

RESEARCH REPORT
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INTERPRETATION OF CALORIMETRIC
DATA FOR TWO BINARY
MIXTURES OF METHANE AND ETHANE

RAVI KANT, A.W. FURTADO
AND J.E. POWERS

THERMAL PROPERTIES OF FLUIDS LABORATORY
THE UNIVERSITY OF MICHIGAN
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INTRODUCTION

The need for accurate thermodynamic data for natural gas mixtures and the components of natural gas has been accentuated by recent developments in the area of natural gas processing at cryogenic conditions including liquefaction. Accurate values of thermodynamic properties are required not only for direct use in design of heat exchangers, compressors, and expanders but also to be used as a basis for testing and comparing various methods of prediction. In recognition of these needs, a calorimetric facility for accurate determinations at cryogenic conditions was developed as the Thermal Properties of Fluids Laboratory at the University of Michigan with financial support from the National Science Foundation, the Petroleum Research Fund of ACS and the Natural Gas Processors Association. Recently, calorimetric data on two binary mixtures of methane and ethane were obtained under sponsorship of NSF but funding to interpret these data was lacking. Such support was authorized by the Enthalpy Steering Committee of NGPA and made available after preliminary analyses gave strong indication that results useful to the natural gas processing industry would be obtained. Therefore, the objective of this report is to summarize the procedures used in interpreting the data and present the results in the form of skeleton tables of enthalpy values.

EXPERIMENTS

Composition

As mentioned in the Introduction, experimental data were obtained on two binary mixtures of methane and ethane. Samples taken from the recycle system were analyzed by chromatograph at frequent intervals during the entire course of the investigation. The methane and ethane content was determined by comparison with results of chromatographic analyses obtained at the same time using samples from a tank containing a standard mixture. The composition of the standard tank was analyzed for trace components in addition to methane and ethane. The results are given in Appendix I. Analyses for individual runs are presented in Tables A2 and A3 in Appendix IV. The analyses of the samples from the recycle system were averaged to give the nominal binary compositions listed in Table I.

TABLE I

Nominal Binary Compositions of
the Methane - Ethane Mixtures Investigated

Methane	77.7	47.7
Ethane	<u>22.3</u>	<u>52.3</u>
	100.0	100.0

In obtaining these average values, added weight was given to the composition of runs made across the two-phase region and near the critical point.

Experimental Data

The range of experimental determinations is indicated on PT diagrams as Figures 1 and 2. Each group of experiments is

identified by a number within a circle. Isobaric measurements over most of the single phase region were made in groups of three to nine runs with the same inlet temperature. Power input was adjusted to yield outlet temperatures increasing in increments of about 20°F. In regions where C_p varied significantly (such as near the critical point) smaller temperature rises were used (as small as 5°F). Isobaric determinations were made across the two phase region to establish bubble and dew points and heats of vaporization as well as enthalpy values within the two phase region. Isothermal determinations were made mainly in the single phase region. Pressure drops were usually between 100 and 500 psia. A limited number of isenthalpic determinations were made at low temperatures in the liquid phase.

The basic experimental results obtained under sponsorship of the National Science Foundation are reported in Appendix IV.

Experimental Difficulties

During the course of time required to make extensive calorimetric determinations on two binary systems a number of operational difficulties are usually encountered. Nothing unusual occurred during this investigation but in the process of checking out equipment after completion of the runs, several small leaks were noted in the all-important section between the calorimeter and flowmeter. In addition, consideration of the possibility of bypassing of fluid which might occur when both the isobaric and throttling calorimeters are connected to the system resulted in a change of operating procedure so that only one calorimeter is connected into the system at a time. Even later it was found that a short in the battery used to power the

potentiometer yielded erroneous results.

It is impossible to determine whether any of these operational problems which were detected after completion of the investigation of two binary systems influenced the results substantially but at a minimum the possibility of systematic error must be taken into account. It should be noted that leaks between the calorimeter and flowmeter will tend to yield property values that are too high.

SELECTION OF BASES

AND

USE OF OTHER PUBLISHED DATA

Bases for Enthalpy Values

Analysis of the basic calorimetric determinations presented in Appendix IV yields values of the derivative properties $C_p \equiv -(\partial H/\partial T)_p$, $\phi \equiv (\partial H/\partial P)_T$ and $\mu \equiv (\partial T/\partial P)_H$ in addition to the enthalpy function itself, H . The bases that $H = 0$ for pure methane and pure ethane as saturated liquids at -280°F were selected to yield results that are consistent with prior analyses of other systems (5-8).

Published Data for Pure Methane and Pure Propane

At zero pressure all gases form ideal mixtures and therefore it is possible to calculate the enthalpy of mixture at zero pressure from a knowledge of the enthalpy of pure components. The procedure not only permits values at low pressure to be included to the final tables, but also provides a basis for comparison with the calorimetric determinations for the mixtures which were made only at elevated pressures.

In brief, for each pure component, one utilizes accurate published data on the heat capacity of saturated liquid, $C_{p\ell}$ and the enthalpy change on vaporization, ΔH_{vap} , together with an estimate of the enthalpy change from the pressure at which ΔH_{vap} is known to zero pressure to estimate the enthalpy of the pure compound as an ideal gas at the temperature of vaporization relative to the reference state of saturated liquid at -280°F .

Further, by using the properties of the ideal gas as calculated from theoretically based analyses of spectroscopic and calorimetric data, one can calculate the enthalpy of all pure components at any temperature of interest and thereby the enthalpy of the mixture

$$\underline{H}^{\circ}_M = \sum y_i \underline{H}^{\circ}_i \quad (1)$$

where the subscripts M and i refer to the mixture and the individual components of the mixture respectively and y_i refers to the mole fractions of the individual pure components. Details of the calculations are presented in Appendix II. The applicable results are summarized in Table II.

TABLE II

Zero Pressure Enthalpies of Methane - Ethane as Calculated from Published Data of Acceptable Accuracy

Nominal Ethane Content

22.3%		52.3%	
Temperature T (°F)	Enthalpy* <u>H</u> (Btu/lb)	Temperature T (°F)	Enthalpy <u>H</u> (Btu/lb)
-58.45	332.4	1.75	351.4
79.0	397.1	101.5	395.8
255.0	490.8	252.5	472.3

*Bases $H = 0$ for pure methane and pure ethane as saturated liquids at -280°F .

Estimates of Excess Enthalpy of Mixing Used in Conjunction with Calorimetric Data for Pure Methane and Pure Propane

In general, excess enthalpy of mixing, \underline{H}^E of liquid hydrocarbons is small and fairly insensitive to pressure. Therefore, approximate values of \underline{H}^E for methane-ethane mixtures can be used together with accurate enthalpy values for the two pure compounds to establish check points in the liquid region

for the mixture data.

The results of calculations described in detail in Appendix III are presented in Table III.

TABLE III

Estimated Values of
Enthalpies of Liquid Methane-Ethane
Mixtures to be Used as Checks on Calorimetric Determinations

Nominal Ethane Composition	T (°F)	P (psia)	CH ₄ (Btu/lb)	C ₂ H ₆ (Btu/lb)	H ^E (Btu/lb)	H _M (Btu/lb)
22.3%	-240	1000	34.7	25.0	1.0	32.8
52.3%	-220	1500	54.0	37.7	0.6	43.5

These estimated values together with the calculated enthalpy values for the ideal gas state serve as severe checks on values obtained from interpretation of the calorimetric data and resulted in systematic correction of the interpreted data as will be discussed in a later section.

CALCULATIONAL PROCEDURES

A number of steps were taken in processing the calorimetric data to obtain the best possible property values that are thermodynamically self-consistent and also in agreement with the other published data presented in a previous section.

Initial Interpretation of Basic Data

The basic data presented in Appendix IV are in terms of differences in enthalpy for a particular experimental mixture, x , corresponding to values of temperature and pressure measured at the inlet, i , and outlet, o , of the calorimeter:

$$\Delta H_{-M} = [H_{T_o, P_o} - H_{T_i, P_i}]_x \quad (2)$$

As mentioned previously, periodic checks were made of the composition of the experimental mixture and variation of as much as 1.2% ethane from the nominal values was noted. Similarly the system pressure during any series of isobaric runs ranged as much as ± 3 psi and the inlet temperature varied as much as $\pm 1.5^\circ\text{F}$ in extreme cases. Final interpretation of the data is both simplified and made more meaningful by adjusting the basic calorimetric data to the binary compositions listed in Table I, normalizing all isobaric determinations obtained at one pressure level to a convenient value (such as 1000 psia) and adjusting to an average value all inlet temperatures for one set of isobaric determinations. The sum total of all such corrections was usually less than 0.1% with a maximum adjustment of 3%.* Details of this normalization procedure are presented elsewhere (5).

In addition to the minor corrections to normalized values mentioned above, additional small corrections are made to account for the small measured pressure drop in the isobaric calorimeter and the fact that small differences in temperature existed between the inlet and outlet of the calorimeter during isothermal runs. These corrections were made in a rigorous manner as described elsewhere (5) and in extreme cases amounted to 0.3% of the experimentally determined enthalpy difference.

Smoothing of Adjusted Calorimetric Data

The isobaric, isothermal and isenthalpic data obtained in the single phase region were analyzed to yield values of the derivative

* These large corrections occurred only for the run made through the critical point for the nominal 52.3% mixture (Run 10). For all other runs the corrections did not exceed 1.5%.

functions C_p , $\phi \equiv (\partial H/\partial P)_T$ and $\mu \equiv (\partial T/\partial P)_H$, respectively. In this process it is possible to identify individual points with considerably greater than average experimental error and therefore the smoothed values are probably of improved accuracy compared to the individual data points. Integration of the smoothed derivative functions yield provisional values of enthalpy differences which must be checked for thermodynamic consistency.

Data taken within and near the two-phase region are generally not interpreted in terms of derivative functions but are merely smoothed graphically to yield enthalpy values in this important region.

Details of the analysis have been presented elsewhere (5). Brief summaries are given below in an attempt to make this report self-contained.

Isobaric Data

Single-Phase. The calorimetric data adjusted as described in the preceding section were used to calculate mean values of \hat{C}_p from the adjusted values of isobaric increases in enthalpy and temperature.

$$\hat{C}_p \equiv \frac{[H_{T_2} - H_{T_1}]_P}{T_2 - T_1} \quad (3)$$

Values thus calculated apply over the temperature interval $T_1 \rightarrow T_2$ and are plotted as solid horizontal lines as illustrated on Figure 3. All values for a set of isobaric runs are adjusted to an average inlet temperature and therefore additional isobaric enthalpy differences can be inferred from the data and used to calculate additional values of \hat{C}_p . Typical values are plotted as dashed horizontal lines on Figure 3.

Point values of the derivative function, C_p , are determined to satisfy the constraint

$$[\underline{H}_{T_j} - \underline{H}_{T_i}]_p = \int_{T_i}^{T_j} C_p dT_p \quad (4)$$

i.e. equal area constraints were applied. Computer aided graphical procedures were used as described in detail elsewhere (5). After each trial curve for $C_p = f(T)$ was established, integration of Equation (4) was carried out by computer using the Gauss-Legendre technique for each individual data point and difference point. Values of percentage error are listed on Figure 3 for each of the original data points used to generate the curve. One point has an indicated error of 1.56 percent. Also note that several values of \hat{C}_p obtained by differences involving this point (indicated by asterisks) deviate markedly from the curve. It was thus concluded that this point was in error and it was given little weight in determining the final curve.

All isobaric data obtained in the single phase were interpreted in this way. The values of C_p so obtained are reported as $C_p(S)$ in the skeleton tables. In general, the difference between the experimental data and values calculated by numerical integration of smoothed values of C_p showed random variation in sign and agreement was of the order of $\pm 0.2\%$ or better.

The same integration procedure was applied to yield isobaric differences in enthalpy between the temperatures of isothermal runs. These differences are used in checking the thermodynamic consistency of the data as described in the next section.

Two-Phase (Enthalpy Traverse). The calorimetric data

in and through the two phase region were obtained with a constant inlet temperature. Plots of temperature vs enthalpy difference were made as illustrated in Figure 4.

Interpretation of such plots yielded not only smoothed values of enthalpy in and near the two-phase region, but also the isobaric heat of vaporization and values of the bubble- and dew-points.

Isothermal Data

Interpretation of the isothermal data to yield smooth values of ϕ was very similar to the interpretation of the isobaric data. Figure 5 is a plot of

$$\hat{\phi} = \frac{[\frac{H}{P_2} - \frac{H}{P_1}]_T}{P_2 - P_1} \quad (5)$$

as represented by horizontal lines extending over the experimentally measured pressure interval. The solid line results from use of the iterative, computer-aided, graphical-numerical procedure described elsewhere (5). Percentage deviations between the experimental data and values calculated by Gauss-Legendre integration of

$$[\frac{H}{P_2} - \frac{H}{P_1}]_T = \int_{P_1}^{P_2} \phi \, dP_T \quad (6)$$

are expressed as percentages for the individual data points on the figure.

The lower limit of pressure which could be attained experimentally was about 100 psia. At lower pressures ϕ values were estimated so as to be in agreement with experimental values and follow the pressure dependence indicated by several prediction methods (5). Thus, the curve drawn on Figure 5 between 0 and 350 psia is in good agreement

with the experimental data between 100 and 350 psia and is of a shape in agreement with predictions made at low pressures.

All isothermal data were interpreted in this manner (Several runs were made completely in the liquid region i.e. above the two phase curve). The values of ϕ so obtained are reported as in the skeleton tables as $\phi(S)$.

The numerical integration procedure was applied to yield isothermal enthalpy differences between the pressures of isobaric determinations for use together with similar isobaric calculations to check the thermodynamic consistency of the data.

Isenthalpic Data

At low temperatures and elevated pressures the fluid temperature increases with a decrease in pressure. Under these conditions no energy was added to the calorimeter and an isenthalpic expansion occurred. The data were first interpreted to yield values of the Joule-Thomson coefficient

$$\mu = (\partial T / \partial P)_{\underline{H}} \quad (7)$$

which were used to establish values of ϕ along an isotherm. The procedure has been described in detail elsewhere (5). Smoothed values of μ thus obtained are reported in the skeleton tables.

Adjustment of Values to Insure Thermodynamic Consistency and Agreement with other Published Data

Checks of Internal Thermodynamic Consistency

The individual enthalpy differences calculated by numerical integration of C_p and ϕ obtained as described in the preceding section are summarized on P-T diagrams as Figures 6 and 7. These values are not in parentheses. Enthalpy is a point function of state and therefore these independently determined values of differences in

enthalpy can be tested against the rigorous thermodynamic requirement that the sum of all differences around a closed loop must equal zero. Values of the actual sums (taken in the clockwise direction with proper attention to sign) and the percentage deviations,

$$\text{percentage deviation} \equiv \frac{\sum \Delta H_i}{\sum |\Delta H_i|} \times 100 \quad (6)$$

are included within each closed loop and provide an excellent measure of the internal thermodynamic consistency of the smoothed data. Consideration of the values presented in Figures 6 and 7 reveal that the data are indeed self-consistent to about 0.4% in most cases.

Unfortunately, if the flow determination for all runs is in error by a constant factor, all values will have an equal percentage error and the results will be thermodynamically consistent but in error. As mentioned previously, leaks were found in the system after completion of the investigation and therefore it was decided to insure not only internal thermodynamic consistency but also agreement with other published data of acceptable accuracy.

Comparison with Other Data

As discussed under the section entitled SELECTION OF BASES AND USE OF OTHER PUBLISHED DATA, accurate data for pure methane and pure ethane were used to establish enthalpy values for the mixture at zero pressure as listed in Table II. Similarly estimates of the excess enthalpy of mixing of liquid methane and ethane established values of enthalpy for one liquid mixture for each binary as listed in Table III. These "check points" were used to calculate differences in enthalpy for comparison with the experimentally reported values as summarized in Table IV.

TABLE IV

Comparison of Differences Between Check Values of Enthalpy
 Estimated from Published Data and
 Direct Calorimetric Determinations

Nominal Ethane Composition	T (°F)	P psia	Enthalpy Values Obtained by	
			Check Values	Integration of D
			H Btu/lb	H Btu/lb
22.3	255.0	0	490.8 ^a	490.8 ^c
	255.0	1000	-	469.7 ^d
	-240.	1000	32.8 ^b	28.8 ^e
			<hr/> 458.0	<hr/> 462.0
	Difference between check values		4.0 Btu/lb	
52.3	252.5	0	472.3 ^a	472.3 ^c
	252.5	1500	-	431.0 ^d
	-220	1500	43.5 ^b	36.4 ^e
			<hr/> 428.8	<hr/> 435.9
	Difference between check values		7.1 Btu/lb	

- a. Zero pressure check point from Table II.
- b. Estimated value from Table III.
- c. Basis of comparison.
- d. Obtained from zero pressure value using calculated isothermal difference from zero pressure to pressure of low temperature check point. For example, 469.7 = 490.8 - 21.08.
- e. Obtained from high temperature value by **integration** of isobaric data. For example, 28.8 = 469.7 - (113.00 + 166.10 + 93.99 + 67.81)

The discrepancies [4.0 Btu/lb (1%) in one case and 7.1 Btu/lb (1.6%) in the other are much larger than had been expected as similar comparisons made on other data (1,9,12) had been exceedingly consistent. Therefore, it was decided that systematic errors were involved in the data and all values were adjusted in accordance with several goals:

- 1) Obtain agreement with the "check points" for enthalpy based on other published data.
- 2) Utilize values of isothermal enthalpy differences estimated by several consistent methods at high temperatures where such estimations have proven to be accurate (5).
- 3) Make adjustments in the derivative functions, C_p and ϕ , such that integration yields thermodynamic consistency. Further, these adjustments should not be excessive i.e. in keeping with corrections made for similar determinations on the same equipment.

With the exception that it was necessary to make corrections to both the isobaric and isothermal data in excess of those applied in the analysis of similar systems, it was possible to satisfy all other conditions by a laborious trial and error procedure. The resulting, thermodynamically-consistent values of enthalpy differences are listed in parentheses on Figures 6 and 7. In some cases, it was necessary to make adjustments to isothermal determinations by as much as 7.1% as indicated by the dashed line in Figure 5. Similarly corrections as large as 1.3% were made on the isobaric values (center line on Figure 3). Thus, these data, though thermodynamically self-consistent to better than 0.5% were judged to be in error by much larger amounts in comparison to other data. Taking into account the possibility of systematic errors during the experiment, unusually large adjustments

were made in preparing the skeleton tables. The values so adjusted are listed as $C_p(A)$ and $\phi(A)$ in the skeleton tables together with values of \underline{H} which are consistent with the values of the derivative functions.

SKELETON TABLES OF
THERMODYNAMIC DATA

The tables which follow contain values of thermodynamic properties for the two methane-ethane mixtures obtained as described in preceding sections.

Tables IXa and IXb include enthalpy values at the intersections of isobaric and isothermal determinations. These values are probably the better known of all reported enthalpy values.

Values of C_p , ϕ , and \underline{H} reported in Tables Va, Vb, VIa, and VIb, comprise the major contribution of this report. Both smooth and adjusted values of C_p and ϕ are listed as discussed previously. The enthalpy values are consistent with the adjusted values of the derivative functions, $C_p(A)$ and $\phi(A)$.

Tables Va, and Vb report C_p and \underline{H} at the pressures of measurement over a temperature range from -260 to +320°F at temperature intervals of 10°F. At pressures below the critical, values of C_p are not reported within and near the two phase region except for the 250 psia isobar in Table Va.

Similarly Tables VIa and VIb contain ϕ and \underline{H} values at the temperatures of isothermal determinations and μ , ϕ , and \underline{H} at temperatures of isenthalpic determinations. Results of isothermal determinations are reported at intervals of 50 psi and those corresponding to isenthalpic determinations at intervals of 100 psi.

Data obtained from enthalpy traverses across the two phase region are reported in Tables VIIa and VIIb.

Near the critical region C_p attains a maxima. In this region C_p is a strong function of temperature i.e. $(\partial C_p / \partial T)_p$ is large and consequently thermodynamic properties change very rapidly. Therefore, it was felt necessary to report C_p and \underline{H} at closer intervals of temperature in this region. Tables VIIIa and VIIIb report these values. The format of these tables is same as Va and Vb.

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TABLE Va
Table of Thermodynamic Properties at the Pressures of Isobaric
Determinations
Mixture of Methane and Ethane Containing Approximately
22.3 Mole Percent Ethane

P = 250 psia			P = 500 psia			P = 1000 psia			P = 1500 psia			P = 2000 psia				
Temp. °F	C_p	H	Temp. °F	$C_p(S)$	$C_p(A)$	Temp. °F	$C_p(S)$	$C_p(A)$	Temp. °F	$C_p(S)$	$C_p(A)$	Temp. °F	$C_p(S)$	$C_p(A)$	H	
	Btu/lb°F	Btu/lb		Btu/lb°F	Btu/lb°F		Btu/lb°F	Btu/lb°F		Btu/lb°F	Btu/lb°F		Btu/lb°F	Btu/lb°F	Btu/lb°F	Btu/lb°F
-260.0			-260.0	0.7247	0.7207	18.26			-260.0			-260.0				
-250.0	0.7209	22.54	-250.0	0.7304	0.7264	25.49			-250.0			-250.0				
-240.0	0.7305	29.80	-240.0	0.7343	0.7303	32.78			-240.0			-240.0				
-230.0	0.7400	37.15	-230.0	0.7377	0.7336	40.09			-230.0			-230.0				
-220.0	0.7495	44.60	-220.0	0.7412	0.7371	47.44			-220.0			-220.0				
-210.0	0.7590	52.14	-210.0	0.7465	0.7424	54.84			-210.0			-210.0				
-200.0	0.7685	59.78	-200.0	0.7526	0.7485	62.29			-200.0			-200.0				
-190.0	0.7780	67.51	-190.0	0.7588	0.7546	69.80			-190.0			-190.0				
-180.0	0.7877	75.34	-180.0	0.7665	0.7623	77.38			-180.0			-180.0				
-170.0	0.7967	83.26	-170.0	0.7767	0.7724	85.03			-170.0			-170.0				
-160.0	0.8058	91.27	-160.0	0.7903	0.7860	92.91			-160.0			-160.0				
-150.0		131.37	-150.0	0.8070	0.8031	100.65			-150.0			-150.0				
-140.0		170.67	-140.0	0.8248	0.8208	109.08			-140.0			-140.0				
-130.0		196.37	-130.0	0.8471	0.8430	117.37			-130.0			-130.0				
-120.0		215.87	-120.0	0.8758	0.8756	125.96			-120.0			-120.0				
-110.0		233.87	-110.0	0.9240	0.9196	134.86			-110.0			-110.0				
-100.0		252.77	-100.0	0.9865	0.9818	144.36			-100.0			-100.0	0.9154	0.9110	178.1	
-90.0		274.27	-90.0	1.0582	1.0531	154.56			-90.0			-90.0	0.9526	0.9480	186.9	
-80.0		296.57	-80.0	1.1458	1.1403	165.46			-80.0			-80.0	0.9885	0.9837	196.6	
-70.0		308.87	-70.0	1.2836	1.2774	177.46			-70.0			-70.0				
-60.0	0.5730	315.10	-60.0	1.5582	1.5507	191.36			-60.0	0.9154	0.9110	-60.0	0.9154	0.9110	178.1	
-50.0	0.5410	320.66	-50.0	2.1815	2.1695	209.97	1.1234	1.1220	192.07	-50.0	0.9526	0.9480	-50.0	0.9526	0.9480	186.9
-40.0	0.5532	326.12	-40.0	2.3519	2.3385	233.08	1.1902	1.1887	203.60	-40.0	0.9885	0.9837	-40.0	0.9885	0.9837	196.6
-30.0	0.5645	331.61	-30.0	1.9485	1.9374	254.79	1.2769	1.2753	215.88	-30.0	1.0246	1.0197	-30.0	1.0246	1.0197	206.6
-20.0	0.5317	337.02	-20.0	1.4988	1.4903	271.79	1.3945	1.3927	229.29	-20.0	1.0596	1.0545	-20.0	1.0596	1.0545	217.0
10.0	0.5772	342.34	-10.0	1.1940	1.1872	285.10	1.4115	1.4097	243.37	-10.0	1.0897	1.0844	-10.0	1.0897	1.0844	227.7
0.0	0.5224	347.59	0.0	1.0170	1.0112	296.00	1.3487	1.3470	257.20	0.0	1.1008	1.0955	0.0	1.1008	1.0955	238.6
10.0	0.5199	352.80	10.0	0.9188	0.9136	305.61	1.2510	1.2494	270.20	10.0	1.1028	1.0975	10.0	1.1028	1.0975	249.55
20.0	0.5186	357.99	20.0	0.8639	0.8590	314.51	1.1423	1.1408	282.18	20.0	1.0917	1.0864	20.0	1.0917	1.0864	260.51
30.0	0.5174	363.17	30.0	0.8203	0.8156	322.81	1.0496	1.0483	293.13	30.0	1.0677	1.0626	30.0	1.0677	1.0626	271.27
40.0	0.5169	368.34	40.0	0.7835	0.7794	330.82	0.9755	0.9743	303.19	40.0	1.0376	1.0326	40.0	1.0376	1.0326	281.70
50.0	0.5169	373.51	50.0	0.7522	0.7479	338.42	0.9252	0.9240	312.65	50.0	1.0055	1.0007	50.0	1.0055	1.0007	291.88
60.0	0.5169	378.68	60.0	0.7225	0.7184	345.72	0.8865	0.8854	321.71	60.0	0.9700	0.9653	60.0	0.9700	0.9653	301.75
70.0	0.5169	383.85	70.0	0.6950	0.6910	352.83	0.8480	0.8469	330.38	70.0	0.9330	0.9285	70.0	0.9330	0.9285	311.23
80.0	0.5169	389.02	80.0	0.6785	0.6741	359.60	0.8160	0.8150	338.64	80.0	0.9000	0.9009	80.0	0.9000	0.9009	320.32
90.0			90.0	0.6680	0.6637	366.20				90.0	0.8729	0.8738	90.0	0.8729	0.8738	329.17
100.0			100.0	0.6597	0.6554	373.00				100.0	0.8464	0.8472	100.0	0.8464	0.8472	337.82
110.0			110.0	0.6531	0.6489	379.59				110.0	0.8205	0.8213	110.0	0.8205	0.8213	346.17
120.0			120.0	0.6477	0.6435	386.09				120.0	0.8005	0.8013	120.0	0.8005	0.8013	354.32
130.0			130.0	0.6427	0.6385	392.54				130.0	0.7826	0.7834	130.0	0.7826	0.7834	362.17
140.0			140.0	0.6385	0.6343	398.97				140.0	0.7678	0.7686	140.0	0.7678	0.7686	370.01
150.0			150.0	0.6356	0.6315	405.25				150.0	0.7518	0.7526	150.0	0.7518	0.7526	377.56
160.0			160.0	0.6335	0.6294	411.53				160.0	0.7403	0.7410	160.0	0.7403	0.7410	385.10
170.0			170.0	0.6319	0.6278	417.79				170.0	0.7333	0.7340	170.0	0.7333	0.7340	392.45
180.0			180.0	0.6310	0.6269	424.04				180.0	0.7274	0.7281	180.0	0.7274	0.7281	399.79
190.0			190.0	0.6305	0.6264	430.29				190.0	0.7227	0.7234	190.0	0.7227	0.7234	407.03
200.0			200.0	0.6307	0.6266	436.53				200.0	0.7186	0.7193	200.0	0.7186	0.7193	414.28
210.0			210.0	0.6320	0.6279	442.78				210.0	0.7147	0.7154	210.0	0.7147	0.7154	421.42
220.0			220.0	0.6345	0.6304	449.05				220.0	0.7112	0.7119	220.0	0.7112	0.7119	428.56
230.0			230.0	0.6373	0.6332	455.34				230.0	0.7080	0.7087	230.0	0.7080	0.7087	435.69
240.0			240.0	0.6400	0.6358	461.67				240.0	0.7048	0.7055	240.0	0.7048	0.7055	442.75
250.0			250.0	0.6426	0.6384	468.02				250.0	0.7033	0.7040	250.0	0.7033	0.7040	449.79
260.0			260.0	0.6450	0.6408	474.39				260.0	0.7018	0.7025	260.0	0.7018	0.7025	456.83
270.0			270.0	0.6476	0.6434	480.79				270.0	0.7003	0.7010	270.0	0.7003	0.7010	463.87
280.0			280.0	0.6510	0.6468	487.22				280.0	0.6988	0.6995	280.0	0.6988	0.6995	470.91
290.0			290.0	0.6542	0.6499	493.60				290.0	0.6972	0.6979	290.0	0.6972	0.6979	477.85
300.0			300.0	0.6575	0.6532	500.17				300.0	0.6960	0.6967	300.0	0.6960	0.6967	484.90
310.0			310.0	0.6598	0.6555	506.70				310.0			310.0			
320.0			320.0	0.6610	0.6567	513.24				320.0			320.0			

1. C_p values at 500 psia are not reported as most of the data lies in two phase region.

2. C_p values at 250 psia are not reported in the two phase region.

TABLE VB
Table of Thermodynamic Properties at the Pressures of Isobaric
Determinations
Mixture of Methane and Ethane Containing Approximately
52.3 Mole Percent Ethane

Temp. °F	P = 250 psia			P = 500 psia			P = 750 psia			P = 978 psia			P = 1250 psia			P = 1500 psia			P = 2000 psia			
	$^{1}C_p$ Btu/lb°F	$\frac{H}{Btu/lb}$	$\frac{H}{Btu/lb}$	$^{1}C_p$ Btu/lb°F	$\frac{H}{Btu/lb}$	$\frac{H}{Btu/lb}$	$^{1}C_p$ Btu/lb°F	$\frac{H}{Btu/lb}$	$\frac{H}{Btu/lb}$	Cp(S) Btu/lb°F	Cp(A) Btu/lb°F	$\frac{H}{Btu/lb}$	Cp(S) Btu/lb°F	Cp(A) Btu/lb°F	$\frac{H}{Btu/lb}$	Cp(S) Btu/lb°F	Cp(A) Btu/lb°F	$\frac{H}{Btu/lb}$	Cp(S) Btu/lb°F	Cp(A) Btu/lb°F	$\frac{H}{Btu/lb}$	
-250.0																						
-240.0																						
-230.0																						
-220.0																						
-210.0																						
-200.0																						
-190.0																						
-180.0																						
-170.0																						
-160.0																						
-150.0																						
-140.0																						
-130.0		99.45																				
-120.0		120.35																				
-110.0		137.65																				
-100.0		153.45																				
-90.0		170.85																				
-80.0		190.55																				
-70.0		211.85																				
-60.0		235.55																				
-50.0		263.35																				
-40.0		299.05																				
-30.0		320.35																				
-20.0		325.05																				
-10.0		330.35																				
0.0		335.35																				
10.0																						
20.0																						
30.0																						
40.0																						
50.0																						
60.0																						
70.0																						
80.0																						
90.0																						
100.0																						
110.0																						
120.0																						
130.0																						
140.0																						
150.0																						
160.0																						
170.0																						
180.0																						
190.0																						
200.0																						
210.0																						
220.0																						
230.0																						
240.0																						
250.0																						
260.0																						
270.0																						
280.0																						
290.0																						
300.0																						
310.0																						

1. Cp values at 250 psia, 500 psia and 750 psia are not reported as most of the data lies in two phase region.

TABLE VIIa

Empirical Data Obtained from Interpretation of
Enthalpy Traverses.
Mixture of Methane and Ethane Containing Approximately
22.3 Mole Percent Ethane.

Pressure psia	<u>Bubble Point</u> °F	<u>Dew Point</u> °F	<u>ΔH_{vap}</u> Btu/lb
250	-154.2	-77.2	204.2
500	-112.5	-46.8	166.5

TABLE VIIb

Empirical Data Obtained from Interpretation
of Enthalpy Traverses.
Mixture of Methane and Ethane Containing Approximately
52.3 Mole Percent Ethane.

Pressure psia	<u>Bubble Point</u> °F	<u>Dew Point</u> °F	<u>ΔH_{vap}</u> Btu/lb
250	-129.0	-35.7	213.80
500	-76.5	2.7	173.40
750	-33.25	14.2	102.30

TABLE VIIIb

Table of Thermodynamic Properties, at the Pressures of Isoobaric Determinations, in the Regions of Rapid Change. (High $(\partial C_p/\partial T)_p$) Mixture of Methane and Ethane Containing Approximately 52.3 Mole Percent Ethane

P = 978 psia			P = 1250 psia			P = 1500 psia					
Cp(S) Btu/lb°F	Cp(A) Btu/lb°F	H Btu/lb	Cp(S) Btu/lb°F	Cp(A) Btu/lb°F	H Btu/lb	Cp(S) Btu/lb°F	Cp(A) Btu/lb°F	H Btu/lb			
Temp. °F			Temp. °F			Temp. °F					
5.00	1.6682	1.6520	219.73	15.00	1.2581	1.2414	221.79	30.00	1.1497	1.1366	232.59
10.00	1.8773	1.8591	228.52	17.50	1.2914	1.2742	224.93	40.00	1.2295	1.2155	244.09
15.00	2.0835	2.0633	238.41	20.00	1.3258	1.3082	228.16	41.00	1.2407	1.2266	245.29
15.50	2.0996	2.0792	239.51	22.50	1.3622	1.3441	231.48	42.00	1.2497	1.2355	246.59
16.00	2.1178	2.0973	240.51	25.00	1.3965	1.3779	234.89	43.00	1.2588	1.2444	247.79
16.50	2.1340	2.1133	241.61	27.50	1.4268	1.4078	238.37	44.00	1.2659	1.2515	249.09
17.00	2.1451	2.1243	242.61	30.00	1.4572	1.4378	241.93	45.00	1.2720	1.2575	250.29
17.50	2.1501	2.1292	243.71	30.62	1.4642	1.4447	242.83	46.00	1.2760	1.2615	251.59
18.00	2.1532	2.1323	244.81	31.25	1.4703	1.4507	243.74	47.00	1.2790	1.2644	252.89
18.50	2.1552	2.1343	245.81	31.88	1.4774	1.4577	244.66	48.00	1.2801	1.2655	254.09
19.00	2.1542	2.1333	246.91	32.50	1.4844	1.4647	245.56	49.00	1.2811	1.2665	255.39
19.50	2.1522	2.1313	248.01	33.13	1.4905	1.4707	246.48	50.00	1.2821	1.2675	256.69
20.00	2.1461	2.1253	249.01	33.75	1.4956	1.4757	247.40	51.00	1.2831	1.2685	257.89
20.50	2.1380	2.1173	250.11	34.38	1.5006	1.4806	248.33	52.00	1.2841	1.2695	259.19
21.00	2.1279	2.1073	251.11	35.00	1.5067	1.4867	249.26	53.00	1.2841	1.2695	260.49
21.50	2.1148	2.0943	252.20	35.62	1.5117	1.4916	250.17	54.00	1.2841	1.2695	261.69
22.00	2.0996	2.0792	253.20	36.25	1.5168	1.4966	251.12	55.00	1.2831	1.2685	262.99
22.50	2.0824	2.0622	254.30	36.87	1.5218	1.5016	252.05	56.00	1.2821	1.2675	264.29
23.00	2.0663	2.0463	255.30	37.50	1.5259	1.5056	253.00	57.00	1.2811	1.2665	265.49
23.50	2.0491	2.0292	256.30	38.13	1.5279	1.5076	253.95	58.00	1.2801	1.2655	266.79
24.00	2.0329	2.0132	257.30	38.75	1.5299	1.5096	254.88	59.00	1.2790	1.2644	268.09
24.50	2.0188	1.9992	258.30	39.38	1.5319	1.5115	255.83	60.00	1.2760	1.2615	269.29
25.00	2.0077	1.9882	259.30	40.00	1.5340	1.5136	256.77	61.00	1.2720	1.2575	270.59
30.00	1.8349	1.8171	268.99	40.63	1.5340	1.5136	257.73	62.00	1.2659	1.2515	271.89
35.00	1.6763	1.6600	277.58	41.25	1.5340	1.5136	258.67	63.00	1.2598	1.2454	273.09
40.00	1.5338	1.5189	285.58	41.87	1.5340	1.5136	259.60	64.00	1.2528	1.2385	274.39
45.00	1.4166	1.4029	292.87	42.50	1.5329	1.5125	260.56	65.00	1.2467	1.2325	275.59
				43.13	1.5299	1.5096	261.51	66.00	1.2407	1.2266	276.79
				43.75	1.5279	1.5076	262.45	67.00	1.2346	1.2205	277.99
				44.38	1.5249	1.5046	263.39	68.00	1.2285	1.2145	279.29
				45.00	1.5208	1.5006	264.33	69.00	1.2225	1.2086	280.49
				45.63	1.5158	1.4956	265.27	70.00	1.2164	1.2025	281.69
				46.25	1.5117	1.4916	266.20	80.00	1.1548	1.1416	293.39
				46.88	1.5067	1.4867	267.14				
				47.50	1.5016	1.4816	268.06				
				48.12	1.4956	1.4757	268.98				
				48.75	1.4895	1.4697	269.91				
				49.38	1.4834	1.4637	270.83				
				50.00	1.4774	1.4577	271.74				
				50.63	1.4703	1.4507	272.65				
				51.25	1.4632	1.4437	273.55				
				51.88	1.4561	1.4367	274.46				
				52.50	1.4501	1.4308	275.35				
				53.13	1.4440	1.4248	276.25				
				53.75	1.4369	1.4178	277.13				
				54.38	1.4289	1.4099	278.02				
				55.00	1.4198	1.4009	278.90				
				57.50	1.3844	1.3660	282.35				
				60.00	1.3511	1.3331	285.74				
				62.50	1.3187	1.3012	289.03				
				65.00	1.2874	1.2703	292.24				

TABLE IXa

Enthalpy Values at the Points of Thermodynamic Consistency
Mixture of Methane and Ethane Containing Approximately
22.3 Mole Percent Ethane

Temperature °F pressure psia	-253.2	-150.55	-58.45	79.0	255.0
0		291.7	332.4	397.1	490.8
250		129.86		388.49	
500		99.565			
1000	23.17	100.22	193.76	358.93	471.2
1500			182.77	337.84	
2000			179.07	319.41	453.31

Base Points:

Basis: $\underline{H} = 0$ Pure Saturated liquids at -280°F

- a) Calculated zero pressure value: $\underline{H} = 397.1$ Btu/lb for mixture at 79.0°F .
- b) Liquid Consistency point: $\underline{H} = 32.8$ Btu/lb for mixture at -240°F and 1000 psia.

TABLE IXb

Enthalpy Values at the Points of Thermodynamic Consistency.
Mixture of Methane and Ethane Containing Approximately
52.3 Mole Percent Ethane.

Temperature °F pressure psia	-228.45	-99.05	1.75	101.5	252.5
0		301.35	351.4	395.8	472.3
250		155.19	336.35		
500		122.15	307.87		
750		122.258	242.23		
978		122.421	214.63	348.03	
1250			206.55	331.21	
1500	38.1	123.154	203.29	316.39	433.89
2000			200.07	295.42	

Base Points:

Basis: $H = 0$ Pure Saturated liquids at -280°F

- a) Calculated zero pressure value: H 395.8 Btu/lb for mixture at 101.5°F
- b) Liquid consistency point: $H = 43.50$ Btu/lb for mixture at -220°F and 1500 psia.

APPENDIX I

Composition of Standard Mixture

As mentioned in the section on EXPERIMENTS under the subheading Composition, the chromatograph was calibrated in conjunction with the analysis of samples withdrawn from the system by use of a Mixture of constant compositions stored in a standard tank. The composition of the standard mixture as determined by chromatograph and mass spectrometer are reported in Table A1.

TABLE A1

Composition of Standard Mixture Used
to Calibrate the Chromatograph

		Nominal Ethane Content	
		22.3%	52.3%
		Composition	
		mol%	mol%
Nitrogen	N ₂	0.08	0.05
Carbon Dioxide	CO ₂	0.03	0.03
Methane	CH ₄	77.71	47.90
Ethane	C ₂ H ₆	22.10	51.70
Propane	C ₃ H ₈	0.03	0.03
Propylene	C ₃ H ₆	<u>0.05</u>	<u>0.29</u>
		100.00	100.00

APPENDIX II

Calculation of Enthalpy Values for the Methane-Ethane Mixtures at Zero Pressure

As a first step in this process, the enthalpy of pure methane and ethane were calculated at 192°F and zero pressure using the bases $H = 0$ for saturated liquids at -280°F. The results are summarized individually below:

<u>Methane</u>	<u>Btu/lb</u>
1. Enthalpy of saturated liquid at -280°F and 5 psia	0.00
2. Enthalpy of vaporization at -280°F and 5 psia. [Experimental data of Frank & Clusius (4)]	227.72
3. Isothermal enthalpy difference between saturated vapor at 5 psia and ideal gas at -280°F [Estimated using a correlation of published data on the second virial coefficient for methane developed by Furtado (5)]	1.15
4. Enthalpy change as an ideal gas between -280°F and +192°F [Calculated by interpolation of tabulated values of $(\underline{H}^\circ - \underline{H}_O^\circ)/T$ published by Rossini <u>et al</u> (10)]	243.32
5. Enthalpy of pure methane as an ideal gas at 192°F	<u>472.19</u>
 <u>Ethane</u>	
1. Enthalpy of saturated liquid at -280°F.	0.00
2. Enthalpy change from saturated liquid at -280°F to saturated liquid at -128.1°F and 14.696 psia [Integration of heat capacity data of Witt and Kemp (11)]	84.50
3. Enthalpy of vaporization at -128°F and 14.696 psia [Experimental data of Witt and Kemp (11)]	210.9
4. Isothermal enthalpy change from saturated vapor at 14.696 psia to the ideal gas state at -128°F. [Estimated using a correlation of published data on the second virial coefficient for propane developed by Furtado (5)].	2.40

5. Enthalpy change as an ideal gas between -128.1°F and $+192^{\circ}\text{F}$ [Calculated by interpolation of tabulated values of $(\underline{H}^{\circ} - \underline{H}^{\circ}_0)/T$ published by Rossini et al (10)] 127.70

6. Enthalpy of pure ethane as an ideal gas at 192°F 394.63

Molecular weights of 16.04 and 30.06 were used for methane and ethane respectively to yield the following values of \underline{H}°_M at 192°F :

Nominal Ethane Composition	\underline{H}°_M at 192°F (Btu/lb)
22.3	445.04
52.3	419.98

The tabulated values of $(\underline{H}^{\circ} - \underline{H}^{\circ}_0)/T$ for methane and ethane as published by Rossini et al were used to calculate values of \underline{H}°_M at other temperatures as listed in Table II.

APPENDIX III

Estimation of Enthalpy Values for Methane-Ethane in the Liquid State at Elevated Pressures to Serve as Checks on the Calorimetric Data

As indicated on Figures 1 and 2, isobaric determinations were made over the entire temperature range (-240°F to $+300^{\circ}\text{F}$) at only one pressure each; 1000 psia for the 22.3% mixture and 1500 psia for the 52.3% mixture. Therefore, enthalpy values were estimated at -240°F , 1000 psia and -220°F , 1500 psia respectively for these mixtures.

Enthalpy values for pure methane were taken from the thesis of Jones (7) and corrected at elevated pressures as suggested by Yesavage (12). For ethane, values were obtained directly from a tabulation by Furtado(5). These values are reported in Table III.

Note that if ideal mixing is assumed, it is predicted that $\underline{H} = 31.4$ Btu/lb for the 22.3% mixture at -240°F and 1000 psia and 42.9 Btu/lb for the 52.3% mixture at -220°F and 1500 psia. \underline{H}^E is positive in sign for mixtures of light hydrocarbons in the liquid state and therefore these values represent a lower limit on the enthalpies of the mixtures.

Estimation of Excess Enthalpy of Methane-Ethane Mixtures.

Unfortunately no published data on the excess enthalpy of liquid methane-ethane mixtures have come to our attention. However, Cutler and Morrison (3) have published data on the excess enthalpy data of methane-propane mixtures and these serve to establish an upper bound to such values for methane-ethane mixtures. These authors report values of \underline{H}^E for liquid methane-propane mixtures at 100°K (-280°F). A broad maximum occurs between 30-50% propane with \underline{H}^E of about 1.6 Btu/lb

These data are for low pressure.

Yesavage (12, 13) has reported enthalpy data for a mixture containing about 50% propane in methane. Using these data in conjunction with the corrected methane values of Jones (7,8) and the corrected propane values of Yesavage (12,2) at 1500 psia and -220°F the calculated value of \underline{H}^E is 1 Btu/lb.

Assuming the \underline{H}^E will be roughly constant for methane-ethane mixtures in the composition range from 22 to 50% (based on the results of Cutler and Morrison for methane-propane), that the heat of mixing of liquid hydrocarbons decreases with pressure and that \underline{H}^E should be less for methane-ethane mixtures than for methane-propane mixtures at similar conditions yields the estimates for \underline{H}^E presented in Table III. Values of \underline{H}_M are calculated according to

$$\underline{H}_M = \sum x_i \underline{H}_i + \underline{H}^E \quad (\text{AIII-1})$$

where x_i refers to the mole fraction in the liquid.

APPENDIX IV

The basic calorimetric determinations made on the two binary mixtures of methane and ethane are reported in this appendix. As indicated by the headings following each run number are listed the mole fractions of methane (XC1), ethane (XC2) and propane (XC3) which are normalized to 1.000 because the other trace impurities were not determined by chromatographic analysis. In sequential columns are listed the experimentally determined values of temperature at the inlet and outlet of the calorimeter, pressure at the inlet and pressure drop and the energy added during the experiment.

Table A2 lists results for the normal 22.3% ethane mixture and Table A3 presents values for the normal 52.3% ethane mixture. In each case isobaric data are presented in Table (a), isothermal data in Table (b) and isenthalpic data in Table (c). In each case the mean value of the corresponding derivative function (C_p , ϕ and μ) as calculated from the raw data are listed in the last column. As mentioned in the text these values were corrected for minor variations in composition, pressure level, inlet temperature, etc. before being processed to fit and smooth the data.

TABLE A2(a)
ISOBARIC DATA FOR NOMINAL 0.777 CH₄, 0.223 C₂H₆*

RUN NO.	XC1 (MOLE FRACTION)	XC2 (MOLE FRACTION)	XC3 (MOLE FRACTION)	INLET TEMP. (F)	OUTLET TEMP. (F)	INLET PRES. (PSIA)	PRES. DROP (PSID)	HEAT INPUT (BTU/LB)	MEAN HEAT CAPACITY (BTU/LB F)
15.010	0.778	0.221	0.001	-240.72	-214.98	249.7	0.10	18.990	0.73771
15.020	0.778	0.221	0.001	-240.71	-185.18	250.1	0.10	41.758	0.75199
15.025	0.778	0.221	0.001	-240.71	-185.18	250.1	0.10	41.853	0.75370
15.030	0.778	0.221	0.001	-240.70	-158.85	251.3	0.10	62.592	0.76470
16.010	0.771	0.228	0.001	-165.84	-161.30	250.1	0.10	3.756	0.82878
16.020	0.771	0.228	0.001	-165.81	-155.50	248.4	0.10	8.551	0.82965
16.030	0.771	0.228	0.001	-165.80	-153.97	250.4	0.34	14.197	1.19996
16.040	0.771	0.228	0.001	-165.81	-153.47	248.9	0.34	21.158	1.71408
16.045	0.771	0.228	0.001	-165.81	-153.47	248.9	0.34	21.214	1.71864
16.050	0.771	0.228	0.001	-165.81	-150.23	248.5	0.34	43.735	2.80600
16.060	0.771	0.228	0.001	-165.78	-137.35	249.7	0.34	92.025	3.23785
16.070	0.769	0.230	0.001	-165.78	-116.63	249.5	0.34	134.749	2.74196
16.080	0.769	0.230	0.001	-165.77	-92.31	249.3	0.34	182.357	2.48231
16.090	0.769	0.230	0.001	-165.77	-90.25	249.1	0.34	186.023	2.46306
16.100	0.769	0.230	0.001	-165.77	-86.45	249.7	0.34	194.764	2.45534
16.110	0.769	0.230	0.001	-165.76	-78.89	248.9	0.34	212.651	2.44794
16.120	0.769	0.230	0.001	-165.69	-75.14	249.5	0.34	218.055	2.40806
16.130	0.769	0.230	0.001	-165.75	-59.92	249.1	0.34	227.104	2.14592
11.010	0.777	0.222	0.001	-59.55	-36.41	251.5	0.38	12.736	0.55042
11.020	0.777	0.222	0.001	-59.56	-18.86	251.2	0.39	22.246	0.54650
11.030	0.777	0.222	0.001	-59.57	1.40	250.3	0.39	32.737	0.53693
11.040	0.778	0.221	0.001	-59.58	25.85	249.7	0.39	45.377	0.53118
11.050	0.778	0.221	0.001	-59.55	50.47	250.0	0.39	58.203	0.52900
11.060	0.778	0.221	0.001	-59.56	75.29	252.1	0.39	71.295	0.52868
17.010	0.771	0.228	0.001	-152.30	-130.83	498.8	0.07	18.797	0.87550
17.020	0.771	0.228	0.001	-152.29	-126.03	500.1	0.07	22.954	0.87423
17.030	0.771	0.228	0.001	-152.31	-116.34	499.4	0.07	32.267	0.89716
17.040	0.771	0.228	0.001	-152.30	-113.10	499.5	0.07	35.137	0.89647
17.050	0.771	0.228	0.001	-152.29	-102.79	501.9	0.17	78.641	1.58857
17.060	0.780	0.219	0.001	-152.28	-90.48	498.9	0.17	111.371	1.80200
17.070	0.780	0.219	0.001	-152.22	-66.00	501.8	0.17	163.664	1.89804
17.080	0.780	0.219	0.001	-152.16	-56.78	500.3	0.17	183.233	1.92109
17.090	0.769	0.230	0.001	-152.17	-51.26	499.5	0.17	193.828	1.92089
17.100	0.769	0.230	0.001	-152.20	-42.23	499.0	0.17	206.370	1.87650
14.010	0.777	0.222	0.001	-240.69	-221.28	999.1	0.05	14.179	0.73050
14.020	0.777	0.222	0.001	-240.76	-189.32	1000.4	0.05	37.998	0.73865
14.030	0.777	0.222	0.001	-240.73	-169.16	1002.2	0.05	53.421	0.74632
14.040	0.777	0.222	0.001	-240.76	-148.43	1002.8	0.05	69.734	0.75530
18.010	0.770	0.229	0.001	-152.14	-127.12	1001.1	0.06	20.524	0.82026
18.015	0.770	0.229	0.001	-152.14	-127.12	1001.1	0.06	20.581	0.82252
18.020	0.770	0.229	0.001	-152.14	-102.44	999.7	0.06	42.507	0.85522
18.030	0.771	0.228	0.001	-152.13	-82.18	999.1	0.06	63.265	0.90444
18.040	0.771	0.228	0.001	-152.10	-60.85	1002.1	0.06	90.203	0.98850
10.010	0.778	0.221	0.001	-59.47	-54.92	998.7	0.06	8.126	1.78589
10.015	0.778	0.221	0.001	-59.47	-54.92	998.7	0.06	8.100	1.78009

10.016	0.778	0.221	0.001	-59.47	-54.92	998.7	0.06	8.152	1.79168
10.020	0.778	0.221	0.001	-59.45	-49.65	1001.4	0.06	19.048	1.94450
10.030	0.778	0.221	0.001	-59.47	-40.21	1000.1	0.06	41.634	2.16154
10.040	0.778	0.221	0.001	-59.47	-29.23	1001.8	0.06	64.717	2.14012
10.050	0.777	0.222	0.001	-59.43	-19.64	1003.1	0.06	80.418	2.02102
10.060	0.777	0.222	0.001	-59.42	0.24	999.1	0.06	104.674	1.75440
10.070	0.777	0.222	0.001	-59.46	26.53	1000.0	0.06	128.013	1.48882
10.080	0.778	0.221	0.001	-59.42	51.65	1000.5	0.06	147.537	1.32833
10.090	0.778	0.221	0.001	-59.49	75.58	1000.9	0.06	164.543	1.21824
3.010	0.779	0.220	0.001	78.23	87.84	1001.9	0.14	6.460	0.67258
3.020	0.779	0.220	0.001	78.00	108.37	999.3	0.16	20.144	0.66325
3.030	0.779	0.220	0.001	78.00	138.47	999.8	0.19	39.768	0.65765
3.035	0.779	0.220	0.001	78.00	138.47	999.8	0.19	39.701	0.65654
3.040	0.778	0.221	0.001	78.01	167.57	1001.7	0.19	57.916	0.64667
3.050	0.778	0.221	0.001	77.92	202.95	1000.0	0.19	80.211	0.64152
5.010	0.778	0.221	0.001	202.28	212.81	998.4	0.18	5.862	0.55682
5.015	0.778	0.221	0.001	202.28	212.81	998.4	0.18	5.957	0.56581
5.020	0.778	0.221	0.001	202.21	227.11	1002.6	0.18	15.756	0.63258
5.030	0.778	0.221	0.001	202.25	251.74	1000.5	0.18	31.443	0.63535
5.040	0.778	0.221	0.001	202.20	276.66	1001.9	0.18	47.491	0.63777
5.050	0.778	0.221	0.001	202.17	300.70	1001.4	0.18	63.208	0.64150
9.010	0.776	0.223	0.001	-59.44	-40.36	1502.2	0.05	21.460	1.12491
9.020	0.776	0.223	0.001	-59.47	-19.66	1501.0	0.05	48.349	1.21457
9.030	0.776	0.223	0.001	-59.46	-29.25	1503.4	0.05	35.028	1.15965
9.040	0.776	0.223	0.001	-59.46	-24.67	1502.4	0.05	41.763	1.20055
9.050	0.777	0.222	0.001	-59.44	1.41	1500.7	0.05	77.449	1.27277
9.060	0.777	0.222	0.001	-59.37	25.36	1499.3	0.05	106.816	1.26073
9.070	0.777	0.222	0.001	-59.28	52.35	1497.9	0.05	132.760	1.18924
9.080	0.777	0.222	0.001	-59.37	77.28	1499.4	0.05	155.126	1.13517
8.010	0.778	0.221	0.001	-59.23	-38.57	2000.1	0.07	19.686	0.95249
8.020	0.778	0.221	0.001	-59.20	-19.20	1999.8	0.07	39.543	0.98870
8.030	0.778	0.221	0.001	-59.13	1.02	2001.9	0.07	61.709	1.02598
8.040	0.778	0.221	0.001	-59.21	26.01	2002.2	0.07	88.872	1.04284
8.050	0.778	0.221	0.001	-59.27	37.80	1999.8	0.07	101.557	1.04624
8.060	0.778	0.221	0.001	-59.28	42.93	2001.8	0.07	106.836	1.04530
8.070	0.778	0.221	0.001	-59.25	52.04	2000.6	0.07	114.794	1.03149
8.080	0.778	0.221	0.001	-59.23	75.73	2000.8	0.07	138.655	1.02736
2.010	0.777	0.222	0.001	78.06	88.37	2001.8	0.05	9.140	0.88683
2.020	0.777	0.222	0.001	78.12	108.64	2002.5	0.05	26.190	0.85831
2.030	0.777	0.222	0.001	78.02	137.38	2001.1	0.06	49.082	0.82684
2.040	0.775	0.224	0.001	78.02	168.68	2002.2	0.09	72.452	0.79915
2.050	0.775	0.224	0.001	78.02	202.04	1999.6	0.09	96.592	0.77885
4.010	0.778	0.221	0.001	202.09	212.68	1999.7	0.11	7.559	0.71395
4.020	0.778	0.221	0.001	202.14	226.74	2003.4	0.11	17.320	0.70433
4.030	0.777	0.222	0.001	202.16	252.35	2003.3	0.12	35.479	0.70691
4.040	0.777	0.222	0.001	202.31	277.43	2002.6	0.14	52.846	0.70349
4.050	0.777	0.222	0.001	202.24	301.15	2001.2	0.14	69.459	0.70220

TABLE A2(b)

ISOTHERMAL DATA FOR NOMINAL 0.777 CH₄, 0.223 C₂H₆

RUN NO.	COMPOSITION			INLET TEMP. (F)	OUTLET TEMP. (F)	INLET PRES. (PSIA)	PRES. DROP (PSID)	HEAT INPUT (BTU/LB)	ISOTHERMAL J.T. COEFF. (BTU/LB PSIA)
	XC1	XC2	XC3						
7.010	0.778	0.221	0.001	-58.37	-58.31	1999.4	178.65	1.033	-0.00578
7.020	0.778	0.221	0.001	-58.46	-58.39	1799.6	70.62	1.595	-0.02258
7.030	0.778	0.221	0.001	-58.45	-58.37	1603.2	263.46	3.138	-0.01191
7.040	0.778	0.221	0.001	-58.44	-58.40	1600.8	432.04	6.312	-0.01461
7.050	0.778	0.221	0.001	-58.49	-58.45	1390.5	394.80	10.130	-0.02566
7.060	0.778	0.221	0.001	-58.60	-58.71	1405.1	517.47	14.667	-0.02834
7.065	0.778	0.221	0.001	-58.60	-58.71	1405.1	504.50	14.667	-0.02907
7.070	0.778	0.221	0.001	-58.47	-58.60	1202.1	243.42	9.285	-0.03814
7.080	0.778	0.221	0.001	-58.32	-58.17	998.8	155.75	20.113	-0.12913
7.090	0.778	0.221	0.001	-58.37	-58.30	984.7	288.02	45.239	-0.15707
7.095	0.778	0.221	0.001	-58.37	-58.30	984.7	275.99	45.232	-0.16389
1.010	0.777	0.222	0.001	79.28	79.31	1996.3	203.70	7.269	-0.03568
1.020	0.777	0.222	0.001	79.14	79.13	2000.0	415.98	15.711	-0.03777
1.025	0.777	0.222	0.001	79.14	79.13	2000.0	415.98	15.772	-0.03792
1.026	0.777	0.222	0.001	79.14	79.13	2000.0	415.98	15.656	-0.03764
1.030	0.777	0.222	0.001	79.16	79.12	1602.6	105.93	4.433	-0.04185
1.040	0.778	0.221	0.001	79.07	79.09	1601.2	339.09	14.464	-0.04266
1.050	0.778	0.221	0.001	79.12	79.06	1600.9	541.47	23.433	-0.04328
1.060	0.778	0.221	0.001	79.06	79.04	1045.8	220.67	9.421	-0.04269
1.070	0.777	0.222	0.001	78.97	78.90	1045.8	439.20	18.576	-0.04230
1.075	0.777	0.222	0.001	78.97	78.90	1045.8	439.20	18.643	-0.04245
1.076	0.777	0.222	0.001	78.97	78.90	1045.8	439.20	18.510	-0.04215
1.080	0.777	0.222	0.001	79.08	79.02	1048.4	636.18	26.555	-0.04174
1.090	0.777	0.222	0.001	79.07	79.09	1045.6	842.79	34.322	-0.04072
1.095	0.777	0.222	0.001	79.07	79.09	1045.6	842.79	34.415	-0.04083
1.096	0.777	0.222	0.001	79.07	79.09	1045.6	842.79	34.231	-0.04062
1.100	0.777	0.222	0.001	79.07	79.09	1045.2	918.97	37.292	-0.04058
6.010	0.778	0.221	0.001	254.86	254.88	1999.9	208.48	3.769	-0.01808
6.020	0.778	0.221	0.001	254.92	254.87	2001.5	424.86	7.876	-0.01854
6.030	0.778	0.221	0.001	254.93	254.93	2000.5	646.95	12.189	-0.01884
6.040	0.778	0.221	0.001	255.00	254.94	2004.1	857.01	16.394	-0.01913
6.050	0.778	0.221	0.001	255.04	255.04	1153.0	228.69	4.647	-0.02032
6.060	0.778	0.221	0.001	256.22	256.24	1148.2	455.62	9.398	-0.02063
6.070	0.778	0.221	0.001	255.81	255.81	1148.9	635.89	13.144	-0.02067
6.080	0.778	0.221	0.001	256.08	256.05	1148.5	846.91	17.570	-0.02075
6.090	0.778	0.221	0.001	256.13	256.11	1145.1	1038.00	21.489	-0.02073

TABLE A2(c)

ISENTHALPIC DATA FOR NOMINAL 0.777 CH₄, 0.223 C₂H₆

RUN NO.	COMPOSITION			INLET TEMP. (F)	OUTLET TEMP. (F)	INLET PRES. (PSIA)	PRES. DROP (PSID)	HEAT INPUT (BTU/LB)	J. THOMSON COEFF. (F/PSIA)
	XC1 (MOLE FRACTION)	XC2	XC3						
13.010	0.777	0.222	0.001	-253.21	-252.39	2008.2	142.38	0.000	-0.00580
13.020	0.777	0.222	0.001	-253.22	-252.29	1703.3	135.72	0.000	-0.00686
13.030	0.777	0.222	0.001	-253.23	-252.22	1393.9	132.89	0.000	-0.00757
13.040	0.777	0.222	0.001	-253.18	-252.09	1035.1	119.97	0.000	-0.00906
13.050	0.777	0.222	0.001	-253.23	-252.17	804.0	129.04	0.000	-0.00823
13.055	0.777	0.222	0.001	-253.23	-252.17	804.0	124.02	0.000	-0.00856
12.010	0.778	0.221	0.001	-150.55	-150.57	2000.6	161.29	0.000	0.00014
12.020	0.778	0.221	0.001	-150.64	-150.56	1701.1	154.23	0.000	-0.00051
12.030	0.778	0.221	0.001	-150.58	-150.47	1401.7	161.12	0.000	-0.00070
12.040	0.778	0.221	0.001	-150.57	-150.38	1099.8	161.50	0.000	-0.00114
12.050	0.778	0.221	0.001	-150.53	-150.27	804.0	171.13	0.000	-0.00151
12.060	0.778	0.221	0.001	-150.51	-150.22	603.9	180.39	0.000	-0.00156
12.070	0.778	0.221	0.001	-150.51	-150.14	499.5	160.69	0.000	-0.00230

TABLE A3(a)

RUN NO.	ISOBARIC DATA FOR NOMINAL 0.477 CH ₄ , 0.523 C ₂ H ₆			INLET TEMP. (F)	OUTLET TEMP. (F)	INLET PRES. (PSIA)	PRES. DROP (PSID)	HEAT INPUT (BTU/LB)	MEAN HEAT CAPACITY (BTU/LB F)
	XC1	XC2	XC3						
	(MOLE FRACTION)								
4.010	0.485	0.512	0.003	-136.77	-132.08	250.7	0.07	3.405	0.72732
4.020	0.485	0.512	0.003	-136.71	-128.23	250.9	0.07	7.054	0.83244
4.030	0.485	0.512	0.003	-136.75	-123.88	249.8	0.07	17.310	1.34503
4.040	0.485	0.512	0.003	-136.77	-125.33	248.8	0.07	14.661	1.28094
4.050	0.485	0.512	0.003	-136.75	-120.92	249.6	0.07	23.426	1.47929
4.060	0.485	0.512	0.003	-136.75	-115.20	249.2	0.07	34.406	1.59674
4.070	0.485	0.512	0.003	-136.81	-81.69	249.6	0.07	92.359	1.67540
4.080	0.485	0.512	0.003	-136.71	-46.55	250.7	0.07	176.913	1.96235
4.090	0.480	0.517	0.003	-136.71	-41.94	250.2	0.07	194.255	2.04988
4.100	0.480	0.517	0.003	-136.70	-37.41	251.3	0.07	213.092	2.14621
4.110	0.480	0.517	0.003	-136.75	-18.40	251.6	0.07	228.971	1.93467
4.120	0.480	0.517	0.003	-136.71	6.27	250.6	0.07	240.602	1.68270
5.010	0.477	0.520	0.003	-99.42	-78.40	499.7	0.14	16.353	0.77818
5.020	0.477	0.520	0.003	-99.35	-75.05	499.6	0.14	19.104	0.78612
5.030	0.477	0.520	0.003	-99.33	-69.80	500.7	0.14	28.842	0.97678
5.040	0.477	0.520	0.003	-99.33	-64.05	501.5	0.14	39.286	1.11329
5.050	0.483	0.514	0.003	-99.35	-59.64	501.6	0.14	47.317	1.19149
5.060	0.483	0.514	0.003	-99.26	-10.74	500.6	0.14	148.787	1.68077
5.070	0.483	0.514	0.003	-99.30	-3.95	499.7	0.14	169.551	1.77817
5.080	0.483	0.514	0.003	-99.33	1.13	500.0	0.14	186.991	1.86118
5.090	0.480	0.517	0.003	-99.33	9.43	500.7	0.14	195.934	1.80148
5.100	0.480	0.517	0.003	-99.20	19.70	500.4	0.14	202.654	1.70444
5.110	0.480	0.517	0.003	-99.35	50.14	501.2	0.14	222.354	1.48749
6.010	0.475	0.522	0.003	-101.11	-70.33	749.9	0.35	23.257	0.75561
6.020	0.475	0.522	0.003	-100.86	-35.97	751.4	0.22	53.394	0.82290
6.030	0.476	0.521	0.003	-101.49	-31.64	749.5	0.22	58.893	0.84311
6.040	0.476	0.521	0.003	-101.48	-26.18	749.1	0.22	69.119	0.91796
6.050	0.476	0.521	0.003	-101.45	-6.30	749.1	0.22	106.737	1.12178
6.060	0.474	0.523	0.003	-101.43	5.83	748.7	0.22	133.614	1.24579
6.070	0.474	0.523	0.003	-101.43	19.99	750.0	0.22	169.160	1.39322
6.080	0.474	0.523	0.003	-101.41	39.13	749.7	0.22	194.937	1.38704
7.010	0.479	0.518	0.003	-100.04	-65.41	975.3	0.08	25.935	0.74883
7.020	0.479	0.518	0.003	-100.04	-32.48	975.4	0.08	53.901	0.79787
7.030	0.479	0.518	0.003	-99.96	0.42	975.2	0.08	91.054	0.90714
7.040	0.479	0.518	0.003	-100.04	4.68	974.5	0.08	98.225	0.93796
7.050	0.479	0.518	0.003	-100.03	8.85	976.3	0.08	105.569	0.96956
10.010	0.480	0.517	0.003	0.90	5.87	979.3	0.07	8.041	1.62060
10.020	0.480	0.517	0.003	1.08	8.66	979.6	0.07	13.121	1.73031
10.030	0.480	0.517	0.003	0.95	11.17	978.8	0.07	18.381	1.79725
10.040	0.480	0.517	0.003	0.88	12.65	979.0	0.07	21.658	1.84047
10.050	0.480	0.517	0.003	1.12	15.83	980.7	0.07	27.496	1.86920
10.060	0.479	0.518	0.003	0.98	20.76	979.8	0.07	38.661	1.95505
10.070	0.479	0.518	0.003	1.16	25.69	982.1	0.07	48.736	1.98622
10.080	0.479	0.518	0.003	0.94	32.55	982.7	0.07	62.617	1.98050
10.090	0.479	0.518	0.003	0.69	70.80	980.8	0.07	110.389	1.57443
10.100	0.479	0.518	0.003	1.38	103.07	980.1	0.07	135.513	1.33259

15.010	0.479	0.518	0.003	0.31	15.62	1253.6	0.10	17.901	1.16871
15.020	0.479	0.518	0.003	0.23	20.10	1253.7	0.10	23.715	1.19314
15.030	0.479	0.518	0.003	0.31	25.69	1253.9	0.10	31.432	1.23812
15.040	0.477	0.520	0.003	0.23	30.38	1251.0	0.10	38.224	1.26791
15.050	0.477	0.520	0.003	0.20	35.91	1249.6	0.10	46.906	1.31361
15.060	0.477	0.520	0.003	0.31	44.70	1248.6	0.10	60.039	1.35234
15.070	0.478	0.519	0.003	0.25	58.62	1251.9	0.10	80.495	1.37893
15.080	0.478	0.519	0.003	-0.44	108.37	1249.6	0.10	133.888	1.23051
3.010	0.479	0.518	0.003	-230.03	-204.41	1490.6	0.05	16.624	0.64877
3.020	0.479	0.518	0.003	-230.01	-176.32	1490.5	0.05	34.522	0.64300
3.030	0.480	0.517	0.003	-229.99	-151.58	1489.3	0.05	50.507	0.64412
3.040	0.480	0.517	0.003	-229.99	-127.44	1490.3	0.05	66.492	0.64839
3.050	0.480	0.517	0.003	-229.94	-99.68	1490.4	0.05	85.413	0.65570
8.010	0.479	0.518	0.003	-100.17	-69.83	1499.5	0.06	21.834	0.71972
8.020	0.479	0.518	0.003	-100.13	-30.16	1499.6	0.06	53.577	0.76564
8.030	0.479	0.518	0.003	-100.13	0.53	1501.3	0.06	80.001	0.79470
16.010	0.475	0.522	0.003	0.32	30.04	1499.8	0.10	31.314	1.05369
16.020	0.475	0.522	0.003	0.36	45.82	1502.0	0.10	49.846	1.09664
16.030	0.475	0.522	0.003	0.29	49.53	1503.1	0.10	54.226	1.10130
16.040	0.475	0.522	0.003	0.14	53.57	1501.0	0.10	59.847	1.12010
16.050	0.475	0.522	0.003	0.16	57.76	1499.7	0.10	65.432	1.13588
16.060	0.475	0.522	0.003	0.21	80.47	1499.1	0.10	93.322	1.16263
16.070	0.475	0.522	0.003	0.25	102.86	1500.0	0.10	117.013	1.14035
14.010	0.477	0.520	0.003	99.95	133.98	1499.0	0.15	31.293	0.91957
14.020	0.477	0.520	0.003	99.72	161.32	1499.8	0.15	53.159	0.86290
14.030	0.477	0.520	0.003	99.41	194.38	1499.3	0.15	77.120	0.81204
14.035	0.477	0.520	0.003	99.41	194.38	1499.3	0.15	75.099	0.79076
14.036	0.477	0.520	0.003	99.41	194.38	1499.3	0.15	76.726	0.80790
14.040	0.478	0.519	0.003	99.81	220.49	1502.1	0.15	96.753	0.80172
14.050	0.478	0.519	0.003	100.20	251.34	1499.9	0.15	117.742	0.77904
11.010	0.482	0.514	0.003	249.88	271.97	1500.2	0.10	15.013	0.67971
11.020	0.482	0.514	0.003	249.90	291.23	1500.8	0.10	28.198	0.68227
11.030	0.482	0.514	0.003	249.96	302.80	1500.9	0.10	36.337	0.68772
17.010	0.480	0.517	0.003	0.40	28.69	1999.4	0.13	25.032	0.88469
17.020	0.480	0.517	0.003	0.25	51.97	1999.8	0.13	46.758	0.90408
17.030	0.480	0.517	0.003	0.28	75.92	1999.4	0.13	71.930	0.95090
17.040	0.477	0.520	0.003	0.32	81.41	2002.8	0.13	76.394	0.94198
17.045	0.477	0.520	0.003	0.32	81.41	2002.8	0.13	75.991	0.93701
17.046	0.477	0.520	0.003	0.32	81.41	2002.8	0.13	76.696	0.94570
17.050	0.477	0.520	0.003	0.28	87.18	2001.4	0.13	83.036	0.95562

TABLE A3(b)

ISOTHERMAL DATA FOR NOMINAL 0.477 CH₄, 0.523 C₂H₆

RUN NO.	COMPOSITION			INLET TEMP. (F)	OUTLET TEMP. (F)	INLET PRES. (PSIA)	PRES. DROP (PSID)	HEAT INPUT (BTU/LB)	ISOTHERMAL J.T. COEFF. (BTU/LB PSIA)
	XC1 (MOLE FRACTION)	XC2	XC3						
18.010	0.479	0.518	0.003	1.71	1.65	2020.7	149.34	0.623	-0.00417
18.020	0.479	0.518	0.003	1.64	1.56	1803.8	152.24	0.940	-0.00618
18.030	0.479	0.518	0.003	1.53	1.47	1602.7	154.55	1.561	-0.01010
18.035	0.479	0.518	0.003	1.53	1.47	1602.7	154.55	1.399	-0.00905
18.040	0.479	0.518	0.003	1.77	1.65	1397.0	157.35	2.191	-0.01392
18.050	0.479	0.518	0.003	1.95	1.90	1202.1	163.50	4.060	-0.02483
18.055	0.479	0.518	0.003	1.95	1.90	1202.1	163.50	4.050	-0.02477
18.056	0.479	0.518	0.003	1.95	1.90	1202.1	163.50	4.068	-0.02488
18.060	0.479	0.518	0.003	1.66	1.86	977.3	134.63	15.876	-0.11792
18.070	0.479	0.518	0.003	2.00	2.04	978.3	270.76	38.601	-0.14257
18.080	0.479	0.518	0.003	1.37	1.34	691.5	293.53	71.912	-0.24499
18.090	0.479	0.518	0.003	0.69	0.55	447.9	341.39	27.609	-0.08087
13.010	0.480	0.517	0.003	101.43	101.31	1959.0	223.91	8.719	-0.03894
13.020	0.480	0.517	0.003	101.45	101.41	1604.8	258.55	15.119	-0.05848
13.030	0.480	0.517	0.003	101.32	101.33	1224.2	301.46	19.197	-0.06368
13.040	0.480	0.517	0.003	101.62	101.63	989.1	358.64	20.807	-0.05802
13.050	0.480	0.517	0.003	101.52	101.50	793.6	344.16	18.330	-0.05326
13.060	0.480	0.517	0.003	101.59	101.67	598.1	281.95	13.995	-0.04964
13.070	0.480	0.517	0.003	101.64	101.55	397.2	294.81	13.333	-0.04522
12.010	0.479	0.518	0.003	252.57	252.55	1996.8	189.09	4.592	-0.02428
12.020	0.479	0.518	0.003	252.23	252.23	1679.5	234.31	6.500	-0.02774
12.030	0.479	0.518	0.003	252.22	252.23	1511.7	282.75	7.721	-0.02731
12.035	0.479	0.518	0.003	252.22	252.23	1511.7	281.08	7.721	-0.02747
12.040	0.478	0.519	0.003	252.38	252.47	1133.9	377.75	10.521	-0.02785
12.050	0.478	0.519	0.003	252.36	252.27	829.7	300.20	8.287	-0.02761
12.055	0.478	0.519	0.003	252.36	252.27	829.7	300.20	8.327	-0.02774
12.056	0.478	0.519	0.003	252.36	252.27	827.7	300.20	8.248	-0.02747
12.060	0.478	0.519	0.003	252.67	252.77	535.9	296.55	8.131	-0.02742
12.070	0.478	0.519	0.003	252.78	252.76	335.4	242.22	3.200	-0.01321

TABLE A3(c)

ISENTHALPIC DATA FOR NOMINAL 0.477 CH₄, 0.523 C₂H₆

RUN NO.	COMPOSITION			INLET TEMP. (F)	OUTLET TEMP. (F)	INLET PRES. (PSIA)	PRES. DROP (PSID)	HEAT INPUT (BTU/LB)	J. THOMSON COEFF. (F/PSIA)
	XC1 (MOLE FRACTION)	XC2	XC3						
1.010	0.481	0.516	0.003	-228.45	-228.40	1961.0	191.09	0.000	-0.00024
1.020	0.481	0.516	0.003	-228.41	-228.32	1648.6	204.90	0.000	-0.00044
1.030	0.481	0.516	0.003	-228.46	-228.40	1331.1	197.28	0.000	-0.00031
1.040	0.481	0.516	0.003	-228.47	-227.91	1005.6	212.41	0.000	-0.00266
1.060	0.468	0.529	0.003	-228.42	-228.18	588.5	204.37	0.000	-0.00119
1.050	0.468	0.529	0.003	-228.45	-228.18	795.0	205.15	0.000	-0.00135
1.040	0.481	0.516	0.003	-228.47	-227.91	1005.6	212.41	0.000	-0.00266
2.010	0.479	0.518	0.003	-99.14	-98.69	1980.7	208.76	0.000	-0.00211
2.020	0.477	0.520	0.003	-99.09	-98.17	1668.5	140.48	0.000	-0.00658
2.030	0.476	0.521	0.003	-99.12	-98.50	1354.5	353.17	0.000	-0.00176
9.010	0.479	0.518	0.003	-99.04	-98.63	1272.5	231.76	0.000	-0.00177
9.020	0.479	0.518	0.003	-99.09	-98.93	883.0	184.57	0.000	-0.00086
9.030	0.486	0.511	0.003	-99.01	-98.92	602.6	218.44	0.000	-0.00041
9.045	0.486	0.511	0.003	-99.00	-98.91	395.5	272.23	83.494	-0.30671

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NOTATION

C_p	Isobaric heat capacity = $(\partial \underline{H} / \partial T)_p$ (Btu/lb°F)
$C_p(A)$	Smoothed C_p after thermodynamic consistency checks.
$C_p(S)$	Smoothed C_p before thermodynamic consistency checks.
\underline{H}	Specific enthalpy (Btu/lb).
\underline{H}_i	Specific enthalpy of ith component (Btu/lb)
\underline{H}_M	Specific enthalpy of mixture (Btu/lb)
\underline{H}^E	Excess enthalpy (Btu/lb)
P	Pressure (psia)
T	Temperature (°F)
x_i	Mole fraction of component i in the liquid phase
y_i	Mole fraction of component i in the vapor phase

Greek Notation

$\Delta \underline{H}_i$	Change in the specific enthalpy between two states (Btu/lb)
$\Delta \underline{H}_P$	Change in specific enthalpy between two temperatures at constant pressure (Btu/lb)
$\Delta \underline{H}_T$	Change in specific enthalpy between two pressures at constant temperature (Btu/lb)
$\Delta \underline{H}_{\text{vap}}$	Specific enthalpy of vaporization (Btu/lb)
μ	Joule-Thomson coefficient. (°F/psia)
ϕ	Isothermal throttling coefficient (Btu/lb-psia)
$\phi(A)$	Smoothed ϕ after thermodynamic consistency checks
$\phi(S)$	Smoothed ϕ before thermodynamic consistency checks.

Subscripts

i	Component in a mixture or a running variable
M	Mixture
l	Liquid
p	Property at pressure p psia
T	Property at temperature T °F

Subscripts cont.

- 1,2 Reference states or component number in a mixture
- o Ideal gas property at absolute zero

Superscripts

- E Excess property
- o Designates ideal gas property
- ^ Mean property

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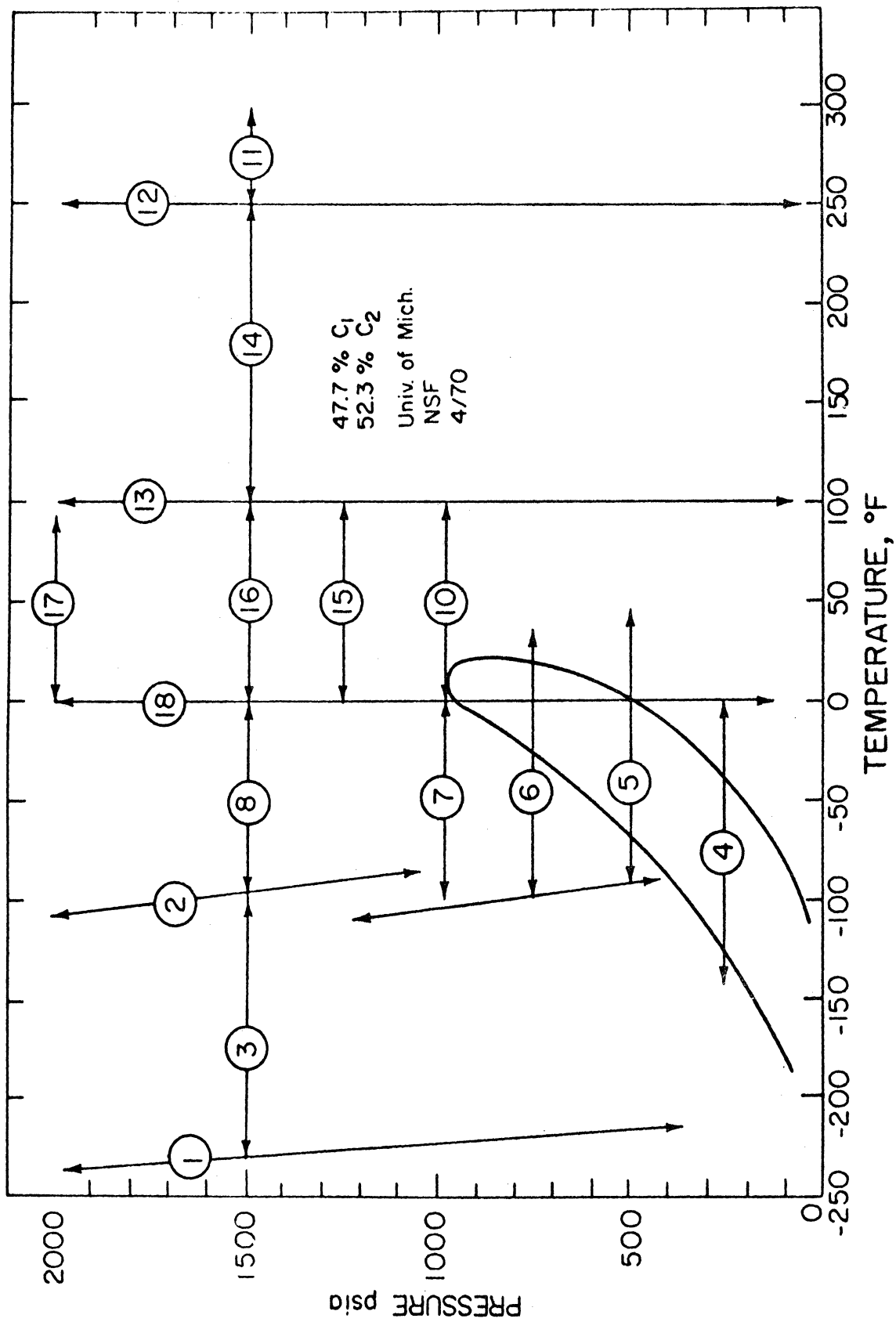


Figure 1. Pressures and Temperatures of Measurements for a 52.3 Mole Percent Ethane in Methane Mixture.

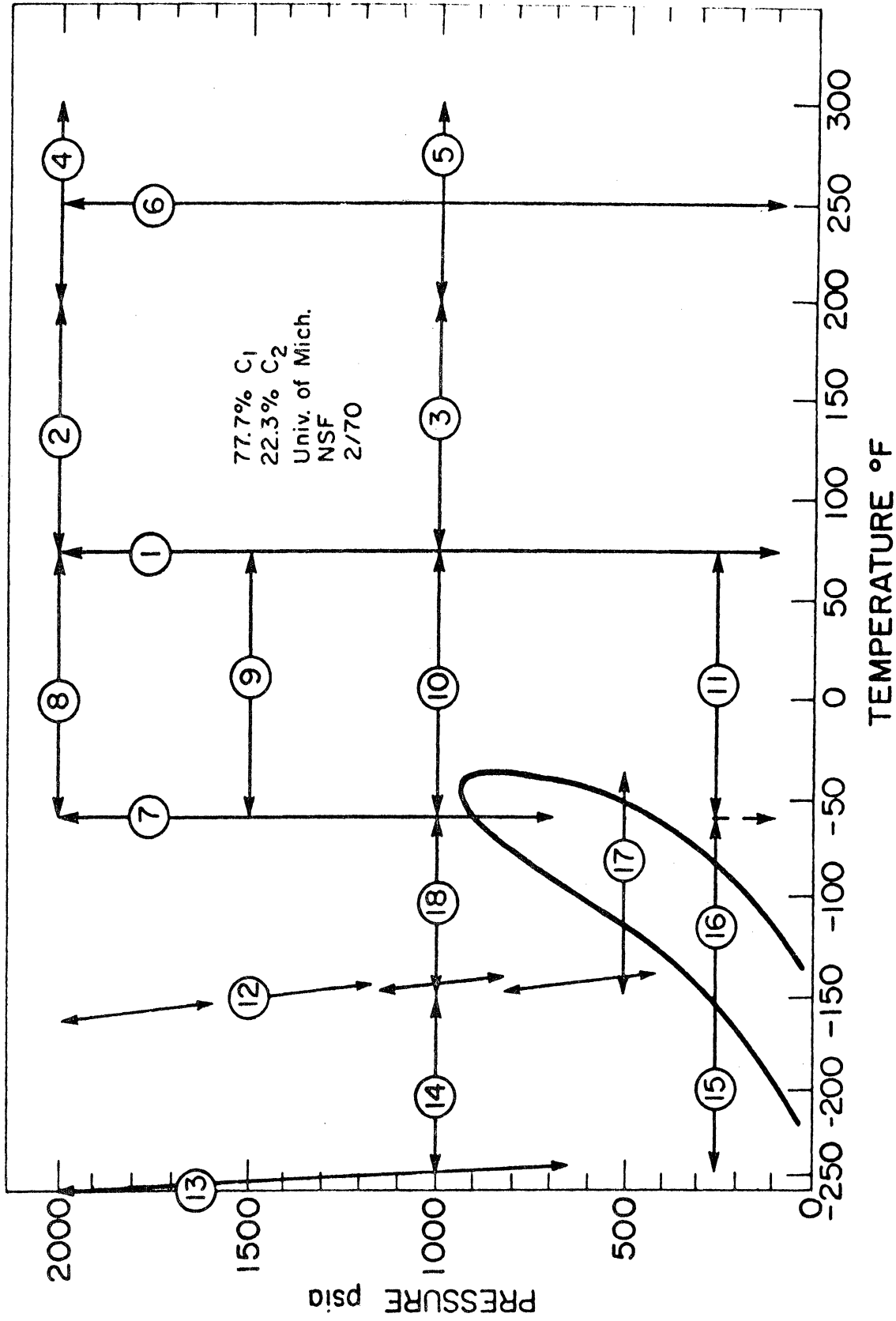


Figure 2. Pressures and Temperatures of Measurements for a 22.3 Mole Percent Ethane in Methane Mixture.

ISOBARIC MEAN HEAT CAPACITY
 CH₄-C₂H₆ (.777 CH₄) 1500PSI

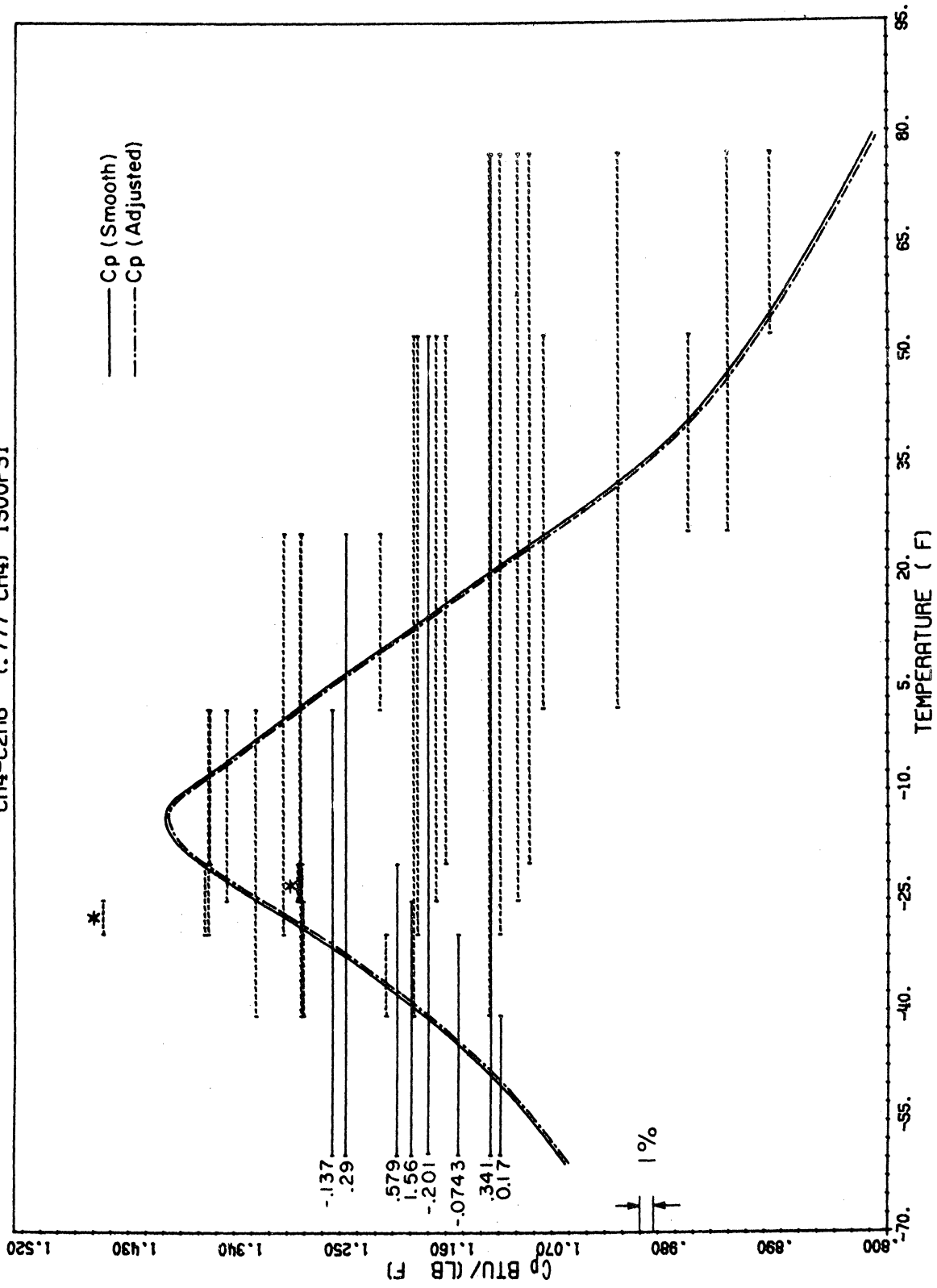


Figure 3. Isobaric Heat Capacity Curve for 22.3 Percent Ethane Mixture at 1500 psia.

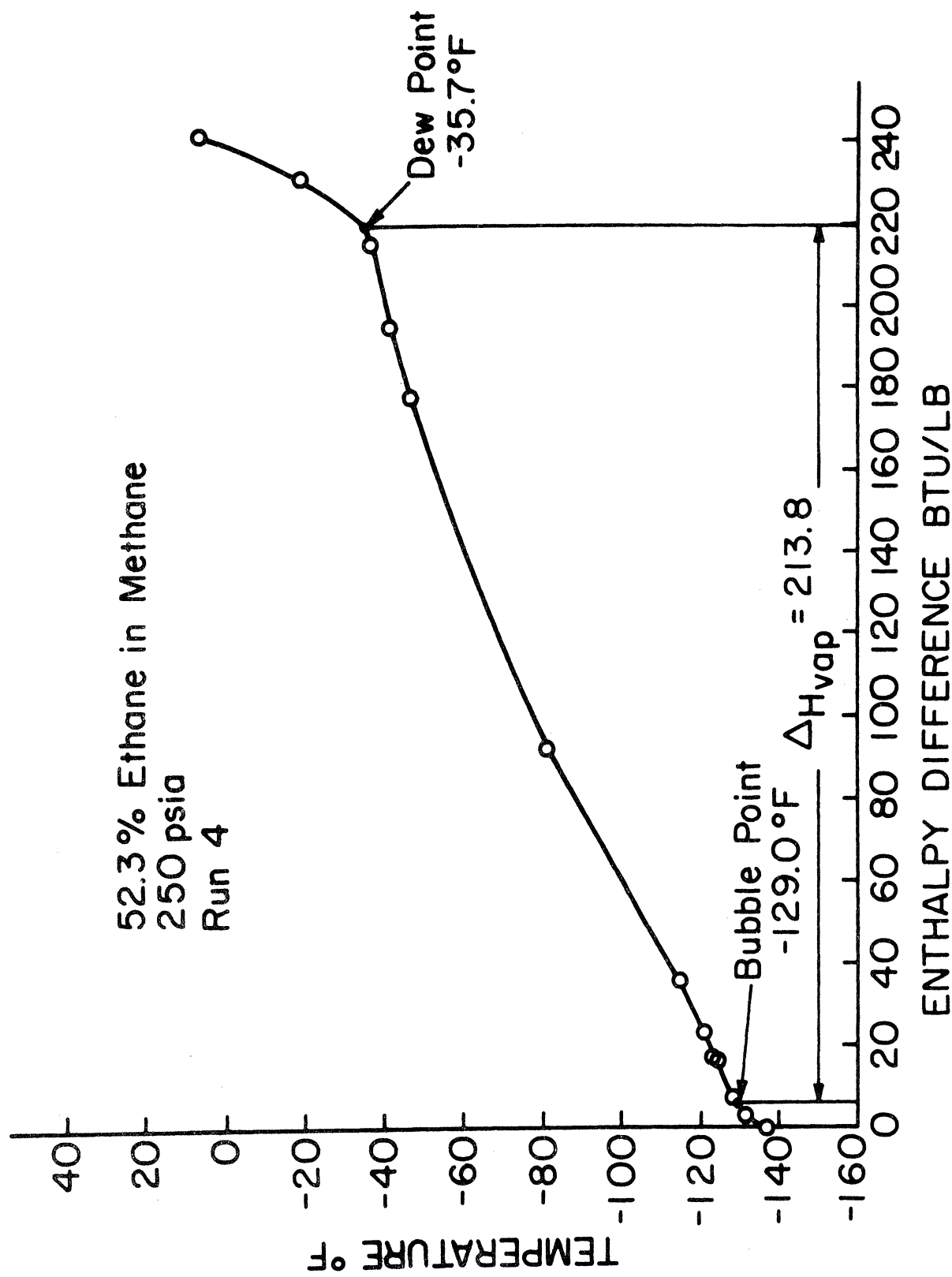


Figure 4. Isobaric Enthalpy Traverse Through Two Phase Region at 250 psia for 52.3 Percent Ethane Mixture.

ISOTHERMAL JOULE-THOMSON COEFFICIENT
 CH₄-C₂H₆ (.477CH₄) 101.5

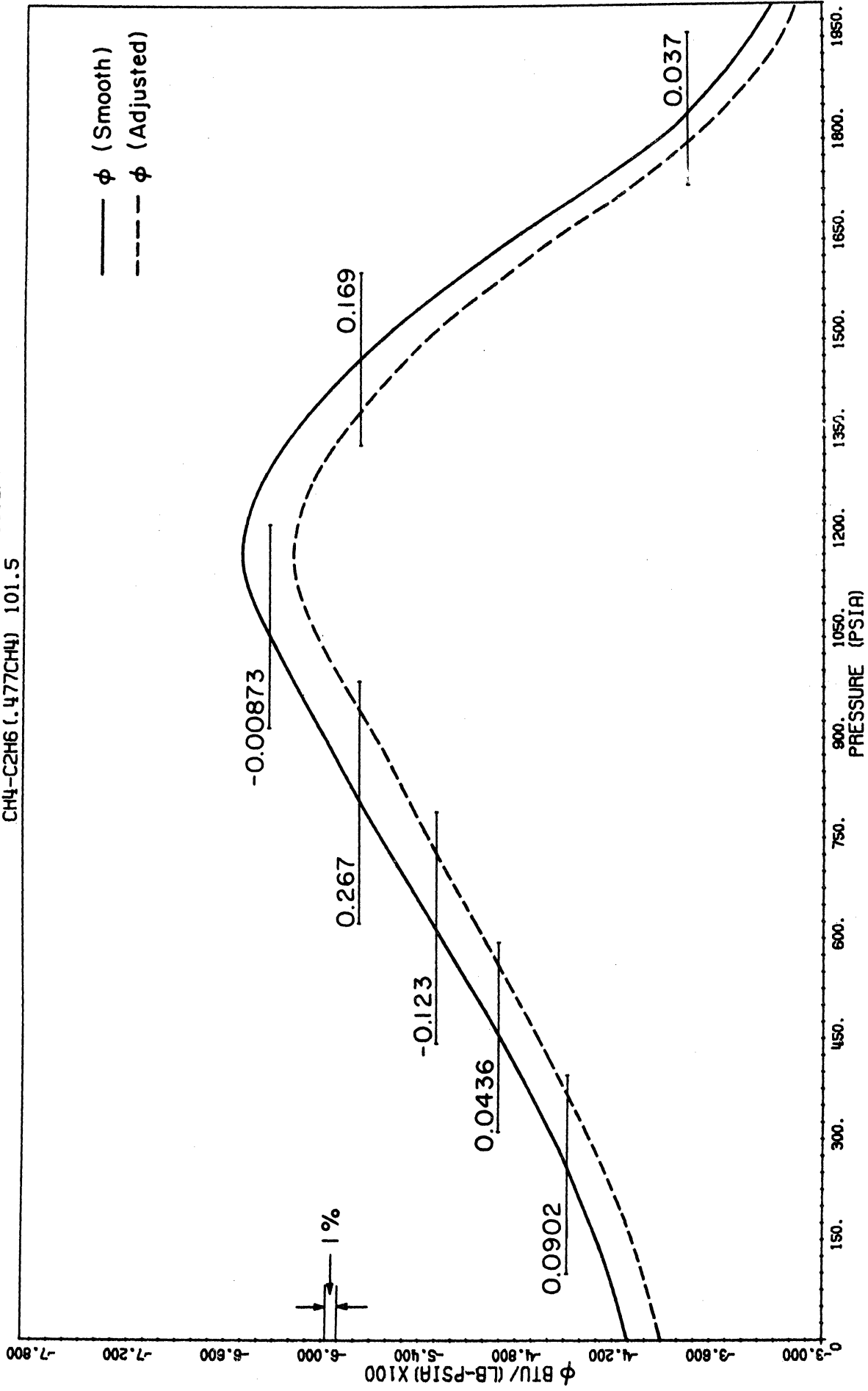
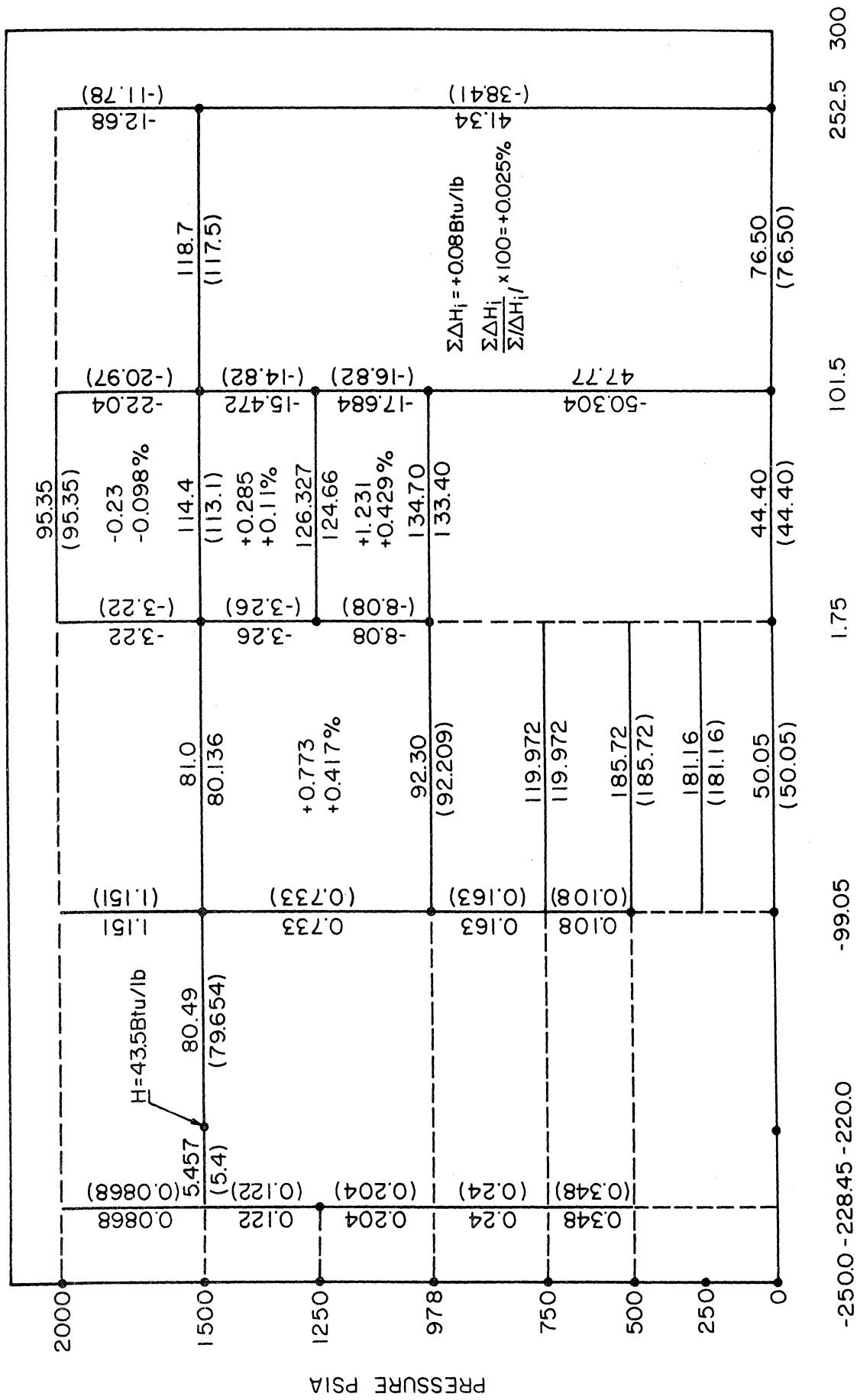


Figure 5. Isothermal Throttling Coefficient for 52.3 Percent Ethane Mixture at 101.5°F.



TEMPERATURE °F

Figure 6. Summary of Consistency Checks. 52.3 Percent Ethane Mixture.

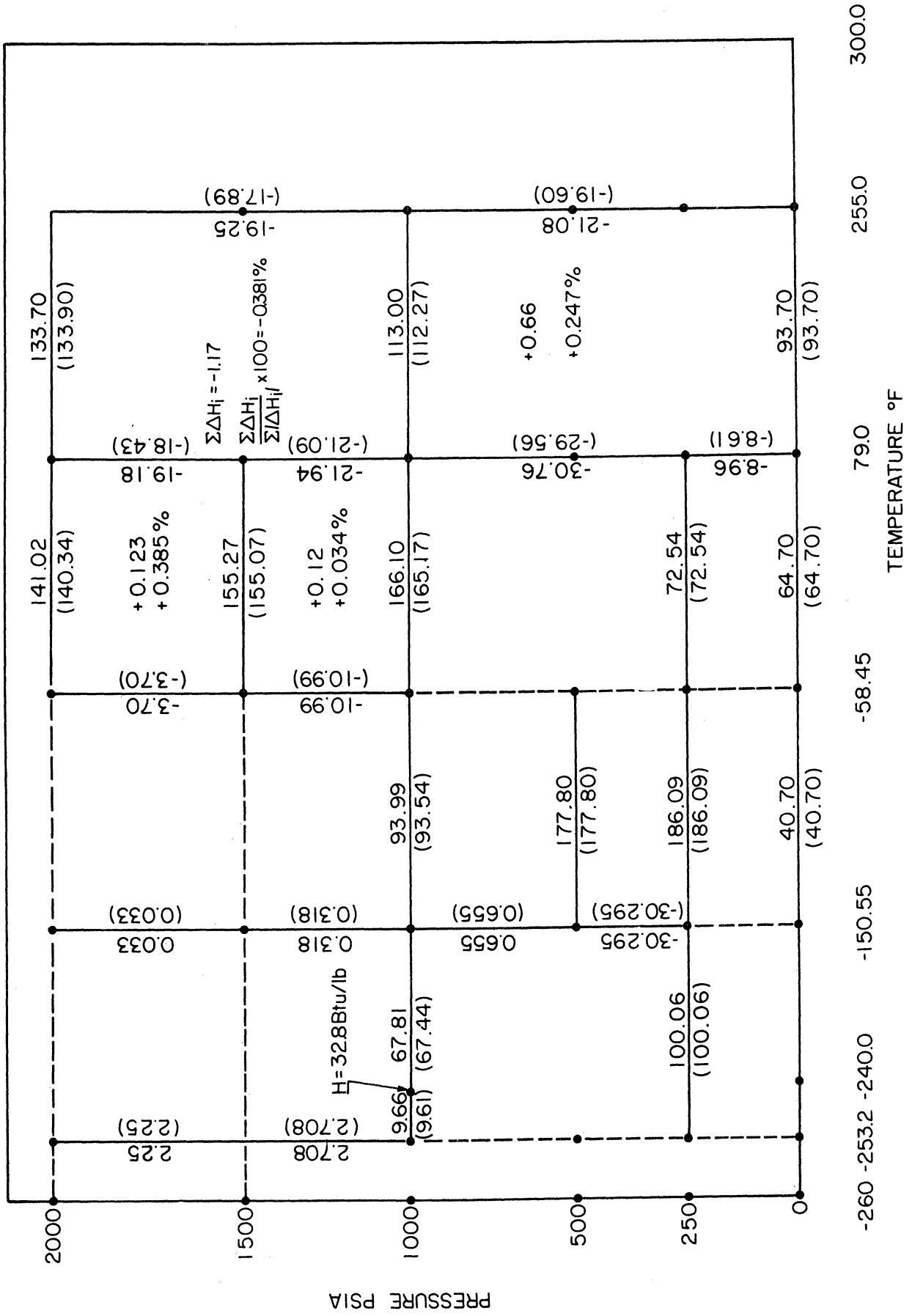


Figure 7. Summary of Consistency Checks. 22.3 Percent Ethane Mixture.

