16:44:11 OCA PAD AMENDMENT - PROJECT HEADER INFORMATION 05/25/94

Active

Project #: E-19-668 Cost share #: Rev #: 17
Center # : R6128-0A0 Center shr #: OCA file #:
Work type : RES
Contract#: BUD REV DTD 870211 Mod #: BR DTD 940427 Document : OTH
Prime #: Contract entity: GTRC

Subprojects ? : N CFDA: N/A
Main project #: PE #: N/A

Project unit: CHEM ENGR Unit code: 02.010.114
Project director(s):
TEJA A S CHEM ENGR (404)894-3098

Sponsor/division names: FLUID PROPERTIES RESEARCH INC /
Sponsor/division codes: 205 / 012

Award period: 850801 to 950630 (performance) 950630 (reports)

Sponsor amount	New this change	Total to date
Contract value	63,991.00	576,212.00
Funded	63,991.00	576,212.00
Cost sharing amount		0.00

Does subcontracting plan apply ?: N

Title: ESTABLISHMENT OF FLUID PROPERTIES RESEARCH CENTER AT GEORGIA TECH

PROJECT ADMINISTRATION DATA

OCA contact: Jacquelyn L. Tyndall 894-4820

Sponsor technical contact

DR AMYN S TEJA
(404)894-3098

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF CHEMICAL ENGINEERING
ATLANTA, GA 30332

Sponsor issuing office

J DAVID CHASE, PRESIDENT
(512)241-2343

CELANESE CHEMICAL COMPANY
TECHNICAL CTR., BOX 9077
CORPUS CHRISTI TX 78408

Security class (U,C,S,TS) : U ONR resident rep. is ACO (Y/N): N
Defense priority rating : NA NA supplemental sheet
Equipment title vests with: Sponsor X GIT

Administrative comments -
ISSUED TO ADD $63,991 TO PROJECT AND EXTEND PROJECT TERMINATION DATE THROUGH JUNE 30, 1995.

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 09/12/95
Original Closeout Started 09/03/92

Project No. E-19-668 Center No. R6128-0A0

Project Director TEJA A S School/Lab CHEM ENGR

Sponsor FLUID PROPERTIES RESEARCH INC/

Contract/Grant No. BUD REV DTD 870211 Contract Entity GTRC

Prime Contract No.

Title ESTABLISHMENT OF FLUID PROPERTIES RESEARCH CENTER AT GEORGIA TECH

Effective Completion Date 950630 (Performance) 950630 (Reports)

Closeout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	N	
Final Report of Inventions and/or Subcontracts	N	
Government Property Inventory & Related Certificate	N	
Classified Material Certificate	N	
Release and Assignment	N	
Other	N	

Comments

Subproject Under Main Project No.

Continues Project No.

Distribution Required:

Project Director	Y
Administrative Network Representative	Y
GTRI Accounting/Grants and Contracts	Y
Procurement/Supply Services	Y
Research Property Managment	Y
Research Security Services	N
Reports Coordinator (OCA)	Y
GTRC	Y
Project File	Y
Other	N
	N

FLUID PROPERTIES RESEARCH, INC.
ANNUAL REPORT, JUNE 1986

Principal Investigator: Amyn S. Teja, Professor and Technical Director

Staff: Paul Locascio (From November 1985), Technician
Wahid Tawfik (From April 1986), Postdoctoral Fellow

Introduction

Fluid Properties Research, Inc. moved from Oklahoma State University to Georgia Institute of Technology in August 1985. During the past nine months, an office and two laboratories have been established at Georgia Tech. As reported at the meetings in November 1985 and May 1986, the equipment received from Oklahoma State University was in a considerable state of disrepair and not functioning when received. Major effort was therefore devoted to equipment overhaul, purchase and installation of new instrumentation, modifications, recalibration and to developing changes in experimental procedures. A grant from the Georgia Tech Research Corporation was used for purchasing instruments and other equipment. As a result, the three experiments (thermal conductivity, viscosity and density) are now operational and a program of measurements on pure liquids is being planned for the 1986-87 year. The current status of the experiments and the modifications made are summarized below.

1. Thermal Conductivity

The relative hot wire apparatus for the measurement of thermal conductivity is shown in Fig. 1. Improvements to the original apparatus include:

(i) the installation of a fluidized bath (TECAM SBL-2D) in place of the original oil bath (not received from OSU). A TECAM TC4D temperature controller, offering temperature control to $\pm$ 0.1K up to 500°C, has also

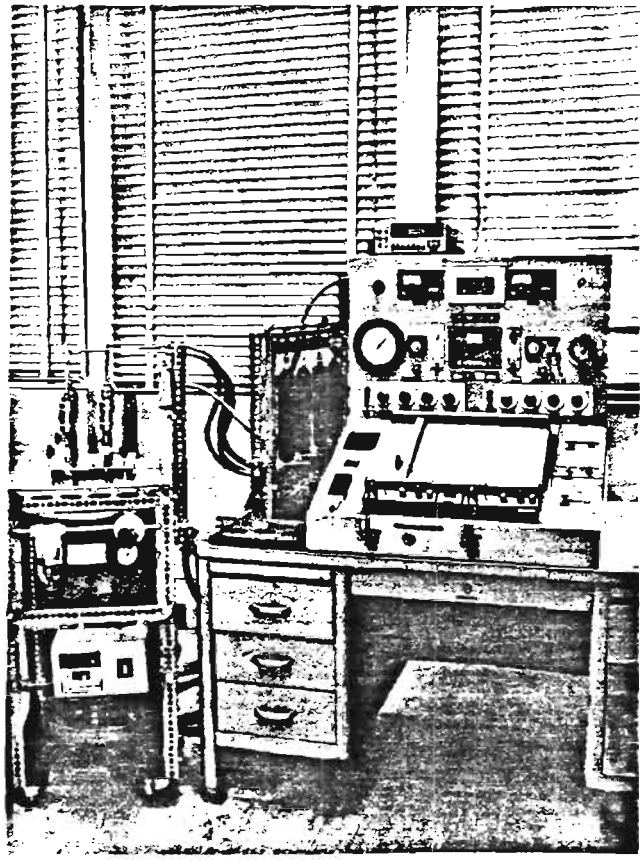

Fig. 1 Thermal Conductivity Apparatus

been installed.

(ii) the insertion of new thermocouples inside the thermal conductivity cell for more accurate measurement of the actual temperature of the sample. The thermocouples are connected to a new Fluke 8840A multimeter which has been calibrated according to NBS standards.

(iii) the use of spot welding instead of gold soldering of the platinum leads to the platinum filament. This eliminates the step change in resistance between the filament and the leads.

(iv) the installation of a new constant temperature bath for the reference cell.

(v) complete overhaul of the pressurizing and electical systems.

(vi) precise calibration of the x-y recorder using an HP multifunction generator over the entire range of inputs between 0.1 to 5 volts.

(vii) calibration of differential amplifiers.

The thermal conductivity of benzene (relative to toluene) was measured in the new apparatus. Two separate tests were carried out using benzene in the reference cell and using silicon oil in the reference cell (as recommended in the OSU procedure). Results and comparisons are shown in Fig. 2.

2. Viscosity

The capillary viscometer has been completely rebuilt and is shown in Fig. 3. Major improvements to the original apparatus include:

(i) installation of a Lindberg air bath in place of the original sand bath. In principle, this will extend the range of measurements to 1000°C.

(ii) installation of a new digital Heise gauge for pressures upto 200 bar (3000 psi). The gauge was calibrated against a dead weight tester (Budenberg).

(iii) replacement of the cooling system.

(iv) installation of a new digital pump speed controller.

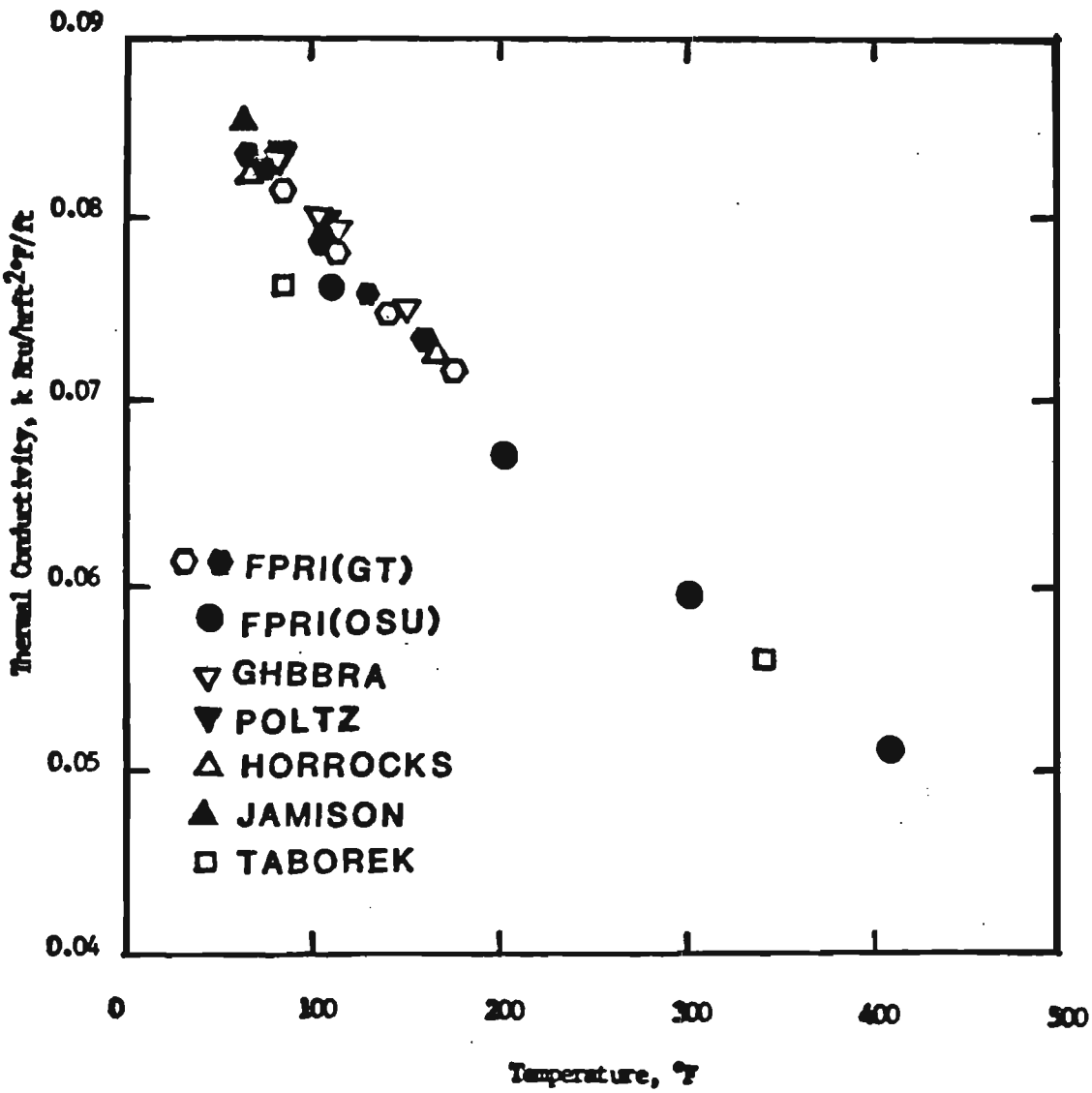

Fig. 2. Thermal Conductivity of Benzene

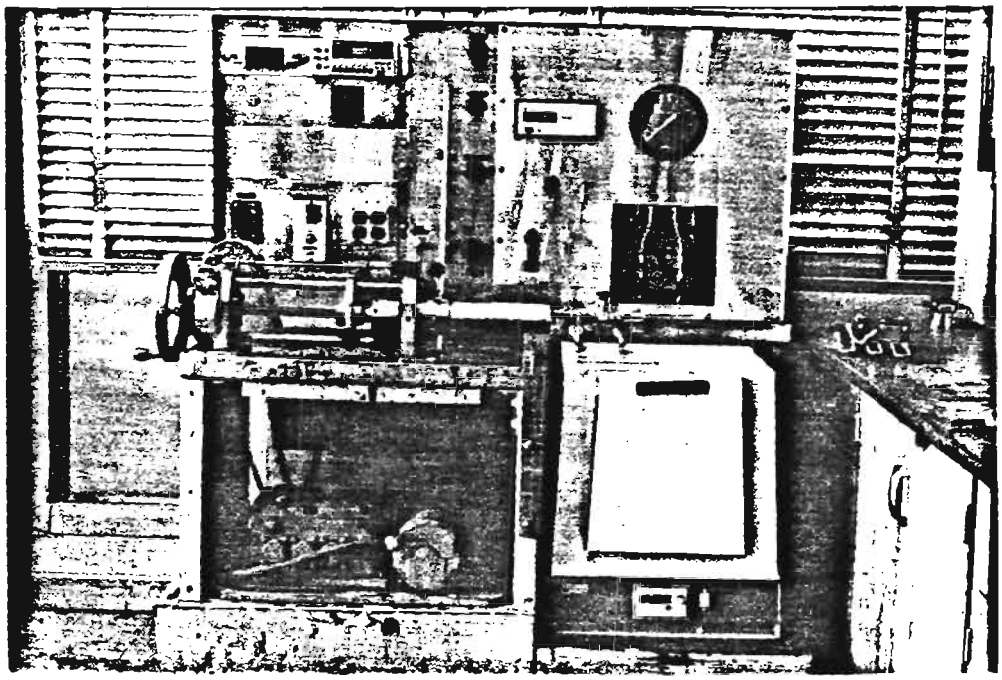

Fig. 3 Capillary Viscometer

(v) installation of new thermocouples and a Fluke 8840A digital multimeter.

(vi) installation of a new 110V wiring system.

(vii) calibration of differential pressure gauge.

The calibration tests are shown in Figs. 4 and 5.

3. Density

A new high pressure density apparatus has been constructed which uses the cells from the previous apparatus. The new apparatus is shown in Fig. 6 and consists of:

(i) a new HAAKE N3 constant temperature oil bath capable of maintaining temperatures constant to ± 0.1°C upto 250°C.

(ii) a new SARTORIUS digital balance for weighing the cells to an accuracy of 1 mg. (Fig. 7)

(iii) a new high pressure pump system for charging the cells (Fig. 8)

(iv) a new Fluke 8840A digital multimeter for recording thermocouple emfs.

In addition, the cells are now weighed empty and then charged with triple distilled water to determine the volume. Calibration with mercury has thus been eliminated.

The density of n-hexadecane has been measured and the data are summarized in Table 1. The measured values agree with those of Dymond and Young to within ± 0.02%.

Other Work

The following reports have been issued based on the work of graduate students in the thermodynamics group at Georgia Tech.

FPRI 8601 Critical Temperatures of Isomeric Pentanols and Heptanols

FPRI 8602 Characteristic Viscosity as a Third Parameter in Corresponding States Calculations of Transport Properties. I. Defined Mixtures

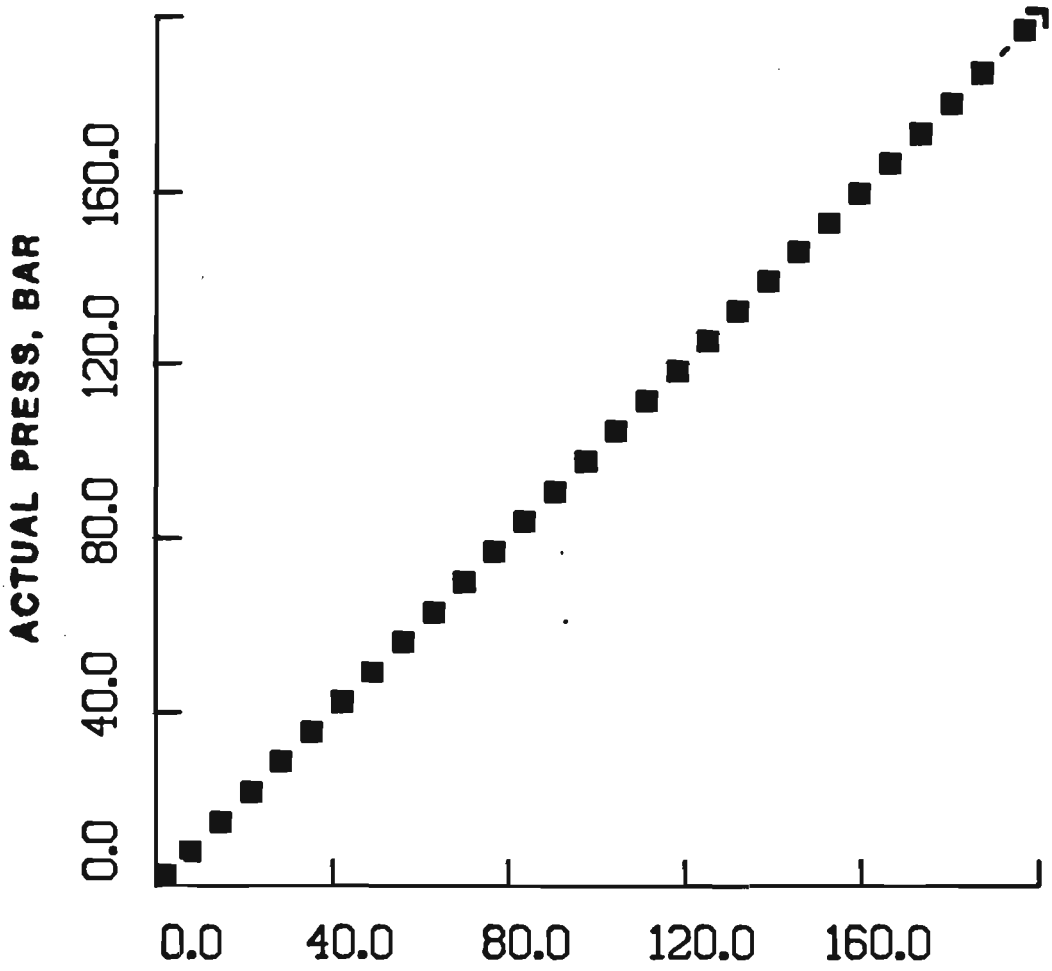

Fig. 4 HEISE Pressure Gauge Calibration

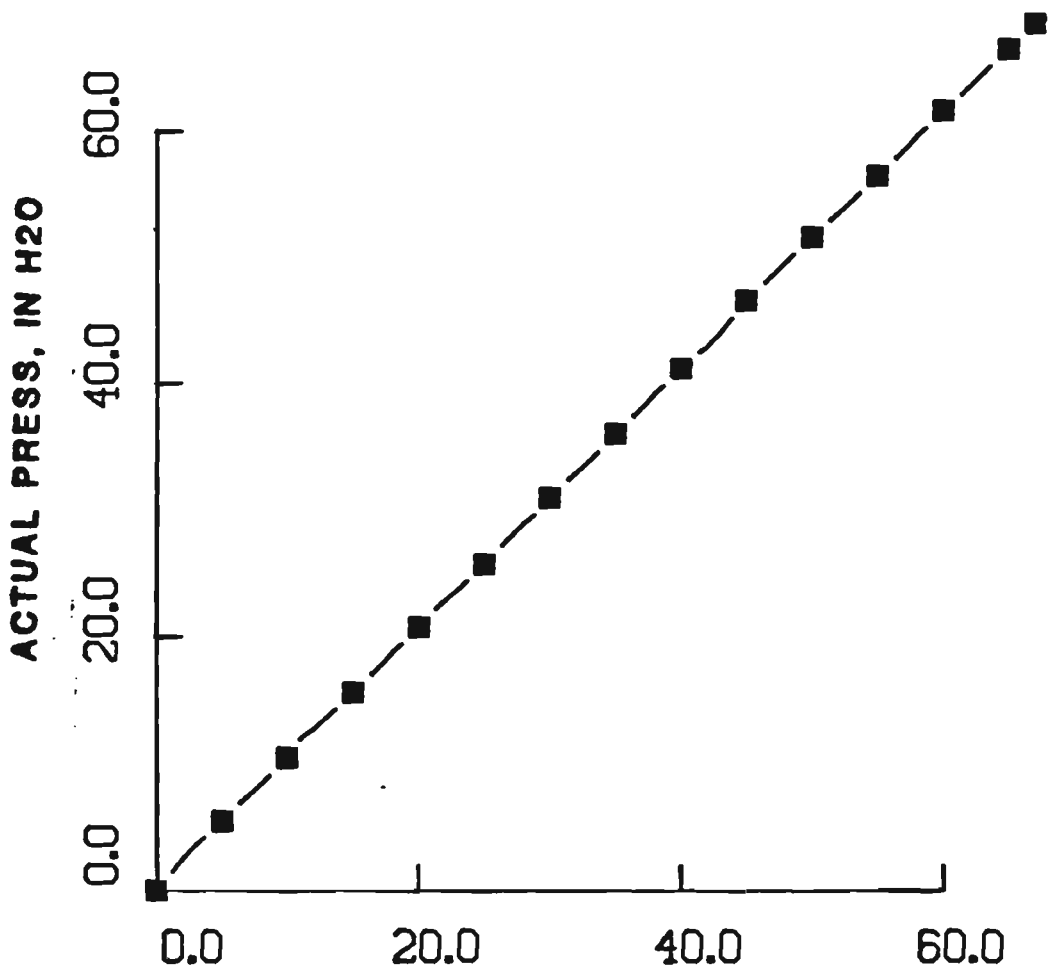

Fig. 5 ITT Barton Gauge Calibration

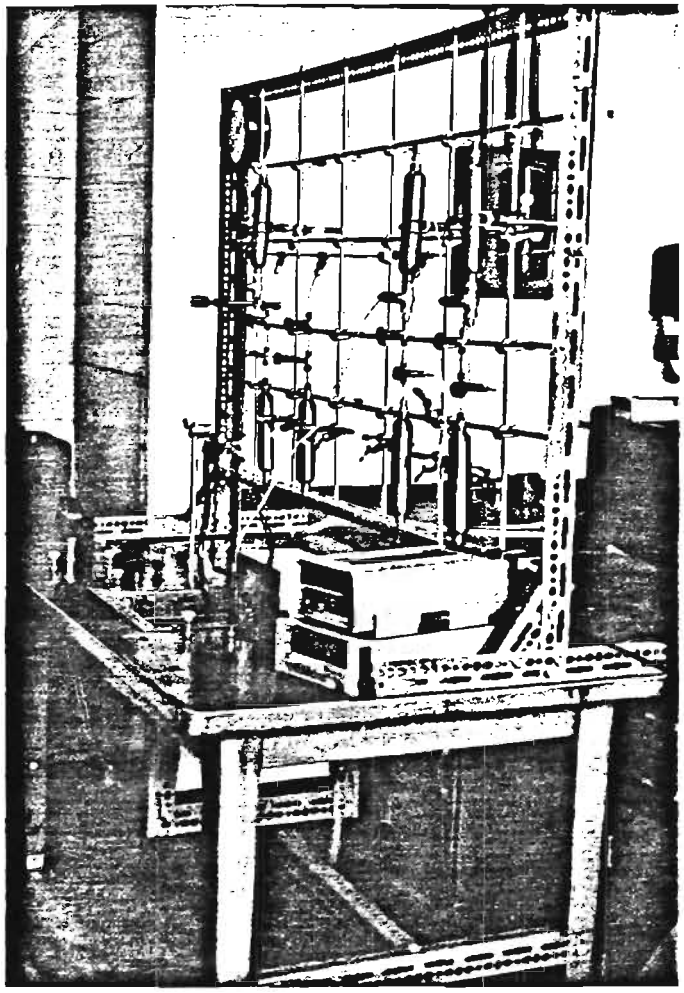

Fig. 6 Density Apparatus

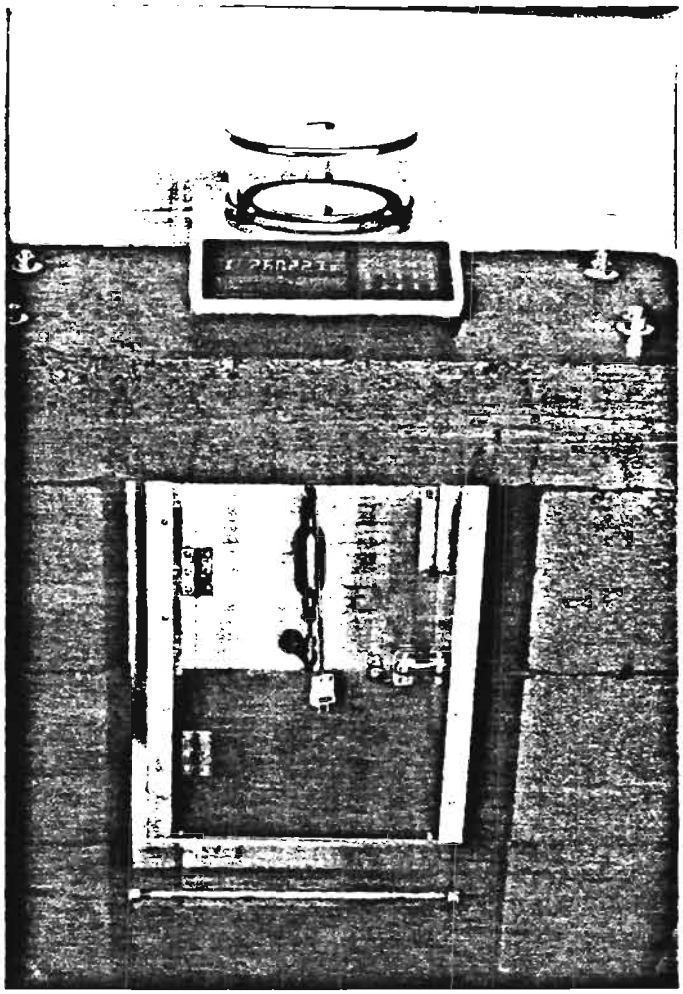

Fig. 7 Digital Balance

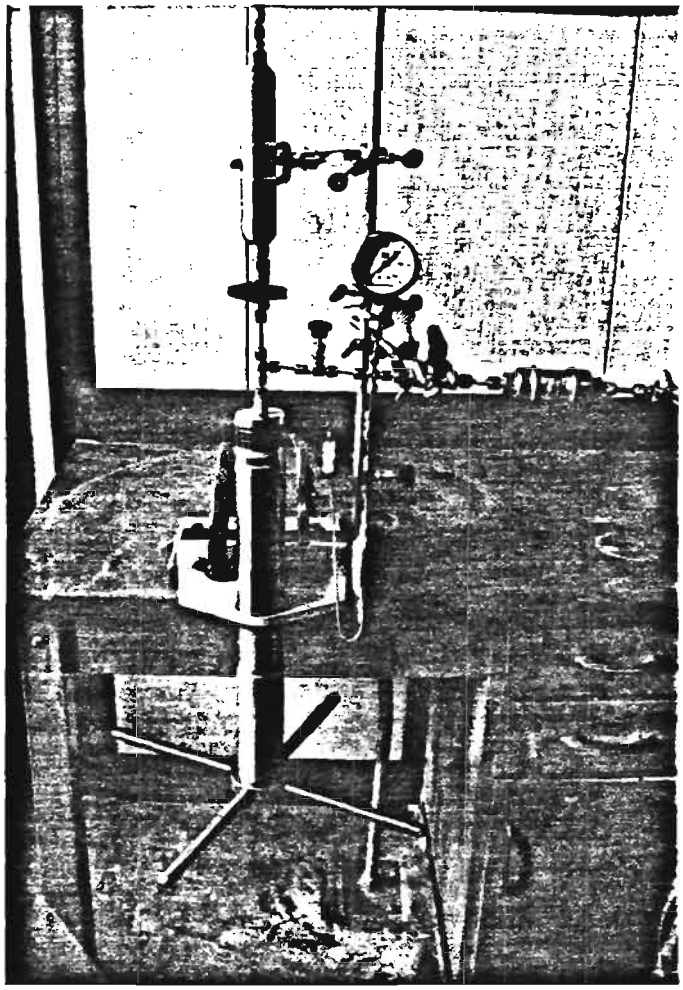

Fig. 8 High Pressure Pump

Table 1. Experimental Values of Hexadecane Density

REFERENCE SYSTEM: HEXADECANE
25 < T < 100

COMPARISON WITH DYMOND AND YOUNG

THIS WORK (P=14.7 PSI)			DYMOND & YOUNG (P=0.1 MPA)	
ρ(GM/CC)	TEMP° K	$\Delta\rho$	ρ(GM/CC)	TEMP° K
0.7700775	298.015	−.0001225	0.77020	298.15
0.75315	323.032	+.00015	0.75300	323.15
0.735947	348.079	+.00015	0.73580	348.15
0.718728	373.112	+.00013	0.71860	373.15

MAXIMUM DEVIATION ±0.02%

FPRI 8603 Characteristic Viscosity as a Third Parameter in Corresponding States Calculations of Transport Properties. II. Undefined Mixtures

FPRI 8604 The Prediction of Dew Points of Semi-Continuous Natural Gas and Petroleum Mixtures. I. Characterization by Use of an Effective Carbon Number and Ideal Solution Predictions

FPRI 8605 The Prediction of Dew Points of Semi-Continuous Natural Gas and Petroleum Mixtures. II. Non-ideal Solution Predictions

FPRI 8606 The Prediction of Vapor Pressures of Carboxylic Acids

FPRI 8607 Solubilities of Solid n-Alkanes in Supercritical Ethane

FPRI 8608 Prediction of Enthalpy and Entropy Departures using a Two Fluid Corresponding States Principle

FPRI 8609 Continuous Thermodynamics of Phase Equilibria using a Multivariate Distribution Function and an Equation of State

Future Plans

The densities, thermal conductivities and viscosities of the following liquids will be measured over a range of temperatures between 25°C and 250°C and pressures between 1 bar and 200 bar:

(i) p-methyl styrene
(ii) ethylene glycol
(iii) diethylene glycol
(iv) triethylene glycol
(v) propylene glycol
+ 5 other liquids of interest

Other related work includes:

(i) the measurement of critical states of thermally unstable substances using pulse laser heating
(ii) the separation of sugars using supercritical fluids
(iii) the separation of alkaloids having anti-tumor properties from plant materials using supercritical fluids
(iv) the measurement of high pressure phase equilibria of thermally unstable mixtures
(v) the separation of fatty acids from aqueous mixtures using supercritical fluids
(vi) development of equation of state and corresponding states methods for complex mixtures

FLUID PROPERTIES RESEARCH, INC.
Administrative Offices

Georgia Institute of Technology
School of Chemical Engineering
Atlanta, Georgia 30332
404-894-

FPRI

January 15, 1987

Dr. David Palmer
Amoco Corporation
P.O. Box 400
Naperville, IL 60566

Dear Dr. Palmer:

Here are the first six design data sheets from the FPRI research effort at Georgia Tech. Although this effort has taken approximately one year to bear fruit, I believe that the results have been worth waiting for. This is particularly true because all FPRI equipment has been completely overhauled and rebuilt with more accurate sensors. The results should therefore be as accurate as is practicable with our present equipment. We hope to issue further design data sheets at regular intervals from now on.

You should also have received nine FPRI reports over the past year (8600 series). These reports present the results of thermophysical property research work at Georgia Tech during 1986. Reports in the 1987 series should be forthcoming in the near future. Please note that theses as well as computer programs mentioned in these reports are available to FPRI members at nominal cost (cost of printing only). A list of recent Ph.D. theses is enclosed, together with abstracts. Please let me know if you would like copies of any of these theses.

FPRI work over the next year will be concerned with extending the range of our measurements to the limits of our equipment. We would welcome suggestions for substances to study, preferably with 1 liter samples of the pure materials. A new apparatus for thermal conductivity of aqueous mixtures will also be built with Georgia Tech funds. A proposal has been submitted to ASHRAE for this work, as well as for rebuilding our drop calorimeter for heat capacity measurements. Other sources of funds are also being actively pursued. Development of two new correlations for viscosity and thermal conductivity should be completed over the next six months. A Ph.D. thesis describing a new group contribution equation of state for phase equilibria should also be completed in the near future.

To sum up, I believe that we have come a long way since FPRI moved to Atlanta - although there is still a long way to go

before we become the premier center for thermodynamic and transport properties research. Your suggestions for improvement, further work, as well as joint work are always very welcome.

With best wishes for 1987

Amyn S. Teja
Technical Director FPRI
Professor of
Chemical Engineering

P.S. 1 I would like to explore the possibility of appointing Professor Arai from Tohoku University to our Board of Directors. Professor Arai could serve as liaison for our Japanese members as well as assist in the recruitment of new members in Japan. Please let me have your thoughts on this matter.

P.S. 2 The School of Chemical Engineering at Georgia Tech has a new Director from Jan. 1, 1987. He is Professor Ron Rousseau from North Carolina State University. I am sure that most of you know Professor Rousseau and will take the opportunity to say "hello" to him at AIChE meetings or when you next come to Atlanta. I am sure you will also want to thank our past Director, Gary Poehlein, for his support of FPRI during 1986.

AST/jvl
encl.

cc. R. Rousseau

LIST OF REPORTS ISSUED IN 1986

8601 Critical temperatures of isomeric pentanols and heptanols

8602 Characteristic viscosity as a third parameter in corresponding states calculations of transport properties I Defined mixtures

8603 Characteristic viscosity as a third parameter in corresponding states calculations of transport properties II Undefined mixtures

8604 The prediction of dew-points of semi-continuous natural gas and petroleum mixtures I Characterization and ideal solution predictions

8605 The prediction of dew-points of semi-continuous natural gas and petroleum mixtures II Non-ideal solution predictions

8606 The prediction of vapor pressures of carboxylic acids

8607 Solubilities of solid n-alkanes in supercritical ethane

8608 Prediction of enthalpy and entropy departures using a two-fluid corresponding states principle

8609 Continuous thermodynamics of phase equilibria using a multivariate distribution function and an equation of state

FORTHCOMING REPORTS AND DESIGN DATA SHEETS

8701 Applications of cubic equations of state to polar fluids and fluid mixtures

8702 The correlation and prediction of the viscosities of mixtures over a wide range of pressures and temperatures

8703 The measurement of the critical temperatures of thermally unstable n-alkanes

8704 Phase equilibria in the carbon dioxide + n-hexadecane system

8705 High pressure phase equilibria in the glucose + fructose + ethanol + water + carbon dioxide system

8706 Determination of the critical properties of thermally unstable substances by extrapolation of the critical locus

DDS-LTC-A3	P. Methyl Styrene
DDS-LD-A3	
DDS-LV-A3	
DDS-LTC-A4	Diethylene Glycol
DDS-LTC-A5	Triethylene Glycol
DDS-LTC-A6	Propylene Glycol
DDS-LTC-A7	Dipropylene Glycol
DDS-LTC-A8	Tripropylene Glycol

LIST OF Ph.D THESES SUPERVISED BY DR. A. S. TEJA IN 1985-86

Bert Willman, Ph.D. (December 1985)
"Continuous Thermodynamics of Fluid Mixtures" (682 pages)

Richard Lee Smith Jr., Ph.D. (December 1985)
"Measurement and Correlation of Critical States"
(253 pages)

Iraj Moradinia, Ph.D. (March 1986)
"The Solubility of High Molecular Weight Solid Hydrocarbons in Supercritical Ethane" (441 pages)

Rupert D'Souza, Ph.D. (August 1986)
"Separation of Fructose From Glucose Using Supercritical Solvents" (214 pages)

Cost of reproduction: 10¢/page + $3.00 for spiral binding

Bert Willman, Ph.D. (December 1985)
"Continuous Thermodynamics of Fluid Mixtures" (682 pages)

SUMMARY

The phase behavior and transport properties of chemically undefined and complex fluid mixtures have been investigated using the methods of continuous thermodynamics. In the continuous thermodynamics approach, the molar composition of the heaviest fraction of the fluid mixture is mathematically approximated by a statistical distribution function. One or more macroscopically distributed quantities such as the boiling point or specific gravity serve as the characterization variable(s) for the distribution function. This approach is preferable to the more arbitrary method of pseudocomponents in which the heavy fraction is characterized by a few lumped "key components". In this work, predictive semi-continuous models have been developed for vapor pressure, ideal and non-ideal solution behavior, high pressure phase equilibria, and viscosities of liquid mixtures.

In the area of vapor pressure predictions, a conventional vapor pressure equation was modified and the constants related to the Effective Carbon Number (ECN). The ECN of any fluid may be obtained from its normal boiling point and the known properties of the n-alkanes. The vapor pressures of paraffinic, napthenic, aromatic, and

sulfur compounds in the range 1 kPa to the critical pressure were predicted using this method and comparisons shown with the predictions of a group-contribution method (UNIFAC).

A semi-continuous ideal solution model was developed using the ECN as the characterization variable in a gamma distribution function. The ECN was preferred over the molecular weight as the characterization variable as it can distinguish between various isomers. This simple model was used to predict dew points of natural gas condensates with surprising accuracy. No density iterations are required with this method and furthermore the method does not suffer from stability and convergence problems.

A semi-continuous non-ideal solution model was developed to account for non-idealities in the vapor and liquid phases. The model uses semi-continuous extensions of the virial equation and regular solution theory. As in the ideal-solution model, the ECN was used as the characterization variable in a gamma distribution function. The non-ideal solution model requires no adjustable constants and was shown to yield accurate predictions of dew point temperatures. Correlations were also obtained for liquid density, acentric factor and the solubility parameter of nonpolar fluids as functions of the effective carbon number.

A semi-continuous high pressure phase equilibrium model was developed using the boiling point and specific gravity as two continuously distributed characterization variables. A bi-variate log normal distribution function was used to describe the molar composition of heavy undefined fractions. An equation of state capable of good phase equilibrium and liquid density predictions (Patel-Teja) was extended to continuous mixtures. Dew points of gas condensates, absorber oils, crude oils, synthetic aromatic heavy oils and coal liquids were predicted using this model and comparisons made with other methods. The new method was shown to give excellent predictions of both phase equilibria and liquid densities of undefined mixtures. The use of a multivariate distribution function allows a wide range of fluids to be treated successfully using a single method.

Finally, a semi-continuous liquid mixture viscosity model was developed using a modification of the three parameter generalized corresponding states principle. A new third parameter characteristic viscosity was proposed. This parameter is based on the reduced viscosity at a reduced temperature of 0.6 and offers advantages over the more conventional acentric factor (which is based on vapor pressure).

Viscosities of undefined mixtures such as crude oil fractions, crude oil mixtures and coal liquid fractions were calculated. The best results were obtained using the new characteristic viscosity parameter. For the crude oil mixtures, viscosity calculations were performed using a variety of characterization methods for the undefined fraction including the method of pseudocomponents and that of continuous thermodynamics. Results were seen to be relatively insensitive to the characterization method employed confirming that transport properties are not particularly sensitive to various compositional lumping schemes.

Richard Lee Smith Jr., Ph.D. (December 1985)
"Measurement and Correlation of Critical States"
(253 pages)

SUMMARY

A modified sealed tube method has been developed for the measurement of the critical temperatures of fluids. The method has been used to obtain the critical temperatures of normal alkanes from n-octane to n-hexadecane, diphenylmethane, two normal alcohols, and five isomeric alcohols. Since alkanes decompose starting with n-decane, a new method of analysis has been developed. This employs reaction kinetics based on an irreversible first order unimolecular reaction and is used to linearize the apparent critical temperature versus time curve and perform a more certain extrapolation to the undecomposed substance. The method is successful because the temperature history of the substance is recorded by computer and ampoule contents are analyzed at the experiment completion. The approach is general since many hydrocarbon decompositions can be described empirically by a first order rate expression. New critical constants are reported and compared with previous experimental values and with available correlations from the literature.

From the analysis of our method it may be concluded that for the determination of critical points: (1) standard methods may be used if the substance is not thermally sensitive (2) an extrapolation to zero time may be used if the substance decomposes very slightly and (3) the temperature history must be known and the time in the hot zone minimized, if the substance decomposes rapidly.

A two fluid generalized corresponding states principle (GCSP) has

extended to the prediction of enthalpies, entropies, and critical loci. The method is applicable to nonpolar, nonpolar-polar, and polar-polar mixtures. The merit of the GCSP lies in the way the model can adapt to the mixture of interest by a judicious choice of refereence fluids. Accurate predictions have been obtained for mixtures of (1) simple spherical molecules, (2) large quasispherical molecules, (3) both spherical and nonspherical molecules, and (4) molecules exhibiting strong dipole moments.

The best predictions are made by using the most accurate reference fluids. Extrapolations in acentric factor about a reference fluid whose properties are not well known are shown to lead to high errors. The calculations are more sensitive to errors for critical pressure prediction with the temperature and the volume being much less effected.

The pseudocritical mixing rules used in the calculations had the advantage that the critical volumes of the components of interest were not required. It is shown how the use of inaccurate critical properties in the mixing rules can lead to large errors, especially in the region of a highly dilute solute.

Iraj Moradinia, Ph.D. (March 1986)
"The Solubility of High Molecular Weight Solid Hydrocarbons in Supercritical Ethane" (441 pages)

SUMMARY

Processes such as distillation and liquid extraction are widely used in the petrochemical, chemical, pulp and paper, food, petroleum and pharmaceutical industries to separate one or more components from a mixture. Supercritical fluid extraction (SFE) is a novel separation technique which utilizes features of both distillation and liquid extraction. It offers considerable advantages as a separation technique, particularly for thermally unstable substances, and it has therefore attracted considerable research interest over the past decade. In this work, the solubilities of higher molecular weight n-alkanes (n-octacosane, n-nonacosane, n-triacontane, n-dotriacontane, n-tritriacontane) were measured in supercritical ethane over a temperature range of 308.1-319.1 K and a pressure range of 6-20.2 MPa. In addition to possible supercritical extraction applications, these longer n-alkanes are also of importance in coal liquefaction, in oil production from shale and tar sands and in enhanced oil recovery.

An additional reason for studying the n-alkane series is that even-numbered n-alkanes exhibit different trends in their solid phase properties (e.g. sublimation pressure, heat of fusion, etc.) than the odd-numbered members of the series.

The solubilities measured in this work were correlated using two cubic equations of state (the Patel-Teja and the Peng-Robinson equations) and two corresponding states methods (the generalized

corresponding states method with two reference fluids and the corresponding states method with shape factors). A binary interaction coefficient was required in all the methods. The two methods based on cubic equations of state gave the best overall agreement with experiment. An interesting outcome of these calculations was that the binary interaction coefficients obtained using the Patel-Teja equation of state were found to exhibit regular trends for mixtures containing odd and even numbered n-alkanes. The extrapolation of these trends should prove useful in the prediction of the solubilities of other members of the n-alkane series. Because of the need to estimate the critical properties (T_c, P_c, V_c), the acentric factor (ω) and the vapor pressure of the solid n-alkanes in the above methods, a new correlation was developed for the solubility as a function of solid state properties.

The solubilities of even and odd-numbered n-alkanes at a given temperature and pressure were found to vary linearly with the n-alkane solid reduced density at the triple point. Separate correlations were required for the odd and even-numbered n-alkanes. These new correlations offer a number of advantages. First, the critical properties are not required. Second, the solubility of any even or odd numbered n-alkanes (e.g. n-$C_{31}H_{61}$, n-$C_{35}H_{72}$, n-$C_{34}H_{70}$) in supercritical ethane near the critical point of ethane can be predicted solely from a knowledge (or estimate) of the triple point pressure (P_t), triple point temperature (T_t) and the solid molar volume (V^S). It should, however, be emphasized that these correlations of data were obtained over a limited range of conditions

and should only be subjected to judicious extrapolation.

New correlations were also developed for the sublimation pressures of odd and even-numbered n-alkanes based on the number of carbon atoms in the molecule.

Rupert D'Souza, Ph.D. (August 1986)
"Separation of Fructose From Glucose Using Supercritical Solvents" (214 pages)

SUMMARY

Glucose and fructose have similar chemical and physical properties in aqueous solutions, but different solubilities in ethanol. In this study fructose was separated from glucose using supercritical carbon dioxide with ethanol as an entrainer.

A high pressure vapor-liquid recirculation apparatus was designed and developed to measure data in the two phase, vapor-liquid region. The coexisting phases were circulated in a countercurrent manner to obtain good mixing. Temperatures were maintained to within ± 0.01 K and pressures to within ± 0.027 MPa with temperature and pressure control systems, respectively. Carbon dioxide + n-hexadecane was first selected as a test system. Our data at 333.15 K were compared with the data of King et al (1984) and Charoensombut-amon et al (1985). The liquid composition compared well with the liquid data of Charaensombut-amon et al but the vapor data did not compare well with their vapor data. However our vapor data compared well with the vapor data of King et al (1984) but the liquid data did not compare well with the liquid data measured by King et al. Since no conclusions could be made, the binary system carbon dioxide + water was then selected as a test system. Our data compared

well with those of Weibe (1941).

Vapor-liquid equilibria were measured for the system carbon dioxide + water + ethanol + glucose + fructose. Two feed compositions (assumed to be glucose + fructose + water + ethanol) were selected and vapor-liquid equilibria were measured at various temperatures and pressures. Good selectivities of fructose with respect to glucose were obtained in narrow ranges of pressure and temperature. The best selectivity was obtained at 333.15 K and for feed F1. However, as in most supercritical fluid extraction processes, the total amount of solute extracted in the vapor phase was relatively low. Three phases (L_1-L_2-G) were observed at all temperatures for both the feeds. The middle phase was ethanol -rich with relatively high concentration of carbon dioxide.

The Patel-Teja equation of state and the Rachford-Rice technique were used to model the five-component system, glucose + fructose + water + ethanol + carbon dioxide. Since the critical temperature and critical pressure for glucose and fructose are not available in the literature, they were estimated. The pure component constants a, b and c in the Patel-Teja equation of state are obtained from the densities and vapor pressures of the pure components at different temperatures. However these properties are not available for pure fructose and glucose. Hence a new technique was developed to extend this equation of state to thermally labile materials. The

constants were obtained knowing the densities and pressures of the aqueous solutions. The overall absolute deviation (AAD) for the prediction of densities of aqueous sugar solutions in the concentration range 5 weight % to 80 weight % and temperature range 303.15 K to 353.15 K using this technique was 1.2% and the maximum error was 2.48%.

Binary interaction parameters were needed to calculate vapor-liquid equilibria for the system glucose + fructose + ethanol + water + carbon dioxide. The Patel-Teja equation of state was used to calculate binary equilibrium data for the binary systems ethanol+water and carbon dioxide + water. The overall AAD between the experimental and calculated equilibrium ratios was 3.57% for carbon dioxide and 3.13% for water. For the ethanol + water system, the AAD was 5.98% for water and 7.42% for ethanol.

The Patel-Teja equation was then used to calculate vapor-liquid equilibria for the five component system. The overall AAD between the experimental and calculated ratios for carbon dioxide, water, ethanol, fructose and glucose were 15.89%, 19.9%, 18.33%, 38.67% and 31.52%. Fair agreement with the experimental data was obtained despite the fact that four of the five components studied were highly polar and two components (glucose and fructose) are thermally labile.

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April 28, 1987

J. David Chase
Celanese Chemical Co.
P.O. Box 9077
Corpus Christi, TX 78408

Dear Mr. Chase:

Please find enclosed eight design data reports relating to FPRI supported research during the past four months. Also enclosed are five technical reports relating to other fluid properties research in the School of Chemical Engineering. Further reports will be forthcoming at the annual meeting in June. We are proposing to hold the annual FPRI meeting in Atlanta on June 19, 1987 (alternative date is June 26). Please let me know which of these two dates fits in with your schedule.

The FPRI laboratories are now fully functional and in good shape for future measurements. The density and thermal conductivity experiments are yielding reliable and accurate data. However, we are having to redesign the capillary viscometer because of concerns about safety at high pressures and temperatures. In the meantime, we will be making viscosity measurements with the Georgia Tech rolling ball viscometer. I have also received funds from ASHRAE to construct a thermal conductivity apparatus for aqueous electrolyte solutions, as well as to refurbish the FPRI heat capacity calorimeter. Hopefully, these apparati will be available for fluid properties research in future years. By the end of the 1986 fiscal year, we hope to have available two new correlations for viscosity and thermal conductivity in the form of IBM PC diskettes and/or hard copy.

I look forward to seeing you all in June. In the meantime, please feel free to call me with your suggestions for future work.

Yours sincerely,

Amyn S. Teja
Technical Director
and Professor

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April, 1987 DDS-LTC-A3

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Diethylene Glycol
$HOCH_2CH_2OCH_2CH_2OH$

Purity =	99+%	
Molecular Weight =	106.121 kg/kmol	[1]
Critical Temperature =	680.0 K	[2]
Critical Pressure =	45.5 atm	[2]
Critical Volume =	0.312 m^3/kmol	[2]
Melting Point =	262.7 K	[3]
Normal Boiling Point =	518.15 K	[3]
Liquid Molar Volume =	0.095174 m^3/kmol	[4]
Acentric Factor =	1.2006	[4]
Dipole Moment =	1.8346 X 10^{-29} cm	[4]
van der Waals Volume =	0.0607 m^3/kmol	[5]
van der Waals Area =	7.920 X 10^8 m^2/kmol	[5]

Experimental Technique : Relative Hot Wire Method

Experimental Data:

pressure = 700 PSI

λ (w/mk)	T (K)
0.2050 ±0.005	298.5 ±0.2
0.2051	329.2
0.2066	329.3
0.2061	369.8
0.2082	370.6
0.2092	384.5
0.2085	405.6
0.2084	424.5

Liquid Thermal Conductivity Correlation:

$$\lambda\,(w/mk) = 0.1954 + 3.2231 \times 10^{-5}\,T(K)$$

%AAD = 0.31%
%MAD = 0.52%

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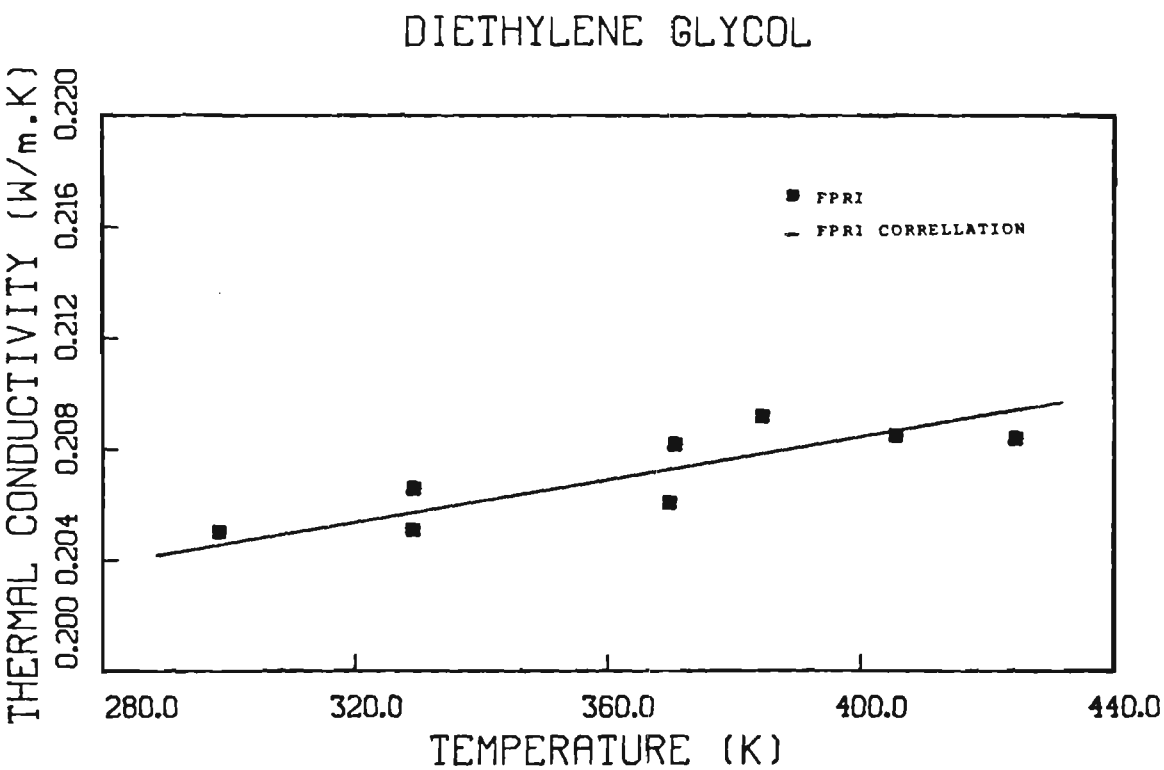

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2. Reid, R.C., J.M. Praunitz, and T.K. Sherwood, "The Properties of Gases and Liquids", 3rd Ed., McGraw-Hill, New York (1977).

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5. Bondi, A., "Physical Properties of Molecular Crystals, Liquids and Glasses", John Wiley, New York (1968).

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April, 1987 DDS-LTC-A4

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Triethylene Glycol
$HOCH_2CH_2OCH_2CH_2OCH_2CH_2OH$

Purity =	98+%	
Molecular Weight =	150.174 kg/kmol	[1]
Critical Temperature =	700.0 K	[2]
Critical Pressure =	33.1 atm	[2]
Critical Volume =	0.443 m^3/kmol	[2]
Melting Point =	265.79 K	[2]
Normal Boiling Point =	551.00 K	[3]
Liquid Molar Volume =	0.133844 m^3/kmol	[4]
Acentric Factor =	1.3863	[4]
Dipole Moment =	1.8612×10^{-29} cm	[4]
van der Waals Volume =	0.08486 m^3/kmol	[5]
van der Waals Area =	1.2200×10^9 m^2/kmol	[5]

Experimental Technique : Relative Hot Wire Method

Experimental Data:

pressure = 750 PSI

λ (w/mk)	T (K)
0.1964 ±0.005	307.6 ±0.2
0.1961	307.7
0.1952	345.3
0.1954	345.7
0.1945	418.3

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (W/mk)} = 0.20099 - 1.5862 \times 10^{-5} \text{ T(K)}$$

%AAD = 0.066%
%MAD = 0.161%

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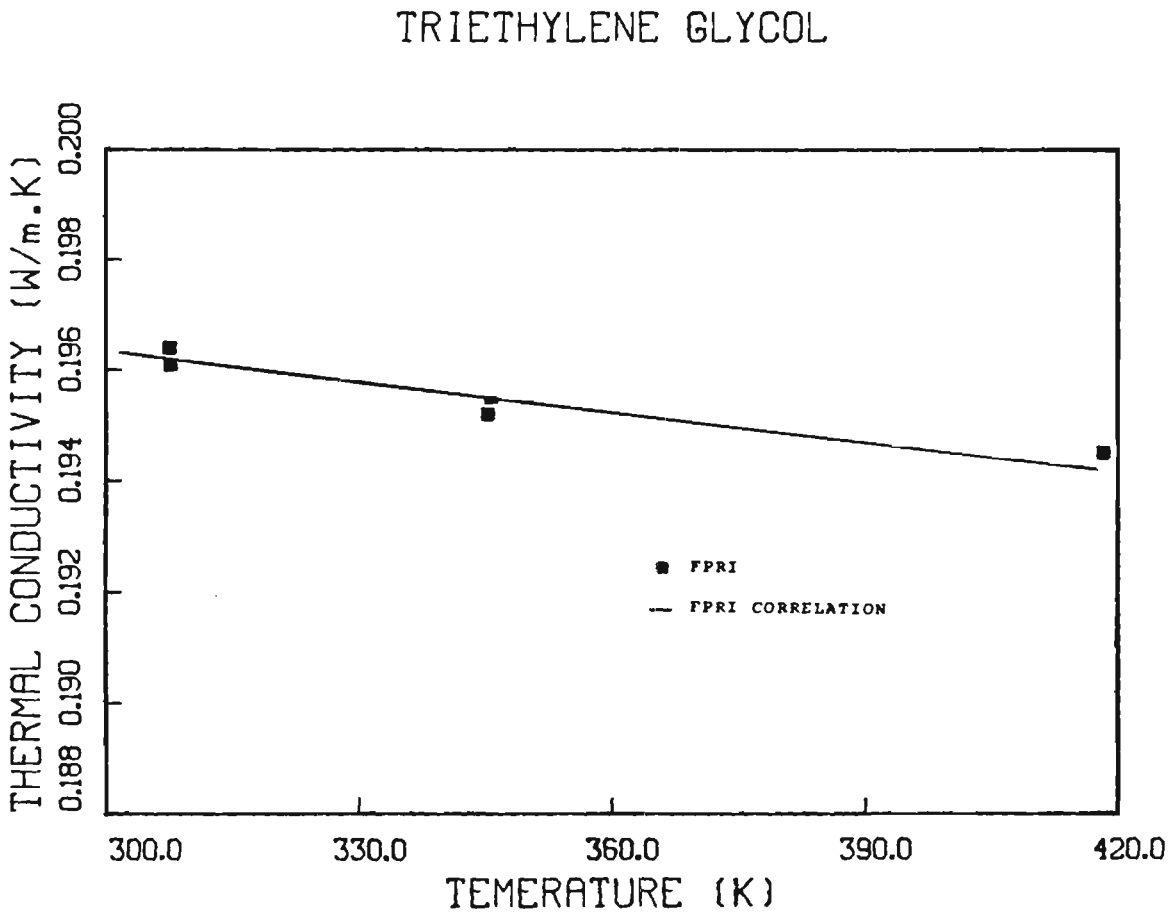

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2. Gallant, R.W.,"Physical Properties of Hydrocarbons", Gulf Publishing Company, Houston, Texas (1970).

3. Curme, G.O.J., editor, "Glycols", Reinhold Publishing Corporation, New York (1952).

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5. Bondi, A., "Physical Properties of Molecular Crystals, Liquids and Glasses", John Wiley, New York (1968).

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April, 1987 DDS-LTC-A5

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Propylene Glycol
$CH_3CH(OH)CH_2OH$

Purity =	99+%	
Molecular Weight =	76.095 kg/kmol	[1]
Critical Temperature =	624 K	[2]
Critical Pressure =	61.1 atm	[2]
Critical Volume =	0.239 m^3/kmol	[2]
Melting Point =	213.15 K	[3]
Normal Boiling Point =	460.75 K	[3]
Liquid Molar Volume =	0.073694 m^3/kmol	[4]
Acentric Factor =	1.1065	[4]
Dipole Moment =	1.2108 X 10^{-29} cm	[4]
van der Waals Volume =	0.04676 m^3/kmol	[5]
van der Waals Area =	0.9600 X 10^8 m^2/kmol	[5]

Experimental Technique : Relative Hot Wire Method

Experimental Data:

pressure = 750 PSI

λ(w/mk)	T (K)
0.2019 +0.005	297.1 +0.2
0.2023	297.2
0.1985	340.9
0.1969	350.4
0.1950	387.7
0.1945	387.7

Liquid Thermal Conductivity Correlation:

$$\lambda\,(W/mk) = 0.22631 - 8.18861 \times 10^{-5}\,T(K)$$

%AAD = 0.181%
%MAD = 0.365%

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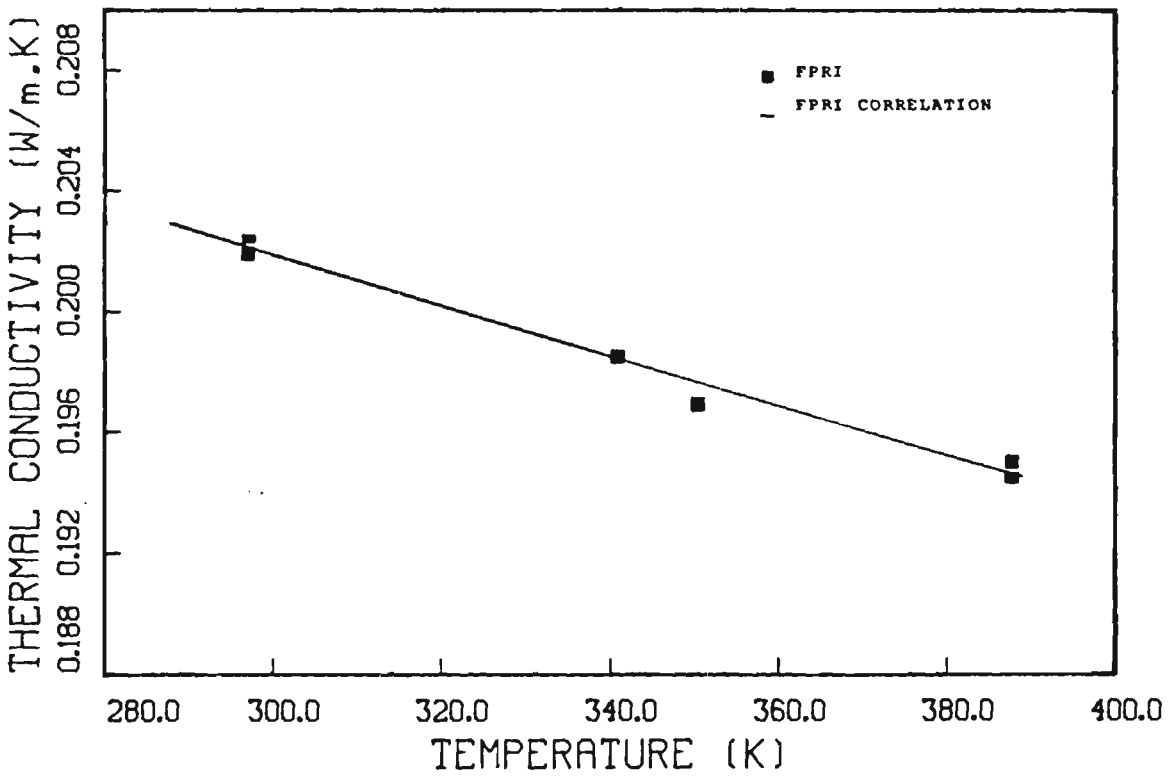
PROPYLENE GLYCOL



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2. Gallant, R.W.,"Physical Properties of Hydrocarbons", Gulf Publishing Company, Houston, Texas (1970).

3. Thermodynamics Research Center, "Selected Values of Properties of Chemical Compounds", Data Project, Texas A&M University, College Station, Texas.

4. AICHE DIPPR Data Compilation Manual, T. Daubert and R.P. Danner (Eds), 1985

5. Bondi, A., "Physical Properties of Molecular Crystals, Liquids and Glasses", John Wiley, New York (1968).

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April, 1987 DDS-LTC-A6

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
P-Methyl Styrene 0.2% Hydro Quinone
$C_6H_4(CH_3)CH:CH_3$

Purity =	98+%	
Molecular Weight =	118.18 kg/kmol	[1]
Critical Temperature =	647.5 K	[2]
Critical Pressure =	33.2 atm	[2]
Critical Volume =	0.405 m^3/kmol	[2]
Melting Point =	---	
Normal Boiling Point =	446.15 K	[3]
Liquid Molar Volume =	---	
Acentric Factor =	---	
Dipole Moment =	---	
van der Waals Volume =	---	
van der Waals Area =	---	

Experimental Technique : Relative Hot Wire Method

Experimental Data:

pressure = 750 PSI

λ (w/mk)	T (K)
0.1356 ±0.005	273.1 ±0.2
0.1361	273.1
0.1323	281.0
0.1299	294.5
0.1298	323.1
0.1242	368.8
0.1211	393.6
0.1183	439.1

Liquid Thermal Conductivity Correlation:

$$\lambda\,(w/mk) = 0.162303 - 1.0245 \times 10^{-4}\ T(K)$$

%AAD = 0.987%
%MAD = 1.717%

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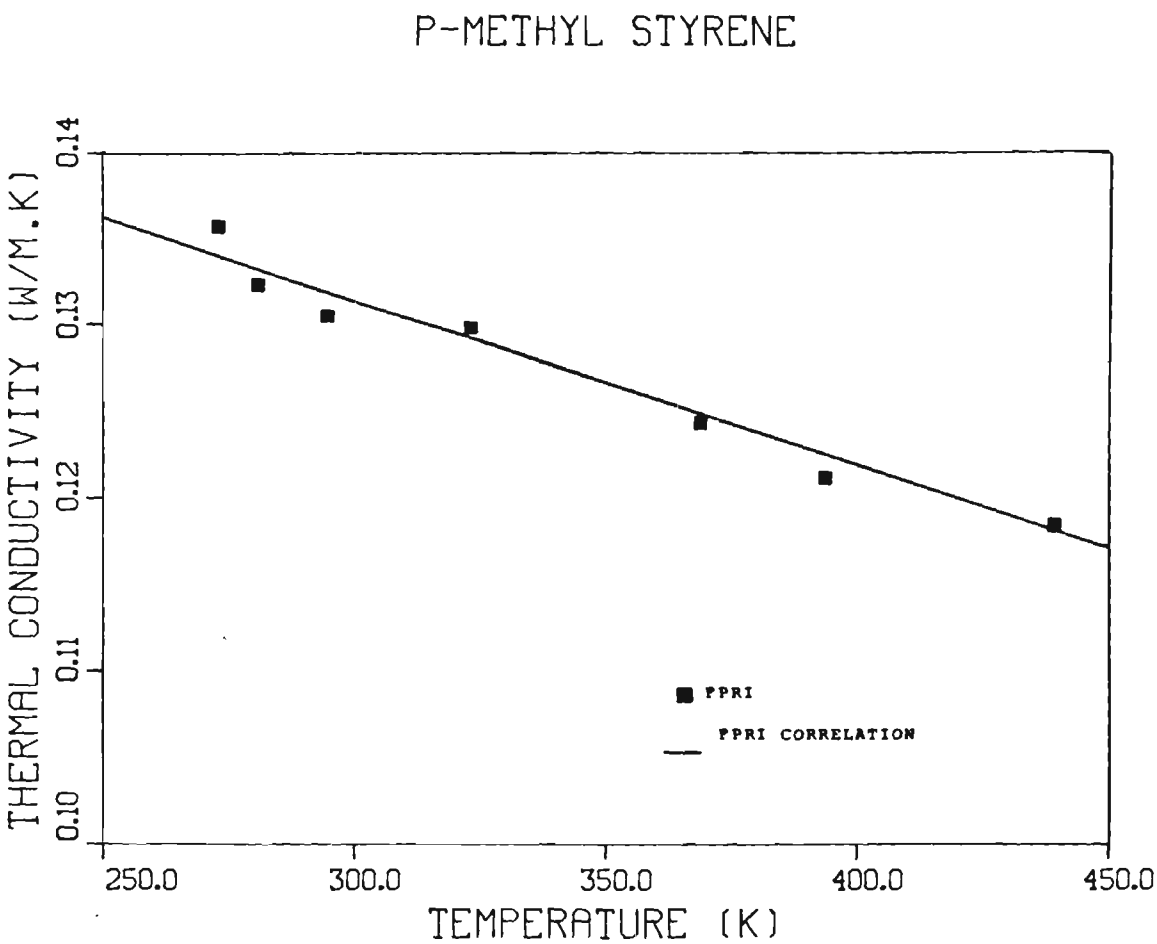

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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem. 52, 2349 (1980).

2. Reid, R.C., J.M. Praunitz, and T.K. Sherwood, "The Properties of Gases and Liquids", 3rd Ed., McGraw-Hill, New York (1977).

3. Brandrup and Immergut, Editors, "Polymer Handbook", John Wiley and Sons, New York (1975)

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April, 1987 DDS-LD-A3

DESIGN DATA STANDARD - LIQUID DENSITY
Diethlyene Glycol
$HOCH_2CH_2OCH_2CH_2OH$

Purity =	99+%	
Molecular Weight =	106.121 kg/kmol	[1]
Critical Temperature =	680.00 K	[2]
Critical Pressure =	45.5 atm	[2]
Critical Volume =	0.312 m^3/kmol	[2]
Melting Point =	262.7 K	[3]
Normal Boiling Point =	518.15 K	[3]
Liquid Molar Volume =	0.095174 m^3/kmol	[4]
Acentric Factor =	1.2006	[4]
Dipole Moment =	1.8346 X 10^{-29} cm	[4]
van der Waals Volume =	0.0607 m^3/kmol	[5]
van der Waals Area =	7.920 X 10^8 m^2/kmol	[5]

Experimental Technique : DMA 45

Experimental Data:

pressure = 14.7 PSI

ρ (kg/m^3)	T (K)
1111.8 ±0.2	303.2 ±0.1
1103.9	313.3
1087.4	335.8
1080.1	343.8
1074.3	354.3
1060.2	373.2
1044.2	393.9
1021.2	423.4

Liquid Density Correlation:

$$\rho\,(kg/m^3) = 492.74401 * (0.382175)^{(T_r-1)^{2/7}}$$

%AAD = 0.055%
%MAD = 0.112%

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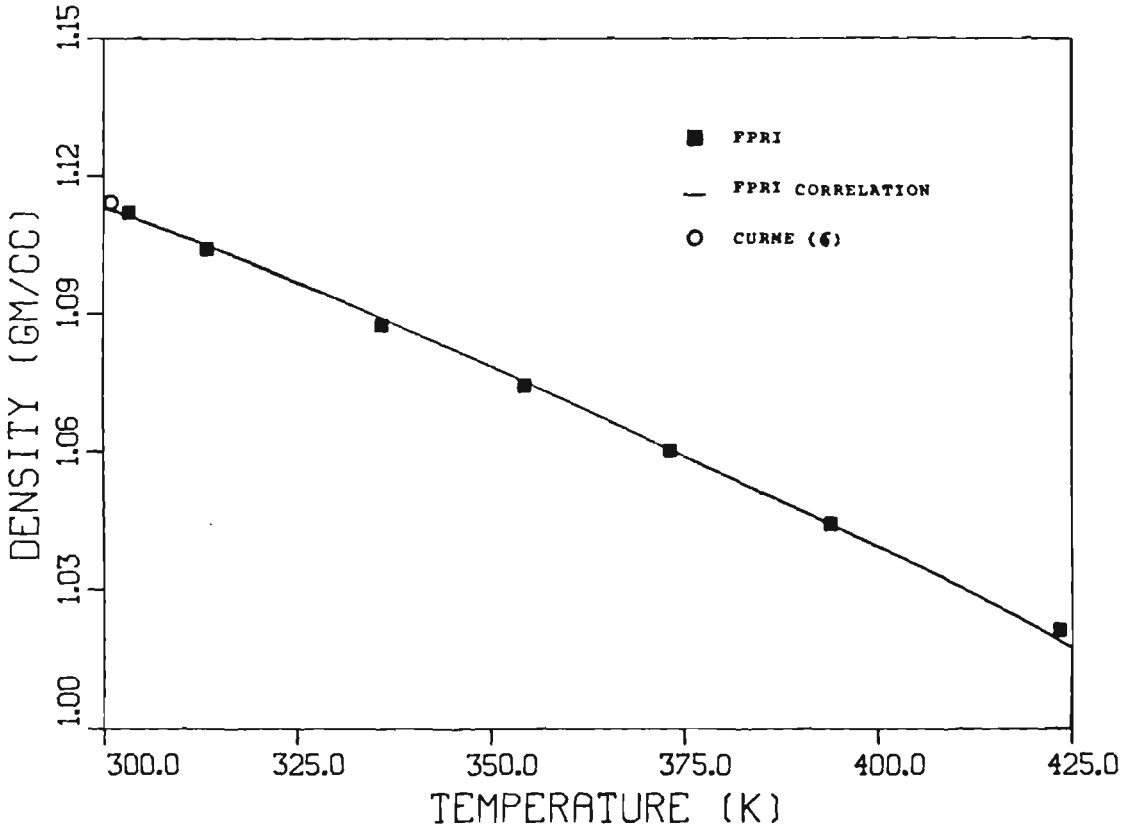
DDS-LD-A3

DI-ETHYLENE GLYCOL



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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem. 52, 2349 (1980).

2. Reid, R.C., J.M. Praunitz, and T.K. Sherwood, "The Properties of Gases and Liquids", 3rd Ed., McGraw-Hill, New York (197 7).

3. Gallant, R.W.,"Physical Properties of Hydrocarbons", Gulf Publishing Company, Houston, Texas (1970).

4. AICHE DIPPR Data Compilation Manual, T. Daubert and R.P. Danner (Eds), 1985

5. Bondi, A., "Physical Properties of Molecular Crystals, Liquids and Glasses", John Wiley, New York (1968).

6. Curme, G.O.J., editor, "Glycols", Reinhold Publishing Corporation, New York (1952).

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April, 1987 DDS-LD-A4

DESIGN DATA STANDARD - LIQUID DENSITY
Triethlyene Glycol
$HOCH_2CH_2OCH_2CH_2OCH_2CH_2OH$

Purity =	98+%	
Molecular Weight =	150.174 kg/kmol	[1]
Critical Temperature =	700.00 K	[2]
Critical Pressure =	33.1 atm	[2]
Critical Volume =	0.443 m^3/kmol	[2]
Melting Point =	265.79 K	[2]
Normal Boiling Point =	551.00 K	[3]
Liquid Molar Volume =	0.133844 m^3/kmol	[4]
Acentric Factor =	1.3863	[4]
Dipole Moment =	1.8612×10^{-29} cm	[4]
van der Waals Volume =	0.08486 m^3/kmol	[5]
van der Waals Area =	1.220×10^9 m^2/kmol	[5]

Experimental Technique : DMA 45

Experimental Data:

pressure = 14.7 PSI

ρ (kg/m^3)	T (K)
1121.2 ±0.2	299.1 ±0.2
1109.3	314.1
1094.9	333.5
1079.2	354.3
1064.8	374.1
1049.5	393.4
1025.6	422.8

Liquid Density Correlation:

$$\rho(kg/m^3) = 462.274417 * (0.35418522)^{(T_r-1)^{2/7}}$$

%AAD = 0.059%
%MAD = 0.086%

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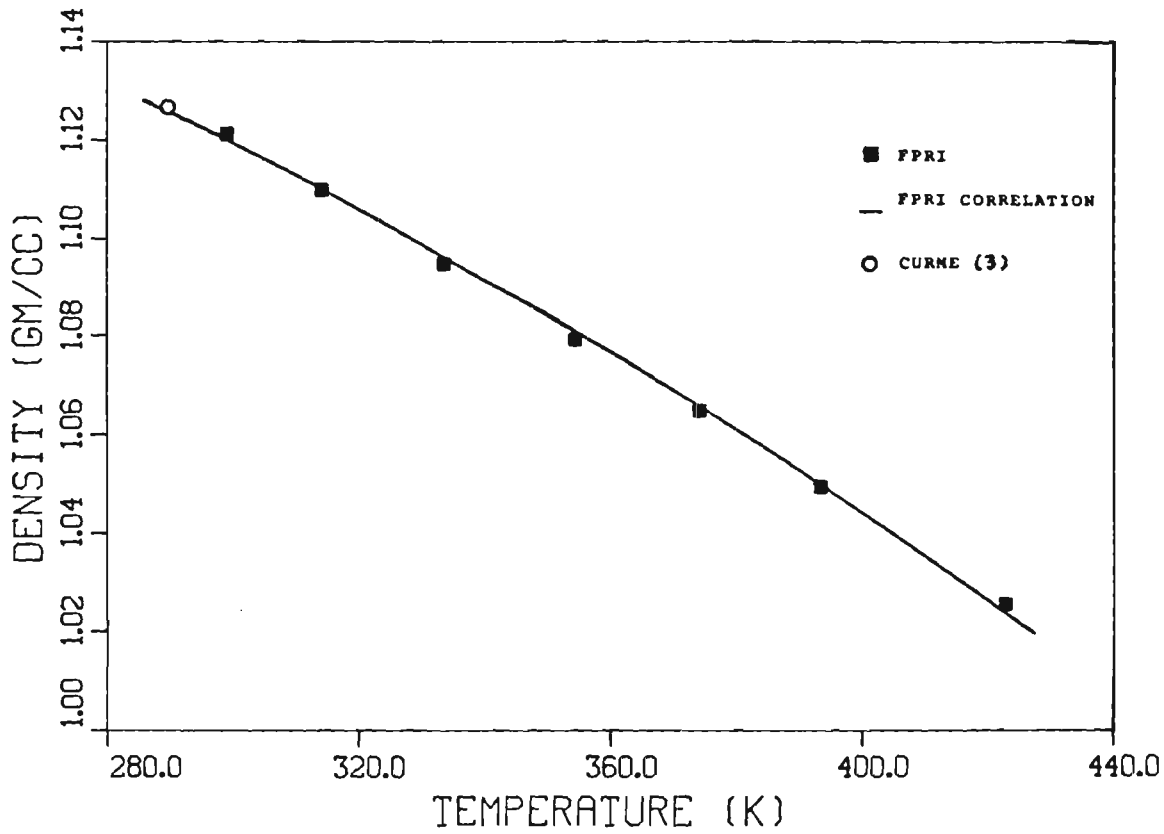
TRI-ETHYLENE GLYCOL



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REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem. 52, 2349 (1980).

2. Gallant, R.W.,"Physical Properties of Hydrocarbons", Gulf Publishing Company, Houston, Texas (1970).

3. Curme, G.O.J., editor, "Glycols", Reinhold Publishing Corporation, New York (1952).

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April, 1987 DDS-LD-A5

DESIGN DATA STANDARD - LIQUID DENSITY
Propylene Glycol
$CH_3CH(OH)CH_2OH$

Purity =	99+%	
Molecular Weight =	76.095 kg/kmol	[1]
Critical Temperature =	624.00 K	[2]
Critical Pressure =	61.1 atm	[2]
Critical Volume =	0.239 m^3/kmol	[2]
Melting Point =	213.15 K	[3]
Normal Boiling Point =	460.75 K	[3]
Liquid Molar Volume =	0.073694 m^3/kmol	[4]
Acentric Factor =	1.1065	[4]
Dipole Moment =	1.2108×10^{-29} cm	[4]
van der Waals Volume =	0.04676 m^3/kmol	[5]
van der Waals Area =	6.960×10^8 m^2/kmol	[5]

Experimental Technique : DMA 45

Experimental Data:

pressure = 14.7 PSI

ρ (kg/m^3)	T (K)
1033.0 ±0.2	303.1 ±0.2
1023.9	313.4
1008.2	334.1
991.4	353.3
973.9	373.4
957.8	393.2
939.9	414.2

Liquid Density Correlation:

$$\rho(kg/m^3) = 450.7411732 * (0.3672593457)^{(T_r-1)^{2/7}}$$

%AAD = 0.101%
%MAD = 0.124%

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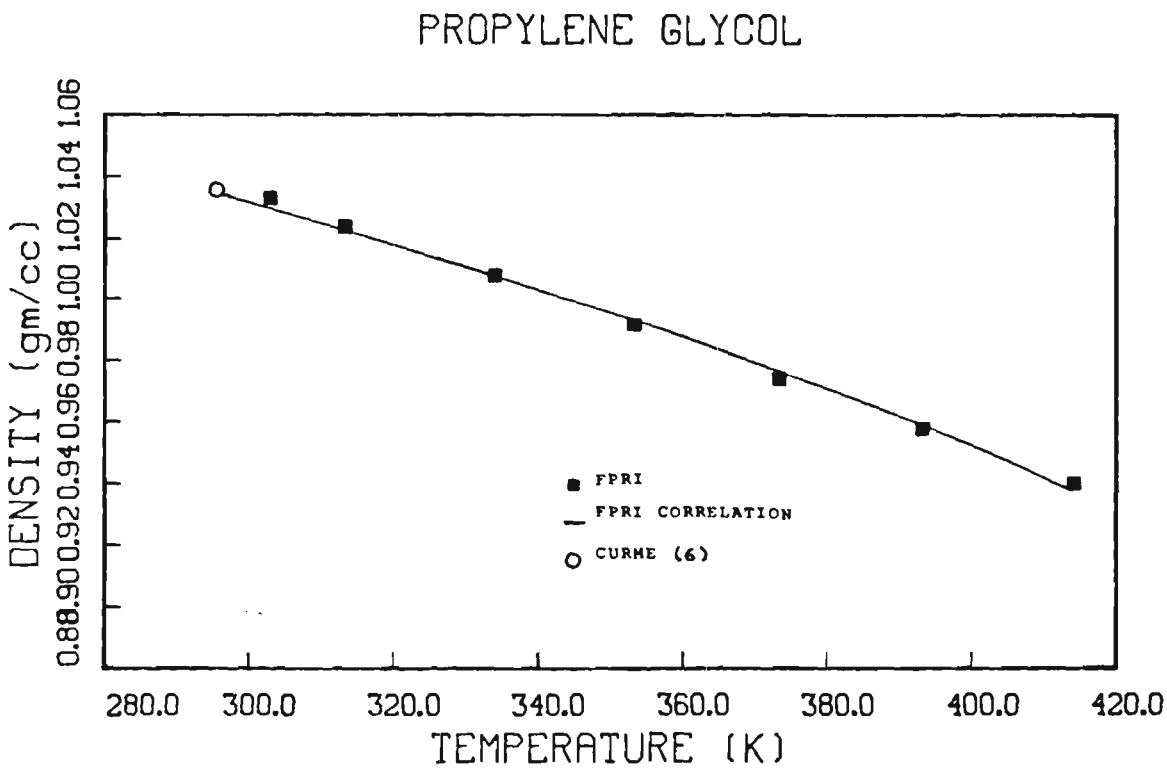

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April, 1987 DDS-LD-A5

REFERENCES

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3. Thermodynamics Research Center, "Selected Values of Properties of Chemical Compounds", Data Project, Texas A&M University, College Station, Texas.

4. AICHE DIPPR Data Compilation Manual, T. Daubert and R.P. Danner (Eds), 1985

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6. Curme, G.O.J. , editor, " Glycols", Reinhold Publication Corporation New York (1952).

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April, 1987

DDS-LD-A6

DESIGN DATA STANDARD - LIQUID DENSITY
P-Methyl Styrene
$C_6H_4(CH_3)CH:CH_2$

Purity =	98+%	
Molecular Weight =	118.18 kg/kmol	[1]
Critical Temperature =	647.5 K	[2]
Critical Pressure =	33.2 atm	[2]
Critical Volume =	0.405 m^3/kmol	[2]
Melting Point =	---	
Normal Boiling Point =	446.15 K	[3]
Liquid Molar Volume =	---	
Acentric Factor =	---	
Dipole Moment =	---	
van der Waals Volume =	---	
van der Waals Area =	---	

Experimental Technique : DMA 45

Experimental Data:

pressure = 14.7 PSI

ρ(kg/m^3)	T (K)
916.2 ±0.2	299.0 ±0.2
912.2	303.3
907.3	308.4
902.6	313.2
892.8	323.4
883.0	334.1
873.6	344.0
865.0	354.1

Liquid Density Correlation:

$$\rho(kg/m^3) = 273.6924649 * (0.2365348879)^{(T_r-1)^{2/7}}$$

%AAD = 0.049%
%MAD = 0.081%

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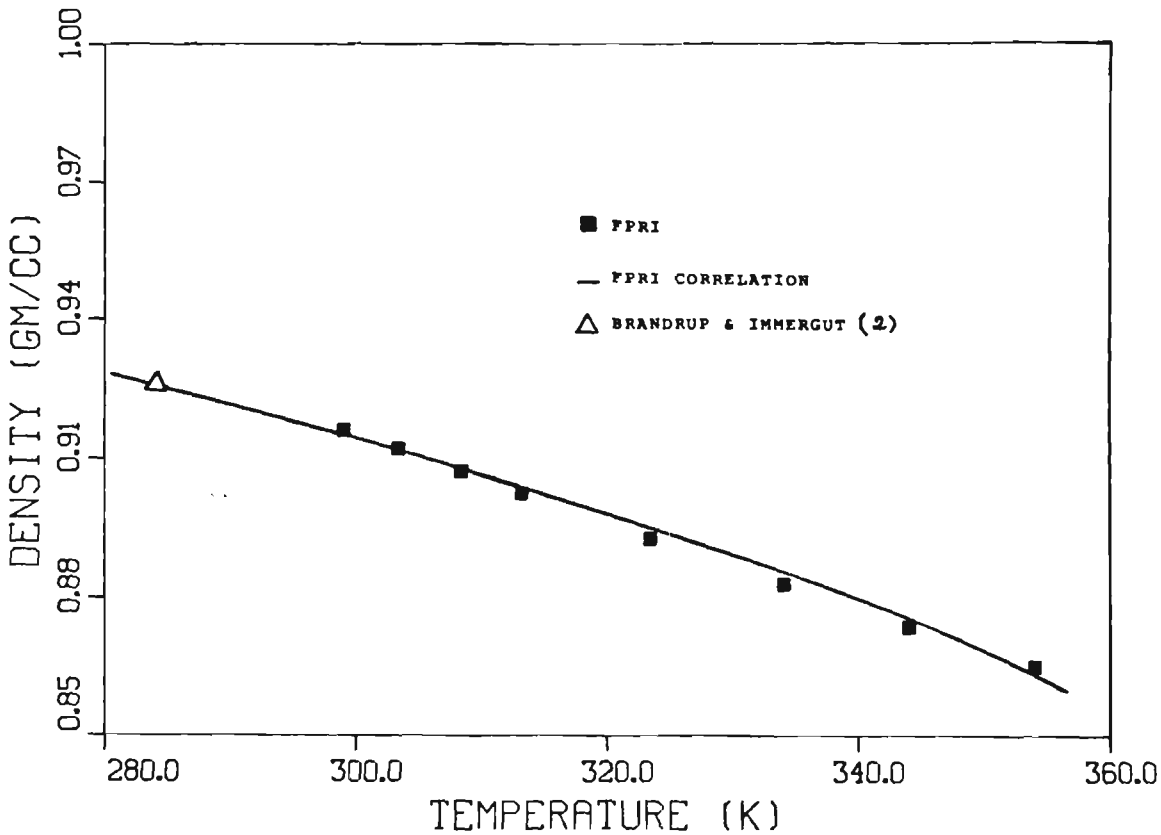
P-METHYL STYRENE



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REFERENCES

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2. Reid, R.C., J.M. Praunitz, and T.K. Sherwood, "The Properties of Gases and Liquids", 3rd Ed., McGraw-Hill, New York (1977).

3. Brandrup and Immergut, Editors, "Polymer Handbook", John Wiley and Sons, New York (1975)

July 23, 1987

J. David Chase
Celanese Chemical Co.
P.O. Box 9077
Corpus Christi, TX 78408

Dear Mr. Chase:

Please find enclosed the final ten design data sheets for the 1986-87 year. You should thus have a total of twenty-four design data sheets which have been issued to date, plus the six reports numbered 8701-8706 issued this year. Reports on the two new correlations for the viscosity and thermal conductivity of mixtures (including crude oils) should be with you shortly. A Ph.D. thesis on group contribution equations of state should also be available to you in September 1987.

I wish to thank you for your support which enabled some of these projects to be carried out. I am confident that the output of the overall research program, together with other services available to member companies, will justify your long-term commitment for continued support of FPRI.

I look forward to working with you in the future.

Yours sincerely,

Dr. A. S. Teja
Technical Director
and Professor

FLUID PROPERTIES RESEARCH, INC.
Administrative Offices

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School of Chemical Engineering
Atlanta, Georgia 30332
404-894-

FPRI

July, 1987 DDS-LV-A3

DESIGN DATA STANDARD - LIQUID VISCOSITY
Diethlyene Glycol
$HOCH_2CH_2OCH_2CH_2OH$

Purity =	99+%	
Molecular Weight =	106.121 kg/kmol	[1]
Critical Temperature =	680.00 K	[2]
Critical Pressure =	45.5 atm	[2]
Critical Volume =	0.312 m^3/kmol	[2]
Melting Point =	262.7 K	[3]
Normal Boiling Point =	518.15 K	[3]
Liquid Molar Volume =	0.095174 m^3/kmol	[4]
Acentric Factor =	1.2006	[4]
Dipole Moment =	1.8346 X 10^{-29} cm	[4]
van der Waals Volume =	0.0607 m^3/kmol	[5]
van der Waals Area =	7.920 X 10^8 m^2/kmol	[5]

Experimental Technique : Capillary viscometer

Experimental Data:

pressure = 14.7 PSI

μ (cp)	T (K)
21.30 ±0.2	306.9 ±0.2
12.03	322.9
5.89	348.9
3.25	372.4
2.00	397.4
1.31	422.5

Liquid Viscosity Correlation:

$$\ln \mu = -48.7093 + (5282.54/T) + 6.03296(\ln T)$$

%AAD = 1.02%
%MAD = 1.94%

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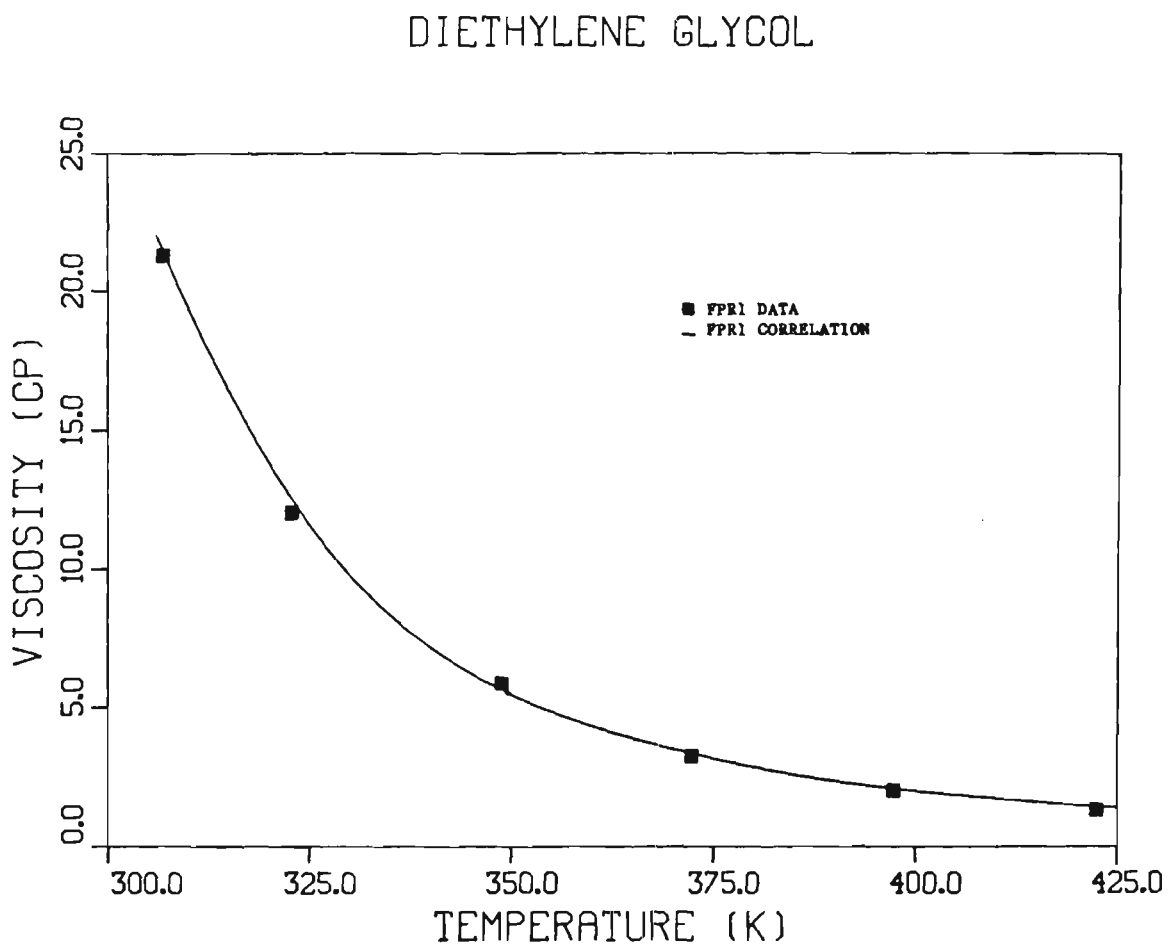
DDS-LV-A3



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July, 1987 DDS-LV-A4

DESIGN DATA STANDARD - LIQUID VISCOSITY
Triethlyene Glycol
$HOCH_2CH_2OCH_2CH_2OCH_2CH_2OH$

Purity =	98+%	
Molecular Weight =	150.174 kg/kmol	[1]
Critical Temperature =	700.00 K	[2]
Critical Pressure =	33.1 atm	[2]
Critical Volume =	0.443 m^3/kmol	[2]
Melting Point =	265.79 K	[2]
Normal Boiling Point =	551.00 K	[3]
Liquid Molar Volume =	0.133844 m^3/kmol	[4]
Acentric Factor =	1.3863	[4]
Dipole Moment =	1.8612×10^{-29} cm	[4]
van der Waals Volume =	0.08486 m^3/kmol	[5]
van der Waals Area =	1.220×10^9 m^2/kmol	[5]

Experimental Technique : Capillary Viscometer

Experimental Data:

pressure = 14.7 PSI

μ(cp)	T (K)
30.629 $\pm$0.2	303.0 $\pm$0.2
10.897	332.8
4.375	363.5
3.218	376.9
2.422	391.8
1.530	422.4

Liquid Viscosity Correlation:

$$\ln \mu = -95.5258 + (7780.11/T) + 12.82429(\ln T)$$

%AAD = 1.98%
%MAD = 3.04%

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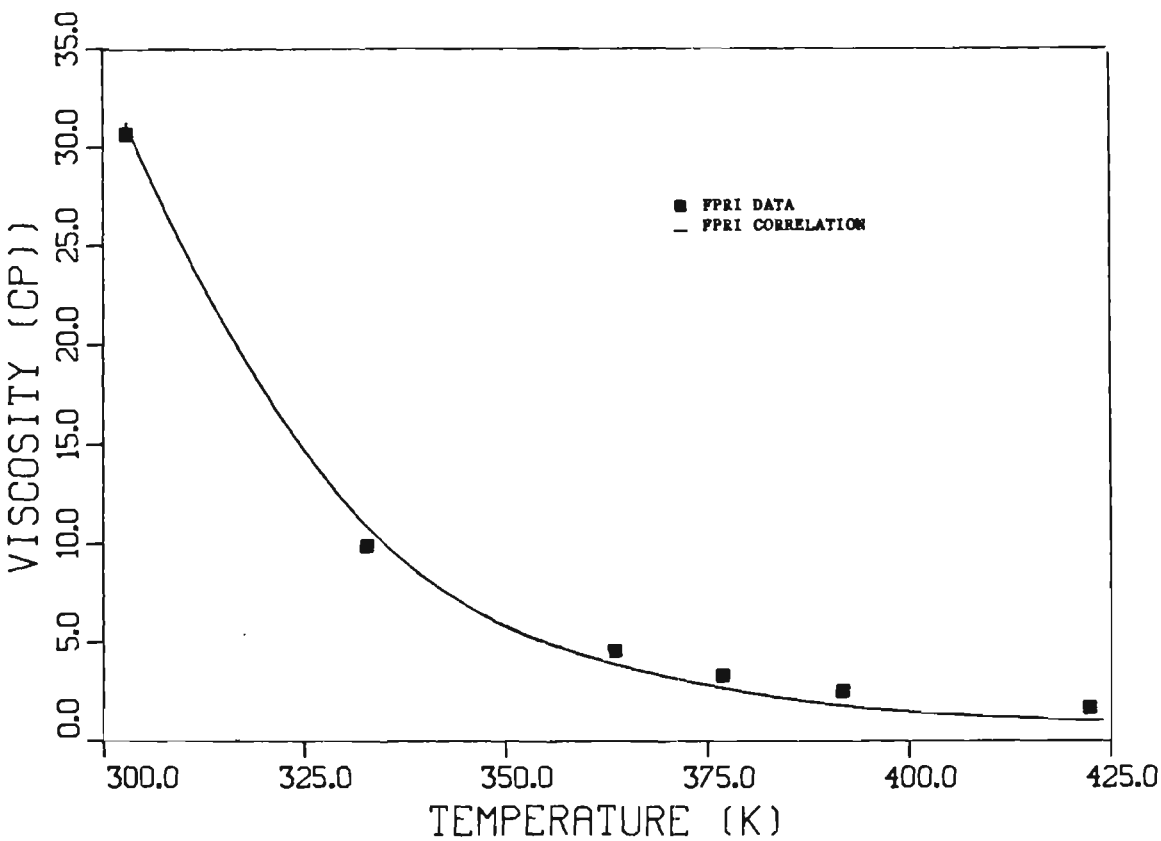
TRIETHYLENE GLYCOL



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DESIGN DATA STANDARD - LIQUID VISCOSITY
Propylene Glycol
$CH_3CH(OH)CH_2OH$

Purity =	99+%	
Molecular Weight =	76.095 kg/kmol	[1]
Critical Temperature =	624.00 K	[2]
Critical Pressure =	61.1 atm	[2]
Critical Volume =	0.239 m^3/kmol	[2]
Melting Point =	213.15 K	[3]
Normal Boiling Point =	460.75 K	[3]
Liquid Molar Volume =	0.073694 m^3/kmol	[4]
Acentric Factor =	1.1065	[4]
Dipole Moment =	1.2108×10^{-29} cm	[4]
van der Waals Volume =	0.04676 m^3/kmol	[5]
van der Waals Area =	6.960×10^8 m^2/kmol	[5]

Experimental Technique : Capillary viscometer

Experimental Data:

pressure = 14.7 PSI

μ (cp)	T (K)
31.72 $\pm$0.2	303.0 $\pm$0.2
8.46	332.8
3.39	363.2
2.31	376.8
1.67	391.5
0.99	422.2

Liquid Viscosity Correlation:

$$\ln \mu = -119.9237 + (9509.54/T) + 16.1007(\ln T)$$

%AAD = 2.89%
%MAD = 4.95%

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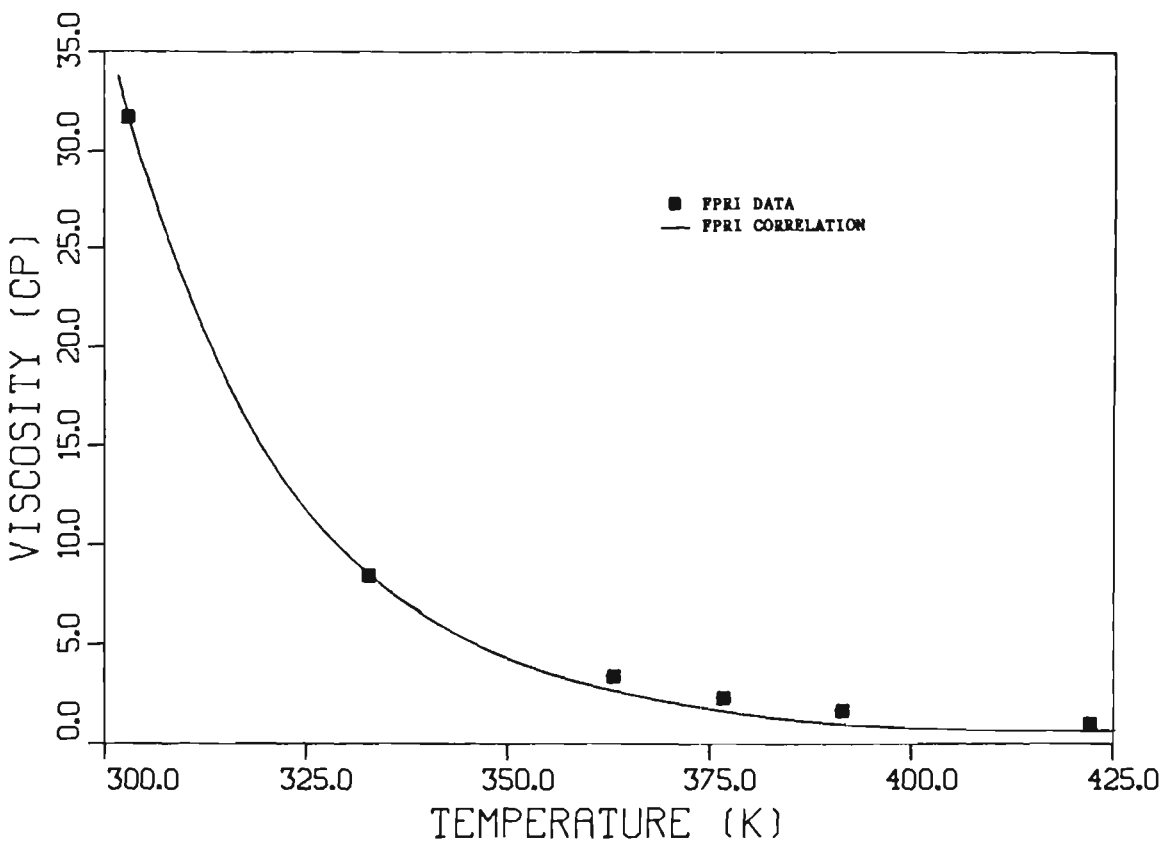
1,2 PROPYLENE GLYCOL



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July, 1987 DDS-LV-A6

DESIGN DATA STANDARD - LIQUID VISCOSITY
P-Methyl Styrene
$C_6H_4(CH_3)CH{:}CH_2$

Purity =	98+%	
Molecular Weight =	118.18 kg/kmol	[1]
Critical Temperature =	647.5 K	[2]
Critical Pressure =	33.2 atm	[2]
Critical Volume =	0.405 m^3/kmol	[2]
Melting Point =	---	
Normal Boiling Point =	446.15 K	[1]
Liquid Molar Volume =	---	
Acentric Factor =	---	
Dipole Moment =	---	
van der Waals Volume =	---	
van der Waals Area =	---	

Experimental Technique : Capillary viscometer

Experimental Data:

pressure = 14.7 PSI

μ(cp)	T (K)
0.852 ±0.2	303.2 +0.2
0.754	313.3
0.706	318.4
0.665	323.4
0.628	328.3
0.593	333.4
0.540	343.4

Liquid Viscosity Correlation:

$$\ln \mu = -7.573742 + (1361.20274/T) + 0.51198889(\ln T)$$

%AAD = 0.317%
%MAD = 0.593%

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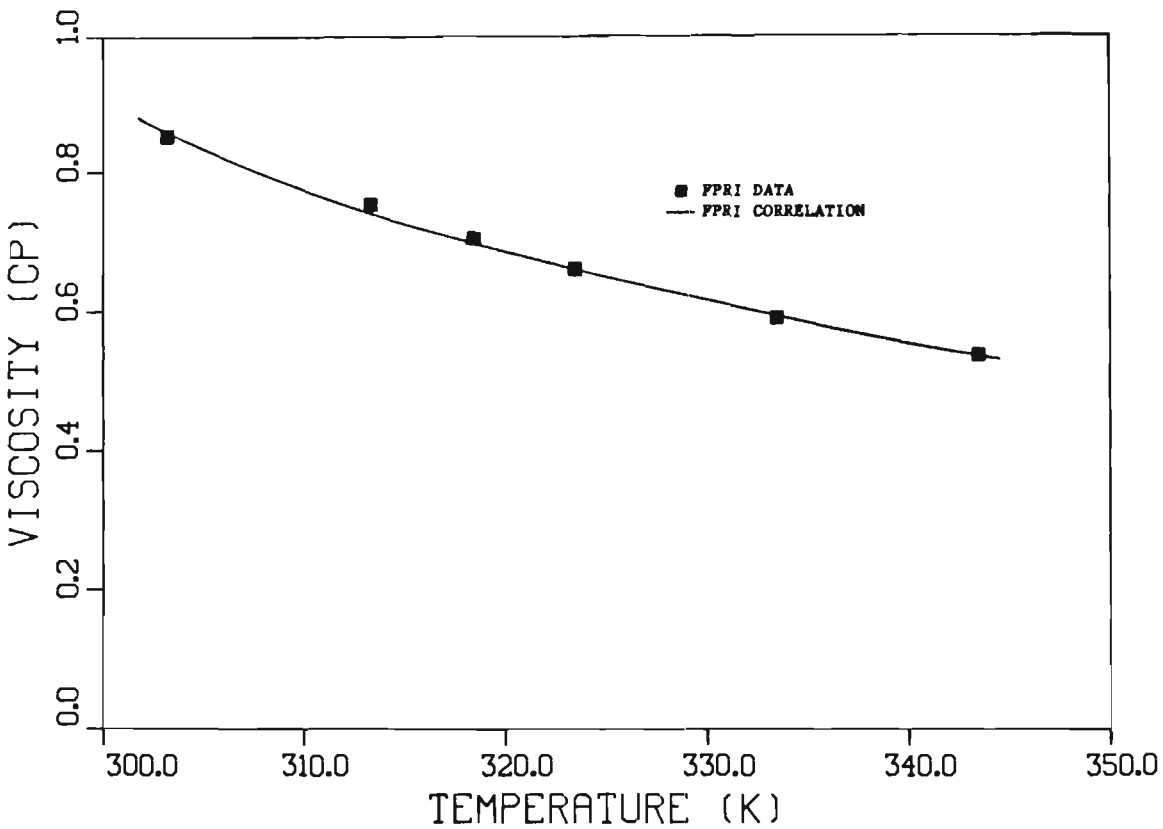
P. METHYL STYRENE



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July, 1987 DDS-LV-A7

DESIGN DATA STANDARD - LIQUID VISCOSITY
Dipropylene Glycol
$(CH_3CH(OH)CH_2)_2O$

Purity =	99+%	
Molecular Weight =	134.18 kg/kmol	[1]
Critical Temperature =	535.66 K	[2]
Critical Pressure =	3.58 MPa	[2]
Critical Volume =	0.419 m^3/kmol	[2]
Melting Point =	------ K	[-]
Normal Boiling Point =	421.05 K	[3]
Liquid Molar Volume =	-------- m^3/kmol	[-]
Acentric Factor =	1.4380	[4]
Dipole Moment =	------- cm	[-]
van der Waals Volume =	------- m^3/kmol	[-]
van der Waals Area =	------- m^2/kmol	[-]

Experimental Technique : Capillary viscometer

Experimental Data:

pressure = 14.7 PSI

μ (cp)	T (K)
54.54 ±0.2	302.8 ±0.2
11.24	332.8
4.09	363.4
2.42	377.0
1.63	391.7
0.91	420.2

Liquid Viscosity Correlation:

$$\ln \mu = -132.2720 + (10737.03/T) + 17.6378(\ln T)$$

%AAD = 3.89%
%MAD = 5.95%

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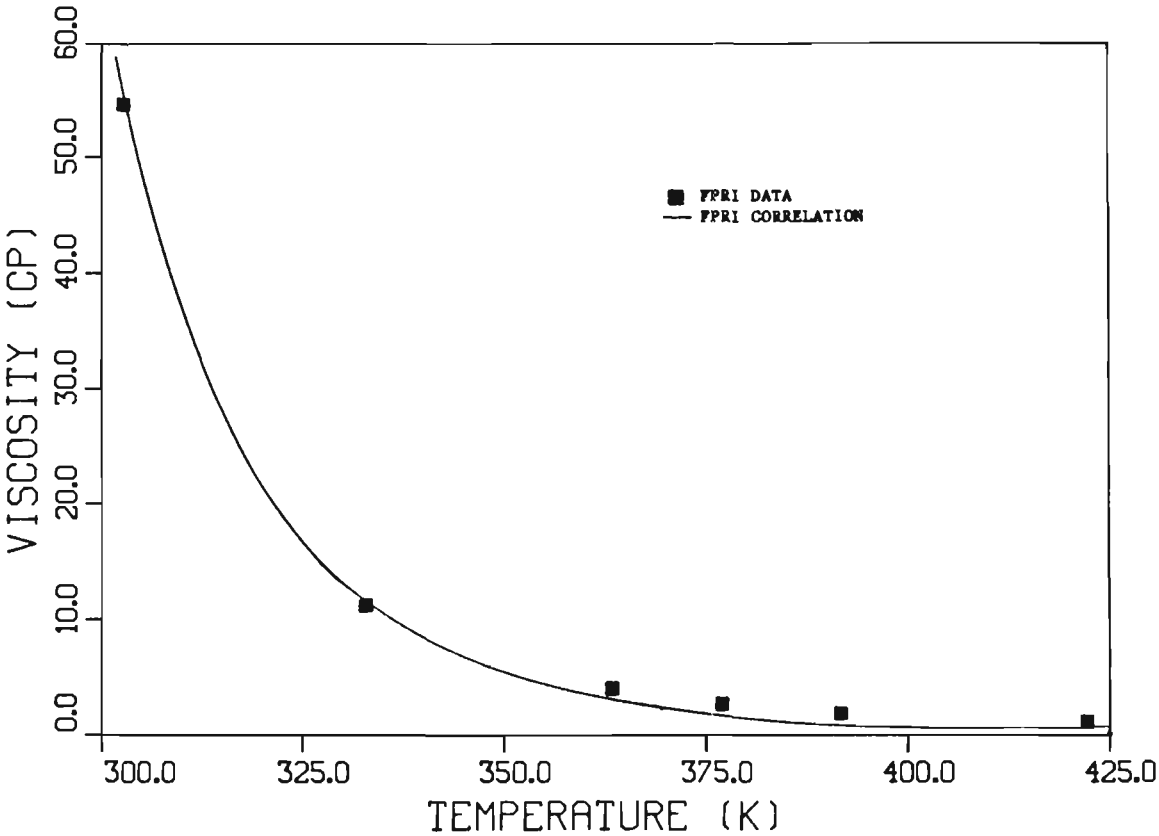
DIPROPYLENE GLYCOL



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July, 1987 DDS-LV-A8

DESIGN DATA STANDARD - LIQUID VISCOSITY
Tripropylene Glycol
$HOCH(CH_3)CH_2OCH_2CH(CH_3)OCH_2CH(CH_3)OH$

Purity =	99+%	
Molecular Weight =	192.25 kg/kmol	[1]
Critical Temperature =	678.20 K	[2]
Critical Pressure =	2.54 MPa	[2]
Critical Volume =	0.599 m^3/kmol	[2]
Melting Point =	------ K	[-]
Normal Boiling Point =	541.20 K	[3]
Liquid Molar Volume =	-------- m^3/kmol	[-]
Acentric Factor =	1.3670	[4]
Dipole Moment =	------- cm	[-]
van der Waals Volume =	------- m^3/kmol	[-]
van der Waals Area =	------- m^2/kmol	[-]

Experimental Technique : Capillary viscometer

Experimental Data:

pressure = 14.7 PSI

μ(cp)	T (K)
40.74 ±0.2	303.6 ±0.2
9.61	333.3
3.53	363.2
2.37	379.0
1.57	394.0
1.02	421.1

Liquid Viscosity Correlation:

$$\ln \mu = -132.6110 + (10443.5/T) + 17.83116 \ln T)$$

%AAD = 3.78%
%MAD = 7.54%

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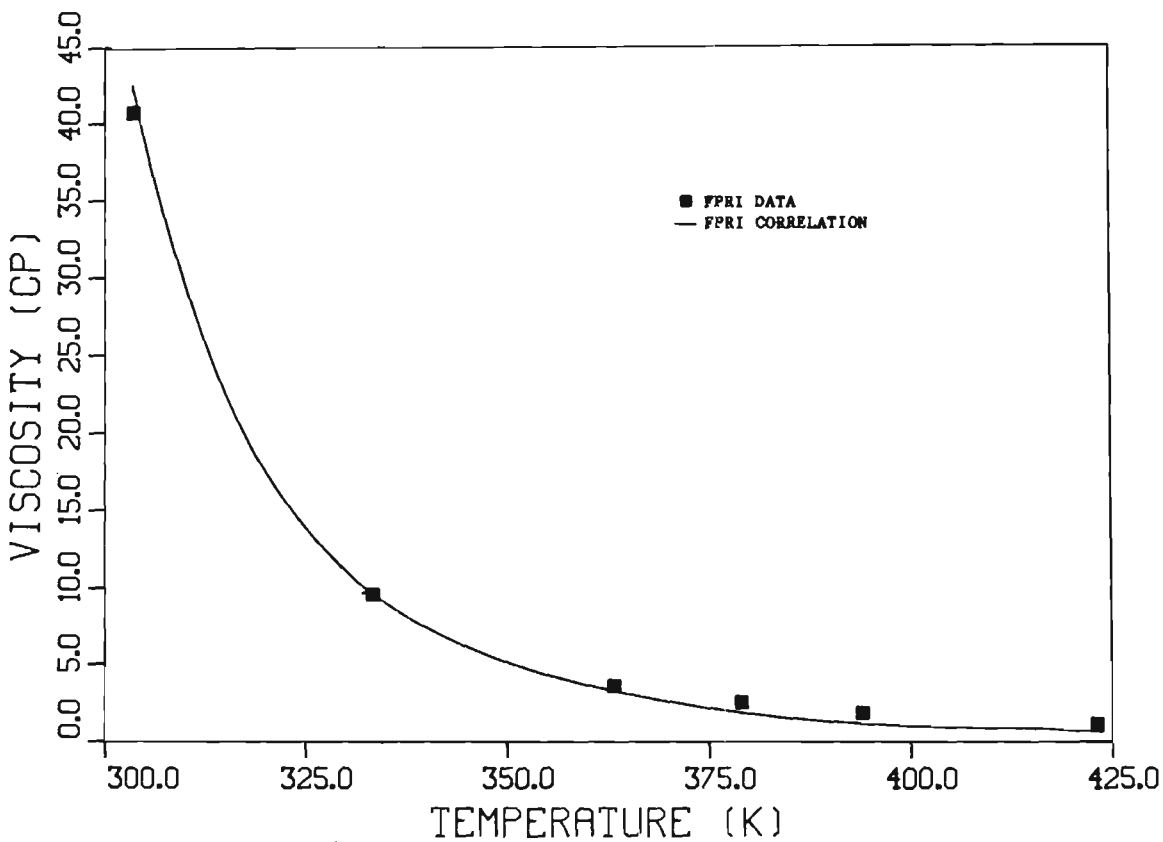

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July, 1987 DDS-LD-A7

DESIGN DATA STANDARD - LIQUID DENSITY
Dipropylene Glycol
$(CH_3CH(OH)CH_2)_2O$

Purity =	99+%	
Molecular Weight =	134.18 kg/kmol	[1]
Critical Temperature =	535.66 K	[2]
Critical Pressure =	3.58 MPa	[2]
Critical Volume =	0.419 m^3/kmol	[2]
Melting Point =	------ K	[-]
Normal Boiling Point =	421.05 K	[3]
Liquid Molar Volume =	-------- m^3/kmol	[-]
Acentric Factor =	1.4380	[4]
Dipole Moment =	------- cm	[-]
van der Waals Volume =	------- m^3/kmol	[-]
van der Waals Area =	------- m^2/kmol	[-]

Experimental Technique : DMA 45

Experimental Data:

pressure = 14.7 PSI

ρ (kg/m^3)	T (K)
1020.4 ±0.2	299.0 ±0.2
1009.7	313.5
996.0	334.3
982.9	353.4
971.8	363.4
965.1	374.1
950.5	393.5
927.4	422.9

Liquid Density Correlation:

$$\rho = 614.856 * (0.528648)^{-(1-T_r)^{2/7}}$$

%AAD = 0.20%
%MAD = 0.32%

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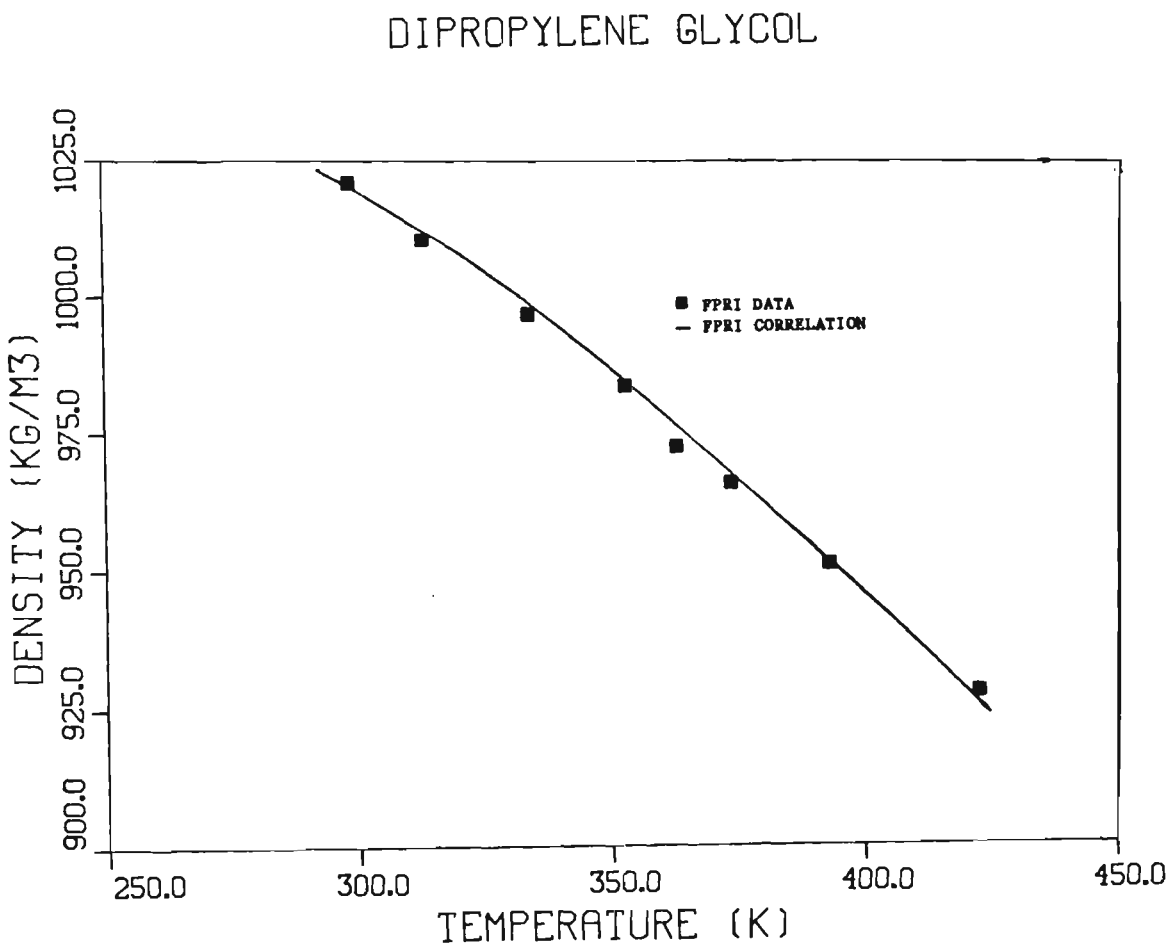

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July, 1987 DDS-LD-A8

DESIGN DATA STANDARD - LIQUID DENSITY
Tripropylene Glycol
$HOCH(CH_3)CH_2OCH_2CH(CH_3)OCH_2CH(CH_3)OH$

Purity =	99+%	
Molecular Weight =	192.25 kg/kmol	[1]
Critical Temperature =	678.20 K	[2]
Critical Pressure =	2.54 MPa	[2]
Critical Volume =	0.599 m^3/kmol	[2]
Melting Point =	------ K	[-]
Normal Boiling Point =	541.20 K	[3]
Liquid Molar Volume =	-------- m^3/kmol	[-]
Acentric Factor =	1.3670	[4]
Dipole Moment =	------- cm	[-]
van der Waals Volume =	------- m^3/kmol	[-]
van der Waals Area =	------- m^2/kmol	[-]

Experimental Technique : DMA 45

Experimental Data:

pressure = 14.7 PSI

ρ (kg/m^3)	T (K)
1014.0 ±0.2	298.2 ±0.2
1009.6	303.6
1002.9	313.4
995.1	323.7
985.6	345.1
970.5	358.5
950.2	377.4
936.8	398.5
920.9	416.5

Liquid Density Correlation:

$$\rho = 388.024 * (0.32150)^{-(1-T_r)^{2/7}}$$

%AAD = 0.311%
%MAD = 0.62%

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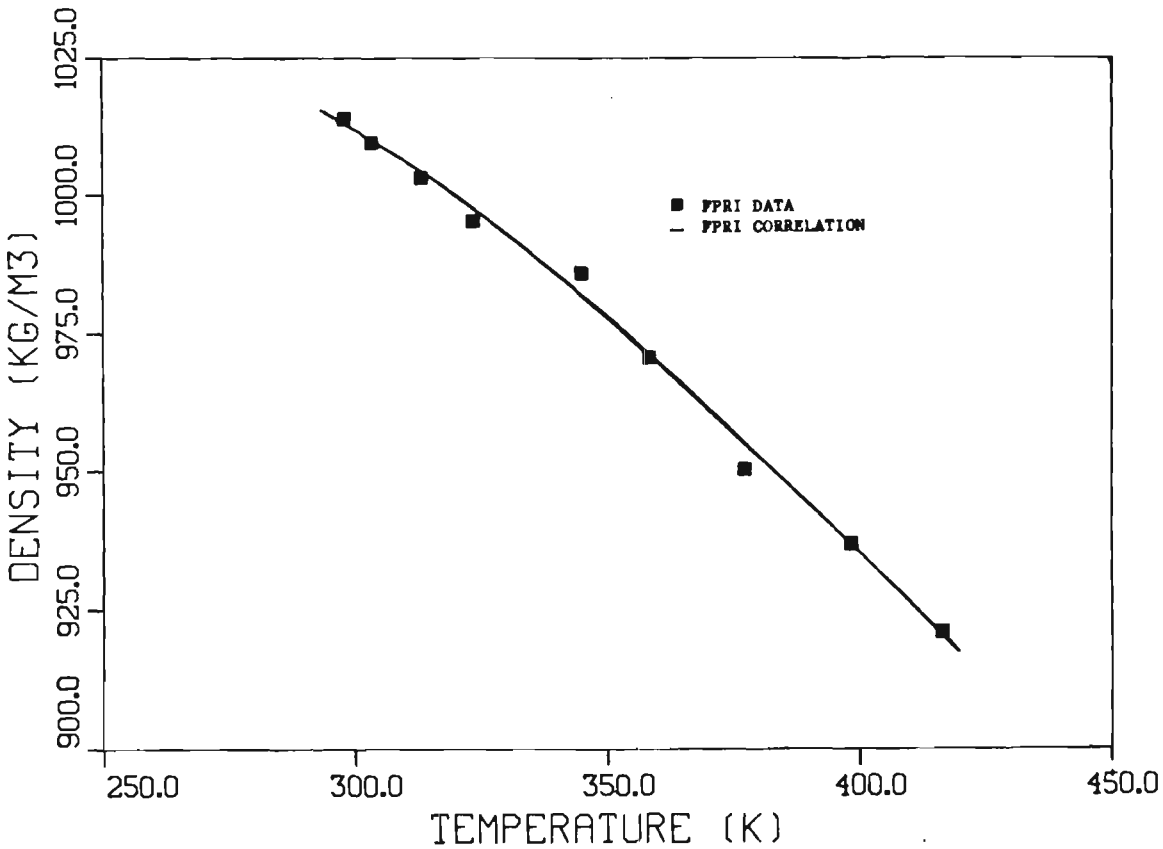

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3. Purarelli, C., Chem. Eng., pp 127 (August 30, 1976).

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July, 1987 DDS-LTC-A7

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Dipropylene Glycol
$(CH_3CH(OH)CH_2)_2O$

Purity =	99+%	
Molecular Weight =	134.18 kg/kmol	[1]
Critical Temperature =	535.66 K	[2]
Critical Pressure =	3.58 MPa	[2]
Critical Volume =	0.419 m^3/kmol	[2]
Melting Point =	------ K	[-]
Normal Boiling Point =	421.05 K	[3]
Liquid Molar Volume =	-------- m^3/kmol	[-]
Acentric Factor =	1.4380	[4]
Dipole Moment =	------- cm	[-]
van der Waals Volume =	------- m^3/kmol	[-]
van der Waals Area =	------- m^2/kmol	[-]

Experimental Technique : Relative Hot Wire Method

Experimental Data:

pressure = 14.7 PSI

λ (mW/mk)	T (K)
167.3 ±5%	297.1 ±0.2
166.1	298.1
163.1	340.9
162.2	341.5
160.7	401.9
159.4	411.8

Liquid Thermal Conductivity Correlation:

$$\lambda = 183.52 - (0.05833)T$$

%AAD = 0.71%
%MAD = 1.48%

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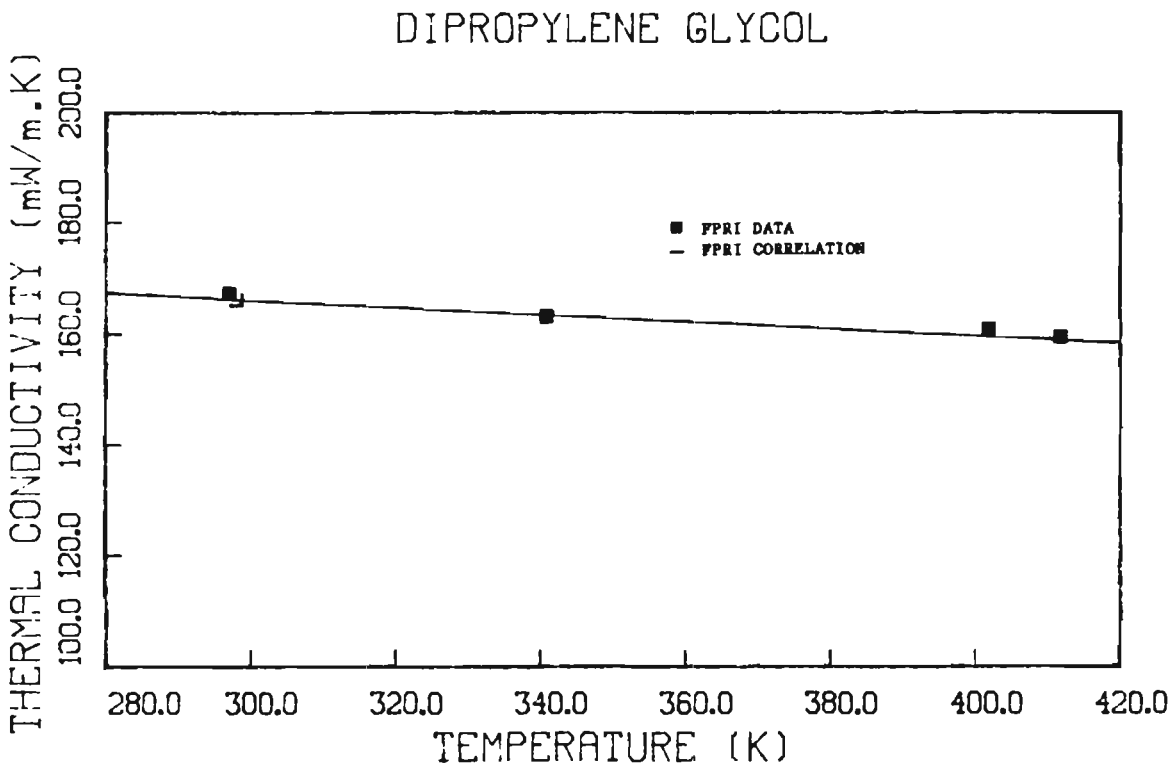

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2. Lydersen, A.L., "Estimation of Critical Properties of Organic Compounds", University of Wisconsin, Coll. Eng., Eng. Exp. Stn, Rep. 3, Madison, Wisconsin (April 1955).

3. Purarelli, C., Chem. Eng., pp 127 (August 30, 1976).

4. Edmister, W.C., Pet. Ref., 37 (4), 173 (1958).

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DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Tripropylene Glycol
$HOCH(CH_3)CH_2OCH_2CH(CH_3)OCH_2CH(CH_3)OH$

Purity =	99+%	
Molecular Weight =	192.25 kg/kmol	[1]
Critical Temperature =	678.20 K	[2]
Critical Pressure =	2.54 MPa	[2]
Critical Volume =	0.599 m^3/kmol	[2]
Melting Point =	------ K	[-]
Normal Boiling Point =	541.20 K	[3]
Liquid Molar Volume =	-------- m^3/kmol	[-]
Acentric Factor =	1.3670	[4]
Dipole Moment =	------- cm	[-]
van der Waals Volume =	------- m^3/kmol	[-]
van der Waals Area =	------- m^2/kmol	[-]

Experimental Technique : Relative Hot Wire Method

Experimental Data:

pressure = 14.7 PSI

λ (mW/mk)	T (K)
160.59 ±5%	303.6 ±0.2
152.41	318.8
151.84	363.9
147.99	350.6
145.44	380.2
134.85	407.8
126.81	425.7
124.00	437.9

Liquid Thermal Conductivity Correlation:

$$\lambda = 246.033 - (0.273553)T$$

%AAD = 2.38%
%MAD = 4.32%

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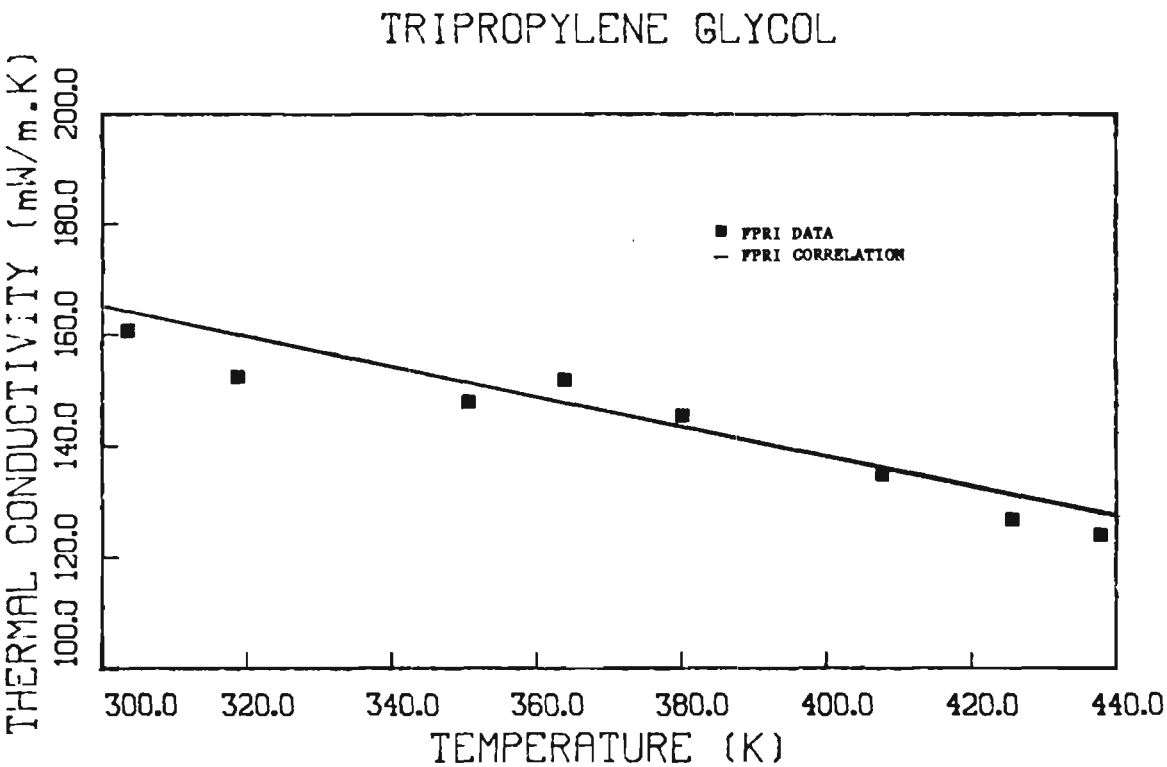

FLUID PROPERTIES RESEARCH, INC.
Administrative Offices

Georgia Institute of Technology
School of Chemical Engineering
Atlanta, Georgia 30332
404-894-

REFERENCES

1. Baker Catalog, "Reagents and Laboratory Products", J.T. Baker Chemical Company, Phillipsburg, New Jersey, 00865 (1980).

2. Lydersen, A.L., "Estimation of Critical Properties of Organic Compounds", University of Wisconsin, Coll. Eng., Eng. Exp. Stn, Rep. 3, Madison, Wisconsin (April 1955).

3. Purarelli, C., Chem. Eng., pp 127 (August 30, 1976).

4. Edmister, W.C., Pet. Ref., 37 (4), 173 (1958).

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FPRI

March 7, 1988

J. David Chase
Celanese Chemical Co.
P.O. Box 9077
Corpus Christi, TX 78408

Dear Mr. Chase:

I am enclosing four design data sheets on the density and viscosity of tetra and pentaethylene glycols. Further data sheets should be forthcoming in the near future.

The best dates for the annual meeting appear to be May 20, 1988 or June 17, 1988. Please let me know as soon as possible which of these dates would be more convenient for you.

Yours sincerely,

Amyn S. Teja
Professor and
Technical Director, FPRI

AST/jvl

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FPRI

February, 1988 DDS-LD-A9

DESIGN DATA STANDARD - LIQUID DENSITY
Tetraethylene Glycol
$(CH_2)_8 O_3 (OH)_2$

Purity =	99+%	
Molecular Weight =	215 kg/kmol	[1]
Critical Temperature =	806K	[2]
Critical Pressure =	1.8 MPa	[2]
Critical Volume =	0.548 m^3/kmol	[3]
Melting Point =	263.8 K	[1]
Normal Boiling Point =	580.9	[4]

Experimental Technique: DMA 45 densiometer

Experimental Data:

pressure = Ambient

T (K)	ρ (kg/m^3)
306.0	1120.5
333.9	1103.2
364.0	1080.2
379.2	1061.1
394.3	1049.0
413.3	1049.0
413.7	1031.4

Liquid Density Correlation:

$$\rho = 391.9405 * (0.30245)^{-(1-T_R)^{2/7}}$$

%AAD = 0.14%
%MAD = 0.31%

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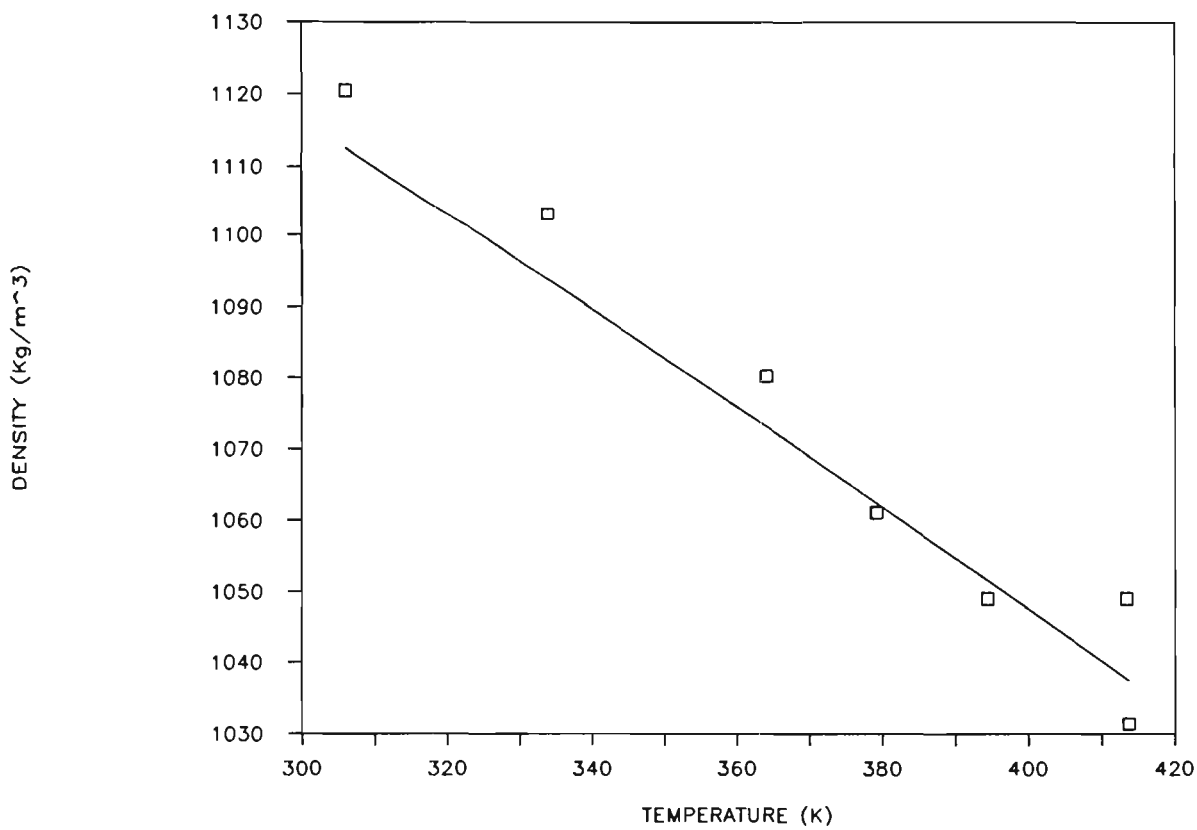
DENSITY OF TETRAETHYLENE GLYCOL



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February, 1988 DDS-LD-A9

REFERENCES

1. Gallaugher, A. F. and Hibbert, H., J. Am. Chem. Soc., 1936, 58, 813-816.

2. Extrapolated from data of: Lyons, R. L., MS Thesis, Penn State University, 1985.

3. Calculated from FPRI density data and modified Rackett correlation.

4. Gallaugher, A. F. and Hibbert, H., J. Am. Chem. Soc., 1937, 59, 2521-2525.

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February, 1988 DDS-LD-A10

DESIGN DATA STANDARD - LIQUID DENSITY
Pentaethylene Glycol
$(CH_2)_{10}\ O_4\ (OH)_2$

Purity =	95+%	
Molecular Weight =	226 kg/kmol	[1]
Critical Temperature =	813K	[2]
Critical Pressure =	1.6 MPa	[2]
Critical Volume =	0.576 m^3/kmol	[3]
Melting Point =	264.5 K	[1]
Normal Boiling Point =	586.2	[4]

Experimental Technique: DMA 45 densiometer

Experimental Data:

pressure = Ambient

T (K)	ρ (kg/m^3)
306.4	1111.9
333.5	1099.1
363.9	1075.4
379.0	1061.0
394.3	1045.0
413.9	1031.3

Liquid Density Correlation:

$$\rho = 391.9405\ (0.30303)^{-(1 - T_R)^{2/7}}$$

%AAD = 0.18%
%MAD = 0.34%

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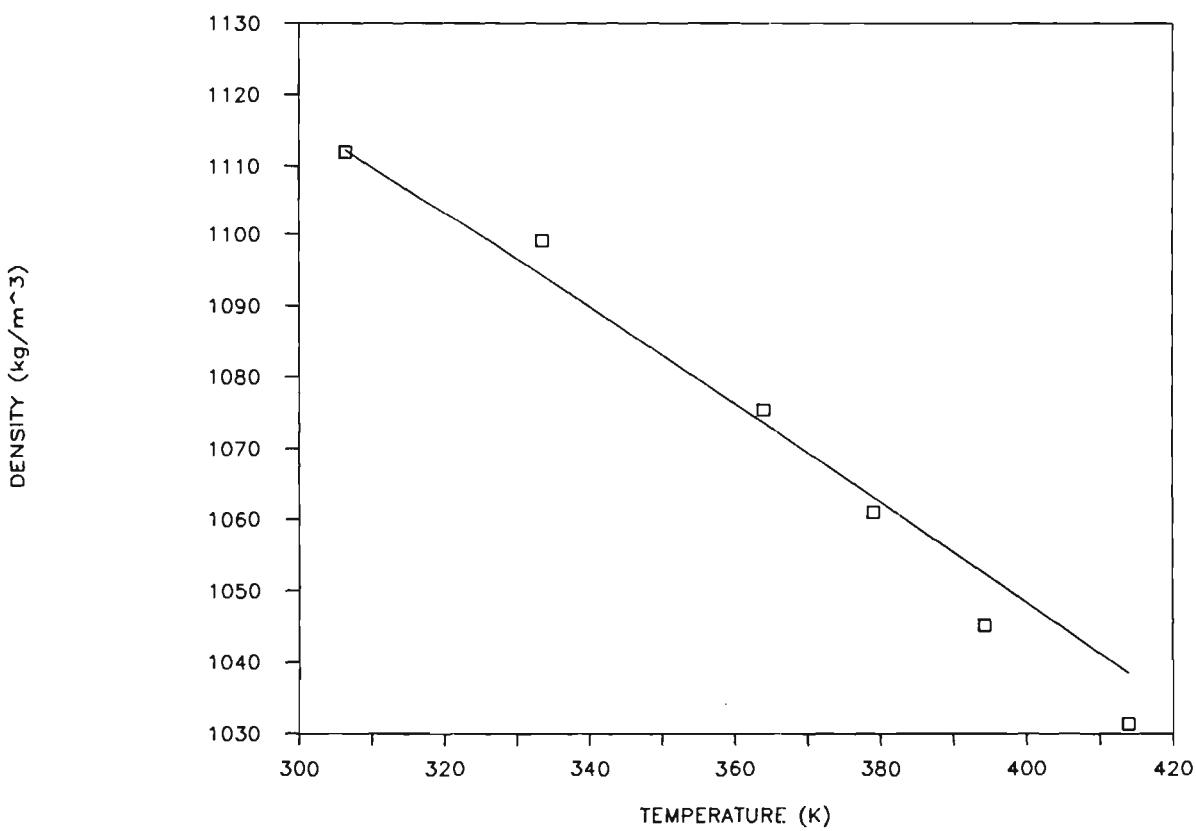
DENSITY OF PENTAETHYLENE GLYCOL



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404-894-

February, 1988 DDS-LD-A10

REFERENCES

1. Gallaugher, A. F. and Hibbert, H., J. Am. Chem. Soc., 1936, 58, 813-816.

2. Extrapolated from data of: Lyons, R. L., MS Thesis, Penn State University, 1985.

3. Calculated from FPRI density data and modified Rackett correlation.

4. Gallaugher, A. F. and Hibbert, H., J. Am. Chem. Soc., 1937, 59, 2521-2525.

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February, 1988 DDS-LV-A9

DESIGN DATA STANDARD - LIQUID VISCOSITY
Tetraethylene Glycol
$(CH_2)_8 O_3 (OH)_2$

Purity =	99+%	
Molecular Weight =	215 kg/kmol	[1]
Critical Temperature =	806K	[2]
Critical Pressure =	1.8 MPa	[2]
Critical Volume =	0.548 m^3/kmol	[3]
Melting Point =	263.8 K	[1]
Normal Boiling Point =	580.9	[4]

Experimental Technique: Capillary Viscometer

Experimental Data:

pressure = Ambient

μ (cp)	T (K)
34.6	303.0
11.1	332.9
5.0	363.4
3.5	378.9
2.6	394.3
1.6	423.7

Liquid Viscosity Correlation:

$$\ln \mu = -92.6257 + \frac{7668.956}{T} + 12.4012 \ln T$$

%AAD = 1.4%
%MAD = 2.1%

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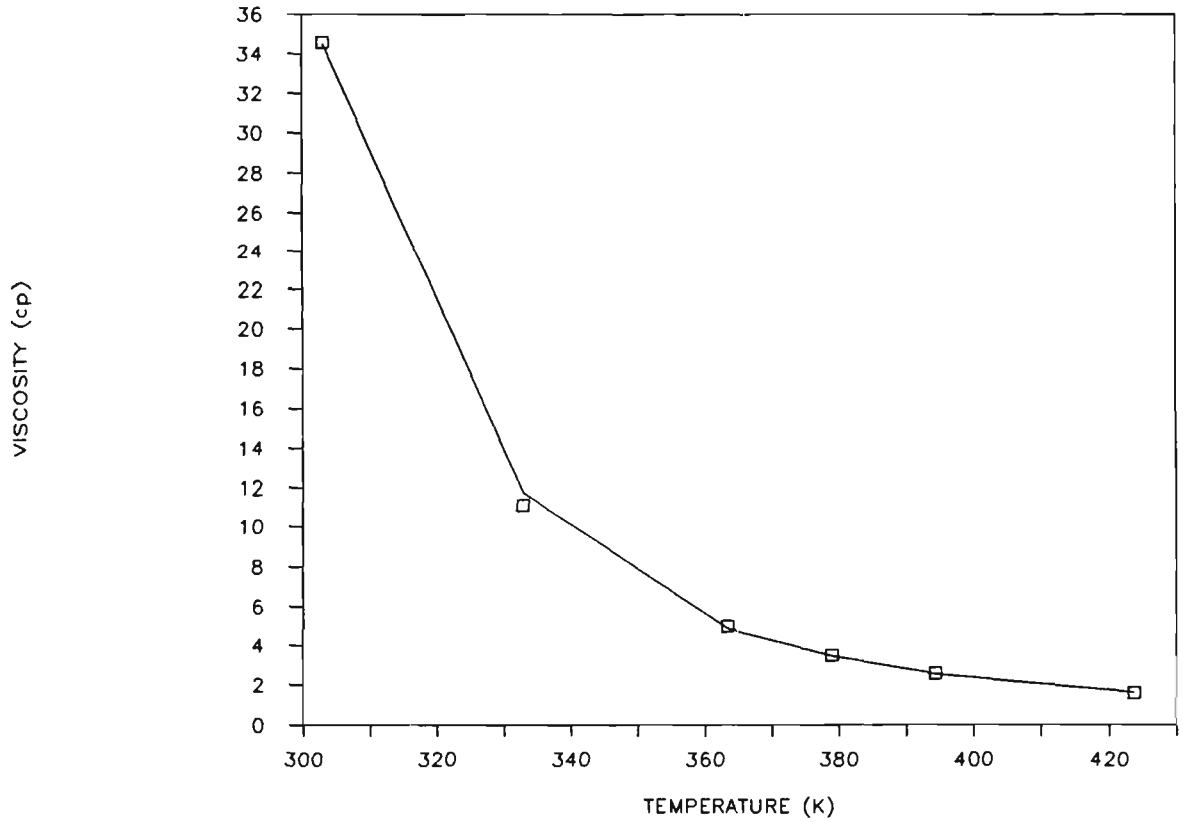
VISCOSITY OF TETRAETHYLENE GLYCOL



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February, 1988 DDS-LV-A9

REFERENCES

1. Gallaugher, A. F. and Hibbert, H., J. Am. Chem. Soc., 1936, 58, 813-816.

2. Extrapolated from data of: Lyons, R. L., MS Thesis, Penn State University, 1985.

3. Calculated from FPRI density data and modified Rackett correlation.

4. Gallaugher, A. F. and Hibbert, H., J. Am. Chem. Soc., 1937, 59, 2521-2525.

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February, 1988 DDS-LV-A10

DESIGN DATA STANDARD - LIQUID VISCOSITY
Pentaethylene Glycol
$(CH_2)_{10}\ O_4\ (OH)_2$

Purity =	95+%	
Molecular Weight =	226 kg/kmol	[1]
Critical Temperature =	813K	[2]
Critical Pressure =	1.6 MPa	[2]
Critical Volume =	0.576 m^3/kmol	[3]
Melting Point =	264.5 K	[1]
Normal Boiling Point =	586.2	[4]

Experimental Technique: Capillary Viscometer

Experimental Data:

pressure = Ambient

μ (cp)	T (K)
41.1	303.7
12.9	333.3
5.8	363.8
4.2	378.2
3.1	393.8
1.9	423.3

Liquid Viscosity Correlation:

$$\ln \mu = -129.8448 + \frac{9589.356}{T} + 17.8419 \ln T$$

%AAD = 2.5%
%MAD = 3.9%

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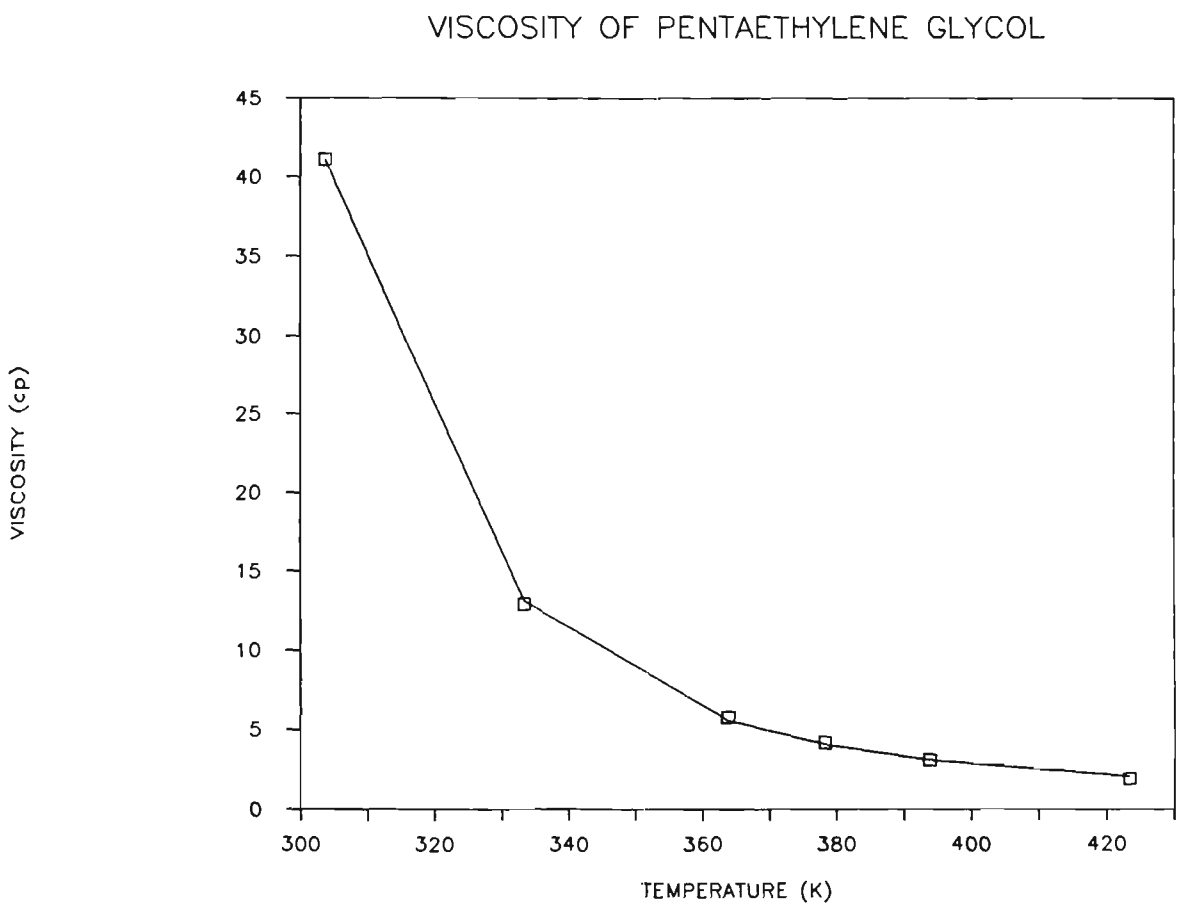

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February, 1988 DDS-LV-A10

REFERENCES

1. Gallaugher, A. F. and Hibbert, H., J. Am. Chem. Soc., 1936, 58, 813-816.

2. Extrapolated from data of: Lyons, R. L., MS Thesis, Penn State University, 1985.

3. Calculated from FPRI density data and modified Rackett correlation.

4. Gallaugher, A. F. and Hibbert, H., J. Am. Chem. Soc., 1937, 59, 2521-2525.

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(404) 894-

DESIGNING TOMORROW TODAY

June 18, 1988

J. David Chase
Celanese Chemical Co.
Specialty Operations
P.O. Box 9077
Corpus Christi, TX 78408

Dear ~~Mr. Chase~~ Dave:

I am enclosing design data sheets LT-A9 through LT-A28. Please add these to your design manual in the section on thermal conductivity data. Design data sheets on viscosity and density will be sent to you in the near future.

Thank you for your support of this work.

Yours sincerely,

Amyn

Amyn S. Teja
Professor and
Technical Director, FPRI

AST/jvl

June 30, 1988 DDS-LT-A9

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Ethylene Glycol
$HOCH_2CH_2OH$

Purity =	99.8 +%	
Molecular Weight =	62.068 kg/kmol	[1]
Critical Temperature =	645 K	[2]
Critical Pressure =	76 atm	[2]
Critical Volume =	0.186 m^3/kmol	[2]
Melting Point =	260.15 K	[3]
Normal Boiling Point =	470.45 K	[3]

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ (mW/mK)
298.6	254.1
333.7	256.9
378.0	257.4
412.9	257.3
424.4	257.0
452.1	250.5
471.3	244.4

Liquid Thermal Conductivity Correlation:

$$\lambda = 88.9562272 + 0.927052533\ T - 1.26187328\ T^2 \times 10^{-3}$$

%AAD = 0.42%

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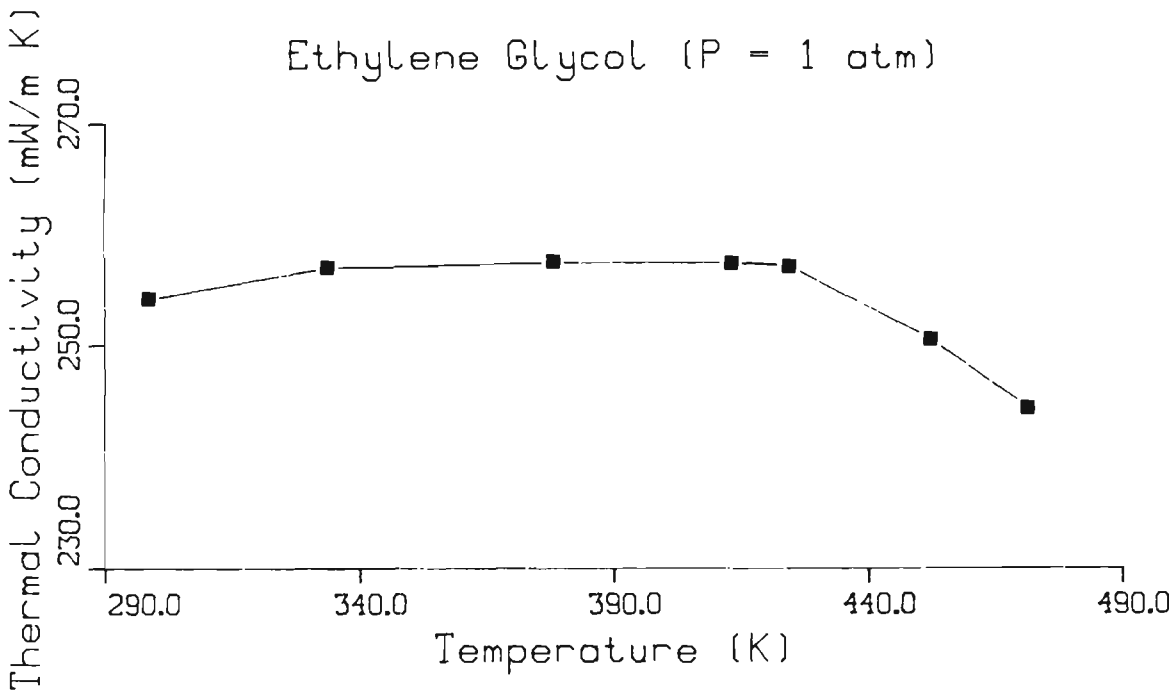
June 30, 1988

DDS-LT-A9



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June, 1988 DDS-LT-A9

REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979," Pure Appl. Chem. 52, 2349 (1980)

2. Reid, R. C, J. M. Praunitz and T. K. Sherwood, "The Properties of Gases and Liquids," 3rd Ed., McGraw-Hill, New York (1977).

3. Thermodynamics Research Center, "Selected Values of Properties of Chemical Compounds," Data Project 44, Texas A&M University, College Station, Texas.

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June 30, 1988 DDS-LT-A10

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Diethylene Glycol
$HOCH_2CH_2OCH_2CH_2OH$

Purity =	99.0 +%	
Molecular Weight =	106.121 kg/kmol	[1]
Critical Temperature =	680.0 K	[2]
Critical Pressure =	45.5 atm	[2]
Critical Volume =	0.312 m^3/kmol	[2]
Melting Point =	262.7 K	[3]
Normal Boiling Point =	585.15 K	[3]

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ (mW/mK)
299.1	201.2 ± 0.24%
334.8	203.7
379.3	203.1
410.4	202.3
444.5	197.5
480.6	189.9

Liquid Thermal Conductivity Correlation:

$$\lambda = 97.5849639 + 0.595566899\ T - 0.833116941\ T^2 \times 10^{-3}$$

%AAD = 0.14%

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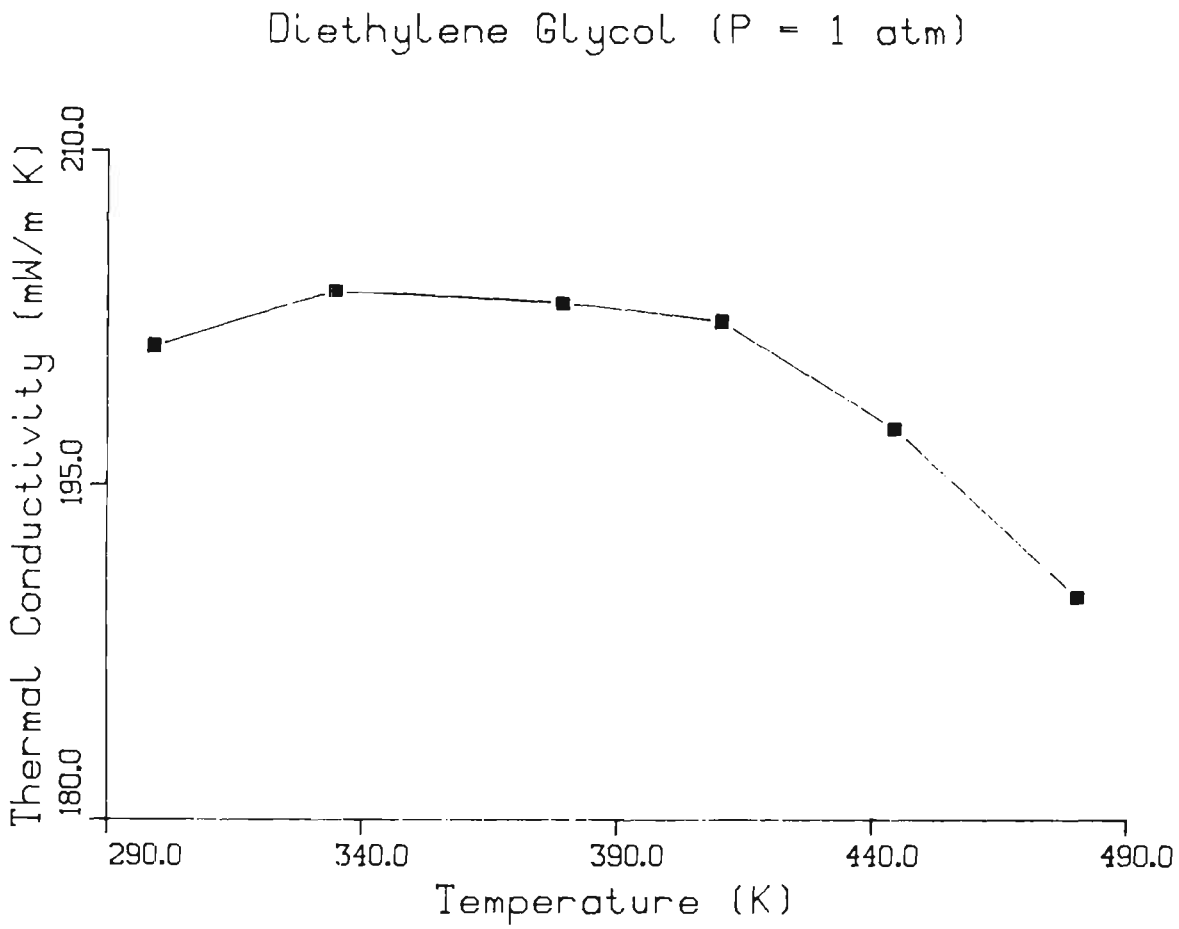
June 30, 1988

DDS-LT-A10



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June, 1988 DDS-LT-A10

REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979," Pure Appl. Chem. 52, 2349 (1980)

2. Reid, R. C, J. M. Praunitz and T. K. Sherwood, "The Properties of Gases and Liquids," 3rd Ed., McGraw-Hill, New York (1970).

3. Gallant, R. W., "Physical Properties of Hydrocarbons," Gulf Publishing Company, Houston, Texas (1977).

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June 30, 1988 DDS-LT-A11

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Triethylene Glycol
$HO\ CH_2CH_2O\ CH_2CH_2O\ CH_2CH_2OH$

Purity =	99.5 +%	
Molecular Weight =	150.174 kg/kmol	[1]
Critical Temperature =	700 K	[2]
Critical Pressure =	33.1 atm	[2]
Critical Volume =	0.443 m^3/kmol	[2]
Melting Point =	265.79 K	[2]
Normal Boiling Point =	551.00 K	[3]

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
299.8	193.2
335.6	193.2
371.2	191.1
404.3	188.2
444.0	183.4
476.2	177.9

Liquid Thermal Conductivity Correlation:

$$\lambda = 140.807711 + 0.340219149\ T - 0.550775447\ T^2 \times 10^{-3}$$

%AAD = 0.06%

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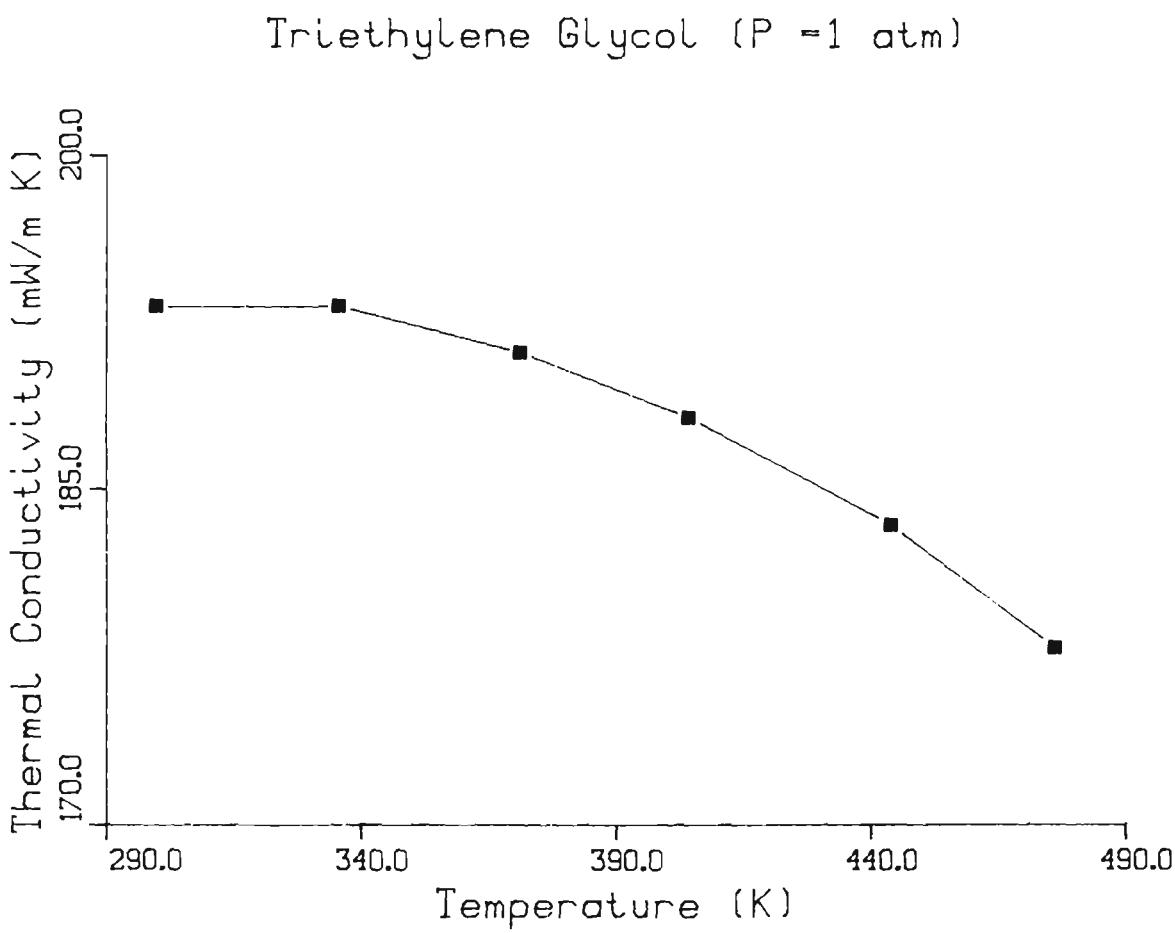
June 30, 1988

DDS-LT-A11



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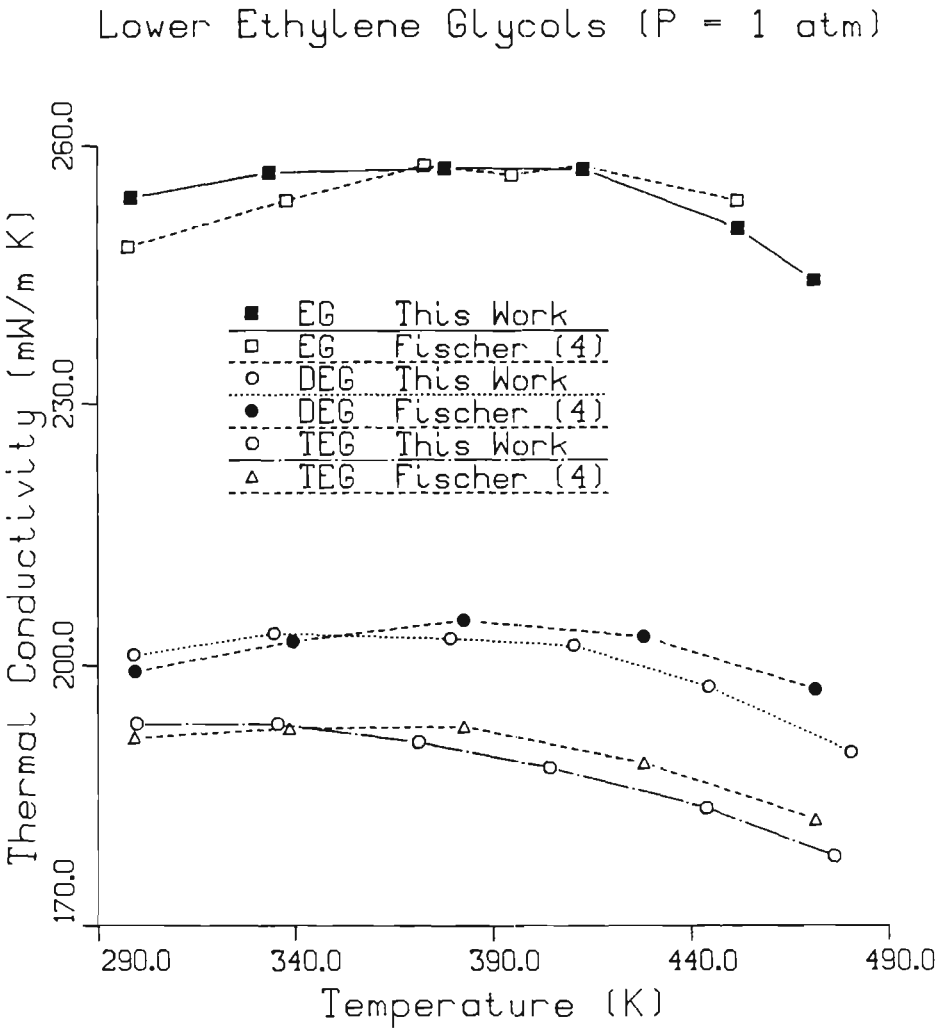

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REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979," Pure Appl. Chem. 52, 2349 (1980)

2. Gallant, R. W., "Physical Properties of Hydrocarbons," Gulf Publishing Company, Houston, Texas (1970).

3. Curme, G. O. J., editor "Glycols, Reinhold Publishing Corporation, New York, (1952).

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June 30, 1988 DDS-LT-A12

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Tetraethylene Glycol
$HO\ CH_2CH_2(O\ CH_2CH_2)_3\ OH$

Purity =	99 +%	
Molecular Weight =	215 kg/kmol	[1]
Critical Temperature =	806 K	[2]
Critical Pressure =	1.8 MPa	[2]
Critical Volume =	0.548 m^3/kmol	[3]
Melting Point =	263.8 K	[1]
Normal Boiling Point =	580.9 K	[4]

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ (mW/mK)
296.5	188.2
335.5	187.1
379.0	184.2
410.6	181.6
451.6	175.6

Liquid Thermal Conductivity Correlation:

$$\lambda = 147.547394 + 0.279257102\ T - 0.48020949\ T^2 \times 10^{-3}$$

%AAD = 0.09%

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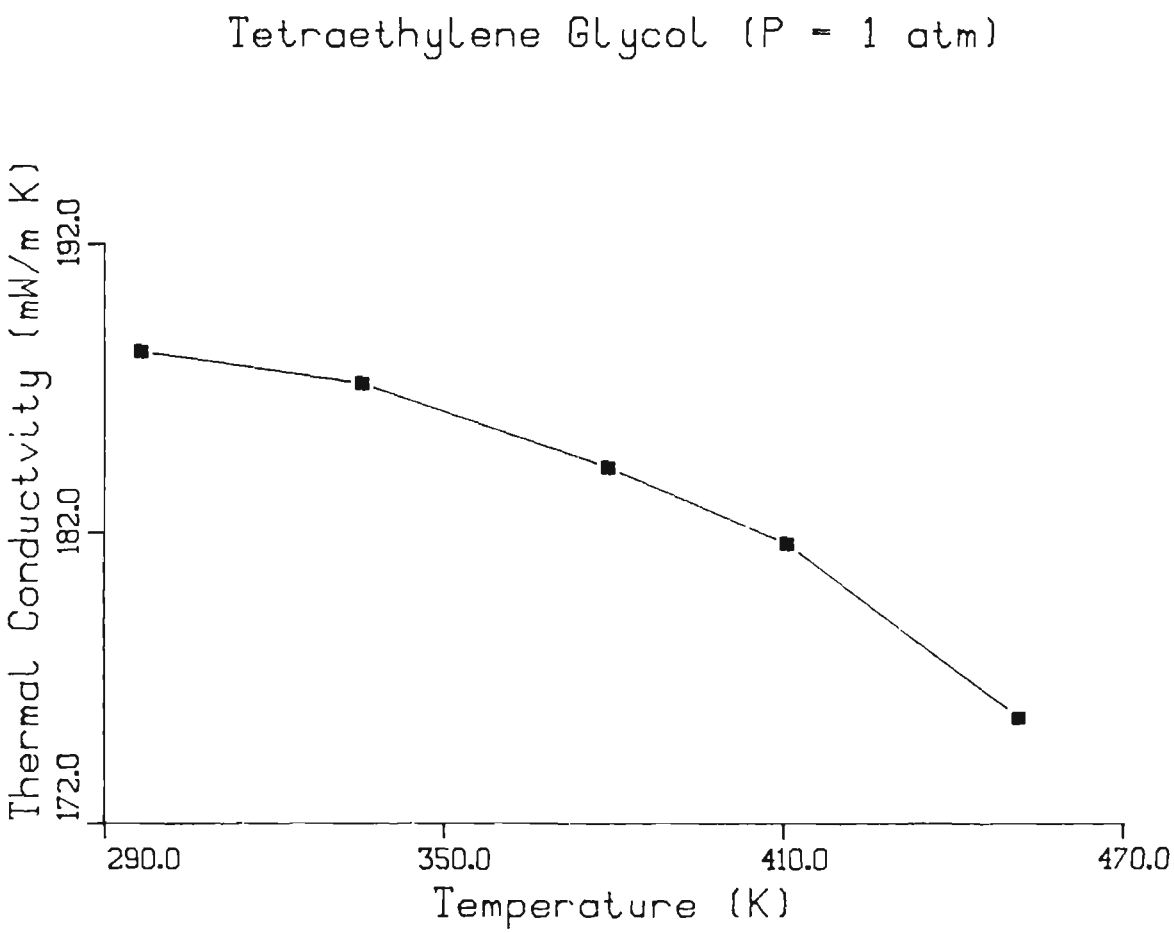
DDS-LT-A12



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June, 1988 DDS-LT-A12

REFERENCES

1. Gallaugher, A. F. and Hibbert, H., J. Am. Chem. Soc., 1936, 58, 813-816.

2. Extrapolated from data of: Lyons, R. L., MS Thesis, Penn State University, 1985.

3. Calculated from FPRI density data and modified Rackett correlation.

4. Gallaugher, A. F. and Hibbert, H., J. Am. Chem. Soc., 1937, 59, 2521-2525.

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June 30, 1988 DDS-LT-A13

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Pentaethylene Glycol
$HO\ CH_2CH_2(O\ CH_2CH_2)_4\ OH$

Purity =	95 +%	
Molecular Weight =	226 kg/kmol	[1]
Critical Temperature =	813 K	[2]
Critical Pressure =	1.6 MPa	[2]
Critical Volume =	0.576 m^3/kmol	[3]
Melting Point =	264.5 K	[1]
Normal Boiling Point =	586.2 K	[4]

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
296.6	186.9
334.8	185.3
384.0	182.0
410.2	177.9

Liquid Thermal Conductivity Correlation:

$$\lambda = 133.379921 + 0.365180861\ T - 0.624265909\ T^2 \times 10^{-3}$$

%AAD = 0.16%

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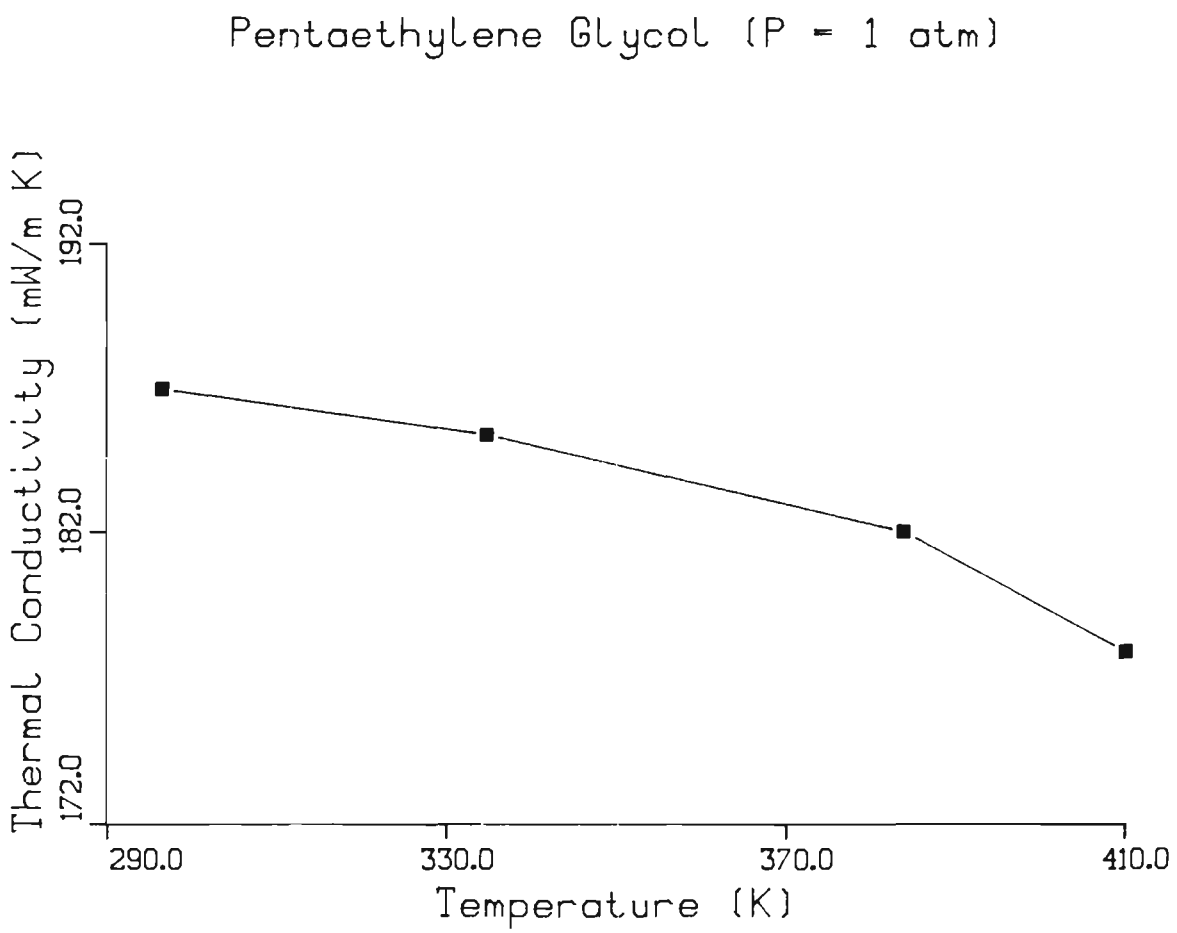

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June, 1988 DDS-LT-A13

REFERENCES

1. Gallaugher, A. F. and Hibbert, H., J. Am. Chem. Soc., 1936, 58, 813-816.

2. Extrapolated from data of: Lyons, R. L., MS Thesis, Penn State University, 1985.

3. Calculated from FPRI density data and modified Rackett correlation.

4. Gallaugher, A. F. and Hibbert, H., J. Am. Chem. Soc., 1937, 59, 2521-2525.

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June 30, 1988 DDS-LT-A14

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Hexaethylene Glycol
$HO\ CH_2CH_2(O\ CH_2CH_2)_5\ OH$

Purity =	98 +%	
Molecular Weight =	298 kg/kmol	[1]
Critical Temperature =	854 K	[2]
Critical Pressure =	- atm	[ ]
Critical Volume =	- m^3/kmol	[ ]
Melting Point =	274.5 K	[1]
Boiling Point at 4mm Hg	490. K	[3]

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
300.3	186.1
335.1	184.2
379.3	181.4
411.3	178.3
451.5	172.9
480.6	167.4

Liquid Thermal Conductivity Correlation:

$$\lambda = 149.786809 + 0.257366019\ T - 0.458169802\ T^2 \times 10^{-3}$$

%AAD = 0.13%

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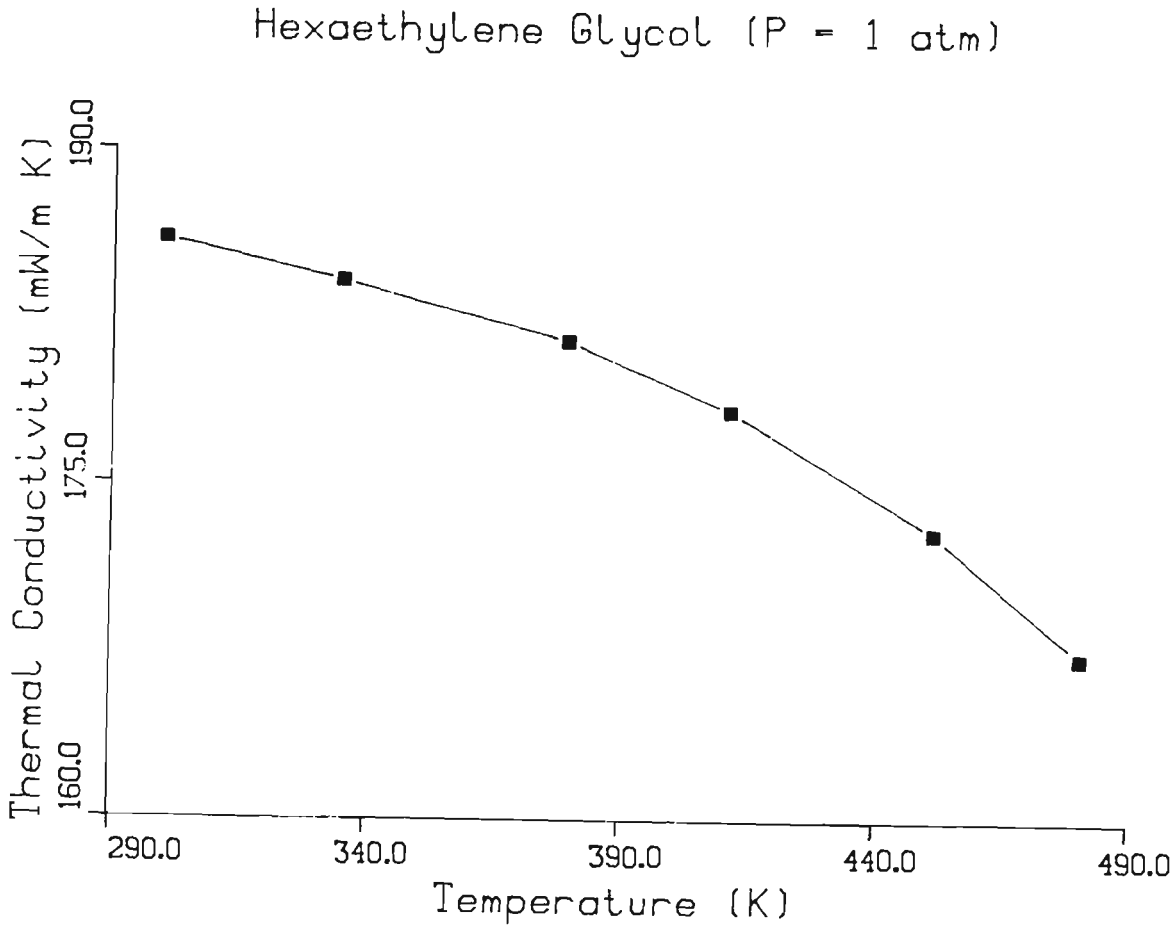
June 30,1988 DDS-LT-A14



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June, 1988 DDS-LT-A14

REFERENCES

1. Gallaugher, A. F. and Hibbert, H., J. Am. Chem. Soc., 1936, 58, 813-816.

2. Extrapolated from data of: Lyons, R. L., MS Thesis, Penn State University, 1985.

3. Aldrich Chemical Catalog, Aldrich Chemical Company, Inc., Milwaukee, Wisconsin, 1988.

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June 30, 1988 DDS-LT-A15

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Ethylene Glycol (1) + Triethylene Glycol (2)
$x_1 = 0.2053$

Purity of 1 = 99.8 +%
Purity of 2 = 99.5 %

Mixtures prepared gravimetrically

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
296.5	199.8
336.2	198.4
379.0	197.2
407.6	195.2
451.5	190.2
480.7	184.8

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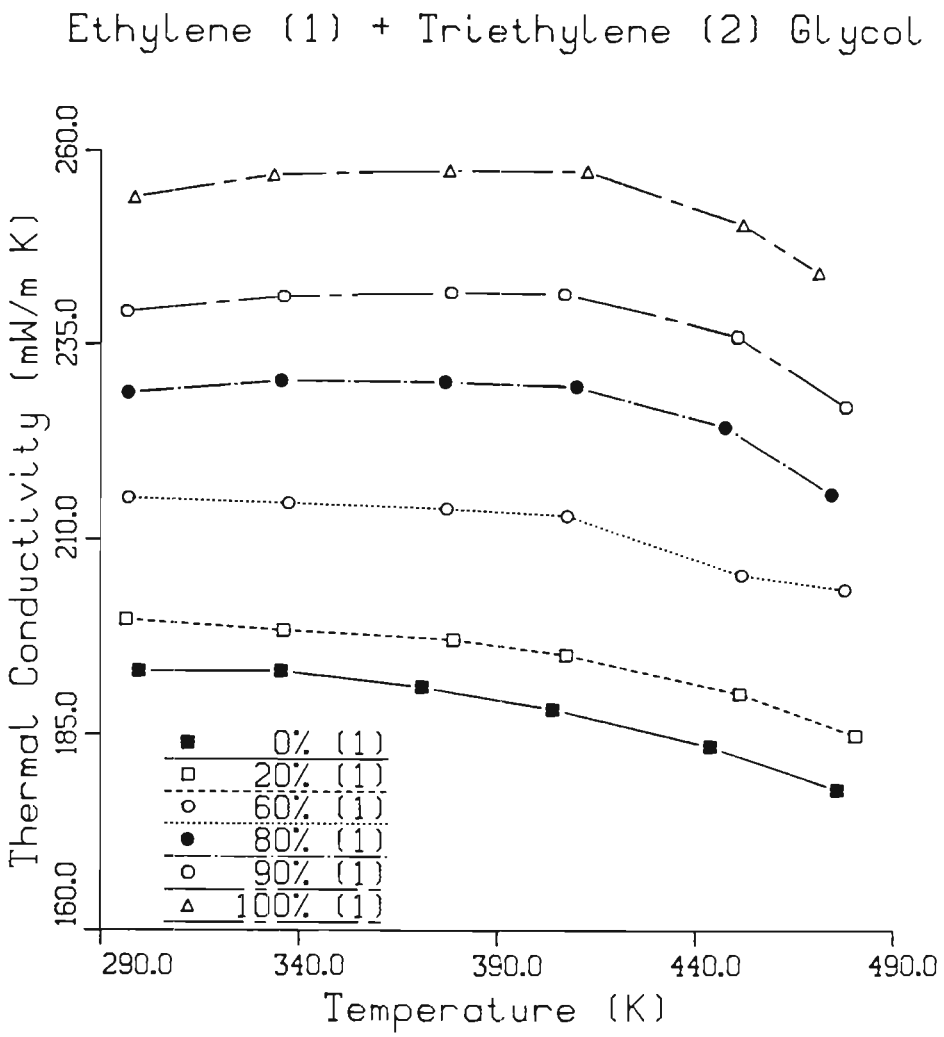
June 30, 1988 DDS-LT-A15



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June 30, 1988 DDS-LT-A16

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Ethylene Glycol (1) + Triethylene Glycol (2)
x_1 = 0.4019

Purity of 1 = 99.8 +%
Purity of 2 = 99.5 %
Mixtures prepared gravimetrically

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
296.3	205.0
333.2	205.3
376.6	203.9
411.1	203.0

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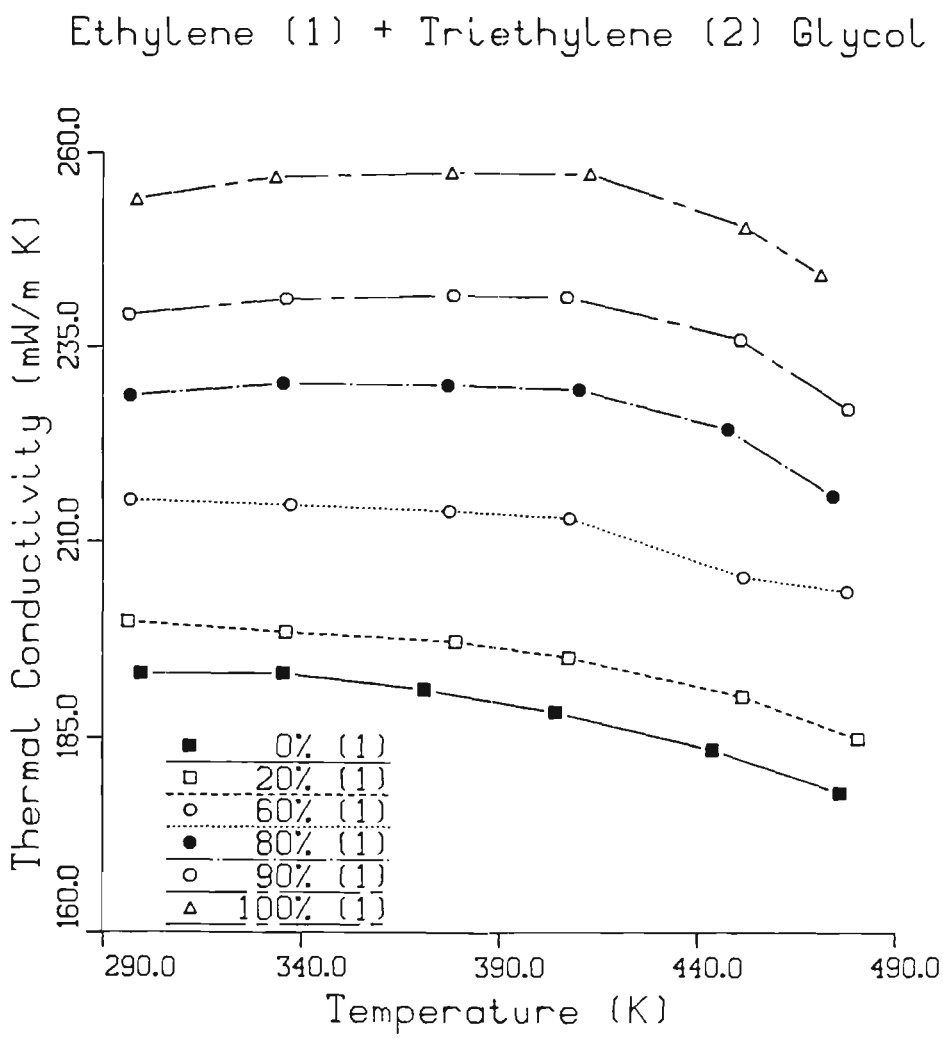
June 30, 1988 DDS-LT-A16



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June 30, 1988 DDS-LT-A17

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Ethylene Glycol (1) + Triethylene Glycol (2)
x_1 = 0.6020

Purity of 1 = 99.8 +%
Purity of 2 = 99.5 %
Mixtures prepared gravimetrically

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
297.0	215.3
337.4	214.6
377.4	213.8
407.8	212.9
451.9	205.4
478.0	203.5

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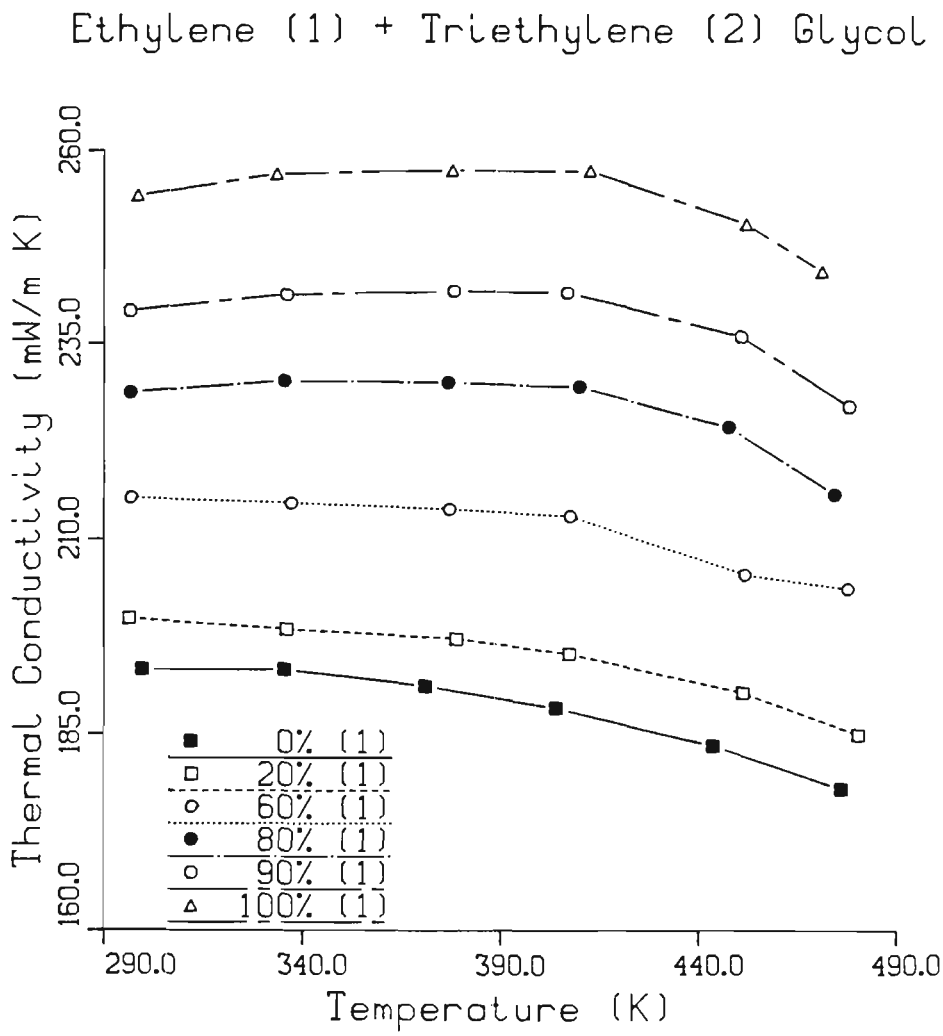
June 30, 1988 DDS-LT-A17



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June 30, 1988 DDS-LT-A18

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Ethylene Glycol (1) + Triethylene Glycol (2)
x_1 = 0.7997

Purity of 1 = 99.8 +%
Purity of 2 = 99.5 %
Mixtures prepared gravimetrically

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
297.0	228.7
335.6	230.2
377.0	230.0
410.3	229.4
447.9	224.3
474.7	215.7

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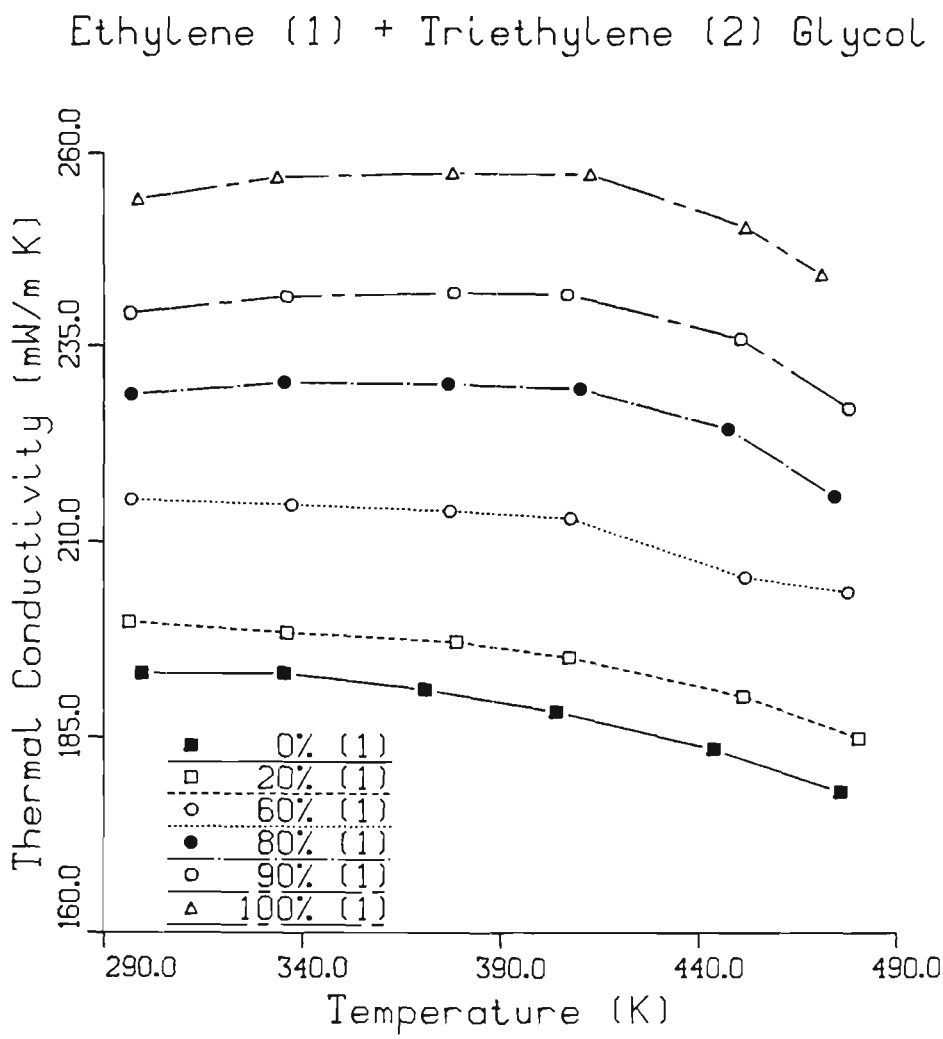
June 30, 1988

DDS-LT-A18



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June 30, 1988 DDS-LT-A19

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Ethylene Glycol (1) + Triethylene Glycol (2)
x_1 = 0.9007

Purity of 1 = 99.8 +%
Purity of 2 = 99.5 %
Mixtures prepared gravimetrically

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
296.7	239.1
336.2	241.2
378.4	241.7
407.1	241.5
450.9	235.9
478.3	226.9

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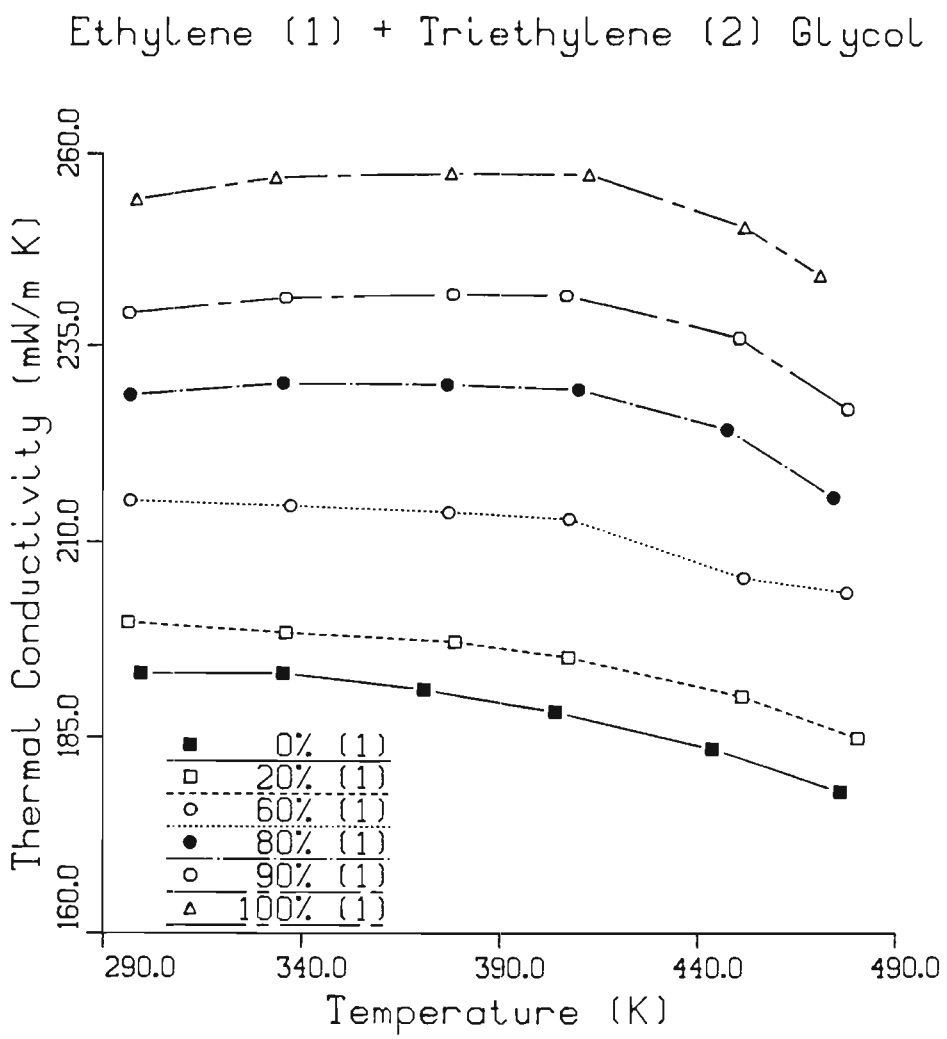
June 30,1988 DDS-LT-A19



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June 30, 1988 DDS-LT-A20

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Diethylene Glycol (1) + Triethylene Glycol (2) Mixtures
x_1 = 0.2008

Purity of 1 = 99.0 +%
Purity of 2 = 99.5 %
Mixtures prepared gravimetrically

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
297.5	194.9
335.6	195.2
376.7	193.2
410.7	191.2
450.2	186.7
479.9	180.2

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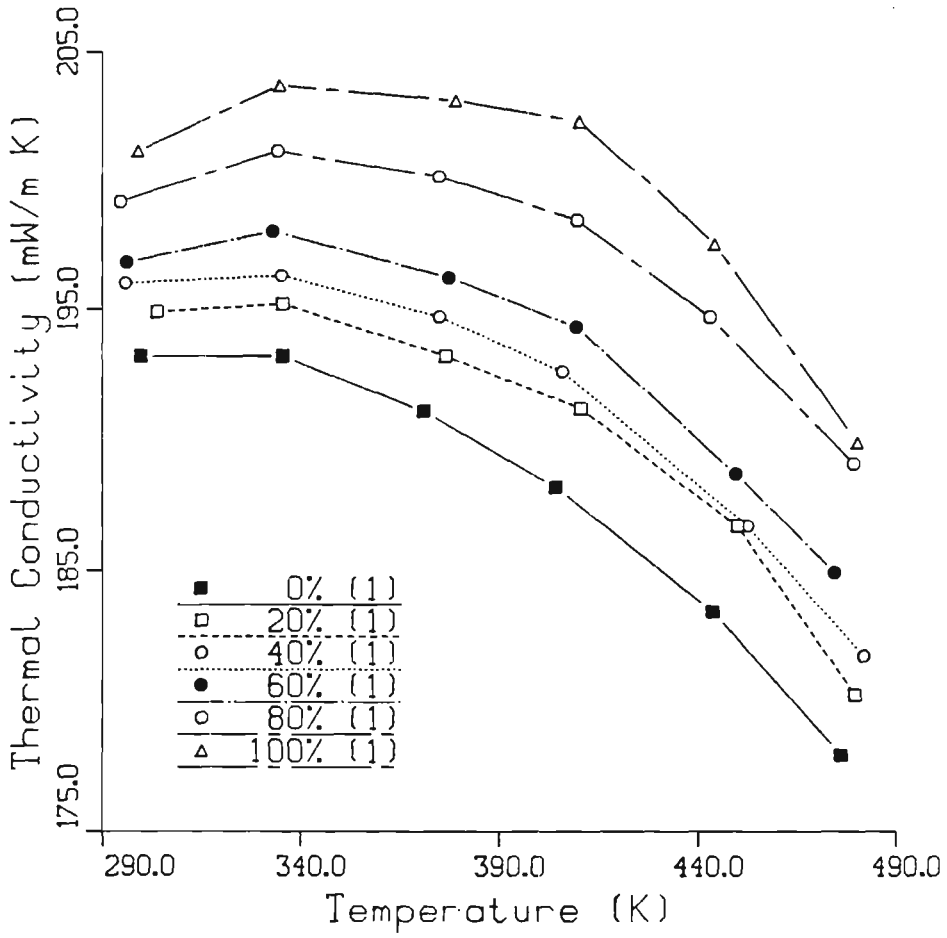
June 30, 1988

DDS-LT-A20

Diethylene (1) + Triethylene (2) Glycol



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June 30, 1988 DDS-LT-A21

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Diethylene Glycol (1) + Triethylene Glycol (2)
$x_1 = 0.4005$

Purity of 1 = 99.0 +%
Purity of 2 = 99.5 %
Mixtures prepared gravimetrically

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
295.8	196.0
335.2	196.3
375.1	194.7
406.1	192.6
452.7	186.7
482.1	181.7

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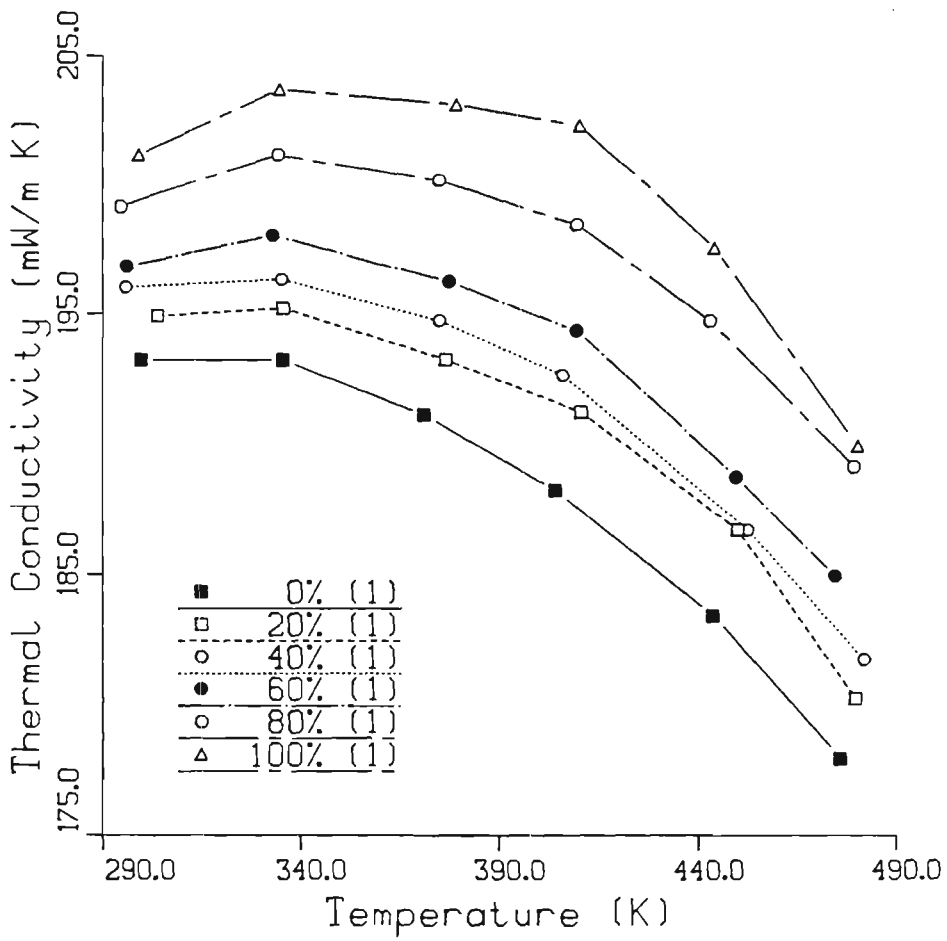
June 30, 1988

DDS-LT-A21

Diethylene (1) + Triethylene (2) Glycol



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June 30, 1988 DDS-LT-A22

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Diethylene Glycol (1) + Triethylene Glycol (2)
$x_1 = 0.6004$

Purity of 1 = 99.0 +%
Purity of 2 = 99.5 %
Mixtures prepared gravimetrically

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
296.2	196.8
333.1	198.0
377.6	196.2
409.7	194.3
446.6	188.7
474.9	184.9

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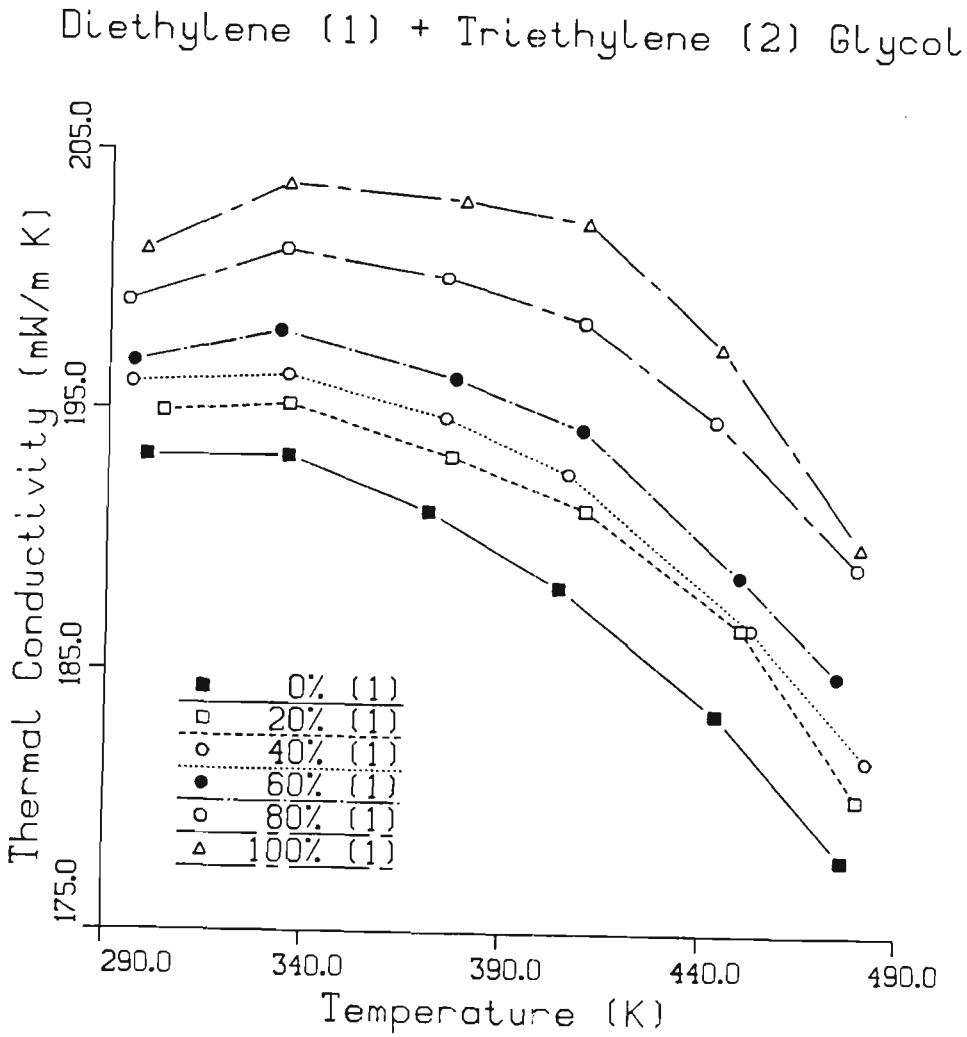
June 30, 1988 DDS-LT-A22



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June 30, 1988 DDS-LT-A23

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Diethylene Glycol (1) + Triethylene Glycol (2)
$x_1 = 0.7992$

Purity of 1 = 99.0 +%
Purity of 2 = 99.5 %
Mixtures prepared gravimetrically

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
294.7	199.1
334.4	201.2
375.0	200.1
411.8	198.4
443.8	194.7
479.7	189.1

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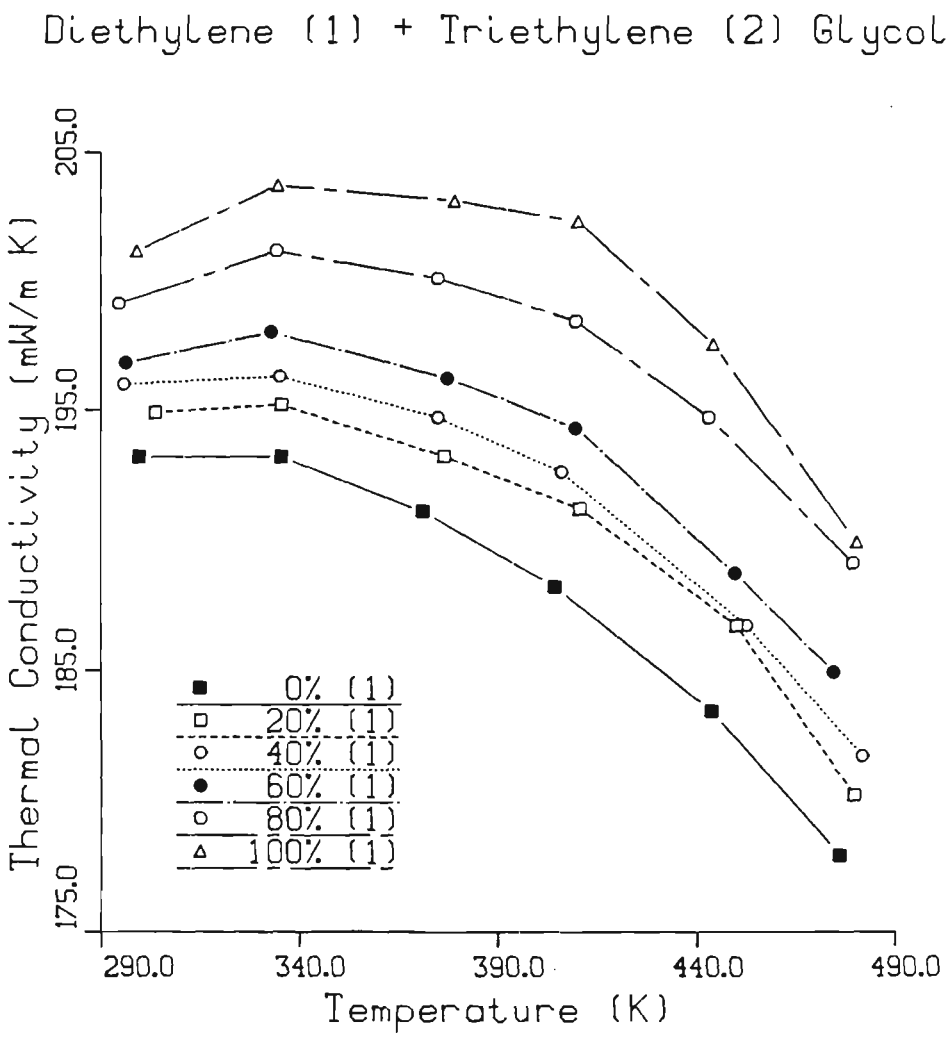
DDS-LT-A23



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June 30, 1988 DDS-LT-A24

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Diethylene Glycol (1) + Hexaethylene Glycol (2)
x_1 = 0.2511

Purity of 1 = 99.0 +%
Purity of 2 = 98.5 %
Mixtures prepared gravimetrically

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
299.4	187.2
333.3	185.8
378.6	183.5
412.4	180.6
451.4	175.3

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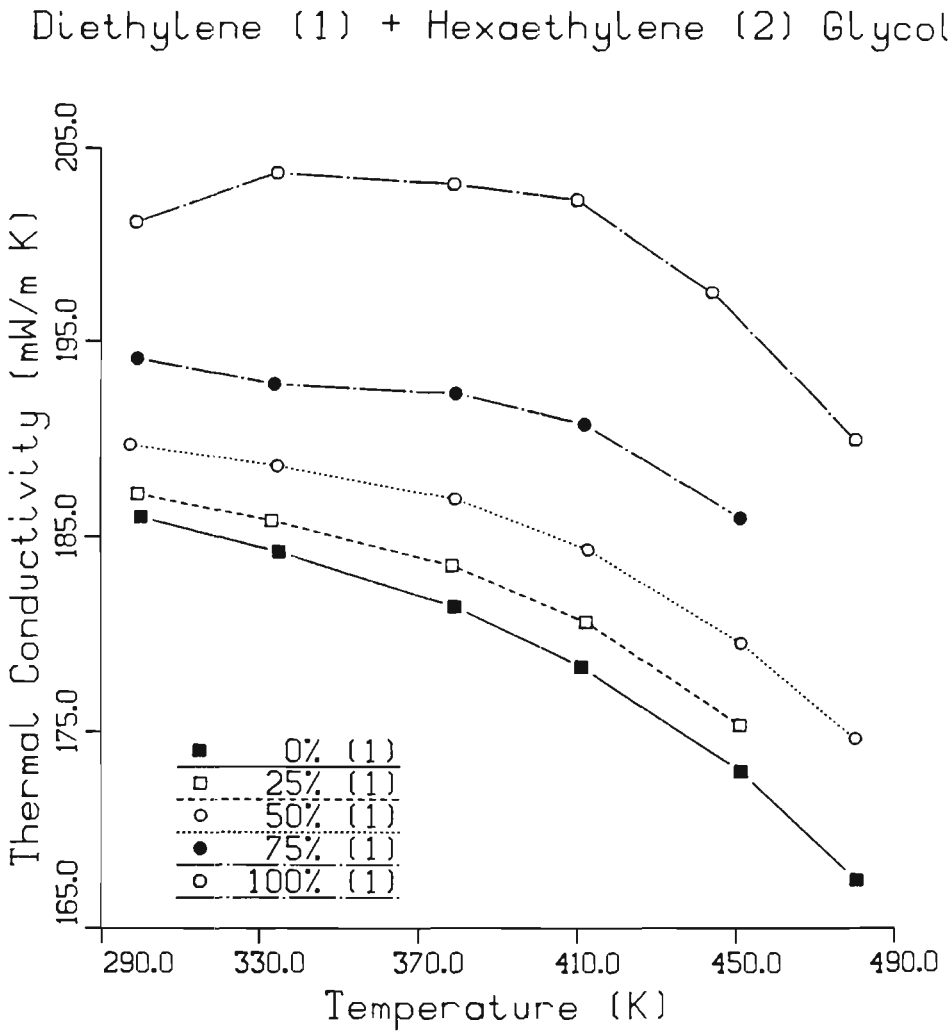
June 30, 1988

DDS-LT-A24



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June 30, 1988 DDS-LT-A25

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Diethylene Glycol (1) + Hexaethylene Glycol (2)
$x_1 = 0.4958$

Purity of 1 = 99 +%
Purity of 2 = 98 %
Mixtures prepared gravimetrically

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
297.4	189.7
334.7	188.6
379.5	186.9
412.9	184.3
451.6	179.5
480.6	174.6

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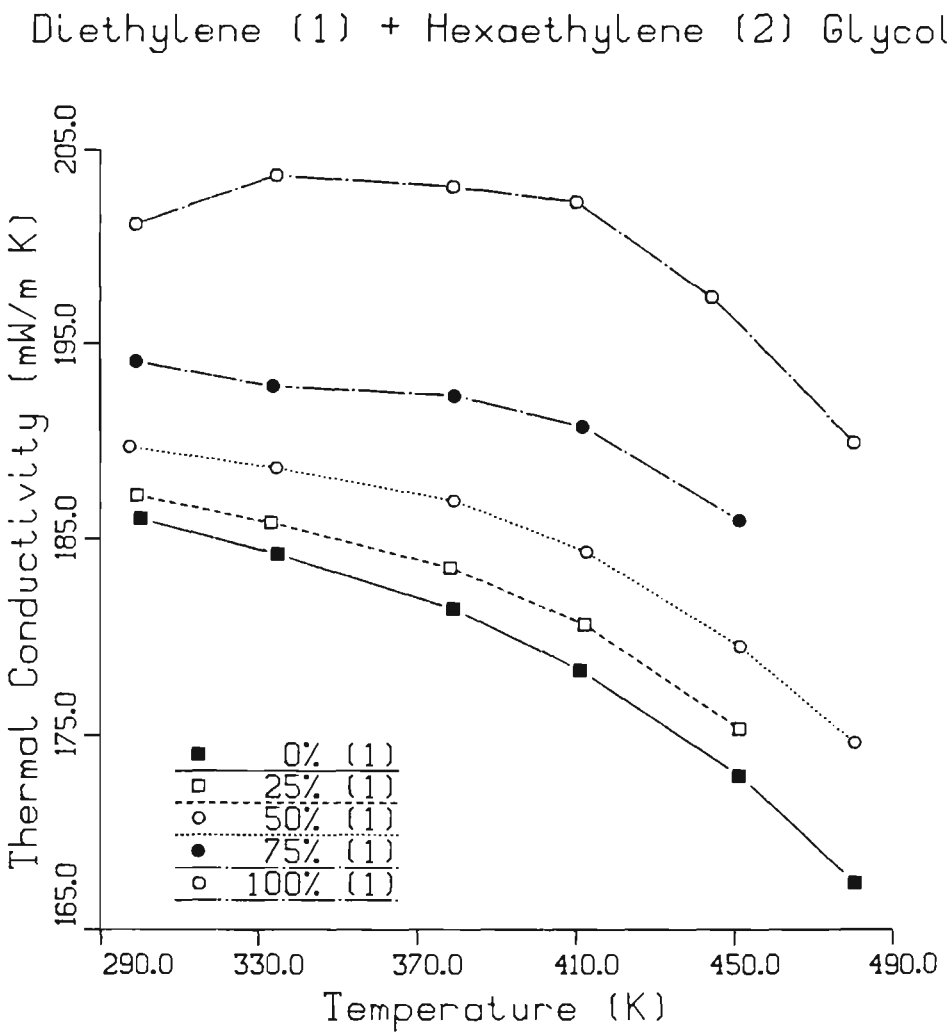
June 30, 1988

DDS-LT-A25



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June 30, 1988 DDS-LT-A26

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Diethylene Glycol (1) + Hexaethylene Glycol (2)
$x_1 = 0.7478$

Purity of 1 = 99 +%
Purity of 2 = 98 %
Mixtures prepared gravimetrically

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
299.2	194.1
334.0	192.8
379.7	192.3
412.2	190.7
451.6	185.9
481.4	175.0

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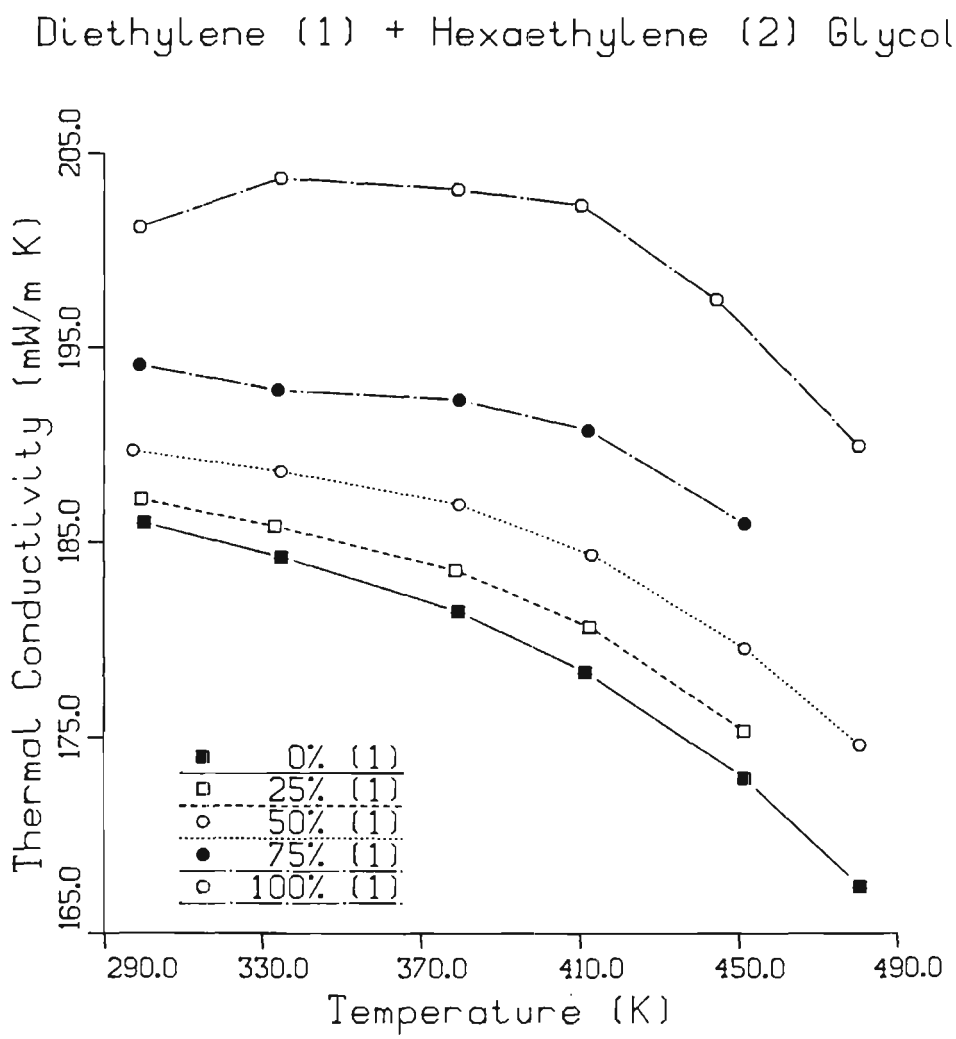
DDS-LT-A26



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June 30, 1988 DDS-LT-A27

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
1-Methyl-2-Pyrrolidinone (NMP)
$CH_2(CH_2)_2CON\ CH_3$

Purity =	99.5 +%	
Molecular Weight =	99.1 kg/kmol	[1]
Critical Temperature =	724.1 K	[2]
Critical Pressure =	47.2 atm	[2]
Critical Volume =	- m^3/kmol	[ ]
Melting Point =	248.8 K	[3]
Boiling Point at 4mm Hg	475.2 K	[3]

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.24%

estimated accuracy = ± 2%

T (K)	λ(mW/mK)
298.3	165.6
303.5	164.4
334.4	156.2
365.2	148.6
393.7	141.9
422.9	135.2
460.7	127.0

Liquid Thermal Conductivity Correlation:

$$\lambda = 260.753783 - 0.371159192\ T + 0.175643322\ T^2 \times 10^{-3}$$

%AAD = 0.03%
%MAD = 0.05%

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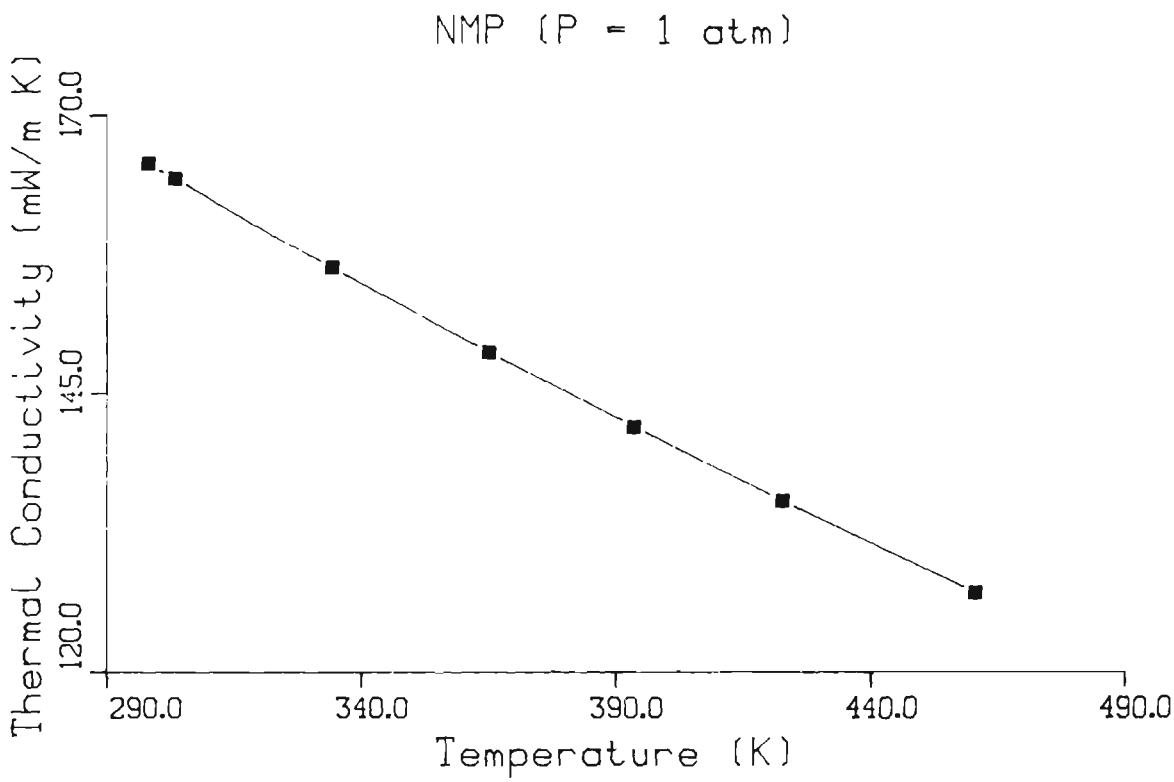
June 30, 1988

DDS-LT-A27



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June 30, 1988 DDS-LT-A28

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Texas City FCU Decanted Oil
(Amoco)

API Gravity at 60°F =		-2.0 °AP
Sulfur wt %		0.17
Nitrogen wt %		1.09
Pour point		50°F
Viscosity at 40°C =		344.2 cst
Distillation Temp. (TBP)		
	IBP	481°F
	20%	722°F
	40%	769°F
	60%	825°F
	80%	936°F
	FBP	1366°F

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.2%

estimated accuracy = ± 3% (Note that some fractionation of components was observed at the higher temperatures)

T (K)	λ(mW/mK)
299.7	123.6
335.6	120.4
379.8	113.4
412.9	107.1
451.6	111.7
477.1	110.8

Liquid Thermal Conductivity Correlation:

$$\lambda = 257.776134 - 0.673249795\ T + 0.76629546\ T^2 \times 10^{-3}$$

%AAD = 1.39%
%MAD = 3.09%

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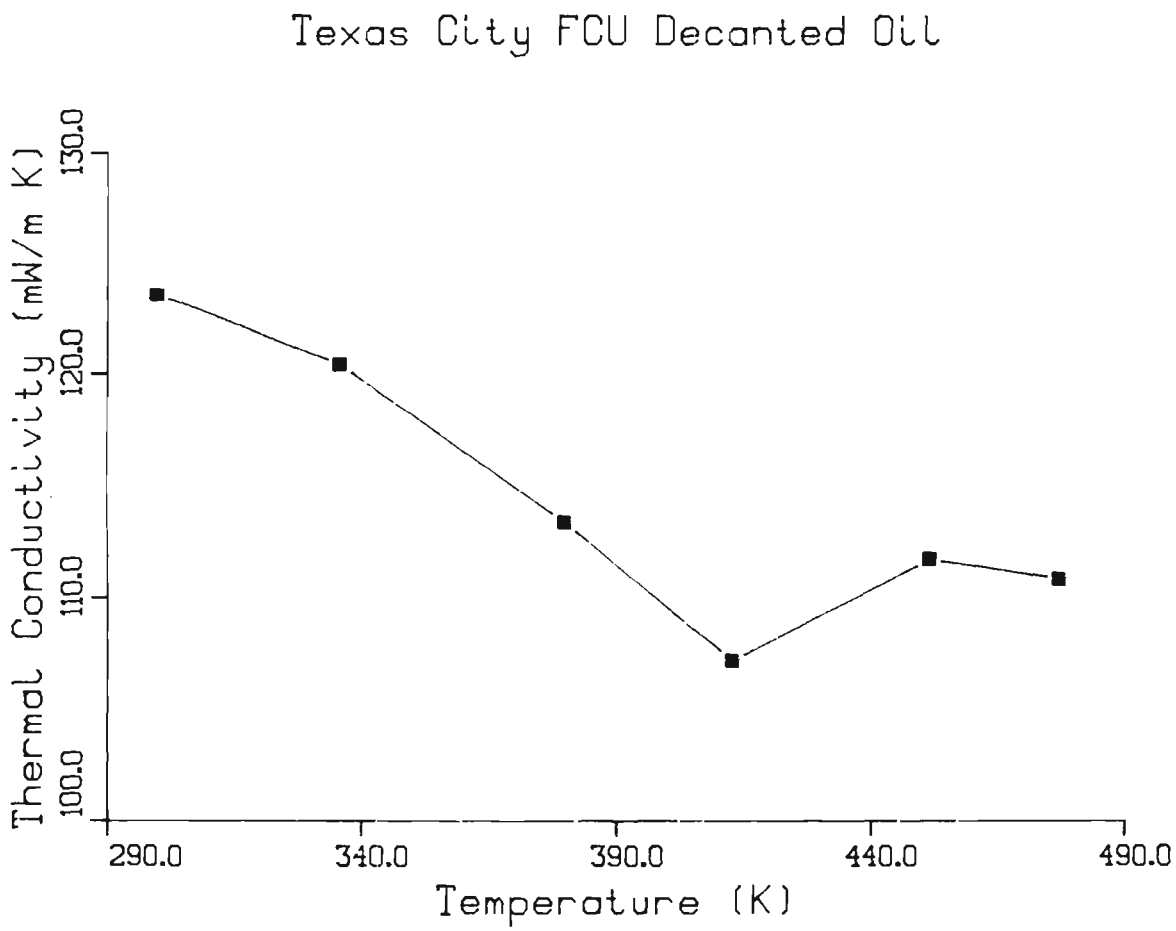
June 30, 1988

DDS-LT-A28



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September 15, 1988

J. David Chase
Celanese Chemical Co.
Specialty Operations
P.O. Box 9077
Corpus Christi, TX 78408

Dear Mr. Chase:

I am enclosing design data sheets DDS-LV-11 through DDS-LV-16 and DDS-LD-11 through DDS-LD-13. These represent the results of work sponsored by FPRI. I would like to express my thanks for your continued support of this research.

Yours sincerely,

Amyn S. Teja
Professor

AST/jvl

August 1988 DDS-LV-A11

DESIGN DATA STANDARD - LIQUID VISCOSITY
1-Methyl-2-Pyrrolidinone
$CH_2\ (CH_2)_2\ CO\ N\ CH_3$

Purity =	99.5+%	
Molecular Weight =	99.1 kg/kmol	[1]
Critical Temperature =	724.1K	[2]
Critical Pressure =	47.2 atm	[2]
Melting Point =	248.8 K	[1]
Normal Boiling Point =	475.2	[3]

Experimental Technique: Capillary Viscometer

Experimental Data:

pressure = Ambient

precision = ± 0.2%

T (K)	ν (cst)	μ* (cp)
293.1	1.790	1.846
313.1	1.323	1.339
333.1	1.042	1.035
353.2	0.8543	0.8318
373.2	0.7236	0.6897
393.1	0.6282	0.5854
413.2	0.5579	0.5076
423.0	0.5305	0.4767

Liquid Viscosity Correlation:

$$\ln \mu = -23.5865 - \frac{2294.45}{T} + 2.8812 \ln T$$

%AAD = 0.3%
%MAD = 0.7%

*Liquid density calculated from reference [4]

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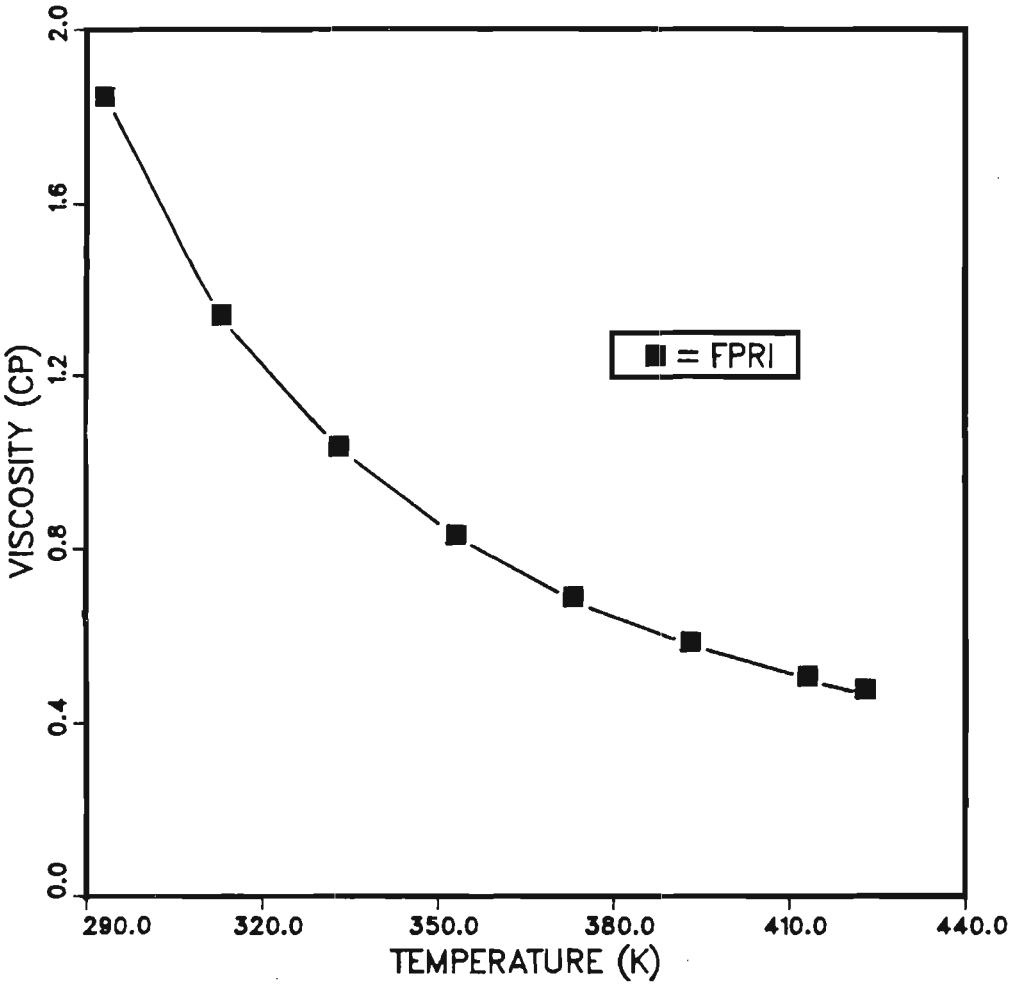
VISCOSITY OF N-METHYL-PYRROLIDINONE



REFERENCES

1. Holden, N. E., Pure Appl. Chem., 1980, 52, 3249.

2. Calculated from Lyderson's Method in Reid, R. C.; Prausnitz, J. M. and Sherwood, T. K., "The Properties of Gases and Liquids," 3rd. ed., McGraw-Hill, New York, 1977.

3. GAF Corp., "M-Prol (n-Methyl-2-Pyrrolidinone) Handbook," New York, 1972.

4. Murrieta-Guevara, F. and Rodriguez, A. T., J. Chem. Eng. Data, 1984, 29, 204.

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August 1988 DDS-LV-A12

DESIGN DATA STANDARD - LIQUID VISCOSITY
Monoethanolamine
$H_2N\ CH_2CH_2OH$

Purity =	99+%	
Molecular Weight =	61.08	[1]
Critical Temperature =	614.5K	[2]
Critical Pressure =	44.1 atm	[2]
Melting Point =	283.68	[3]
Normal Boiling Point =	444.1	[3]

Experimental Technique: Capillary Viscometer

Experimental Data:

pressure = Ambient

precision = ± 0.2%

T (K)	ν (cst)	μ * (cp)
303.6	14.67	14.86
313.4	9.83	9.89
333.4	5.04	4.99
353.4	2.97	2.90
373.4	1.93	1.85
393.5	1.345	1.268
413.6	0.992	0.918
423.7	0.868	0.796

Liquid Viscosity Correlation:

$$\ln \mu = -94.8059 + \frac{7633.51}{T} + 12.6681 \ln T$$

%AAD = 0.8%
%MAD = 1.5%

*liquid density calculated from reference [4]

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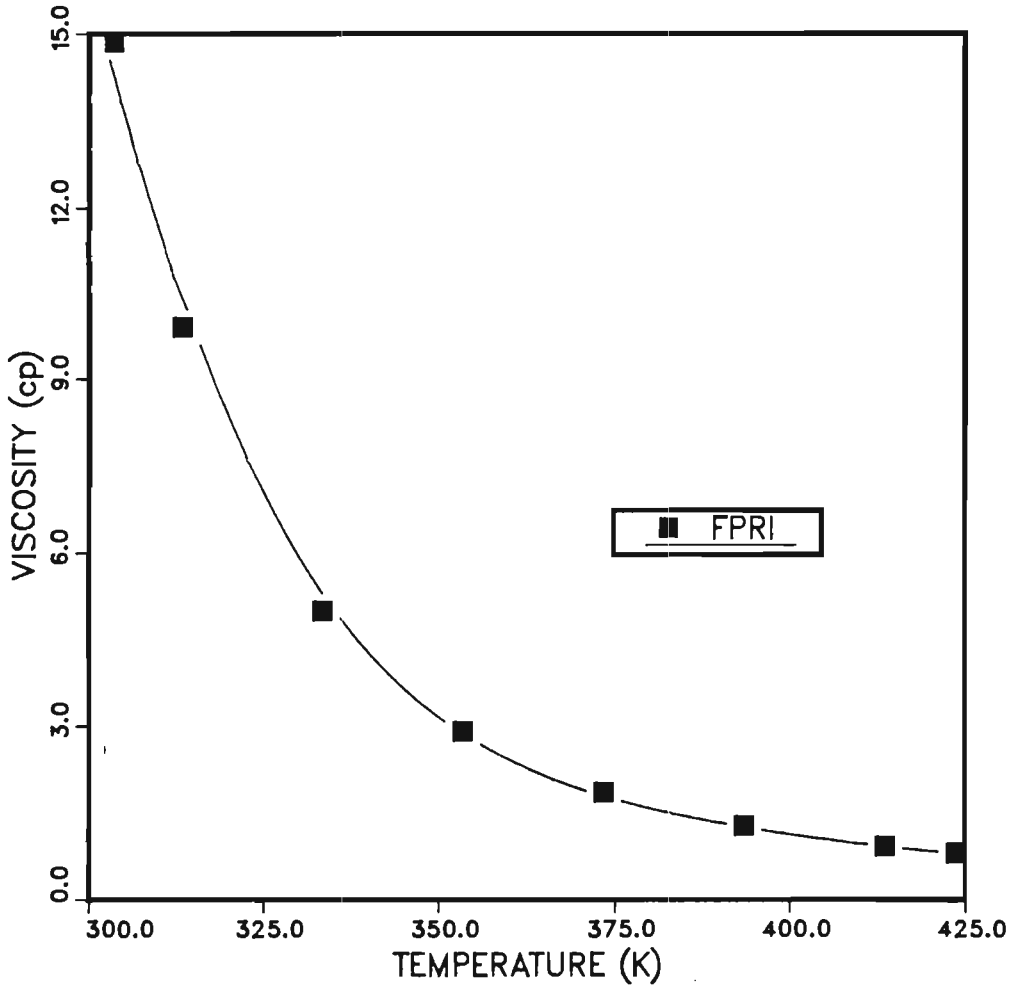
VISCOSITY OF MONOETHANOLAMINE



August 1988 DDS-LV-A12

REFERENCES

1. Holden, N. E., Pure Appl. Chem., 1980, 52, 3249.

2. Dow Chemical Co., "Ethanolamines," Midland, Michigan 1954.

3. Dow Chemical Co., "Alkanolamines Handbook," 3rd ed., Midland, MI 1964.

4. Ratcliffe, A. E., Maddox R. D., Parham, W. F., and Maddox, R. N. FPRI Reports # LDR-19, Vol. II B 1979.

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August 1988 DDS-LV-A13

DESIGN DATA STANDARD - LIQUID VISCOSITY
Diethanolamine
$HN(CH_2CH_2OH)_2$

Purity =	99+%	
Molecular Weight =	105.14 kg/kmol	[1]
Critical Temperature =	715.3K	[2]
Critical Pressure =	32.3 atm	[2]
Melting Point =	301.1 K	[3]
Normal Boiling Point =	541.5	[2]

Experimental Technique: Capillary Viscometer

Experimental Data:

pressure = Ambient

precision = ± 0.4%

T (K)	ν (cst)	μ*(cp)
292.9	811.8	890.5
303.8	326.6	356.0
313.2	185.4	200.9
333.1	57.2	61.2
353.1	22.2	23.4
373.2	10.12	10.53
393.1	5.53	5.67
413.2	3.36	3.38
423.2	2.70	2.70

Liquid Viscosity Correlation:

$$\ln \mu = -188.034 + \frac{14446.07}{T} + 25.6129 \ln T$$

%AAD = 1.6%
%MAD = 5.6%

*liquid density calculated from reference [4]

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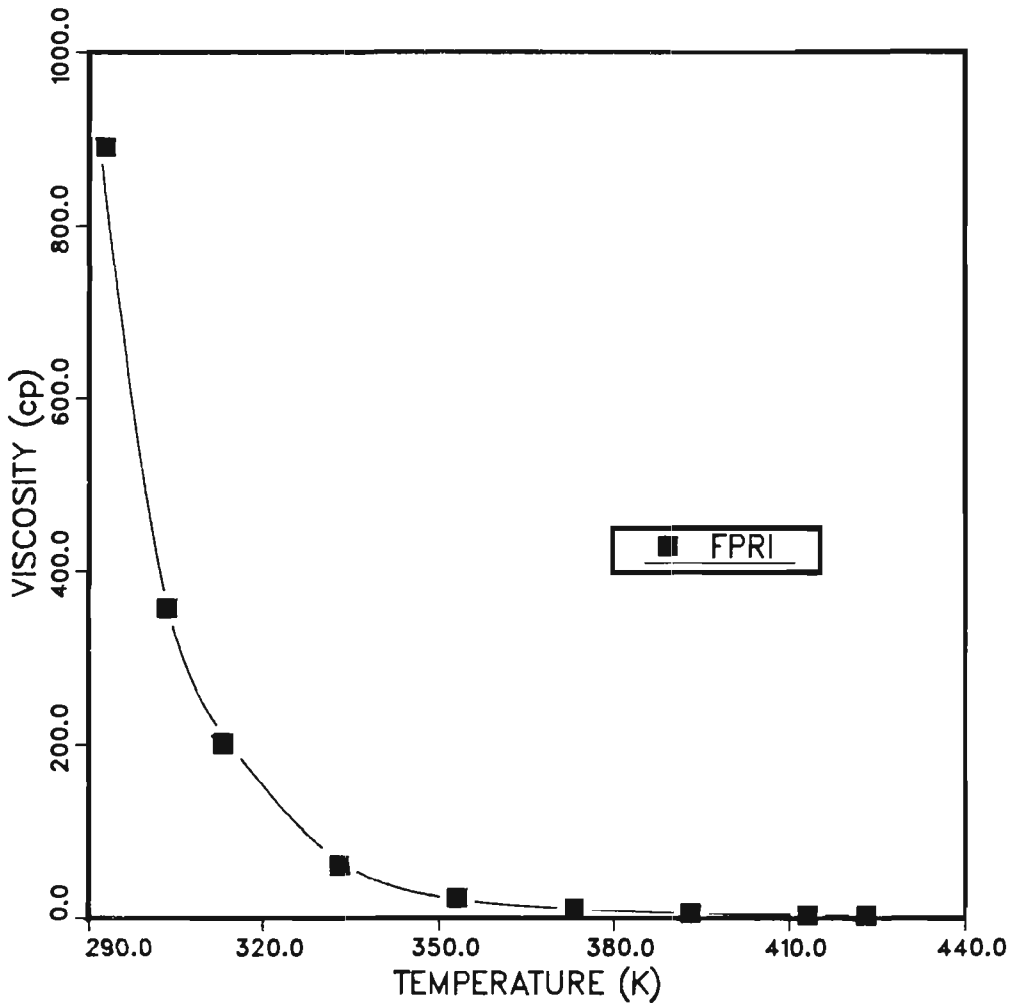
VISCOSITY OF DIETHANOLAMINE



August 1988 DDS-LV-A13

REFERENCES

1. Holden, N. E., Pure Appl. Chem., 1980, 52, 3249.

2. Dow Chemical Co., "Ethanolamines," Midland, Michigan 1954.

3. Riddick, J. A.; Bunger, W. B. and Sakano, T. K., "Organic Solvents. Physical Properties and Methods of Purification," 4th ed., Wiley. New York, 1972.

4. Murrieta-Guevara, F. and Rodriguez, A. T., J. Chem. Eng. Data, 1984, 29, 204.

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June 30, 1988 DDS-LV-A14

DESIGN DATA STANDARD - LIQUID VISCOSITY
Triethanol-amine
$N(CH_2CH_2OH)_3$

Purity =	99 Fisher-Certified +%	
Molecular Weight =	149.2 kg/kmol	[1]
Critical Temperature =	787.5 K	[2]
Critical Pressure =	24.2 atm	[2]
Melting Point =	294.7 K	[3]
Normal Boiling Point =	608.5	[3]

Experimental Technique: Capillary Viscometer

Experimental Data:

pressure = Ambient

precision = ± 0.3%

T (K)	ν (cst)	μ* (cp)
293.5	806.4	912.4
303.5	359.0	404.2
313.5	181.6	203.4
333.5	59.1	65.5
353.6	24.9	27.3
373.5	12.54	13.62
393.5	7.18	7.70
413.7	4.52	4.80
423.7	3.69	3.89

Liquid Viscosity Correlation:

$$\ln \mu = -214.5452 + \frac{15532.04}{T} + 29.6369 \ln T$$

%AAD = 2.6%
%MAD = 4.7%

*liquid density calculated from reference [4]

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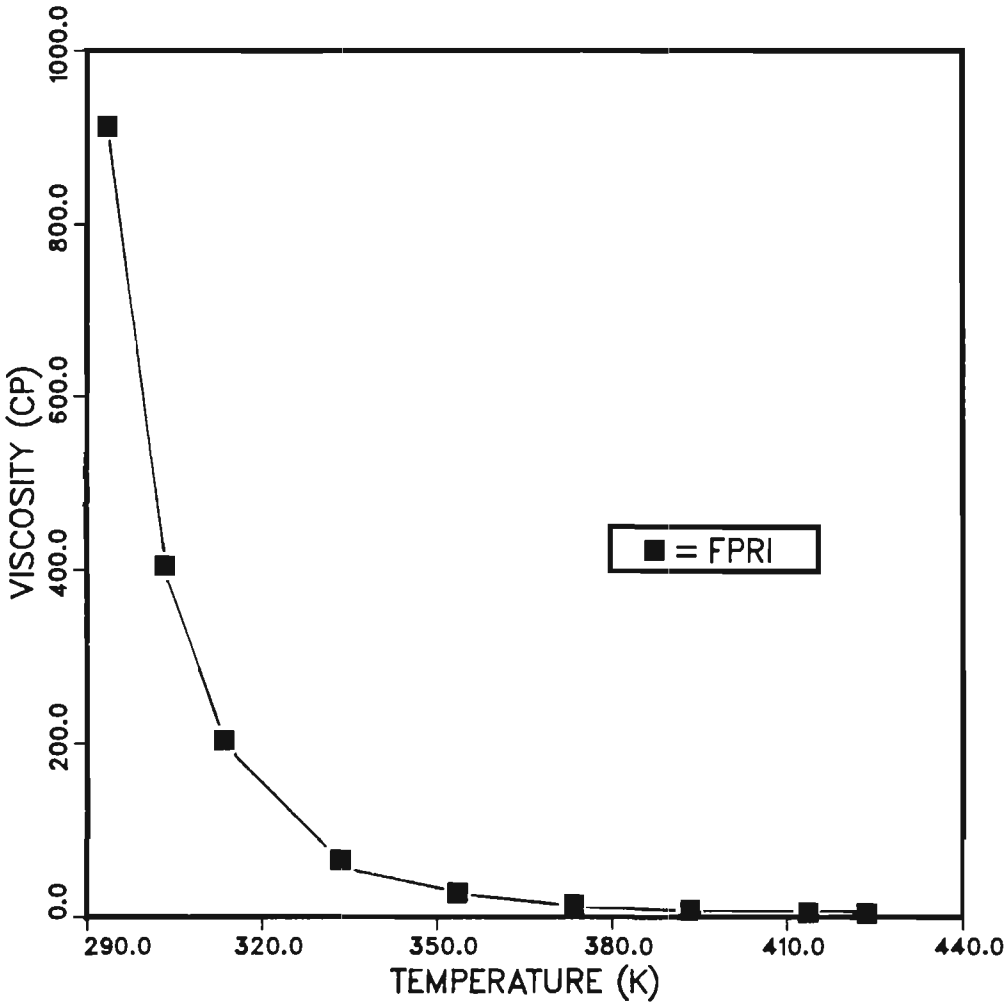
VISCOSITY OF TRIETHANOLAMINE



August 1988 DDS-LV-A14

REFERENCES

1. Holden, N. E., Pure Appl. Chem., 1980, 52, 3249.

2. Dow Chemical Co., "Ethanolamines," Midland, Michigan 1954.

3. Riddick, J. A.; Bunger, W. B. and Sakano, T. K., "Organic Solvents. Physical Properties and Methods of Purification," 4th ed., Wiley. New York, 1986.

4. Ratcliffe, A. E., Maddox R. D., Parham, W. F., and Maddox, R. N. FPRI Reports # LDR-19, Vol. IIB 1979.

August 1988 DDS-LV-A15

DESIGN DATA STANDARD - LIQUID VISCOSITY
Texas City FCU Decanted Oil
(Amoco)

API Gravity at 60°F =		-2.0 °API
Sulfur wt %		0.17
Nitrogen wt %		1.09
Pour point		50°F
50% Distillation Temp. (TBP)		
	IBP	481°F
	10%	684°F
	30%	744°F
	50%	798°F
	70%	865°F
	90%	936°F
	FBP	1366°F

Data supplied by Amoco Oil Co.

Experimental Technique: Capillary Viscometer

Experimental Data:

pressure = Ambient

precision = ± 0.2%

T (K)	μ^* (cp)	ν(cSt)
333.4	103.8	97.3
353.4	31.4	29.8
368.3	16.5	15.8
378.5	11.7	11.3
393.5	7.49	7.28
408.5	5.17	5.08
423.7	3.83	3.80

Liquid Viscosity Correlation:

$$\ln \mu = -324.025 + \frac{22034.7}{T} + 45.1913 \ln T$$

%AAD = 2.3%
%MAD = 4.6%

*liquid density from FPRI report DDS-LD-A13

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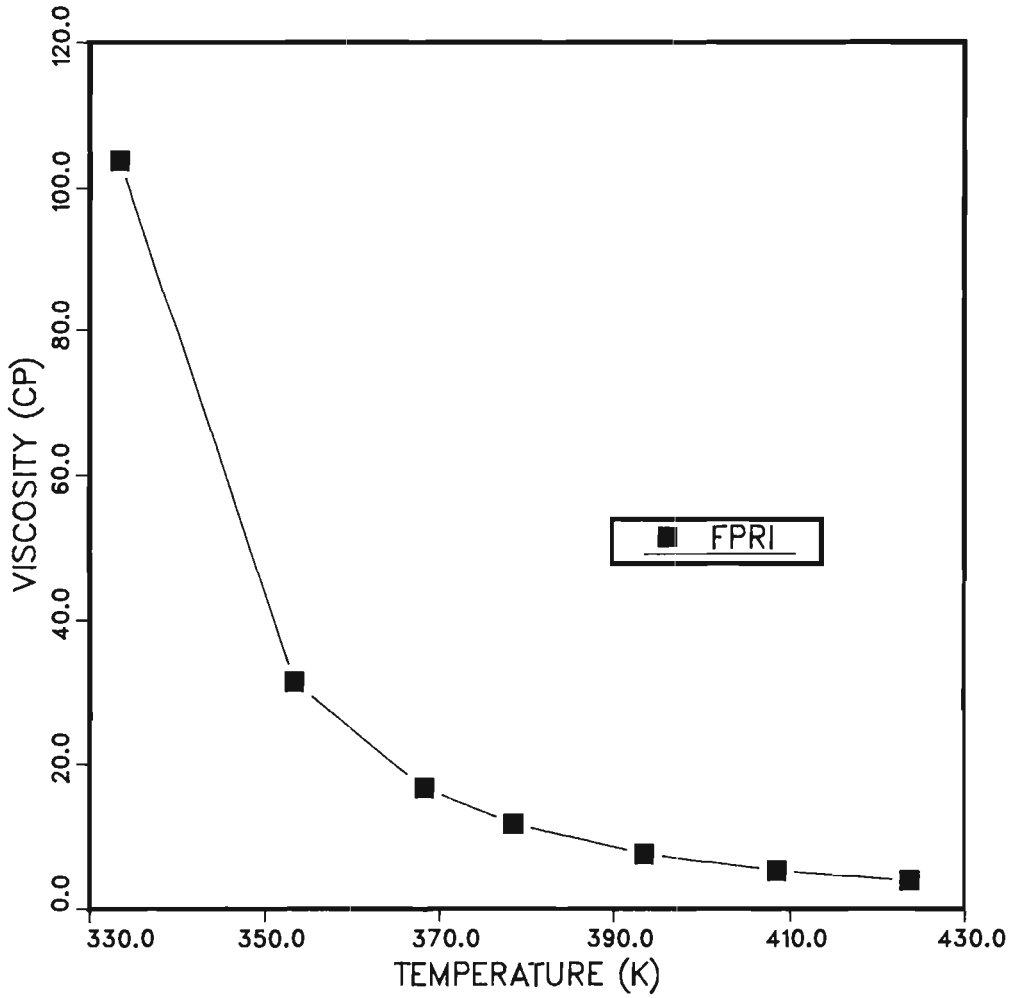
VISCOSITY OF DECANTED OIL – AMOCO



August 1988 DDS-LV-A16

DESIGN DATA STANDARD - LIQUID VISCOSITY
Hexaethylene Glycol
$(CH_2)_{12}O_5(OH)_2$

Purity =	98%	
Molecular Weight =	282.2 kg/kmol	[1]
Critical Temperature =	853.8K	[2]
Critical Volume =	0.720 m^3/kmol	[3]
Melting Point =	274.5 K	[1]

Experimental Technique: Capillary Viscometer

Experimental Data:

pressure = Ambient

precision = ± 0.2%

T (K)	ν (cSt)	μ* (cp)
293.2	75.18	84.09
303.4	44.13	49.09
313.4	28.36	31.38
333.3	13.86	15.16
353.4	7.974	8.625
373.4	5.126	5.480
393.4	3.544	3.743
413.5	2.616	2.728
423.6	2.296	2.379

Liquid Viscosity Correlation:

$$\ln \mu = -131.779 + \frac{9704.73}{T} + 18.1447 \ln T$$

%AAD = 1.7%
%MAD = 3.1%

*liquid density calculated from reference [3]

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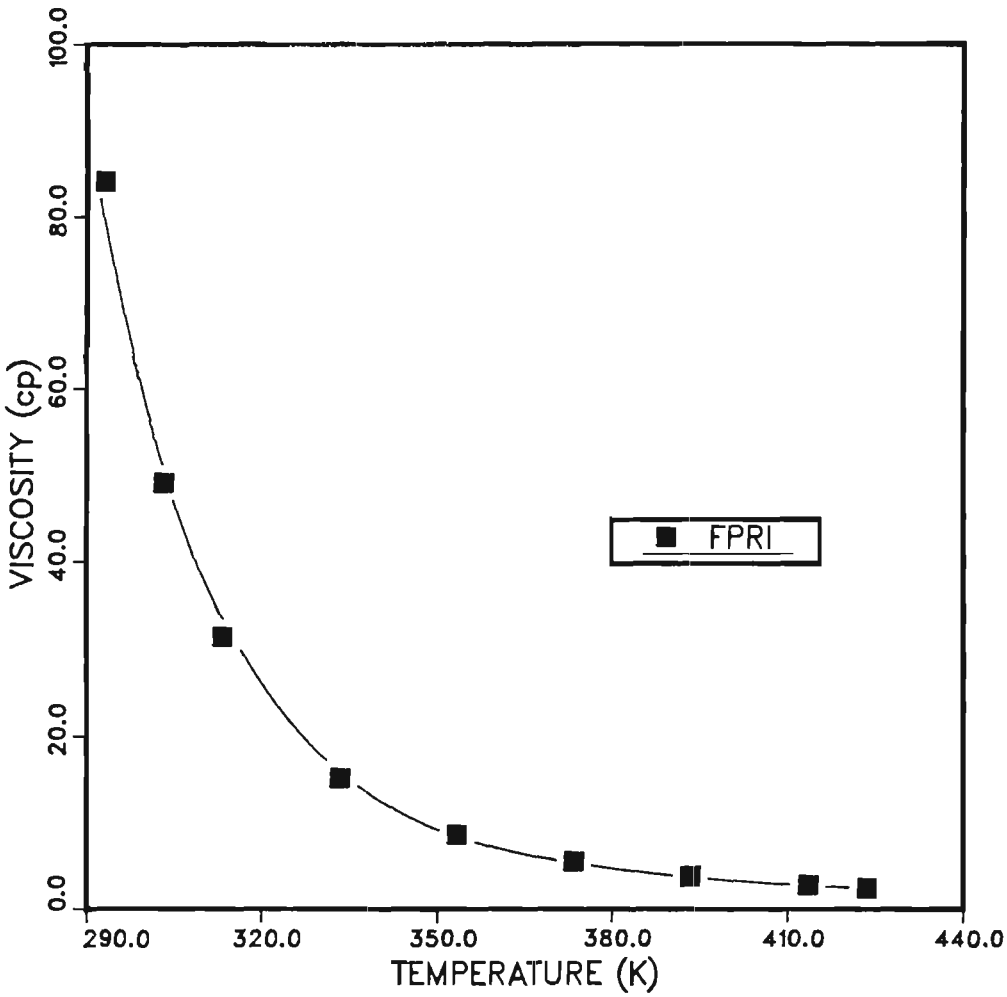
VISCOSITY OF HEXAETHYLENE GLYCOL



August 1988 DDS-LV-A16

REFERENCES

1. Gallaugher, A. F. and Hibbert, H., J. Am. Chem. Soc., 1936, 58, 813-816.

2. Calculated from correlation of: Tawfik, W. and Teja, A. S. FPRI Report 8802.

3. Calculated from FPRI density data and modified Rackett correlation.

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August 1988 DDS-LD-A11

DESIGN DATA STANDARD - LIQUID DENSITY
N-Methylpyrrolidinone
$CH_3(CH_2)_3NCO$

Purity =	99.5%	
Molecular Weight =	99.13 kg/kmol	[1]
Critical Temperature =	721.8 K	[2]
Critical Volume =	0.319 g/cc	[2]
Melting Point =	248.8 K	[3]
Normal Boiling Point =	475 K	[3]

Experimental Technique: High Pressure Pycnometer

Experimental Data:

pressure = Ambient

precision = ± 0.1%

T(K)	ρ(kg/m^3)
299.9	1026.3
318.7	1010.3
331.8	998.52
347.4	985.52
362.5	971.71
382.2	953.93
402.5	935.00

Liquid Density Correlation:

$$\rho = 304.029 \times (0.242135)^{-(1-T_r)^{2/7}}$$

%AAD = 0.01%
%MAD = 0.04%

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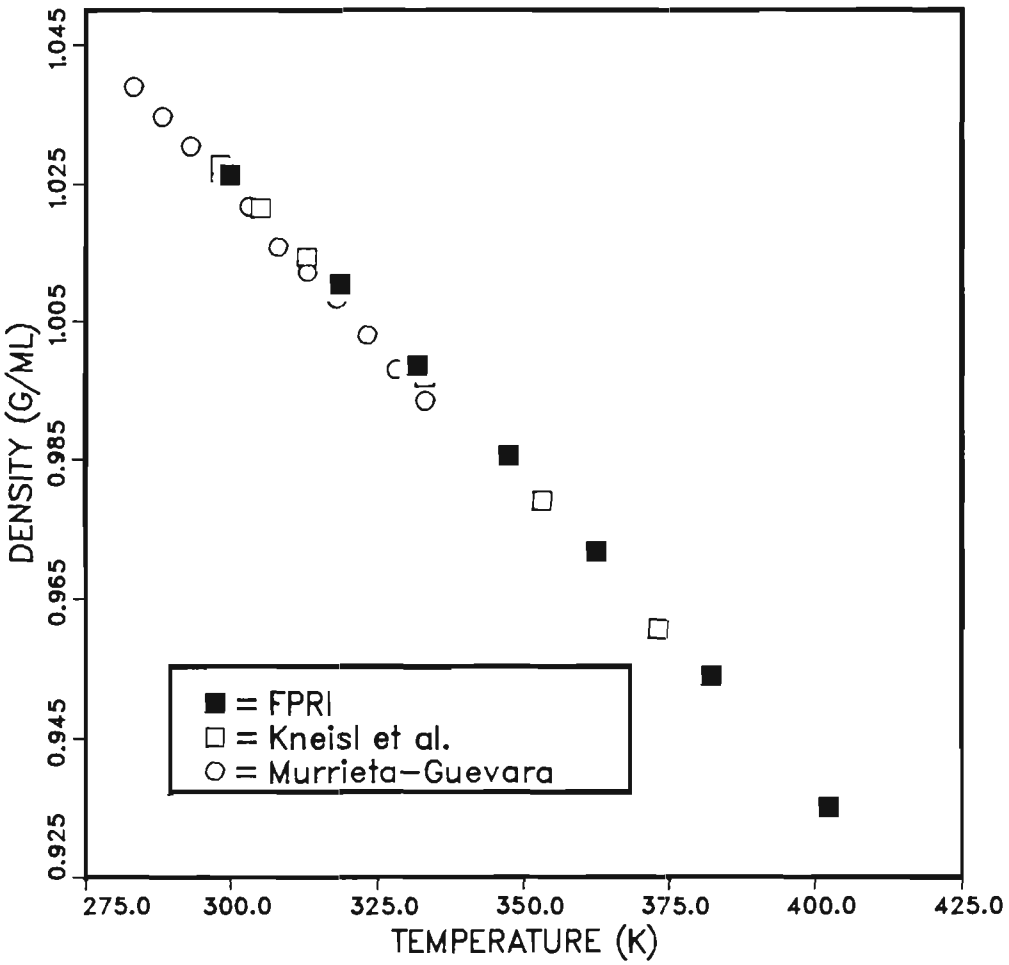
DENSITY OF N-METHYLPYRROLIDINONE



REFERENCES

1. Holden, N. E., Pure Appl. Chem., 1980, 52, 3249.

2. M. Anselme, Ph.D. Thesis, Georgia Tech, 1988.

3. GAF Corp. "N-methyl-pyrrolidinone Handbook," N.Y., 1972.

4. Kneisl, P. and J. W. Zondlo, J. Chem. Eng. Data, 1987, 32, 11.

5. Murrieta-Guevara, F. and A. T. Rodriguez, J. Chem. Eng. Data, 1984, 29, 204.

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August 1988 DDS-LD-A12

DESIGN DATA STANDARD - LIQUID DENSITY
Hexaethylene Glycol
$(CH_2)_{12}O_5(OH)_2$

Purity =	98%	
Molecular Weight =	282.2 kg/kmol	[1]
Critical Temperature =	853.8 K	[2]
Critical Volume =	0.720 m^3/kmol	[3]
Melting Point =	274.5 K	[1]

Experimental Technique: Transient Hot Wire Technique, dimethylphthalate reference.

Experimental Data:

pressure = Ambient

precision = ± 0.1%

T(K)	ρ (kg/m^3)
303.3	1116.7
308.6	1112.1
313.1	1108.3
318.1	1104.3
323.6	1099.9
329.0	1095.2
333.8	1091.5

Liquid Density Correlation:

$$\ln\rho = 391.9405 \times (0.306485)^{-(1-T_r)^{2/7}}$$

%AAD = 0.18%
%MAD = 0.38%

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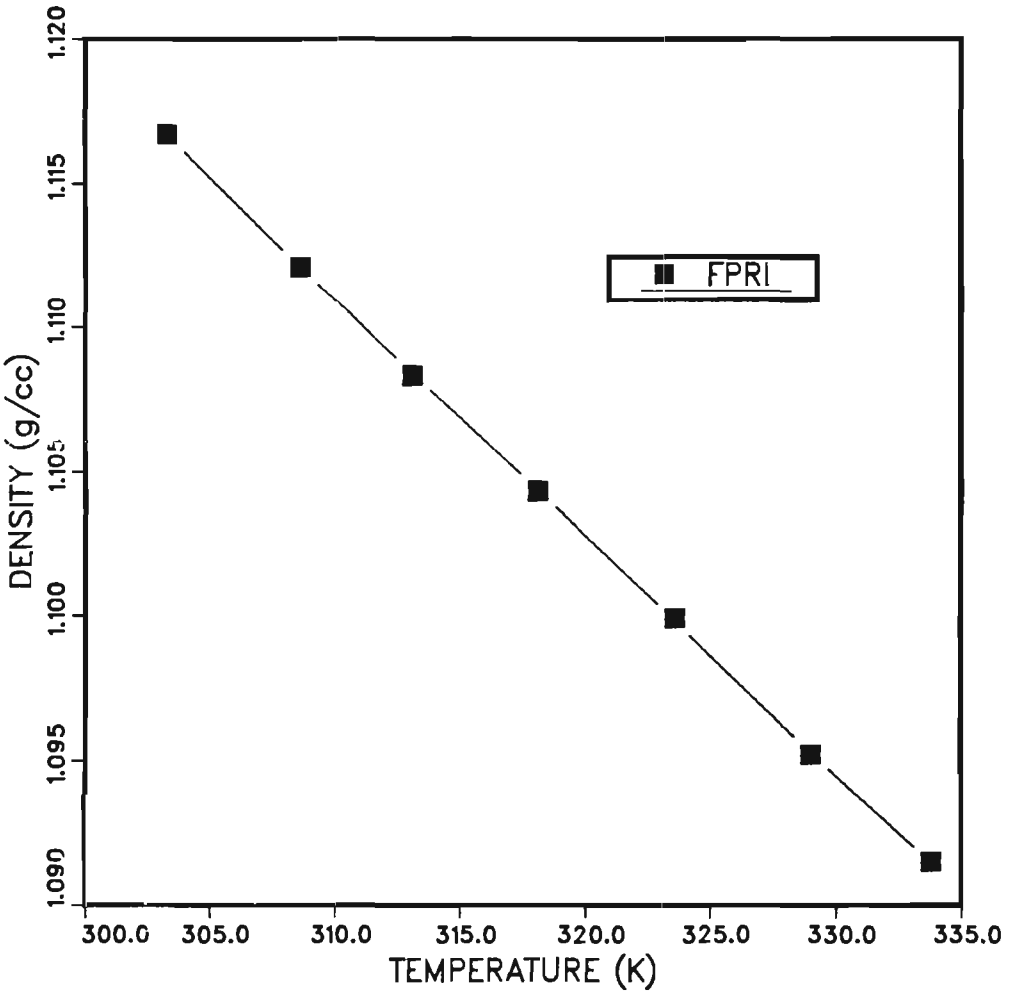
DENSITY OF HEXAETHYLENE GLYCOL



August 1988 DDS-LD-A12

REFERENCES

1. Gallaugher, A. F. and Hibbert, H., J. Am. Chem. Soc., 1936, 58, 813-816.

2. Calculated from correlation of: Tawfik, W. and Teja, A. S. FPRI Report 8802.

3. Calculated from FPRI density data and modified Rackett correlation.

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August 1988 DDS-LD-A13

DESIGN DATA STANDARD - LIQUID DENSITY
Texas City FCU Decanted Oil
(Amoco)

API Gravity at 60°F =		-2.0 °API
Sulfur wt %		0.17
Nitrogen wt %		1.09
Pour point		50°F
50% Distillation Temp. (TBP)		
	IBP	481°F
	10%	684°F
	30%	744°F
	50%	798°F
	70%	865°F
	90%	936°F
	FBP	1366°F

Data supplied by Amoco Oil Co.

Experimental Technique: High pressure pycnometer

Experimental Data:

pressure = Ambient

precision = ± 0.1%

T (°K)	ρ (Kg/m^3)
304.9	1085.4
333.1	1067.7
363.2	1048.1
382.8	1035.2
403.5	1021.5
422.8	1008.9

Liquid Density Correlation:

$$\rho = 1264.98 - 0.544379\ T - 0.145529 \times 10^{-3}\ T^2$$

%AAD = 0.01%
%MAD = 0.02%

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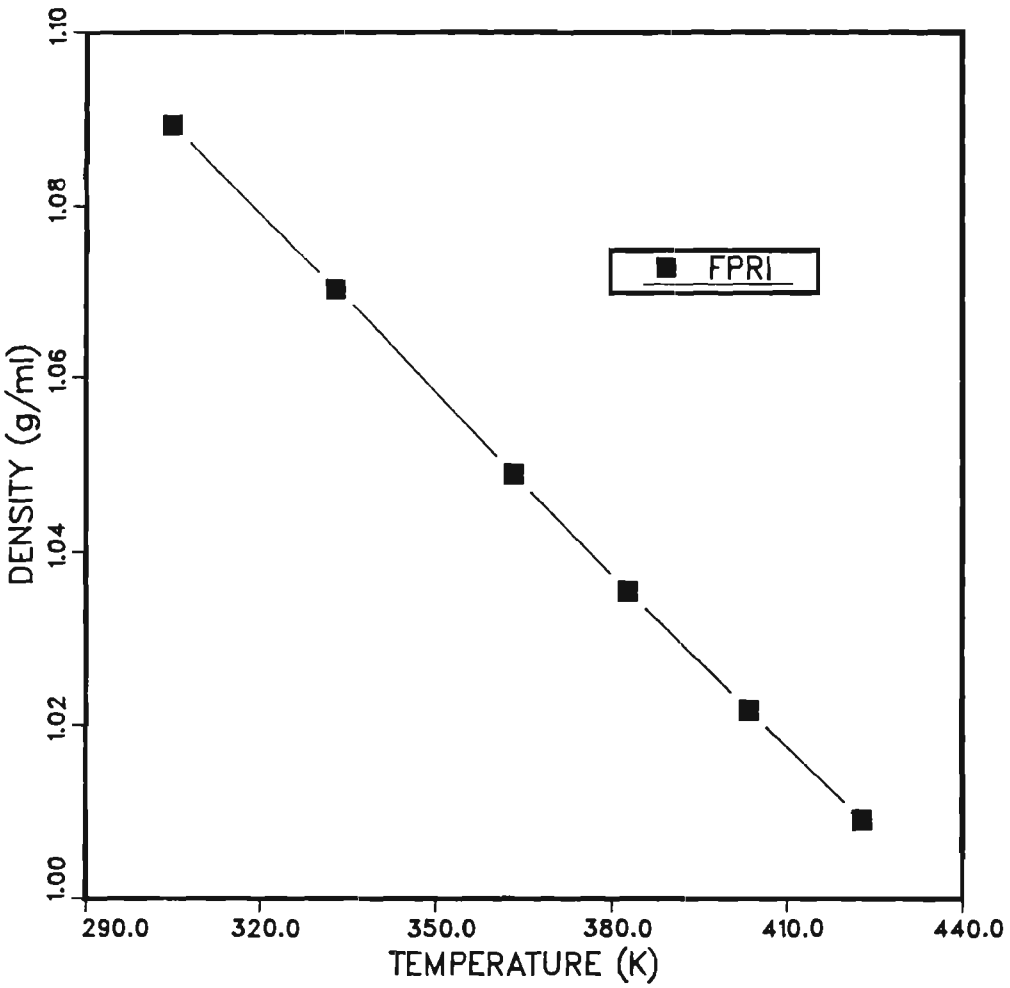
DENSITY OF DECANTED OIL – AMOCO



June 15, 1989

Mr. J. David Chase
President, FPRI
Hoechst- Celanese Corporation
Technical Center
P. O. Box 9077
Corpus Christi, TX 78408

Dear Dave:

Please find enclosed the Design Data Sheets DDS-LTC-29 thru 35, DDS-LD-14 thru 20 and DDS-LV-17 thru 23 representing the results of FPRI sponsored measurements for the year July 1, 1988 to June 30,1989. I would like to take this opportunity to thank the FPRI members for sponsoring this work.

Yours sincerely,

Amyn S. Teja
Professor

;

FLUID PROPERTIES RESEARCH, INC.
Administrative Offices

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May, 1989 DDS-LTC-A30

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Diphenyl Ether

$(C_6H_5)_2O$

Purity =	99 +%	
Molecular Weight =	170.21 kg/kmol	[1]
Critical Temperature =	766.8 K	[2]
Critical Pressure =	30.4 atm	[2]
Critical Volume =	0.545 m^3/kmol	[3]
Melting Point =	300.0 K	[2]
Normal Boiling Point =	531.2 K	[2]
Liquid Molar Volume =	0.1596 m^3/kmol	[2]
Dipole Moment =	0.3870 x 10^{-29} Cm	[4]
van der Waals Volume =	0.09488 m^3/kmol	[5]
van der Waals Area =	1.120 x 10^9 m^2/kmol	[5]

Experimental Technique : Transient Hot Wire Technique

Experimental Data:

Pressure = 14.7 PSI
Accuracy = ± 2.0 %

T (K)	λ (mW/m-K)
306.5	137.0
334.5	133.0
364.4	128.0
393.2	122.7
421.6	117.7
451.3	113.2
474.6	109.5

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m-K)} = 188.234 - 0.16625\ T(K)$$

%AAD = 0.2 %
%MAD = 0.3 %

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REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).
2. Riddick, J. A., W. B. Bunger, and T. E. Sakano, "Organic Solvents - Physical Properties ans Methods of Purification", Wiley Interscience, N. Y., 1986.
3. Dreisbach, R. R., "Physical Properties of Chemical Compounds", ACS, Washington D. C., Vol. 15, 1955.
4. McClellan, A. L., "Tables of Experimental Diople Moments", W. H. Freeman Pub., San Francisco, 1963.
5. Bondi, A., "Physical Properties of Molecular Crystals, Liquids, and Glasses", John Wiley, N. Y., 1968.
6. Zeibland, H., and J. T. A. Burton, J. Chem. Eng. Data, 6, 579 (1961).
7. Schmidt, E., and W. Leidenfrost, Forsch Geb. Ing. Wes., 21, 176 (1955).

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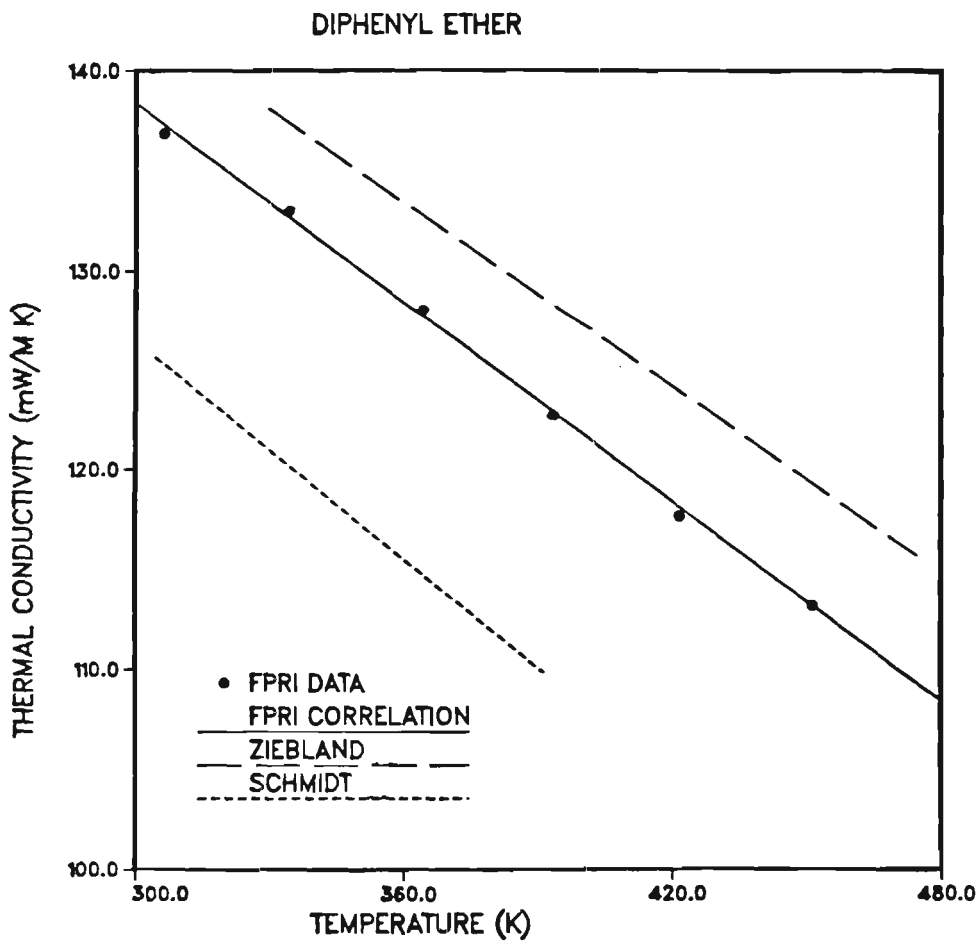

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May, 1989 DDS-LTC-A31

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

N,N-Dimethylacetamine

$CH_3CON(CH_3)_2$

Purity =	99 +%	
Molecular Weight =	87.121 kg/kmol	[1]
Critical Temperature =	637 K	[2]
Critical Pressure =	38.7 atm	[2]
Melting Point =	253 K	[2]
Normal Boiling Point =	439.3 K	[2]
Liquid Molar Volume =	0.09304 m^3/kmol	[2]
Dipole Moment =	1.238×10^{-28} Cm	[2]
van der Waals Volume =	0.05704 m^3/kmol	[3]
van der Waals Area =	8.19×10^8 m^2/kmol	[3]

Experimental Technique : Transient Hot Wire Technique

Experimental Data:

Pressure = 65 PSI
Accuracy = ± 2.0 %

T (K)	λ (mW/m-K)
293.7	169.8
324.3	160.7
362.2	149.3
399.7	137.4
436.0	128.6
462.2	119.2

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m-K)} = 256.994 - 0.29717\ T(K)$$

%AAD = 0.3 %
%MAD = 0.9 %

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REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).
2. Riddick, J. A., W. B. Bunger, and T. E. Sakano, "Organic Solvents - Physical Properties ans Methods of Purification", Wiley Interscience, N. Y., 1986.
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4. Mallan, G. M., "Thermal Conductivity of Liquids", Ph. D. Thesis, U. of South California, Los Angeles, CA, 1968.
5. Pagerey, P. S., C. R. St. Clair, and W. L. Sibbitt, Trans. Amer. Soc. Mech. Engrs., 78, 1169 (1956).

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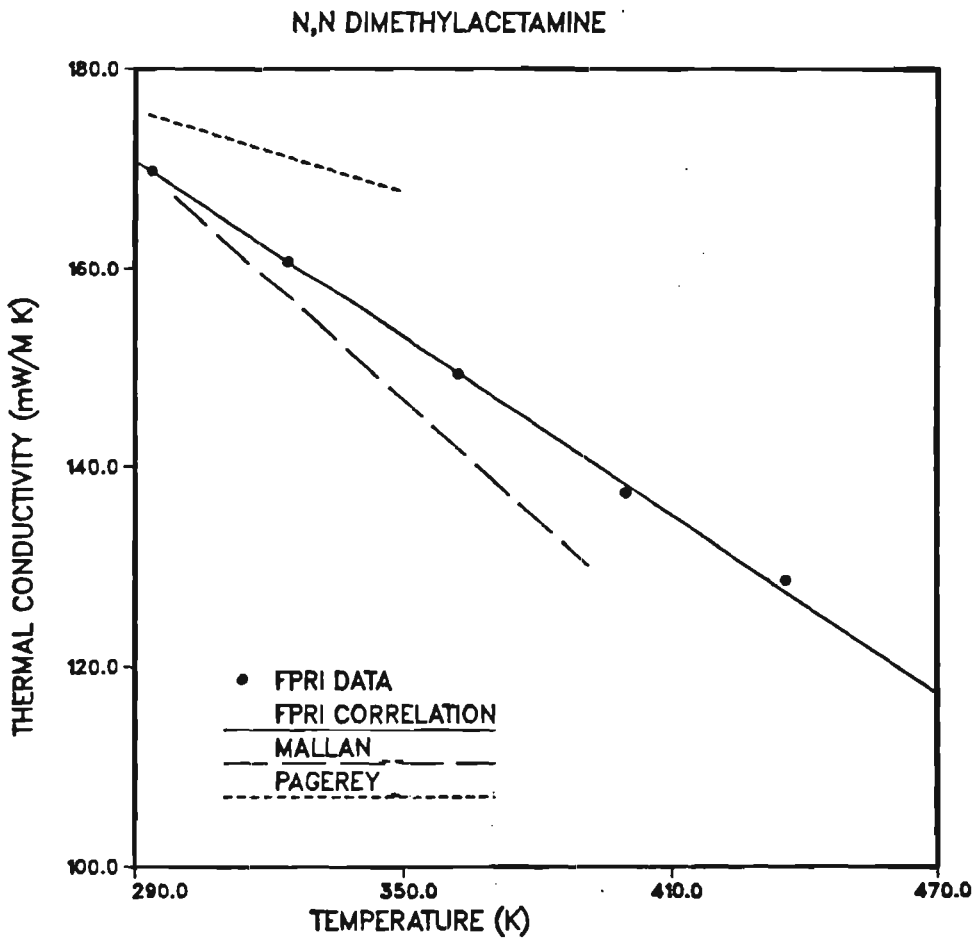

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May, 1989 DDS-LTC-A32

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

2-Ethyl-1-Hexanol

$CH_3(CH_2)_3CH(C_2H_5)CH_2OH$

Purity =	99 +%	
Molecular Weight =	130.23 kg/kmol	[1]
Critical Temperature =	640.2 K	[2]
Critical Pressure =	27.2 atm	[3]
Critical Volume =	0.494 m^3/kmol	[3]
Melting Point =	197 K	[2]
Normal Boiling Point =	457.5 K	[2]
Liquid Molar Volume =	0.15697 m^3/kmol	[4]
Dipole Moment =	0.5871 x 10^{-29} Cm	[5]
van der Waals Volume =	0.09331 m^3/kmol	[6]
van der Waals Area =	1.302 x 10^9 m^2/kmol	[6]

Experimental Technique : Transient Hot Wire Technique

Experimental Data:

Pressure = 80 PSI
Accuracy = ± 2.0 %

T (K)	λ (mW/m-K)
297.4	140.9
336.8	133.9
366.0	128.3
394.1	122.7
423.2	116.0
453.0	109.0
480.5	102.5

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m-K)} = 204.829 - 0.21105\ T(K)$$

%AAD = 0.6 %
%MAD = 0.9 %

REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).
2. Riddick, J. A., W. B. Bunger, and T. E. Sakano, "Organic Solvents - Physical Properties ans Methods of Purification", Wiley Interscience, N. Y., 1986.
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4. AIChE DIPPR Data Compilation Manual, T. Daubert, and R. P. Danner (Eds), 1985.
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6. Bondi, A., "Physical Properties of Molecular Crystals, Liquids, and Glasses", John Wiley, N. Y., 1968.

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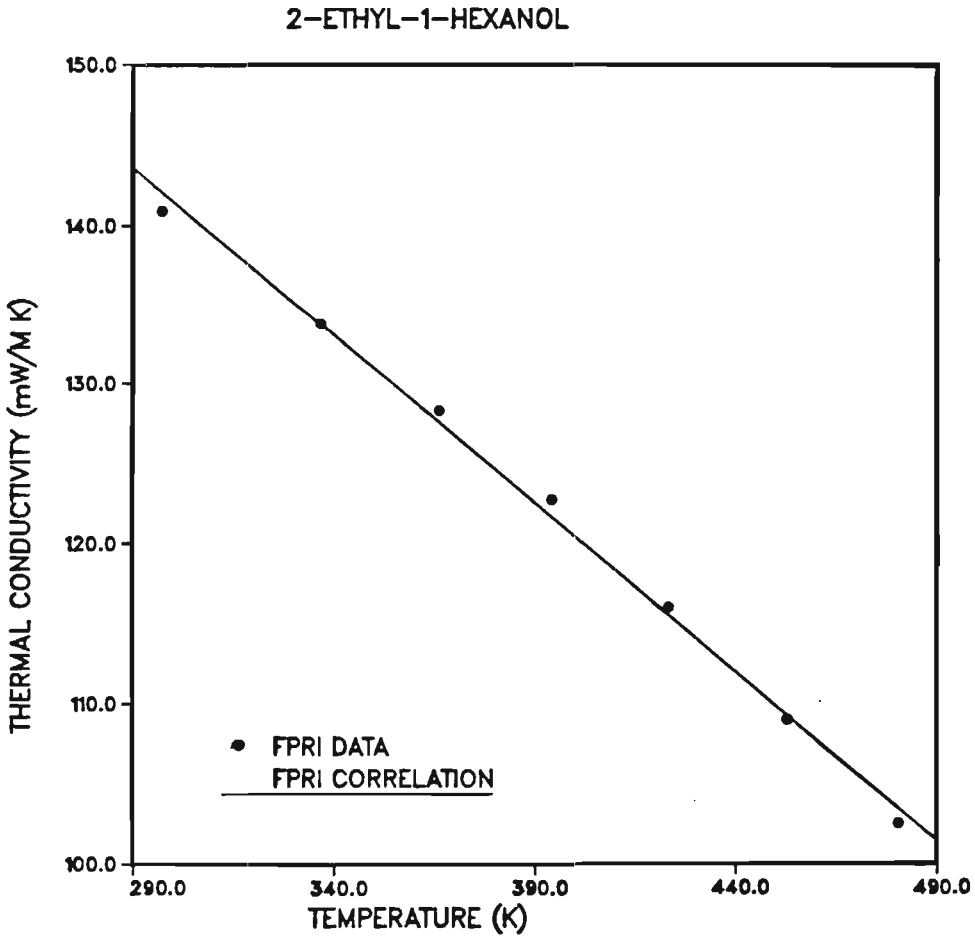

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May, 1989 DDS-LTC-A33

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
North Slope Resid - Amoco

100 °F+ Properties

Carbon, wt.% =	85.46
Hydrogen, wt.% =	10.65
Sulfur, wt.% =	2.6
Vanadium, ppm by wt. =	97.
Nickel, ppm by wt. =	47.
Oil, wt.% =	23.7
Resin, wt.% =	70.1
Asphaltene, wt.% =	6.2

Experimental Technique : Transient Hot Wire Technique

Experimental Data:

Pressure = 65 PSI
Accuracy = ± 2.0 %

T (K)	λ (mW/m-K)
365.3	146.1
390.8	144.2
412.3	141.9
434.6	140.7
455.9	138.7
477.9	136.9

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m-K)} = 175.96 - 0.08175\ T(K)$$

%AAD = 0.10 %
%MAD = 0.25 %

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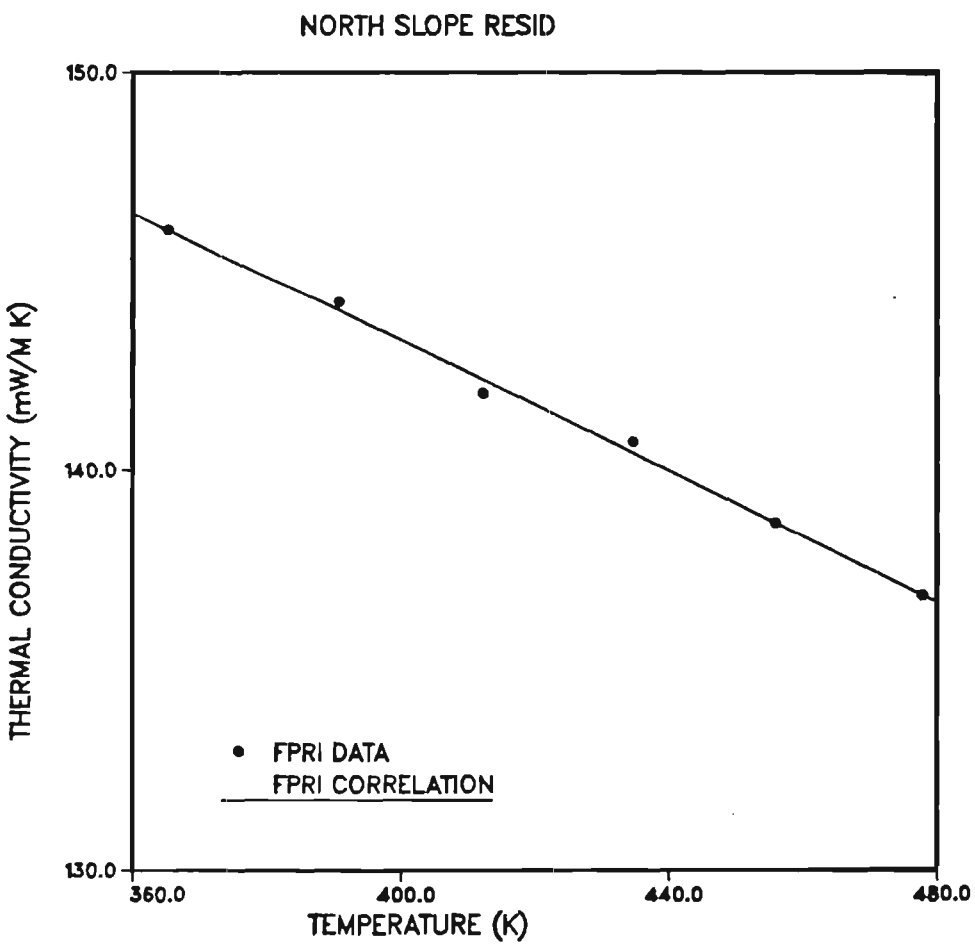
May, 1989

DDS-LTC-A33



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May, 1989 DDS-LTC-A34

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
High Sulfur Resid Blend - Amoco

100 °F+ Properties

API gravity at 60 °F, °API =	5.3
Carbon, wt.% =	84.55
Hydrogen, wt.% =	10.07
Sulfur, wt.% =	4.17
Nitrogen, wt.% =	0.55
Vanadium, ppm by wt. =	286.
Nickel, ppm by wt. =	61.
Iron, wt.% =	13.
Oil, wt.% =	26.8
Resin, wt.% =	58.0
Asphaltene, wt.% =	15.2

Experimental Technique : Transient Hot Wire Technique

Experimental Data:

Pressure = 65 PSI
Accuracy = ± 2.0 %

T (K)	λ (mW/m-K)
393.8	143.6
415.2	141.6
434.4	139.8
455.1	138.1
478.8	135.9

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m-K)} = 178.95 - 0.08986\ T(K)$$

%AAD = 0.03 %
%MAD = 0.08 %

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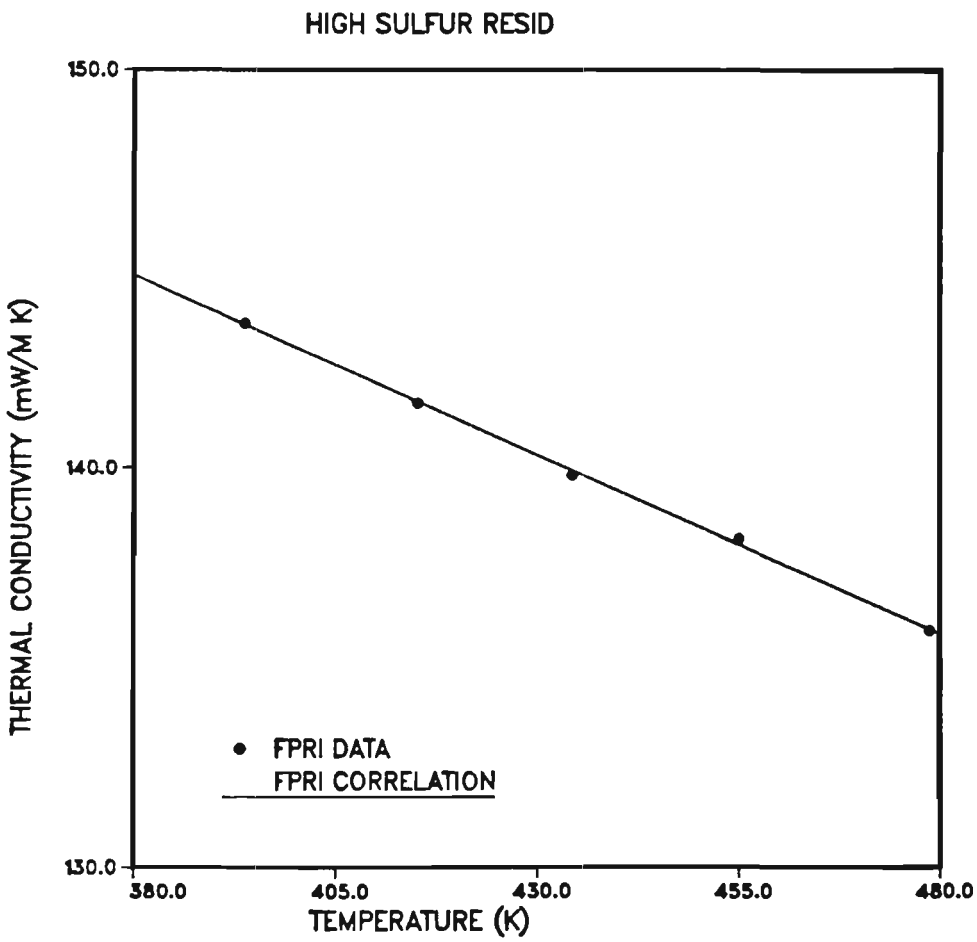
May, 1989

DDS-LTC-A34



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May, 1989 DDS-LTC-A35

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Acetoxy Phenyl Methyl Carbinol

$(CH_3COO)(C_6H_5)C(CH_3)OH$

Purity =	99 +%	
Molecular Weight =	180.20 kg/kmol	[1]
van der Waals Volume =	0.09953 m^3/kmol	[2]
van der Waals Area =	1.323 x 10^9 m^2/kmol	[2]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = 14.7 PSI
Accuracy = ± 2.0 %

T (K)	λ (mW/m-K)
306.6	157.5
335.3	154.4
365.9	152.1
392.9	149.2
428.1	145.9

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m-K)} = 186.28 - 0.09423 \text{ T(K)}$$

%AAD = 0.1 %
%MAD = 0.2 %

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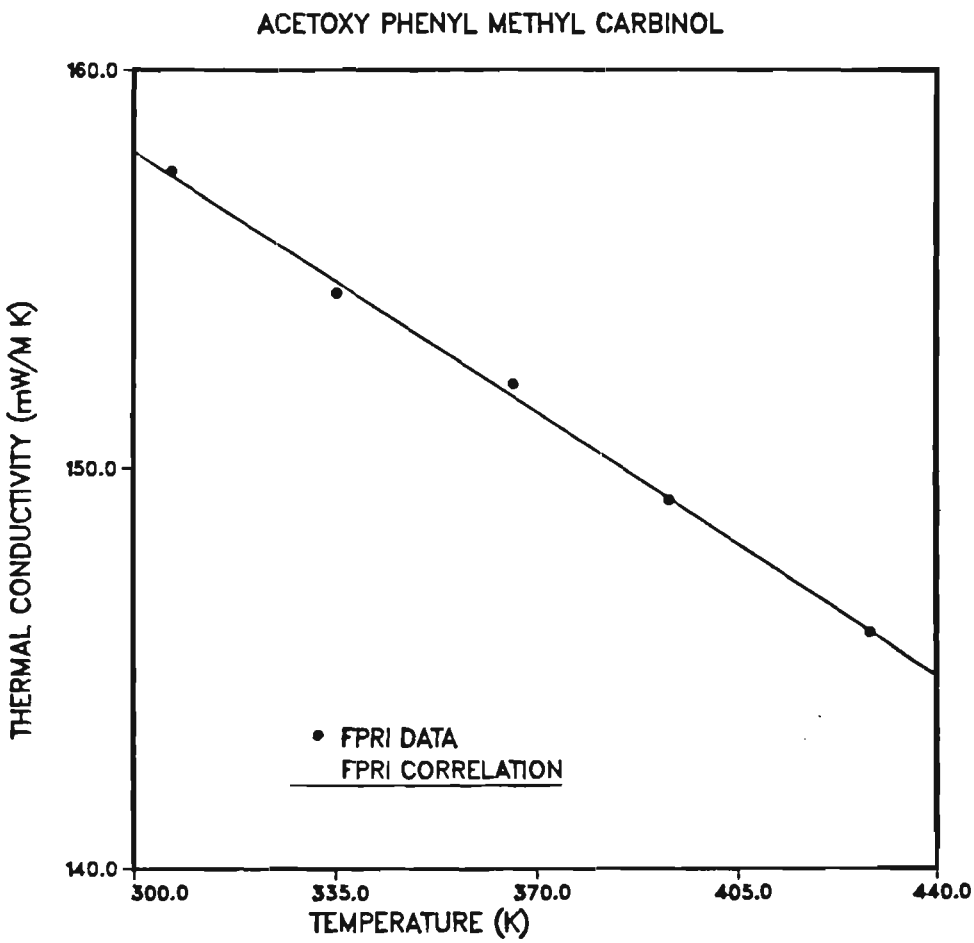
May, 1989

DDS-LTC-A35



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May, 1989 DDS-LD-A14

DESIGN DATA STANDARD - LIQUID DENSITY
Tetramethylene Sulfone
$(CH_2)_4SO_2$

Purity =	99 +%	
Molecular Weight =	120.17 kg/kmol	[1]
Critical Temperature =	855.0 K	[2]
Critical Pressure =	49.7 atm	[2]
Critical Volume =	0.300 m^3/kmol	[3]
Melting Point =	301.6 K	[4]
Normal Boiling Point =	560.5 K	[4]
Liquid Molar Volume =	0.09517 m^3/kmol	[5]
Dipole Moment =	1.605 x 10^{-29} Cm	[4]
van der Waals Volume =	0.06122 m^3/kmol	[6]
van der Waals Area =	8.00 x 10^8 m^2/kmol	[6]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = 14.7 PSI
Accuracy = ± 0.15 %

T (K)	ρ (kg/m^3)
304.7	1260.4
323.7	1243.3
349.0	1221.8
373.8	1200.6
398.4	1178.7
423.1	1156.9
448.3	1134.4
468.9	1116.1

Liquid Density Correlation:

$$\rho(kg/m^3) = 1510.44 - 0.78344\,T(K) - 0.12309x10^{-3}\,T(K)^2$$

%AAD = 0.02 %
%MAD = 0.06 %

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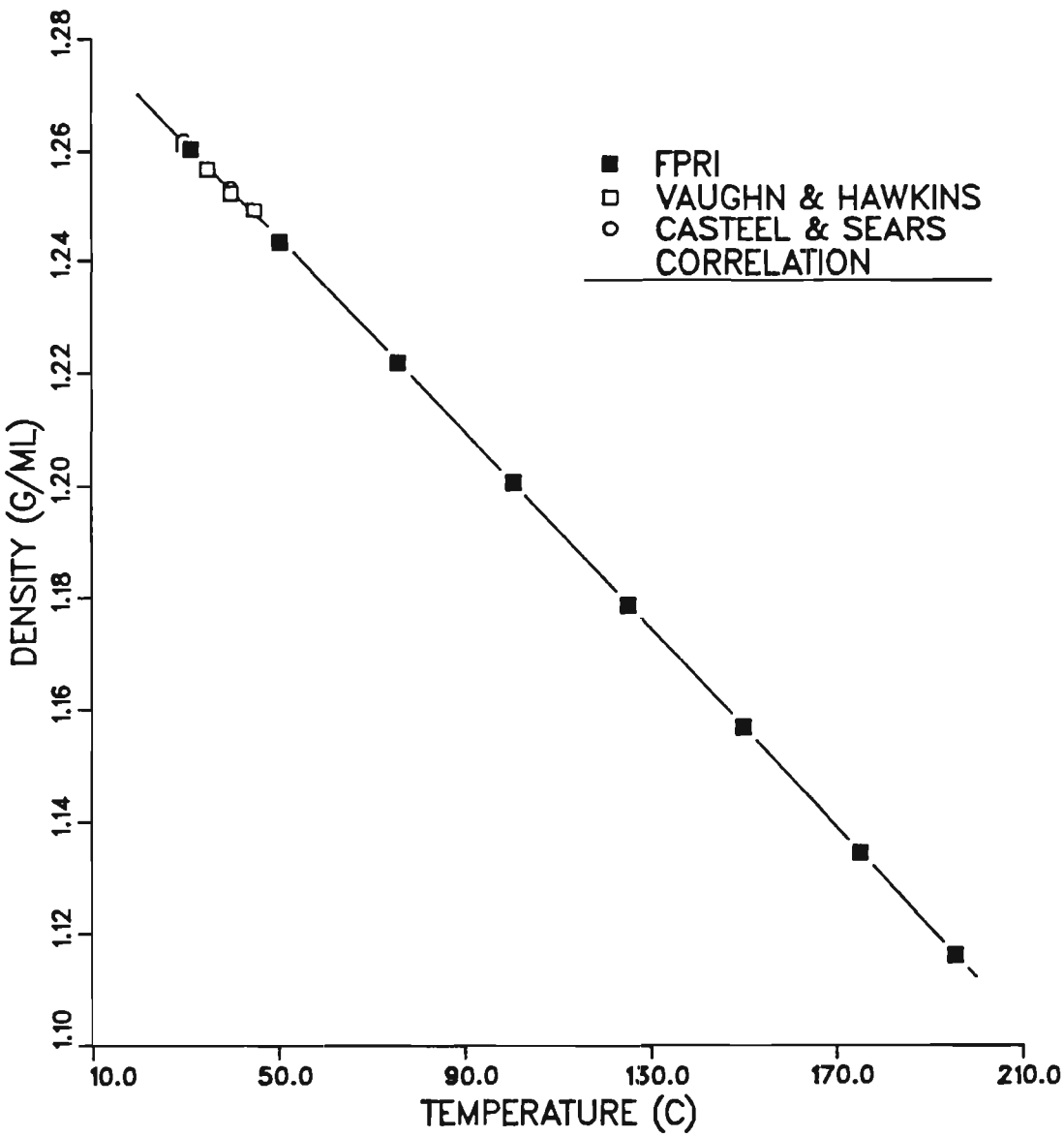
DDS-LD-A14

DENSITY OF SULFOLANE



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5. AIChE DIPPR Data Compilation Manual, T. Daubert, and R. P. Danner (Eds), 1985.
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May, 1989 DDS-LD-A15

DESIGN DATA STANDARD - LIQUID DENSITY
Diphenyl Ether
$(C_6H_5)_2O$

Purity =	99 +%	
Molecular Weight =	170.21 kg/kmol	[1]
Critical Temperature =	766.8 K	[2]
Critical Pressure =	30.4 atm	[2]
Critical Volume =	0.545 m^3/kmol	[3]
Melting Point =	300.0 K	[2]
Normal Boiling Point =	531.2 K	[2]
Liquid Molar Volume =	0.1596 m^3/kmol	[2]
Dipole Moment =	0.3870 x 10^{-29} Cm	[4]
van der Waals Volume =	0.09488 m^3/kmol	[5]
van der Waals Area =	1.120 x 10^9 m^2/kmol	[5]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = 14.7 PSI
Accuracy = ± 0.15 %

T (K)	ρ (kg/m^3)
303.5	1066.2
324.0	1049.1
348.5	1028.2
373.9	1006.4
397.4	986.0
423.3	963.5
448.8	941.4

Liquid Density Correlation:

$$\rho(kg/m^3) = 312.0 \; x \; 0.2421^{-(1-T_r)^{2/7}}$$

%AAD = 0.05 %
%MAD = 0.13 %

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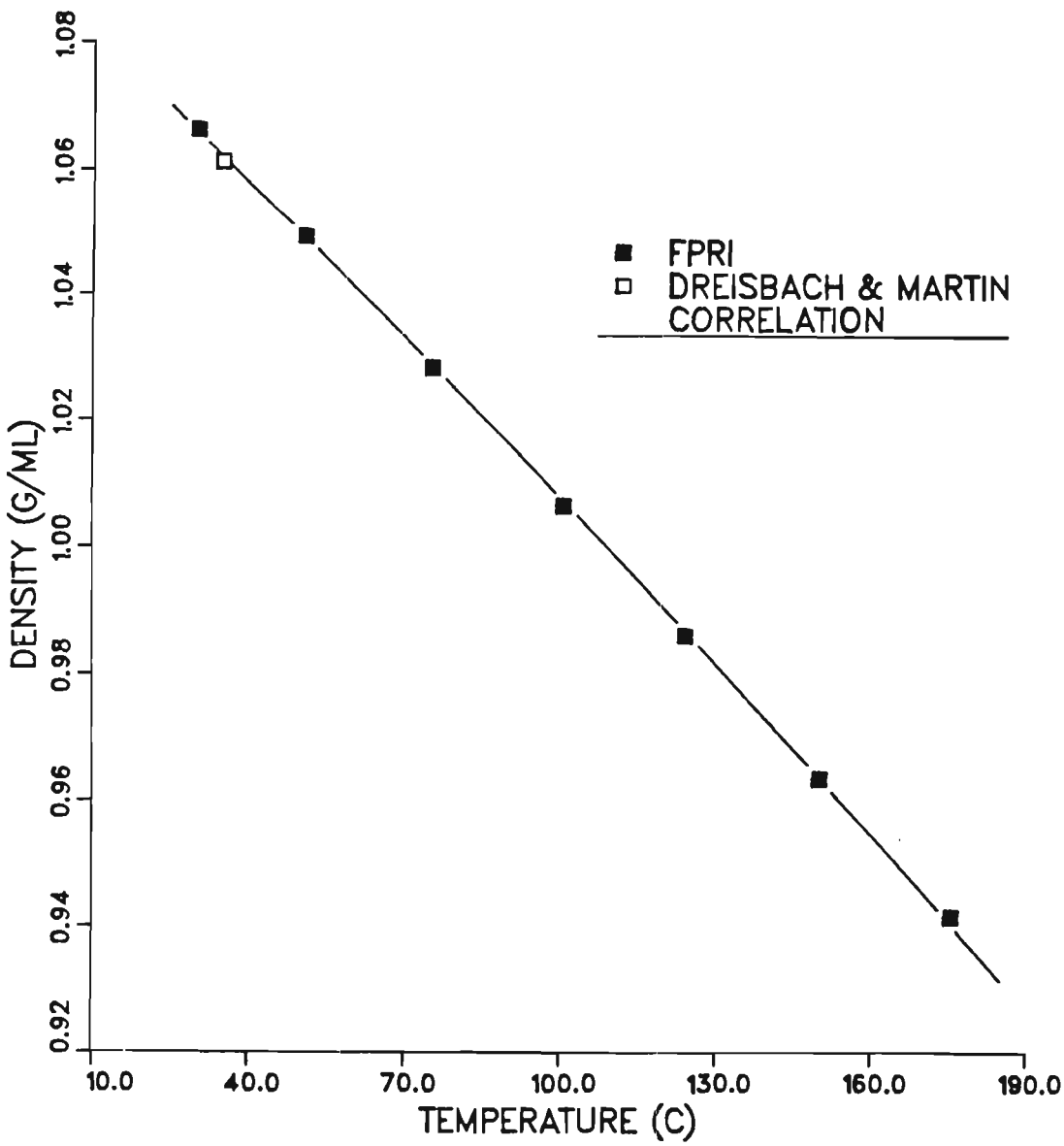
DDS-LD-A15

DENSITY OF DIPHENYL ETHER



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May, 1989 DDS-LD-A16

DESIGN DATA STANDARD - LIQUID DENSITY
N,N-Dimethylacetamine
$CH_3CON(CH_3)_2$

Purity =	99 +%	
Molecular Weight =	87.121 kg/kmol	[1]
Critical Temperature =	637 K	[2]
Critical Pressure =	38.7 atm	[2]
Melting Point =	253 K	[2]
Normal Boiling Point =	439.3 K	[2]
Liquid Molar Volume =	0.09304 m^3/kmol	[2]
Dipole Moment =	1.238 x 10^{-28} Cm	[2]
van der Waals Volume =	0.05704 m^3/kmol	[3]
van der Waals Area =	8.19 x 10^8 m^2/kmol	[3]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = 14.7 PSI
Accuracy = ± 0.15 %

T (K)	ρ (kg/m^3)
295.6	938.9
323.3	913.8
347.4	891.5
372.0	868.6
396.9	844.6
418.8	823.2
437.5	804.8

Liquid Density Correlation:

$$\rho(kg/m^3) = 317.174\ x\ 0.27381^{-(1-T_r)^{2/7}}$$

%AAD = 0.08 %
%MAD = 0.13 %

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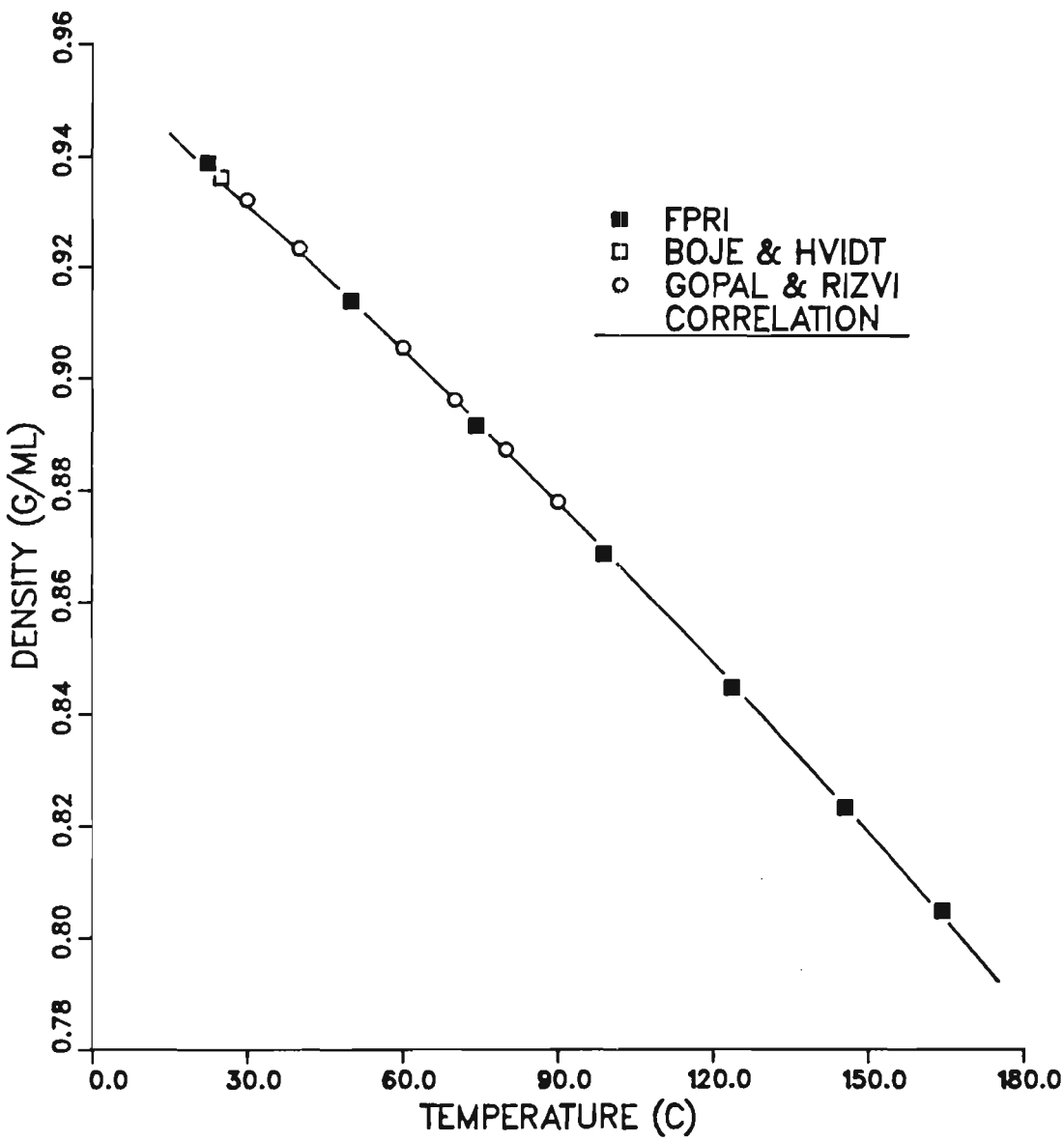
DDS-LD-A16

DENSITY OF N,N-DIMETHYLACETAMINE



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3. Bondi, A., "Physical Properties of Molecular Crystals, Liquids, and Glasses", John Wiley, N. Y., 1968.
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FPRI

May, 1989 DDS-LD-A17

DESIGN DATA STANDARD - LIQUID DENSITY
2-Ethyl-1-Hexanol
$CH_3(CH_2)_3CH(C_2H_5)CH_2OH$

Purity =	99 +%	
Molecular Weight =	130.23 kg/kmol	[1]
Critical Temperature =	640.2 K	[2]
Critical Pressure =	27.2 atm	[3]
Critical Volume =	0.494 m^3/kmol	[3]
Melting Point =	197 K	[2]
Normal Boiling Point =	457.5 K	[2]
Liquid Molar Volume =	0.15697 m^3/kmol	[4]
Dipole Moment =	0.5871 x 10^{-29} Cm	[5]
van der Waals Volume =	0.09331 m^3/kmol	[6]
van der Waals Area =	1.302 x 10^9 m^2/kmol	[6]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = 14.7 PSI
Accuracy = ± 0.15 %

T (K)	ρ (kg/m^3)
293.1	833.1
323.7	810.5
348.6	791.9
373.1	771.6
396.6	751.6
423.4	727.3
449.1	702.4

Liquid Density Correlation:

$$\rho(kg/m^3) = 953.03 - 0.13214\,T(K) - 0.94811x10^{-3}\,T(K)^2$$

%AAD = 0.02 %
%MAD = 0.05 %

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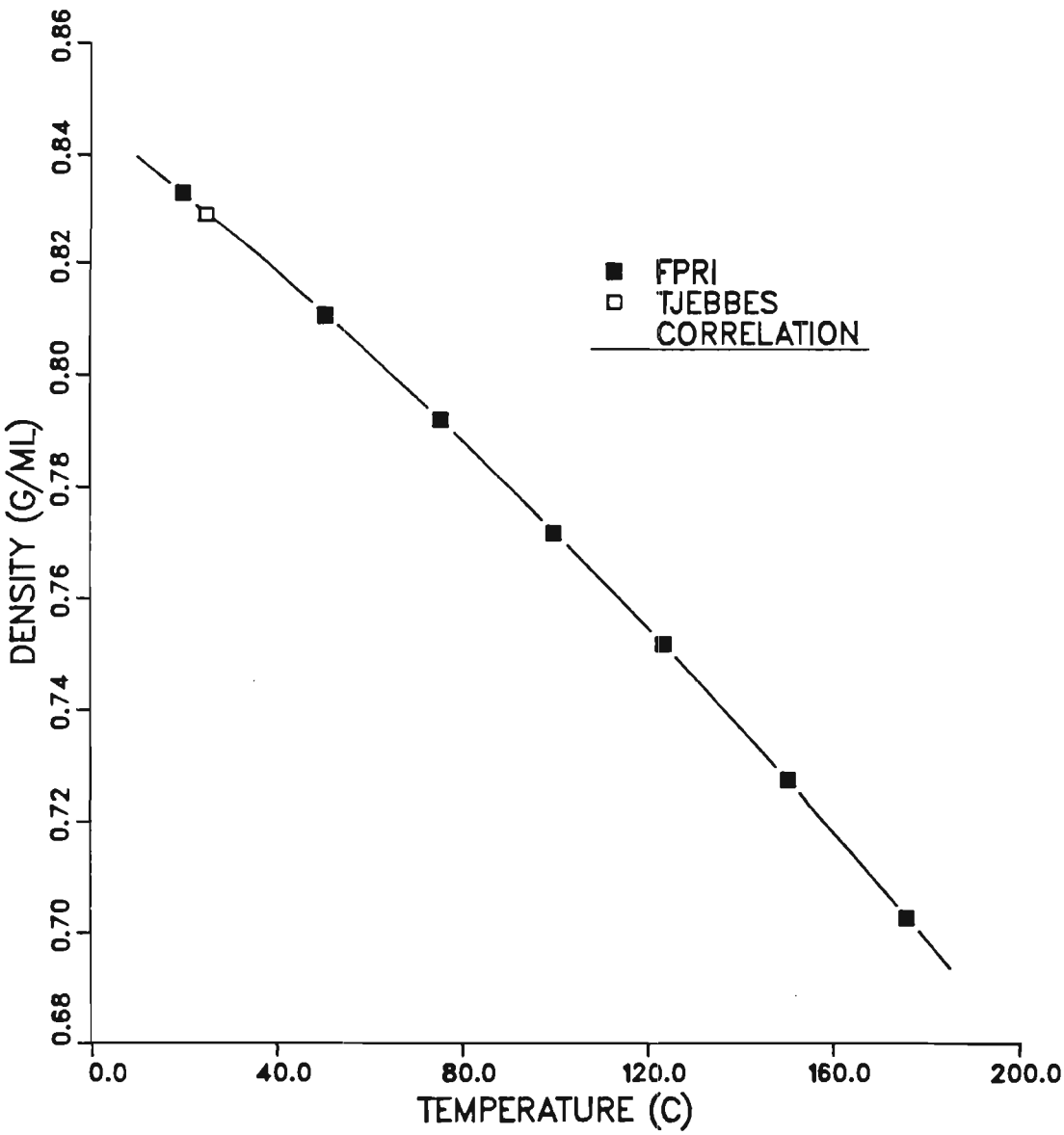
DDS-LD-A17

DENSITY OF 2-ETHYL-1-HEXANOL



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7. Tjebbes, J., Pure Appl. Chem., 2, 129 (1961).

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May, 1989 DDS-LD-A18

DESIGN DATA STANDARD - LIQUID DENSITY
North Slope Resid - Amoco

100 °F+ Properties

Carbon, wt.% =	85.46
Hydrogen, wt.% =	10.65
Sulfur, wt.% =	2.6
Vanadium, ppm by wt. =	97.
Nickel, ppm by wt. =	47.
Oil, wt.% =	23.7
Resin, wt.% =	70.1
Asphaltene, wt.% =	6.2

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = 14.7 PSI
Accuracy = ± 0.2 %

T (K)	ρ (kg/m^3)
352.9	973.9
373.4	966.0
394.2	956.3
413.6	944.7
433.4	933.6
453.9	920.5

Liquid Density Correlation:

$$\rho(kg/m^3) = 928.84 + 0.643351\,T(K) - 1.45885x10^{-3}\,T(K)^2$$

%AAD = 0.04 %
%MAD = 0.07 %

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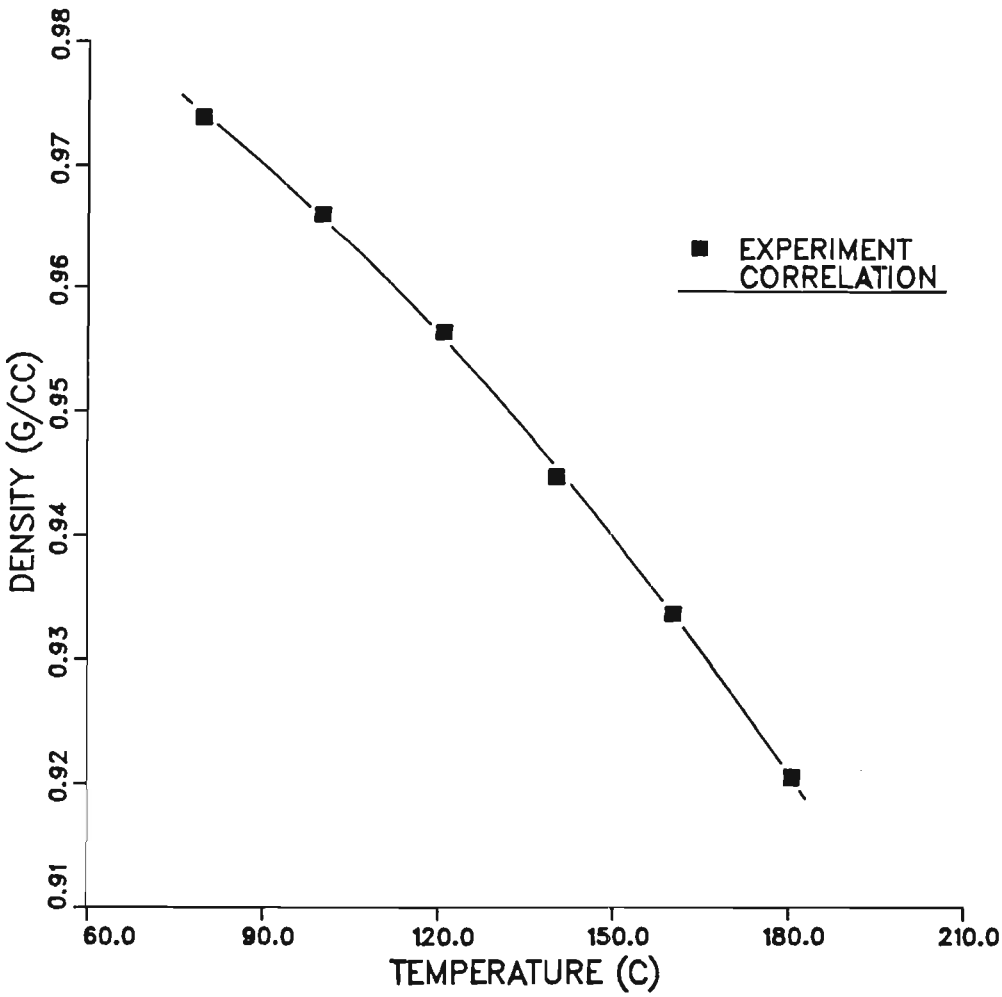
May, 1989

DDS-LD-A18

NORTH SLOPE RESID – AMOCO



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May, 1989 DDS-LD-A19

DESIGN DATA STANDARD - LIQUID DENSITY
High Sulfur Resid Blend - Amoco

100 °F+ Properties

API gravity at 60 °F, °API =	5.3
Carbon, wt.% =	84.55
Hydrogen, wt.% =	10.07
Sulfur, wt.% =	4.17
Nitrogen, wt.% =	0.55
Vanadium, ppm by wt. =	286.
Nickel, ppm by wt. =	61.
Iron, wt.% =	13.
Oil, wt.% =	26.8
Resin, wt.% =	58.0
Asphaltene, wt.% =	15.2

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = 14.7 PSI
Accuracy = ± 0.2 %

T (K)	ρ (kg/m^3)
351.4	986.0
372.1	974.2
391.2	962.6
413.8	949.3
433.7	937.1
453.6	924.9

Liquid Density Correlation:

$$\rho(kg/m^3) = 1166.5 - 0.44730\,T(K) - 0.18787x10^{-3}\,T(K)^2$$

%AAD = 0.007 %
%MAD = 0.015 %

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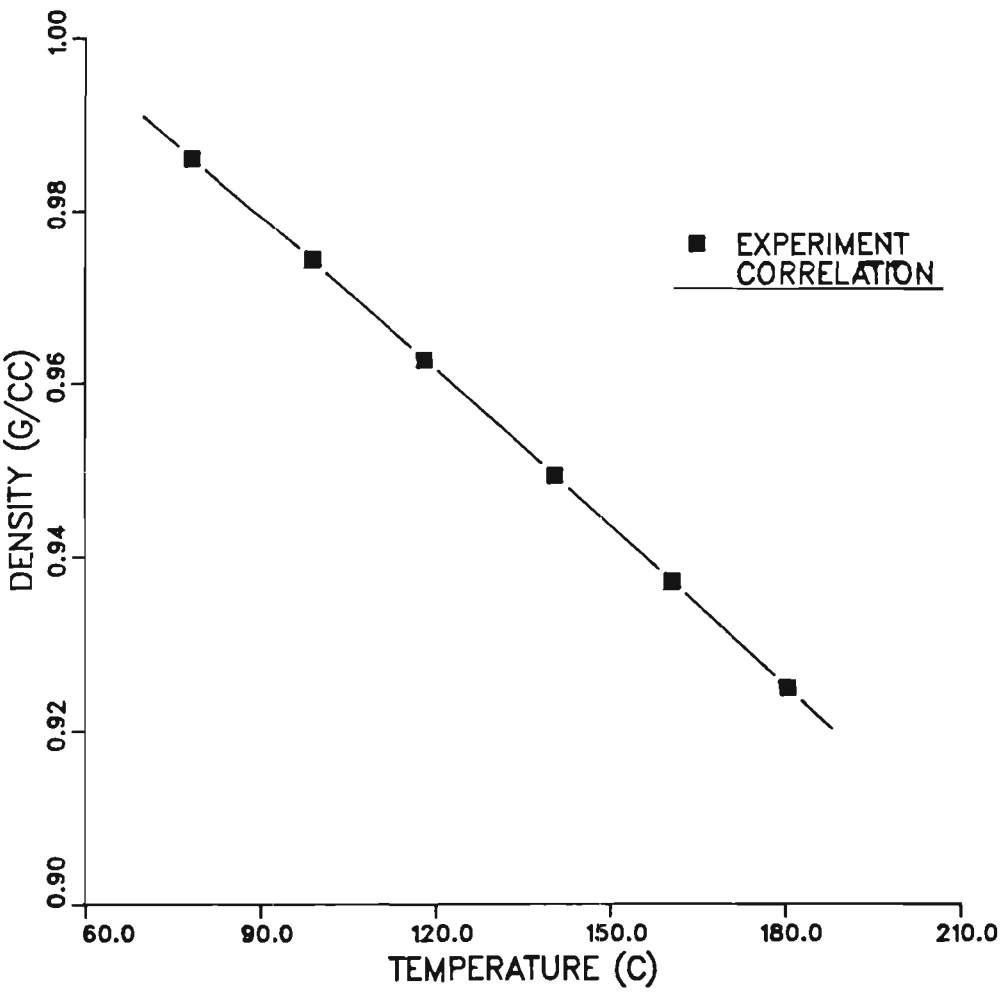
HIGH SULFUR RESID BLEND – AMOCO



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May, 1989 DDS-LD-A20

DESIGN DATA STANDARD - LIQUID DENSITY

Acetoxy Phenyl Methyl Carbinol

$(CH_3COO)(C_6H_5)C(CH_3)OH$

Purity =	99 +%	
Molecular Weight =	180.20 kg/kmol	[1]
van der Waals Volume =	0.09953 m^3/kmol	[2]
van der Waals Area =	1.323 x 10^9 m^2/kmol	[2]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = 14.7 PSI
Accuracy = ± 0.2 %

T (K)	ρ (kg/m^3)
293.2	1133.7
323.8	1107.2
352.8	1082.4
381.9	1055.9
413.3	1030.0
444.2	1004.9

Liquid Density Correlation:

$$\rho(kg/m^3) = 1417.98 - 1.04213\,T(K) + 0.25123x10^{-3}\,T(K)^2$$

%AAD = 0.04 %
%MAD = 0.07 %

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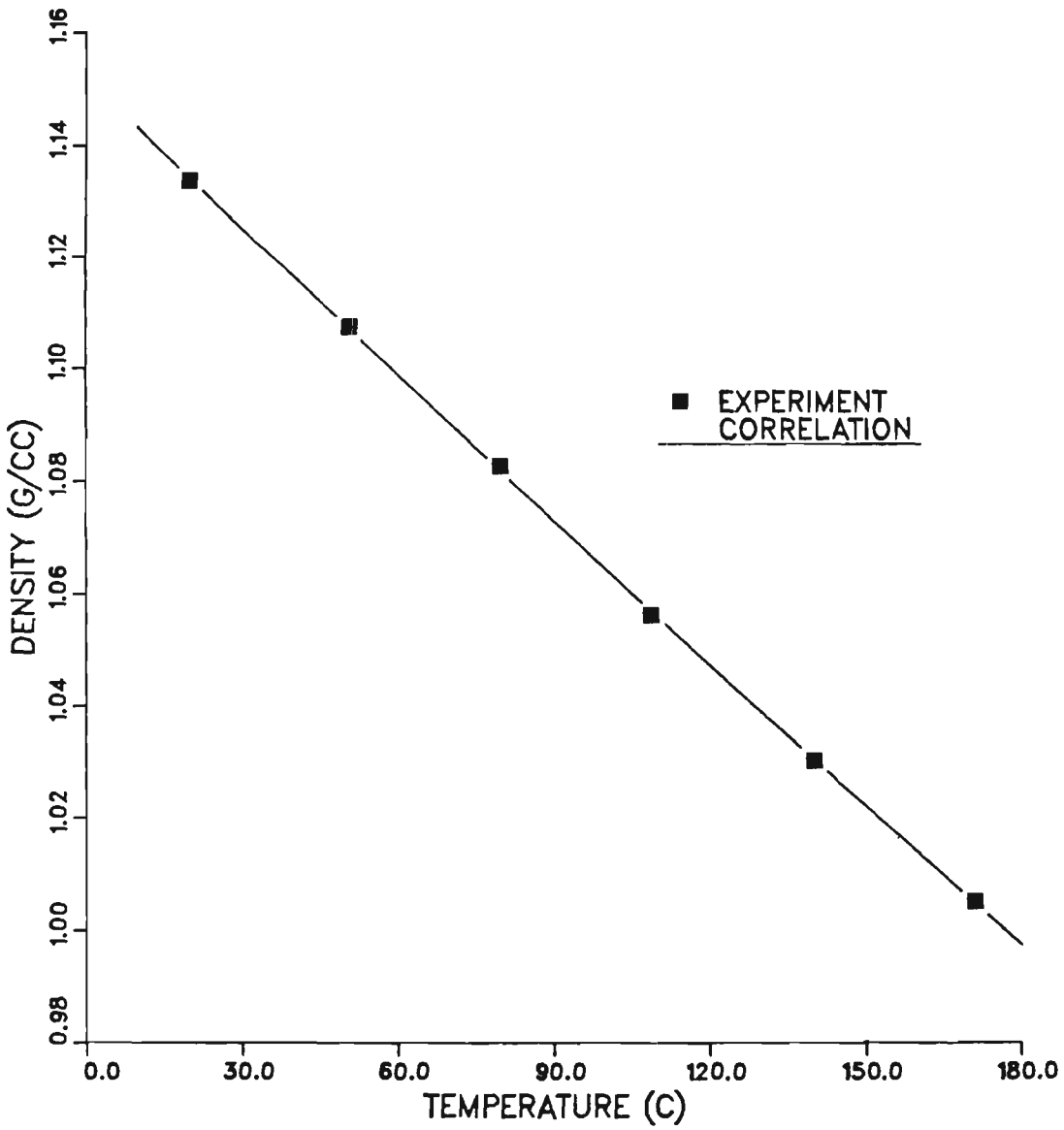
ACETOXY PHENYL METHYL CARBINOL



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May, 1989 DDS-LV-A18

DESIGN DATA STANDARD - LIQUID VISCOSITY
Diphenyl Ether
$(C_6H_5)_2O$

Purity =	99 +%	
Molecular Weight =	170.21 kg/kmol	[1]
Critical Temperature =	766.8 K	[2]
Critical Pressure =	30.4 atm	[2]
Critical Volume =	0.545 m^3/kmol	[3]
Melting Point =	300.0 K	[2]
Normal Boiling Point =	531.2 K	[2]
Liquid Molar Volume =	0.1596 m^3/kmol	[2]
Dipole Moment =	0.3870 x 10^{-29} Cm	[4]
van der Waals Volume =	0.09488 m^3/kmol	[5]
van der Waals Area =	1.120 x 10^9 m^2/kmol	[5]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = 14.7 PSI
Accuracy = ± 1.0 %

T (K)	μ (cp)
303.2	3.30
313.3	2.61
333.3	1.78
353.3	1.31
373.2	1.003
393.2	0.802
413.2	0.660
426.4	0.588

Liquid Viscosity Correlation:

$$ln\ \mu(cp) = -41.6254 + 3709.86/T(K) + 5.3504\ ln\ T(K)$$

%AAD = 0.49 %
%MAD = 0.81 %

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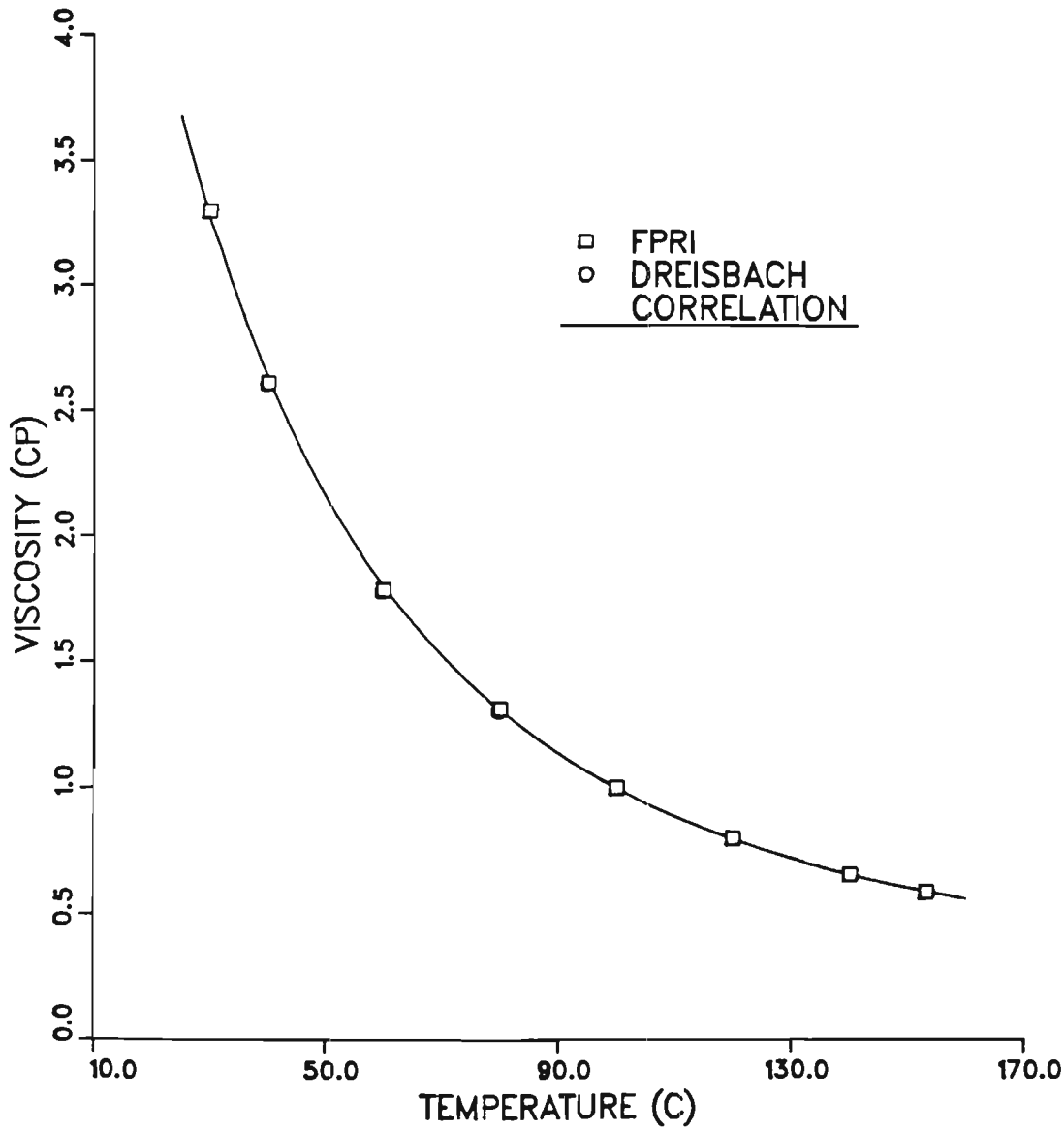
VISCOSITY OF DIPHENYL ETHER



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May, 1989 DDS-LV-A19

DESIGN DATA STANDARD - LIQUID VISCOSITY
N,N-Dimethylacetamine
$CH_3CON(CH_3)_2$

Purity =	99 +%	
Molecular Weight =	87.121 kg/kmol	[1]
Critical Temperature =	637 K	[2]
Critical Pressure =	38.7 atm	[2]
Melting Point =	253 K	[2]
Normal Boiling Point =	439.3 K	[2]
Liquid Molar Volume =	0.09304 m^3/kmol	[2]
Dipole Moment =	1.238 x 10^{-28} Cm	[2]
van der Waals Volume =	0.05704 m^3/kmol	[3]
van der Waals Area =	8.19 x 10^8 m^2/kmol	[3]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = 14.7 PSI
Accuracy = ± 1.0 %

T (K)	μ (cp)
293.3	1.002
313.3	0.764
333.3	0.609
353.3	0.502
373.4	0.412
393.3	0.351
413.3	0.303
425.4	0.279

Liquid Viscosity Correlation:

$$ln\ \mu(cp) = -4.57174 + 1228.30/T(K) + 0.067546\ ln\ T(K)$$

%AAD = 0.30 %
%MAD = 0.88 %

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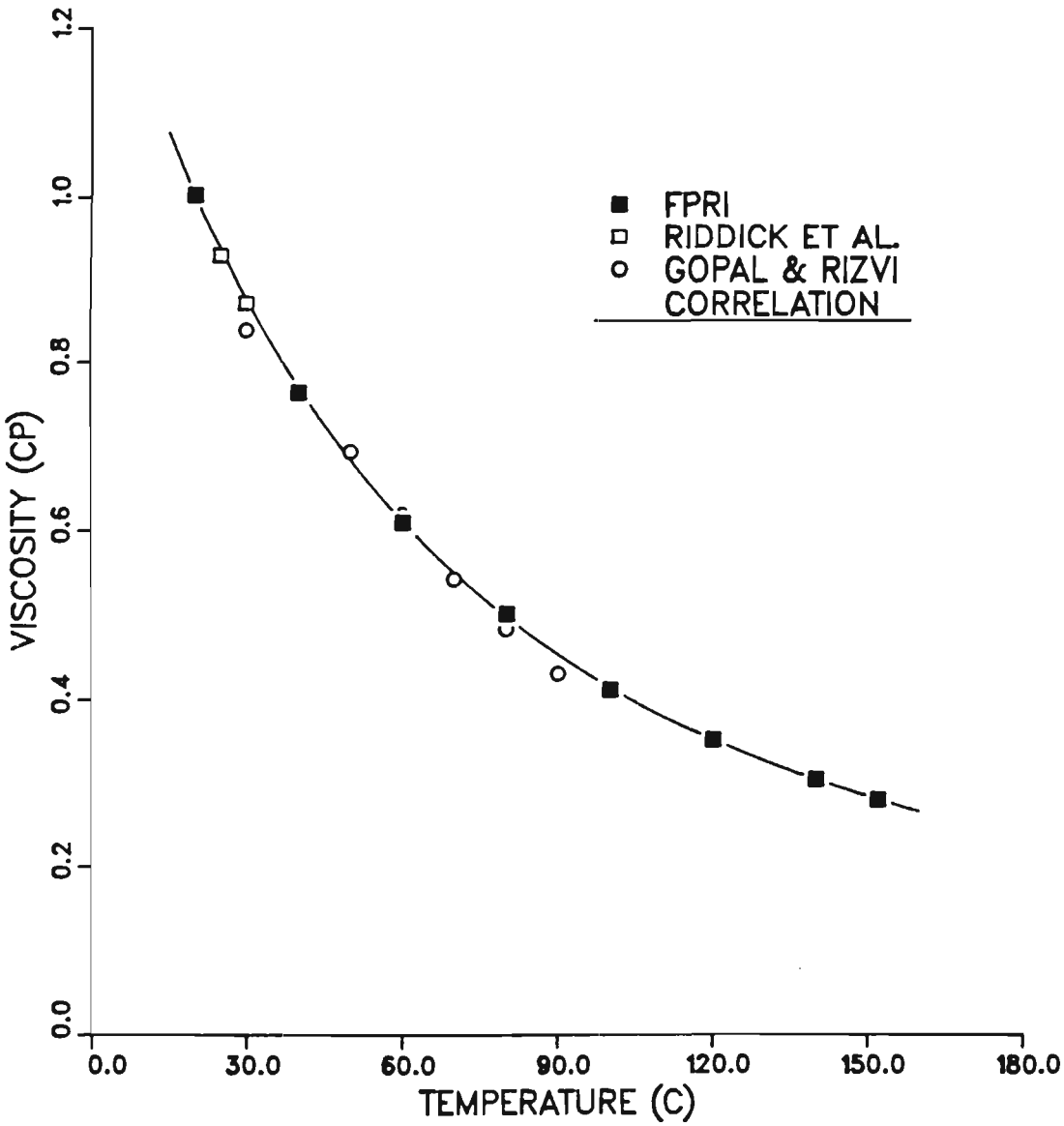
VISCOSITY OF N,N–DIMETHYLACETAMINE



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4. Gopal, R., and S. A. Rizvi, J. Indian Chem. Soc., 43, 179 (1966).

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May, 1989 DDS-LV-A20

DESIGN DATA STANDARD - LIQUID VISCOSITY
2-Ethyl-1-Hexanol
$CH_3(CH_2)_3CH(C_2H_5)CH_2OH$

Purity =	99 +%	
Molecular Weight =	130.23 kg/kmol	[1]
Critical Temperature =	640.2 K	[2]
Critical Pressure =	27.2 atm	[3]
Critical Volume =	0.494 m^3/kmol	[3]
Melting Point =	197 K	[2]
Normal Boiling Point =	457.5 K	[2]
Liquid Molar Volume =	0.15697 m^3/kmol	[4]
Dipole Moment =	0.5871 x 10^{-29} Cm	[5]
van der Waals Volume =	0.09331 m^3/kmol	[6]
van der Waals Area =	1.302 x 10^9 m^2/kmol	[6]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = 14.7 PSI
Accuracy = ± 1.0 %

T (K)	μ (cp)
293.4	9.75
313.3	4.30
333.4	2.26
353.3	1.344
373.3	0.872
393.3	0.610
413.3	0.454
425.4	0.389

Liquid Viscosity Correlation:

$$ln\ \mu(cp) = -98.4296 + 7643.36/T(K) + 13.1382\ ln\ T(K)$$

%AAD = 0.8 %
%MAD = 1.6 %

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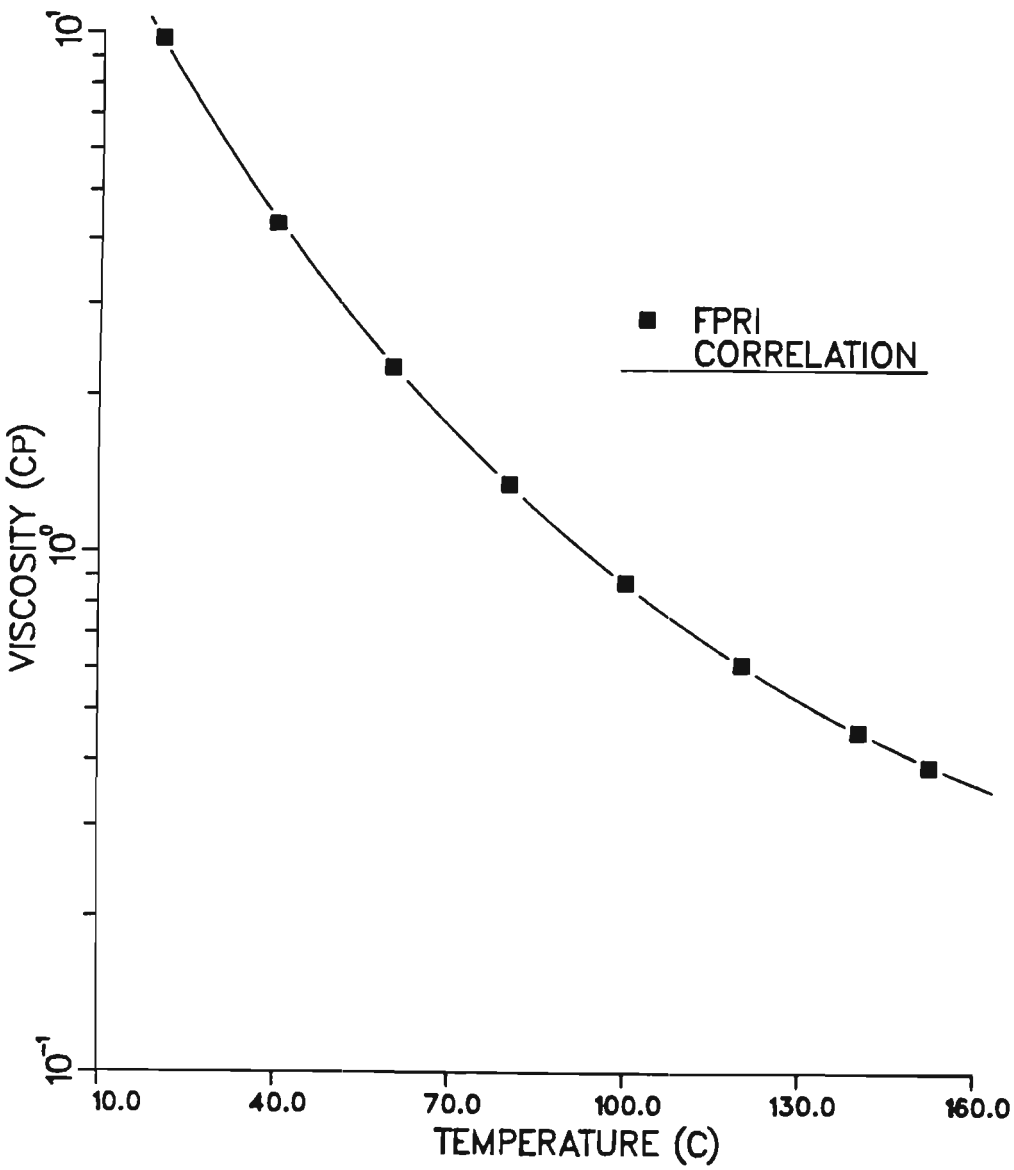
VISCOSITY OF 2-ETHYL-1-HEXANOL



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DESIGN DATA STANDARD - LIQUID VISCOSITY
North Slope Resid - Amoco

100 °F+ Properties

Carbon, wt.% =	85.46
Hydrogen, wt.% =	10.65
Sulfur, wt.% =	2.6
Vanadium, ppm by wt. =	97.
Nickel, ppm by wt. =	47.
Oil, wt.% =	23.7
Resin, wt.% =	70.1
Asphaltene, wt.% =	6.2

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = 14.7 PSI
Accuracy = ± 1.0 %

T (K)	μ (cp)
373.2	3123.
383.2	1531.
393.1	866.9
403.0	502.2
413.3	302.7
428.5	161.2

Liquid Viscosity Correlation:

$$ln\ \mu(cp) = -519.74 + 37390.6/T(K) + 72.2059\ ln\ T(K)$$

%AAD = 1.9 %
%MAD = 2.9 %

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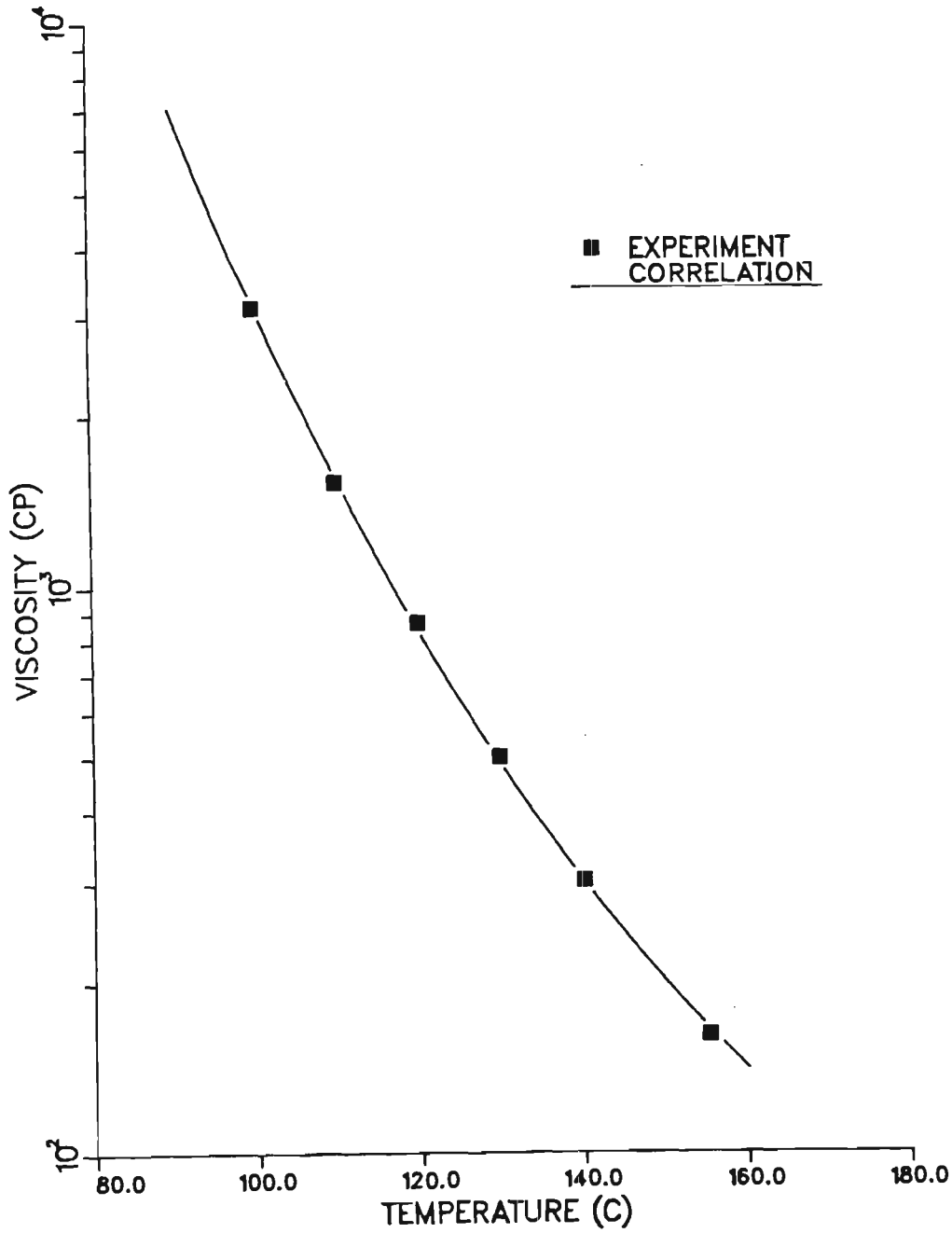
NORTH SLOPE RESID – AMOCO



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DESIGN DATA STANDARD - LIQUID VISCOSITY
High Sulfur Resid Blend - Amoco

100 °F+ Properties

API gravity at 60 °F, °API =	5.3
Carbon, wt.% =	84.55
Hydrogen, wt.% =	10.07
Sulfur, wt.% =	4.17
Nitrogen, wt.% =	0.55
Vanadium, ppm by wt. =	286.
Nickel, ppm by wt. =	61.
Iron, wt.% =	13.
Oil, wt.% =	26.8
Resin, wt.% =	58.0
Asphaltene, wt.% =	15.2

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = 14.7 PSI
Accuracy = ± 1.0 %

T (K)	μ (cp)
373.1	1901.
383.1	974.8
393.2	532.1
402.9	329.7
413.4	210.7
428.1	119.8

Liquid Viscosity Correlation:

$$ln\ \mu(cp) = -519.49 + 36879.3/T(K) + 72.3082\ ln\ T(K)$$

%AAD = 0.9 %
%MAD = 1.9 %

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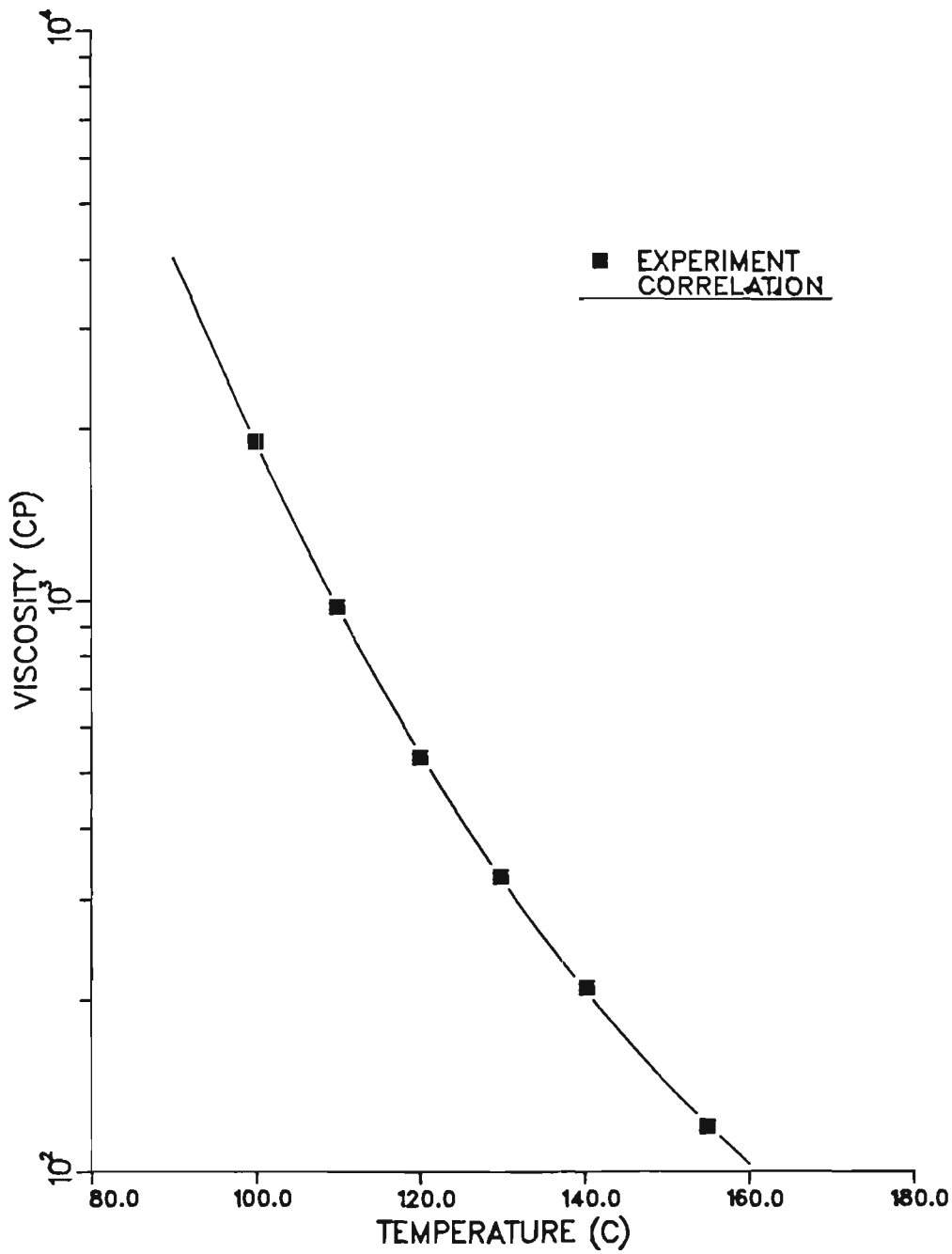
HIGH SULFUR RESID BLEND – AMOCO



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DESIGN DATA STANDARD - LIQUID DENSITY
Acetoxy Phenyl Methyl Carbinol
$(CH_3COO)(C_6H_5)C(CH_3)OH$

Purity =	99 +%	
Molecular Weight =	180.20 kg/kmol	[1]
van der Waals Volume =	0.09953 m^3/kmol	[2]
van der Waals Area =	1.323 x 10^9 m^2/kmol	[2]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = 14.7 PSI
Accuracy = ± 1.0 %

T (K)	μ (cp)
296.6	213.4
304.3	108.3
313.5	50.5
323.5	26.7
333.5	15.7
353.5	6.97
373.3	3.87
393.1	2.45
413.2	1.76
428.4	1.42

Liquid Viscosity Correlation:

$$ln\ \mu(cp) = -2.48689 + 577.74/(T(K) - 223.29)$$

%AAD = 1.5 %
%MAD = 4.0 %

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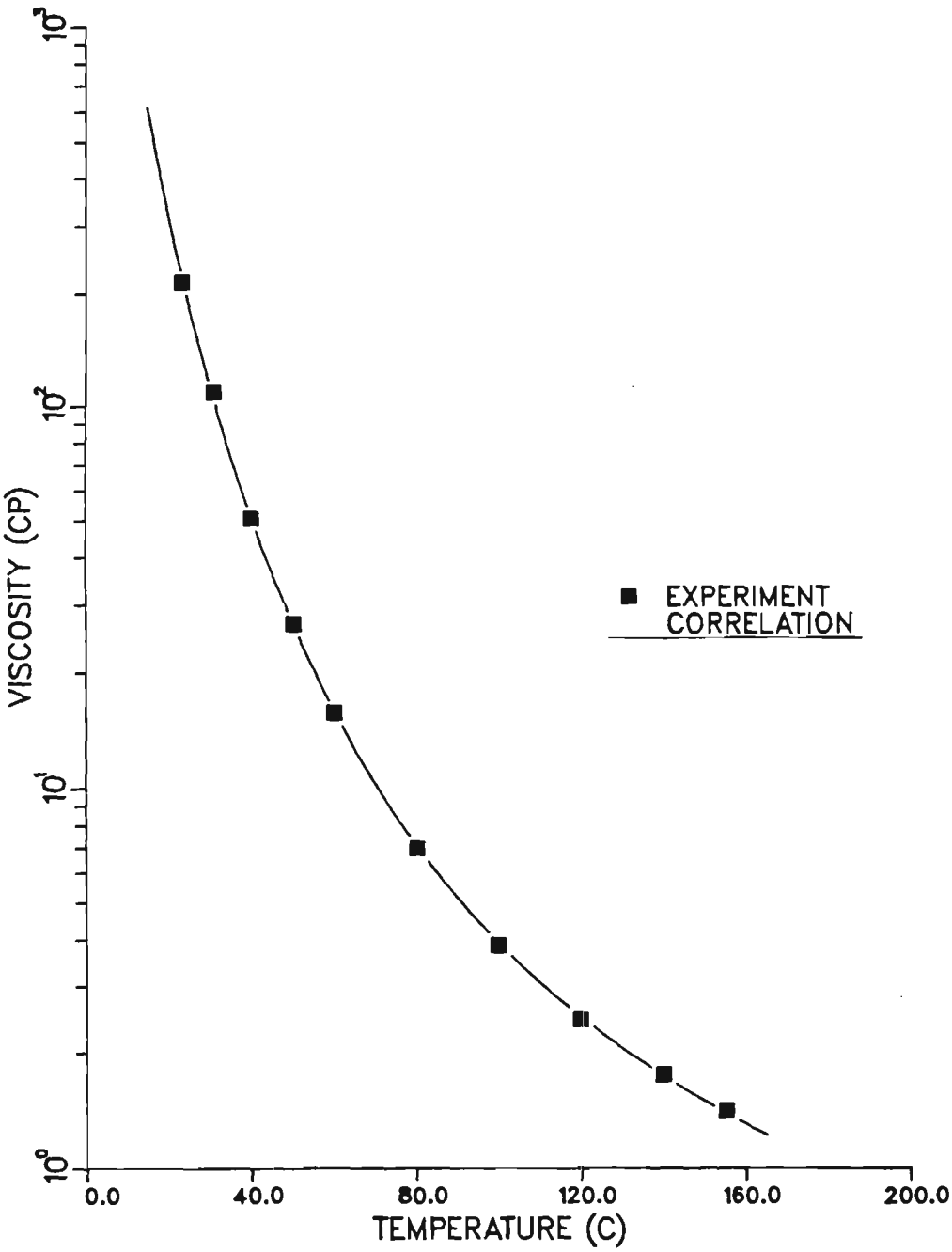
ACETOXY PHENYL METHYL CARBINOL



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2. Bondi, A. "Physical Properties of Molecular Crystals, Liquids, and Glasses", John Wiley, N. Y., 1968.

June 15, 1990

Mr. J. David Chase
President, FPRI
Hoechst- Celanese Corporation
Technical Center
P. O. Box 9077
Corpus Christi, TX 78408

Dear Dave:

Please find enclosed Design Data Sheets DDS-LTC-36 thru 46, DDS-LD-21 thru 32 and DDS-LV-24 thru 32 representing the results of FPRI sponsored measurements for the year July 1, 1989 to June 30,1990. I would like to take this opportunity to thank the FPRI members for sponsoring this work.

With best wishes,

Amyn S. Teja
Regents Professor

;

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April, 1990 DDS-LD-A21

DESIGN DATA STANDARD - LIQUID DENSITY
Dimethyl Ethanolamine
$(C_2H_5O)N(CH_3)_2$

Purity =	99 %	
Molecular Weight =	89.13 kg/kmol	[1]
Critical Temperature =	585.1 K	[2]
Critical Pressure =	41.8 atm	[3]
Critical Volume =	0.305 m^3/kmol	[3]
Melting Point =	214.2 K	[4]
Normal Boiling Point =	407.2 K	[4]
Liquid Molar Volume =	0.1008 m^3/kmol	[5]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (kg/m^3)
299.4	883.7
308.3	874.4
323.7	861.3
337.7	848.9
352.2	835.6
367.0	821.3
382.9	806.6
397.5	791.6

Liquid Density Correlation:

$$\rho(kg/m^3) = 1088.09 - 0.50208\,T(K) - 0.61169x10^{-3}\,T(K)^2$$

%AAD = 0.04 %
%MAD = 0.09 %

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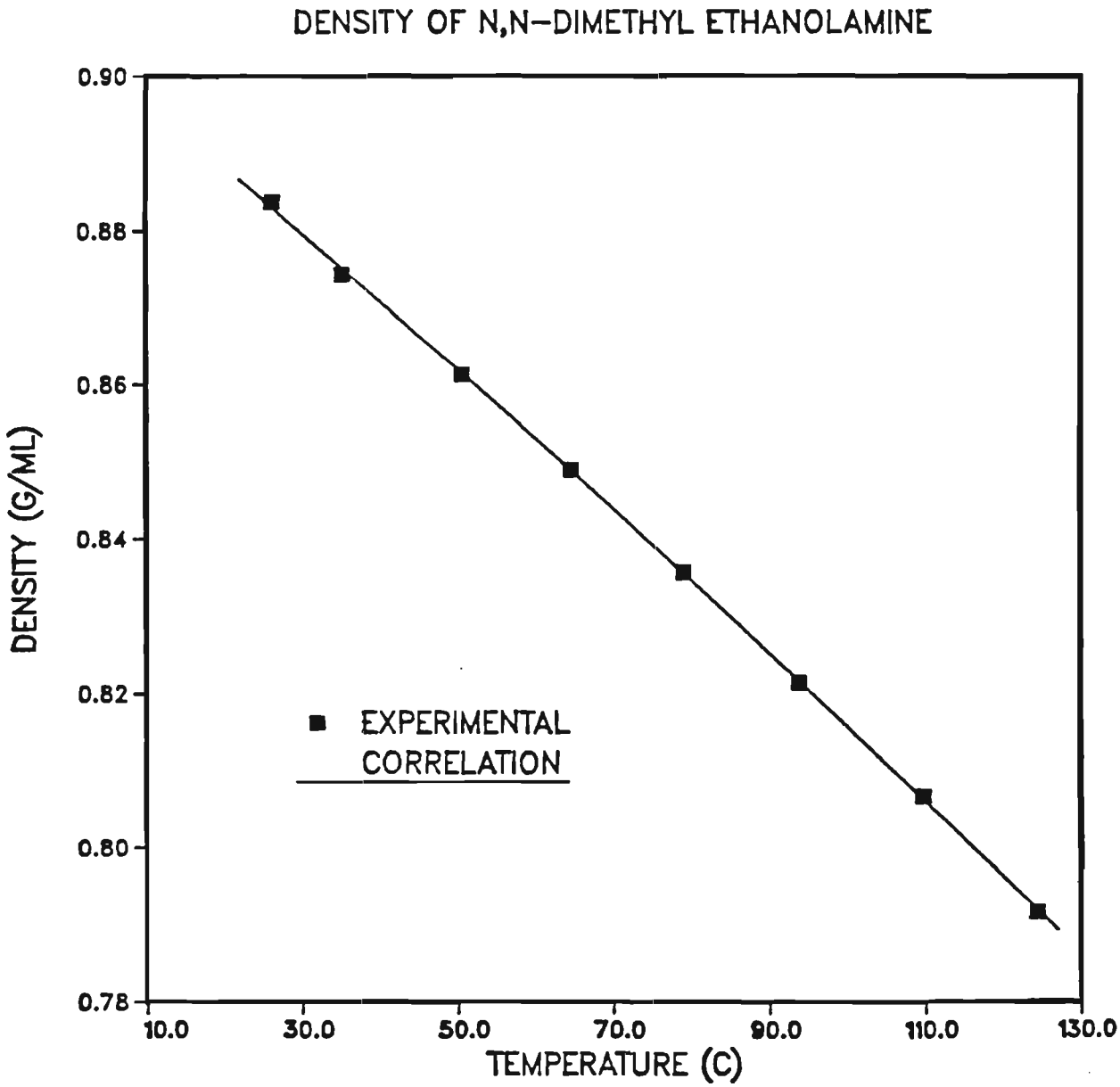
DDS-LD-A21



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3. Ambrose, D.,"Correlation and Estimation of Vapor-Liquid Critical Properties, II. Critical Pressures and Critical Volumes of Organic Compounds", NPL Report 98, 1979.
4. Weast, R. C.; Grasselli, J. G., "CRC Handbook of Data on Organic Compounds", 2nd Edition, CRC Press, 1985.
5. Estimated from density correlation reported in this data sheet.

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April, 1990 DDS-LD-A22

DESIGN DATA STANDARD - LIQUID DENSITY
Diethyl Ethanolamine
$(C_2H_5O)N(C_2H_5)_2$

Purity =	99 %	
Molecular Weight =	117.19 kg/kmol	[1]
Critical Temperature =	614.2 K	[2]
Critical Pressure =	32.6 atm	[3]
Critical Volume =	0.416 m^3/kmol	[3]
Normal Boiling Point =	436.2 K	[4]
Liquid Molar Volume =	0.13326 m^3/kmol	[5]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (kg/m^3)
296.0	880.9
313.1	866.7
332.9	848.0
353.7	829.0
372.3	809.8
392.0	790.4
413.4	768.7

Liquid Density Correlation:

$$\rho(kg/m^3) = 1071.4 - 0.41388\,T(K) - 0.77194x10^{-3}\,T(K)^2$$

%AAD = 0.04 %
%MAD = 0.07 %

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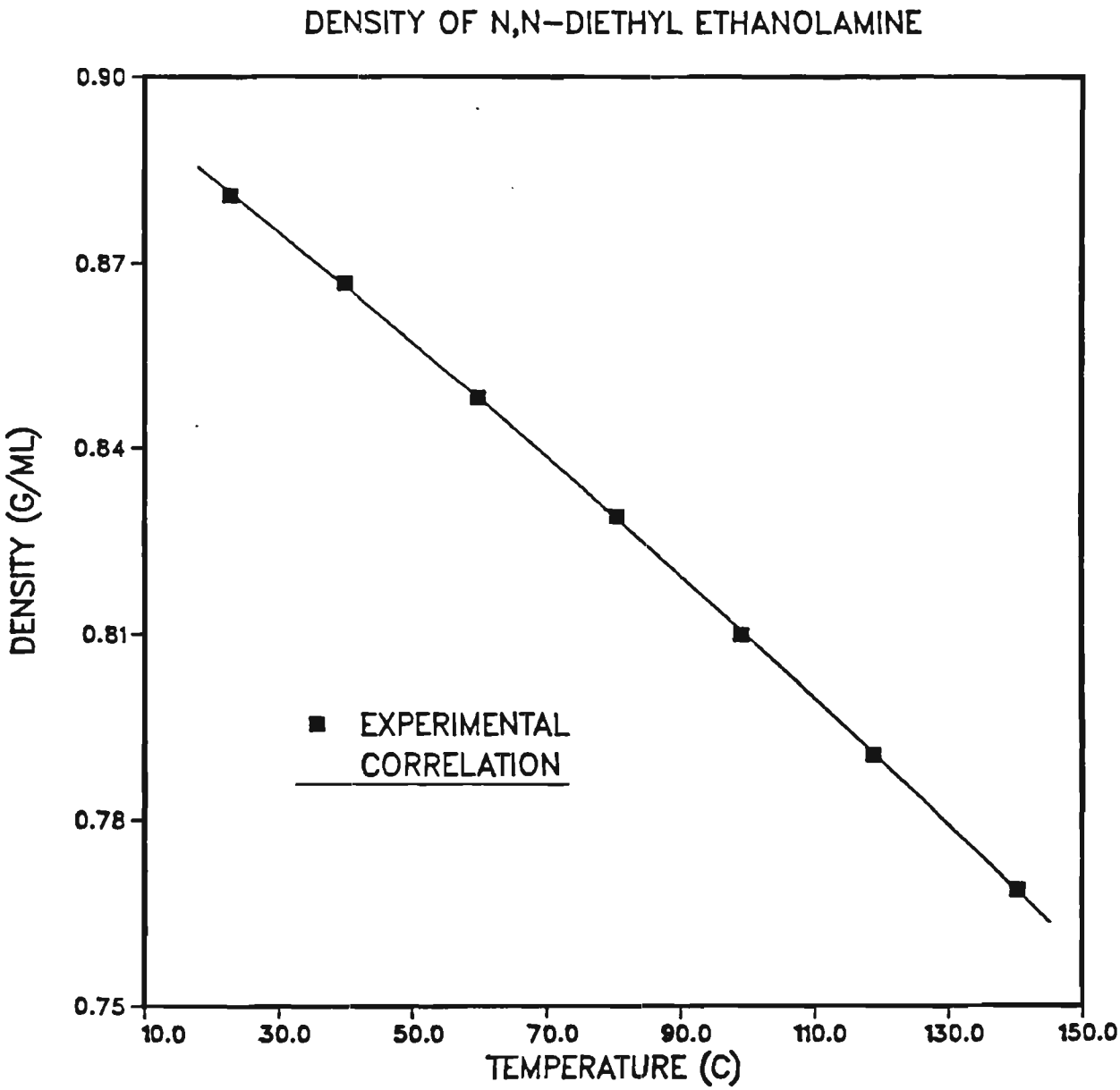
DDS-LD-A22



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2. Ambrose, D.,"Correlation and Estimation of Vapor-Liquid Critical Properties, I. Critical Temperatures of Organic Compounds", NPL Report 92, 1979.
3. Ambrose, D.,"Correlation and Estimation of Vapor-Liquid Critical Properties, II. Critical Pressures and Critical Volumes of Organic Compounds", NPL Report 98, 1979.
4. Weast, R. C.; Grasselli, J. G., "CRC Handbook of Data on Organic Compounds", 2nd Edition, CRC Press, 1985.
5. Estimated from density correlation reported in this data sheet.

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DESIGN DATA STANDARD - LIQUID DENSITY

Methyl Diethanolamine

$(C_2H_5O)_2NCH_3$

Purity =	99 %	
Molecular Weight =	119.16 kg/kmol	[1]
Critical Temperature =	680.0 K	[2]
Critical Pressure =	42.9 atm	[2]
Critical Volume =	0.372 m^3/kmol	[2]
Melting Point =	252.2 K	[3]
Normal Boiling Point =	520.2 K	[3]
Liquid Molar Volume =	0.11507 m^3/kmol	[4]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (kg/m^3)
296.3	1037.1
327.4	1014.3
346.3	999.6
373.5	978.4
397.6	959.3
422.4	939.1
445.8	920.5
470.9	896.6

Liquid Density Correlation:

$$\rho(kg/m^3) = 1207.0 - 0.43265\,T(K) - 0.47755x10^{-3}\,T(K)^2$$

%AAD = 0.05 %
%MAD = 0.14 %

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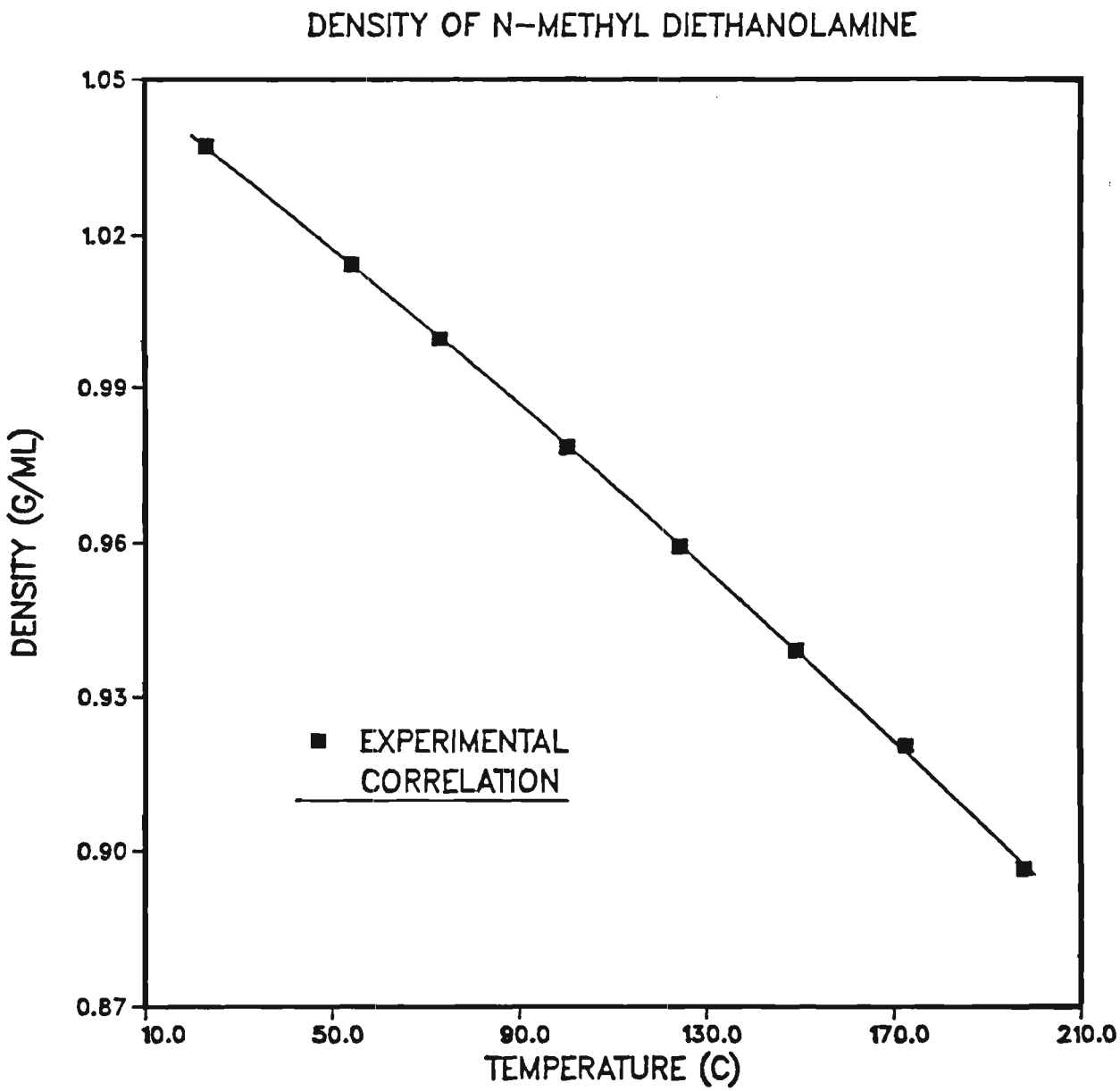

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3. Weast, R. C.; Grasselli, J. G., "CRC Handbook of Data on Organic Compounds", 2nd Edition, CRC Press, 1985.
4. Estimated from density correlation reported in this data sheet.

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April, 1990 DDS-LD-A24

DESIGN DATA STANDARD - LIQUID DENSITY

Ethyl Diethanolamine

$(C_2H_5O)_2NC_2H_5$

Purity =	99 %	
Molecular Weight =	133.18 kg/kmol	[1]
Critical Temperature =	672.8 K	[2]
Critical Pressure =	38.0 atm	[2]
Critical Volume =	0.428 m^3/kmol	[2]
Melting Point =	223.2 K	[3]
Normal Boiling Point =	520.2 K	[4]
Liquid Molar Volume =	0.13182 m^3/kmol	[5]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (kg/m^3)
294.2	1013.3
322.5	992.1
346.6	972.7
371.3	953.2
395.1	934.0
421.4	912.8
445.4	892.4
472.1	869.5

Liquid Density Correlation:

$$\rho(kg/m^3) = 1209.4 - 0.57829\,T(K) - 0.29971x10^{-3}\,T(K)^2$$

%AAD = 0.02 %
%MAD = 0.04 %

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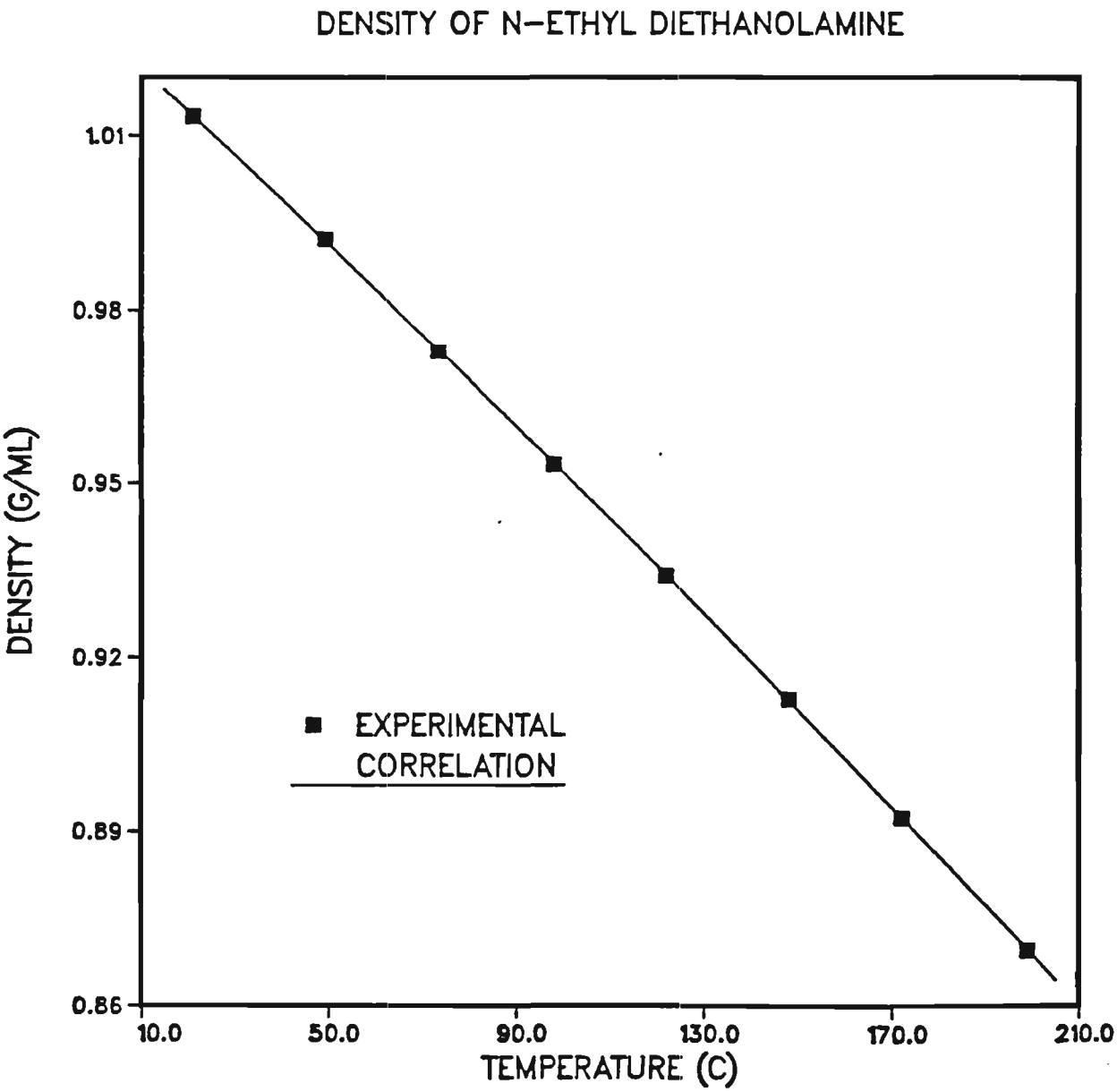

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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).
2. Joback, K. G., M.S. Thesis, Mass. Inst. of Tech., Cambridge, Mass., June, 1984.
3. "Catalog - Handbook of Fine Chemicals", Aldrich Chem. Co., 1989.
4. Weast, R. C.; Grasselli, J. G., "CRC Handbook of Data on Organic Compounds", 2nd Edition, CRC Press, 1985.
5. Estimated from density correlation reported in this data sheet.

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April, 1990 DDS-LD-A25

DESIGN DATA STANDARD - LIQUID DENSITY
2-Butanone
C_4H_8O

Purity =	99+ %	
Molecular Weight =	72.107 kg/kmol	[1]
Critical Temperature =	536.78 K	[2]
Critical Pressure =	41.52 atm	[3]
Critical Volume =	0.267 m^3/kmol	[3]
Melting Point =	186.46 K	[4]
Normal Boiling Point =	352.74 K	[4]
Liquid Molar Volume =	0.090066 m^3/kmol	[5]
Dipole Moment =	9.2064 x 10^{-30} C-m	[6]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (kg/m^3)
291.8	807.3
299.1	799.8
305.3	793.1
313.8	783.5
323.7	773.2
333.5	763.0
342.9	752.3

Liquid Density Correlation:

$$\rho(kg/m^3) = 270.0\ x\ 0.25403^{-(1-T(K)/536.78)^{2/7}}$$

%AAD = 0.03 %
%MAD = 0.08 %

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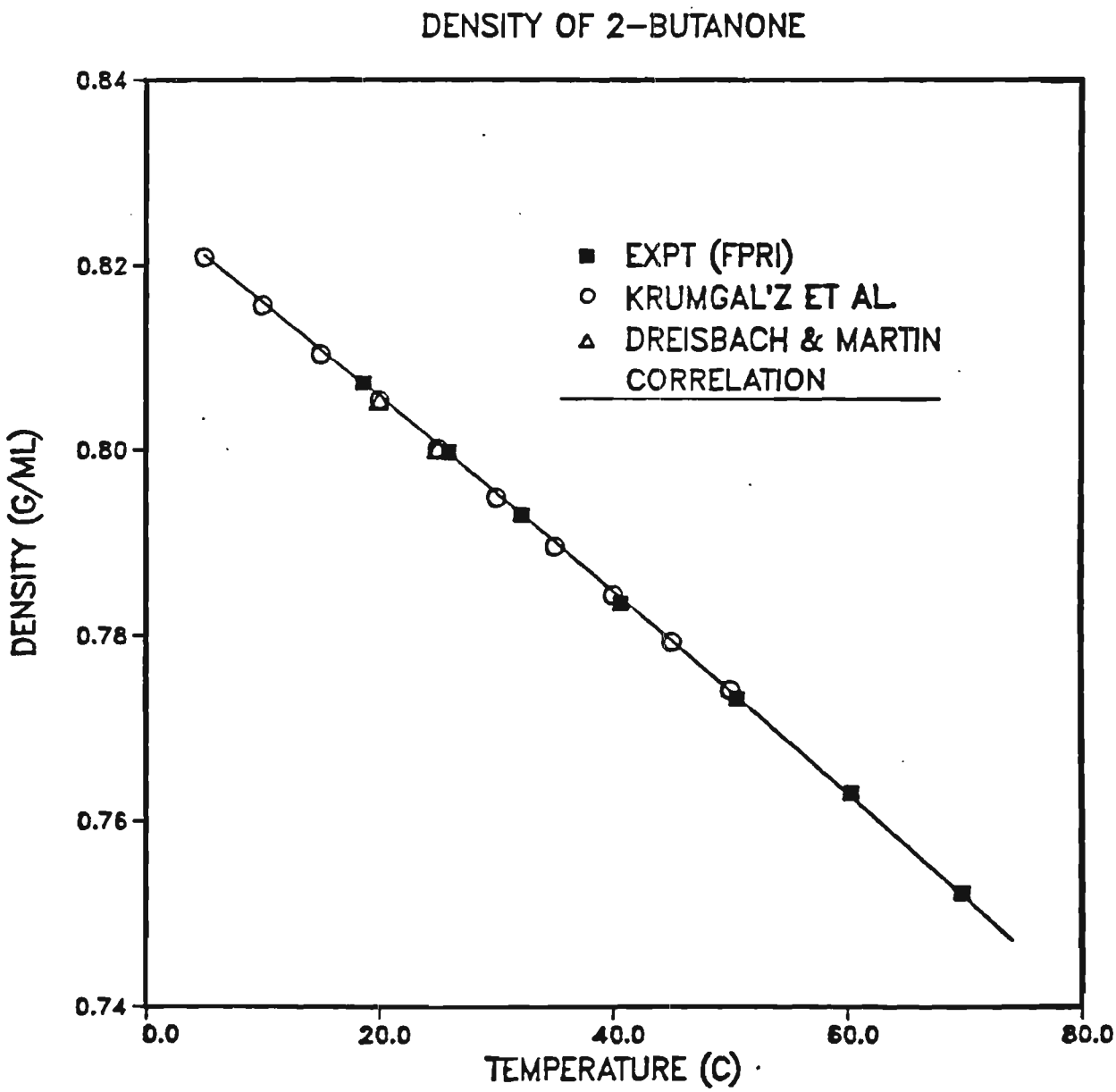

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4. Riddick, J. A.; Bunger, W. B.; Sakano, T. E., "Organic Solvents - Physical Proeprties and Methods of Purification", Wiley Interscience, N. Y., 1986.
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April, 1990 DDS-LD-A26

DESIGN DATA STANDARD - LIQUID DENSITY
Tripropylene Glycol Methyl Ether
$CH_3(OC_3H_6)_3OH$

Purity =	99 %	
Molecular Weight =	206.29 kg/kmol	[1]
Critical Temperature =	740.0 K	[2]
Critical Pressure =	21.6 atm	[3]
Critical Volume =	0.663 m^3/kmol	[4]
Liquid Molar Volume =	0.21298 m^3/kmol	[5]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (kg/m^3)
290.8	974.8
313.8	955.2
333.5	937.6
354.1	919.6
373.6	901.5
392.4	884.5
412.8	864.9

Liquid Density Correlation:

$$\rho(kg/m^3) = 1184.8 - 0.59666\,T(K) - 0.43107x10^{-3}\,T(K)^2$$

%AAD = 0.02 %
%MAD = 0.03 %

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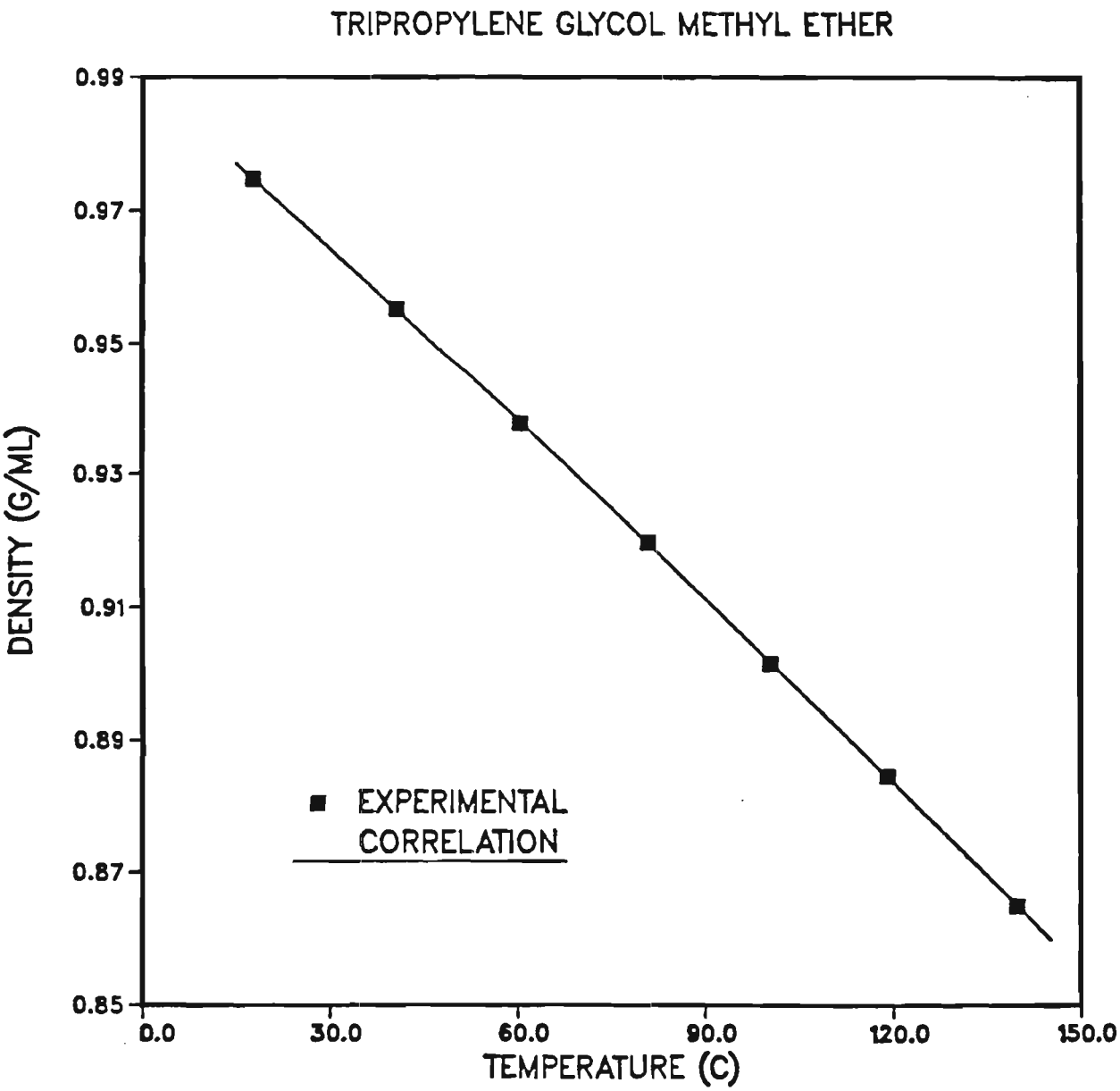

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2. Fedors, R. F., "A Relationship Between Chemical Structure and the Critical Temperature", Chem. Eng. Commun., 16, 149 (1982).
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4. Vetere, A. O., "Methods for the Estimation of Critical Volumes", Chem. Eng. J., 34, 151 (1987).
5. Estimated from density correlation reported in this data sheet.

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April, 1990 DDS-LD-A27

DESIGN DATA STANDARD - LIQUID DENSITY

2-(Isopropyl)-5-methyl Cyclohexanol; (-)-Menthol

$C_{10}H_{20}O$

Purity =	99 %	
Molecular Weight =	156.26 kg/kmol	[1]
Critical Temperature =	694.1 K	[2]
Critical Pressure =	28.5 atm	[2]
Critical Volume =	0.559 m^3/kmol	[2]
Melting Point =	229.2 K	[3]
Normal Boiling Point =	489.6 K	[3]
Liquid Molar Volume =	0.17469 m^3/kmol	[4]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (kg/m^3)
322.7	876.5
338.1	864.5
353.4	852.5
372.6	836.9
393.2	820.2
412.4	803.7
433.5	784.9

Liquid Density Correlation:

$$\rho(kg/m^3) = 1053.8 - 0.34527\,T(K) - 0.63387x10^{-3}\,T(K)^2$$

%AAD = 0.01 %
%MAD = 0.03 %

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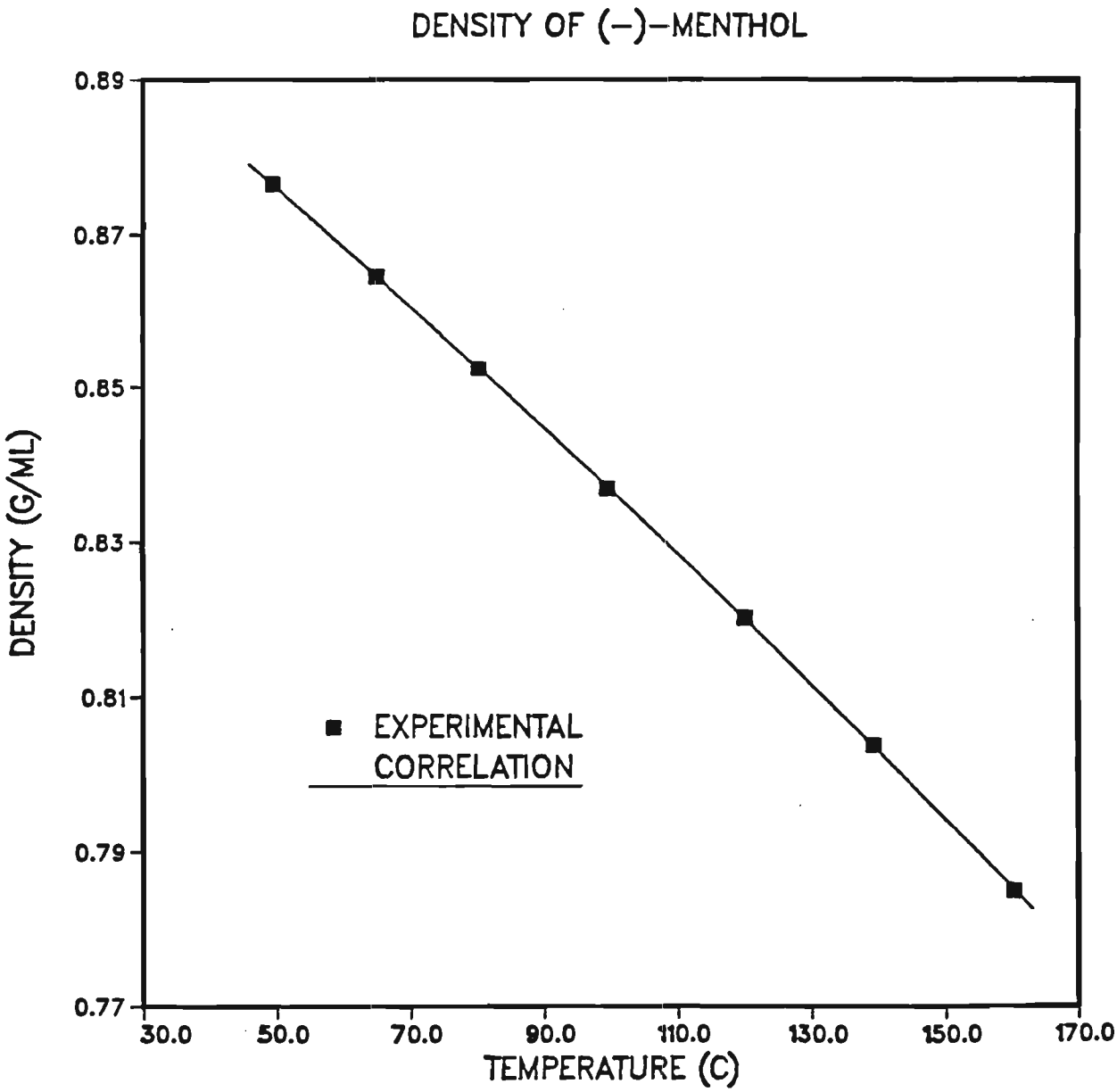
April, 1990

DDS-LD-A27



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3. Weast, R. C.; Grasselli, J. G., "CRC Handbook of Data on Organic Compounds", 2nd Ed., CRC Press, 1985.
4. Estimated from density correlation reported in this data sheet.

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April, 1990 DDS-LD-A28

DESIGN DATA STANDARD - LIQUID DENSITY
38 USP White Oil - Amoco

*** No physical properties are available ***

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (kg/m^3)
295.3	868.3
313.9	857.6
333.5	846.1
353.8	832.5
373.9	820.0
398.6	805.3
424.1	789.8
447.4	775.4

Liquid Density Correlation:

$$\rho(kg/m^3) = 1049.97 - 0.61370\,T(K)$$

%AAD = 0.04 %
%MAD = 0.09 %

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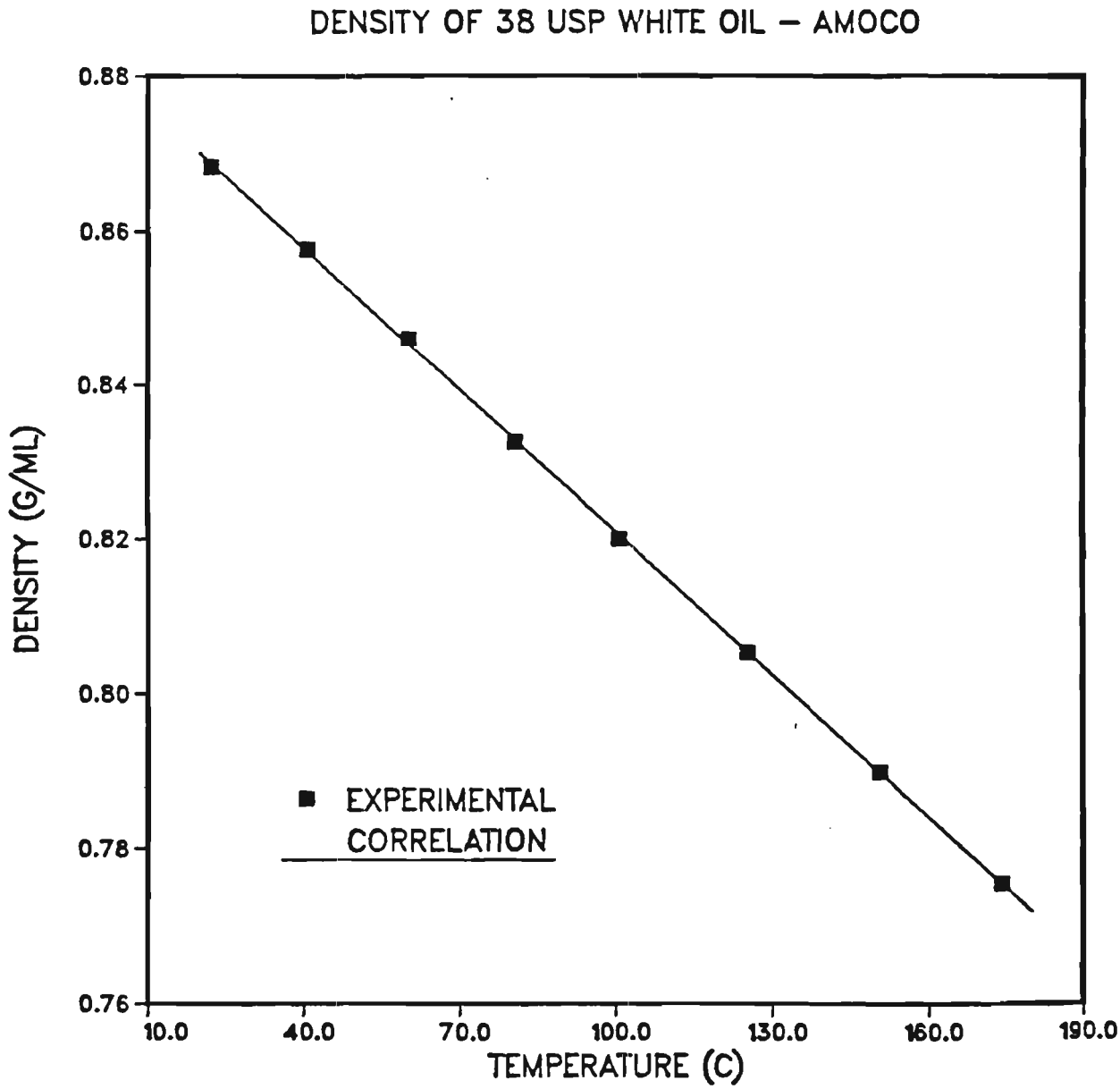

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April, 1990 DDS-LD-A29

DESIGN DATA STANDARD - LIQUID DENSITY

Unpurified 4-Chlorobenzene Sulfonic Acid - Amoco

$ClC_6H_4SO_3H$

Analysis :

4-chlorobenzene sulfonic acid	85.933	wt.%
p-dichlorobenzene	0.261	wt.%
sulfuric acid	0.064	wt.%
o-dichlorobenzene	0.013	wt.%
3,4-dichlorodiphenylsulfone	0.750	wt.%
4,4-dichlorodiphenylsulfone	4.130	wt.%
water	0.700	wt.%
unknowns	7.949	wt.%

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.4 %

T (K)	ρ (kg/m^3)
352.1	1436.4
373.5	1422.8
393.3	1408.4
413.9	1393.2
434.1	1375.1

Liquid Density Correlation:

$$\rho(kg/m^3) = 1405.2 + 0.76133\,T(K) - 0.19136x10^{-2}\,T(K)^2$$

%AAD = 0.02 %
%MAD = 0.04 %

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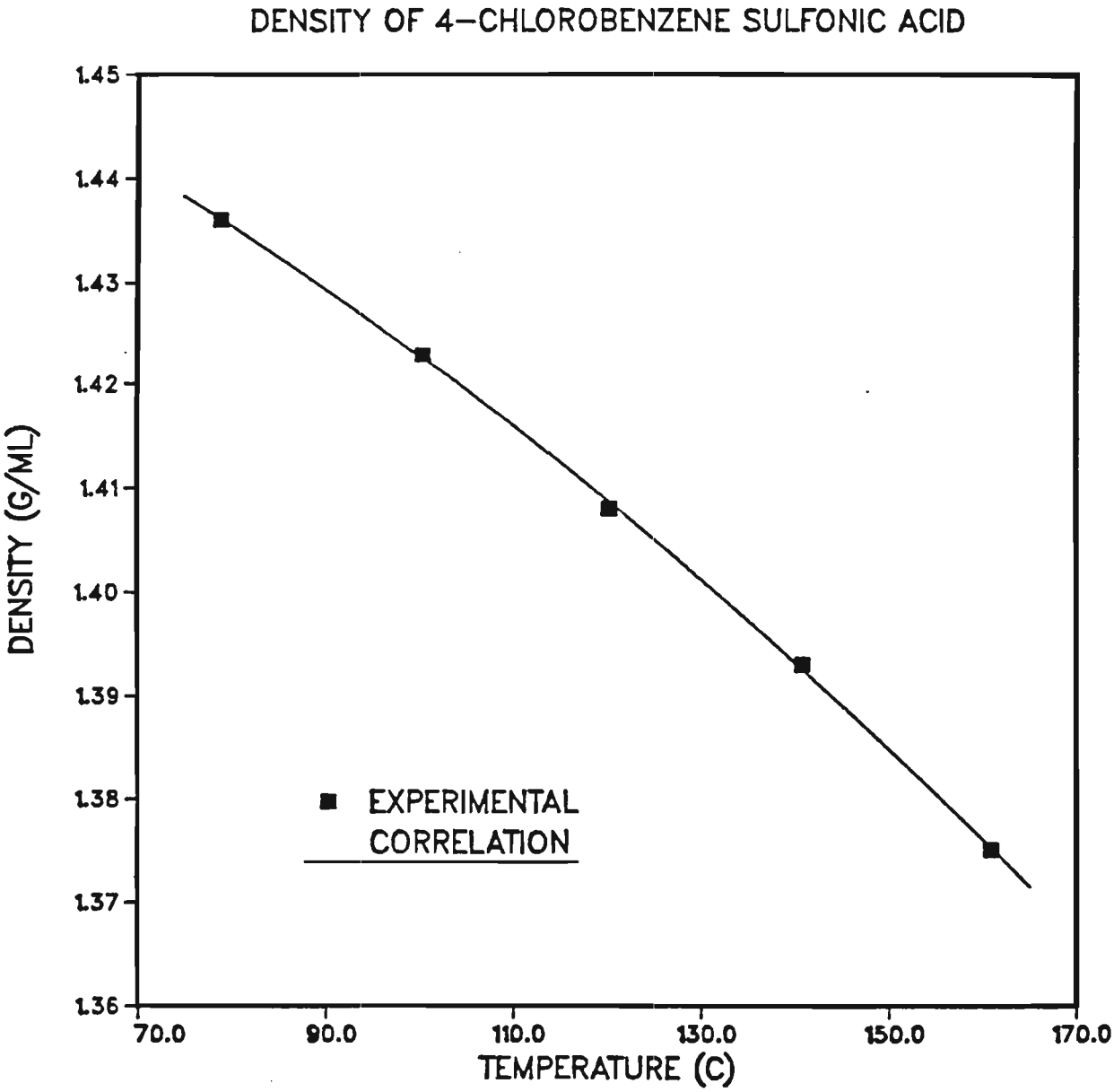

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April, 1990 DDS-LD-A30

DESIGN DATA STANDARD - LIQUID DENSITY

Monoethanol Amine

$(C_2H_5O)NH_2$

Purity =	99 %	
Molecular Weight =	61.083 kg/kmol	[1]
Critical Temperature =	614.5 K	[2]
Critical Pressure =	44.1 atm	[2]
Critical Volume =	0.225 m^3/kmol	[3]
Melting Point =	283.68 K	[2]
Normal Boiling Point =	444.10 K	[2]
Liquid Molar Volume =	0.06038 m^3/kmol	[4]
Dipole Moment =	2.590 x 10^{-30} C-m	[5]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (kg/m^3)
294.4	1014.7
313.4	999.8
333.6	984.3
353.2	967.6
373.0	951.7
392.5	935.2
412.4	917.9
431.3	899.8

Liquid Density Correlation:

$$\rho(kg/m^3) = 1181.94 - 0.387236\,T(K) - 0.616683x10^{-3}\,T(K)^2$$

%AAD = 0.03 %
%MAD = 0.06 %

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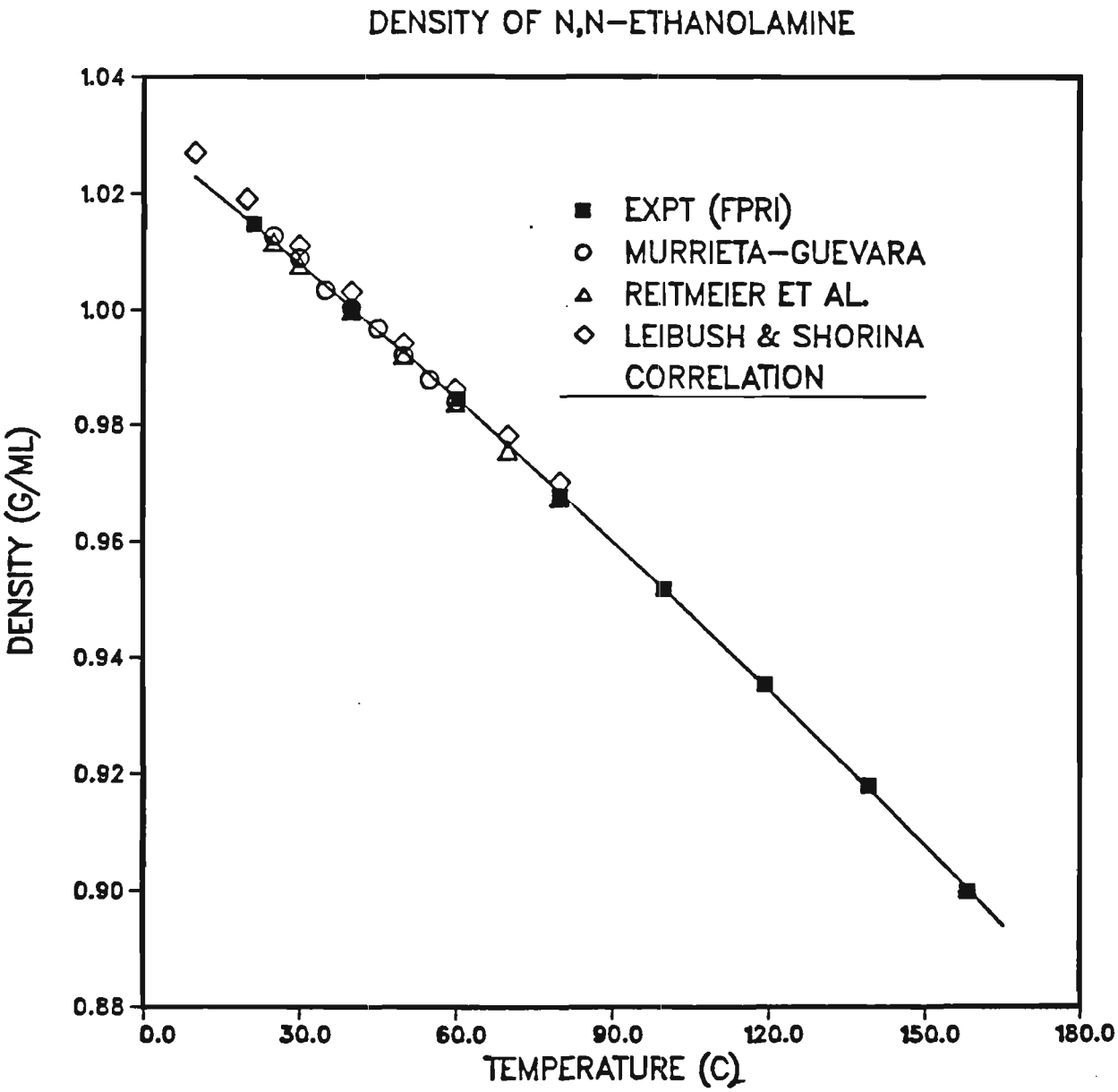

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8. Leibush, A. G.; Shorina, E. D., "Physico-Chemical Properties of Ethanolamines", Zhur. Priklad. Klim., 20, 69 (1947).

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April, 1990 DDS-LD-A31

DESIGN DATA STANDARD - LIQUID DENSITY
Diethanol Amine
$(C_2H_5O)_2NH$

Purity =	99 %	
Molecular Weight =	105.136 kg/kmol	[1]
Critical Temperature =	715.3 K	[2]
Critical Pressure =	32.3 atm	[2]
Critical Volume =	0.349 m^3/kmol	[3]
Melting Point =	301.1 K	[2]
Normal Boiling Point =	541.54 K	[2]
Liquid Molar Volume =	0.096105 m^3/kmol	[4]
Dipole Moment =	2.840 x 10^{-30} C-m	[5]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (kg/m^3)
297.2	1094.2
313.8	1084.4
333.7	1071.5
354.3	1057.7
374.4	1042.5
394.7	1027.9
413.5	1013.0
432.9	998.5

Liquid Density Correlation:

$$\rho(kg/m^3) = 1212.05 - 0.178614\,T(K) - 0.729223x10^{-3}\,T(K)^2$$

%AAD = 0.03 %
%MAD = 0.05 %

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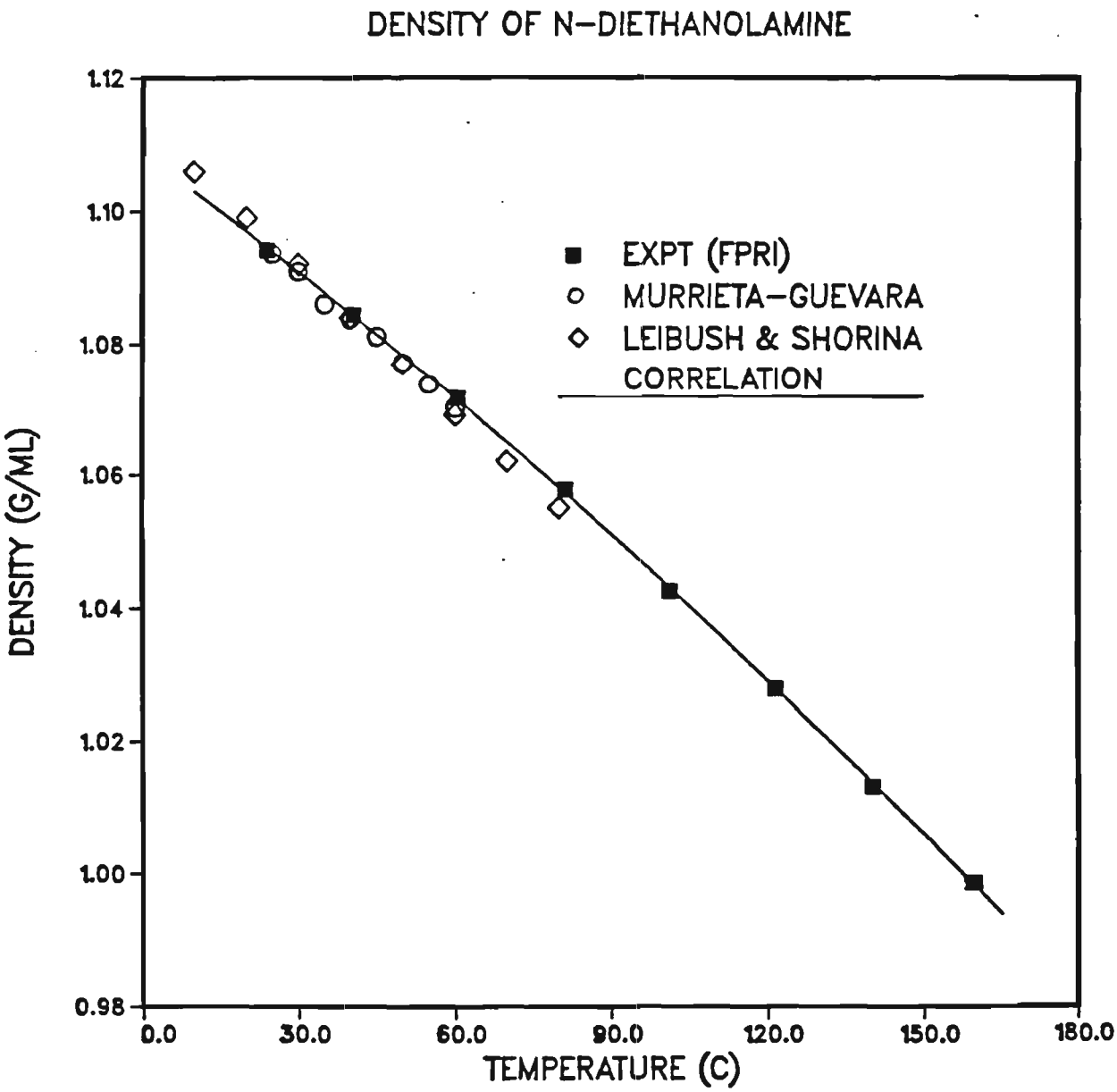

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April, 1990 DDS-LD-A32

DESIGN DATA STANDARD - LIQUID DENSITY
Triethanol Amine
$(C_2H_5O)_3N$

Purity =	99 %	
Molecular Weight =	149.189 kg/kmol	[1]
Critical Temperature =	787.5 K	[2]
Critical Pressure =	24.2 atm	[2]
Critical Volume =	0.472 m^3/kmol	[3]
Melting Point =	294.72 K	[2]
Normal Boiling Point =	608.54 K	[2]
Liquid Molar Volume =	0.13311 m^3/kmol	[4]
Dipole Moment =	3.600 x 10^{-30} C-m	[5]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (kg/m^3)
295.1	1122.2
313.1	1112.3
333.9	1100.6
354.4	1088.7
374.4	1075.2
395.1	1061.1
415.4	1047.5
434.6	1035.2

Liquid Density Correlation:

$$\rho(kg/m^3) = 1233.21 - 0.202359\,T(K) - 0.586079x10^{-3}\,T(K)^2$$

%AAD = 0.04 %
%MAD = 0.08 %

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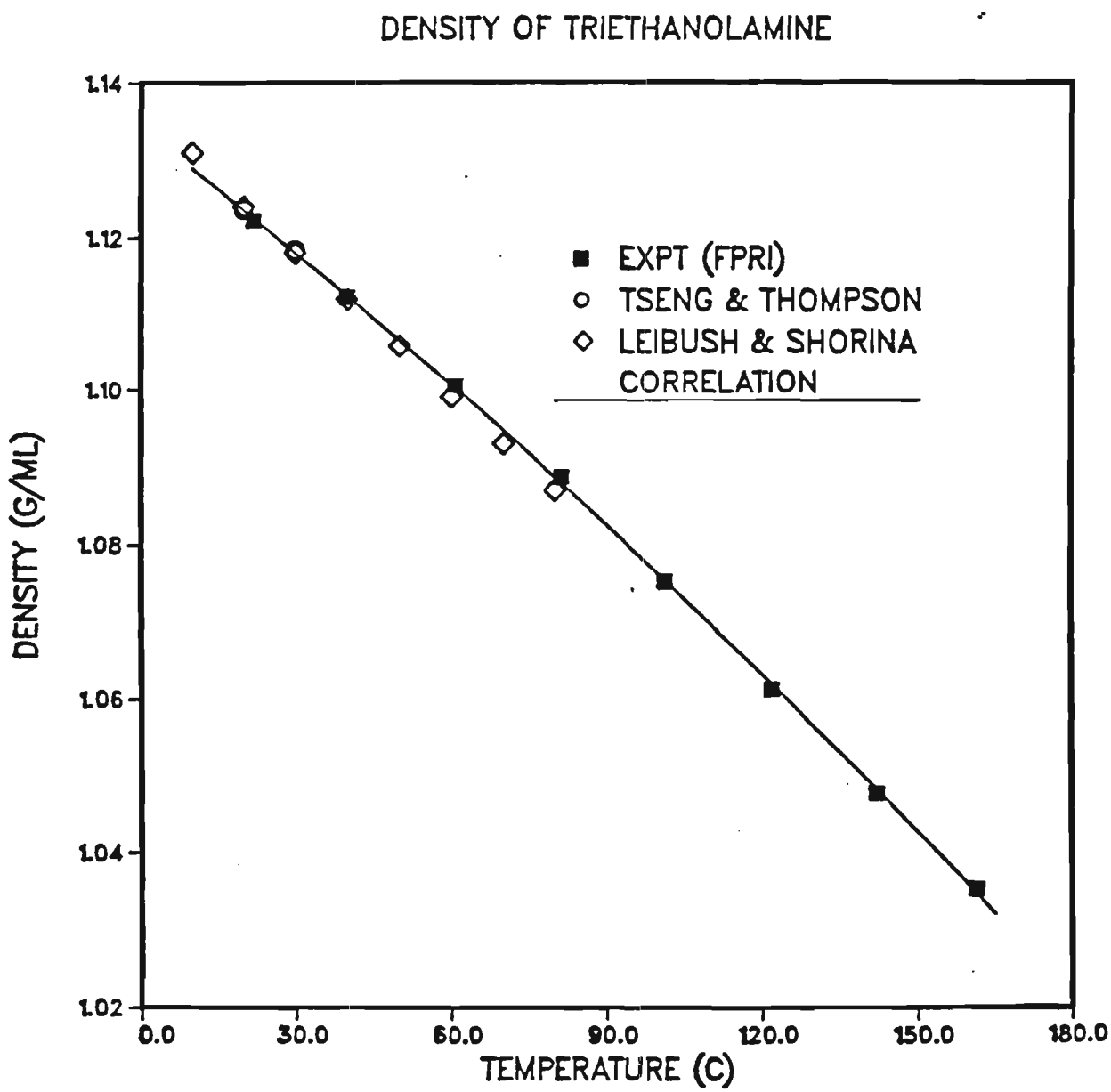

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April, 1990 DDS-LV-A24

DESIGN DATA STANDARD - LIQUID VISCOSITY
Dimethyl Ethanolamine
$(C_2H_5O)N(CH_3)_2$

Purity =	99 %	
Molecular Weight =	89.13 kg/kmol	[1]
Critical Temperature =	585.1 K	[2]
Critical Pressure =	41.8 atm	[3]
Critical Volume =	0.305 m^3/kmol	[3]
Melting Point =	214.2 K	[4]
Normal Boiling Point =	407.2 K	[4]
Liquid Molar Volume =	0.1008 m^3/kmol	[5]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cp)
294.3	3.661
303.1	2.849
313.2	2.194
323.2	1.734
333.2	1.394
343.3	1.140
353.5	0.916
363.6	0.773
378.9	0.606
393.9	0.488

Liquid Viscosity Correlation:

$$ln\,(\,\mu(cp)\,) = -5.2335 + 1453.6\,/\,(T(K) - 71.773)$$

%AAD = 0.5 %
%MAD = 1.3 %

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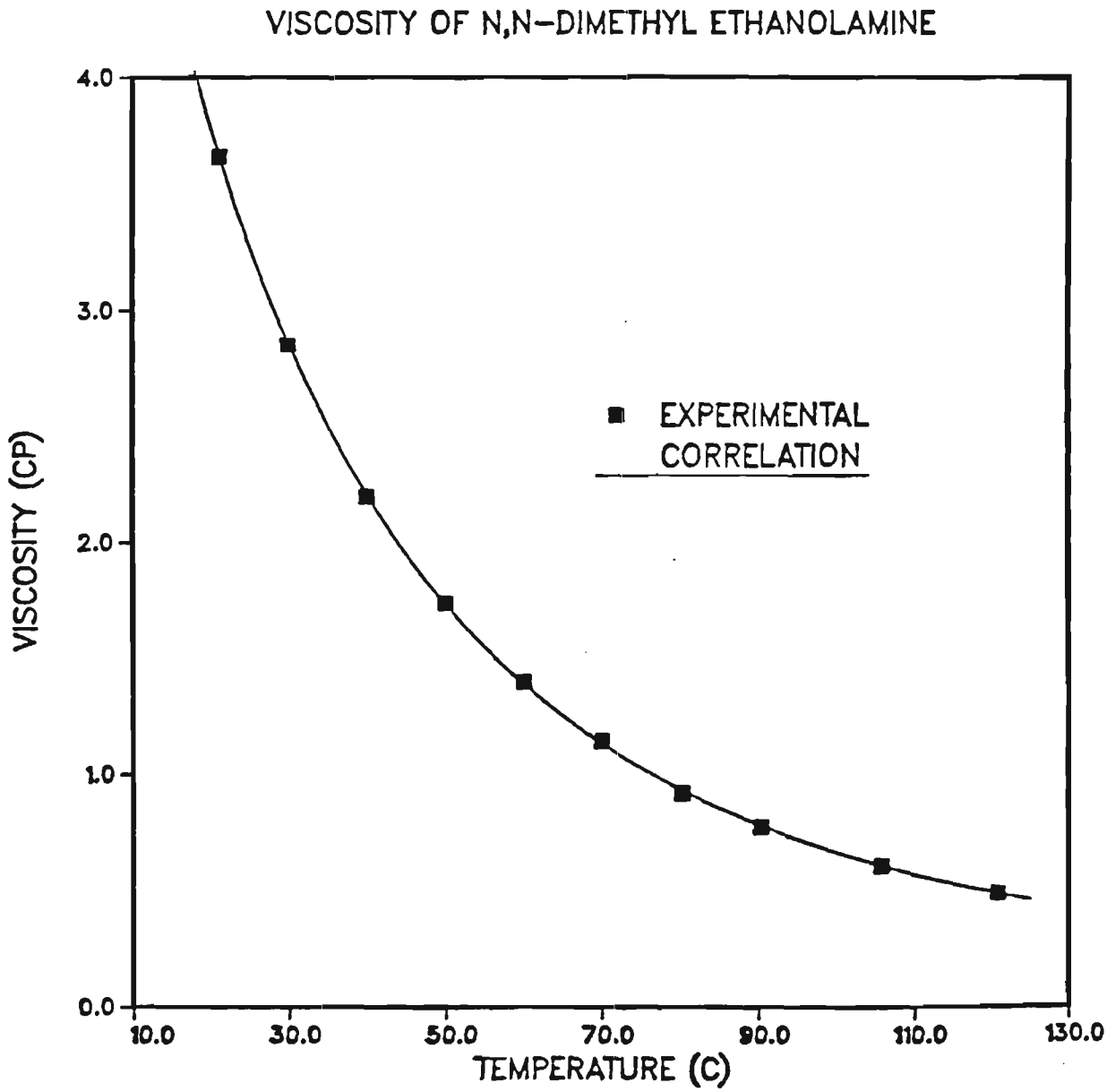

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4. Weast, R. C.; Grasselli, J. G., "CRC Handbook of Data on Organic Compounds", 2nd Edition, CRC Press, 1985.
5. Estimated from density correlation reported in this data sheet.

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April, 1990 DDS-LV-A25

DESIGN DATA STANDARD - LIQUID VISCOSITY

Diethyl Ethanolamine

$(C_2H_5O)N(C_2H_5)_2$

Purity =	99 %	
Molecular Weight =	117.19 kg/kmol	[1]
Critical Temperature =	614.2 K	[2]
Critical Pressure =	32.6 atm	[3]
Critical Volume =	0.416 m^3/kmol	[3]
Normal Boiling Point =	436.2 K	[4]
Liquid Molar Volume =	0.13326 m^3/kmol	[5]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cp)
295.3	4.496
303.1	3.405
313.2	2.475
323.2	1.862
338.1	1.291
353.2	0.946
374.0	0.643
394.0	0.478
414.1	0.371

Liquid Viscosity Correlation:

$$ln\,(\,\mu(cp)\,) = -4.2337 + 884.19\,/\,(T(K) - 141.15)$$

%AAD = 0.23 %
%MAD = 0.72 %

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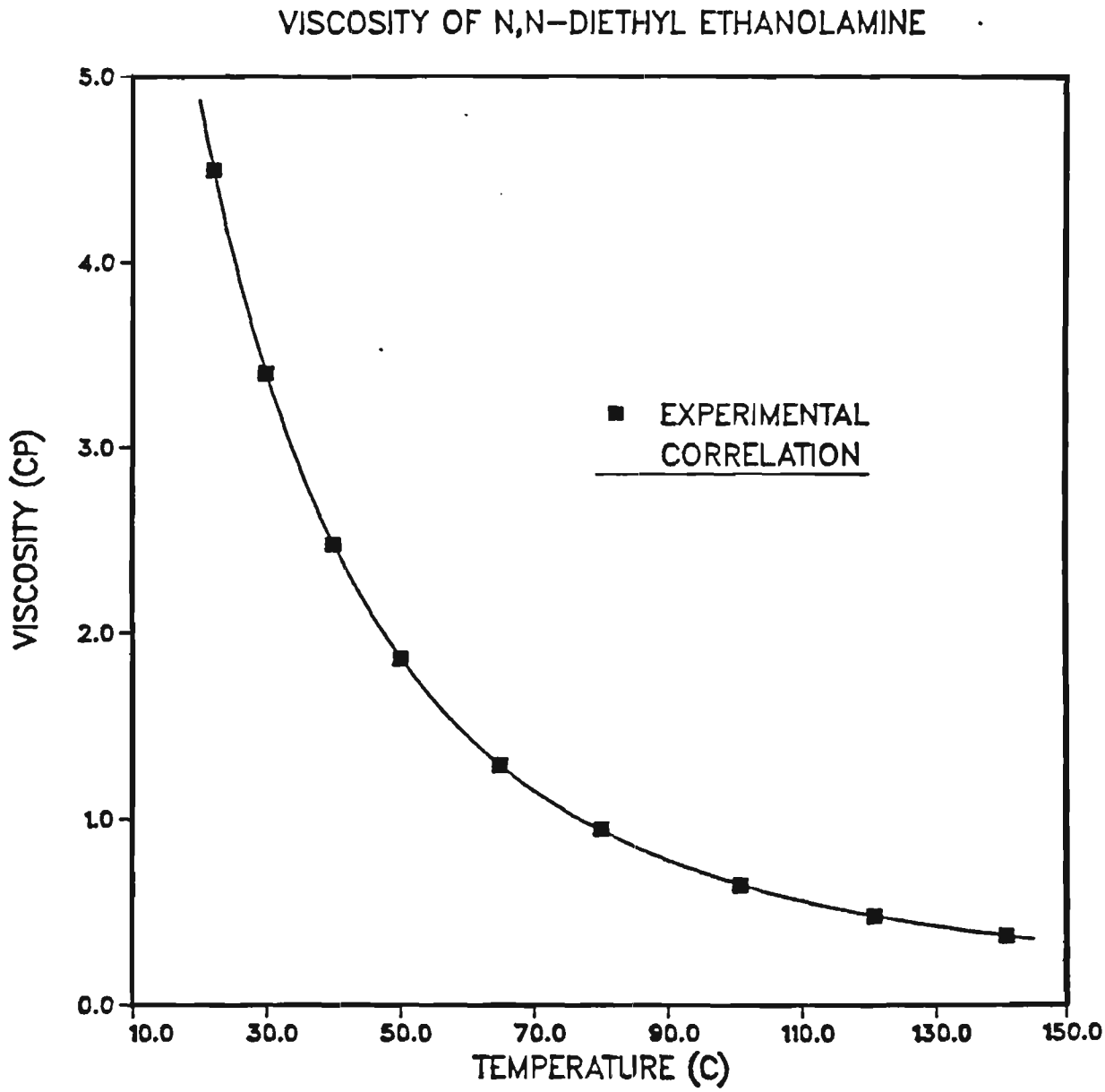

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April, 1990 DDS-LV-A26

DESIGN DATA STANDARD - LIQUID VISCOSITY

Methyl Diethanolamine

$(C_2H_5O)_2NCH_3$

Purity =	99 %	
Molecular Weight =	119.16 kg/kmol	[1]
Critical Temperature =	680.0 K	[2]
Critical Pressure =	42.9 atm	[2]
Critical Volume =	0.372 m^3/kmol	[2]
Melting Point =	252.2 K	[3]
Normal Boiling Point =	520.2 K	[3]
Liquid Molar Volume =	0.11507 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cp)
293.1	102.7
302.8	57.95
313.2	34.02
323.2	21.50
338.1	11.88
353.2	7.151
374.0	3.987
394.0	2.504
414.0	1.679
424.1	1.406

Liquid Viscosity Correlation:

$$ln\,(\,\mu(cp)\,) = -4.3039 + 1266.2\,/\,(T(K) - 151.40)$$

%AAD = 0.23 %
%MAD = 0.43 %

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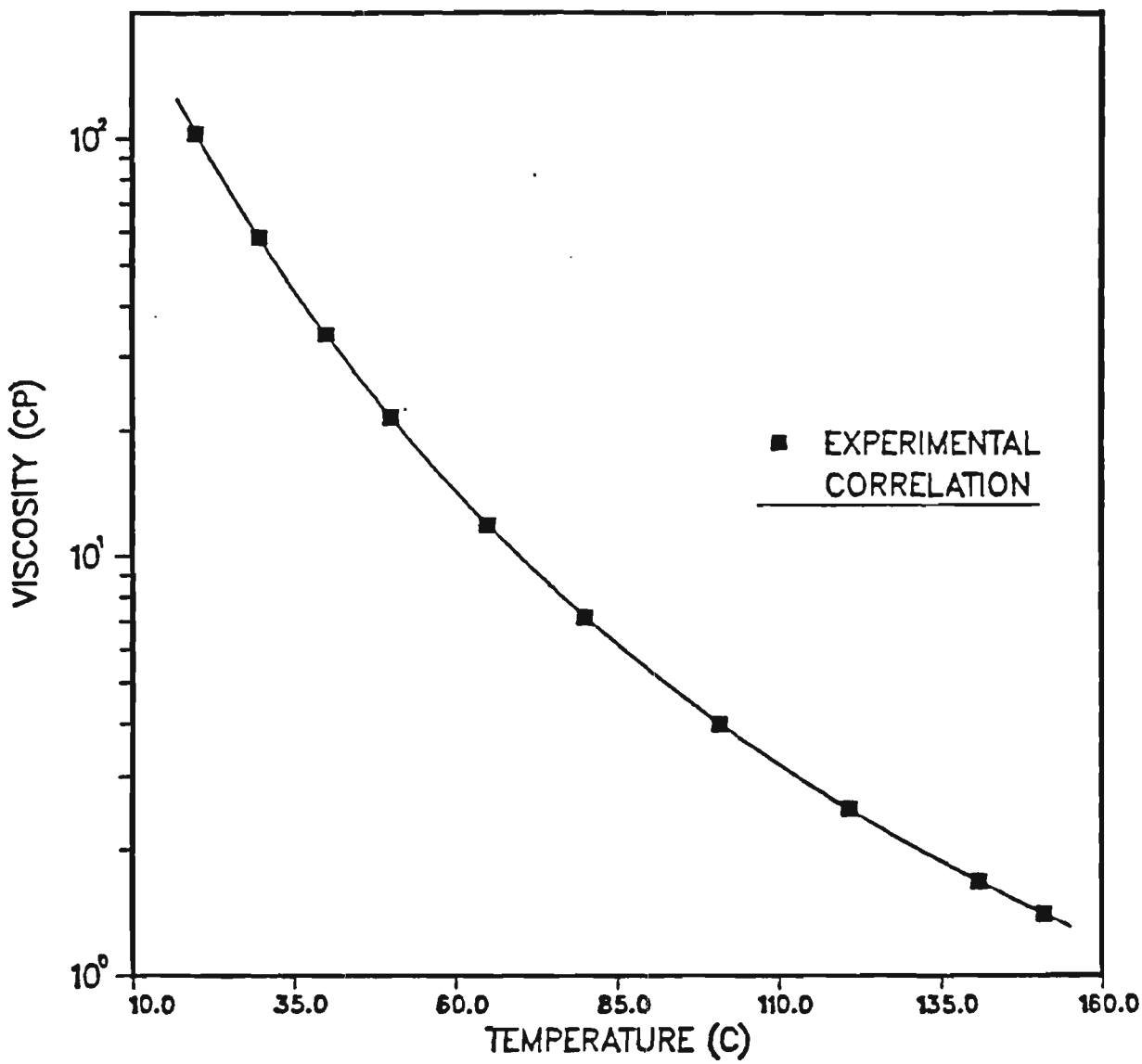
VISCOSITY OF N-METHYL DIETHANOLAMINE



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DESIGN DATA STANDARD - LIQUID VISCOSITY
Ethyl Diethanolamine
$(C_2H_5O)_2NC_2H_5$

Purity =	99 %	
Molecular Weight =	133.18 kg/kmol	[1]
Critical Temperature =	672.8 K	[2]
Critical Pressure =	38.0 atm	[2]
Critical Volume =	0.428 m^3/kmol	[2]
Melting Point =	223.2 K	[3]
Normal Boiling Point =	520.2 K	[4]
Liquid Molar Volume =	0.13182 m^3/kmol	[5]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cp)
292.2	92.52
303.1	47.65
313.2	28.07
323.1	17.72
338.2	9.750
353.2	5.893
374.1	3.332
394.0	2.116
414.1	1.457
424.2	1.228

Liquid Viscosity Correlation:

$$ln\,(\,\mu(cp)\,) = -3.9927 + 1090.8\,/\,(T(K) - 164.21)$$

%AAD = 0.35 %
%MAD = 0.56 %

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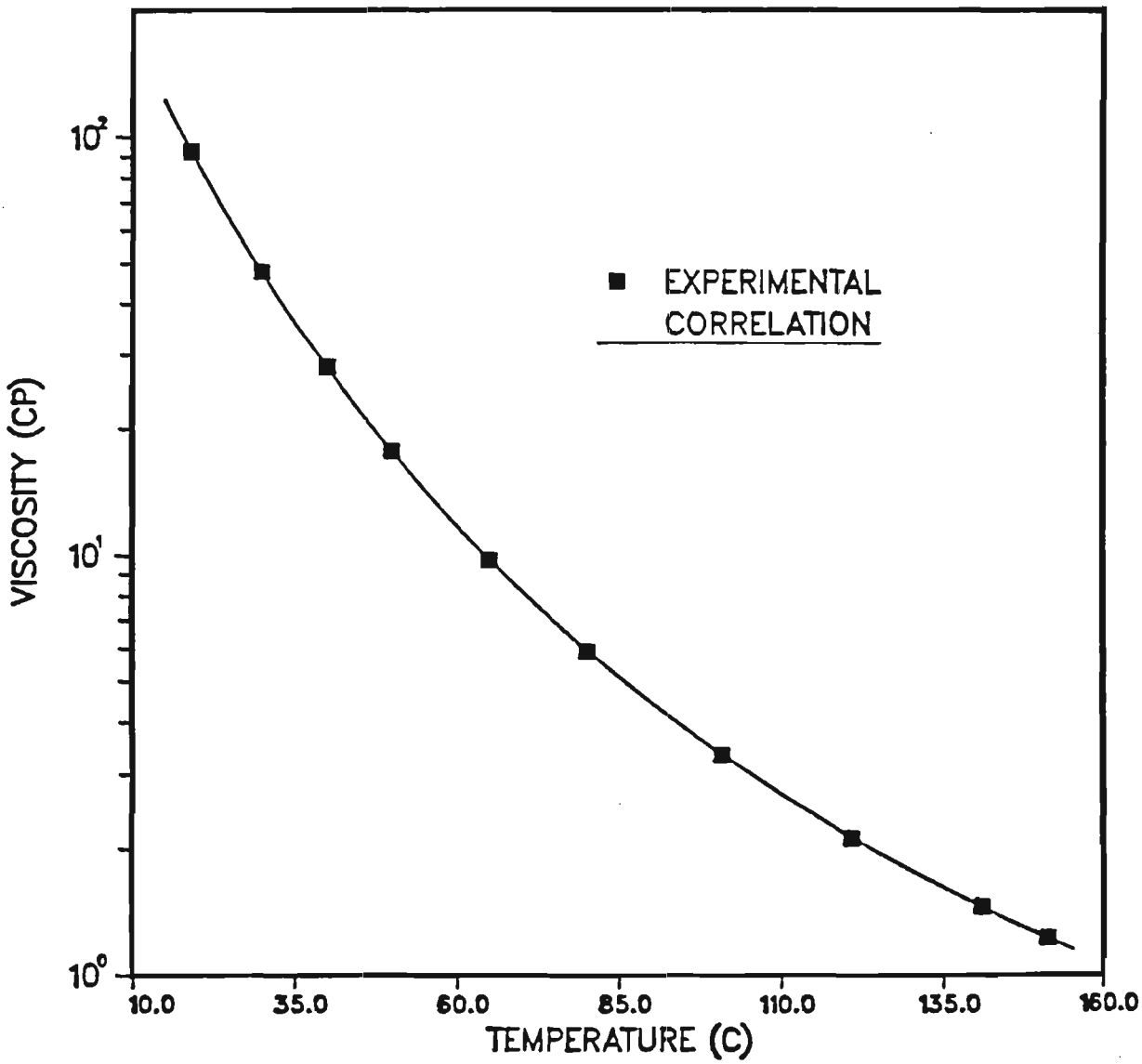
VISCOSITY OF N-ETHYL DIETHANOLAMINE



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April, 1990 DDS-LV-A28

DESIGN DATA STANDARD - LIQUID VISCOSITY
2-Butanone
C_4H_8O

Purity =	99+ %	
Molecular Weight =	72.107 kg/kmol	[1]
Critical Temperature =	536.78 K	[2]
Critical Pressure =	41.52 atm	[3]
Critical Volume =	0.267 m^3/kmol	[3]
Melting Point =	186.46 K	[4]
Normal Boiling Point =	352.74 K	[4]
Liquid Molar Volume =	0.090066 m^3/kmol	[5]
Dipole Moment =	9.2064 x 10^{-30} C-m	[6]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cp)
282.9	0.4395
288.1	0.4141
293.2	0.3918
298.2	0.3720
303.1	0.3521
313.1	0.3193
323.1	0.2918
333.1	0.2669
343.2	0.2467

Liquid Viscosity Correlation:

$$ln\,(\,\mu(cp)\,) = -6.48639 + 1041.9\,/T(K) + 0.351136\,ln(\,T(K)\,)$$

%AAD = 0.11 %
%MAD = 0.24 %

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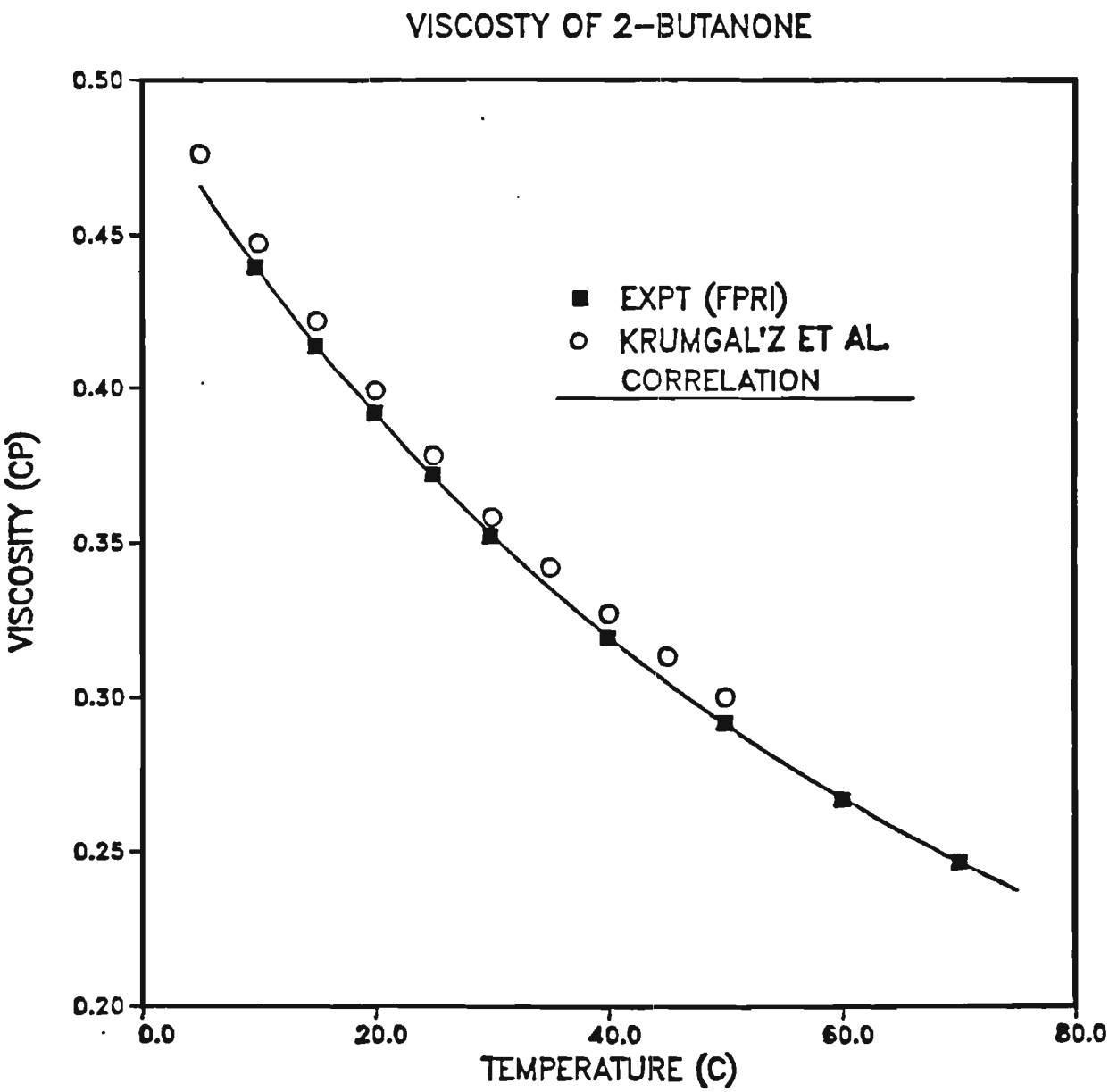

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5. Estimated from the density correlation reported in this data sheet.
6. AICHE DIPPR Data Compilation Manual, Daubert, T.; Danner, R. P. (Eds), 1985.
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April, 1990 DDS-LV-A29

DESIGN DATA STANDARD - LIQUID VISCOSITY
Tripropylene Glycol Methyl Ether
$CH_3(OC_3H_6)_3OH$

Purity =	99 %	
Molecular Weight =	206.29 kg/kmol	[1]
Critical Temperature =	740.0 K	[2]
Critical Pressure =	21.6 atm	[3]
Critical Volume =	0.663 m^3/kmol	[4]
Liquid Molar Volume =	0.21298 m^3/kmol	[5]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cp)
292.0	8.071
302.8	5.390
312.9	3.934
322.9	2.978
338.0	2.084
353.1	1.543
374.0	1.074
393.9	0.804
414.1	0.628
424.1	0.565

Liquid Viscosity Correlation:

$$ln(\mu(cp)) = -3.4058 + 775.69 / (T(K) - 150.60)$$

%AAD = 0.39 %
%MAD = 0.79 %

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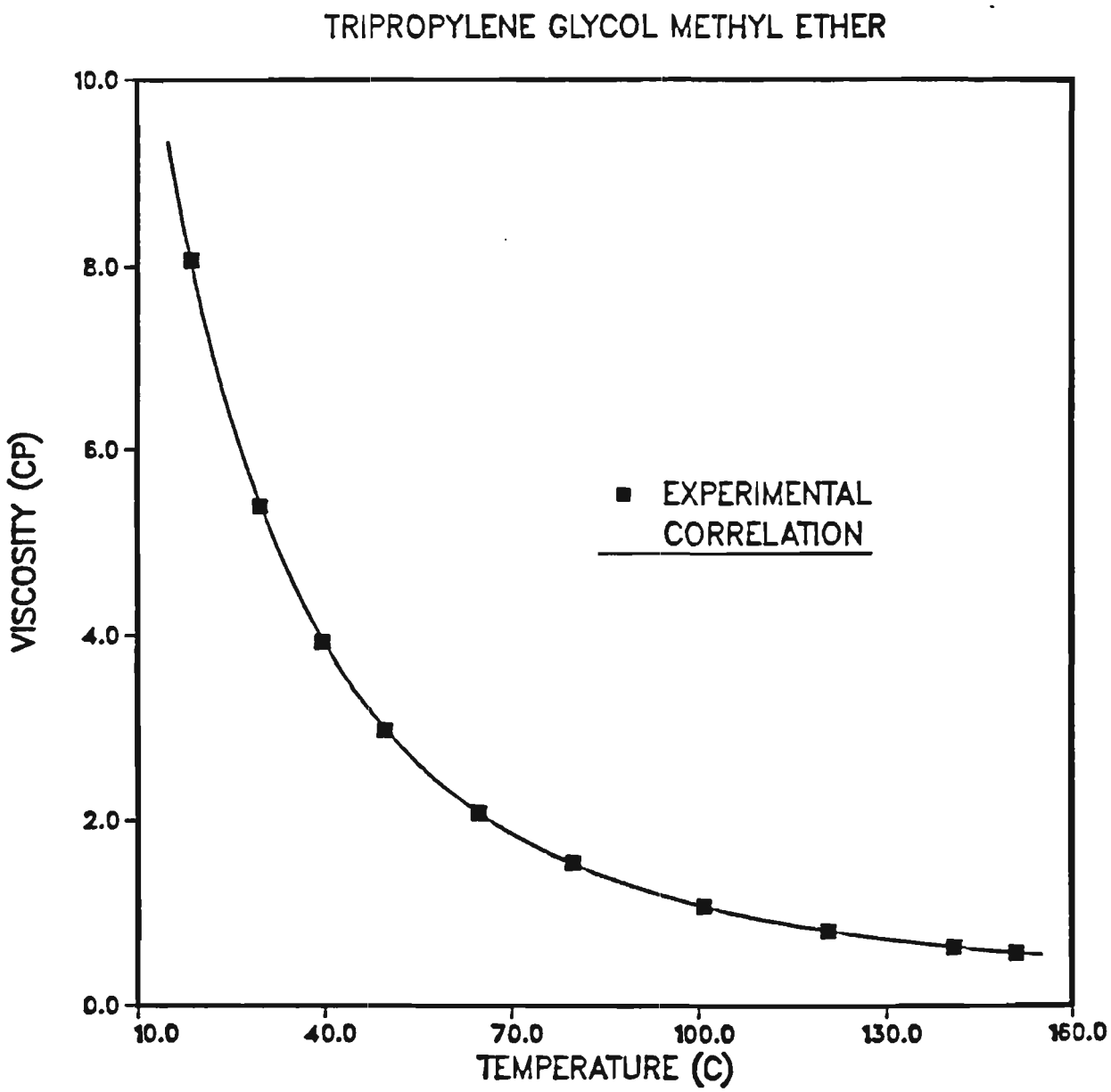

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4. Vetere, A. O., "Methods for the Estimation of Critical Volumes", Chem. Eng. J., 34, 151 (1987).
5. Estimated from density correlation reported in this data sheet.

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April, 1990 DDS-LV-A30

DESIGN DATA STANDARD - LIQUID VISCOSITY
2-(Isopropyl)-5-methyl Cyclohexanol; (-)-Menthol
$C_{10}H_{20}O$

Purity =	99 %	
Molecular Weight =	156.26 kg/kmol	[1]
Critical Temperature =	694.1 K	[2]
Critical Pressure =	28.5 atm	[2]
Critical Volume =	0.559 m^3/kmol	[2]
Melting Point =	229.2 K	[3]
Normal Boiling Point =	489.6 K	[3]
Liquid Molar Volume =	0.17469 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cp)
323.1	9.549
333.2	5.705
343.2	3.653
353.1	2.522
373.2	1.389
393.8	0.896
413.8	0.628

Liquid Viscosity Correlation:

$$ln(\mu(cp)) = -3.3683 + 543.74 / (T(K) - 226.54)$$

%AAD = 0.49 %
%MAD = 0.99 %

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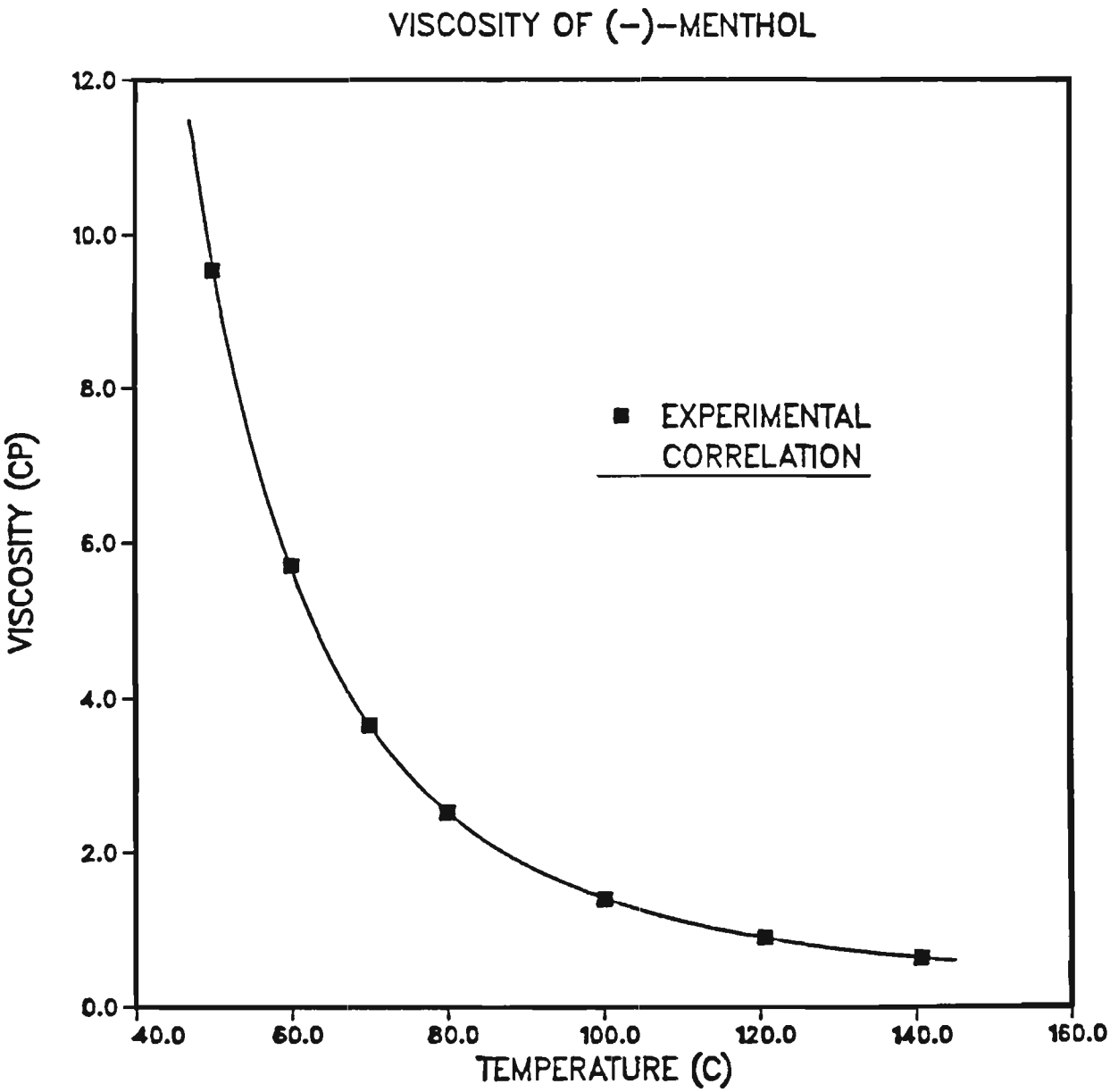

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April, 1990 DDS-LV-A31

DESIGN DATA STANDARD - LIQUID VISCOSITY
38 USP White Oil - Amoco

*** No physical properties are available ***

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

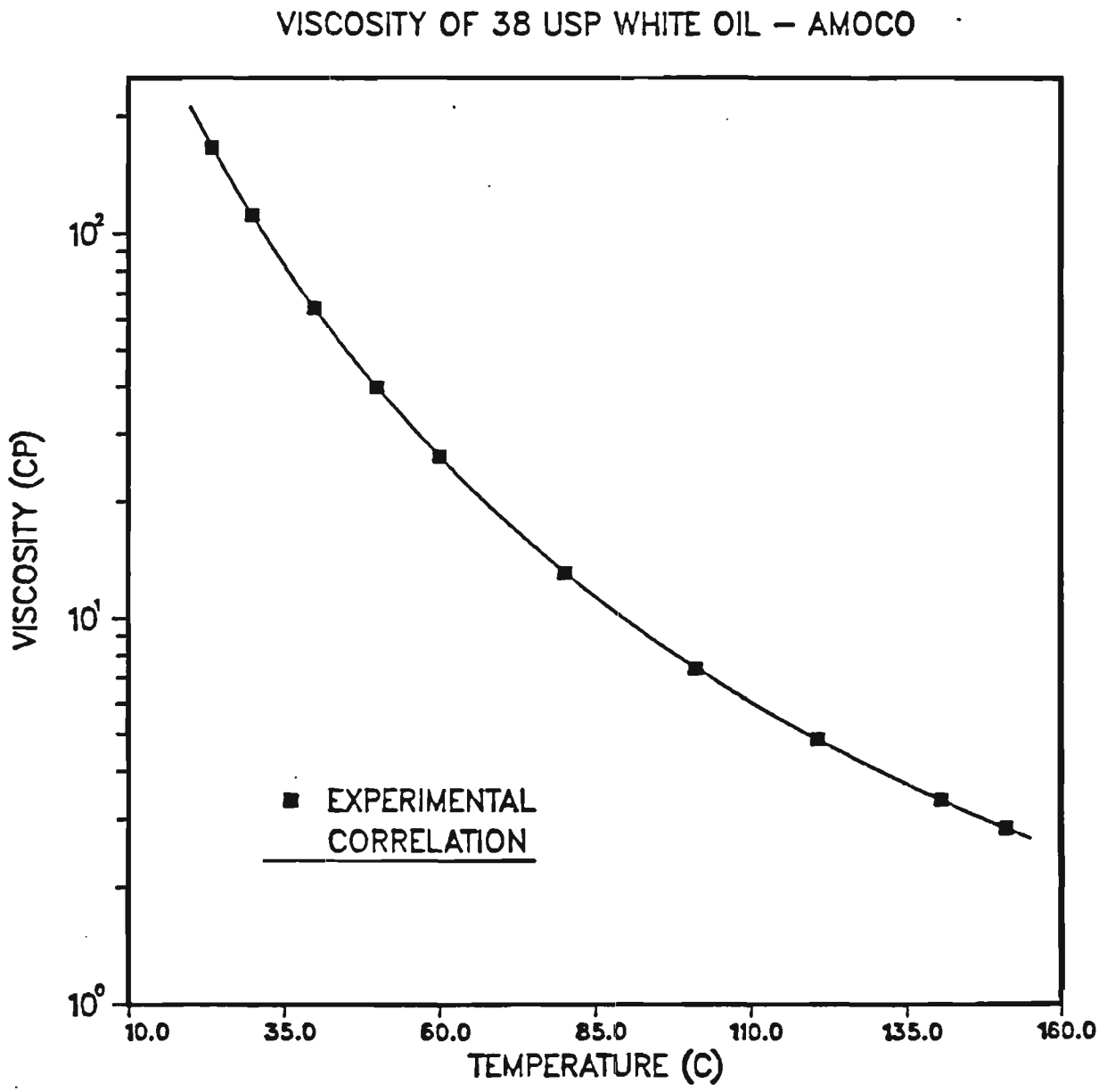
T (K)	μ (cp)
296.6	166.5
303.0	111.7
313.1	64.29
323.1	39.79
333.2	26.14
353.2	13.10
374.2	7.385
393.9	4.835
413.8	3.355
424.2	2.841

Liquid Viscosity Correlation:

$$ln(\mu(cp)) = -2.7401 + 930.65 / (T(K) - 178.17)$$

%AAD = 0.34 %
%MAD = 0.71 %

April, 1990 DDS-LV-A31



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April, 1990 DDS-LV-A32

DESIGN DATA STANDARD - LIQUID VISCOSITY

Unpurified 4-Chlorobenzene Sulfonic Acid - Amoco

$ClC_6H_4SO_3H$

Analysis :

4-chlorobenzene sulfonic acid	85.933	wt.%
p-dichlorobenzene	0.261	wt.%
sulfuric acid	0.064	wt.%
o-dichlorobenzene	0.013	wt.%
3,4-dichlorodiphenylsulfone	0.750	wt.%
4,4-dichlorodiphenylsulfone	4.130	wt.%
water	0.700	wt.%
unknowns	7.949	wt.%

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	ν (cst)
353.6	13.15
363.6	9.691
374.0	7.305
384.0	5.741
393.9	4.621
404.0	3.787
414.0	3.155
424.1	2.658

Liquid Viscosity Correlation:

$$ln(\nu(cst)) = -2.8112 + 902.37 / (T(K) - 186.07)$$

%AAD = 0.11 %
%MAD = 0.19 %

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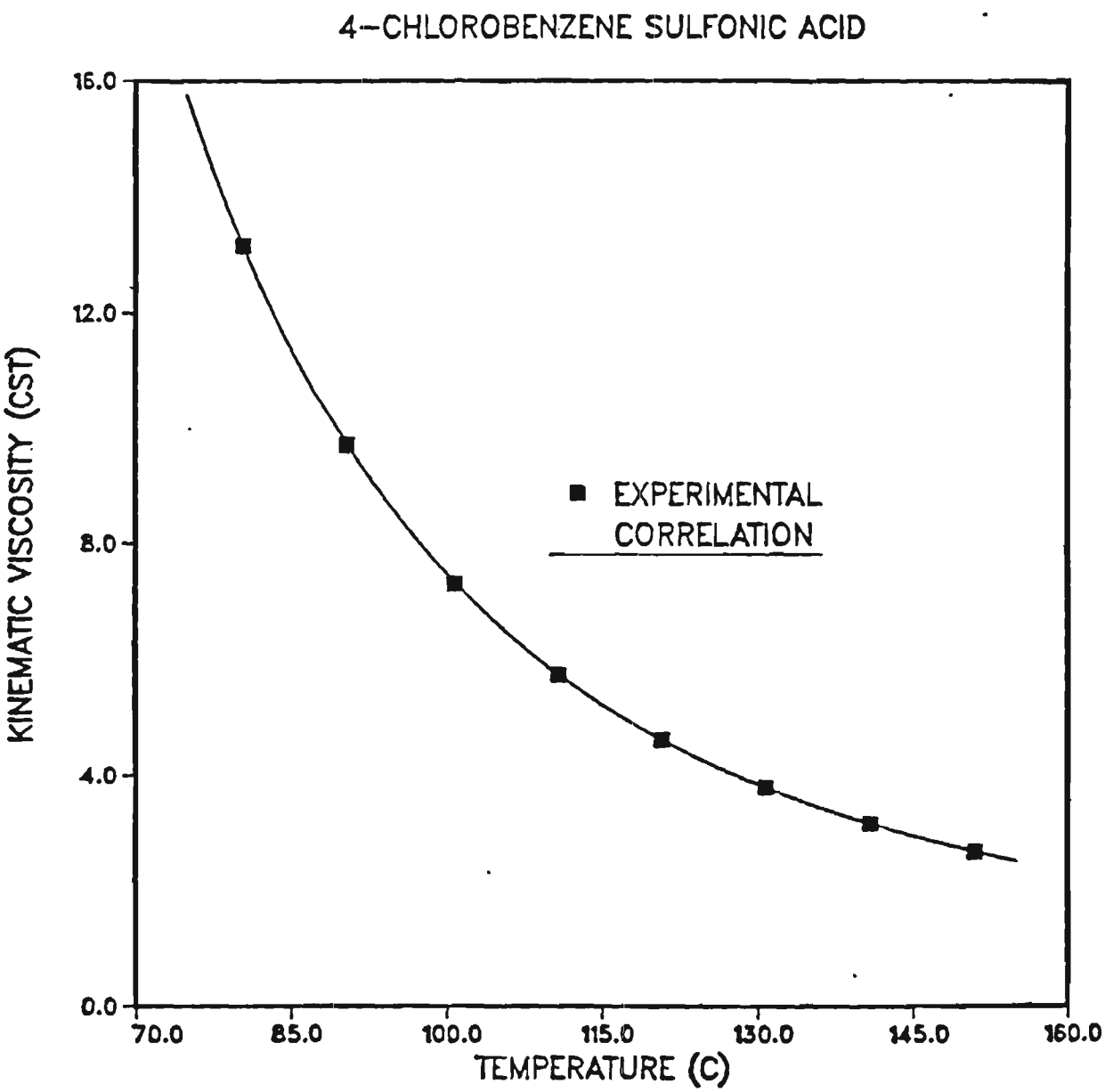

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April, 1990 DDS-LTC-A36

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Dimethyl Ethanolamine

$(C_2H_5O)N(CH_3)_2$

Purity =	99 %	
Molecular Weight =	89.13 kg/kmol	[1]
Critical Temperature =	585.1 K	[2]
Critical Pressure =	41.8 atm	[3]
Critical Volume =	0.305 m^3/kmol	[3]
Melting Point =	214.2 K	[4]
Normal Boiling Point =	407.2 K	[4]
Liquid Molar Volume =	0.1008 m^3/kmol	[5]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = 15 Bars
Accuracy = ± 2 %

T [K]	λ [W/m K]
297.6	0.1357
298.2	0.1346
324.5	0.1302
329.5	0.1305
353.6	0.1263
356.1	0.1266
378.9	0.1226
388.8	0.1219
412.1	0.1165
425.1	0.1156
464.5	0.1074

Liquid Thermal Conductivity Correlation:

$$\lambda\ [W/m\ K] = 0.183468 - 1.61348 \times 10^{-4}\ T[K]$$

%AAD = 0.4 %
%MAD = 1.0 %

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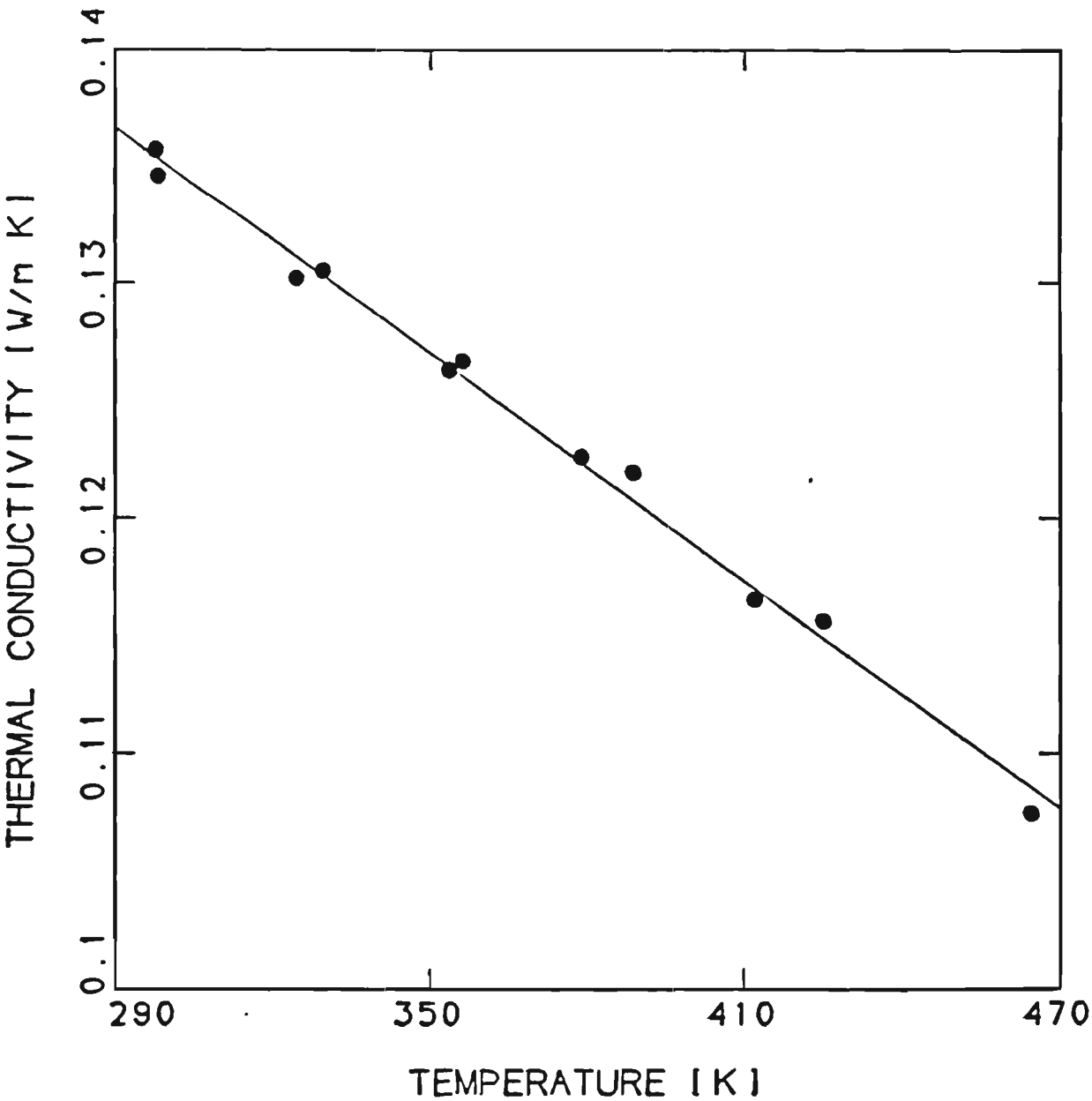
April, 1990

DDS-LTC-A36

THERMAL CONDUCTIVITY OF DIMETHYLETHANOLAMINE
(P = 15 BARS)



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3. Ambrose, D.,"Correlation and Estimation of Vapor-Liquid Critical Properties, II. Critical Pressures and Critical Volumes of Organic Compounds", NPL Report 98, 1979.
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April, 1990 DDS-LTC-A37

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Diethyl Ethanolamine

$(C_2H_5O)N(C_2H_5)_2$

Purity =	99 %	
Molecular Weight =	117.19 kg/kmol	[1]
Critical Temperature =	614.2 K	[2]
Critical Pressure =	32.6 atm	[3]
Critical Volume =	0.416 m^3/kmol	[3]
Normal Boiling Point =	436.2 K	[4]
Liquid Molar Volume =	0.13326 m^3/kmol	[5]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = 15 Bars
Accuracy = ± 2 %

T [K]	λ [W/m K]
297.5	0.1400
325.8	0.1330
354.1	0.1281
383.5	0.1214
412.6	0.1150
443.0	0.1088

Liquid Thermal Conductivity Correlation:

$$\lambda\ [W/m\ K] = 0.203074 - 2.13052 \times 10^{-4}\ T[K]$$

%AAD = 0.2 %
%MAD = 0.5 %

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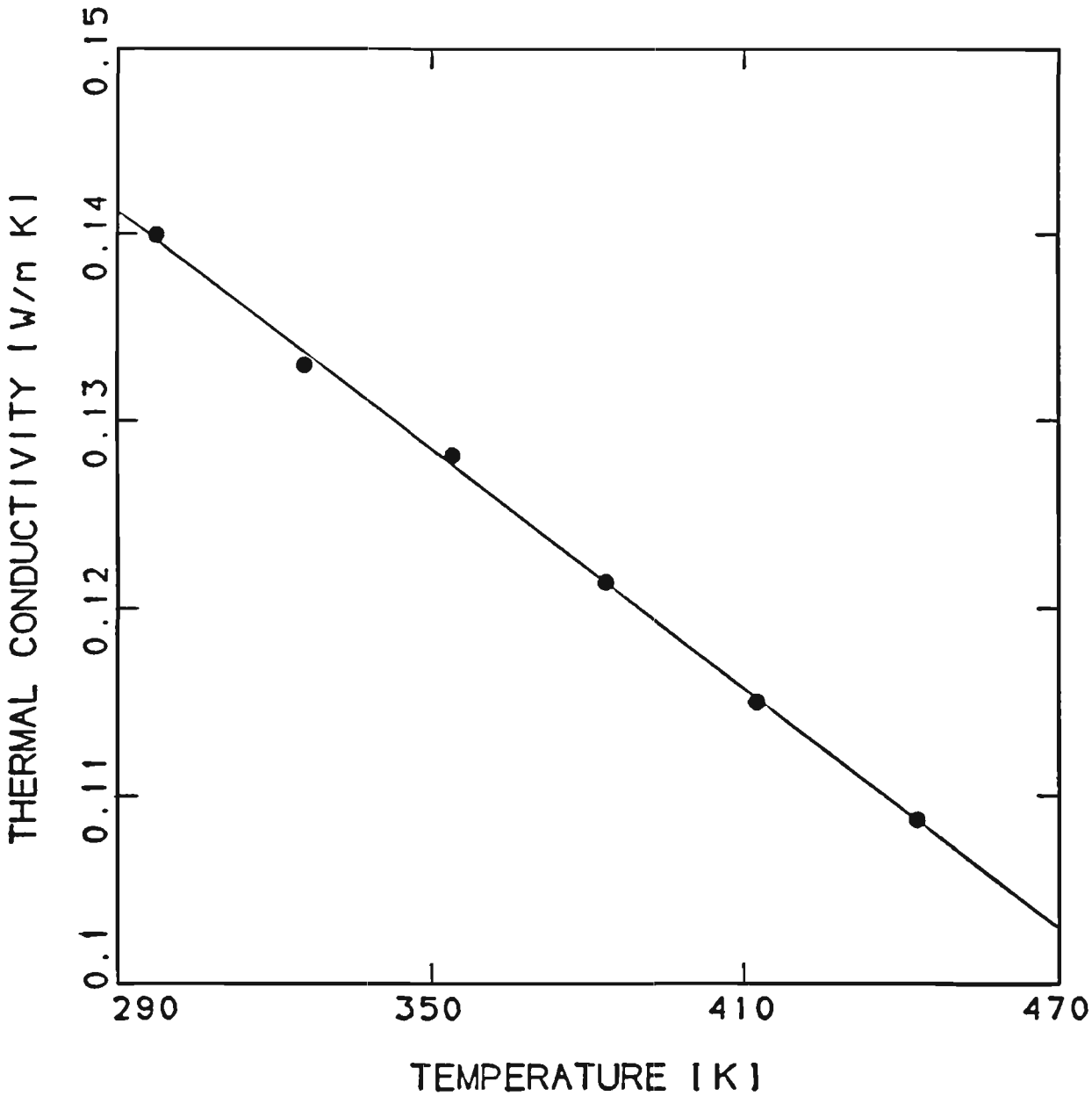
DDS-LTC-A37

THERMAL CONDUCTIVITY OF DIETHYLETHANOLAMINE
(P = 15 BARS)



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5. Estimated from density correlation reported in DDS-LD-A22.

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April, 1990 DDS-LTC-A38

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Methyl Diethanolamine

$(C_2H_5O)_2NCH_3$

Purity =	99 %	
Molecular Weight =	119.16 kg/kmol	[1]
Critical Temperature =	680.0 K	[2]
Critical Pressure =	42.9 atm	[2]
Critical Volume =	0.372 m^3/kmol	[2]
Melting Point =	252.2 K	[3]
Normal Boiling Point =	520.2 K	[3]
Liquid Molar Volume =	0.11507 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = 1 Bar
Accuracy = ± 2 %

T [K]	λ [W/m K]
297.7	0.1685
325.1	0.1676
353.9	0.1663
381.1	0.1653
410.9	0.1636
440.2	0.1613

Liquid Thermal Conductivity Correlation:

$$\lambda\ [W/m\ K] = 0.183678 - 4.95760 \times 10^{-5}\ T[K]$$

%AAD = 0.2 %
%MAD = 0.4 %

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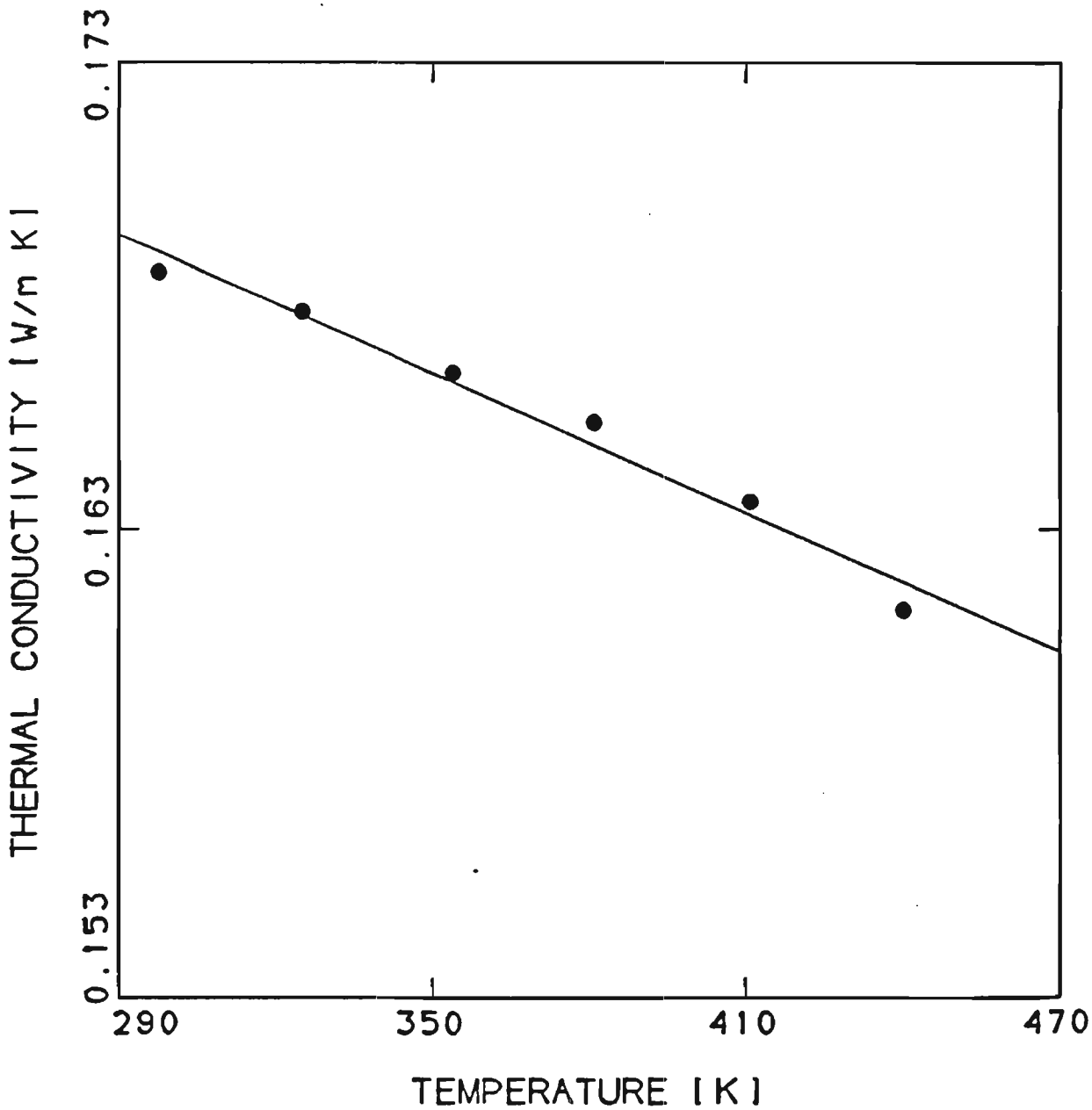
DDS-LTC-A38

THERMAL CONDUCTIVITY OF METHYLDIETHANOLAMINE
(P = 1 BAR)



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4. Estimated from density correlation reported in DDS-LD-A23.

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April, 1990 DDS-LTC-A39

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Ethyl Diethanolamine
$(C_2H_5O)_2NC_2H_5$

Purity =	99 %	
Molecular Weight =	133.18 kg/kmol	[1]
Critical Temperature =	672.8 K	[2]
Critical Pressure =	38.0 atm	[2]
Critical Volume =	0.428 m^3/kmol	[2]
Melting Point =	223.2 K	[3]
Normal Boiling Point =	520.2 K	[4]
Liquid Molar Volume =	0.13182 m^3/kmol	[5]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = 1 Bar
Accuracy = ± 2 %

T [K]	λ [W/m K]
297.1	0.1666
300.8	0.1655
333.5	0.1628
365.8	0.1597
394.8	0.1571
430.1	0.1536
463.8	0.1490

Liquid Thermal Conductivity Correlation:

$$\lambda = 0.196220 - 1.00319 \times 10^{-4}\ T[K]$$

%AAD = 0.2 %
%MAD = 0.5 %

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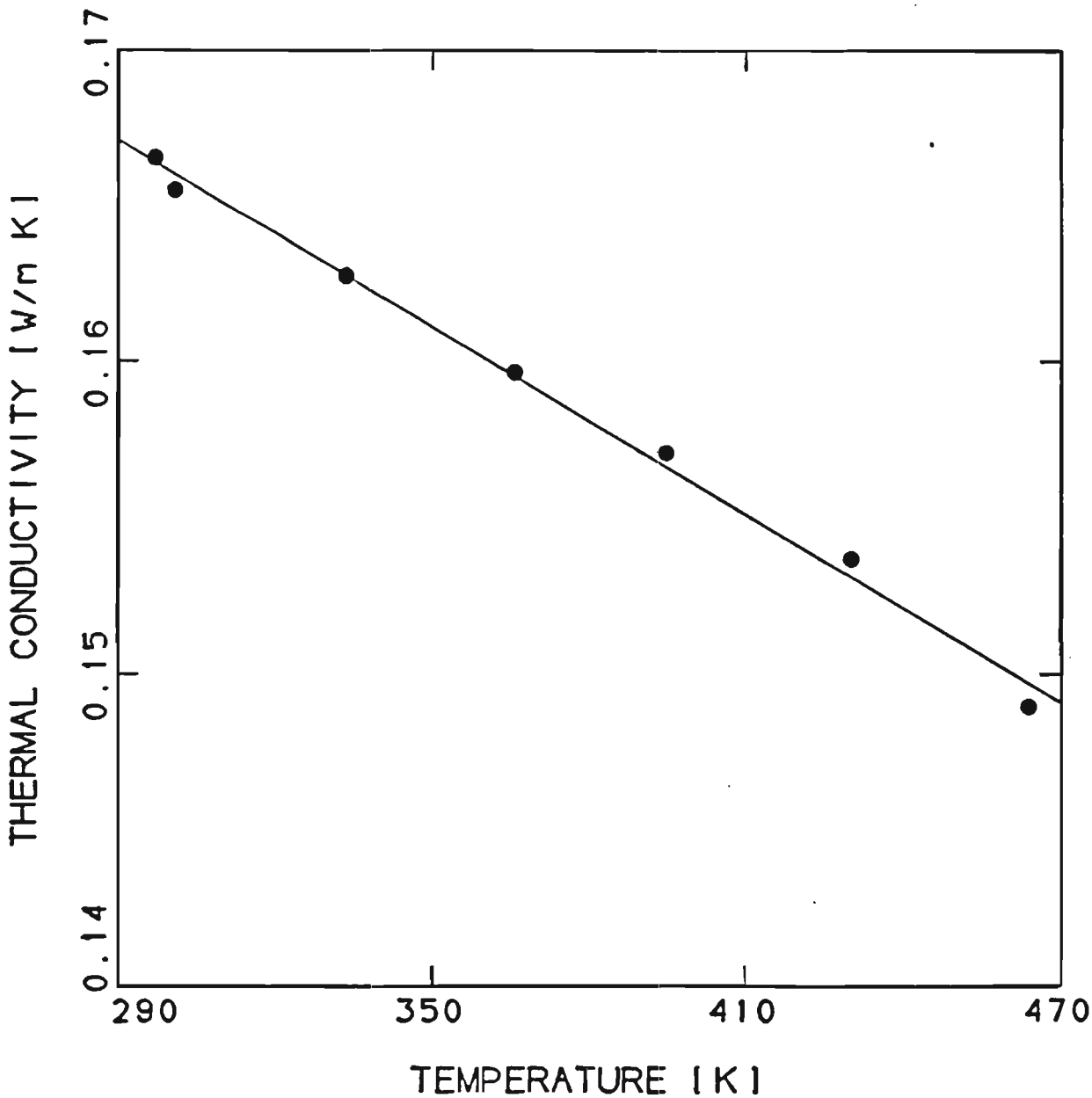
DDS-LTC-A39

THERMAL CONDUCTIVITY OF ETHYLDIETHANOL AMINE
(P = 1 BAR)



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April, 1990 DDS-LTC-A40

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

2-Butanone

C_4H_8O

Purity =	99+ %	
Molecular Weight =	72.107 kg/kmol	[1]
Critical Temperature =	536.78 K	[2]
Critical Pressure =	41.52 atm	[3]
Critical Volume =	0.267 m^3/kmol	[3]
Melting Point =	186.46 K	[4]
Normal Boiling Point =	352.74 K	[4]
Liquid Molar Volume =	0.090066 m^3/kmol	[5]
Dipole Moment =	9.2064 x 10^{-30} C-m	[6]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = 15 Bars
Accuracy = ± 2 %

T [K]	λ [W/m K]
298.1	0.1444
324.8	0.1364
354.1	0.1246
382.5	0.1177

Liquid Thermal Conductivity Correlation:

$$\lambda\ [W/m\ K] = 0.241259 - 3.25090 \times 10^{-4}\ T[K]$$

%AAD = 0.6 %
%MAD = 1.2 %

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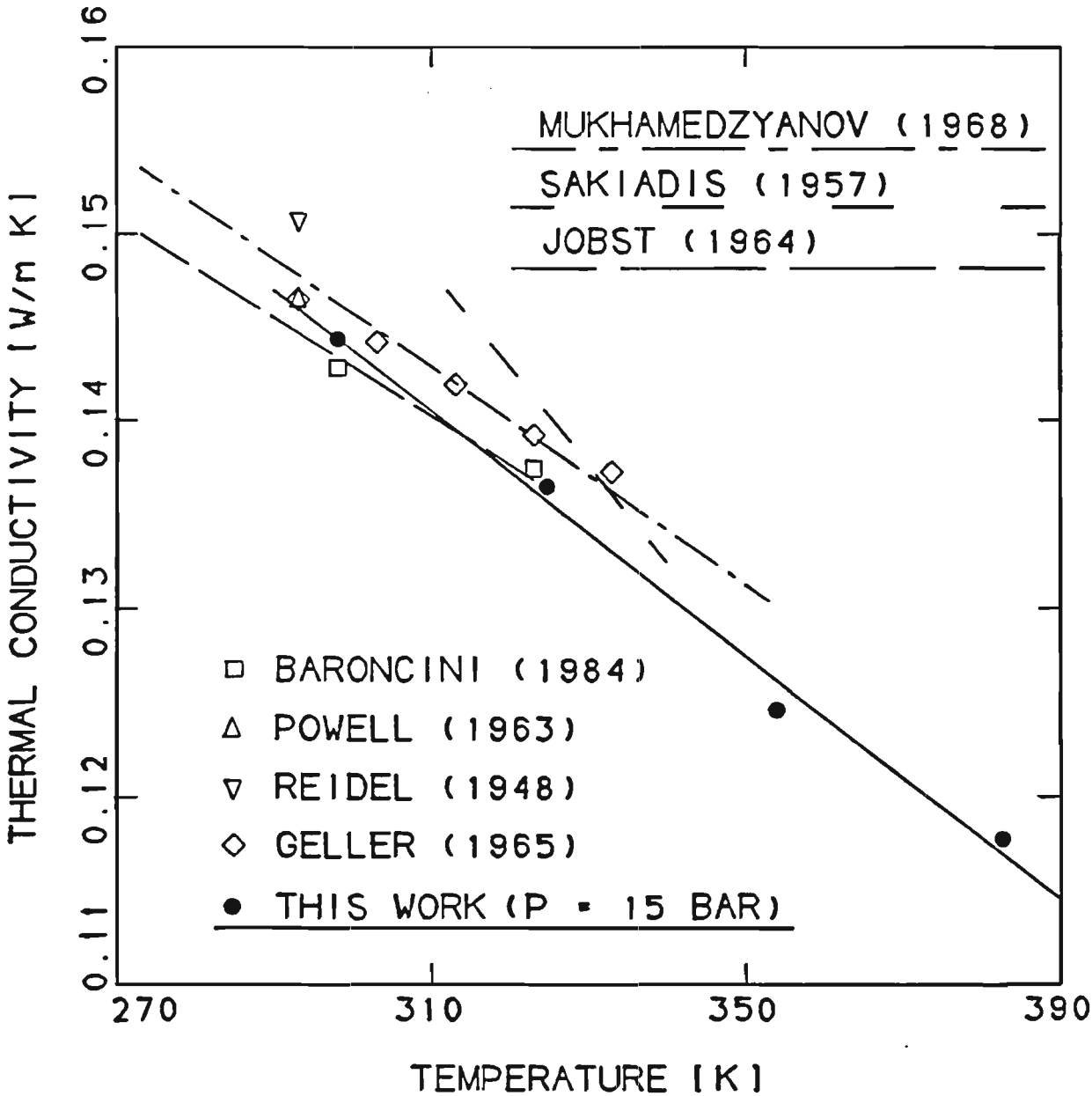
DDS-LTC-A40

THERMAL CONDUCTIVITY OF BUTANONE



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April, 1990 DDS-LTC-A41

DESIGN DATA STANDARD - LIQUID DENSITY
Tripropylene Glycol Methyl Ether
$CH_3(OC_3H_6)_3OH$

Purity =	99 %	
Molecular Weight =	206.29 kg/kmol	[1]
Critical Temperature =	740.0 K	[2]
Critical Pressure =	21.6 atm	[3]
Critical Volume =	0.663 m^3/kmol	[4]
Liquid Molar Volume =	0.21298 m^3/kmol	[5]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = 15 Bars
Accuracy = ± 2 %

T [K]	λ [W/m K]
297.6	0.1438
353.9	0.1347
381.1	0.1303
409.5	0.1250
439.0	0.1193
467.0	0.1140

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ [W/m K]} = 0.196817 - 1.76226 \times 10^{-4} \text{ T[K]}$$

%AAD = 0.3 %
%MAD = 0.5 %

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REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).
2. Fedors, R. F., "A Relationship Between Chemical Structure and the Critical Temperature", Chem. Eng. Commun., 16, 149 (1982).
3. Joback, K. G., M.S. Thesis, Mass. Inst. of Tech., Cambridge, Mass., June, 1984.
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5. Estimated from density correlation reported in DDS-LD-A26.

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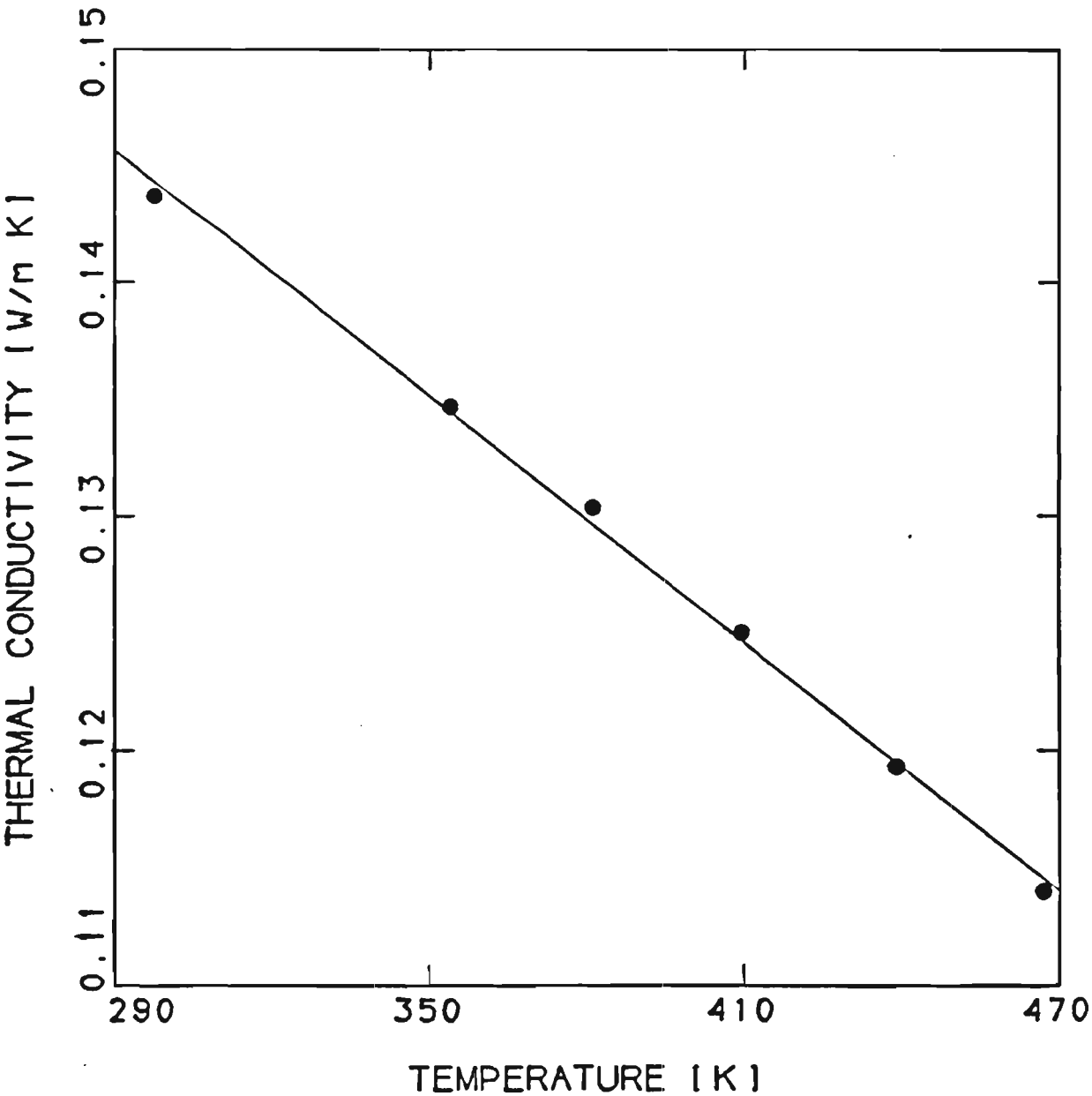
DDS-LTC-A41

THERMAL CONDUCTIVITY OF TRIPROPYLENE GLYCOL METHYL ETHER (P = 15 BAR)



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April, 1990 DDS-LTC-A42

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

2-(Isopropyl)-5-methyl Cyclohexanol; (-)-Menthol

$C_{10}H_{20}O$

Purity =	99 %	
Molecular Weight =	156.26 kg/kmol	[1]
Critical Temperature =	694.1 K	[2]
Critical Pressure =	28.5 atm	[2]
Critical Volume =	0.559 m^3/kmol	[2]
Melting Point =	229.2 K	[3]
Normal Boiling Point =	489.6 K	[3]
Liquid Molar Volume =	0.17469 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = 1 Bar
Accuracy = ± 2 %

T [K]	λ [W/m K]
345.1	0.1096
371.9	0.1073
401.2	0.1038
429.8	0.0998
459.3	0.0956

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ [W/m K]} = 0.153273 - 1.24678 \times 10^{-4} \text{ T[K]}$$

%AAD = 0.4 %
%MAD = 0.6 %

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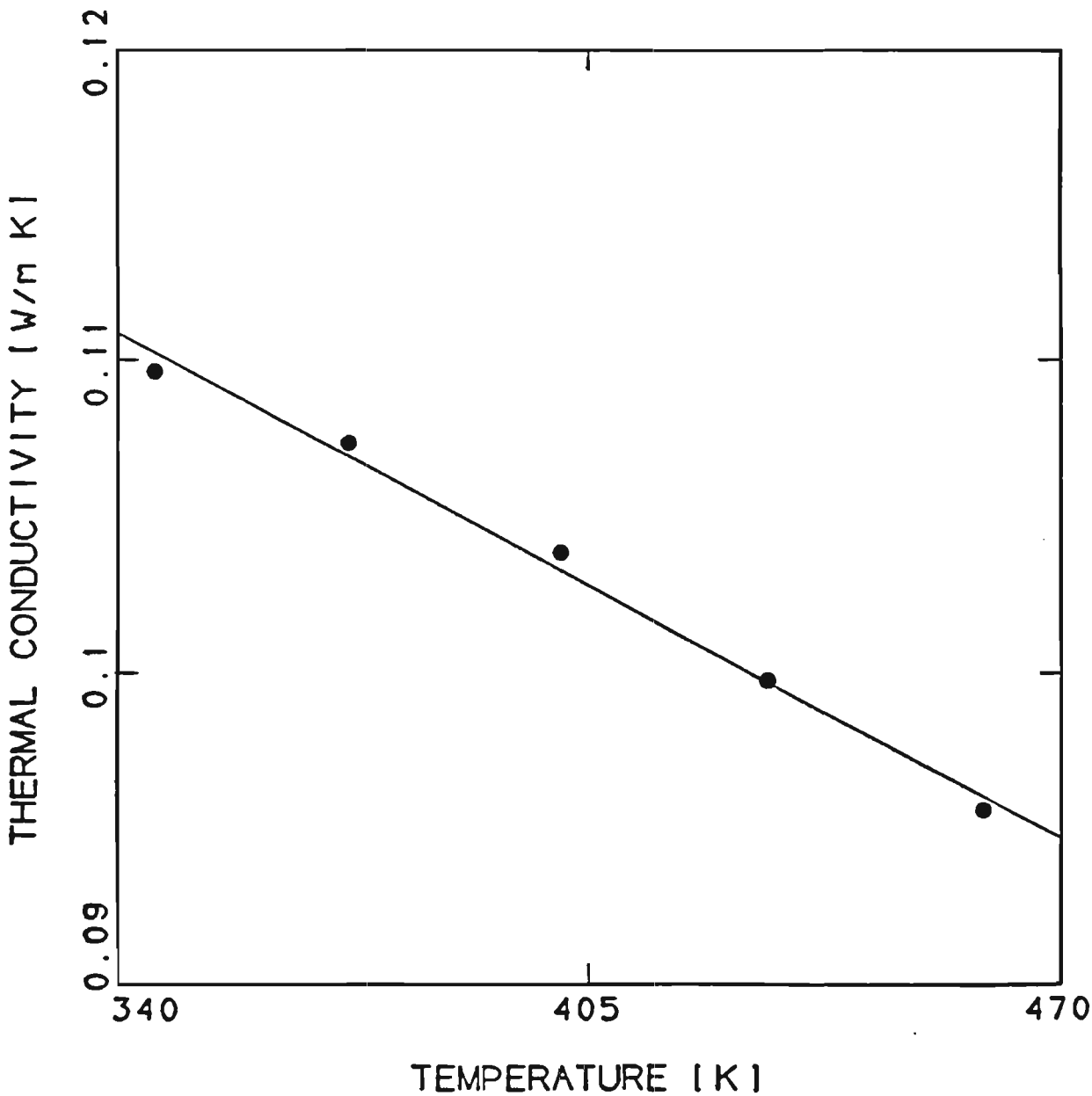
DDS-LTC-A42

THERMAL CONDUCTIVITY OF MENTHOL
(P = 1 BAR)



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3. Weast, R. C.; Grasselli, J. G., "CRC Handbook of Data on Organic Compounds", 2nd Ed., CRC Press, 1985.
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April, 1990 DDS-LTC-A43

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
38 USP White Oil - Amoco

*** No physical properties are available ***

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = 5 Bars
Accuracy = ± 2 %

T [K]	λ [W/m K]
295.6	0.1331
323.8	0.1310
355.0	0.1262
383.6	0.1232
411.3	0.1203
441.1	0.1171
465.9	0.1149

Liquid Thermal Conductivity Correlation:

$$\lambda\ [W/m\ K] = 0.165765 - 1.10084 \times 10^{-4}\ T[K]$$

%AAD = 0.3 %
%MAD = 0.6 %

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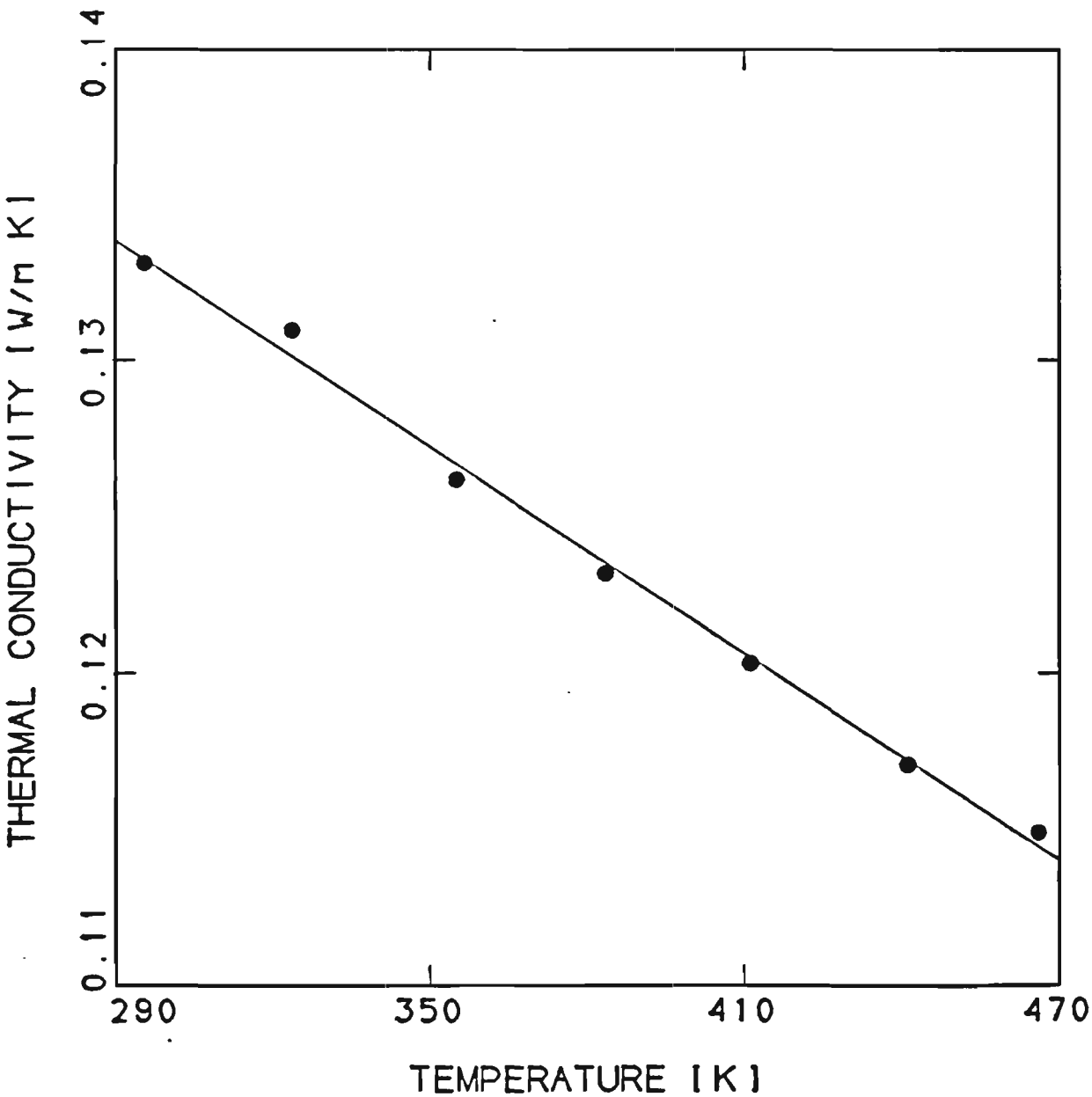
DDS-LTC-A43

THERMAL CONDUCTIVITY OF 38 USP WHITE OIL - AMOCO
(P = 5 BAR)



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April, 1990 DDS-LTC-A44

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Monoethanol Amine
$(C_2H_5O)NH_2$

Purity =	99 %	
Molecular Weight =	61.083 kg/kmol	[1]
Critical Temperature =	614.5 K	[2]
Critical Pressure =	44.1 atm	[2]
Critical Volume =	0.225 m^3/kmol	[3]
Melting Point =	283.68 K	[2]
Normal Boiling Point =	444.10 K	[2]
Liquid Molar Volume =	0.06038 m^3/kmol	[4]
Dipole Moment =	2.590 x 10^{-30} C-m	[5]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = 1 Bar (denoted by *) and 15 Bar
Accuracy = ± 2 %

T [K]	λ [W/m K]
297.8	0.2399 *
328.1	0.2357 *
356.3	0.2329 *
382.0	0.2280 *
297.9	0.2401
352.8	0.2334
383.3	0.2298
411.3	0.2262
430.4	0.2242
447.1	0.2204

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ [W/m K]} = 0.277193 - 1.25093 \times 10^{-4} \text{ T[K]}$$

%AAD = 0.2 %
%MAD = 0.6 %

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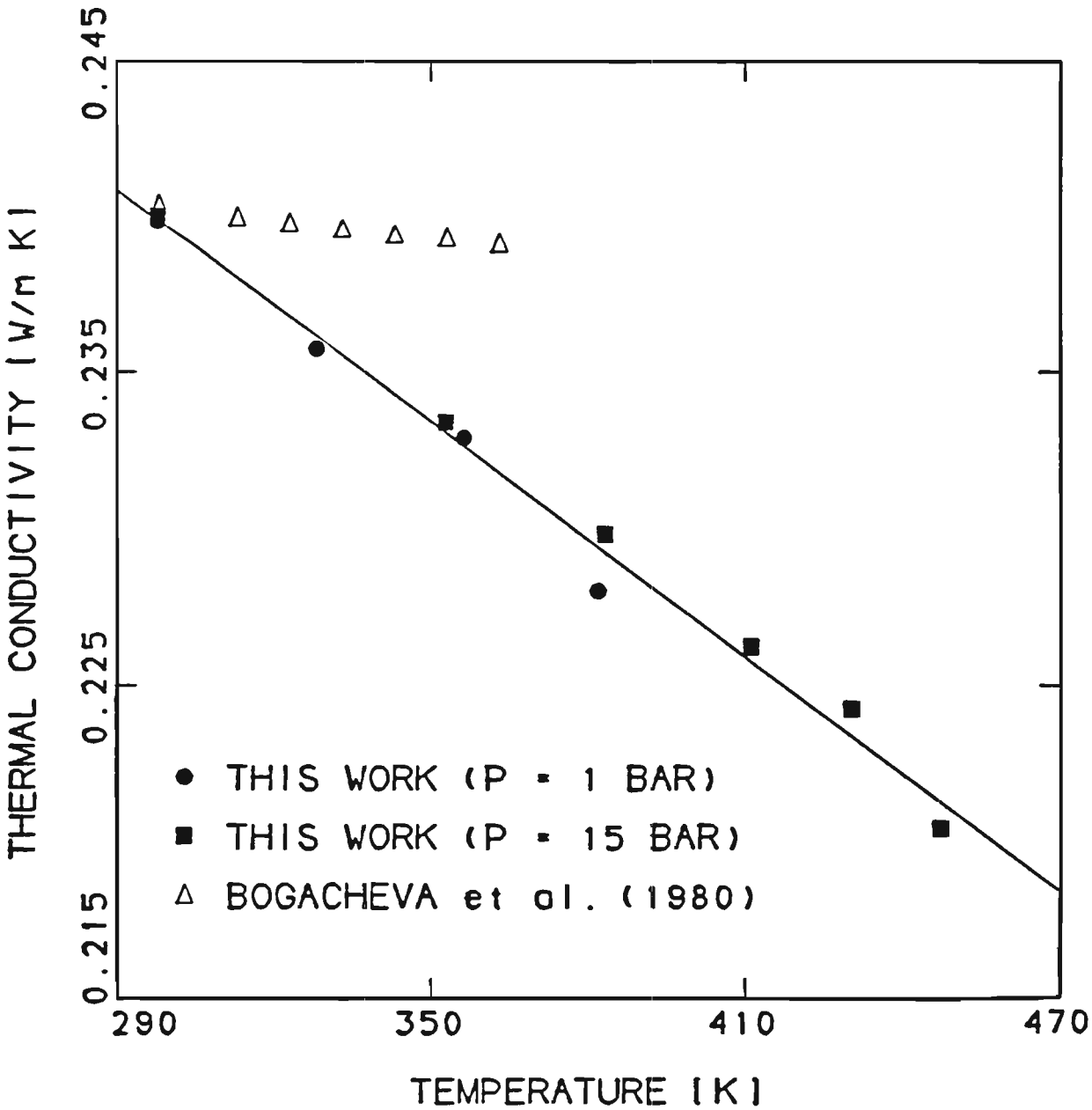
DDS-LTC-A44

THERMAL CONDUCTIVITY OF MONOETHANOLAMINE



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2. Riddick, J. A.; Bunger, W. B.; Sakano, T. E., "Organic Solvents - Physical Proeprties and Methods of Purification", Wiley Interscience, N. Y., 1986.
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4. Estimated from the density correlation reported in DDS-LD-A30.
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6. Bogacheva, I. S.; Zemdikhanov, K. B.; Mukhamedzyanov, G. Kh.; Sadykov, A. Kh.; Usmanov, A. G.,"Heat Conductivity of Mixtures of Organic Liquids", Zhurnal Fizicheskoi Khimii, 54, 1468, (1980).

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April, 1990 DDS-LTC-A45

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Diethanol Amine

$(C_2H_5O)_2NH$

Purity =	99 %	
Molecular Weight =	105.136 kg/kmol	[1]
Critical Temperature =	715.3 K	[2]
Critical Pressure =	32.3 atm	[2]
Critical Volume =	0.349 m^3/kmol	[3]
Melting Point =	301.1 K	[2]
Normal Boiling Point =	541.54 K	[2]
Liquid Molar Volume =	0.096105 m^3/kmol	[4]
Dipole Moment =	2.840 x 10^{-30} C-m	[5]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = 1 Bar
Accuracy = ± 2 %

T [K]	λ [W/m K]
295.8	0.2171
325.4	0.2159
354.8	0.2137
383.3	0.2126
412.5	0.2115
442.1	0.2080

Liquid Thermal Conductivity Correlation:

$$\lambda\ [W/m\ K] = 0.234898 - 5.89517 \times 10^{-5}\ T[K]$$

%AAD = 0.2 %
%MAD = 0.4 %

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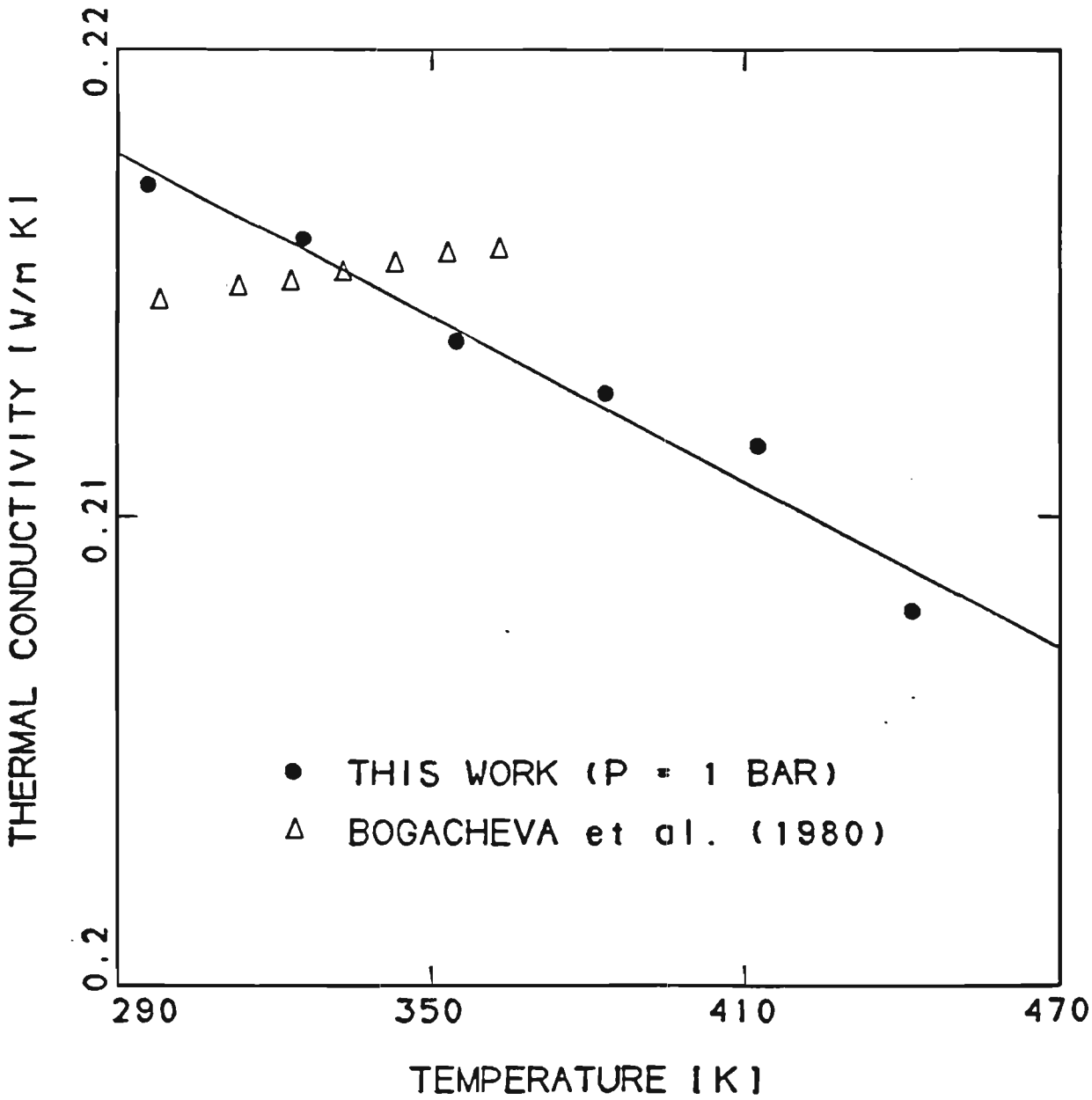
THERMAL CONDUCTIVITY OF DIETHANOLAMINE



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3. Fedors, R. F., "A Method to Estimate Critical Volumes", AIChE J., 25, 202 (1979).
4. Estimated from the density correlation reported in DDS-LD-A31.
5. AICHE DIPPR Data Compilation Manual, Daubert, T.; Danner, R. P. (Eds), 1985.
6. Bogacheva, I. S.; Zemdikhanov, K. B.; Mukhamedzyanov, G. Kh.; Sadykov, A. Kh.; Usmanov, A. G., "Heat Conductivity of Mixtures of Organic Liquids", Zhurnal Fizicheskoi Khimii, 54, 1468 (1980).

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April, 1990 DDS-LTC-A46

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY
Triethanol Amine
$(C_2H_5O)_3N$

Purity =	99 %	
Molecular Weight =	149.189 kg/kmol	[1]
Critical Temperature =	787.5 K	[2]
Critical Pressure =	24.2 atm	[2]
Critical Volume =	0.472 m^3/kmol	[3]
Melting Point =	294.72 K	[2]
Normal Boiling Point =	608.54 K	[2]
Liquid Molar Volume =	0.13311 m^3/kmol	[4]
Dipole Moment =	3.600 x 10^{-30} C-m	[5]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = 1 Bar
Accuracy = ± 2 %

T [K]	λ [W/m K]
296.8	0.1885
327.3	0.1941
356.3	0.1956
383.9	0.1983
411.6	0.2000
440.2	0.2005
466.2	0.2003

Liquid Thermal Conductivity Correlation:

$$\lambda\ [W/m\ K] = 0.0965956 + 4.65960 \times 10^{-4}\ T[K] - 5.22549 \times 10^{-7} T[K]^2$$

%AAD = 0.2 %
%MAD = 0.5 %

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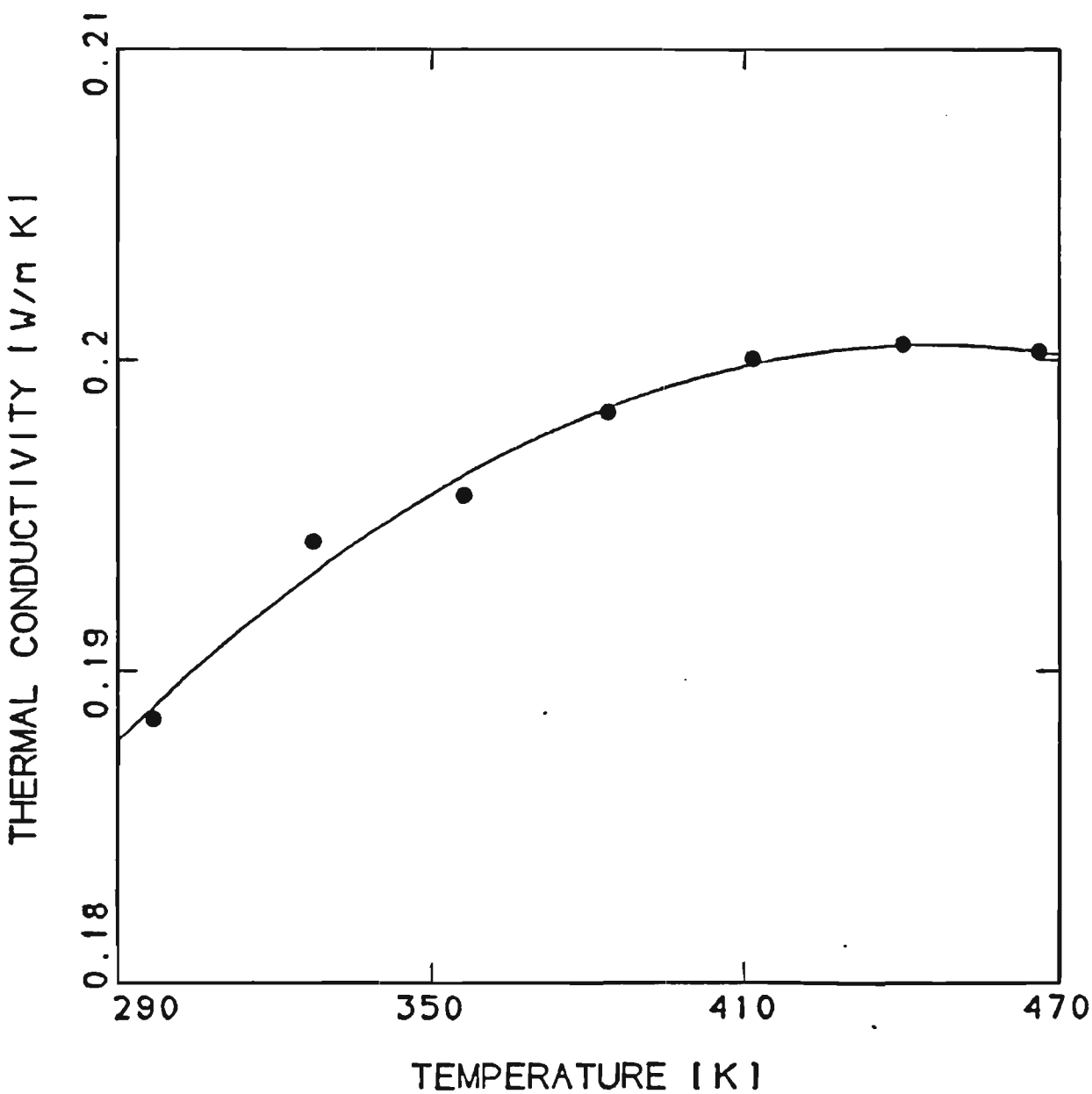
DDS-LTC-A46

THERMAL CONDUCTIVITY OF TRIETHANOLAMINE
(P = 1 BAR)



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2. Riddick, J. A.; Bunger, W. B.; Sakano, T. E., "Organic Solvents - Physical Proeprties and Methods of Purification", Wiley Interscience, N. Y., 1986.
3. Fedors, R. F., "A Method to Estimate Critical Volumes", AIChE J., 25, 202 (1979).
4. Estimated from the density correlation reported in DDS-LD-A32.
5. AICHE DIPPR Data Compilation Manual, Daubert, T.; Danner, R. P. (Eds), 1985.

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June 18, 1992

Mr. J. David Chase
President, FPRI
Hoechst- Celanese Corporation
Technical Center
P. O. Box 9077
Corpus Christi, TX 78408

Dear Dave:

Please find enclosed Design Data Sheets DDS-LTC-A56 thru 66, DDS-LD-A42 thru 52 and DDS-LV-42 thru 52 representing the results of FPRI sponsored measurements for the year July 1, 1991 to June 30,1992. I would like to take this opportunity to thank the FPRI members for sponsoring this work.

With best wishes,

Yours sincerely,

Amyn S. Teja
Regents Professor

Georgia Institute of Technology
School of Chemical Engineering
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May, 1992 DDS-LTC-A56

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

1,2 - Propanediol

$CH_3CH(OH)CH_2OH$
CA - No: 57-55-6

Purity =	99 %	
Molecular Weight =	76.095 kg/kmol	[1]
Critical Temperature =	626 K	[2]
Critical Pressure =	61.0 bar	[2]
Critical Volume =	0.239 m^3/kmol	[2]
Melting Point =	213.2 K	[2]
Normal Boiling Point =	460.8 K	[2]
Liquid Molar Volume at 25 °C =	0.073694 m^3/kmol	[2]

Experimental Technique : Relative Transient Hot-Platinum Wire

Experiment Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/mK)
299.1	195.6
313.6	195.2
332.9	194.7
352.3	194.1
371.6	193.3
391.1	191.9
411.4	189.5
430.4	186.6
450.8	183.0

Liquid Thermal Conductivity Correlation:

$$\lambda / \text{mW mK}^{-1} = 289.8242 - 0.8891881\ T/K + 2.850704 \times 10^{-3} (T/K)^2 - 3.115443 \times 10^{-6} (T/K)^3$$

% AAD = 0.1 %
% MAD = 0.2 %

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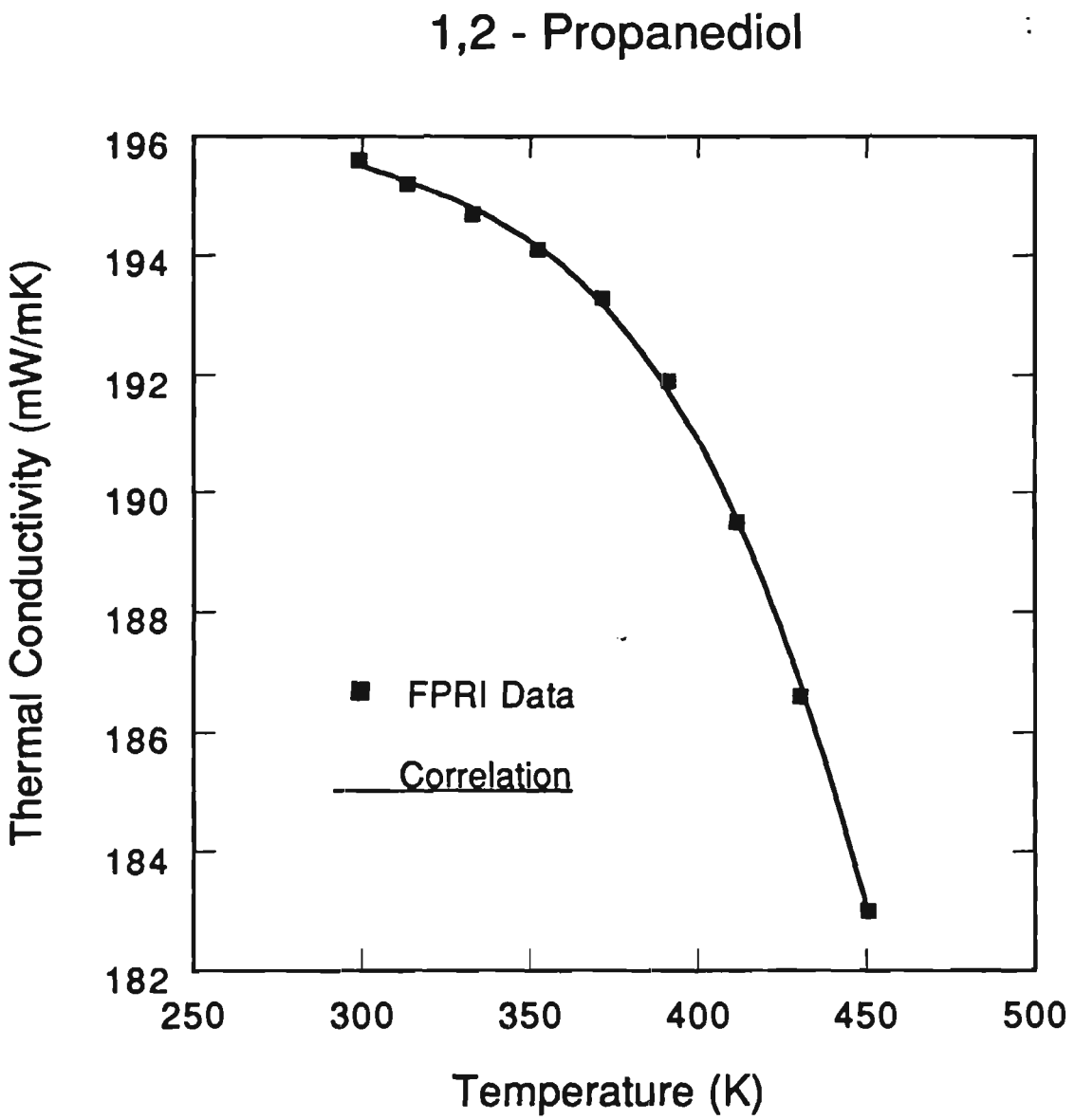
May, 1992 DDS-LTC-A56



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REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Daubert, T.E.; Danner, R.P., "Data Compilation Tables of Properties of Pure Compounds", Design Institute for Physical Property Data, American Institute of Chemical Engineers, New York, N. Y. (1985).

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May, 1992 DDS-LTC-A57

DESIGN DATA STANDARD - THERMAL CONDUCTIVITY

1,3 - Propanediol

$HO(CH_2)_3OH$
CA - No: 504-63-2

Purity =	98 %	
Molecular Weight =	76.095 kg/kmol	[1]
Critical Temperature =	658 K	[2]
Critical Pressure =	59.2 bar	[2]
Critical Volume =	0.217 m^3/kmol	[2]
Melting Point =	246.5 K	[2]
Normal Boiling Point =	487.6 K	[2]
Liquid Molar Volume at 25 °C =	0.072364 m^3/kmol	[2]

Experimental Technique : Relative Transient Hot-Platinum Wire

Experiment Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/mK)
297.6	220.0
312.6	219.5
332.2	219.5
352.3	219.3
370.9	218.8
390.9	218.0
409.8	216.3
429.6	214.2
449.3	210.8
469.7	206.1

Liquid Thermal Conductivity Correlation:

$$\lambda\ /\mathrm{mW\ mK^{-1}} = 374.3226 - 1.397478\ T/K + 4.231223 \times 10^{-3}\ (T/K)^2 - 4.297452 \times 10^{-6}\ (T/K)^3$$

% AAD = 0.1 %
% MAD = 0.1 %

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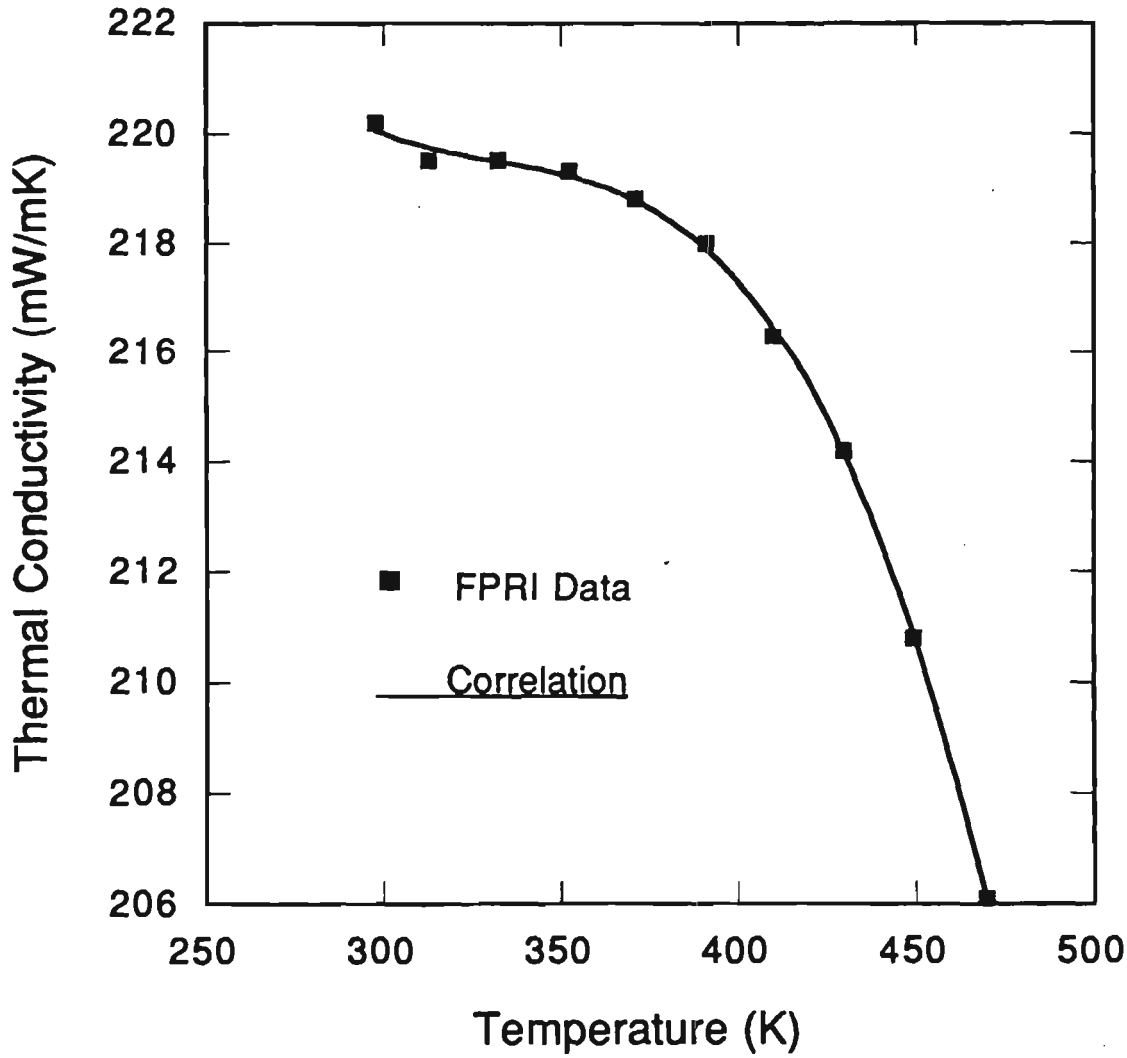
1,3 - Propanediol



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2. Daubert, T.E.; Danner, R.P., "Data Compilation Tables of Properties of Pure Compounds", Design Institute for Physical Property Data, American Institute of Chemical Engineers, New York, N. Y. (1985).

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May, 1992 DDS-LTC-A58

DESIGN DATA STANDARD - THERMAL CONDUCTIVITY

Diethylene Triamine

$H_2NCH_2CH_2NHCH_2CH_2NH_2$
CA - No: 111-40-0

Purity =	99 %	
Molecular Weight =	103.169 kg/kmol	[1]
Critical Temperature =	677.0 K	[2]
Critical Pressure =	46.0 bar	[2]
Critical Volume =	0.3525 m^3/kmol	[2]
Melting Point =	234.2 K	[3]
Normal Boiling Point =	480.1 K	[3]
Liquid Molar Volume at 25 °C =	0.10869 m^3/kmol	[3]

Experimental Technique : Relative Transient Hot-Platinum Wire

Experiment Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/mK)
298.0	216.9
312.5	216.3
333.2	213.7
352.7	210.5
372.3	206.3
390.5	202.3
410.2	194.5
429.6	190.1

Liquid Thermal Conductivity Correlation:

$$\lambda \,/\text{mW mK}^{-1} = 134.7704 + 0.615176\ T/K - 1.136199 \times 10^{-3}\ (T/K)^2$$

% AAD = 0.4 %
% MAD = 0.8 %

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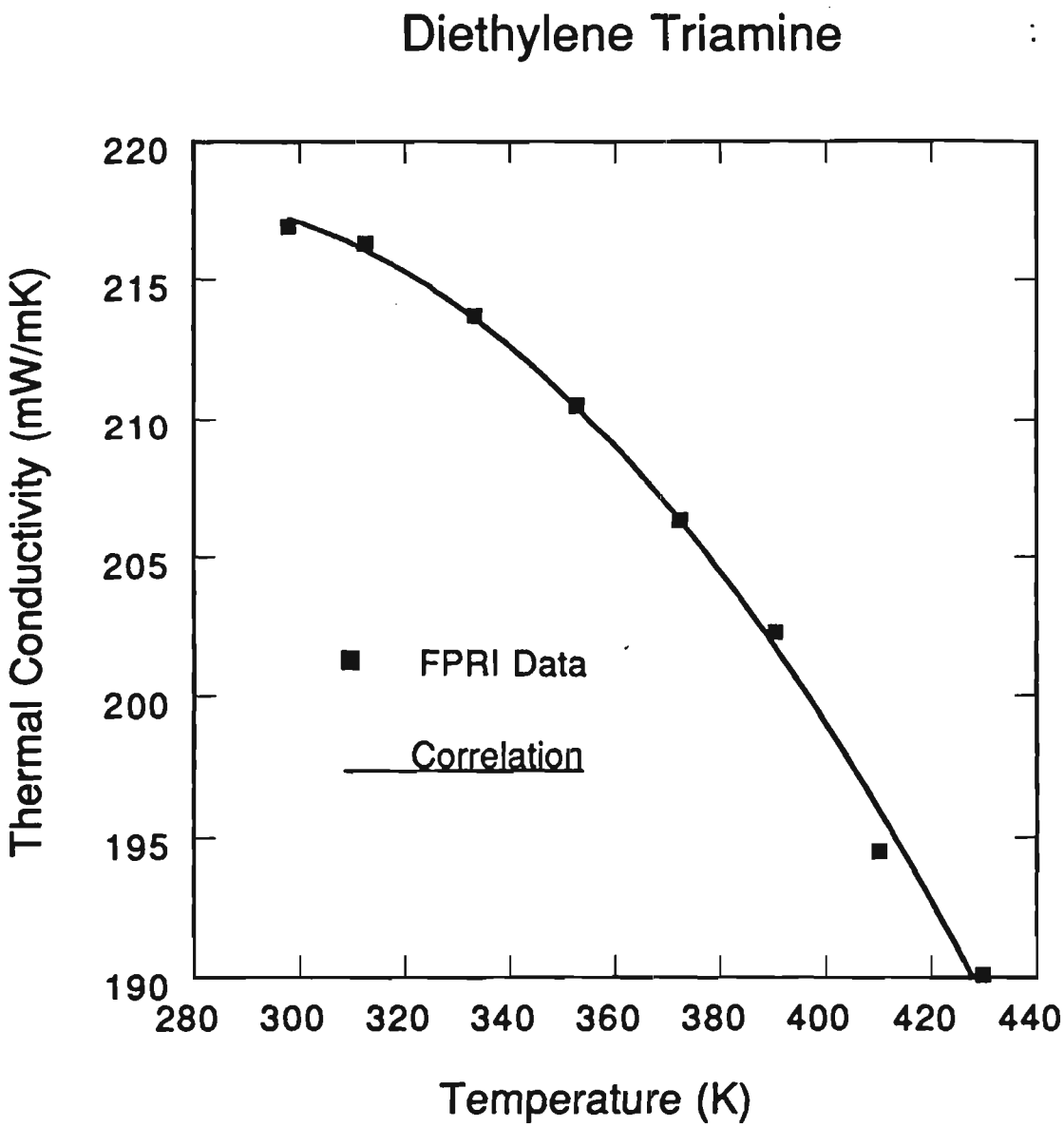

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3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1992 DDS-LTC-A59

DESIGN DATA STANDARD - THERMAL CONDUCTIVITY

Ethylene Diamine

$H_2NCH_2CH_2NH_2$
CA - No: 107-15-3

Purity =	99 %	
Molecular Weight =	60.099 kg/kmol	[1]
Critical Temperature =	593.0 K	[2]
Critical Pressure =	62.9 bar	[2]
Critical Volume =	0.206 m^3/kmol	[2]
Melting Point =	284.5 K	[2]
Normal Boiling Point =	390.1 K	[2]
Liquid Molar Volume at 25 °C =	0.06729 m^3/kmol	[2]

Experimental Technique : Relative Transient Hot-Platinum Wire

Experiment Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/mK)
292.7	255.5
305.5	252.6
332.7	244.9
353.4	237.9
371.0	231.6
381.7	226.9

Liquid Thermal Conductivity Correlation:

$$\lambda\ /\mathrm{mW\ mK^{-1}} = 223.3681 + 0.4399347\ T/K - 1.127573 \times 10^{-3}\ (T/K)^2$$

% AAD = 0.1 %
% MAD = 0.1 %

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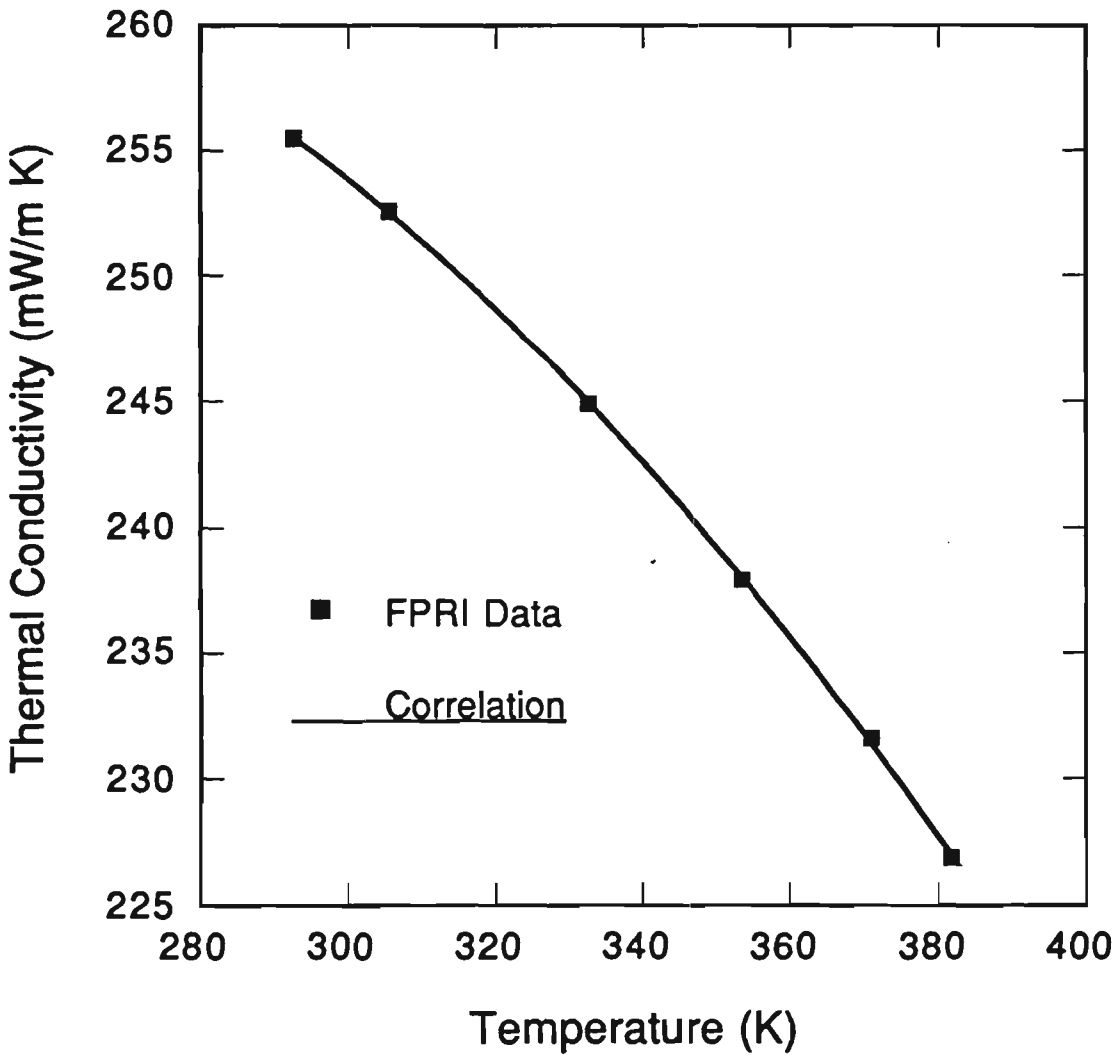
Ethylene Diamine



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2. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1992 DDS-LTC-A60

DESIGN DATA STANDARD - THERMAL CONDUCTIVITY

25 wt% Acetic Acid + 75 wt% Water

$CH_3COOH_2 + H_2O$
CA - No: 64-19-7

Properties of Acetic Acid

Purity =	99.7 %	
Molecular Weight =	60.052 kg/kmol	[1]
Critical Temperature =	592.7 K	[2]
Critical Pressure =	57.86 bar	[2]
Critical Volume =	0.1713 m^3/kmol	[2]
Melting Point =	289.81 K	[2]
Normal Boiling Point =	390.04 K	[2]

Experimental Technique : Relative Transient Hot-Wire (Mercury Filled Pyrex Capillary)

Experiment Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/mK)
298.8	470.9
307.9	478.5
311.9	483.4
322.8	491.3
333.0	499.3
343.3	506.1
350.6	509.4
352.7	511.5
372.5	510.3
371.6	531.8

Liquid Thermal Conductivity Correlation:

$$\lambda / \text{mW mK}^{-1} = 3260.269 - 28.50422\ T/K + 9.432532 \times 10^{-2} (T/K)^2 - 1.009685 \times 10^{-4} (T/K)^3$$

% AAD = 0.2 %
% MAD = 0.4 %

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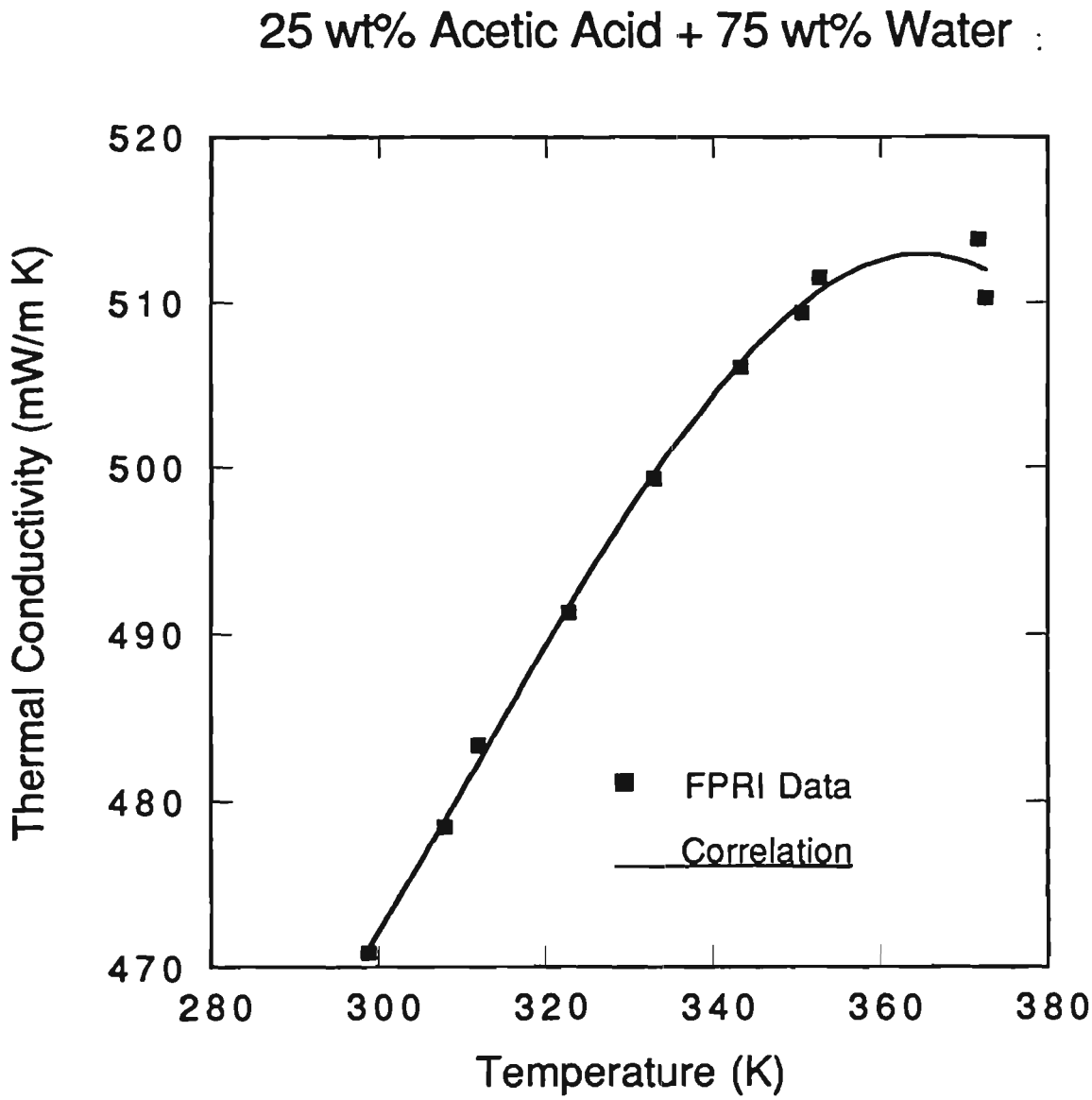

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2. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1992 DDS-LTC-A61

DESIGN DATA STANDARD - THERMAL CONDUCTIVITY

50 wt% Acetic Acid + 50 wt% Water

$CH_3COOH_2 + H_2O$
CA - No: 64-19-7

Properties of Acetic Acid

Purity =	99.7 %	
Molecular Weight =	60.052 kg/kmol	[1]
Critical Temperature =	592.7 K	[2]
Critical Pressure =	57.86 bar	[2]
Critical Volume =	0.1713 m^3/kmol	[2]
Melting Point =	289.81 K	[2]
Normal Boiling Point =	390.04 K	[2]

Experimental Technique : Relative Transient Hot-Wire (Mercury Filled Pyrex Capillary)

Experiment Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/mK)
297.5	350.7
313.5	356.7
332.5	365.9
352.1	378.5
372.6	379.2
392.7	380.7
411.9	377.0

Liquid Thermal Conductivity Correlation:

$$\lambda \,/\text{mW mK}^{-1} = -208.9798 + 3.044648\ T/K - 3.933395 \times 10^{-3}\ (T/K)^2$$

% AAD = 0.6 %
% MAD = 0.9 %

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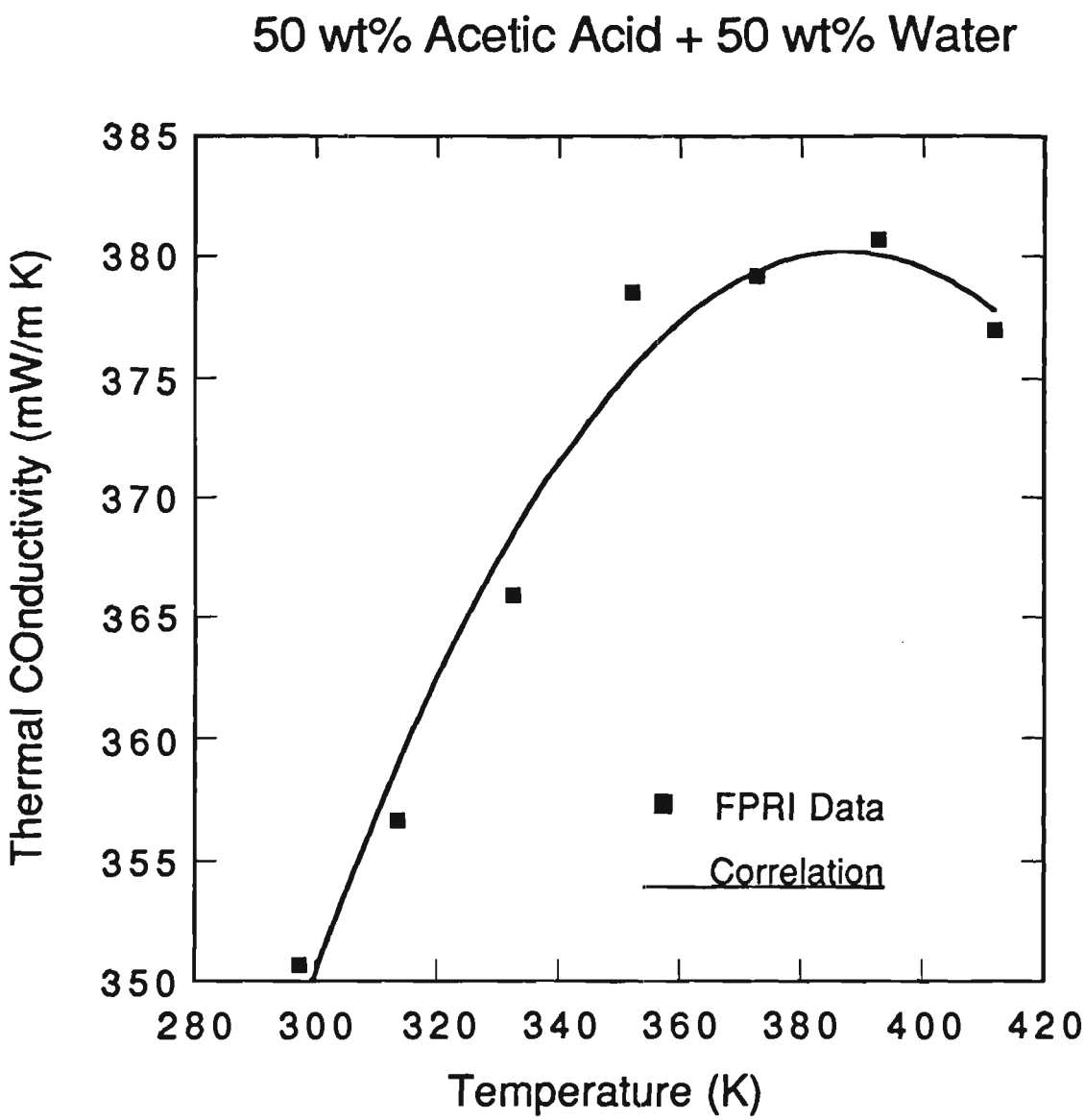

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May, 1992 DDS-LTC-A62

DESIGN DATA STANDARD - THERMAL CONDUCTIVITY

75 wt% Acetic Acid + 25 wt% Water

$CH_3COOH_2 + H_2O$
CA - No: 64-19-7

Properties of Acetic Acid

Purity =	99.7 %	
Molecular Weight =	60.052 kg/kmol	[1]
Critical Temperature =	592.7 K	[2]
Critical Pressure =	57.86 bar	[2]
Critical Volume =	0.1713 m^3/kmol	[2]
Melting Point =	289.81 K	[2]
Normal Boiling Point =	390.04 K	[2]

Experimental Technique : Relative Transient Hot-Wire (Mercury Filled Pyrex Capillary)

Experiment Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/mK)
296.3	243.2
313.2	242.6
333.4	242.4
352.9	242.2
371.8	241.0
391.5	243.4
410.4	242.3

Liquid Thermal Conductivity Correlation:

$$\lambda / \text{mW mK}^{-1} = 244.0435 - 4.537215 \times 10^{-3}\ T/K$$

% AAD = 0.3 %
% MAD = 0.6 %

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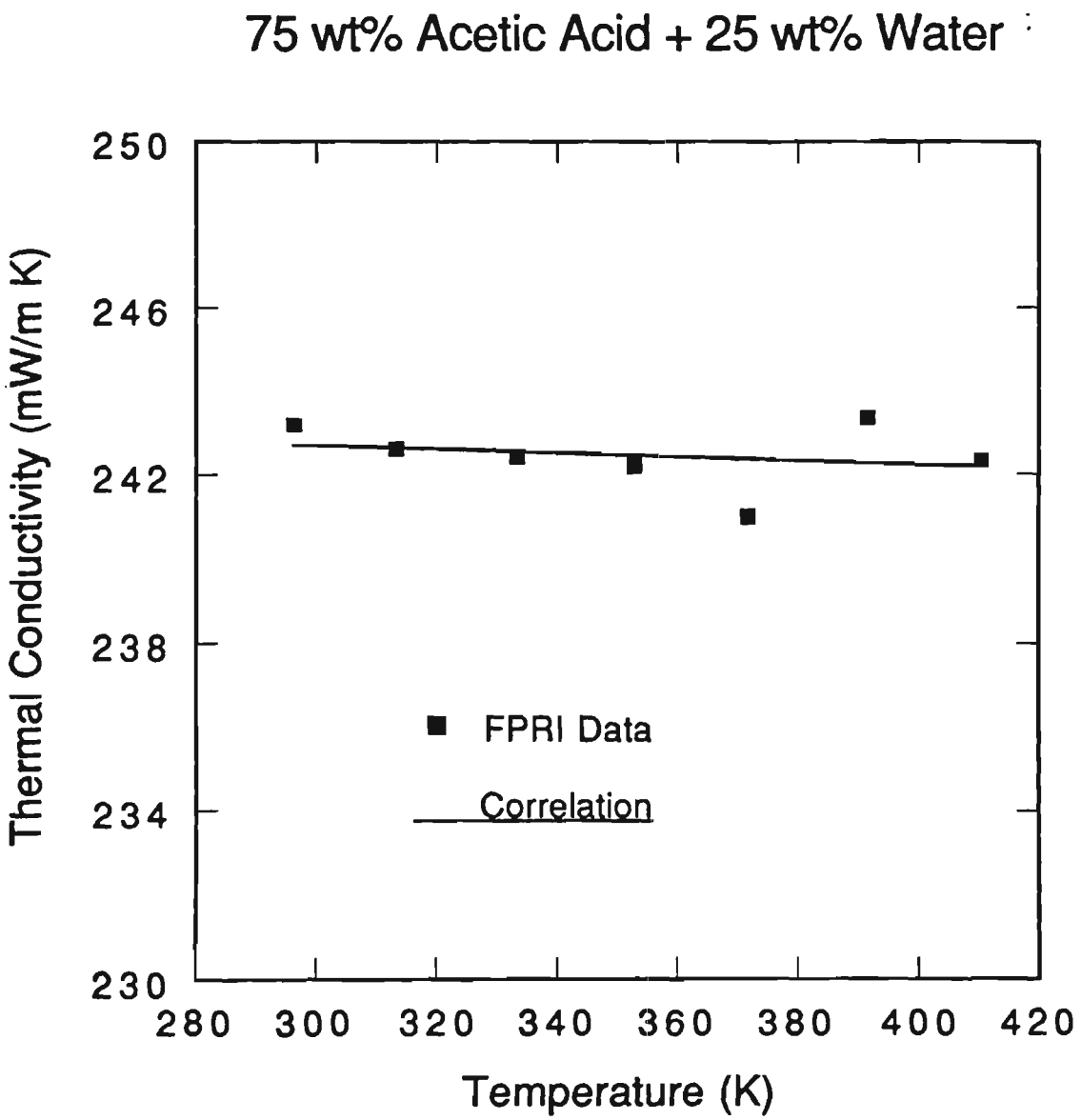

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May, 1992 DDS-LTC-A63

DESIGN DATA STANDARD - THERMAL CONDUCTIVITY

1 - Methoxy - 2 - Propanol

$CH_3CH(OH)CH_2OCH_3$
CA - No: 107-98-2

Purity =	98 %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	551 K	[2]
Critical Pressure =	43.3 bar	[2]
Critical Volume =	0.2905 m^3/kmol	[2]
Melting Point =	203 K	[2]
Normal Boiling Point =	391 K	[3]
Liquid Molar Volume at 25 °C =	0.09838 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Platinum Wire

Experiment Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/mK)
298.2	149.8
307.5	147.7
316.2	146.1
338.4	143.9
348.3	139.9
362.9	136.8
372.8	134.5
381.8	133.8

Liquid Thermal Conductivity Correlation:

$$\lambda / \text{mW mK}^{-1} = 161.265 + 0.08407036\ T/K - 4.133685 \times 10^{-4}\ (T/K)^2$$

% AAD = 0.6 %
% MAD = 1.0 %

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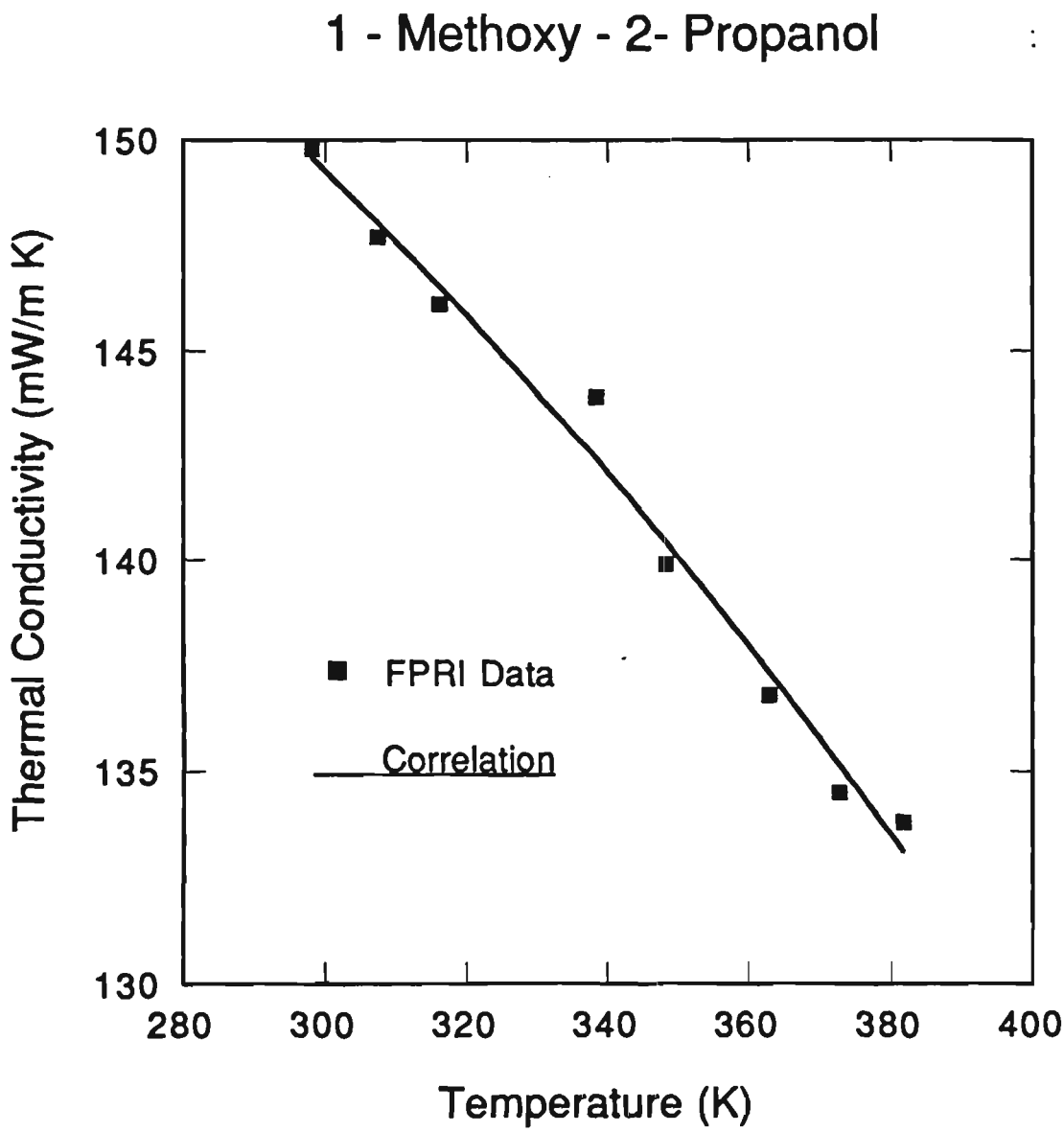

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4. Fermeglia, M.; Lapasin, R.; Torriano, G., "Excess Volumes and Viscosities of Binary Systems Containing 4 - Methyl -2- Pentanone", J. Chem. Eng. Data, 35, 260 (1990).

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May, 1992 DDS-LTC-A64

DESIGN DATA STANDARD - THERMAL CONDUCTIVITY

Dipropylene Glycol Methyl Ether

$CH_3OC_3H_6OC_3H_6OH$
CA - No: 34590-94-8

Purity =	97 %	
Molecular Weight =	148.202 kg/kmol	[1]
Critical Temperature =	658 K	[2]
Critical Pressure =	29.8 bar	[2]
Critical Volume =	0.483 m^3/kmol	[2]
Melting Point =	273 K	[2]
Normal Boiling Point =	497 K	[2]
Liquid Molar Volume at 25 °C =	0.1565 m^3/kmol	[3]

Experimental Technique : Relative Transient Hot-PlatinumWire

Experiment Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/mK)
299.3	141.2
309.7	139.7
319.9	138.0
332.9	135.9
343.2	134.2
352.9	132.2
357.9	131.9

Liquid Thermal Conductivity Correlation:

$$\lambda\ /mWmK^{-1} = 190.3693 - 0.1638678\ T/K$$

% AAD = 0.1 %
% MAD = 0.3 %

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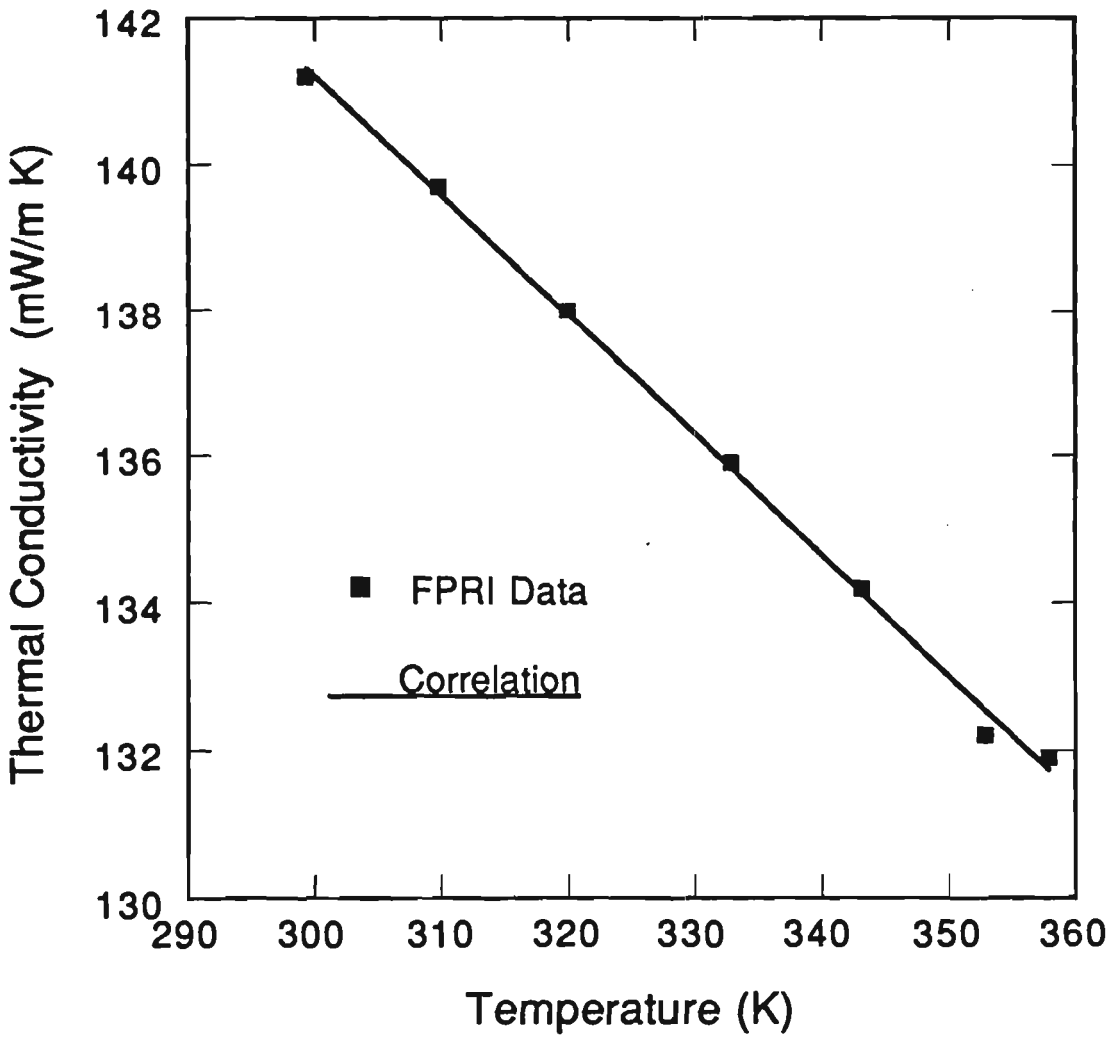
Dipropylene Glycol Methyl Ether



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3. Estimated from FPRI density correlation.

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DESIGN DATA STANDARD - THERMAL CONDUCTIVITY

Dipropylene Glycol Ether

$HOC_3H_6OC_3H_6OH$
CA - No: 110-98-5

Purity =	99 %	
Molecular Weight =	134.175 kg/kmol	[1]
Critical Temperature =	700 K	[2]
Critical Pressure =	37.8 bar	[2]
Critical Volume =	0.4275 m^3/kmol	[2]
Melting Point =	301 K	[2]
Normal Boiling Point =	543 K	[2]
Liquid Molar Volume at 25 °C =	0.1320 m^3/kmol	[3]

Experimental Technique : Relative Transient Hot-PlatinumWire

Experiment Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/mK)
298.2	156.2
309.8	156.5
316.9	156.3
347.4	156.0
363.0	155.6
377.6	155.3
391.6	154.1
405.7	152.7
420.6	150.7
435.1	148.8

Liquid Thermal Conductivity Correlation:

$$\lambda / \text{mW mK}^{-1} = 222.5137 - 0.7056745\ T/K + 2.469703 \times 10^{-3} (T/K)^2 - 2.845018 \times 10^{-6} (T/K)^3$$

% AAD = 0.1 %
% MAD = 0.2 %

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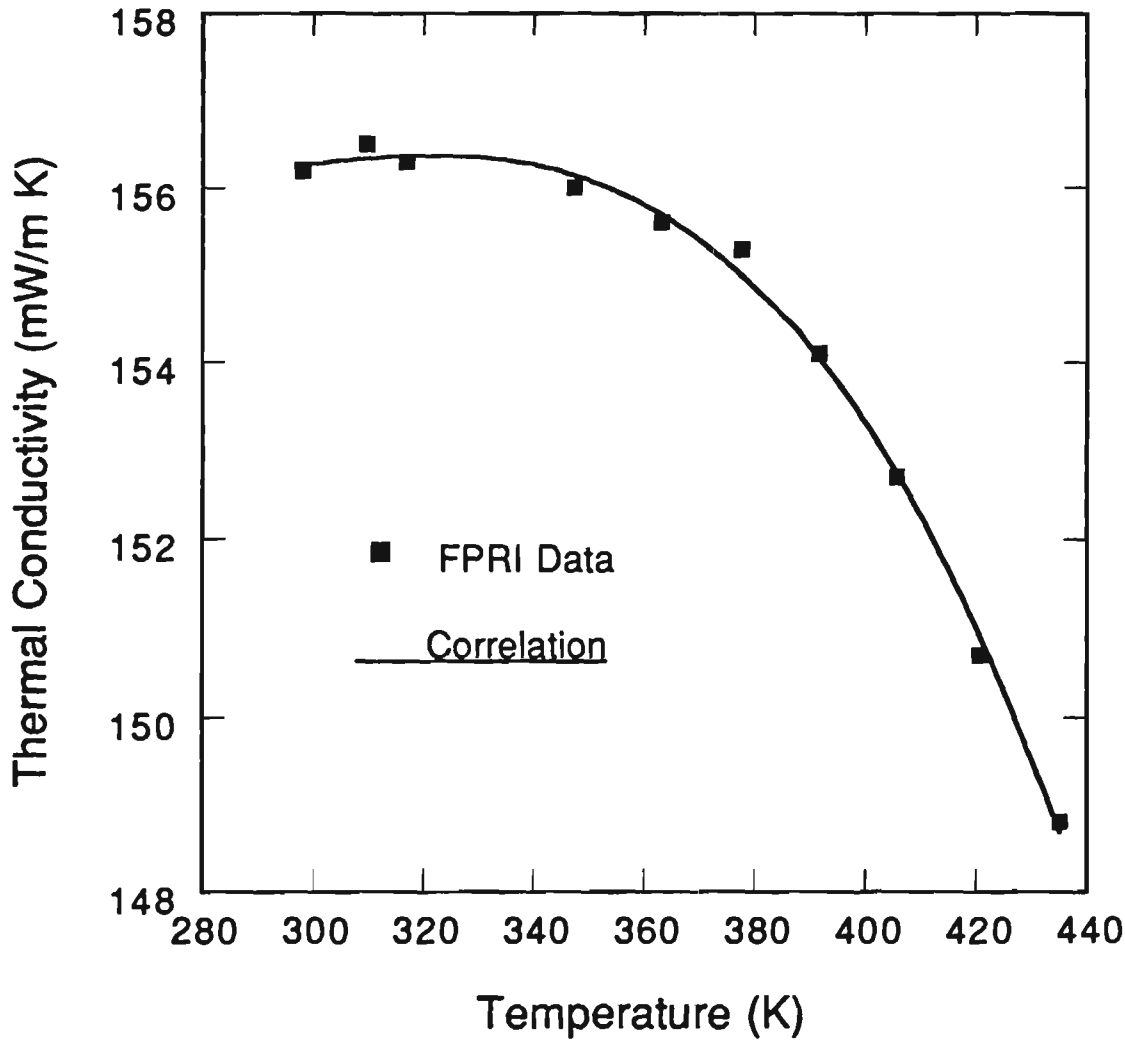
Dipropylene Glycol Ether



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3. Estimated from FPRI density correlation.

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May, 1992 DDS-LTC-A66

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Ethylene Glycol Dimethyl Ether

$CH_3OCH_2CH_2OCH_3$
CA - No: 110-71-4

Purity =	99.9 %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	536 K	[2]
Critical Pressure =	38.7 bar	[2]
Critical Volume =	0.271 m^3/kmol	[2]
Melting Point =	204 K	[2]
Normal Boiling Point =	357.7 K	[2]
Liquid Molar Volume at 25 °C =	0.10434 m^3/kmol	[2]

Experimental Technique : Relative Transient Hot-PlatinumWire

Experiment Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/mK)
299.3	146.7
308.1	143.4
312.2	142.0
314.6	141.3
323.2	137.5
333.4	133.6
343.7	129.9
351.2	127.2

Liquid Thermal Conductivity Correlation:

$$\lambda / \text{mW mK}^{-1} = 260.5505 - 0.380092\ T/K$$

% AAD = 0.1 %
% MAD = 0.2 %

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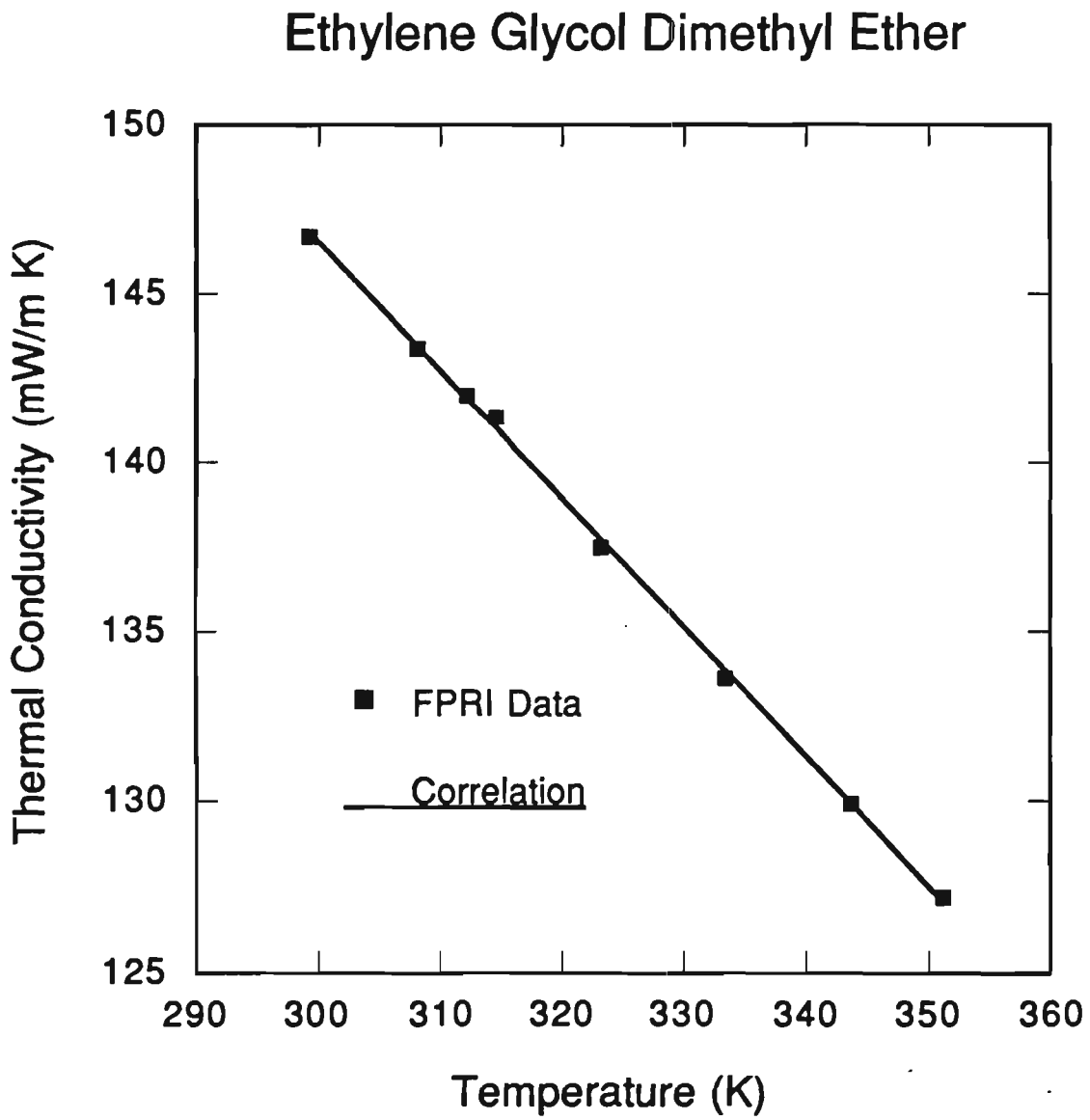

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May, 1992 DDS-LD-A42

DESIGN DATA STANDARD - LIQUID DENSITY

1,2 - Propanediol

$CH_3CH(OH)CH_2OH$
CA - No: 57-55-6

Purity =	99 %	
Molecular Weight =	76.095 kg/kmol	[1]
Critical Temperature =	626 K	[2]
Critical Pressure =	61.0 bar	[2]
Critical Volume =	0.239 m^3/kmol	[2]
Melting Point =	213.2 K	[2]
Normal Boiling Point =	460.8 K	[2]
Liquid Molar Volume at 25 °C =	0.073694 m^3/kmol	[2]

Experimental Technique : High Pressure Pycnometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
298.85	1032.7
318.05	1018.3
339.00	1002.8
359.40	986.1
380.95	967.6
399.60	951.2
420.20	931.7
440.35	912.2

Liquid Density Correlation:

$$\rho / \mathrm{kgm^{-3}} = 82.94257 / 0.2615256^{[1+(1-T/K/626)^{0.1964304}]}$$

% AAD = 0.02 %
% MAD = 0.05 %

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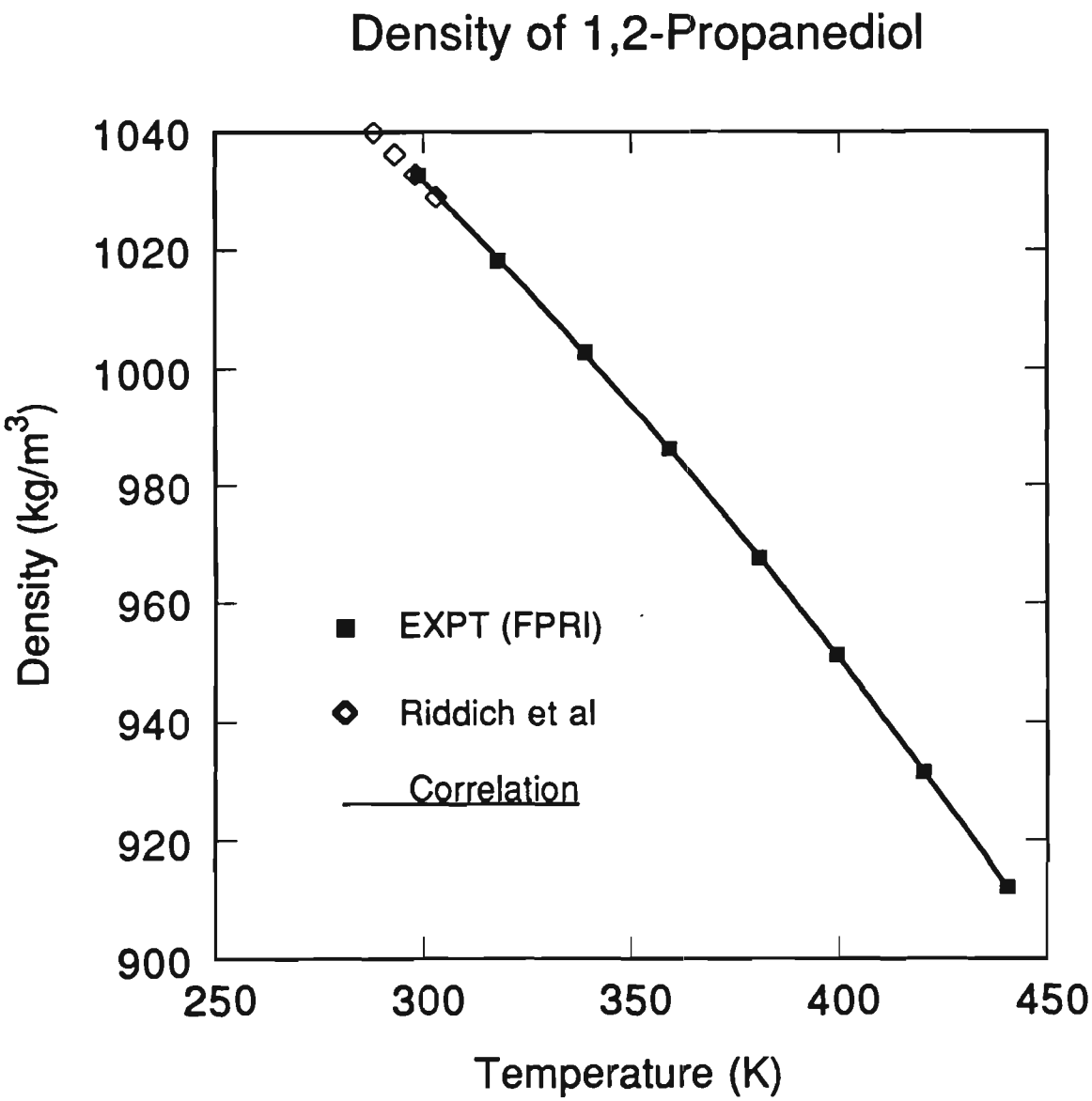

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May, 1992 DDS-LD-A43

DESIGN DATA STANDARD - LIQUID DENSITY

1,3 - Propanediol

$HO(CH_2)_3OH$
CA - No: 504-63-2

Purity =	98 %	
Molecular Weight =	76.095 kg/kmol	[1]
Critical Temperature =	658 K	[2]
Critical Pressure =	59.2 bar	[2]
Critical Volume =	0.217 m^3/kmol	[2]
Melting Point =	246.5 K	[2]
Normal Boiling Point =	487.6 K	[2]
Liquid Molar Volume at 25 °C =	0.072364 m^3/kmol	[2]

Experimental Technique : High Pressure Pycnometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
298.95	1049.6
318.55	1035.6
339.45	1022.7
360.20	1009.0
381.65	994.5
399.95	981.1
421.60	965.2
440.60	949.5
460.25	931.9

Liquid Density Correlation:

$$\rho / \mathrm{kgm^{-3}} = 82.52718 / 0.2626006^{[1+(1-T/K/658)^{0.1718759}]}$$

% AAD = 0.04 %
% MAD = 0.07 %

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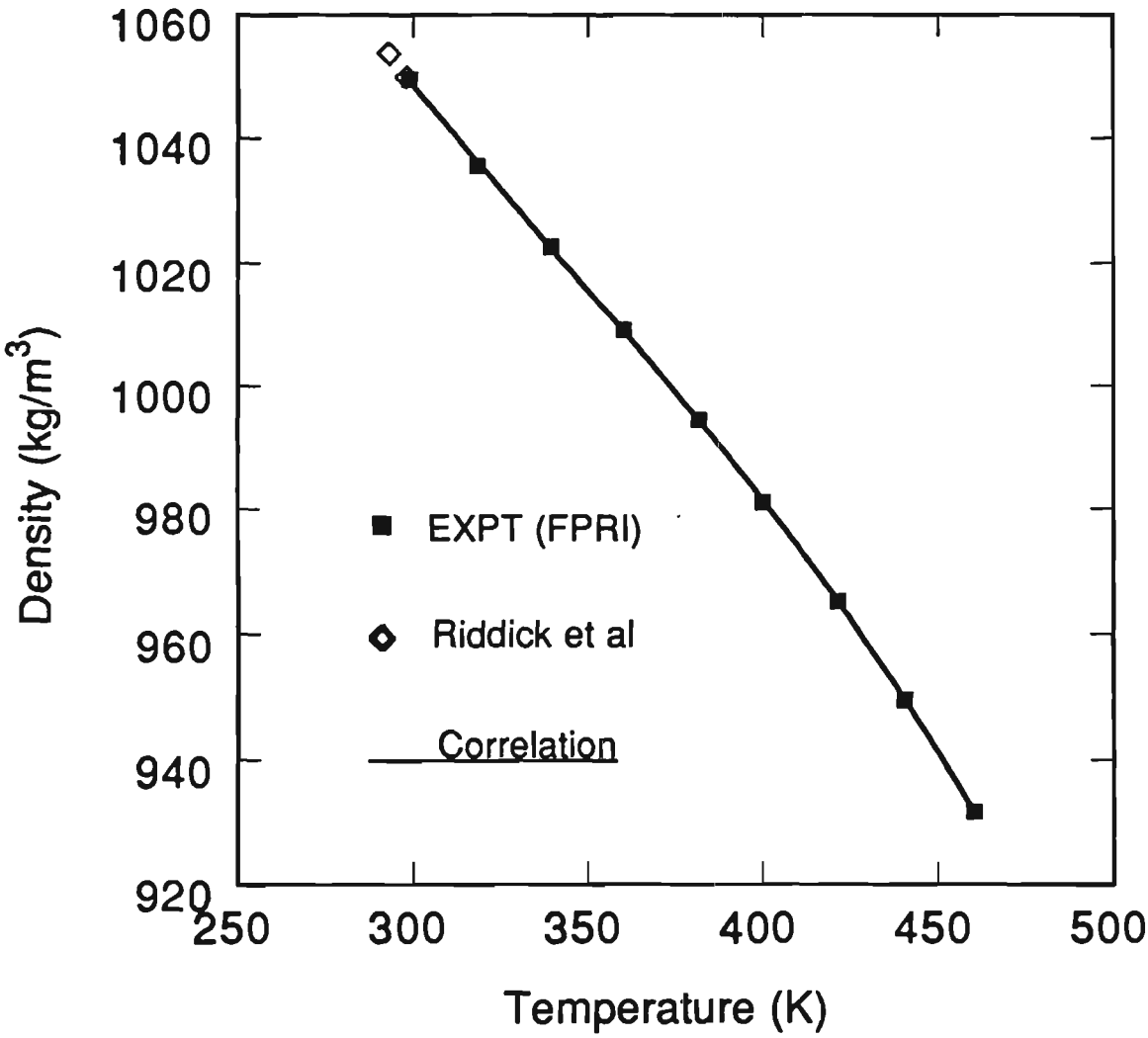
Density of 1,3-Propanediol



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May, 1992 DDS-LD-A44

DESIGN DATA STANDARD - LIQUID DENSITY

Diethylene Triamine

$H_2NCH_2CH_2NHCH_2CH_2NH_2$
CA - No: 111-40-0

Purity =	99 %	
Molecular Weight =	103.169 kg/kmol	[1]
Critical Temperature =	677.0 K	[2]
Critical Pressure =	46.0 bar	[2]
Critical Volume =	0.3525 m^3/kmol	[2]
Melting Point =	234.2 K	[3]
Normal Boiling Point =	480.1 K	[3]
Liquid Molar Volume at 25 °C =	0.10869 m^3/kmol	[3]

Experimental Technique : High Pressure Pycnometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
301.85	948.1
318.25	935.0
338.55	918.0
359.65	904.1
381.25	886.0
400.00	870.5
420.65	851.1
440.15	834.0
459.55	817.0

Liquid Density Correlation:

$$\rho / \mathrm{kgm}^{-3} = 93.29919 / 0.2855743^{[1+(1-T/K/677)^{0.2760789}]}$$

% AAD = 0.08 %
% MAD = 0.18 %

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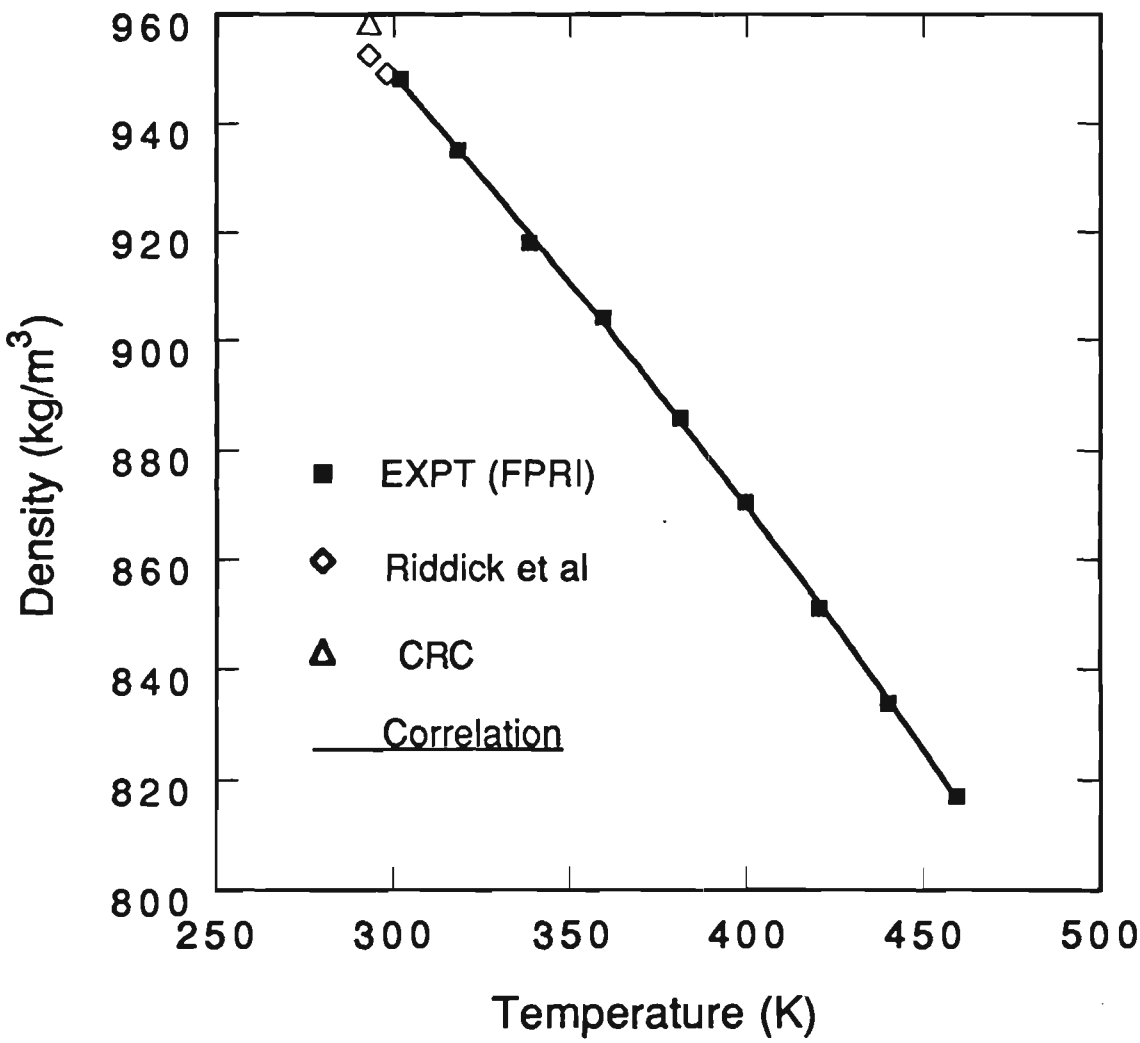
Density of Diethylene Triamine



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May, 1992 DDS-LD-A45

DESIGN DATA STANDARD - LIQUID DENSITY

Ethylene Diamine

$H_2NCH_2CH_2NH_2$
CA - No: 107-15-3

Purity =	99 %	
Molecular Weight =	60.099 kg/kmol	[1]
Critical Temperature =	593.0 K	[2]
Critical Pressure =	62.9 bar	[2]
Critical Volume =	0.206 m^3/kmol	[2]
Melting Point =	284.5 K	[2]
Normal Boiling Point =	390.1 K	[2]
Liquid Molar Volume at 25 °C =	0.06729 m^3/kmol	[2]

Experimental Technique : High Pressure Pycnometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
299.25	892.3
309.05	883.5
319.85	874.0
331.40	863.2
342.15	853.5
353.55	843.0
366.55	830.6
377.05	821.3
388.25	810.4

Liquid Density Correlation:

$$\rho / \mathrm{kgm}^{-3} = 69.69922 / 0.2513052^{[1+(1-T/K/593)^{0.2387593}]}$$

% AAD = 0.05 %
% MAD = 0.08 %

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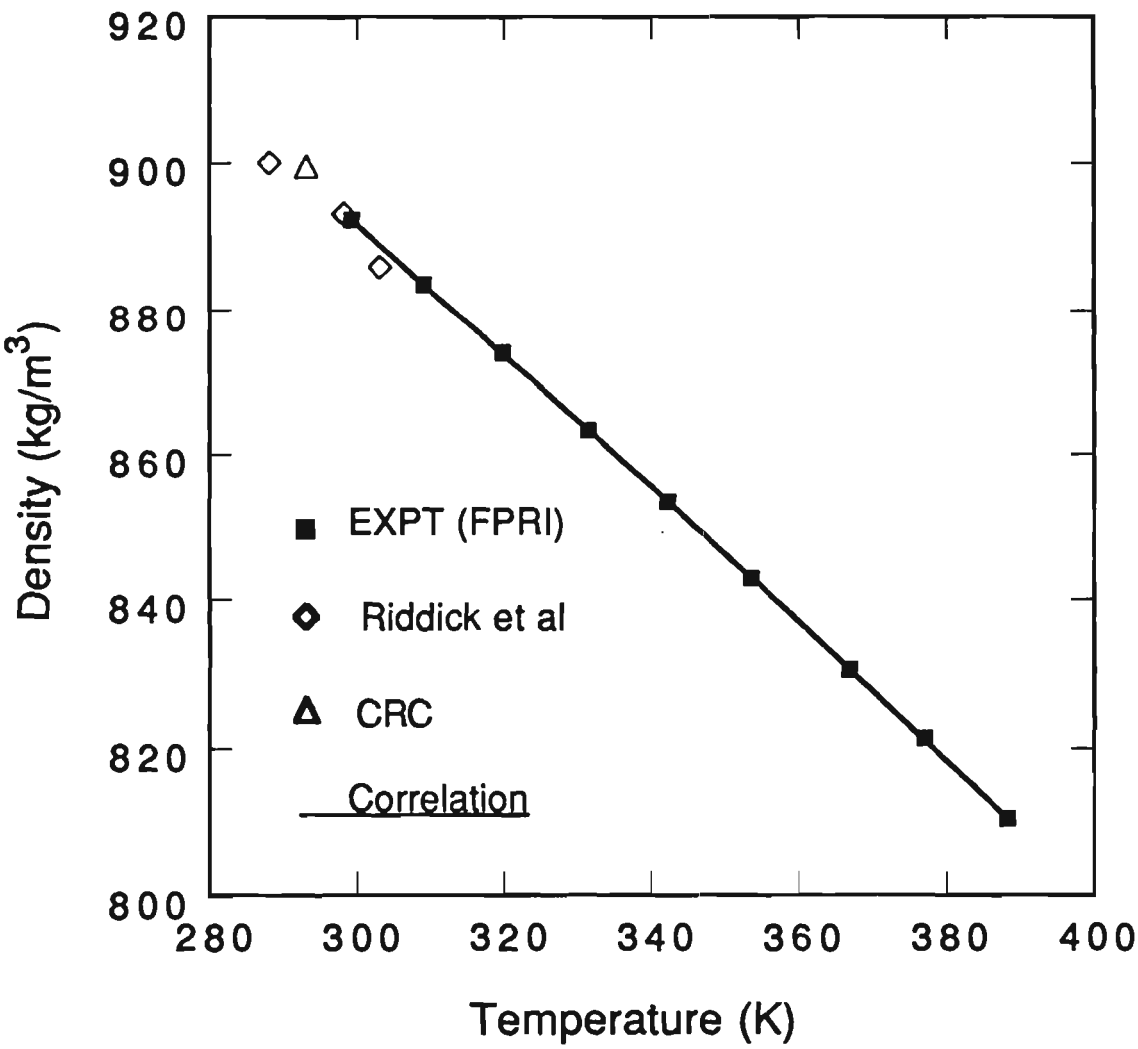
May, 1992 DDS-LD-A45

Density of Ethylene Diamine



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May, 1992 DDS-LD-A46

DESIGN DATA STANDARD - LIQUID DENSITY

25 wt% Acetic Acid + 75 wt% Water

$CH_3COOH_2 + H_2O$
CA - No: 64-19-7

Properties of Acetic Acid

Purity =	99.7 %	
Molecular Weight =	60.052 kg/kmol	[1]
Critical Temperature =	592.7 K	[2]
Critical Pressure =	57.86 bar	[2]
Critical Volume =	0.1713 m^3/kmol	[2]
Melting Point =	289.81 K	[2]
Normal Boiling Point =	390.04 K	[2]

Experimental Technique : High Pressure Pycnometer

Experiment Data:

Pressure = Saturated
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
297.80	1028.3
306.05	1023.7
314.30	1018.0
322.55	1012.7
330.85	1007.2
339.15	1000.3
347.35	994.1
355.85	987.1
364.35	980.0
372.90	973.3
388.85	960.1
409.15	942.4
427.55	927.4
445.65	910.8
463.75	894.9

Liquid Density Correlation:

$$\rho\ /\mathrm{Kg\ m^{-3}} = 899.5884 + 1.934467\ T/K - 6.561255 \times 10^{-3}\ (T/K)^2 + 5.109236 \times 10^{-6}\ (T/K)^3$$

% AAD = 0.05 %
% MAD = 0.09 %

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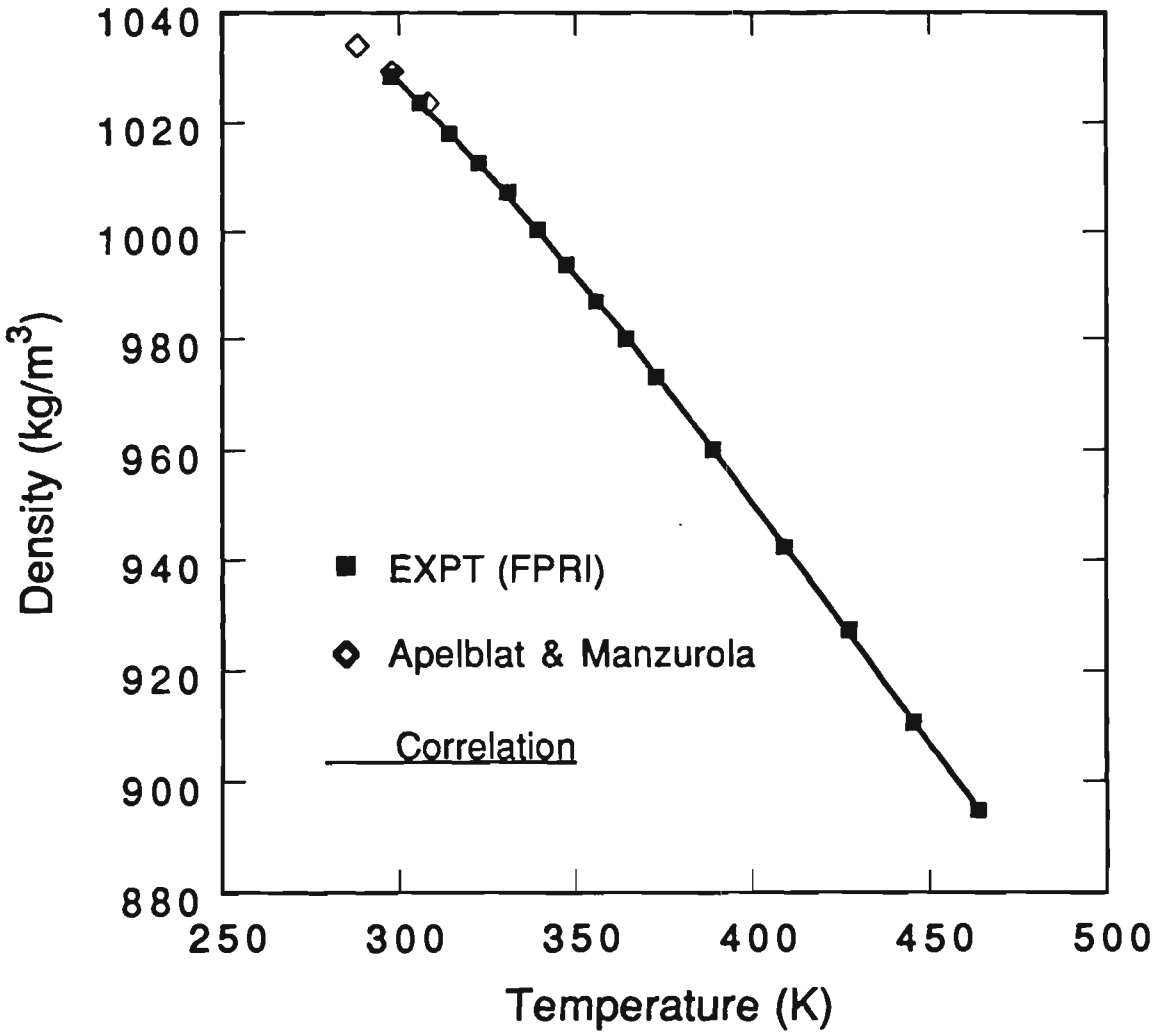
25 wt% Acetic Acid + 75 wt% Water



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3. Apelblat, A.; Manzurola, E., "Excess Molar Volumes of Formic Acid + Water, Acetic Acid + Water and Propionic Acid + Water Systems at 288.15, 298.15 and 308.15 K", Fluid Phase Equilibria, 32 , 163 (1987).

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May, 1992 DDS-LD-A47

DESIGN DATA STANDARD - LIQUID DENSITY

50 wt% Acetic Acid + 50 wt% Water

$CH_3COOH_2 + H_2O$
CA - No: 64-19-7

Properties of Acetic Acid

Purity =	99.7 %	
Molecular Weight =	60.052 kg/kmol	[1]
Critical Temperature =	592.7 K	[2]
Critical Pressure =	57.86 bar	[2]
Critical Volume =	0.1713 m^3/kmol	[2]
Melting Point =	289.81 K	[2]
Normal Boiling Point =	390.04 K	[2]

Experimental Technique : High Pressure Pycnometer

Experiment Data:

Pressure = Saturated
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
301.90	1051.1
311.65	1042.5
321.35	1034.3
330.45	1026.7
339.45	1019.0
348.85	1012.3
358.05	1003.7
366.85	994.6
375.05	987.5
394.80	968.9
411.75	951.2
430.15	933.1
447.75	916.1
461.75	900.4

Liquid Density Correlation:

$$\rho / Kg\ m^{-3} = 1141.377 + 0.3083773\ T/K - 2.436812 \times 10^{-3} (T/K)^2 + 1.385781 \times 10^{-6} (T/K)^3$$

% AAD = 0.07 %
% MAD = 0.11 %

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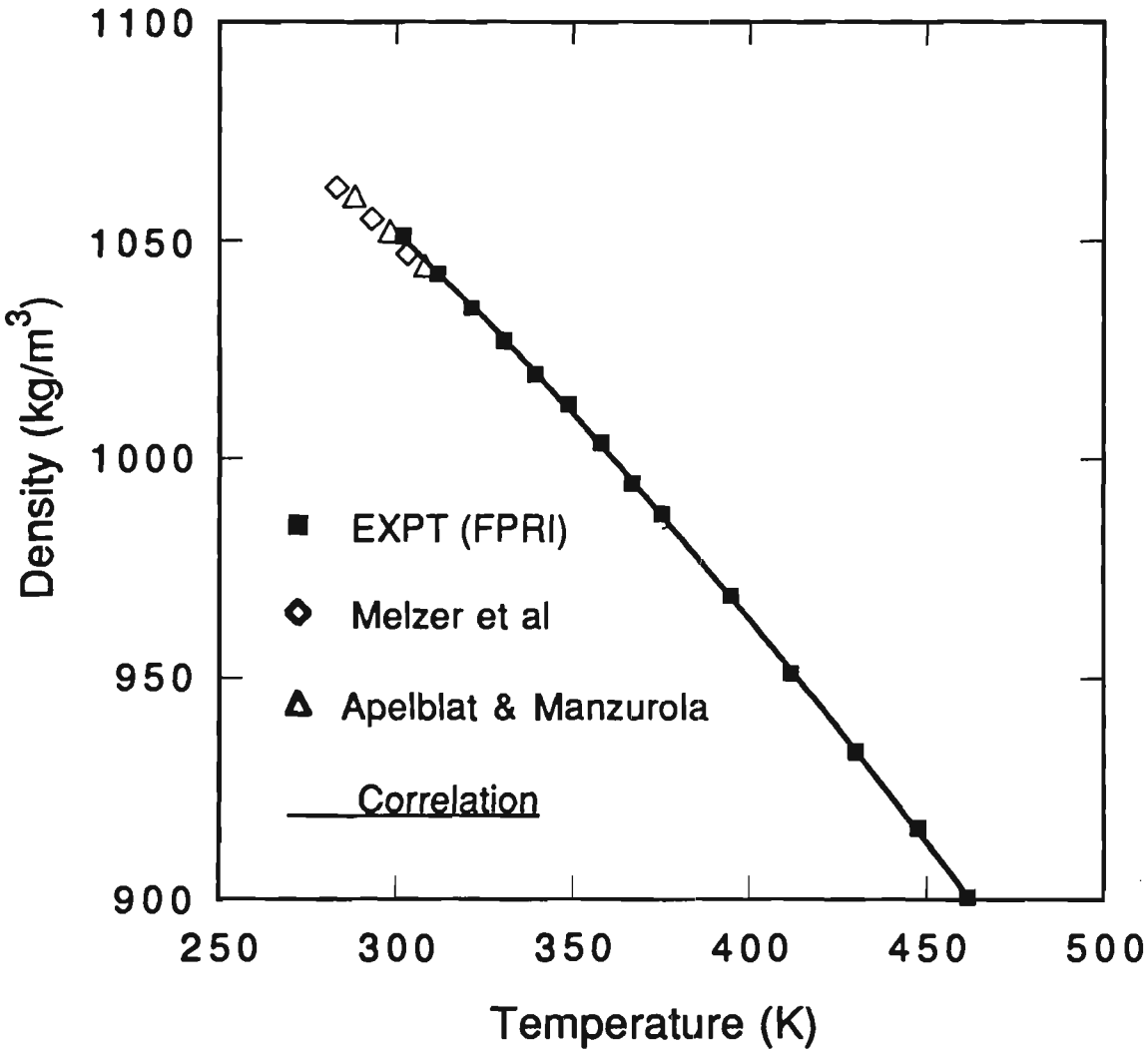
50 wt% Acetic Acid + 50 wt% Water



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4. Apelblat, A.; Manzurola, E., "Excess Molar Volumes of Formic Acid + Water, Acetic Acid + Water and Propionic Acid + Water Systems at 288.15, 298.15 and 308.15 K", Fluid Phase Equilibria, 32 , 163 (1987).

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May, 1992 DDS-LD-A48

DESIGN DATA STANDARD - LIQUID DENSITY

75 wt% Acetic Acid + 25 wt% Water

$CH_3COOH_2 + H_2O$
CA - No: 64-19-7

Properties of Acetic Acid

Purity =	99.7 %	
Molecular Weight =	60.052 kg/kmol	[1]
Critical Temperature =	592.7 K	[2]
Critical Pressure =	57.86 bar	[2]
Critical Volume =	0.1713 m^3/kmol	[2]
Melting Point =	289.81 K	[2]
Normal Boiling Point =	390.04 K	[2]

Experimental Technique : High Pressure Pycnometer

Experiment Data:

Pressure = Saturated
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
302.75	1059.3
311.65	1051.4
321.40	1042.5
330.65	1031.3
339.55	1022.3
348.95	1013.4
358.55	1003.4
366.70	994.4
378.70	981.7
400.15	960.7
421.95	938.4
444.60	916.7
462.70	898.2

Liquid Density Correlation:

$$\rho\ /\mathrm{Kg\ m^{-3}} = 1240.742 + 0.05782883\ T/K - 2.995144 \times 10^{-3}\ (T/K)^2 + 2.749512 \times 10^{-6}\ (T/K)^3$$

% AAD = 0.07 %
% MAD = 0.13 %

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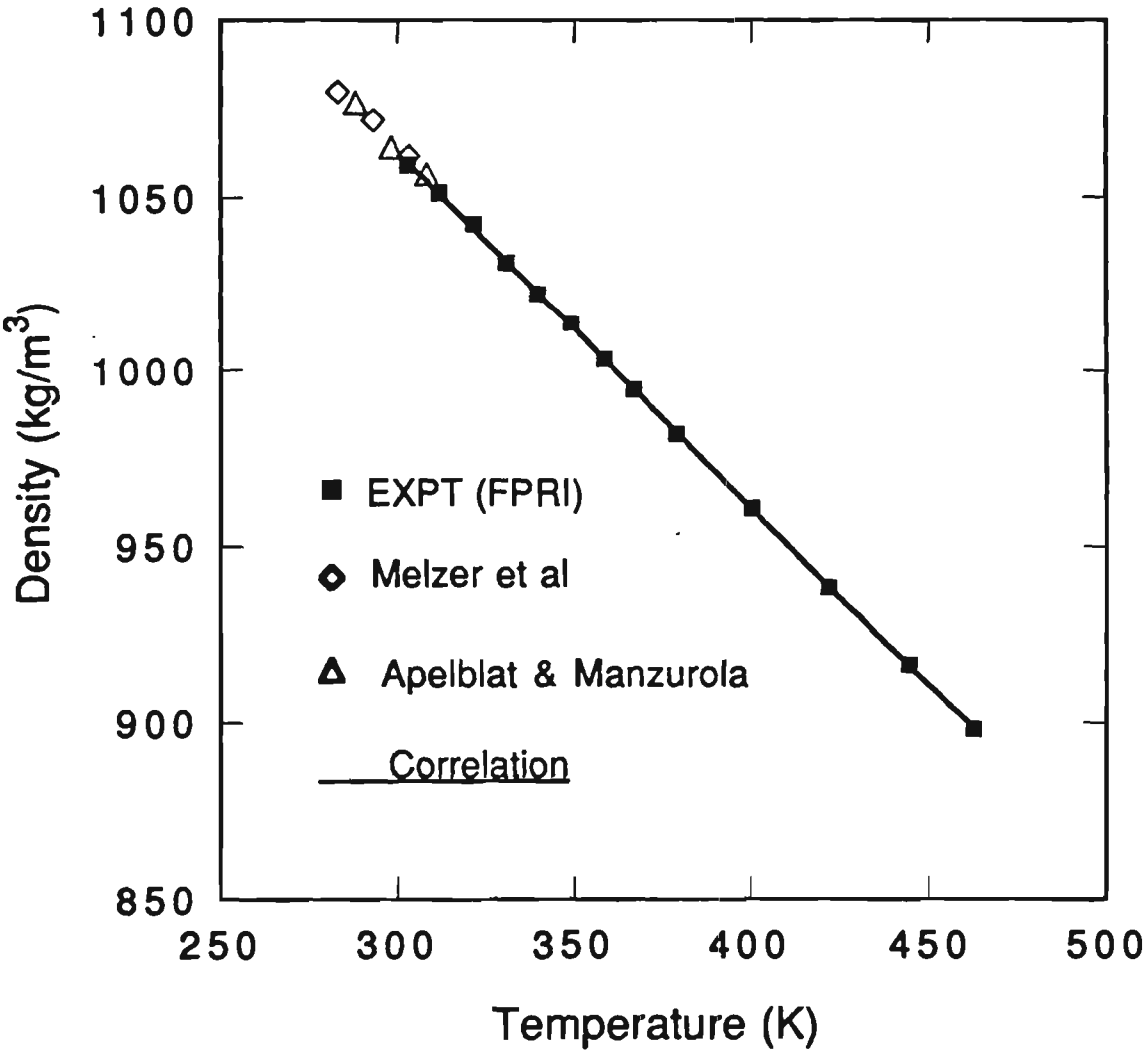
75 wt% Acetic Acid + 25 wt% Water



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3. Melzer, W. M.; Baldauf, W.; Knapp, H., "Measurement of Diffusivity, Viscosity, Density and Refractivity of Eight Binary Liquid Mixtures", Chem. Eng. Process., 26, 71 (1989).

4. Apelblat, A.; Manzurola, E., "Excess Molar Volumes of Formic Acid + Water, Acetic Acid + Water and Propionic Acid + Water Systems at 288.15, 298.15 and 308.15 K", Fluid Phase Equilibria, 32 , 163 (1987).

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May, 1992 DDS-LD-A49

DESIGN DATA STANDARD - LIQUID DENSITY

1 - Methoxy - 2 - Propanol

$CH_3CH(OH)CH_2OCH_3$
CA - No: 107-98-2

Purity =	98 %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	551 K	[2]
Critical Pressure =	43.3 bar	[2]
Critical Volume =	0.2905 m^3/kmol	[2]
Melting Point =	203 K	[2]
Normal Boiling Point =	391 K	[3]
Liquid Molar Volume at 25 °C =	0.09838 m^3/kmol	[4]

Experimental Technique : High Pressure Pycnometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
299.70	918.6
309.35	909.55
320.55	898.6
331.75	887.8
342.55	876.4
353.25	865.0
364.95	852.9
375.95	840.8
388.30	827.5

Liquid Density Correlation:

$$\rho / \mathrm{kgm^{-3}} = 181.2054 / 0.3940172^{[1+(1-T/K/551)^{0.3782342}]}$$

% AAD = 0.02 %
% MAD = 0.05 %

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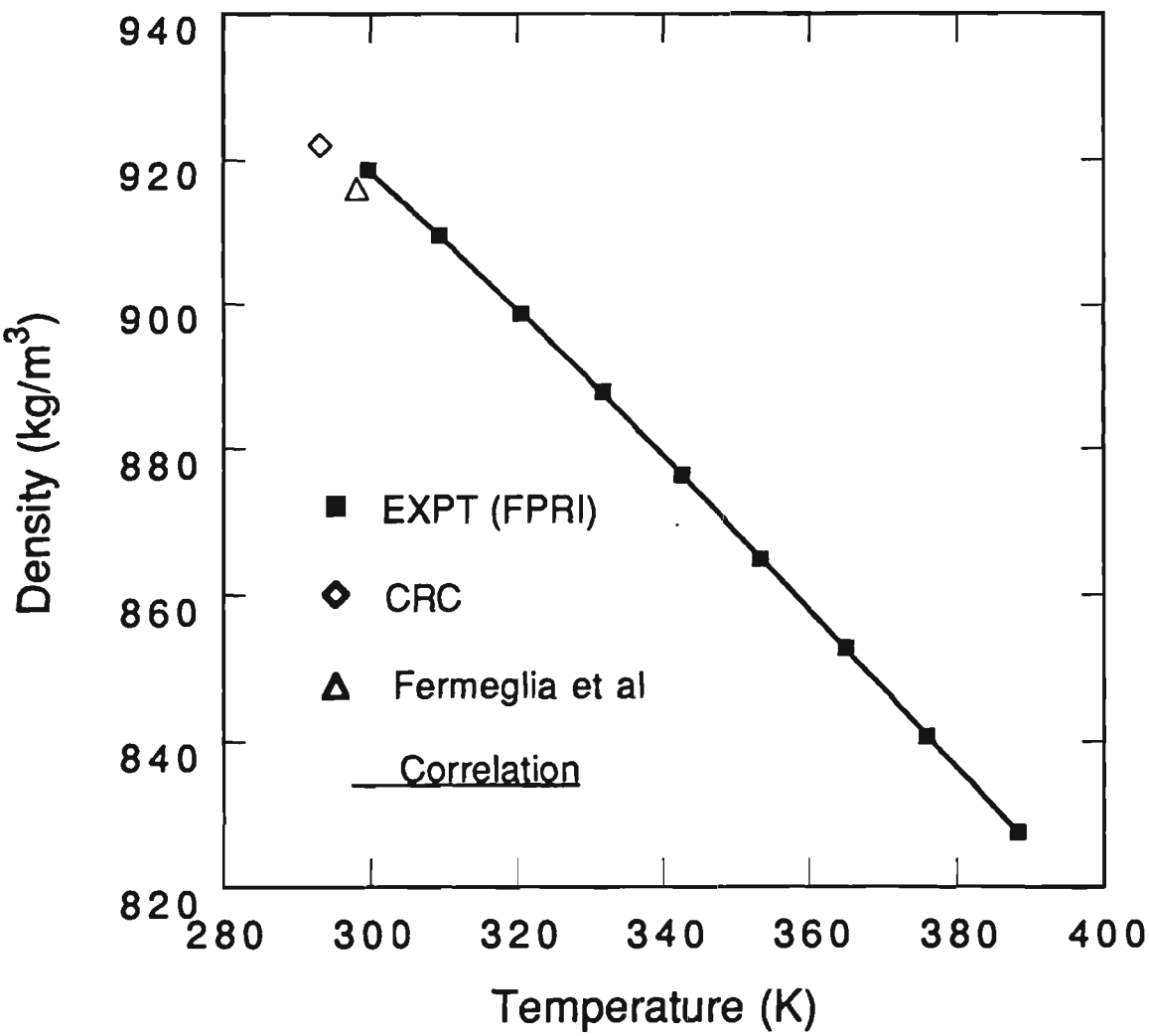
Density of 1-Methoxy -2-Propanal



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May, 1992 DDS-LD-A50

DESIGN DATA STANDARD - LIQUID DENSITY

Dipropylene Glycol Methyl Ether

$CH_3OC_3H_6OC_3H_6OH$
CA - No: 34590-94-8

Purity =	97 %	
Molecular Weight =	148.202 kg/kmol	[1]
Critical Temperature =	658 K	[2]
Critical Pressure =	29.8 bar	[2]
Critical Volume =	0.483 m^3/kmol	[2]
Melting Point =	273 K	[2]
Normal Boiling Point =	497 K	[2]
Liquid Molar Volume at 25 °C =	0.1565 m^3/kmol	[3]

Experimental Technique : High Pressure Pycnometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
297.15	947.6
309.45	937.2
320.30	926.5
331.50	916.4
342.70	905.9
353.60	895.9
364.95	882.8
376.05	874.2
387.85	863.0
399.45	852.1
411.05	840.2
422.95	828.1

Liquid Density Correlation:

$$\rho / \mathrm{kgm}^{-3} = 185.4560 / 0.3911873^{[1+(1-T/K/658)^{0.5050317}]}$$

% AAD = 0.05 %
% MAD = 0.21 %

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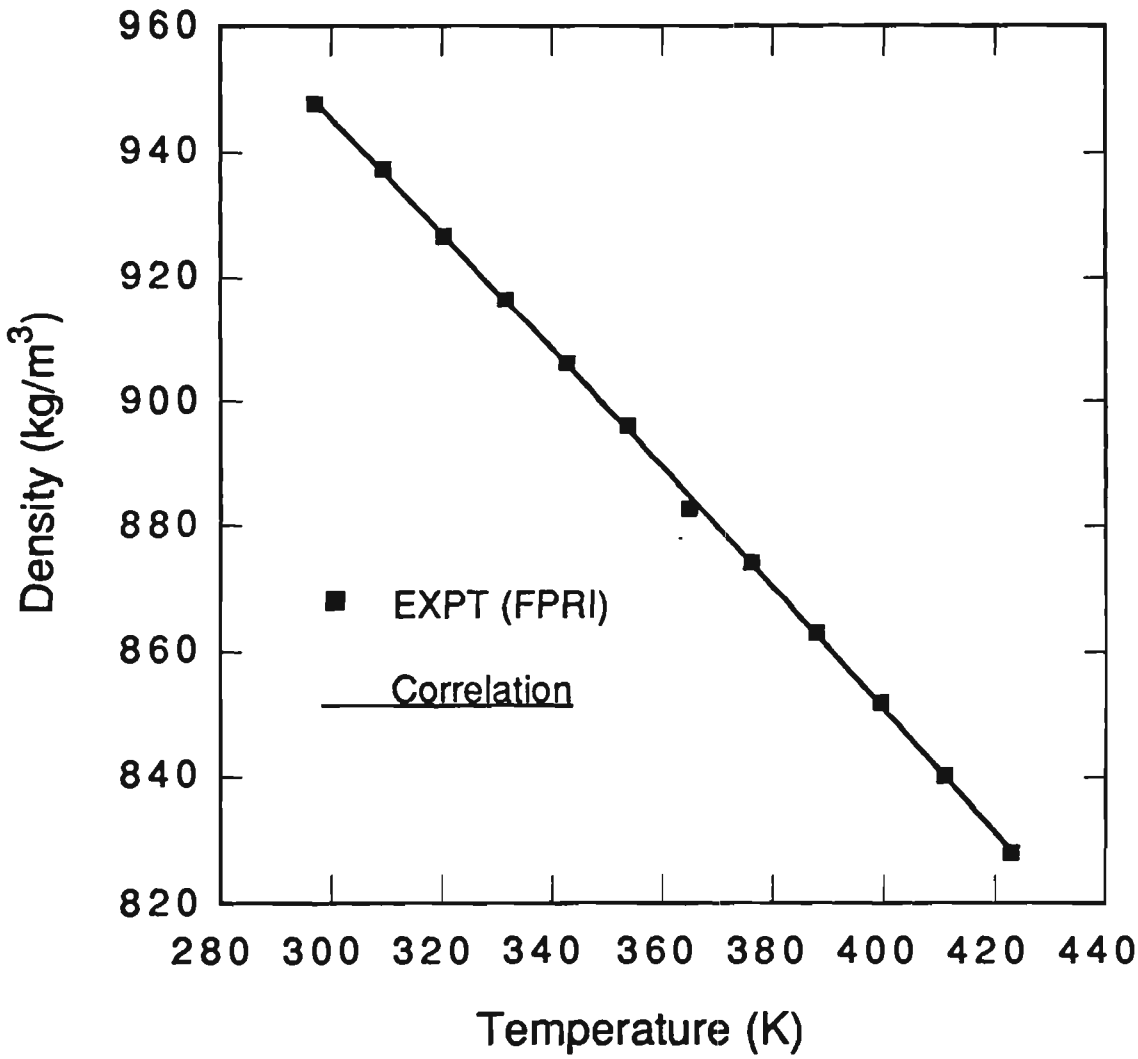
Denisty of Dipropylene Glycol Methyl Ether



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3. Estimated from FPRI density correlation.

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May, 1992 DDS-LD-A51

DESIGN DATA STANDARD - LIQUID DENSITY

Dipropylene Glycol Ether

$HOC_3H_6OC_3H_6OH$
CA - No: 110-98-5

Purity =	99 %	
Molecular Weight =	134.175 kg/kmol	[1]
Critical Temperature =	700 K	[2]
Critical Pressure =	37.8 bar	[2]
Critical Volume =	0.4275 m^3/kmol	[2]
Melting Point =	301 K	[2]
Normal Boiling Point =	543 K	[2]
Liquid Molar Volume at 25 °C =	0.1320 m^3/kmol	[3]

Experimental Technique : High Pressure Pycnometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
297.95	1016.5
312.75	1005.4
331.75	990.0
349.55	975.7
367.05	961.9
383.40	948.1
400.75	933.6
419.85	915.3
439.65	897.3

Liquid Density Correlation:

$$\rho / \mathrm{kgm}^{-3} = 82.89703 / 0.2608639^{[1+(1-T/K/700)^{0.2605987}]}$$

% AAD = 0.04 %
% MAD = 0.09 %

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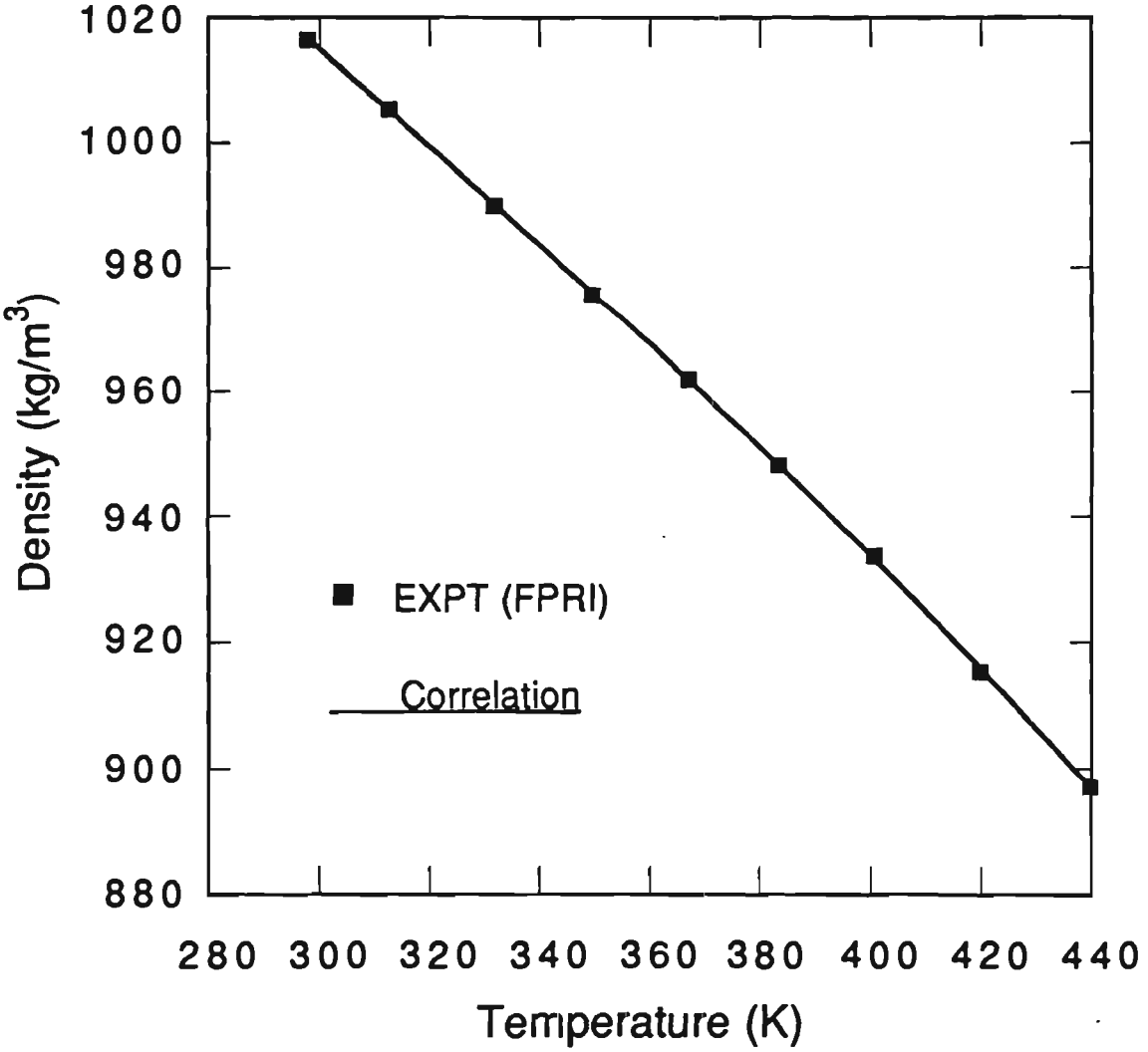
Density of Dipropylene Glycol Ether



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3. Estimated from FPRI density correlation.

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May, 1992 DDS-LD-A52

DESIGN DATA STANDARD - LIQUID DENSITY

Ethylene Glycol Dimethyl Ether

$CH_3OCH_2CH_2OCH_3$
CA - No: 110-71-4

Purity =	99.9 %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	536 K	[2]
Critical Pressure =	38.7 bar	[2]
Critical Volume =	0.271 m^3/kmol	[2]
Melting Point =	204 K	[2]
Normal Boiling Point =	357.7 K	[2]
Liquid Molar Volume at 25 °C =	0.10434 m^3/kmol	[2]

Experimental Technique : High Pressure Pycnometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
298.15	864.4
307.35	854.5
317.00	844.3
326.95	834.8
337.30	824.6
347.45	813.2
356.65	804.3

Liquid Density Correlation:

$$\rho / \mathrm{kgm}^{-3} = 93.01057 / 0.2910953^{[1+(1-T/K/536)^{0.2659738}]}$$

% AAD = 0.06 %
% MAD = 0.10 %

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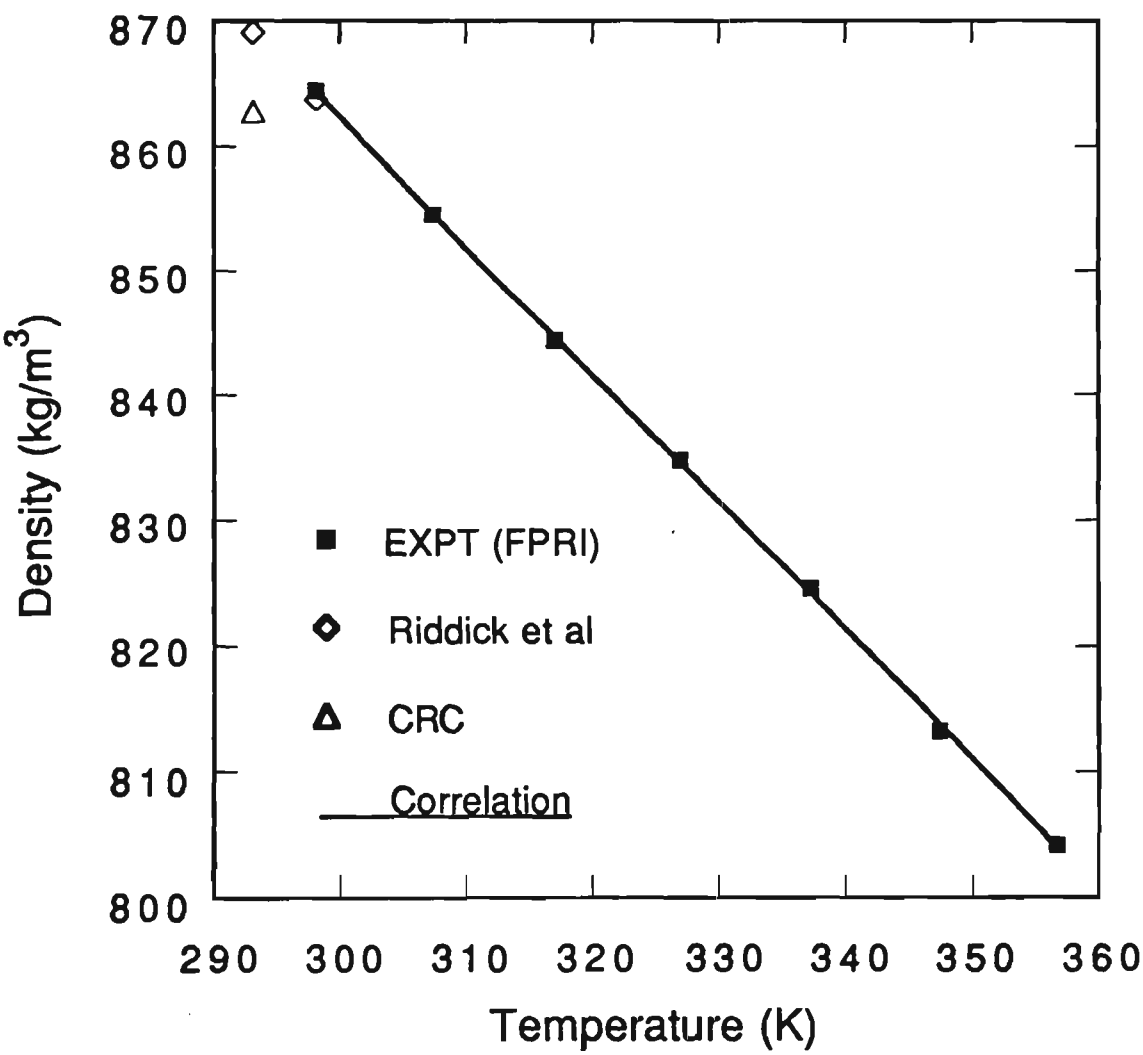
Density of Ethylene Glycol Dimethyl Ether



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May, 1992 DDS-LV-A42

DESIGN DATA STANDARD - LIQUID VISCOSITY

1,2 - Propanediol

$CH_3CH(OH)CH_2OH$
CA - No: 57-55-6

Purity =	99 %	
Molecular Weight =	76.095 kg/kmol	[1]
Critical Temperature =	626 K	[2]
Critical Pressure =	61.0 bar	[2]
Critical Volume =	0.239 m^3/kmol	[2]
Melting Point =	213.2 K	[2]
Normal Boiling Point =	460.8 K	[2]
Liquid Molar Volume at 25 °C =	0.073694 m^3/kmol	[2]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
297.25	46.37
302.55	33.98
317.10	16.45
332.30	8.75
347.40	5.26
362.05	3.422
376.45	2.342
391.05	1.669
406.05	1.266
420.85	0.982

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -4.25928 + 1099.328 / (T/K - 161.417)$$

% AAD = 0.8 %
% MAD = 1.6 %

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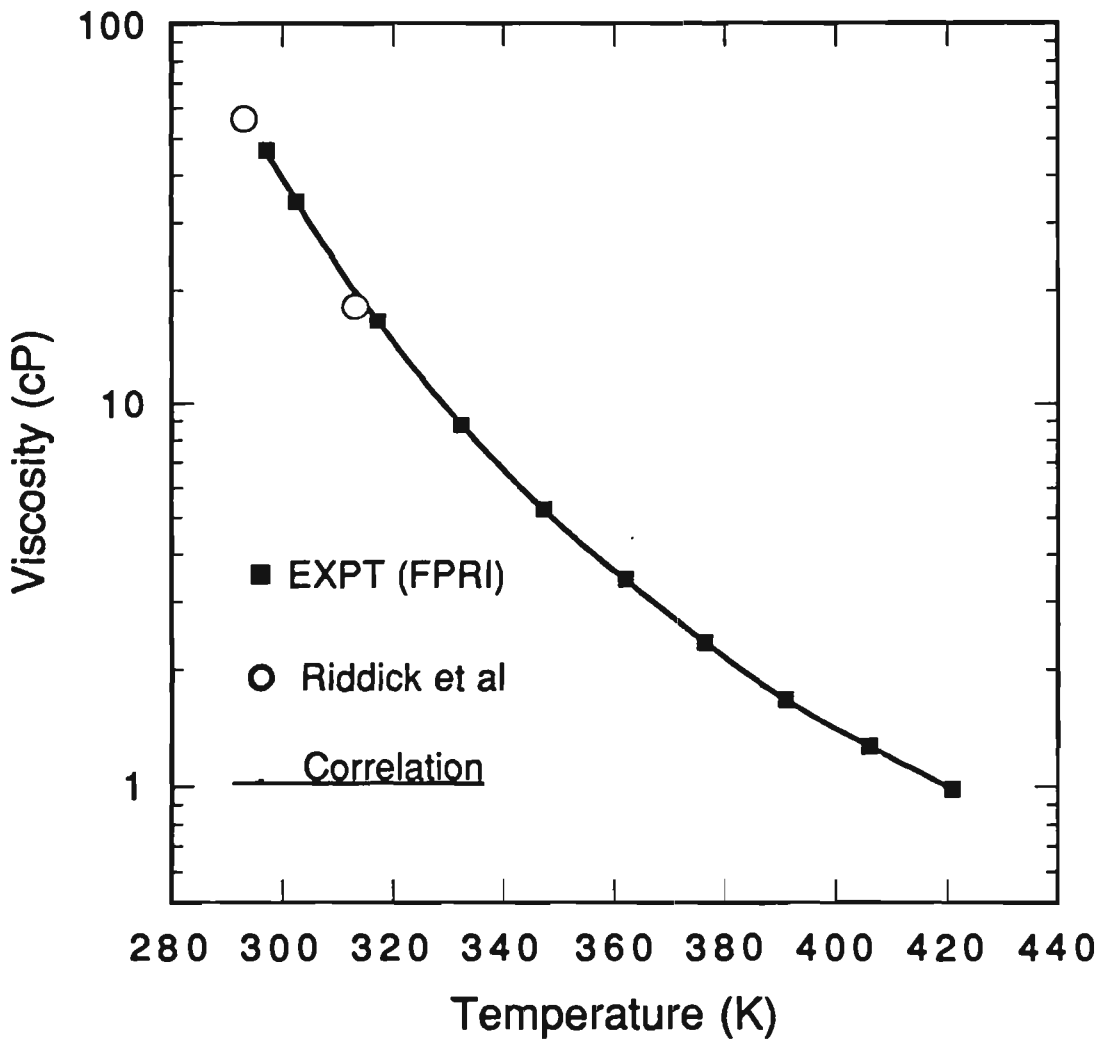
Viscosity of 1,2-Propanediol



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May, 1992 DDS-LV-A43

DESIGN DATA STANDARD - LIQUID VISCOSITY

1,3 - Propanediol

$HO(CH_2)_3OH$
CA - No: 504-63-2

Purity =	98 %	
Molecular Weight =	76.095 kg/kmol	[1]
Critical Temperature =	658 K	[2]
Critical Pressure =	59.2 bar	[2]
Critical Volume =	0.217 m^3/kmol	[2]
Melting Point =	246.5 K	[2]
Normal Boiling Point =	487.6 K	[2]
Liquid Molar Volume at 25 °C =	0.072364 m^3/kmol	[2]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
298.20	42.24
303.55	34.09
317.35	19.01
332.60	11.35
347.35	7.16
361.90	4.86
376.70	3.53
391.40	2.487
406.05	1.838
420.80	1.431

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -4.853169 + 1618.849 / (T/K - 110.0843)$$

% AAD = 1.0 %
% MAD = 1.4 %

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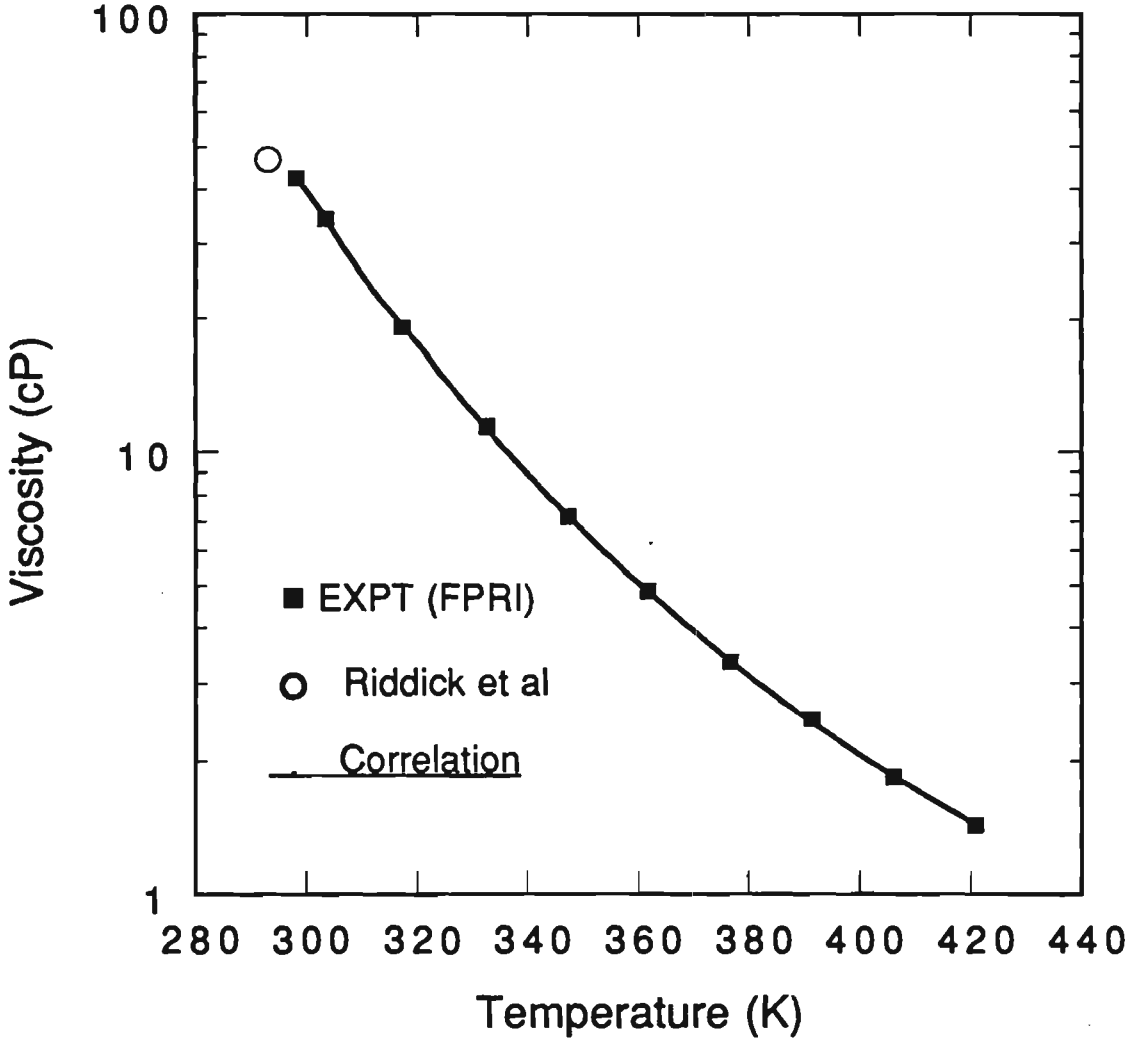
May, 1992 DDS-LV-A43

Viscosity of 1,3-Propanediol



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May, 1992 DDS-LV-A44

DESIGN DATA STANDARD - LIQUID VISCOSITY

Diethylene Triamine

$H_2NCH_2CH_2NHCH_2CH_2NH_2$
CA - No: 111-40-0

Purity =	99 %	
Molecular Weight =	103.169 kg/kmol	[1]
Critical Temperature =	677.0 K	[2]
Critical Pressure =	46.0 bar	[2]
Critical Volume =	0.3525 m^3/kmol	[2]
Melting Point =	234.2 K	[3]
Normal Boiling Point =	480.1 K	[3]
Liquid Molar Volume at 25 °C =	0.10869 m^3/kmol	[3]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
298.10	5.961
303.05	4.926
317.15	3.131
332.45	2.137
347.20	1.576
361.75	1.226
376.60	0.982
391.25	0.814
405.95	0.694
420.90	0.602

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -2.630833 + 503.0826 / (T/K - 184.0475)$$

% AAD = 0.3 %
% MAD = 0.5 %

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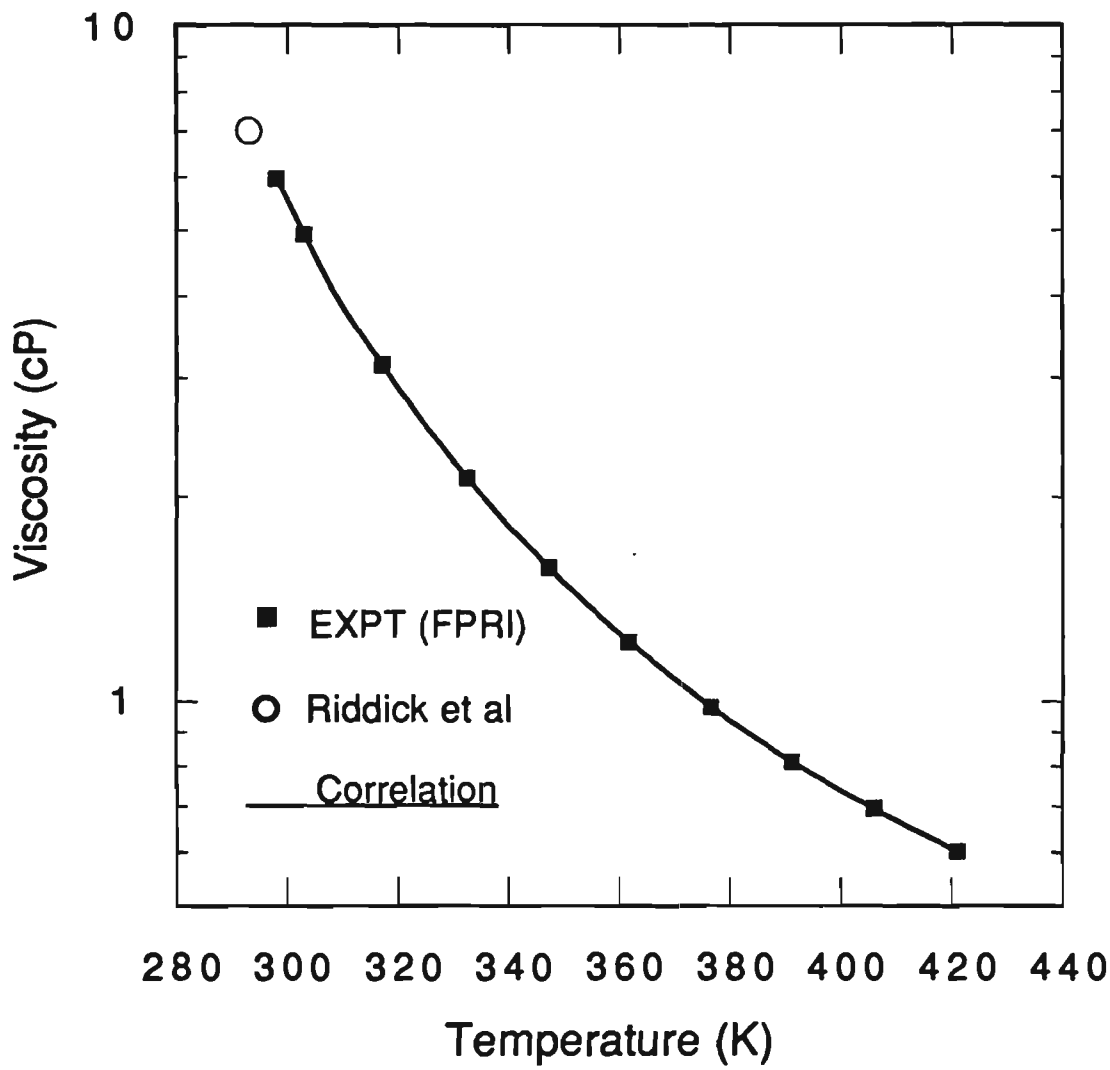
Viscosity of Diethylenetriamine



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May, 1992 DDS-LV-A45

DESIGN DATA STANDARD - LIQUID VISCOSITY

Ethylene Diamine

$H_2NCH_2CH_2NH_2$
CA - No: 107-15-3

Purity =	99 %	
Molecular Weight =	60.099 kg/kmol	[1]
Critical Temperature =	593.0 K	[2]
Critical Pressure =	62.9 bar	[2]
Critical Volume =	0.206 m^3/kmol	[2]
Melting Point =	284.5 K	[2]
Normal Boiling Point =	390.1 K	[2]
Liquid Molar Volume at 25 °C =	0.06729 m^3/kmol	[2]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
297.35	1.510
307.35	1.226
317.70	1.016
328.95	0.843
339.60	0.730
350.25	0.639
359.95	0.570
369.50	0.521
379.85	0.475
389.45	0.439

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -64.83916 + 4527.128 / (T/K) + 8.784016 \ln(T/K)$$

% AAD = 0.3 %
% MAD = 0.6 %

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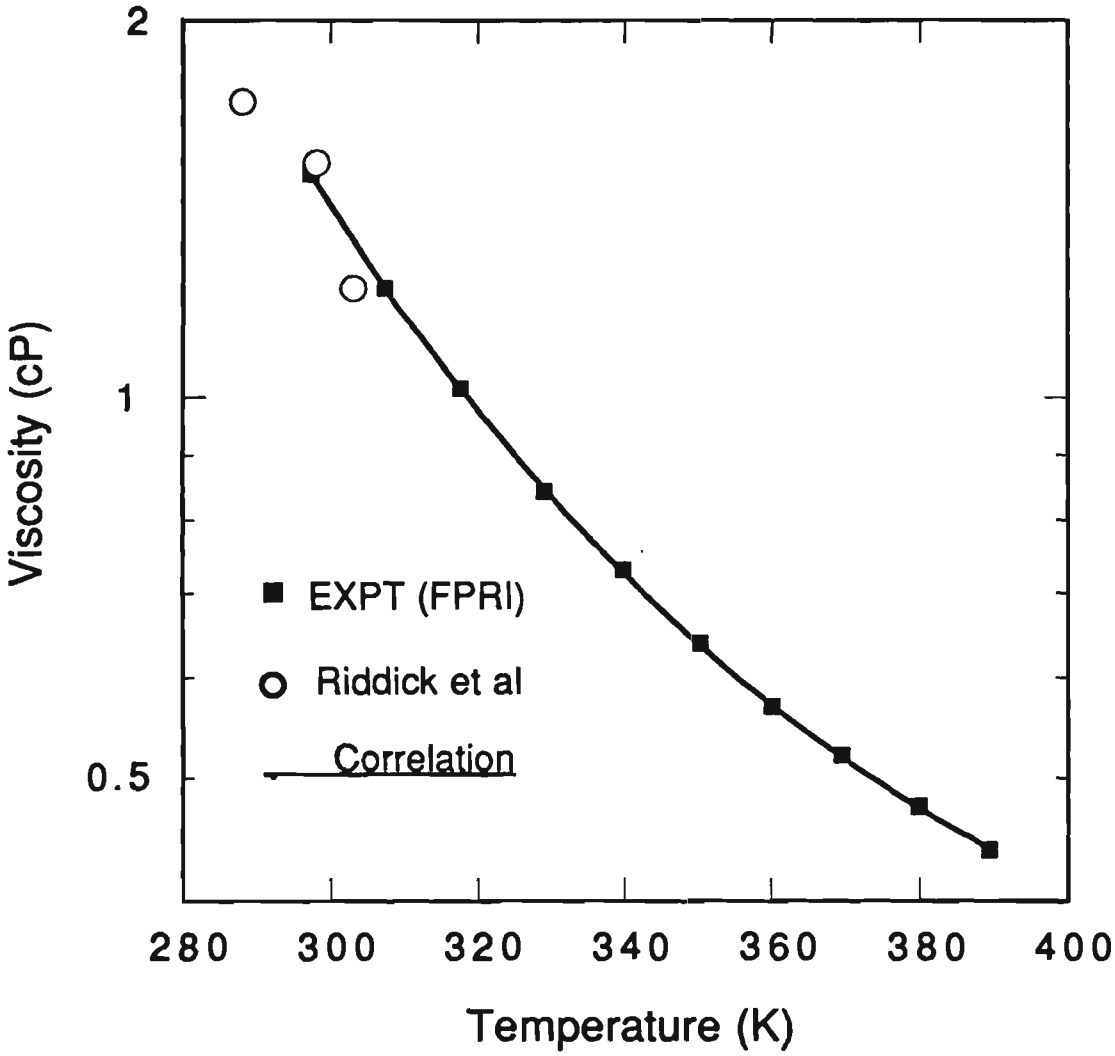
May, 1992 DDS-LV-A45

Viscosity of Ethylenediamine



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FPRI

May, 1992 DDS-LV-A46

DESIGN DATA STANDARD - LIQUID VISCOSITY

25 wt% Acetic Acid + 75 wt% Water

$CH_3COOH_2 + H_2O$
CA - No: 64-19-7

Properties of Acetic Acid

Purity =	99.7 %	
Molecular Weight =	60.052 kg/kmol	[1]
Critical Temperature =	592.7 K	[2]
Critical Pressure =	57.86 bar	[2]
Critical Volume =	0.1713 m^3/kmol	[2]
Melting Point =	289.81 K	[2]
Normal Boiling Point =	390.04 K	[2]

Experimental Technique : High Pressure Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	μ (cP)
296.15	1.509
303.75	1.247
312.65	1.024
322.35	0.852
332.65	0.709
342.60	0.613
352.25	0.535
362.15	0.464
372.30	0.408
393.35	0.317
411.00	0.272
430.00	0.231
450.15	0.210

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -44.3799 + 3757.269/(T/K) + 5.639407 \ln(T/K)$$

% AAD = 1.3 %
% MAD = 2.0 %

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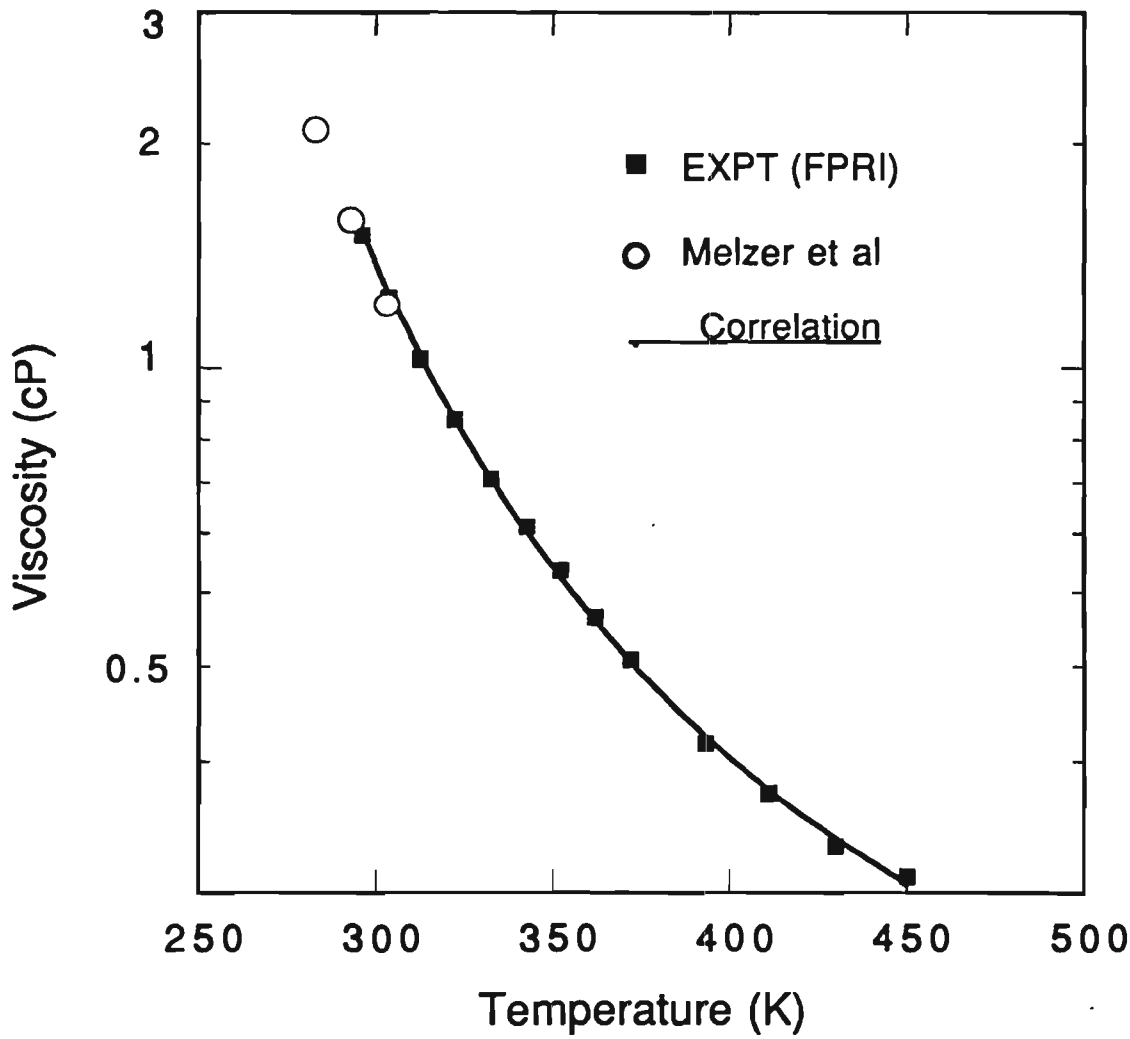
25 wt% Acetic Acid + 75 wt% Water



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2. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

3. Melzer, W. M.; Baldauf, W.; Knapp, H., "Measurement of Diffusivity, Viscosity, Density and Refractivity of Eight Binary Liquid Mixtures", Chem. Eng. Process., 26, 71 (1989).

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DESIGN DATA STANDARD - LIQUID VISCOSITY

50 wt% Acetic Acid + 50 wt% Water

$CH_3COOH_2 + H_2O$
CA - No: 64-19-7

Properties of Acetic Acid

Purity =	99 %	
Molecular Weight =	60.052 kg/kmol	[1]
Critical Temperature =	592.7 K	[2]
Critical Pressure =	57.86 bar	[2]
Critical Volume =	0.1713 m^3/kmol	[2]
Melting Point =	289.81 K	[2]
Normal Boiling Point =	390.04 K	[2]

Experimental Technique : High Pressure Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	μ (cP)
298.95	1.803
307.35	1.446
315.60	1.194
325.40	0.995
333.55	0.868
342.50	0.752
352.35	0.655
362.15	0.574
372.95	0.512
385.95	0.440
407.50	0.343
426.75	0.285
447.55	0.244

Liquid Viscosity Correlation:

$$\ln(\mu\ (cP)) = -3.91595 + 849.7644 / (T\ (°C) - 109.1664)$$

% AAD = 1.8 %
% MAD = 2.6 %

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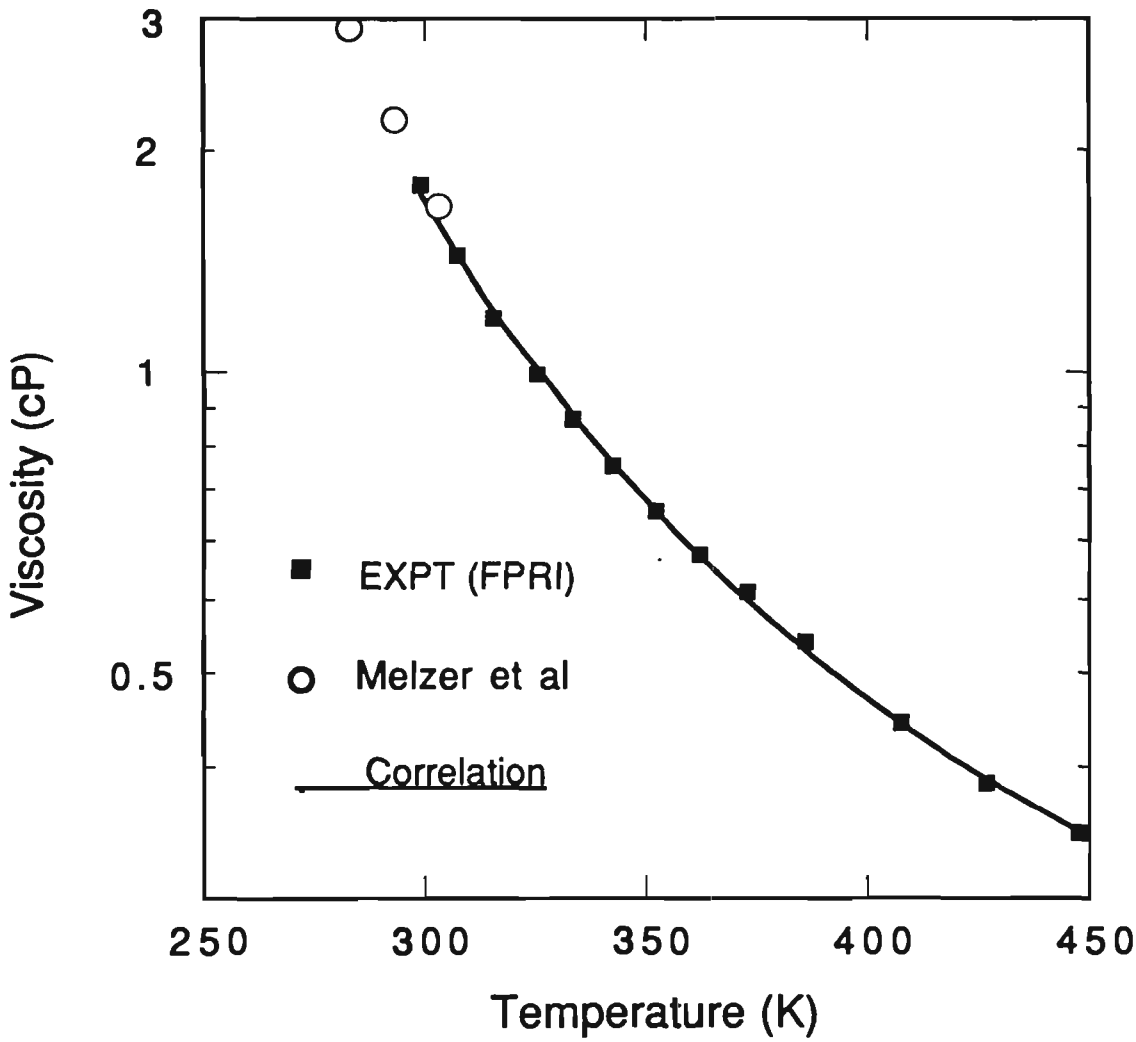
50 wt% Acetic Acid + 50 wt% Water



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2. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

3. Melzer, W. M.; Baldauf, W.; Knapp, H., "Measurement of Diffusivity, Viscosity, Density and Refractivity of Eight Binary Liquid Mixtures", Chem. Eng. Process., 26, 71 (1989).

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May, 1992 DDS-LV-A48

DESIGN DATA STANDARD - LIQUID VISCOSITY

75 wt% Acetic Acid + 25 wt% Water

$CH_3COOH_2 + H_2O$
CA - No: 64-19-7

Properties of Acetic Acid

Purity =	99.7 %	
Molecular Weight =	60.052 kg/kmol	[1]
Critical Temperature =	592.7 K	[2]
Critical Pressure =	57.86 bar	[2]
Critical Volume =	0.1713 m^3/kmol	[2]
Melting Point =	289.81 K	[2]
Normal Boiling Point =	390.04 K	[2]

Experimental Technique : High Pressure Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	μ (cP)
297.60	2.341
307.40	1.822
316.80	1.496
326.20	1.237
334.60	1.059
343.30	0.922
353.30	0.800
363.20	0.675
372.95	0.595
379.30	0.554
386.00	0.479
405.60	0.408
425.40	0.317
445.65	0.269
459.95	0.241

Liquid Viscosity Correlation:

$$\ln(\mu\ (cP)) = -4.355031 + 1090.626 / (T\ (°C) - 87.88444)$$

% AAD = 1.8 %
% MAD = 3.9 %

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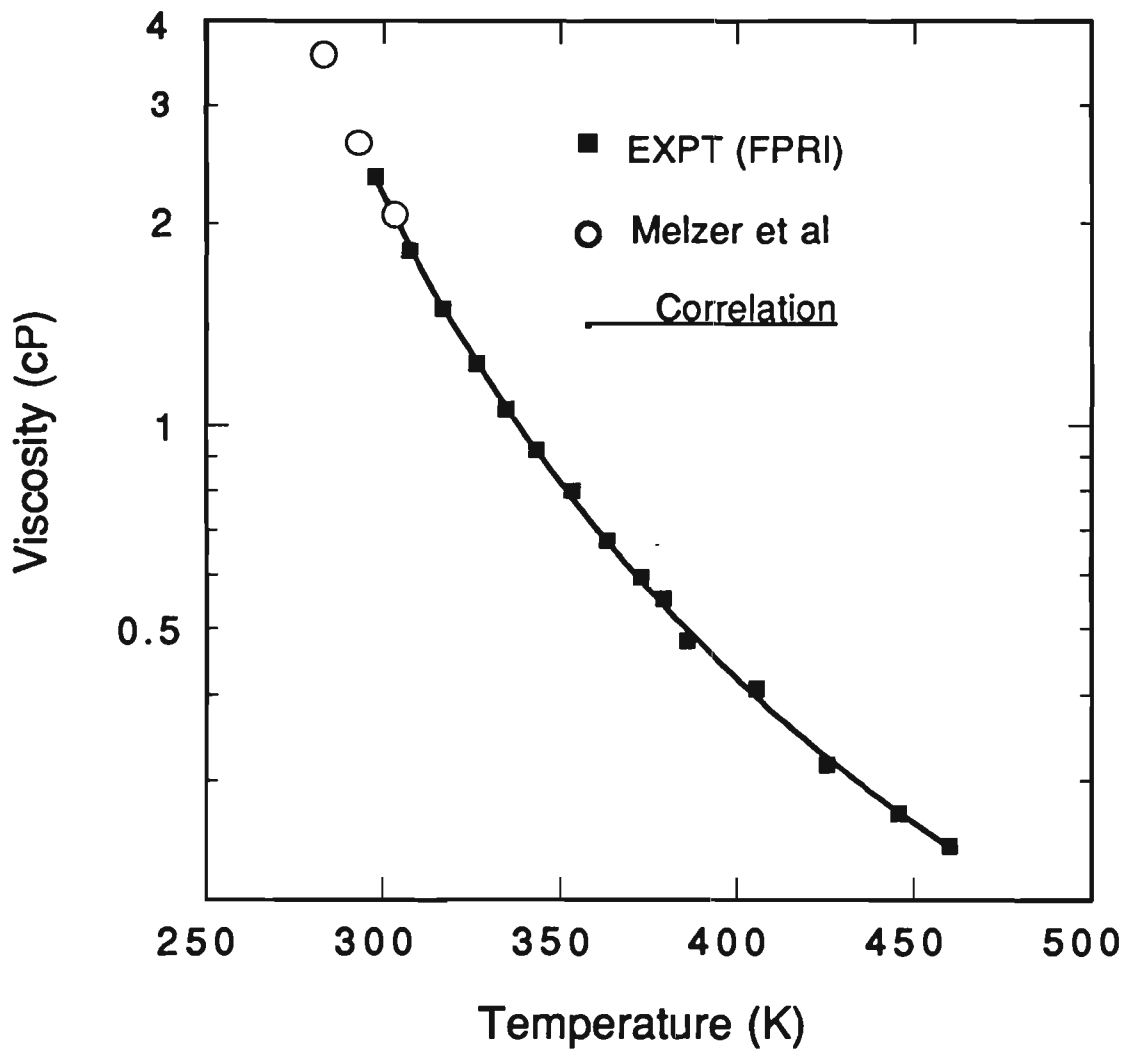
75 wt% Acetic Acid + 25 wt% Water



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2. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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DESIGN DATA STANDARD - LIQUID VISCOSITY

1 - Methoxy - 2 - Propanol

$CH_3CH(OH)CH_2OCH_3$
CA - No: 107-98-2

Purity =	98 %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	551 K	[2]
Critical Pressure =	43.3 bar	[2]
Critical Volume =	0.2905 m^3/kmol	[2]
Melting Point =	203 K	[2]
Normal Boiling Point =	391 K	[3]
Liquid Molar Volume at 25 °C =	0.09838 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
297.2	42.24
311.25	34.09
322.65	19.01
333.60	11.35
345.45	7.16
357.25	4.86
369.10	3.53
380.50	2.487
391.40	1.838

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -43.00283 + 3795.995/(T/K) + 5.407228 \ln(T/K)$$

% AAD = 0.9 %
% MAD = 1.2 %

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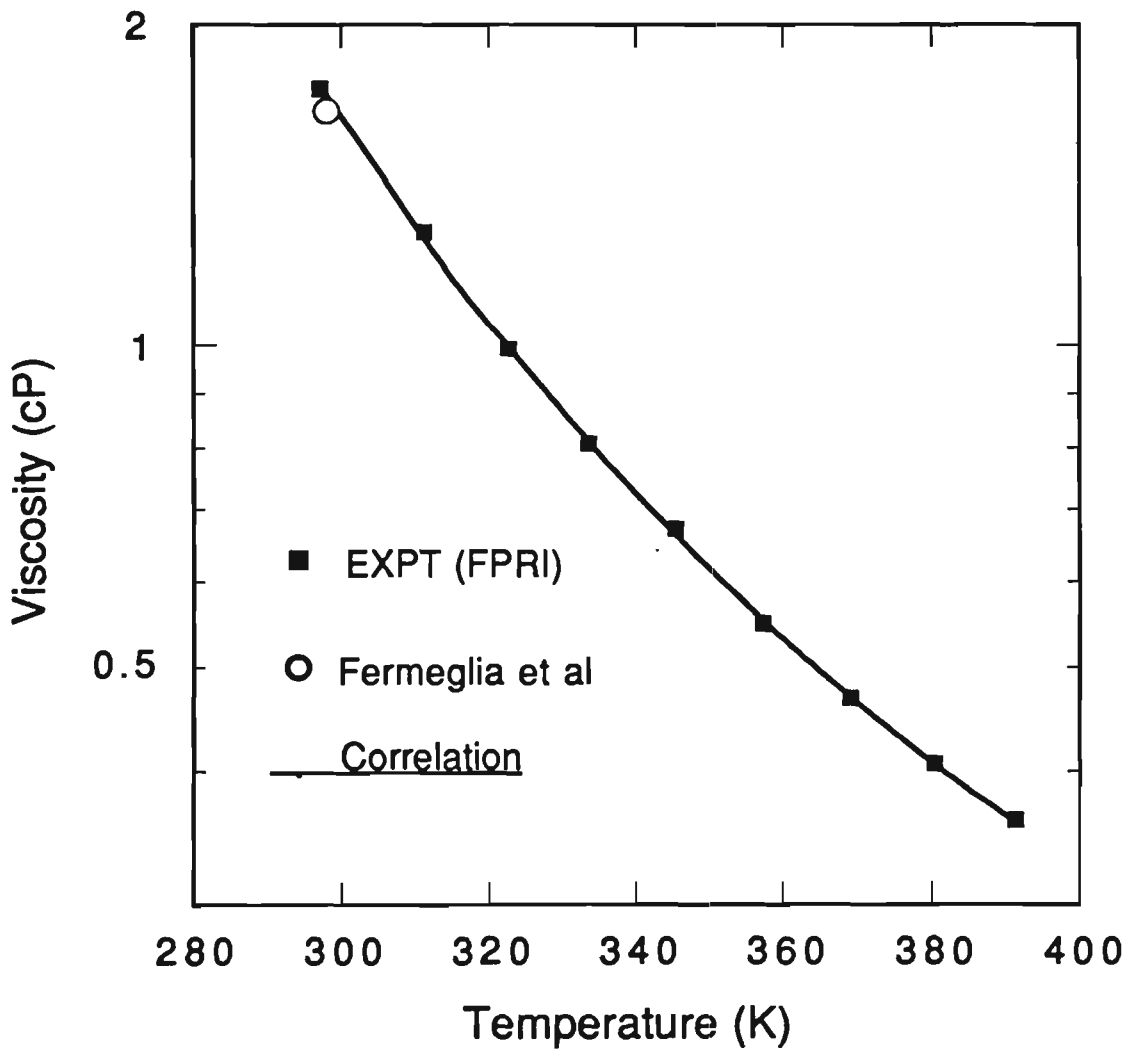
Viscosity of 1-Methoxy-2-Propanol



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2. Estimated from Joback modification of Lydersen's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Weast R.C.; Astle, M.J., "CRC Handbook of Data on Organic Compounds", CRC Press, Boca Raton, Fla. (1985).

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DESIGN DATA STANDARD - LIQUID VISCOSITY

Dipropylene Glycol Methyl Ether

$CH_3OC_3H_6OC_3H_6OH$
CA - No: 34590-94-8

Purity =	97 %	
Molecular Weight =	148.202 kg/kmol	[1]
Critical Temperature =	658 K	[2]
Critical Pressure =	29.8 bar	[2]
Critical Volume =	0.483 m^3/kmol	[2]
Melting Point =	273 K	[2]
Normal Boiling Point =	497 K	[2]
Liquid Molar Volume at 25 °C =	0.1565 m^3/kmol	[3]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
296.30	1.084
309.50	0.746
321.75	0.552
333.85	0.428
345.45	0.342
357.20	0.282
369.15	0.236
380.95	0.202
391.80	0.179
402.65	0.159
412.55	0.145

Liquid Viscosity Correlation:

$$\ln (\mu /cP) = -74.99543 + 5552.772 / (T/K) + 9.897799 \ln (T/K)$$

% AAD = 0.3 %
% MAD = 0.5 %

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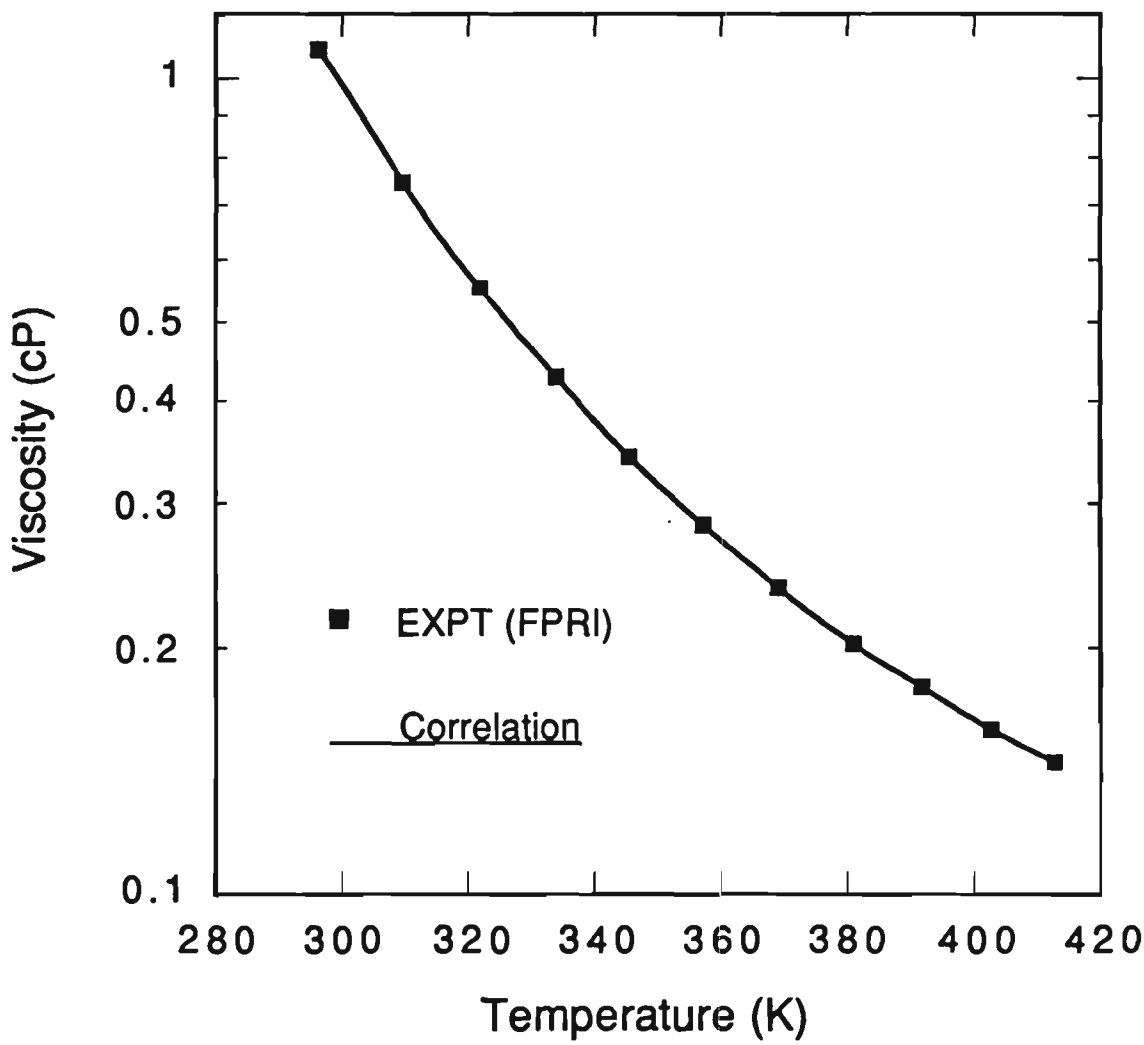
Viscosity of Dipropylene Glycol Methyl Ether



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2. Estimated from Joback modification of Lydersen's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Estimated from FPRI density correlation.

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May, 1992 DDS-LV-A51

DESIGN DATA STANDARD - LIQUID VISCOSITY

Dipropylene Glycol Ether

$HOC_3H_6OC_3H_6OH$
CA - No: 110-98-5

Purity =	99 %	
Molecular Weight =	134.175 kg/kmol	[1]
Critical Temperature =	700 K	[2]
Critical Pressure =	37.8 bar	[2]
Critical Volume =	0.4275 m^3/kmol	[2]
Melting Point =	301 K	[2]
Normal Boiling Point =	543 K	[2]
Liquid Molar Volume at 25 °C =	0.1320 m^3/kmol	[3]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
296.20	91.59
303.45	54.47
318.45	22.00
333.45	10.74
348.30	6.089
363.25	3.801
378.65	2.509
393.55	1.818
408.25	1.345
423.65	1.044

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -3.61732 + 847.3872 / (T/K - 192.0904)$$

% AAD = 0.5 %
% MAD = 0.8 %

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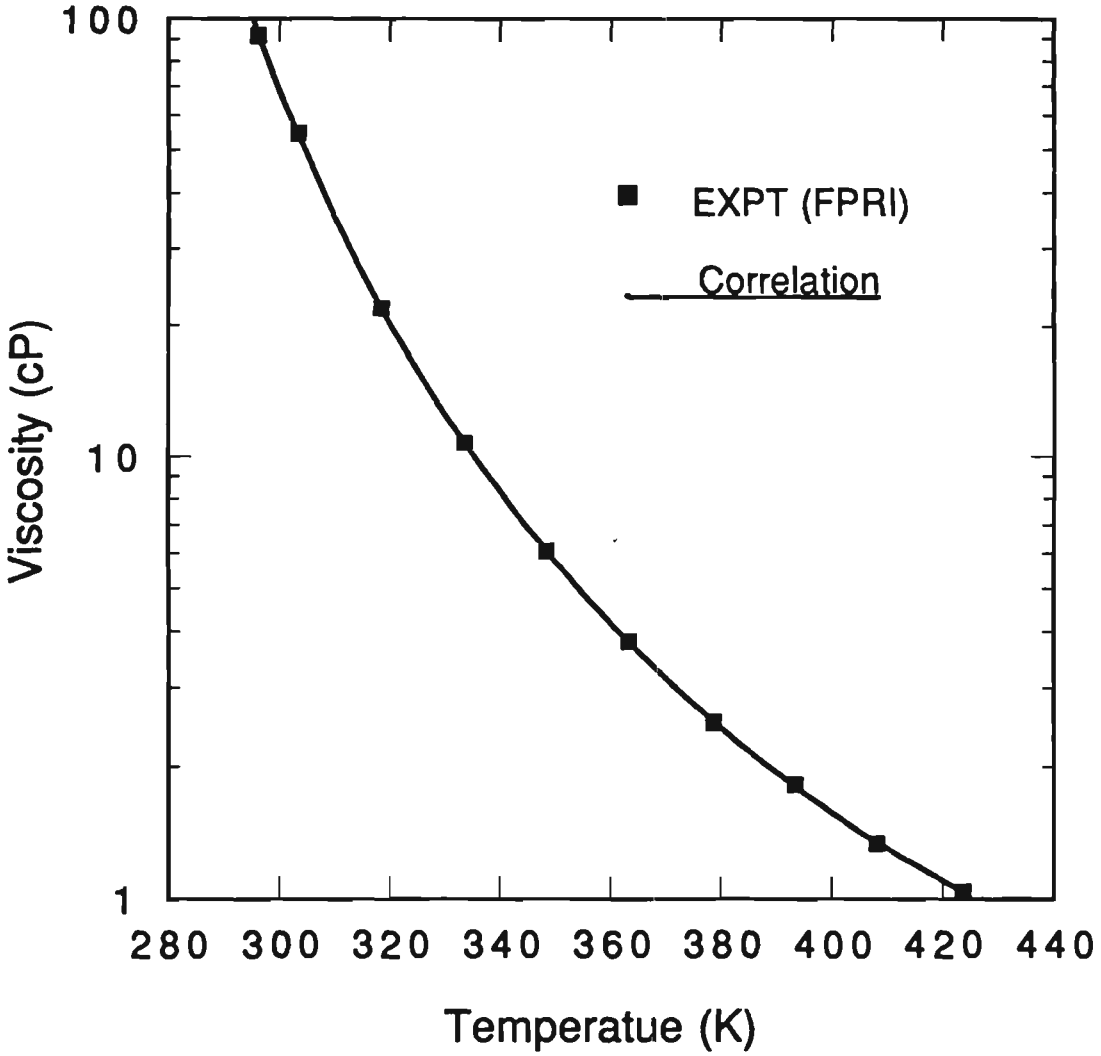
Viscosity of Dipropylene Glycol Ether



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3. Estimated from FPRI density correlation.

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May, 1992 DDS-LV-A52

DESIGN DATA STANDARD - LIQUID VISCOSITY

Ethylene Glycol Dimethyl Ether

$CH_3OCH_2CH_2OCH_3$
CA - No: 110-71-4

Purity =	99.9 %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	536 K	[2]
Critical Pressure =	38.7 bar	[2]
Critical Volume =	0.271 m^3/kmol	[2]
Melting Point =	204 K	[2]
Normal Boiling Point =	357.7 K	[2]
Liquid Molar Volume at 25 °C =	0.10434 m^3/kmol	[2]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
293.00	0.462
303.00	0.421
313.05	0.389
323.05	0.359
333.05	0.336
341.00	0.319
349.00	0.304
357.05	0.289

Liquid Viscosity Correlation:

$$\ln (\mu / cP) = -12.71281 + 1205.618 / (T/K) + 1.377538 \ln (T/K)$$

% AAD = 0.2 %
% MAD = 0.3 %

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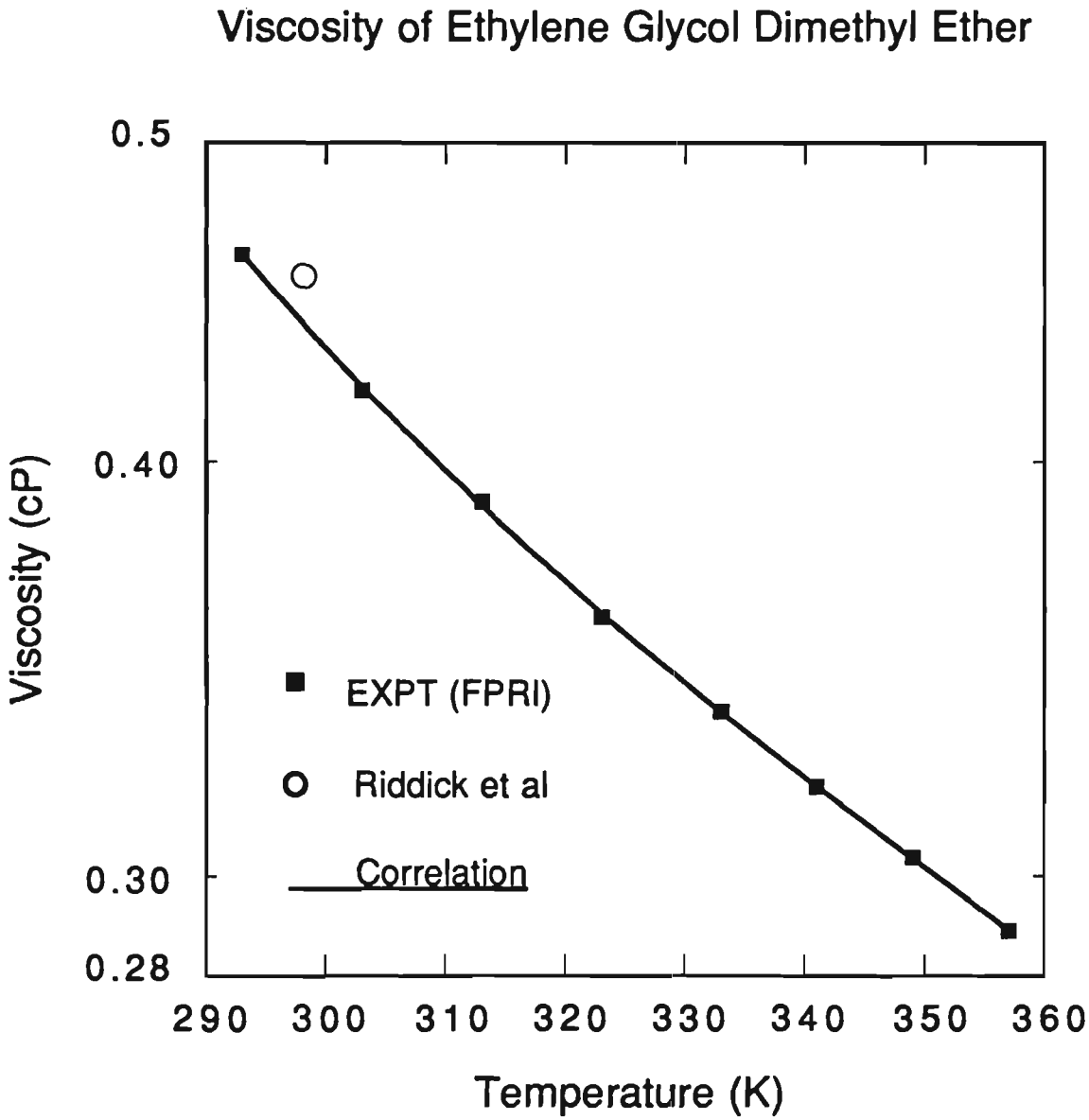

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2. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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June 28, 1993

Mr. J. David Chase
President, FPRI
Hoechst- Celanese Corporation
Technical Center
P. O. Box 9077
Corpus Christi, TX 78408

Dear Dave:

Please find enclosed Design Data Sheets DDS-LTC-A67 thru 77, DDS-LD-A53 thru 65 and DDS-LV-53 thru 66 representing the results of FPRI sponsored measurements for the year July 1, 1992 to June 30,1993. I would like to take this opportunity to thank the FPRI members for sponsoring this work.

With best wishes,

Yours sincerely,

Amyn S. Teja
Regents Professor

INDEX TO DESIGN SHEET

SERIES A 1992-93 RESULTS

Viscosity

A53	1,5 - Pentanediol
A54	1,6 - Hexanediol
A55	2,5 - Hexanediol
A56	2 - Methoxyethyl Ether
A57	Triethylene Glycol Dimethyl Ether
A58	Tetraethylene Glycol Dimethyl Ether
A59	2 - Ethoxyethanol
A60	2 - (2 - Ethoxyethoxy) Ethanol
A61	N,N - Dimethyl Ethylenediamine
A62	Triethylamine
A63	Acetic Acid
A64	84 wt% Acetic Acid + 16 wt% Water
A65	92 wt% Acetic Acid + 8 wt% Water
A66	12 wt% Acetic Acid + 88 wt% Water

Density

A53	1,5 - Pentanediol
A54	1,6 - Hexanediol
A55	2,5 - Hexanediol
A56	2 - Methoxyethyl Ether
A57	Triethylene Glycol Dimethyl Ether
A58	Tetraethylene Glycol Dimethyl Ether
A59	2 - Ethoxyethanol
A60	2 - (2 - Ethoxyethoxy) Ethanol
A61	N,N - Dimethyl Ethylenediamine
A62	Triethylamine
A63	Acetic Acid
A64	84 wt% Acetic Acid + 16 wt% Water
A65	92 wt% Acetic Acid + 8 wt% Water

Thermal Conductivity

A67	1,5 - Pentanediol
A68	1,6 - Hexanediol
A69	2,5 - Hexanediol
A70	2 - Methoxyethyl Ether
A71	Triethylene Glycol Dimethyl Ether
A72	Tetraethylene Glycol Dimethyl Ether
A73	2 - Ethoxyethanol
A74	2 - (2 - Ethoxyethoxy) Ethanol
A75	N,N - Dimethyl Ethylenediamine
A76	Triethylamine
A77	Acetic Acid

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May, 1993 DDS-LV-A53

DESIGN DATA STANDARD - LIQUID VISCOSITY

1,5 - Pentanediol

$HO(CH_2)_5OH$
CA - No: 111-29-5

Purity =	96 %	
Molecular Weight =	104.14 kg/kmol	[1]
Critical Temperature =	673 K	[2]
Critical Pressure =	41.5 bar	[2]
Critical Volume =	0.345 m^3/kmol	[2]
Melting Point =	257.2 K	[2]
Normal Boiling Point =	512.2 K	[2]
Liquid Molar Volume at 25 °C =	0.104809 m^3/kmol	[2]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
298.15	96.05
313.50	46.63
328.40	25.01
343.25	14.40
358.05	8.829
373.45	5.427
388.45	3.678
403.25	2.596
418.15	1.915
433.05	1.474

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = 222.209 - 1692.227/(T/K) - 40.80677 \ln(T/K) + 0.0688538\,(T/K)$$

% AAD = 0.4 %
% MAD = 1.3 %

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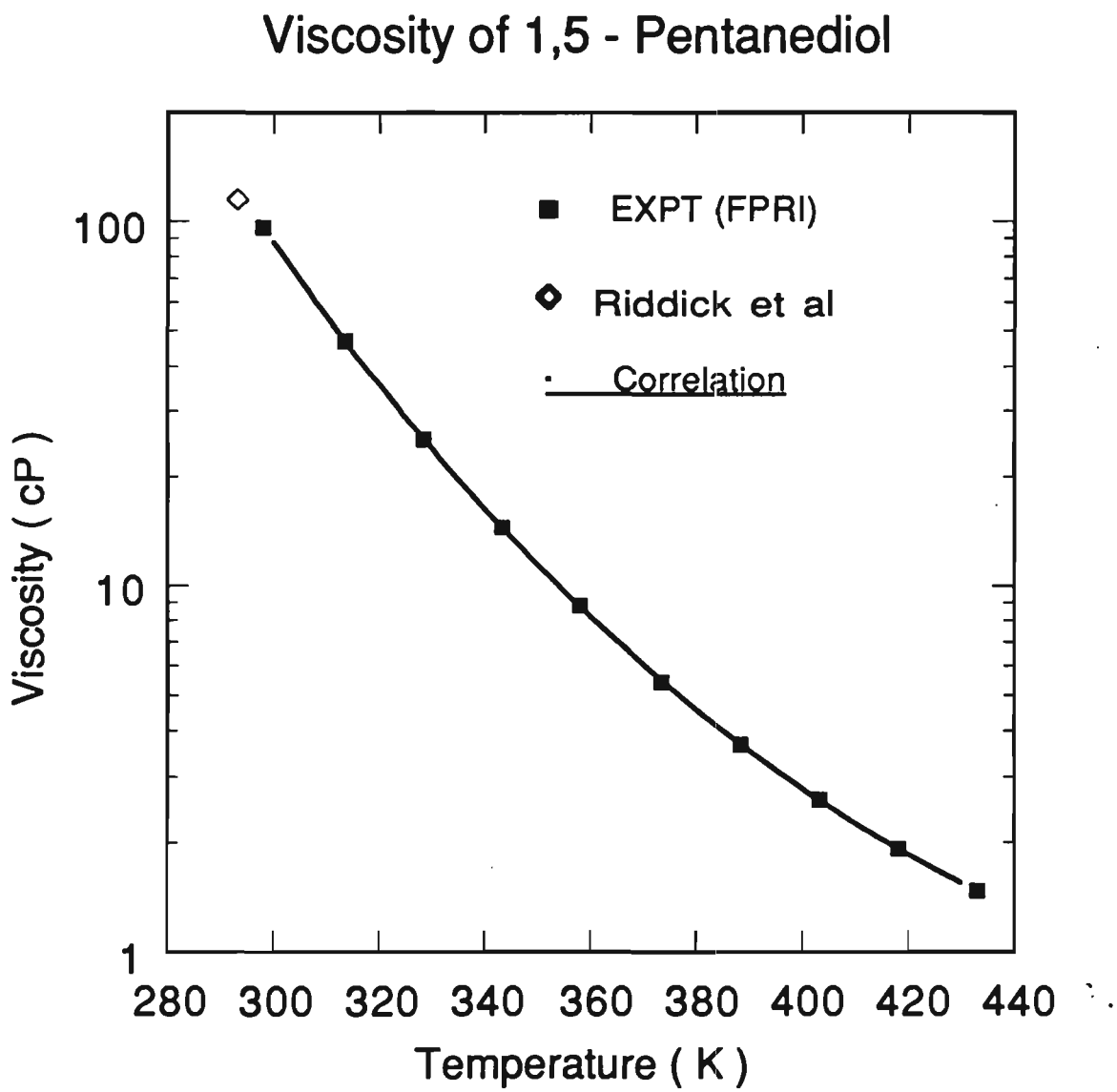

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2. Daubert, T.E.; Danner, R.P., "Data Compilation Tables of Properties of Pure Compounds", Design Institute for Physical Property Data, American Institute of Chemical Engineers, New York, N. Y. (1985).

3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1993 DDS-LV-A54

DESIGN DATA STANDARD - LIQUID VISCOSITY

1,6 - Hexanediol

$HO(CH_2)_6OH$
CA - No: 629-11-8

Purity =	99 %	
Molecular Weight =	118.18 kg/kmol	[1]
Critical Temperature =	670 K	[2]
Critical Pressure =	36.1 bar	[2]
Critical Volume =	0.398 m^3/kmol	[2]
Melting Point =	315.2 K	[2]
Normal Boiling Point =	516.2 K	[2]
Liquid Molar Volume at 25 °C =	0.12248 m^3/kmol	[2]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
318.40	48.49
328.40	31.60
343.35	17.52
358.20	10.47
373.40	6.503
388.25	4.299
403.15	2.973
418.15	2.141
433.15	1.620

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -78.37536 + 7808.127/(T/K) + 10.01843 \ln(T/K)$$

% AAD = 0.4 %
% MAD = 0.8 %

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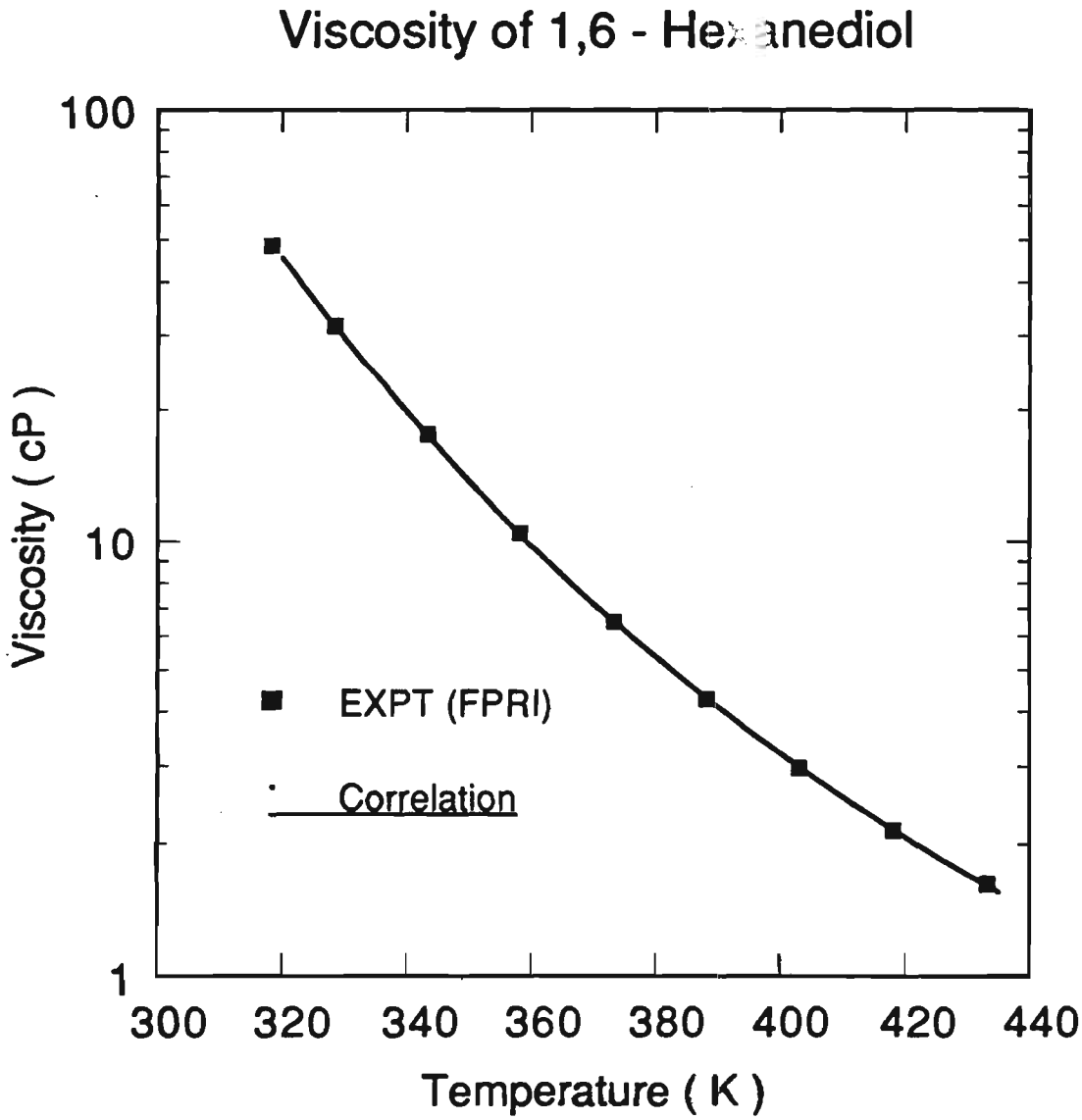
DDS-LV-A54



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May, 1993 DDS-LV-A55

DESIGN DATA STANDARD - LIQUID VISCOSITY

2,5 - Hexanediol

$CH_3CH(OH)CH_2CH_2CH(OH)CH_3$
CA - No: 2935-44-6

Purity =	99 %	
Molecular Weight =	118.18 kg/kmol	[1]
Critical Temperature =	638.2 K	[2]
Critical Pressure =	38.5 bar	[2]
Critical Volume =	0.409 m^3/kmol	[2]
Melting Point =	278.5 K	[2]
Normal Boiling Point =	490.2 K	[3]
Liquid Molar Volume at 25 °C =	0.12349 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
298.05	624.3
313.00	167.0
328.00	55.80
342.95	22.12
358.30	10.65
373.40	5.868
388.20	3.666
403.20	2.450
418.25	1.726
433.20	1.251

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -1151.50 + 46613.09/(T/K) + 186.2768 \ln(T/K) - 0.2003481\,(T/K)$$

% AAD = 1.2 %
% MAD = 2.0 %

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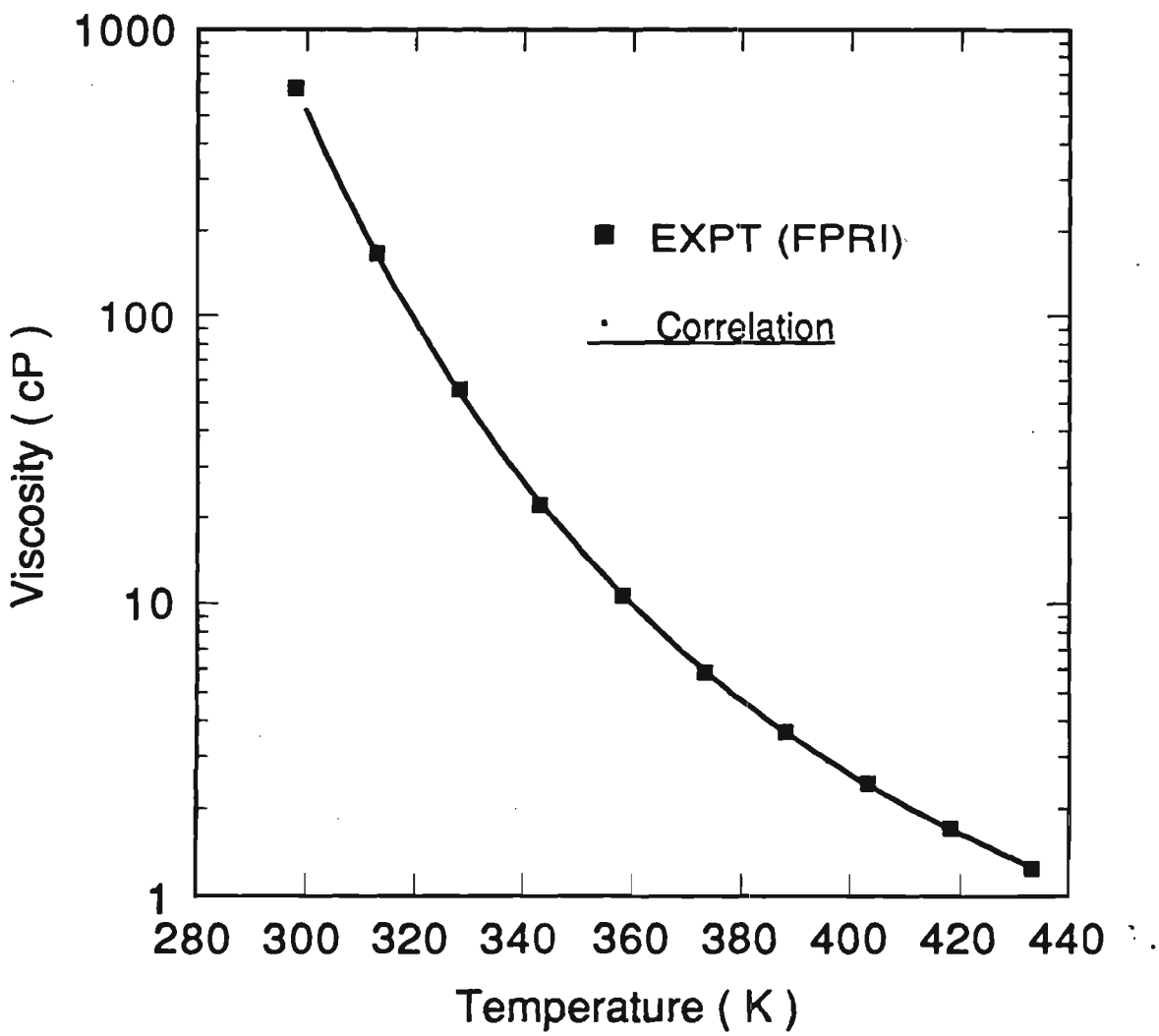
Viscosity of 2,5-Hexanediol



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1993 DDS-LV-A56

DESIGN DATA STANDARD - LIQUID VISCOSITY

2 - Methoxyethyl Ether

$(CH_3OCH_2CH_2)_2O$
CA - No: 111-96-6

Purity =	99+ %	
Molecular Weight =	134.18 kg/kmol	[1]
Critical Temperature =	613.8 K	[2]
Critical Pressure =	30.4 bar	[2]
Critical Volume =	0.425 m^3/kmol	[2]
Melting Point =	209.2 K	[3]
Normal Boiling Point =	435.2 K	[3]
Liquid Molar Volume at 25 °C =	0.144814 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
298.15	0.9414
313.25	0.7531
328.35	0.6171
343.35	0.5213
358.25	0.4462
373.40	0.3858
388.40	0.3386
403.25	0.2975
418.15	0.2649
433.15	0.2354

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -5.068586 + 1342.76/(T/K) + 0.08728621 \ln(T/K)$$

% AAD = 0.4 %
% MAD = 0.9 %

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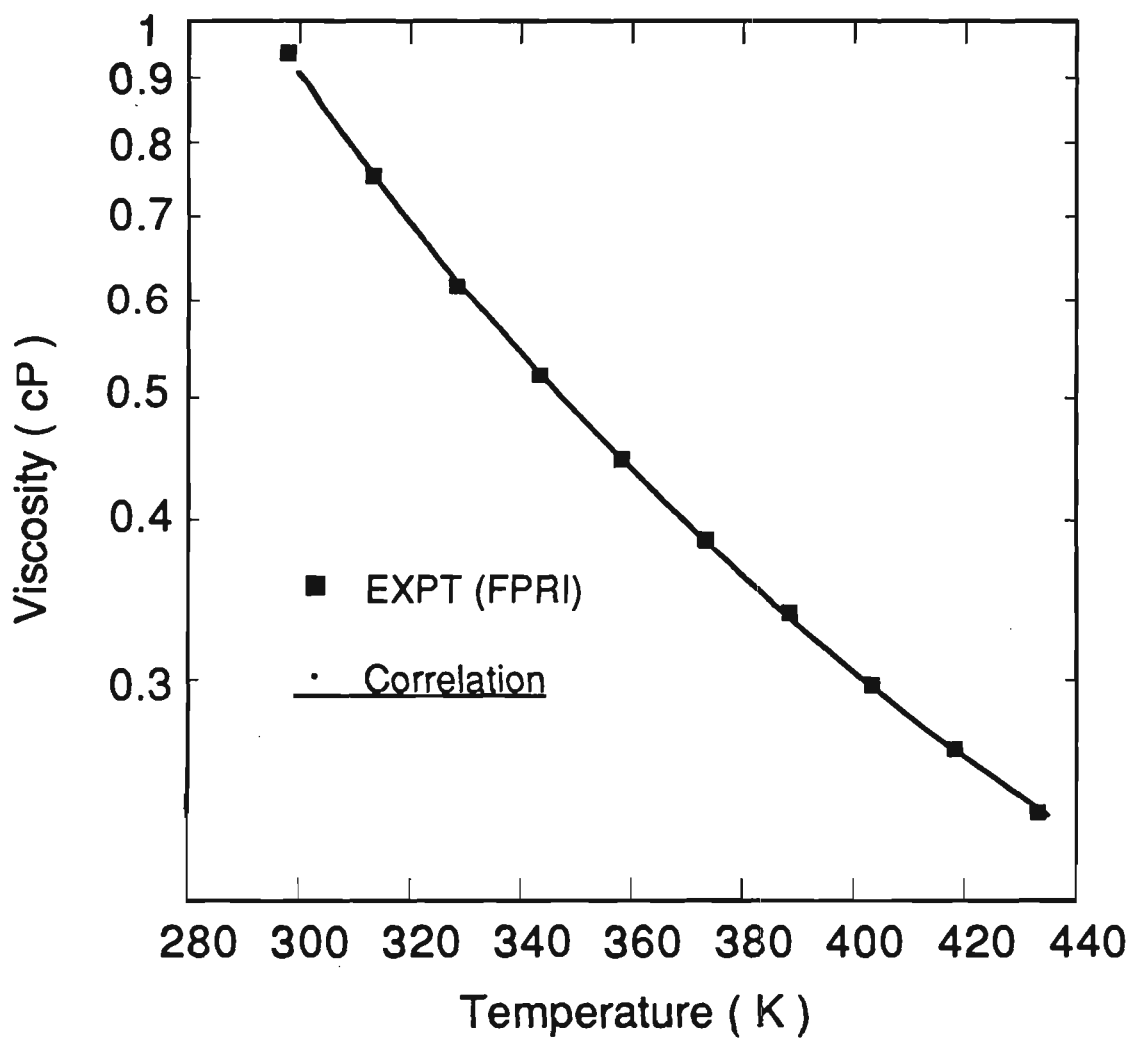
May, 1993 DDS-LV-A56

Viscosity of 2-Methoxyethyl Ether



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REFERENCES

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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1993 DDS-LV-A57

DESIGN DATA STANDARD - LIQUID VISCOSITY

Triethylene Glycol Dimethyl Ether

$CH_3OCH_2CH_2OCH_2CH_2OCH_2CH_2OCH_3$
CA - No: 112-49-2

Purity =	99 %	
Molecular Weight =	178.23 kg/kmol	[1]
Critical Temperature =	659.3 K	[2]
Critical Pressure =	23.7 bar	[2]
Critical Volume =	0.555 m^3/kmol	[2]
Melting Point =	228.2 K	[3]
Normal Boiling Point =	489.2 K	[3]
Liquid Molar Volume at 25 °C =	0.181617 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
298.15	1.8528
313.30	1.4069
328.35	1.1105
343.35	0.9061
358.15	0.7616
373.40	0.6510
388.35	0.5677
403.20	0.5006
418.15	0.4490
433.00	0.4055

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -2.902921 + 625.5983 / (T/K - 120.4004)$$

% AAD = 0.1 %
% MAD = 0.2 %

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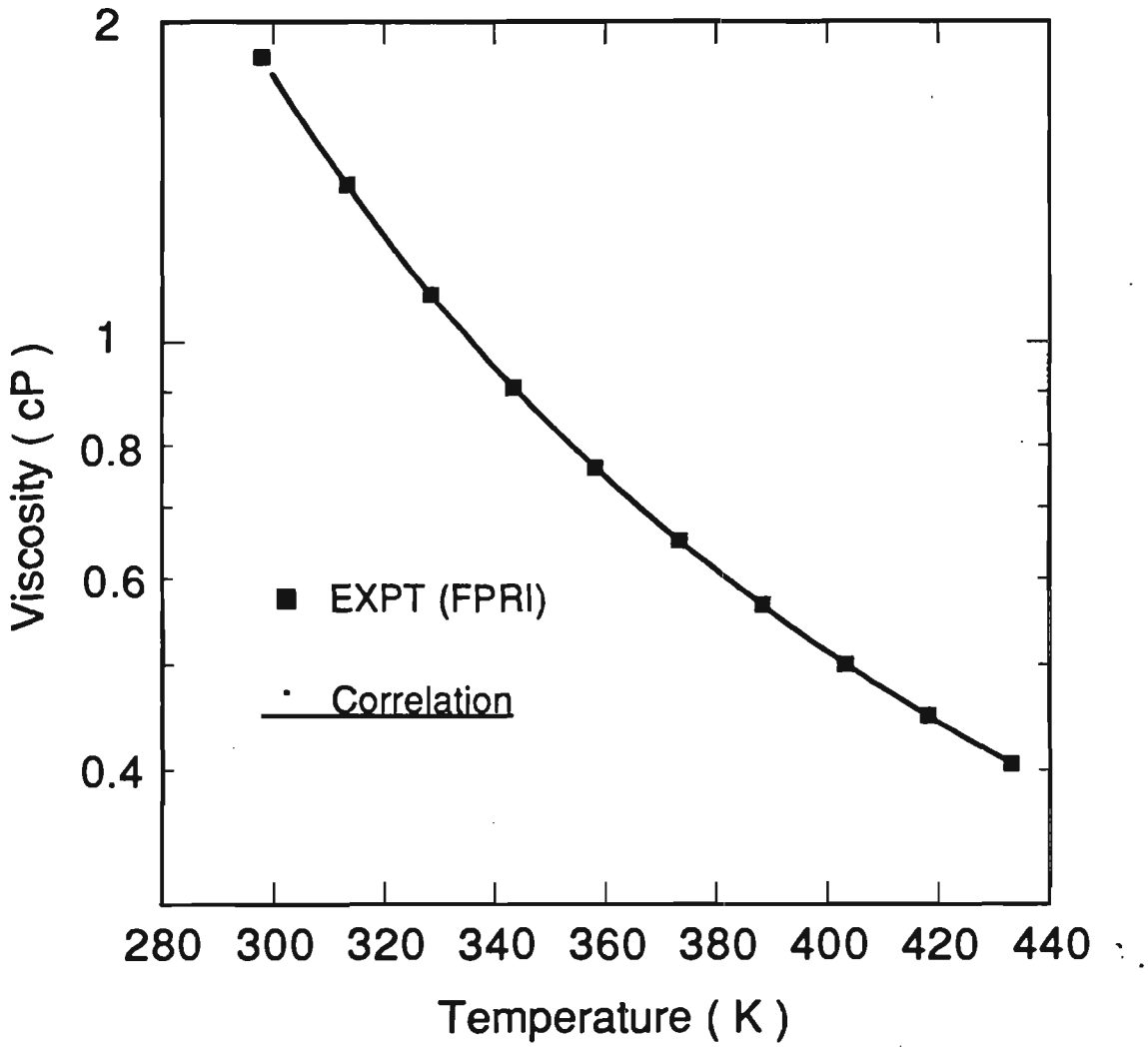
Triethylene Glycol Dimethyl Ether



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

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4. Estimated from FPRI density correlation.

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May, 1993 DDS-LV-A58

DESIGN DATA STANDARD - LIQUID VISCOSITY

Tetraethylene Glycol Dimethyl Ether

$CH_3(OCH_2CH_2)_4OCH_3$
CA - No: 143-24-8

Purity =	99 %	
Molecular Weight =	222.28 kg/kmol	[1]
Critical Temperature =	713.7 K	[2]
Critical Pressure =	19.5 bar	[2]
Critical Volume =	0.685 m^3/kmol	[2]
Melting Point =	313.1 K	[2]
Normal Boiling Point =	548.7 K	[3]
Liquid Molar Volume at 25 °C =	0.220810 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
298.00	3.186
313.00	2.292
328.05	1.738
342.95	1.374
358.35	1.113
373.40	0.9287
388.35	0.7916
403.35	0.6869
418.05	0.6043
433.10	0.5369

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -2.878275 + 693.1562 / (T/K - 126.1637)$$

% AAD = 0.1 %
% MAD = 0.3 %

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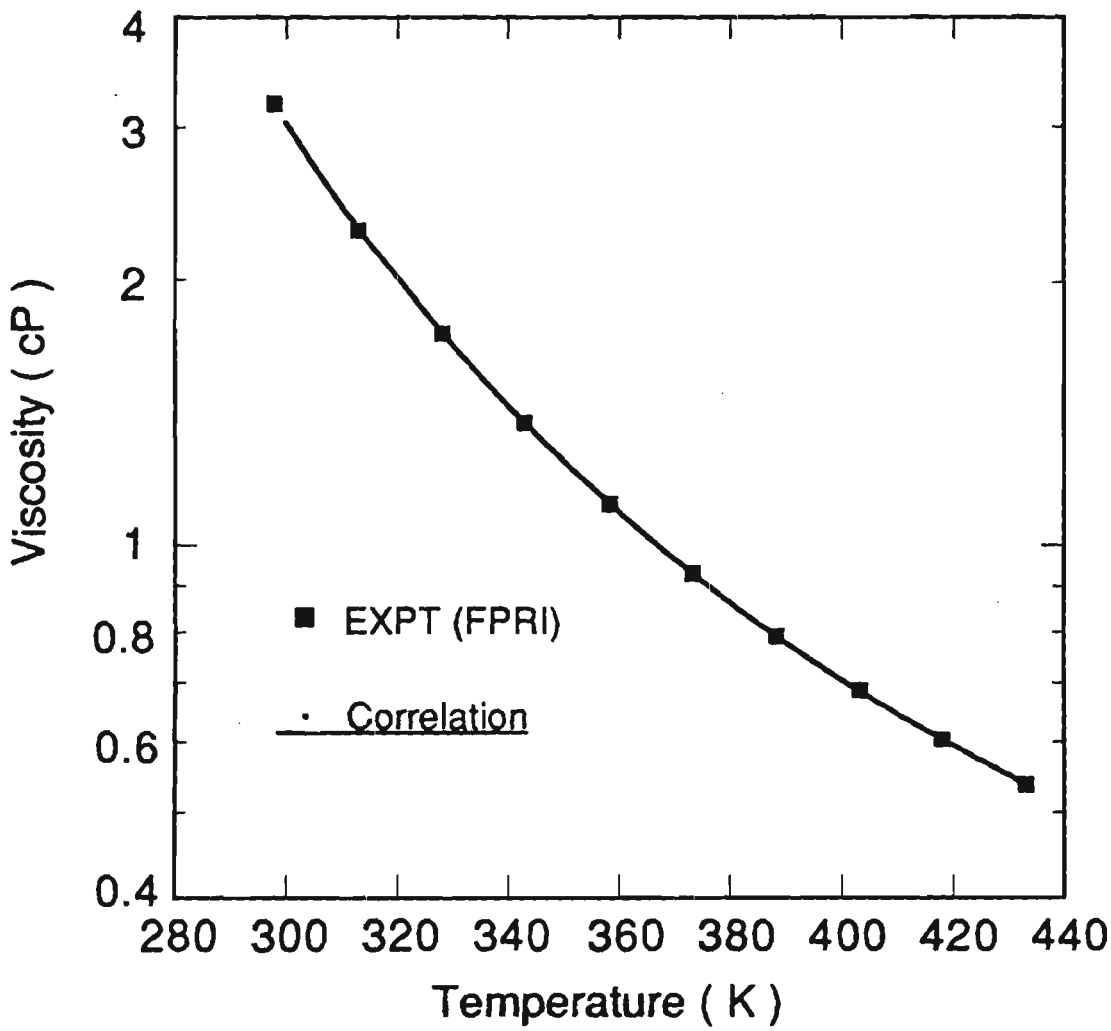
Tetraethylene Glycol Dimethyl Ether



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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

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May, 1993 DDS-LV-A59

DESIGN DATA STANDARD - LIQUID VISCOSITY

2 - Ethoxyethanol

$C_2H_5OCH_2CH_2OH$
CA - No: 110-80-5

Purity =	99+ %	
Molecular Weight =	90.12 kg/kmol	[1]
Critical Temperature =	571.7 K	[2]
Critical Pressure =	42.8 bar	[2]
Critical Volume =	0.296 m^3/kmol	[2]
Melting Point =	183.2 K	[2]
Normal Boiling Point =	408.2 K	[3]
Liquid Molar Volume at 25 °C =	0.097383 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
293.70	2.004
308.00	1.502
323.00	1.135
337.95	0.887
353.30	0.707
368.25	0.587
383.15	0.496
398.15	0.429
407.15	0.397

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -39.37908 + 3447.419/(T/K) + 4.989923 \ln(T/K)$$

% AAD = 0.1 %
% MAD = 0.3 %

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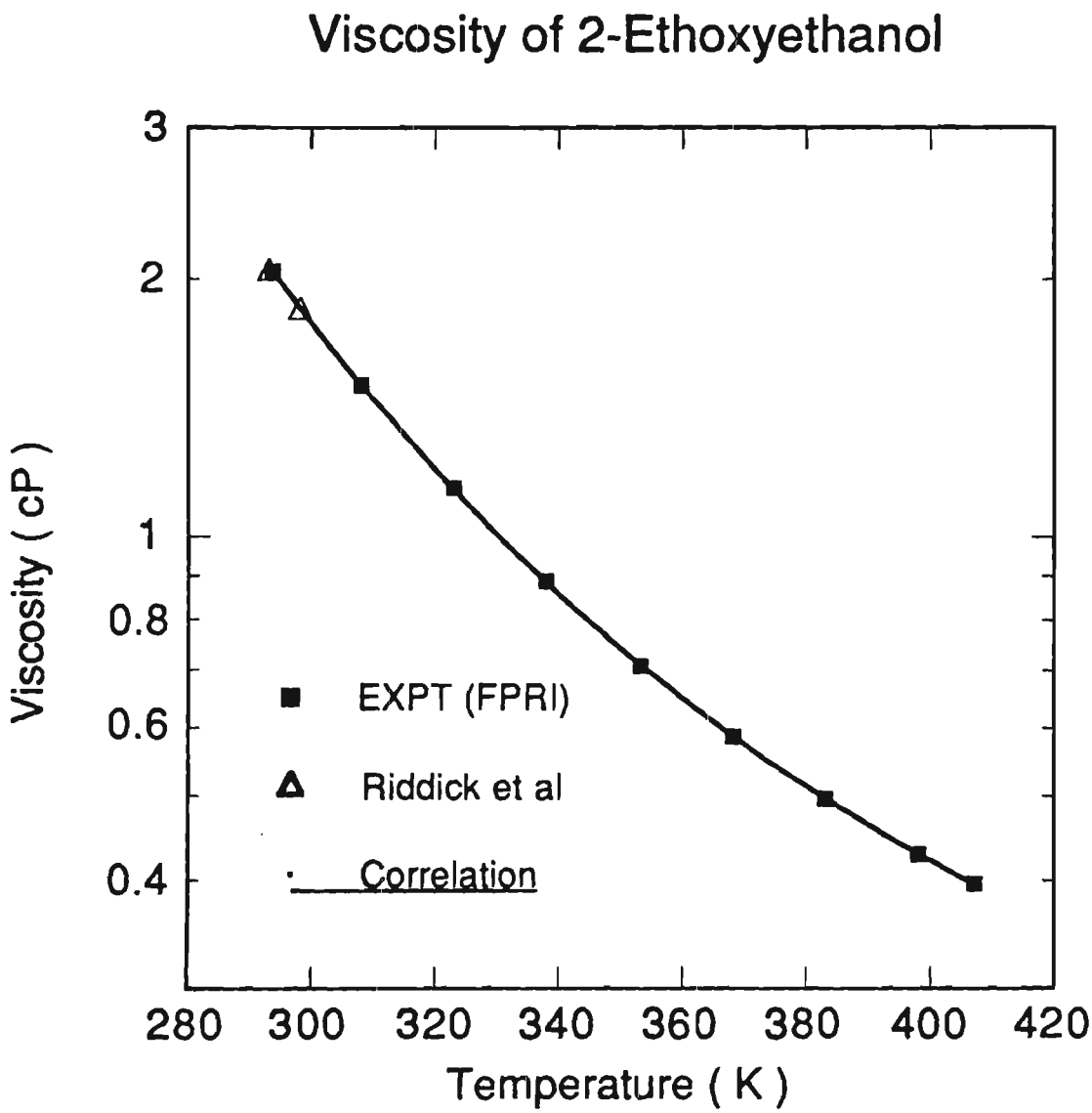
DDS-LV-A59



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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

5. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1993 DDS-LV-A60

DESIGN DATA STANDARD - LIQUID VISCOSITY

2 - (2- Ethoxyethoxy) Ethanol

$C_2H_5OCH_2CH_2OCH_2CH_2OH$
CA - No: 111-90-0

Purity =	99+ %	
Molecular Weight =	134.18 kg/kmol	[1]
Critical Temperature =	637 K	[2]
Critical Pressure =	34.4 bar	[2]
Critical Volume =	0.426 m^3/kmol	[2]
Melting Point =	262.1 K	[2]
Normal Boiling Point =	475.2 K	[3]
Liquid Molar Volume at 25 °C =	0.136301 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
299.40	3.655
313.35	2.570
328.35	1.872
343.35	1.423
358.25	1.123
373.40	0.9063
388.30	0.7547
403.25	0.6401
418.15	0.5518
433.05	0.4848

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -3.292147 + 779.0925 / (T/K - 129.5506)$$

% AAD = 0.1 %
% MAD = 0.2 %

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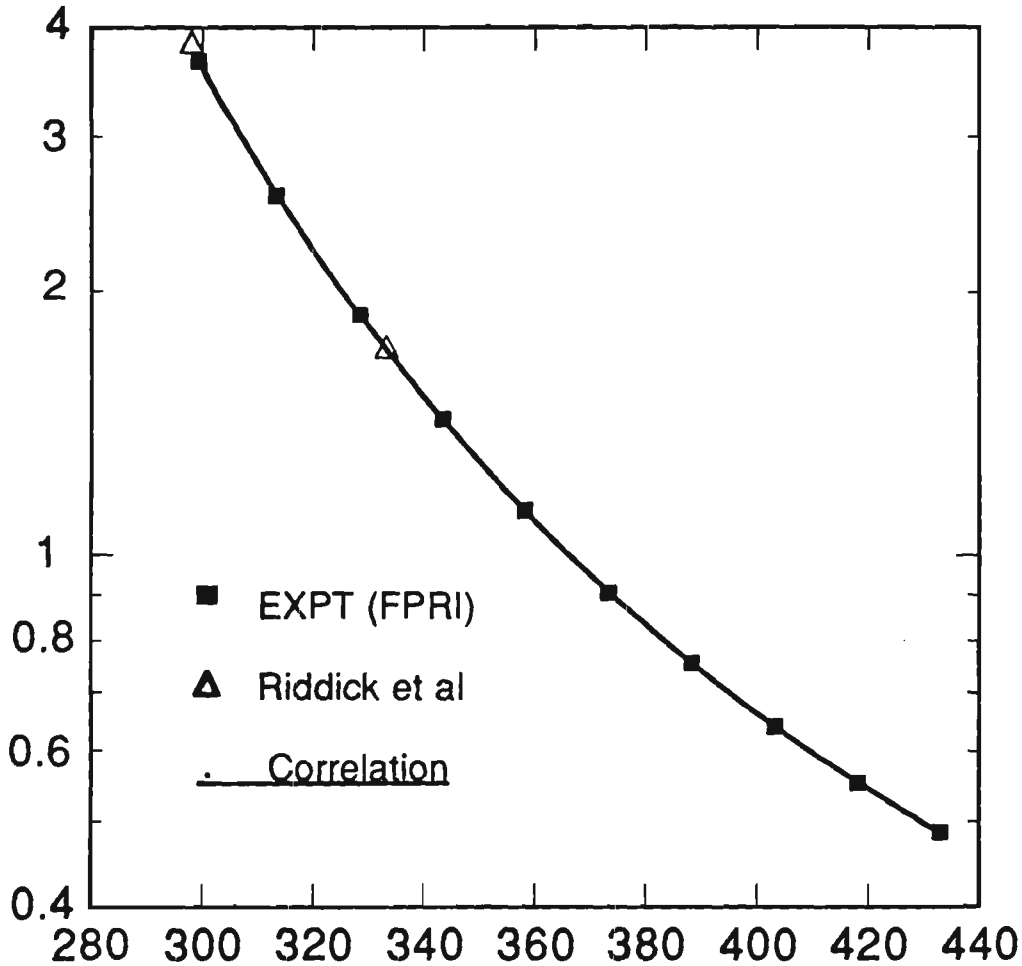
DDS-LV-A60

Viscosity of 2-(2-Ethoxyethoxy)ethanol



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

5. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1993 DDS-LV-A61

DESIGN DATA STANDARD - LIQUID VISCOSITY

N,N - Dimethyl Ethylenediamine

$(CH_3)_2NCH_2CH_2NH_2$
CA - No: 108-00-9

Purity =	95 %	
Molecular Weight =	88.15 kg/kmol	[1]
Critical Temperature =	409.6 K	[2]
Critical Pressure =	40.1 bar	[2]
Critical Volume =	0.303 m^3/kmol	[2]
Melting Point =	235.8 K	[2]
Normal Boiling Point =	278.5 K	[3]
Liquid Molar Volume at 25 °C =	0.109447 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
294.15	0.7811
305.90	0.6478
316.00	0.5614
325.95	0.4934
335.95	0.4381
345.90	0.3917
356.35	0.3535
365.65	0.3236
375.90	0.2953

Liquid Viscosity Correlation:

$$\ln (\mu / cP) = -25.9077 + 2343.657 / (T/K) + 3.11249 \ln (T/K)$$

% AAD = 0.1 %
% MAD = 0.2 %

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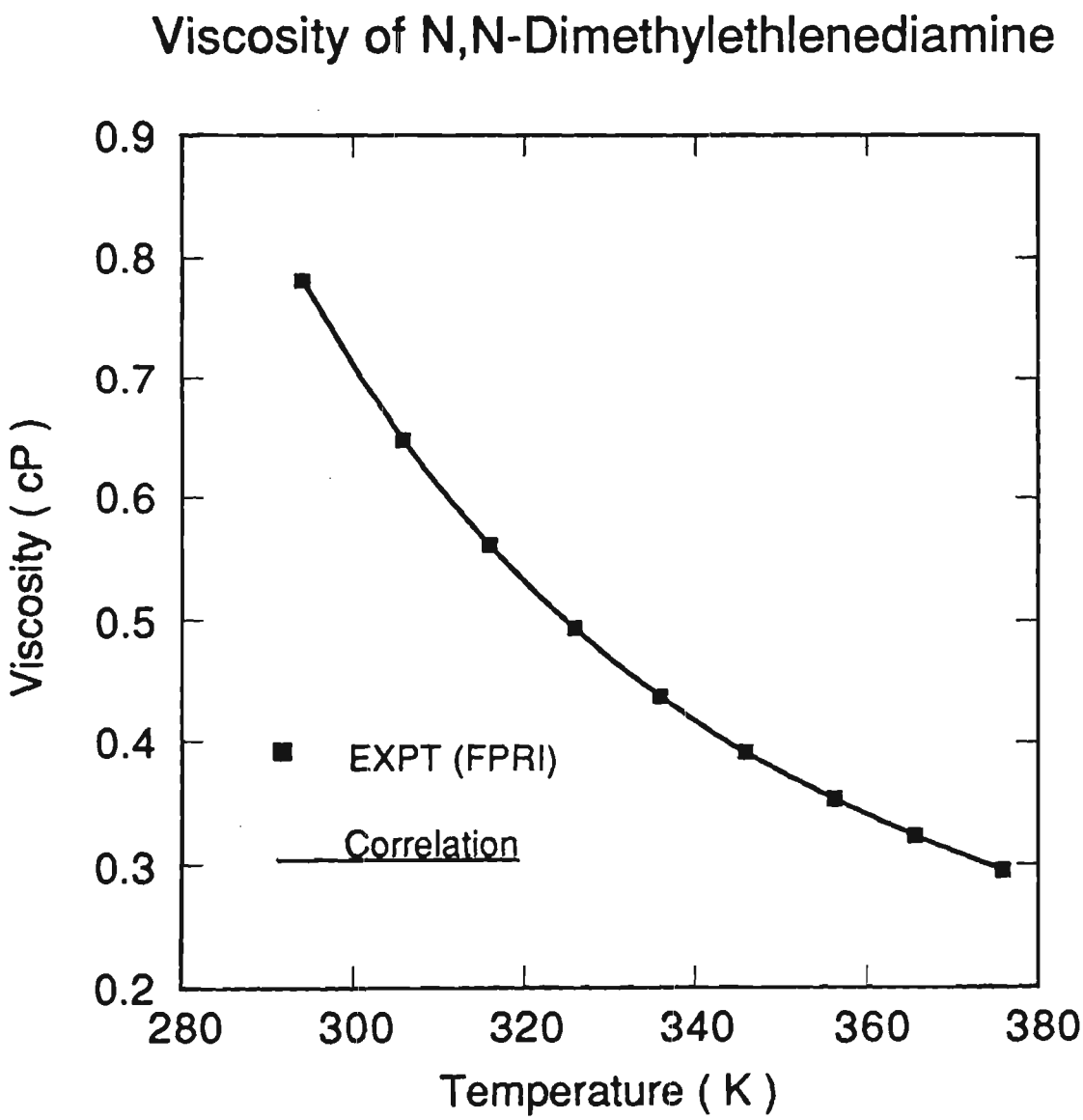

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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1993 DDS-LV-A62

DESIGN DATA STANDARD - LIQUID VISCOSITY

Triethylamine

$(C_2H_5)_3N$
CA - No: 121-44-8

Purity =	99 %	
Molecular Weight =	101.19 kg/kmol	[1]
Critical Temperature =	530.4 K	[2]
Critical Pressure =	31.0 bar	[2]
Critical Volume =	0.389 m^3/kmol	[2]
Melting Point =	158.2 K	[3]
Normal Boiling Point =	362.0 K	[3]
Liquid Molar Volume at 25 °C =	0.139837 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
293.05	0.3675
302.95	0.3324
313.00	0.3023
323.00	0.2763
333.00	0.2538
342.95	0.2347
352.90	0.2176
358.90	0.2081

Liquid Viscosity Correlation:

$$\ln (\mu / cP) = -1.29127 + 773.3238 / (T/K) - 0.4134942 \ln (T/K)$$

% AAD < 0.1 %
% MAD = 0.1 %

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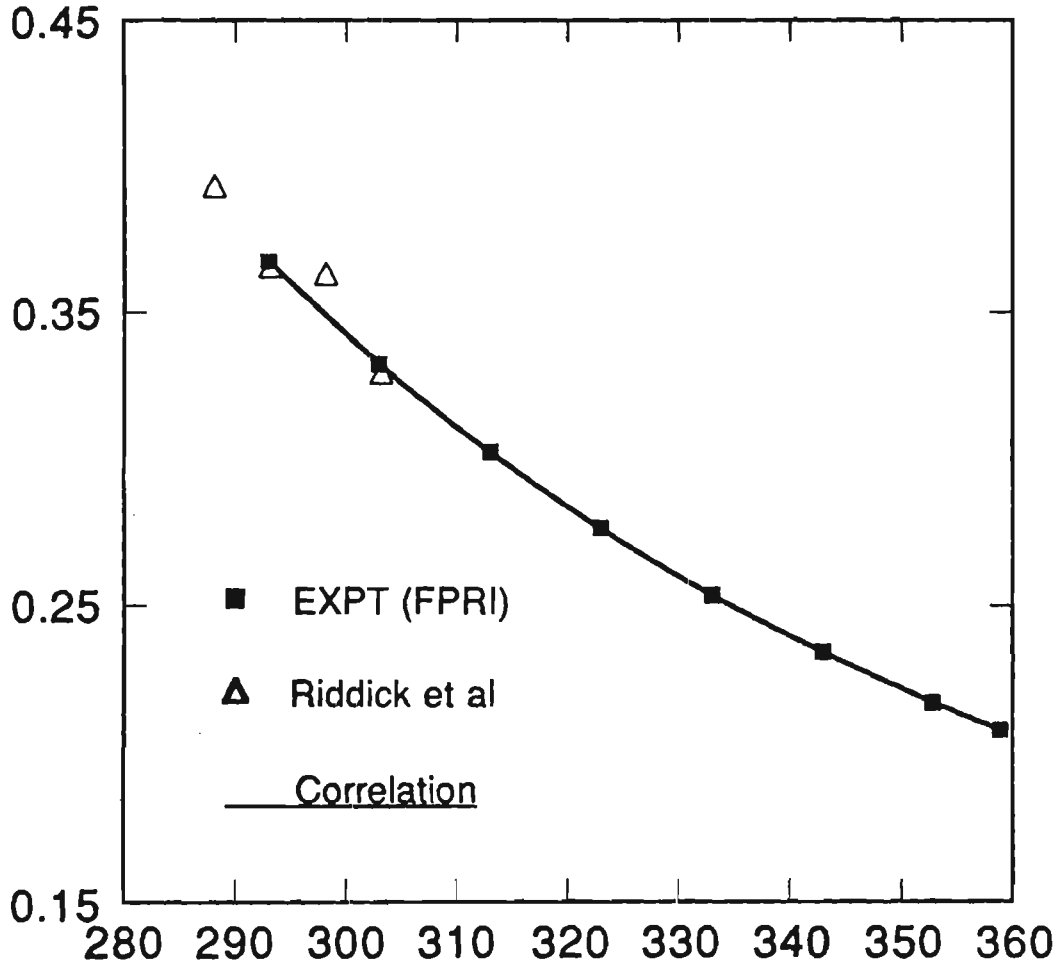
May, 1993

DDS-LV-A62

Viscosity of Triethylamine



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REFERENCES

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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

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5. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1993 DDS-LV-A63

DESIGN DATA STANDARD - LIQUID VISCOSITY

Acetic Acid

CH_3COOH
CA - No: 64-19-7

Purity =	99.7 %	
Molecular Weight =	60.052 kg/kmol	[1]
Critical Temperature =	592.9 K	[2]
Critical Pressure =	57.86 bar	[3]
Critical Volume =	0.1711 m^3/kmol	[2]
Melting Point =	289.81 K	[3]
Normal Boiling Point =	391.05 K	[3]
Liquid Molar Volume at 25 °C =	0.05758 m^3/kmol	[2]

Experimental Technique : High Pressure Capillary Viscometer

Experiment Data:

Pressure = ~ 20 bar
Accuracy = ± 2.0 %

T (K)	μ (cP)
296.20	1.136
313.40	0.887
328.30	0.744
343.40	0.634
358.15	0.549
373.35	0.482
377.25	0.457
388.30	0.425
402.83	0.370
416.40	0.326
431.39	0.289
445.46	0.252
452.45	0.239

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -270.0099 + 9068.621 / (T/K) + 45.50753 \ln(T/K) - 0.06571948 (T/K)$$

% AAD = 0.4 %
% MAD = 1.2 %

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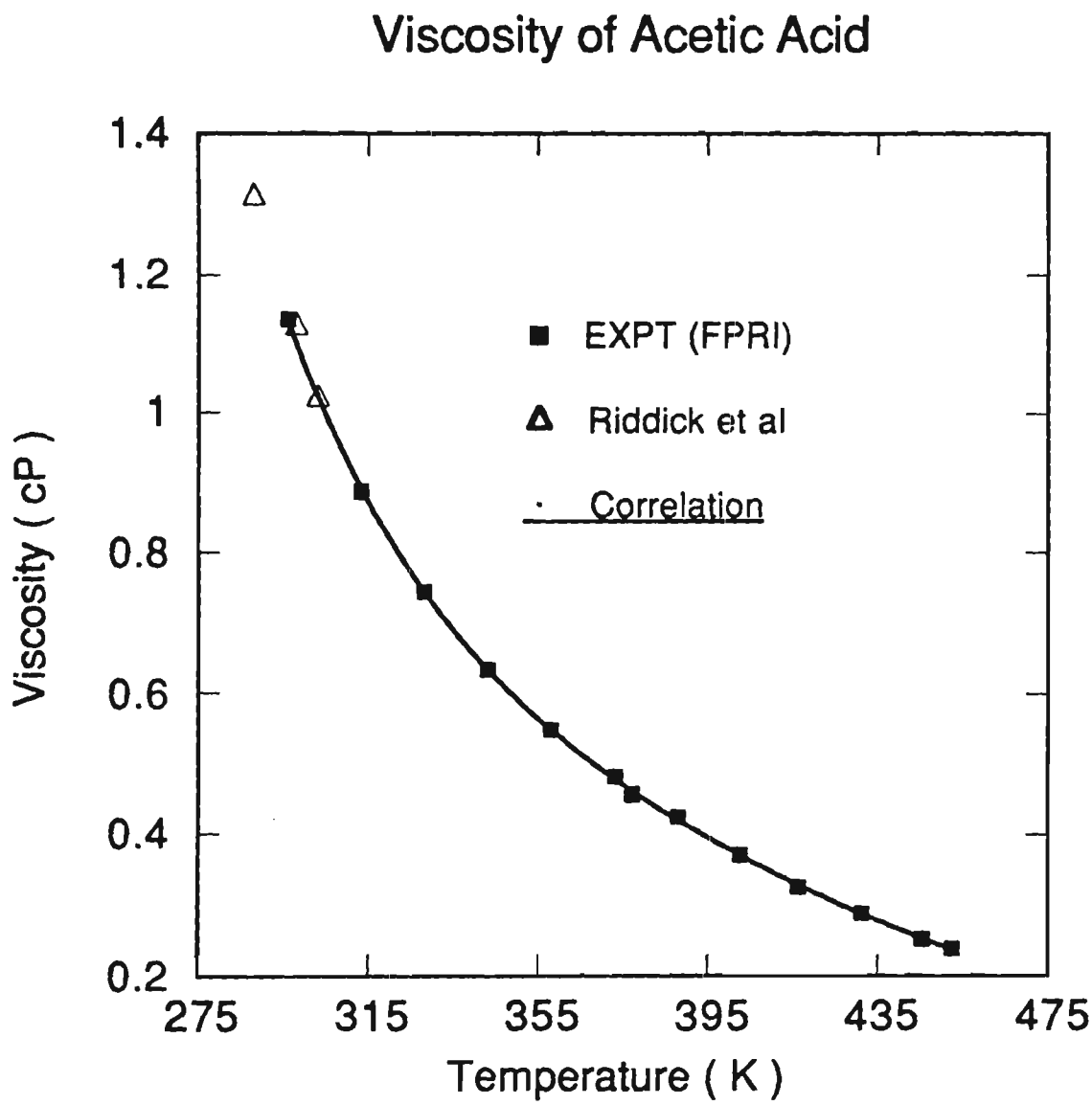
DDS-LV-A63



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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Data measured in FPRI laboratory, 1992.

3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1993 DDS-LV-A64

DESIGN DATA STANDARD - LIQUID VISCOSITY

84 wt% Acetic Acid + 16 wt% Water

$CH_3COOH + H_2O$
CA - No: 64-19-7

Purity =	99.7 %	
Molecular Weight =	57.778 kg/kmol	[1]
Critical Temperature =	602.2 K	[2]
Critical Pressure =		
Critical Volume =	0.1651 m^3/kmol	[2]
Melting Point =		
Normal Boiling Point =		
Liquid Molar Volume at 25 °C =	0.05440 m^3/kmol	[3]

Experimental Technique : High Pressure Capillary Viscometer

Experiment Data:

Pressure = ~ 20 bar
Accuracy = ± 2.0 %

T (K)	μ (cP)
295.25	2.381
308.40	1.736
323.40	1.276
338.20	0.986
353.15	0.792
368.10	0.660
378.35	0.581
383.15	0.549
396.55	0.460
408.55	0.412
420.75	0.366
436.25	0.309
449.45	0.277

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -334.8634 + 12315.76/(T/K) + 55.44353 \ln(T/K) - 0.0722709\,(T/K)$$

% AAD = 0.7 %
% MAD = 1.9 %

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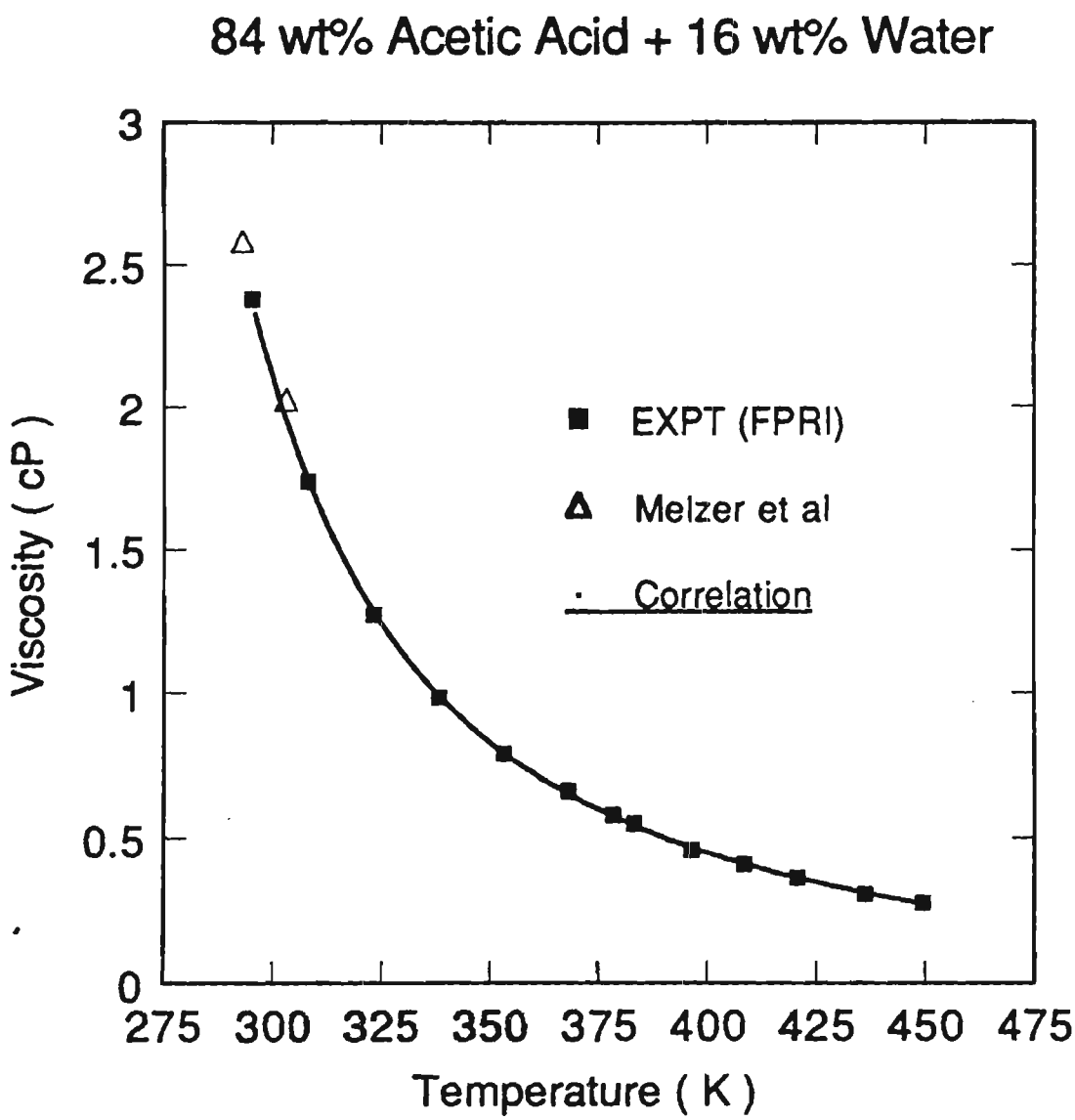
FPRI

May, 1993 DDS-LV-A64



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REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Data measured in FPRI laboratory, 1992.

3. Estimated from FPRI density correlation.

4. Melzer, W. M.; Baldauf, W.; Knapp, H., "Measurement of Diffusivity, Viscosity, Density and Refractivity of Eight Binary Liquid Mixtures", Chem. Eng. Process., 26, 71 (1989).

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May, 1993 DDS-LV-A65

DESIGN DATA STANDARD - LIQUID VISCOSITY

92 wt% Acetic Acid + 8 wt% Water

$CH_3COOH + H_2O$
CA - No: 64-19-7

Purity =	99.7 %	
Molecular Weight =	58.984 kg/kmol	[1]
Critical Temperature =	598.6 K	[2]
Critical Pressure =		
Critical Volume =	0.1700 m^3/kmol	[2]
Melting Point =		
Normal Boiling Point =		
Liquid Molar Volume at 25 °C =	0.05574 m^3/kmol	[3]

Experimental Technique : High Pressure Capillary Viscometer

Experiment Data:

Pressure = ~ 20 bar
Accuracy = ± 2.0 %

T (K)	μ (cP)
295.35	1.991
313.48	1.356
328.40	1.042
343.30	0.833
358.25	0.686
373.35	0.570
379.35	0.518
391.85	0.458
401.85	0.412
411.45	0.376
420.65	0.345
431.05	0.317
439.70	0.298
452.95	0.267

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -99.71347 + 5005.974/(T/K) + 15.58311 \ln(T/K) - 0.01757938 (T/K)$$

% AAD = 0.6 %
% MAD = 1.5 %

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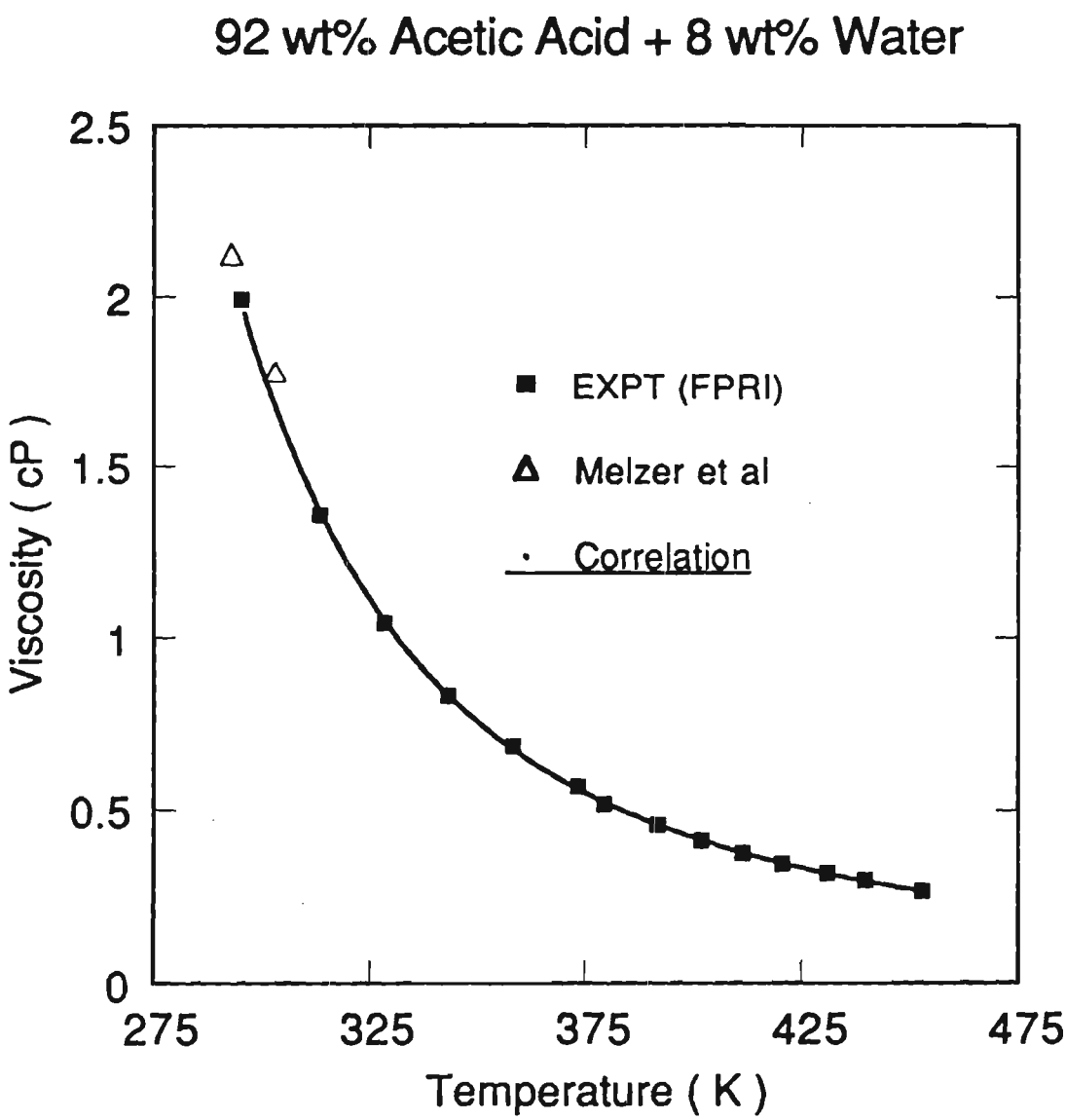
FPRI

May, 1993

DDS-LV-A65



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REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Data measured in FPRI laboratory, 1992.

3. Estimated from FPRI density correlation.

4. Melzer, W. M.; Baldauf, W.; Knapp, H., "Measurement of Diffusivity, Viscosity, Density and Refractivity of Eight Binary Liquid Mixtures", Chem. Eng. Process., 26, 71 (1989).

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FPRI

May, 1993 DDS-LV-A66

DESIGN DATA STANDARD - LIQUID VISCOSITY

12 wt% Acetic Acid + 88 wt% Water

$CH_3COOH + H_2O$
CA - No: 64-19-7

Purity = 99.7 %
Molecular Weight = 16.667 kg/kmol [1]
Critical Temperature =
Critical Pressure =
Critical Volume =
Melting Point =
Normal Boiling Point =
Liquid Molar Volume at 25 °C =

Experimental Technique : High Pressure Capillary Viscometer

Experiment Data:

Pressure = ~ 20 bar
Accuracy = ± 2.0 %

T (K)	μ (cP)
294.05	1.991
308.30	1.356
323.35	1.042
338.25	0.833
353.20	0.686
368.05	0.570
378.05	0.518
383.15	0.458
394.45	0.412
405.25	0.376
413.45	0.345
424.15	0.317
433.45	0.298
444.35	0.267
452.95	0.171

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -74.61543 + 4527.93 / (T/K) + 10.84803 \ln(T/K) - 0.007699032 (T/K)$$

% AAD = 0.4 %
% MAD = 1.2 %

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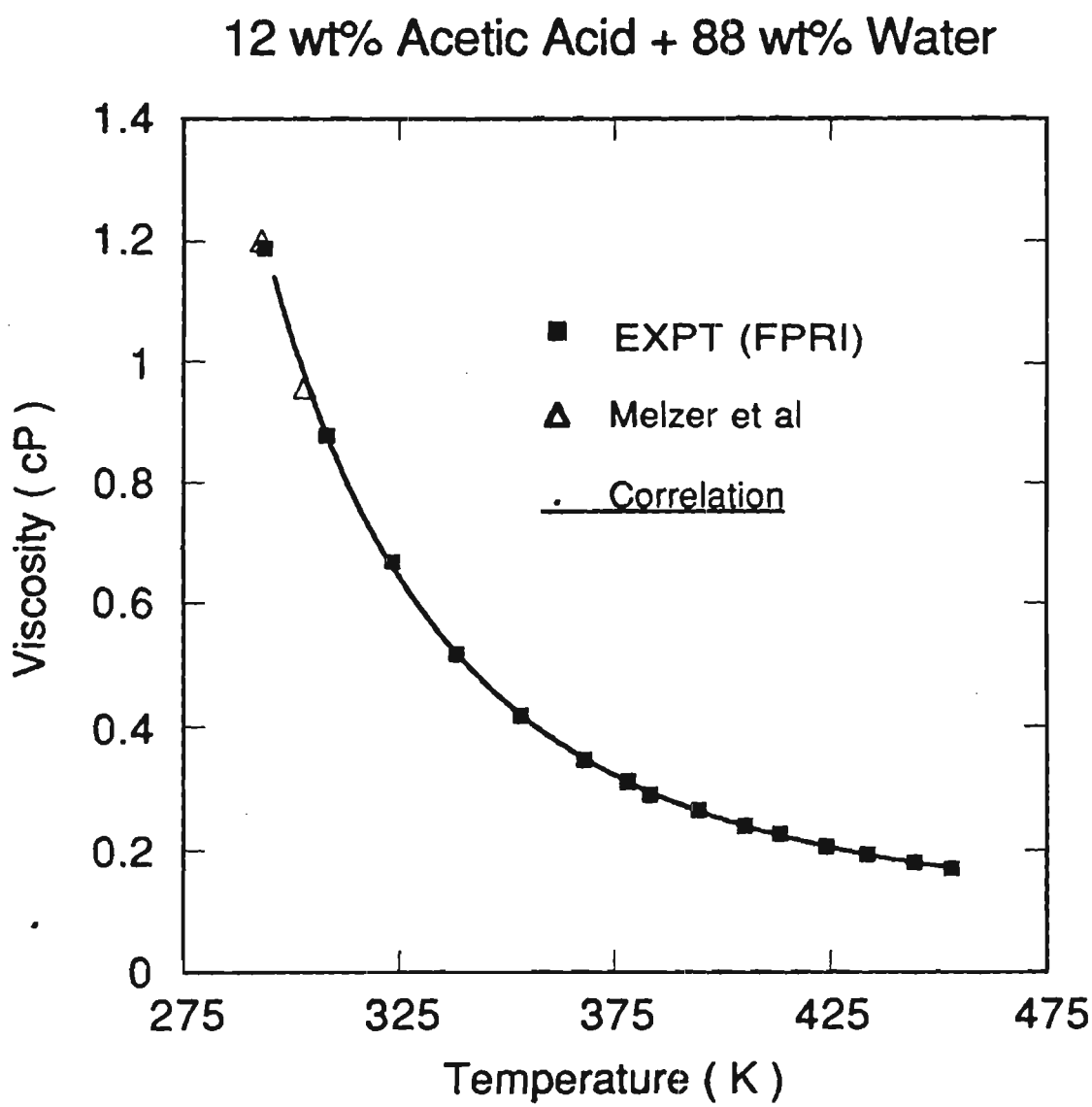
May, 1993

DDS-LV-A66



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May, 1993 DDS-LD-A53

DESIGN DATA STANDARD - LIQUID DENSITY

1,5 - Pentanediol

$HO(CH_2)_5OH$
CA - No: 111-29-5

Purity =	96 %	
Molecular Weight =	104.14 kg/kmol	[1]
Critical Temperature =	673 K	[2]
Critical Pressure =	41.5 bar	[2]
Critical Volume =	0.345 m^3/kmol	[2]
Melting Point =	257.2 K	[2]
Normal Boiling Point =	512.2 K	[2]
Liquid Molar Volume at 25 °C =	0.104809 m^3/kmol	[2]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
295.95	987.7
313.00	977.5
328.00	968.5
343.25	959.2
358.15	950.1
373.45	940.2
388.30	930.7
403.30	919.8
418.25	908.8
433.15	897.2

Liquid Density Correlation:

1) $\rho / kgm^{-3} = 1305.88 - 1.969575\ T/K + 4.429085 \times 10^{-3} (T/K)^2 - 4.756965 \times 10^{-6} (T/K)^3$
% AAD = 0.009 % % MAD = 0.027 %

2) $\rho / kgm^{-3} = 4.193949 / 0.061147515^{[1+(1-T/K/673)^{0.080609225}]}$
% AAD = 0.019 % % MAD = 0.053 %

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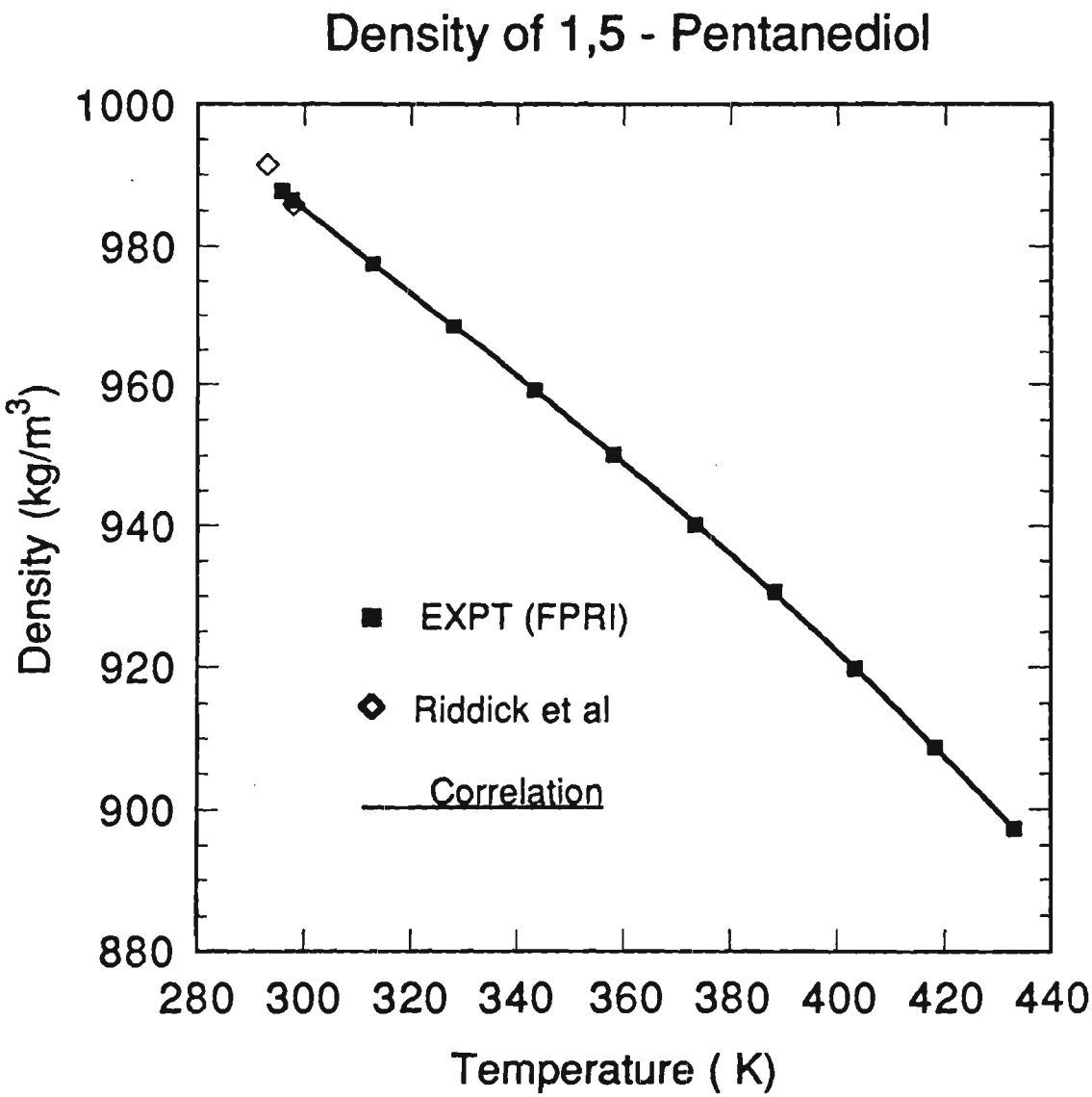
DDS-LD-A53



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2. Daubert, T.E.; Danner, R.P., "Data Compilation Tables of Properties of Pure Compounds", Design Institute for Physical Property Data, American Institute of Chemical Engineers, New York, N. Y. (1985).

3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1993 DDS-LD-A54

DESIGN DATA STANDARD - LIQUID DENSITY

1,6 - Hexanediol

$HO(CH_2)_6OH$
CA - No: 629-11-8

Purity =	99 %	
Molecular Weight =	118.18 kg/kmol	[1]
Critical Temperature =	670 K	[2]
Critical Pressure =	36.1 bar	[2]
Critical Volume =	0.398 m^3/kmol	[2]
Melting Point =	315.2 K	[2]
Normal Boiling Point =	516.2 K	[2]
Liquid Molar Volume at 25 °C =	0.12248 m^3/kmol	[2]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
317.95	958.0
327.95	952.0
343.35	942.4
358.25	933.3
373.35	923.7
388.25	913.8
403.15	903.2
418.15	892.0
432.95	880.8

Liquid Density Correlation:

1) $\rho / kgm^{-3} = 1286.28 - 1.920432\ T/K + 4.232807 \times 10^{-3}\ (T/K)^2 - 4.529223 \times 10^{-6} (T/K)^3$
% AAD = 0.010 % % MAD = 0.022 %

2) $\rho / kgm^{-3} = 2.987681 / 0.052020147^{[1 + (1 - T/K/670)^{0.076465733}]}$
% AAD = 0.015 % % MAD = 0.035 %

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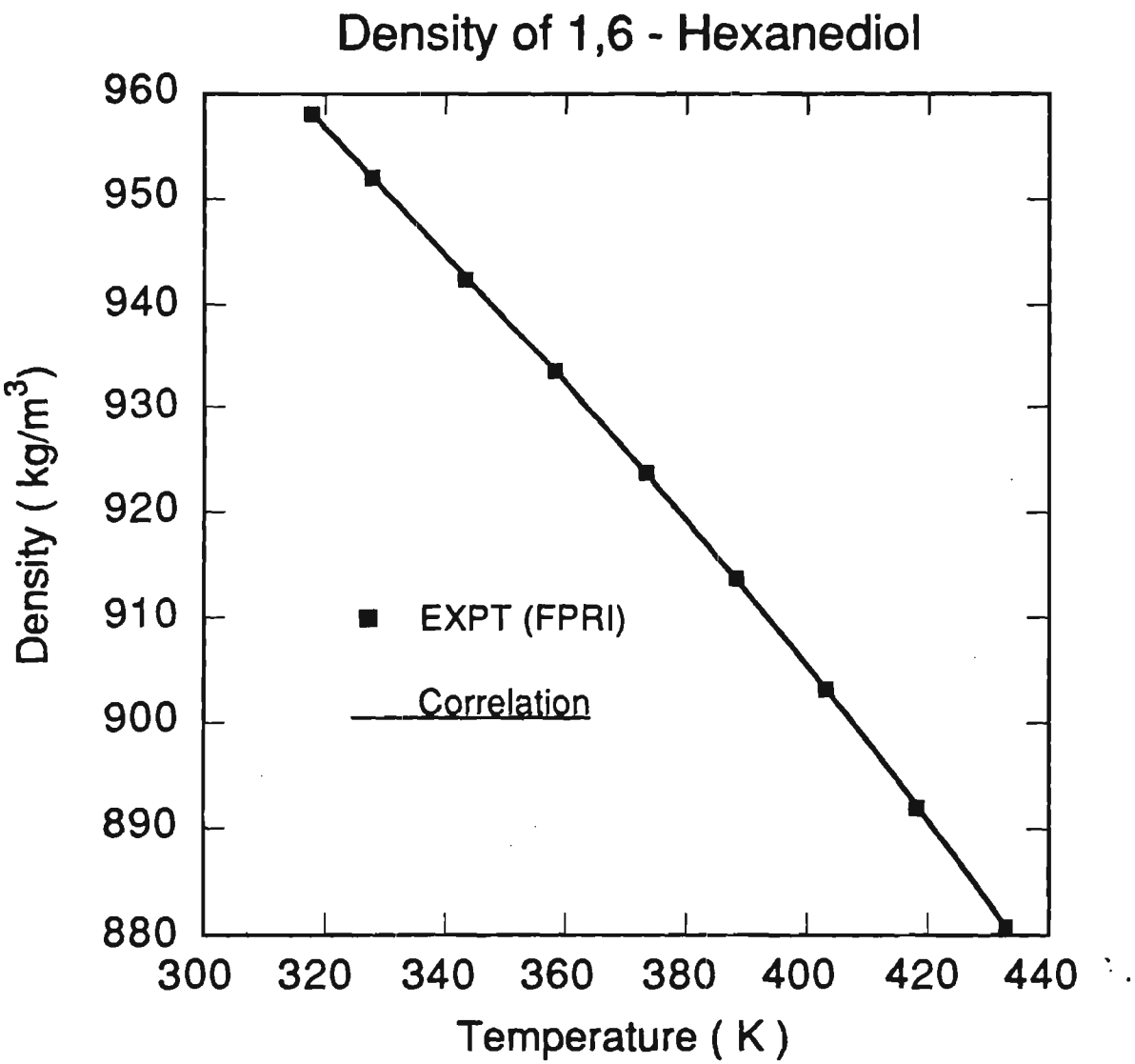

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2. Daubert, T.E.; Danner, R.P., "Data Compilation Tables of Properties of Pure Compounds", Design Institute for Physical Property Data, American Institute of Chemical Engineers, New York, N. Y. (1985).

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May, 1993 DDS-LD-A55

DESIGN DATA STANDARD - LIQUID DENSITY

2,5 - Hexanediol

$CH_3CH(OH)CH_2CH_2CH(OH)CH_3$
CA - No: 2935-44-6

Purity =	99 %	
Molecular Weight =	118.18 kg/kmol	[1]
Critical Temperature =	638.2 K	[2]
Critical Pressure =	38.5 bar	[2]
Critical Volume =	0.409 m^3/kmol	[2]
Melting Point =	278.5 K	[2]
Normal Boiling Point =	490.2 K	[3]
Liquid Molar Volume at 25 °C =	0.12349 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
298.60	956.8
313.05	947.2
328.05	936.8
342.95	926.0
358.30	914.5
373.40	902.2
388.25	889.6
403.25	876.9
418.25	863.3
433.20	849.0

Liquid Density Correlation:

1) $\rho / kgm^{-3} = 1040.398 + 0.07765285\ T/K - 1.198891 \times 10^{-3}\ (T/K)^2$
% AAD = 0.010 % % MAD = 0.021 %

2) $\rho / kgm^{-3} = 1.977510 / 0.042025398^{[1+(1-T/K/638.2)^{0.080332175}]}$
% AAD = 0.029 % % MAD = 0.064 %

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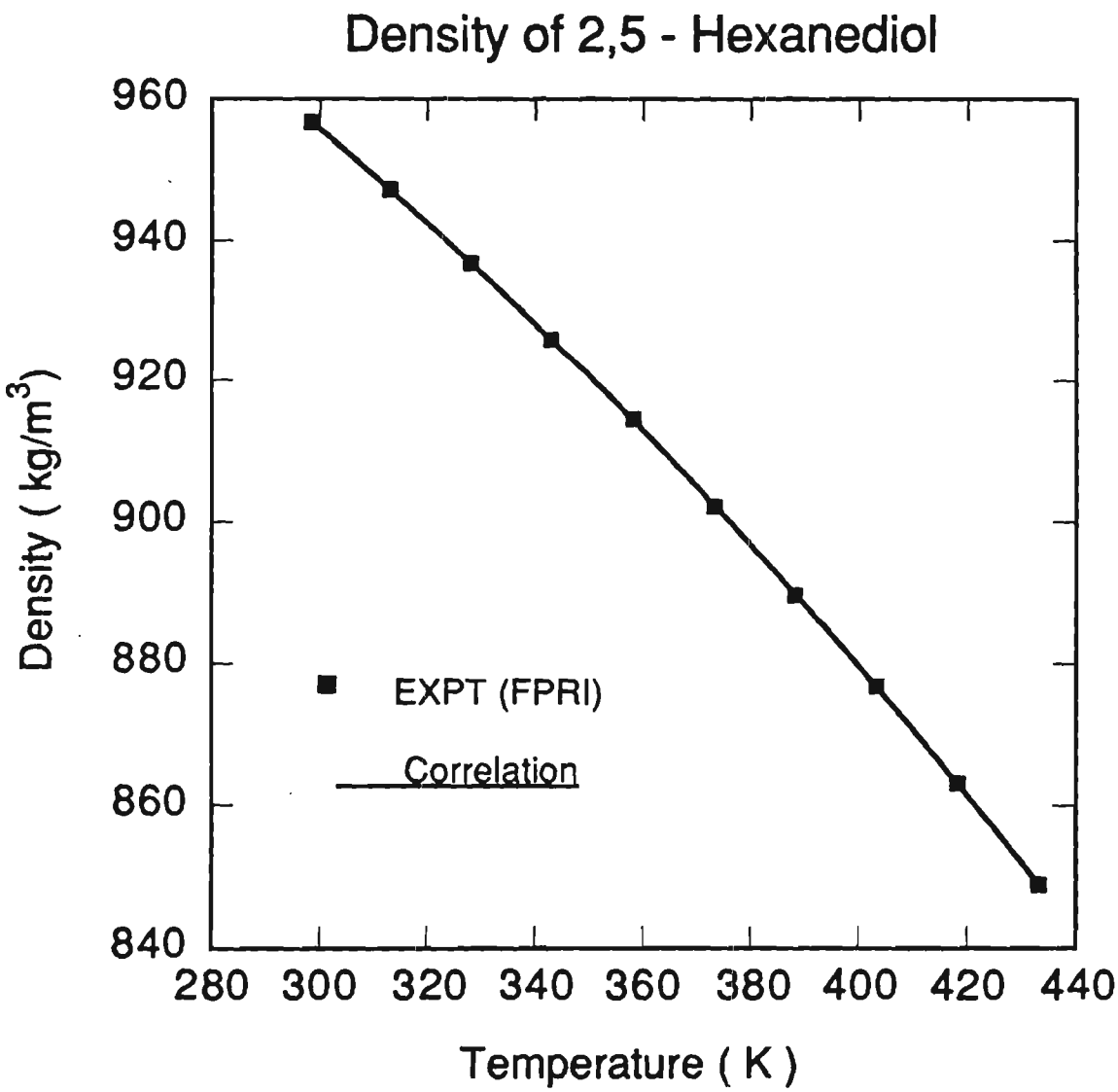

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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1993 DDS-LD-A56

DESIGN DATA STANDARD - LIQUID DENSITY

2 - Methoxyethyl Ether

$(CH_3OCH_2CH_2)_2O$
CA - No: 111-96-6

Purity =	99+ %	
Molecular Weight =	134.18 kg/kmol	[1]
Critical Temperature =	613.8 K	[2]
Critical Pressure =	30.4 bar	[2]
Critical Volume =	0.425 m^3/kmol	[2]
Melting Point =	209.2 K	[3]
Normal Boiling Point =	435.2 K	[3]
Liquid Molar Volume at 25 °C =	0.144814 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
300.70	937.1
313.00	924.5
328.05	909.4
343.35	893.3
358.25	878.0
373.45	861.8
388.45	845.6
403.30	829.3
418.15	812.3
429.10	800.0

Liquid Density Correlation:

1) $\rho / kgm^{-3} = 1292.656 - 1.556061\ T/K + 1.925181 \times 10^{-3}\ (T/K)^2 - 2.270119 \times 10^{-6} (T/K)^3$
% AAD = 0.010 % % MAD = 0.022 %

2) $\rho / kgm^{-3} = 156.8788 / 0.3588026^{[1 + (1 - T/K/613.8)^{0.4399487}]}$
% AAD = 0.011 % % MAD = 0.028 %

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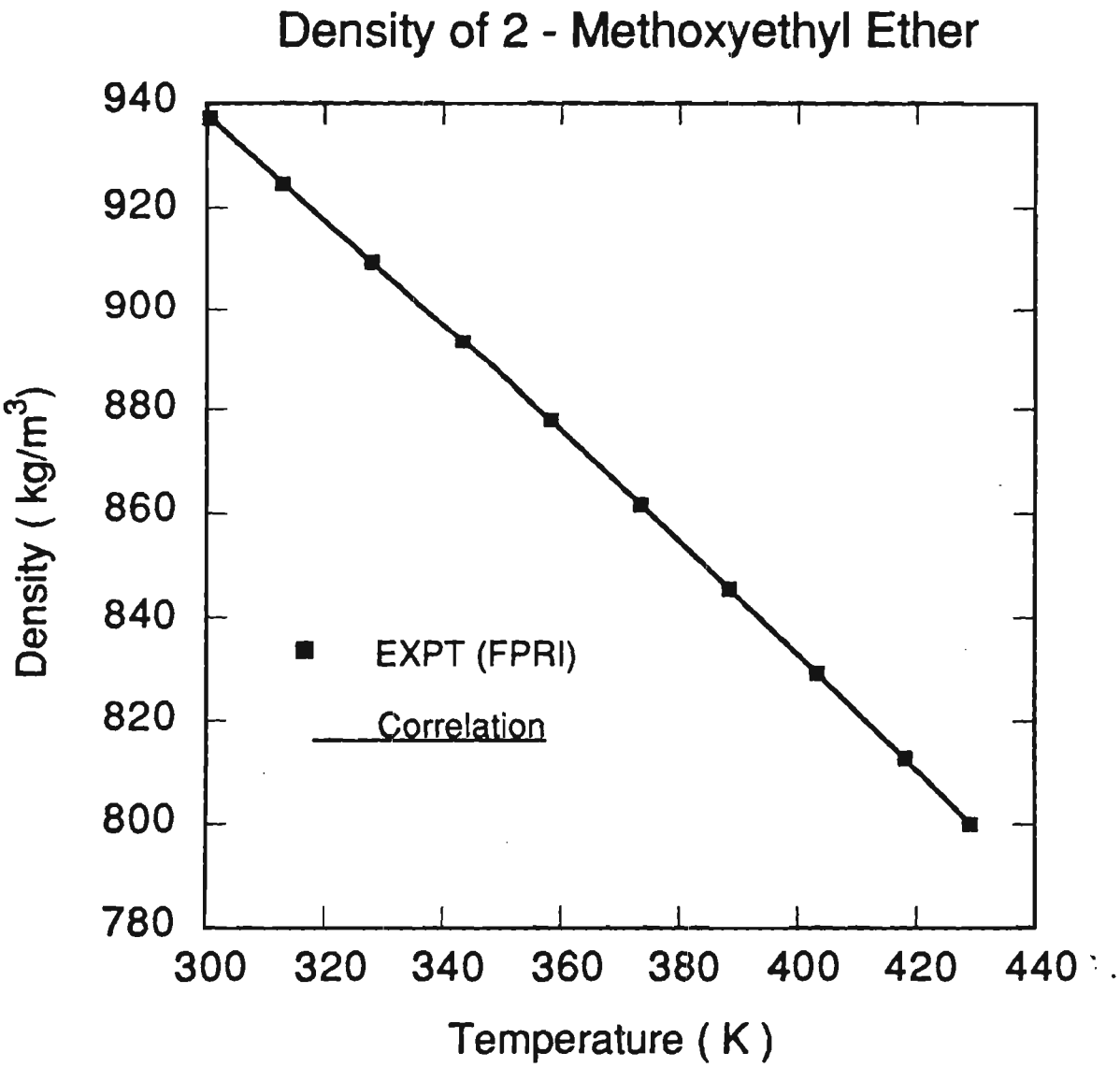

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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1993 DDS-LD-A57

DESIGN DATA STANDARD - LIQUID DENSITY

Triethylene Glycol Dimethyl Ether

$CH_3OCH_2CH_2OCH_2CH_2OCH_2CH_2OCH_3$
CA - No: 112-49-2

Purity =	99 %	
Molecular Weight =	178.23 kg/kmol	[1]
Critical Temperature =	659.3 K	[2]
Critical Pressure =	23.7 bar	[2]
Critical Volume =	0.555 m^3/kmol	[2]
Melting Point =	228.2 K	[3]
Normal Boiling Point =	489.2 K	[3]
Liquid Molar Volume at 25 °C =	0.181617 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
297.95	981.5
313.00	967.2
327.95	952.6
343.35	938.0
358.15	923.5
373.40	908.6
388.35	893.7
403.25	879.0
418.15	863.7
433.00	848.6

Liquid Density Correlation:

1) $\rho / \mathrm{kgm}^{-3} = 197.9178 / 0.3969111^{[1+(1-T/K/659.3)^{0.5168825}]}$
% AAD = 0.007 % % MAD = 0.021 %

2) $\rho / \mathrm{kgm}^{-3} = 1237.27 - 0.772902\ T/K - 2.877345 \times 10^{-4}\ (T/K)^2$
% AAD = 0.008 % % MAD = 0.026 %

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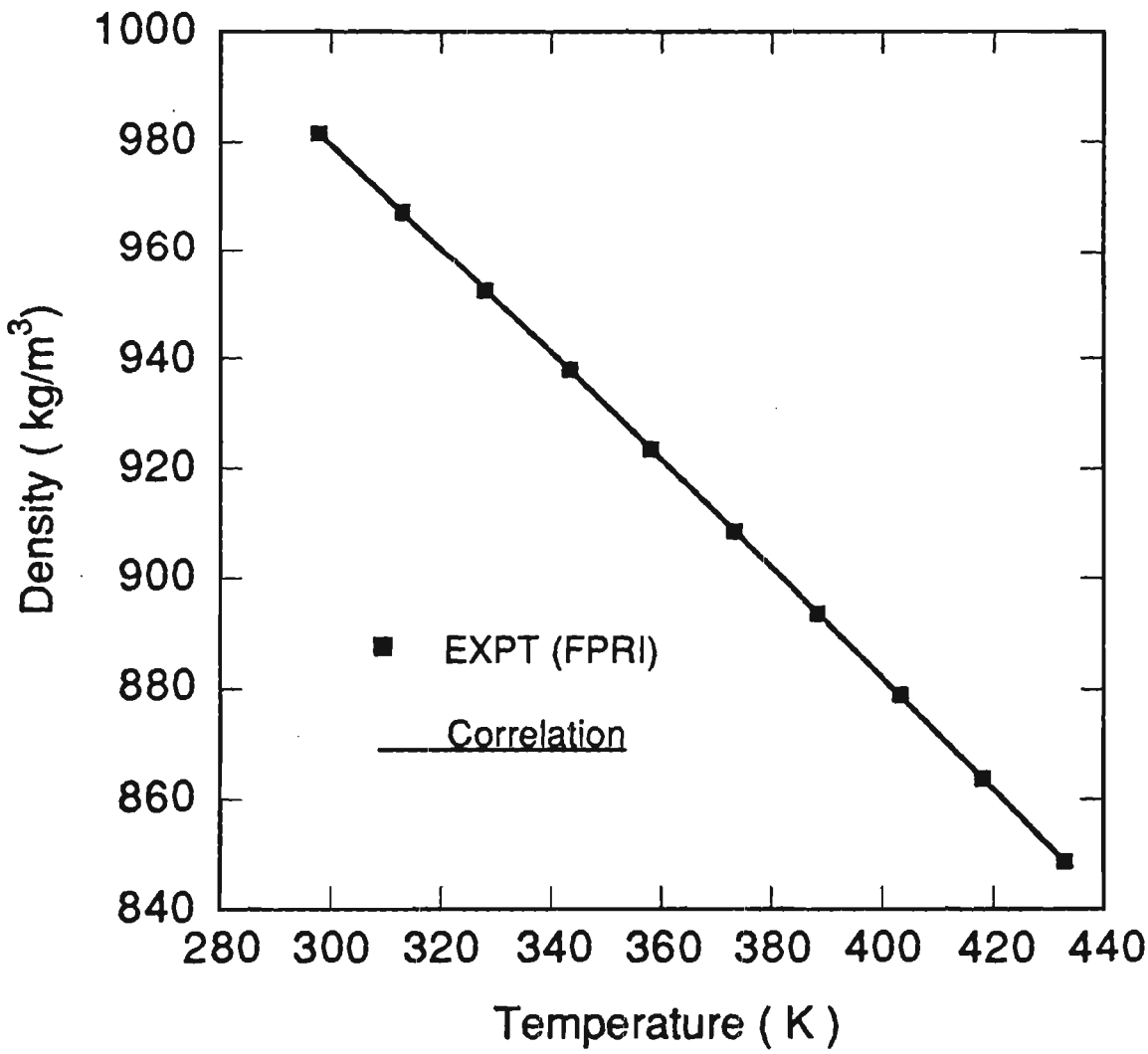
Density of Triethylene Glycol Dimethyl Ether



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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1993 DDS-LD-A58

DESIGN DATA STANDARD - LIQUID DENSITY

Tetraethylene Glycol Dimethyl Ether

$CH_3(OCH_2CH_2)_4OCH_3$
CA - No: 143-24-8

Purity =	99 %	
Molecular Weight =	222.28 kg/kmol	[1]
Critical Temperature =	713.7 K	[2]
Critical Pressure =	19.5 bar	[2]
Critical Volume =	0.685 m^3/kmol	[2]
Melting Point =	313.1 K	[2]
Normal Boiling Point =	548.7 K	[3]
Liquid Molar Volume at 25 °C =	0.220810 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
298.00	1006.8
313.00	992.8
328.05	978.9
342.90	965.1
357.75	951.3
373.45	936.6
388.35	922.7
403.35	908.8
418.10	894.6
433.15	880.5

Liquid Density Correlation:

1) $\rho / kgm^{-3} = 215.9360 / 0.4101176^{[1+(1-T/K/713.7)^{0.5892665}]}$
% AAD = 0.006 % % MAD = 0.024 %

2) $\rho / kgm^{-3} = 1273.40 - 0.8677826\ T/K - 9.0812871 \times 10^{-5}\ (T/K)^2$
% AAD = 0.007 % % MAD = 0.026 %

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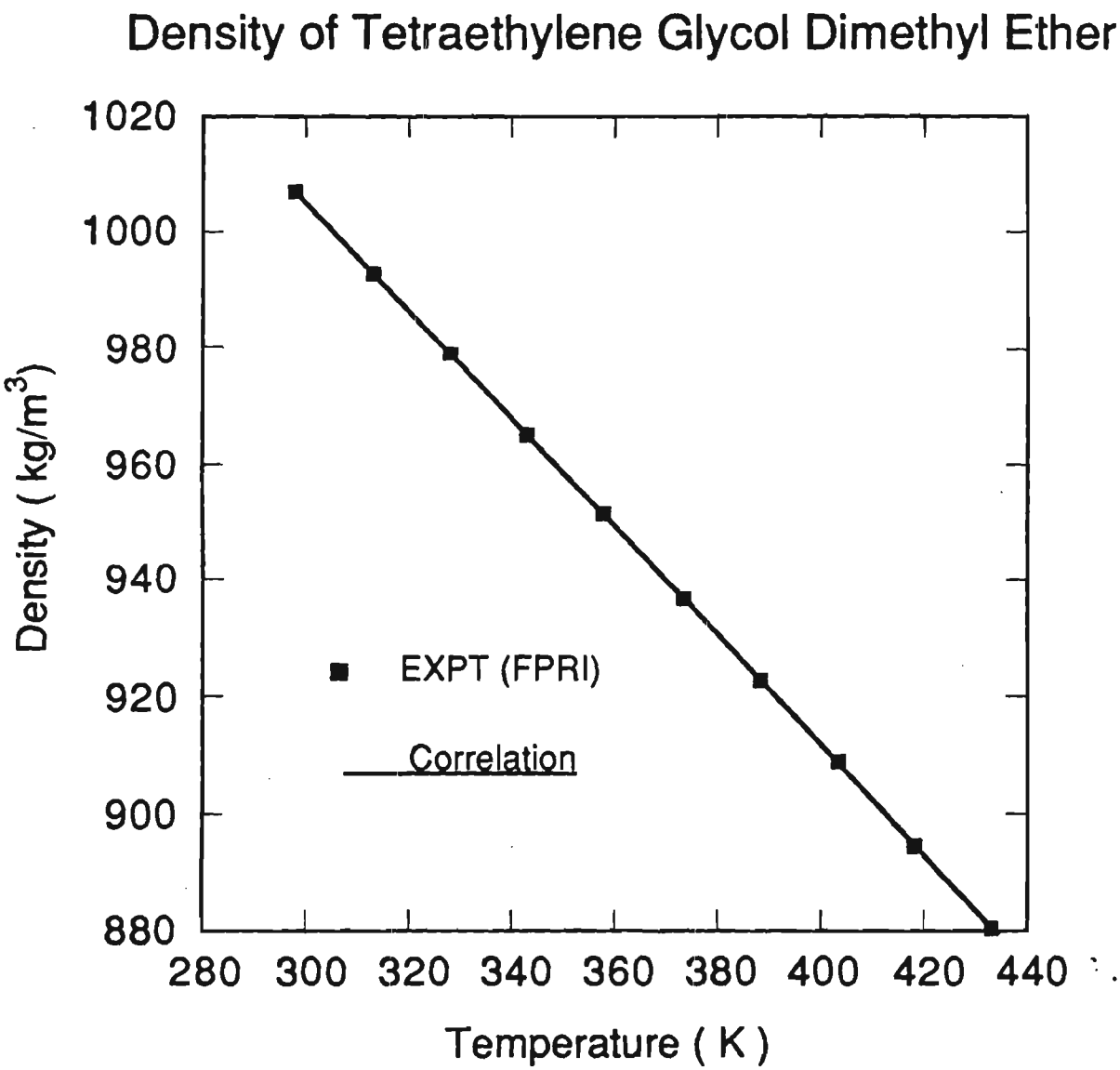

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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1993 DDS-LD-A59

DESIGN DATA STANDARD - LIQUID DENSITY

2 - Ethoxyethanol

$C_2H_5OCH_2CH_2OH$
CA - No: 110-80-5

Purity =	99+ %	
Molecular Weight =	90.12 kg/kmol	[1]
Critical Temperature =	571.7 K	[2]
Critical Pressure =	42.8 bar	[2]
Critical Volume =	0.296 m^3/kmol	[2]
Melting Point =	183.2 K	[2]
Normal Boiling Point =	408.2 K	[3]
Liquid Molar Volume at 25 °C =	0.097383 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
294.15	929.1
307.95	916.3
323.00	902.3
337.95	888.0
352.90	873.1
368.25	857.6
383.25	841.5
398.35	825.1
406.35	815.9

Liquid Density Correlation:

1) $\rho / kgm^{-3} = 1257.34 - 1.641670\ T/K + 2.889456 \times 10^{-3}\ (T/K)^2 - 3.747004 \times 10^{-6}\ (T/K)^3$
% AAD = 0.008 % % MAD = 0.014 %

2 $\rho / kgm^{-3} = 118.0715 / 0.3198080^{[1+(1-T/K/571.7)^{0.2925394}]}$
% AAD = 0.010 % % MAD = 0.016 %

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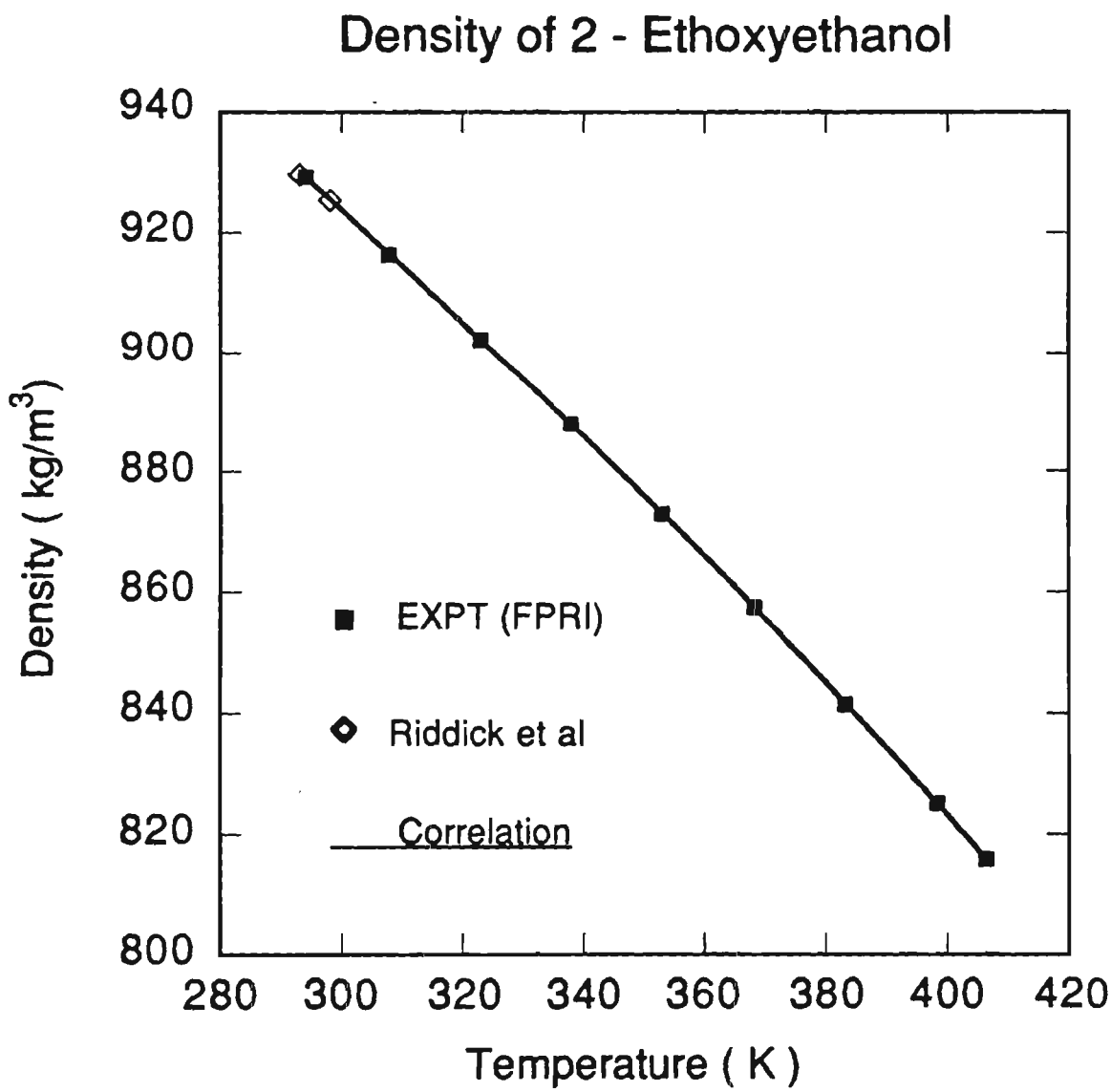

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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

5. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1993 DDS-LD-A60

DESIGN DATA STANDARD - LIQUID DENSITY

2 - (2- Ethoxyethoxy) Ethanol

$C_2H_5OCH_2CH_2OCH_2CH_2OH$
CA - No: 111-90-0

Purity =	99+ %	
Molecular Weight =	134.18 kg/kmol	[1]
Critical Temperature =	637 K	[2]
Critical Pressure =	34.4 bar	[2]
Critical Volume =	0.426 m^3/kmol	[2]
Melting Point =	262.1 K	[2]
Normal Boiling Point =	475.2 K	[3]
Liquid Molar Volume at 25 °C =	0.136301 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
298.10	984.4
312.95	971.2
328.05	957.3
342.95	943.6
358.15	929.4
373.45	914.8
388.30	900.3
403.25	885.5
418.15	870.4
432.95	854.9

Liquid Density Correlation:

1) $\rho / kgm^{-3} = 1300.269 - 1.417133\ T/K + 1.870377 \times 10^{-3} (T/K)^2 - 2.24783 \times 10^{-6} (T/K)^3$

% AAD = 0.005 % % MAD = 0.016 %

2 $\rho / kgm^{-3} = 162.7527 / 0.3644871^{[1 + (1 - T/K/637)^{0.3870963}]}$

% AAD = 0.008 % % MAD = 0.019 %

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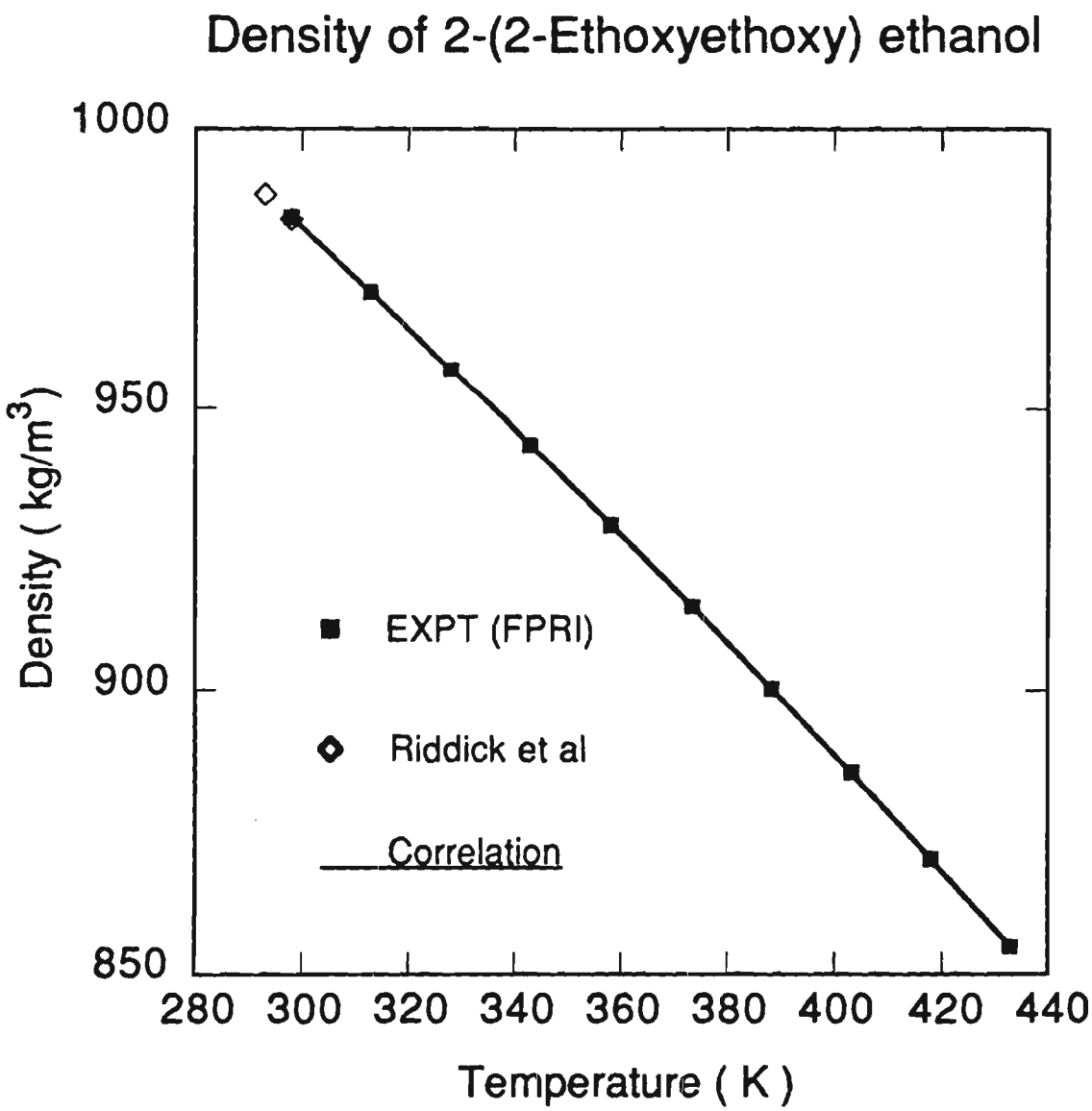
DDS-LD-A60



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

5. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1993 DDS-LD-A61

DESIGN DATA STANDARD - LIQUID DENSITY

N,N - Dimethyl Ethylenediamine

$(CH_3)_2NCH_2CH_2NH_2$
CA - No: 108-00-9

Purity =	95 %	
Molecular Weight =	88.15 kg/kmol	[1]
Critical Temperature =	409.6 K	[2]
Critical Pressure =	40.1 bar	[2]
Critical Volume =	0.303 m^3/kmol	[2]
Melting Point =	235.8 K	[2]
Normal Boiling Point =	378.5 K	[3]
Liquid Molar Volume at 25 °C =	0.109447 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
294.65	808.7
305.95	798.1
315.95	788.7
326.20	778.9
336.00	769.7
345.90	760.2
355.65	750.7
365.65	741.0
375.55	730.8

Liquid Density Correlation:

1) $\rho / kgm^{-3} = 435.7559 / 0.6306478^{[1+(1-T/K/409.6)^{0.8460799}]}$
% AAD = 0.007 % % MAD = 0.020 %

2) $\rho / kgm^{-3} = 1041.297 - 0.6565718\ T/K - 4.517566 \times 10^{-4}\ (T/K)^2$
% AAD = 0.009 % % MAD = 0.028 %

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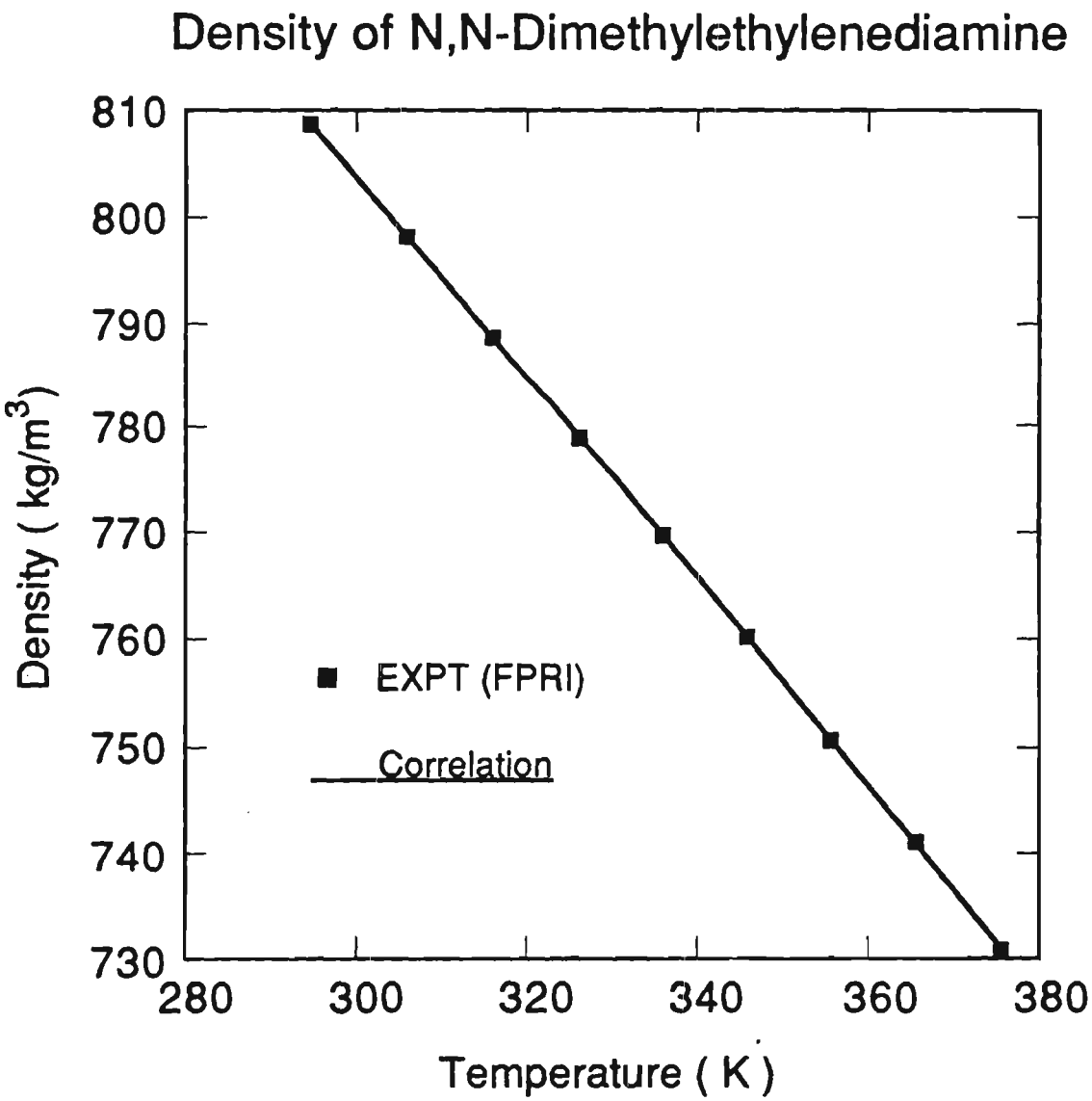
May, 1993 DDS-LD-A61



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REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1993 DDS-LD-A62

DESIGN DATA STANDARD - LIQUID DENSITY

Triethylamine

$(C_2H_5)_3N$
CA - No: 121-44-8

Purity =	99 %	
Molecular Weight =	101.19 kg/kmol	[1]
Critical Temperature =	530.4 K	[2]
Critical Pressure =	31.0 bar	[2]
Critical Volume =	0.389 m^3/kmol	[2]
Melting Point =	158.2 K	[3]
Normal Boiling Point =	362.0 K	[3]
Liquid Molar Volume at 25 °C =	0.139837 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
298.05	808.7
307.95	798.1
317.95	788.7
328.00	778.9
337.95	769.7
347.90	760.2
357.80	750.7

Liquid Density Correlation:

1) $\rho / kgm^{-3} = 211.7686 / 0.4557864^{[1+(1-T/K/530.4)^{0.6941758}]}$
% AAD = 0.013 % % MAD = 0.028 %

2) $\rho / kgm^{-3} = 1003.492 - 0.921523\ T/K - 5.874308 \times 10^{-5}\ (T/K)^2$
% AAD = 0.013 % % MAD = 0.028 %

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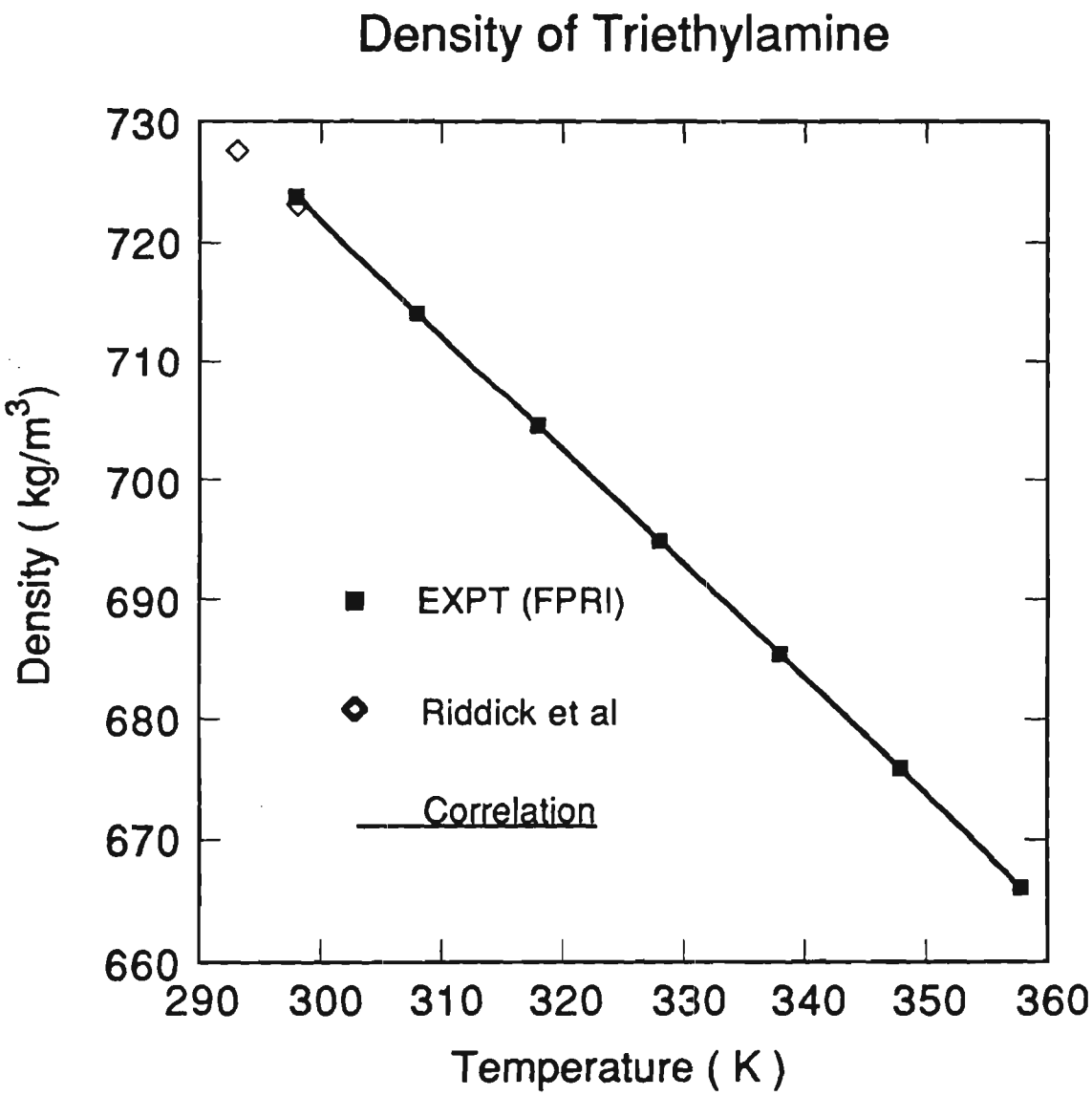
May, 1993 DDS-LD-A62



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

5. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1993 DDS-LD-A63

DESIGN DATA STANDARD - LIQUID DENSITY

Acetic Acid

CH_3COOH
CA - No: 64-19-7

Purity =	99.7 %	
Molecular Weight =	60.052 kg/kmol	[1]
Critical Temperature =	592.9 K	[2]
Critical Pressure =	57.86 bar	[3]
Critical Volume =	0.1711 m^3/kmol	[2]
Melting Point =	289.81 K	[3]
Normal Boiling Point =	391.05 K	[3]
Liquid Molar Volume at 25 °C =	0.05758 m^3/kmol	[2]

Experimental Technique : High Pressure Pycnometer

Experiment Data:
Pressure = ~ 20 bar
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
296.00	1047.2
304.00	1039.3
313.75	1028.0
324.35	1015.1
333.35	1004.2
343.45	993.3
353.35	981.3
363.15	970.2
376.25	954.5
388.26	940.4
402.58	924.0
420.45	901.3
432.15	886.4
441.51	873.9
444.87	868.9
455.35	856.0

Liquid Density Correlation:

$$\rho / kgm^{-3} = 1541.068 - 2.537689\ T/K + 4.204838 \times 10^{-3}\ (T/K)^2 - 4.255529 \times 10^{-6} (T/K)^3$$

% AAD = 0.038 %
% MAD = 0.084 %

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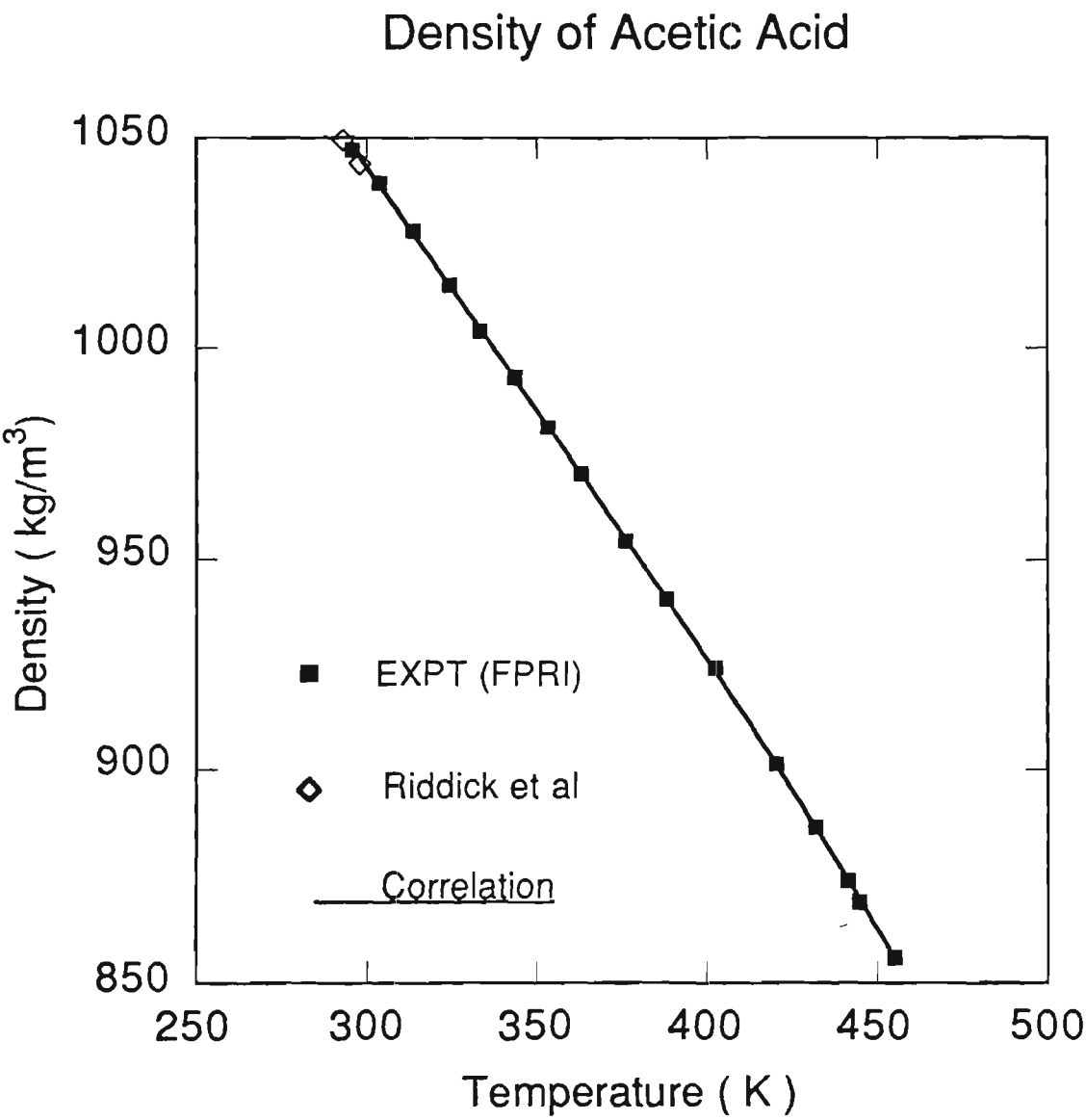
DDS-LD-A63



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2. Data measured in FPRI laboratory, 1992.

3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1993 DDS-LD-A64

DESIGN DATA STANDARD - LIQUID DENSITY

84 wt% Acetic Acid + 16 wt% Water

$CH_3COOH + H_2O$
CA - No: 64-19-7

Purity =	99.7 %	
Molecular Weight =	57.778 kg/kmol	[1]
Critical Temperature =	602.2 K	[2]
Critical Pressure =		
Critical Volume =	0.1651 m^3/kmol	[2]
Melting Point =		
Normal Boiling Point =		
Liquid Molar Volume at 25 °C =	0.05440 m^3/kmol	[3]

Experimental Technique : High Pressure Pycnometer

Experiment Data:
Pressure = ~ 20 bar
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
294.15	1067.6
308.40	1053.2
323.25	1037.9
338.40	1022.1
356.15	1002.8
371.15	987.7
375.85	982.3
383.25	973.3
392.35	963.2
402.95	950.6
413.15	937.3
422.95	925.7
433.15	913.5
443.15	901.1
449.15	893.8
461.35	880.0

Liquid Density Correlation:

$$\rho / kgm^{-3} = 1164.243 - 0.4707199\ T/K - 3.362323 \times 10^{-3}\ (T/K)^2 + 2.172329 \times 10^{-6} (T/K)^3$$

% AAD = 0.057 %
% MAD = 0.105 %

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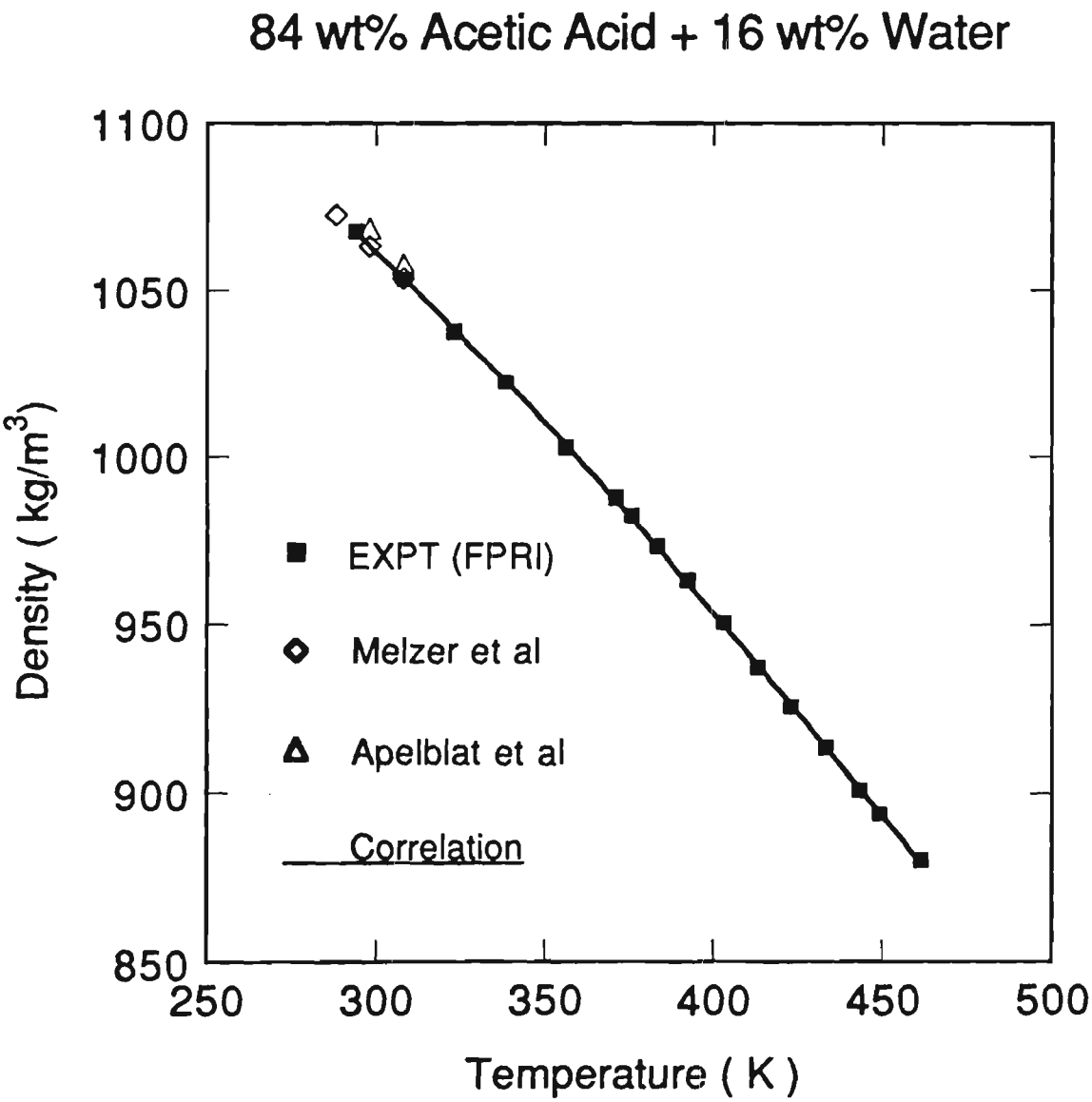

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2. Data measured in FPRI laboratory, 1992.

3. Estimated from FPRI density correlation.

4. Melzer, W. M.; Baldauf, W.; Knapp, H., "Measurement of Diffusivity, Viscosity, Density and Refractivity of Eight Binary Liquid Mixtures", Chem. Eng. Process., 26, 71 (1989).

5. Apelblat, A.; Manzurola, E., "Excess Molar Volumes of Formic Acid + Water, Acetic Acid + Water and Propionic Acid + Water Systems at 288.15, 298.15 and 308.15 K", Fluid Phase Equilibria, 32, 163 (1987).

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DESIGN DATA STANDARD - LIQUID DENSITY

92 wt% Acetic Acid + 8 wt% Water

$CH_3COOH + H_2O$
CA - No: 64-19-7

Purity =	99.7 %	
Molecular Weight =	58.984 kg/kmol	[1]
Critical Temperature =	598.6 K	[2]
Critical Pressure =		
Critical Volume =	0.1700 m^3/kmol	[2]
Melting Point =		
Normal Boiling Point =		
Liquid Molar Volume at 25 °C =	0.05574 m^3/kmol	[3]

Experimental Technique : High Pressure Pycnometer

Experiment Data:
Pressure = ~ 20 bar
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
297.20	1059.1
313.45	1042.1
328.50	1026.6
343.50	1009.0
358.20	992.0
373.45	975.3
391.87	952.8
402.58	940.7
412.44	928.1
422.12	916.2
433.41	901.6
442.02	890.2
448.40	882.2
461.25	866.0

Liquid Density Correlation:

$$\rho / kgm^{-3} = 1272.697 - 0.3692999\ T/K - 1.286878 \times 10^{-3} (T/K)^2 + 3.780387 \times 10^{-7} (T/K)^3$$

% AAD = 0.033 %
% MAD = 0.067 %

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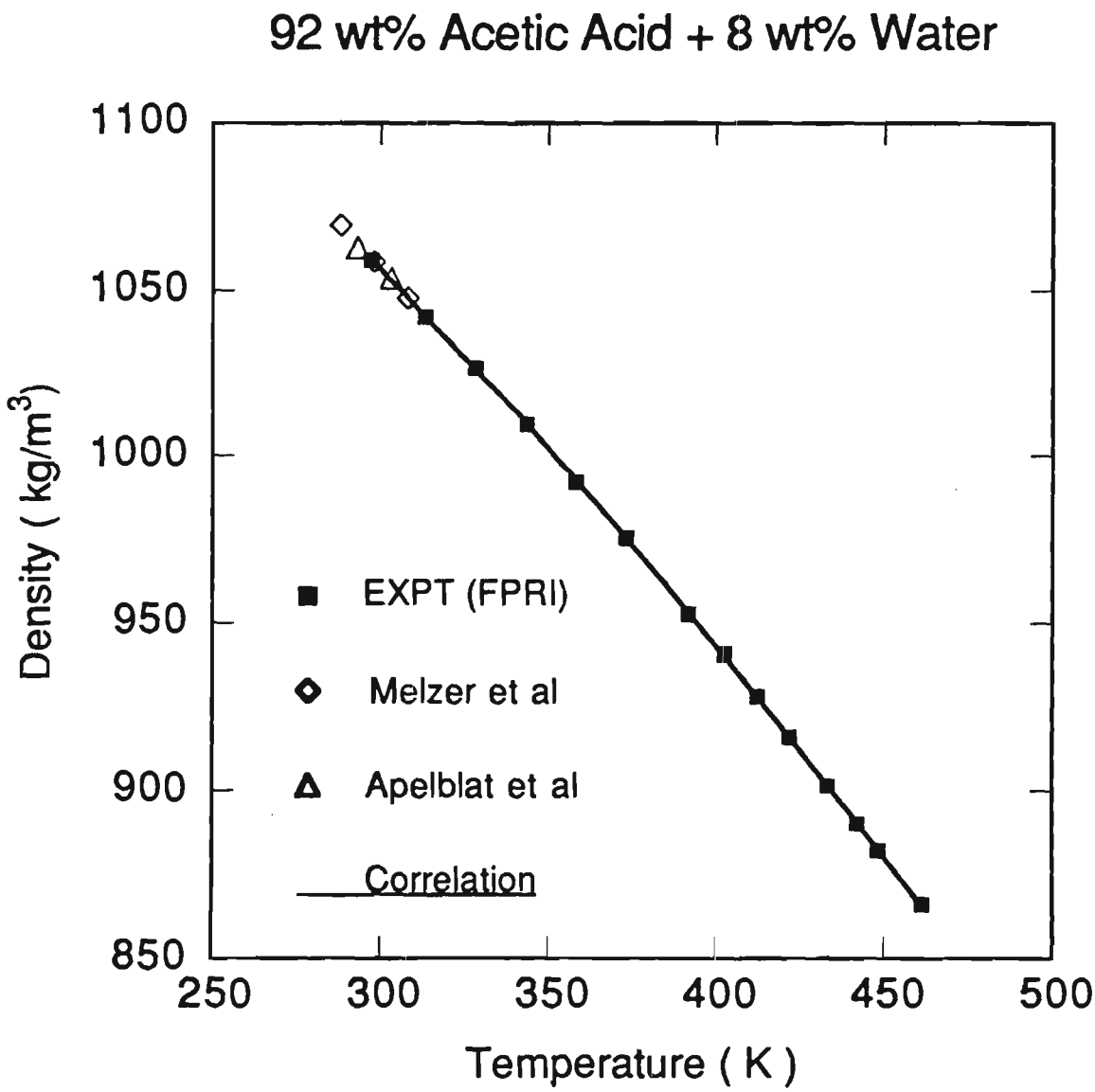

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4. Melzer, W. M.; Baldauf, W.; Knapp, H., "Measurement of Diffusivity, Viscosity, Density and Refractivity of Eight Binary Liquid Mixtures", Chem. Eng. Process., 26, 71 (1989).

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May, 1993 DDS-LTC-A67

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

1,5 - Pentanediol

$HO(CH_2)_5OH$
CA - No: 111-29-5

Purity =	96 %	
Molecular Weight =	104.14 kg/kmol	[1]
Critical Temperature =	673 K	[2]
Critical Pressure =	41.5 bar	[2]
Critical Volume =	0.345 m^3/kmol	[2]
Melting Point =	257.2 K	[2]
Normal Boiling Point =	512.2 K	[2]
Liquid Molar Volume at 25 °C =	0.104809 m^3/kmol	[2]

Experimental Technique : Relative Transient Hot-Wire

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/m K)
296.7	201.2
323.8	199.5
352.2	197.5
381.5	195.4
410.8	192.7
440.9	188.0
471.1	182.1

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m K)} = 165.738 + 0.2584718 \times T/K - 4.731952 \times 10^{-4} (T/K)^2$$

% AAD = 0.2% % MAD = 0.3 %

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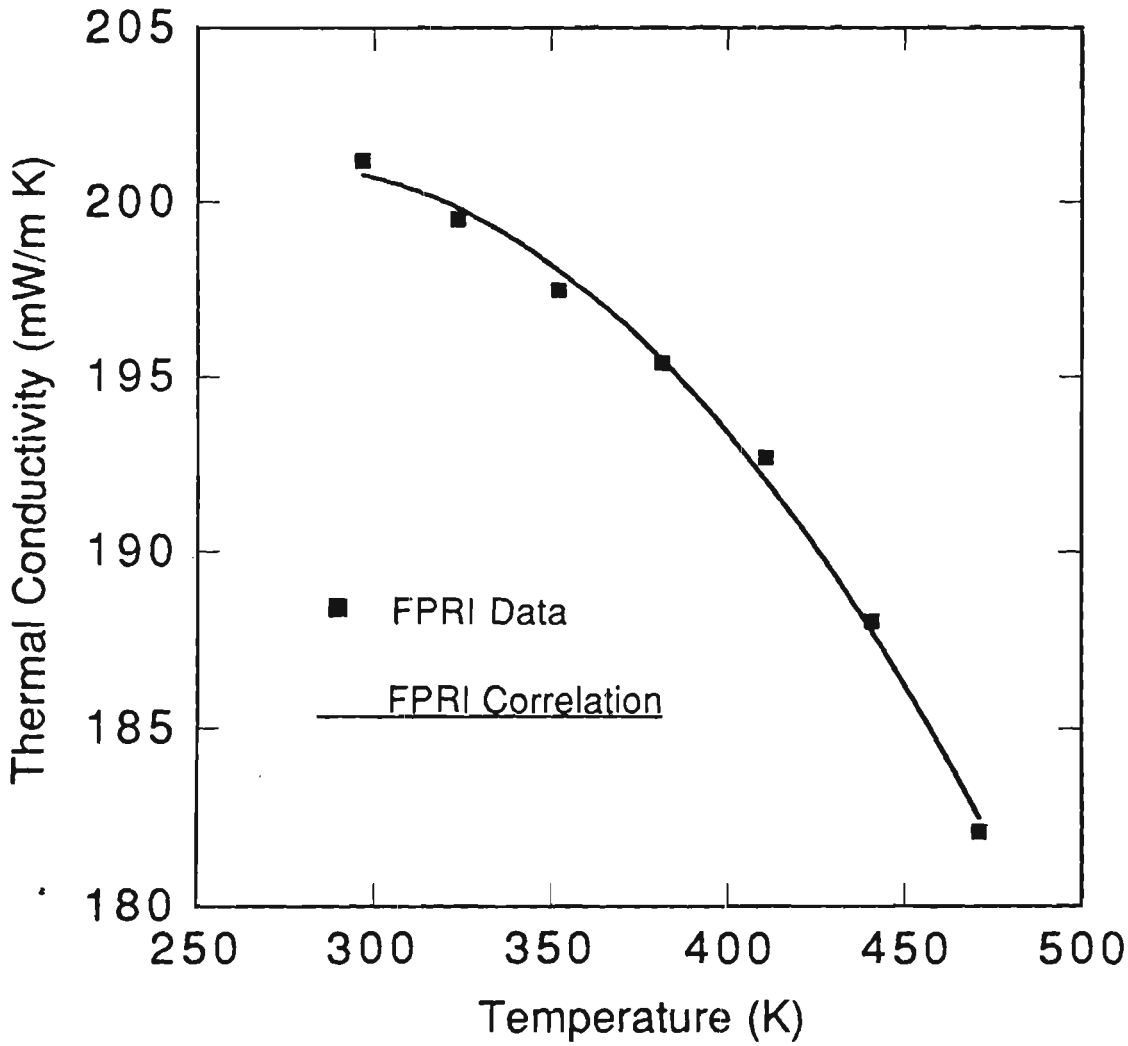
May, 1993 DDS-LTC-A67

1,5 - Pentanediol



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2. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1993 DDS-LTC-A68

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

1,6 - Hexanediol

$HO(CH_2)_6OH$
CA - No: 629-11-8

Purity =	99 %	
Molecular Weight =	118.18 kg/kmol	[1]
Critical Temperature =	670 K	[2]
Critical Pressure =	36.1 bar	[2]
Critical Volume =	0.398 m^3/kmol	[2]
Melting Point =	315.2 K	[2]
Normal Boiling Point =	516.2 K	[2]
Liquid Molar Volume at 25 °C =	0.12248 m^3/kmol	[2]

Experimental Technique : Relative Transient Hot-Wire

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/m K)
323.2	198.2
347.9	196.3
372.1	193.9
396.3	191.1
420.4	187.9
446.6	182.8
470.8	177.6

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m K)} = 153.4589 + 0.3271571 \times T/K - 5.854481 \times 10^{-4} (T/K)^2$$

% AAD = 0.1% % MAD = 0.2 %

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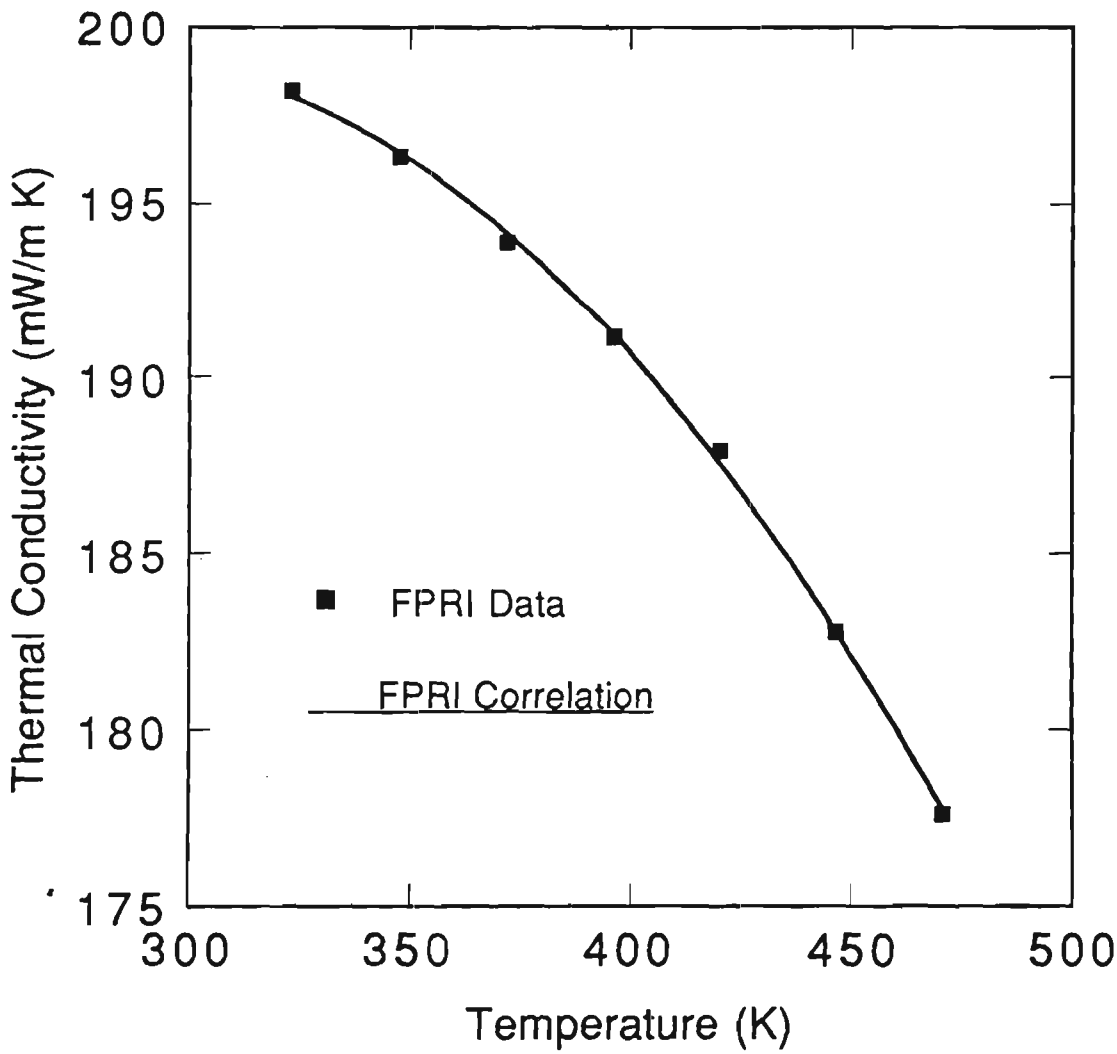
May, 1993 DDS-LTC-A68

1,6 - Hexanediol



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2. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1993 DDS-LTC-A69

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

2,5 - Hexanediol

$CH_3CH(OH)CH_2CH_2CH(OH)CH_3$
CA - No: 2935-44-6

Purity =	99 %	
Molecular Weight =	118.18 kg/kmol	[1]
Critical Temperature =	638.2 K	[2]
Critical Pressure =	38.5 bar	[2]
Critical Volume =	0.409 m^3/kmol	[2]
Melting Point =	278.5 K	[2]
Normal Boiling Point =	490.2 K	[3]
Liquid Molar Volume at 25 °C =	0.12349 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/m K)
297.3	163.5
334.1	158.0
352.5	156.0
381.3	153.1
410.9	149.8
411.1	149.4
441.6	145.3
471.4	140.2

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m K)} = 184.9257 - 0.04058225 \times T/K - 1.12917 \times 10^{-4} (T/K)^2$$

% AAD = 0.3% % MAD = 0.5 %

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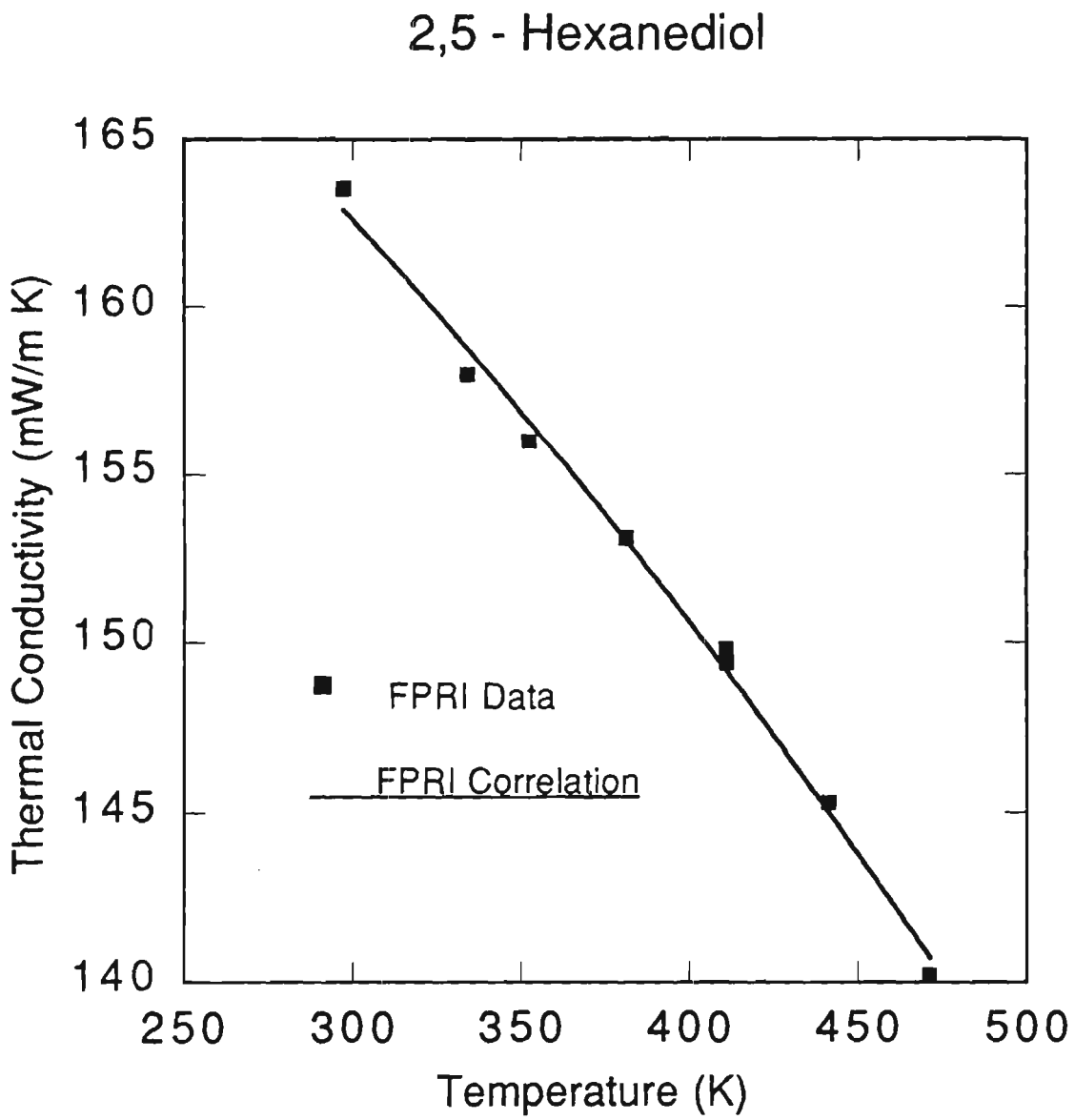
DDS-LTC-A69



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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1993 DDS-LTC-A70

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

2 - Methoxyethyl Ether

$(CH_3OCH_2CH_2)_2O$
CA - No: 111-96-6

Purity =	99+ %	
Molecular Weight =	134.18 kg/kmol	[1]
Critical Temperature =	613.8 K	[2]
Critical Pressure =	30.4 bar	[2]
Critical Volume =	0.425 m^3/kmol	[2]
Melting Point =	209.2 K	[3]
Normal Boiling Point =	435.2 K	[3]
Liquid Molar Volume at 25 °C =	0.144814 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/m K)
297.6	153.0
323.5	145.2
333.1	142.3
352.5	136.4
372.8	130.1
391.4	124.3
412.0	118.8

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m K)} = 242.782 - 0.3018139 \times T/K$$

% AAD = 0.1% % MAD = 0.3 %

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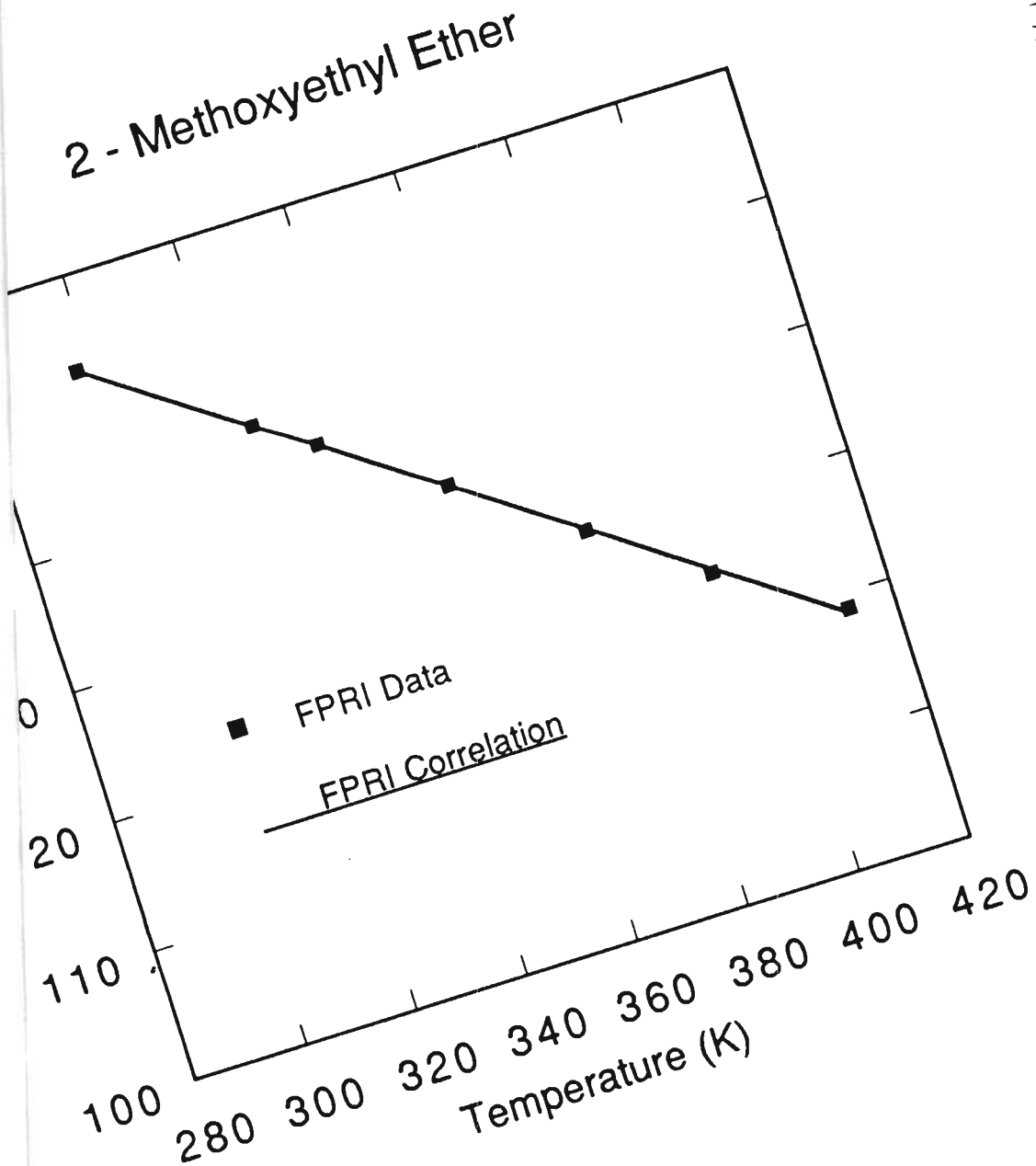
DDS-LTC-A70



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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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FPRI

May, 1993 DDS-LTC-A71

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Triethylene Glycol Dimethyl Ether

$CH_3OCH_2CH_2OCH_2CH_2OCH_2CH_2OCH_3$
CA - No: 112-49-2

Purity =	99 %	
Molecular Weight =	178.23 kg/kmol	[1]
Critical Temperature =	659.3 K	[2]
Critical Pressure =	23.7 bar	[2]
Critical Volume =	0.555 m^3/kmol	[2]
Melting Point =	228.2 K	[3]
Normal Boiling Point =	489.2 K	[3]
Liquid Molar Volume at 25 °C =	0.181617 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/m K)
295.0	157.4
322.8	151.0
352.9	142.7
381.9	134.7
411.9	126.8
441.3	118.9
471.4	112.3

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m K)} = 234.6621 - 0.2610319 \times T/K$$

% AAD = 0.3% % MAD = 0.6 %

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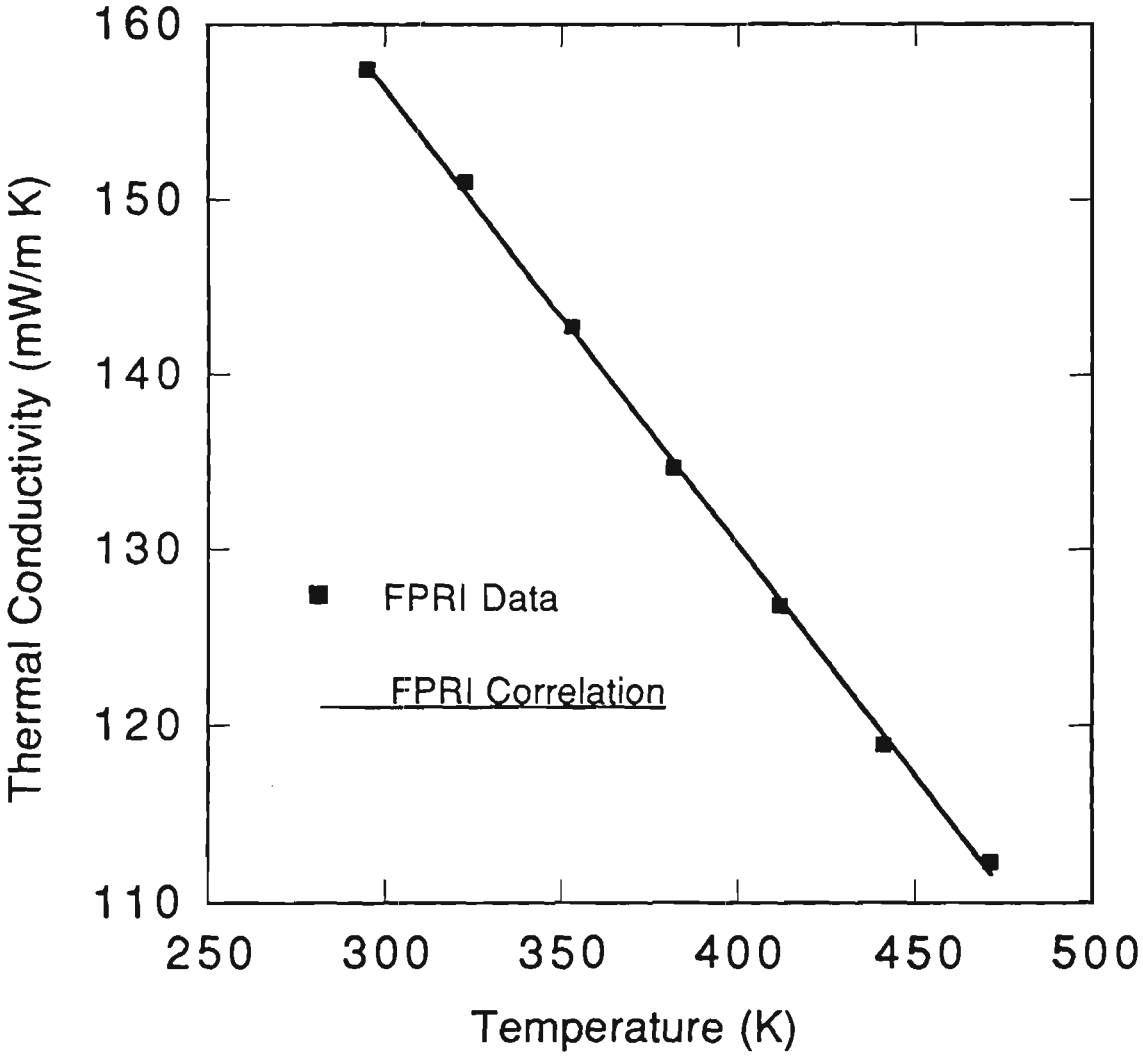
DDS-LTC-A71

Trimethylene Glycol Dimethyl Ether



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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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FPRI

May, 1993 DDS-LTC-A72

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Tetraethylene Glycol Dimethyl Ether

$CH_3(OCH_2CH_2)_4OCH_3$
CA - No: 143-24-8

Purity =	99 %	
Molecular Weight =	222.28 kg/kmol	[1]
Critical Temperature =	713.7 K	[2]
Critical Pressure =	19.5 bar	[2]
Critical Volume =	0.685 m^3/kmol	[2]
Melting Point =	313.1 K	[2]
Normal Boiling Point =	548.7 K	[3]
Liquid Molar Volume at 25 °C =	0.220810 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/m K)
296.9	160.4
323.8	154.8
352.0	148.1
382.3	140.4
382.5	140.6
411.4	133.4
441.7	126.2
472.0	119.4

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m K)} = 231.367 - 0.2375878 \times T/K$$

% AAD = 0.2 % % MAD = 0.3 %

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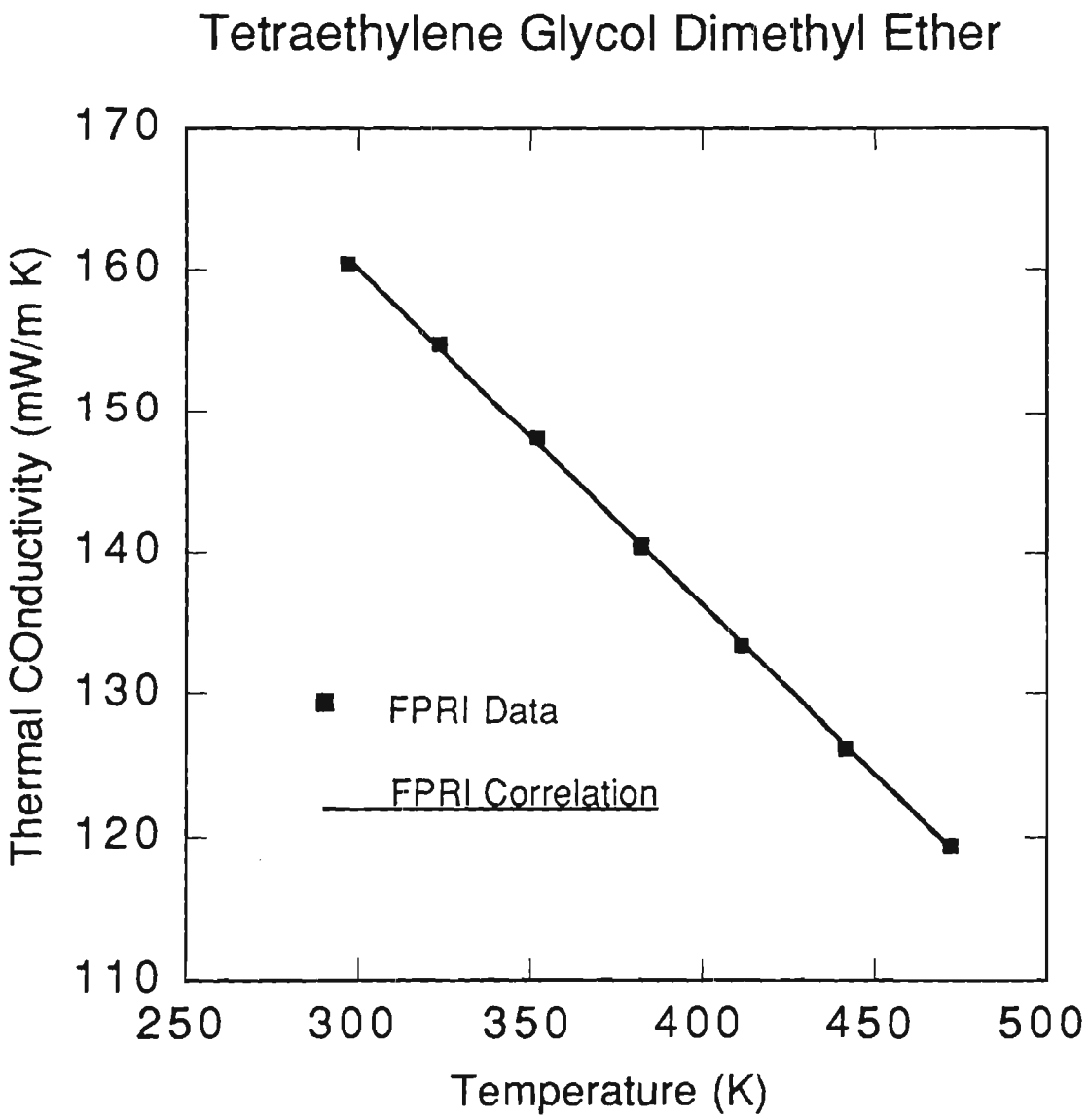
May, 1993

DDS-LTC-A72



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1993 DDS-LTC-A73

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

2 - Ethoxyethanol

$C_2H_5OCH_2CH_2OH$
CA - No: 110-80-5

Purity =	99+ %	
Molecular Weight =	90.12 kg/kmol	[1]
Critical Temperature =	571.7 K	[2]
Critical Pressure =	42.8 bar	[2]
Critical Volume =	0.296 m^3/kmol	[2]
Melting Point =	183.2 K	[2]
Normal Boiling Point =	408.2 K	[3]
Liquid Molar Volume at 25 °C =	0.097383 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/m K)
296.1	160.7
298.0	160.1
313.7	156.3
332.8	151.5
352.6	146.4
372.4	141.3
386.5	137.9
401.9	134.7

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m K)} = 234.2871 - 0.2488732 \times T/K$$

% AAD = 0.1 % % MAD = 0.3 %

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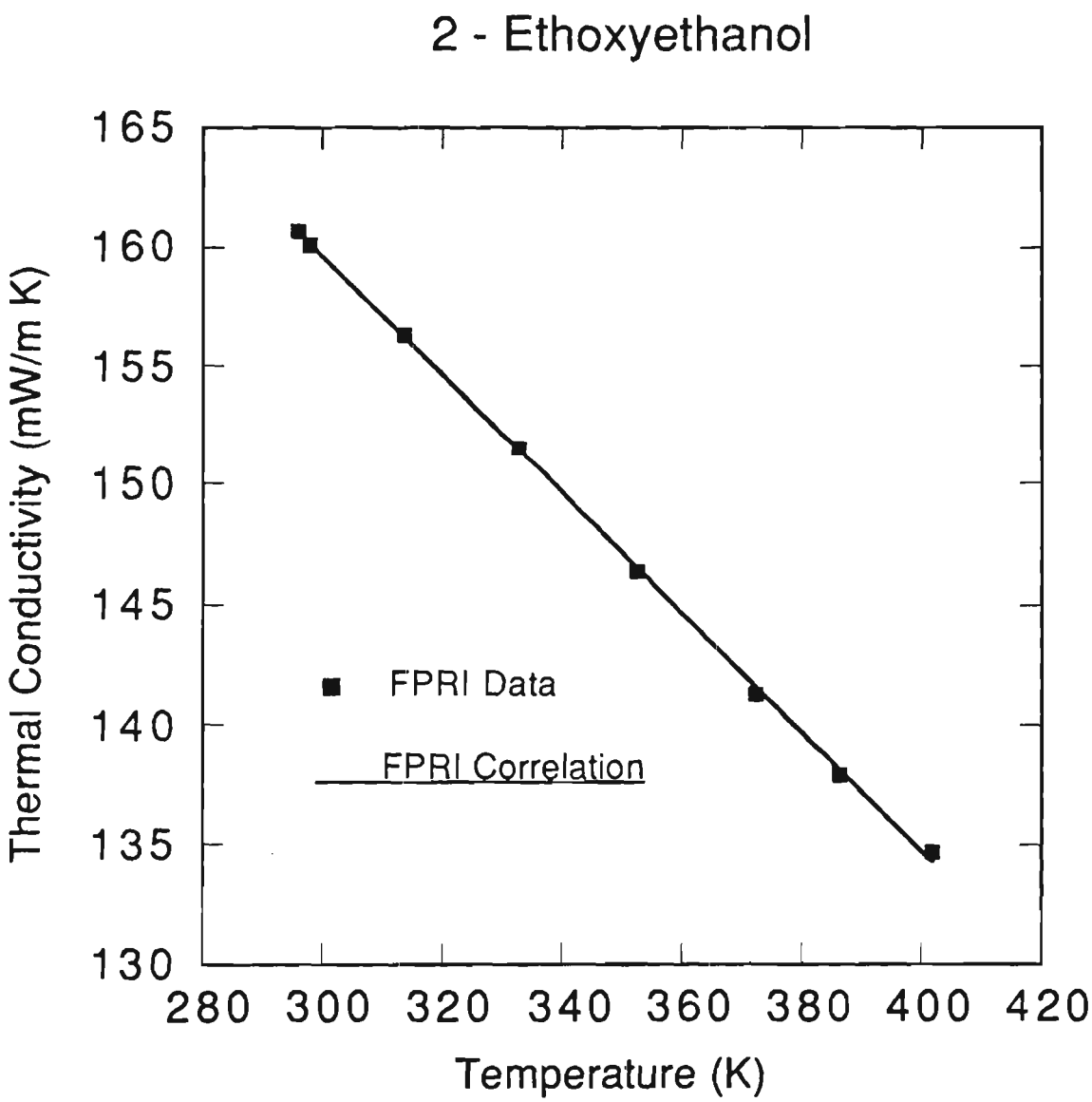
May, 1993 DDS-LTC-A73



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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1993 DDS-LTC-A74

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

2 - (2- Ethoxyethoxy) Ethanol

$C_2H_5OCH_2CH_2OCH_2CH_2OH$
CA - No: 111-90-0

Purity =	99+ %	
Molecular Weight =	134.18 kg/kmol	[1]
Critical Temperature =	637 K	[2]
Critical Pressure =	34.4 bar	[2]
Critical Volume =	0.426 m^3/kmol	[2]
Melting Point =	262.1 K	[2]
Normal Boiling Point =	475.2 K	[3]
Liquid Molar Volume at 25 °C =	0.136301 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/m K)
297.5	160.7
323.1	157.2
352.4	151.9
381.8	145.5
411.3	138.8
440.0	132.2
460.7	127.8

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m K)} = 183.1952 + 0.01061664 \times T/K - 2.855256 \times 10^{-4} (T/K)^2$$

% AAD = 0.2% % MAD = 0.3 %

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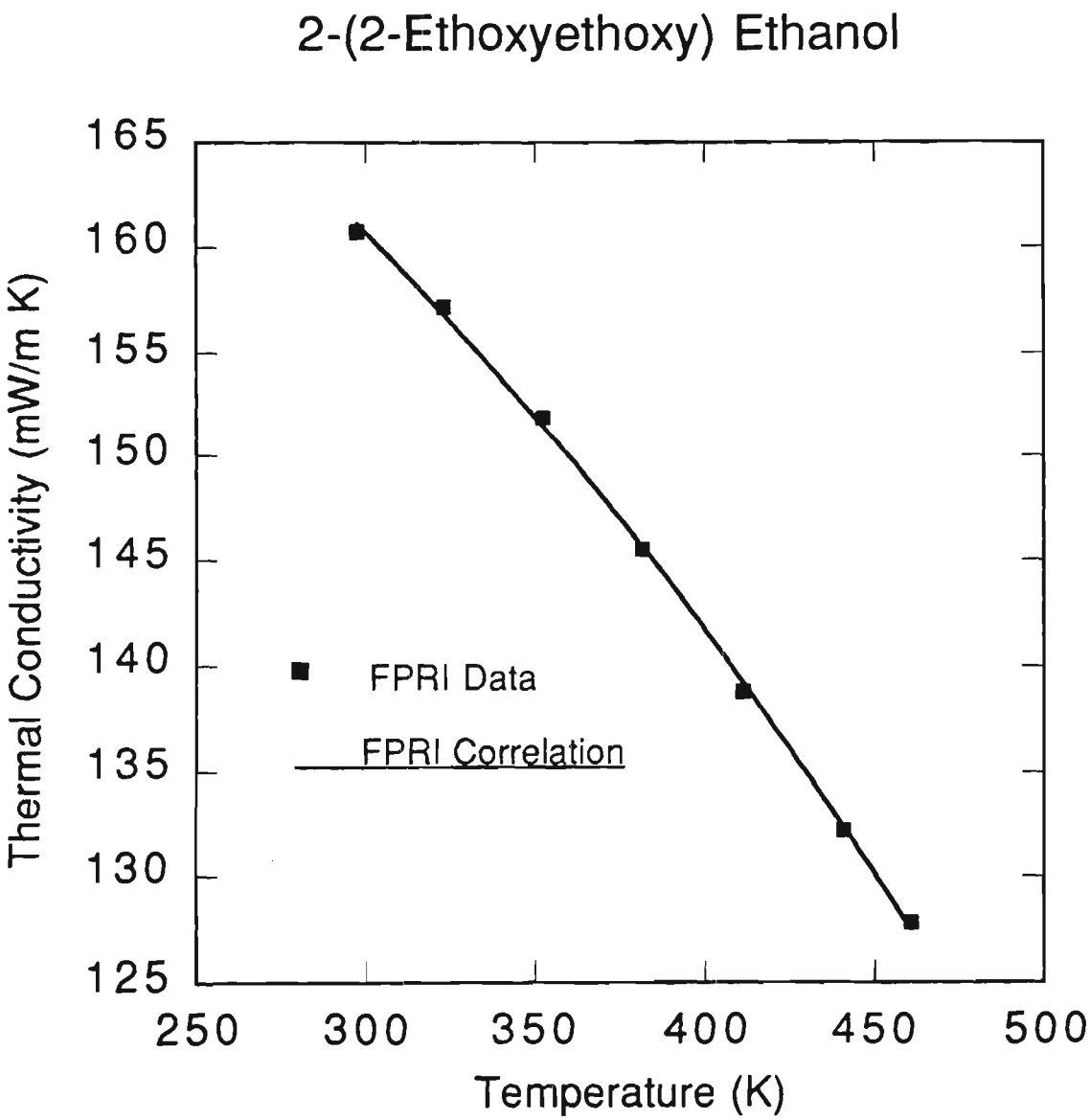

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May, 1993 DDS-LTC-A75

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

N,N - Dimethyl Ethylenediamine

$(CH_3)_2NCH_2CH_2NH_2$
CA - No: 108-00-9

Purity =	95 %	
Molecular Weight =	88.15 kg/kmol	[1]
Critical Temperature =	409.6 K	[2]
Critical Pressure =	40.1 bar	[2]
Critical Volume =	0.303 m^3/kmol	[2]
Melting Point =	235.8 K	[2]
Normal Boiling Point =	378.5 K	[3]
Liquid Molar Volume at 25 °C =	0.109447 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/m K)
300.8	139.9
300.8	140.4
307.2	139.1
318.4	136.3
332.9	132.4
347.6	128.4
362.9	124.3
371.7	122.4

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m K)} = 190.2639 - 0.09272455 \times T/K - 2.435673 \times 10^{-4} (T/K)^2$$

% AAD = 0.2% % MAD = 0.3 %

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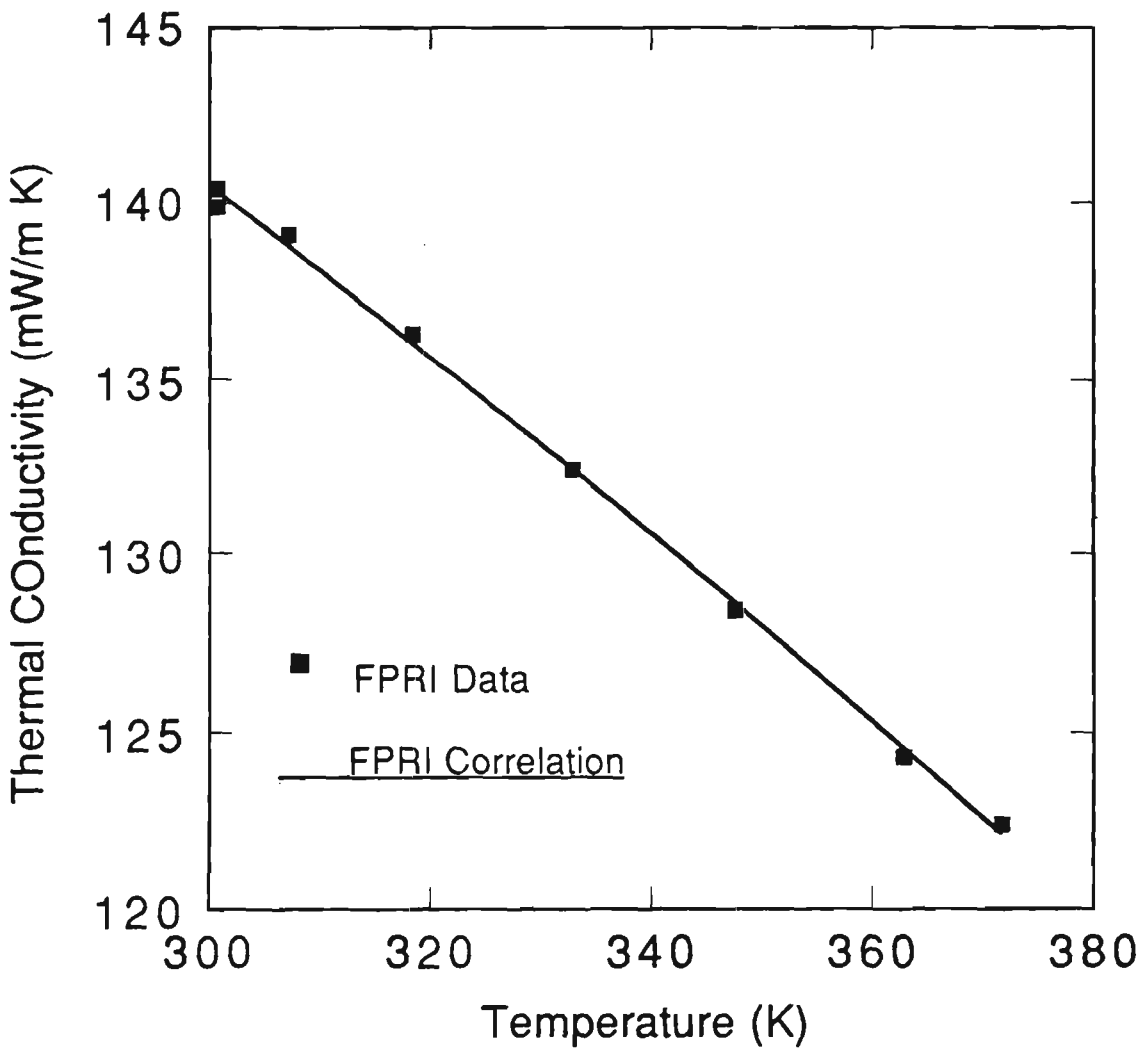
N,N - Dimethyl Ethylenediamine



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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

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May, 1993 DDS-LTC-A76

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Triethylamine

$(C_2H_5)_3N$
CA - No: 121-44-8

Purity =	99 %	
Molecular Weight =	101.19 kg/kmol	[1]
Critical Temperature =	530.4 K	[2]
Critical Pressure =	31.0 bar	[2]
Critical Volume =	0.389 m^3/kmol	[2]
Melting Point =	158.2 K	[3]
Normal Boiling Point =	362.0 K	[3]
Liquid Molar Volume at 25 °C =	0.139837 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/m K)
294.9	113.9
303.9	111.5
314.1	108.7
323.4	105.3
333.2	103.0
343.1	100.5
352.7	99.7

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m K)} = 354.4419 - 1.278406 \times T/K + 1.573254 \times 10^{-3} (T/K)^2$$

% AAD = 0.3% % MAD = 0.5 %

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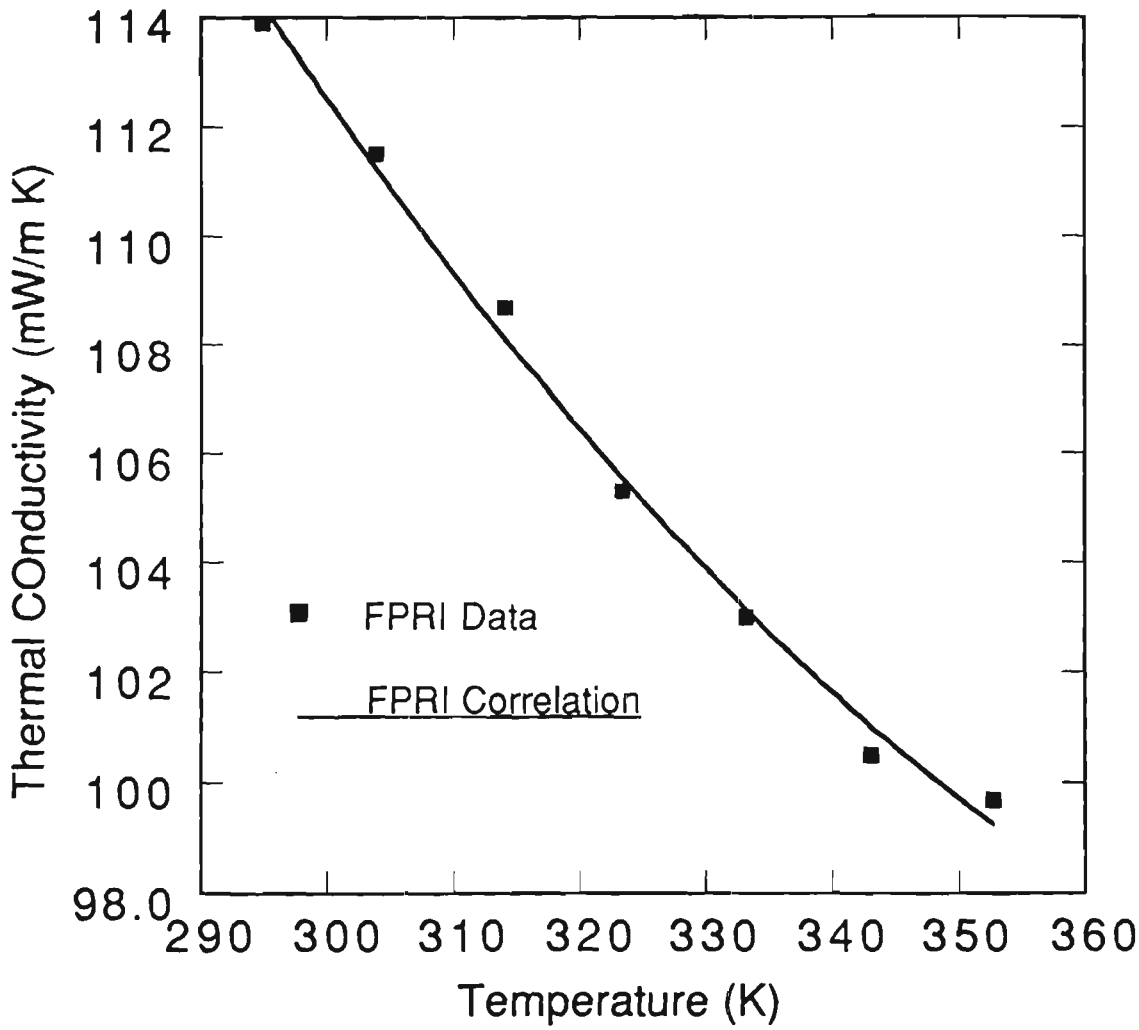
Triethylamine



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Acetic Acid

CH_3COOH
CA - No: 64-19-7

Purity =	99.7 %	
Molecular Weight =	60.052 kg/kmol	[1]
Critical Temperature =	592.9 K	[2]
Critical Pressure =	57.86 bar	[3]
Critical Volume =	0.1711 m^3/kmol	[2]
Melting Point =	289.81 K	[3]
Normal Boiling Point =	391.05 K	[3]
Liquid Molar Volume at 25 °C =	0.05758 m^3/kmol	[2]

Experimental Technique : Relative Transient Hot-Wire

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (mW/m K)
298.44	155.1
313.96	152.4
333.25	149.1
353.35	145.9
372.97	144.5
391.99	142.4
392.03	141.3
411.39	139.0

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (mW/m K)} = 230.1523 - 0.335636 \times T/K + 2.798937 \times 10^{-4} (T/K)^2$$

% AAD = 0.3% % MAD = 0.6 %

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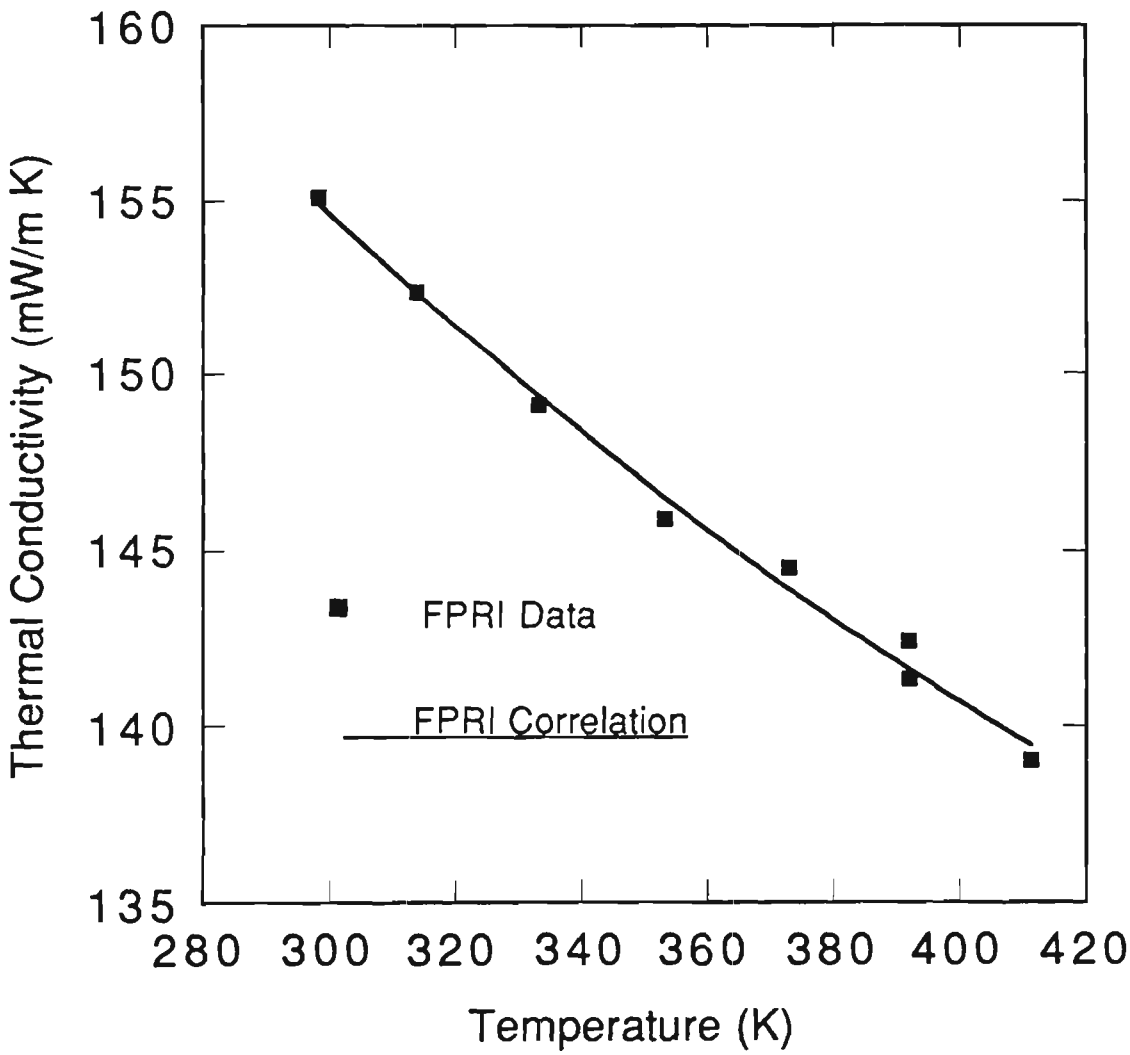
Acetic Acid



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2. Data measured in FPRI laboratory, 1992.

3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

GEORGIA TECH

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ATLANTA, GA 30332-0100
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June 30, 1994

Mr. J. David Chase
President, FPRI
Hoechst- Celanese Corporation
Technical Center
P. O. Box 9077
Corpus Christi, TX 78408

Dear Dave:

Please find enclosed Design Data Sheets DDS-LTC-A78 thru 88, DDS-LD-A66 thru 78 and DDS-LV-67 thru 79 representing the results of FPRI sponsored measurements for the year July 1, 1993 to June 30, 1994. I would like to take this opportunity to thank the FPRI members for sponsoring this work.

With best wishes,

Yours sincerely,

Amyn S. Teja
Regents Professor

INDEX TO DESIGN SHEET

SERIES A 1993-94 RESULTS

Viscosity

A67	2 - Cyanopyridine
A68	3,5 - Dichloropyridine
A69	1,2 - Octanediol
A70	1,8 - Octanediol
A71	N,N - Diethyl Ethylene Diamine
A72	N,N - Diisopropyl Ethylamine
A73	N,N,N',N' - Tetramethyl Ethylene Diamine
A74	Propionic Acid
A75	86 wt% Propionic Acid + 14 wt% Water
A76	70 wt% Propionic Acid + 30 wt% Water
A77	58 wt% Propionic Acid + 42 wt% Water
A78	42 wt% Propionic Acid + 58 wt% Water
A79	18 wt% Propionic Acid + 82 wt% Water

Density

A66	2 - Cyanopyridine
A67	3,5 - Dichloropyridine
A68	1,2 - Octanediol
A69	1,8 - Octanediol
A70	N,N - Diethyl Ethylene Diamine
A71	N,N - Diisopropyl Ethylamine
A72	N,N,N',N' - Tetramethyl Ethylene Diamine
A73	Propionic Acid
A74	86 wt% Propionic Acid + 14 wt% Water
A75	70 wt% Propionic Acid + 30 wt% Water
A76	58 wt% Propionic Acid + 42 wt% Water
A77	42 wt% Propionic Acid + 58 wt% Water
A78	18 wt% Propionic Acid + 82 wt% Water

Thermal Conductivity

A78	2 - Cyanopyridine
A79	3,5 - Dichloropyridine
A80	1,2 - Octanediol
A81	1,8 - Octanediol
A82	N,N - Diethyl Ethylene Diamine
A83	N,N - Diisopropyl Ethylamine
A84	N,N,N',N' - Tetramethyl Ethylene Diamine
A85	Propionic Acid
A86	75 wt% Propionic Acid + 25 wt% Water
A87	50 wt% Propionic Acid + 50 wt% Water
A88	25 wt% Propionic Acid + 75 wt% Water

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May, 1994 DDS-LV-A67

DESIGN DATA STANDARD - LIQUID VISCOSITY

2 - Cyanopyridine

$C_6H_4N_2$
CA - No: 100-70-9

Purity =	99 %	
Molecular Weight =	104.11 kg/kmol	[1]
Critical Temperature =	720.0 K	[2]
Critical Pressure =	46.2 bar	[2]
Critical Volume =	0.3755 m^3/kmol	[2]
Normal Boiling Point =	486.7 K	[3]
Melting Point =	300.2 K	[3]
Liquid Molar Volume at 25 °C =	0.09591 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
306.85	1.717
318.35	1.424
333.40	1.152
348.25	0.963
363.05	0.825
378.20	0.717
393.05	0.635
405.95	0.576
418.80	0.525
432.80	0.485

Liquid Viscosity Correlation:

$$\ln (\mu /cP) = -2.49461 + 535.9645 / (T /K - 130.1938)$$

% AAD = 0.08 %
% MAD = 0.15 %

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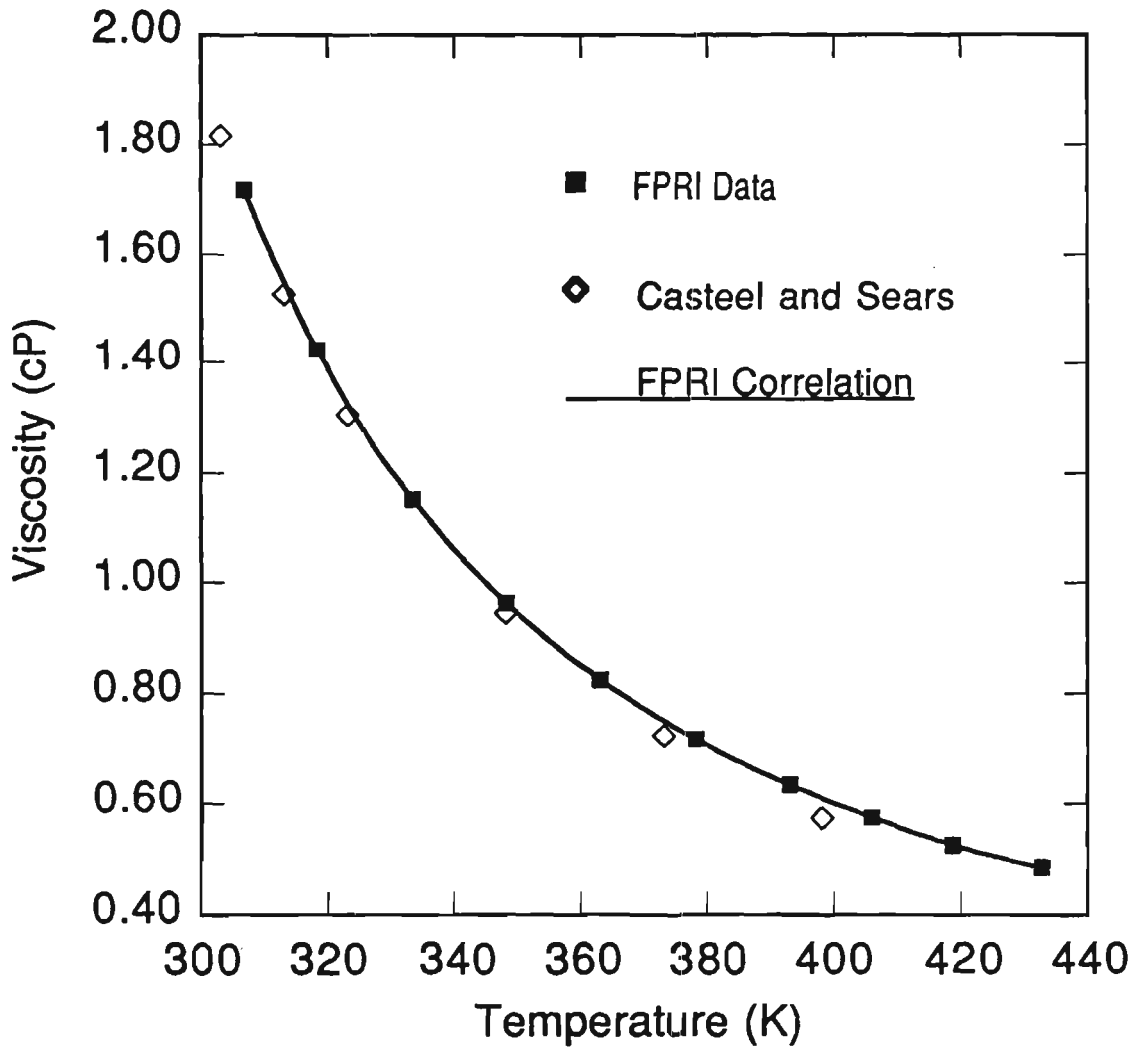
2 - Cyanopyridine



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

5. Casteel, J.F., and Sears, P.G., J. Chem. Eng. Data 20, 10 (1975).

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May, 1994 DDS-LV-A68

DESIGN DATA STANDARD - LIQUID VISCOSITY

3,5 - Dichloropyridine

$C_5H_3Cl_2N$
CA - No: 2547-47-8

Purity =	98 %	
Molecular Weight =	147.99 kg/kmol	[1]
Critical Temperature =	721.5 K	[2]
Critical Pressure =	47.2 bar	[2]
Critical Volume =	0.3545 m^3/kmol	[2]
Normal Boiling Point =	474.0 K	[2]
Melting Point =	339.2 K	[3]
Liquid Molar Volume at 25 °C =	0.10779 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
343.40	0.952
358.25	0.804
373.25	0.683
388.00	0.588
402.95	0.516
417.95	0.462
433.05	0.420

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -29.48589 + 2780.201 / (T/K) + 3.655807 \ln(T/K)$$

% AAD = 0.47 %
% MAD = 0.66 %

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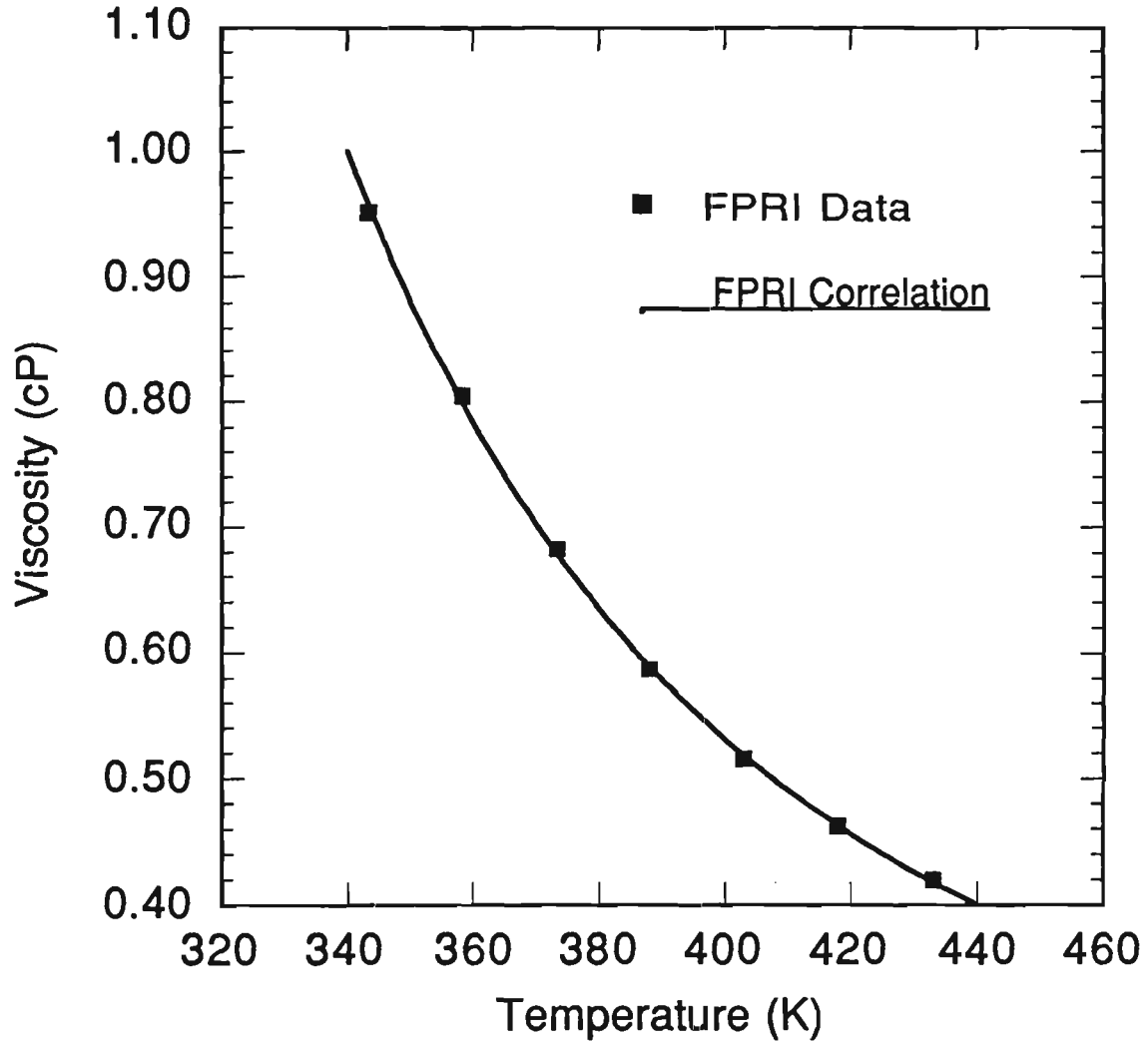
3,5 - Dichloropyridine



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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1994 DDS-LV-A69

DESIGN DATA STANDARD - LIQUID VISCOSITY

1,2 - Octanediol

$CH_3(CH_2)_5CH(OH)CH_2OH$
CA - No: 1117-86-8

Purity =	98 +%	
Molecular Weight =	146.23 kg/kmol	[1]
Critical Temperature =	725.6 K	[2]
Critical Pressure =	31.1 bar	[2]
Critical Volume =	0.5155 m^3/kmol	[2]
Normal Boiling Point =	566.4 K	[2]
Melting Point =	310.2 K	[3]
Liquid Molar Volume at 25 °C =	0.15768 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
313.35	30.310
328.40	15.261
343.45	8.331
358.10	5.067
373.30	3.290
388.05	2.255
402.95	1.614
417.75	1.238
432.75	0.967

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -130.5039 + 10344.97/(T/K) + 17.55608 \ln(T/K)$$

% AAD = 0.50 %
% MAD = 0.87 %

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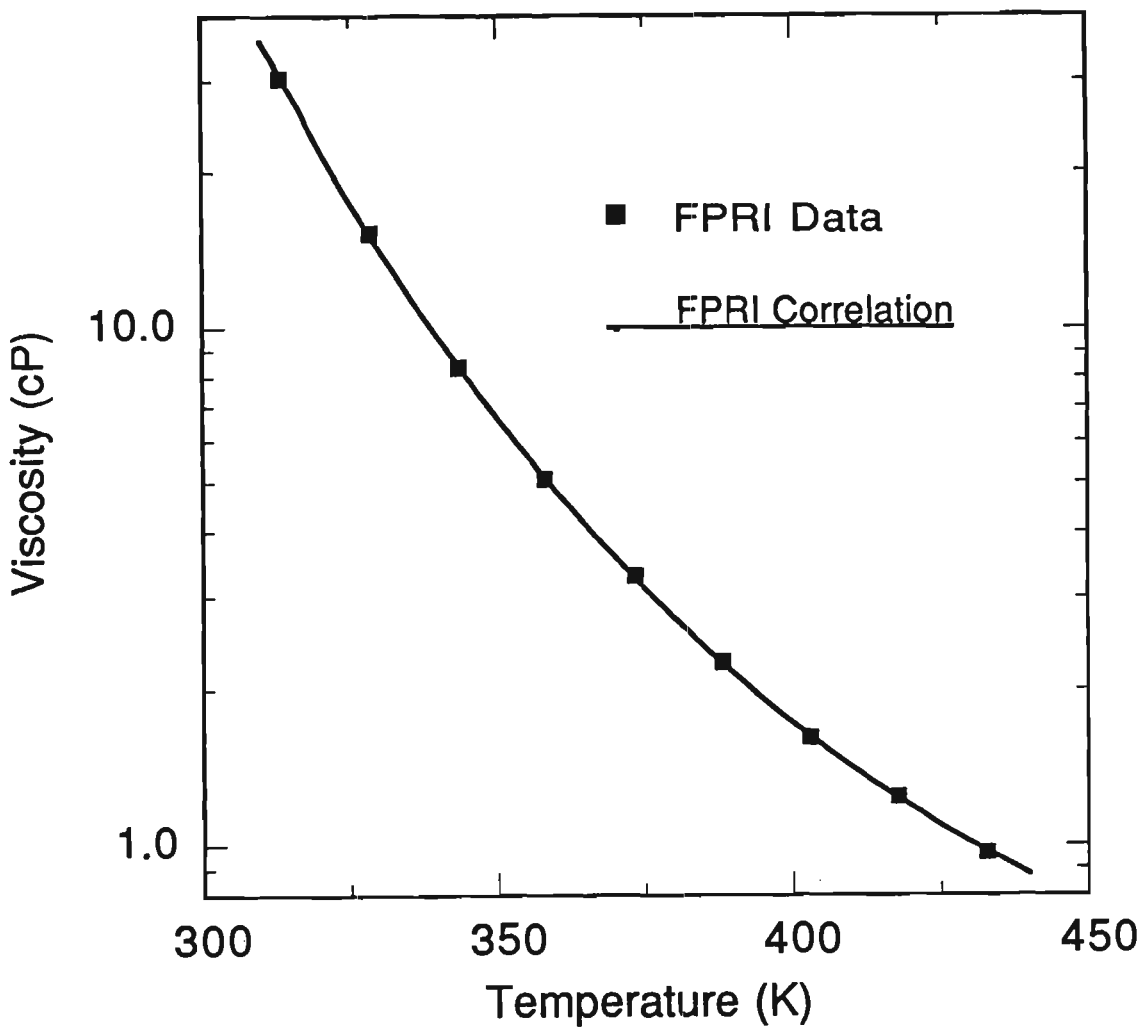
May, 1994 DDS-LV-A69

1,2 - Octanediol



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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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FPRI

May, 1994 DDS-LV-A70

DESIGN DATA STANDARD - LIQUID VISCOSITY

1,8 - Octanediol

$HO(CH_2)_8OH$
CA - No: 629-41-4

Purity =	98 %	
Molecular Weight =	146.23 kg/kmol	[1]
Critical Temperature =	723.6 K	[2]
Critical Pressure =	30.8 bar	[2]
Critical Volume =	0.5215 m^3/kmol	[2]
Normal Boiling Point =	566.8 K	[2]
Melting Point =	333.2 K	[3]
Liquid Molar Volume at 25 °C =	0.15544 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
335.40	25.216
348.25	16.139
363.05	9.718
378.00	6.027
392.90	3.966
407.95	2.740
423.05	1.972
432.95	1.641

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = 1129.584 - 31076.05/(T/K) - 192.9145 \ln(T/K) + 0.2628529\ (T/K)$$

% AAD = 0.37 %
% MAD = 0.73 %

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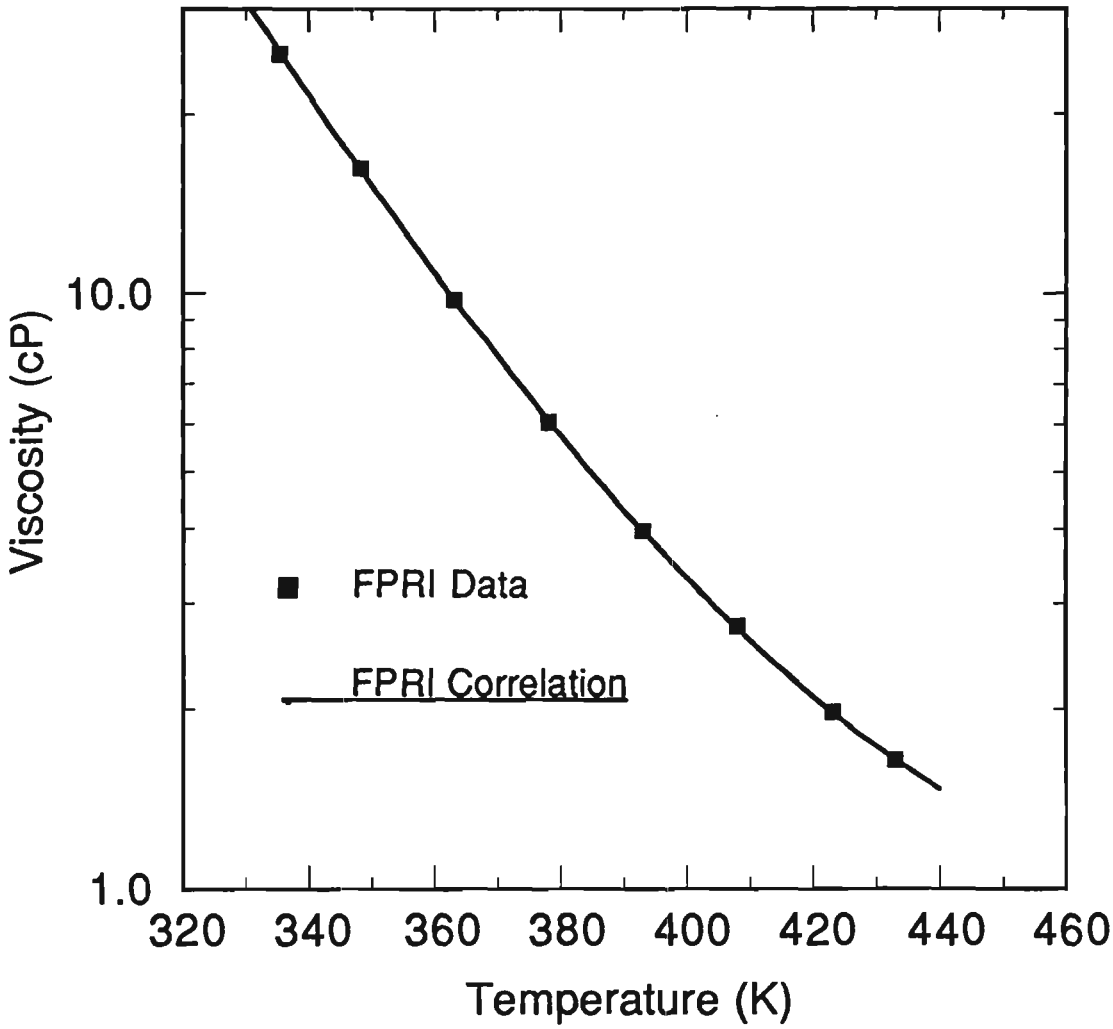
DDS-LV-A70

1,8 - Octanediol



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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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FPRI

May, 1994 DDS-LV-A71

DESIGN DATA STANDARD - LIQUID VISCOSITY

N,N - Diethyl Ethylene Diamine

$(C_2H_5)_2NCH_2CH_2NH_2$
CA - No: 100-36-7

Purity =	99 %	
Molecular Weight =	116.21 kg/kmol	[1]
Critical Temperature =	600.7 K	[2]
Critical Pressure =	31.8 bar	[2]
Critical Volume =	0.3895 m^3/kmol	[2]
Normal Boiling Point =	419.2 K	[3]
Melting Point =	254.6 K	[2]
Liquid Molar Volume at 25 °C =	0.14274 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
293.30	1.013
307.90	0.788
322.95	0.623
337.95	0.514
352.85	0.433
367.75	0.372
382.65	0.326
397.60	0.288
410.55	0.260

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -3.519244 + 664.3903 / (T/K - 105.1943)$$

% AAD = 0.21 %
% MAD = 0.49 %

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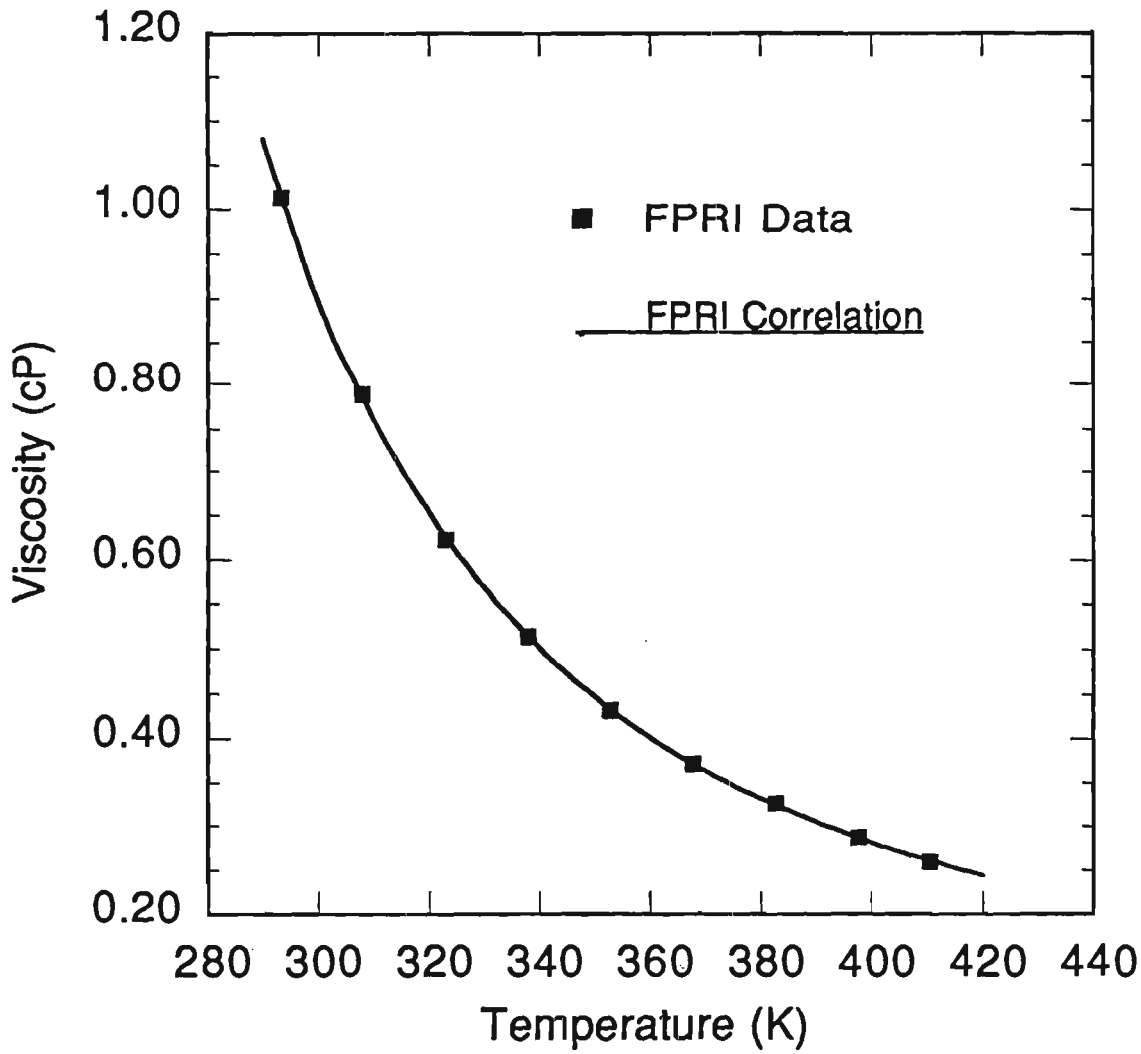
DDS-LV-A71

N,N - Diethyl Ethylene Diamine



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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1994 DDS-LV-A72

DESIGN DATA STANDARD - LIQUID VISCOSITY

N,N - Disiopropyl Ethylamine

$[(CH_3)_2CH]_2 N C_2H_5$
CA - No: 7087-68-5

Purity =	99 %	
Molecular Weight =	129.25 kg/kmol	[1]
Critical Temperature =	572.6 K	[2]
Critical Pressure =	25.7 bar	[2]
Critical Volume =	0.4895 m^3/kmol	[2]
Normal Boiling Point =	400.2 K	[3]
Melting Point =	181.9 K	[2]
Liquid Molar Volume at 25 °C =	0.17186 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
292.95	0.656
307.90	0.541
322.95	0.456
338.00	0.390
352.95	0.340
367.65	0.298
382.95	0.264
392.95	0.245

Liquid Viscosity Correlation:

$$\ln (\mu / cP) = -4.157021 + 1044.739 / (T / K - 13.17282)$$

% AAD = 0.12 %
% MAD = 0.34 %

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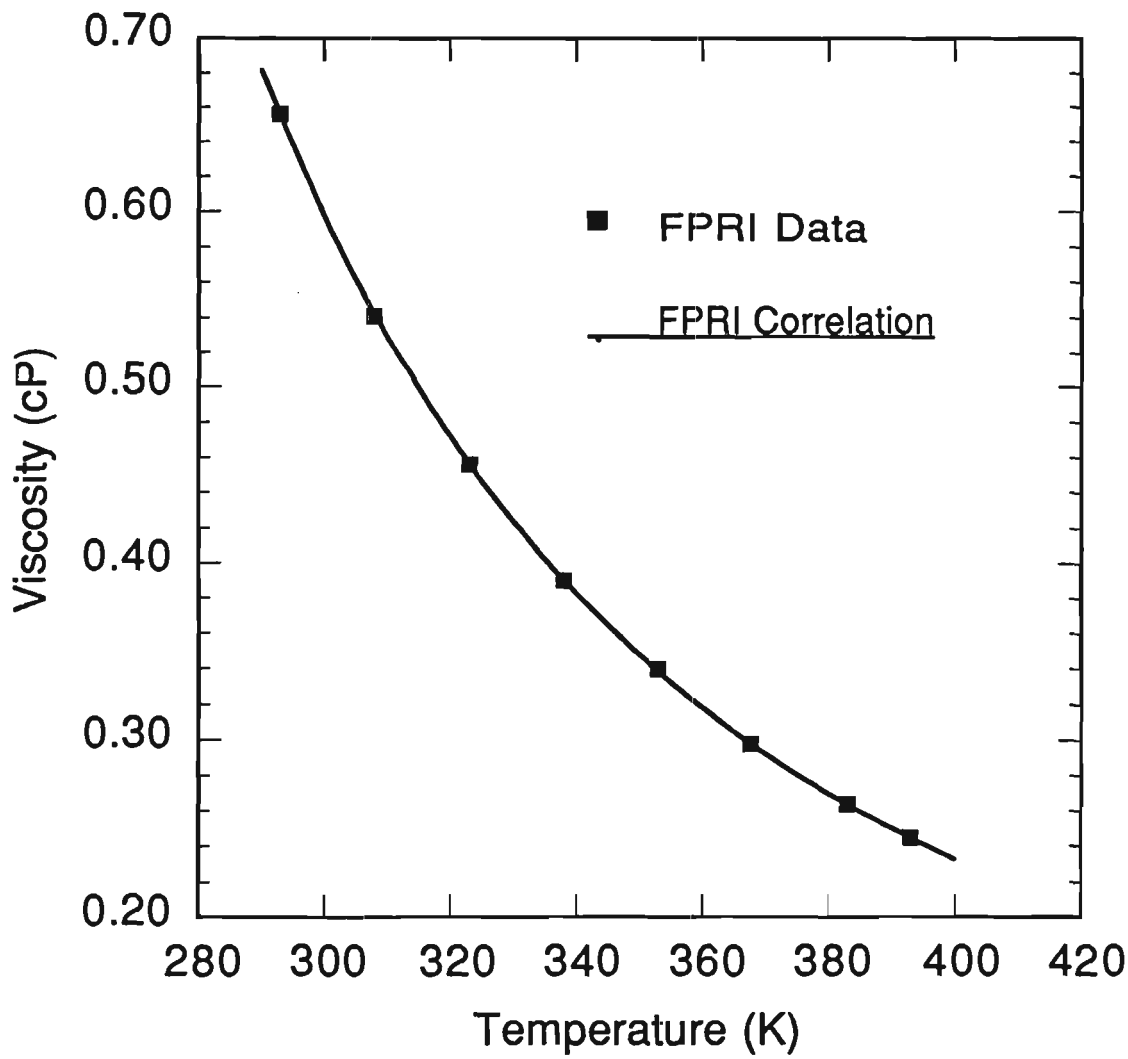
May, 1994 DDS-LV-A72

N,N - Diisopropyl Ethylamine



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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1994 DDS-LV-A73

DESIGN DATA STANDARD - LIQUID VISCOSITY

N,N,N',N' - Tetramethyl Ethylene Diamine

$(CH_3)_2 N CH_2CH_2 N (CH_3)_2$
CA - No: 110-18-9

Purity =	99 %	
Molecular Weight =	116.21 kg/kmol	[1]
Critical Temperature =	570.4 K	[2]
Critical Pressure =	30.9 bar	[2]
Critical Volume =	0.4075 m^3/kmol	[2]
Normal Boiling Point =	394.2 K	[3]
Melting Point =	218.2 K	[3]
Liquid Molar Volume at 25 °C =	0.15042 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experiment Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
294.10	0.582
302.90	0.523
312.95	0.466
328.00	0.399
343.00	0.347
357.95	0.305
373.20	0.271
382.95	0.251
391.85	0.238

Liquid Viscosity Correlation:

$$\ln (\mu /cP) = -3.854529 + 872.2919 / (T /K - 30.83787)$$

% AAD = 0.14 %
% MAD = 0.51 %

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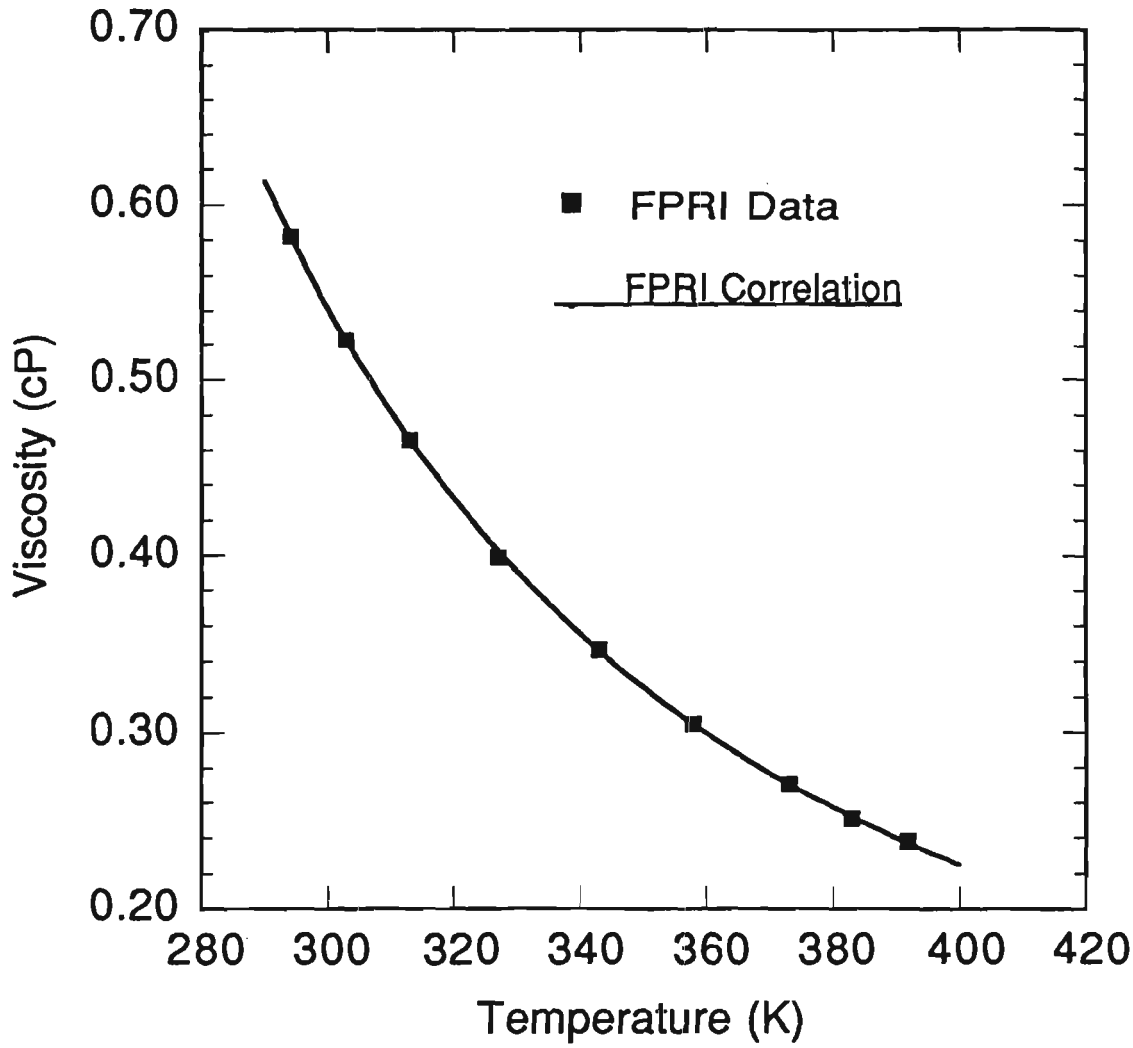
DDS-LV-A73

N,N,N',N' - Tetramethyl Ethylene Diamine



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1994 DDS-LV-A74

DESIGN DATA STANDARD - LIQUID VISCOSITY

Propionic Acid

C_2H_5COOH
CA - No: 79-09-4

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =	601.3 K	[3]
Critical Pressure =	53.7 bar	[2]
Critical Volume =	0.233 m^3/kmol	[3]
Normal Boiling Point =	413.98 K	[2]
Melting Point =	252.45 K	[2]
Liquid Molar Volume at 25 °C =	0.074883 m^3/kmol	[2]

Experimental Technique : High Pressure Capillary Viscometer

Experiment Data:
Pressure = ~ 20 bar
Accuracy = ± 2.0 %

T (K)	μ (cP)
298.05	1.0538
313.00	0.8758
328.00	0.7286
342.90	0.6228
358.35	0.5361
373.45	0.4670
388.20	0.4142
403.20	0.3644
412.15	0.3405
412.45	0.3400
424.90	0.3130
436.65	0.2860
447.35	0.2664
454.95	0.2497

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -64.46654 + 2943.157/(T/K) + 10.40198 \ln(T/K) - 0.01548633\,(T/K)$$

% AAD = 0.35 %
% MAD = 0.71 %

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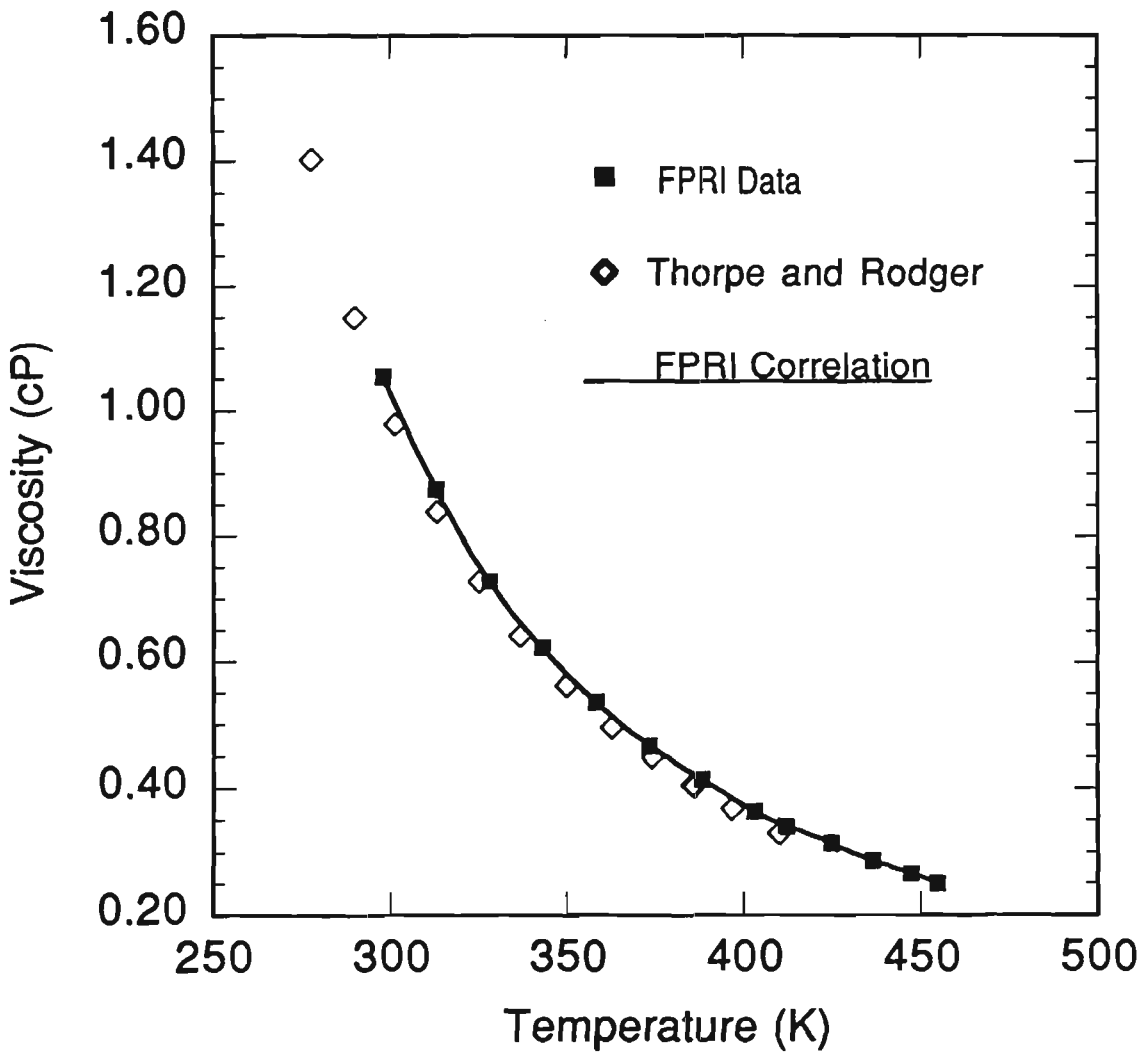
DDS-LV-A74

Propionic Acid



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2. Daubert, T.E.; Danner, R.P., "Data Compilation Tables of Properties of Pure Compounds", Design Institute for Physical Property Data, American Institute of Chemical Engineers, New York, N. Y. (1985).

3. Gude, M.T., MS Thesis, Georgia Institute of Technology (1989).

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May, 1994 DDS-LV-A75

DESIGN DATA STANDARD - LIQUID VISCOSITY

86 wt% Propionic Acid + 14 wt% Water

$C_2H_5COOH + H_2O$

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =		
Critical Pressure =		
Critical Volume =		
Normal Boiling Point =		
Melting Point =		
Liquid Molar Volume at 25 °C =	0.07331 m^3/kmol	[2]

Experimental Technique : High Pressure Capillary Viscometer

Experiment Data:
Pressure = ~ 20 bar
Accuracy = ± 2.0 %

T (K)	μ (cP)
298.05	2.2803
312.95	1.6505
328.10	1.2360
342.95	0.9711
358.35	0.7793
368.25	0.6960
373.40	0.6521
387.10	0.5781
396.25	0.5270
406.55	0.4832
417.45	0.4378
427.15	0.4009
438.20	0.3671
448.80	0.3393

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -323.6800 + 12270.82/(T/K) + 53.14661 \ln(T/K) - 0.06525403\ (T/K)$$

% AAD = 0.63 %
% MAD = 1.29 %

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May, 1994

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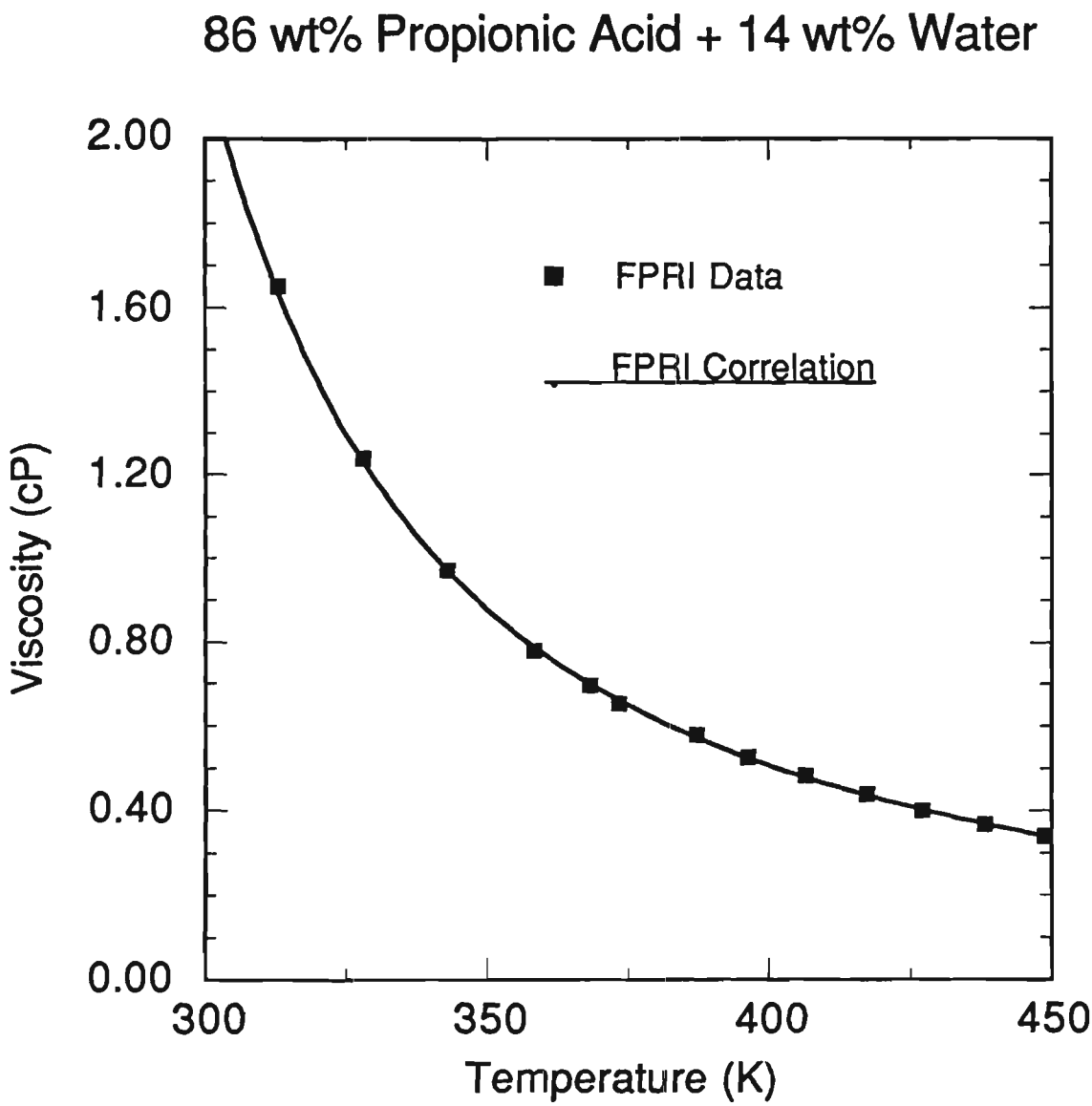

REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from FPRI density correlation.

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May, 1994 DDS-LV-A76

DESIGN DATA STANDARD - LIQUID VISCOSITY

70 wt% Propionic Acid + 30 wt% Water

$C_2H_5COOH + H_2O$

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =		
Critical Pressure =		
Critical Volume =		
Normal Boiling Point =		
Melting Point =		
Liquid Molar Volume at 25 °C =	0.07256 m^3/kmol	[2]

Experimental Technique : High Pressure Capillary Viscometer

Experiment Data:

Pressure = ~ 20 bar
Accuracy = ± 2.0 %

T (K)	μ (cP)
300.20	2.4039
313.00	1.7640
328.00	1.2940
342.90	0.9948
357.35	0.7997
368.30	0.7001
370.55	0.6859
377.35	0.6408
387.95	0.5740
397.55	0.5208
406.30	0.4753
418.15	0.4313
427.90	0.3942
437.80	0.3646
447.65	0.3383

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -415.9243 + 15433.48 / (T/K) + 68.47846 \ln(T/K) - 0.08406705\ (T/K)$$

% AAD = 0.52 %
% MAD = 1.20 %

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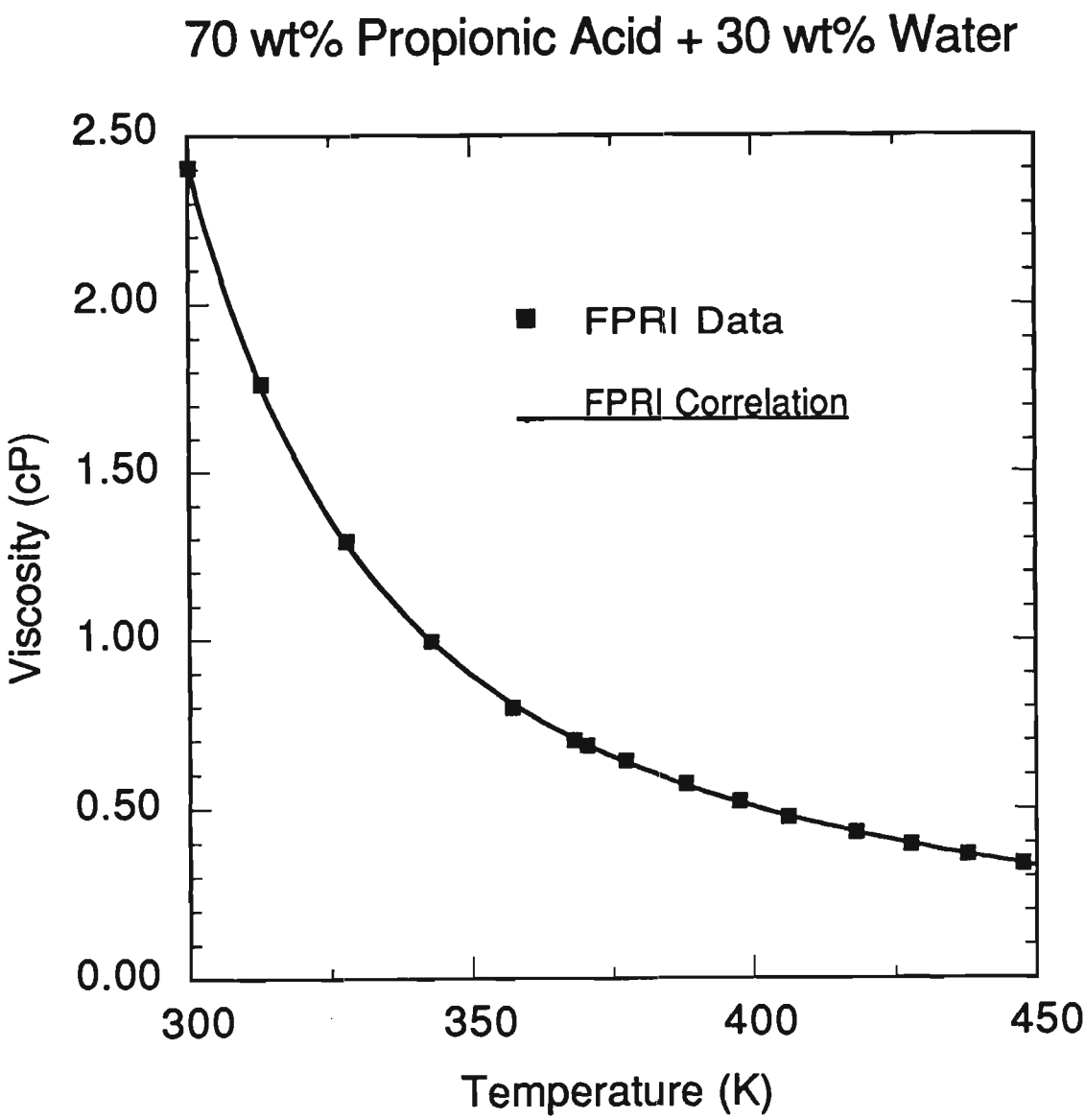

REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from FPRI density correlation.

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May, 1994 DDS-LV-A77

DESIGN DATA STANDARD - LIQUID VISCOSITY

58 wt% Propionic Acid + 42 wt% Water

$C_2H_5COOH + H_2O$

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =		
Critical Pressure =		
Critical Volume =		
Normal Boiling Point =		
Melting Point =		
Liquid Molar Volume at 25 °C =	0.07247 m^3/kmol	[2]

Experimental Technique : High Pressure Capillary Viscometer

Experiment Data:
Pressure = ~ 20 bar
Accuracy = ± 2.0 %

T (K)	μ (cP)
300.05	2.2738
313.00	1.6472
328.00	1.2083
343.40	0.9197
357.35	0.7481
368.25	0.6505
378.70	0.5849
389.55	0.5209
400.95	0.4719
413.65	0.4229
426.05	0.3826
438.75	0.3478

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -359.5599 + 13893.97 / (T/K) + 58.68046 \ln(T/K) - 0.06876108\ (T/K)$$

% AAD = 0.33 %
% MAD = 0.75 %

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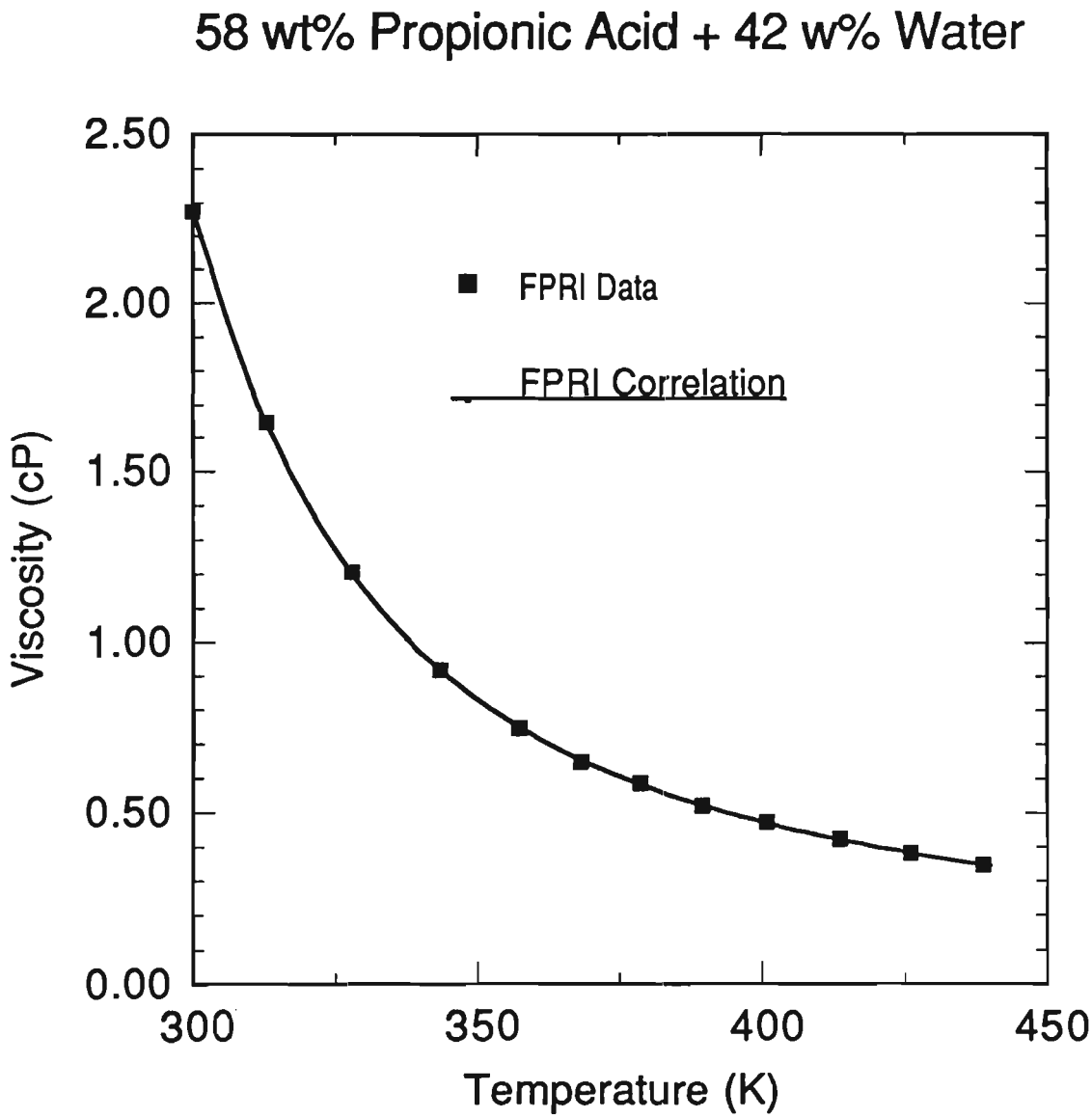

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2. Estimated from FPRI density correlation.

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May, 1994 DDS-LV-A78

DESIGN DATA STANDARD - LIQUID VISCOSITY

42 wt% Propionic Acid + 58 wt% Water

$C_2H_5COOH + H_2O$

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =		
Critical Pressure =		
Critical Volume =		
Normal Boiling Point =		
Melting Point =		
Liquid Molar Volume at 25 °C =	0.07273 m^3/kmol	[2]

Experimental Technique : High Pressure Capillary Viscometer

Experiment Data:
Pressure = ~ 20 bar
Accuracy = ± 2.0 %

T (K)	μ (cP)
295.25	2.1837
308.35	1.5468
323.00	1.1254
338.00	0.8576
353.25	0.6829
367.25	0.5729
379.90	0.5051
391.95	0.4453
403.45	0.4030
415.65	0.3702
427.75	0.3402
440.35	0.3102
450.85	0.2903

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -347.9298 + 13546.36/(T/K) + 56.62955 \ln(T/K) - 0.06526098\ (T/K)$$

% AAD = 0.29 %
% MAD = 0.74 %

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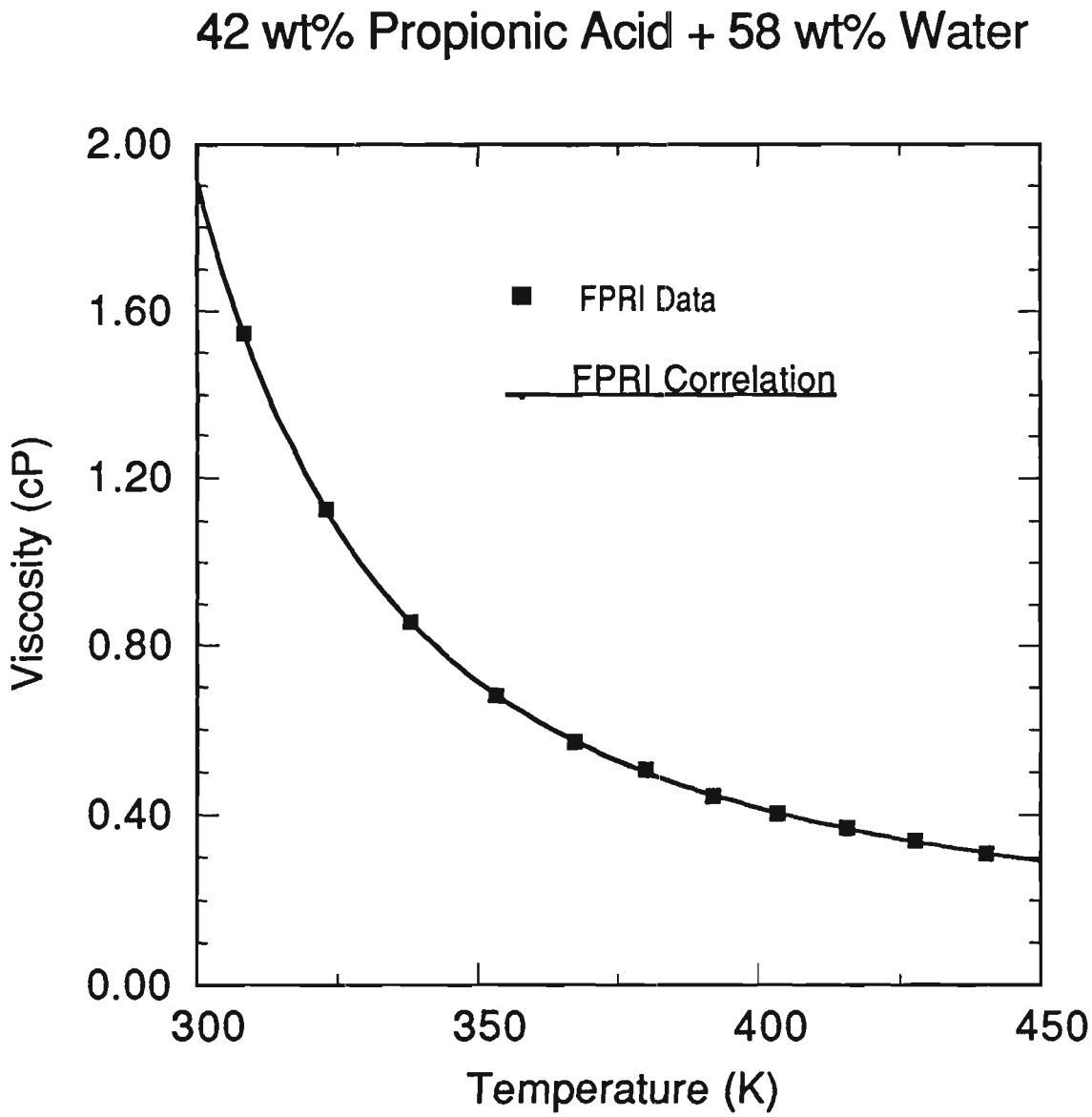
May, 1994 DDS-LV-A78



REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from FPRI density correlation.

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FPRI

May, 1994 DDS-LV-A79

DESIGN DATA STANDARD - LIQUID VISCOSITY

18 wt% Propionic Acid + 82 wt% Water

$C_2H_5COOH + H_2O$

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =		
Critical Pressure =		
Critical Volume =		
Normal Boiling Point =		
Melting Point =		
Liquid Molar Volume at 25 °C =	0.07349 m^3/kmol	[2]

Experimental Technique : High Pressure Capillary Viscometer

Experiment Data:
Pressure = ~ 20 bar
Accuracy = ± 2.0 %

T (K)	μ (cP)
303.95	1.1750
313.20	0.9586
323.15	0.7942
338.00	0.6225
353.30	0.5164
366.25	0.4420
385.45	0.3602
395.15	0.3323
405.75	0.3011
416.25	0.2810
426.80	0.2591
436.25	0.2432
448.60	0.2233

Liquid Viscosity Correlation:

$$\ln(\mu/cP) = -277.7385 + 10859.20/(T/K) + 45.20168 \ln(T/K) - 0.05344476\ (T/K)$$

% AAD = 0.46 %
% MAD = 1.05 %

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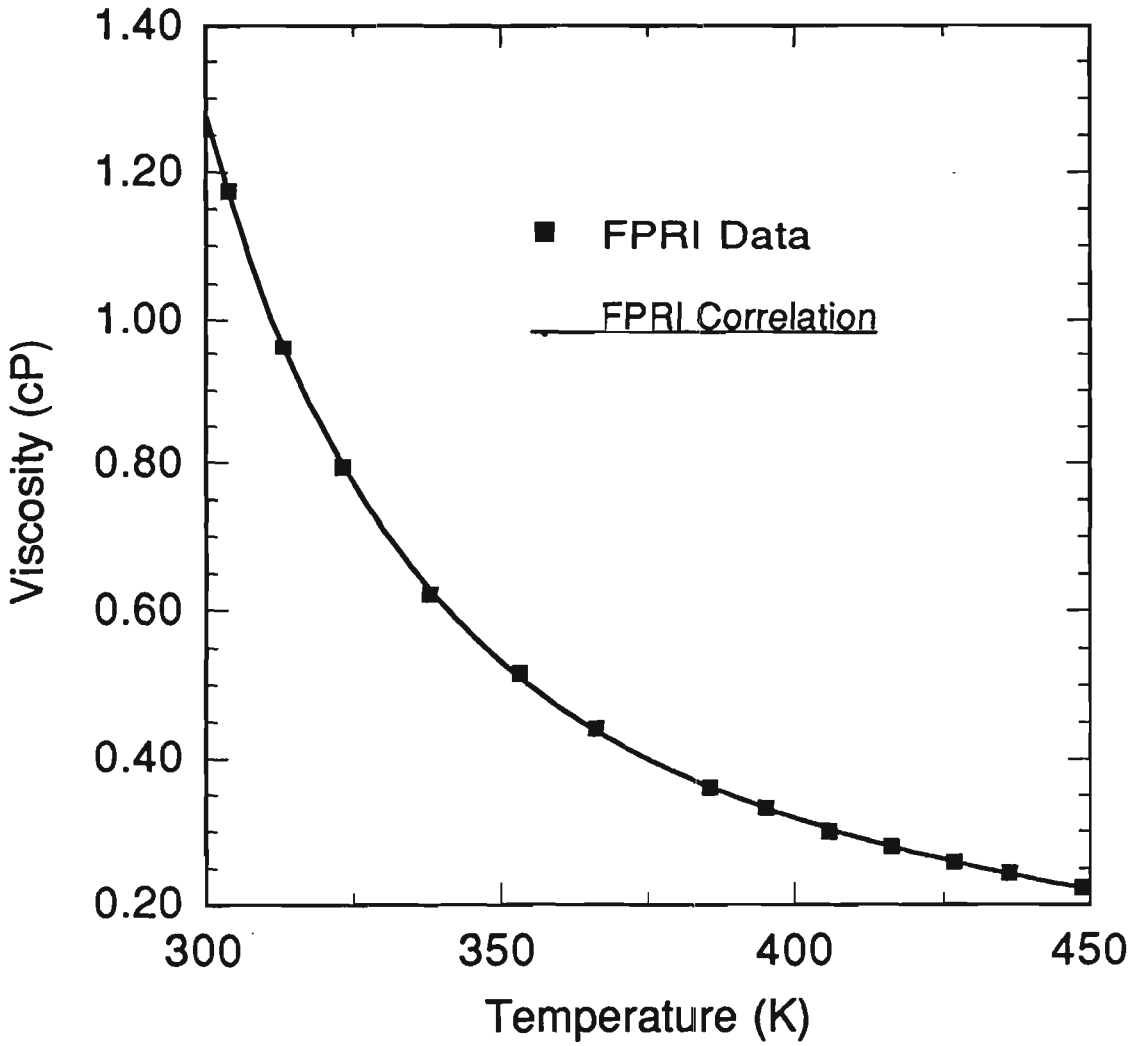
FPRI

May, 1994 DDS-LV-A79

18 wt% Propionic Acid + 82 wt% Water



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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from FPRI density correlation.

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FPRI

May, 1994 DDS-LD-A66

DESIGN DATA STANDARD - LIQUID DENSITY

2 - Cyanopyridine

$C_6H_4N_2$
CA - No: 100-70-9

Purity =	99 %	
Molecular Weight =	104.11 kg/kmol	[1]
Critical Temperature =	720.0 K	[2]
Critical Pressure =	46.2 bar	[2]
Critical Volume =	0.3755 m^3/kmol	[2]
Normal Boiling Point =	486.7 K	[3]
Melting Point =	300.2 K	[3]
Liquid Molar Volume at 25 °C =	0.09591 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
306.95	1076.8
318.40	1067.5
333.45	1052.6
348.25	1038.5
363.05	1024.6
378.20	1010.7
393.05	996.8
405.95	985.3
419.80	971.9
432.80	959.3

Liquid Density Correlation:

1) $$\rho / \mathrm{kgm}^{-3} = 285.3884 / 0.4564147^{[1+(1-T/K/720)^{0.6583926}]}$$
% AAD = 0.029 % % MAD = 0.082 %

2) $$\rho / \mathrm{kgm}^{-3} = 1360.663 - 0.9144329\ T/K - 0.2837796 \times 10^{-4}\ (T/K)^2$$
% AAD = 0.030 % % MAD = 0.081 %

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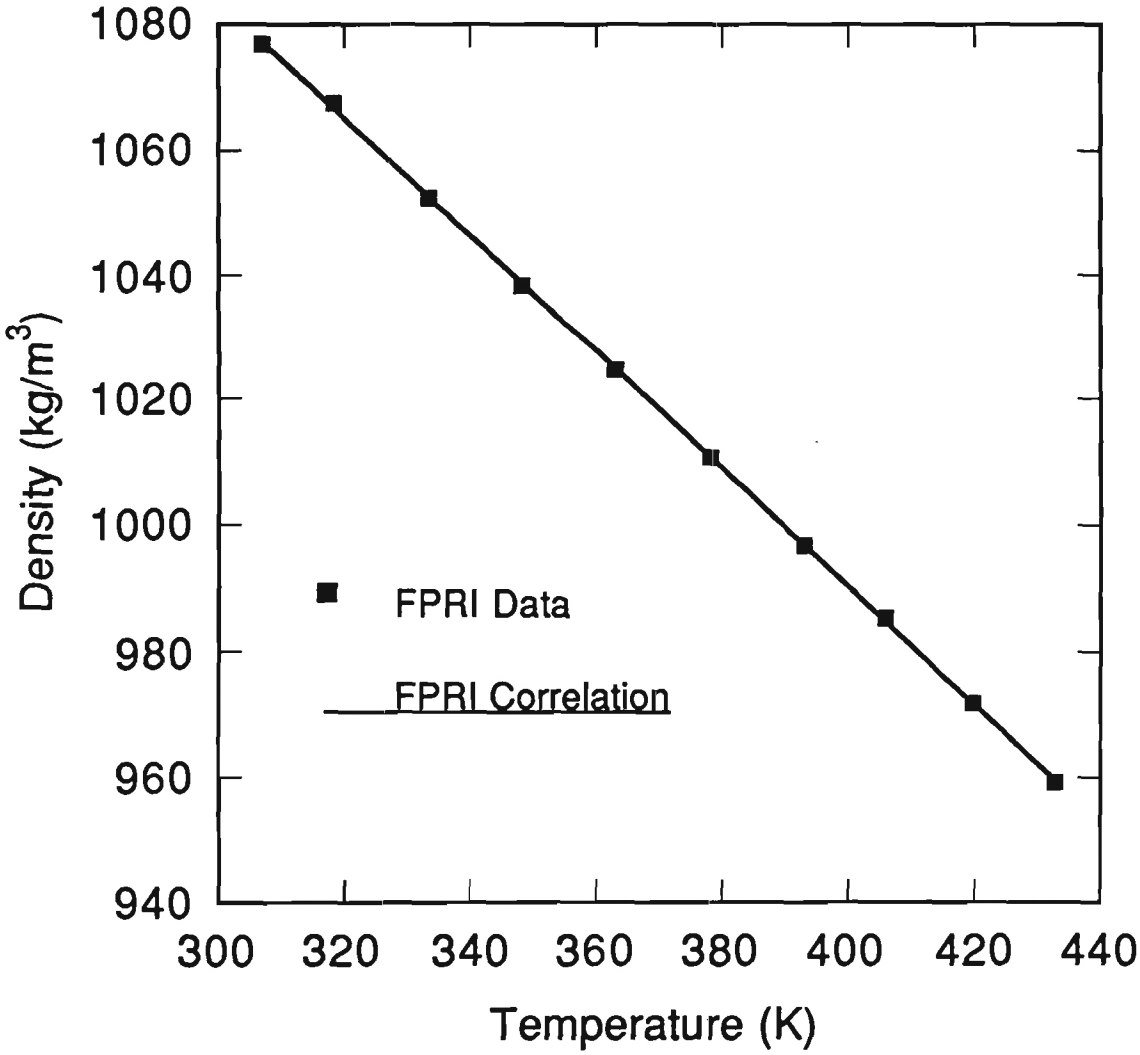
2 - Cyanopyridine



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1994 DDS-LD-A67

DESIGN DATA STANDARD - LIQUID DENSITY

3,5 - Dichloropyridine

$C_5H_3Cl_2N$
CA - No: 2547-47-8

Purity =	98 %	
Molecular Weight =	147.99 kg/kmol	[1]
Critical Temperature =	721.5 K	[2]
Critical Pressure =	47.2 bar	[2]
Critical Volume =	0.3545 m^3/kmol	[2]
Normal Boiling Point =	474.0 K	[2]
Melting Point =	339.2 K	[3]
Liquid Molar Volume at 25 °C =	0.10779 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
343.40	1321.6
358.25	1303.8
373.25	1285.5
388.00	1267.0
402.95	1248.4
417.95	1229.1
433.05	1208.9
447.45	1189.3

Liquid Density Correlation:

1) $$\rho / kgm^{-3} = 43.42367 / 0.1612025^{[1+(1-T/K/721.50)^{0.2129687}]}$$
% AAD = 0.007 % % MAD = 0.019 %

2) $$\rho / kgm^{-3} = 1620.036 - 0.5625741\ T/K - 0.8934208 \times 10^{-3}\ (T/K)^2$$
% AAD = 0.010 % % MAD = 0.021 %

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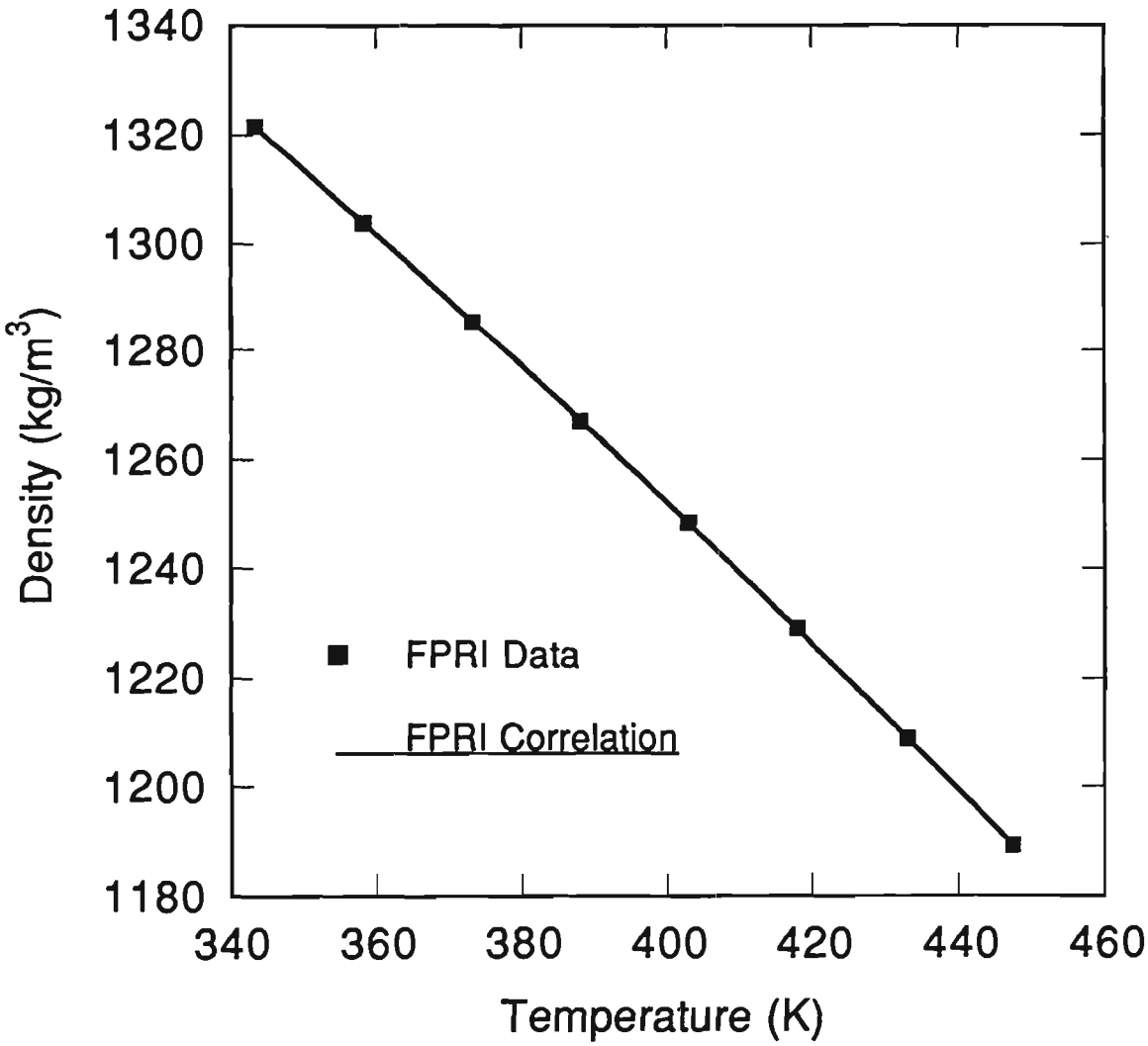
3,5 - Dichloropyridine



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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FPRI

May, 1994 DDS-LD-A68

DESIGN DATA STANDARD - LIQUID DENSITY

1,2 - Octanediol

$CH_3(CH_2)_5CH(OH)CH_2OH$
CA - No: 1117-86-8

Purity =	98 +%	
Molecular Weight =	146.23 kg/kmol	[1]
Critical Temperature =	725.6 K	[2]
Critical Pressure =	31.1 bar	[2]
Critical Volume =	0.5155 m^3/kmol	[2]
Normal Boiling Point =	566.4 K	[2]
Melting Point =	310.2 K	[3]
Liquid Molar Volume at 25 °C =	0.15768 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
313.35	916.2
328.40	905.4
343.40	894.0
358.00	882.8
373.30	871.1
388.05	859.3
402.95	847.4
417.75	835.6
432.75	823.3

Liquid Density Correlation:

1) $$\rho / kgm^{-3} = 103.9480 / 0.3037230^{[1+(1-T/K/725.60)^{0.3370195}]}$$
% AAD = 0.012 % % MAD = 0.021 %

2) $$\rho / kgm^{-3} = 1107.610 - 0.4877924\ T/K - 0.3912525 \times 10^{-3}\ (T/K)^2$$
% AAD = 0.010 % % MAD = 0.019 %

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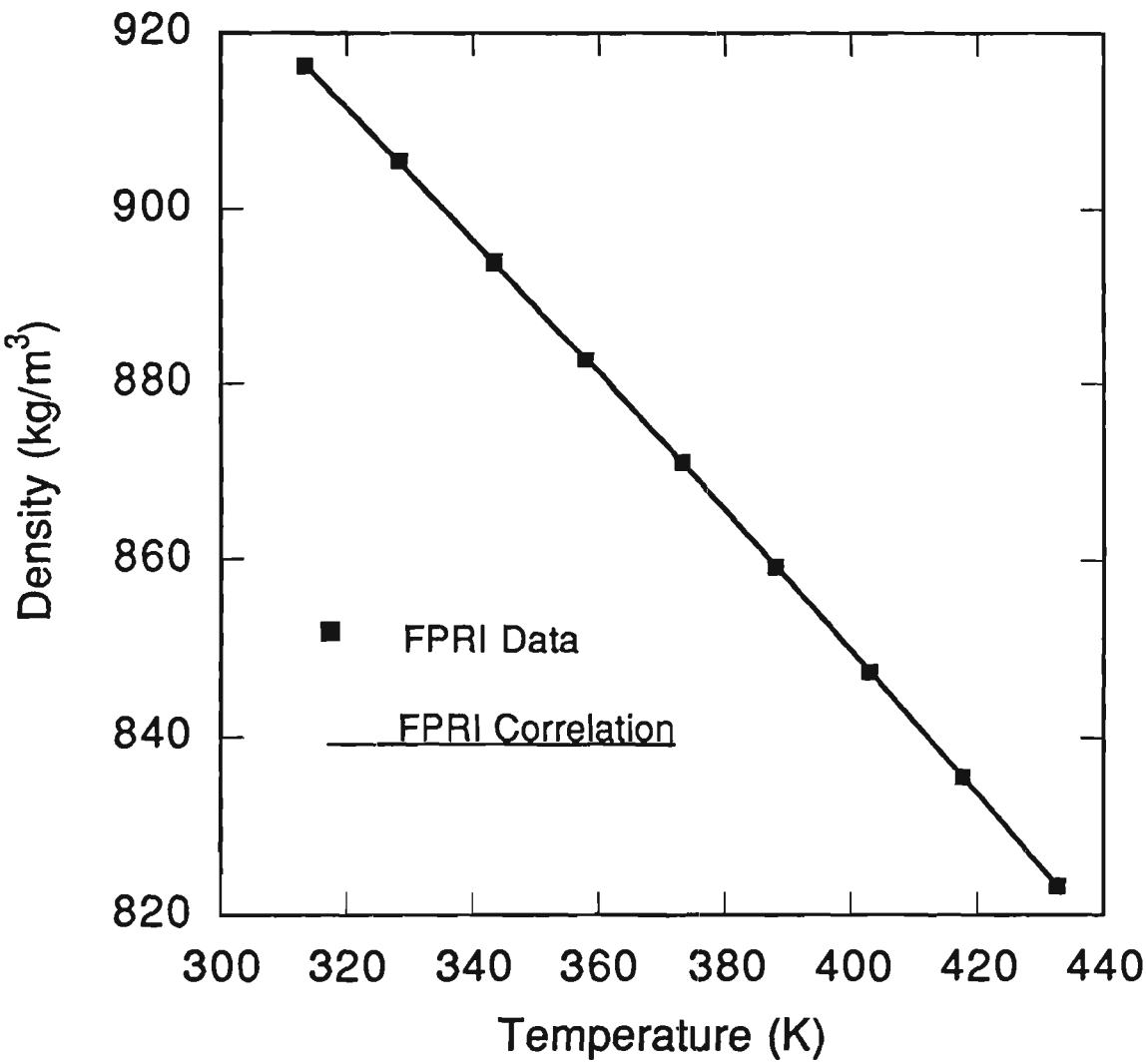
1,2 - Octanediol



REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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FPRI

May, 1994 DDS-LD-A69

DESIGN DATA STANDARD - LIQUID DENSITY

1,8 - Octanediol

$HO(CH_2)_8OH$
CA - No: 629-41-4

Purity =	98 %	
Molecular Weight =	146.23 kg/kmol	[1]
Critical Temperature =	723.6 K	[2]
Critical Pressure =	30.8 bar	[2]
Critical Volume =	0.5215 m^3/kmol	[2]
Normal Boiling Point =	566.8 K	[2]
Melting Point =	333.2 K	[3]
Liquid Molar Volume at 25 °C =	0.15544 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
335.40	918.5
348.25	910.3
363.05	901.1
378.00	891.0
392.90	880.8
407.95	870.2
423.05	859.6
432.95	852.3

Liquid Density Correlation:

1) $$\rho / kgm^{-3} = 24.79052 / 0.1506790^{[1+(1-T/K/723.60)^{0.1538315}]}$$
% AAD = 0.010 % % MAD = 0.027 %

2) $$\rho / kgm^{-3} = 1059.160 - 0.2184317\ T/K - 0.5991381 \times 10^{-3}\ (T/K)^2$$
% AAD = 0.009 % % MAD = 0.023 %

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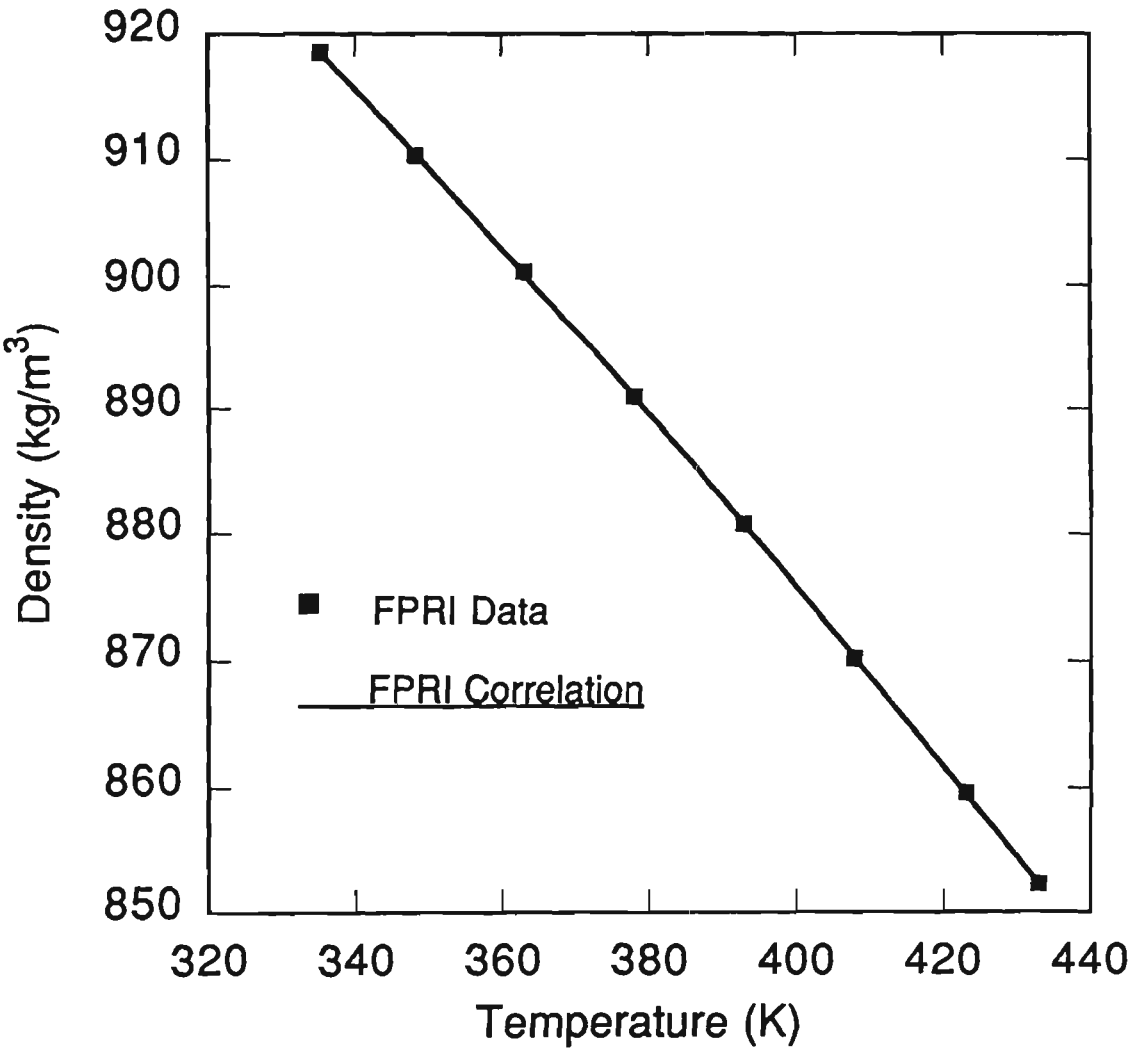
1,8 - Octanediol



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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1994 DDS-LD-A70

DESIGN DATA STANDARD - LIQUID DENSITY

N,N - Diethyl Ethylene Diamine

$(C_2H_5)_2NCH_2CH_2NH_2$
CA - No: 100-36-7

Purity =	99 %	
Molecular Weight =	116.21 kg/kmol	[1]
Critical Temperature =	600.7 K	[2]
Critical Pressure =	31.8 bar	[2]
Critical Volume =	0.3895 m^3/kmol	[2]
Normal Boiling Point =	419.2 K	[3]
Melting Point =	254.6 K	[2]
Liquid Molar Volume at 25 °C =	0.14274 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
293.30	818.5
307.90	805.5
322.95	792.1
337.95	778.8
352.85	765.5
367.75	751.5
382.65	737.7
397.60	723.9
410.55	711.5

Liquid Density Correlation:

1) $$\rho / kgm^{-3} = 179.7470 / 0.4104205^{[1+(1-T/K/600.70)^{0.5278878}]}$$
% AAD = 0.013 % % MAD = 0.033 %

2) $$\rho / kgm^{-3} = 1045.738 - 0.6777409\ T/K - 0.3319419 \times 10^{-3}\ (T/K)^2$$
% AAD = 0.013 % % MAD = 0.033 %

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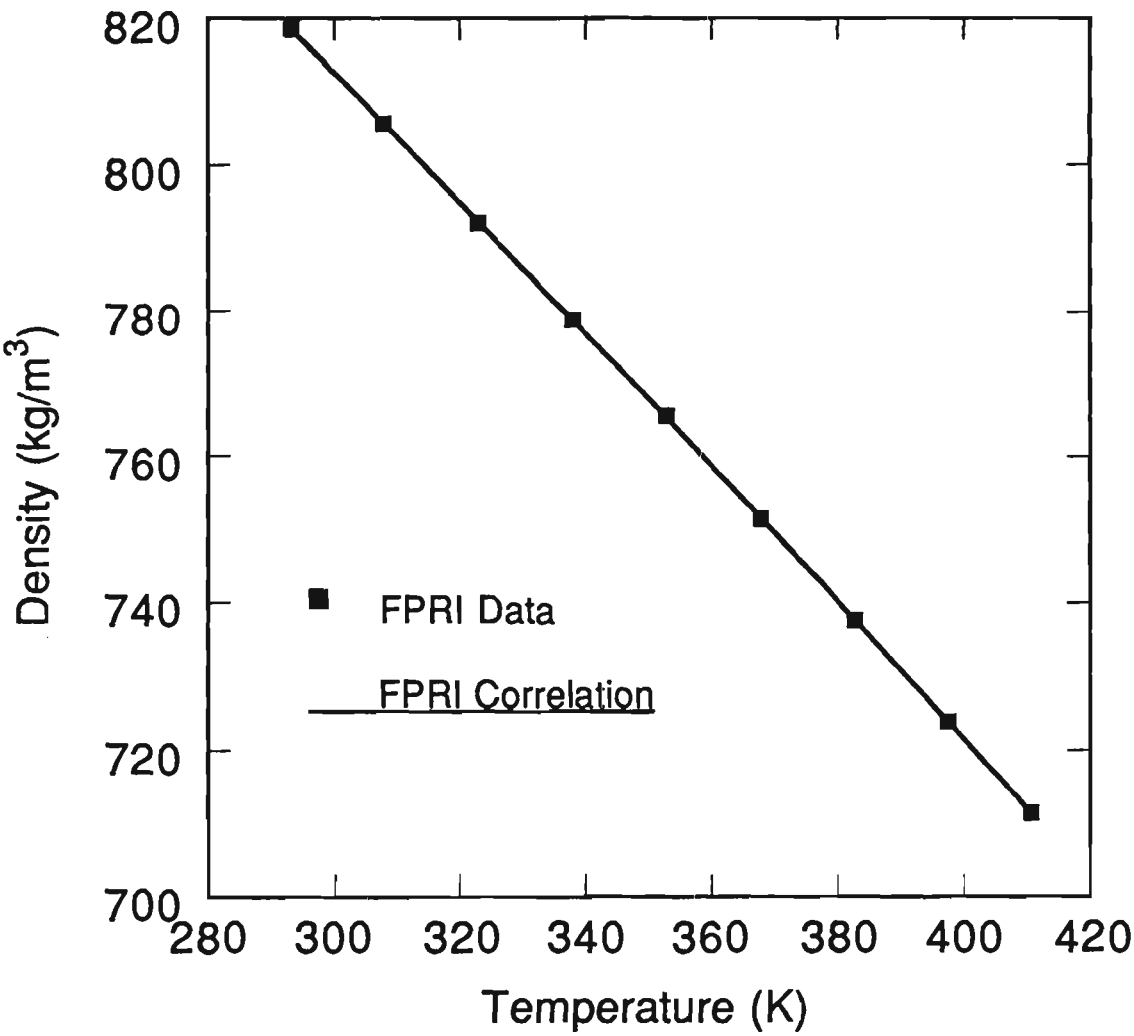
May, 1994 DDS-LD-A70

N,N - Diethyl Ethylene Diamine



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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1994 DDS-LD-A71

DESIGN DATA STANDARD - LIQUID DENSITY

N,N - Disiopropyl Ethylamine

$[(CH_3)_2CH]_2 N C_2H_5$
CA - No: 7087-68-5

Purity =	99 %	
Molecular Weight =	129.25 kg/kmol	[1]
Critical Temperature =	572.6 K	[2]
Critical Pressure =	25.7 bar	[2]
Critical Volume =	0.4895 m^3/kmol	[2]
Normal Boiling Point =	400.2 K	[3]
Melting Point =	181.9 K	[2]
Liquid Molar Volume at 25 °C =	0.17186 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
292.95	756.2
307.95	743.8
322.95	731.1
338.00	718.0
352.95	705.1
367.65	691.9
382.95	678.1
393.15	669.5

Liquid Density Correlation:

1) $$\rho / kgm^{-3} = 189.8025 / 0.4363568^{[1+(1-T/K/572.60)^{0.5643931}]}$$
% AAD = 0.020 % % MAD = 0.047 %

2) $$\rho / kgm^{-3} = 976.0353 - 0.6594686\ T/K - 0.3074656 \times 10^{-3}\ (T/K)^2$$
% AAD = 0.018 % % MAD = 0.044 %

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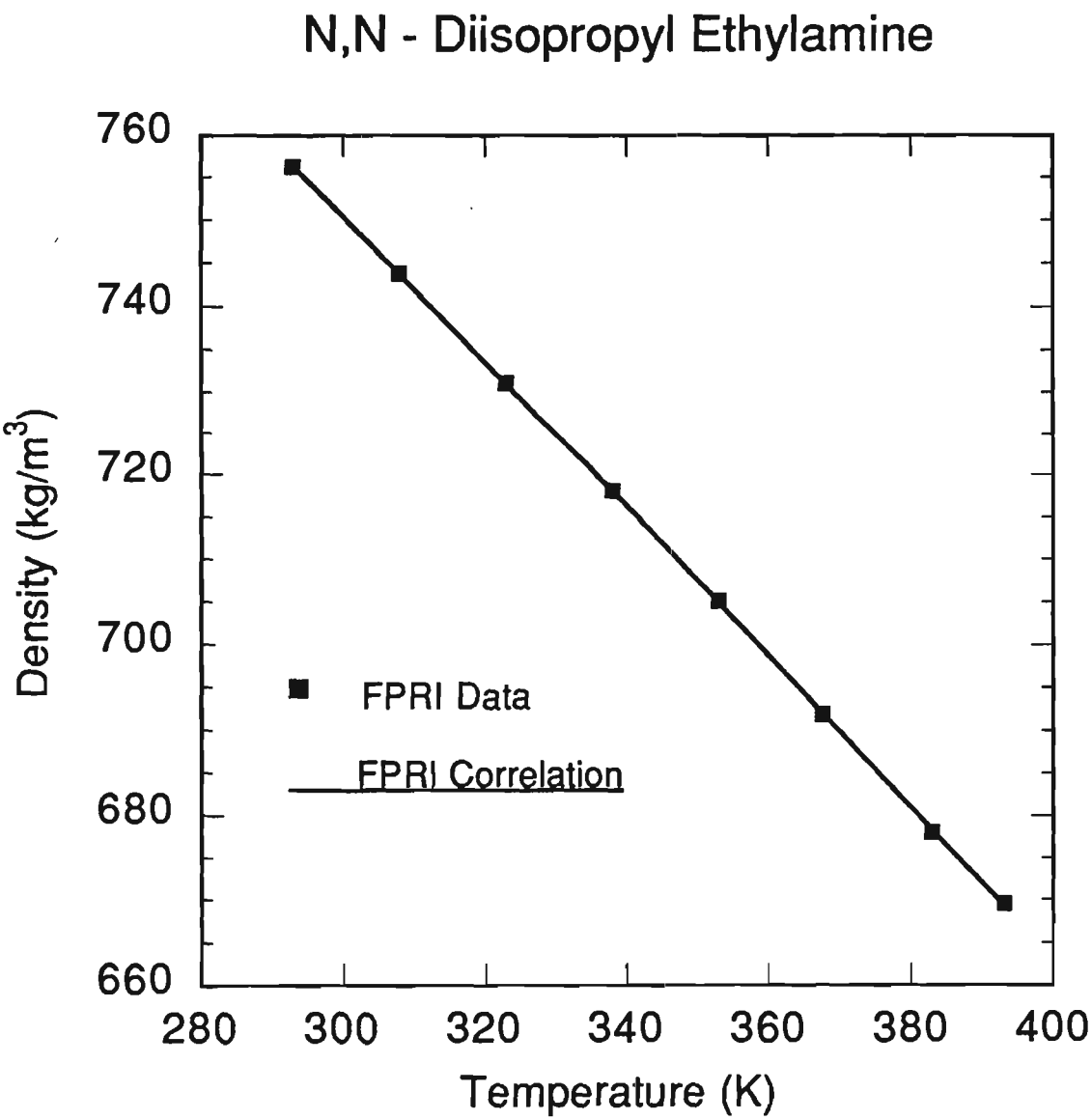
May, 1994 DDS-LD-A71



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1994 DDS-LD-A72

DESIGN DATA STANDARD - LIQUID DENSITY

N,N,N',N' - Tetramethyl Ethylene Diamine

$(CH_3)_2 N CH_2CH_2 N (CH_3)_2$
CA - No: 110-18-9

Purity =	99 %	
Molecular Weight =	116.21 kg/kmol	[1]
Critical Temperature =	570.4 K	[2]
Critical Pressure =	30.9 bar	[2]
Critical Volume =	0.4075 m^3/kmol	[2]
Normal Boiling Point =	394.2 K	[3]
Melting Point =	218.2 K	[3]
Liquid Molar Volume at 25 °C =	0.15042 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experiment Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (Kg/m^3)
294.10	776.3
302.90	768.2
312.95	759.2
328.00	745.6
343.00	731.7
357.95	717.8
373.20	702.9
383.05	693.4
393.15	683.8

Liquid Density Correlation:

1) $$\rho / kgm^{-3} = 159.9182 / 0.3952414^{[1+(1-T/K/570.40)^{0.4884052}]}$$
% AAD = 0.016 % % MAD = 0.027 %

2) $$\rho / kgm^{-3} = 996.7095 - 0.6122750\ T/K - 0.4678229 \times 10^{-3}\ (T/K)^2$$
% AAD = 0.015 % % MAD = 0.027 %

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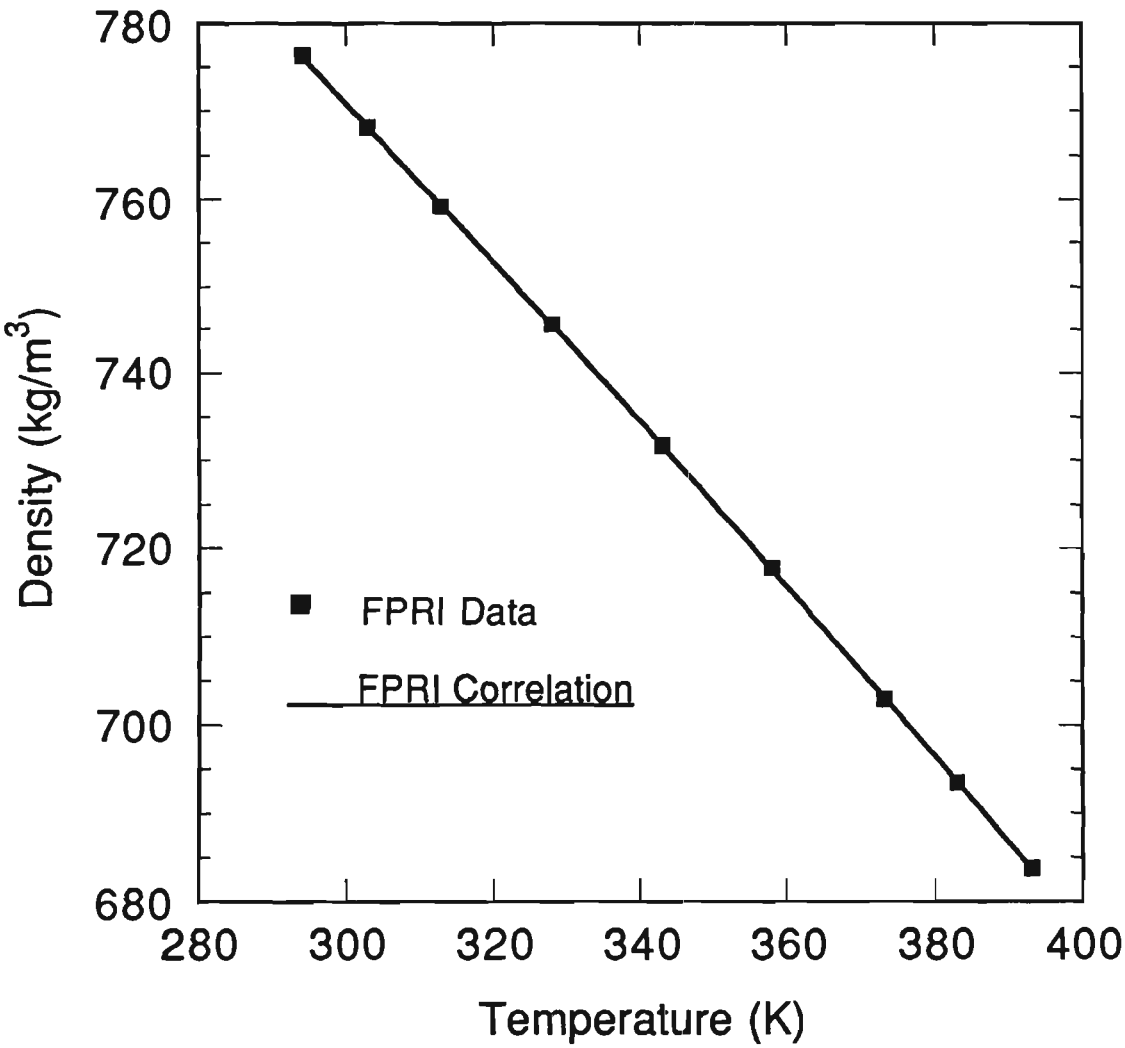
DDS-LD-A72

N,N,N',N' - Tetramethyl Ethylene Diamine



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1994 DDS-LD-A73

DESIGN DATA STANDARD - LIQUID DENSITY

Propionic Acid

C_2H_5COOH
CA - No: 79-09-4

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =	601.3 K	[3]
Critical Pressure =	53.7 bar	[2]
Critical Volume =	0.233 m^3/kmol	[3]
Normal Boiling Point =	413.98 K	[2]
Melting Point =	252.45 K	[2]
Liquid Molar Volume at 25 °C =	0.074883 m^3/kmol	[2]

Experimental Technique : High Pressure Pycnometer

Experiment Data:
Pressure = ~ 20 bar
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
299.55	987.38
312.95	972.74
328.00	956.14
342.90	939.99
357.75	923.83
363.20	917.97
378.45	900.49
388.35	889.13
403.25	872.10
412.25	862.12
413.80	860.91
426.15	846.14
436.75	833.15
446.55	819.78

Liquid Density Correlation:

$$\rho / kgm^{-3} = 1514.837 - 2.867724\ T/K + 0.005239542\ (T/K)^2 - 0.5150982 \times 10^{-5}\ (T/K)^3$$

% AAD = 0.036 % % MAD = 0.074 %

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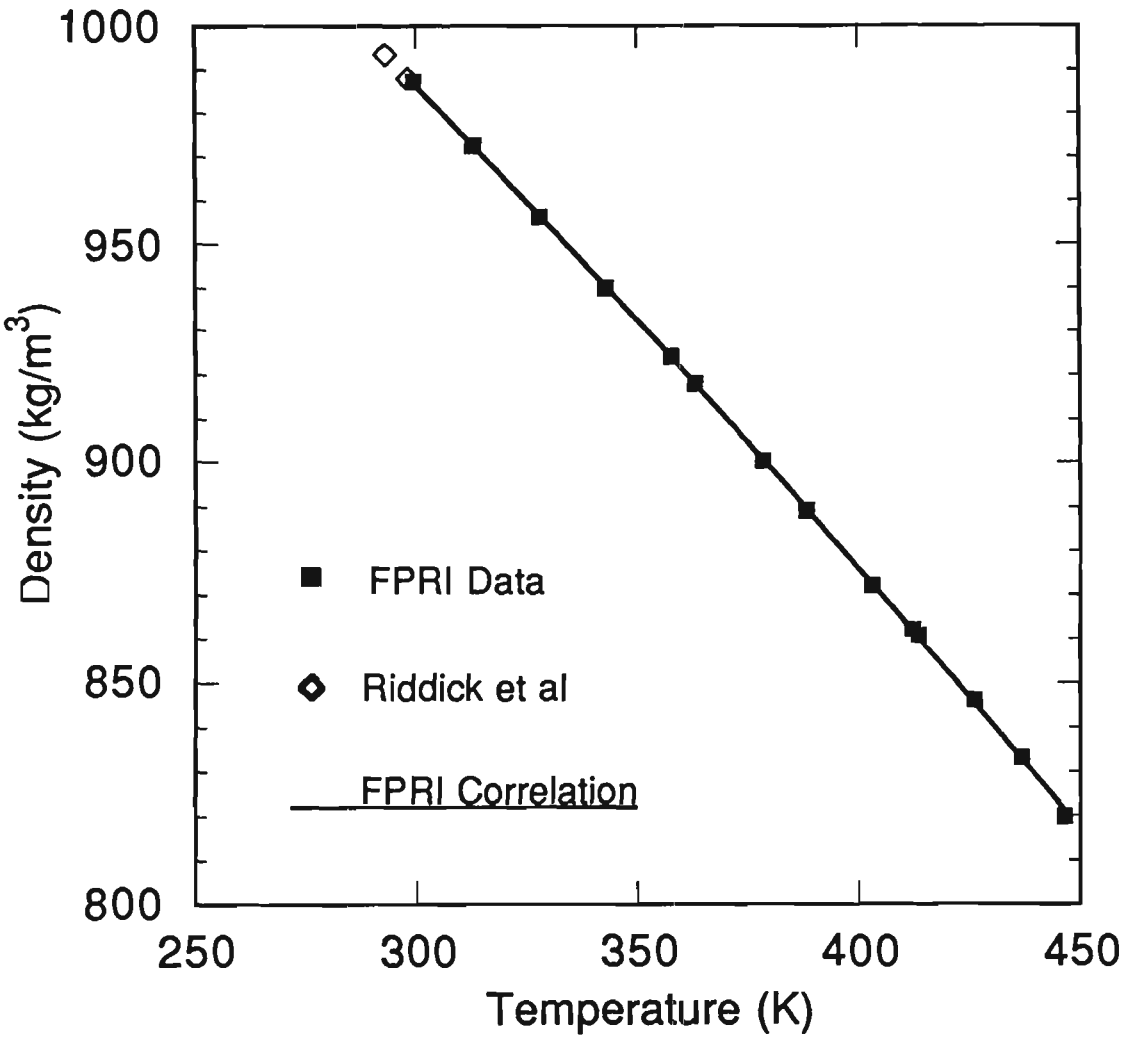
DDS-LD-A73

Propionic Acid



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2. Daubert, T.E.; Danner, R.P., "Data Compilation Tables of Properties of Pure Compounds", Design Institute for Physical Property Data, American Institute of Chemical Engineers, New York, N. Y. (1985).

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4. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

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May, 1994 DDS-LD-A74

DESIGN DATA STANDARD - LIQUID DENSITY

86 wt% Propionic Acid + 14 wt% Water

$C_2H_5COOH + H_2O$

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =		
Critical Pressure =		
Critical Volume =		
Normal Boiling Point =		
Melting Point =		
Liquid Molar Volume at 25 °C =	0.07331 m^3/kmol	[2]

Experimental Technique : High Pressure Pycnometer

Experiment Data:
Pressure = ~ 20 bar
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
297.40	1011.62
312.95	996.00
327.95	980.50
342.90	964.96
358.25	948.79
368.20	937.56
377.65	927.62
387.15	916.82
397.95	904.44
407.65	892.99
417.75	880.73
427.45	868.80
434.95	859.04

Liquid Density Correlation:

$$\rho / kgm^{-3} = 1424.359 - 2.155273\ T/K + 0.003908560\ (T/K)^2 - 0.4462729 \times 10^{-5}\ (T/K)^3$$

% AAD = 0.009 % % MAD = 0.037 %

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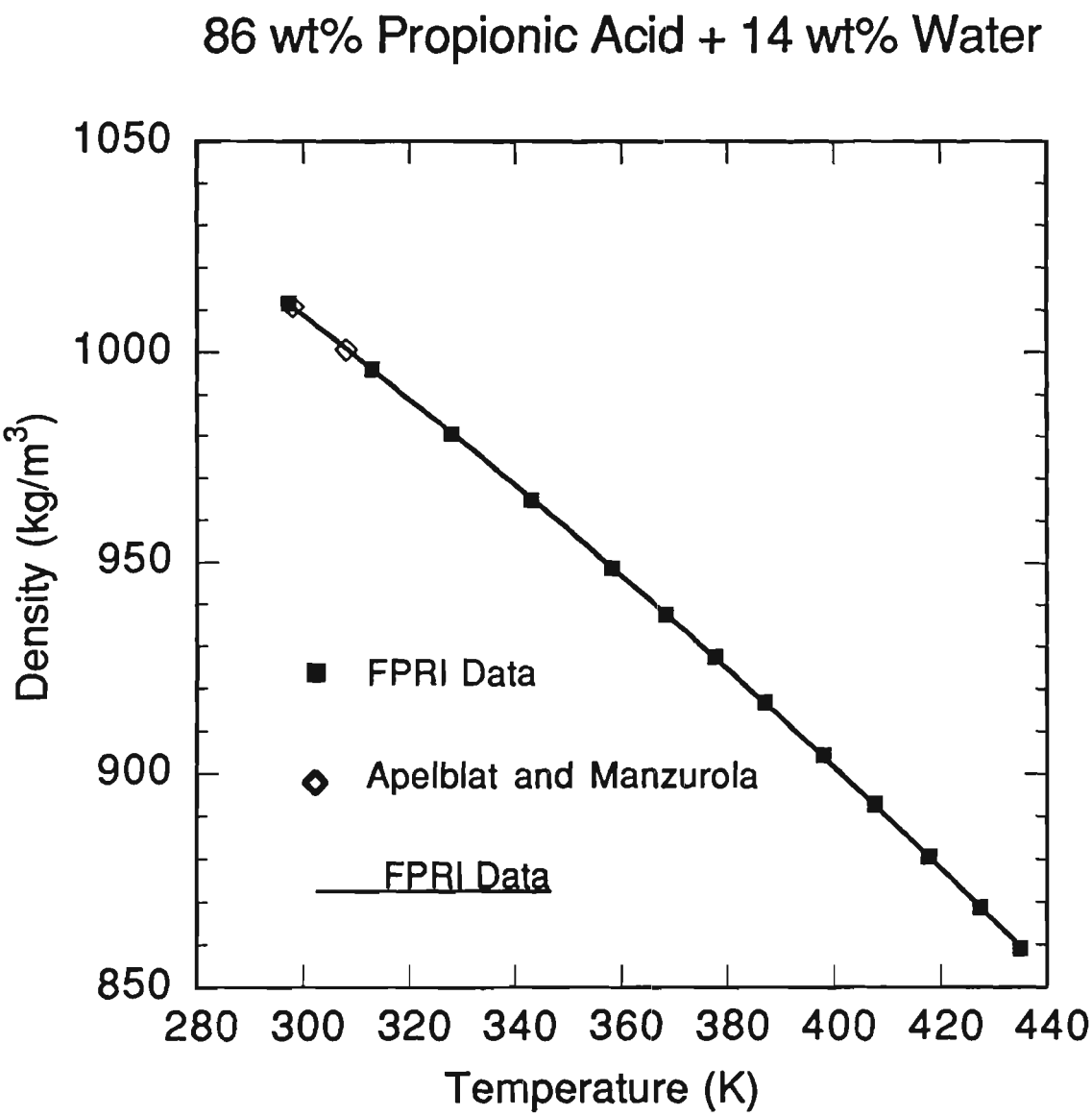
May, 1994

DDS-LD-A74



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2. Estimated from FPRI density correlation.

3. Apelblat, A., and Manzurola, E., Fluid Phase Equilibria, 32, 163 (1987).

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FPRI

May, 1994 DDS-LD-A75

DESIGN DATA STANDARD - LIQUID DENSITY

70 wt% Propionic Acid + 30 wt% Water

$C_2H_5COOH + H_2O$

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =		
Critical Pressure =		
Critical Volume =		
Normal Boiling Point =		
Melting Point =		
Liquid Molar Volume at 25 °C =	0.07256 m^3/kmol	[2]

Experimental Technique : High Pressure Pycnometer

Experiment Data:

Pressure = ~ 20 bar
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
298.30	1019.23
313.00	1006.13
328.00	991.78
342.95	976.78
357.35	961.88
367.30	951.80
377.50	941.45
387.15	930.82
397.25	919.52
406.75	908.55
416.95	896.23
427.55	883.67
437.05	871.87

Liquid Density Correlation:

$$\rho / kgm^{-3} = 1296.886 - 1.170068\ T/K + 0.001562632\ (T/K)^2 - 0.2541215 \times 10^{-5}\ (T/K)^3$$

% AAD = 0.020 % % MAD = 0.048 %

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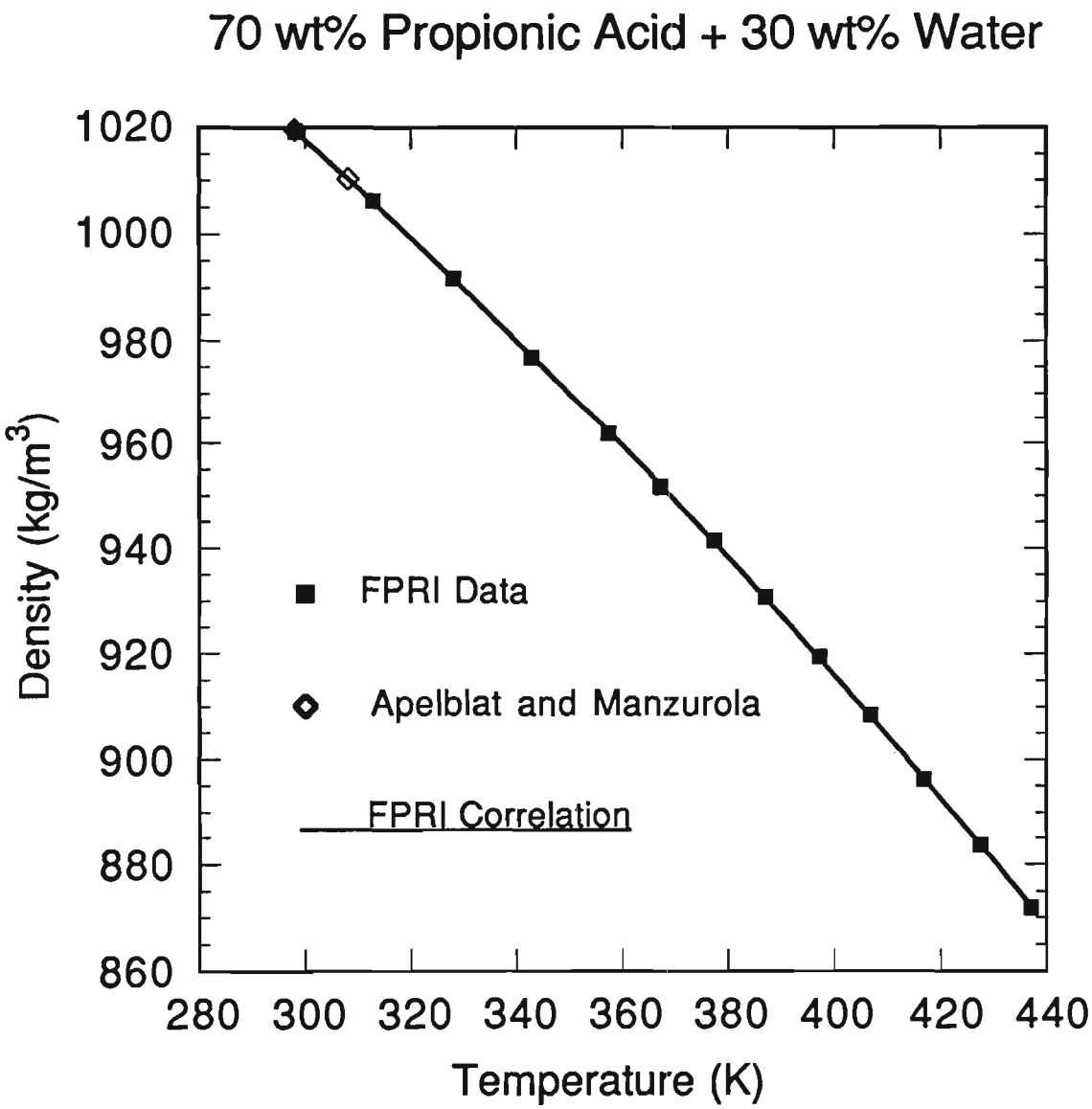
May, 1994 DDS-LD-A75



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2. Estimated from FPRI density correlation.

3. Apelblat, A., and Manzurola, E., Fluid Phase Equilibria, 32, 163 (1987).

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May, 1994 DDS-LD-A76

DESIGN DATA STANDARD - LIQUID DENSITY

58 wt% Propionic Acid + 42 wt% Water

$C_2H_5COOH + H_2O$

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =		
Critical Pressure =		
Critical Volume =		
Normal Boiling Point =		
Melting Point =		
Liquid Molar Volume at 25 °C =	0.07247 m^3/kmol	[2]

Experimental Technique : High Pressure Pycnometer

Experiment Data:
Pressure = ~ 20 bar
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
295.10	1024.94
308.00	1013.79
323.00	1000.37
338.00	986.47
353.25	972.09
367.20	958.80
378.90	946.79
389.35	935.67
401.45	922.38
413.25	908.72
423.35	896.09
433.40	884.43
437.55	878.69

Liquid Density Correlation:

$$\rho / kgm^{-3} = 1401.787 - 2.176606\ T/K + 0.004719354\ (T/K)^2 - 0.5661016 \times 10^{-5}\ (T/K)^3$$

% AAD = 0.016 % % MAD = 0.059 %

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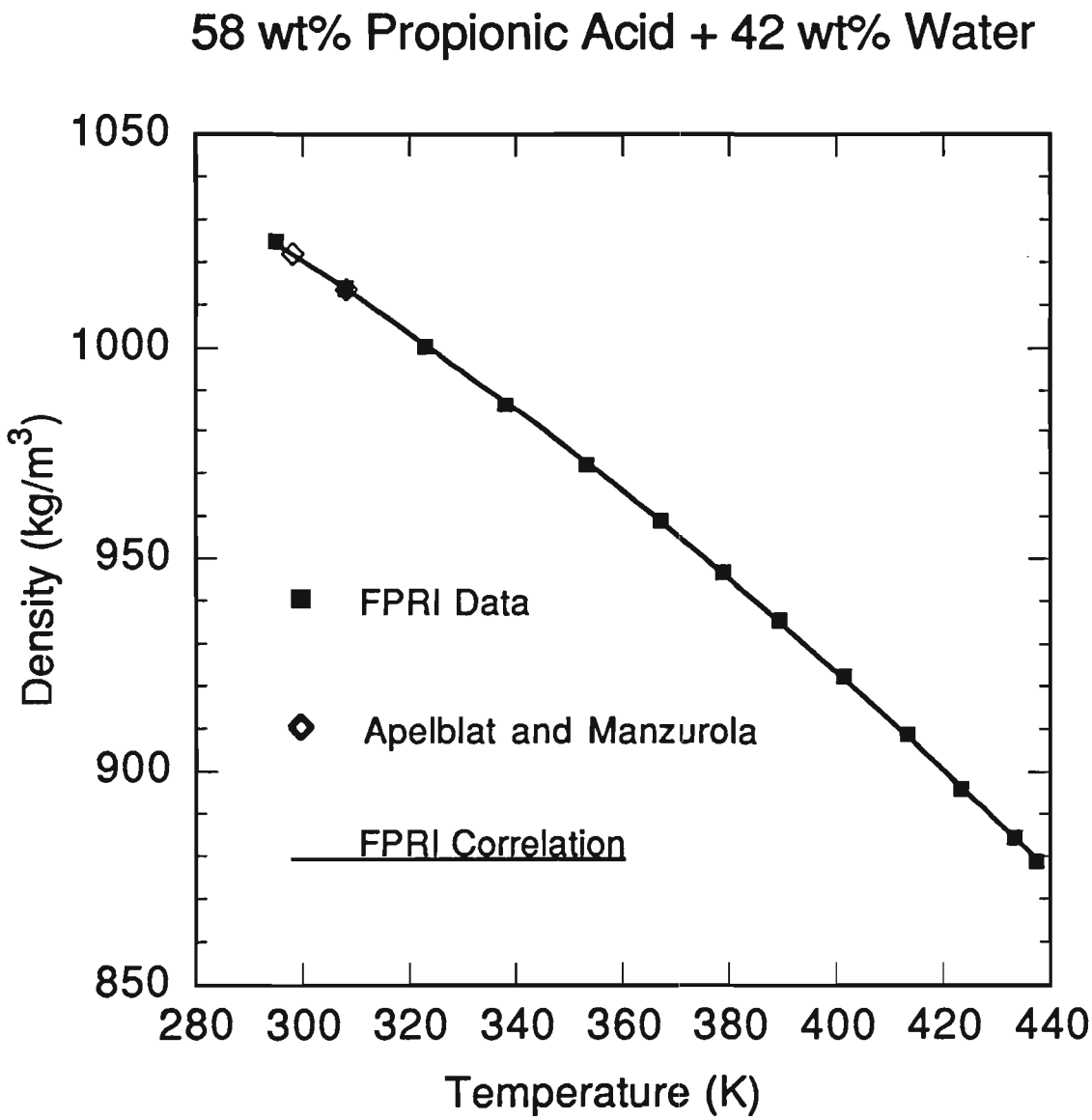
May, 1994

DDS-LD-A76



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2. Estimated from FPRI density correlation.

3. Apelblat, A., and Manzurola, E., Fluid Phase Equilibria, 32, 163 (1987).

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FPRI

May, 1994 DDS-LD-A77

DESIGN DATA STANDARD - LIQUID DENSITY

42 wt% Propionic Acid + 58 wt% Water

$C_2H_5COOH + H_2O$

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =		
Critical Pressure =		
Critical Volume =		
Normal Boiling Point =		
Melting Point =		
Liquid Molar Volume at 25 °C =	0.07273 m^3/kmol	[2]

Experimental Technique : High Pressure Pycnometer

Experiment Data:
Pressure = ~ 20 bar
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
297.75	1021.69
308.00	1013.90
323.00	1002.12
338.00	989.43
353.40	976.24
366.25	965.33
385.15	948.25
394.40	938.47
407.65	924.60
418.55	912.01
428.95	900.03
438.80	888.06
443.25	882.40

Liquid Density Correlation:

$$\rho / kgm^{-3} = 1465.155 - 2.905674\ T/K + 0.007151276\ (T/K)^2 - 0.8037802 \times 10^{-5}\ (T/K)^3$$

% AAD = 0.022 % % MAD = 0.095 %

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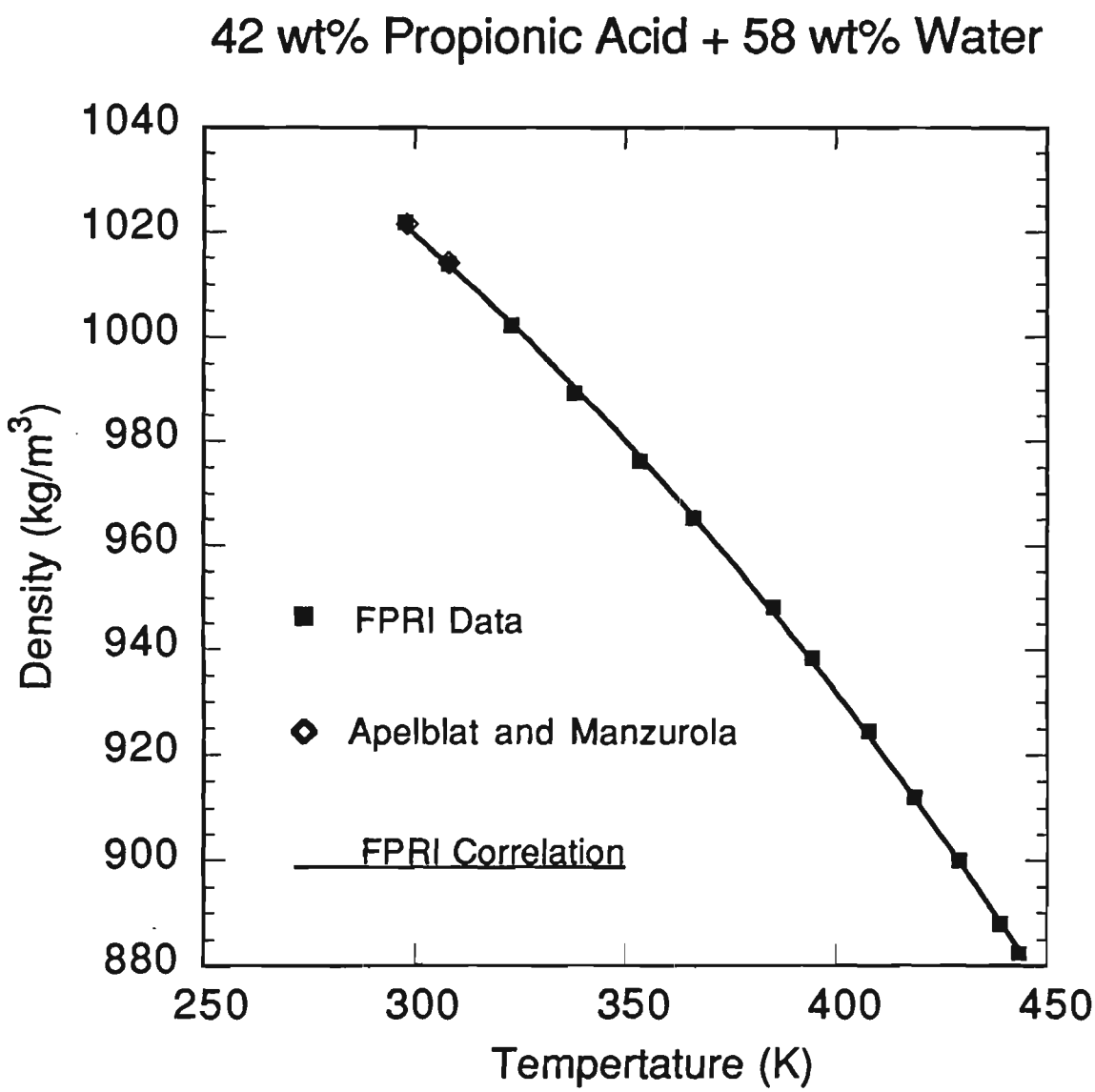
May, 1994

DDS-LD-A77



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2. Estimated from FPRI density correlation.

3. Apelblat, A., and Manzurola, E., Fluid Phase Equilibria, 32, 163 (1987).

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FPRI

May, 1994 DDS-LD-A78

DESIGN DATA STANDARD - LIQUID DENSITY

18 wt% Propionic Acid + 82 wt% Water

$C_2H_5COOH + H_2O$

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =		
Critical Pressure =		
Critical Volume =		
Normal Boiling Point =		
Melting Point =		
Liquid Molar Volume at 25 °C =	0.07349 m^3/kmol	[2]

Experimental Technique : High Pressure Pycnometer

Experiment Data:
Pressure = ~ 20 bar
Accuracy = ± 0.2 %

T (K)	ρ (Kg/m^3)
293.85	1011.34
308.00	1004.64
323.05	995.77
338.00	985.99
353.35	974.89
366.25	965.56
379.65	956.25
389.90	947.06
399.75	937.82
409.45	928.03
419.45	917.95
429.10	907.17
439.45	895.80
448.95	885.02

Liquid Density Correlation:

$$\rho / kgm^{-3} = 1141.239 - 0.7181101\ T/K + 0.002110353\ (T/K)^2 - 0.3973717 \times 10^{-5}\ (T/K)^3$$

% AAD = 0.042 % % MAD = 0.095 %

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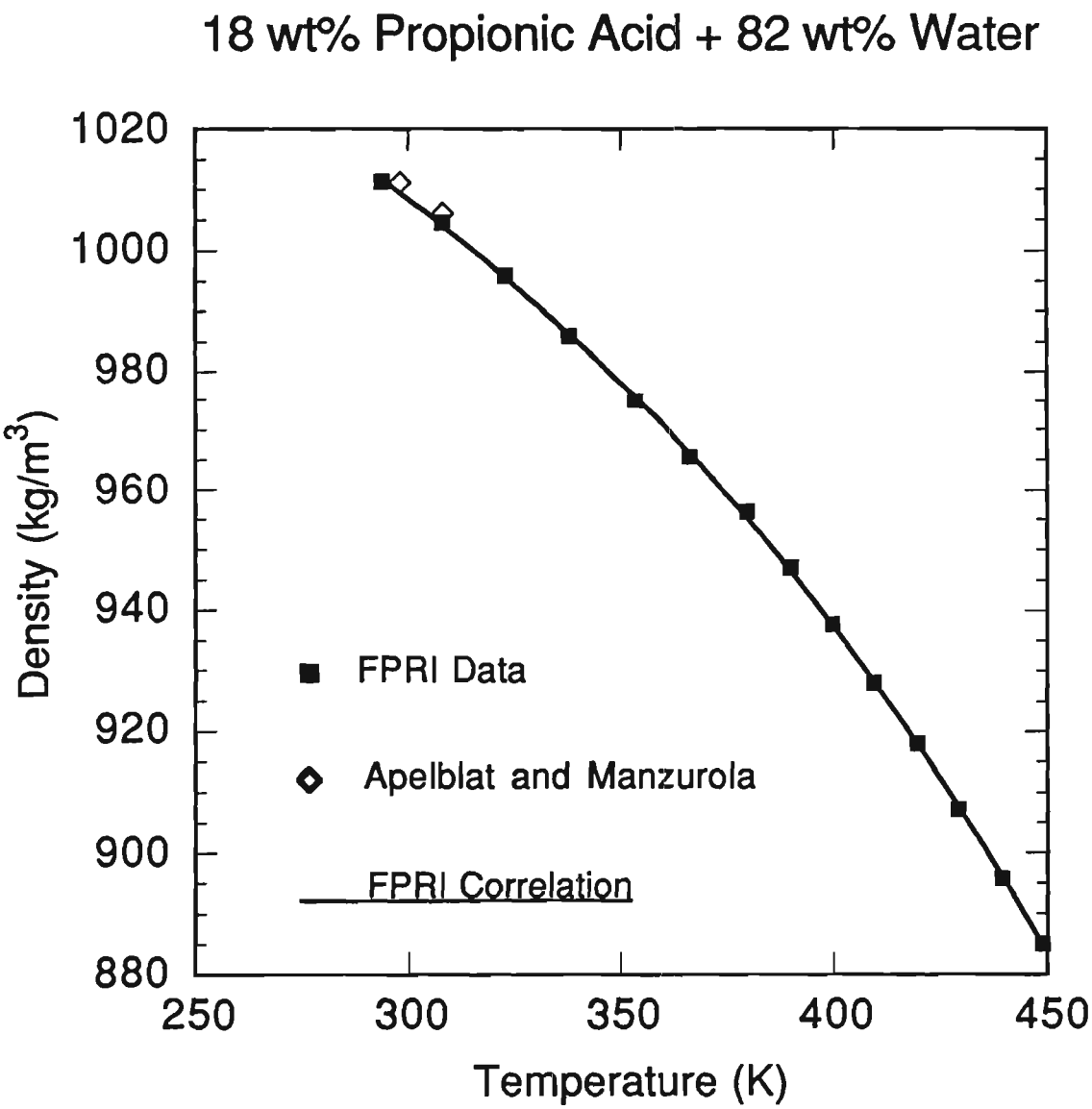
FPRI

May, 1994

DDS-LD-A78



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2. Estimated from FPRI density correlation.

3. Apelblat, A., and Manzurola, E., Fluid Phase Equilibria, 32, 163 (1987).

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FPRI

May, 1994 DDS-LTC-A78

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

2 - Cyanopyridine

$C_6H_4N_2$
CA - No: 100-70-9

Purity =	99 %	
Molecular Weight =	104.11 kg/kmol	[1]
Critical Temperature =	720.0 K	[2]
Critical Pressure =	46.2 bar	[2]
Critical Volume =	0.3755 m^3/kmol	[2]
Normal Boiling Point =	486.7 K	[3]
Melting Point =	300.2 K	[3]
Liquid Molar Volume at 25 °C =	0.09591 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire
Platinum Wire
Reference Fluid: Dimethylphthalate

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
308.85	0.1550
333.55	0.1498
358.10	0.1444
381.70	0.1392
412.45	0.1322
442.70	0.1256
468.70	0.1205

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (W/m K)} = 0.2268414 - 2.411826 \times 10^{-4}\, T/K + 2.950478 \times 10^{-8}\, (T/K)^2$$

% AAD = 0.13 % % MAD = 0.20 %

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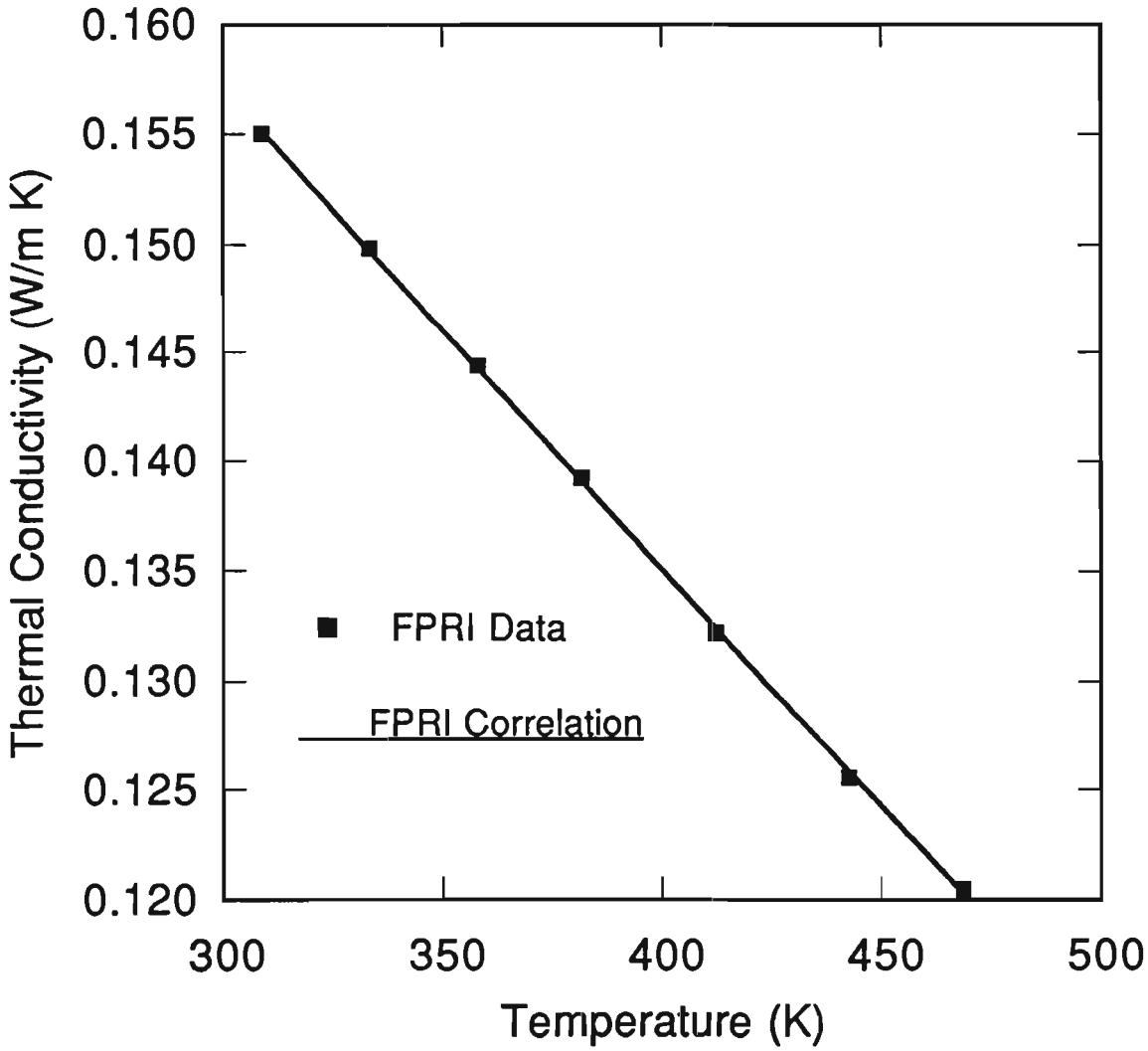
2 - Cyanopyridine



REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1994 DDS-LTC-A79

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

3,5 - Dichloropyridine

$C_5H_3Cl_2N$
CA - No: 2547-47-8

Purity =	98 %	
Molecular Weight =	147.99 kg/kmol	[1]
Critical Temperature =	721.5 K	[2]
Critical Pressure =	47.2 bar	[2]
Critical Volume =	0.3545 m^3/kmol	[2]
Normal Boiling Point =	474.0 K	[2]
Melting Point =	339.2 K	[3]
Liquid Molar Volume at 25 °C =	0.10779 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire
Platinum Wire
Reference Fluid: Dimethylphthalate

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
348.80	0.1121
363.20	0.1093
382.40	0.1053
402.85	0.1008
422.35	0.0970
447.45	0.0911

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (W/m K)} = 0.1633612 - 9.5937 \times 10^{-5}\ T/K - 1.4615 \times 10^{-7}\ (T/K)^2$$

% AAD = 0.10 % % MAD = 0.24 %

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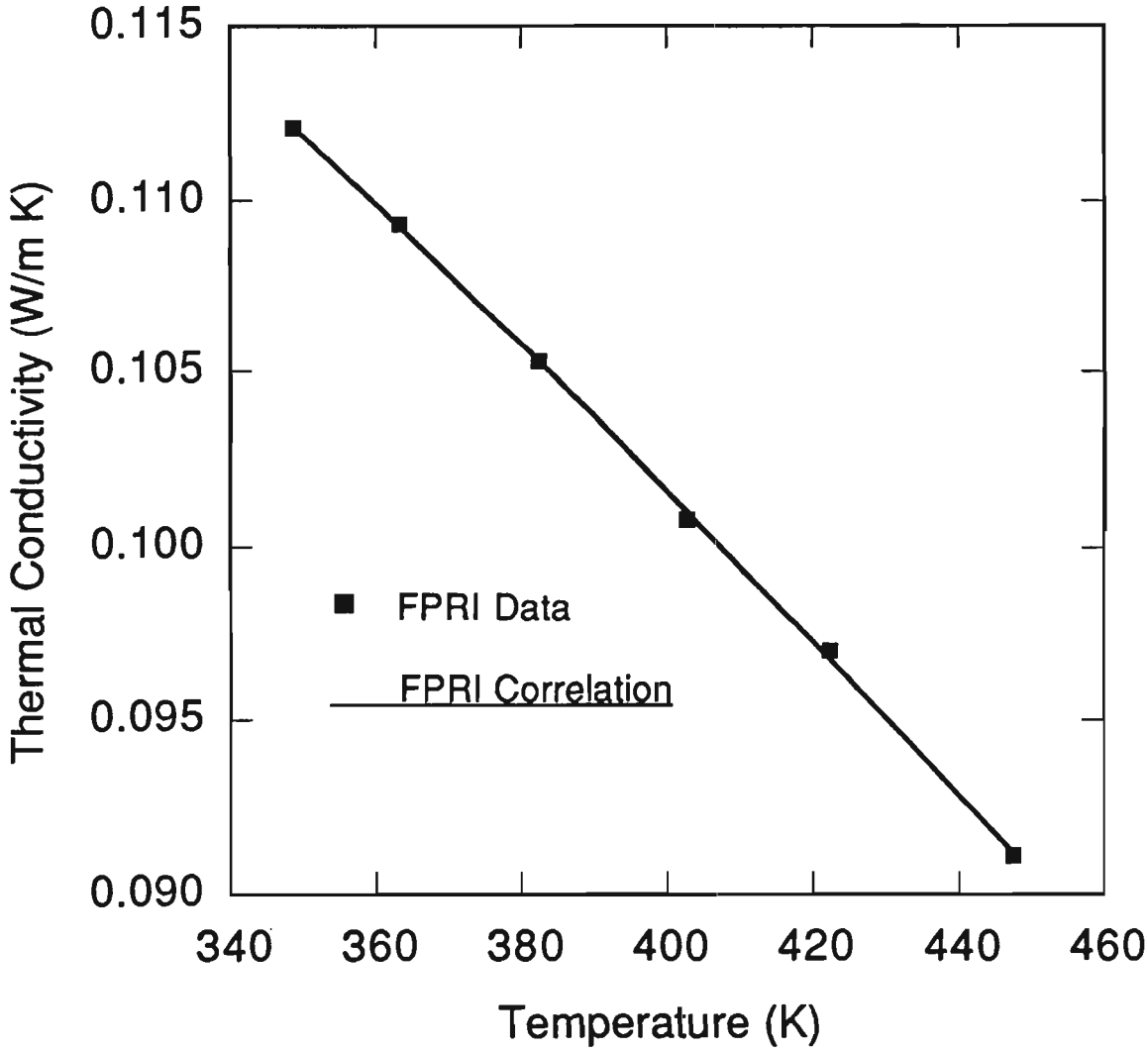
May, 1994 DDS-LTC-A79

3,5 - Dichloropyridine



REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1994 DDS-LTC-A80

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

1,2 - Octanediol

$CH_3(CH_2)_5CH(OH)CH_2OH$
CA - No: 1117-86-8

Purity =	98 +%	
Molecular Weight =	146.23 kg/kmol	[1]
Critical Temperature =	725.6 K	[2]
Critical Pressure =	31.1 bar	[2]
Critical Volume =	0.5155 m^3/kmol	[2]
Normal Boiling Point =	566.4 K	[2]
Melting Point =	310.2 K	[3]
Liquid Molar Volume at 25 °C =	0.15768 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire
Platinum Wire
Reference Fluid: Dimethylphthalate

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
315.65	0.1646
334.00	0.1625
348.10	0.1606
362.80	0.1584
368.95	0.1574
392.35	0.1537
407.40	0.1509

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (W/m K)} = 0.1603792 + 1.398089 \times 10^{-4}\ T/K - 4.001577 \times 10^{-7}\ (T/K)^2$$

% AAD = 0.03 % % MAD = 0.06 %

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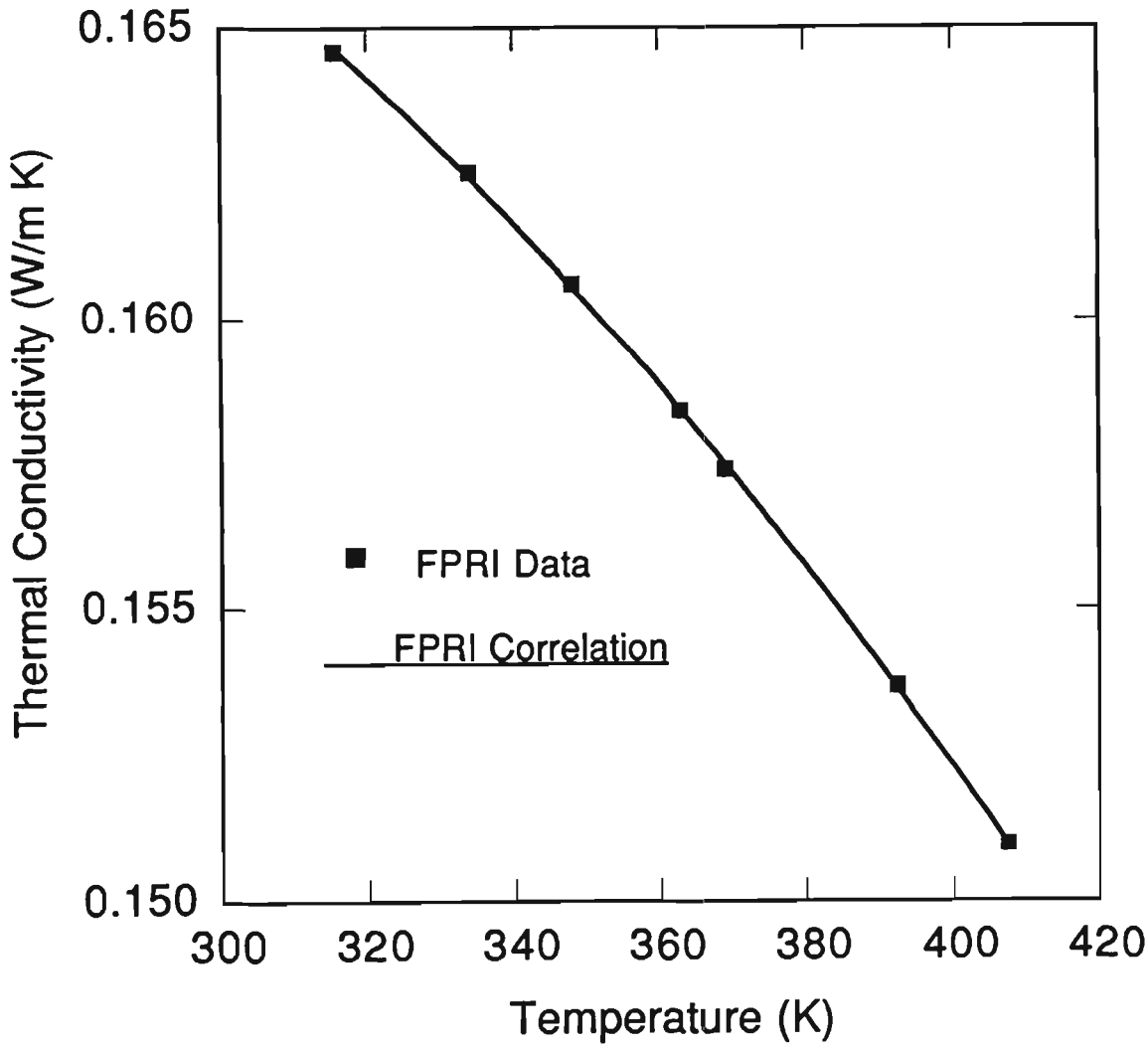
1,2 - Octanediol



REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1994 DDS-LTC-A81

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

1,8 - Octanediol

$HO(CH_2)_8OH$
CA - No: 629-41-4

Purity =	98 %	
Molecular Weight =	146.23 kg/kmol	[1]
Critical Temperature =	723.6 K	[2]
Critical Pressure =	30.8 bar	[2]
Critical Volume =	0.5215 m^3/kmol	[2]
Normal Boiling Point =	566.8 K	[2]
Melting Point =	333.2 K	[3]
Liquid Molar Volume at 25 °C =	0.15544 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire
Platinum Wire
Reference Fluid: Dimethylphthalate

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
338.30	0.1929
353.05	0.1916
367.25	0.1898
381.85	0.1877
396.95	0.1851
411.85	0.1822
442.40	0.1750
472.55	0.1666

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (W/m K)} = 0.1271945 + 4.744756 \times 10^{-4}\ T/K - 8.278199 \times 10^{-7}\ (T/K)^2$$

% AAD = 0.02 % % MAD = 0.05 %

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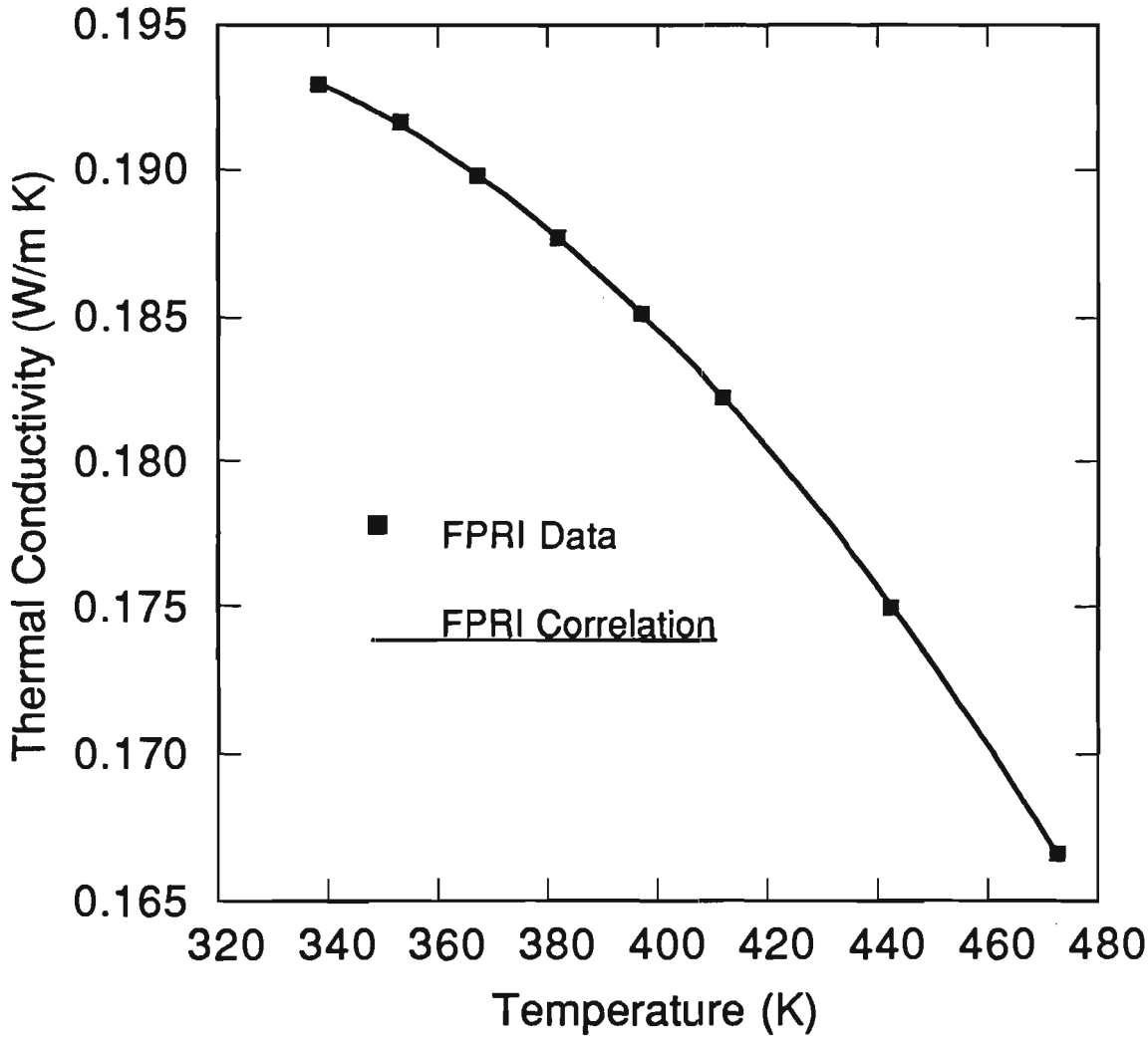
1,8 - Octanediol



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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1994 DDS-LTC-A82

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

N,N - Diethyl Ethylene Diamine

$(C_2H_5)_2NCH_2CH_2NH_2$
CA - No: 100-36-7

Purity =	99 %	
Molecular Weight =	116.21 kg/kmol	[1]
Critical Temperature =	600.7 K	[2]
Critical Pressure =	31.8 bar	[2]
Critical Volume =	0.3895 m^3/kmol	[2]
Normal Boiling Point =	419.2 K	[3]
Melting Point =	254.6 K	[2]
Liquid Molar Volume at 25 °C =	0.14274 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire
Platinum Wire
Reference Fluid: Dimethylphthalate

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
294.90	0.1393
323.80	0.1324
342.90	0.1275
363.40	0.1223
366.70	0.1216
406.15	0.1122
431.85	0.1064

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (W/m K)} = 0.2227688 - 3.104592 \times 10^{-4}\, T/K + 9.454902 \times 10^{-8}\, (T/K)^2$$

% AAD = 0.09 % % MAD = 0.18 %

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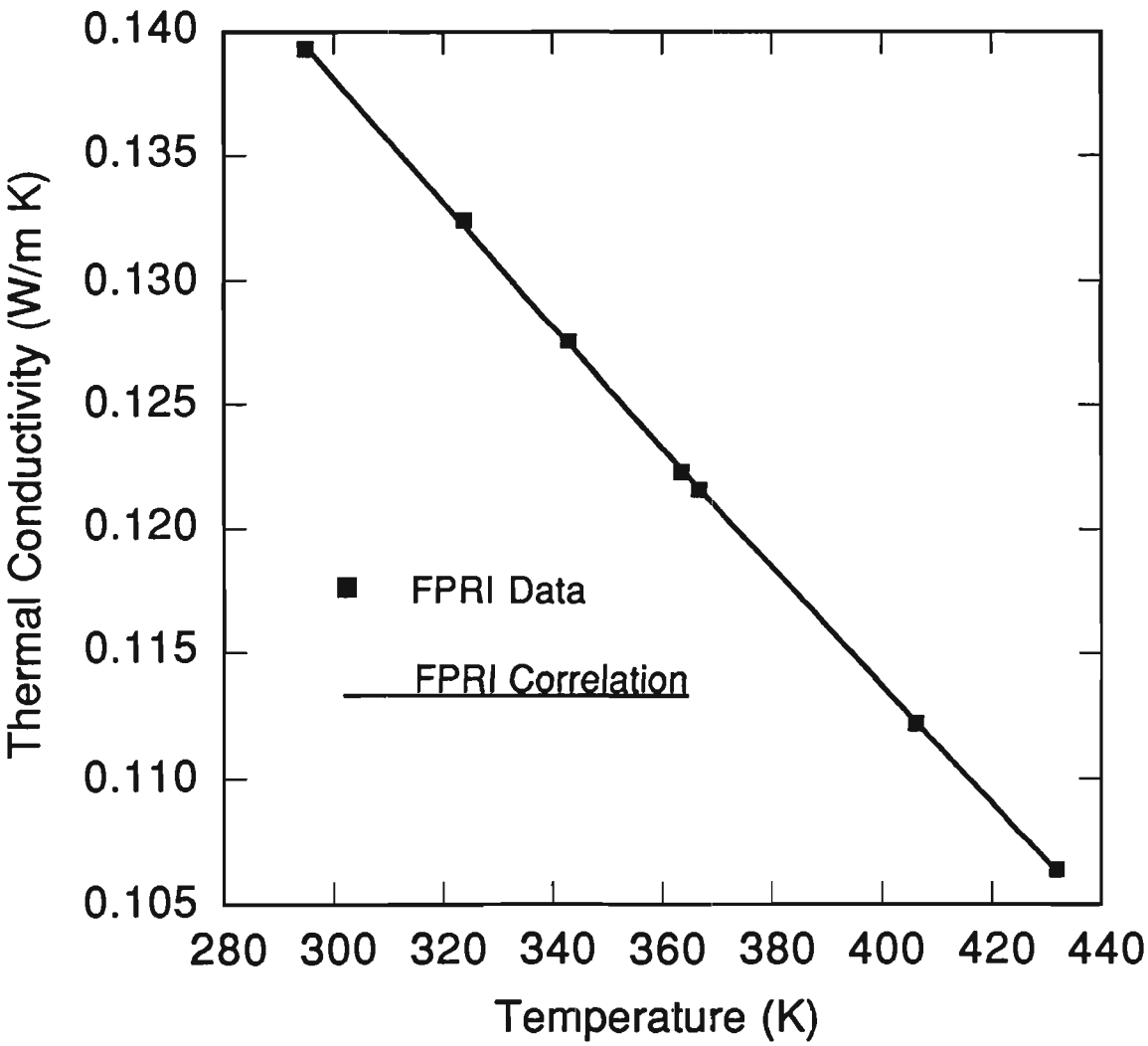
May, 1994 DDS-LTC-A82

N,N - Diethyl Ethylene Diamine



REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1994 DDS-LTC-A83

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

N,N - Disiopropyl Ethylamine

$[(CH_3)_2CH]_2 N C_2H_5$
CA - No: 7087-68-5

Purity =	99 %	
Molecular Weight =	129.25 kg/kmol	[1]
Critical Temperature =	572.6 K	[2]
Critical Pressure =	25.7 bar	[2]
Critical Volume =	0.4895 m^3/kmol	[2]
Normal Boiling Point =	400.2 K	[3]
Melting Point =	181.9 K	[2]
Liquid Molar Volume at 25 °C =	0.17186 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire
Platinum Wire
Reference Fluid: Dimethylphthalate

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
295.20	0.1079
343.55	0.0970
362.65	0.0925
387.70	0.0874
407.10	0.0836
431.95	0.0791

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (W/m K)} = 0.198166 - 3.69844 \times 10^{-4}\ T/K + 2.176522 \times 10^{-7}\ (T/K)^2$$

% AAD = 0.10 % % MAD = 0.21 %

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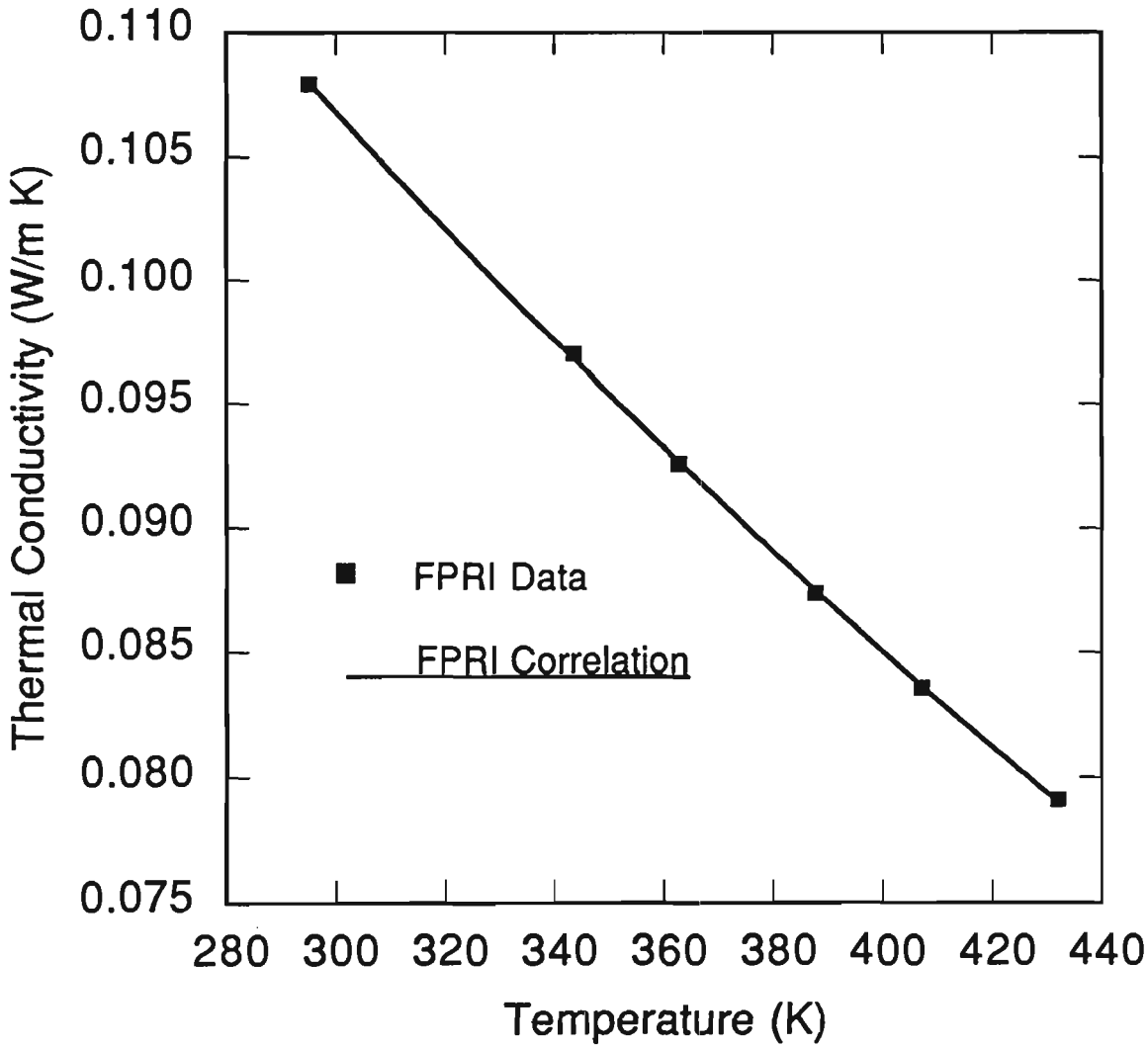
May, 1994 DDS-LTC-A83

N,N - Diisopropyl Ethylamine



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1994 DDS-LTC-A84

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

N,N,N',N' - Tetramethyl Ethylene Diamine

$(CH_3)_2 N CH_2CH_2 N (CH_3)_2$
CA - No: 110-18-9

Purity =	99 %	
Molecular Weight =	116.21 kg/kmol	[1]
Critical Temperature =	570.4 K	[2]
Critical Pressure =	30.9 bar	[2]
Critical Volume =	0.4075 m^3/kmol	[2]
Normal Boiling Point =	394.2 K	[3]
Melting Point =	218.2 K	[3]
Liquid Molar Volume at 25 °C =	0.15042 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire
Platinum Wire
Reference Fluid: Dimethylphthalate

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
295.80	0.1144
323.70	0.1081
343.40	0.1034
363.05	0.0988
382.90	0.0946
407.20	0.0897

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (W/m K)} = 0.2014327 - 3.44872 \times 10^{-4}\, T/K + 1.725505 \times 10^{-7}\, (T/K)^2$$

% AAD = 0.12 % % MAD = 0.21 %

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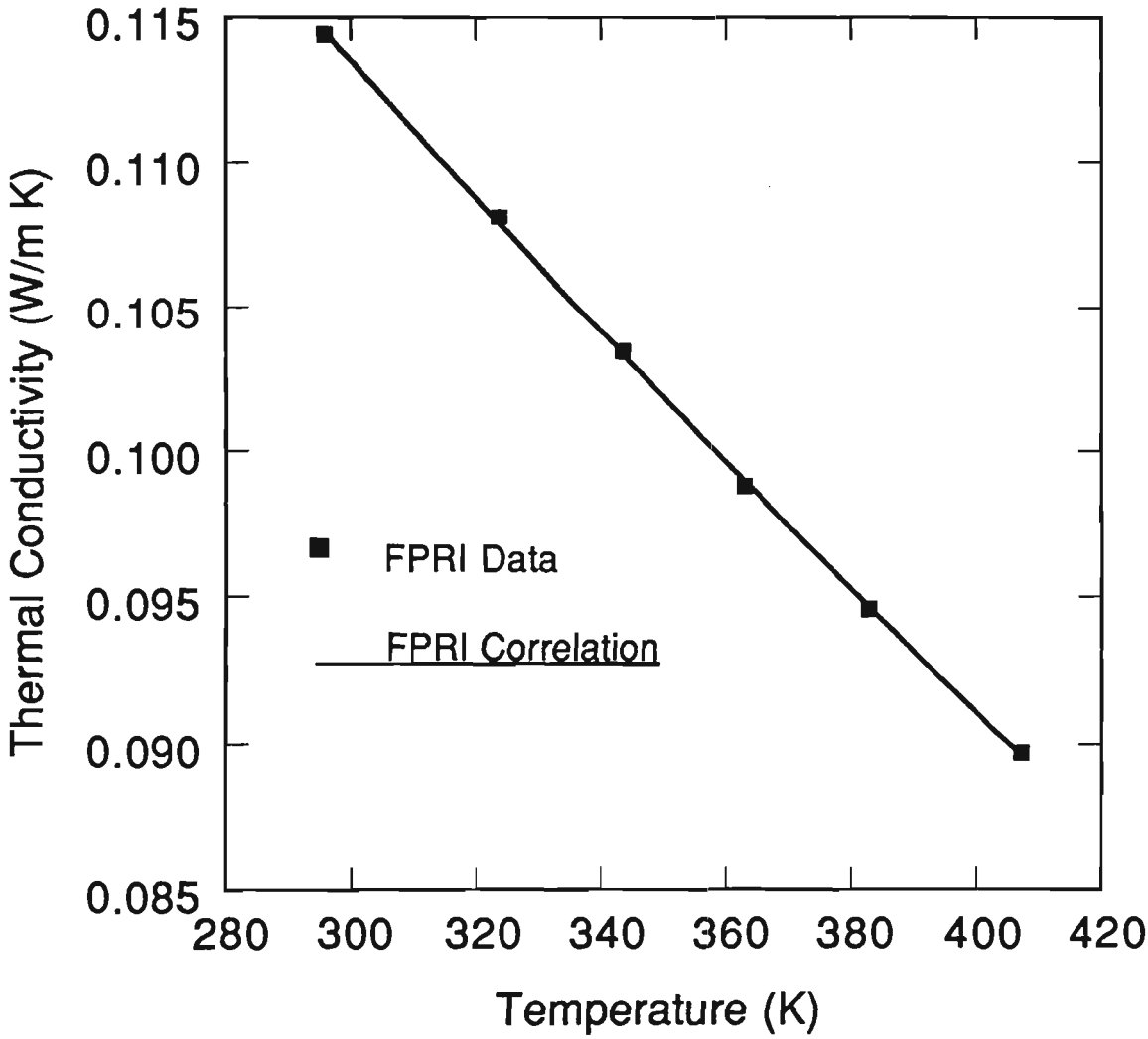
May, 1994

DDS-LTC-A84

N,N,N',N' - Tetramethyl Ethylene Diamine



REFERENCES

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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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FPRI

May, 1994 DDS-LTC-A85

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Propionic Acid

C_2H_5COOH
CA - No: 79-09-4

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =	601.3 K	[3]
Critical Pressure =	53.7 bar	[2]
Critical Volume =	0.233 m^3/kmol	[3]
Normal Boiling Point =	413.98 K	[2]
Melting Point =	252.45 K	[2]
Liquid Molar Volume at 25 °C =	0.074883 m^3/kmol	[2]

Experimental Technique : Relative Transient Hot-Wire
Pyrex Capillary filled with Mercury
Reference Fluid: Water

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
294.70	0.1434
323.10	0.1387
343.30	0.1350
362.20	0.1327
387.35	0.1291

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (W/m K)} = 0.2223874 - 3.543434 \times 10^{-4}\, T/K + 2.932437 \times 10^{-7}\, (T/K)^2$$

% AAD = 0.11 % % MAD = 0.23 %

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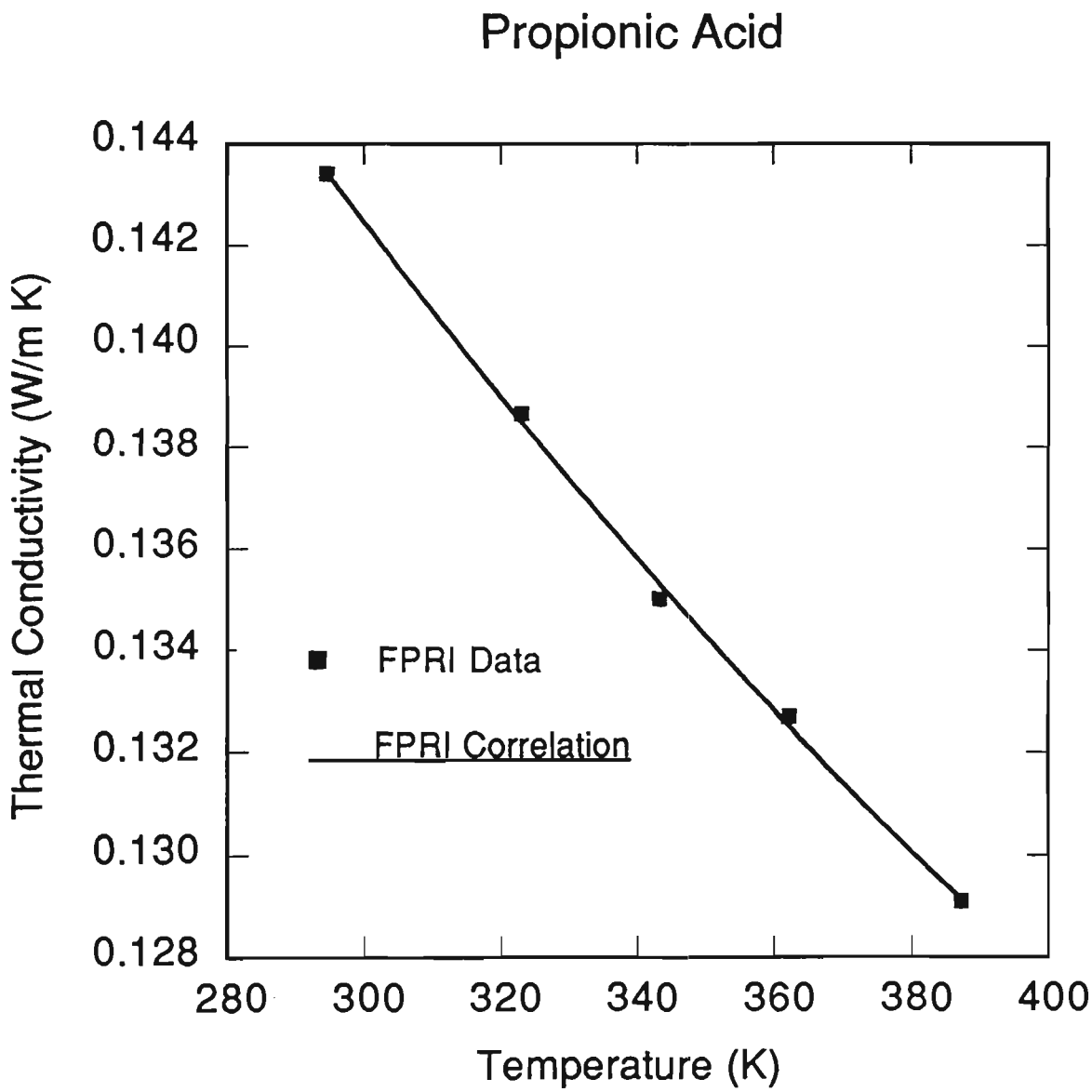
May, 1994 DDS-LTC-A85



REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Daubert, T.E.; Danner, R.P., "Data Compilation Tables of Properties of Pure Compounds", Design Institute for Physical Property Data, American Institute of Chemical Engineers, New York, N. Y. (1985).

3. Gude, M.T., MS Thesis, Georgia Institute of Technology (1989).

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FPRI

May, 1994 DDS-LTC-A86

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

75 wt% Propionic Acid + 25 wt% Water

$C_2H_5COOH + H_2O$

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =		
Critical Pressure =		
Critical Volume =		
Normal Boiling Point =		
Melting Point =		
Liquid Molar Volume at 25 °C =	0.07271 m^3/kmol	[2]

Experimental Technique : Relative Transient Hot-Wire
Pyrex Capillary filled with Mercury
Reference Fluid: Water

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
293.95	0.2214
322.95	0.2225
342.20	0.2216
362.90	0.2201
365.30	0.2216
405.20	0.2177

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (W/m K)} = 0.1563186 + 4.083672 \times 10^{-4}\ T/K - 6.342357 \times 10^{-7}\ (T/K)^2$$

% AAD = 0.19 % % MAD = 0.40 %

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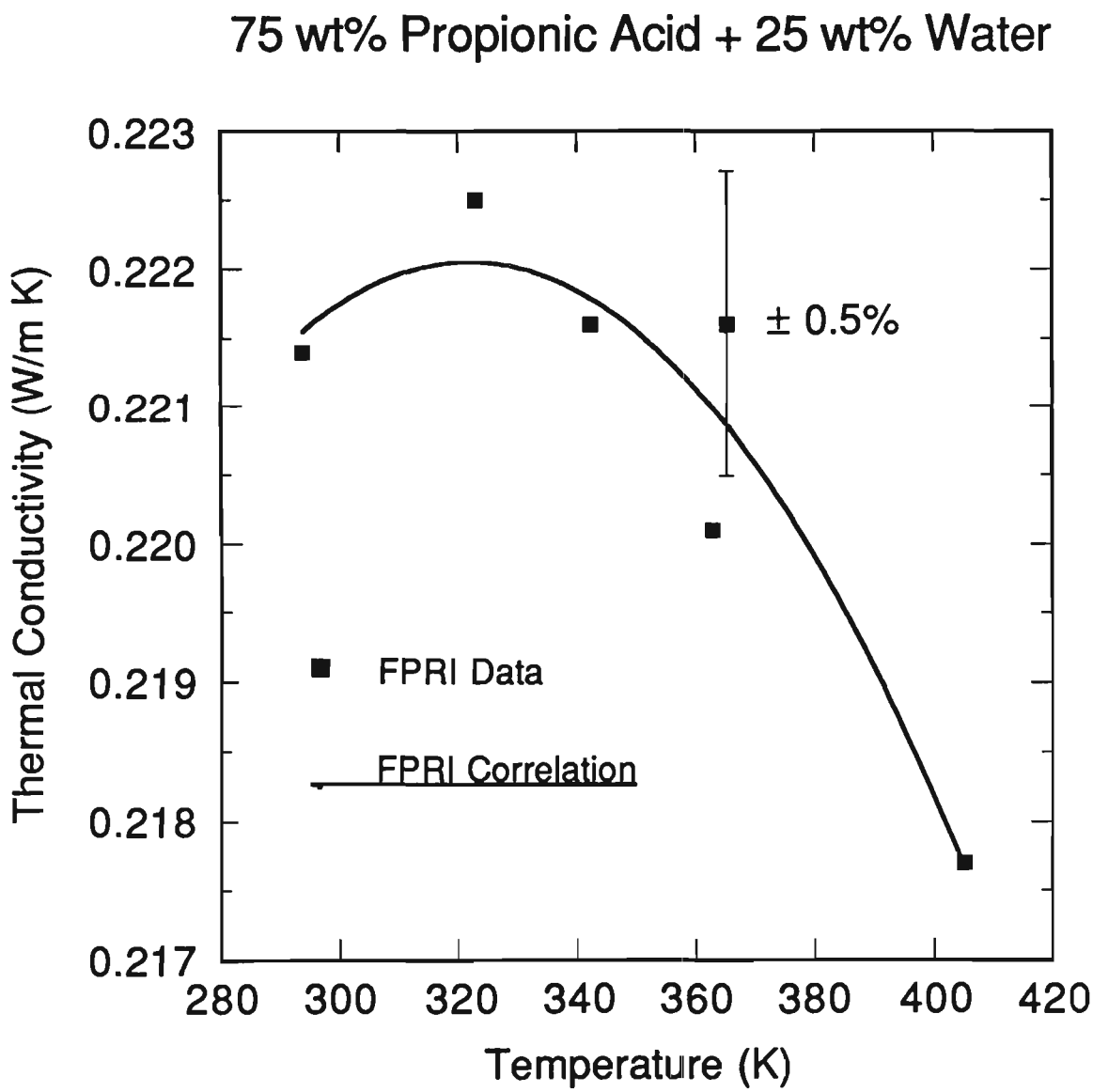
May, 1994 DDS-LTC-A86



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REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from FPRI density correlation.

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FPRI

May, 1994 DDS-LTC-A87

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

50 wt% Propionic Acid + 50 wt% Water

$C_2H_5COOH + H_2O$

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =		
Critical Pressure =		
Critical Volume =		
Normal Boiling Point =		
Melting Point =		
Liquid Molar Volume at 25 °C =	0.07256 m^3/kmol	[2]

Experimental Technique : Relative Transient Hot-Wire
Pyrex Capillary filled with Mercury
Reference Fluid: Water

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
294.75	0.3285
322.55	0.3374
342.50	0.3424
362.25	0.3426
382.05	0.3496
405.85	0.3511

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (W/m K)} = 0.1580203 + 8.555632 \times 10^{-4}\ T/K - 9.354663 \times 10^{-7}\ (T/K)^2$$

% AAD = 0.30 % % MAD = 0.76 %

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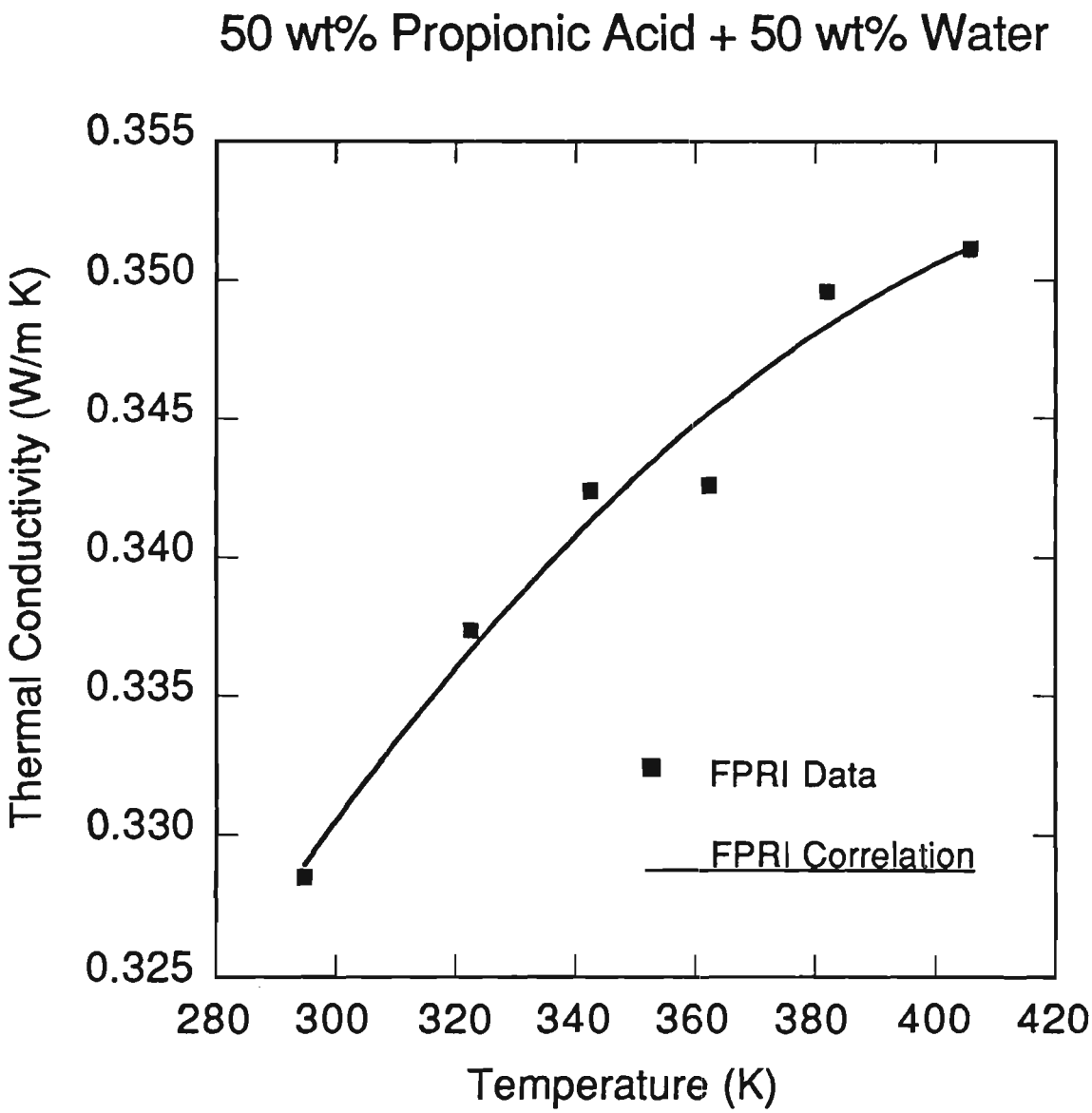
May, 1994 DDS-LTC-A87



REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from FPRI density correlation.

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FPRI

May, 1994 DDS-LTC-A88

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

25 wt% Propionic Acid + 75 wt% Water

$C_2H_5COOH + H_2O$

Purity =	99 +%	
Molecular Weight =	74.079 kg/kmol	[1]
Critical Temperature =		
Critical Pressure =		
Critical Volume =		
Normal Boiling Point =		
Melting Point =		
Liquid Molar Volume at 25 °C =	0.07324 m^3/kmol	[2]

Experimental Technique : Relative Transient Hot-Wire
Pyrex Capillary filled with Mercury
Reference Fluid: Water

Experiment Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
294.25	0.4557
294.25	0.4614
322.75	0.4862
342.35	0.4940
362.10	0.4962
362.10	0.5032

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ (W/m K)} = -0.594786 + 6.001094 \times 10^{-3}\, T/K - 8.227482 \times 10^{-6}\, (T/K)^2$$

% AAD = 0.53 % % MAD = 0.74 %

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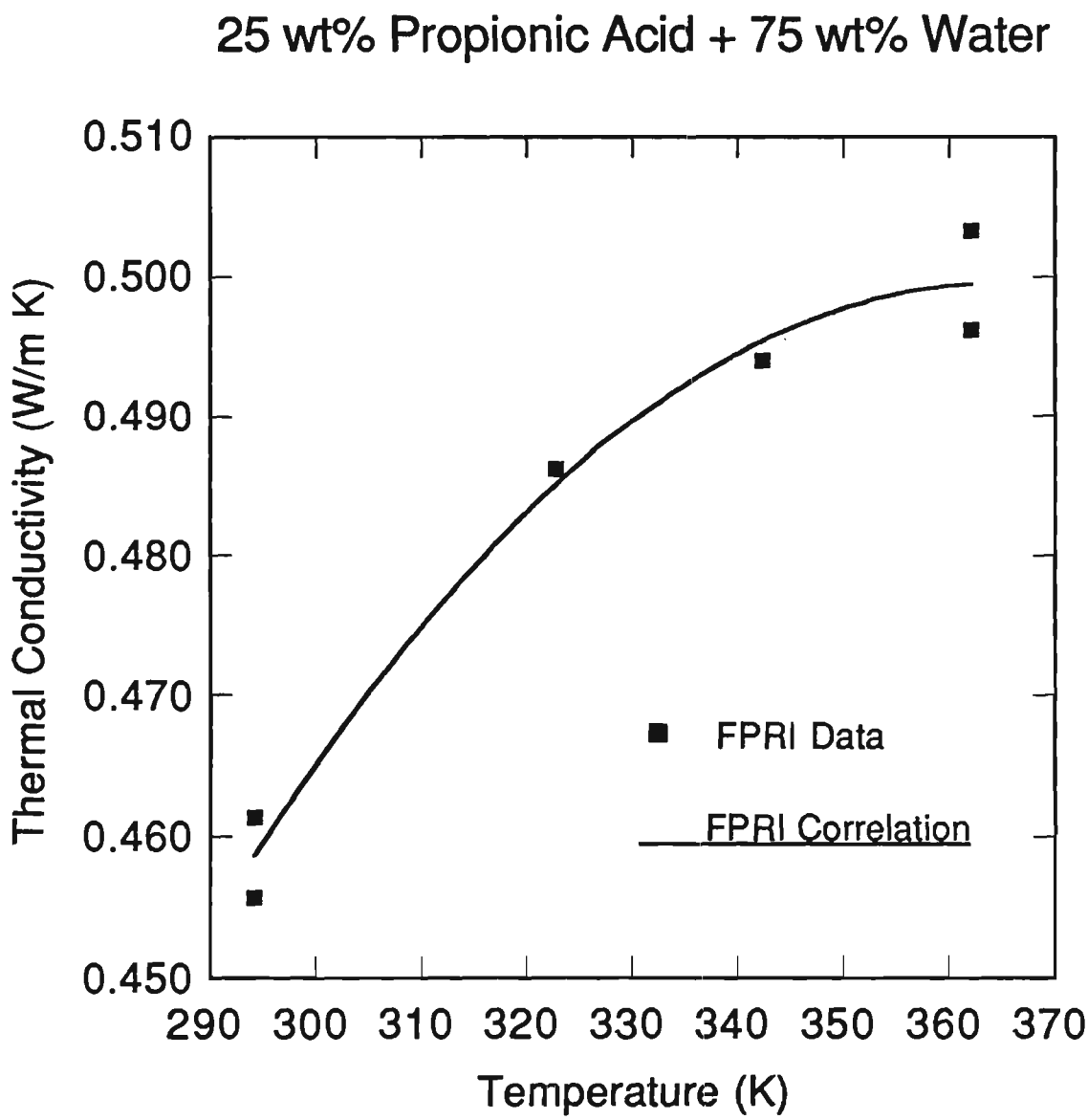
May, 1994 DDS-LTC-A88



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REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from FPRI density correlation.

FLUID PROPERTIES RESEARCH

ANNUAL TECHNICAL REPORT

JULY 1, 1990

TO

JUNE 30, 1991

PROJECT E-19-668

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF CHEMICAL ENGINEERING
ATLANTA, GA 30332-0100

INDEX TO DESIGN DATA SHEETS

SERIES A 1990-1991 RESULTS

Viscosity

A33	1,2 - Butanediol
A34	1,3 - Butanediol
A35	1,4 - Butanediol
A36	2,3 - Butanediol
A37	Dimethyl Disulfide
A38	Diethyl Disulfide
A39	2 - Methoxyethanol
A40	2 - (2-Methoxyethoxy) ethanol
A41	2 - [2- (2-Methoxyethoxy) ethoxy] ethanol

Density

A33	1,2 - Butanediol
A34	1,3 - Butanediol
A35	1,4 - Butanediol
A36	2,3 - Butanediol
A37	Dimethyl Disulfide
A38	Diethyl Disulfide
A39	2 - Methoxyethanol
A40	2 - (2-Methoxyethoxy) ethanol
A41	2 - [2- (2-Methoxyethoxy) ethoxy] ethanol

Thermal Conductivity

A47	1,2 - Butanediol
A48	1,3 - Butanediol
A49	1,4 - Butanediol
A50	2,3 - Butanediol
A51	Dimethyl Disulfide
A52	Diethyl Disulfide
A53	2 - Methoxyethanol
A54	2 - (2-Methoxyethoxy) ethanol
A55	2 - [2- (2-Methoxyethoxy) ethoxy] ethanol

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FPRI

May, 1991 DDS-LD-A33

DESIGN DATA STANDARD - LIQUID DENSITY

1,2- Butanediol

$C_2H_5CH(OH)CH_2OH$
CA-No: 26171-83-5

Purity =	98 %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	621.8 K	[2]
Critical Pressure =	50.0 bar	[2]
Critical Volume =	0.292 m^3/kmol	[3]
Melting Point =	---	
Normal Boiling Point =	464.7 K	[4]
Liquid Molar Volume at 25 °C =	0.09016 m^3/kmol	[5]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (°C)	ρ (kg/m³)
28.6	997.1
45.6	984.8
64.5	967.0
84.5	954.7
97.7	943.7
120.7	923.9
140.1	907.4
161.4	886.5
181.5	863.4

Liquid Density Correlation:

$$\rho\ (kg/m^3) = 1020.31 - 0.829293\ T(°C) + 1.26446 \times 10^{-3}\ T(°C)^2 - 7.97047 \times 10^{-6}\ T(°C)^3$$

% AAD = 0.04 %
% MAD = 0.08 %

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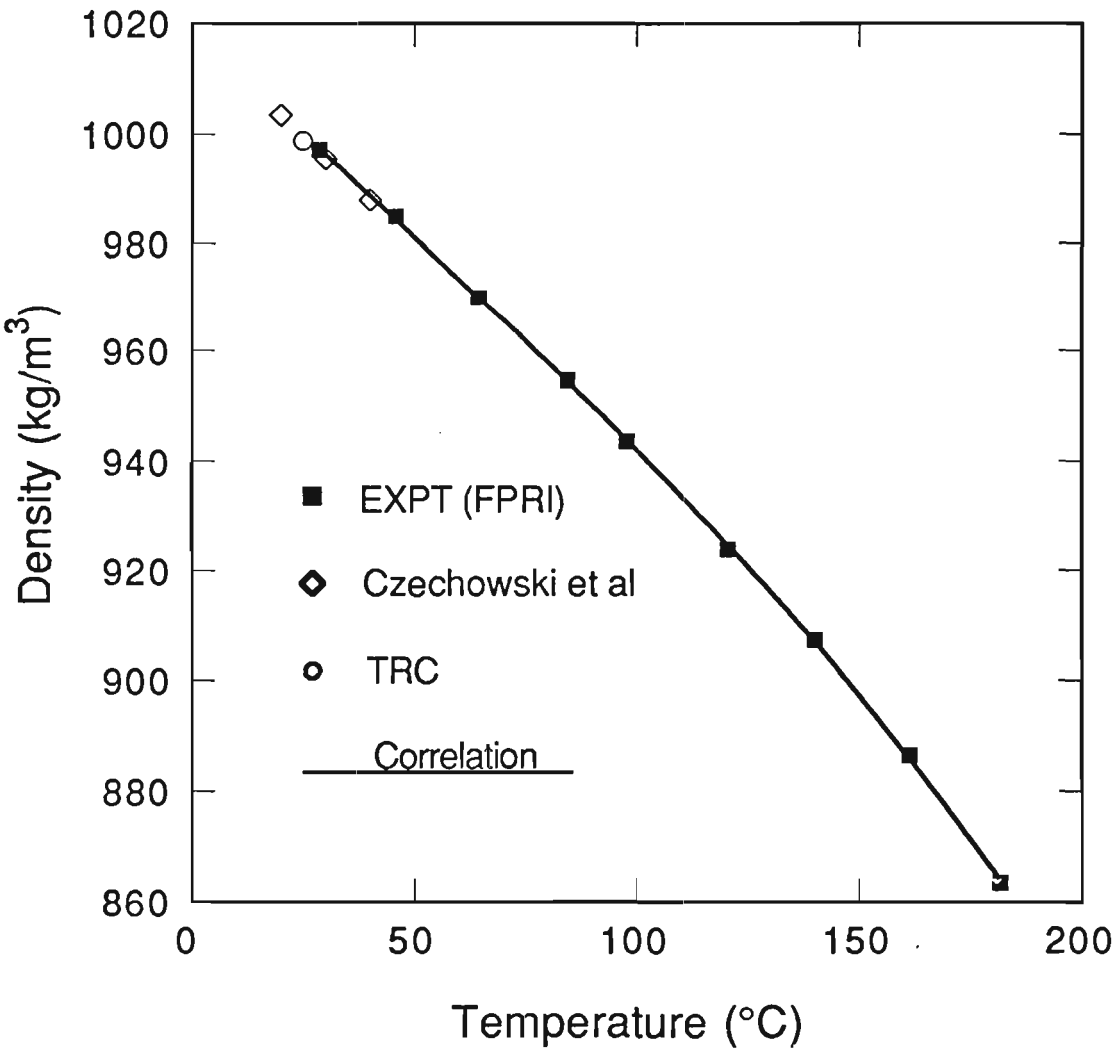
Density of 1,2-Butanediol



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3. Estimated from the Fedors method: Fedors, R.F., "A Method to Estimate Critical Volumes", AIChE J., 25, 202 (1979).

4. Weast R. C.; Astle, M. J., "CRC Handbook of Data on Organic Compounds", CRC Press, Boca Raton, Fla. (1985).

5. Estimated from the density correlation reported in this data sheet.

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May, 1991 DDS-LD-A34

DESIGN DATA STANDARD - LIQUID DENSITY

1,3- Butanediol

$CH_3CH(OH)CH_2CH_2OH$
CA-No: 107-88-0

Purity =	99+ %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	643.00 K	[2]
Critical Pressure =	50.0 bar	[2]
Critical Volume =	0.292 m^3/kmol	[2]
Melting Point =	196.15 K	[2]
Normal Boiling Point =	480.15 K	[2]
Liquid Molar Volume at 25 °C =	0.089913 m^3/kmol	[2]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (°C)	ρ (kg/m³)
29.2	1000.6
49.9	986.1
69.7	970.8
89.8	957.2
110.0	941.5
127.7	927.0
147.1	910.4
166.4	893.1
185.7	874.8

Liquid Density Correlation:

$$\rho\ (kg/m^3) = 1021.36 - 0.718584\ T(°C) + 3.38579 \times 10^{-4}\ T(°C)^2 - 3.89231 \times 10^{-6}\ T(°C)^3$$

% AAD = 0.03 %
% MAD = 0.08 %

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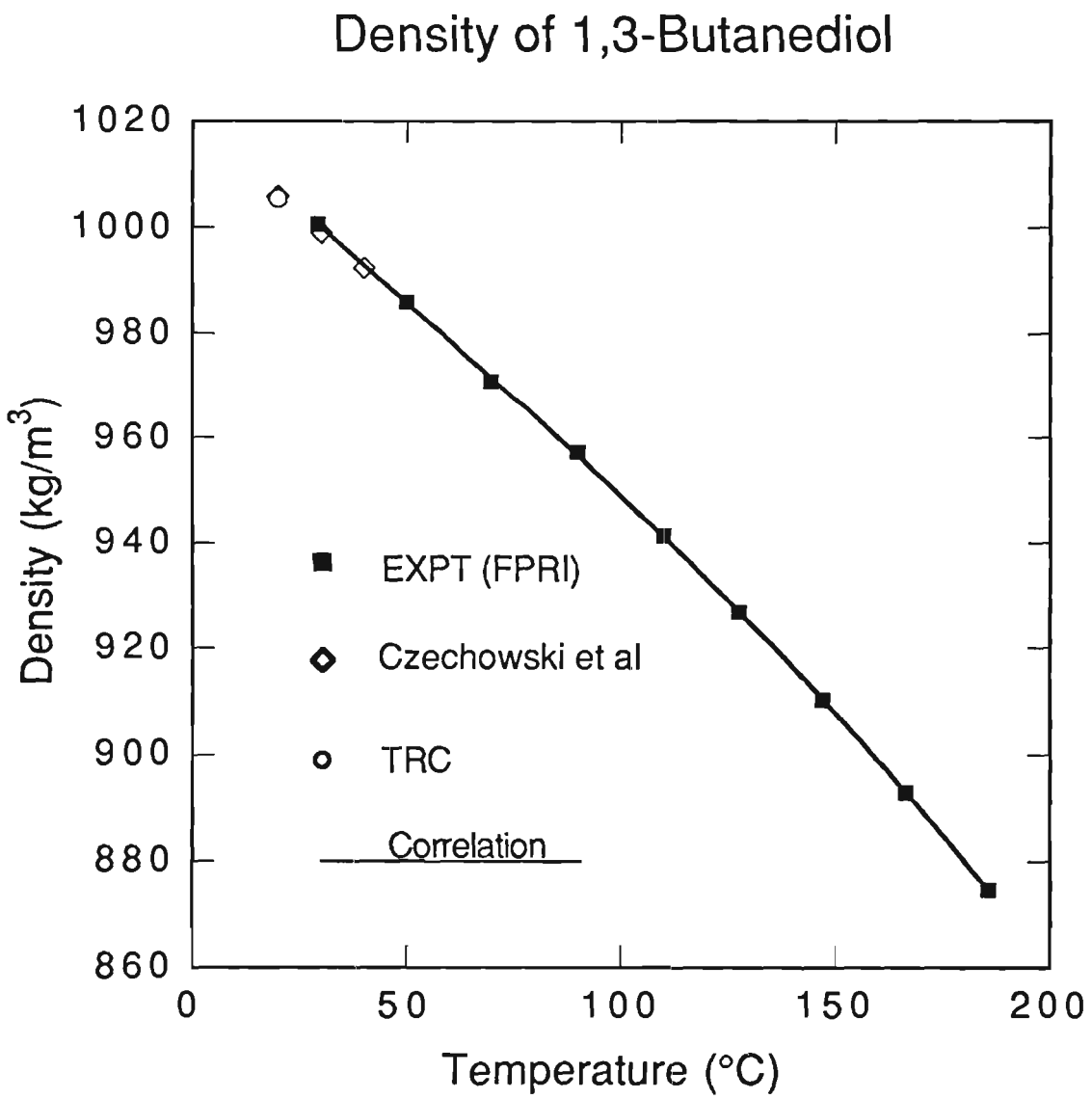

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DESIGN DATA STANDARD - LIQUID DENSITY

1,4- Butanediol

$HO(CH_2)_4OH$
CA-No: 110-63-4

Purity =	99+ %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	667.0 K	[2]
Critical Pressure =	48.8 bar	[2]
Critical Volume =	0.297 m^3/kmol	[2]
Melting Point =	293.05 K	[2]
Normal Boiling Point =	501.15 K	[2]
Liquid Molar Volume at 25 °C =	0.088974 m^3/kmol	[2]
Dipole Moment =	1.311×10^{-29} C-m	[3]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (°C)	ρ (kg/m³)
30.1	1011.4
48.9	999.0
69.8	986.4
90.4	973.3
111.6	959.3
129.0	946.5
150.1	930.5
169.1	915.6
187.1	899.0

Liquid Density Correlation:

$$\rho\ (kg/m^3) = 1030.84 - 0.676134\ T(°C) + 9.5705 \times 10^{-4}\ T(°C)^2 - 5.91718 \times 10^{-6}\ T(°C)^3$$

% AAD = 0.02%
% MAD = 0.05 %

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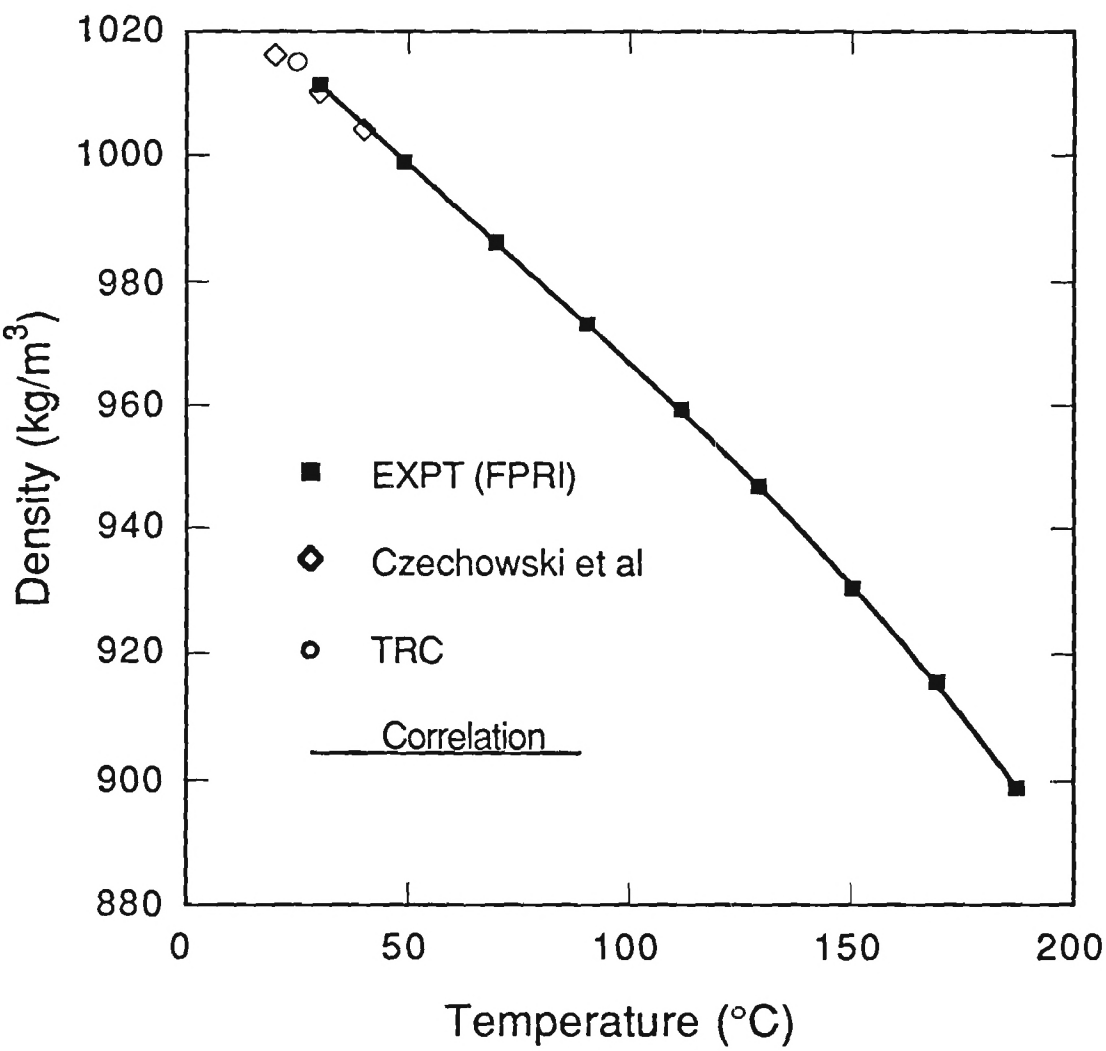
Density of 1,4-Butanediol



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May, 1991 DDS-LD-A36

DESIGN DATA STANDARD - LIQUID DENSITY

2,3- Butanediol

$CH_3CH(OH)CH(OH)CH_3$
CA-No: 513-85-9

Purity =	99 %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	612.6 K	[2]
Critical Pressure =	51.3 bar	[2]
Critical Volume =	0.292 m^3/kmol	[3]
Melting Point =	295.7 K	[4]
Normal Boiling Point =	455.2 K	[4]
Liquid Molar Volume at 25 °C =	0.09130 m^3/kmol	[5]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (°C)	ρ (kg/m³)
30.1	984.9
49.7	968.5
70.4	950.2
88.5	934.0
108.0	917.7
127.4	899.8
146.3	880.2
166.5	860.0
179.0	847.1

Liquid Density Correlation:

$$\rho\ (kg/m^3) = 1011.10 - 0.880955\ T(°C) + 5.76727 \times 10^{-4}\ T(°C)^2 - 4.3641 \times 10^{-6}\ T(°C)^3$$

% AAD = 0.04 %
% MAD = 0.07 %

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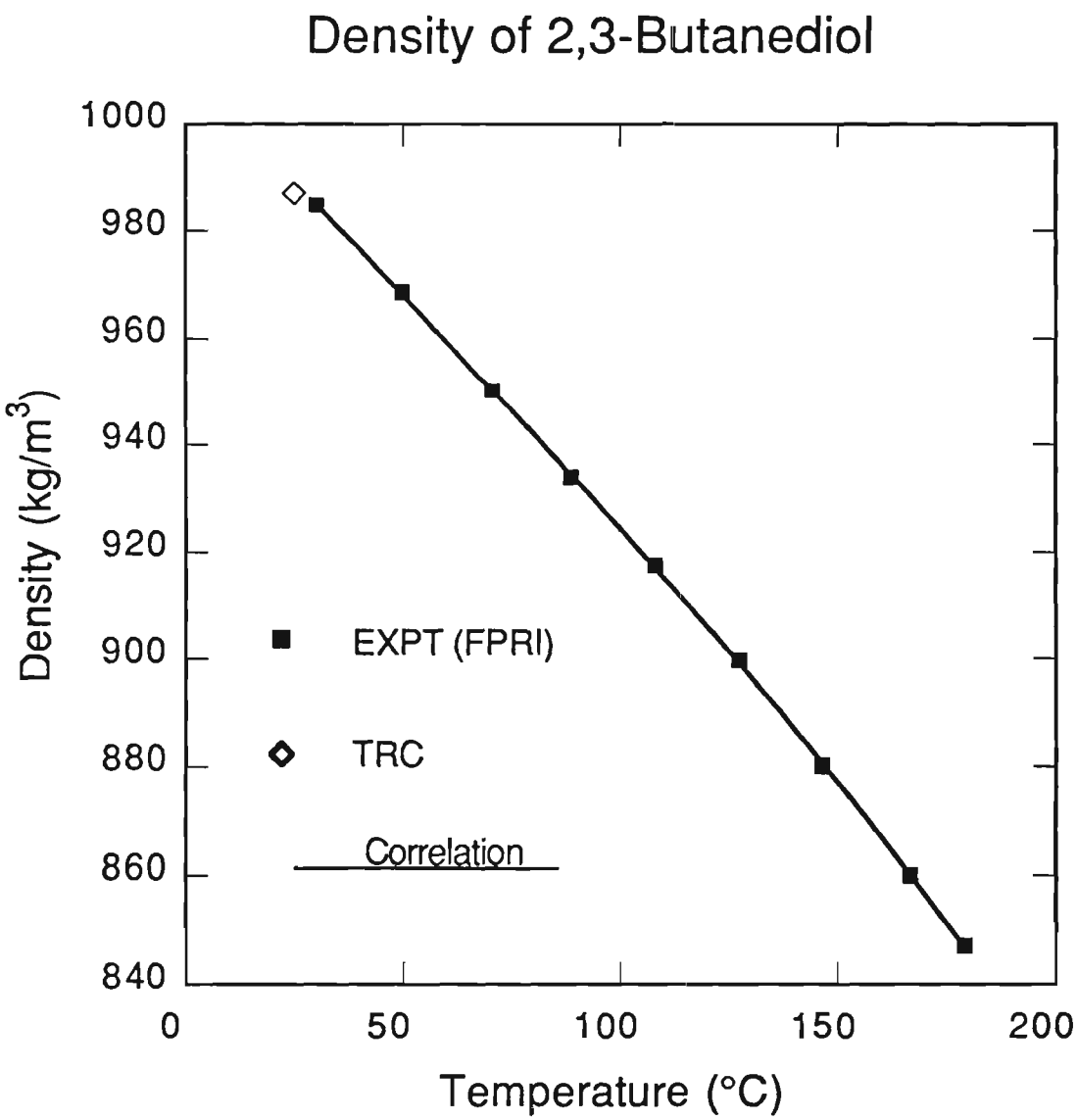

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DESIGN DATA STANDARD - LIQUID DENSITY

Dimethyl Disulfide

$(CH_3)_2 S_2$
CA-No: 624-92-0

Purity =	99+ %	
Molecular Weight =	94.189 kg/kmol	[1]
Critical Temperature =	605.0 K	[2]
Critical Pressure =	48.0 bar	[2]
Critical Volume =	0.358 m^3/kmol	[2]
Melting Point =	188.43 K	[3]
Normal Boiling Point =	382.89 K	[3]
Liquid Molar Volume at 25 °C =	0.08912 m^3/kmol	[3]
Dipole Moment =	6.57×10^{-30} C-m	[4]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (°C)	ρ (kg/m^3)
28.9	1051.8
41.3	1038.4
53.4	1024.9
66.5	1010.1
78.7	996.3
90.7	982.0
103.9	966.9

Liquid Density Correlation:

$$\rho\ (kg/m^3) = 1081.16 - 0.957690\ T(°C) - 0.002161\ T(°C)^2 + 7.6108 \times 10^{-6}\ T(°C)^3$$

% AAD = 0.01 %
% MAD = 0.02 %

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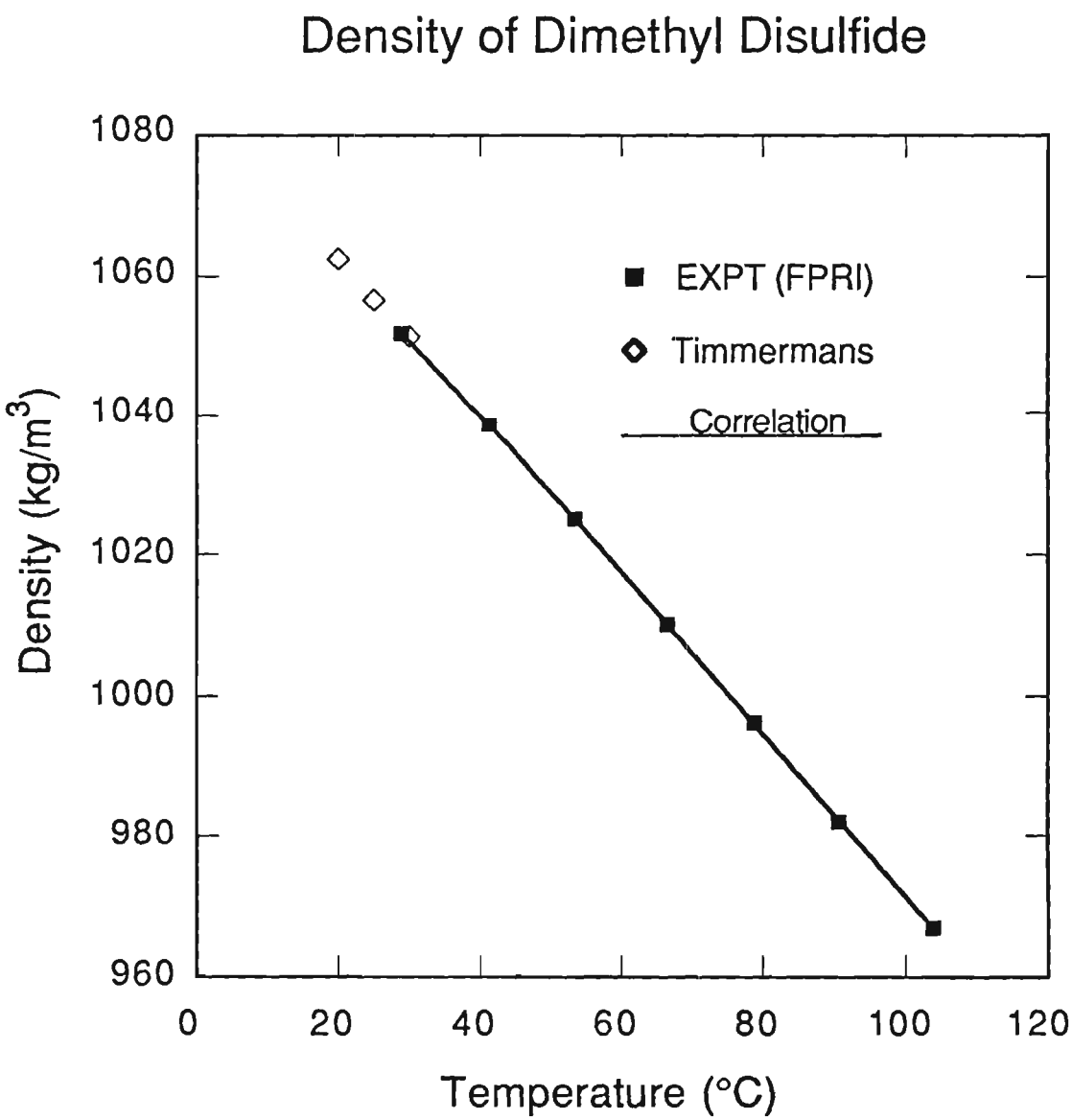

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DESIGN DATA STANDARD - LIQUID DENSITY

Diethyl Disulfide

$(C_2H_5)_2 S_2$
CA-No: 110-81-6

Purity =	99 %	
Molecular Weight =	122.243 kg/kmol	[1]
Critical Temperature =	642.1 K	[2]
Critical Pressure =	35.0 bar	[2]
Critical Volume =	0.472 m^3/kmol	[2]
Melting Point =	171.63 K	[3]
Normal Boiling Point =	427.13 K	[3]
Liquid Molar Volume at 25 °C =	0.12371 m^3/kmol	[3]
Dipole Moment =	6.64 x 10^{-30} C-m	[4]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (°C)	ρ (kg/m³)
29.1	984.8
43.0	971.2
61.6	953.1
78.0	936.6
94.8	920.0
112.2	902.2
128.1	885.9
146.0	868.5

Liquid Density Correlation:

$$\rho\ (kg/m^3) = 1011.49 - 0.887631\ T(°C) - 0.0012275\ T(°C)^2 + 4.0744 \times 10^{-6}\ T(°C)^3$$

% AAD = 0.02 %
% MAD = 0.03 %

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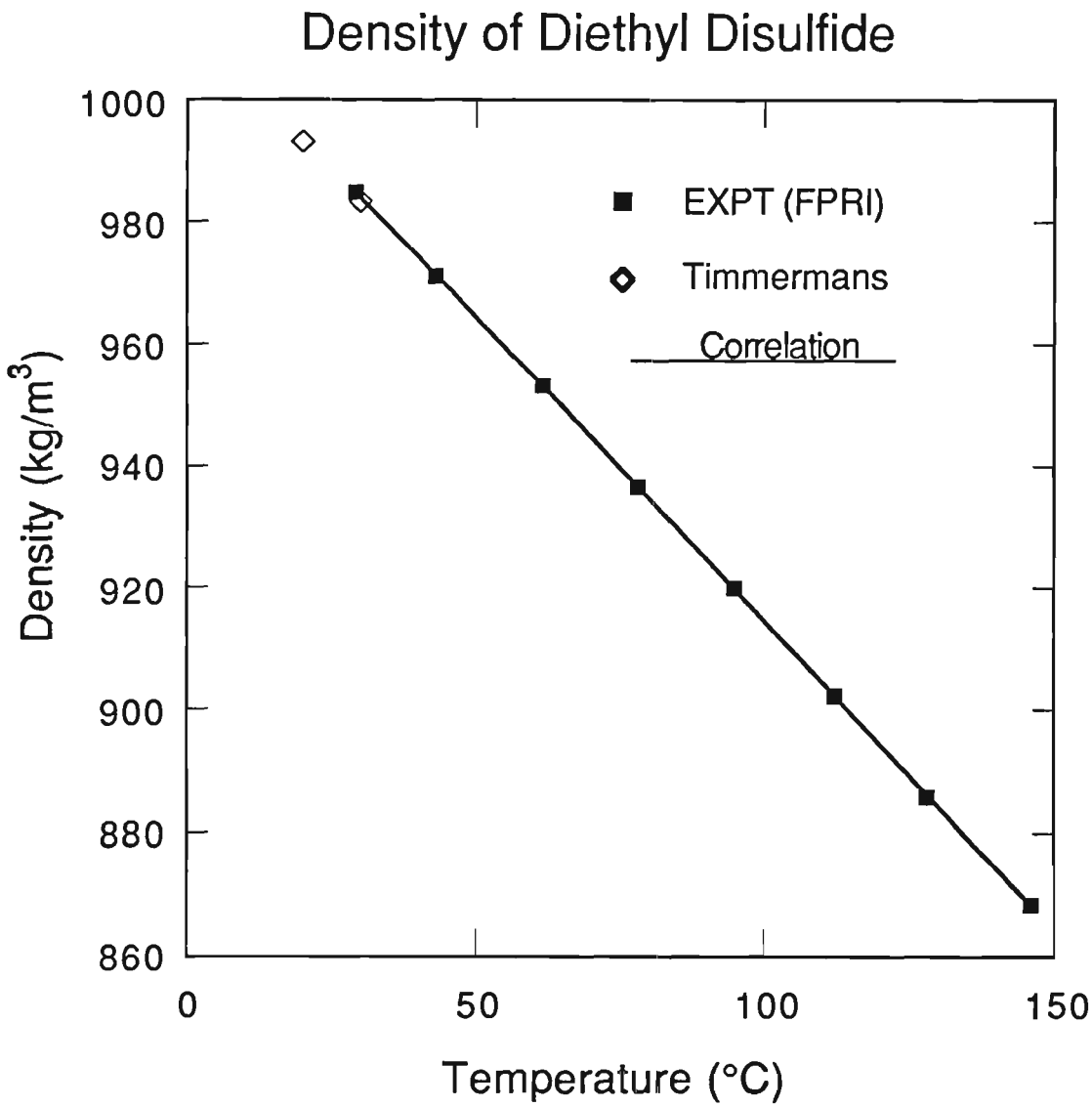

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May, 1991 DDS-LD-A39

DESIGN DATA STANDARD - LIQUID DENSITY

2-Methoxyethanol

$CH_3OCH_2CH_2OH$
CA-No: 109-86-4

Purity =	99.99 %	
Molecular Weight =	76.095 kg/kmol	[1]
Critical Temperature =	565.5 K	[2]
Critical Pressure =	50.1 bar	[2]
Critical Volume =	0.242 m^3/kmol	[3]
Melting Point =	188.1	[4]
Normal Boiling Point =	397.8 K	[4]
Liquid Molar Volume at 25 °C =	0.079266 m^3/kmol	[5]
Dipole Moment =	6.8×10^{-30} C-m	[4]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (°C)	ρ (kg/m³)
23.5	962.4
38.6	948.4
52.1	935.6
66.0	922.7
79.8	909.5
93.7	895.5
107.3	881.4
120.6	866.8

Liquid Density Correlation:

$$\rho\ (kg/m^3) = 985.22 - 0.995452\ T(°C) + 1.45354 \times 10^{-3}\ T(°C)^2 - 1.10985 \times 10^{-5}\ T(°C)^3$$

% AAD = 0.01 %
% MAD = 0.02 %

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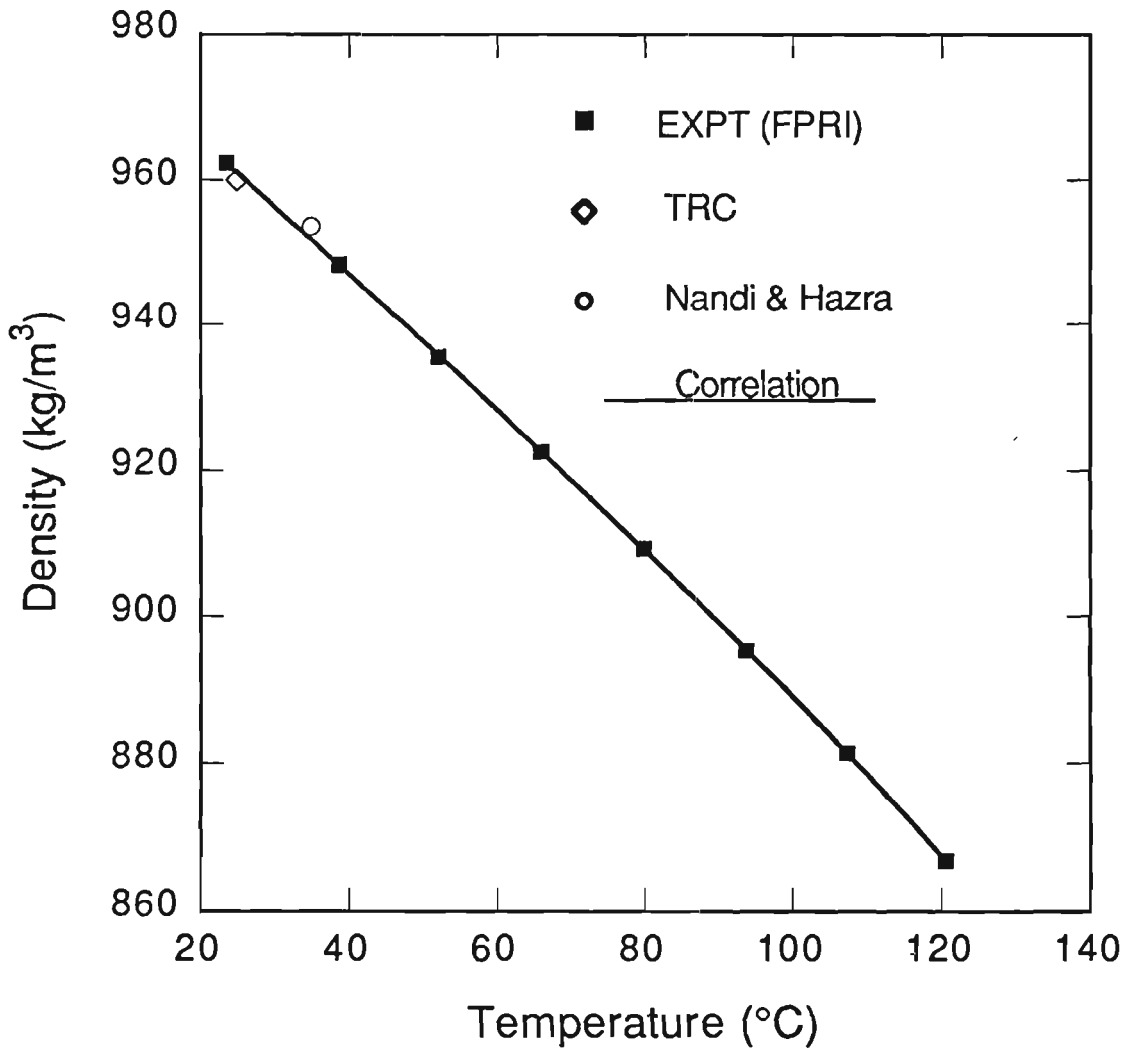
Density of Methoxy Ethanol



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May, 1991 DDS-LD-A40

DESIGN DATA STANDARD - LIQUID DENSITY

2-(2-Methoxyethoxy) ethanol

$CH_3OCH_2CH_2OCH_2CH_2OH$
CA-No: 111-77-3

Purity =	99 %	
Molecular Weight =	120.148 kg/kmol	[1]
Critical Temperature =	630.8 K	[2]
Critical Pressure =	35.4 bar	[2]
Critical Volume =	0.367 m^3/kmol	[3]
Melting Point =	197.0 K	[4]
Normal Boiling Point =	467.3 K	[4]
Liquid Molar Volume at 25 °C =	0.11839 m^3/kmol	[5]
Dipole Moment =	5.3×10^{-30} C-m	[4]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (°C)	ρ (kg/m³)
24.6	1017.7
43.5	1001.0
61.8	984.4
80.3	967.6
104.3	945.2
123.1	926.8
142.3	908.8
161.0	891.9
180.3	876.1

Liquid Density Correlation:

$$\rho\ (kg/m^3) = 1036.73 - 0.732068\ T(°C) - 2.20986 \times 10^{-3}\ T(°C)^2 + 7.34438 \times 10^{-6}\ T(°C)^3$$

% AAD = 0.03 %
% MAD = 0.06 %

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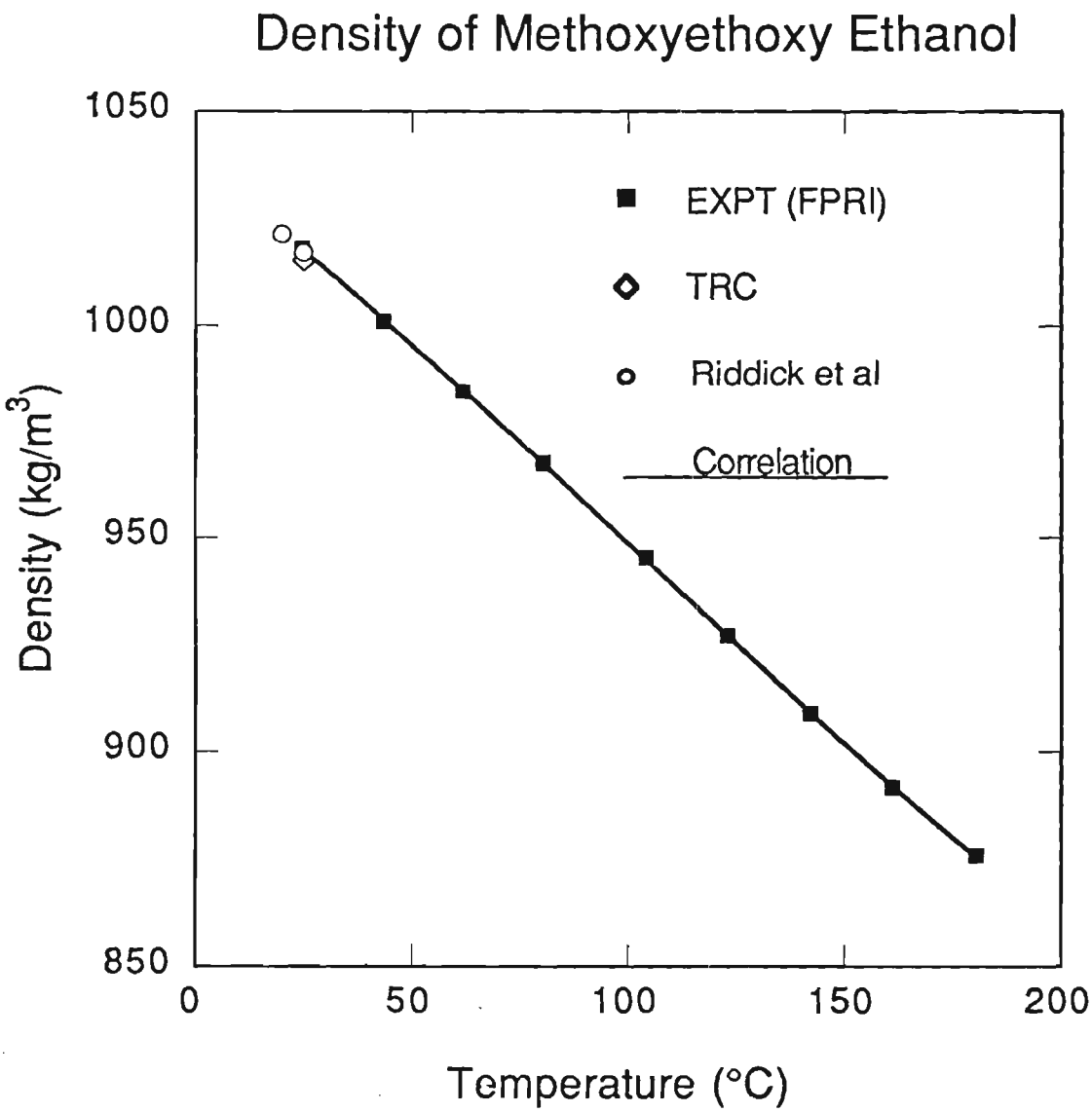
May, 1991 DDS-LD-A40



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May, 1991 DDS-LD-A41

DESIGN DATA STANDARD - LIQUID DENSITY

2-[2-(2-Methoxyethoxy) ethoxy]- Ethanol

$CH_3(OCH_2CH_2)_3OH$
CA-No: 112-35-6

Purity =	95 %	
Molecular Weight =	164.201 kg/kmol	[1]
Critical Temperature =	677.2 K	[2]
Critical Pressure =	27.3 bar	[2]
Critical Volume =	0.493 m^3/kmol	[3]
Melting Point =	---	
Normal Boiling Point =	522 K	[4]
Liquid Molar Volume at 25 °C =	0.15735 m^3/kmol	[5]

Experimental Technique : High Pressure Pycnometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 0.2 %

T (°C)	ρ (kg/m³)
27.0	1042.2
43.3	1028.0
60.6	1013.4
78.6	997.9
97.6	981.9
115.6	965.2
133.4	949.5
151.3	932.5
169.7	914.5

Liquid Density Correlation:

$$\rho\ (kg/m^3) = 1065.77 - 0.889911\ T(°C) + 6.527245 \times 10^{-4}\ T(°C)^2 - 3.894967 \times 10^{-6}\ T(°C)^3$$

% AAD = 0.02 %
% MAD = 0.04 %

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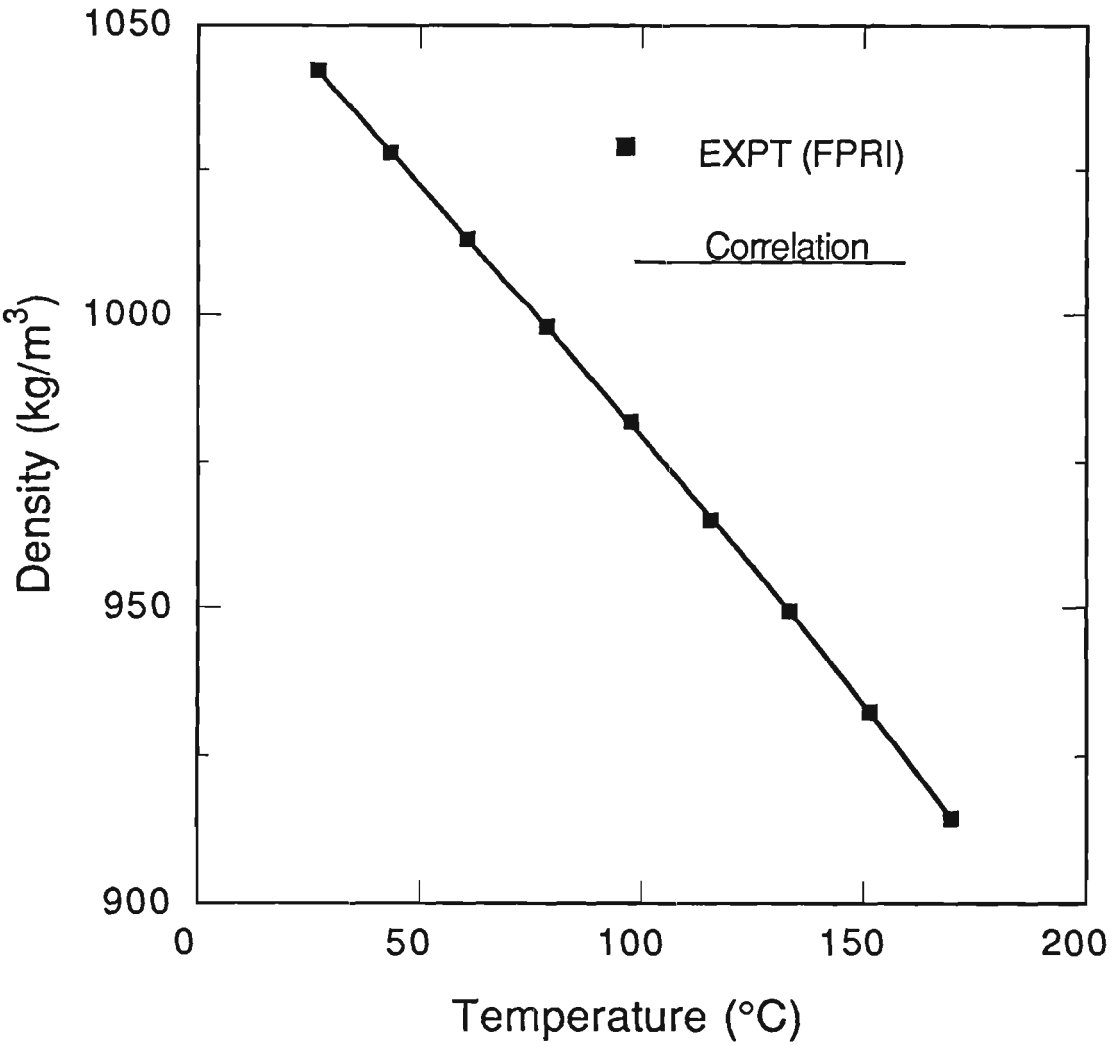
May, 1991 DDS-LD-A41

Denisty of Methoxyethoxyethoxy Ethanol



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3. Estimated from the Fedors method: Fedors, R.F., "A Method to Estimate Critical Volumes", AIChE J., 25, 202 (1979).

4. Weast, R. C.; Grasselli, J. G., "Handbook of Data on Organic Compounds", CRC Press, Boca Raton, Fla. (1989).

5. Estimated from the density correlation reported in this data sheet.

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May, 1991 DDS-LV-A33

DESIGN DATA STANDARD - LIQUID VISCOSITY

1,2- Butanediol

$C_2H_5CH(OH)CH_2OH$
CA-No: 26171-83-5

Purity =	98 %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	621.8 K	[2]
Critical Pressure =	50.0 bar	[2]
Critical Volume =	0.292 m^3/kmol	[3]
Melting Point =	---	
Normal Boiling Point =	464.7 K	[4]
Liquid Molar Volume at 25 °C =	0.09016 m^3/kmol	[5]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (°C)	μ (cP)
22.8	66.47
30.2	40.72
45.3	17.04
60.3	8.782
75.2	5.155
89.8	3.204
105.1	2.165
120.0	1.555
134.8	1.169
149.6	0.914

Liquid Viscosity Correlation:

$$ln\ (\mu\ (cP)) = -3.87764 + 903.311\ /\ (\ T(°C) + 89.023\ )$$

% AAD = 0.6 %
% MAD = 1.8 %

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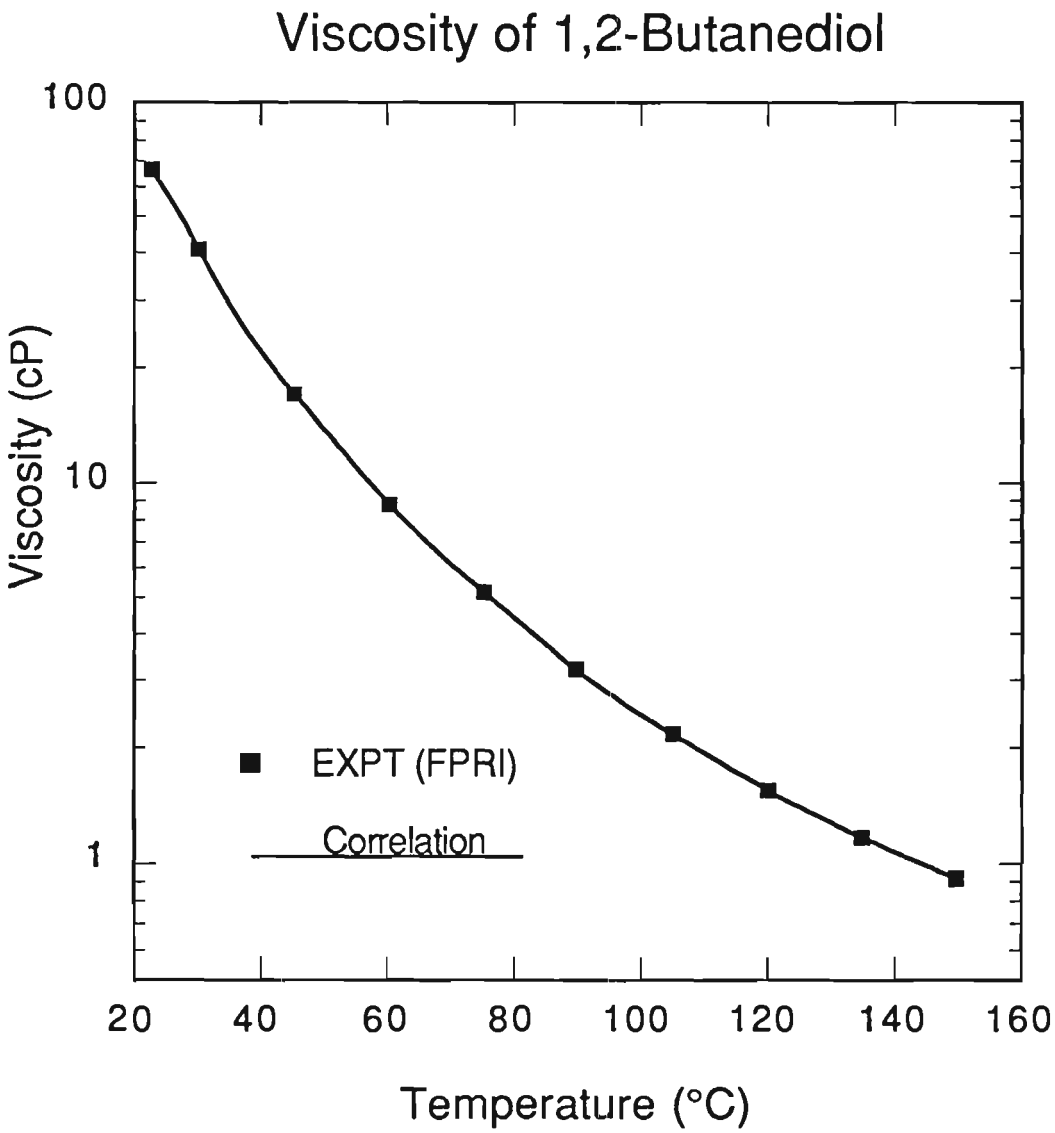
May, 1991 DDS-LV-A33



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2. Estimated from the Lydersen method: Reid, R. C.; Prausnitz, J. M.; Sherwood, T. K., "The Properties of Gases and Liquids", 3rd ed., McGraw-Hill, New York (1977).

3. Estimated from the Fedors method: Fedors, R.F., "A Method to Estimate Critical Volumes", AIChE J., 25, 202 (1979).

4. Weast R. C.; Astle, M. J., "CRC Handbook of Data on Organic Compounds", CRC Press, Boca Raton, Fla. (1985).

5. Estimated from the density correlation reported in this data sheet.

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May, 1991 DDS-LV-A34

DESIGN DATA STANDARD - LIQUID VISCOSITY

1,3- Butanediol

$CH_3CH(OH)CH_2CH_2OH$
CA-No: 107-88-0

Purity =	99+ %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	643.00 K	[2]
Critical Pressure =	50.0 bar	[2]
Critical Volume =	0.292 m^3/kmol	[2]
Melting Point =	196.15 K	[2]
Normal Boiling Point =	480.15 K	[2]
Liquid Molar Volume at 25 °C =	0.089913 m^3/kmol	[2]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (°C)	μ (cP)
22.0	116.4
30.5	68.79
45.3	30.60
60.3	15.16
75.3	8.397
89.7	5.077
105.4	3.243
120.0	2.247
134.8	1.620
149.6	1.212

Liquid Viscosity Correlation:

$$ln\ (\mu\ (cP)) = -4.85601 + 1350.58 / (\ T(°C) + 118.218\ )$$

% AAD = 0.9 %
% MAD = 1.7 %

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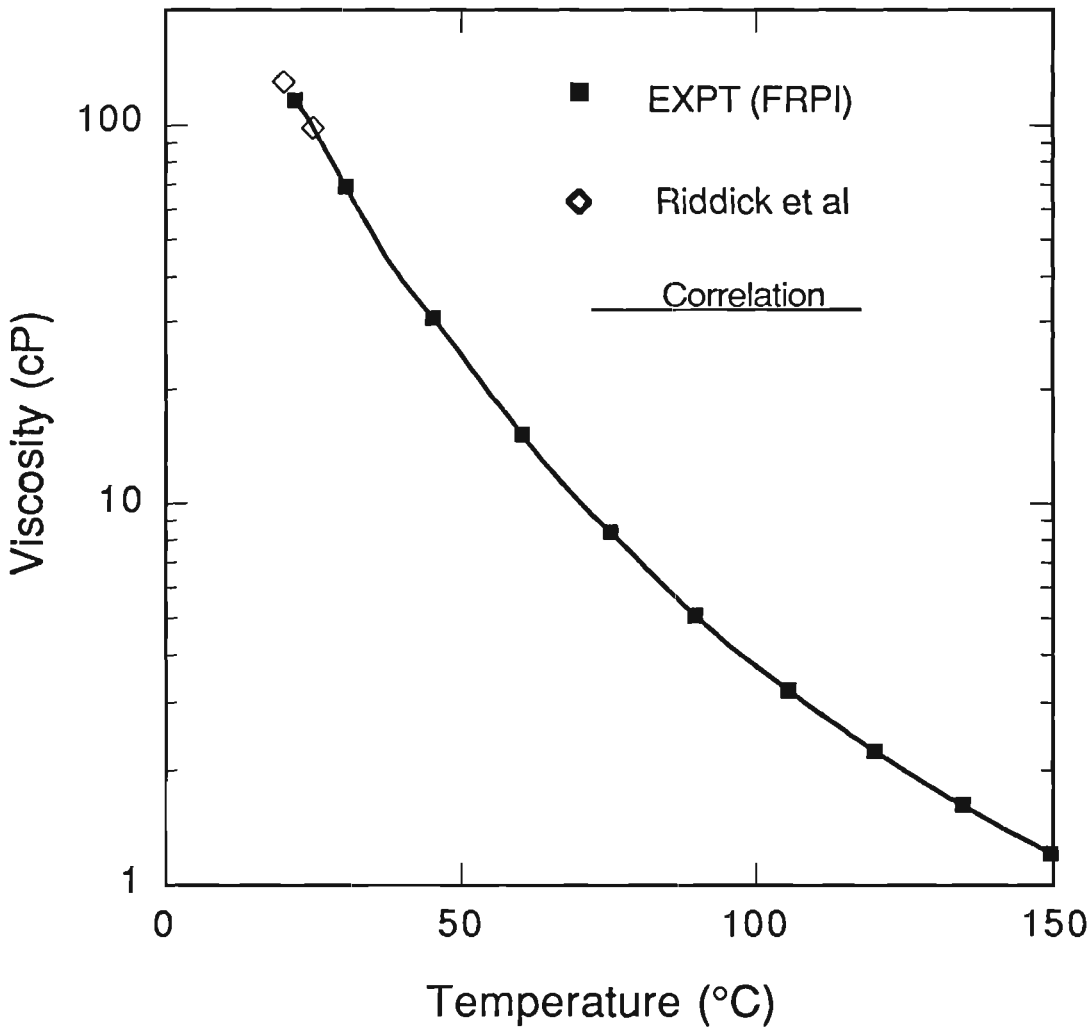
May, 1991 DDS-LV-A34

Viscosity of 1,3-Butanediol



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May, 1991 DDS-LV-A35

DESIGN DATA STANDARD - LIQUID VISCOSITY

1,4- Butanediol

$HO(CH_2)_4OH$
CA-No: 110-63-4

Purity =	99+ %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	667.0 K	[2]
Critical Pressure =	48.8 bar	[2]
Critical Volume =	0.297 m^3/kmol	[2]
Melting Point =	293.05 K	[2]
Normal Boiling Point =	501.15 K	[2]
Liquid Molar Volume at 25 °C =	0.088974 m^3/kmol	[2]
Dipole Moment =	1.311×10^{-29} C-m	[3]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (°C)	μ (cP)
25.3	71.13
30.7	54.93
45.3	28.56
60.2	16.09
75.2	9.787
90.0	6.243
105.1	4.149
120.0	2.923
134.8	3.137
149.7	1.615

Liquid Viscosity Correlation:

$$\ln(\mu\ (cP)) = -5.26327 + 1793.03 / (T(°C) + 162.766)$$

% AAD = 0.4 %
% MAD = 1.1 %

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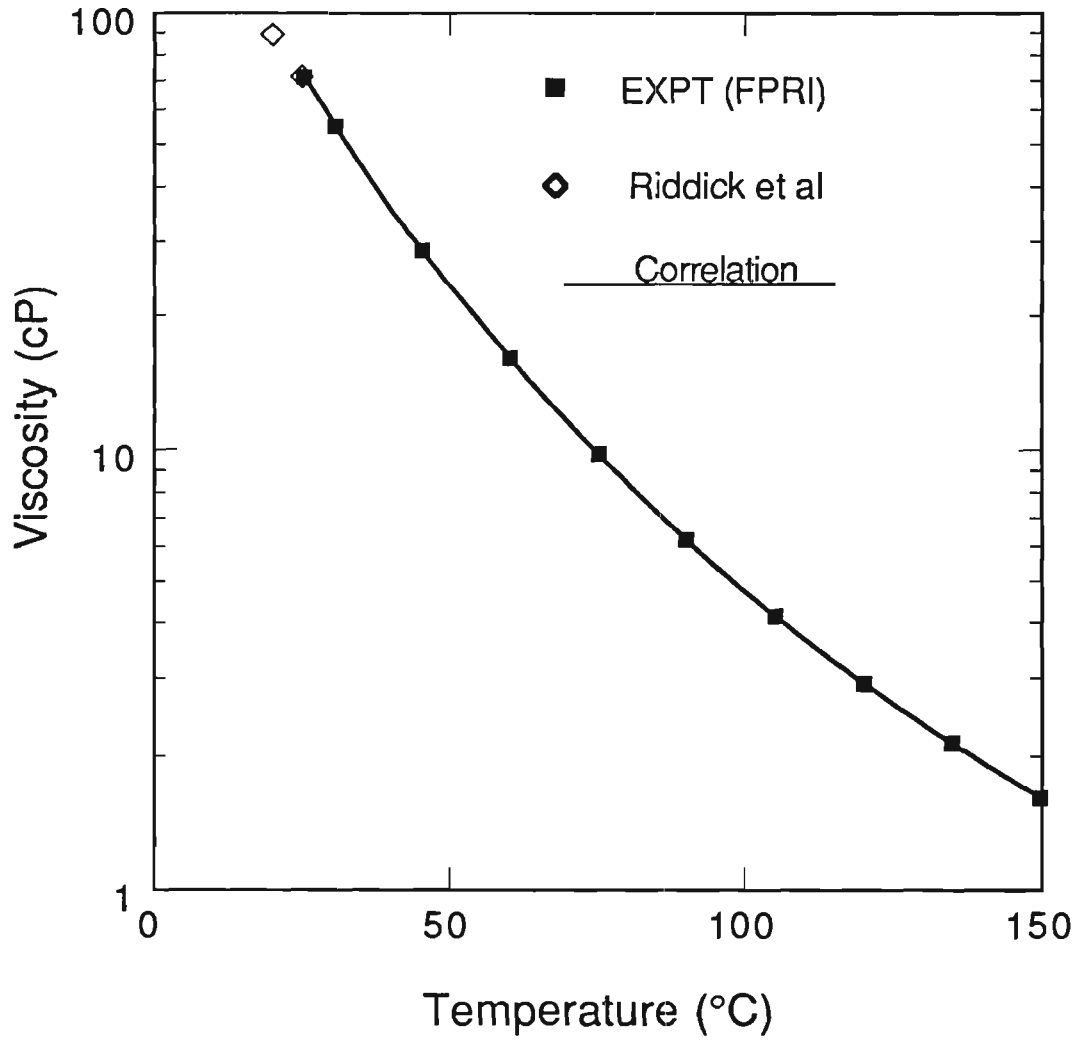
Viscosity of 1,4-Butanediol



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May, 1991 DDS-LV-A36

DESIGN DATA STANDARD - LIQUID VISCOSITY

2,3- Butanediol

$CH_3CH(OH)CH(OH)CH_3$
CA-No: 513-85-9

Purity =	99 %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	612.6 K	[2]
Critical Pressure =	51.3 bar	[2]
Critical Volume =	0.292 m^3/kmol	[3]
Melting Point =	295.7 K	[4]
Normal Boiling Point =	455.2 K	[4]
Liquid Molar Volume at 25 °C =	0.09130 m^3/kmol	[5]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (°C)	μ (cP)
22.4	54.51
30.1	31.87
45.3	12.83
60.2	6.576
75.1	3.832
89.8	2.453
105.1	1.683
120.0	1.229
134.9	0.940
149.7	0.746

Liquid Viscosity Correlation:

$$ln\ (\mu\ (cP)) = -3.56552 + 733.926 / (\ T(°C) + 74.510\ )$$

% AAD = 0.5 %
% MAD = 1.4 %

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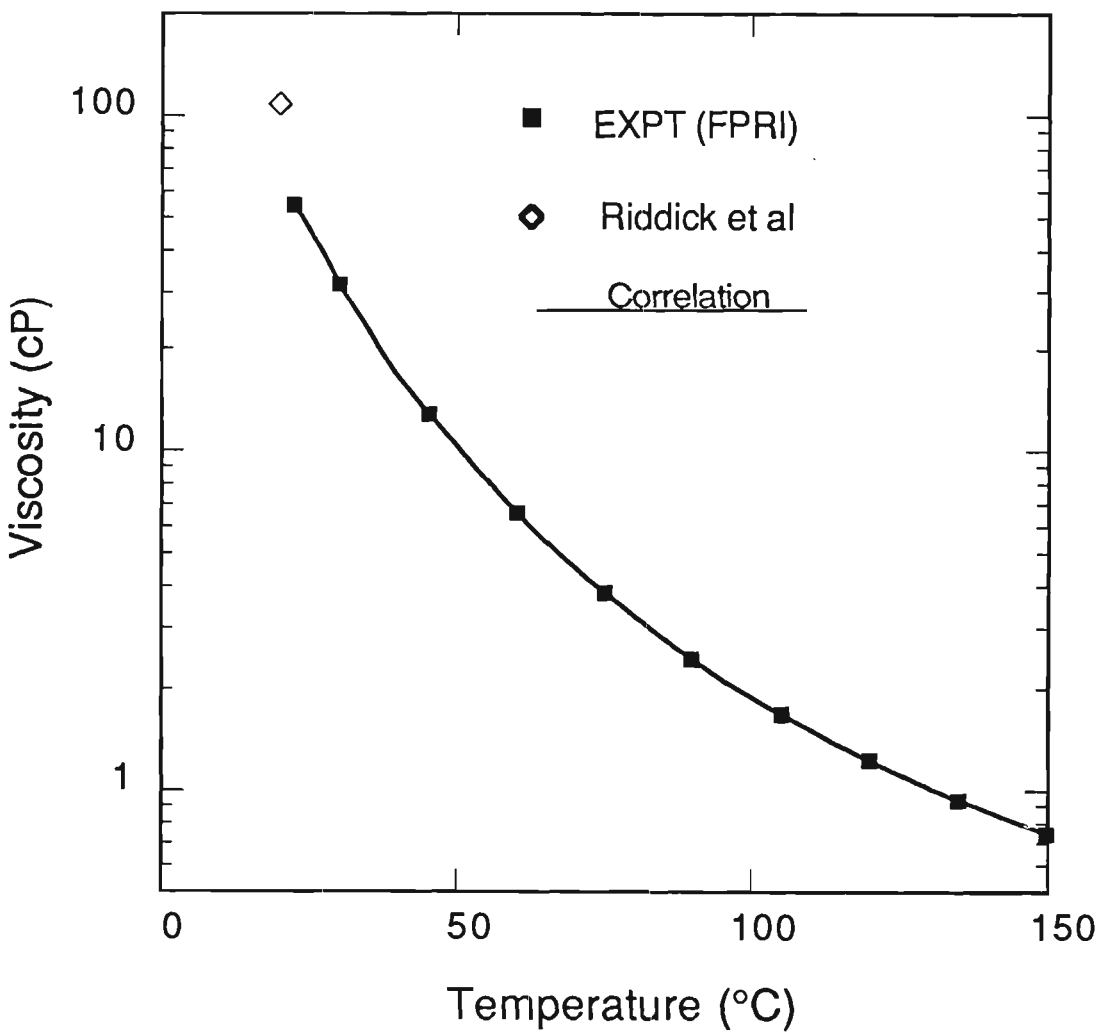
May, 1991 DDS-LV-A36

Viscosity of 2,3-Butanediol



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May, 1991 DDS-LV-A37

DESIGN DATA STANDARD - LIQUID DENSITY

Dimethyl Disulfide

$(CH_3)_2 S_2$
CA-No: 624-92-0

Purity =	99+ %	
Molecular Weight =	94.189 kg/kmol	[1]
Critical Temperature =	605.0 K	[2]
Critical Pressure =	48.0 bar	[2]
Critical Volume =	0.358 m^3/kmol	[2]
Melting Point =	188.43 K	[3]
Normal Boiling Point =	382.89 K	[3]
Liquid Molar Volume at 25 °C =	0.08912 m^3/kmol	[3]
Dipole Moment =	6.57 x 10^{-30} C-m	[4]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (°C)	μ (cP)
22.5	0.616
32.6	0.556
43.4	0.505
54.3	0.456
64.2	0.421
74.2	0.390
83.8	0.364
93.7	0.340
105.1	0.316

Liquid Viscosity Correlation:

$$ln\ (\mu\ (cP)) = -3.37692 + 796.543 / (\ T(°C) + 252.679\ )$$

% AAD = 0.2 %
% MAD = 0.5 %

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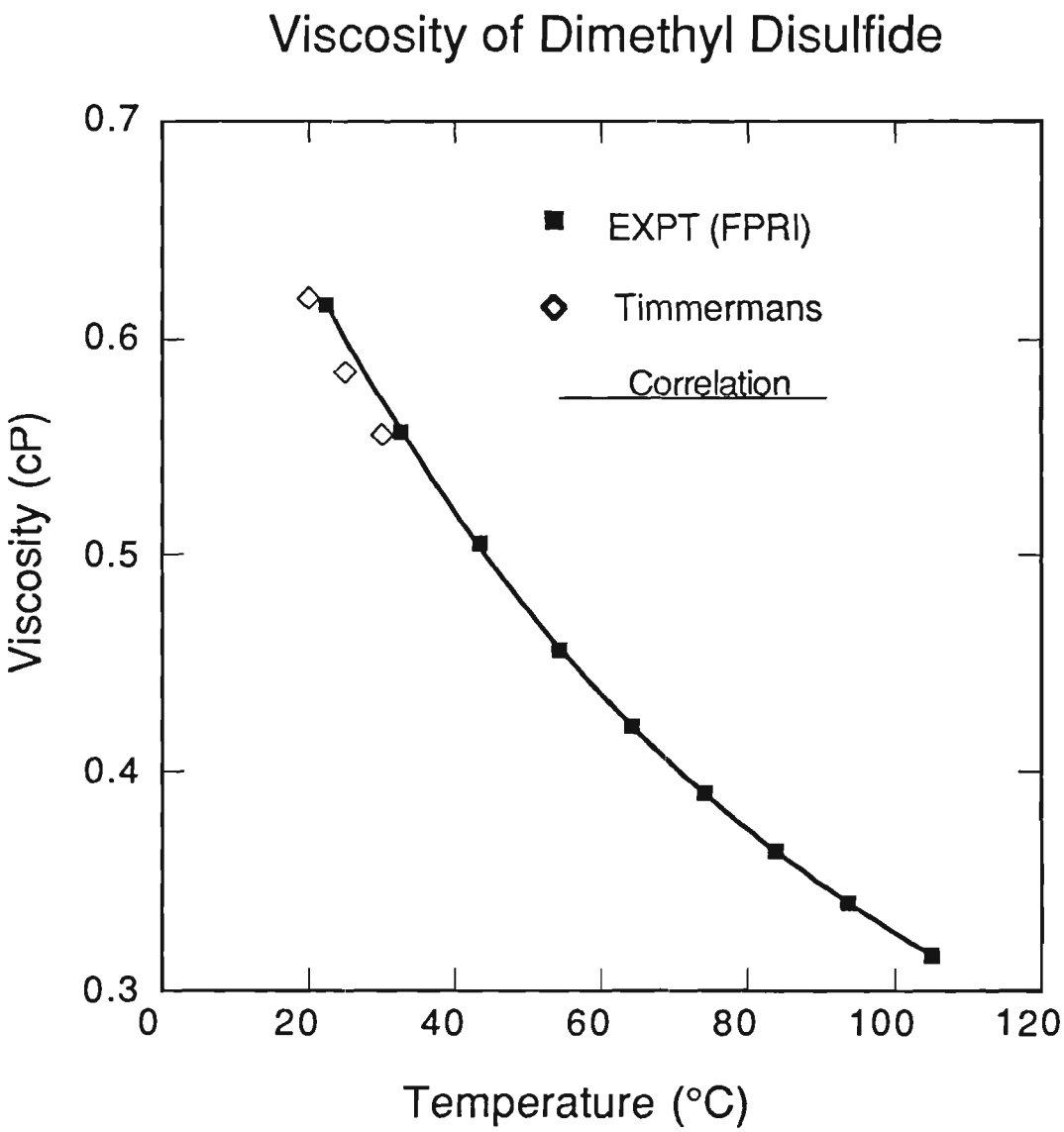
May, 1991 DDS-LV-A37



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4. McClellan, A. L., "Tables of Experimental Dipole Moments", W. H. Freeman Pub., San Francisco (1963).

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May, 1991 DDS-LV-A38

DESIGN DATA STANDARD - LIQUID VISCOSITY

Diethyl Disulfide

$(C_2H_5)_2 S_2$
CA-No: 110-81-6

Purity =	99 %	
Molecular Weight =	122.243 kg/kmol	[1]
Critical Temperature =	642.1 K	[2]
Critical Pressure =	35.0 bar	[2]
Critical Volume =	0.472 m^3/kmol	[2]
Melting Point =	171.63 K	[3]
Normal Boiling Point =	427.13 K	[3]
Liquid Molar Volume at 25 °C =	0.12371 m^3/kmol	[3]
Dipole Moment =	6.64 x 10^{-30} C-m	[4]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (°C)	μ (cP)
22.3	0.862
30.4	0.762
45.3	0.642
60.3	0.549
75.2	0.479
89.9	0.421
105.1	0.375
120.0	0.337
134.9	0.306
144.8	0.285

Liquid Viscosity Correlation:

$$ln\ (\mu\ (cP)) = -3.40470 + 788.565 / (\ T(°C) + 220.5\ )$$

% AAD = 0.5 %
% MAD = 1.0 %

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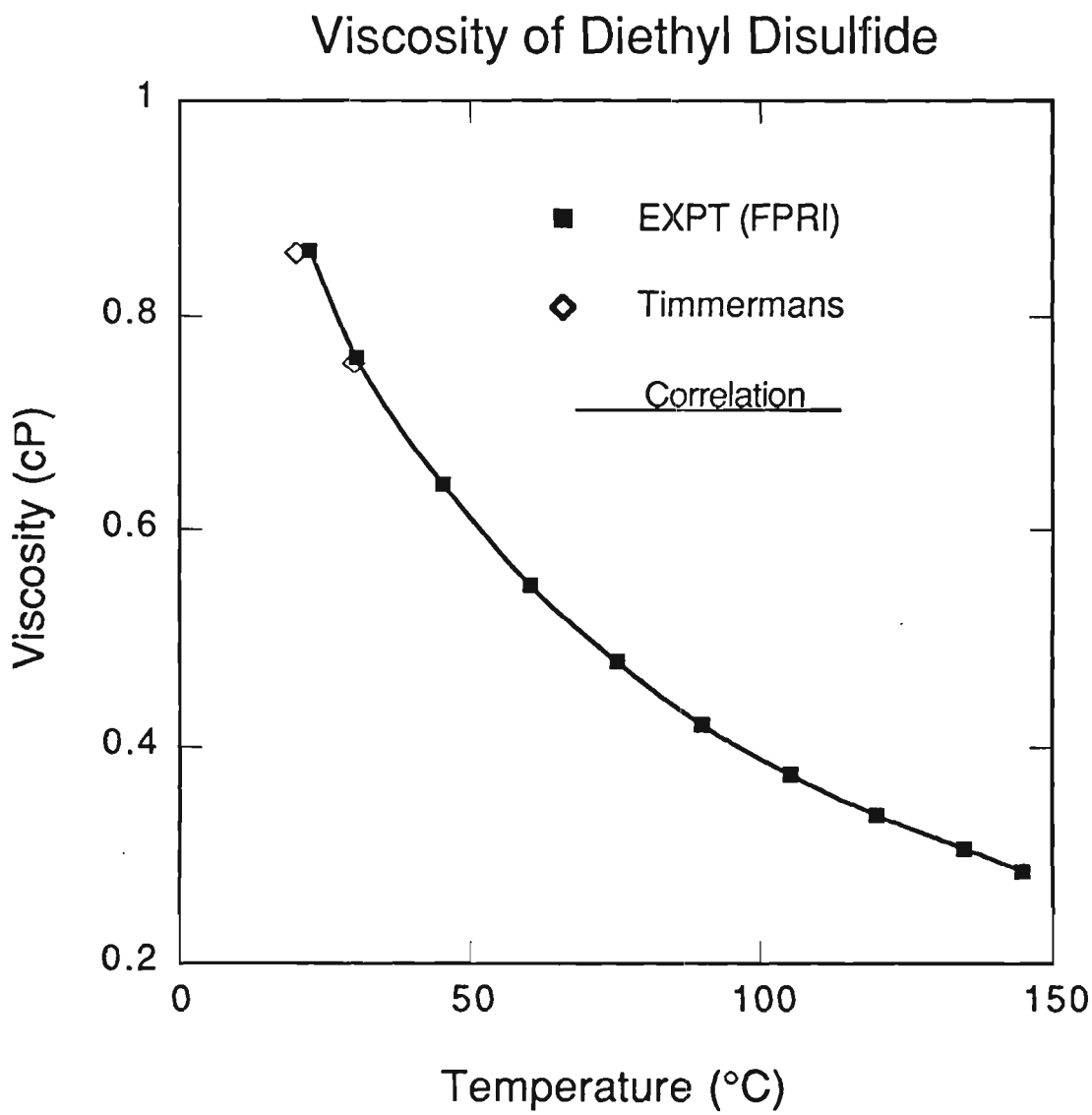
May, 1991 DDS-LV-A38



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May, 1991 DDS-LV-A39

DESIGN DATA STANDARD - LIQUID DENSITY

2-Methoxyethanol

$CH_3OCH_2CH_2OH$
CA-No: 109-86-4

Purity =	99.99 %	
Molecular Weight =	76.095 kg/kmol	[1]
Critical Temperature =	565.5 K	[2]
Critical Pressure =	50.1 bar	[2]
Critical Volume =	0.242 m^3/kmol	[3]
Melting Point =	188.1	[4]
Normal Boiling Point =	397.8 K	[4]
Liquid Molar Volume at 25 °C =	0.079266 m^3/kmol	[5]
Dipole Moment =	6.8×10^{-30} C-m	[4]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (°C)	μ (cP)
22.6	1.615
35.3	1.261
50.4	0.971
65.3	0.776
80.1	0.635
95.0	0.530
110.2	0.447
120.1	0.404

Liquid Viscosity Correlation:

$$ln\ (\mu\ (cP)) = -3.99451 + 975.143 / (\ T(°C) + 195.368\ )$$

% AAD = 0.1 %
% MAD = 0.3 %

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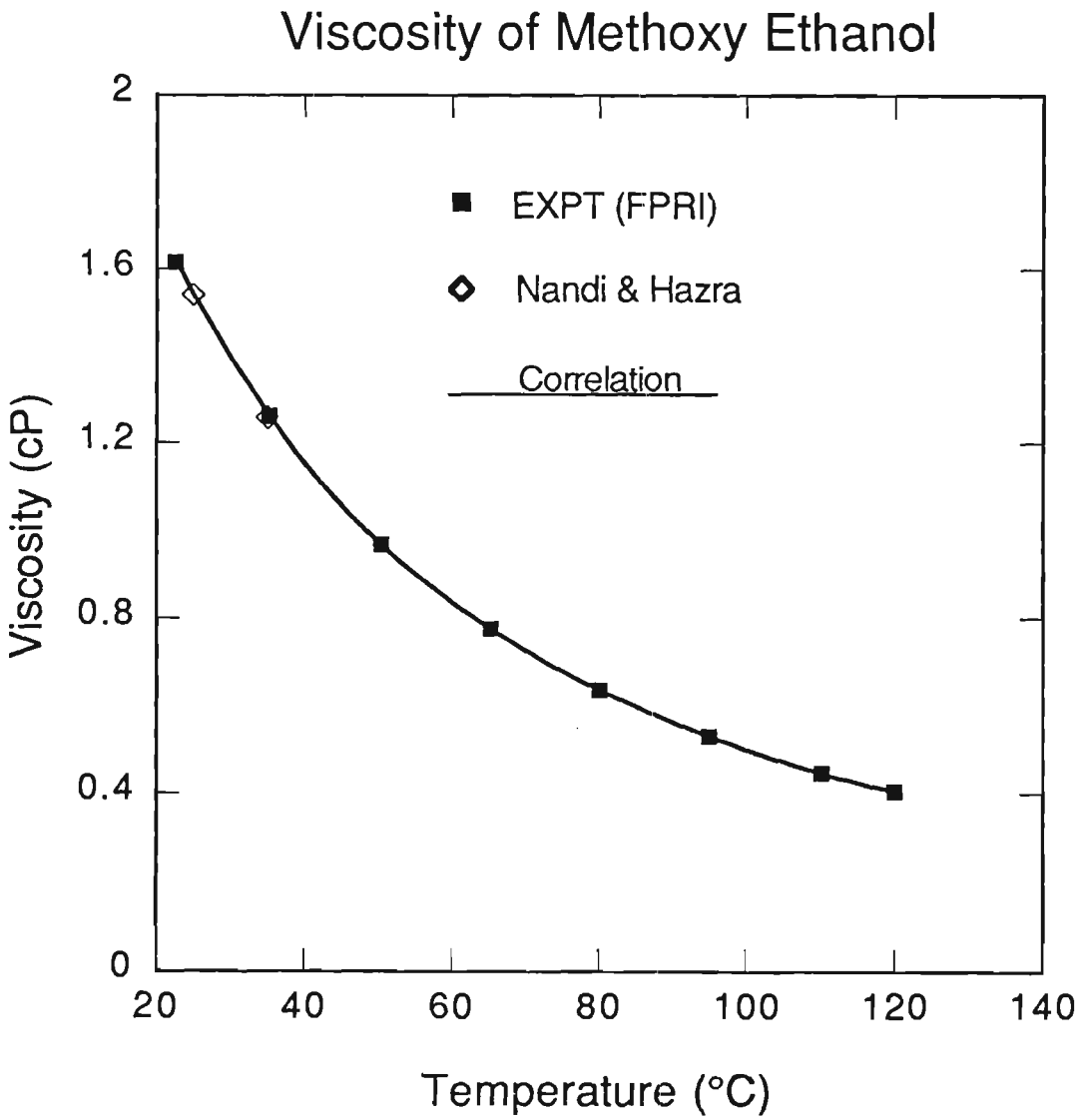
May, 1991 DDS-LV-A39



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May, 1991 DDS-LV-A40

DESIGN DATA STANDARD - LIQUID DENSITY

2-(2-Methoxyethoxy) ethanol

$CH_3OCH_2CH_2OCH_2CH_2OH$
CA-No: 111-77-3

Purity =	99 %	
Molecular Weight =	120.148 kg/kmol	[1]
Critical Temperature =	630.8 K	[2]
Critical Pressure =	35.4 bar	[2]
Critical Volume =	0.367 m^3/kmol	[3]
Melting Point =	197.0 K	[4]
Normal Boiling Point =	467.3 K	[4]
Liquid Molar Volume at 25 °C =	0.11839 m^3/kmol	[5]
Dipole Moment =	5.3 x 10^{-30} C-m	[4]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (°C)	μ (cP)
23.5	3.673
30.8	3.018
45.4	2.169
60.1	1.624
75.2	1.265
89.9	1.023
105.1	0.827
120.0	0.691
135.0	0.584
149.7	0.504

Liquid Viscosity Correlation:

$$ln\ (\mu\ (cP)) = -3.66706 + 948.09 / (\ T(°C) + 167.714\ )$$

% AAD = 0.5 %
% MAD = 1.0 %

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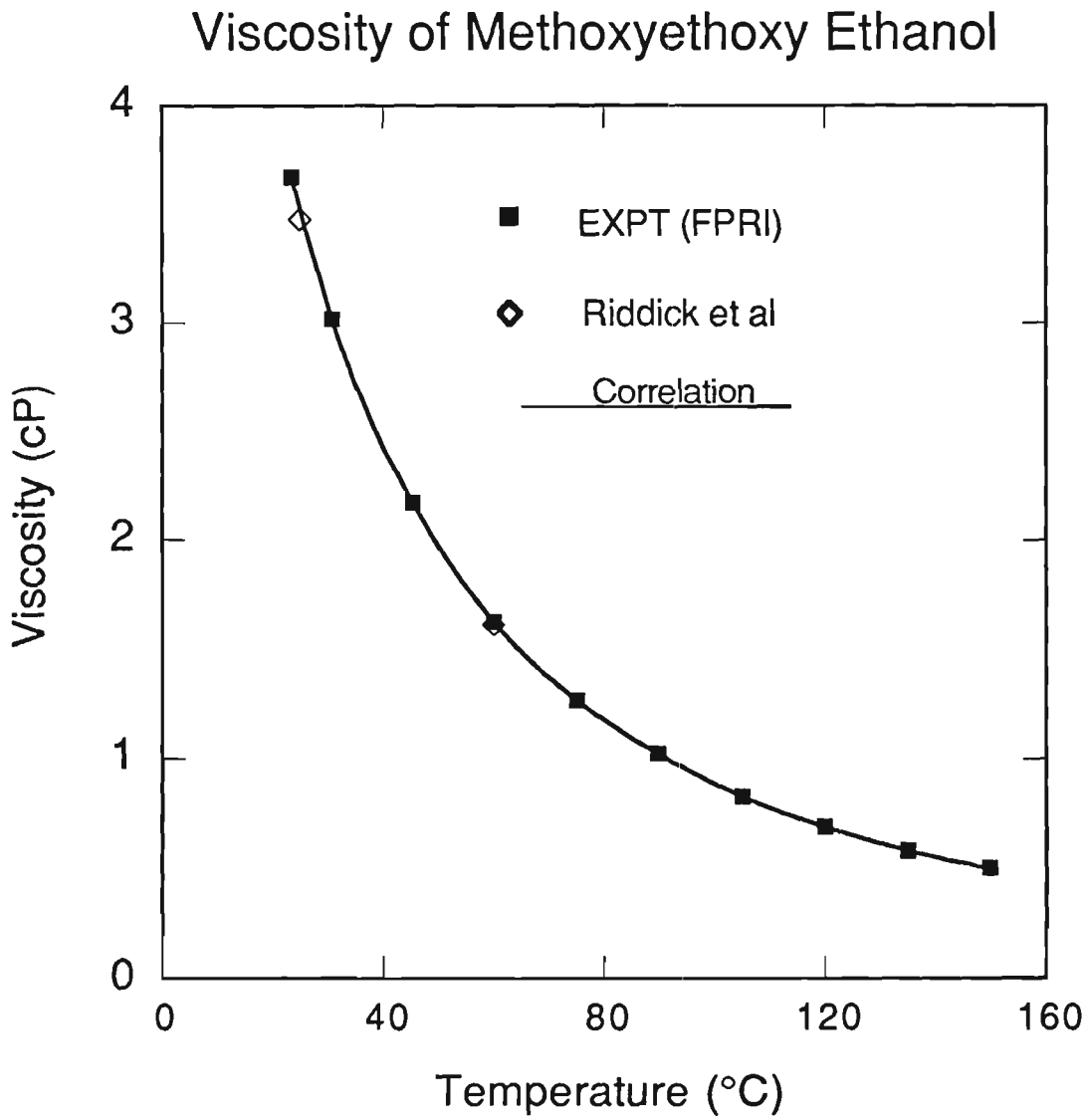
May, 1991 DDS-LV-A40



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May, 1991 DDS-LV-A41

DESIGN DATA STANDARD - LIQUID DENSITY

2-[2-(2-Methoxyethoxy) ethoxy]- Ethanol

$CH_3(OCH_2CH_2)_3OH$
CA-No: 112-35-6

Purity =	95 %	
Molecular Weight =	164.201 kg/kmol	[1]
Critical Temperature =	677.2 K	[2]
Critical Pressure =	27.3 bar	[2]
Critical Volume =	0.493 m^3/kmol	[3]
Melting Point =	---	
Normal Boiling Point =	522 K	[4]
Liquid Molar Volume at 25 °C =	0.15735 m^3/kmol	[5]

Experimental Technique : Capillary Viscometer

Experimental Data:

Pressure = Ambient
Accuracy = ± 1.0 %

T (°C)	μ (cP)
23.4	6.432
30.5	5.260
45.4	3.503
60.5	2.509
75.2	1.915
89.9	1.500
105.1	1.207
120.0	1.002
134.9	0.847
149.8	0.729

Liquid Viscosity Correlation:

$$ln\ (\mu\ (cP)) = -2.944549 + 734.13 / (\ T(°C) + 129.215\ )$$

% AAD = 0.3 %
% MAD = 0.9 %

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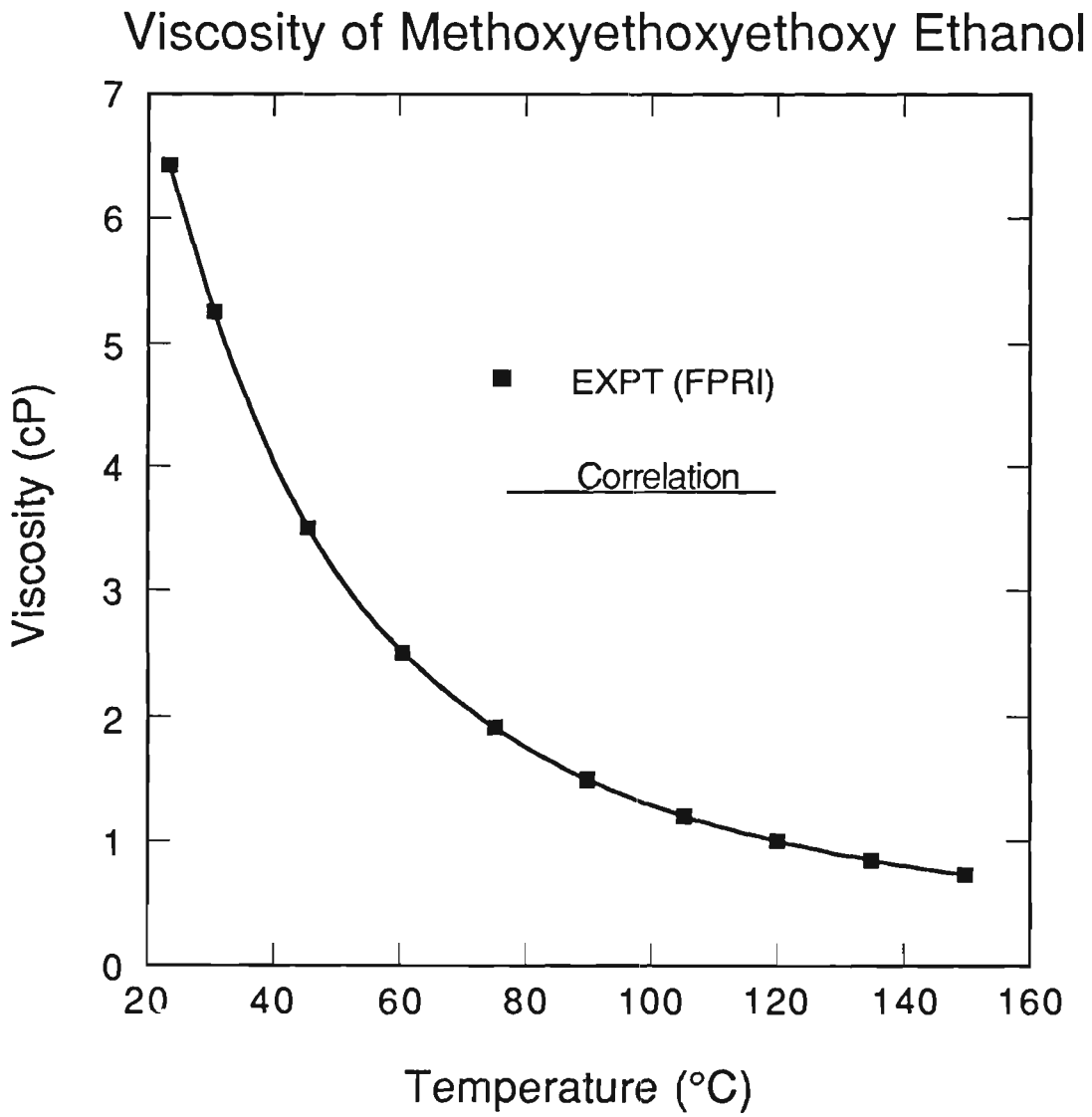
May, 1991 DDS-LV-A41



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3. Estimated from the Fedors method: Fedors, R.F., "A Method to Estimate Critical Volumes", AIChE J., 25, 202 (1979).

4. Weast, R. C.; Grasselli, J. G., "Handbook of Data on Organic Compounds", CRC Press, Boca Raton, Fla. (1989).

5. Estimated from the density correlation reported in this data sheet.

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June, 1991 DDS-LTC-A47

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

1,2- Butanediol

$C_2H_5CH(OH)CH_2OH$
CA-No: 26171-83-5

Purity =	98 %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	621.8 K	[2]
Critical Pressure =	50.0 bar	[2]
Critical Volume =	0.292 m^3/kmol	[3]
Melting Point =	---	
Normal Boiling Point =	464.7 K	[4]
Liquid Molar Volume at 25 °C =	0.09016 m^3/kmol	[5]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ [mW/m K]
298.3	179.0
327.2	178.8
358.2	176.4
391.2	174.0
418.9	170.8
448.4	166.2

Liquid Thermal Conductivity Correlation:

$$\lambda\ [mW/m\ K] = 206.0404 - 0.085203 \times T\ [K]$$

% AAD = 0.6 %
% MAD = 1.0 %

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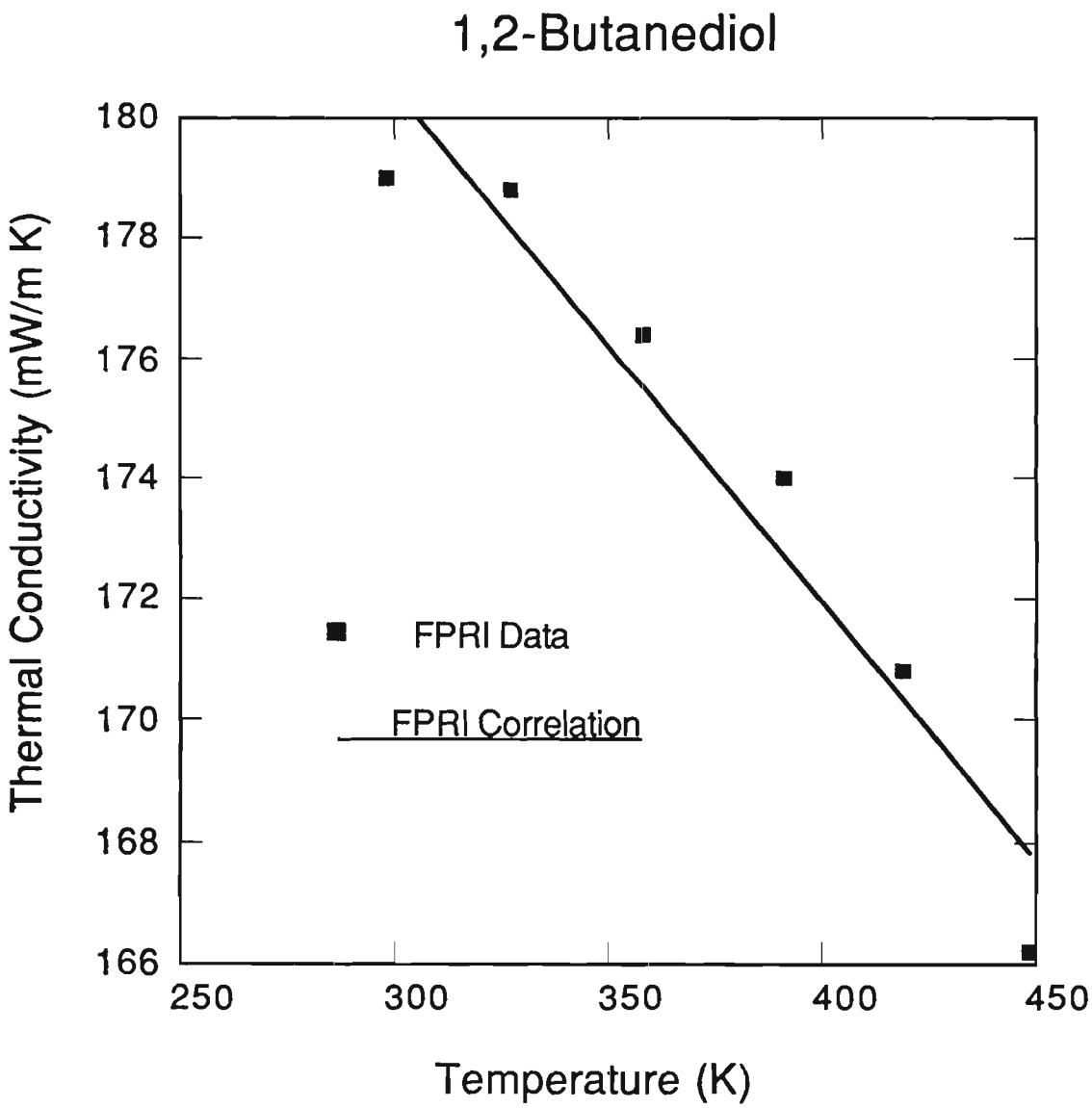
June, 1991 DDS-LTC-A47



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4. Weast R. C.; Astle, M. J., "CRC Handbook of Data on Organic Compounds", CRC Press, Boca Raton, Fla. (1985).

5. Estimated from the density correlation reported in this data sheet.

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FPRI

June, 1991 DDS-LTC-A48

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

1,3- Butanediol

$CH_3CH(OH)CH_2CH_2OH$
CA-No: 107-88-0

Purity =	99+ %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	643.00 K	[2]
Critical Pressure =	50.0 bar	[2]
Critical Volume =	0.292 m^3/kmol	[2]
Melting Point =	196.15 K	[2]
Normal Boiling Point =	480.15 K	[2]
Liquid Molar Volume at 25 °C =	0.089913 m^3/kmol	[2]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ [mW/m K]
294.2	184.9
318.3	180.2
352.1	179.7
378.9	177.7
407.3	175.1
436.8	171.1
458.8	167.5

Liquid Thermal Conductivity Correlation:

$$\lambda\ [mW/m\ K] = 212.3894 - 0.0946667 \times T\ [K]$$

% AAD = 0.5 %
% MAD = 1.2 %

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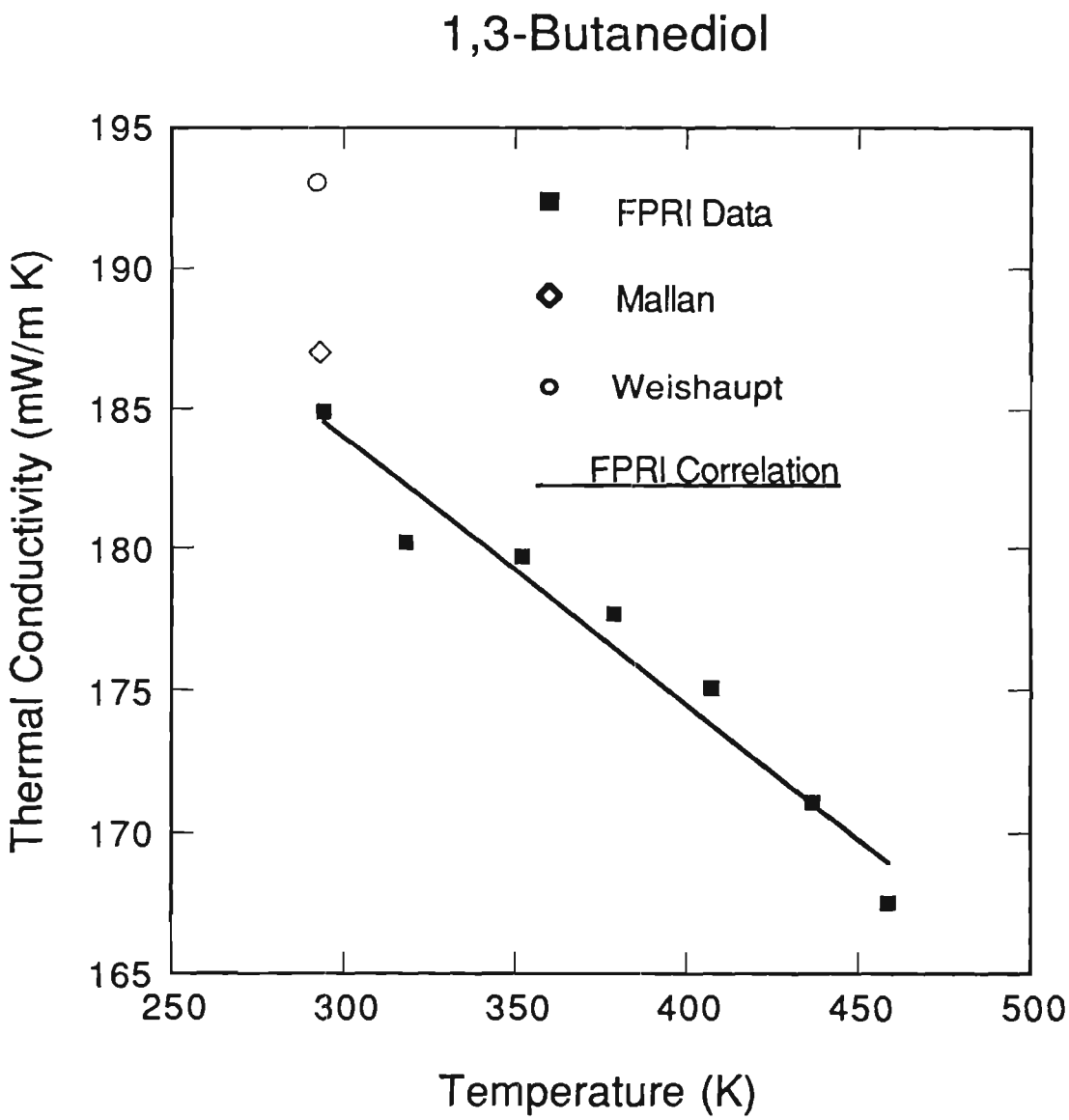
June, 1991

DDS-LTC-A48



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June, 1991 DDS-LTC-A49

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

1,4- Butanediol

$HO(CH_2)_4OH$
CA-No: 110-63-4

Purity =	99+ %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	667.0 K	[2]
Critical Pressure =	48.8 bar	[2]
Critical Volume =	0.297 m^3/kmol	[2]
Melting Point =	293.05 K	[2]
Normal Boiling Point =	501.15 K	[2]
Liquid Molar Volume at 25 °C =	0.088974 m^3/kmol	[2]
Dipole Moment =	1.311×10^{-29} C-m	[3]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ [mW/m K]
292.2	207.7
333.0	207.5
355.2	205.8
381.6	205.0
410.1	203.0
441.0	199.5
466.1	195.2

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ [mW/m K]} = 230.284 - 0.0702787 \times T \text{ [K]}$$

% AAD = 0.6 %
% MAD = 1.2 %

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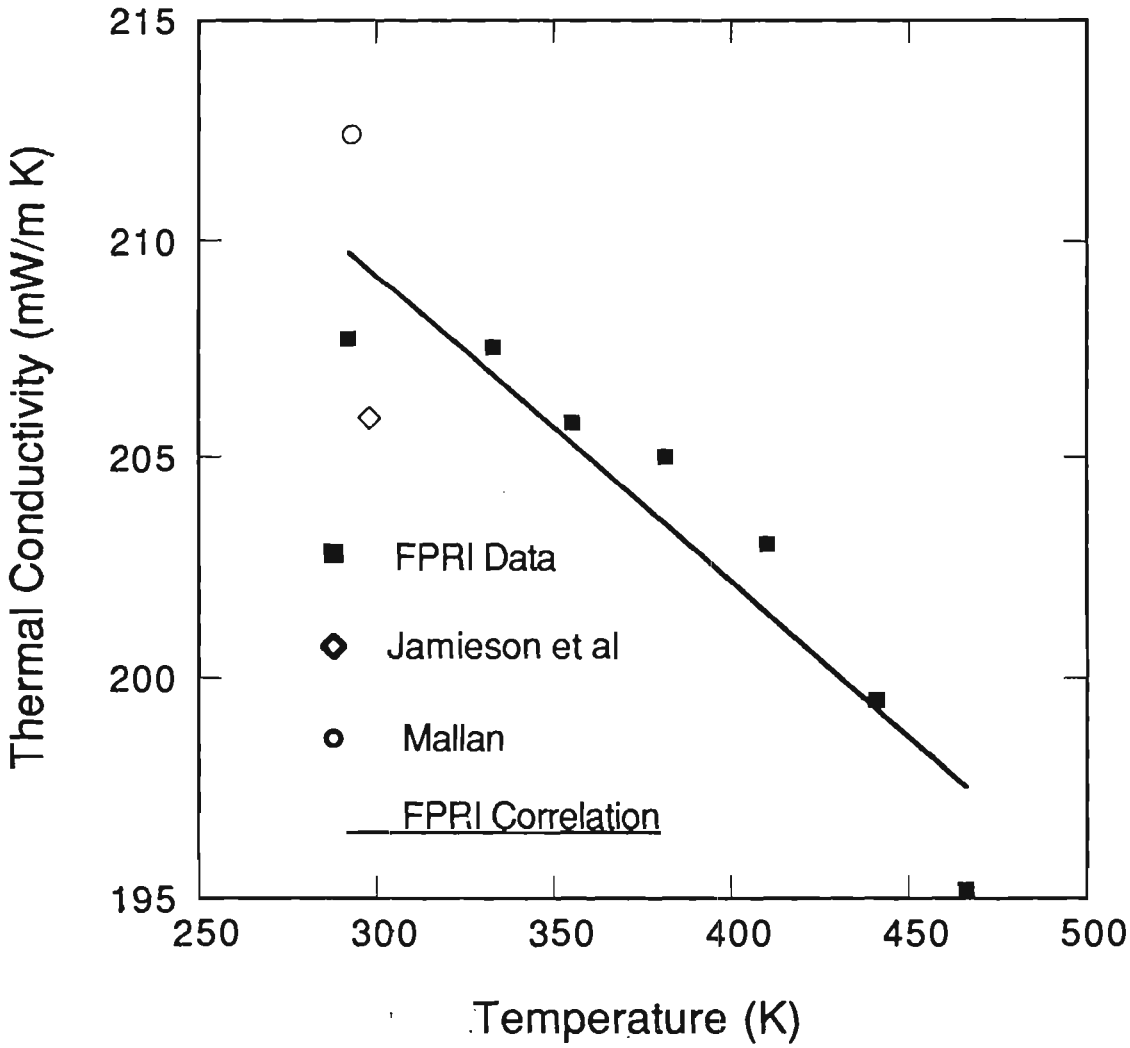
June, 1991 DDS-LTC-A49

1,4-Butanediol



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June, 1991 DDS-LTC-A50

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

2,3- Butanediol

$CH_3CH(OH)CH(OH)CH_3$
CA-No: 513-85-9

Purity =	99 %	
Molecular Weight =	90.122 kg/kmol	[1]
Critical Temperature =	612.6 K	[2]
Critical Pressure =	51.3 bar	[2]
Critical Volume =	0.292 m^3/kmol	[3]
Melting Point =	295.7 K	[4]
Normal Boiling Point =	455.2 K	[4]
Liquid Molar Volume at 25 °C =	0.09130 m^3/kmol	[5]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ [mW/m K]
294.5	164.1
322.7	161.0
358.8	160.8
390.2	158.4
418.5	155.4
446.4	151.4

Liquid Thermal Conductivity Correlation:

$$\lambda\ [mW/m\ K] = 186.714 - 0.0759310 \times T\ [K]$$

% AAD = 0.6 %
% MAD = 1.0 %

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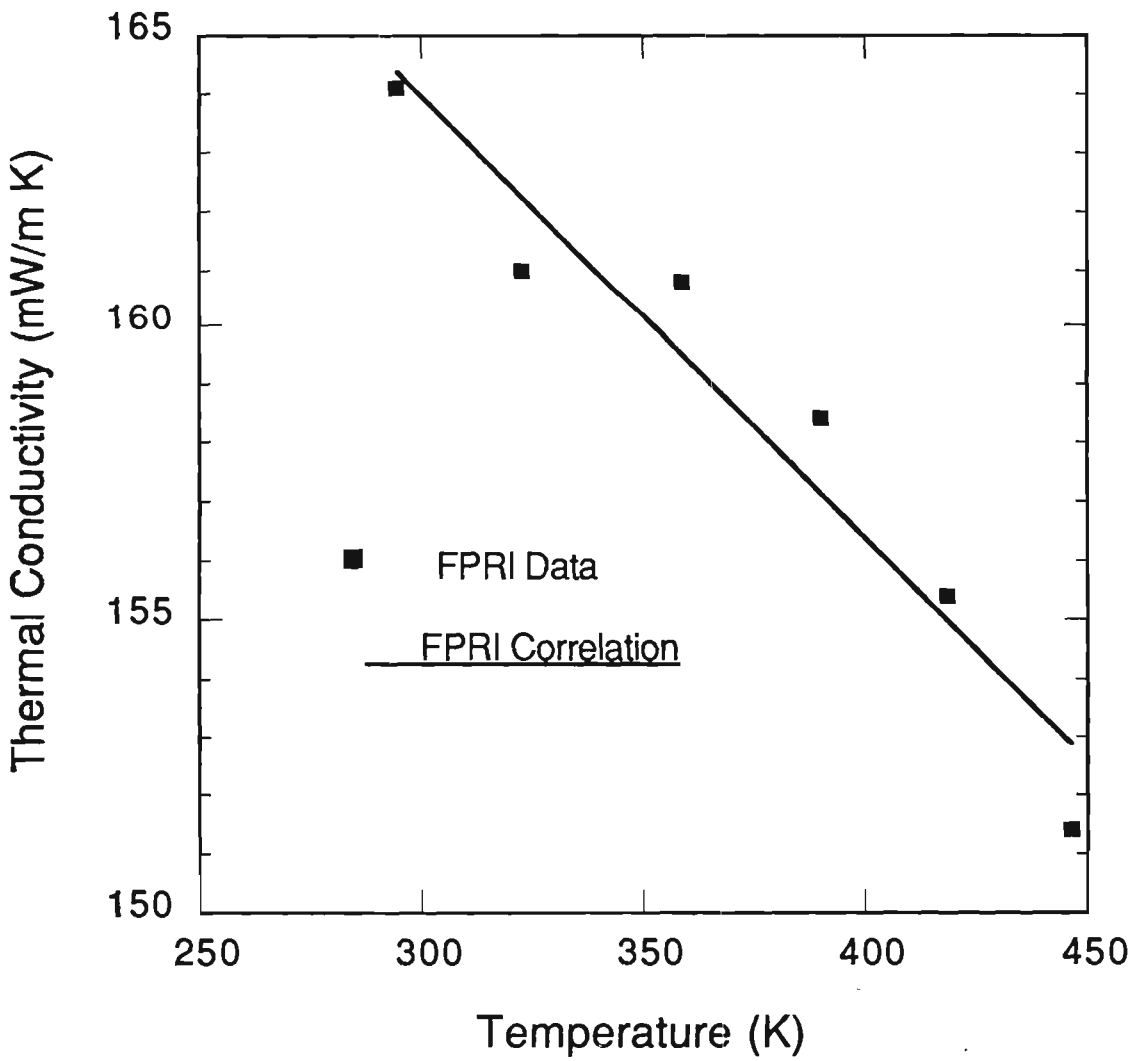
2,3-Butanediol



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June, 1991 DDS-LTC-A51

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

$(CH_3)_2 S_2$
CA-No: 624-92-0

Purity =	99+ %	
Molecular Weight =	94.189 kg/kmol	[1]
Critical Temperature =	605.0 K	[2]
Critical Pressure =	48.0 bar	[2]
Critical Volume =	0.358 m^3/kmol	[2]
Melting Point =	188.43 K	[3]
Normal Boiling Point =	382.89 K	[3]
Liquid Molar Volume at 25 °C =	0.08912 m^3/kmol	[3]
Dipole Moment =	6.57 x 10^{-30} C-m	[4]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ [mW/m K]
297.6	143.0
319.9	135.9
342.3	128.2
369.2	120.5

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ [mW/m K]} = 237.066 - 0.3165263 \times T \text{ [K]}$$

% AAD = 0.2 %
% MAD = 0.5 %

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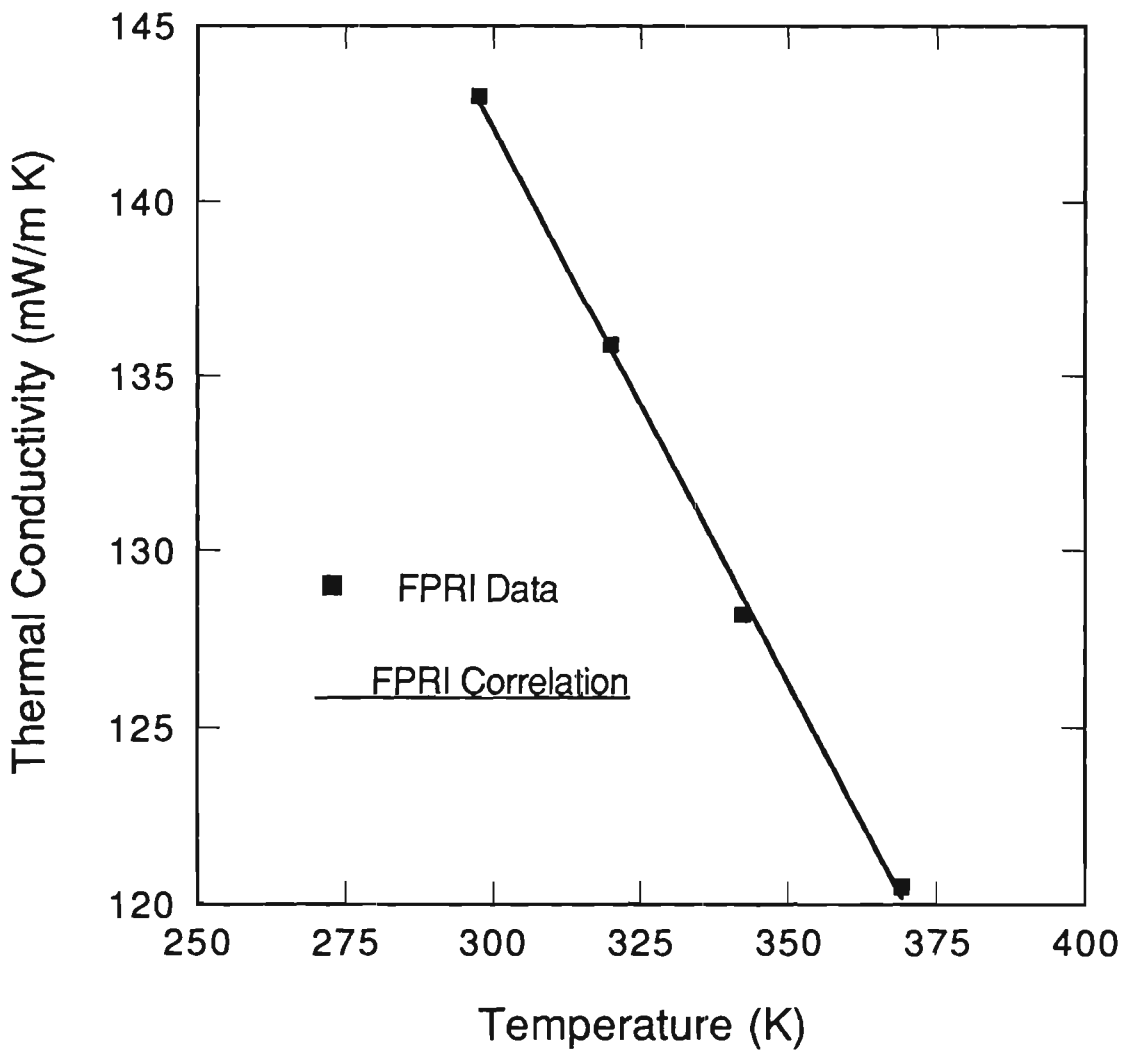
June, 1991 DDS-LTC-A51

Dimethyl Disulfide



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June, 1991 DDS-LTC-A52

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

$(C_2H_5)_2 S_2$
CA-No: 110-81-6

Purity =	99 %	
Molecular Weight =	122.243 kg/kmol	[1]
Critical Temperature =	642.1 K	[2]
Critical Pressure =	35.0 bar	[2]
Critical Volume =	0.472 m^3/kmol	[2]
Melting Point =	171.63 K	[3]
Normal Boiling Point =	427.13 K	[3]
Liquid Molar Volume at 25 °C =	0.12371 m^3/kmol	[3]
Dipole Moment =	6.64 x 10^{-30} C-m	[4]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ [mW/m K]
298.2	131.0
327.5	123.6
357.1	115.7
386.8	108.8
419.0	101.7

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ [mW/m K]} = 203.366 - 0.2437816 \times T \text{ [K]}$$

% AAD = 0.3 %
% MAD = 0.6 %

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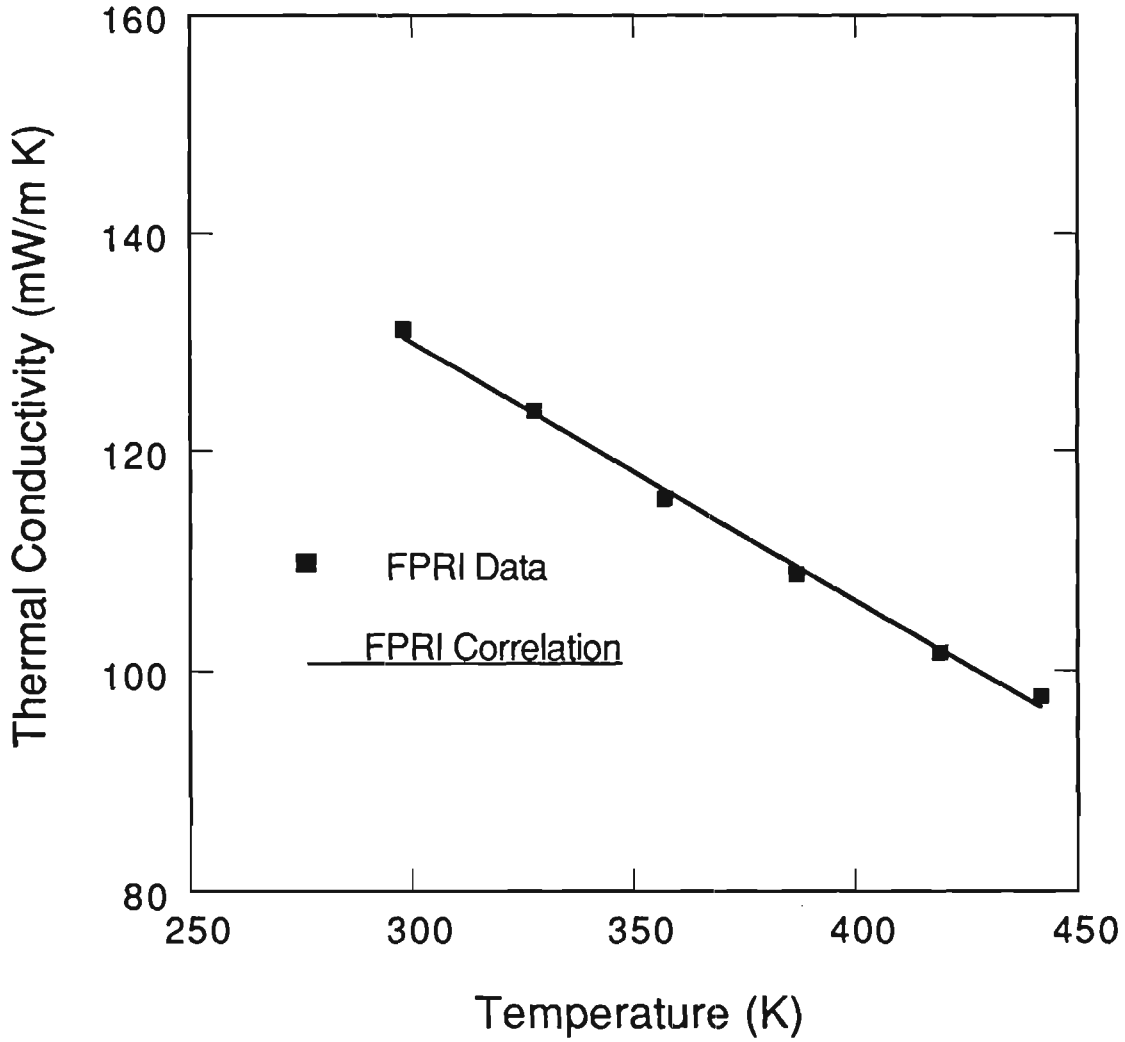
June, 1991 DDS-LTC-A52

Diethyl Disulfide



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June, 1991 DDS-LTC-A53

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

2-Methoxyethanol

$CH_3OCH_2CH_2OH$
CA-No: 109-86-4

Purity =	99.99 %	
Molecular Weight =	76.095 kg/kmol	[1]
Critical Temperature =	565.5 K	[2]
Critical Pressure =	50.1 bar	[2]
Critical Volume =	0.242 m^3/kmol	[3]
Melting Point =	188.1	[4]
Normal Boiling Point =	397.8 K	[4]
Liquid Molar Volume at 25 °C =	0.079266 m^3/kmol	[5]
Dipole Moment =	6.8×10^{-30} C-m	[4]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ [mW/m K]
297.7	176.3
319.2	173.7
339.1	167.6
362.3	162.2
388.7	155.1

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ [mW/m K]} = 248.92 - 0.2400117 \times T \text{ [K]}$$

% AAD = 0.3 %
% MAD = 0.8 %

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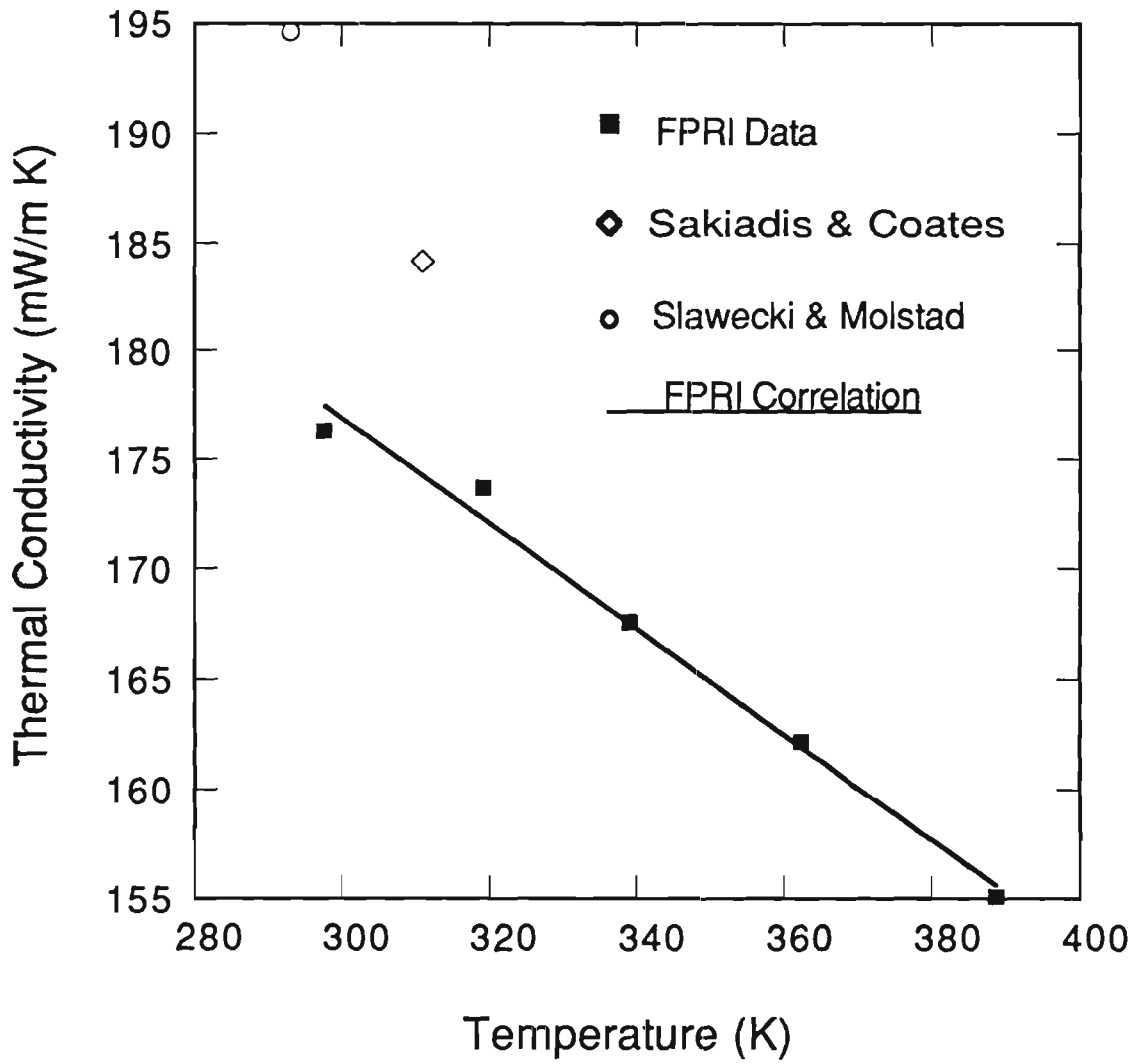
2-Methoxyethanol



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June, 1991 DDS-LTC-A54

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

2-(2-Methoxyethoxy) ethanol

$CH_3OCH_2CH_2OCH_2CH_2OH$
CA-No: 111-77-3

Purity =	99 %	
Molecular Weight =	120.148 kg/kmol	[1]
Critical Temperature =	630.8 K	[2]
Critical Pressure =	35.4 bar	[2]
Critical Volume =	0.367 m^3/kmol	[3]
Melting Point =	197.0 K	[4]
Normal Boiling Point =	467.3 K	[4]
Liquid Molar Volume at 25 °C =	0.11839 m^3/kmol	[5]
Dipole Moment =	5.3×10^{-30} C-m	[4]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ [mW/m K]
296.5	167.6
331.9	164.7
360.8	159.1
388.5	153.6
417.9	145.5
447.7	138.0

Liquid Thermal Conductivity Correlation:

$$\lambda \text{ [mW/m K]} = 230.129 - 0.201612 \times T \text{ [K]}$$

% AAD = 1.0 %
% MAD = 1.7 %

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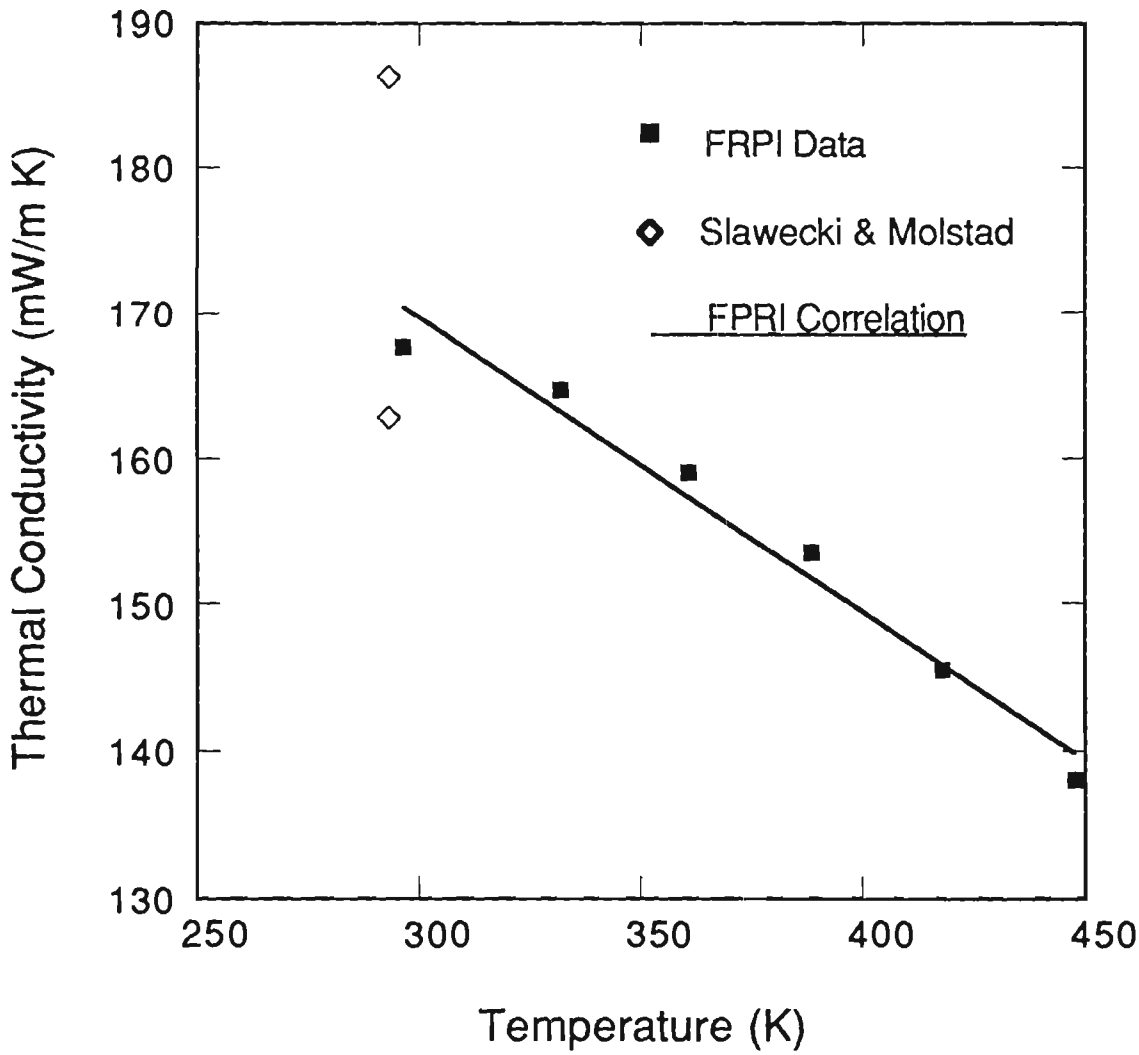
June, 1991 DDS-LTC-A54

2 -(2-Methoxyethoxy) Ethanol



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June, 1991 DDS-LTC-A55

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

2-[2-(2-Methoxyethoxy) ethoxy]- Ethanol

$CH_3(OCH_2CH_2)_3OH$
CA-No: 112-35-6

Purity =	95 %	
Molecular Weight =	164.201 kg/kmol	[1]
Critical Temperature =	677.2 K	[2]
Critical Pressure =	27.3 bar	[2]
Critical Volume =	0.493 m^3/kmol	[3]
Melting Point =	---	
Normal Boiling Point =	522 K	[4]
Liquid Molar Volume at 25 °C =	0.15735 m^3/kmol	[5]

Experimental Technique : Relative Transient Hot-Wire

Experimental Data:

Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ [mW/m K]
297.8	169.5
331.7	165.1
362.6	159.7
388.5	155.1
417.9	148.1
438.1	143.9

Liquid Thermal Conductivity Correlation:

$$\lambda\ [mW/m\ K] = 225.902 - 0.1851071 \times T\ [K]$$

% AAD = 0.5 %
% MAD = 0.8 %

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June, 1991

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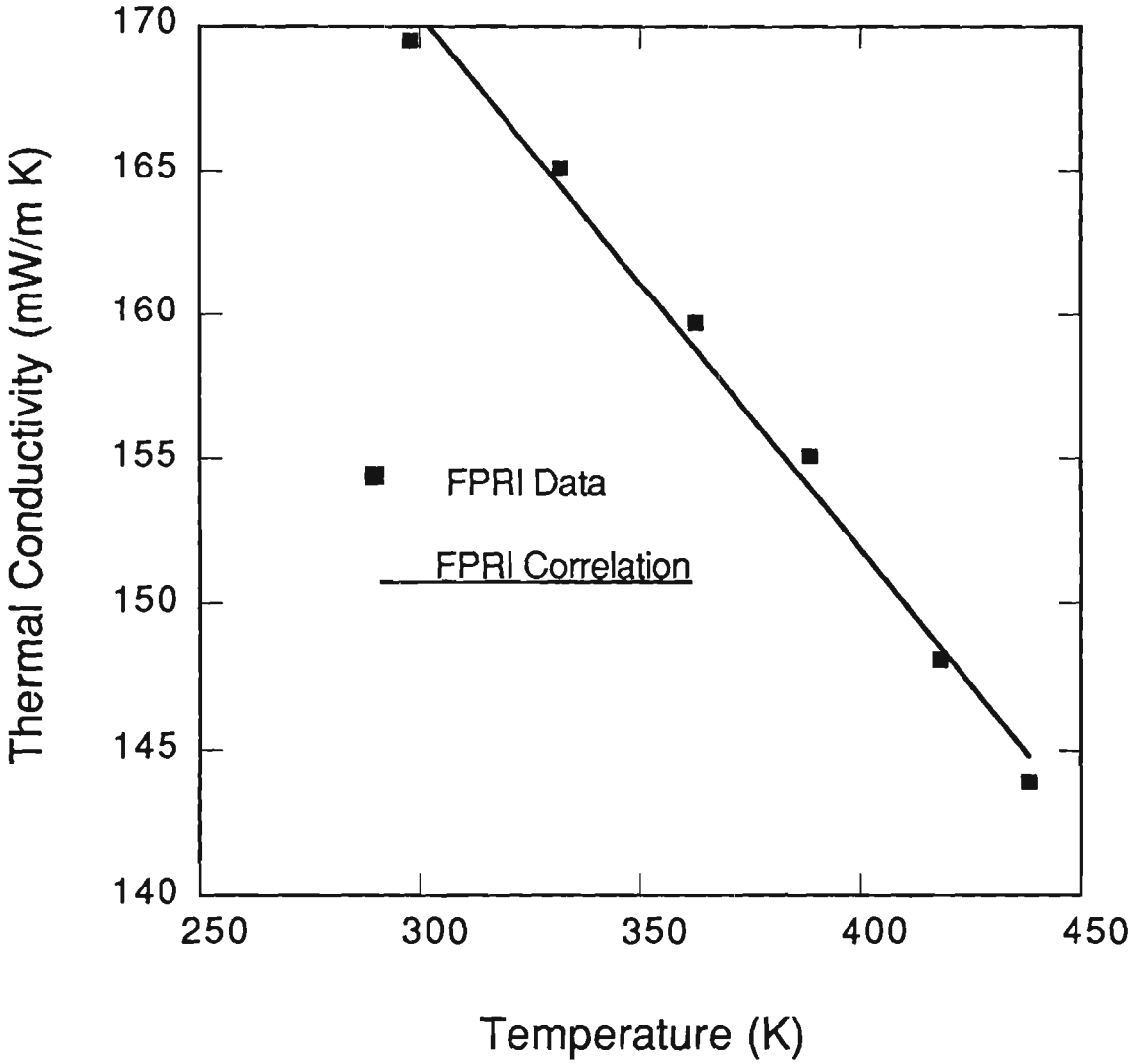
2 -[2-(2-Methoxyethoxy) ethoxy] Ethanol



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4. Weast, R. C.; Grasselli, J. G., "Handbook of Data on Organic Compounds", CRC Press, Boca Raton, Fla. (1989).

5. Estimated from the density correlation reported in this data sheet.

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ANNUAL REPORT

July 1, 1994 - June 30, 1995

INDEX TO DESIGN SHEET
SERIES A 1994-95 RESULTS

Viscosity

A80	Butyl Ethanoate (Butyl Acetate)
A81	Pentyl Ethanoate (Pentyl Acetate)
A82	Hexyl Ethanoate (Hexyl Acetate)
A83	Octyl Ethanoate (Octyl Acetate)
A84	Heptanoic Acid
A85	Octanoic Acid
A86	Nonanoic Acid
A87	1,9-Nonanediol
A88	1,2-Decanediol
A89	1,10-Decanediol
A90	Dimethyl 2,6-Naphthalene Dicarboxylate

Density

A79	Butyl Ethanoate (Butyl Acetate)
A80	Pentyl Ethanoate (Pentyl Acetate)
A81	Hexyl Ethanoate (Hexyl Acetate)
A82	Octyl Ethanoate (Octyl Acetate)
A83	Heptanoic Acid
A84	Octanoic Acid
A85	Nonanoic Acid
A86	1,9-Nonanediol
A87	1,2-Decanediol
A88	1,10-Decanediol
A89	Dimethyl 2,6-Naphthalene Dicarboxylate

Thermal Conductivity

A89	Butyl Ethanoate (Butyl Acetate)
A90	Pentyl Ethanoate (Pentyl Acetate)
A91	Hexyl Ethanoate (Hexyl Acetate)
A92	Octyl Ethanoate (Octyl Acetate)
A93	Heptanoic Acid
A94	Octanoic Acid
A95	Nonanoic Acid
A96	1,9-Nonanediol
A97	1,2-Decanediol
A98	1,10-Decanediol
A99	Dimethyl 2,6-Naphthalene Dicarboxylate

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May, 1995 DDS-LV-A80

DESIGN DATA STANDARD - LIQUID VISCOSITY

Butyl Ethanoate (Butyl Acetate)

$CH_3CO_2(CH_2)_3CH_3$
CA - No: 123-86-4

Purity =	99.7 %	
Molecular Weight =	116.16 kg/kmol	[1]
Critical Temperature =	570.9 K	[2]
Critical Pressure =	32.7 bar	[2]
Critical Volume =	0.3955 m^3/kmol	[2]
Normal Boiling Point =	399.2 K	[3]
Melting Point =	195 K	[4]
Liquid Molar Volume at 25 °C =	0.13243 m^3/kmol	[5]

Experimental Technique : Capillary Viscometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
293.20	0.728
305.05	0.622
317.05	0.538
329.05	0.472
341.05	0.416
353.05	0.372
365.00	0.336
377.05	0.303
389.05	0.275
397.05	0.259

Liquid Viscosity Correlation:

1) $\ln(\mu/cP) = -4.14560 + 1079.60 / (T/K - 11.0310)$
% AAD = 0.19 % % MAD = 0.50 %

2) $\ln(\mu/cP) = -5.81038 + 1230.95 / (T/K) + 0.227500 \ln(T/K)$
% AAD = 0.19 % % MAD = 0.50 %

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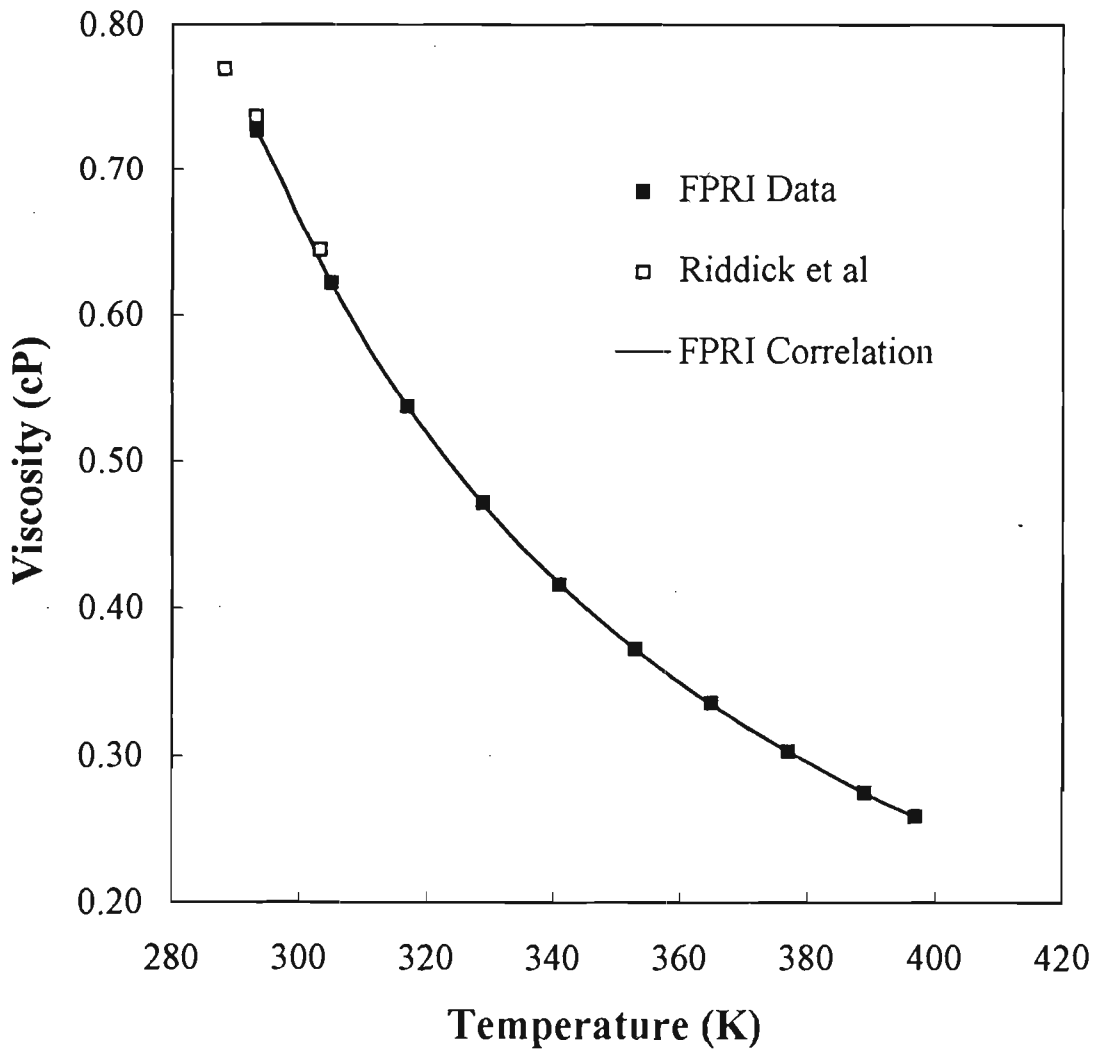
May, 1995 DDS-LV-A80

Butyl Ethanoate



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4. Provided by Aldrich Company.

5. Estimated from FPRI density correlation.

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FPRI

May, 1995 DDS-LV-A81

DESIGN DATA STANDARD - LIQUID VISCOSITY

Pentyl Ethanoate (Pentyl Acetate)

$CH_3CO_2(CH_2)_4CH_3$
CA - No: 628-63-7

Purity =	99 %	
Molecular Weight =	130.19 kg/kmol	[1]
Critical Temperature =	593.3 K	[2]
Critical Pressure =	29.4 bar	[2]
Critical Volume =	0.4515 m^3/kmol	[2]
Normal Boiling Point =	422.4 K	[3]
Melting Point =	173.2 K	[4]
Liquid Molar Volume at 25 °C =	0.14907 m^3/kmol	[5]

Experimental Technique : Capillary Viscometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
293.05	0.950
309.05	0.750
325.05	0.623
341.05	0.519
357.05	0.435
373.15	0.374
389.10	0.330
405.00	0.292
420.95	0.262

Liquid Viscosity Correlation:

1) $\ln(\mu/cP) = -3.84102 + 938.411 / (T/K - 45.5632)$
% AAD = 0.49 % % MAD = 1.01 %

2) $\ln(\mu/cP) = -10.4145 + 1555.09 / (T/K) + 0.890089 \ln(T/K)$
% AAD = 0.47 % % MAD = 0.89 %

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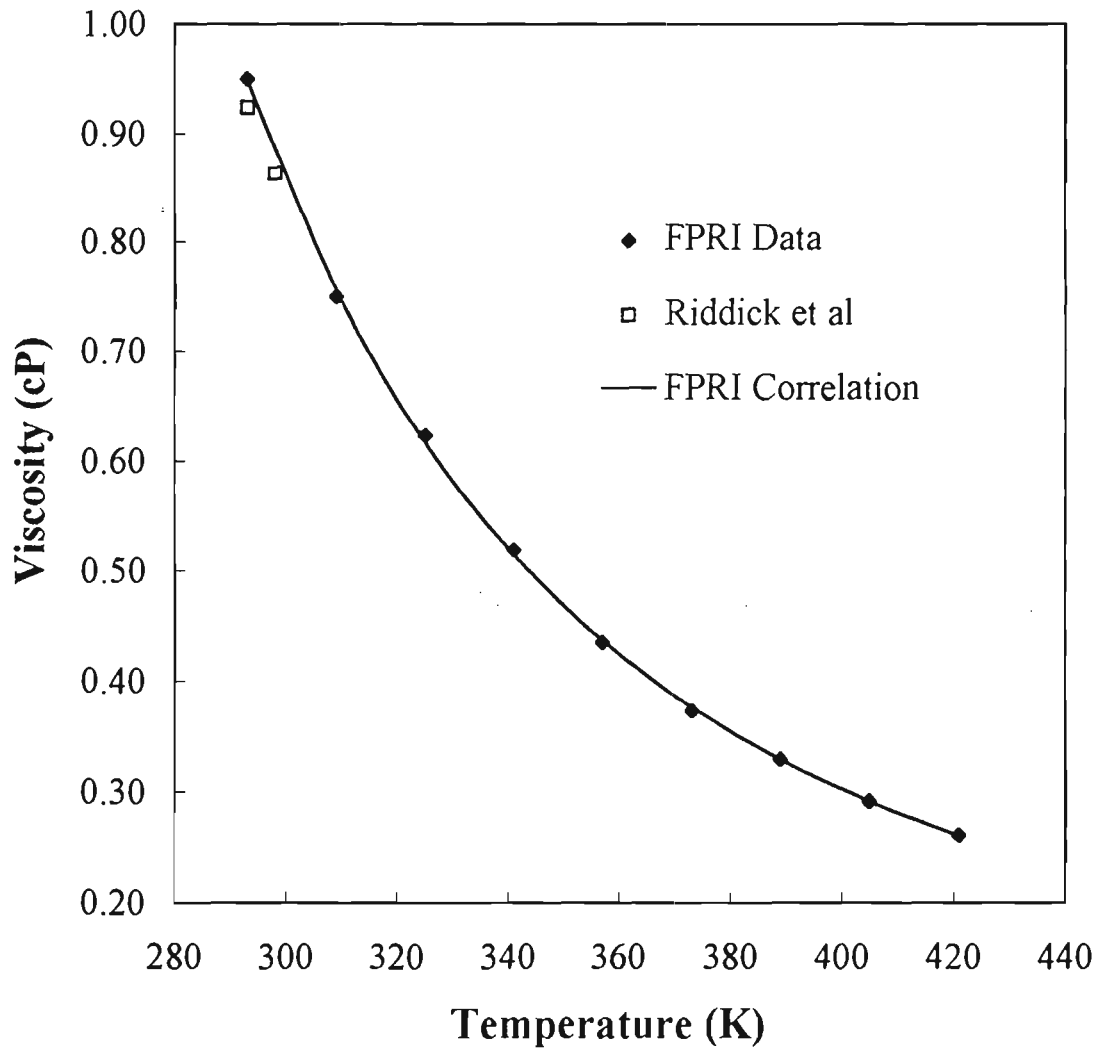
Pentyl Ethanoate



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

4. Provided by Aldrich Company.

5. Estimated from FPRI density correlation.

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May, 1995 DDS-LV-A82

DESIGN DATA STANDARD - LIQUID VISCOSITY

Hexyl Ethanoate (Hexyl Acetate)

$CH_3CO_2(CH_2)_5CH_3$
CA - No: 142-92-7

Purity =	99 %	
Molecular Weight =	144.21 kg/kmol	[1]
Critical Temperature =	613.0 K	[2]
Critical Pressure =	26.6 bar	[2]
Critical Volume =	0.5075 m^3/kmol	[2]
Normal Boiling Point =	443.7 K	[3]
Melting Point =	193 K	[4]
Liquid Molar Volume at 25 °C =	0.16601 m^3/kmol	[5]

Experimental Technique : Capillary Viscometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
293.65	1.163
310.75	0.884
328.05	0.703
345.05	0.575
363.05	0.478
390.05	0.371
398.05	0.348
414.95	0.304
424.75	0.283

Liquid Viscosity Correlation:

1) $\ln(\mu/cP) = -3.91928 + 1008.17 / (T/K - 45.6281)$
% AAD = 0.31 % % MAD = 0.67 %

2) $\ln(\mu/cP) = -12.4051 + 1744.38 / (T/K) + 1.16320 \ln(T/K)$
% AAD = 0.37 % % MAD = 0.73 %

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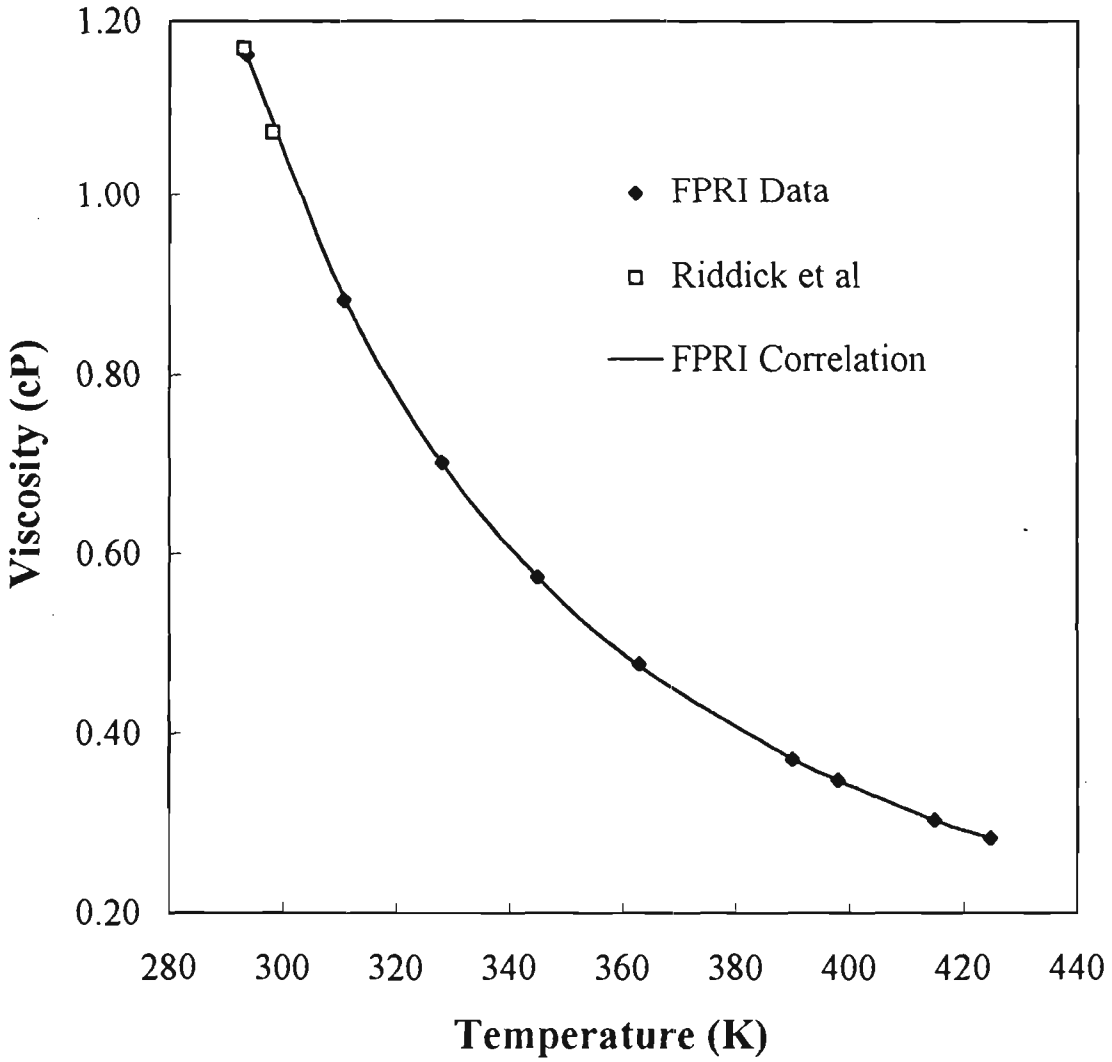
May, 1995 DDS-LV-A82

Hexyl Ethanoate



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

4. Provided by Aldrich Company.

5. Estimated from FPRI density correlation.

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May, 1995 DDS-LV-A83

DESIGN DATA STANDARD - LIQUID VISCOSITY

Octyl Ethanoate (Octyl Acetate)

$CH_3CO_2(CH_2)_7CH_3$
CA - No: 112-14-1

Purity =	99+ %	
Molecular Weight =	172.27 kg/kmol	[1]
Critical Temperature =	649.6 K	[2]
Critical Pressure =	22.0 bar	[2]
Critical Volume =	0.6195 m^3/kmol	[2]
Normal Boiling Point =	484.2 K	[3]
Melting Point =	274.1 K	[2]
Liquid Molar Volume at 25 °C =	0.19911 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
293.90	1.801
307.95	1.395
322.85	1.126
338.05	0.903
353.05	0.758
367.75	0.643
383.20	0.553
397.85	0.487
412.75	0.435
427.65	0.384

Liquid Viscosity Correlation:

1) $\ln(\mu/cP) = -3.40445 + 851.878 / (T/K - 80.4550)$
% AAD = 0.44 % % MAD = 0.87 %

2) $\ln(\mu/cP) = -20.6538 + 2277.16 / (T/K) + 2.37358 \ln(T/K)$
% AAD = 0.48 % % MAD = 0.87 %

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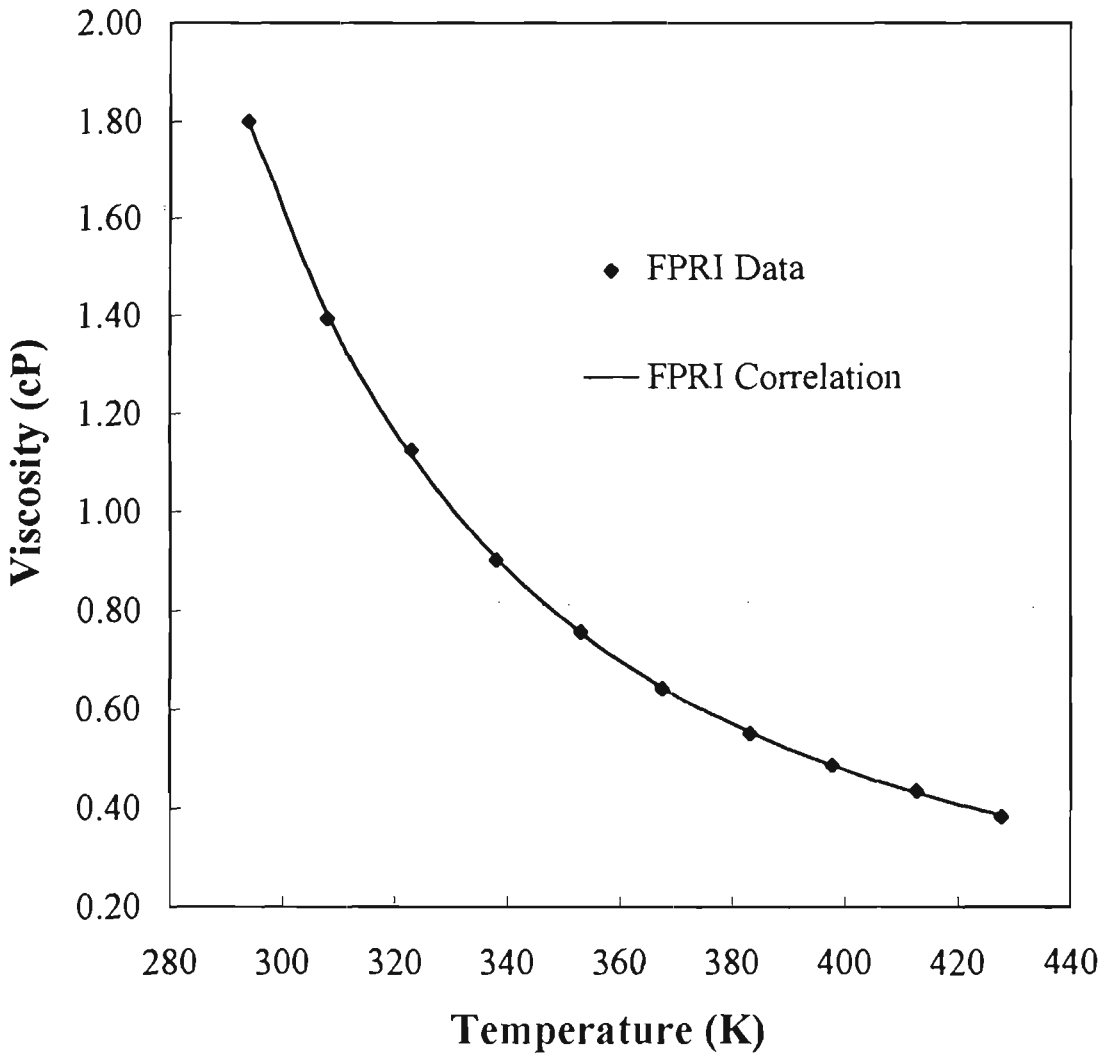
May, 1995 DDS-LV-A83

Octyl Ethanoate



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1995 DDS-LV-A84

DESIGN DATA STANDARD - LIQUID VISCOSITY

Heptanoic Acid

$CH_3 (CH_2)_5CO_2H$
CA - No: 111-14-8

Purity =	99 %	
Molecular Weight =	130.19 kg/kmol	[1]
Critical Temperature =	663.1 K	[2]
Critical Pressure =	33.2 bar	[2]
Critical Volume =	0.4525 m^3/kmol	[2]
Normal Boiling Point =	496.2 K	[3]
Melting Point =	264.3 K	[3]
Liquid Molar Volume at 25 °C =	0.14245 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
290.25	4.634
307.95	3.059
323.05	2.298
338.05	1.745
353.05	1.387
367.05	1.129
383.15	0.937
397.90	0.793
412.85	0.681
427.65	0.590

Liquid Viscosity Correlation:

1) $\ln (\mu /cP) = -3.51816 + 1009.60 / (T /K - 90.4194)$
% AAD = 0.42 % % MAD = 1.02 %

2) $\ln (\mu /cP) = -29.9684 + 3131.35 / (T /K) + 3.65202 \ln (T /K)$
% AAD = 0.54 % % MAD = 0.84 %

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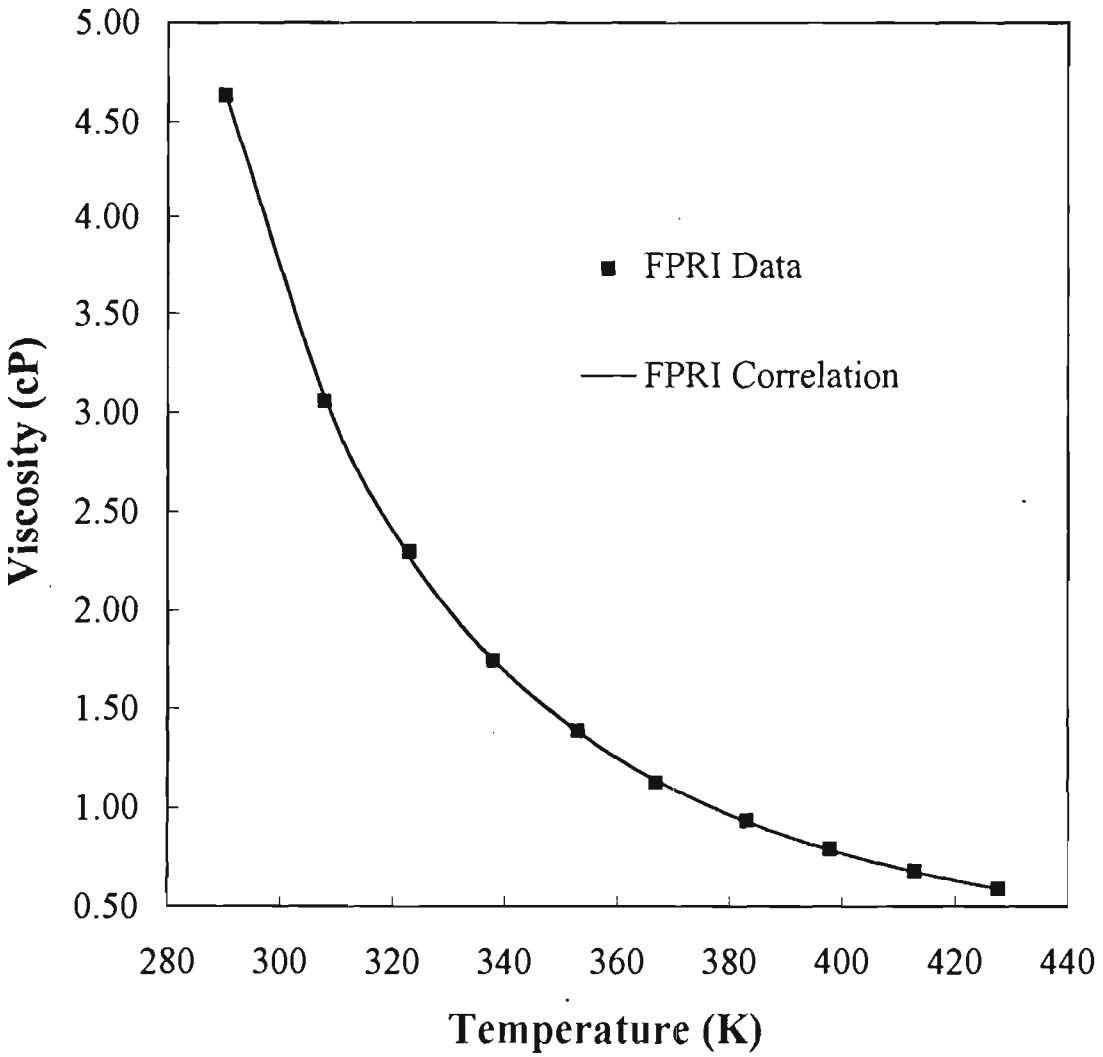
Heptanoic Acid



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1995 DDS-LV-A85

DESIGN DATA STANDARD - LIQUID VISCOSITY

Octanoic Acid

$CH_3 (CH_2)_6CO_2H$
CA - No: 124-07-2

Purity =	99.5+ %	
Molecular Weight =	144.22 kg/kmol	[1]
Critical Temperature =	677.1 K	[2]
Critical Pressure =	29.8 bar	[2]
Critical Volume =	0.5085 m^3/kmol	[2]
Normal Boiling Point =	513.1 K	[3]
Melting Point =	289.5 K	[4]
Liquid Molar Volume at 25 °C =	0.15916 m^3/kmol	[5]

Experimental Technique : Capillary Viscometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
293.25	5.859
307.95	3.982
323.05	2.875
338.05	2.168
353.05	1.691
367.75	1.360
383.05	1.107
398.05	0.923
412.85	0.784
427.70	0.671

Liquid Viscosity Correlation:

1) $\ln (\mu /cP) = -3.55945 + 1052.12 / (T /K - 95.3985)$
% AAD = 0.46 % % MAD = 0.97 %

2) $\ln (\mu /cP) = -243.592 +9785.76 / (T /K) + 39.9001 \ln (T /K) - 0.050081\ T /K$
% AAD = 0.20 % % MAD = 0.58 %

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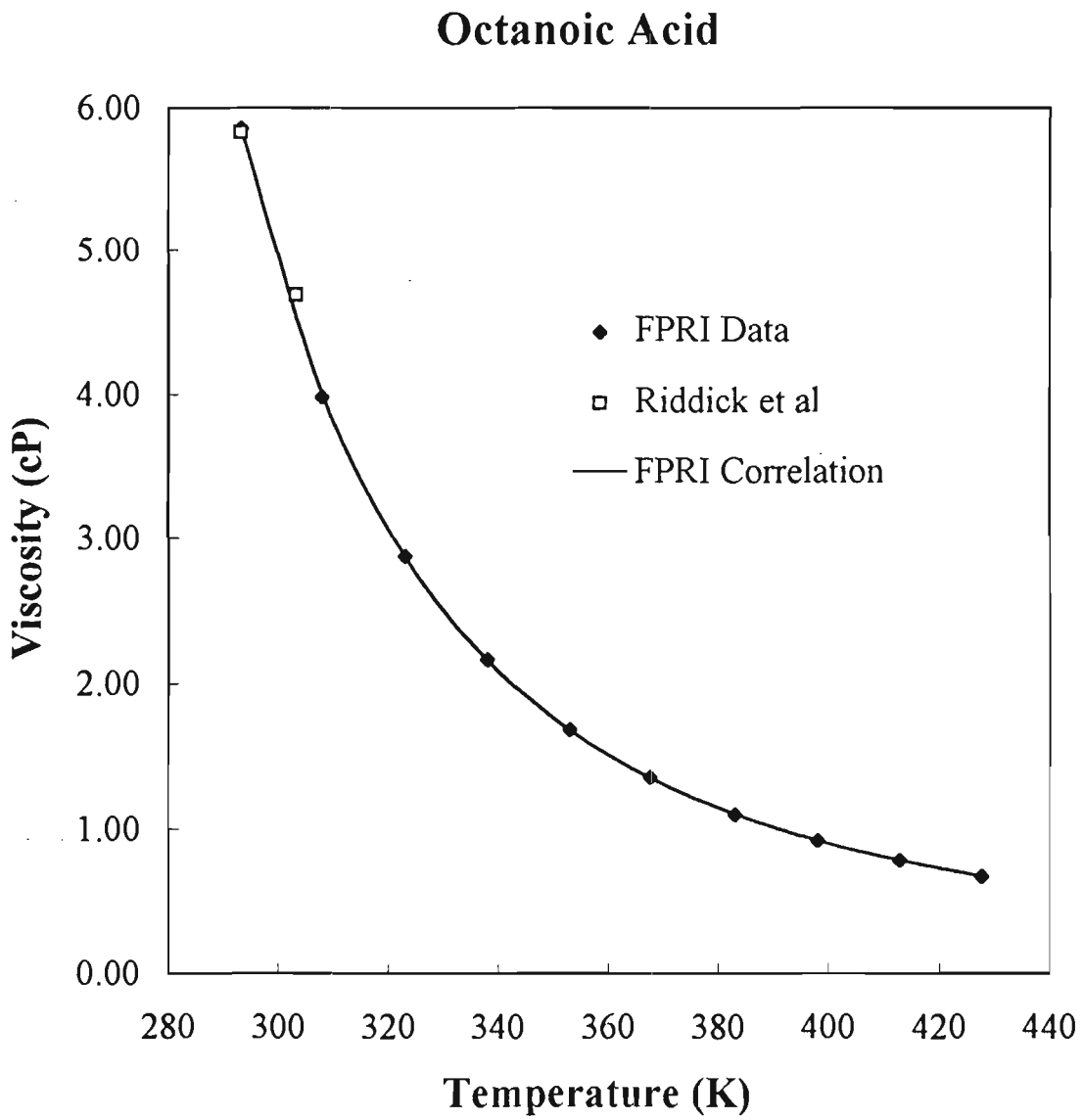

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3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

4. Provided by Aldrich Company.

5. Estimated from FPRI density correlation.

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May, 1995 DDS-LV-A86

DESIGN DATA STANDARD - LIQUID VISCOSITY

Nonanoic Acid

$CH_3 (CH_2)_7CO_2H$
CA - No: 112-05-0

Purity =	96 %	
Molecular Weight =	158.24 kg/kmol	[1]
Critical Temperature =	689.8 K	[2]
Critical Pressure =	26.9 bar	[2]
Critical Volume =	0.5645 m^3/kmol	[2]
Normal Boiling Point =	528.8 K	[3]
Melting Point =	282.2 K	[4]
Liquid Molar Volume at 25 °C =	0.17553 m^3/kmol	[5]

Experimental Technique : Capillary Viscometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
292.50	8.203
307.95	5.248
323.05	3.665
338.05	2.698
353.05	2.068
368.00	1.627
383.25	1.307
398.10	1.078
413.00	0.902
427.90	0.765

Liquid Viscosity Correlation:

1) $\ln (\mu /cP) = -3.53968 + 1061.73 / (T /K - 104.018)$
% AAD = 0.57 % % MAD = 1.11 %

2) $\ln (\mu /cP) = -299.919 +11769.2 / (T /K) + 49.2940 \ln (T /K) - 0.0619834\ T /K$
% AAD = 0.24 % % MAD = 0.49 %

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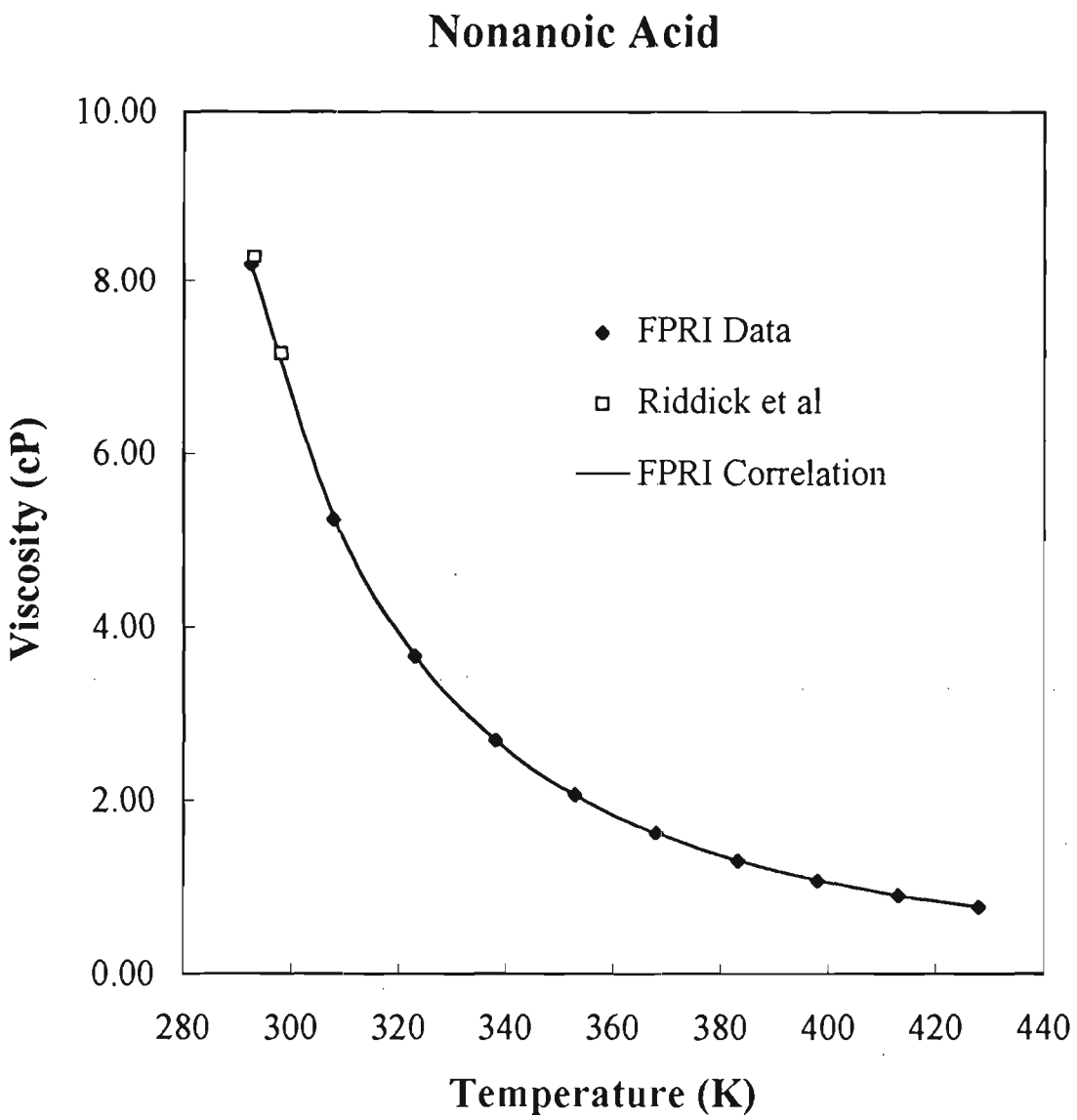
May, 1995 DDS-LV-A86



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3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

4. Provided by Aldrich Company.

5. Estimated from FPRI density correlation.

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May, 1995 DDS-LV-A87

DESIGN DATA STANDARD - LIQUID VISCOSITY

1,9-Nonanediol

$HO\ (CH_2)_9\ OH$
CA - No: 3937-56-2

Purity =	98 %	
Molecular Weight =	160.26 kg/kmol	[1]
Critical Temperature =	746.6 K	[2]
Critical Pressure =	27.8 bar	[2]
Critical Volume =	0.5775 m^3/kmol	[2]
Normal Boiling Point =	589.7 K	[2]
Melting Point =	312.3 K	[3]
Liquid Molar Volume at 25 °C =	0.17233 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
323.45	50.79
338.55	26.40
353.25	14.78
368.15	8.785
383.15	5.493
398.05	3.662
413.05	2.556
422.85	2.064
432.75	1.695

Liquid Viscosity Correlation:

1) $\ln(\mu/cP) = -5.62654 + 1877.54 / (T/K - 127.267)$
% AAD = 0.85 % % MAD = 1.62 %

2) $\ln(\mu/cP) = 195.252 - 253.421 / (T/K) - 36.5818 \ln(T/K) + 0.0645189\ T/K$
% AAD = 0.19 % % MAD = 0.38 %

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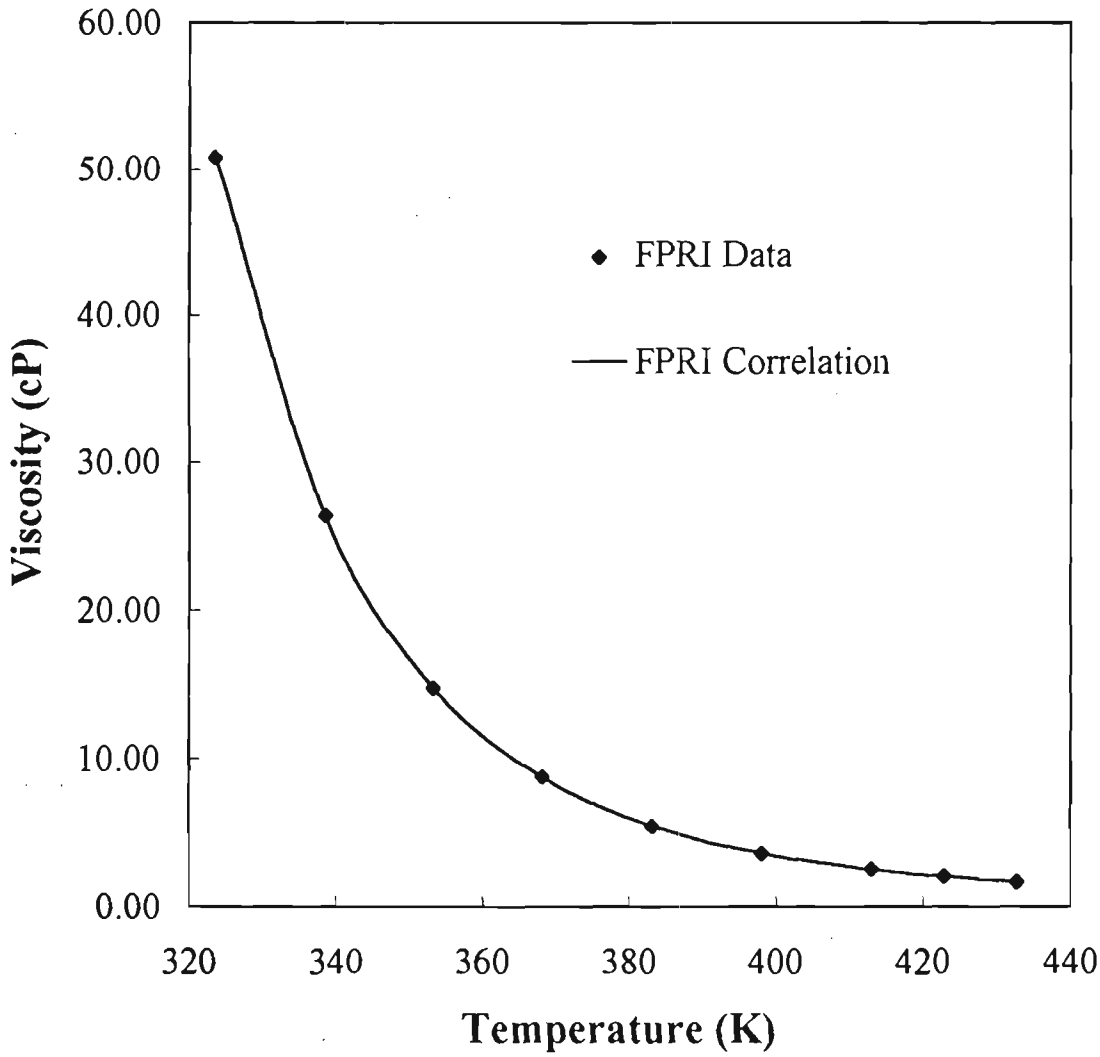
May, 1995 DDS-LV-A87

1,9-Nonanediol



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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1995 DDS-LV-A88

DESIGN DATA STANDARD - LIQUID VISCOSITY

1,2-Decanediol

$CH_3 (CH_2)_7 CH(OH) CH_2 OH$
CA - No: 1119-86-4

Purity =	98 %	
Molecular Weight =	174.28 kg/kmol	[1]
Critical Temperature =	665.6 K	[2]
Critical Pressure =	25.4 bar	[2]
Critical Volume =	0.6275 m^3/kmol	[2]
Normal Boiling Point =	528.2 K	[3]
Melting Point =	308.6 K	[3]
Liquid Molar Volume at 25 °C =	0.19037 m^3/kmol	[4]

Experimental Technique : Capillary Viscometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
324.25	26.29
338.35	14.24
353.30	8.197
368.15	5.126
383.25	3.382
398.05	2.379
413.05	1.742
423.05	1.449
432.95	1.232

Liquid Viscosity Correlation:

1) $\ln (\mu /cP) = -4.18479 + 1157.75 / (T /K - 169.046)$
% AAD = 0.41 % % MAD = 0.64 %

2) $\ln (\mu /cP) = -336.945 + 16984.0 / (T /K) + 52.3948 \ln (T /K) - 0.046534\ T /K$
% AAD = 0.17 % % MAD = 0.29 %

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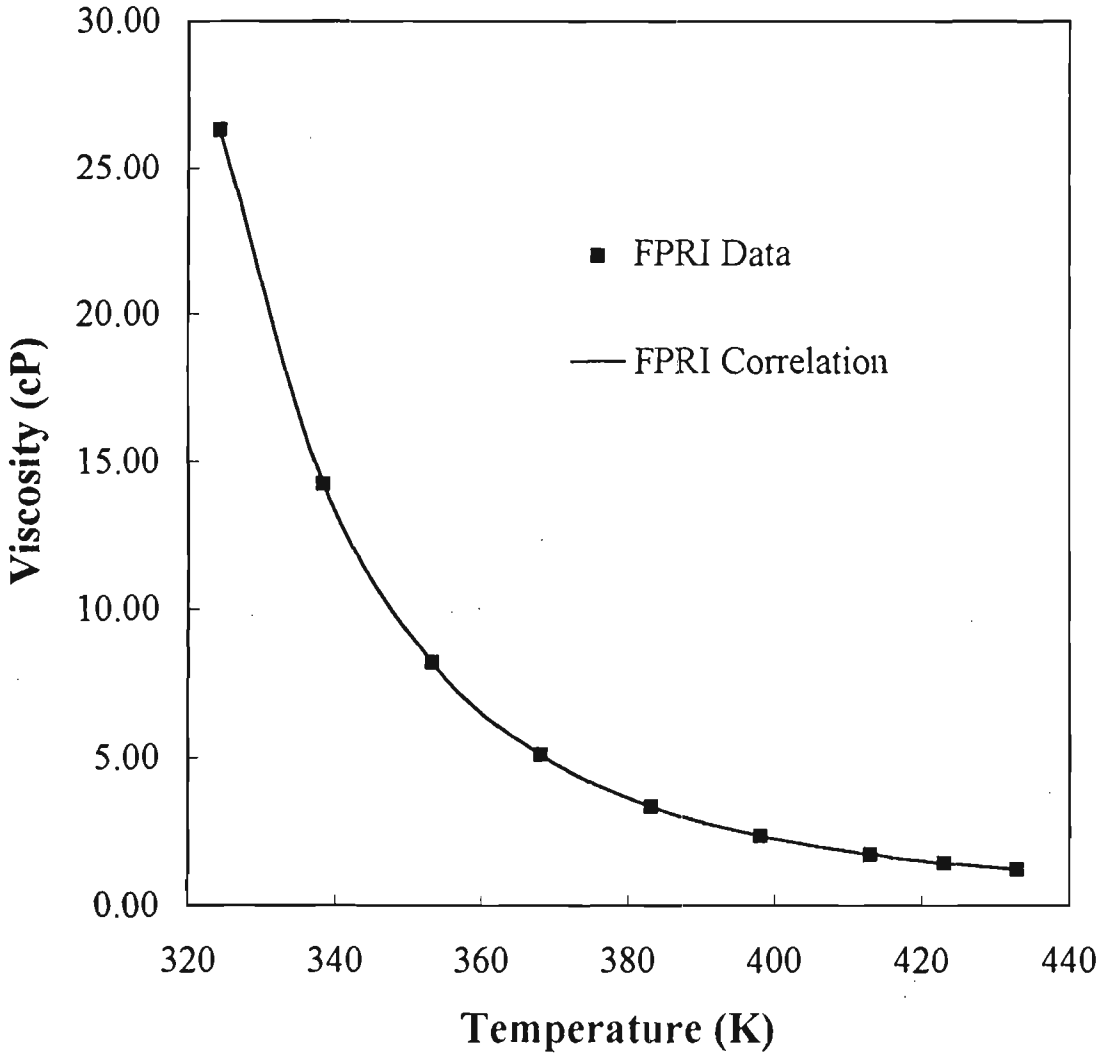
1,2-Decanediol



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1995 DDS-LV-A89

DESIGN DATA STANDARD - LIQUID VISCOSITY

1,10-Decanediol

$HO\ (CH_2)_{10}\ OH$
CA - No: 112-47-0

Purity =	98 %	
Molecular Weight =	174.28 kg/kmol	[1]
Critical Temperature =	769.8 K	[2]
Critical Pressure =	25.2 bar	[2]
Critical Volume =	0.6335 m^3/kmol	[2]
Normal Boiling Point =	612.6 K	[2]
Melting Point =	323.6 K	[2]
Liquid Molar Volume at 25 °C =	0.18933 m^3/kmol	[3]

Experimental Technique : Capillary Viscometer

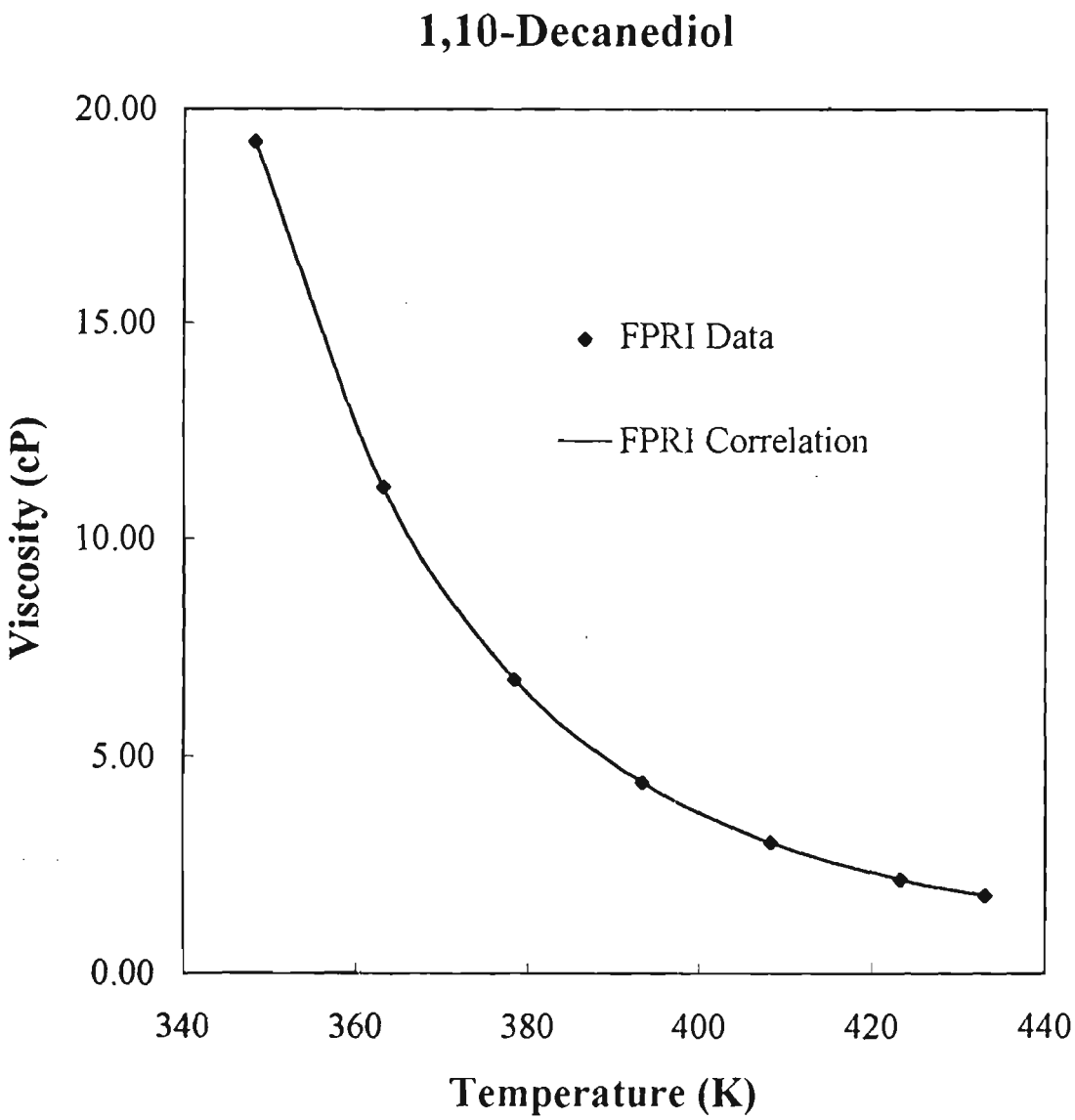
Experimental Data:
Pressure = Ambient
Accuracy = ± 1.0 %

T (K)	μ (cP)
348.20	19.24
363.25	11.20
378.45	6.776
393.35	4.411
408.25	3.021
423.25	2.170
433.05	1.786

Liquid Viscosity Correlation:

1) $\ln(\mu/cP) = -5.00991 + 1581.44 / (T/K - 149.93)$
% AAD = 0.57 % % MAD = 1.26 %

2) $\ln(\mu/cP) = 435.041 - 8037.01 / (T/K) - 76.7848 \ln(T/K) + 0.116035\ T/K$
% AAD = 0.21 % % MAD = 0.42 %


1,10-Decanediol
20.00
15.00
10.00
5.00
0.00
Viscosity (cP)
FPRI Data
FPRI Correlation
340
360
380
400
420
440
Temperature (K)

REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Estimated from FPRI density correlation.

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May, 1995 DDS-LV-A90

DESIGN DATA STANDARD - LIQUID VISCOSITY

Dimethyl 2,6-Naphthalene Dicarboxylate

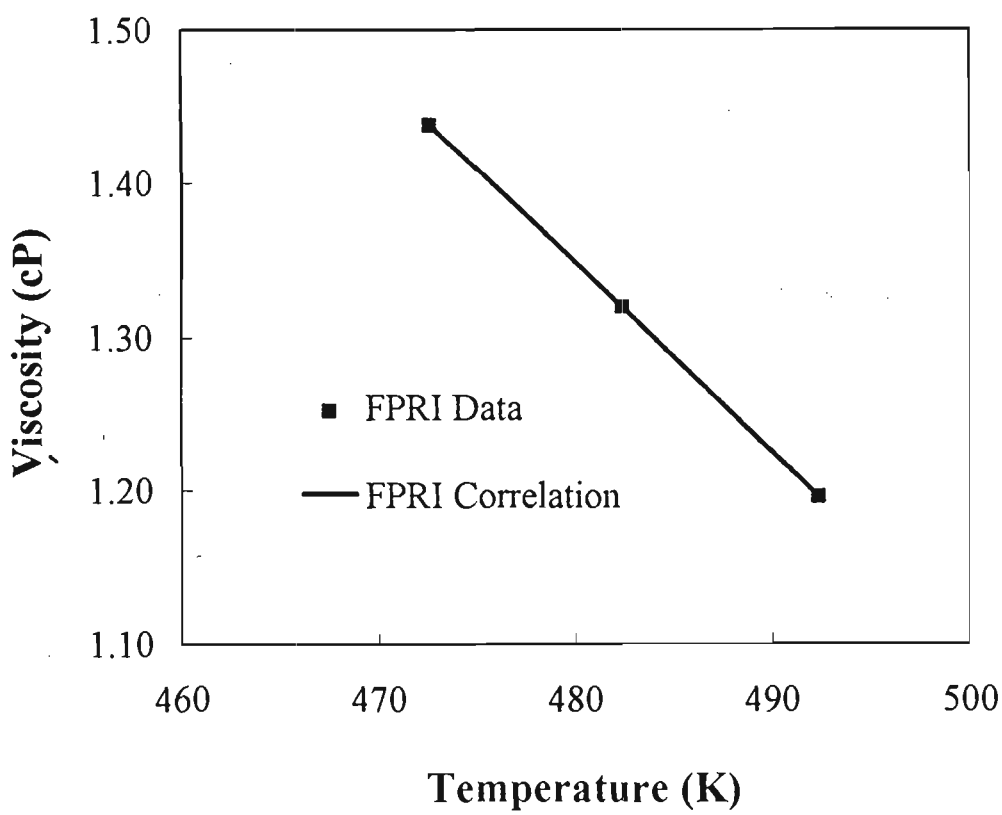
Melting Point = 473 K Provided by AMOCO

Experimental Technique : Capillary Viscometer

Pressure = Ambient Accuracy = ± 2 %

T (K)	μ (cP)
472.65	1.438
482.40	1.320
492.35	1.196

Viscosity Correlation: $\ln(\mu/cP) = 1.79177 + 246.306 / (T/K - 645.07)$



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FPRI

May, 1995 DDS-LD-A79

DESIGN DATA STANDARD - LIQUID DENSITY

Butyl Ethanoate (Butyl Acetate)

$CH_3CO_2(CH_2)_3CH_3$
CA - No: 123-86-4

Purity =	99.7 %	
Molecular Weight =	116.16 kg/kmol	[1]
Critical Temperature =	570.9 K	[2]
Critical Pressure =	32.7 bar	[2]
Critical Volume =	0.3955 m^3/kmol	[2]
Normal Boiling Point =	399.2 K	[3]
Melting Point =	195 K	[4]
Liquid Molar Volume at 25 °C =	0.13243 m^3/kmol	[5]

Experimental Technique : Pycnometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (kg/m^3)
293.20	882.4
305.05	869.9
317.05	857.4
329.05	844.6
341.05	831.7
353.05	818.9
365.00	805.3
377.05	791.4
389.05	777.7
397.05	768.5

Liquid Density Correlation:

1) $$\rho / \text{kg m}^{-3} = 137.8427 / 0.3450077^{[1+(1-T/K/570.9)^{0.4094916}]}$$
% AAD = 0.013 % % MAD = 0.038 %

2) $$\rho / \text{kg m}^{-3} = 1119.395 - 0.5970281\ T/K - 0.7224772\times10^{-3}(T/K)^2$$
% AAD = 0.015 % % MAD = 0.041 %

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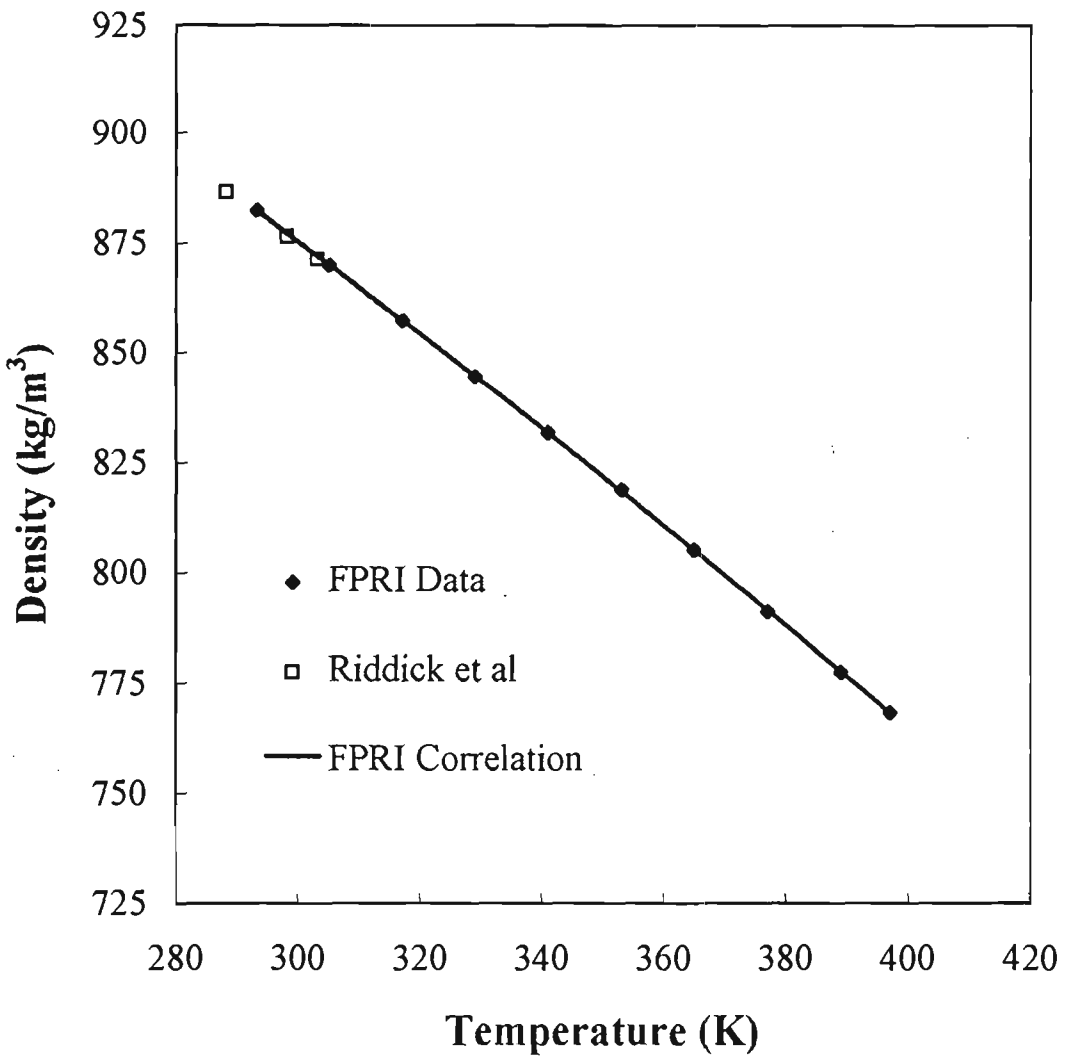
May, 1995 DDS-LD-A79

Butyl Ethanoate



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

4. Provided by Aldrich Company.

5. Estimated from FPRI density correlation.

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May, 1995 DDS-LD-A80

DESIGN DATA STANDARD - LIQUID DENSITY

Pentyl Ethanoate (Pentyl Acetate)

$CH_3CO_2(CH_2)_4CH_3$
CA - No: 628-63-7

Purity =	99 %	
Molecular Weight =	130.19 kg/kmol	[1]
Critical Temperature =	593.3 K	[2]
Critical Pressure =	29.4 bar	[2]
Critical Volume =	0.4515 m^3/kmol	[2]
Normal Boiling Point =	422.4 K	[3]
Melting Point =	173.2 K	[4]
Liquid Molar Volume at 25 °C =	0.14907 m^3/kmol	[5]

Experimental Technique : Pycnometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (kg/m^3)
293.05	878.3
309.05	862.8
325.05	846.7
341.05	830.8
357.05	814.6
373.15	797.6
389.10	780.8
405.00	763.5
420.95	745.9

Liquid Density Correlation:

1) ρ /kg m^{-3} = $149.22 / 0.361274^{[1+(1-T/K/593.3)^{0.4400002}]}$
% AAD = 0.010 % % MAD = 0.020 %

2) ρ /kg m^{-3} = 1108.926 - 0.6152576 T/K - 0.5867629×10^{-3} $(T/K)^2$
% AAD = 0.010 % % MAD = 0.028 %

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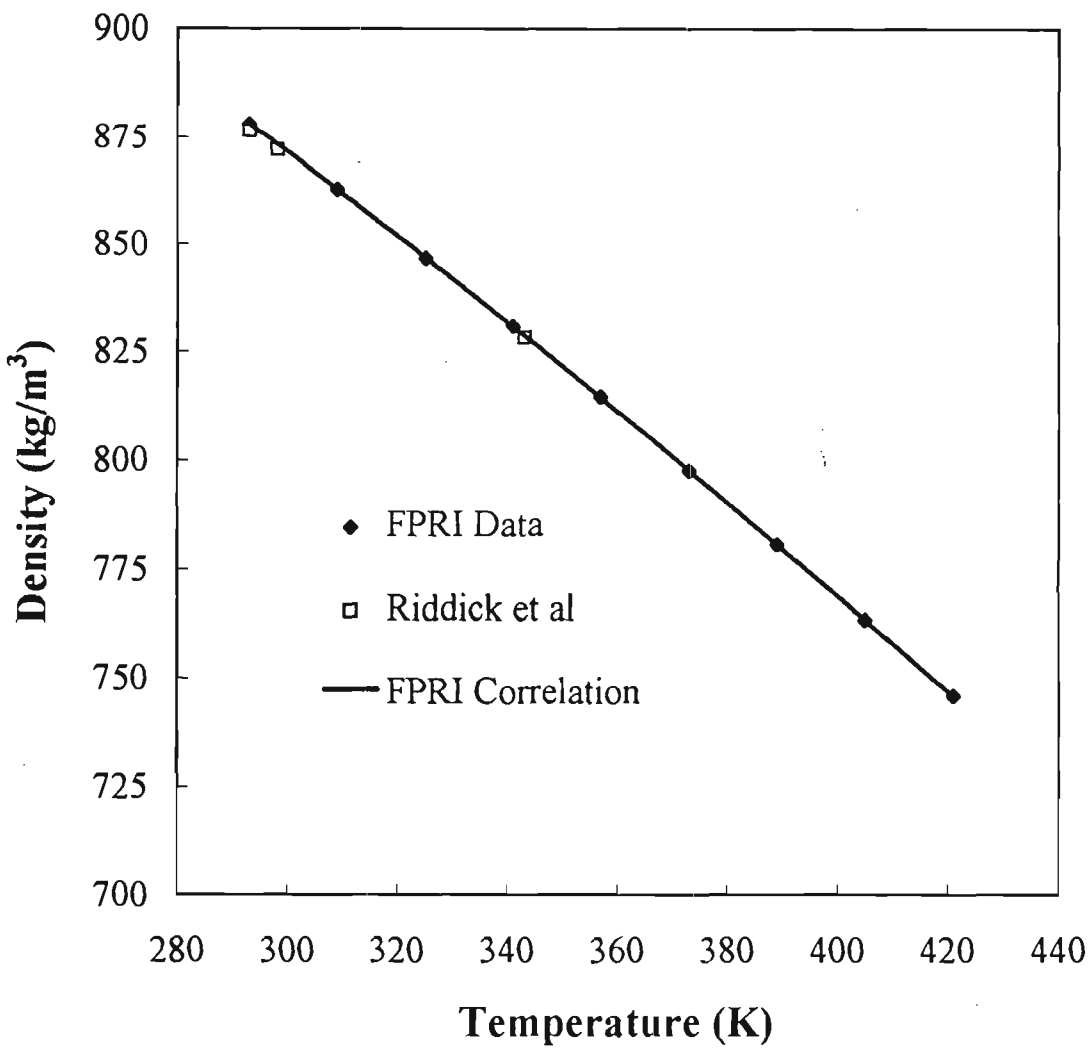
Pentyl Ethanoate



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

4. Provided by Aldrich Company.

5. Estimated from FPRI density correlation.

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May, 1995 DDS-LD-A81

DESIGN DATA STANDARD - LIQUID DENSITY

Hexyl Ethanoate (Hexyl Acetate)

$CH_3CO_2(CH_2)_5CH_3$
CA - No: 142-92-7

Purity =	99 %	
Molecular Weight =	144.21 kg/kmol	[1]
Critical Temperature =	613.0 K	[2]
Critical Pressure =	26.6 bar	[2]
Critical Volume =	0.5075 m^3/kmol	[2]
Normal Boiling Point =	443.7 K	[3]
Melting Point =	193 K	[4]
Liquid Molar Volume at 25 °C =	0.16601 m^3/kmol	[5]

Experimental Technique : Pycnometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (kg/m^3)
293.65	873.0
310.75	857.0
328.05	841.1
345.05	825.2
363.05	808.0
390.05	781.1
398.05	773.4
414.95	756.0
424.75	745.5

Liquid Density Correlation:

1) ρ /kg m^{-3} = $136.8670 / 0.3497494^{[1+(1-T/K/613)^{0.413618}]}$
% AAD = 0.017 % % MAD = 0.025 %

2) ρ /kg m^{-3} = $1088.342 - 0.5719477\ T/K - 0.5524885\times10^{-3}(T/K)^2$
% AAD = 0.021 % % MAD = 0.034 %

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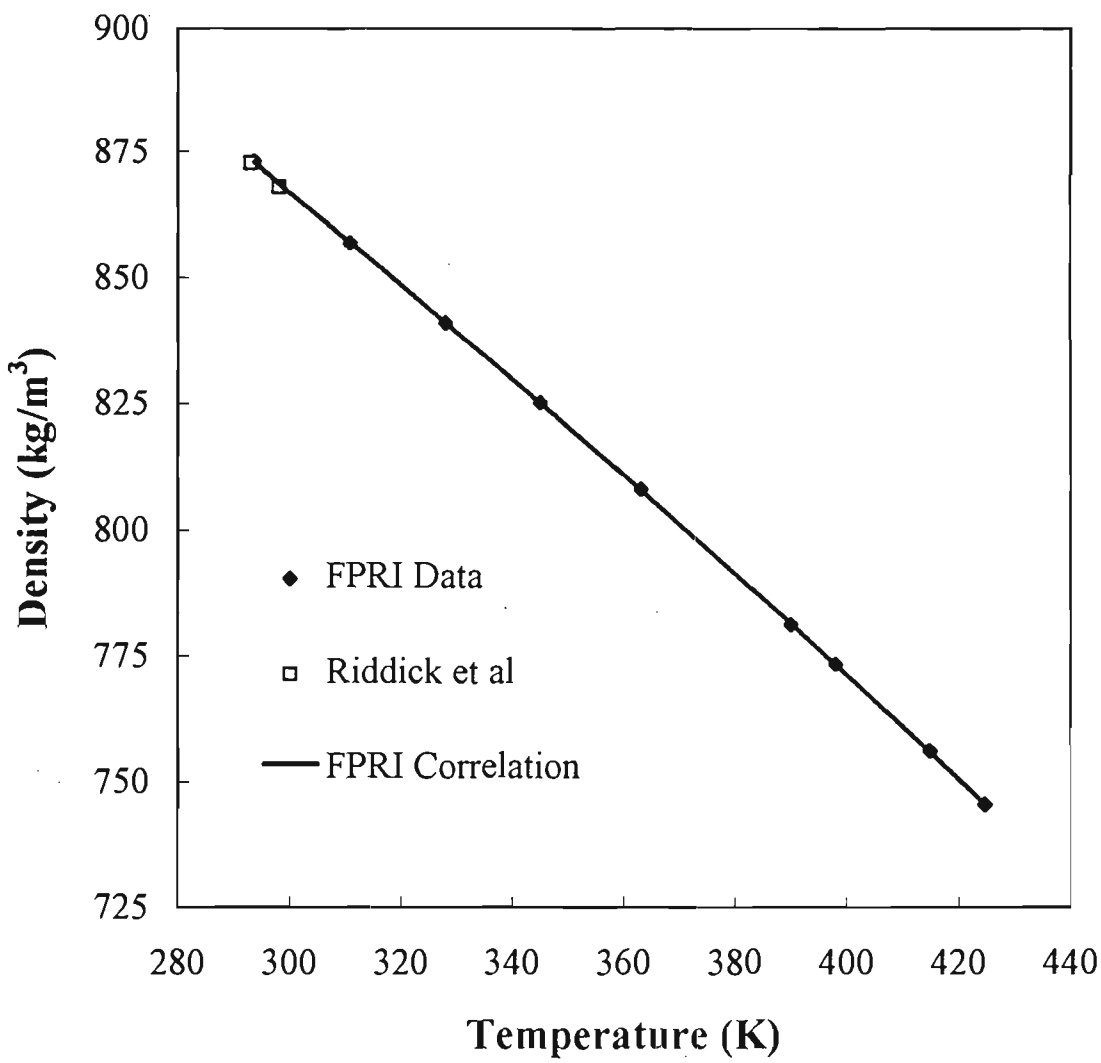
Hexyl Ethanoate



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3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

4. Provided by Aldrich Company.

5. Estimated from FPRI density correlation.

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May, 1995 DDS-LD-A82

DESIGN DATA STANDARD - LIQUID DENSITY

Octyl Ethanoate (Octyl Acetate)

$CH_3CO_2(CH_2)_7CH_3$
CA - No: 112-14-1

Purity =	99+ %	
Molecular Weight =	172.27 kg/kmol	[1]
Critical Temperature =	649.6 K	[2]
Critical Pressure =	22.0 bar	[2]
Critical Volume =	0.6195 m^3/kmol	[2]
Normal Boiling Point =	484.2 K	[3]
Melting Point =	274.1 K	[2]
Liquid Molar Volume at 25 °C =	0.19911 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (kg/m^3)
293.90	868.9
307.95	856.7
322.85	843.8
338.05	830.8
353.05	817.6
367.75	804.2
383.20	790.0
397.85	776.6
412.75	762.8
427.65	749.0

Liquid Density Correlation:

1) ρ /kg m^{-3} = $146.8329 / 0.364046^{[1+(1-T/K/649.6)^{0.4567712}]}$
% AAD = 0.017 % % MAD = 0.033 %

2) ρ /kg m^{-3} = $1087.397 - 0.6384055\ T/K - 0.3582102\times10^{-3}(T/K)^2$
% AAD = 0.015 % % MAD = 0.030 %

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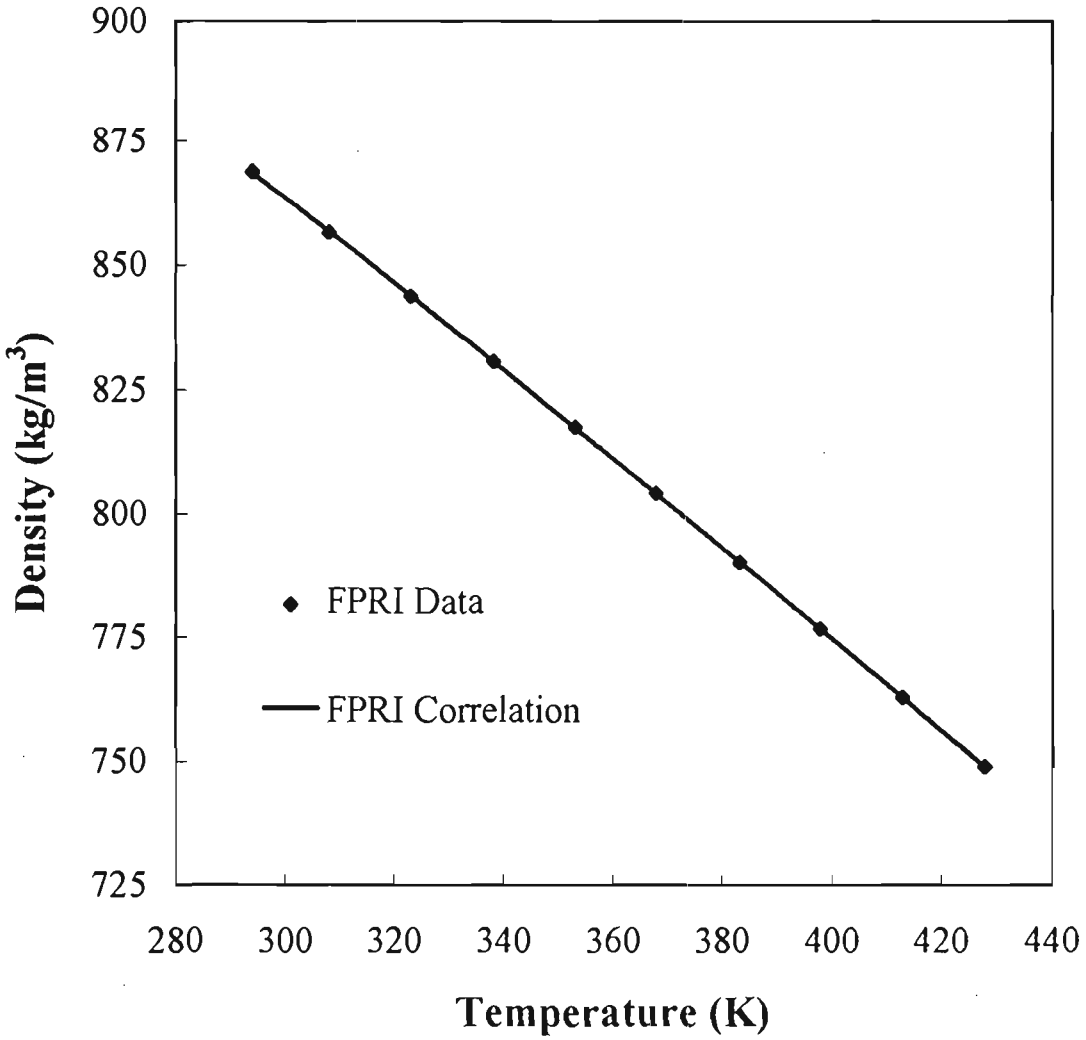
Octyl Ethanoate



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2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1995 DDS-LD-A83

DESIGN DATA STANDARD - LIQUID DENSITY

Heptanoic Acid

$CH_3\ (CH_2)_5CO_2H$
CA - No: 111-14-8

Purity =	99 %	
Molecular Weight =	130.19 kg/kmol	[1]
Critical Temperature =	663.1 K	[2]
Critical Pressure =	33.2 bar	[2]
Critical Volume =	0.4525 m^3/kmol	[2]
Normal Boiling Point =	496.2 K	[3]
Melting Point =	264.3 K	[3]
Liquid Molar Volume at 25 °C =	0.14245 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (kg/m^3)
290.25	920.6
307.95	905.7
323.05	893.0
338.05	880.4
353.05	867.8
367.05	855.4
383.15	842.3
397.90	829.4
412.85	816.6
427.65	803.4

Liquid Density Correlation:

1) $\rho\ /\mathrm{kg\ m^{-3}} = 238.7234 / 0.4531046^{[1+(1-T/K/663.1)^{0.607334}]}$

% AAD = 0.014 % % MAD = 0.046 %

2) $\rho\ /\mathrm{kg\ m^{-3}} = 1150.976 - 0.7553412\ T/K - 0.133189\times10^{-3}(T/K)^2$

% AAD = 0.016 % % MAD = 0.045 %

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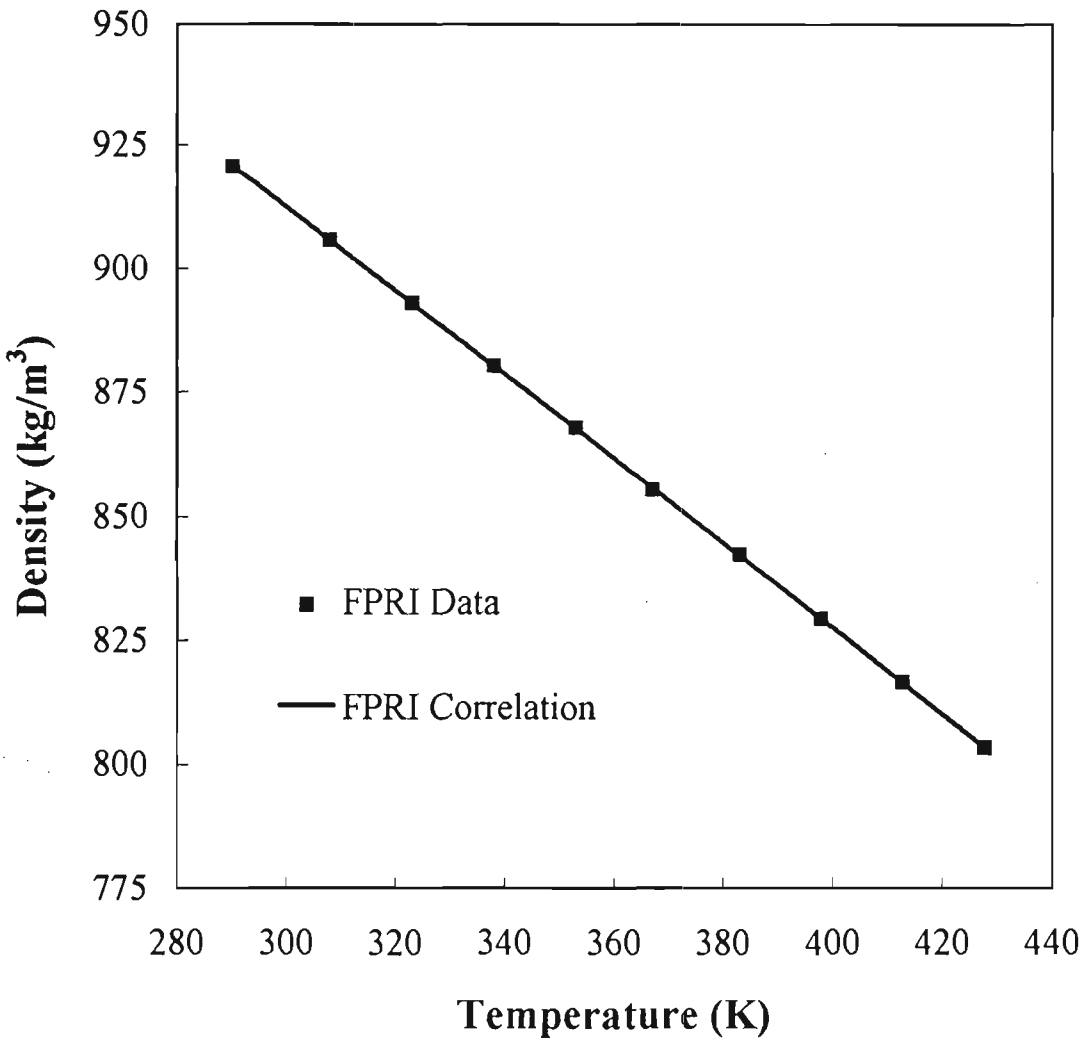
May, 1995 DDS-LD-A83

Heptanoic Acid



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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1995 DDS-LD-A84

DESIGN DATA STANDARD - LIQUID DENSITY

Octanoic Acid

$CH_3 (CH_2)_6CO_2H$
CA - No: 124-07-2

Purity =	99.5+ %	
Molecular Weight =	144.22 kg/kmol	[1]
Critical Temperature =	677.1 K	[2]
Critical Pressure =	29.8 bar	[2]
Critical Volume =	0.5085 m^3/kmol	[2]
Normal Boiling Point =	513.1 K	[3]
Melting Point =	289.5 K	[4]
Liquid Molar Volume at 25 °C =	0.15916 m^3/kmol	[5]

Experimental Technique : Pycnometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (kg/m^3)
290.25	910.3
307.95	898.2
323.05	885.9
338.05	873.8
353.05	861.8
367.75	849.7
383.05	837.2
398.05	824.6
412.85	812.3
427.70	799.2

Liquid Density Correlation:

1) ρ /kg m^{-3} = $210.2432 / 0.4297049^{[1+(1-T/K/677.1)^{0.5431394}]}$
% AAD = 0.017 % % MAD = 0.032 %

2) ρ /kg m^{-3} = $1126.097 - 0.6783923\ T/K - 0.1992105\times10^{-3}(T/K)^2$
% AAD = 0.020 % % MAD = 0.039 %

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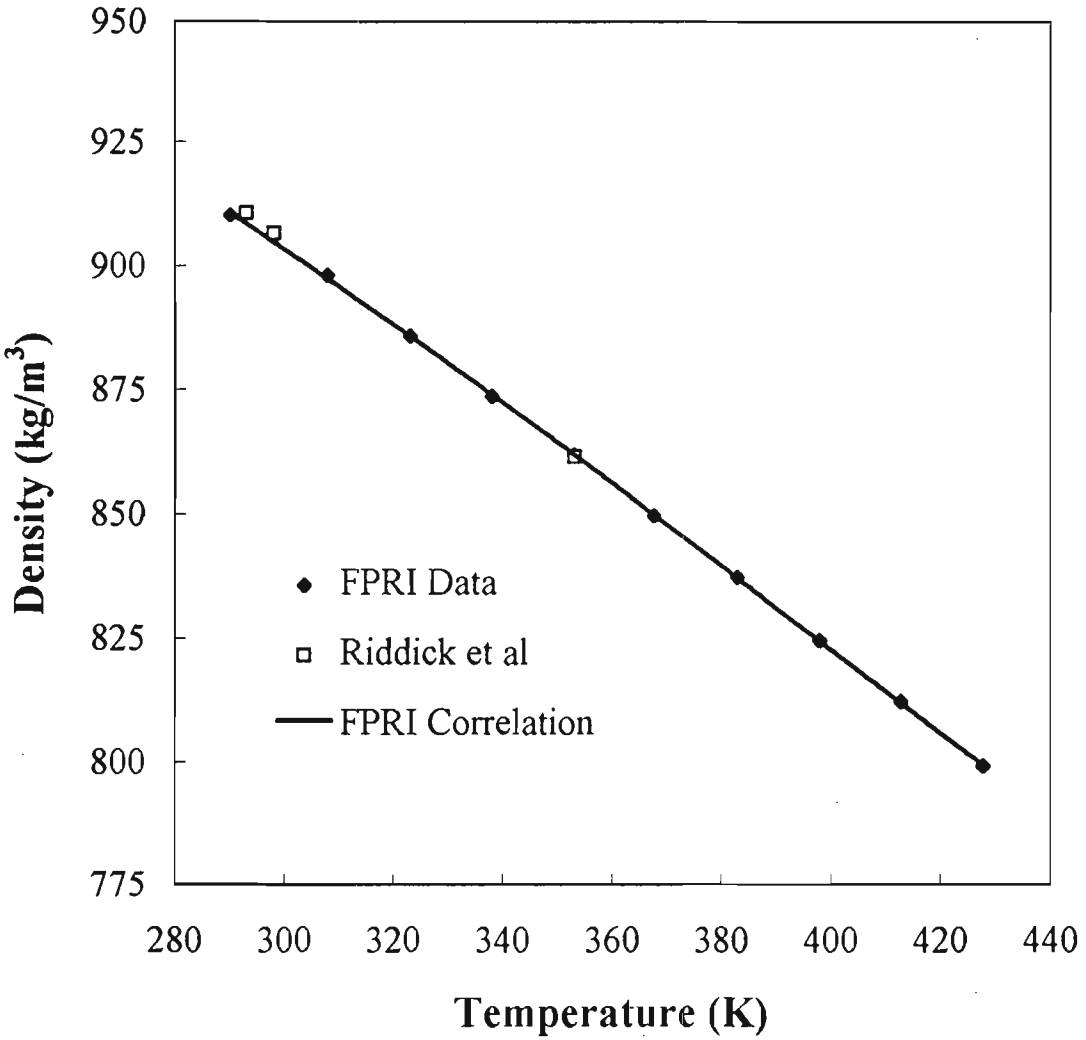
Octanoic Acid



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3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

4. Provided by Aldrich Company.

5. Estimated from FPRI density correlation.

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May, 1995 DDS-LD-A85

DESIGN DATA STANDARD - LIQUID DENSITY

Nonanoic Acid

$CH_3(CH_2)_7CO_2H$
CA - No: 112-05-0

Purity =	96 %	
Molecular Weight =	158.24 kg/kmol	[1]
Critical Temperature =	689.8 K	[2]
Critical Pressure =	26.9 bar	[2]
Critical Volume =	0.5645 m^3/kmol	[2]
Normal Boiling Point =	528.8 K	[3]
Melting Point =	282.2 K	[4]
Liquid Molar Volume at 25 °C =	0.17553 m^3/kmol	[5]

Experimental Technique : Pycnometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (kg/m^3)
292.50	906.0
307.95	893.8
323.05	881.9
338.05	870.1
353.05	858.4
368.00	846.7
383.25	834.1
398.10	822.3
413.00	810.3
427.90	798.0

Liquid Density Correlation:

1) ρ /kg m^{-3} = $219.214 / 0.4403086^{[1+(1-T/K/689.8)^{0.5710257}]}$
% AAD = 0.011 % % MAD = 0.029 %

2) ρ /kg m^{-3} = $1120.028 - 0.6884400\ T/K - 0.1494232\times10^{-3}(T/K)^2$
% AAD = 0.013 % % MAD = 0.030 %

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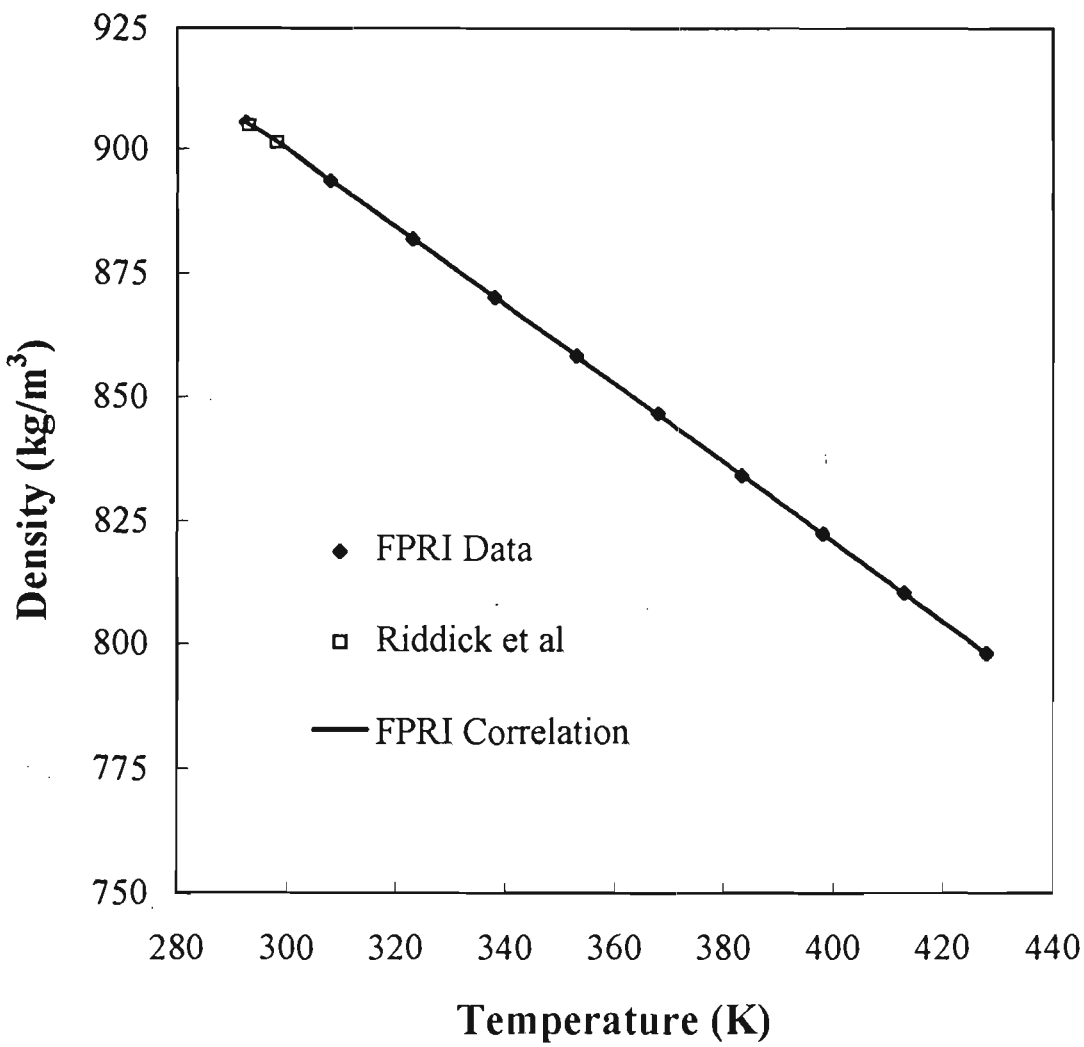
May, 1995 DDS-LD-A85

Nonanoic Acid



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3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

4. Provided by Aldrich Company.

5. Estimated from FPRI density correlation.

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May, 1995 DDS-LD-A86

DESIGN DATA STANDARD - LIQUID DENSITY

1,9-Nonanediol

$HO\ (CH_2)_9\ OH$
CA - No: 3937-56-2

Purity =	98 %	
Molecular Weight =	160.26 kg/kmol	[1]
Critical Temperature =	746.6 K	[2]
Critical Pressure =	27.8 bar	[2]
Critical Volume =	0.5775 m^3/kmol	[2]
Normal Boiling Point =	589.7 K	[2]
Melting Point =	312.3 K	[3]
Liquid Molar Volume at 25 °C =	0.17233 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (kg/m^3)
323.45	915.5
338.55	906.4
353.25	896.9
368.15	887.2
383.15	876.8
398.05	866.6
413.05	856.0
422.85	848.3
432.75	840.5
447.55	829.5
462.25	817.0

Liquid Density Correlation:

1) $\rho\ /\mathrm{kg\ m^{-3}} = 0.06423831 / 0.07702461^{[1+(1-T/K/746.6)^{0.06159793}]}$
% AAD = 0.029 % % MAD = 0.072 %

2) $\rho\ /\mathrm{kg\ m^{-3}} = 1022.617 - 0.06802514\ T/K - 0.8139916\times10^{-3}(T/K)^2$
% AAD = 0.019 % % MAD = 0.045 %

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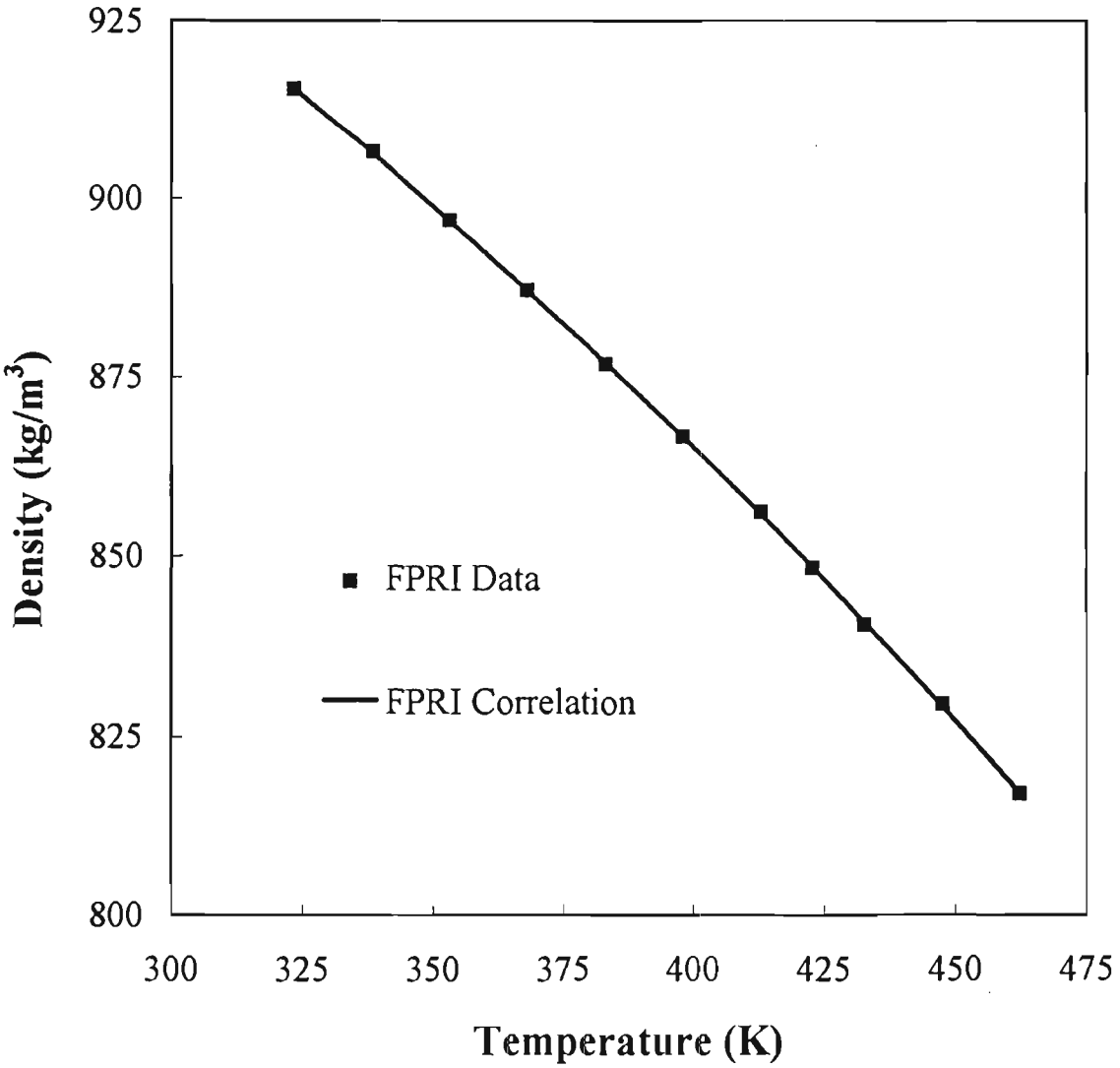
1,9-Nonanediol



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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1995 DDS-LD-A87

DESIGN DATA STANDARD - LIQUID DENSITY

1,2-Decanediol

$CH_3\ (CH_2)_7\ CH(OH)\ CH_2\ OH$
CA - No: 1119-86-4

Purity =	98 %	
Molecular Weight =	174.28 kg/kmol	[1]
Critical Temperature =	665.6 K	[2]
Critical Pressure =	25.4 bar	[2]
Critical Volume =	0.6275 m^3/kmol	[2]
Normal Boiling Point =	528.2 K	[3]
Melting Point =	308.6 K	[3]
Liquid Molar Volume at 25 °C =	0.19037 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (kg/m^3)
324.25	892.9
338.35	882.7
353.30	871.9
368.25	860.8
383.15	849.5
398.05	838.4
413.05	826.8
423.05	818.8
432.95	810.8
447.55	799.2
462.45	786.3

Liquid Density Correlation:

1) $\rho\ /\mathrm{kg\ m^{-3}} = 197.1488 / 0.4232141^{[1+(1-T/K/665.6)^{0.4177788}]}$
% AAD = 0.012 % % MAD = 0.032 %

2) $\rho\ /\mathrm{kg\ m^{-3}} = 1069.754 - 0.3902562\ T/K - 0.4801424\times10^{-3}(T/K)^2$
% AAD = 0.017 % % MAD = 0.038 %

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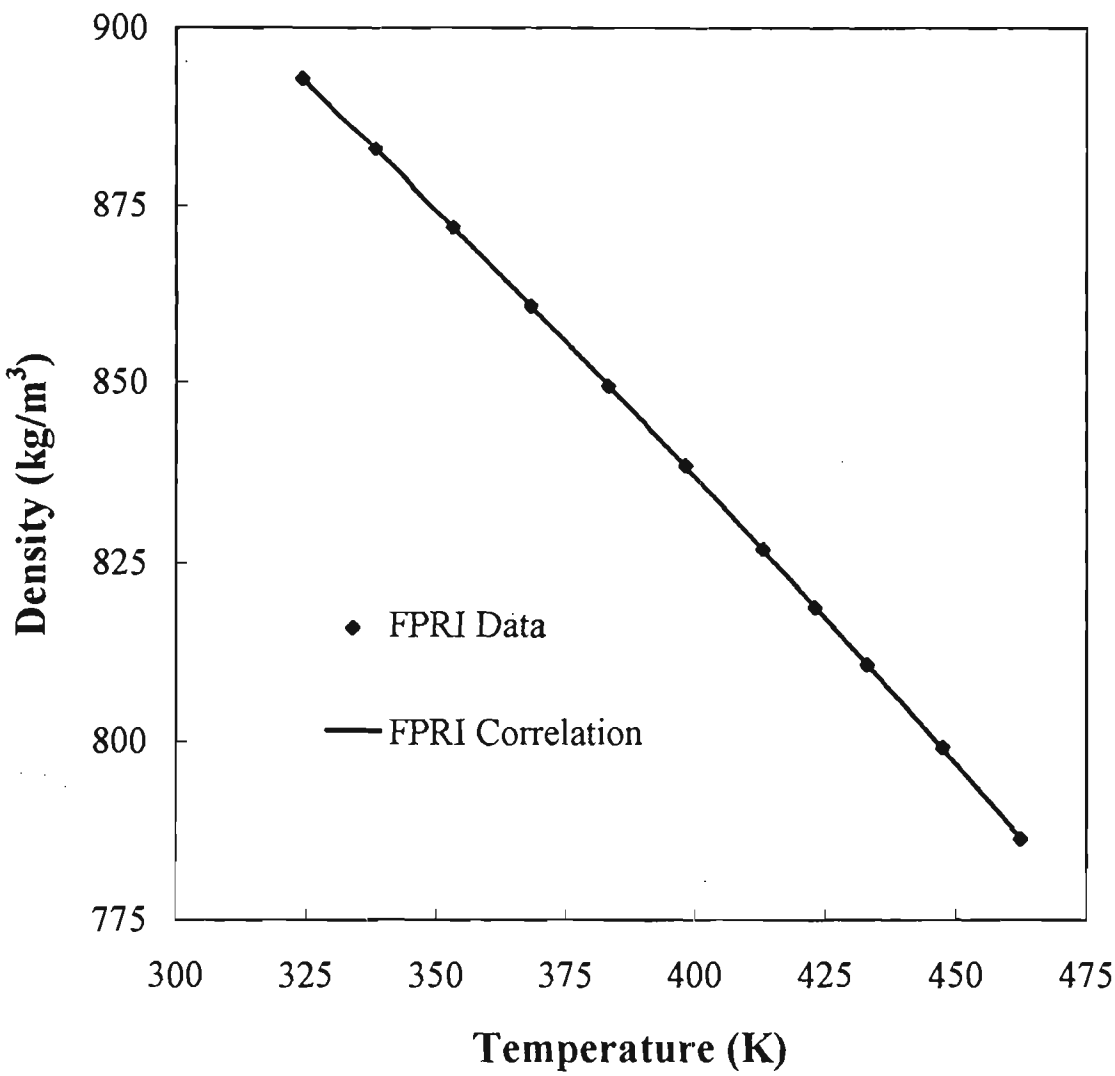
1,2-Decanediol



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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1995 DDS-LD-A88

DESIGN DATA STANDARD - LIQUID DENSITY

1,10-Decanediol

$HO\ (CH_2)_{10}\ OH$
CA - No: 112-47-0

Purity =	98 %	
Molecular Weight =	174.28 kg/kmol	[1]
Critical Temperature =	769.8 K	[2]
Critical Pressure =	25.2 bar	[2]
Critical Volume =	0.6335 m^3/kmol	[2]
Normal Boiling Point =	612.6 K	[2]
Melting Point =	323.6 K	[2]
Liquid Molar Volume at 25 °C =	0.18933 m^3/kmol	[3]

Experimental Technique : Pycnometer

Experimental Data:
Pressure = Ambient
Accuracy = ± 0.1 %

T (K)	ρ (kg/m^3)
348.20	892.1
363.20	882.3
378.45	872.2
393.35	862.0
408.25	851.4
423.25	840.3
433.05	833.1
447.55	821.2
462.65	808.8

Liquid Density Correlation:

1) $$\rho\ /\mathrm{kg\ m^{-3}} = 0.06960358 / 0.008024325^{[1+(1-T/K/769.8)^{0.06727424}]}$$
% AAD = 0.042 % % MAD = 0.084 %

2) $$\rho\ /\mathrm{kg\ m^{-3}} = 994.098 + 0.03133477\ T/K - 0.9328191\times10^{-3}(T/K)^2$$
% AAD = 0.016 % % MAD = 0.044 %

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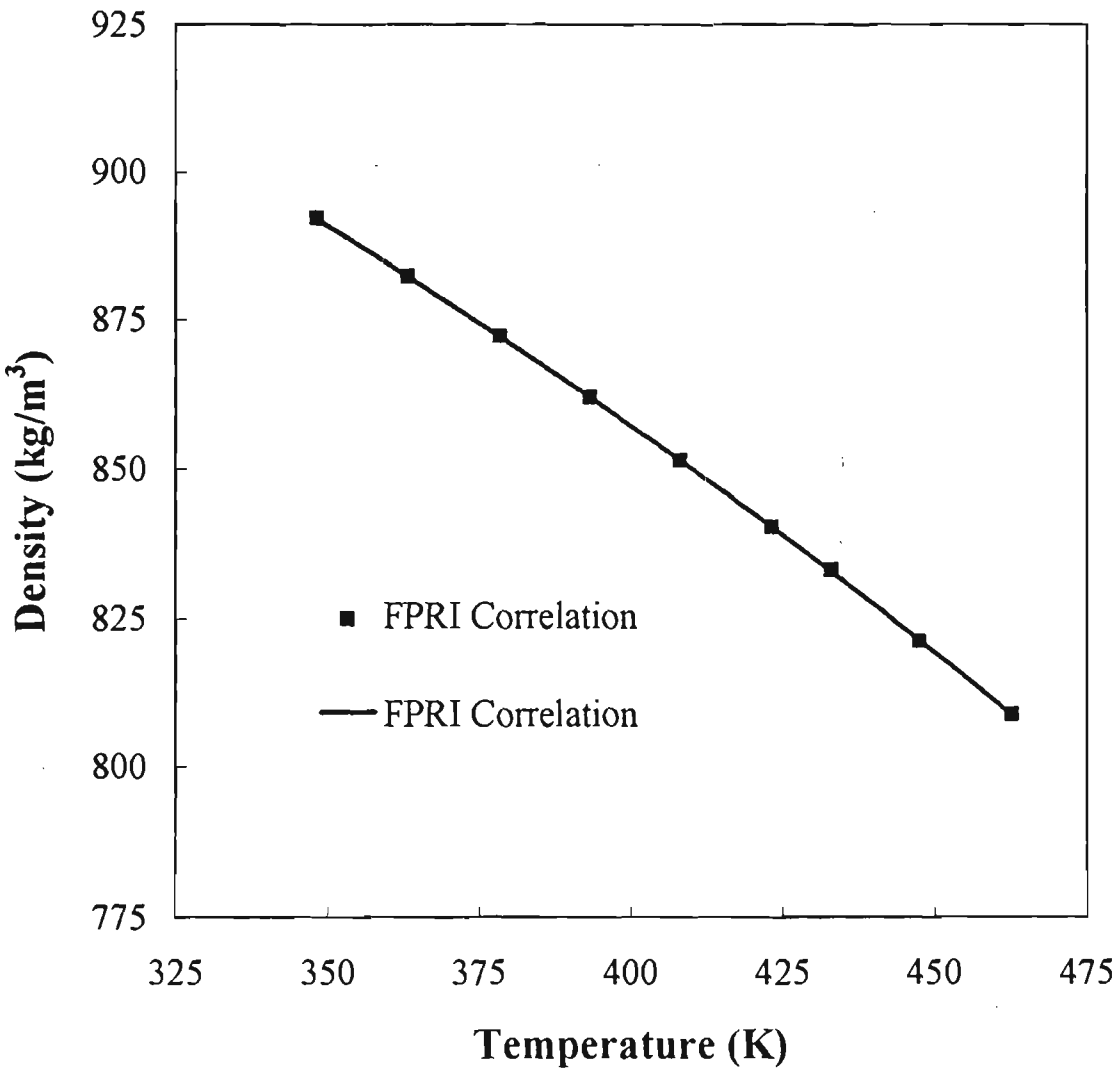
1,10-Decanediol



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1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Estimated from FPRI density correlation.

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FPRI

May, 1995 DDS-LD-A89

DESIGN DATA STANDARD - LIQUID DENSITY

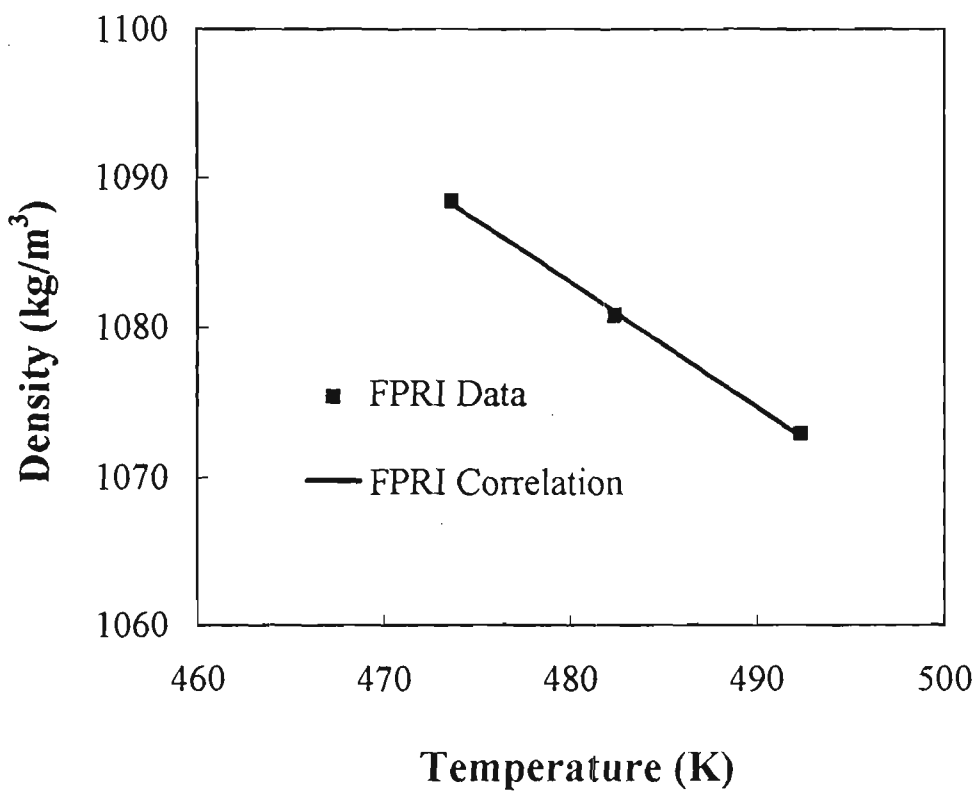
Dimethyl 2,6-Naphthalene Dicarboxylate

Melting Point = 473 K Provided by AMOCO

Experimental Technique : Pycnometer
Pressure = Ambient Accuracy = ± 0.2 %

T (K)	ρ (kg/m^3)
472.65	1088.4
482.40	1080.7
492.35	1072.9

Density Correlation: ρ /kg m^{-3} = 1460.268 - 0.7867922 T/K



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May, 1995 DDS-LTC-A89

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Butyl Ethanoate (Butyl Acetate)

$CH_3CO_2(CH_2)_3CH_3$
CA - No: 123-86-4

Purity =	99.7 %	
Molecular Weight =	116.16 kg/kmol	[1]
Critical Temperature =	570.9 K	[2]
Critical Pressure =	32.7 bar	[2]
Critical Volume =	0.3955 m^3/kmol	[2]
Normal Boiling Point =	399.2 K	[3]
Melting Point =	195 K	[4]
Liquid Molar Volume at 25 °C =	0.13243 m^3/kmol	[5]

Experimental Technique : Relative Transient Hot-Wire
Platinum Wire
Reference Fluid: Dimethylphthalate

Experimental Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
295.90	0.1324
308.90	0.1297
324.50	0.1251
338.90	0.1209
353.80	0.1165
367.10	0.1128
387.60	0.1070

Liquid Thermal Conductivity Correlation:

1) λ /(W/m K) = 0.216381 - 0.282016x10^{-3} T/K
% AAD = 0.17 % % MAD = 0.40 %

2) λ /(W/m K) = 0.197217 - 0.168764x10^{-3} T/K- 0.166016x10^{-6}(T/K)^2
% AAD = 0.17 % % MAD = 0.35 %

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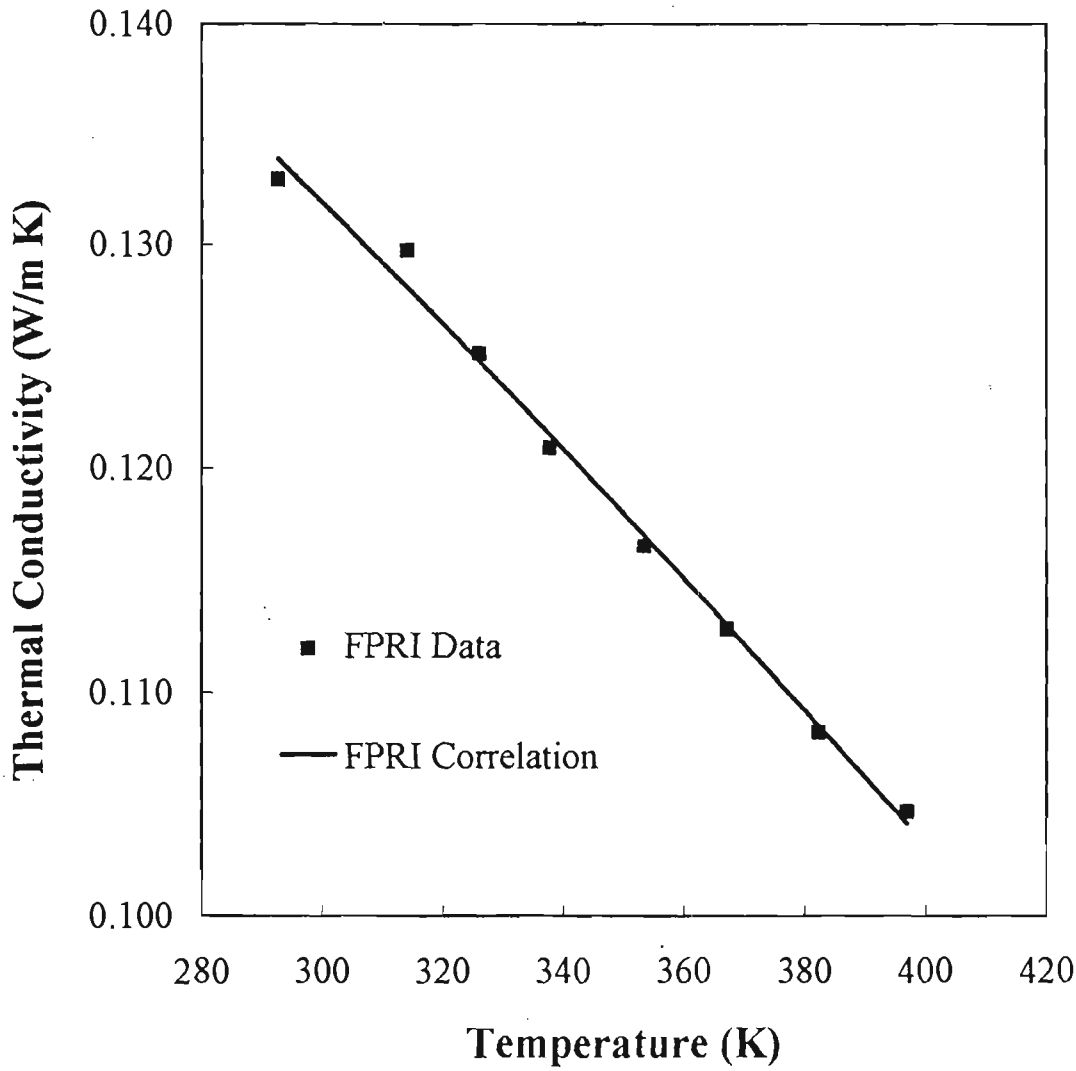
May, 1995 DDS-LTC-A89

Butyl Ethanoate



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3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

4. Provided by Aldrich Company.

5. Estimated from FPRI density correlation.

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May, 1995 DDS-LTC-A90

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Pentyl Ethanoate (Pentyl Acetate)

$CH_3CO_2(CH_2)_4CH_3$
CA - No: 628-63-7

Purity =	99 %	
Molecular Weight =	130.19 kg/kmol	[1]
Critical Temperature =	593.3 K	[2]
Critical Pressure =	29.4 bar	[2]
Critical Volume =	0.4515 m^3/kmol	[2]
Normal Boiling Point =	422.4 K	[3]
Melting Point =	173.2 K	[4]
Liquid Molar Volume at 25 °C =	0.14907 m^3/kmol	[5]

Experimental Technique : Relative Transient Hot-Wire
Platinum Wire
Reference Fluid: Dimethylphthalate

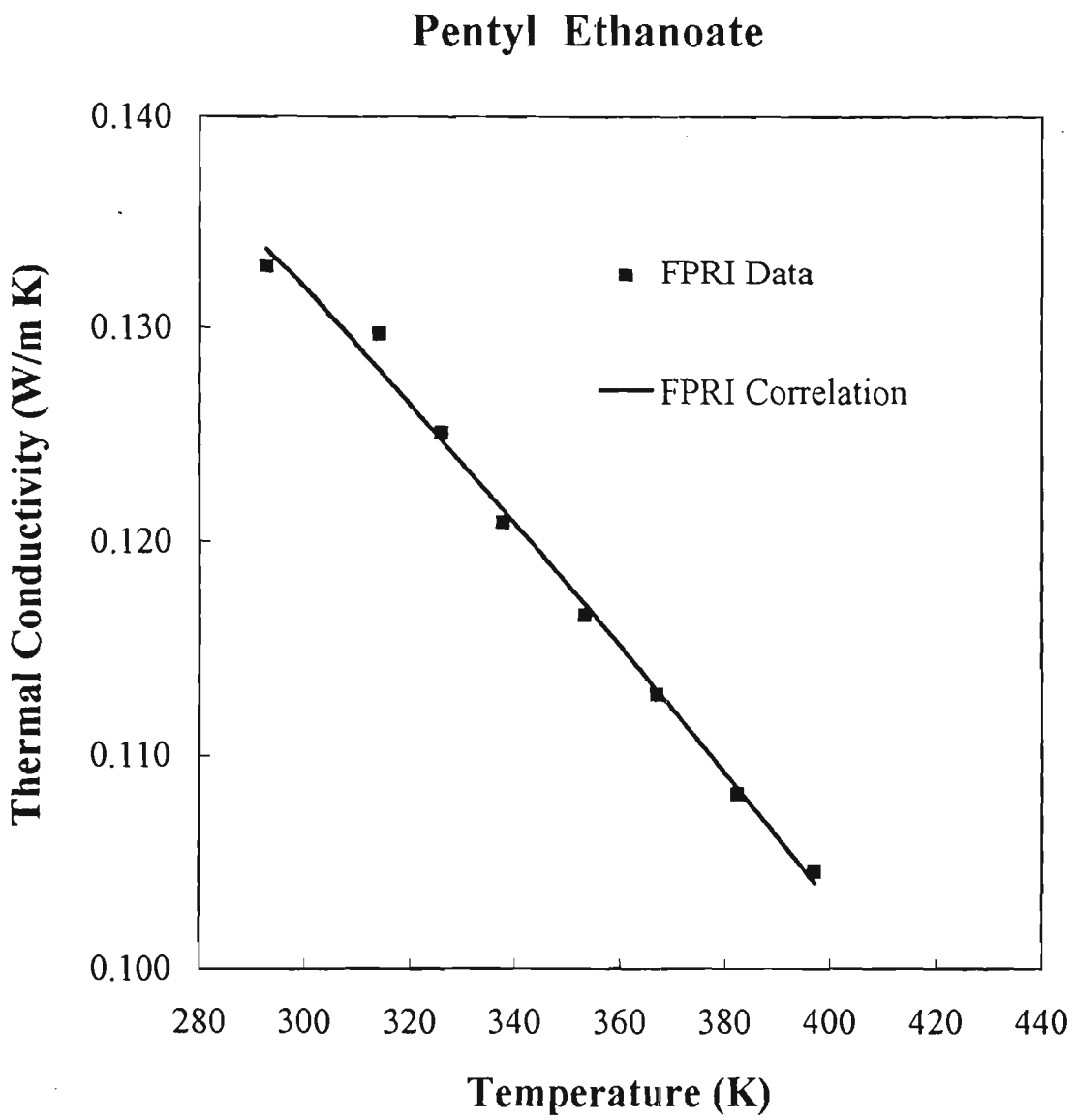
Experimental Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
292.80	0.1335
314.10	0.1282
326.10	0.1250
337.80	0.1214
353.50	0.1164
367.20	0.1128
382.40	0.1082
397.00	0.1046

Liquid Thermal Conductivity Correlation:

1) λ /(W/m K) = 0.217093- 0.283896x10^{-3} T/K
% AAD = 0.25 % % MAD = 0.39 %

2) λ /(W/m K) = 0.206319- 0.221001x10^{-3} T/K- 0.909455x10^{-7}(T/K)^2
% AAD = 0.24 % % MAD = 0.37 %


Pentyl Ethanoate
0.140
0.130
0.120
0.110
0.100
Thermal Conductivity (W/m K)
FPRI Data
FPRI Correlation
280
300
320
340
360
380
400
420
440
Temperature (K)

REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

4. Provided by Aldrich Company.

5. Estimated from FPRI density correlation.

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DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Hexyl Ethanoate (Hexyl Acetate)

$CH_3CO_2(CH_2)_5CH_3$
CA - No: 142-92-7

Purity =	99 %	
Molecular Weight =	144.21 kg/kmol	[1]
Critical Temperature =	613.0 K	[2]
Critical Pressure =	26.6 bar	[2]
Critical Volume =	0.5075 m^3/kmol	[2]
Normal Boiling Point =	443.7 K	[3]
Melting Point =	193 K	[4]
Liquid Molar Volume at 25 °C =	0.16601 m^3/kmol	[5]

Experimental Technique : Relative Transient Hot-Wire
Platinum Wire
Reference Fluid: Dimethylphthalate

Experimental Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
293.30	0.1334
314.30	0.1290
333.70	0.1240
353.40	0.1188
372.30	0.1132
393.20	0.1085
412.40	0.1038
425.30	0.1007

Liquid Thermal Conductivity Correlation:

1) λ /(W/m K) = 0.207896- 0.252516x10^{-3} T/K
% AAD = 0.26 % % MAD = 0.60 %

2) λ /(W/m K) = 0.208262- 0.254577x10^{-3} T/K +0.285916x10^{-8}(T/K)^2
% AAD = 0.26 % % MAD = 0.60 %

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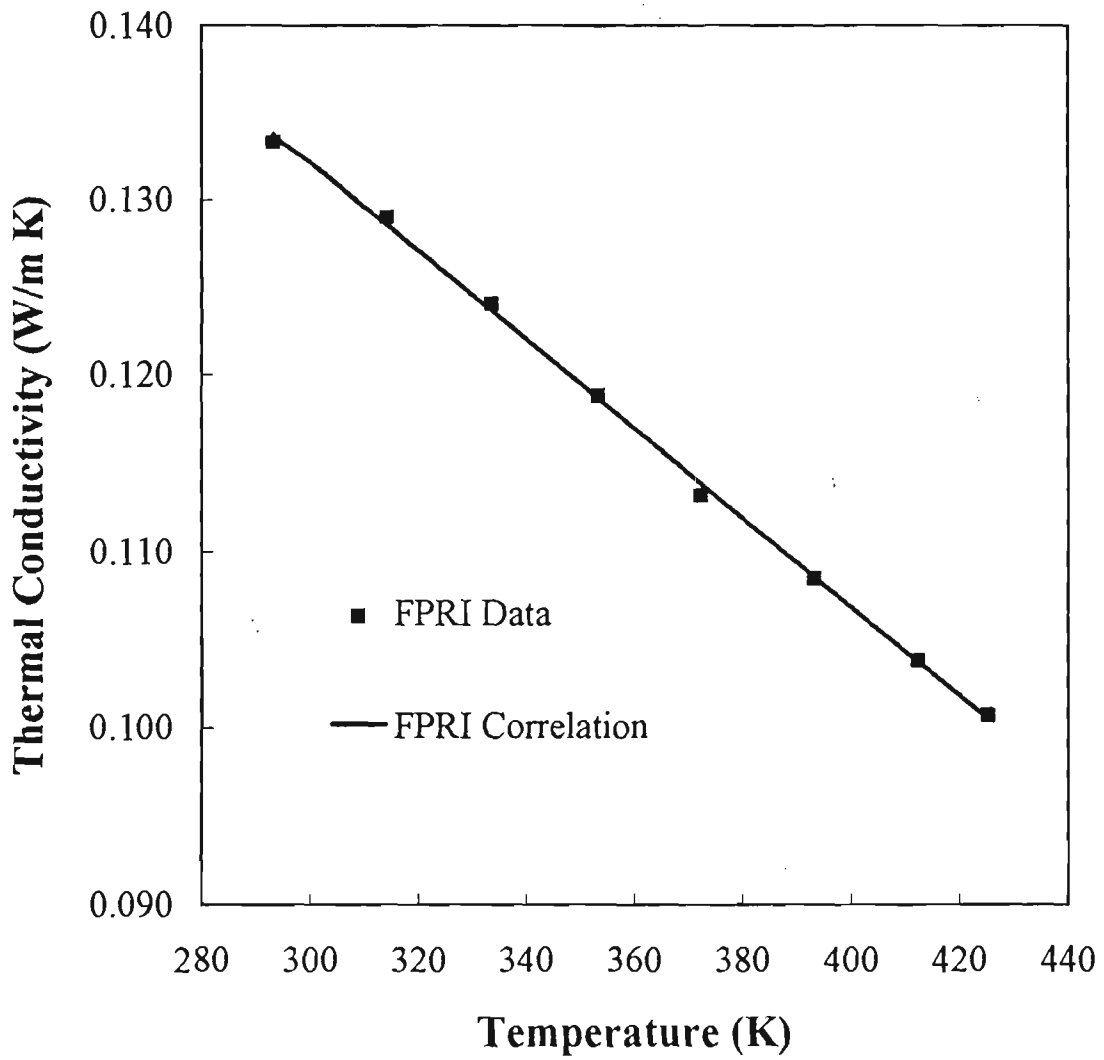
Hexyl Ethanoate



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3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

4. Provided by Aldrich Company.

5. Estimated from FPRI density correlation.

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DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Octyl Ethanoate (Octyl Acetate)

$CH_3CO_2(CH_2)_7CH_3$
CA - No: 112-14-1

Purity =	99+ %	
Molecular Weight =	172.27 kg/kmol	[1]
Critical Temperature =	649.6 K	[2]
Critical Pressure =	22.0 bar	[2]
Critical Volume =	0.6195 m^3/kmol	[2]
Normal Boiling Point =	484.2 K	[3]
Melting Point =	274.1 K	[2]
Liquid Molar Volume at 25 °C =	0.19911 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire
Platinum Wire
Reference Fluid: Dimethylphthalate

Experimental Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
295.90	0.1358
314.40	0.1322
333.20	0.1277
353.10	0.1226
372.60	0.1178
392.50	0.1121
411.70	0.1078
432.10	0.1033
451.90	0.0992

Liquid Thermal Conductivity Correlation:

1) λ /(W/m K) = 0.207705- 0.241510x10^{-3} T/K
% AAD = 0.34 % % MAD = 0.72 %

2) λ /(W/m K) = 0.215063- 0.281622x10^{-3} T/K +0.536713x10^{-7}(T/K)^2
% AAD = 0.35 % % MAD = 0.62 %

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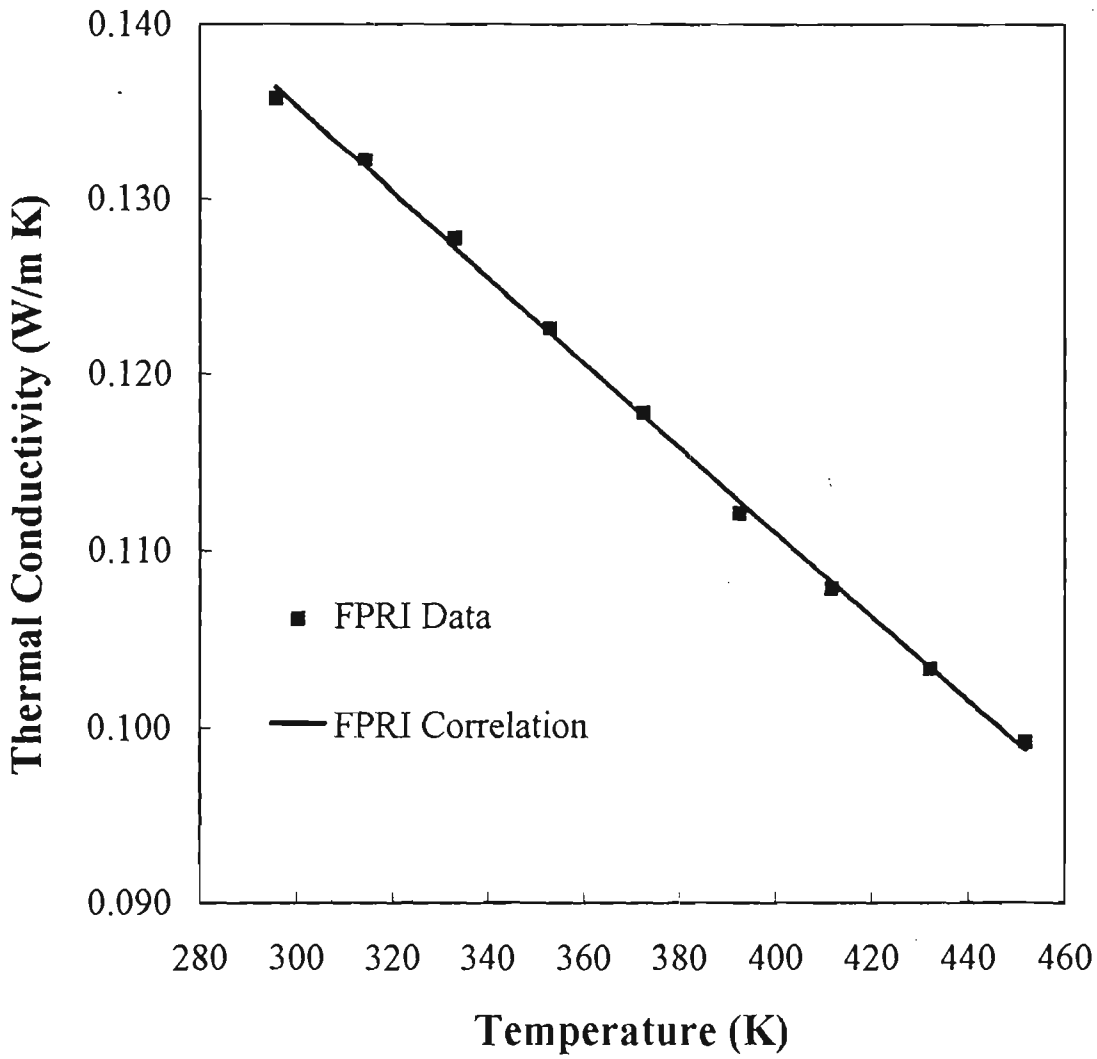
Octyl Ethanoate



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4. Estimated from FPRI density correlation.

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May, 1995 DDS-LTC-A93

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Heptanoic Acid

$CH_3(CH_2)_5CO_2H$
CA - No: 111-14-8

Purity =	99 %	
Molecular Weight =	130.19 kg/kmol	[1]
Critical Temperature =	663.1 K	[2]
Critical Pressure =	33.2 bar	[2]
Critical Volume =	0.4525 m^3/kmol	[2]
Normal Boiling Point =	496.2 K	[3]
Melting Point =	264.3 K	[3]
Liquid Molar Volume at 25 °C =	0.14245 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire
Pyrex Capillary filled with Mercury
Reference Fluid: Water

Experimental Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
296.00	0.1437
314.30	0.1403
332.40	0.1371
352.60	0.1333
372.20	0.1296
382.00	0.1274
391.90	0.1239
412.40	0.1211
441.70	0.1157
471.40	0.1105

Liquid Thermal Conductivity Correlation:

1) $\lambda/(W/m\,K) = 0.200903 - 0.192845\times10^{-3}\ T/K$
% AAD = 0.30% % MAD = 1.15 %

2) $\lambda/(W/m\,K) = 0.207610 - 0.228628\times10^{-3}\ T/K + 0.468143\times10^{-7}\ (T/K)^2$
% AAD = 0.31 % % MAD = 1.05 %

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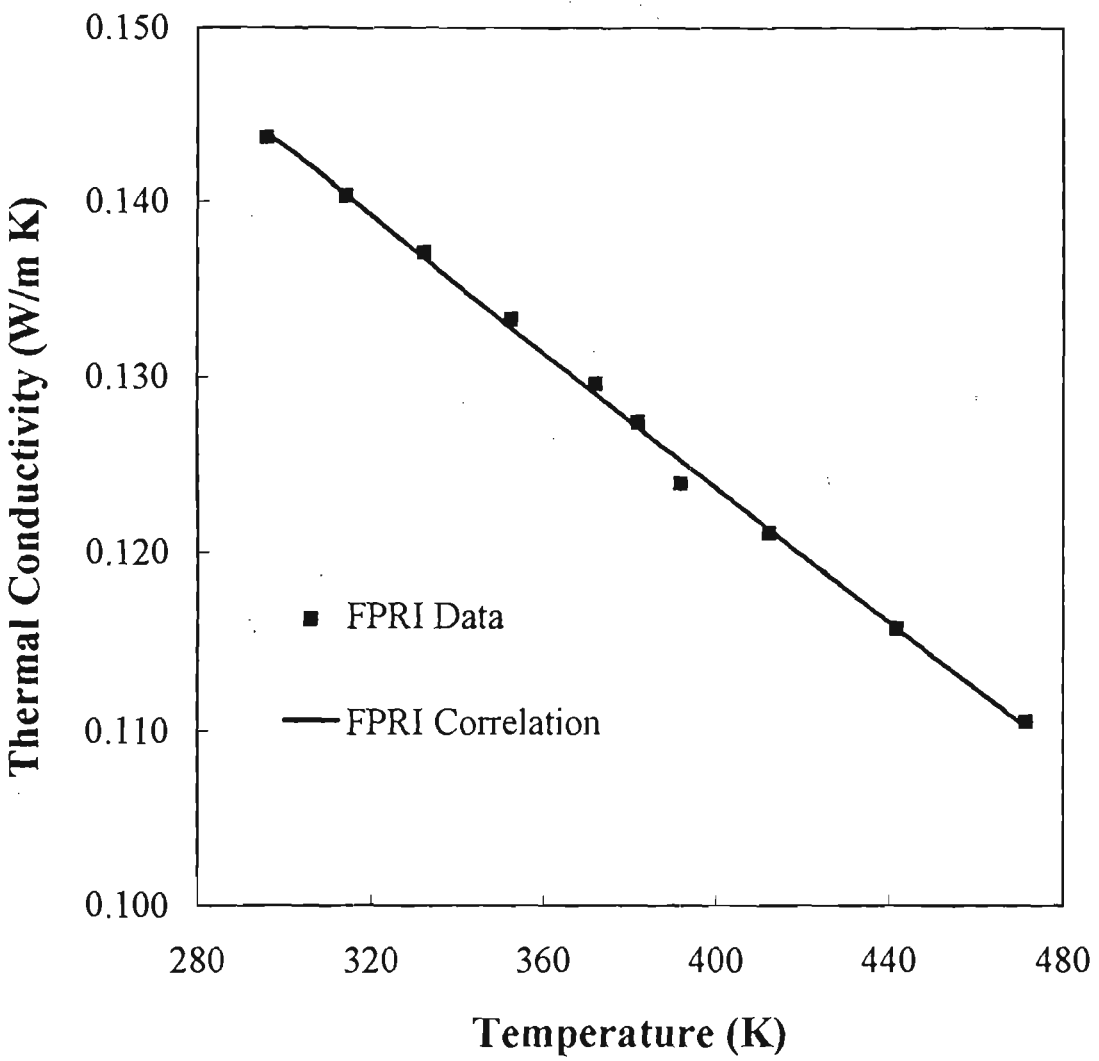
Heptanoic Acid



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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1995 DDS-LTC-A94

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Octanoic Acid

$CH_3 (CH_2)_6CO_2H$
CA - No: 124-07-2

Purity =	99.5+ %	
Molecular Weight =	144.22 kg/kmol	[1]
Critical Temperature =	677.1 K	[2]
Critical Pressure =	29.8 bar	[2]
Critical Volume =	0.5085 m^3/kmol	[2]
Normal Boiling Point =	513.1 K	[3]
Melting Point =	289.5 K	[4]
Liquid Molar Volume at 25 °C =	0.15916 m^3/kmol	[5]

Experimental Technique : Relative Transient Hot-Wire
Pyrex Capillary filled with Mercury
Reference Fluid: Water

Experimental Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
297.20	0.1472
322.30	0.1422
352.80	0.1358
387.60	0.1297
411.30	0.1242
442.00	0.1176
471.70	0.1122

Liquid Thermal Conductivity Correlation:

1) λ /(W/m K) = 0.207214- 0.201719x10^{-3} T/K
% AAD = 0.18% % MAD = 0.52 %

2) λ /(W/m K) = 0.204321- 0.186275x10^{-3} T/K -0.201301x10^{-7} $(T/K)^2$
% AAD = 0.20 % % MAD = 0.47 %

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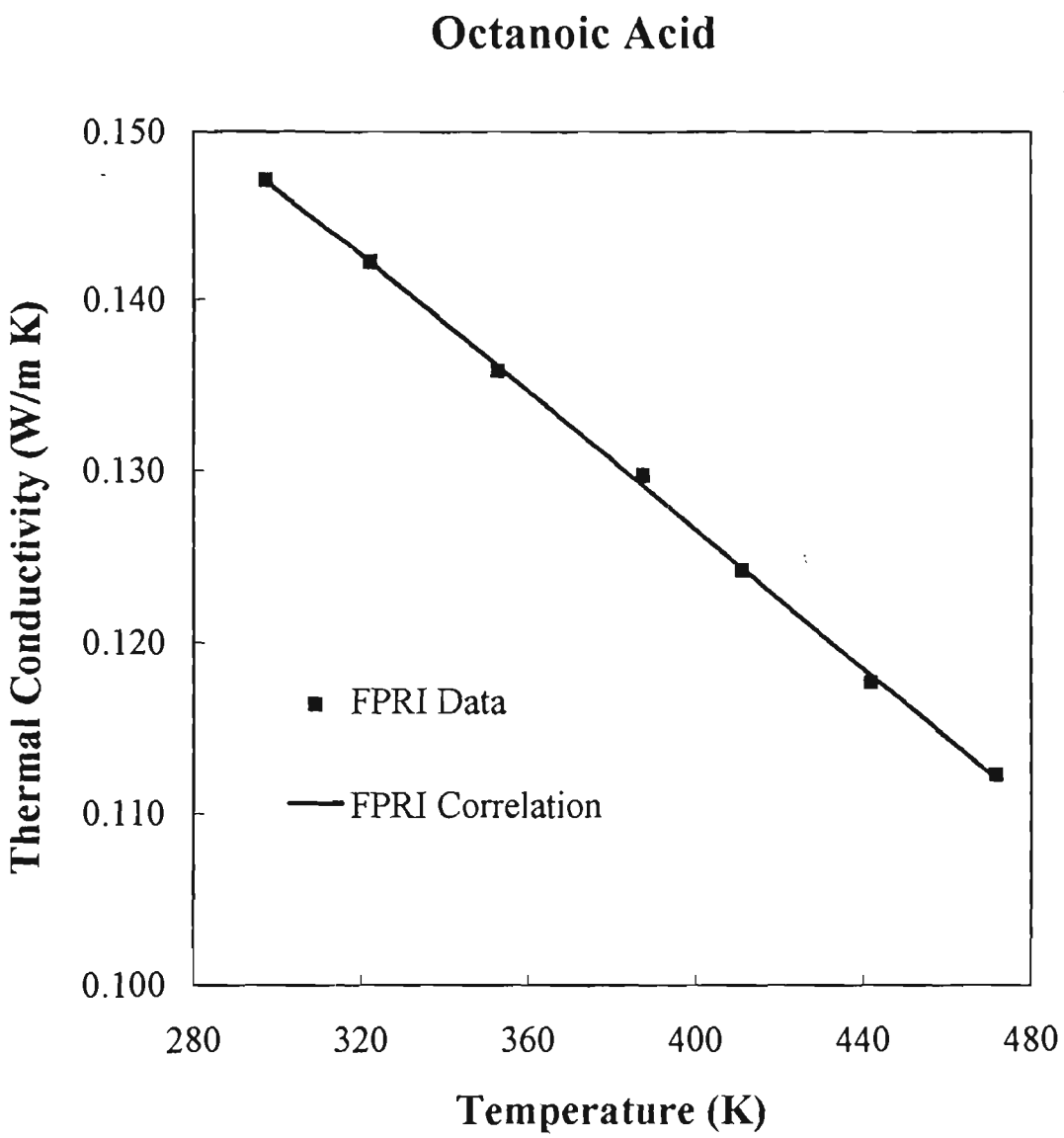

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3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

4. Provided by Aldrich Company.

5. Estimated from FPRI density correlation.

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May, 1995 DDS-LTC-A95

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Nonanoic Acid

$CH_3(CH_2)_7CO_2H$
CA - No: 112-05-0

Purity =	96 %	
Molecular Weight =	158.24 kg/kmol	[1]
Critical Temperature =	689.8 K	[2]
Critical Pressure =	26.9 bar	[2]
Critical Volume =	0.5645 m^3/kmol	[2]
Normal Boiling Point =	528.8 K	[3]
Melting Point =	282.2 K	[4]
Liquid Molar Volume at 25 °C =	0.17553 m^3/kmol	[5]

Experimental Technique : Relative Transient Hot-Wire
Pyrex Capillary filled with Mercury
Reference Fluid: Water

Experimental Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
296.30	0.1496
322.60	0.1444
352.90	0.1386
381.30	0.1327
412.20	0.1265
441.40	0.1206
471.60	0.1150

Liquid Thermal Conductivity Correlation:

1) $\lambda/(W/m\ K) = 0.208514 - 0.198709\times10^{-3}\ T/K$
% AAD = 0.09% % MAD = 0.17 %

2) $\lambda/(W/m\ K) = 0.209986 - 0.206566\times10^{-3}\ T/K + 0.102419\times10^{-7}\ (T/K)^2$
% AAD = 0.09 % % MAD = 0.17 %

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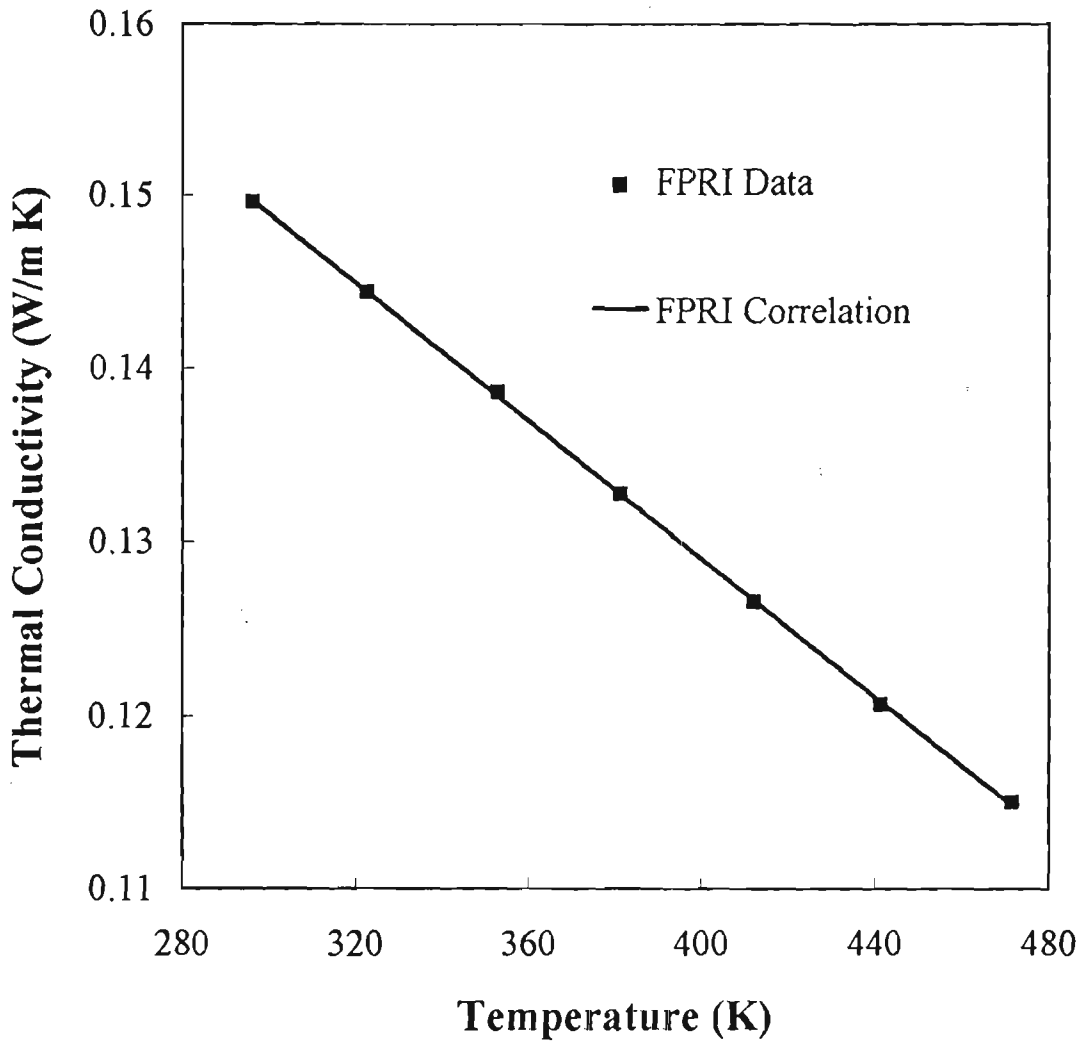
Nonanoic Acid



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3. Riddick, J.A.; Bunger, W. B.; Sakano, T.K., "Organic Solvents: Physical Properties and Methods of Purification", 4th ed., Wiley, New York (1986).

4. Provided by Aldrich Company.

5. Estimated from FPRI density correlation.

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May, 1995 DDS-LTC-A96

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

1,9-Nonanediol

$HO(CH_2)_9OH$
CA - No: 3937-56-2

Purity =	98 %	
Molecular Weight =	160.26 kg/kmol	[1]
Critical Temperature =	746.6 K	[2]
Critical Pressure =	27.8 bar	[2]
Critical Volume =	0.5775 m^3/kmol	[2]
Normal Boiling Point =	589.7 K	[2]
Melting Point =	312.3 K	[3]
Liquid Molar Volume at 25 °C =	0.17233 m^3/kmol	[4]

Experimental Technique : Relative Transient Hot-Wire
Platinum Wire
Reference Fluid: Dimethylphthalate

Experimental Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
328.60	0.1939
343.20	0.1923
361.20	0.1898
387.30	0.1853
410.70	0.1806
435.90	0.1747
465.90	0.1662

Liquid Thermal Conductivity Correlation:

1) λ /(W/m K) = 0.261199 - 0.199646x10^{-3} T/K
% AAD = 0.64 % % MAD = 1.19 %

2) λ /(W/m K) = 0.150612 + 0.366882x10^{-3} T/K- 0.715445x10^{-6}(T/K)^2
% AAD = 0.03 % % MAD = 0.06 %

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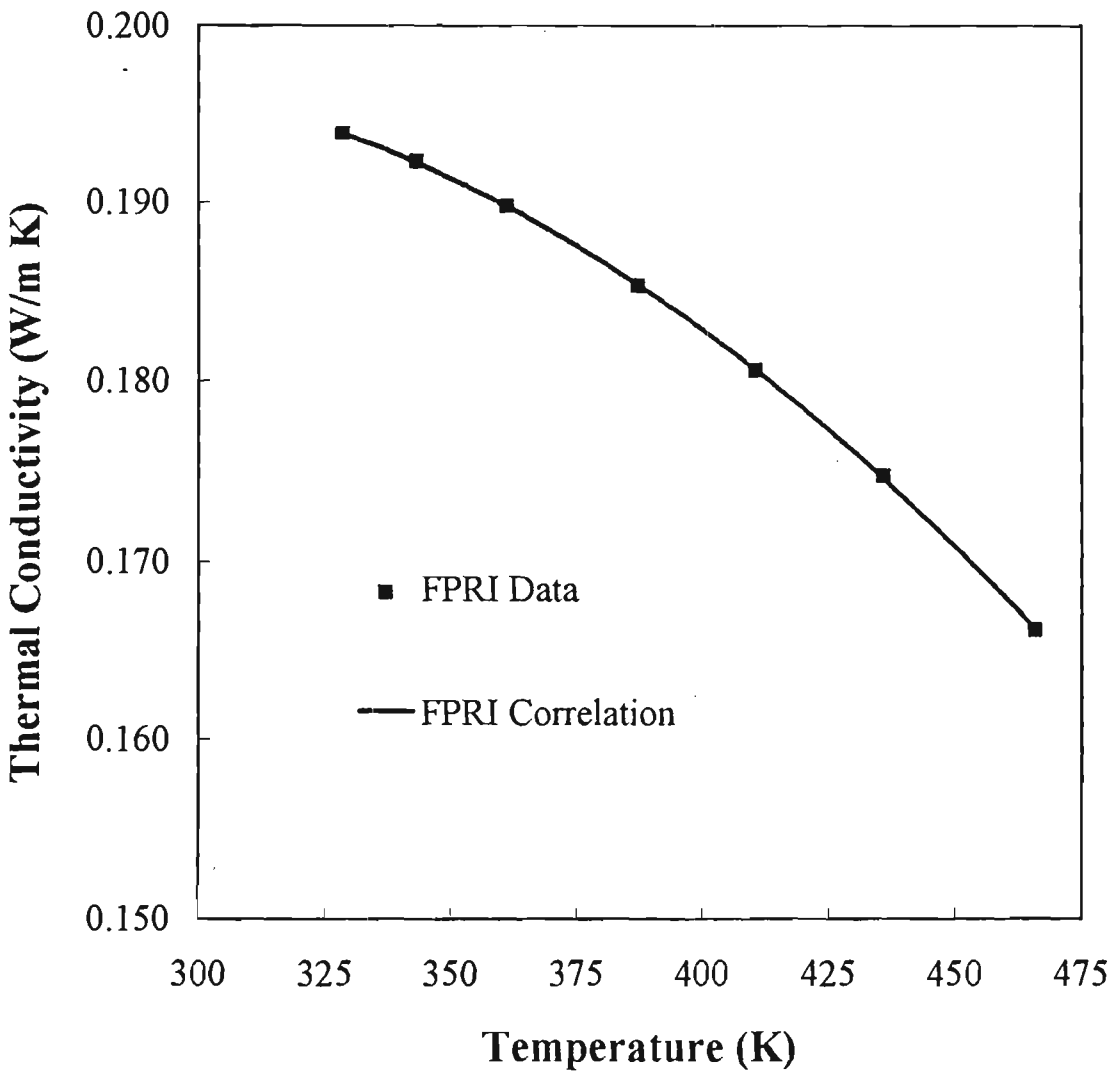
1,9-Nonanediol



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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1995 DDS-LTC-A97

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

1,2-Decanediol

$CH_3 (CH_2)_7 CH(OH) CH_2 OH$
CA - No: 1119-86-4

Purity =	98 %	
Molecular Weight =	174.28 kg/kmol	[1]
Critical Temperature =	665.6 K	[2]
Critical Pressure =	25.4 bar	[2]
Critical Volume =	0.6275 m^3/kmol	[2]
Normal Boiling Point =	528.2 K	[3]
Melting Point =	308.6 K	[3]
Liquid Molar Volume at 25 °C =	0.19037 m^3/kmol	[4]

Experimental Technique : Pycnometer

Experimental Technique : Relative Transient Hot-Wire
Platinum Wire
Reference Fluid: Dimethylphthalate

Experimental Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
333.70	0.1637
358.50	0.1597
381.70	0.1559
411.70	0.1497
441.90	0.1429
470.00	0.1361

Liquid Thermal Conductivity Correlation:

1) λ /(W/m K) = 0.232476 - 0.203068x10^{-3} T/K
% AAD = 0.43 % % MAD = 0.69 %

2) λ /(W/m K) = 0.166642+ 0.128961x10^{-3} T/K- 0.412907x10^{-6}(T/K)^2
% AAD = 0.06 % % MAD = 0.12 %

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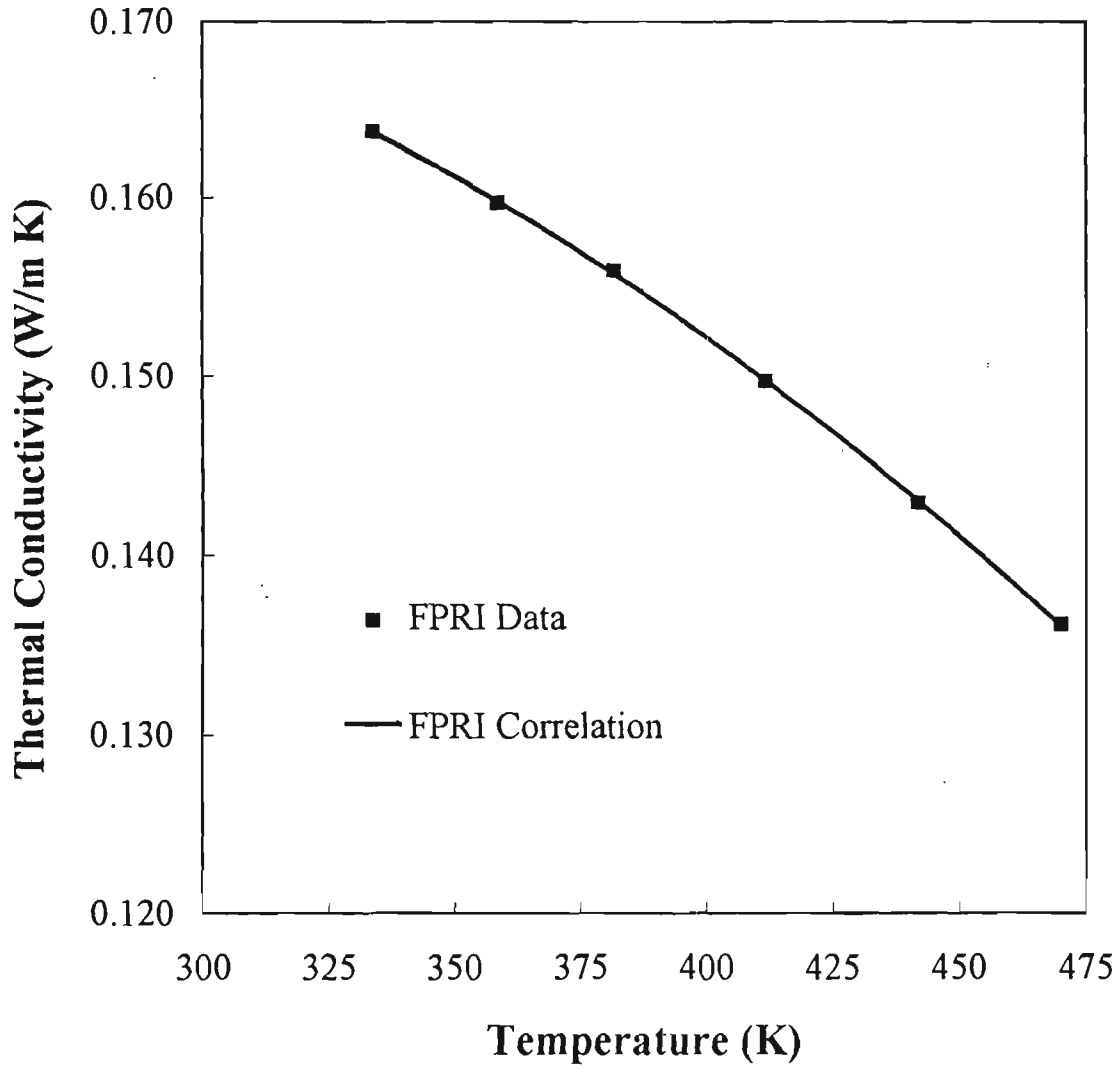
1,2-Decanediol



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3. Provided by Aldrich Company.

4. Estimated from FPRI density correlation.

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May, 1995 DDS-LTC-A98

DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

1,10-Decanediol

$HO\ (CH_2)_{10}\ OH$
CA - No: 112-47-0

Purity =	98 %	
Molecular Weight =	174.28 kg/kmol	[1]
Critical Temperature =	769.8 K	[2]
Critical Pressure =	25.2 bar	[2]
Critical Volume =	0.6335 m^3/kmol	[2]
Normal Boiling Point =	612.6 K	[2]
Melting Point =	323.6 K	[2]
Liquid Molar Volume at 25 °C =	0.18933 m^3/kmol	[3]

Experimental Technique : Relative Transient Hot-Wire
Platinum Wire
Reference Fluid: Dimethylphthalate

Experimental Data:
Pressure = Ambient
Accuracy = ± 2.0 %

T (K)	λ (W/m K)
352.50	0.1890
372.40	0.1856
392.00	0.1818
411.80	0.1779
431.50	0.1726
452.10	0.1672
471.10	0.1615

Liquid Thermal Conductivity Correlation:

1) λ /(W/m K) = 0.271940 - 0.231664x10^{-3} T/K
% AAD = 0.43 % % MAD = 0.81 %

2) λ /(W/m K) = 0.158115 + 0.326136x10^{-3} T/K- 0.677052x$10^{-6}$$(T/K)^2$
% AAD = 0.06 % % MAD = 0.17 %

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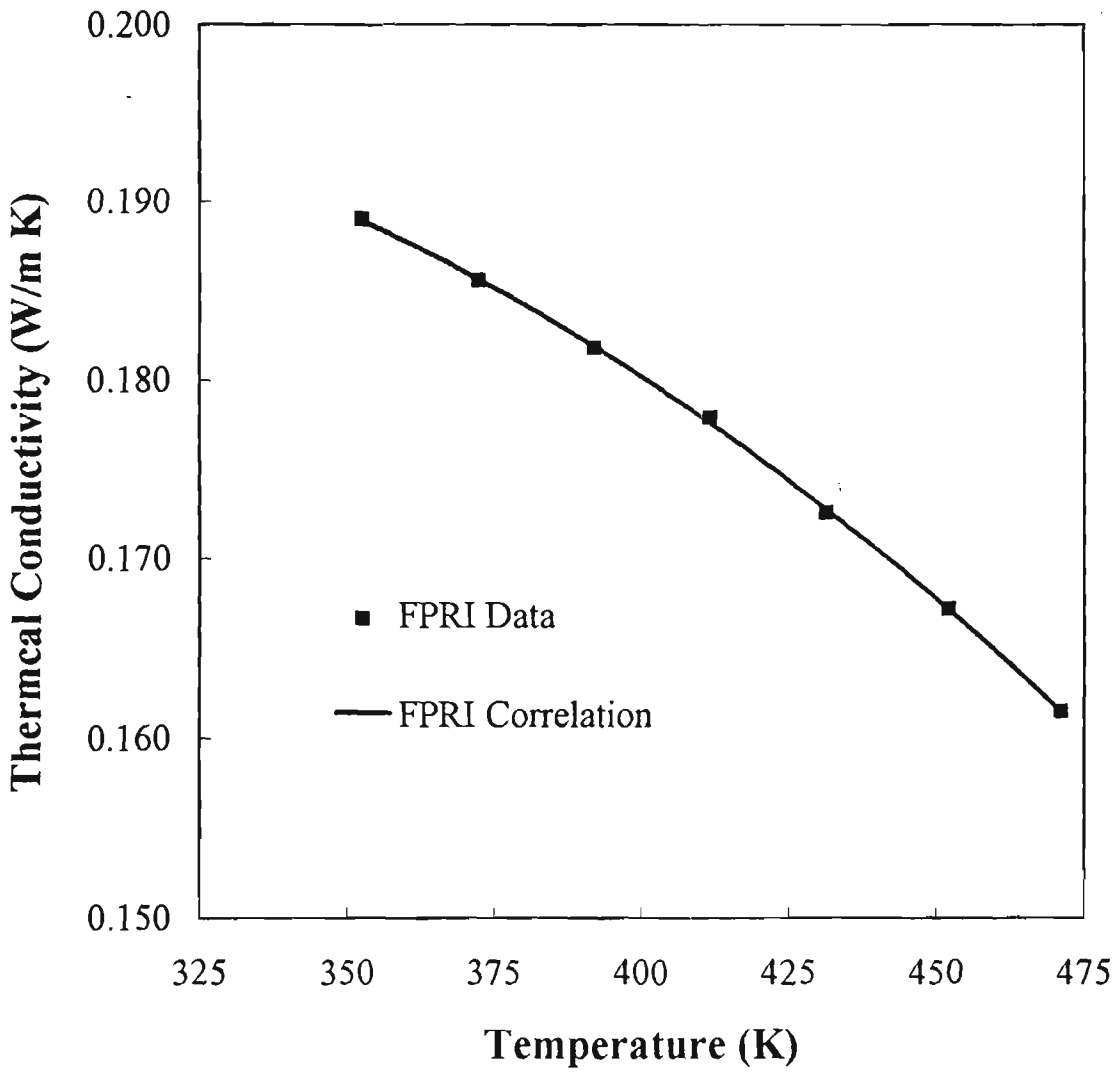
1,10-Decanediol



REFERENCES

1. IUPAC, "Atomic Weights of the Elements - 1979", Pure Appl. Chem., 52, 2349 (1980).

2. Estimated from Joback modification of Lyderson's method: Reid, R.C.; Prausnitz, J.M.; Poling, B.E., "The Properties of Gases and Liquids", 4th ed., pp 14-15, McGraw - Hill, New York (1988).

3. Estimated from FPRI density correlation.

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FPRI

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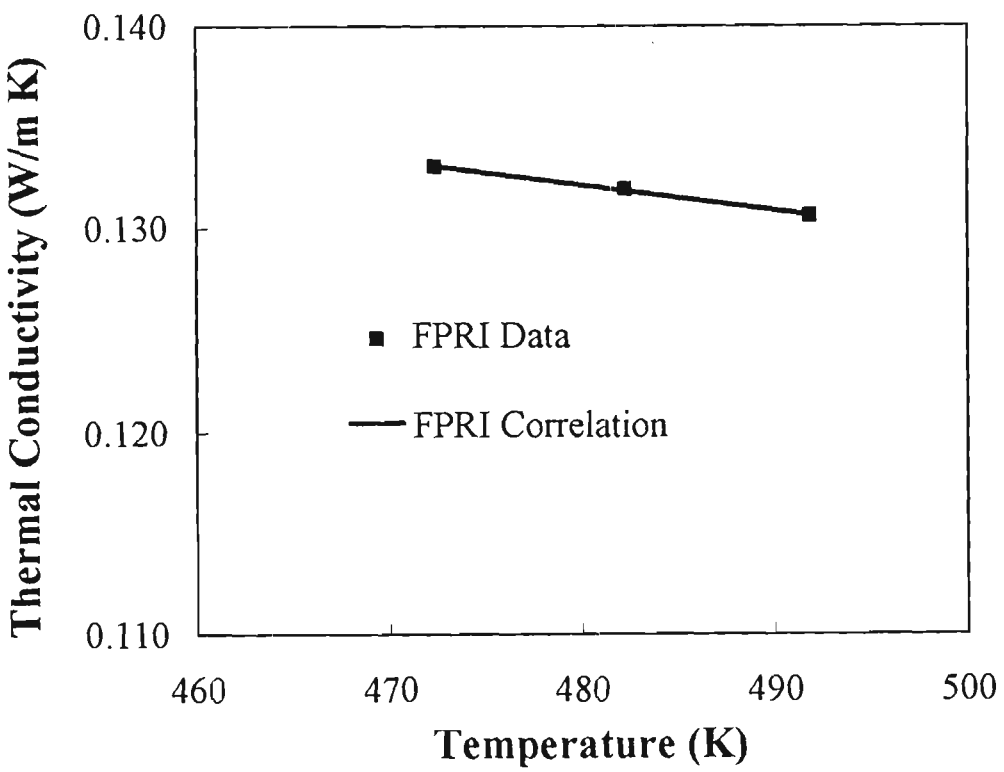
DESIGN DATA STANDARD - LIQUID THERMAL CONDUCTIVITY

Dimethyl 2,6-Naphthalene Dicarboxylate

Melting Point = 473 K Provided by AMOCO

Experimental Technique : Relative Transient Hot-Wire
Platinum Wire
Reference Fluid: Dimethylphthalate

Pressure = Ambient Accuracy = ± 2 %

T (K)	λ (W/m K)
472.4	0.1330
482.3	0.1319
491.9	0.1306

Liquid Thermal Conductivity Correlation: λ /(W/m K) = 0.191151 - 0.1230146x10^{-3} T/K