325
45	1.0689	1.0469	1.1485	1.1313	1.1569	1.0707	1.0689	1.0654	1.1485
50	1.0852	1.0741	1.1458	1.1356	1.1645	1.0654	1.0852	1.0741	1.1458
55	1.0873	1.0589	1.1566	1.1589	1.1603	1.0703	1.0657	1.0756	1.1566
60	1.0917	1.0893	1.1531	1.1421	1.1608	1.0711	1.0874	1.0847	1.1515

when 1* = VK. @ 100 Deg.C.= 14 cSt., 12 cm diameter of tank, 300 rpm.
2* = VK. @ 100 Deg.C.= 14 cSt., 12 cm diameter of tank, 400 rpm.
3* = VK. @ 100 Deg.C.= 14 cSt., 12 cm diameter of tank, 500 rpm.
4* = VK. @ 100 Deg.C.= 14 cSt., 25 cm diameter of tank, 300 rpm.
5* = VK. @ 100 Deg.C.= 14 cSt., 25 cm diameter of tank, 400 rpm.
6* = VK. @ 100 Deg.C.= 14 cSt., 25 cm diameter of tank, 500 rpm.
7* = VK. @ 100 Deg.C.= 14 cSt., 36 cm diameter of tank, 300 rpm.
8* = VK. @ 100 Deg.C.= 14 cSt., 36 cm diameter of tank, 400 rpm.
9* = VK. @ 100 Deg.C.= 14 cSt., 36 cm diameter of tank, 500 rpm.

Table G-1 (c) Data from experiments

Time	Concentration of Ca (% Wt.)								
	1*	2*	3*	4*	5*	6*	7*	8*	9*
0	0.0582	0.0942	0.0952	0.0952	0.0998	0.1231	0.0799	0.0842	0.0746
0.25	0.0761	0.1041	0.1231	0.1234	0.1254	0.2364	0.1098	0.0652	0.0856
0.5	0.0998	0.0986	0.2364	0.2364	0.1958	0.3081	0.1123	0.0942	0.0987
0.75	0.1263	0.0998	0.3081	0.3085	0.2456	0.4082	0.2345	0.1041	0.0923
1	0.1041	0.0876	0.4082	0.4085	0.3564	0.5691	0.4124	0.1112	0.0876
1.25	0.0986	0.0999	0.5691	0.4321	0.3214	0.6739	0.3762	0.0998	0.0799
1.5	0.1326	0.1152	0.6739	0.6732	0.3698	0.9562	0.3975	0.1024	0.1098
1.75	0.1763	0.1192	0.9562	0.8759	0.4126	0.9987	0.4687	0.9954	0.1123
2	0.1954	0.1452	0.9987	0.9984	0.6732	1.1231	0.5894	0.9857	1.1254
2.25	0.2215	0.1792	1.1123	1.1253	0.8759	1.5435	0.7772	1.0952	1.1462
2.5	0.1192	0.2165	1.1632	1.4327	0.9984	1.7632	0.8847	1.1254	1.1478
2.75	0.1673	0.2921	1.2182	1.6743	1.1253	2.0123	0.9954	1.1462	1.0854
3	0.1792	0.3694	1.3211	1.8653	1.4327	2.3411	0.9857	1.1253	1.0571
3.25	0.2165	0.4253	1.5628	1.9987	1.6743	2.5672	1.0952	1.4327	1.1458
3.5	0.2921	0.4384	1.7853	2.2671	1.8653	2.3212	1.1254	1.6743	1.6743
3.75	0.3694	0.7853	1.9256	2.1254	1.9987	2.6574	1.1462	1.8653	1.8653
4	0.4321	0.9843	2.1472	2.3213	2.2671	2.4678	1.1478	1.9987	1.9987
4.25	0.6732	1.1231	2.5439	2.5412	2.2984	2.3654	1.0854	2.2671	2.2671
4.5	0.8759	1.5435	2.5873	2.7783	2.3213	2.3211	1.1253	2.1254	2.1254
4.75	0.9984	1.7632	2.382	2.6853	2.5412	2.3876	1.4327	2.3213	2.2671
5	1.1253	2.0123	2.4875	2.9874	2.7783	2.3987	1.6743	2.3411	2.1254
5.25	1.4327	2.3411	2.4998	2.8745	2.6853	2.3654	1.8653	2.5672	2.3213
5.5	1.6743	2.5672	2.5001	2.5789	2.9874	2.3976	1.9987	2.3212	2.5412
5.75	1.8653	2.3212	2.5111	2.6794	2.8745	2.3786	2.2671	2.6574	2.7783
6	1.9987	2.6574	2.5101	2.5342	2.6745	2.3291	2.1254	2.4678	2.6853
6.25	2.2671	2.4678	2.4874	2.5436	2.5328	2.3218	2.3213	2.3654	2.9874
6.5	2.1254	2.3654	2.4974	2.5126	2.4945	2.3321	2.5412	2.3211	2.8745

Table G-1 (c) Data from experiments (continued)

Time	Concentration of Ca (% Wt.)								
	1*	2*	3*	4*	5*	6*	7*	8*	9*
6.75	2.3213	2.3211	2.5111	2.5986	2.4785	2.3326	2.7783	2.3876	2.6748
7	2.5412	2.3876	2.5127	2.6432	2.5429	2.3217	2.6853	2.3213	2.6894
7.25	2.7783	2.3987	2.4895	2.6895	2.5455	2.3222	2.9874	2.5412	2.6984
7.5	2.6853	2.3654	2.4999	2.6431	2.5123	2.3278	2.8745	2.7783	2.7001
7.75	2.9874	2.3976	2.5012	2.6587	2.5034	2.3289	2.5789	2.6853	2.6879
8	2.8745	2.3786	2.4986	2.6364	2.5321	2.3189	2.6794	2.5738	2.6984
8.25	2.5789	2.3291	2.4785	2.5674	2.5643	2.3401	2.5342	2.4389	2.6784
8.5	2.6794	2.3218	2.5219	2.5237	2.5399	2.3328	2.5436	2.4217	2.6984
8.75	2.5342	2.3674	2.5211	2.5011	2.5388	2.3222	2.5126	2.4456	2.6879
9	2.5436	2.3671	2.4987	2.5768	2.5432	2.3189	2.5986	2.4367	2.6922
9.25	2.5126	2.3679	2.5198	2.5892	2.5543	2.3375	2.6145	2.4418	2.6897
9.5	2.5555	2.3749	2.4999	2.5873	2.4965	2.3451	2.6843	2.4386	2.6999
9.75	2.5863	2.3651	2.4869	2.5789	2.5438	2.32118	2.6431	2.4523	2.6895
10	2.4984	2.3896	2.5001	2.5983	2.5344	2.3222	2.6321	2.4378	2.6912
10.25	2.5321	2.3764	2.5111	2.5999	2.5399	2.3117	2.6124	2.4563	2.6789
10.5	2.5643	2.3984	2.5151	2.6001	2.5611	2.3117	2.6213	2.4437	2.6988
10.75	2.5399	2.3641	2.5009	2.5982	2.5962	2.3215	2.6127	2.4487	2.6919
11	2.5388	2.3666	2.5129	2.5769	2.5555	2.3222	2.6099	2.4438	2.6899
11.25	2.5432	2.3636	2.5003	2.5673	2.6011	2.3232	2.6111	2.4378	2.6948
11.5	2.5543	2.3671	2.4978	2.5896	2.5399	2.3418	2.6091	2.4532	2.6896
11.75	2.4965	2.3333	2.5002	2.5983	2.5421	2.3284	2.6201	2.4387	2.6984
12	2.5438	2.3431	2.505	2.5891	2.5327	2.3351	2.6197	2.4473	2.7004
12.25	2.5344	2.3645	2.5121	2.5955	2.5411	2.3213	2.6111	2.4444	2.6968
12.5	2.5399	2.3569	2.5001	2.5812	2.5333	2.3333	2.61	2.4376	2.7005
12.75	2.5611	2.367	2.4949	2.5912	2.5632	2.3217	2.6192	2.4376	2.6988
13	2.5962	2.3741	2.4975	2.5879	2.5952	2.3421	2.6078	2.4344	2.6977
13.25	2.5555	2.3555	2.5012	2.5876	2.5396	2.3216	2.6186	2.4444	2.6956
13.5	2.6011	2.3643	2.5151	2.5987	2.5377	2.3321	2.6205	2.4431	2.6873
13.75	2.5399	2.3876	2.5115	2.5888	2.5444	2.3015	2.6301	2.4563	2.6974
14	2.5421	2.3659	2.5221	2.5649	2.5831	2.3321	2.6172	2.4321	2.6988
14.25	2.5327	2.3655	2.5118	2.5783	2.5439	2.3231	2.62	2.4367	2.6945
14.5	2.5411	2.3256	2.5007	2.5999	2.5491	2.3222	2.6142	2.4435	2.6874
14.75	2.5333	2.3874	2.4997	2.5782	2.53	2.3117	2.6161	2.4536	2.6888
15	2.5632	2.3698	2.4984	2.5799	2.519	2.3218	2.6161	2.4299	2.6894
16	2.5952	2.3636	2.4999	2.58	2.5178	2.3221	2.6109	2.44	2.6957
17	2.5396	2.3441	2.5002	2.5781	2.5127	2.32	2.61	2.45	2.6968
18	2.5377	2.3846	2.4938	2.5892	2.5423	2.3201	2.6092	2.4437	2.6999
19	2.5444	2.3649	2.5002	2.5987	2.5333	2.3216	2.6128	2.4478	2.6893

Table G-1 (c) Data from experiments (continued)

Time	Concentration of Ca (% Wt.)								
	1*	2*	3*	4*	5*	6*	7*	8*	9*
20	2.5831	2.3633	2.4967	2.5789	2.5412	2.3232	2.6194	2.4583	2.69
25	2.5439	2.36	2.5101	2.5888	2.5543	2.3211	2.6188	2.4367	2.6902
30	2.5491	2.3649	2.5006	2.5871	2.5487	2.3219	2.6111	2.4433	2.6894
35	2.53	2.3345	2.4999	2.5888	2.5399	2.3228	2.6142	2.4411	2.6991
40	2.519	2.3366	2.5004	2.5879	2.5462	2.3328	2.6129	2.4467	2.6981
45	2.5178	2.3674	2.5111	2.5789	2.54	2.3221	2.6111	2.4432	2.6998
50	2.5127	2.3888	2.4955	2.5897	2.5501	2.3264	2.6102	2.4432	2.689
55	2.5423	2.3564	2.4856	2.5834	2.5414	2.3275	2.6142	2.4437	2.6941
60	2.5333	2.3599	2.5008	2.5971	2.5437	2.3214	2.6119	2.4439	2.6894

when 1* = VK. @ 100 Deg.C.= 19 cSt., 12 cm diameter of tank, 300 rpm.

2* = VK. @ 100 Deg.C.= 19 cSt., 12 cm diameter of tank, 400 rpm.

3* = VK. @ 100 Deg.C.= 19 cSt., 12 cm diameter of tank, 500 rpm.

4* = VK. @ 100 Deg.C.= 19 cSt., 25 cm diameter of tank, 300 rpm.

5* = VK. @ 100 Deg.C.= 19 cSt., 25 cm diameter of tank, 400 rpm.

6* = VK. @ 100 Deg.C.= 19 cSt., 25 cm diameter of tank, 500 rpm.

7* = VK. @ 100 Deg.C.= 19 cSt., 36 cm diameter of tank, 300 rpm.

8* = VK. @ 100 Deg.C.= 19 cSt., 36 cm diameter of tank, 400 rpm.

9* = VK. @ 100 Deg.C.= 19 cSt., 36 cm diameter of tank, 500 rpm.

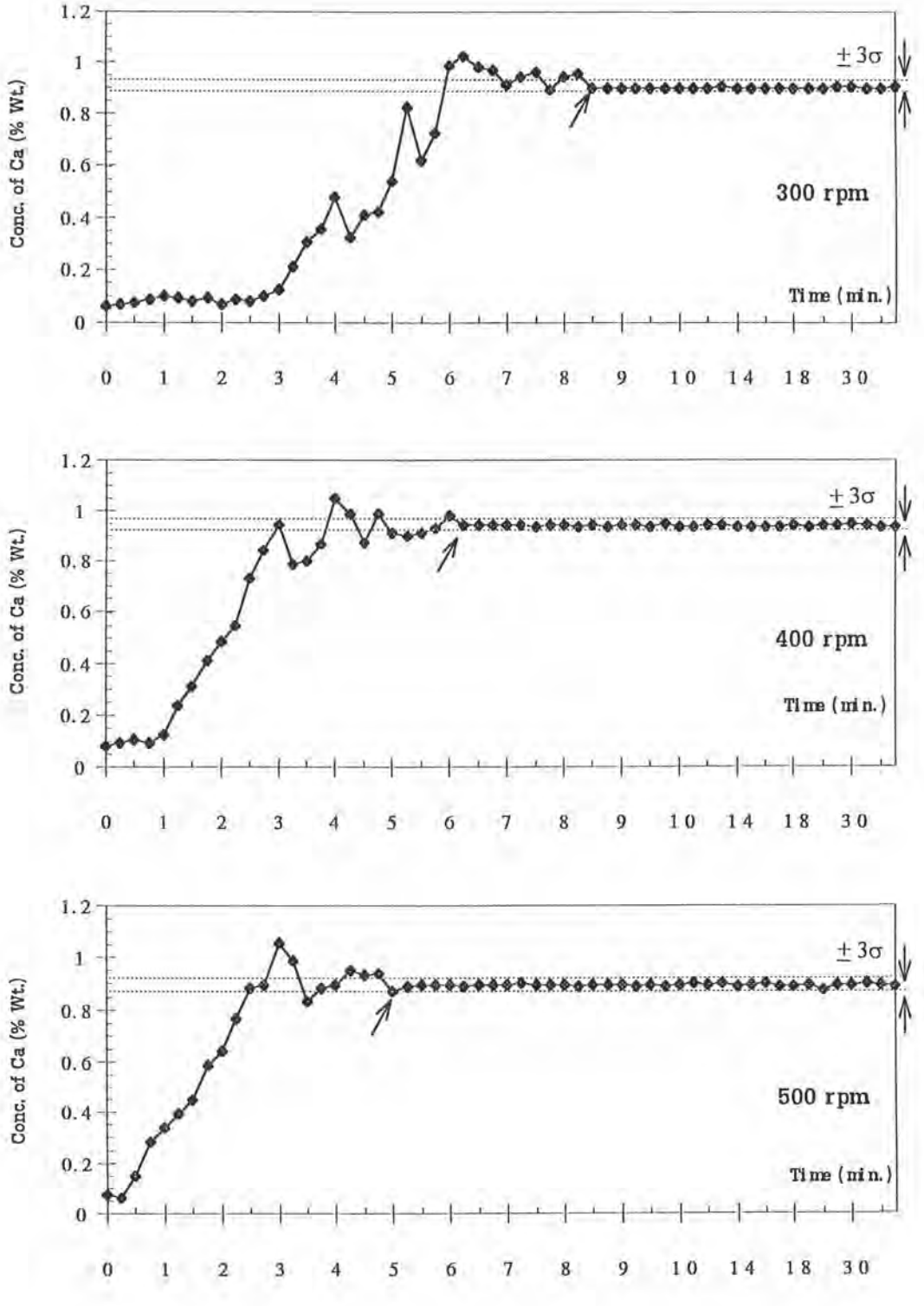


Figure G-1 Mixing time curve, 12 cm. diameter tank

Viscosity @ 100 ^{o}C = 12 cSt., N = 300, 400, 500 rpm.

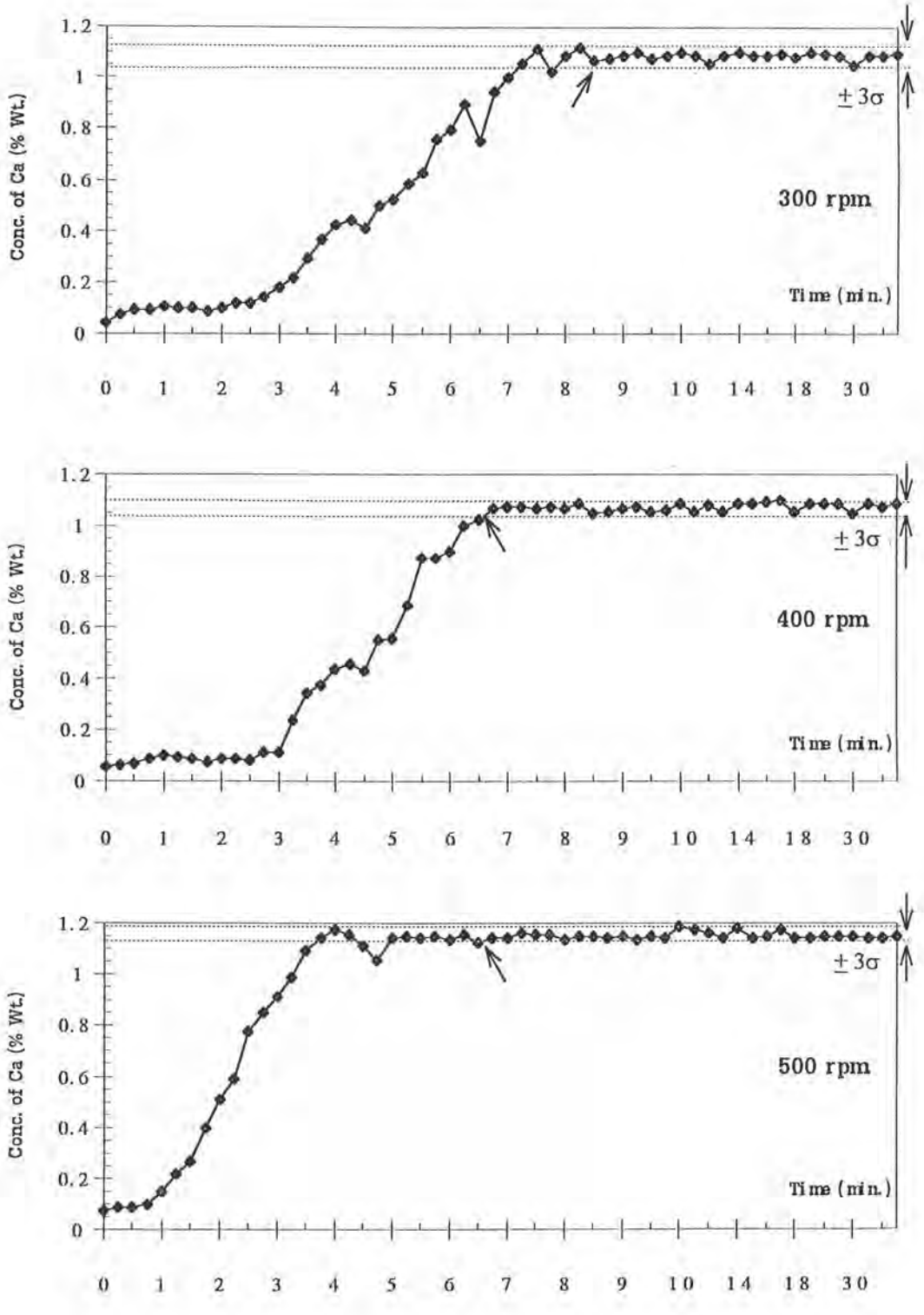


Figure G-2 Mixing time curve, 12 cm. diameter tank

Viscosity @ 100 ^{o}C = 14 cSt., N = 300, 400, 500 rpm.

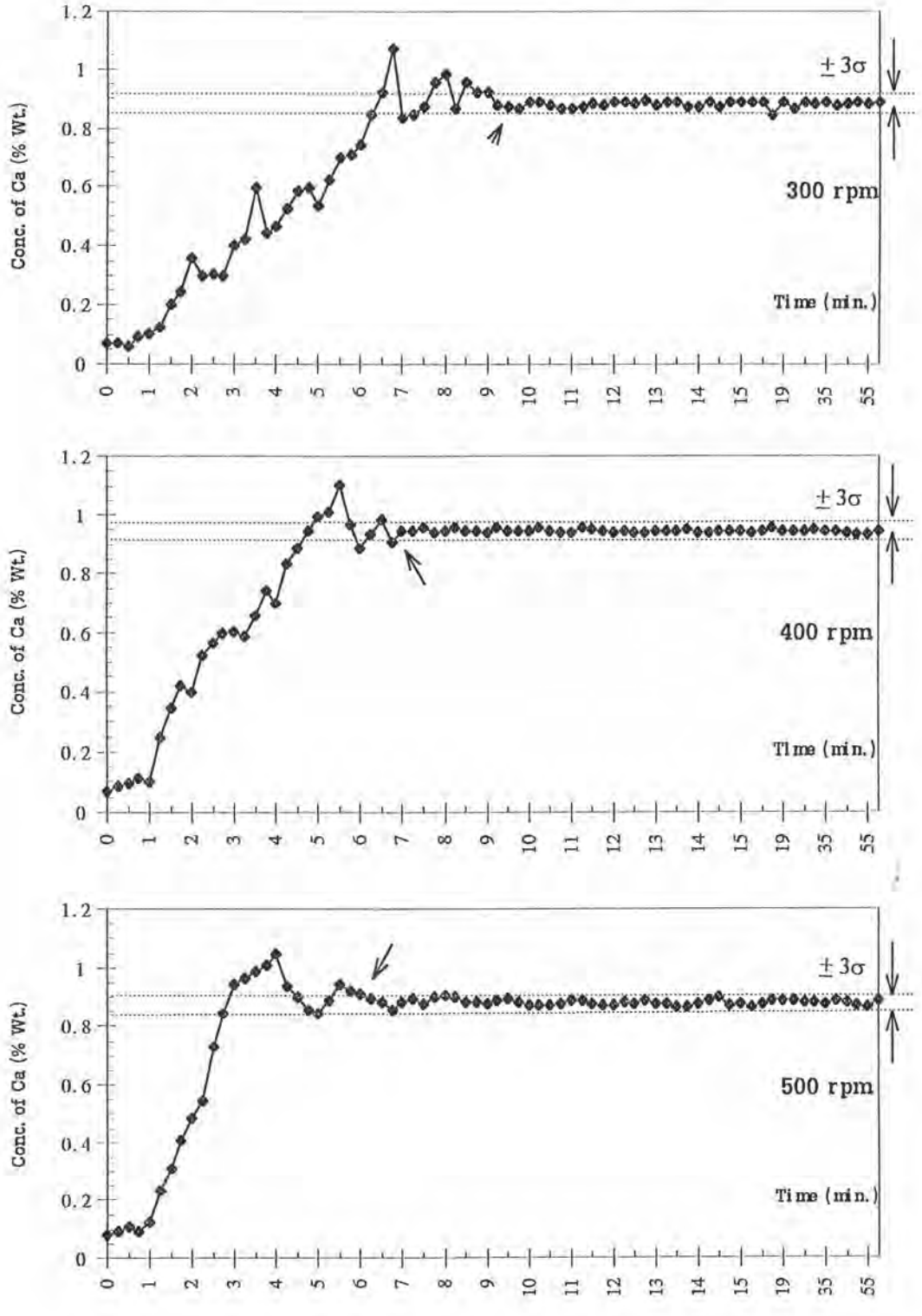


Figure G-3 Mixing time curve, 25 cm. diameter tank

Viscosity @ 100 ^{o}C = 12 cSt., N = 300, 400, 500 rpm.

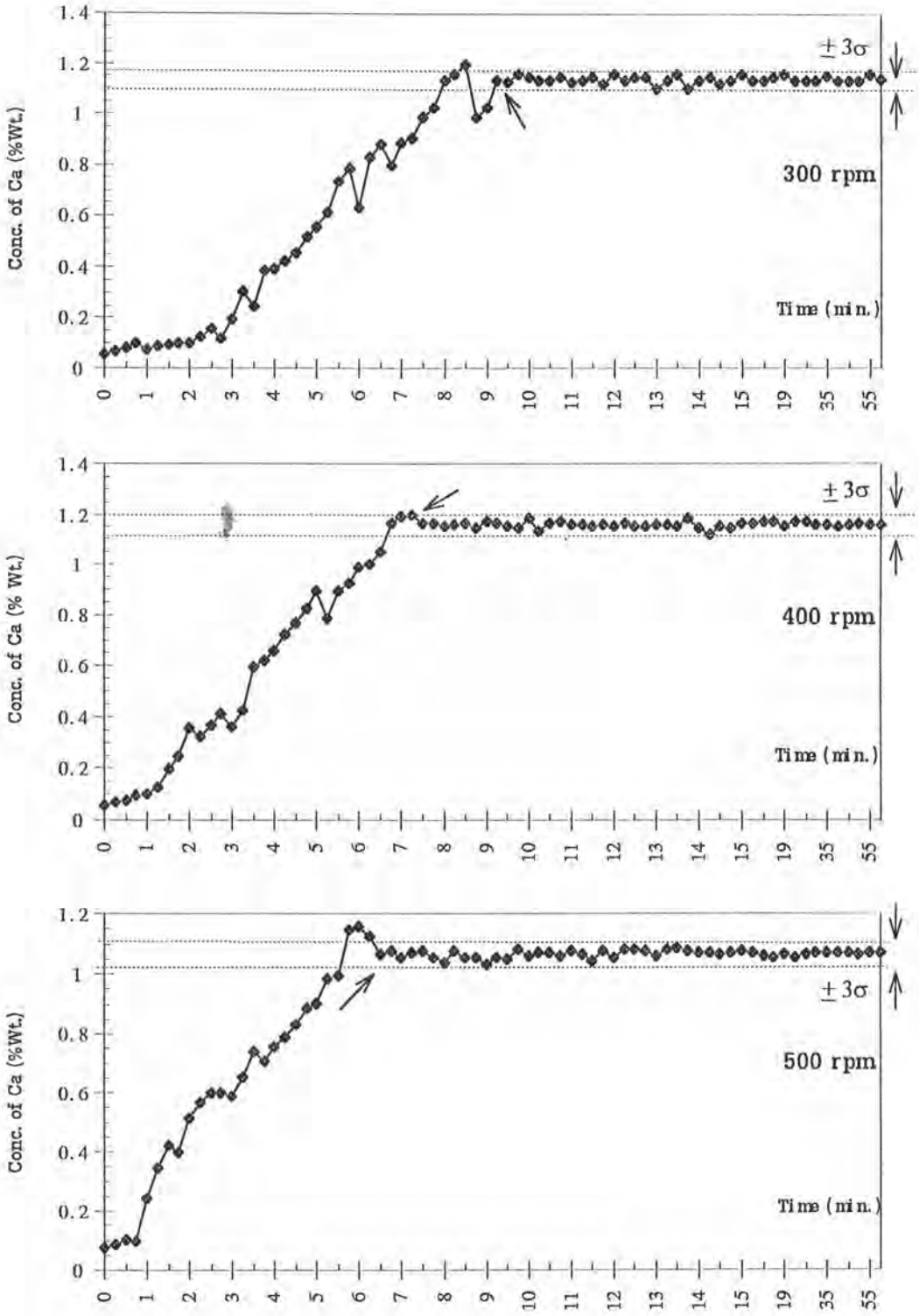


Figure G-4 Mixing time curve, 25 cm. diameter tank

Viscosity @ 100 ^{o}C = 14 cSt., N = 300, 400, 500 rpm.

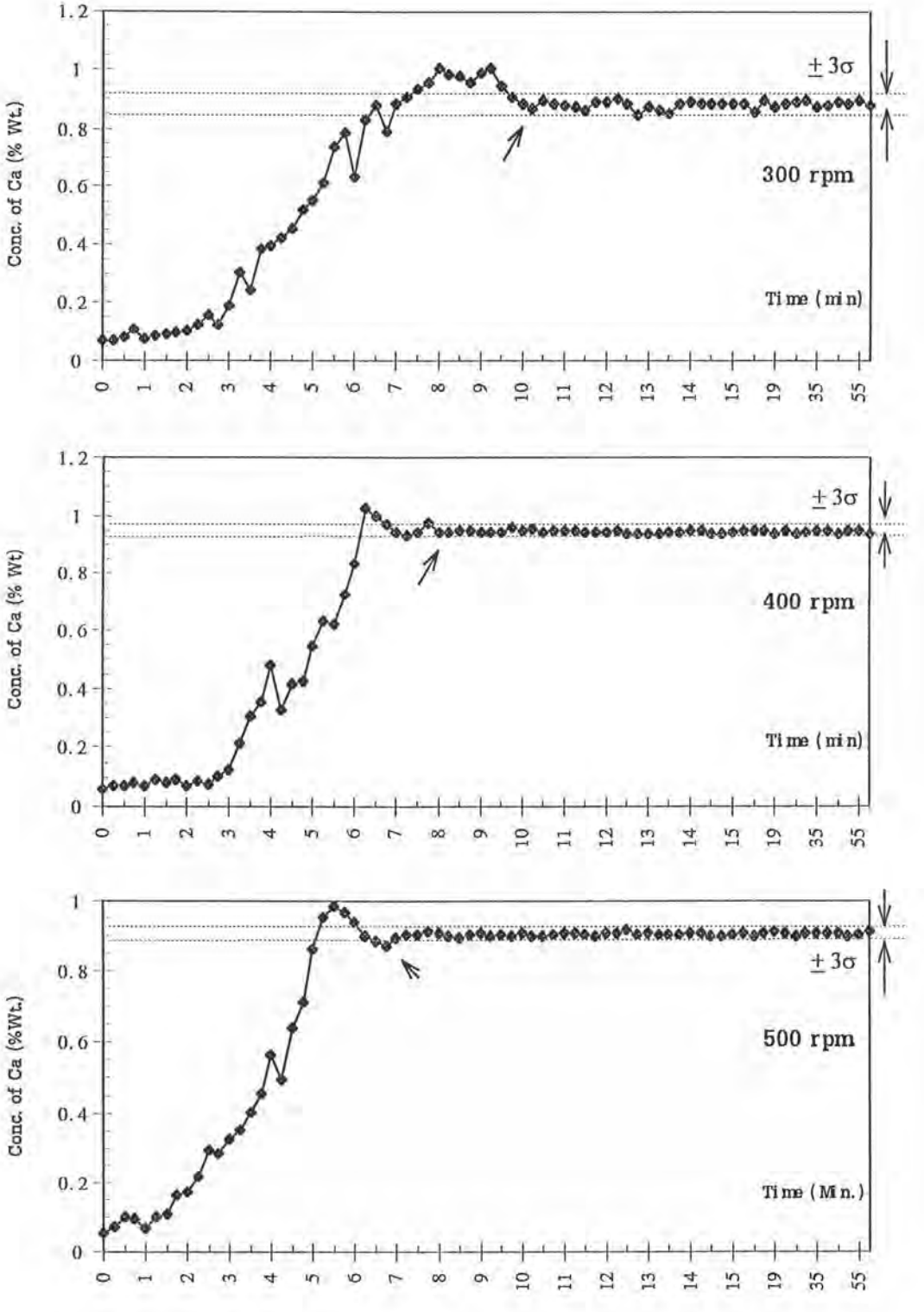


Figure G-5 Mixing time curve, 36 cm. diameter tank

Viscosity @ 100 ^{o}C = 12 cSt., N = 300, 400, 500 rpm.

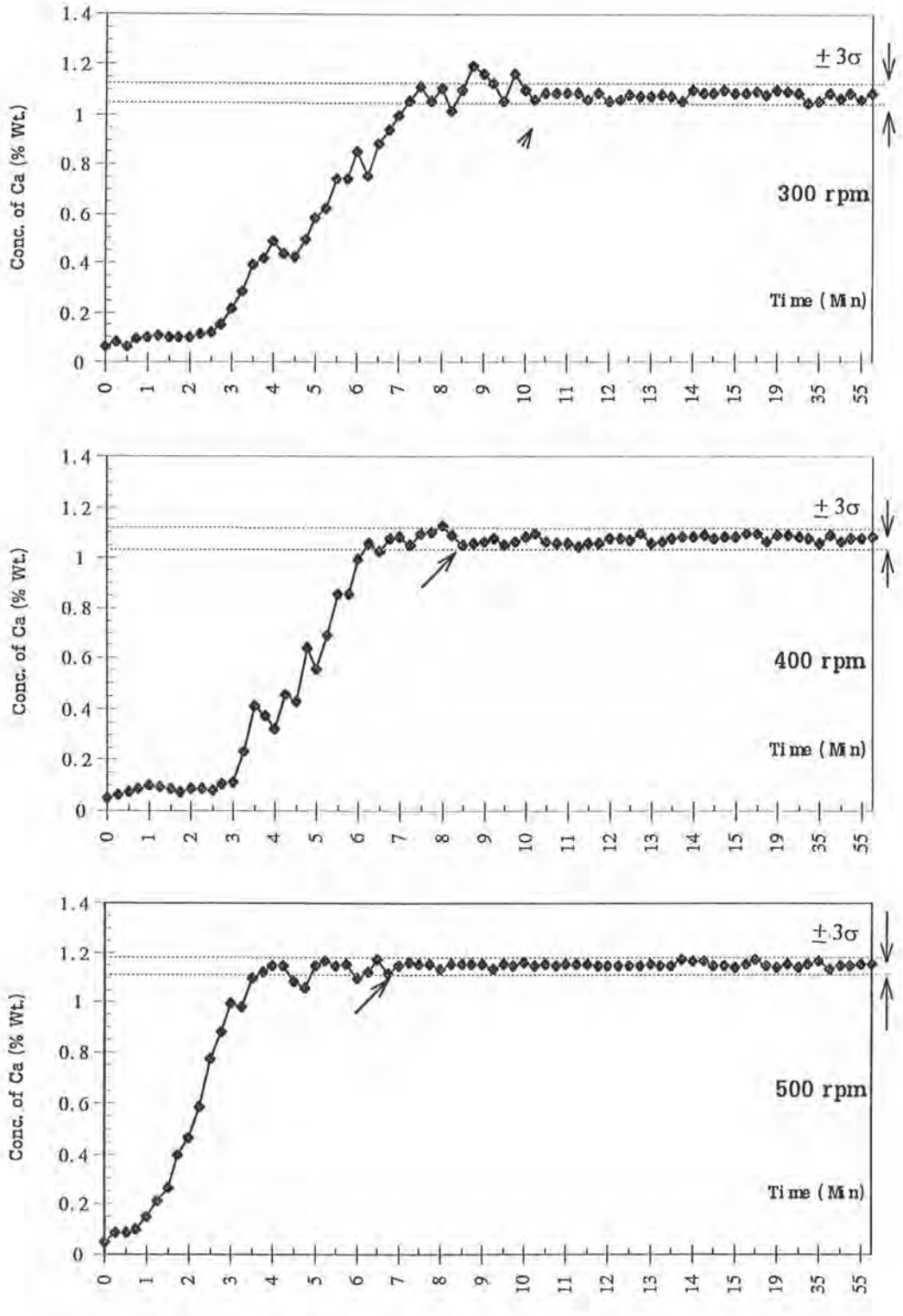


Figure G-6 Mixing time curve, 36 cm. diameter tank

Viscosity @ 100 ^{o}C = 14 cSt., N = 300, 400, 500 rpm.

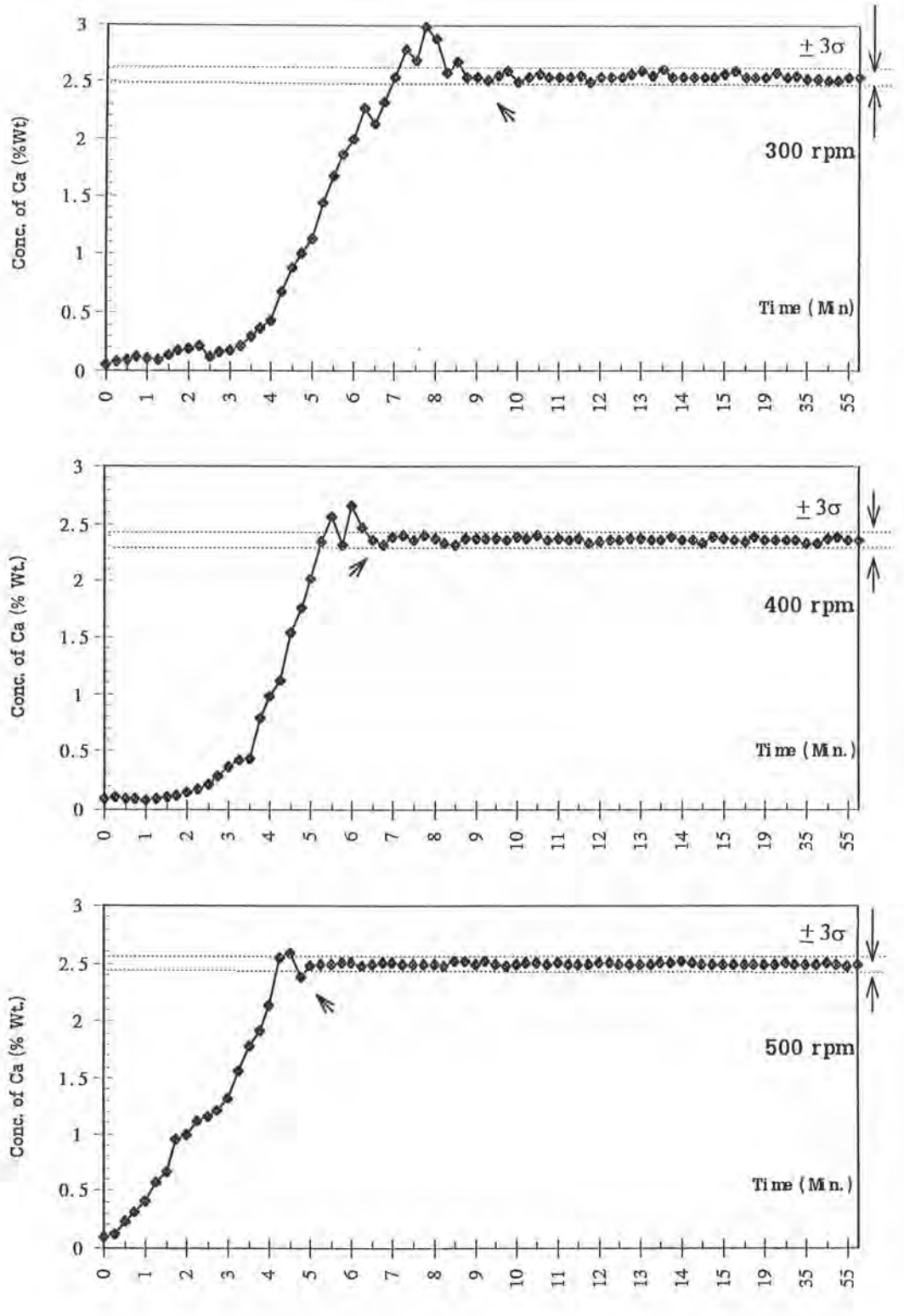


Figure G-7 Mixing time curve, 12 cm. diameter tank

Viscosity @ 100 ^{o}C = 19 cSt., N = 300, 400, 500 rpm.

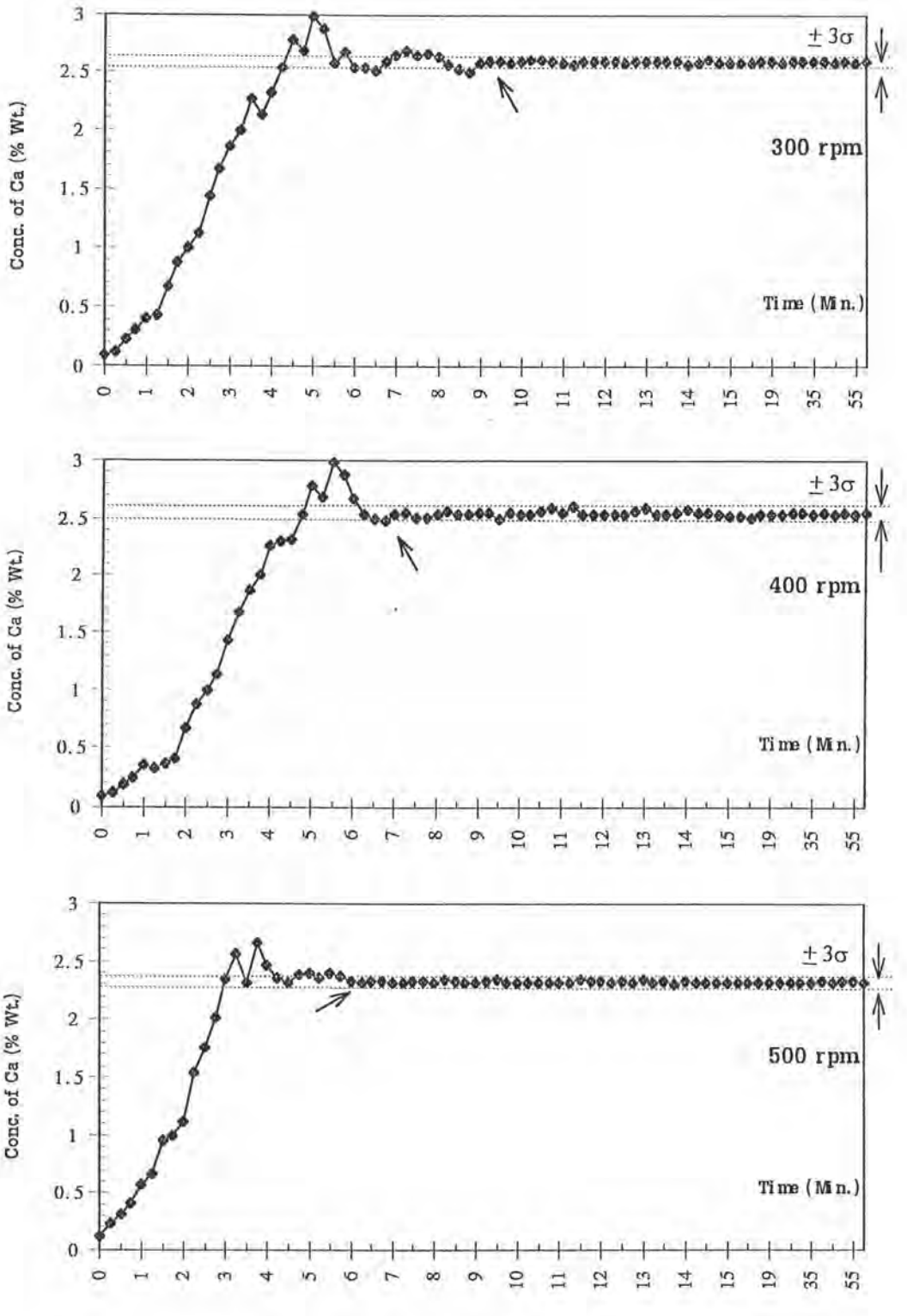


Figure G-8 Mixing time curve, 25 cm. diameter tank

Viscosity @ 100 ^{o}C = 19 cSt., N = 300, 400, 500 rpm

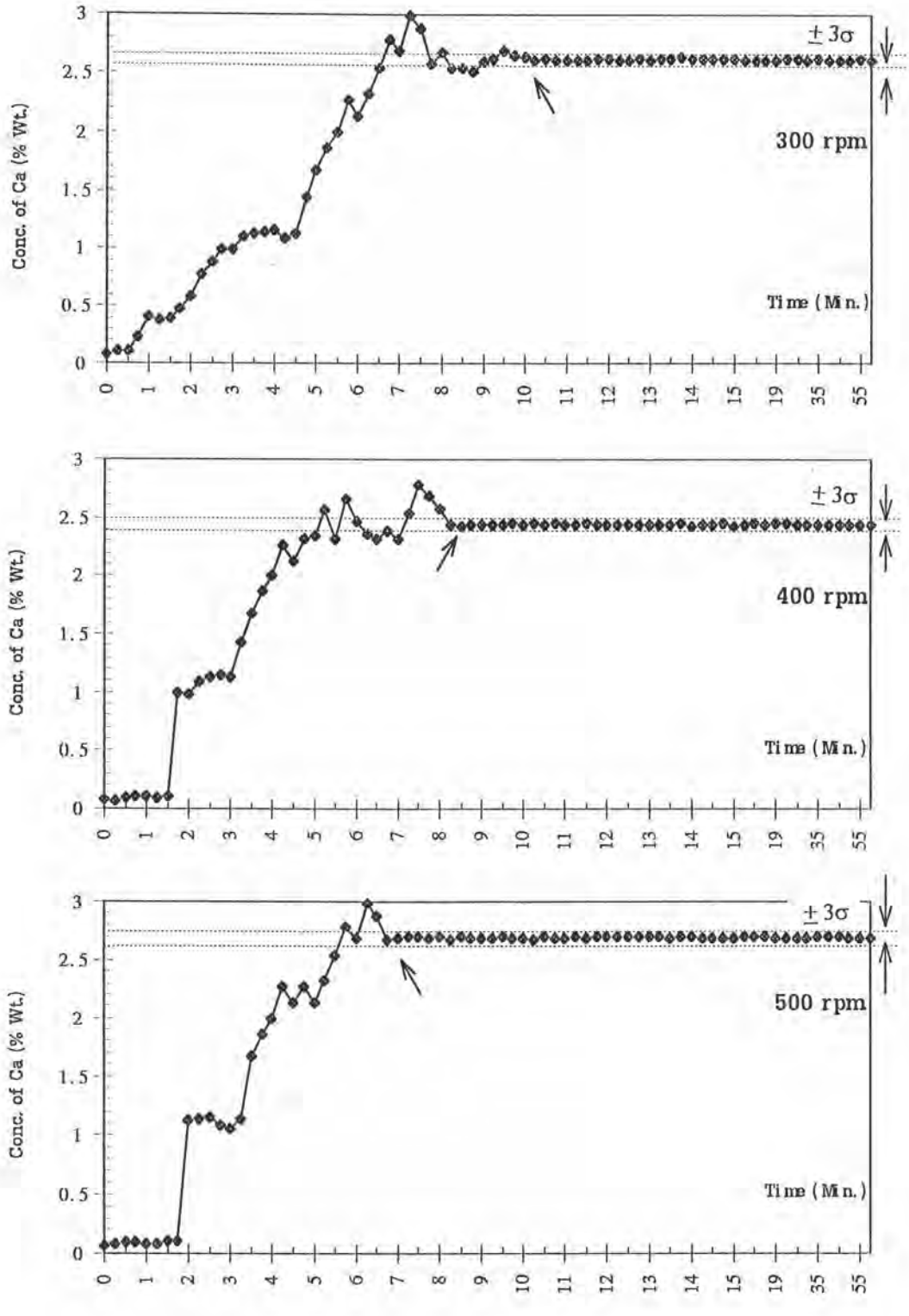


Figure G-9 Mixing time curve, 36 cm. diameter tank

Viscosity @ 100 ^{o}C = 19 cSt., N = 300, 400, 500 rpm.

APPENDIX I

PREDICTION ACCURACY OF THE PRESENT GENERAL CORRELATIONS.

Table I-1 show, the relative errors between the experimental mixing time and the calculated mixing time. The calculated mixing time are obtained from the correlation. The relative errors are based on the experimental mixing time.

From Figure 5.7, A linear regression analysis was provided by curve fitting as below :-

CURVE EQUATION-FORM
1 Y = A+B*X

A	B	R-SQUARED	ADJ. R^2
+2582.422900	+0.367216	0.842828	0.836279

OBSN	X	Y	FITTED-Y	RESID.ERROR	%ERROR
1	152.1450	2550.0000	2638.2930	-88.2930	3.46
2	202.8600	2520.0000	2656.9163	-136.9163	5.43
3	253.5750	2600.0000	2675.5398	-75.5398	2.91
4	655.0790	2760.0000	2822.9785	-62.9785	2.28
5	873.4390	2840.0000	2903.1638	-63.1638	2.22
6	1091.7990	2950.0000	2983.3491	-33.3491	1.13
7	1369.3060	3000.0000	3085.2542	-85.2542	2.84
8	1825.7410	3200.0000	3252.8643	-52.8643	1.65
9	2282.1760	3400.0000	3420.4746	-20.4746	0.60
10	140.3500	2580.0000	2633.9617	-53.9617	2.09
11	187.1330	2560.0000	2651.1411	-91.1411	3.56
12	233.9170	2600.0000	2668.3210	-68.3210	2.63
13	604.2950	2760.0000	2804.3298	-44.3298	1.61
14	805.7260	2880.0000	2878.2983	1.7017	0.06
15	1007.1580	3000.0000	2952.2676	47.7324	1.59
16	1263.1500	3030.0000	3046.2720	-16.2720	0.54
17	1684.2011	3200.0000	3200.8887	-0.8887	0.03
18	2105.2500	3300.0000	3355.5046	-55.5046	1.68
19	79.3650	2640.0000	2611.5669	28.4331	1.08
20	105.8210	2600.0000	2621.2820	-21.2820	0.82
21	132.2760	2600.0000	2630.9968	-30.9968	1.19
22	341.7180	2790.0000	2707.9072	82.0928	2.94
23	455.6240	2920.0000	2749.7354	170.2646	5.83
24	569.9290	3000.0000	2791.7100	208.2900	6.94
25	714.2890	3060.0000	2844.7212	215.2788	7.04
26	952.6850	3180.0000	2932.2642	247.7358	7.79
27	1190.4821	3450.0000	3052.4321	347.5679	10.22

MEAN ABSOLUTE % ERROR 2.690222
MEAN SQUARE ERROR 10166.6

Table I-1 Prediction accuracy of data from table 5.5 by correlation

Viscosity of lubp. oil @ 100 °C , cSt.	Diameter tank, cm.	Speed, rpm.	t_m		% Error
			$t_{m,\ Exper.}$	$t_{m,\ Calc.}$	$(t_{me} - t_{mc})/t_{me}$ x100
12	12	300	8.5	8.5	0.00
		400	6.3	6.5	-3.17
		500	5.2	5.2	0.00
	25	300	9.2	9.4	-2.17
		400	7.1	7.3	-2.82
		500	5.9	6.0	-1.69
	36	300	10.0	10.5	-5.00
		400	8.0	8.4	-5.00
		500	6.8	7.2	-5.88
14	12	300	8.6	8.5	1.16
		400	6.4	6.4	0.00
		500	5.2	5.2	0.00
	25	300	9.2	9.2	0.00
		400	7.2	7.2	0.00
		500	6.0	6.0	0.00
	36	300	10.1	10.3	-1.98
		400	8.0	8.3	-3.75
		500	6.8	7.0	-2.94
19	12	300	8.8	8.4	4.54
		400	6.5	6.4	1.54
		500	5.2	5.1	1.92
	25	300	9.3	8.9	4.31
		400	7.3	6.9	5.48
		500	6.0	5.6	6.67
	36	300	10.2	9.5	6.86
		400	8.2	7.4	9.75
		500	6.8	6.2	8.82

APPENDIX J

SPECIFICATIONS OF FINISHED LUBRICATING OILS

Specification of finished product

Table J.1 STD-Oil-1 (SAE 30)

Properties	Unit	Limit (Shell)	Limit (DCR)
Density @ 15 Deg C	kg/l	0.8993-0.9190	-
Viscosity @ 100 Deg C	cSt	11.3-12.4	9.3-12.5
Ca-content		0.891-1.05	-
Crackle test	-	none	none
Pour point	Deg C	-18 Max	-6 Max
Foam test	-	0	nil

Table J.2 STD-Oil-2 (SAE 40)

Properties	Unit	Limit (Shell)	Limit (DCR)
Density @ 15 Deg C	kg/l	0.8080-0.9845	-
Viscosity @ 100 Deg C	cSt	13.7-15.1	12.5-16.3
Ca-content		0.111-0.129	-
Crackle test	-	none	none
Pour point	Deg C	-9 Max	-6 Max
Foam test	-	0	nil

Table J.3 STD-Oil-3 (SAE 50)

Properties	Unit	Limit (Shell)	Limit (DCR)
Density @ 15 Deg C	kg/l	0.8003-0.9780	-
Viscosity @ 100 Deg C	cSt	18.1-20.0	16.3-21.9
Ca-content		0.117-0.138	-
Crackle test	-	none	none
Pour point	Deg C	-27 Max	-6 Max
Foam test	-	0	nil

DCR = Department of Commercial Registration

VITA

Thawatchai Sirinan was born on January 23, 1971 in Chonburi, Thailand. He received his Bachelor of Science Degree in Industrial Chemistry from King Mongkut Instituted of Technology Ladkrabang (KMITL), Bangkok, Thailand, in 1993. He has worked at The Shell company of Thailand since 1993. He has been a graduate student of the Master degree in Chemical Engineering, Graduate School, Chulalongkorn University, since 1994.