SECTION 24

Thermodynamic Properties

This section contains thermodynamic charts, correlations, and calculation procedures.

The enthalpy correlation presents a rigorous method for calculation of enthalpy, followed by an example calculation illustrating the use of the associated charts. Also included is a quicker, approximate method for enthalpy determinations by the use of total enthalpy charts.

An entropy correlation and an example calculation showing its use are also presented.

FIG. 24-1

Nomenclature

H = enthalpy at desired conditions, Btu/lb mole, or Btu/lb
H^0 = ideal gas state enthalpy
H_0^0 = enthalpy datum at zero pressure and zero temperature
H_T^0 = ideal gas state enthalpy at temperature T
H_T^P = enthalpy at desired pressure and temperature
MW = molecular weight
P = absolute pressure, psia
P_c = critical or pseudocritical pressure, psia
P_r = reduced pressure = P/P_c
P_k = convergence pressure for multi-component systems, psia
T = absolute temperature, °R
T_c = critical or pseudocritical temperature, °R
T_r = reduced temperature = T/T_c
R = gas constant, Fig.1-4
°R = degrees Rankine = °F + 459.7
S = entropy, Btu/(lb mole • °R), or Btu/(lb • °R)
S^0 = ideal gas state entropy
Sp gr = specific gravity, dimensionless
V = specific volume, cu ft/lb
h_f = enthalpy of liquid, Btu/lb (Steam Tables)
h_g = enthalpy of gas, Btu/lb
h_{fg} = enthalpy of vaporization ($h_g - h_f$)
s_f = entropy of liquid, Btu/(lb • °R)(Steam Tables)
s_g = entropy of gas, Btu/(lb • °R)
s_{fg} = entropy change on vaporization ($s_g - s_f$)
v_f = specific volume of liquid, cu ft/lb (Steam Tables)
v_g = specific volume of gas, cu ft/lb
v_{fg} = specific volume change on vaporization ($v_g - v_f$)
x_i = mole fraction of component i in liquid phase
y_i = mole fraction of component i in vapor phase

Greek

Σ_i = summation for all components
ω = acentric factor

Subscripts

m = mixture property
i = any one component in a multicomponent mixture

Acentric Factor: A factor frequently used in correlating thermodynamic properties — defined by $\omega = \log P_{vr} - 1.00$ where P_{vr} = reduced vapor pressure at $T_r = 0.7$.

Corresponding States: The theory that proposes pure components and mixtures have the same relative thermodynamic properties when at the same relative thermodynamic state.

Critical Pressure: The vapor pressure at the critical temperature.

Critical Temperature: The temperature above which a component cannot be liquefied. For mixtures, the temperature above which all of the mixture cannot be liquid.

Datum: A reference point.

Density: Mass per unit volume of a substance.

Enthalpy: Heat content, H, composed of internal energy, E, and flow energy, PV. Usually expressed as $H = E + PV$.

Entropy: A thermodynamic quantity, S, defined by the equation $-dS = dQ/T$ where Q is the amount of heat entering or leaving the system at absolute temperature, T.

Ideal Gas: A gas which follows the equation $PV = nRT$ where n = number of moles.

Irreversibility: The degree of heat or work that is lost when a system is taken from one pressure and temperature to another pressure and/or temperature and returned to its original condition.

Mole(s): A mass of substance corresponding to its molecular weight, expressed usually either as lb-moles or gm-moles.

Phase Envelope: The boundaries of an area on the P-T diagram for the material which encloses the region where both vapor and liquid coexist.

Quality: The weight fraction of vapor in a vapor-liquid mixture.

Reduced Pressure: The ratio of the absolute pressure to the critical pressure.

Reduced Temperature: The ratio of the absolute temperature to the critical temperature.

Saturated Water: Water at its boiling temperature for the pressure exerted on it.

Saturated Steam: Steam at the boiling temperature of water for the pressure exerted on it but containing no liquid water.

Specific Volume: The volume of a substance per unit mass. (Inverse of density.)

Thermodynamics: The science which deals with the energy of systems and its changes and effects.

PILOT EXHIBIT 2027 PAGE 001
SCOUT/CHEVRON v. PILOT - IPR2024-00385

ENTHALPY BEHAVIOR

The change of enthalpy with temperature and pressure is complex. Predicting the enthalpy for a pure component or mixture is multi-step procedure that requires information that can only be obtained by experimental measurement. For pure components, use of a P-H diagram like those shown in Figs. 24-22 to 24-35 is recommended.

The enthalpy behavior of mixtures can be predicted through thermodynamic correlations. Use of a good contemporary equation of state is recommended for mixture enthalpy predictions. Fig. 24-2 shows graphically the change in enthalpy of three gas streams and two liquid streams as pressure is changed at constant temperature. Values for the plot were calculated by the Soave[10] version of the Redlich-Kwong equation of state[11]. The curves in Fig. 24-2 are for no phase change and show typical behavior of gas phase enthalpy decreasing and liquid phase enthalpy increasing with increasing pressure.

Enthalpies for mixtures of real gases and liquids can be predicted by hand calculation methods. The ones recommended for use are based on an extension of the principle of corresponding states and are shown graphically in Fig. 24-6 and 24-7.

Ideal Gas State Enthalpies

Enthalpies for pure component gases are readily correlated as a power series of temperature for a wide range of components including all of those that occur in natural gas streams. Typical values for natural gas components are plotted in Figs. 24-3 and 24-4 for temperatures from -200 to 900°F. Enthalpies for gas mixtures can be obtained as the mole fraction average if molar enthalpies are used, or the weight fraction average if mass enthalpies are used.

Many natural gas streams contain undefined, or pseudo, components. Ideal gas enthalpies for pseudo components are shown in Fig. 24-5. To use Fig. 24-5 the specific gravity, molecular weight and temperature (relative density, molecular mass and temperature) must be known. Fig. 24-5 is for paraffinic mixtures and should not be used for pseudo components derived form aromatic crude oils.

The enthalpy datum chosen is zero enthalpy at zero absolute pressure and zero absolute temperature, the same datum as used in API Project 44.[1] The choice of datum is arbitrary and a matter of convenience. Enthalpy differences, the values of interest, are not affected by the datum chosen. However, the same enthalpy datum should be used for all components in any one calculation.

CHANGE OF ENTHALPY WITH PRESSURE

For purposes of correlation and calculation, the ideal and real gas behaviors are treated separately. The mixture ideal gas enthalpy at a specified temperature is calculated; the enthalpy change of the real gas mixture is calculated from a correlation prepared from experimental enthalpy measurements on a variety of mixtures. This relation can be expressed as:

$$H_T^P - H_0^0 = (H_T^0 - H_0^0) - (H_T^0 - H_T^P) \qquad \textbf{Eq 24-1}$$

where:

$(H_T^0 - H_0^0)$ the ideal gas state enthalpy above the datum, H^0, at the desired temperature (subscript T), Btu/lb mole

$(H_T^0 - H_T^P)$ the change of enthalpy with pressure, given by the enthalpy difference between the ideal gas state enthalpy and the enthalpy at the desired pressure, both quantities at the specified temperature, Btu/lb mole.

Since H_0^0 is zero at the chosen datum, zero absolute temperature, Equation 24-1 can be written:

$$H_T^P = H_T^0 - (H_T^0 - H_T^P) \qquad \textbf{Eq 24-2}$$

Which can be simplified to:

$$H = H^0 - (H^0 - H) \qquad \textbf{Eq 24-3}$$

Values for the change of enthalpy with pressure for a real gas or liquid are obtained from a correlation based on the principle of corresponding states.[2] The original correlation was extended to low reduced temperatures[3] to cover low temperature gas processing applications. The correlation shown in Figs. 24-6 and 24-7 consists of two parts. One part gives the change of enthalpy with pressure for a simple fluid (fluid with zero acentric factor). The second part is a correction for deviation of a real fluid from the ideal fluid change of enthalpy with pressure. The value of $(H^0 - H)$ in Eq. 24-3 is calculated by:

$$(H^0 - H) = RT_c \left\{ \left[\frac{(H^0 - H)}{RT_c} \right]^{(0)} + \omega \left[\frac{(H^0 - H)}{RT_c} \right]^{(')} \right\} \qquad \textbf{Eq 24-4}$$

where:

$[(H^0 - H) / RT_c]^{(0)}$ the change of enthalpy of a simple fluid with pressure from Fig. 24-6.

$[(H^0 - H) / RT_c]^{(')}$ deviation from the change for a simple fluid from Fig. 24-7

Figs. 24-6 and 24-7 can be used for gas and liquid mixtures. If the mixture is a gas, use the lower chart in each figure. For liquids read the value from the isotherms at the top of the chart. The units of $(H^0 - H)$ will depend on the units of the universal gas constant, R, and Tc. For $(H^0 - H)$ in Btu/lb mole, R=1.986 Btu/(lb mole • °R) and T_c is in °R.

The reduced temperature and pressure are defined as $T_r = T/T_c$ and $P_r = P/P_c$, where absolute temperature and pressure must be used. Values for pure component critical temperature, pressure and acentric factor are in Section 23 Physical Properties. Section 23 also contains graphs relating ASTM distillation temperature, molecular weight, specific gravity (relative density), critical temperature, and critical pressure for undefined fractions. The fraction acentric factor can be estimated from Eq 23-17.

To use Figs. 24-6 and 24-7, the mixture composition must be known. The mole fraction average (pseudo) critical temperature and pressure are calculated using Kay's Rule[4] as illustrated in Fig. 23-3 ($T_{Cm} = \Sigma y_i T_{Ci}$ and $P_{Cm} = \Sigma y_i P_{Ci}$). The mole fraction average mixture enthalpy is calculated from:

$$H_m^0 = \Sigma y_i H_i^0 \qquad \textbf{Eq 24-5}$$

The values of H_i^0 are obtained by multiplying the enthalpy value from Figs. 24-3 and 24-4 by the molecular weight of the individual component.

The mole fraction average acentric factor is calculated:

$$\omega_m = \Sigma y_i \, \omega_i \qquad \textbf{Eq 24-6}$$

The information necessary to evaluate enthalpies for the mixture from Figs. 24-3 to 24-7 is now known. Use of the method will be clearer after study of the following illustrative calculation.

PILOT EXHIBIT 2027 PAGE 002
SCOUT/CHEVRON v. PILOT - IPR2024-00385

EXAMPLE CALCULATION USING ENTHALPY CORRELATION

A gas with the composition shown in Fig. 24-8 is at 120°F and 1010 psia. Using Figs. 24-3 and 24-4 calculate the enthalpy of the gas. Following the example in Fig. 23-6, the mole fraction average critical temperature is calculated as 370.7°R, and the pseudo critical pressure as 669.1 psia. Following the same procedure, the mixture acentric factor is 0.02476 and the molar enthalpy 4885.7 Btu/lb mole. With a reduced temperature of 1.564 and a reduced pressure of 1.509, the reading from Fig. 24-6 is 0.70 and from Fig. 24-7 is 0.020, which give a mixture enthalpy at 120°F and 1010 psia of 4370.0 Btu/lb mole.

The total enthalpy charts shown in Figs. 24-9 to 24-17 offer a rapid means of calculating enthalpy changes on essentially the same basis as previously described. They may be used instead of carrying out the detailed component-wise calculations for mixture enthalpies. The charts cover the range of compositions, pressures and temperatures encountered in most natural gas systems.

The total enthalpy charts were developed from results calculated for synthesized binary mixtures of the pure component normal paraffin hydrocarbons next lighter and heavier than the mixture mole weights indicated. The calculations were carried out by a computer program which interpolated between adjacent values in the tabulated values of enthalpy departure reported by Curl and Pitzer.[2]

Ideal gas enthalpy values for each pure normal paraffin component were calculated and used to calculate the ideal gas mixture enthalpy. The ideal gas state enthalpy equation used for methane, ethane and propane was a curve fit of the data shown in Fig. 24-3. For butane and heavier components, a fourth order polynomial was used with coefficients taken from the API Data Book, Table A1.2.[9] The fifth coefficient reported in the API table was dropped to convert to the 0°R, 0 psia enthalpy datum.

Ideal gas enthalpies were corrected for pressure changes by interpolating the tabular data used to compile Figs. 24-6 and 24-7. Pressure calculations were made from reduced pressures of 0.2 to 3,000 psia. Temperatures ranged from -300°F or T_r = 0.35 minimum to 600°F maximum.

Caution. *Some mixtures encountered in the calculations fell inside the phase envelopes of Figs. 24-6 and 24-7, Rather than extrapolate into the phase envelopes of Figs. 24-6 and 24-7. for enthalpy pressure corrections, the total enthalpies were first generated, plotted, and then extrapolated.*

Vapor enthalpies at 150 psia were extended to lower temperatures by assuming the relative enthalpy change with temperature to be the same as for an ideal gas.

ENTROPY CORRELATION

Entropy is most used as a guide for interpreting the behavior of gases and liquids in compression and expansion processes. The entropy of a multicomponent mixture may be calculated by combing ideal gas state entropies from API 44[1] with the Curl and Pitzer[2] tables of values for the change of entropy with pressure. Entropy equations for undefined mixtures (pseudo components) are not available but, for most uses where the pseudo components are present in small concentration, they can satisfactorily be approximated by the nearest molecular weight paraffin hydrocarbon.

EXAMPLE CALCULATION USING ENTROPY CORRELATION

The same gas as in the enthalpy example (shown in Fig. 24-18) is at 120°F and 1010 psia. The pseudo criticals, acentric factor, reduced temperature, and reduced pressure have the same values as in the enthalpy example. The mixture ideal gas state entropy is 52.2 Btu/(lb mole •°R). The value read from Fig. 24-20 is 0.345 and that from Fig. 24-21 is 0.065. These combine to give (remember P in lnP must be in atmospheres) a real gas entropy of 44.05 Btu/(lb mole •°R).

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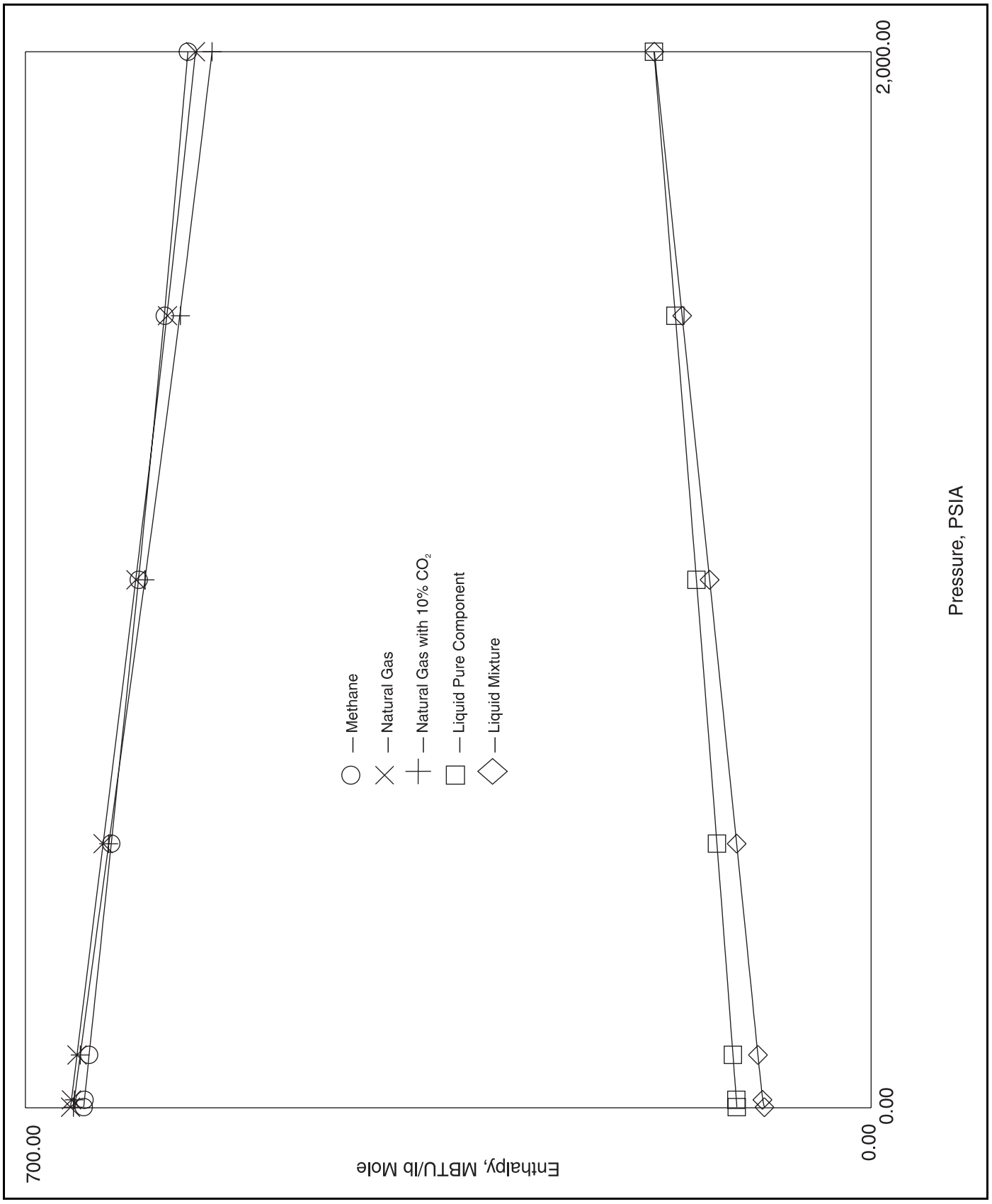
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SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-2

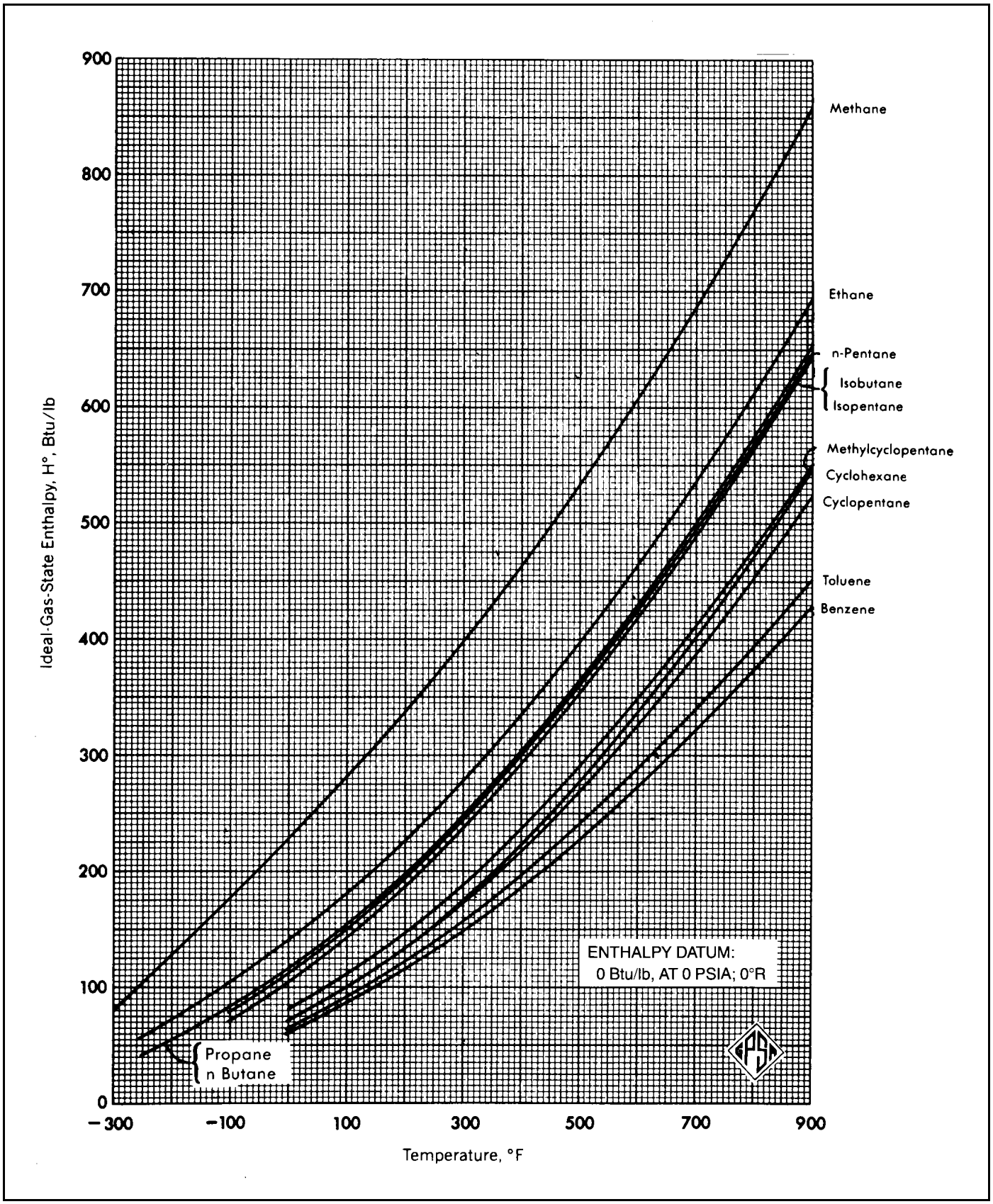
Influence of Pressure on Enthalpy for Typical Natural Gas Streams



PILOT EXHIBIT 2027 PAGE 004
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-3

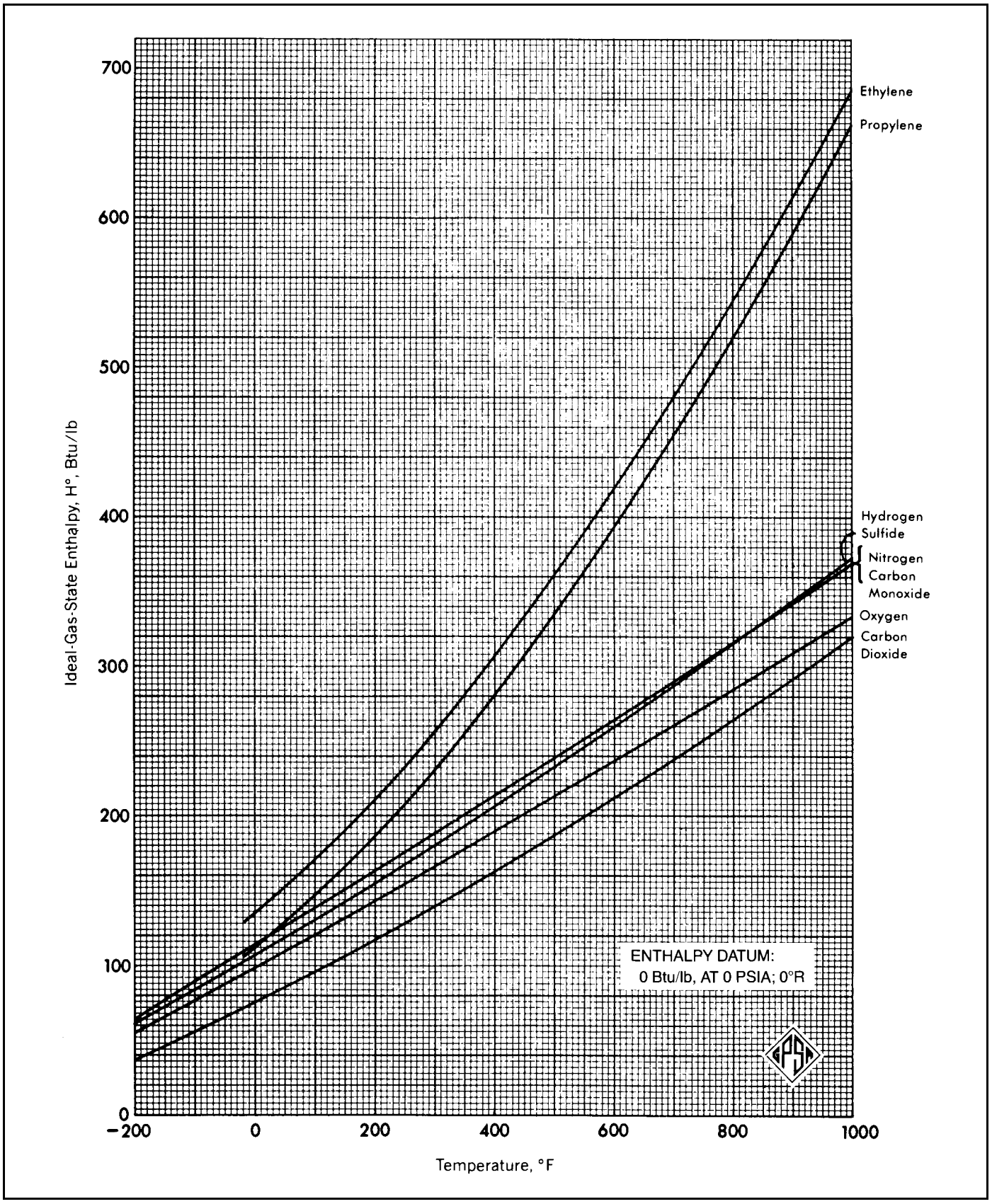
Ideal-Gas-State Enthalpy of Pure Components



PILOT EXHIBIT 2027 PAGE 005
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-4

Ideal-Gas-State Enthalpy of Pure Components

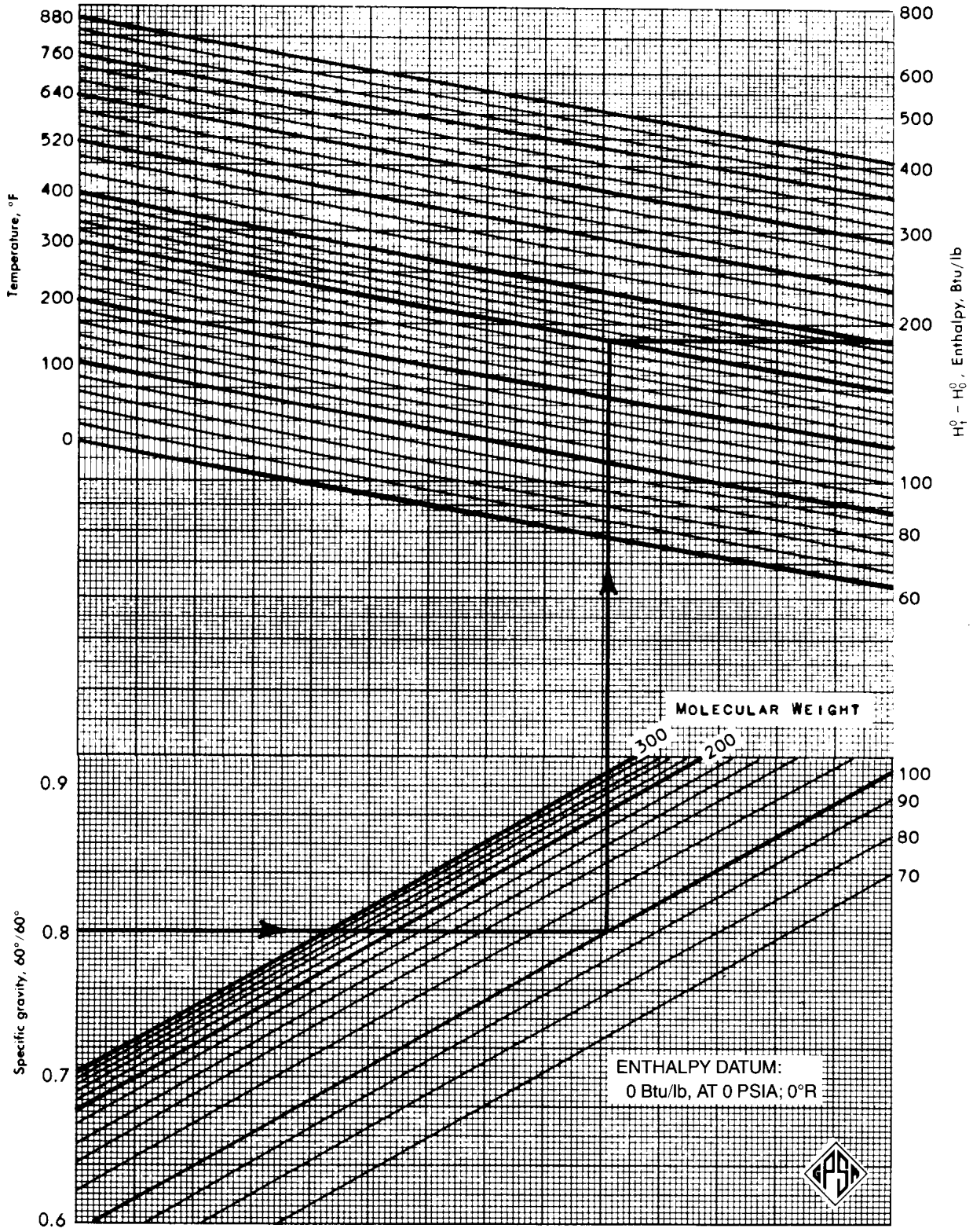


PILOT EXHIBIT 2027 PAGE 006
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-5

Ideal-Gas-State Enthalpy of Petroleum Fractions

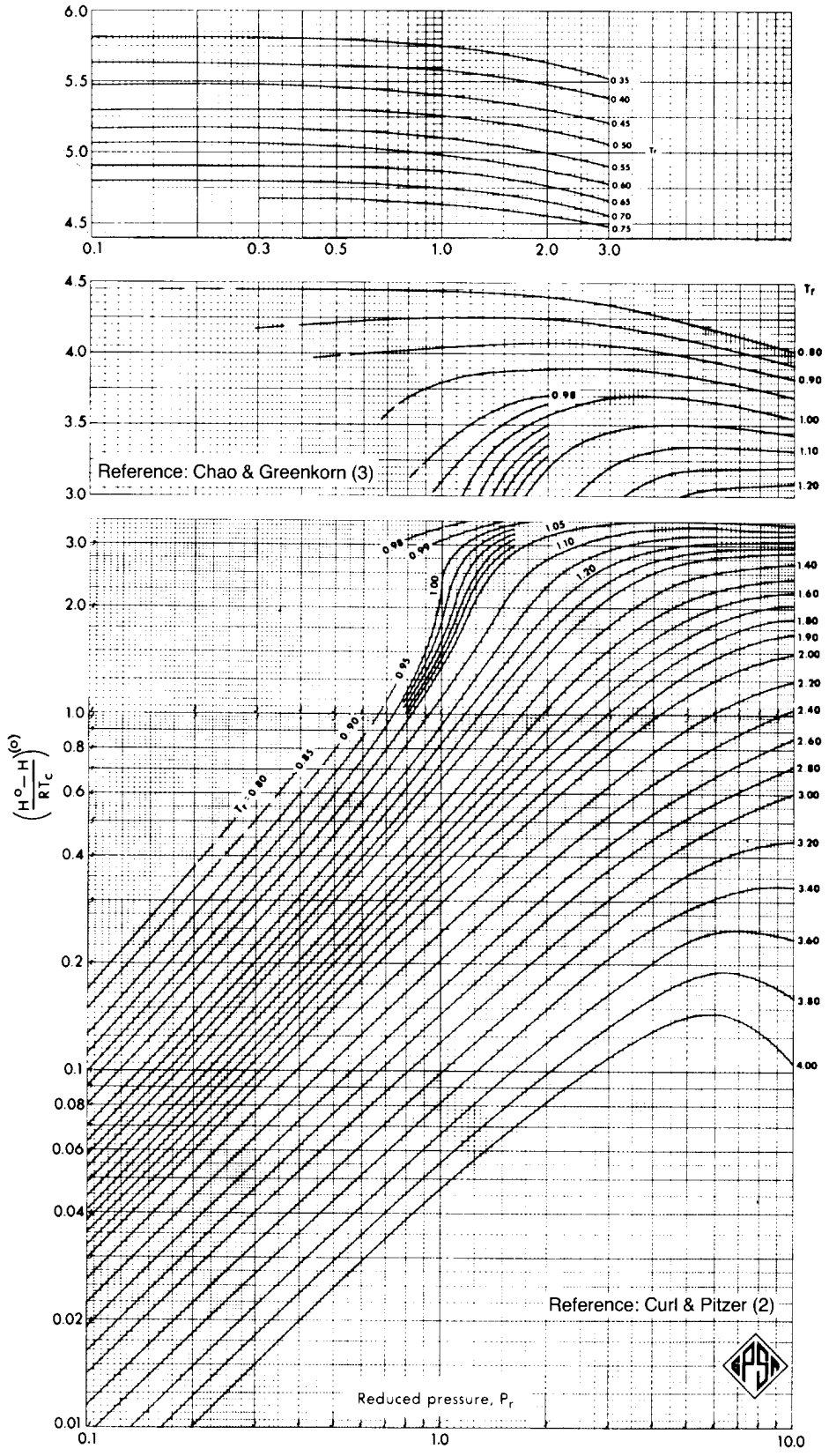
$$\ln [\ln (H_t^0 - H_0^0)] = 2.61456 - \frac{\ln T}{\sqrt{T}}\left[2.49639 + 1.56283(\text{Sp. gr.}) + \frac{25.1591}{MW}\right]$$



PILOT EXHIBIT 2027 PAGE 007
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-6

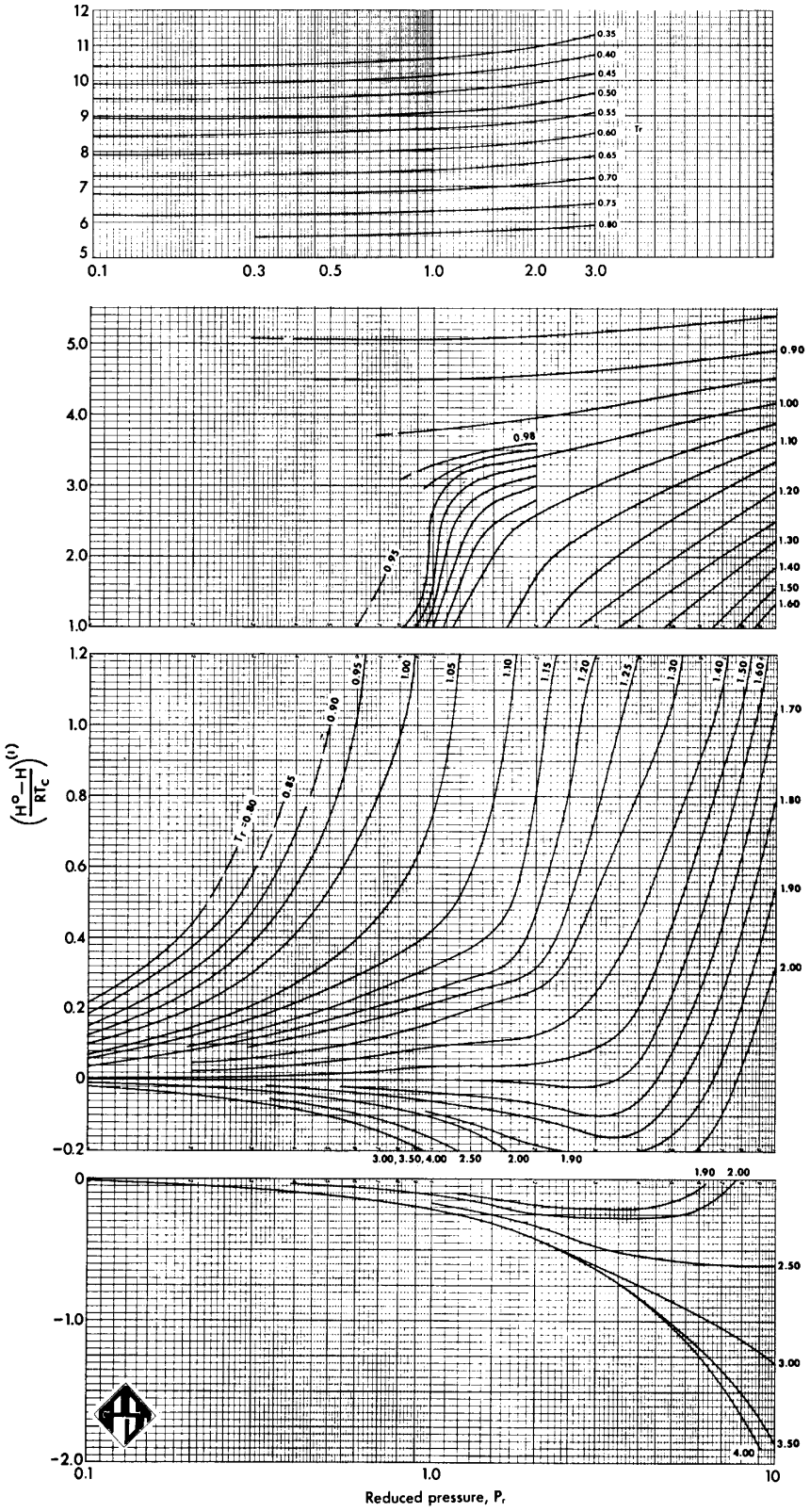
Effect of Pressure on Enthalpy (Simple Fluid)



PILOT EXHIBIT 2027 PAGE 008
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-7

Effect of Pressure on Enthalpy
(Correction for Real Fluids)



PILOT EXHIBIT 2027 PAGE 009
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-8
Example Enthalpy Calculation

Component	Mole Fraction	Molecular Weight	Critical Temp. °R.	Critical Pressure psia	Acentric Factor	Ideal Gas Enthalpy Btu/lb
Methane	0.9010	16.04	343.0	667.0	0.0108	292
Carbon Dioxide	0.0106	44.01	547.4	1069.5	0.2667	100
Ethane	0.0499	30.07	549.7	707.8	0.0972	189
Propane	0.0187	44.1	665.6	615.0	0.1515	162
i-Butane	0.0065	58.12	734.1	527.9	0.1852	151
n-Butane	0.0045	58.12	765.2	548.8	0.1981	162
i-Pentane	0.0017	72.15	828.6	490.4	0.2286	151
n-Pentane	0.0019	72.15	845.4	488.1	0.2510	158
Hexane	0.0052	86.18	911.5	439.5	0.2990	139

IDEAL GAS STATE ENTHALPY	Btu/lb mol	4885.7
PSEUDO CRITICAL TEMPERATURE	°R	370.7
REDUCED TEMPERATURE		1.564
PSEUDO CRITICAL PRESSURE	psia	669.1
REDUCED PRESSURE		1.509
MOLE FRACTION AVERAGE ACENTRIC FACTOR		0.02476

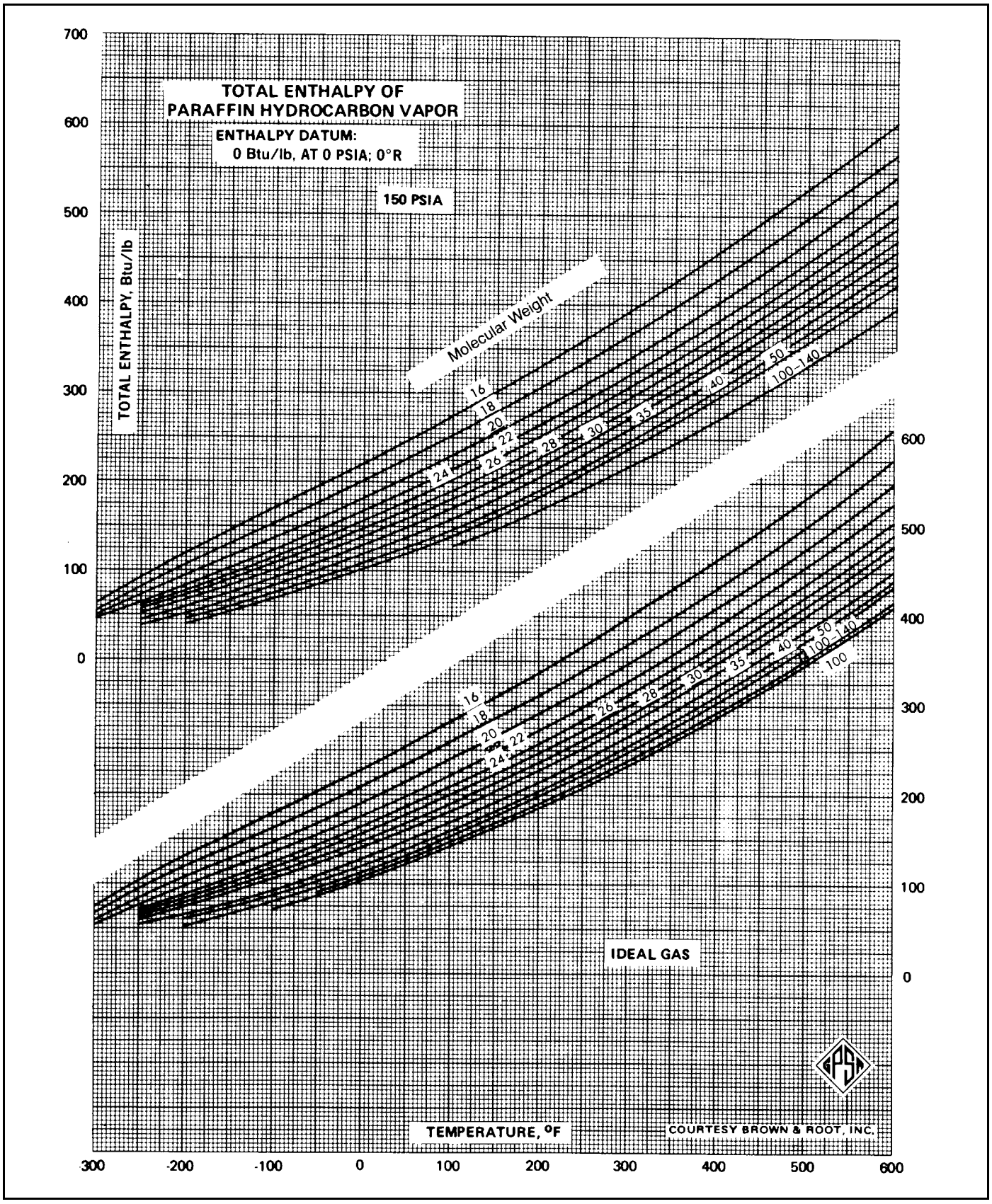
$[(H^0 - H) / RT_C]^{(0)}$ from Fig. 24-6	0.70
$[(H^0 - H) / RT_C]^{(')}$ from Fig. 24-7	0.020
$[(H^0 - H)_m / RT_C] = [(H^0 - H) / RT_C]^{(0)} + [w_m [(H^0 - H) / RT_C]^{(')}$	0.7005
$(H^0 - H)_m$, Btu/lb mole	515.7
H, Btu/lb mole	4370.0

NOTE: Ideal Gas Enthalpy for Hexane from Fig. 24-9.
Wichert and Aziz correction not applied to critical properties.

PILOT EXHIBIT 2027 PAGE 010
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-9

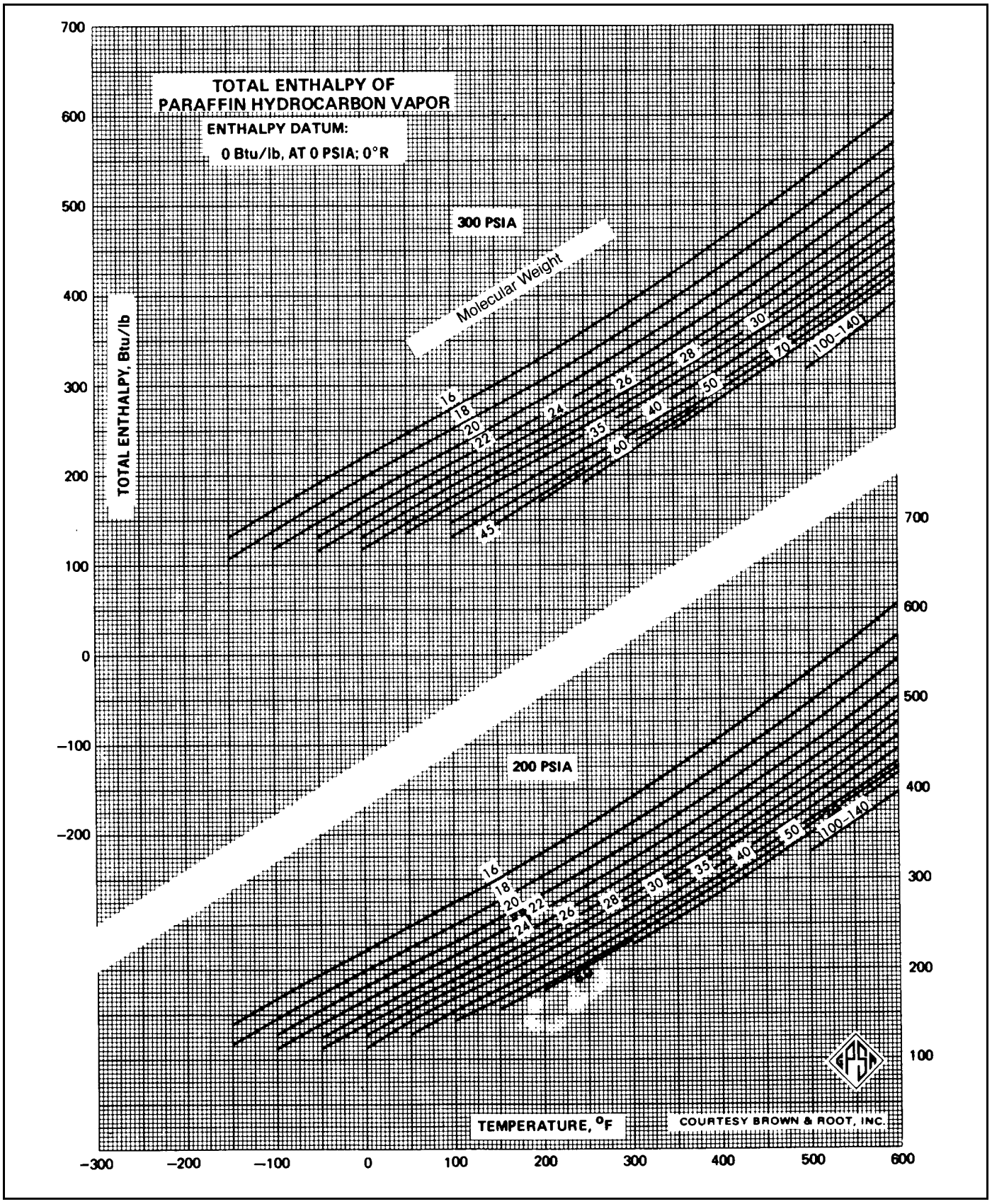
Total Enthalpy of Paraffin Hydrocarbon Vapor



PILOT EXHIBIT 2027 PAGE 011
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-10

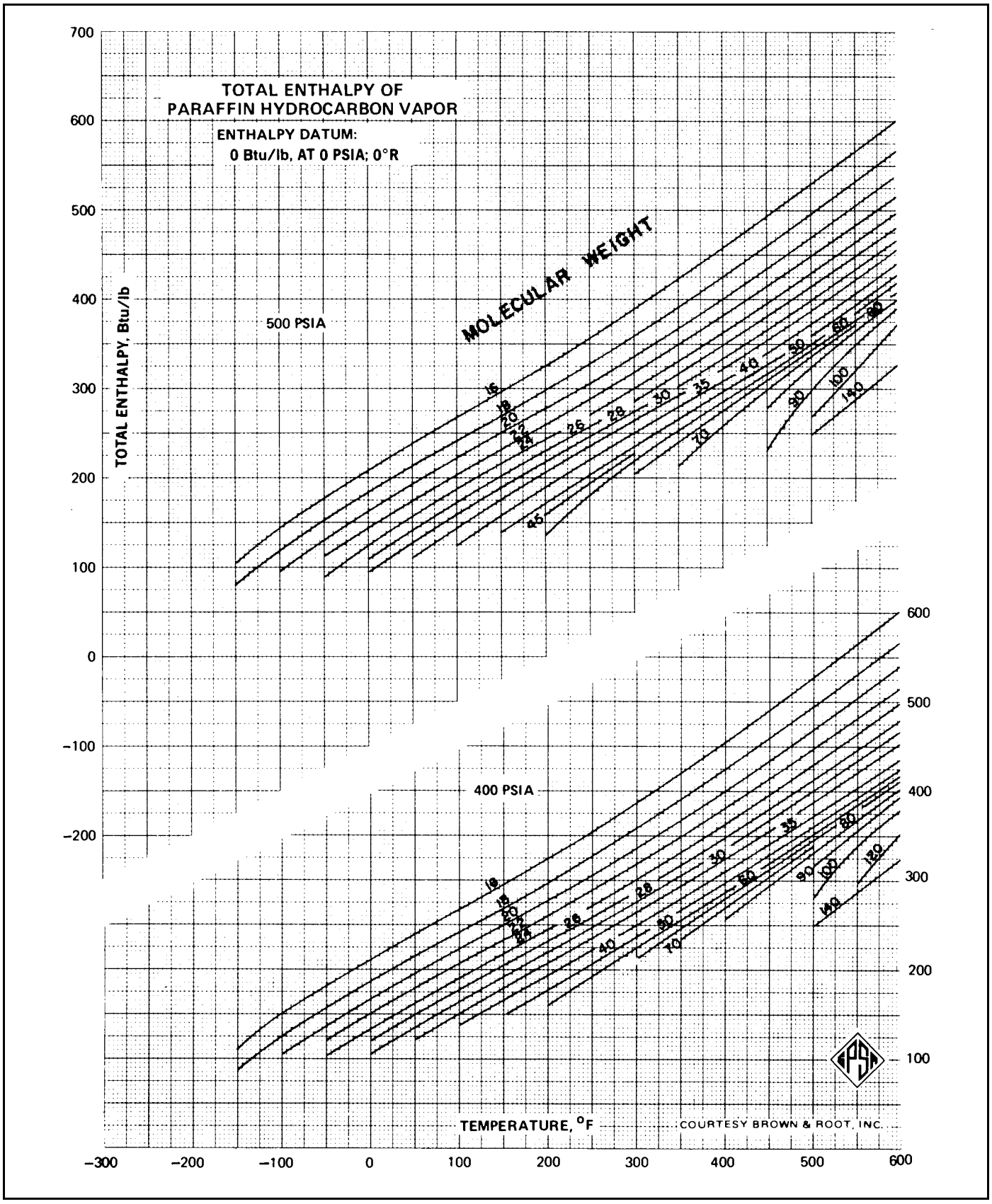
Total Enthalpy of Paraffin Hydrocarbon Vapor



PILOT EXHIBIT 2027 PAGE 012
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-11

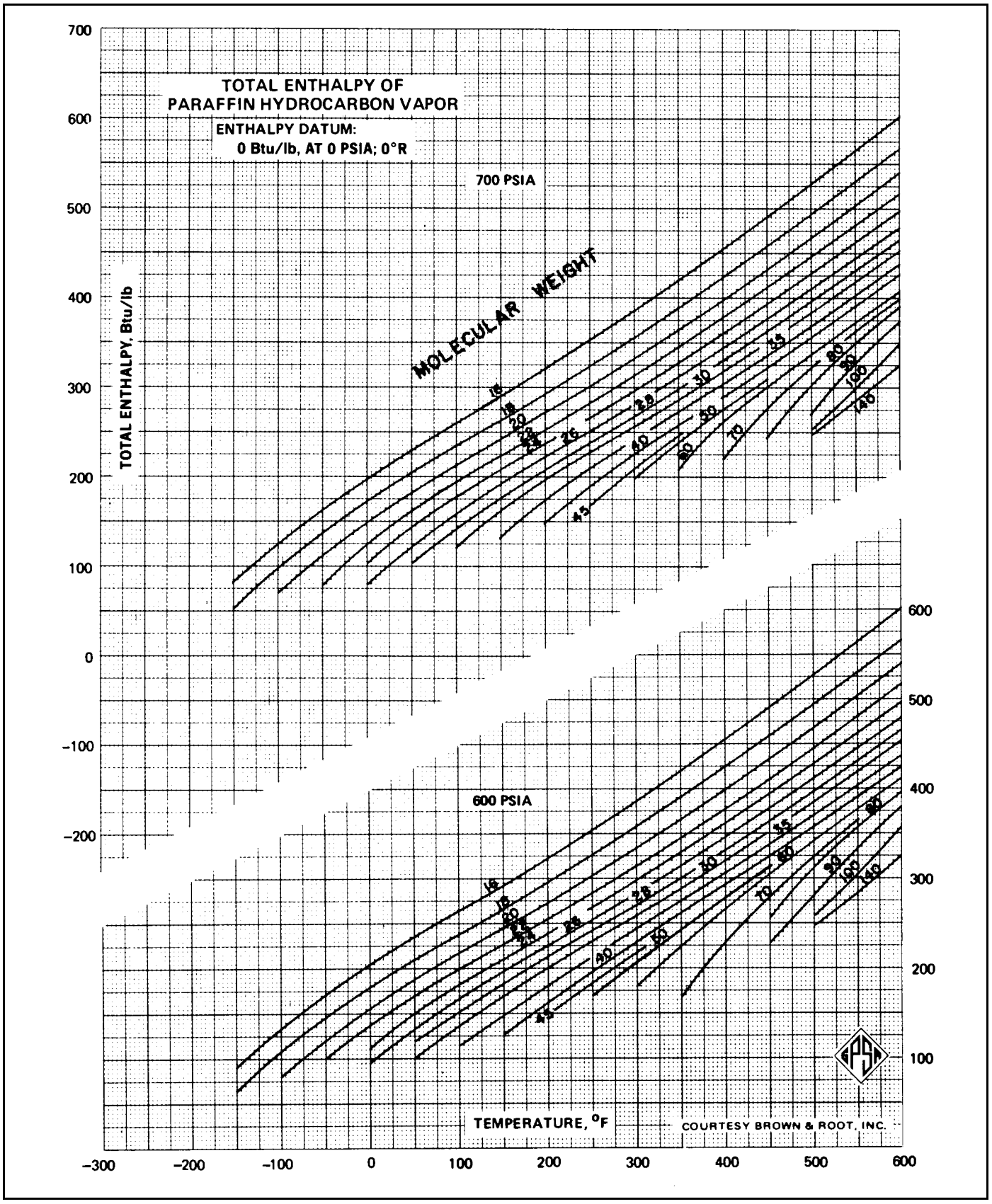
Total Enthalpy of Paraffin Hydrocarbon Vapor



PILOT EXHIBIT 2027 PAGE 013
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-12

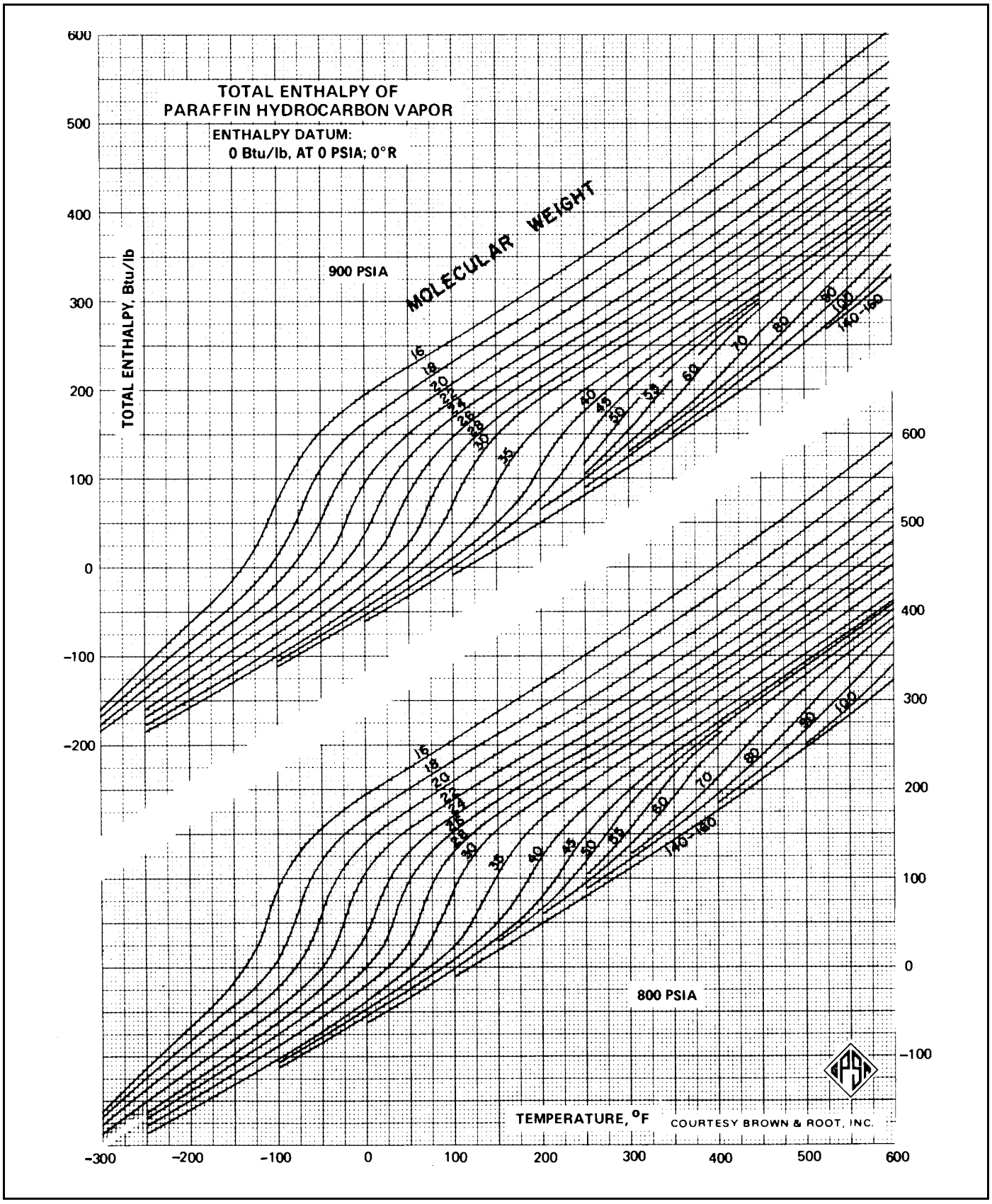
Total Enthalpy of Paraffin Hydrocarbon Vapor



PILOT EXHIBIT 2027 PAGE 014
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-13

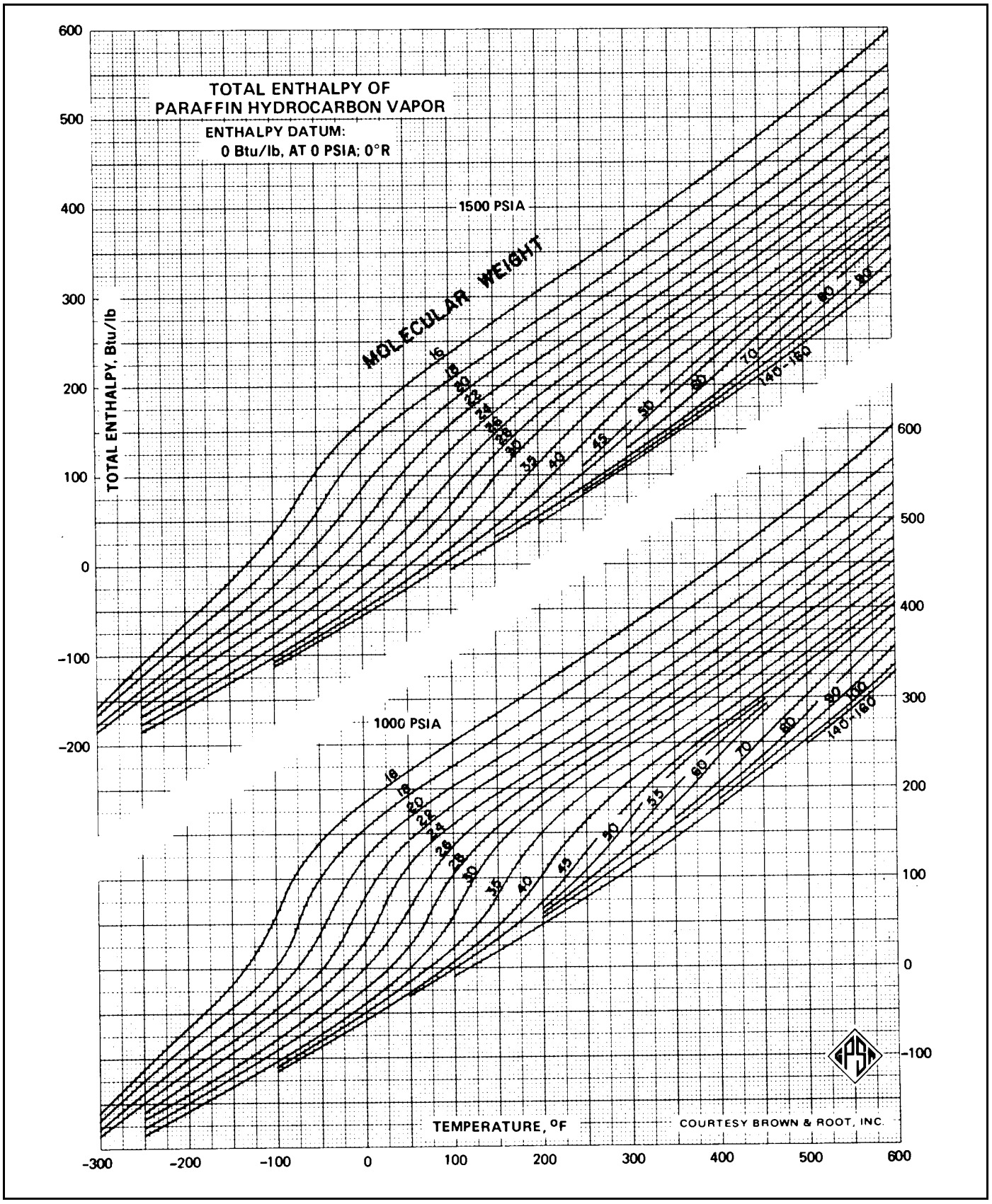
Total Enthalpy of Paraffin Hydrocarbon Vapor



PILOT EXHIBIT 2027 PAGE 015
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-14

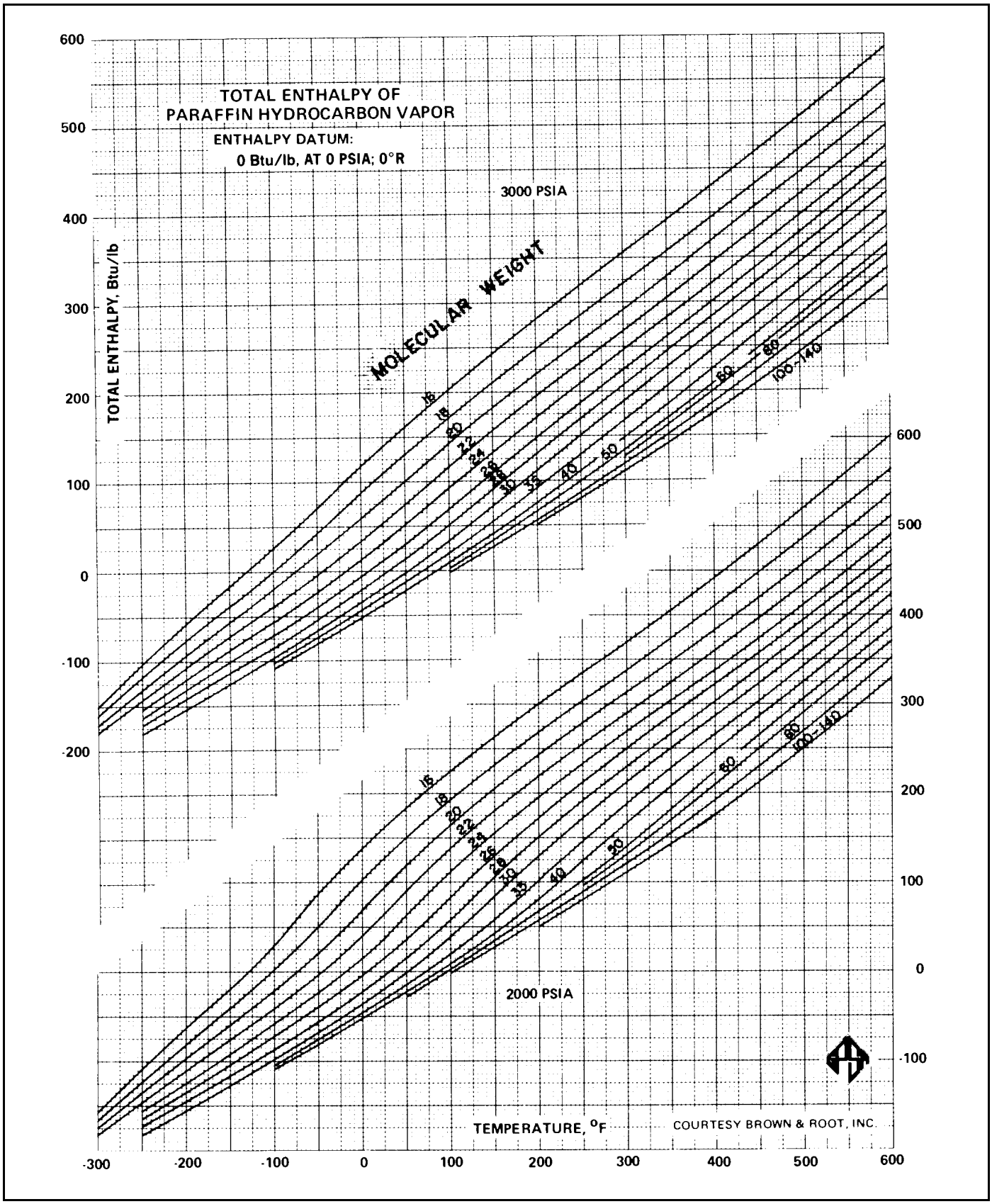
Total Enthalpy of Paraffin Hydrocarbon Vapor



PILOT EXHIBIT 2027 PAGE 016
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-15

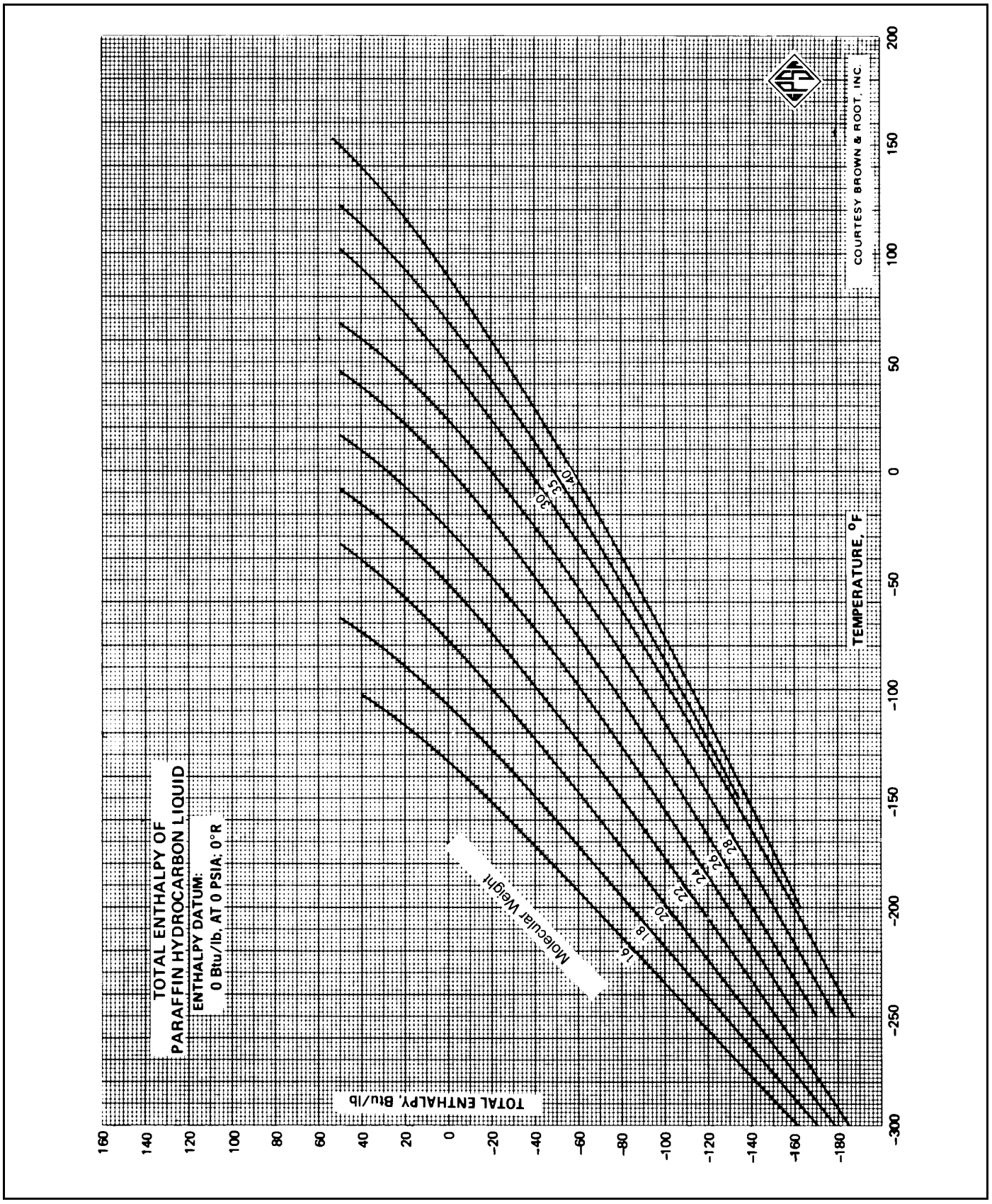
Total Enthalpy of Paraffin Hydrocarbon Vapor



PILOT EXHIBIT 2027 PAGE 017
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-16

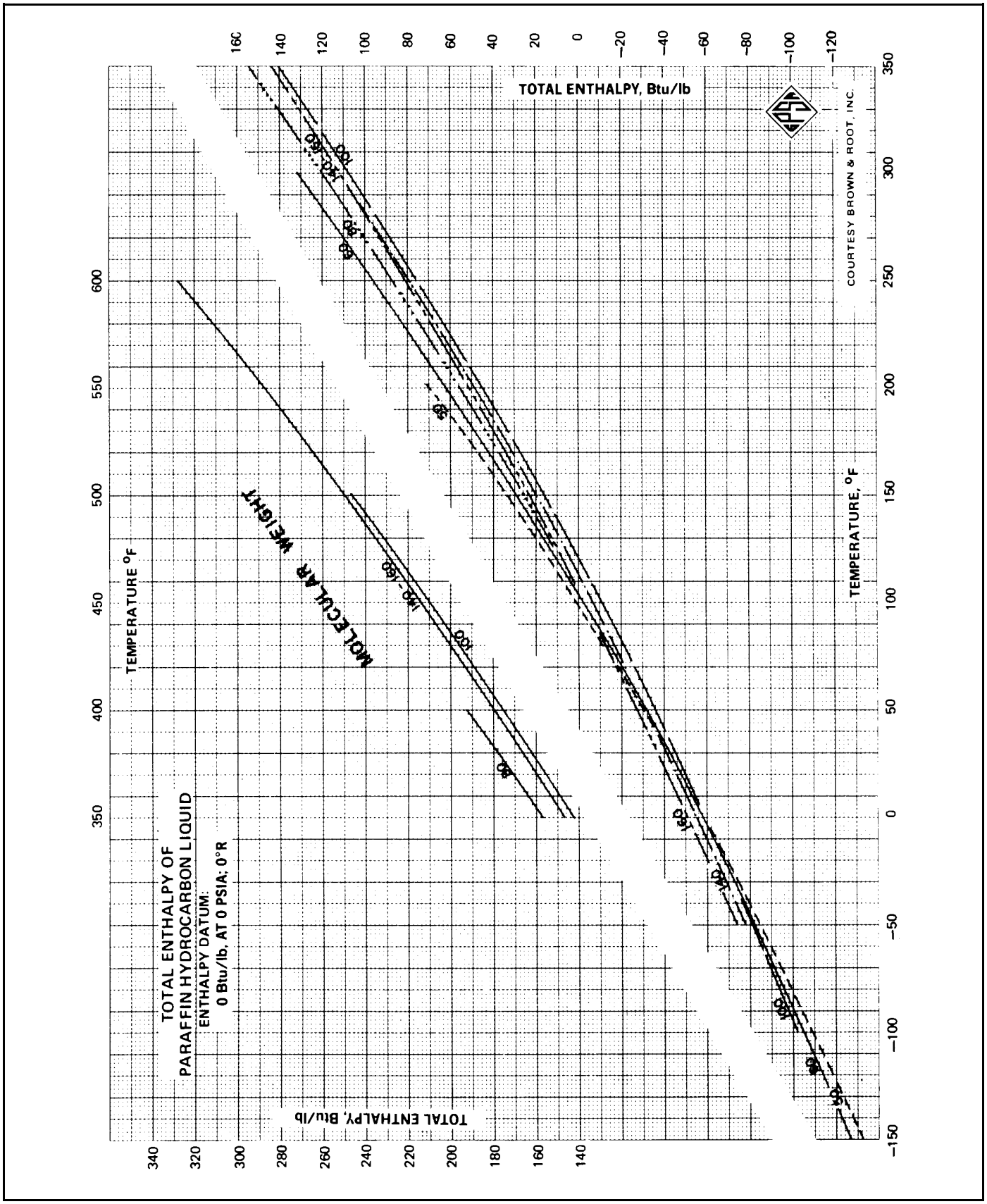
Total Enthalpy of Paraffin Hydrocarbon Liquid



PILOT EXHIBIT 2027 PAGE 018
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-17

Total Enthalpy of Paraffin Hydrcarbon Liquid



PILOT EXHIBIT 2027 PAGE 019
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-18
Example Entropy Calculation

Component	Mole Fraction	Molecular Weight	Critical Temp. °R.	Critical Pressure psia	Acentric Factor	Ideal Gas Entropy Btu/(lb•°R)
Methane	0.9010	16.04	343.0	667.0	0.0108	3.150
Carbon Dioxide	0.0106	44.01	547.4	1069.5	0.2667	1.176
Ethane	0.0499	30.07	549.7	707.8	0.0972	2.036
Propane	0.0187	44.1	665.6	615.0	0.1515	1.624
i-Butane	0.0065	58.12	734.1	527.9	0.1852	1.400
n-Butane	0.0045	58.12	765.2	548.8	0.1981	1.338
i-Pentane	0.0017	72.15	828.6	490.4	0.2286	1.260
n-Pentane	0.0019	72.15	845.4	488.1	0.2510	1.245
Hexane	0.0052	86.18	911.5	439.5	0.2990	1.198

IDEAL GAS STATE ENTROPY	Btu/(lb mol • °R)	52.2
PSEUDO CRITICAL TEMPERATURE	°R	370.7
REDUCED TEMPERATURE		1.564
PSEUDO CRITICAL PRESSURE	psia	669.1
REDUCED PRESSURE		1.509
MOLE FRACTION AVERAGE ACENTRIC FACTOR		0.02476
$[(S^0 - S) / R]^{(o)}$ from Fig. 24-20		0.345
$[(S^0 - S) / R]^{(')}$ from Fig. 24-21		0.065
ln P (P in atmospheres)		4.2301
$(S^0 - S) = R\left[\left(\frac{S^o - S}{R}\right)^{(o)} + w\left(\frac{S^o - S}{R}\right)^{(')} + \ln P\right]$		9.089
$R \Sigma y_i \bullet \ln (y_i)$		-0.9404
$S_m^o = (\Sigma y_i S_i^o - R \Sigma y_i \bullet \ln (y_i))$		53.14
$S_m = [S_m^o - (S_m^o - S_m)]$		44.05

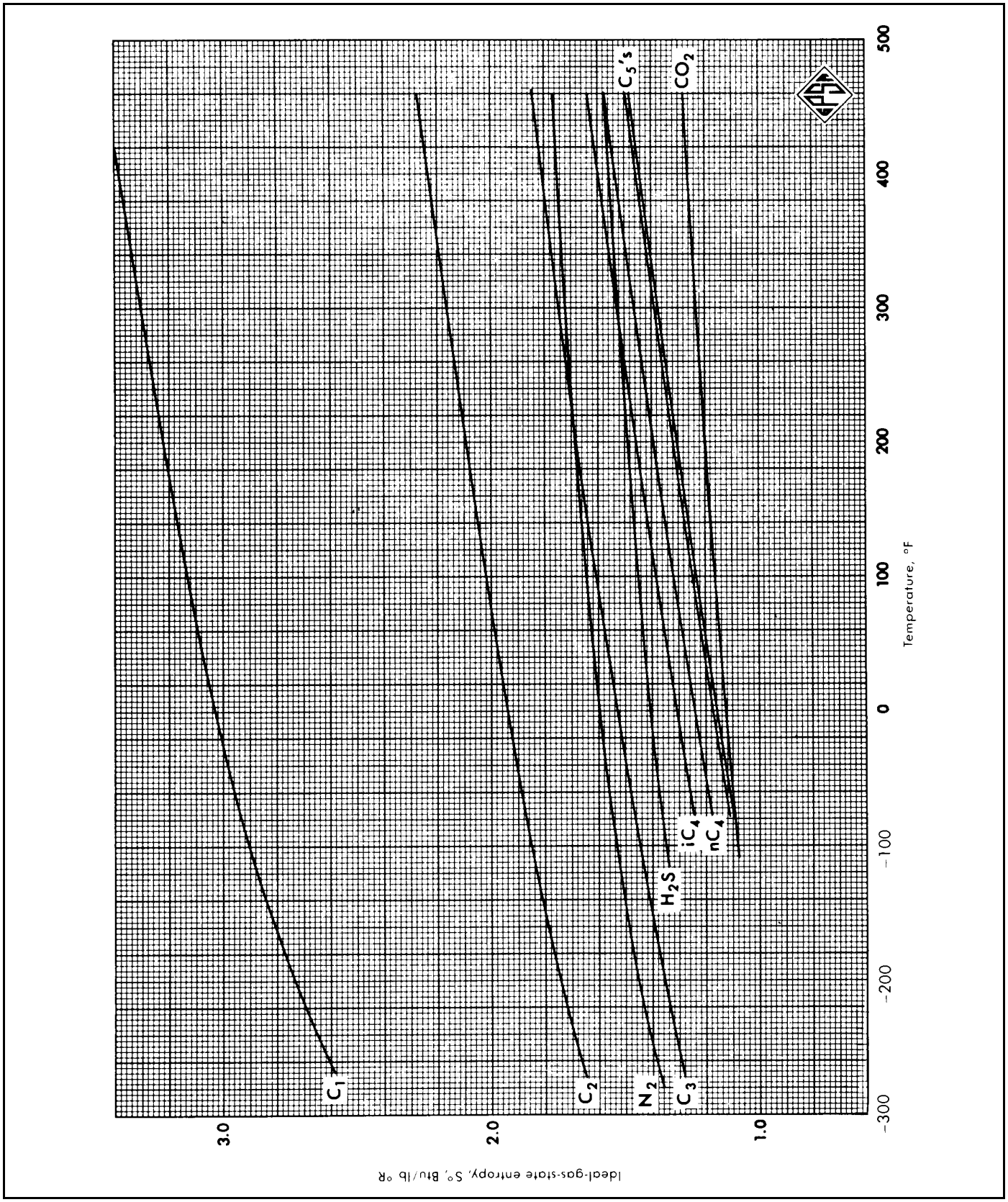
NOTE: Entropy for Hexane was estimated.

Wichert and Aziz correction not applied to critical properties.

PILOT EXHIBIT 2027 PAGE 020
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-19

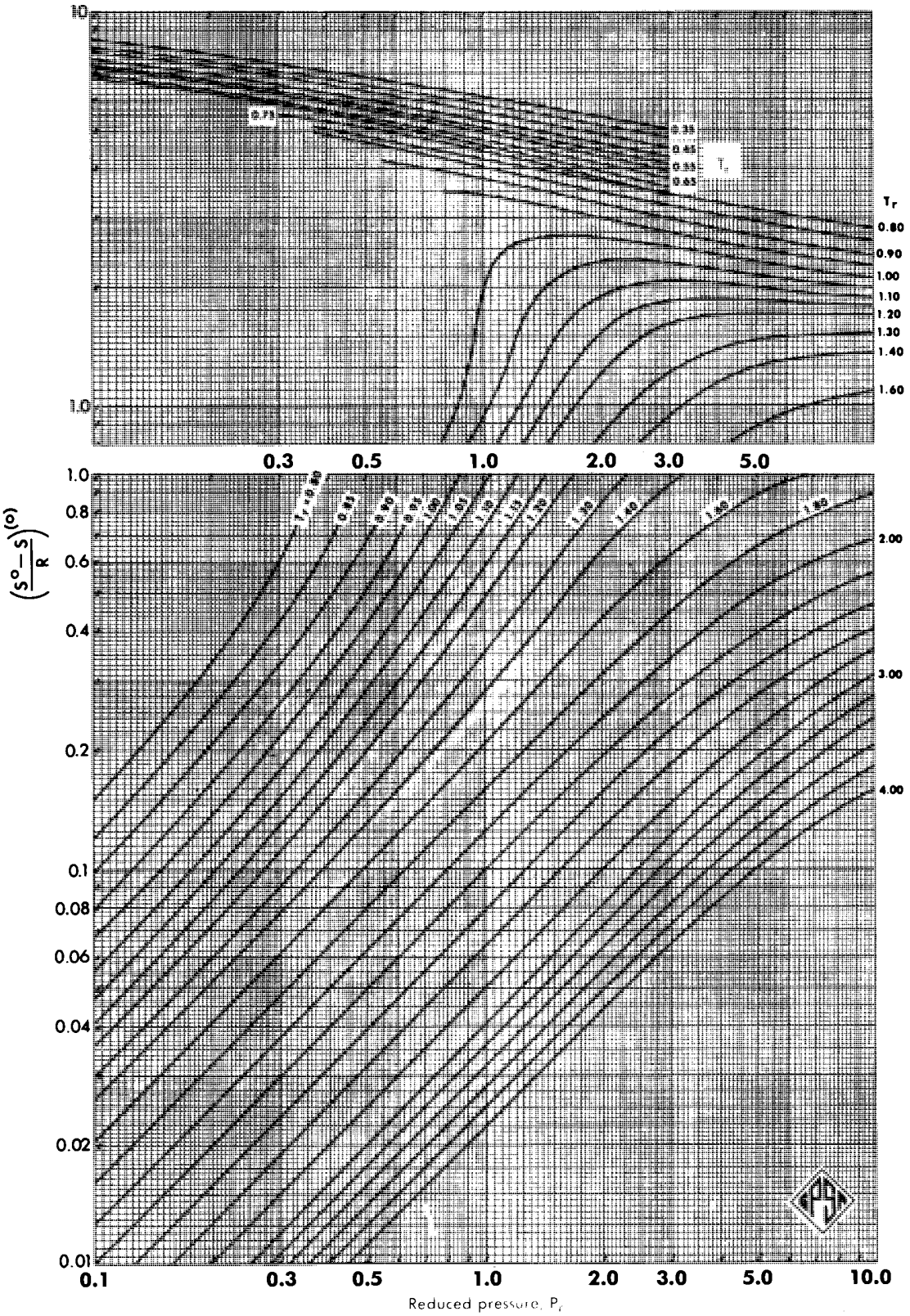
Ideal Gas State Entropy of Pure Components



PILOT EXHIBIT 2027 PAGE 021
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-20

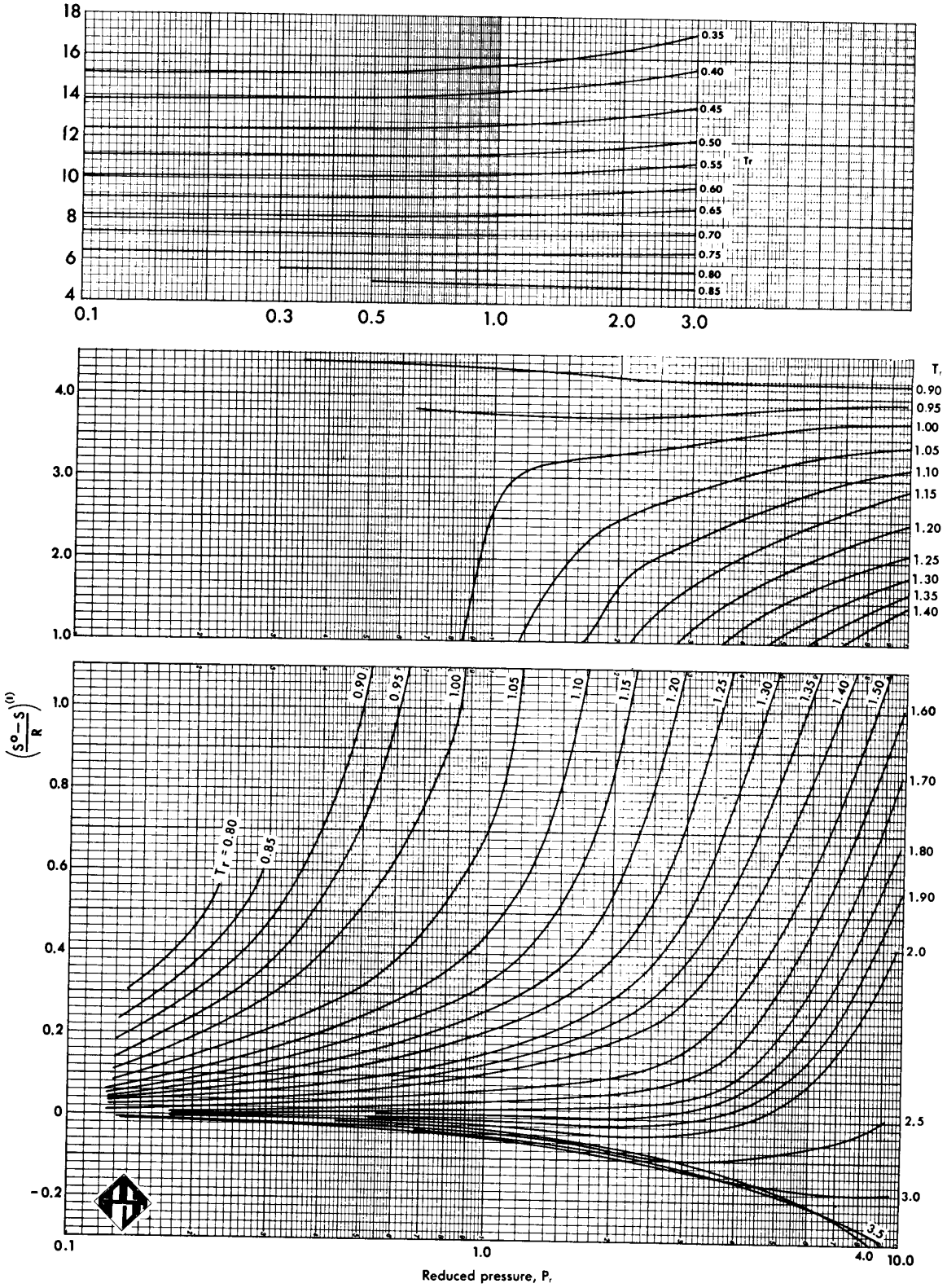
Effect of Pressure on Entropy
(Simple Fluid)



PILOT EXHIBIT 2027 PAGE 022
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-21

Effect of Pressure on Entropy
(Correction for Real Fluids)



PILOT EXHIBIT 2027 PAGE 023
SCOUT/CHEVRON v. PILOT - IPR2024-00385

Acknowledgments

Virtual Materials Group gratefully acknowledges the assistance provided by Dr. Eric Lemmon and Dr. Michael Frenkel from the National Institute of Standards and Technology (NIST) for their assistance in the preparation of the P-H Diagrams presented in Figure 24-22 through Figure 24-33.

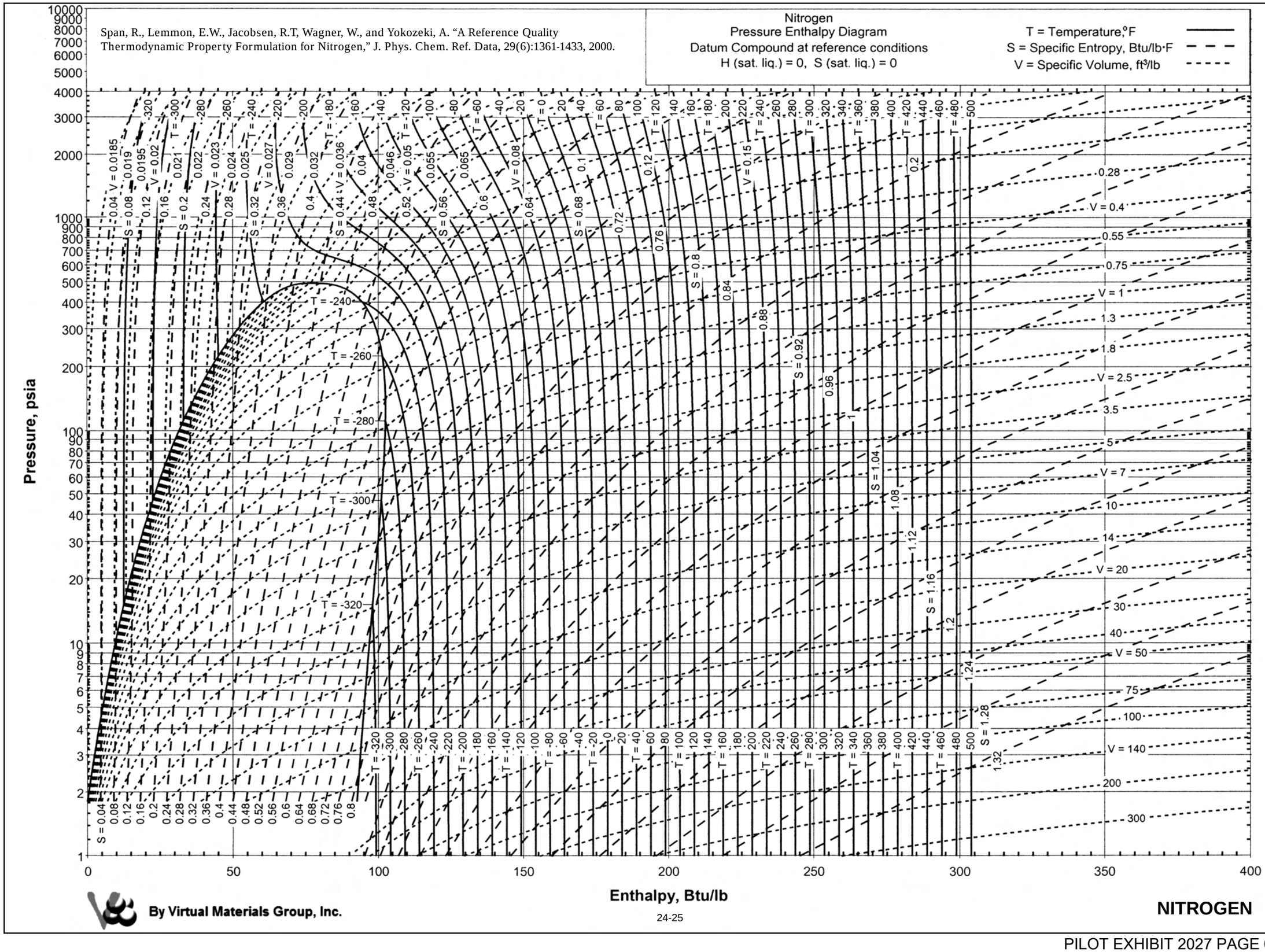
Substance	TPT K	NBP K	TC K	PC kPa	RHOC Mol/L	ACEN	TMIN K	TMAX K	PMAX kPa	RHOMAX Mol/L
Methane	90.6941	111.667	190.564	4599.2	10.139	.01142	90.6941	625	1000000	40.072
Ethane	90.352	184.552	305.33	4871.8	6.87	.0993	90.352	625	70000	22.419
Propane	85.48	231.06	369.825	4247.09	4.95514	.1524	85.48	623	103000	17.41
Isobutane	113.56	261.48	407.817	3640.0	3.860	.185	113.56	573	35000	12.90
n-Butane	134.87	272.6	425.125	3796.0	3.920	.2	134.87	589	69000	13.15
Isopentane	112.65	300.97	460.35	3396.0	3.271	.2296	112.65	600	1000000	10.93
n-Pentane	143.47	309.21	469.7	3370.0	3.2156	.251	143.47	600	100000	10.57
Ethylene	103.986	169.379	282.35	5041.8	7.637	.0866	103.986	450	260000	26.67
Propylene	87.95	225.46	365.57	4664.6	5.3086	.1408	100.0	600	200000	17.95
Nitrogen	63.151	77.355	126.192	3395.8	11.1839	.0372	63.151	2000	2200000	53.15
Oxygen	54.361	90.1878	154.581	5043.0	13.63	.0222	54.361	1000	82000	43.348
Carbon Dioxide	216.592	194.75	304.1282	7377.3	10.6249	.22394	216.592	1100	800000	37.24

TPT	Triple point temperature	RHOC	Critical Density	PMAX	Maximum Recommended Pressure
NBP	Normal Boiling Point	ACEN	Acentric Factor	RHOMAX	Maximum Recommended Density
TC	Critical Temperature	TMIN	Minimum Recommended Temperature		
PC	Critical Pressure	TMAX	Maximum Recommended Temperature		

	Reference Temperature		Reference Pressure	
	Value (F)	Database	Value (Psia)	Database
Ethane	-297.04	NIST	1.640E-04	TRC
Methane	-296.42	NIST	1.696E+00	TRC
N2	-346.00	NIST	1.816E+00	TRC
CO2	-69.80	NIST	7.512E+01	TRC
Ethylene	-272.50	NIST	1.827E-02	TRC
Propane	-305.81	NIST	2.451E-08	TRC
Propylene	-279.67	NIST	1.349E-07	TRC
I-Butane	-255.26	NIST	1.749E-06	TRC
n-Butane	-216.90	NIST	9.770E-05	TRC
I-Pentane	-256.90	TRC	1.755E-08	TRC
n-Pentane	-201.42	NIST	1.107E-05	TRC
Oxygen	-361.82	NIST	2.176E-02	TRC

PILOT EXHIBIT 2027 PAGE 024
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-22 Nitrogen P-H Diagram



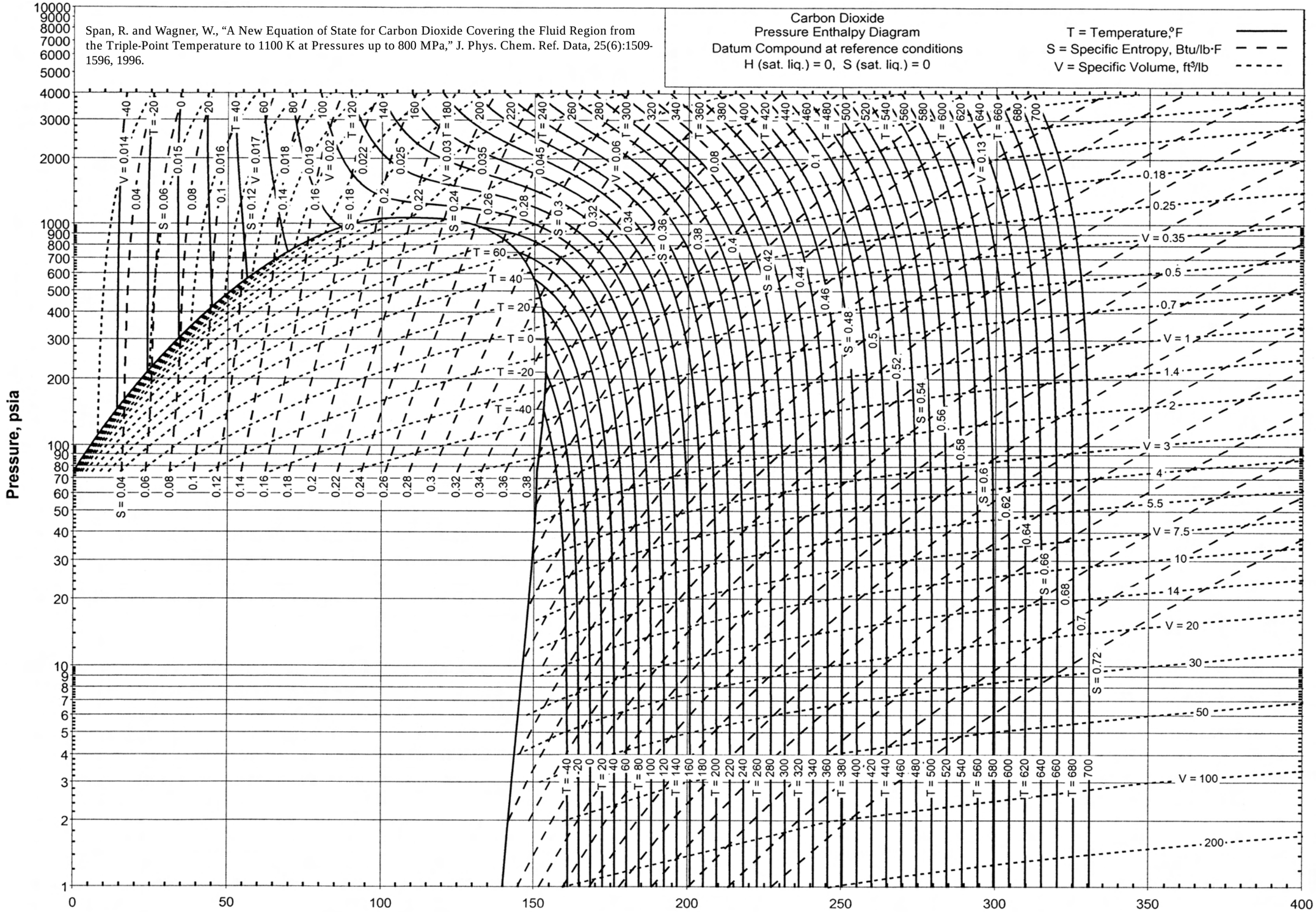
PILOT EXHIBIT 2027 PAGE 025
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-23 Carbon Dioxide P-H Diagram

Span, R. and Wagner, W., "A New Equation of State for Carbon Dioxide Covering the Fluid Region from the Triple-Point Temperature to 1100 K at Pressures up to 800 MPa," J. Phys. Chem. Ref. Data, 25(6):1509-1596, 1996.

Carbon Dioxide
Pressure Enthalpy Diagram
Datum Compound at reference conditions
H (sat. liq.) = 0, S (sat. liq.) = 0

T = Temperature,°F
S = Specific Entropy, Btu/lb·F
V = Specific Volume, ft³/lb

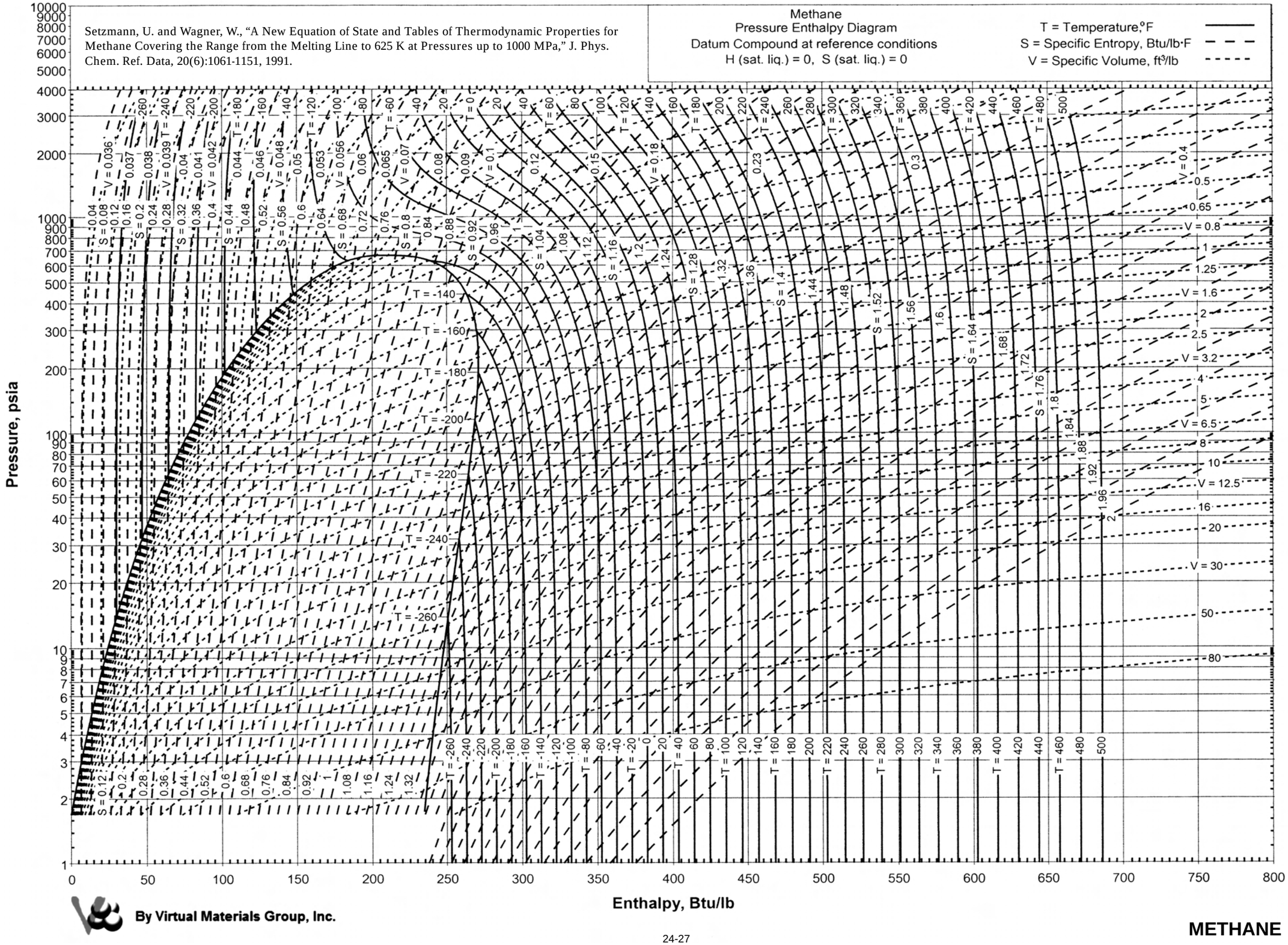


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CARBON DIOXIDE

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FIG. 24-24 Methane P-H Diagram



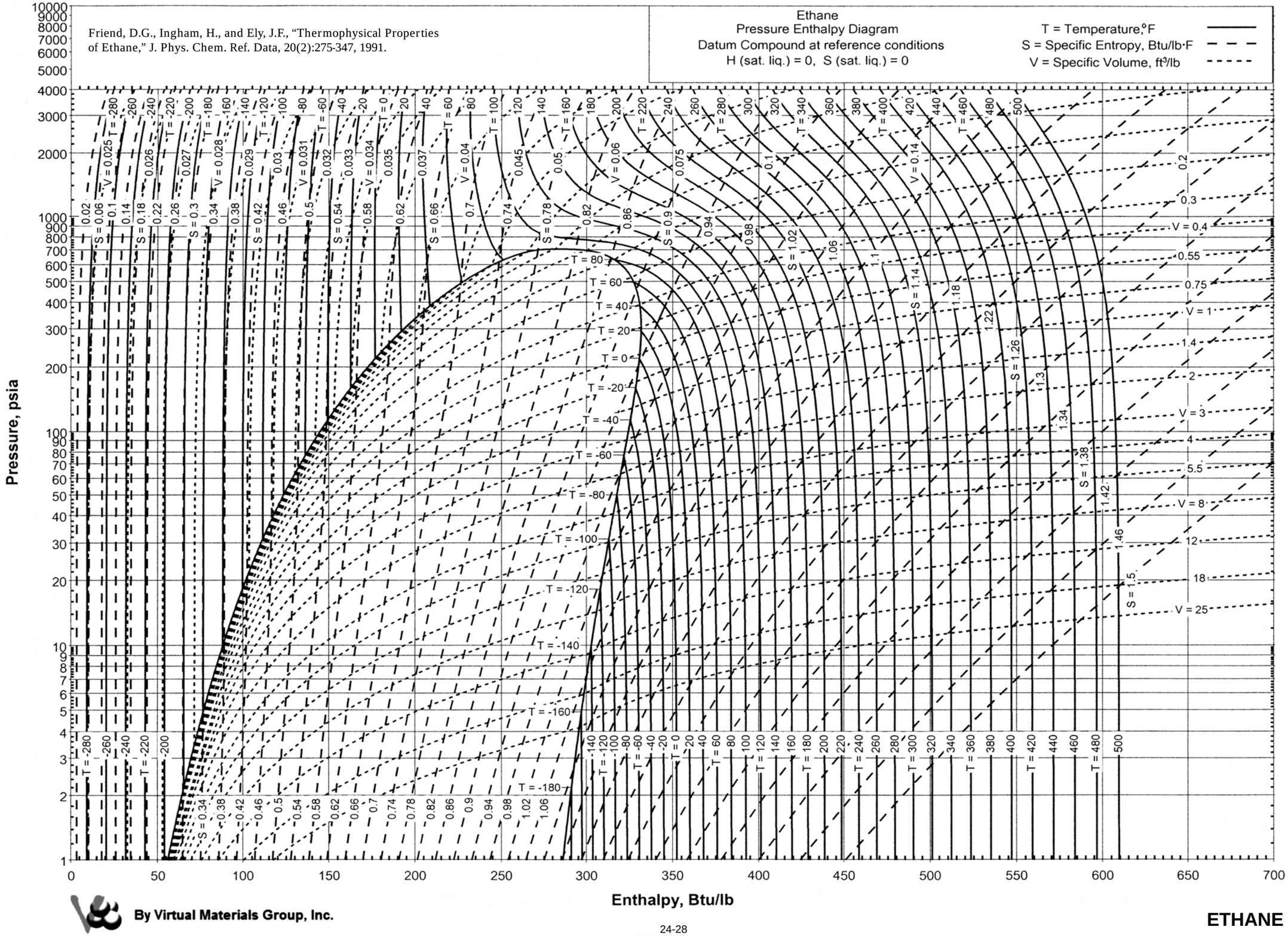
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FIG. 24-25 Ethane P-H Diagram

Friend, D.G., Ingham, H., and Ely, J.F., "Thermophysical Properties of Ethane," J. Phys. Chem. Ref. Data, 20(2):275-347, 1991.

Ethane
Pressure Enthalpy Diagram
Datum Compound at reference conditions
H (sat. liq.) = 0, S (sat. liq.) = 0

T = Temperature, °F
S = Specific Entropy, Btu/lb·F
V = Specific Volume, ft³/lb

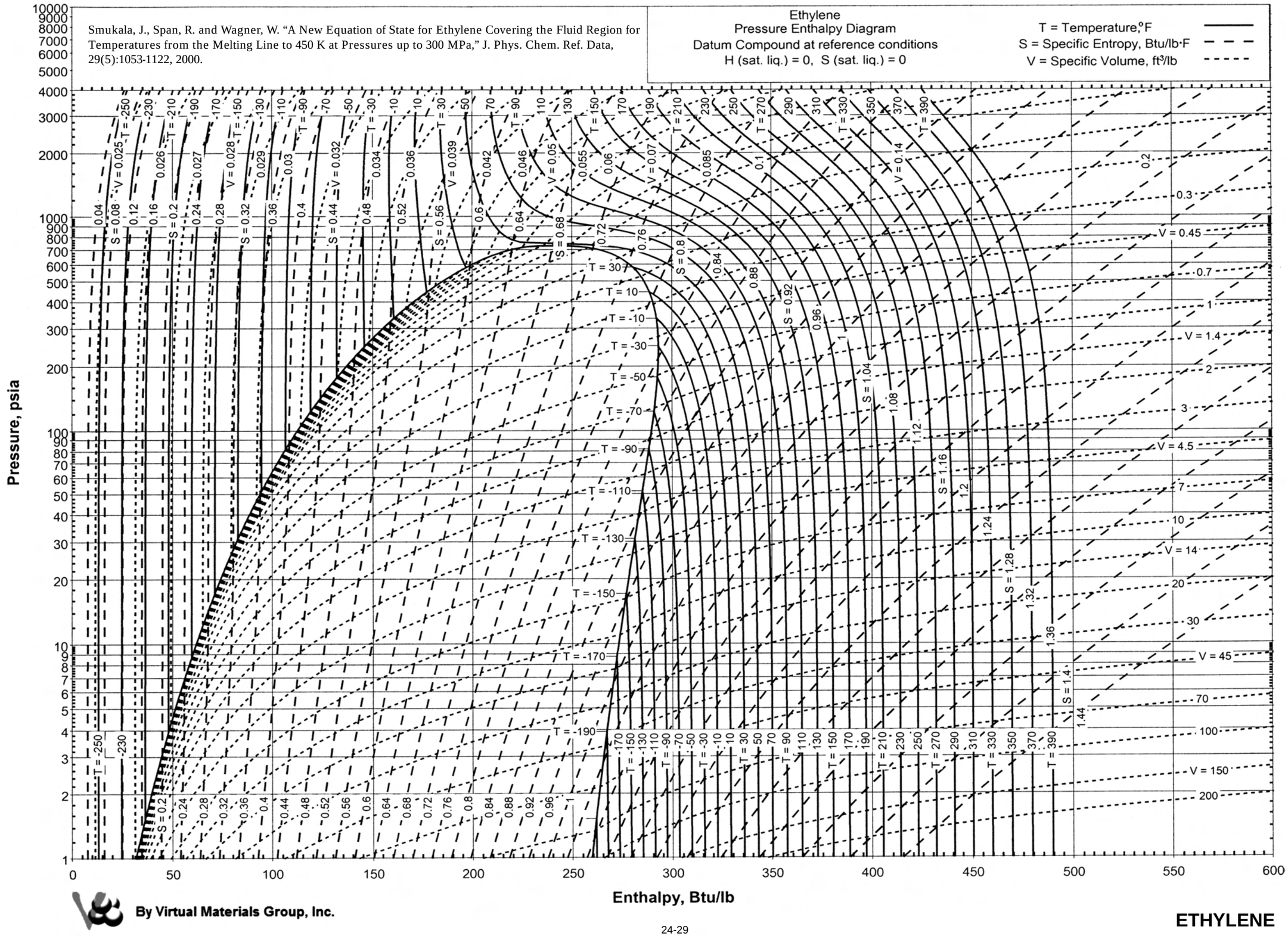


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ETHANE

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FIG. 24-26 Ethylene P-H Diagram



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FIG. 24-27 Propane P-H Diagram

Miyamoto, H., and Watanabe, K., "A Thermodynamic Property Model for Fluid-phase Propane," Int. J. Thermophys., 21(5):1045-1072, 2000.

Propane
Pressure Enthalpy Diagram
Datum Compound at reference conditions
H (sat. liq.) = 0, S (sat. liq.) = 0

T = Temperature, °F
S = Specific Entropy, Btu/lb·F
V = Specific Volume, ft³/lb

Pressure, psia

Enthalpy, Btu/lb

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PROPANE

PILOT EXHIBIT 2027 PAGE 030
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-28 Propylene P-H Diagram

Angus, S., Armstrong, B., and de Reuck, K.M., "International Thermodynamic Tables of the Fluid State-7 Propylene," International Union of Pure and Applied Chemistry, Pergamon Press, Oxford, 1980..

Propylene
Pressure Enthalpy Diagram
Datum Compound at reference conditions
H (sat. liq.) = 0, S (sat. liq.) = 0

T = Temperature, °F
S = Specific Entropy, Btu/lb·F
V = Specific Volume, ft³/lb

Pressure, psia

Enthalpy, Btu/lb

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PROPYLENE

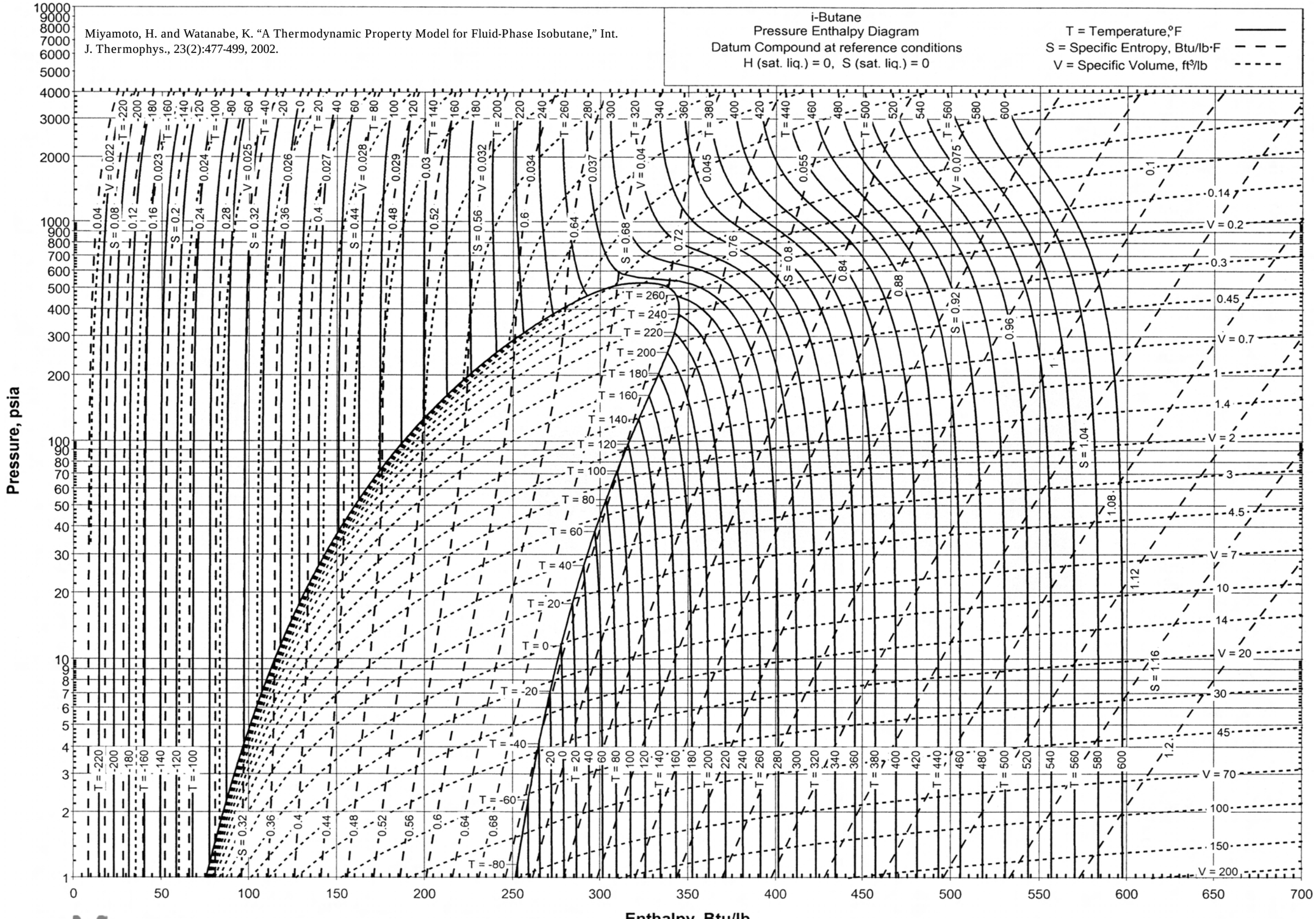
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SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-29 i-Butane P-H Diagram

Miyamoto, H. and Watanabe, K. "A Thermodynamic Property Model for Fluid-Phase Isobutane," Int. J. Thermophys., 23(2):477-499, 2002.

i-Butane
Pressure Enthalpy Diagram
Datum Compound at reference conditions
H (sat. liq.) = 0, S (sat. liq.) = 0

T = Temperature, °F
S = Specific Entropy, Btu/lb·F
V = Specific Volume, ft³/lb

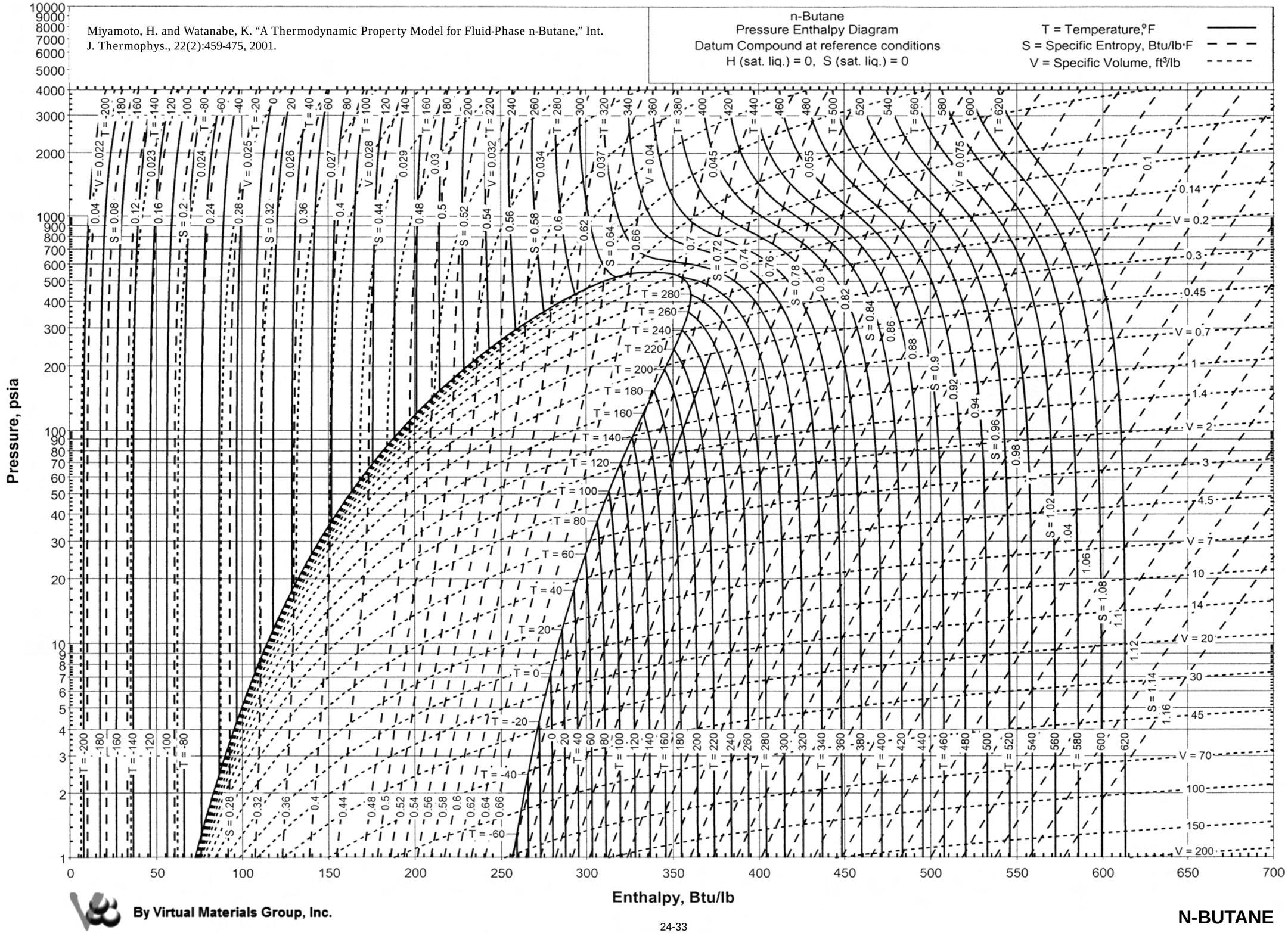


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I-BUTANE

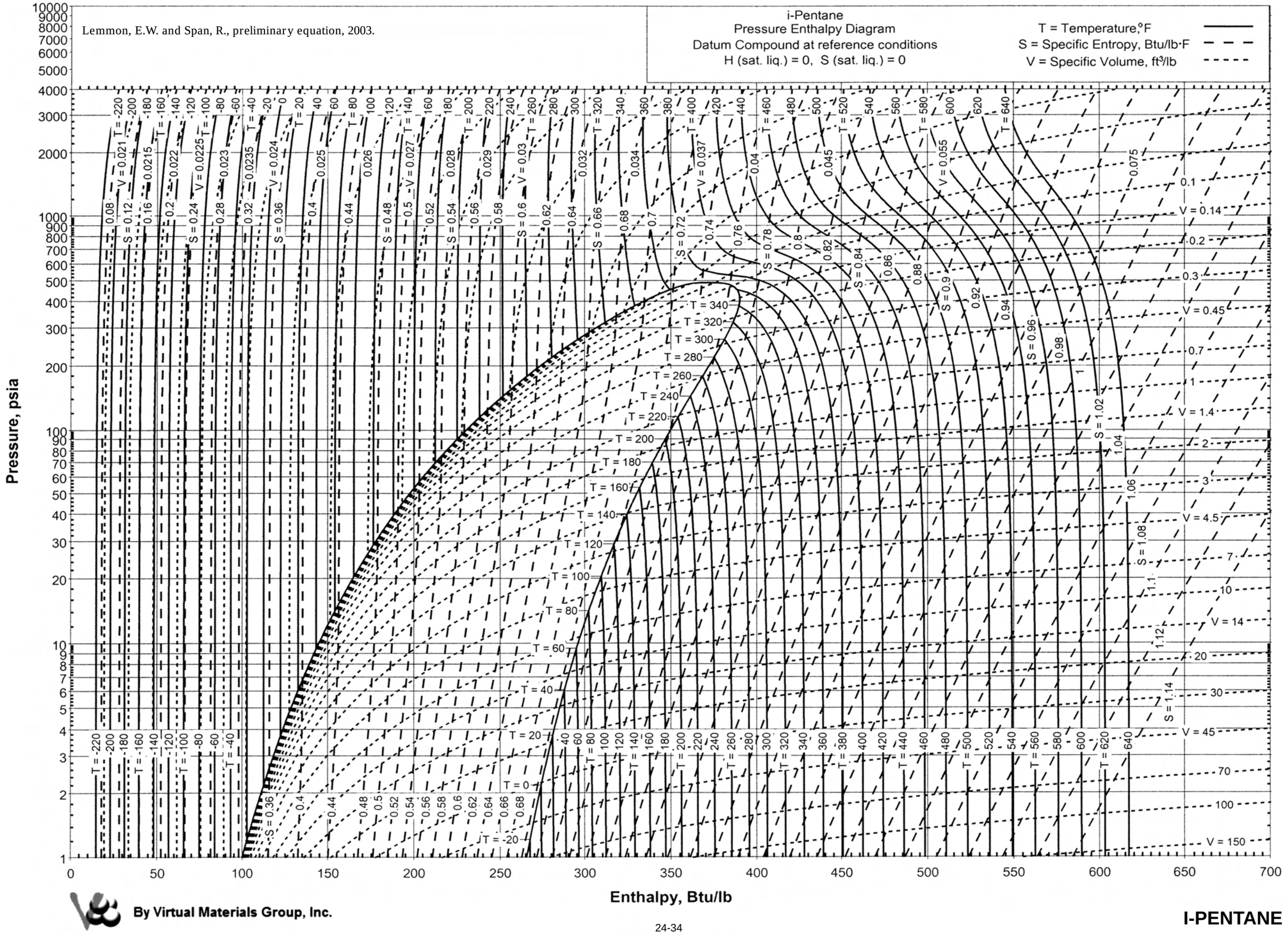
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SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-30 n-Butane P-H Diagram



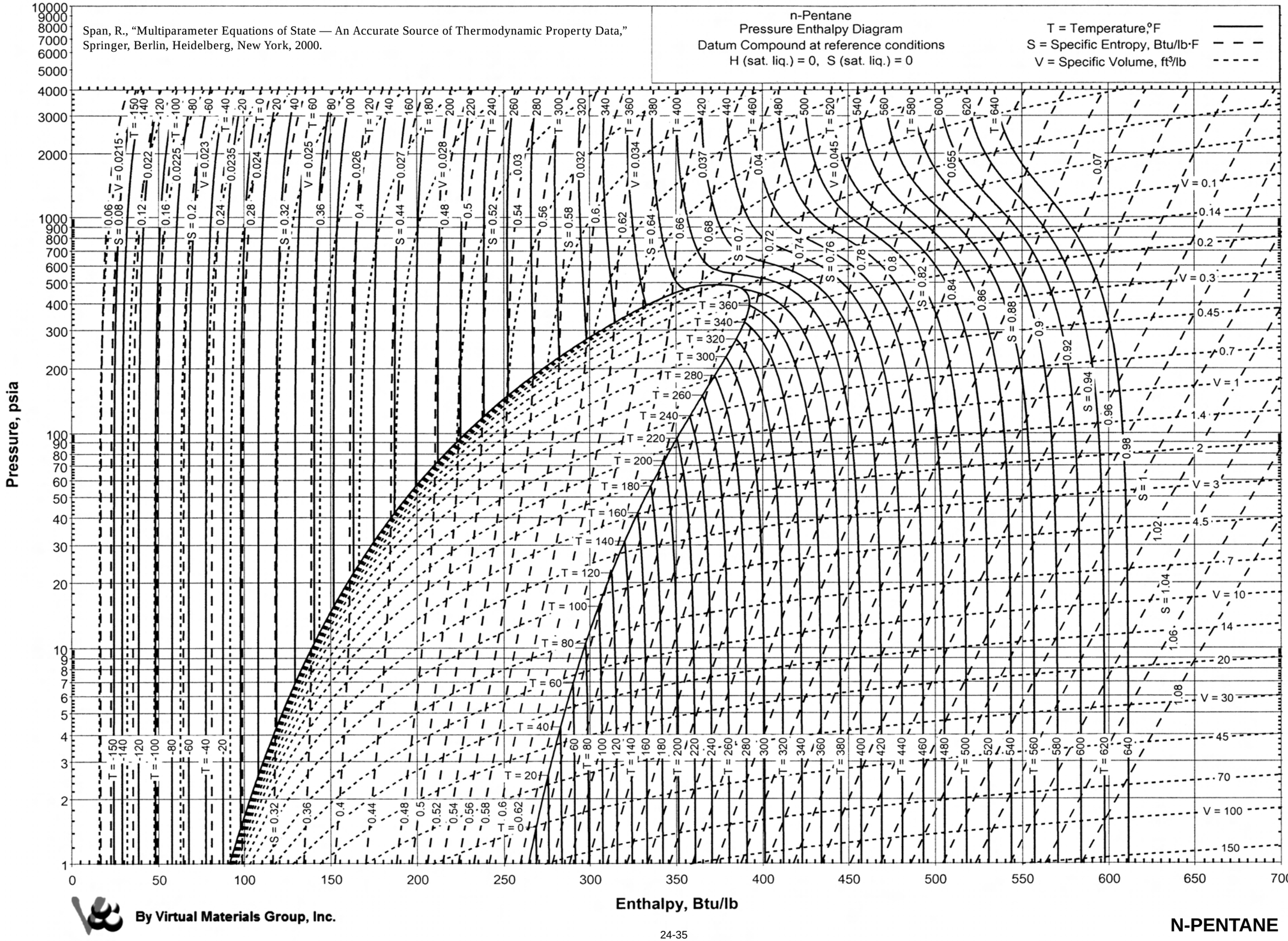
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SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-31 i-Pentane P-H Diagram



PILOT EXHIBIT 2027 PAGE 034
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-32 n-Pentane P-H Diagram



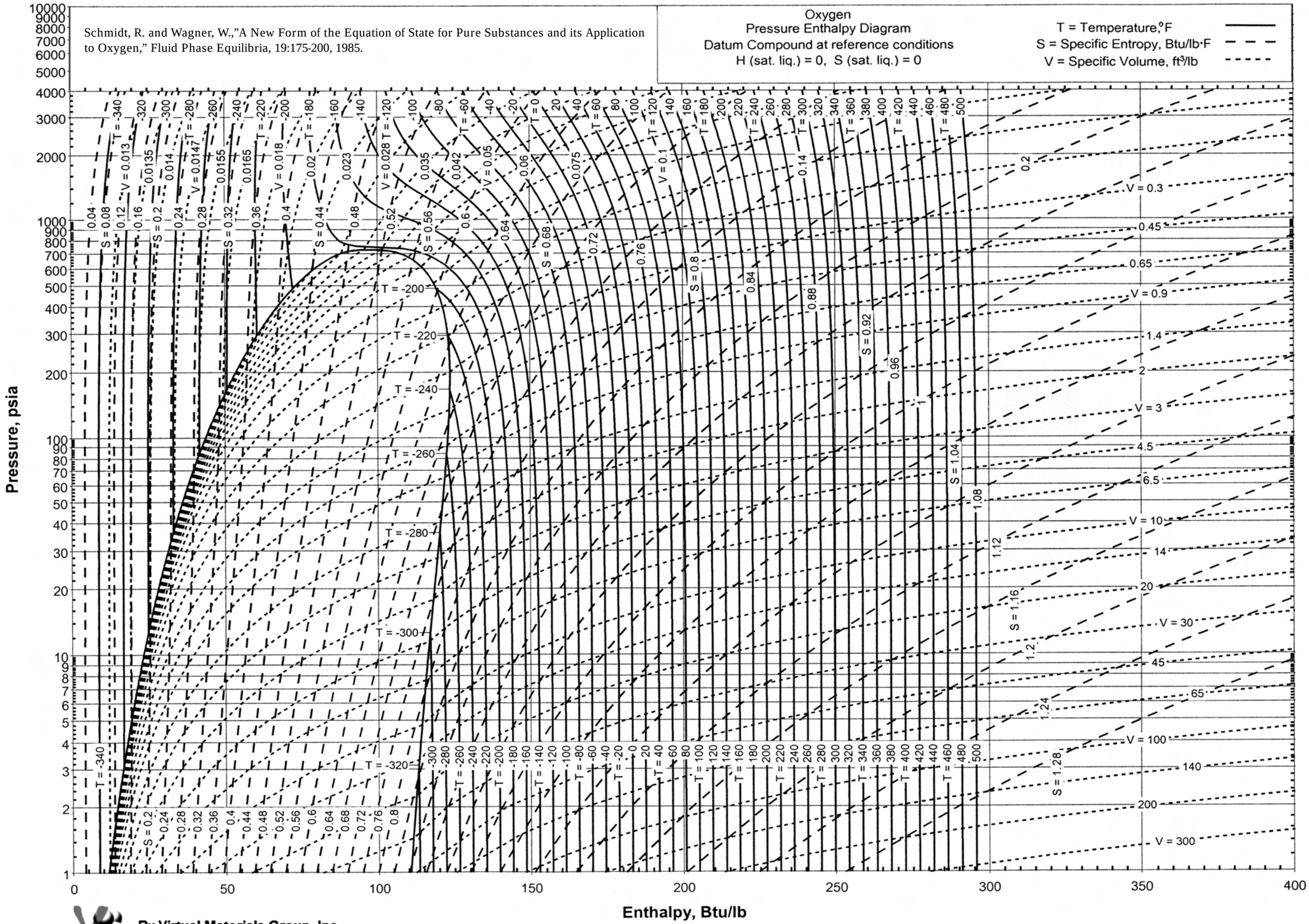
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FIG. 24-33 Oxygen P-H Diagram

Schmidt, R. and Wagner, W.,"A New Form of the Equation of State for Pure Substances and its Application to Oxygen," Fluid Phase Equilibria, 19:175-200, 1985.

Oxygen
Pressure Enthalpy Diagram
Datum Compound at reference conditions
H (sat. liq.) = 0, S (sat. liq.) = 0

T = Temperature,°F
S = Specific Entropy, Btu/lb·F
V = Specific Volume, ft³/lb



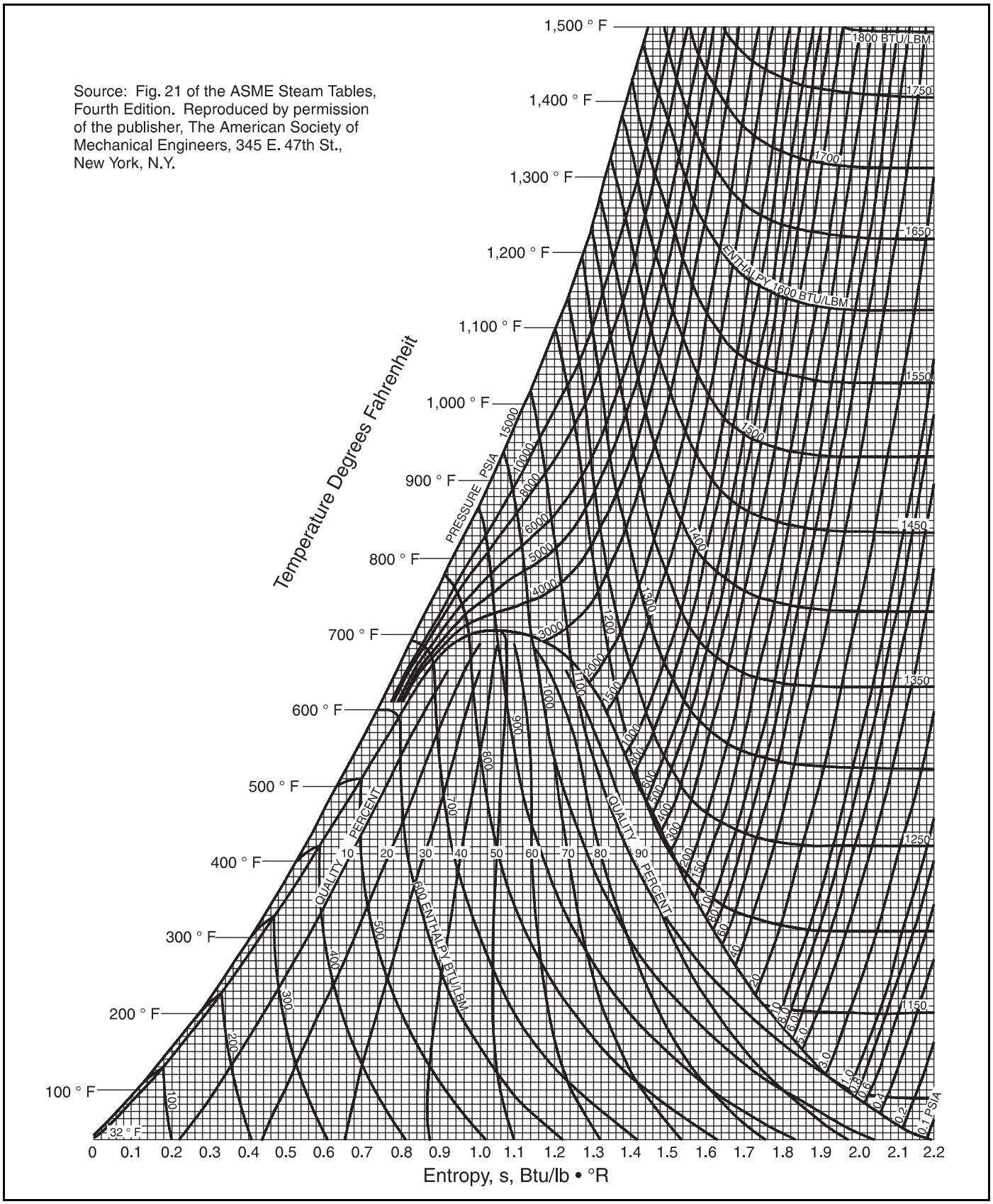
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OXYGEN

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FIG. 24-34

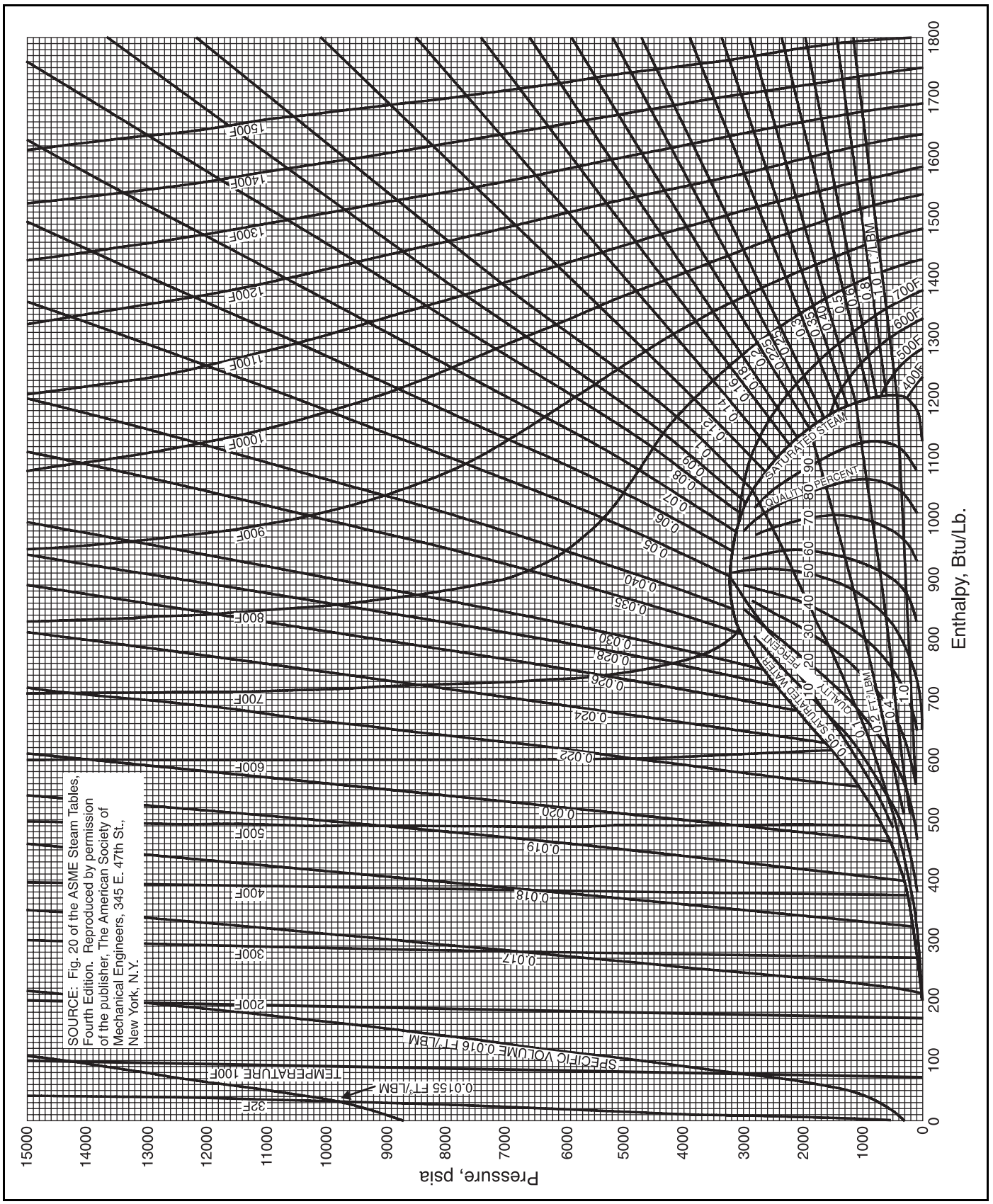
Thermodynamic Properties of Water



PILOT EXHIBIT 2027 PAGE 037
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-35

Thermodynamic Properties of Water



PILOT EXHIBIT 2027 PAGE 038
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-36

Water Properties at Saturation Pressure

Temp °F	Pressure lb/in² abs	Specific volume ft³/lb	Specific volume gal/lb	Density lb/ft³	Density gm/cm³	Conversion factor ft/lb/in²	Temp °F
32	.0885	.01602	.1198	62.42	.9999	2.307	32
33	.0922	.01602	.1198	62.42	.9999	2.307	33
34	.0960	.01602	.1198	62.42	.9999	2.307	34
35	.1000	.01602	.1198	62.424	1.0000	2.307	35
36	.1040	.01602	.1198	62.425	1.0000	2.307	36
37	.1082	.01602	.1198	62.426	1.0000	2.307	37
38	.1126	.01602	.1198	62.426	1.0000	2.307	38
39	.1171	.01602	.1198	62.426	1.0000	2.307	39
40	.1217	.01602	.1198	62.426	1.0000	2.307	40
41	.1265	.01602	.1198	62.426	1.0000	2.307	41
42	.1315	.01602	.1198	62.425	1.0000	2.307	42
43	.1367	.01602	.1198	62.424	1.0000	2.307	43
44	.1420	.01602	.1198	62.42	.9999	2.307	44
45	.1475	.01602	.1198	62.42	.9999	2.307	45
46	.1532	.01602	.1198	62.42	.9999	2.307	46
47	.1591	.01603	.1199	62.42	.9999	2.307	47
48	.1653	.01603	.1199	62.41	.9998	2.307	48
49	.1716	.01603	.1199	62.41	.9998	2.307	49
50	.1781	.01603	.1199	62.41	.9997	2.307	50
51	.1849	.01603	.1199	62.41	.9997	2.307	51
52	.1918	.01603	.1199	62.40	.9996	2.308	52
53	.1990	.01603	.1199	62.40	.9996	2.308	53
54	.2064	.01603	.1199	62.40	.9995	2.308	54
55	.2141	.01603	.1199	62.39	.9994	2.308	55
56	.2220	.01603	.1199	62.39	.9994	2.308	56
57	.2302	.01603	.1199	62.38	.9993	2.308	57
58	.2386	.01604	.1200	62.38	.9992	2.308	58
59	.2473	.01604	.1200	62.37	.9991	2.309	59
60	.2563	.01604	.1200	62.37	.9990	2.309	60
62	.2751	.01604	.1200	62.36	.9989	2.309	62
64	.2951	.01605	.1201	62.35	.9987	2.310	64
66	.3164	.01605	.1201	62.33	.9985	2.310	66
68	.3390	.01605	.1201	62.32	.9982	2.311	68
70	.3631	.01606	.1201	62.30	.9980	2.311	70
75	.4298	.01607	.1202	62.27	.9974	2.313	75
80	.5069	.01608	.1203	62.22	.9966	2.315	80
85	.5959	.01609	.1204	62.17	.9959	2.316	85
90	.6982	.01610	.1205	62.12	.9950	2.318	90
95	.8153	.01612	.1206	62.06	.9941	2.320	95
100	.9492	.01613	.1207	62.00	.9931	2.323	100
110	1.275	.01617	.1210	61.84	.9906	2.328	110
120	1.692	.01620	.1212	61.73	.9888	2.333	120
130	2.223	.01625	.1215	61.54	.9857	2.340	130
140	2.889	.01629	.1219	61.39	.9833	2.346	140
150	3.718	.01634	.1222	61.20	.9803	2.353	150
160	4.741	.01639	.1226	61.01	.9773	2.360	160
170	5.992	.01645	.1230	60.79	.9738	2.369	170
180	7.510	.01651	.1235	60.57	.9702	2.377	180
190	9.339	.01657	.1240	60.35	.9667	2.386	190
200	11.53	.01663	.1244	60.13	.9632	2.395	200
210	14.12	.01670	.1249	59.88	.9592	2.405	210
220	17.19	.01677	.1254	59.63	.9552	2.415	220
230	20.78	.01684	.1260	59.38	.9512	2.425	230
240	24.97	.01692	.1266	59.10	.9467	2.436	240
250	29.83	.01700	.1272	58.82	.9423	2.448	250
260	35.43	.01709	.1278	58.51	.9373	2.461	260
270	41.85	.01717	.1284	58.24	.9331	2.472	270
280	49.20	.01726	.1291	57.94	.9281	2.485	280
290	57.56	.01735	.1298	57.64	.9232	2.498	290
300	67.01	.01745	.1305	57.31	.9180	2.513	300
310	77.68	.01755	.1313	56.98	.9127	2.527	310
320	89.66	.01765	.1320	56.66	.9076	2.542	320
330	103.1	.01776	.1329	56.31	.9019	2.557	330
340	118.0	.01787	.1337	55.96	.8964	2.573	340
350	135	.01799	.1346	55.59	.8904	2.591	350
360	153	.01811	.1355	55.22	.8845	2.608	360
370	173	.01823	.1364	54.85	.8787	2.625	370
380	196	.01836	.1373	54.47	.8725	2.644	380
390	220	.01850	.1384	54.05	.8659	2.664	390
400	247	.01864	.1394	53.65	.8594	2.684	400
410	277	.01878	.1405	53.25	.8529	2.704	410
420	309	.01894	.1417	52.80	.8457	2.727	420
430	344	.01910	.1429	52.36	.8387	2.750	430
440	382	.01926	.1441	51.92	.8317	2.773	440
450	423	.0194	.145	51.5	.826	2.79	450
460	467	.0196	.147	51.0	.817	2.82	460
470	515	.0198	.148	50.5	.809	2.85	470
480	566	.0200	.150	50.0	.801	2.88	480
490	621	.0202	.151	49.5	.793	2.91	490
500	681	.0204	.153	49.0	.785	2.94	500
510	744	.0207	.155	48.3	.774	2.98	510
520	812	.0209	.156	47.8	.766	3.01	520
530	885	.0212	.159	47.2	.756	3.05	530
540	963	.0215	.161	46.5	.745	3.10	540
550	1045	.0218	.163	45.9	.735	3.14	550
560	1133	.0221	.165	45.2	.725	3.18	560
570	1227	.0224	.168	44.6	.715	3.23	570
580	1326	.0228	.171	43.9	.703	3.28	580
590	1431	.0232	.174	43.1	.690	3.34	590
600	1543	.0236	.177	42.4	.679	3.40	600
610	1661	.0241	.180	41.5	.665	3.47	610
620	1787	.0247	.185	40.5	.649	3.56	620
630	1919	.0253	.189	39.5	.633	3.64	630
640	2060	.0260	.194	38.5	.616	3.74	640
650	2208	.0268	.200	37.3	.598	3.86	650
670	2532	.0290	.217	34.5	.552	4.18	670
690	2895.	.0328	.245	30.5	.488	4.71	690
705.4	3206.	.0503	.376	19.9	.318	7.24	705.4

PILOT EXHIBIT 2027 PAGE 039
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-37

Saturated Steam: Temperature Table

Temp., °F	Pressure, psia	Volume cu ft/lb		Enthalpy, Btu/lb		Entropy, Btu/(lb • °F)	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
32.018	0.08865	0.016022	3302.4	0.000	1075.5	0.0000	2.1872
35	0.09991	0.016020	2948.1	3.002	1076.8	0.0061	2.1767
40	0.12163	0.016019	2445.8	8.027	1079.0	0.0162	2.1594
45	0.14744	0.016020	2037.8	13.044	1081.2	0.0262	2.1426
50	0.17796	0.016023	1704.8	18.054	1083.4	0.0361	2.1262
55	0.21392	0.016027	1432.0	23.059	1085.6	0.0458	2.1102
60	0.25611	0.016033	1207.6	28.060	1087.7	0.0555	2.0946
65	0.30545	0.016041	1022.1	33.057	1089.9	0.0651	2.0794
70	0.36292	0.016050	868.4	38.052	1092.1	0.0745	2.0645
75	0.42964	0.016060	740.3	43.045	1094.3	0.0839	2.0500
80	0.50683	0.016072	633.3	48.037	1096.4	0.0932	2.0359
85	0.59583	0.016085	543.6	53.027	1098.6	0.1024	2.0221
90	0.69813	0.016099	468.1	58.018	1100.8	0.1115	2.0086
95	0.81534	0.016114	404.4	63.008	1102.9	0.1206	1.9954
100	0.94294	0.016130	350.4	67.999	1105.1	0.1295	1.9825
110	1.2750	0.016165	265.39	77.98	1109.3	0.1472	1.9577
120	1.6927	0.016204	203.26	87.97	1113.6	0.1646	1.9339
130	2.2230	0.016247	157.33	97.96	1117.8	0.1817	1.9112
140	2.8892	0.016293	122.98	123.00	1122.0	0.1985	1.8895
150	3.7184	0.016343	97.07	117.95	1126.1	0.2150	1.8686
160	4.7414	0.016395	77.27	127.96	1130.2	0.2313	1.8487
170	5.9926	0.016451	62.08	137.97	1134.2	0.2473	1.8295
180	7.5110	0.016510	50.225	148.00	1138.2	0.2631	1.8111
190	9.340	0.016572	40.957	158.04	1142.1	0.2787	1.7934
200	11.526	0.016637	33.639	168.09	1146.0	0.2940	1.7764
210	14.123	0.016705	27.816	178.15	1149.7	0.3091	1.7600
212	14.696	0.016719	26.799	180.17	1150.5	0.3121	1.7568
220	17.186	0.016775	23.148	188.23	1153.4	0.3241	1.7442
230	20.779	0.016849	19.381	198.33	1157.1	0.3388	1.7290
240	24.968	0.016926	16.321	208.45	1160.6	0.3533	1.7142
250	29.825	0.017066	13.819	218.59	1164.0	0.3677	1.7000
260	35.427	0.017089	11.762	228.76	1167.4	0.3819	1.6862
270	41.856	0.017175	10.060	238.95	1170.6	0.3960	1.6729
280	49.200	0.017264	8.644	249.17	1173.8	0.4098	1.6599
290	57.550	0.01736	7.4603	259.4	1167.8	0.4236	1.6473
300	67.005	0.01745	6.4658	269.7	1179.7	0.4372	1.6351
320	89.643	0.01766	4.9138	290.4	1185.2	0.4640	1.6116
340	117.992	0.01787	3.7878	311.3	1190.1	0.4902	1.5892
360	153.01	0.01811	2.9573	332.3	1194.4	0.5161	1.5678
380	195.73	0.01836	2.3353	353.6	1198.0	0.5416	1.5473
400	247.26	0.01864	1.8630	375.1	1201.0	0.5667	1.5274
420	308.78	0.01894	1.4997	396.9	1203.1	0.5915	1.5080
440	381.54	0.01926	1.2169	419.0	1204.4	0.6161	1.4890
460	466.87	0.01961	0.99424	441.5	1204.8	0.6405	1.4704
480	566.15	0.02000	0.81717	464.5	1204.1	0.6648	1.4518
500	680.86	0.02043	0. 67492	487.9	1202.2	0.6890	1.4333
520	812.53	0.02091	0.55956	512.0	1199.0	0.7133	1.4146
540	962.79	0.02146	0.46513	536.8	1194.3	0.7378	1.3954
560	1133.38	0.02207	0.38714	562.4	1187.7	0.7625	1.3757
580	1326.17	0.02279	0.32216	589.1	1179.0	0.7876	1.3550
600	1543.2	0.02364	0.26747	617.1	1167.7	0.8134	1.3330
620	1786.9	0.02466	0.22081	646.9	1153.2	0.8403	1.3092
640	2059.9	0.02595	0.18021	679.1	1133.7	0.8686	1.2821
660	2065.7	0.02768	0.14431	714.9	1107.0	0.8995	1.2498
680	2708.6	0.03037	0.11117	758.5	1068.5	0.9365	1.2086
700	3094.3	0.03662	0.07519	825.2	991.7	0.9924	1.1359
702	3135.5	0.03824	0.06997	835.0	979.7	1.0006	1.1210
704	3177.2	0.04108	0.06300	854.2	956.2	1.0169	1.1046
705.47	3208.2	0.05078	0.05078	906.0	906.0	1.0612	1.0612

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PILOT EXHIBIT 2027 PAGE 040
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-37 (Cont'd)

Saturated Steam: Pressure Table

Pressure, psia	Temp., °F	Volume, cu ft/lb		Enthalpy, Btu/lb		Entropy, Btu/(lb • °F)	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
0.10	35.02	0.016020	2945.5	3.03	1076.8	0.0061	2.1766
0.20	53.16	0.016025	1526.3	21.22	1084.7	0.0422	2.1060
0.30	64.48	0.016040	1039.7	32.54	1089.7	0.0641	2.0809
0.40	72.87	0.016056	792.1	40.92	1093.3	0.0799	2.0562
0.60	85.22	0.016085	540.1	53.25	1098.7	0.1028	2.0215
0.80	94.38	0.016112	411.69	62.39	1102.6	0.1195	1.9970
1.0	101.74	0.016136	333.60	69.73	1105.8	0.1326	1.9781
2.0	126.07	0.016230	173.76	94.03	1116.2	0.1750	1.9200
3.0	141.47	0.016300	118.73	109.42	1122.6	0.2009	1.8864
4.0	152.96	0.016358	90.64	120.92	1127.3	0.2199	1.5626
6	170.05	0.016451	61.984	138.03	1134.2	0.2174	1.8294
8	182.80	0.016527	47.345	150.87	1139.3	0.2676	1.8060
10	193.21	0.016592	38.420	161.26	1143.3	0.2836	1.7879
20	227.96	0.016834	20.087	196.27	1156.3	0.3358	1.7320
30	250.34	0.017009	13.744	218.9	1164.1	0.3682	1.6995
40	267.25	0.017151	10.4965	236.1	1169.8	0.3921	1.6765
50	281.02	0.017274	8.5140	250.2	1174.1	0.4112	1.6586
60	292.71	0.017383	7.1736	262.2	1177.6	0.4273	1.6440
70	302.93	0.017482	6.2050	272.7	1180.6	0.4411	1.6316
80	312.04	0.017573	5.4711	282.1	1183.1	0.4534	1.6208
90	320.28	0.017659	4.8953	290.7	1185.3	0.4643	1.6113
100	327.82	0.017740	4.4310	298.5	1187.2	0.4743	1.6027
150	358.43	0.01809	3.0139	330.6	1194.1	0.5141	1.5695
200	381.80	0.01839	2.2873	355.5	1198.3	0.5438	1.5454
250	400.97	0.01865	1.84317	376.1	1201.1	0.5679	1.5264
300	417.35	0.01889	1.54274	394.0	1202.9	0.5882	1.5105
350	431.73	0.01912	1.32554	409.8	1204.0	0.6059	1.4968
400	444.60	0.01934	1.16095	424.2	1204.6	0.6217	1.4847
450	456.28	0.01954	1.03179	437.3	1204.8	0.6360	1.4738
500	467.01	0.01975	0.92762	449.5	1204.7	0.6490	1.4639
600	486.20	0.02013	0.76975	471.7	1203.7	0.6723	1.4461
700	503.08	0.02050	0.65556	491.6	1201.8	0.6928	1.4304
800	518.21	0.02087	0.56896	509.8	1199.4	0.7111	1.4163
900	531.95	0.02123	0.50091	526.7	1196.4	0.7279	1.4032
1000	544.58	0.02159	0.44596	542.6	1192.9	0.7434	1.3910
1200	567.19	0.02232	0.36245	571.9	1184.8	0.7714	1.3683
1400	587.07	0.02307	0.30178	598.8	1175.8	0.7966	1.3474
1600	604.87	0.02387	0.25545	624.2	1164.5	0.8199	1.3274
1800	621.02	0.02472	0.21861	648.5	1152.3	0.8417	1.3079
2000	635.80	0.02565	0.18831	672.1	1138.3	0.8625	1.2881
2200	649.45	0.02669	0.16272	695.5	1122.2	0.8828	1.2676
2400	662.11	0.02790	0.14076	719.0	1103.7	0.9031	1.2460
2600	673.91	0.02938	0.12110	744.5	1082.0	0.9247	1.2225
2800	684.96	0.03134	0.10305	770.7	1055.5	0.9468	1.1958
3000	695.33	0.03428	0.08500	801.8	1020.3	0.9728	1.1619
3100	700.28	0.03681	0.07452	824.0	993.3	0.9914	1.1373
3200	705.08	0.04472	0.05663	875.5	931.6	1.0351	1.0832
3208.2	705.47	0.05078	0.05078	906.0	906.0	1.0612	1.0612

PILOT EXHIBIT 2027 PAGE 041
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-38

Properties of Superheated Steam

Abs. Press., P, psia (Sat. Temp.)		Temperature, °F												
		200	300	400	500	600	700	800	900	1000	1100	1200	1400	1600
1 (101.74)	v . . .	392.6	452.3	512.0	571.6	631.2	690.8	750.4	809.9	869.5	929.1	988.7	1107.8	1227.0
	h . . .	1150.4	1195.8	1241.7	1288.3	1335.7	1383.8	1432.8	1482.7	1533.5	1585.2	1637.7	1745.7	1857.5
	s . . .	2.0512	2.1153	2.1720	2.2233	2.2702	2.3137	2.3542	2.3923	2.4283	2.4625	2.4952	2.5566	2.6137
5 (162.24)	v . . .	78.16	90.25	102.26	114.22	126.16	138.10	150.03	161.95	173.87	185.79	197.71	221.6	245.4
	h . . .	1148.8	1195.0	1241.2	1288.0	1335.4	1383.6	1432.7	1482.6	1533.4	1585.1	1637.7	1745.7	1857.4
	s . . .	1.8718	1.9370	1.9942	2.0456	2.0927	2.1361	2.1767	2.2148	2.2509	2.2851	2.3178	2.3792	2.4363
10 (193.21)	v . . .	38.85	45.00	51.04	57.05	63.03	69.01	74.98	80.95	86.92	92.88	98.84	110.77	122.69
	h . . .	1146.6	1193.9	1240.6	1287.5	1335.1	1383.4	1432.5	1482.4	1533.2	1585.0	1637.6	1745.6	1857.3
	s . . .	1.7927	1.8595	1.9172	1.9689	2.0160	2.0596	2.1002	2.1383	2.1744	2.2086	2.2413	2.3028	2.3598
14.696 (212.00)	v . . .	. . . .	30.53	34.68	38.78	42.86	46.94	51.00	55.07	59.13	63.19	67.25	75.37	83.48
	h . . .	. . . .	1192.8	1239.9	1287.1	1334.8	1383.2	1432.3	1482.3	1533.1	1584.8	1637.5	1745.5	1857.3
	s . . .	. . . .	1.8160	1.8743	1.9261	1.9734	2.0170	2.0576	2.0958	2.1319	2.1662	2.1989	2.2603	2.3174
20 (227.96)	v . . .	. . . .	22.36	25.43	28.46	31.47	34.47	37.46	40.45	43.44	46.42	49.41	55.37	61.34
	h . . .	. . . .	1191.6	1239.2	1286.6	1334.4	1382.9	1432.1	1482.1	1533.0	1584.7	1637.4	1745.4	1857.2
	s . . .	. . . .	1.7808	1.8396	1.8918	1.9392	1.9829	2.0235	2.0618	2.0978	2.1321	2.1648	2.2263	2.2834
40 (267.25)	v . . .	. . . .	11.040	12.628	14.168	15.688	17.198	18.702	20.20	21.70	23.20	24.69	27.68	30.66
	h . . .	. . . .	1186.8	1236.5	1284.8	1333.1	1381.9	1431.3	1481.4	1532.4	1584.3	1637.0	1745.1	1857.0
	s . . .	. . . .	1.6994	1.7608	1.8140	1.8619	1.9058	1.9467	1.9850	2.0212	2.0555	2.0883	2.1498	2.2069
60 (292.71)	v . . .	. . . .	7.259	8.357	9.403	10.427	11.441	12.449	13.452	14.454	15.453	16.451	18.446	20.44
	h . . .	. . . .	1181.6	1233.6	1283.0	1331.8	1380.9	1430.5	1480.8	1531.9	1583.8	1636.6	1744.8	1856.7
	s . . .	. . . .	1.6492	1.7135	1.7678	1.8162	1.8605	1.9015	1.9400	1.9762	2.0106	2.0434	2.1049	2.1621
80 (312.03)	v . . .	. . . .	. . . .	6.220	7.020	7.797	8.562	9.322	10.077	10.830	11.582	12.332	13.830	15.325
	h . . .	. . . .	. . . .	1230.7	1281.1	1330.5	1379.9	1429.7	1480.1	1531.3	1583.4	1636.2	1744.5	1856.5
	s . . .	. . . .	. . . .	1.6791	1.7346	1.7836	1.8281	1.8694	1.9079	1.9442	1.9787	2.0115	2.0731	2.1303
100 (327.81)	v . . .	. . . .	. . . .	4.937	5.589	6.218	6.835	7.446	8.052	8.656	9.259	9.860	11.060	12.258
	h . . .	. . . .	. . . .	1227.6	1279.1	1329.1	1378.9	1428.9	1479.5	1530.8	1582.9	1635.7	1744.2	1856.2
	s . . .	. . . .	. . . .	1.6518	1.7085	1.7581	1.8029	1.8443	1.8829	1.9193	1.9538	1.9867	2.0484	2.1056
120 (341.25)	v . . .	. . . .	. . . .	4.081	4.636	5.165	5.683	6.195	6.702	7.207	7.710	8.212	9.214	10.213
	h . . .	. . . .	. . . .	1224.4	1277.2	1327.7	1377.8	1428.1	1478.8	1530.2	1582.4	1635.3	1743.9	1856.0
	s . . .	. . . .	. . . .	1.6287	1.6869	1.7370	1.7822	1.8237	1.8625	1.8990	1.9335	1.9664	2.0281	2.0854
140 (353.02)	v . . .	. . . .	. . . .	3.468	3.954	4.413	4.861	5.301	5.738	6.172	6.604	7.035	7.895	8.752
	h . . .	. . . .	. . . .	1221.1	1275.2	1326.4	1376.8	1427.3	1478.2	1529.7	1581.9	1634.9	1743.5	1855.7
	s . . .	. . . .	. . . .	1.6087	1.6683	1.7190	1.7645	1.8063	1.8451	1.8817	1.9163	1.9493	2.0110	2.0683
160 (363.53)	v . . .	. . . .	. . . .	3.008	3.443	3.849	4.244	4.631	5.015	5.396	5.775	6.152	6.906	7.656
	h . . .	. . . .	. . . .	1217.6	1273.1	1325.0	1375.7	1426.4	1477.5	1529.1	1581.4	1634.5	1743.2	1855.5
	s . . .	. . . .	. . . .	1.5908	1.6519	1.7033	1.7491	1.7911	1.8301	1.8667	1.9014	1.9344	1.9962	2.0535
180 (373.06)	v . . .	. . . .	. . . .	2.649	3.044	3.411	3.764	4.110	4.452	4.792	5.129	5.466	6.136	6.804
	h . . .	. . . .	. . . .	1214.0	1271.0	1323.5	1374.7	1425.6	1476.8	1528.6	1581.0	1634.1	1742.9	1855.2
	s . . .	. . . .	. . . .	1.5745	1.6373	1.6894	1.7355	1.7776	1.8167	1.8534	1.8882	1.9212	1.9831	2.0404
200 (381.79)	v . . .	. . . .	. . . .	2.361	2.726	3.060	3.380	3.693	4.002	4.309	4.613	4.917	5.521	6.123
	h . . .	. . . .	. . . .	1210.3	1268.9	1322.1	1373.6	1424.8	1476.2	1528.0	1580.5	1633.7	1742.6	1855.0
	s . . .	. . . .	. . . .	1.5594	1.6240	1.6767	1.7232	1.7655	1.8048	1.8415	1.8763	1.9094	1.9713	2.0287
220 (389.86)	v . . .	. . . .	. . . .	2.125	2.465	2.772	3.066	3.352	3.634	3.913	4.191	4.467	5.017	5.565
	h . . .	. . . .	. . . .	1206.5	1266.7	1320.7	1372.6	1424.0	1475.5	1527.5	1580.0	1633.3	1742.3	1854.7
	s . . .	. . . .	. . . .	1.5453	1.6117	1.6652	1.7120	1.7545	1.7939	1.8308	1.8656	1.8987	1.9607	2.0181
240 (397.37)	v . . .	. . . .	. . . .	1.9276	2.247	2.533	2.804	3.068	3.327	3.584	3.839	4.093	4.597	5.100
	h . . .	. . . .	. . . .	1202.5	1264.5	1319.2	1371.5	1423.2	1474.8	1526.9	1579.6	1632.9	1742.0	1854.5
	s . . .	. . . .	. . . .	1.5319	1.6003	1.6546	1.7017	1.7444	1.7839	1.8209	1.8558	1.8889	1.9510	2.0084
260 (404.42)	v . . .	. . . .	. . . .	. . . .	2.063	2.330	2.582	2.827	3.067	3.305	3.541	3.776	4.242	4.707
	h . . .	. . . .	. . . .	. . . .	1262.3	1317.7	1370.4	1422.3	1474.2	1526.3	1579.1	1632.5	1741.7	1854.2
	s . . .	. . . .	. . . .	. . . .	1.5897	1.6447	1.6922	1.7352	1.7748	1.8118	1.8467	1.8799	1.9420	1.9995
280 (411.05)	v . . .	. . . .	. . . .	. . . .	1.9047	2.156	2.392	2.621	2.845	3.066	3.286	3.504	3.938	4.370
	h . . .	. . . .	. . . .	. . . .	1260.0	1316.2	1369.4	1421.5	1473.5	1525.8	1578.6	1632.1	1741.4	1854.0
	s . . .	. . . .	. . . .	. . . .	1.5796	1.6354	1.6834	1.7265	1.7662	1.8033	1.8383	1.8716	1.9337	1.9912
300 (417.33)	v . . .	. . . .	. . . .	. . . .	1.7675	2.005	2.227	2.442	2.652	2.859	3.065	3.269	3.674	4.078
	h . . .	. . . .	. . . .	. . . .	1257.6	1314.7	1368.3	1420.6	1472.8	1525.2	1578.1	1631.7	1741.0	1853.7
	s . . .	. . . .	. . . .	. . . .	1.5701	1.6268	1.6751	1.7184	1.7582	1.7954	1.8305	1.8638	1.9260	1.9835
350 (431.72)	v . . .	. . . .	. . . .	. . . .	1.4923	1.7036	1.8980	2.084	2.266	2.445	2.622	2.798	3.147	3.493
	h . . .	. . . .	. . . .	. . . .	1251.5	1310.9	1365.5	1418.5	1471.1	1523.8	1577.0	1630.7	1740.3	1853.1
	s . . .	. . . .	. . . .	. . . .	1.5481	1.6070	1.6563	1.7002	1.7403	1.7777	1.8130	1.8463	1.9086	1.9663
400 (444.59)	v . . .	. . . .	. . . .	. . . .	1.2851	1.4770	1.6508	1.8161	1.9767	2.134	2.290	2.445	2.751	3.055
	h . . .	. . . .	. . . .	. . . .	1245.1	1306.9	1362.7	1416.4	1469.4	1522.4	1575.8	1629.6	1739.5	1852.5
	s . . .	. . . .	. . . .	. . . .	1.5281	1.5894	1.6398	1.6842	1.7247	1.7623	1.7977	1.8311	1.8936	1.9513

PILOT EXHIBIT 2027 PAGE 042
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 24-38 (Cont'd)

Properties of Superheated Steam

Abs. Press., P, psia (Sat. Temp.)		Temperature, °F													
		500	550	600	620	640	660	680	700	800	900	1000	1200	1400	1600
450 (456.28)	v	1.1231	1.2155	1.3005	1.3332	1.3652	1.3967	1.4278	1.4584	1.6074	1.7516	1.8928	2.170	2.443	2.714
	h	1238.4	1272.0	1302.8	1314.6	1326.2	1337.5	1348.8	1359.9	1414.3	1467.7	1521.0	1628.6	1738.7	1851.9
	s	1.5095	1.5437	1.5735	1.5845	1.5951	1.6054	1.6153	1.6250	1.6699	1.7108	1.7486	1.8177	1.8803	1.9381
500 (467.01)	v	0.9927	1.0800	1.1591	1.1893	1.2188	1.2478	1.2763	1.3044	1.4405	1.5715	1.6996	1.9504	2.197	2.442
	h	1231.3	1266.8	1298.6	1310.7	1322.6	1334.2	1345.7	1357.0	1412.1	1466.0	1519.6	1627.6	1737.9	1851.3
	s	1.4919	1.5280	1.5588	1.5701	1.5810	1.5915	1.6016	1.6115	1.6571	1.6982	1.7363	1.8056	1.8683	1.9262
550 (476.94)	v	0.8852	0.9686	1.0431	1.0714	1.0989	1.1259	1.1523	1.1783	1.3038	1.4241	1.5414	1.7706	1.9957	2.219
	h	1223.7	1261.2	1294.3	1306.8	1318.9	1330.8	1342.5	1354.0	1409.9	1464.3	1518.2	1626.6	1737.1	1850.6
	s	1.4751	1.5131	1.5451	1.5568	1.5680	1.5787	1.5890	1.5991	1.6452	1.6868	1.7250	1.7946	1.8575	1.9155
600 (486.21)	v	0.7947	0.8753	0.9463	0.9729	0.9988	1.0241	1.0489	1.0732	1.1899	1.3013	1.4096	1.6208	1.8279	2.033
	h	1215.7	1255.5	1289.9	1302.7	1315.2	1327.4	1339.3	1351.1	1407.7	1462.5	1516.7	1625.5	1736.3	1850.0
	s	1.4586	1.4990	1.5323	1.5443	1.5558	1.5667	1.5773	1.5875	1.6343	1.6762	1.7147	1.7846	1.8476	1.9056
700 (503.10)	v	....	0.7277	0.7934	0.8177	0.8411	0.8639	0.8860	0.9077	1.0108	1.1082	1.2024	1.3853	1.5641	1.7405
	h	....	1243.2	1280.6	1294.3	1307.5	1320.3	1332.8	1345.0	1403.2	1459.0	1513.9	1623.5	1734.8	1848.8
	s	....	1.4722	1.5084	1.5212	1.5333	1.5449	1.5559	1.5665	1.6147	1.6573	1.6963	1.7666	1.8299	1.8881
800 (518.23)	v	....	0.6154	0.6779	0.7006	0.7223	0.7433	0.7635	0.7833	0.8763	0.9633	1.0470	1.2088	1.3662	1.5214
	h	....	1229.8	1270.7	1285.4	1299.4	1312.9	1325.9	1338.6	1398.6	1455.4	1511.0	1621.4	1733.2	1847.5
	s	....	1.4467	1.4863	1.5000	1.5129	1.5250	1.5366	1.5476	1.5972	1.6407	1.6801	1.7510	1.8146	1.8729
900 (531.98)	v	....	0.5264	0.5873	0.6089	0.6294	0.6491	0.6680	0.6863	0.7716	0.8506	0.9262	1.0714	1.2124	1.3509
	h	....	1215.0	1260.1	1275.9	1290.9	1305.1	1318.8	1332.1	1393.9	1451.8	1508.1	1619.3	1731.6	1846.3
	s	....	1.4216	1.4653	1.4800	1.4938	1.5066	1.5187	1.5303	1.5814	1.6257	1.6656	1.7371	1.8009	1.8595
1000 (544.61)	v	....	0.4533	0.5140	0.5350	0.5546	0.5733	0.5912	0.6084	0.6878	0.7604	0.8294	0.9615	1.0893	1.2146
	h	....	1198.3	1248.8	1265.9	1281.9	1297.0	1311.4	1325.3	1389.2	1448.2	1505.1	1617.3	1730.0	1845.0
	s	....	1.3961	1.4450	1.4610	1.4757	1.4893	1.5021	1.5141	1.5670	1.6121	1.6525	1.7245	1.7886	1.8474
1100 (556.31)	v	....	....	0.4532	0.4738	0.4929	0.5110	0.5281	0.5445	0.6191	0.6866	0.7503	0.8716	0.9885	1.1031
	h	....	....	1236.7	1255.3	1272.4	1288.5	1303.7	1318.3	1384.3	1444.5	1502.2	1615.2	1728.4	1843.8
	s	....	....	1.4251	1.4425	1.4583	1.4728	1.4862	1.4989	1.5535	1.5995	1.6405	1.7130	1.7775	1.8363
1200 (567.22)	v	....	....	0.4016	0.4222	0.4410	0.4586	0.4752	0.4909	0.5617	0.6250	0.6843	0.7967	0.9046	1.0101
	h	....	....	1223.5	1243.9	1262.4	1279.6	1295.7	1311.0	1379.3	1440.7	1499.2	1613.1	1726.9	1842.5
	s	....	....	1.4052	1.4243	1.4413	1.4568	1.4710	1.4843	1.5409	1.5879	1.6293	1.7025	1.7672	1.8263
1400 (587.10)	v	....	....	0.3174	0.3390	0.3580	0.3753	0.3912	0.4062	0.4714	0.5281	0.5805	0.6789	0.7727	0.8640
	h	....	....	1193.0	1218.4	1240.4	1260.3	1278.5	1295.5	1369.1	1433.1	1493.2	1608.9	1723.7	1840.0
	s	....	....	1.3639	1.3877	1.4079	1.4258	1.4419	1.4567	1.5177	1.5666	1.6093	1.6836	1.7489	1.8083
1600 (604.90)	v	....	....	....	0.2733	0.2936	0.3112	0.3271	0.3417	0.4034	0.4553	0.5027	0.5906	0.6738	0.7545
	h	....	....	....	1187.8	1215.2	1238.7	1259.6	1278.7	1358.4	1425.3	1487.0	1604.6	1720.5	1837.5
	s	....	....	....	1.3489	1.3741	1.3952	1.4137	1.4303	1.4964	1.5476	1.5914	1.6669	1.7328	1.7926
1800 (621.03)	v	....	....	....	....	0.2407	0.2597	0.2760	0.2907	0.3502	0.3986	0.4421	0.5218	0.5968	0.6693
	h	....	....	....	....	1185.1	1214.0	1238.5	1260.3	1347.2	1417.4	1480.8	1600.4	1717.3	1835.0
	s	....	....	....	....	1.3377	1.3638	1.3855	1.4044	1.4765	1.5301	1.5752	1.6520	1.7185	1.7786
2000 (635.82)	v	....	....	....	....	0.1936	0.2161	0.2337	0.2489	0.3074	0.3532	0.3935	0.4668	0.5352	0.6011
	h	....	....	....	....	1145.6	1184.9	1214.8	1240.0	1335.5	1409.2	1474.5	1596.1	1714.1	1832.5
	s	....	....	....	....	1.2945	1.3300	1.3564	1.3783	1.4576	1.5139	1.5603	1.6384	1.7055	1.7660
2500 (668.13)	v	....	....	....	....	....	....	0.1484	0.1686	0.2294	0.2710	0.3061	0.3678	0.4244	0.4784
	h	....	....	....	....	....	....	1132.3	1176.8	1303.6	1387.8	1458.4	1585.3	1706.1	1826.2
	s	....	....	....	....	....	....	1.2687	1.3073	1.4127	1.4772	1.5273	1.6088	1.6775	1.7389
3000 (695.36)	v	....	....	....	....	....	....	....	0.0984	0.1760	0.2159	0.2476	0.3018	0.3505	0.3966
	h	....	....	....	....	....	....	....	1060.7	1267.2	1365.0	1441.8	1574.3	1698.0	1819.9
	s	....	....	....	....	....	....	....	1.1966	1.3690	1.4439	1.4984	1.5837	1.6540	1.7163
3206.2 (705.40)	v	....	....	....	....	....	....	....	....	0.1583	0.1981	0.2288	0.2806	0.3267	0.3703
	h	....	....	....	....	....	....	....	....	1250.5	1355.2	1434.7	1569.8	1694.6	1817.2
	s	....	....	....	....	....	....	....	....	1.3508	1.4309	1.4874	1.5742	1.6452	1.7080
3500	v	....	....	....	....	....	....	....	0.0306	0.1364	0.1762	0.2058	0.2546	0.2977	0.3381
	h	....	....	....	....	....	....	....	780.5	1224.9	1340.7	1424.5	1563.3	1689.8	1813.6
	s	....	....	....	....	....	....	....	0.9515	1.3241	1.4127	1.4723	1.5615	1.6336	1.6968
4000	v	....	....	....	....	....	....	....	0.0287	0.1052	0.1462	0.1743	0.2192	0.2581	0.2943
	h	....	....	....	....	....	....	....	763.8	1174.8	1314.4	1406.8	1552.1	1681.7	1807.2
	s	....	....	....	....	....	....	....	0.9347	1.2757	1.3827	1.4482	1.5417	1.6154	1.6795
4500	v	....	....	....	....	....	....	....	0.0276	0.0798	0.1226	0.1500	0.1917	0.2273	0.2602
	h	....	....	....	....	....	....	....	753.5	1113.9	1286.5	1388.4	1540.8	1673.5	1800.9
	s	....	....	....	....	....	....	....	0.9235	1.2204	1.3529	1.4253	1.5235	1.5990	1.6640
5000	v	....	....	....	....	....	....	....	0.0268	0.0593	0.1036	0.1303	0.1696	0.2027	0.2329
	h	....	....	....	....	....	....	....	746.4	1047.1	1256.5	1369.5	1529.5	1665.3	1794.5
	s	....	....	....	....	....	....	....	0.9152	1.1622	1.3231	1.4034	1.5066	1.5839	1.6499
5500	v	....	....	....	....	....	....	....	0.0262	0.0463	0.0880	0.1143	0.1516	0.1825	0.2106
	h	....	....	....	....	....	....	....	741.3	985.0	1224.1	1349.3	1518.2	1657.0	1788.1
	s	....	....	....	....	....	....	....	0.9090	1.1093	1.2930	1.3821	1.4908	1.5699	1.6369

PILOT EXHIBIT 2027 PAGE 043
SCOUT/CHEVRON v. PILOT - IPR2024-00385

NOTES:

PILOT EXHIBIT 2027 PAGE 044
SCOUT/CHEVRON v. PILOT - IPR2024-00385

SECTION 25

Equilibrium Ratio (K) Data

The equilibrium ratio (K_i) of a component i in a multicomponent mixture of liquid and vapor phases is defined as the ratio of the mole fraction of that component in the vapor phase to that in the liquid phase.

$$K_i = \frac{y_i}{x_i} \qquad \textbf{Eq 25-1}$$

For an ideal system (ideal gas and ideal solution), this equilibrium ratio is reduced to the ratio of the vapor pressure of component i to the total pressure of the system.

$$K_i = \frac{P_i^*}{P} \qquad \textbf{Eq 25-2}$$

This section presents an outline procedure to calculate the liquid and vapor compositions of a two-phase mixture in equilibrium using the concept of a pseudobinary system and the convergence pressure equilibrium charts. Discussion of CO_2 separation, alternate methods to obtain K values, and equations of state follow.

K-DATA CHARTS

These charts show the vapor-liquid equilibrium ratio, K_i, for use in example and approximate flash calculations. The charts will not give accurate answers, particularly in the case of nitrogen. They are included only to support example flash calculations and to support quick estimation of K-values in other hand calculations.

Previous editions of this data book presented extensive sets of K-data based on the GPA Convergence Pressure, P_k, method. A component's K-data is a strong function of temperature and pressure and a weaker function of composition. The convergence pressure method recognizes composition effects in predicting K-data. The convergence pressure technique can be used in hand calculations, and it is still available as computer correlations for K-data prediction.

There is now general availability of computers. This availability coupled with the more refined K-value correlations in modern process simulators has rendered the previous GPA convergence pressure charts outdated. Complete sets of these charts are available from GPA as a Technical Paper, TP-22.

Data for N_2-CH_4 and N_2-C_2H_6 show that the K-values in this system have strong compositional dependence. The component volatility sequence is N_2-CH_4-C_2H_6 and the K-values are functions of the amount of methane in the liquid phase. For example, at –190°F and 300 psia, the K-values depending on composition vary from:

N_2	CH_4	C_2H_6
10.2	0.824*	0.0118
3.05	0.635	0.035*

where * indicates the limiting infinite dilution K-value. See reference 5 for the data on this ternary.

The charts retained in this edition represent roughly 12% of the charts included in previous editions. These charts are a compromise set for gas processing as follows:

a. hydrocarbons — 3000 psia P_k
b. nitrogen — 2000 psia P_k
c. hydrogen sulfide — 3000 psia P_k

The pressures in a. through c. above refer to convergence pressure, P_k, of the charts from the Tenth Edition of this data book. They should not be used for design work or related activities. Again, their retention in this edition is for illustration and approximation purposes only; however, they can be very useful in such a role. The critical locus chart used in the convergence pressure method has also been retained (Fig. 25-8).

The GPA/GPSA sponsors investigations in hydrocarbon systems of interest to gas processors. Detailed results are given in the annual proceedings and in various research reports and technical publications, which are listed in Section 1.

Example 25-1 — Binary System Calculation

To illustrate the use of binary system K-value charts, assume a mixture of 60 lb moles of methane and 40 lb moles of ethane at –125°F and 50 psia. From the chart on page 25-10, the K-values for methane and ethane are 10 and 0.35 respectively.

Solution Steps

FIG. 25-1

Nomenclature

K_i = equilibrium ratio, $\frac{y_i}{x_i}$
L = ratio of moles of liquid to moles of total mixture
N = mole fraction in the total mixture or system
ω = acentric factor
P = absolute pressure, psia
P_k = convergence pressure, psia
P^* = vapor pressure, psia
R = universal gas constant, (psia • cu ft) / (lbmole • °R)
T = temperature, °R or °F
V = ratio of moles of vapor to moles of total mixture
x_i = mole fraction of component i in the liquid phase
y_i = mole fraction of component i in the vapor phase

Subscripts

i = component

PILOT EXHIBIT 2027 PAGE 045
SCOUT/CHEVRON v. PILOT - IPR2024-00385

From the definition of K-value, Eq 25-1:

$$K_{C1} = \frac{y_{C1}}{x_{C1}} = 10$$

$$K_{C2} = \frac{y_{C2}}{x_{C2}} = 0.35$$

Rewriting for this binary mixture:

$$\frac{1 - y_{C1}}{1 - x_{C1}} = 0.35$$

Solving the above equations simultaneously:

$$x_{C1} = 0.0674$$

$$y_{C1} = 0.674$$

Also by solving in the same way:

$$x_{C2} = 0.9326$$

$$y_{C2} = 0.326$$

To find the amount of vapor in the mixture, let v denote lb moles of vapor. Summing the moles of methane in each phase gives:

$$\Sigma \text{ kmols } C_1 + C_2 = 100 \text{ kmols}$$

$$\underset{\text{in vapor}}{\text{kmols } C_1} + \underset{\text{in liquid}}{\text{kmols } C_1} = 60 \text{ kmols}$$

$$(y_{C1} \times v) + (x_{c_1}[100 - v]) = 60 \text{ kmols}$$

$$(0.674 \times v) + (0.0674[100 - v]) = 60 \text{ kmols}$$

$$v = 87.8$$

The mixture consists of 87.8 kmols of vapor and 12.2 kmols of liquid.

FLASH CALCULATION PROBLEM

To illustrate the calculation of multicomponent vapor-liquid equilibrium using the flash equations and the K-charts, a problem is worked out in detail below.

The variables are defined in Fig. 25-1. Note that the K-value is implied to be at thermodynamic equilibrium.

A situation of reproducible steady state conditions in a piece of equipment does not necessarily imply that classical thermodynamic equilibrium exists. If the steady composition differs from that for equilibrium, the reason can be the result of time-limited mass transfer and diffusion rates. This warning is made because it is not at all unusual for flow rates through equipment to be so high that equilibrium is not attained or even closely approached. In such cases, equilibrium flash calculations as described here fail to predict conditions in the system accurately, and the K-values are suspected for this failure—when in fact they are not at fault.

Using the relationships

$$K_i = y_i/x_i \qquad \textbf{Eq 25-3}$$

$$L + V = 1.0 \qquad \textbf{Eq 25-4}$$

By writing a material balance for each component in the liquid, vapor, and total mixture, one may derive the flash equation in various forms. A common one is,

$$\Sigma x_i = \Sigma \frac{N_i}{L + VK_i} = 1.0 \qquad \textbf{Eq 25-5}$$

Other useful versions may be written as

$$L = \Sigma \frac{N_i}{1 + (V/L)\,K_i} \qquad \textbf{Eq 25-6}$$

$$\Sigma y_i = \frac{K_i N_i}{L + VK_i} \qquad \textbf{Eq 25-7}$$

At the phase boundary conditions of bubble point (L = 1.00) and dew point (V = 1.00), these equations reduce to

$$\Sigma\, K_i\, N_i = 1.0 \text{ (bubble point)} \qquad \textbf{Eq 25-8}$$

and

$$\Sigma\, N_i/K_i = 1.0 \text{ (dew point)} \qquad \textbf{Eq 25-9}$$

These are often helpful for preliminary calculations where the phase condition of a system at a given pressure and temperature is in doubt. If $\Sigma K_i N_i$ and $\Sigma N_i/K_i$ are both greater than 1.0, the system is in the two phase region. If $\Sigma K_i N_i$ is less than 1.0, the system is all liquid. If $\Sigma N_i/K_i$ is less than 1.0, the system is all vapor.

Example 25-2 — A typical high pressure separator gas is used for feed to a natural gas liquefaction plant, and a preliminary step in the process involves cooling to –20°F at 600 psia to liquefy heavier hydrocarbons prior to cooling to lower temperatures where these components would freeze out as solids.

Solution Steps

The feed gas composition is shown in Fig. 25-3. The flash equation 25-5 is solved for three estimated values of L as shown in columns 3, 4, and 5. By plotting estimated L versus calculated Σx_i, the correct value of L where $\Sigma x_i = 1.00$ is L = 0.030, whose solution is shown in columns 6 and 7. The gas composition is then calculated using $y_i = K_i x_i$ in column 8. This "correct" value is used for purposes of illustration. It is not a completely converged solution, for $x_i = 1.00049$ and $y_i = 0.99998$, columns 7 and 8 of Fig. 25-3. This error may be too large for some applications.

Example 25-3 — Dew Point Calculation

A gas stream at 100°F and 800 psia is being cooled in a heat exchanger. Find the temperature at which the gas starts to condense.

Solution Steps

The approach to find the dew point of the gas stream is similar to the previous example. The equation for dew point condition ($\Sigma N_i/K_i = 1.0$) is solved for two estimated dew point temperatures as shown in Fig. 25-4. By interpolation, the temperature at which $\Sigma N_i/K_i = 1.0$ is estimated at –41.6°F.

Note that the heaviest component is quite important in dew point calculations. For more complex mixtures, the characterization of the heavy fraction as a pseudocomponent such as hexane or octane will have a significant effect on dew point calculations.

Carbon Dioxide

Early conflicting data on CO_2 systems was used to prepare K-data ($P_k = 4000$) charts for the 1966 Edition. Later, experience showed that at low concentrations of CO_2, the rule of thumb

$$K_{CO_2} = \sqrt{K_{C_1} \cdot K_{C_2}} \qquad \textbf{Eq 25-10}$$

could be used with a plus or minus 10% accuracy. Developments in the use of CO_2 for reservoir drive have led to exten-

PILOT EXHIBIT 2027 PAGE 046
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 25-2

Sources of K-Value Charts

Component	Charts available from sources as indicated							
	Binary Data	Convergence pressures, psia						
		800	1000	1500	2000	3000	5000	10,000
Nitrogen	*	□	□		□			
Methane	*	∇	∇	∇	∇	∇	∇	
Ethylene		□	□		□			
Ethane	*	∇	∇	∇	∇	∇	×	×
Propylene		□	□		□			
Propane	*	∇	∇	∇	∇	∇	××	
iso-Butane		□	□	×	×	×	×	×
n-Butane	*†	□	□	×	×	×	×	×
iso-Pentane		□	□	×	×	×	×	×
n-Pentane	*†	□	□	×	×	×	×	×
Hexane	*†	□	□	×	×	×	×	×
Heptane	*†			×	×	×	×	×
Octane		□	□	×	×	×	×	×
Nonane				×	×	×	×	×
Decane		□	□	×	×	×	×	×
Hydrogen sulfide			×			×		
Carbon dioxide	** Use $K_{CO_2} = \sqrt{K_{C_1} \cdot K_{C_2}}$							

* Binary data from Price & Kobayashi; Wichterle & Kobayashi; Stryjek, Chappelear, & Kobayashi; and Chen & Kobayashi
∇ Drawn for 1972 Edition based on available data
□ Reused from 1966 Edition
× Reused from 1957 Edition
† Prepared for Second Revisions 1972 Edition or revised
** Limited to CO_2 concentration of 10 mole percent of feed or less

Note: The charts shown in bold outline are published in this edition of the data book. The charts shown in the shaded area are published in a separate GPA Technical Publication (TP-22) as well as the 10th Edition.

sive investigations in CO_2 processing. See the GPA research reports (listed in Section 1) and the Proceedings of GPA conventions. The reverse volatility at high concentration of propane and/or butane has been used effectively in extractive distillation to effect CO_2 separation from methane and ethane.[23] In general, CO_2 lies between methane and ethane in relative volatility.

Separation of CO_2 and Methane

The relative volatility of CO_2 and methane at typical operating pressures is quite high, usually about 5 to 1. From this standpoint, this separation should be quite easy. However, at processing conditions, the CO_2 will form a solid phase if the distillation is carried to the point of producing high purity methane.

Fig. 25-5 depicts the phase diagram for the methane-CO_2 binary system.[21] The pure component lines for methane and CO_2 vapor-liquid equilibrium form the left and right boundaries of the phase envelope. Each curve terminates at its critical point; methane at –116.7°F, 668 psia and CO_2 at 88°F, 1071 psia. The unshaded area is the vapor-liquid region. The shaded area represents the vapor-CO_2 solid region which extends to a pressure of 705 psia.

Because the solid region extends to a pressure above the methane critical pressure, it is not possible to fractionate pure methane from a CO_2-methane system without entering the solid formation region. It is possible to perform a limited separation of CO_2 and methane if the desired methane can contain significant quantities of CO_2.

At an operating pressure above 705 psia, the methane purity is limited by the CO_2-methane critical locus (Fig. 25-6). For example, operating at 715 psia, it is theoretically possible to avoid solid CO_2 formation (Fig. 25-7 and 16-33). The limit on methane purity is fixed by the approach to the mixture critical. In this case, the critical binary contains 6% CO_2. A practical operating limit might be 10-15% CO_2.

One approach to solving the methane-CO_2 distillation problem is by using extractive distillation (See Section 16, Hydrocarbon Recovery). The concept is to add a heavier hydrocarbon stream to the condenser in a fractionation column. Around 10 GPA research reports present data on various CO_2 systems which are pertinent to the design of such a process.

CO_2-Ethane Separation

The separation of CO_2 and ethane by distillation is limited by the azeotrope formation between these components. An azeotropic composition of approximately 67% CO_2, 33% ethane is formed at virtually any pressure.[24]

Fig. 25-7 shows the CO_2-ethane system at two different pressures. The binary is a minimum boiling azeotrope at both pressures with a composition of about two-thirds CO_2 and

PILOT EXHIBIT 2027 PAGE 047
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 25-3

Flash Calculation at 600 psia and –20°F

Component	Column 1	2	3	4	5	6	7	8
	Feed Gas Composition	Pk = 2000	Trial values of L			Final L = 0.030		
			L = 0.020	L = 0.060	L = 0.040	$L + VK_i$	Liquid	Vapor
	N_i	K_i	$\frac{N_i}{L+VK_i}$	$\frac{N_i}{L+VK_i}$	$\frac{N_i}{L+VK_i}$		$x_i = \frac{N_i}{L+VK_i}$	y_i
C_1	0.9010	3.7	0.24712	0.25466	0.25084	3.61900	0.24896	0.92117
CO_2**	0.0106	1.23	0.00865	0.00872	0.00868	1.22310	0.00867	0.01066
C_2	0.0499	0.41	0.11830	0.11203	0.11508	0.42770	0.11667	0.04783
C_3	0.0187	0.082	0.18633	0.13642	0.15751	0.10954	0.17071	0.01400
iC_4	0.0065	0.034	0.12191	0.07068	0.08948	0.06298	0.10321	0.00351
nC_4	0.0045	0.023	0.10578	0.05513	0.07249	0.05231	0.08603	0.00198
iC_5	0.0017	0.0085	0.06001	0.02500	0.03530	0.03825	0.04445	0.00038
nC_5	0.0019	0.0058	0.07398	0.02903	0.04170	0.03563	0.05333	0.00031
C_6	0.0029	0.0014	0.13569	0.04730	0.07014	0.03136	0.09248	0.00013
C_7+*	0.0023	0.00028	0.11334	0.03817	0.05712	0.03027	0.07598	0.00002
TOTALS	1.0000		1.17121	0.77714	0.89834		1.00049	0.99998
C_7		0.00042						
C_8		0.00014						

* Average of $nC_7 + nC_{8\ \text{properties}}$

** $\sqrt{K_{C_1} \cdot K_{C_2}}$

FIG. 25-4

Dew Point Calculation at 800 psia

Component	Column 1	2	3	4	5
	Feed	Pk = 1000, T = -50°F		Pk = 1000, T = -40°F	
	N_i	K_i	$\frac{N_i}{K_i}$	K_i	$\frac{N_i}{K_i}$
CH_4	0.854	2.25	0.313	2.30	0.311
CO_2	0.051	0.787	0.059	0.844	0.056
C_2H_6	0.063	0.275	0.229	0.31	0.210
C_3H_8	0.032	0.092	0.457	0.105	0.400
Σ =	1.000		1.058		0.977

K_{CO_2} calculated as $\sqrt{K_{C_1} \cdot K_{C_2}}$

Linear interpolation: $T_{dew} = -40 - [-40 - (-50)]\left(\frac{1.000 - 0.977}{1.058 - 0.977}\right) = -42.8°F$

one-third ethane. Thus, an attempt to separate CO_2 and ethane to nearly pure components by distillation cannot be achieved by traditional methods, and extractive distillation is required[26] (See Section 16, Hydrocarbon Recovery).

Separation of CO_2 and H_2S

The distillative separation of CO_2 and H_2S can be performed with traditional methods. The relative volatility of CO_2 to H_2S is quite small. While an azeotrope between H_2S and CO_2 does not exist, vapor-liquid equilibrium behavior for this binary approaches azeotropic character at high CO_2 concentrations[25] (See Section 16, Hydrocarbon Recovery).

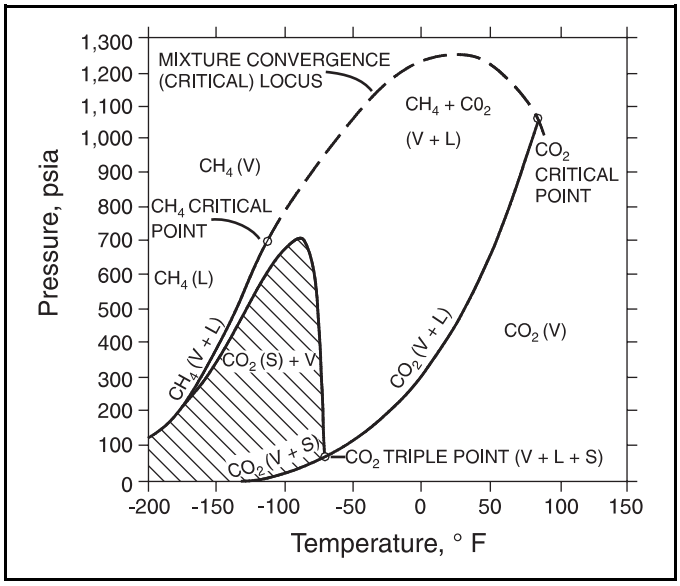
K-VALUE CORRELATIONS

Numerous procedures have been devised to predict K-values. These include equations of state (EOS), combinations of equations of state with liquid theory or with tabular data, and corresponding states correlations. This section describes sev-

PILOT EXHIBIT 2027 PAGE 048
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 25-5

Phase Diagram CH_4-CO_2 Binary[21]



eral of the more popular procedures currently available. It does not purport to be all-inclusive or comparative.

Equations of state have appeal for predicting thermodynamic properties because they provide internally consistent values for all properties in convenient analytical form. Two popular state equations for K-value predictions are the Benedict-Webb-Rubin (BWR) equation and the Redlich-Kwong equation.

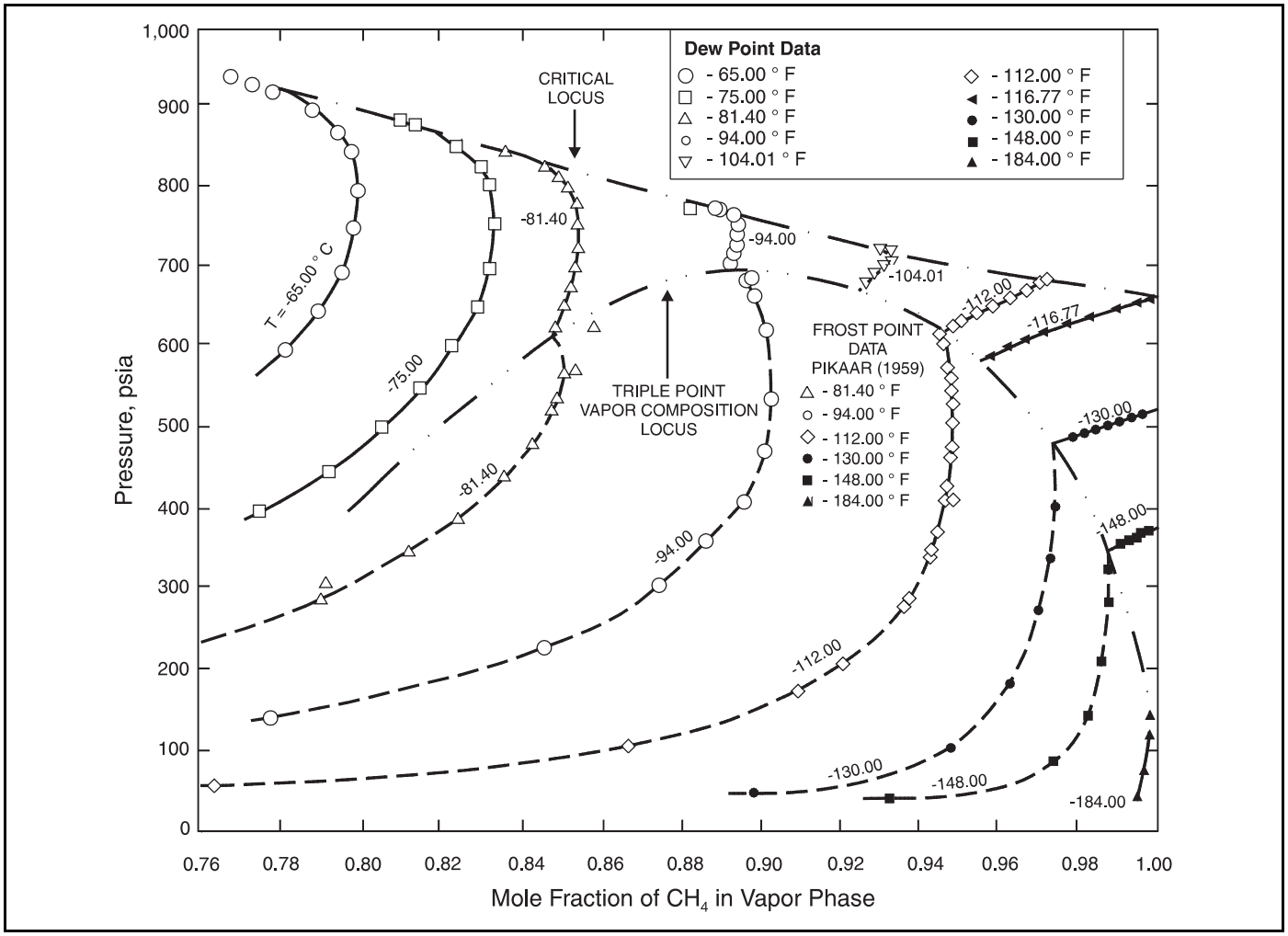
The original BWR equation[17] uses eight parameters for each component in a mixture plus a tabular temperature dependence for one of the parameters to improve the fit of vapor-pressure data. This original equation is reasonably accurate for light paraffin mixtures at reduced temperatures of 0.6 and above.[8] The equation has difficulty with low temperatures, non-hydrocarbons, non-paraffins, and heavy paraffins.

Improvements to the BWR include additional terms for temperature dependence, parameters for additional compounds, and generalized forms of the parameters.

Starling[20] has included explicit parameter temperature dependence in a modified BWR equation which is capable of predicting light paraffin K-values at cryogenic temperatures.

FIG. 25-6

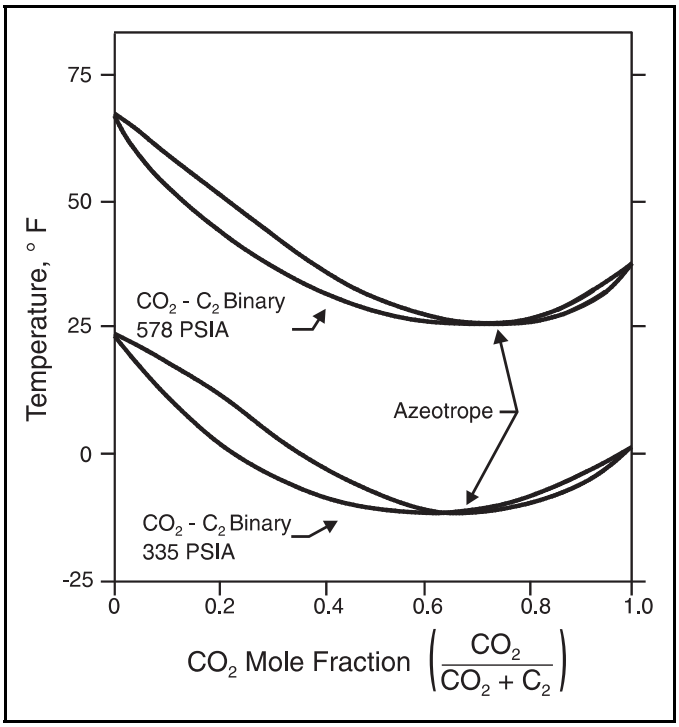
Isothermal Dew Point and Frost Point Data for Methane-Carbon Dioxide[32]



PILOT EXHIBIT 2027 PAGE 049
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 25-7

Vapor-Liquid Equilibria CO_2-C_2H_6[21]



The Redlich-Kwong equation has the advantage of a simple analytical form which permits direct solution for density at specified pressure and temperature. The equation uses two parameters for each mixture component, which in principle permits parameter values to be determined from critical properties.

However, as with the BWR equation, the Redlich-Kwong equation has been made useful for K-value predictions by empirical variation of the parameters with temperature and with acentric factor[11, 18, 19] and by modification of the parameter-combination rules.[15, 19] Considering the simplicity of the Redlich-Kwong equation form, the various modified versions predict K-values remarkably well.

Interaction parameters for non-hydrocarbons with hydrocarbon components are necessary in the Redlich-Kwong equation to predict the K-values accurately when high concentrations of non-hydrocarbon components are present. They are especially important in CO_2 fractionation processes, and in conventional fractionation plants to predict sulfur compound distribution.

The Chao-Seader correlation[7] uses the Redlich-Kwong equation for the vapor phase, the regular solution model for liquid-mixture non-ideality, and a pure-liquid property correlation for effects of component identity, pressure, and temperature in the liquid phase. The correlation has been applied to a broad spectrum of compositions at temperatures from –50°F to 300°F and pressures to 2000 psia. The original (P,T) limitations have been reviewed.[12]

Prausnitz and Chueh have developed[16] a procedure for high-pressure systems employing a modified Redlich-Kwong equation for the vapor phase and for liquid-phase compressibility together with a modified Wohl-equation model for liquid phase activity coefficients. Complete computer program listings are given in their book. Parameters are given for most natural gas components. Adler et al. also use the Redlich-Kwong equation for the vapor and the Wohl equation form for the liquid phase.[6]

The corresponding states principle[10] is used in all the procedures discussed above. The principle assumes that the behavior of all substances follows the same equation forms and equation parameters are correlated versus reduced critical properties and acentric factor. An alternate corresponding states approach is to refer the behavior of all substances to the properties of a reference substance, these properties being given by tabular data or a highly accurate state equation developed specifically for the reference substance.

The deviations of other substances from the simple critical-parameter-ratio correspondence to the reference substance are then correlated. Mixture rules and combination rules, as usual, extend the procedure to mixture calculations. Leland and co-workers have developed[9] this approach extensively for hydrocarbon mixtures.

"Shape factors" are used to account for departure from simple corresponding states relationships, with the usual reference substance being methane. The shape factors are developed from PVT and fugacity data for pure components. The procedure has been tested over a reduced temperature range of 0.4 to 3.3 and for pressures to 4000 psia. Sixty-two components have been correlated including olefinic, naphthenic, and aromatic hydrocarbons.

The Soave Redlich-Kwong (SRK)[13] is a modified version of the Redlich-Kwong equation. One of the parameters in the original Redlich-Kwong equation, a, is modified to a more temperature dependent term. It is expressed as a function of the acentric factor. The SRK correlation has improved accuracy in predicting the saturation conditions of both pure substances and mixtures. It can also predict phase behavior in the critical region, although at times the calculations become unstable around the critical point. Less accuracy has been obtained when applying the correlation to hydrogen-containing mixtures.

Peng and Robinson[14] similarly developed a two-constant Redlich-Kwong equation of state in 1976. In this correlation, the attractive pressure term of the semi-empirical van der Waals equation has been modified. It accurately predicts the vapor pressures of pure substances and equilibrium ratios of mixtures. In addition to offering the same simplicity as the SRK equation, the Peng-Robinson equation is more accurate in predicting the liquid density.

In applying any of the above correlations, the original critical/physical properties used in the derivation must be inserted into the appropriate equations. One may obtain slightly different solutions from different computer programs, even for the same correlation. This can be attributed to different iteration techniques, convergence criteria, initial estimation values, etc. Determination and selection of interaction parameters and selection of a particular equation of state must be done carefully, considering the system components, the operating conditions, etc.

EQUATIONS OF STATE

Refer to original papers for mixing rules for multicomponent mixtures.

PILOT EXHIBIT 2027 PAGE 050
SCOUT/CHEVRON v. PILOT - IPR2024-00385

van der Waals [30]

$$Z^3 - (1 + B)\,Z^2 + AZ - AB = 0$$

$$A = \frac{aP}{R^2\,T^2}$$

$$B = \frac{bP}{RT}$$

$$a = \frac{27\,R^2\,T_c^2}{64\,P_c}$$

$$b = \frac{R\,T_c}{8\,P_c}$$

Redlich-Kwong [28]

$$Z^3 - Z^2 + (A - B - B^2)\,Z - AB = 0$$

$$A = \frac{aP}{R^2\,T^{2.5}}$$

$$B = \frac{b\,P}{R\,T}$$

$$a = 0.42747\left(\frac{R^2\,T_c^{2.5}}{P_c}\right)$$

$$b = 0.0867\left(\frac{R\,T_c}{P_c}\right)$$

Soave Redlich-Kwong (SRK) [13]

$$Z^3 - Z^2 + (A - B - B^2)\,Z - AB = 0$$

$$A = \frac{a\,P}{R^2\,T^2}$$

$$B = \frac{b\,P}{R\,T}$$

$$a = a_c\,\alpha$$

$$a_c = 0.42747\left(\frac{R^2\,T_c^2}{P_c}\right)$$

$$\alpha^{1/2} = 1 + m\,(1 - T_r^{1/2})$$

$$m = 0.48 + 1.574\,\omega - 0.176\,\omega^2$$

$$b = 0.08664\left(\frac{R\,T_c}{P_c}\right)$$

Peng Robinson [31]

$$Z^3 - (1 - B)\,Z^2 + (A - 3B^2 - 2B)\,Z - (AB - B^2 - B^3) = 0$$

$$A = \frac{a\,P}{R^2\,T^2}$$

$$B = \frac{bP}{RT}$$

$$a = 0.45724\left(\frac{R^2\,T_c^2}{P_c}\right)\alpha$$

$$\alpha^{1/2} = 1 + m\,(1 - T_r^{1/2})$$

$$m = 0.37464 + 1.54226\,\omega - 0.26992\,\omega^2$$

$$b = 0.0778\left(\frac{R\,T_c}{P_c}\right)$$

Benedict-Webb-Rubin-Starling (BWRS) [20, 29]

$$P = \frac{R\,T}{V} + \left(B_o\,R\,T - A_o - \frac{C_o}{T^2} + \frac{D_o}{T^3} - \frac{E_o}{T^4}\right)\frac{1}{V^2} + \left(bRT - a - \frac{d}{T}\right)\frac{1}{V^3} + \alpha\left(a + \frac{d}{T}\right)\frac{1}{V^6} + \frac{c}{V^3}\left(\frac{1}{T^2}\right)\left(1 + \frac{\gamma}{V^2}\right)^{-\gamma/V^2}$$

Note: ω, the acentric factor is defined in Section 23, p. 23-30

PILOT EXHIBIT 2027 PAGE 051
SCOUT/CHEVRON v. PILOT - IPR2024-00385

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Additional References

See listing in Section 1 for GPA Technical Publications (TP) and Research Reports (RR). Note that RR-64, RR-77, and RR-84 provide extensive evaluated references for binary, ternary, and multicomponent systems. Also as a part of GPA/GPSA Project 806, a computer data bank is available through the GPA Tulsa office.

Another extensive tabulation of references only is available from Elsevier Publishers of Amsterdam for the work of E. Hala and I. Wichterle of the Institute of Chemical Process Fundamentals, Czechoslovak Academy of Sciences, Prague-Suchdol, Czechoslovakia.

Also, Hiza, M. J., Kidnay, A. J., and Miller, R. C., Equilibrium Properties of Fluid Mixtures Volumes I and II, IFI/Plenum, New York, 1975. See Fluid Phase Equilibria for various symposia.

K-DATA CHARTS FOLLOW AS LISTED BELOW

Methane-Ethane Binary

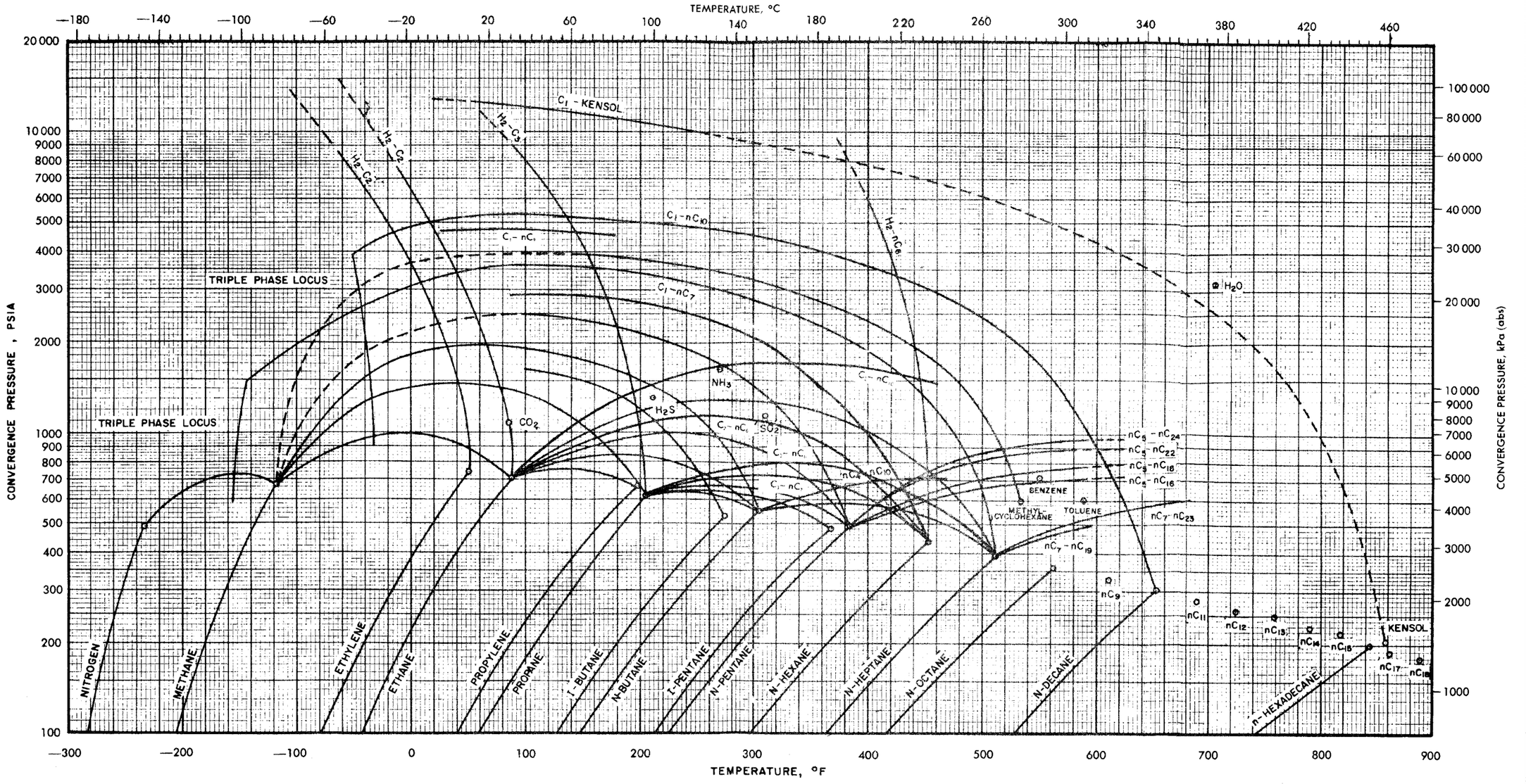
Nitrogen P_k 2000 psia (13 800 kPa)

Methane through Decane P_k 3000 psia (20 700 kPa)

Hydrogen Sulfide P_k 3000 psia (20 700 kPa)

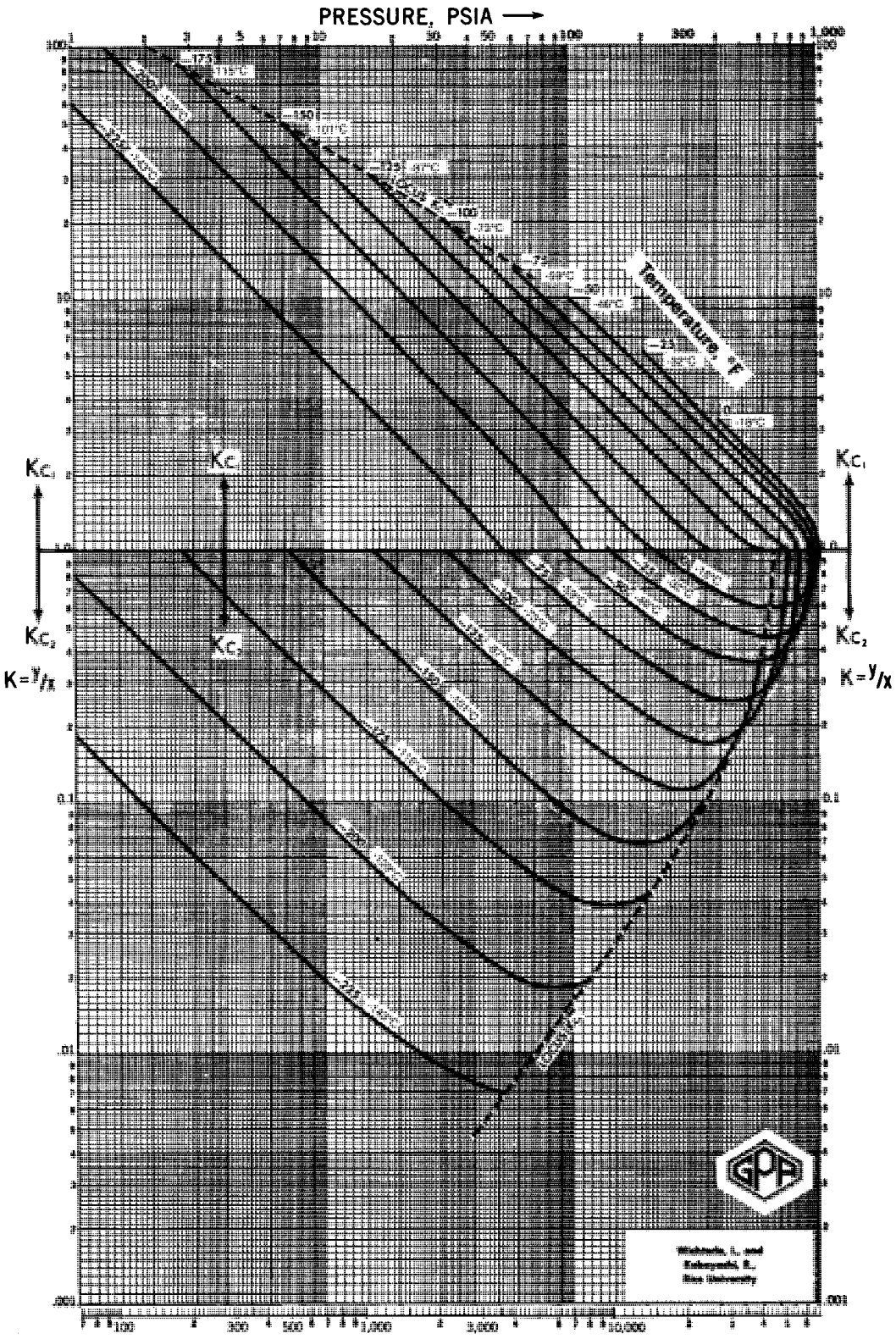
PILOT EXHIBIT 2027 PAGE 052
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FIG. 25-8
Critical Locus as Developed for Convergence Pressure
(Formerly used for Convergence Pressure for Hydrocarbons)



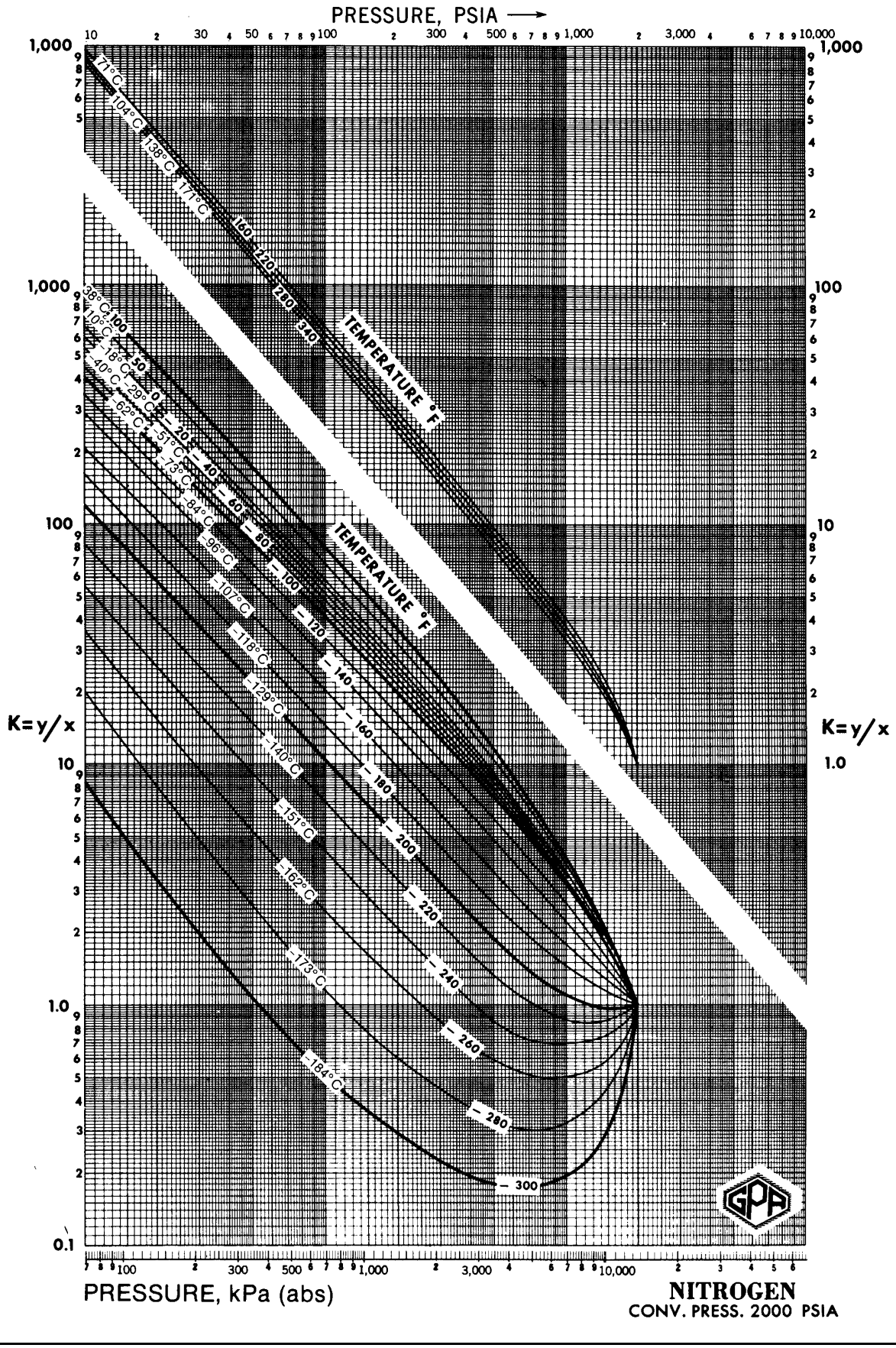
NOTE: See TP-22 for an explanation of the development of this figure.

PILOT EXHIBIT 2027 PAGE 053
SCOUT/CHEVRON v. PILOT - IPR2024-00385

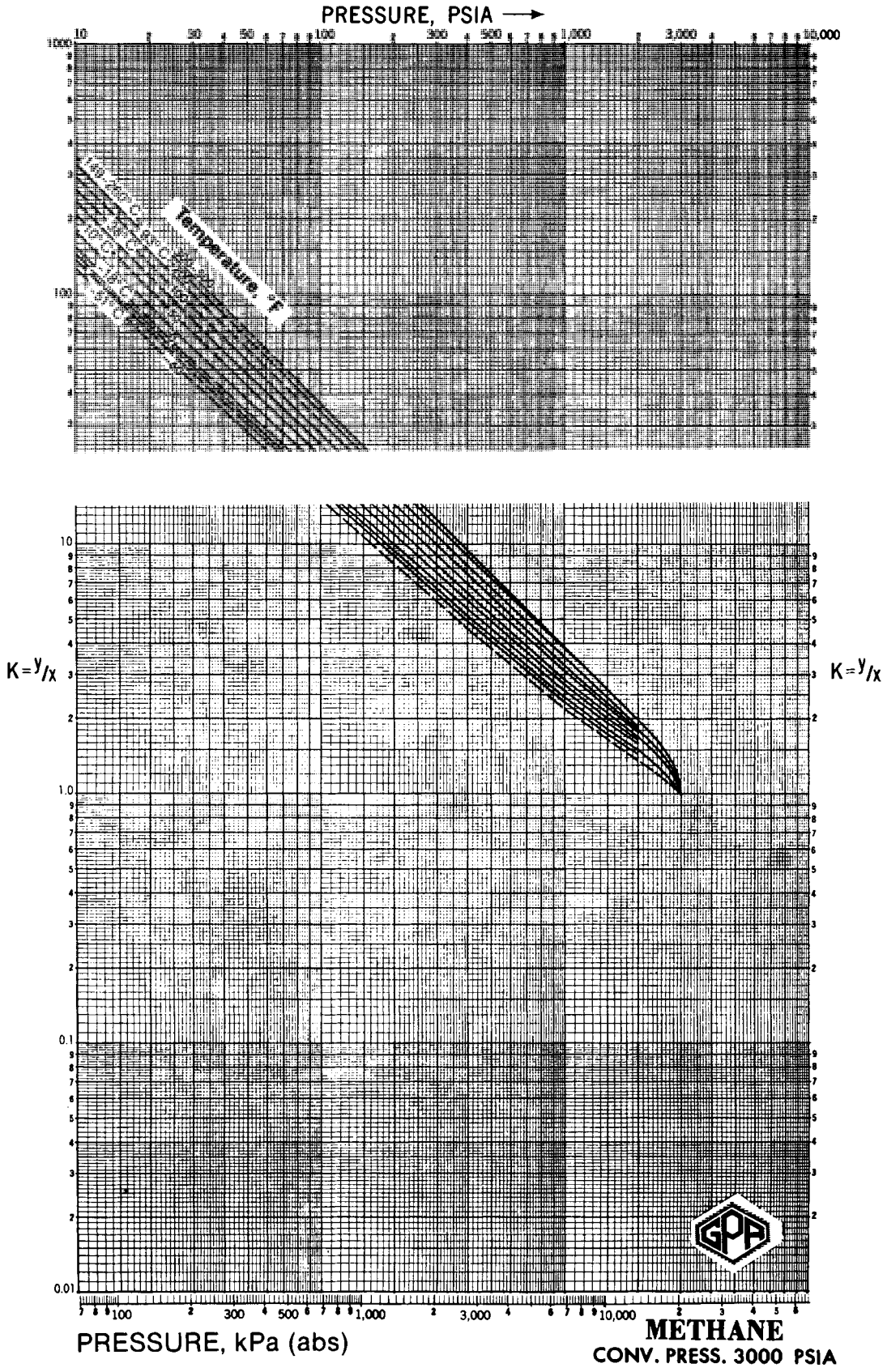


METHANE-ETHANE BINARY

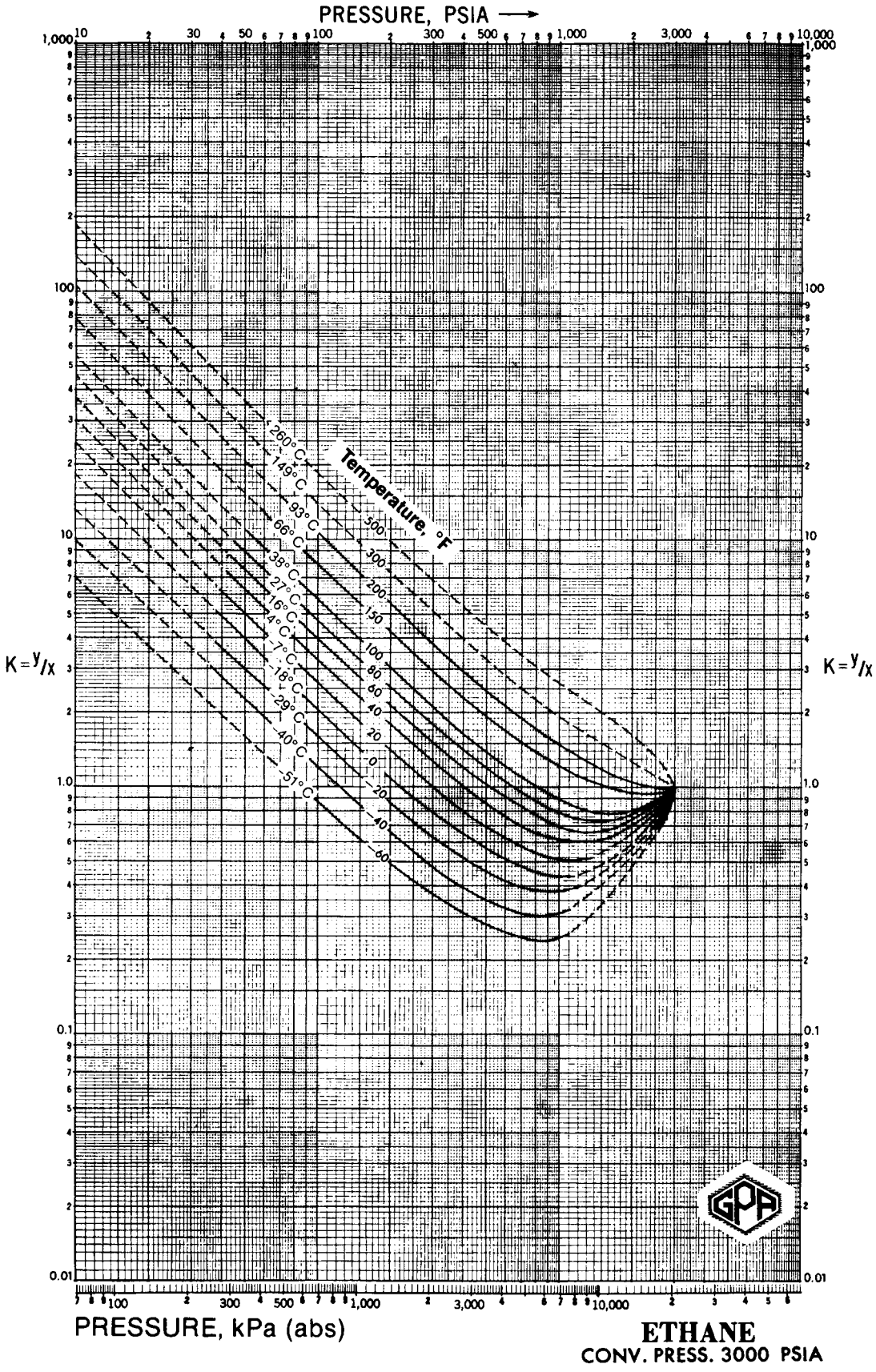
PILOT EXHIBIT 2027 PAGE 054
SCOUT/CHEVRON v. PILOT - IPR2024-00385



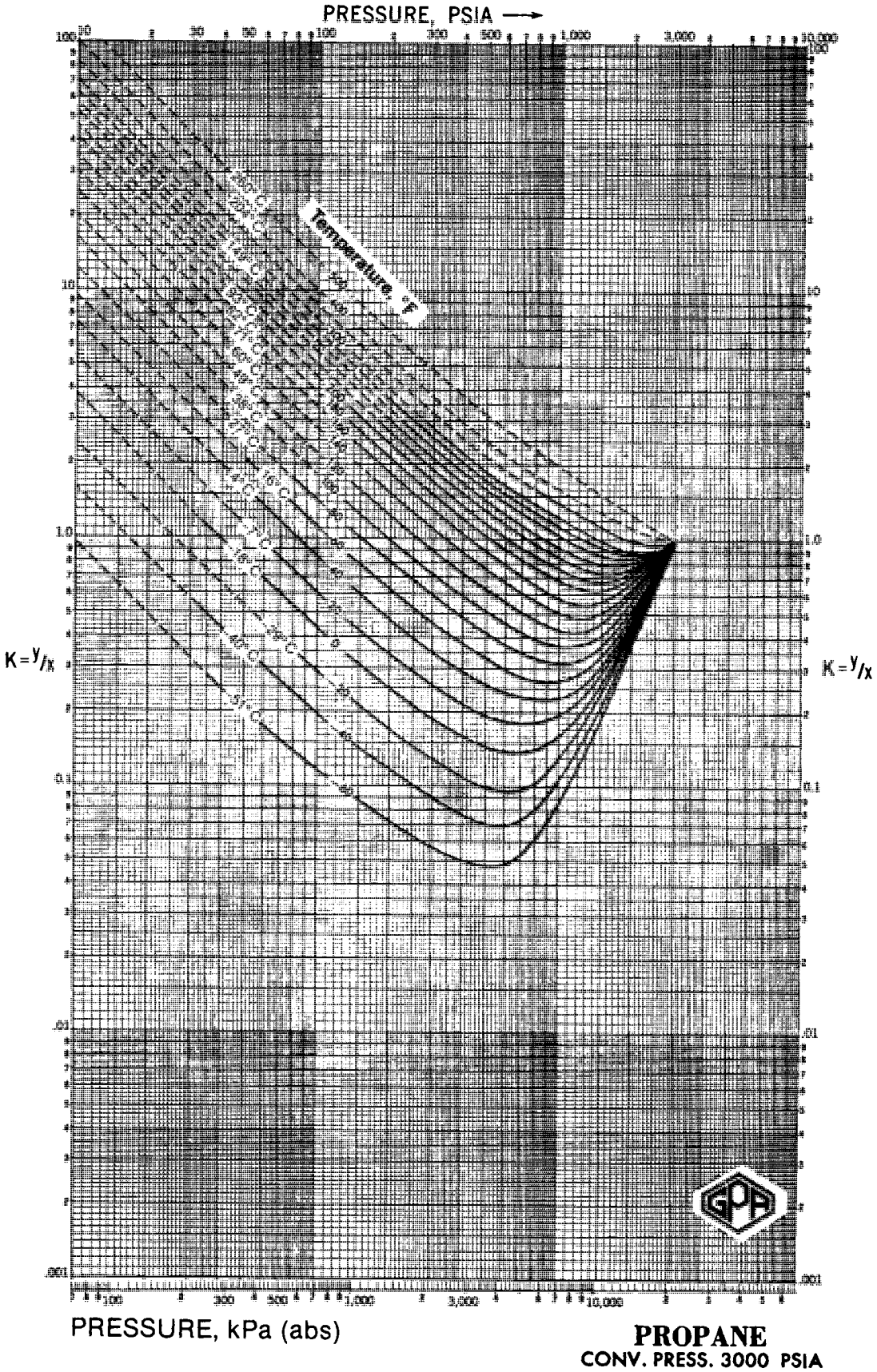
PILOT EXHIBIT 2027 PAGE 055
SCOUT/CHEVRON v. PILOT - IPR2024-00385



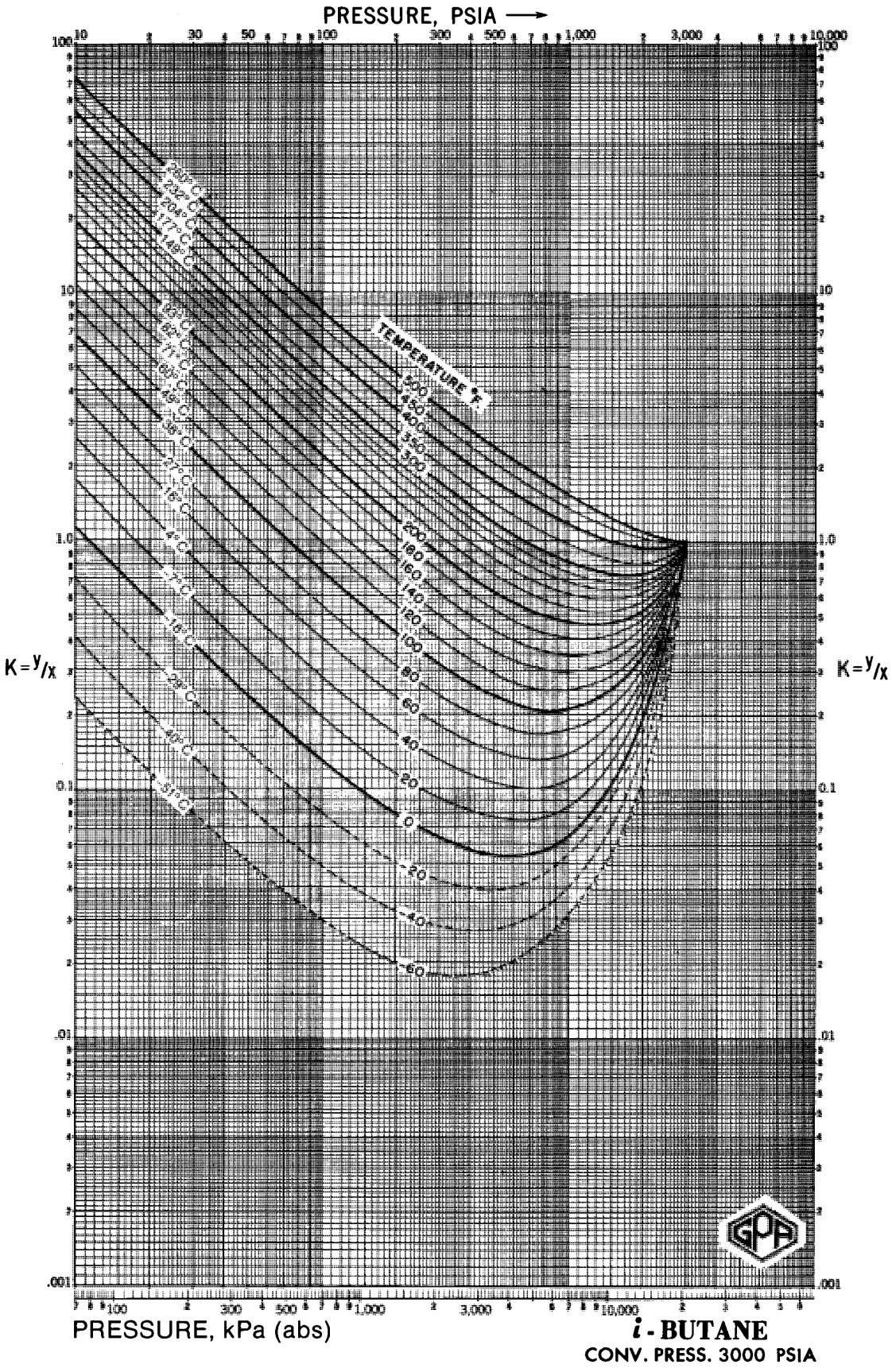
PILOT EXHIBIT 2027 PAGE 056
SCOUT/CHEVRON v. PILOT - IPR2024-00385



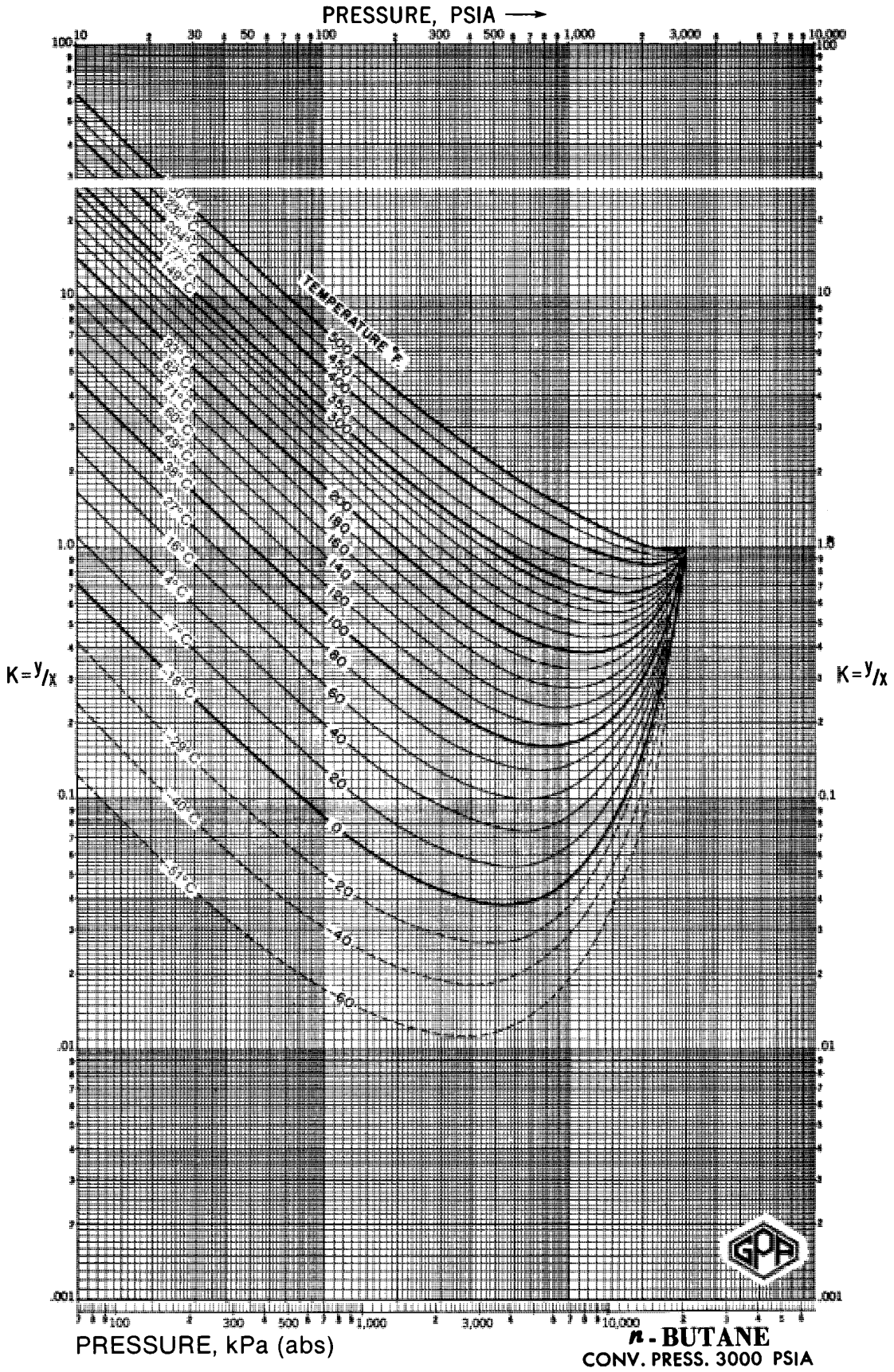
PILOT EXHIBIT 2027 PAGE 057
SCOUT/CHEVRON v. PILOT - IPR2024-00385



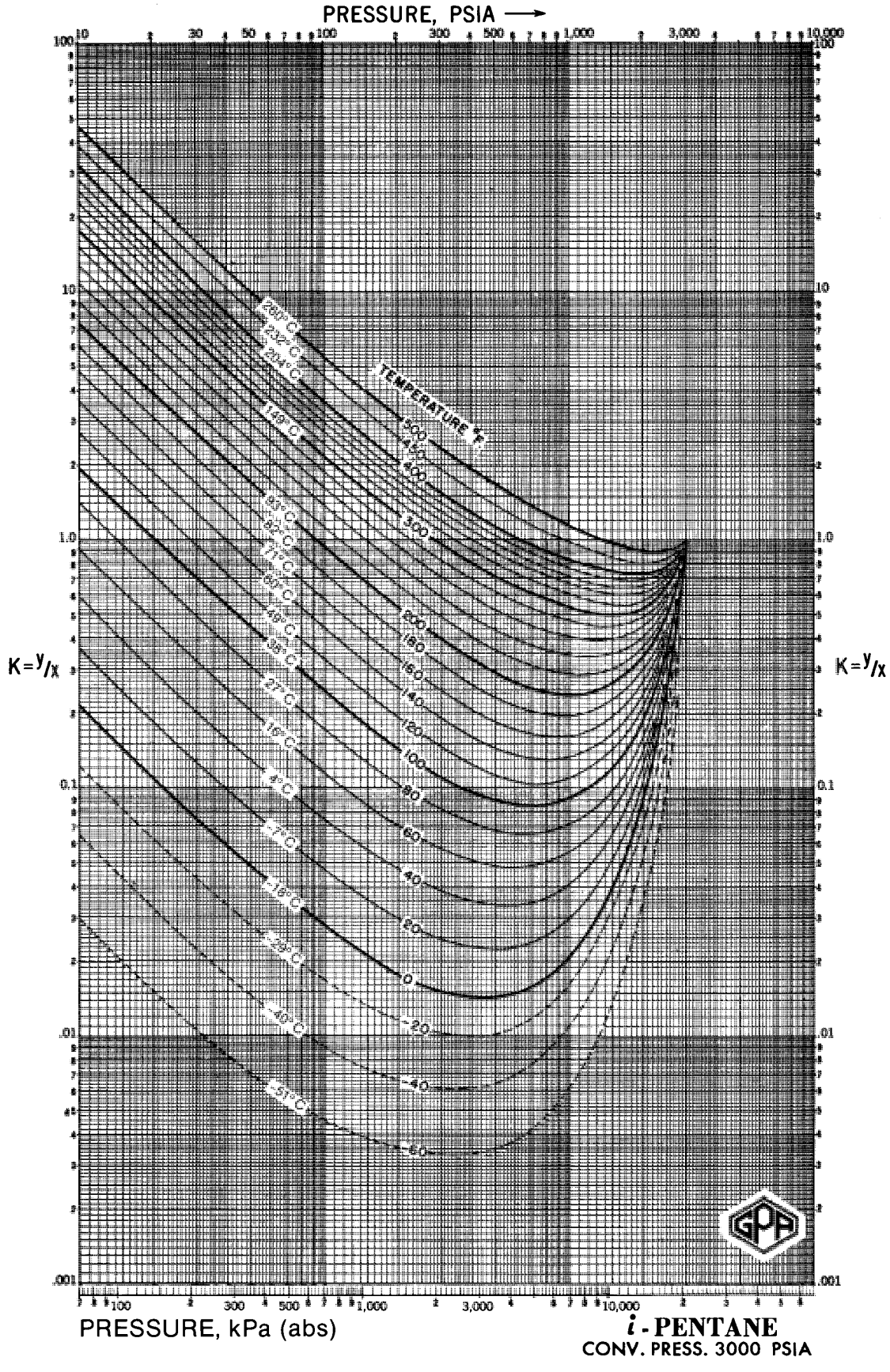
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SCOUT/CHEVRON v. PILOT - IPR2024-00385



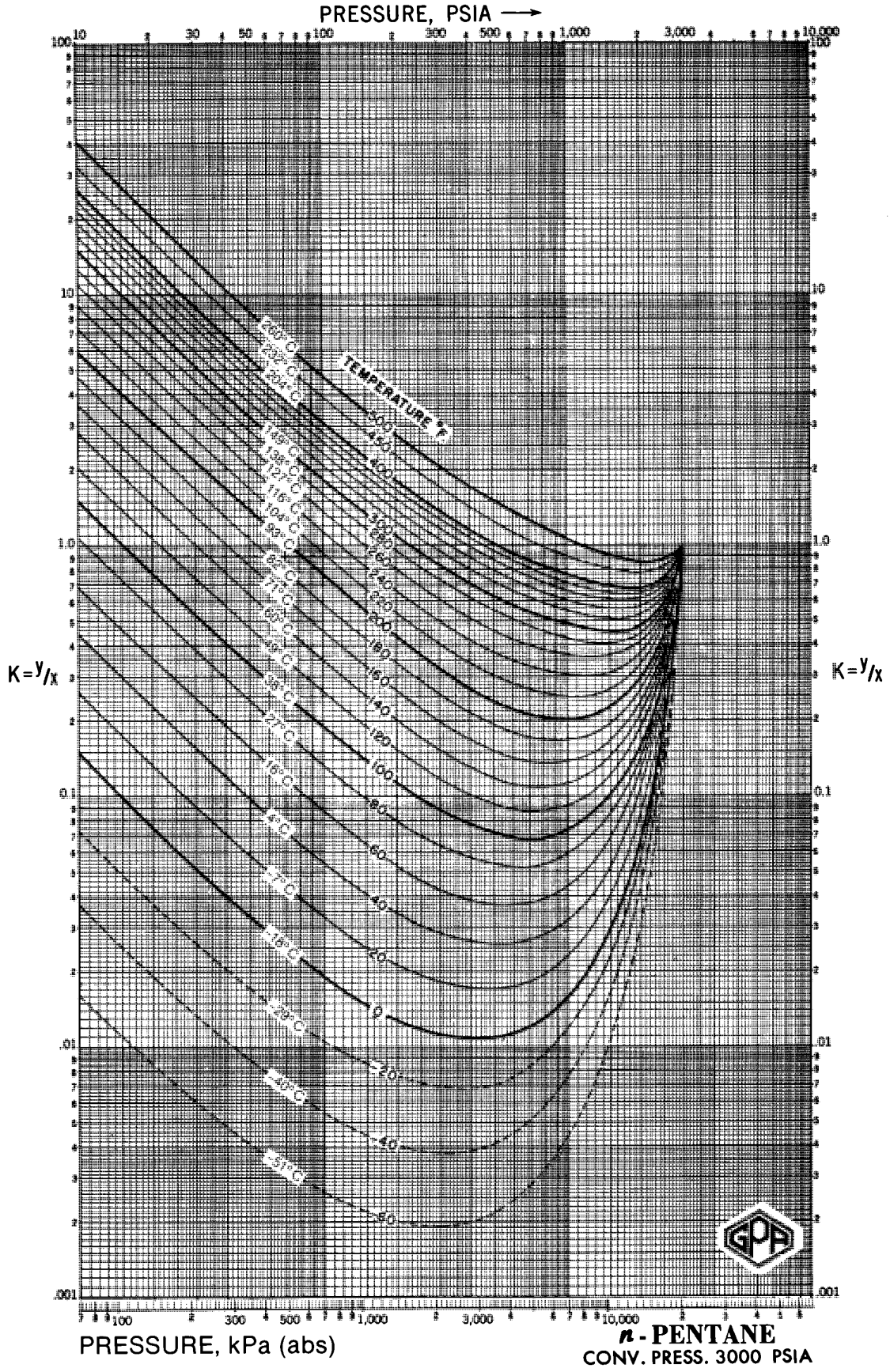
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SCOUT/CHEVRON v. PILOT - IPR2024-00385



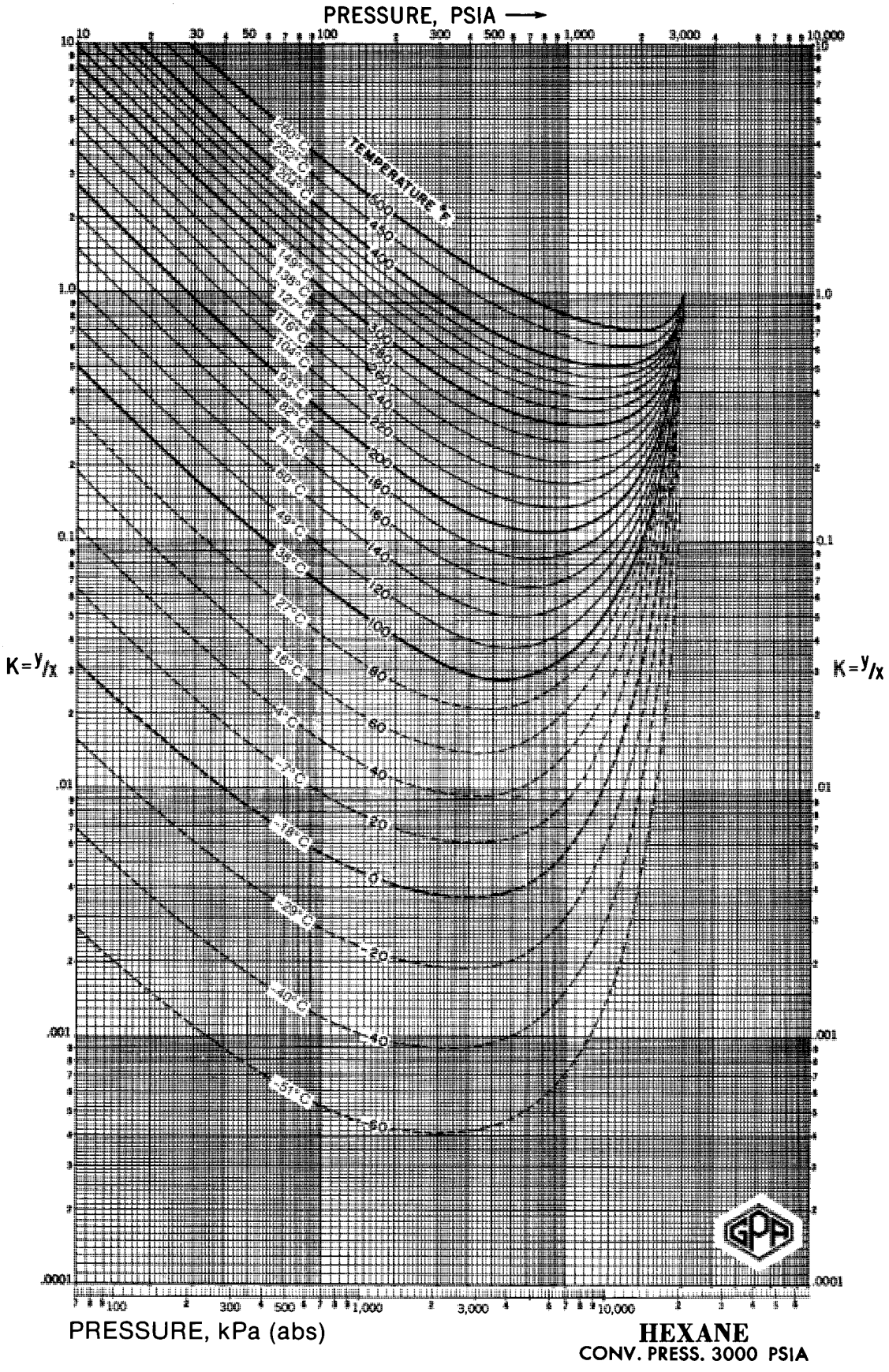
PILOT EXHIBIT 2027 PAGE 060
SCOUT/CHEVRON v. PILOT - IPR2024-00385



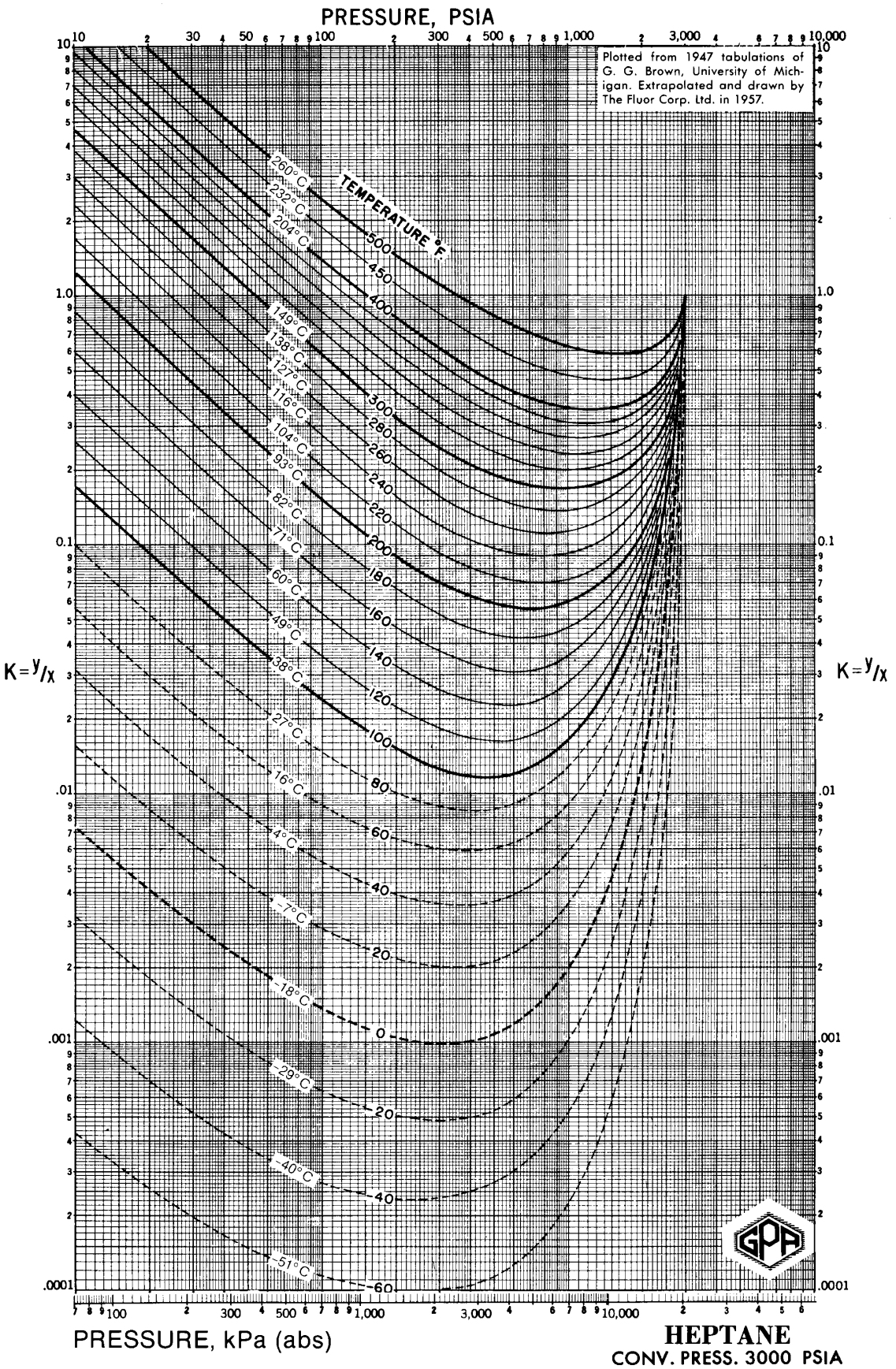
PILOT EXHIBIT 2027 PAGE 061
SCOUT/CHEVRON v. PILOT - IPR2024-00385



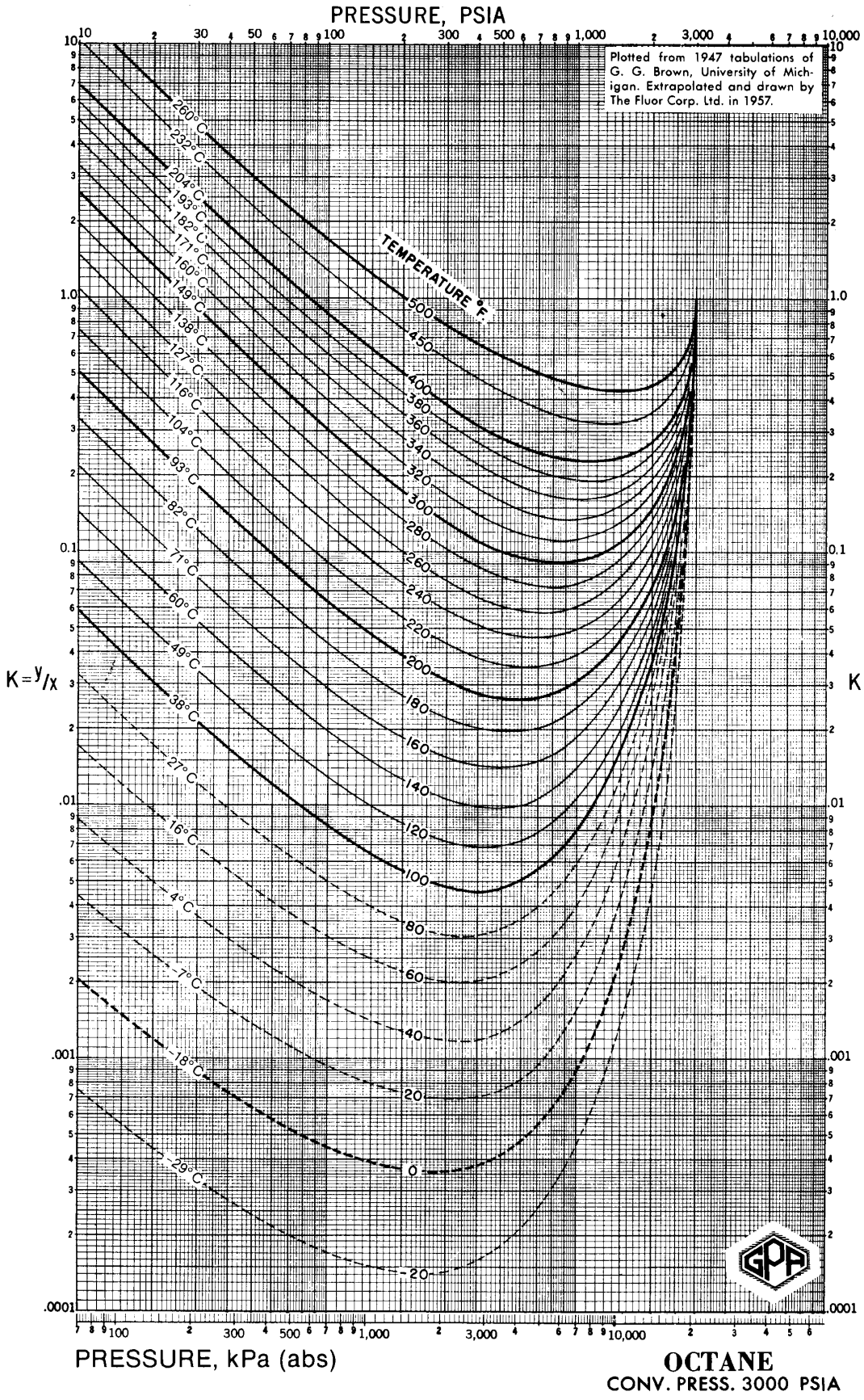
PILOT EXHIBIT 2027 PAGE 062
SCOUT/CHEVRON v. PILOT - IPR2024-00385



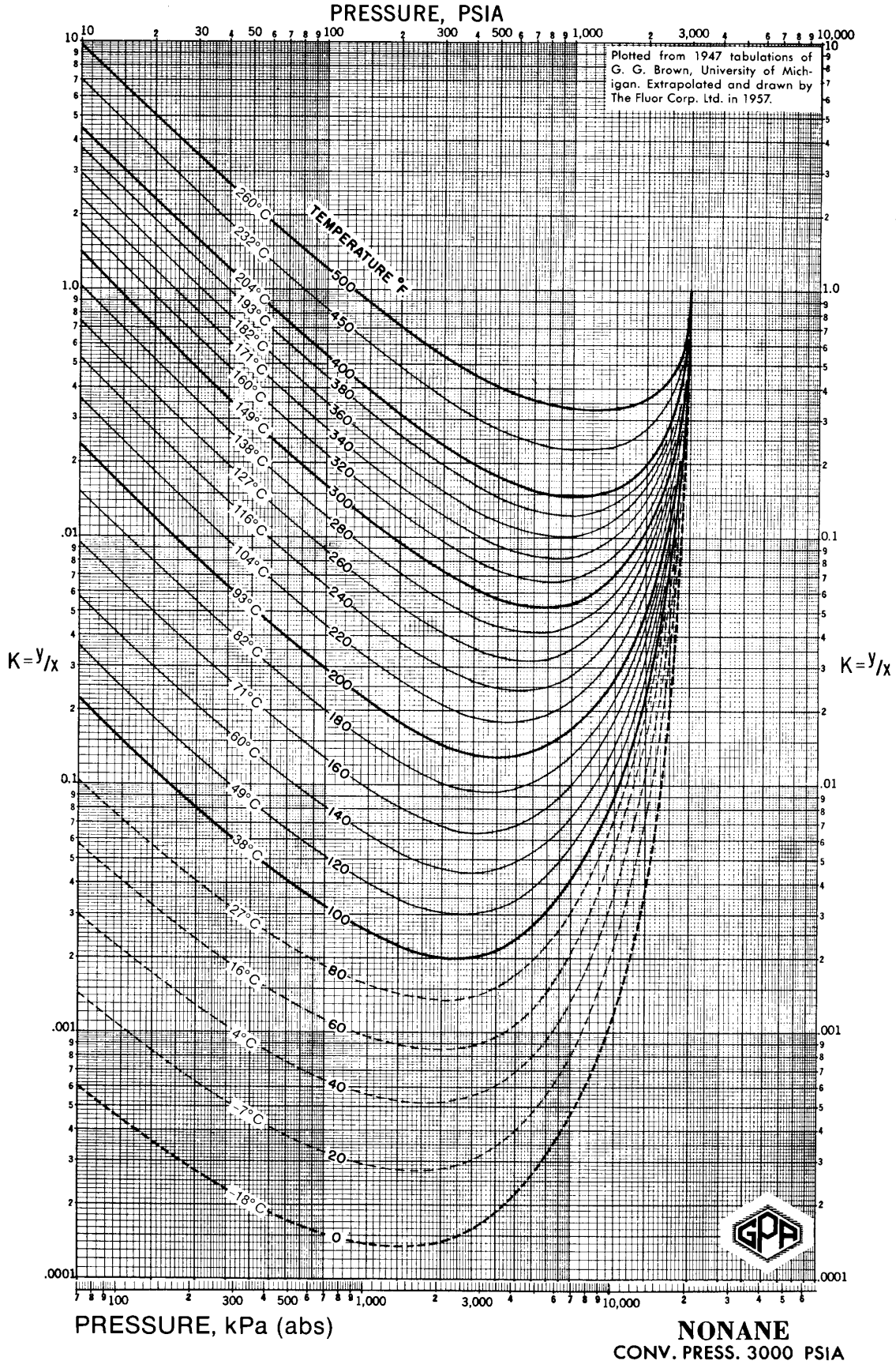
PILOT EXHIBIT 2027 PAGE 063
SCOUT/CHEVRON v. PILOT - IPR2024-00385



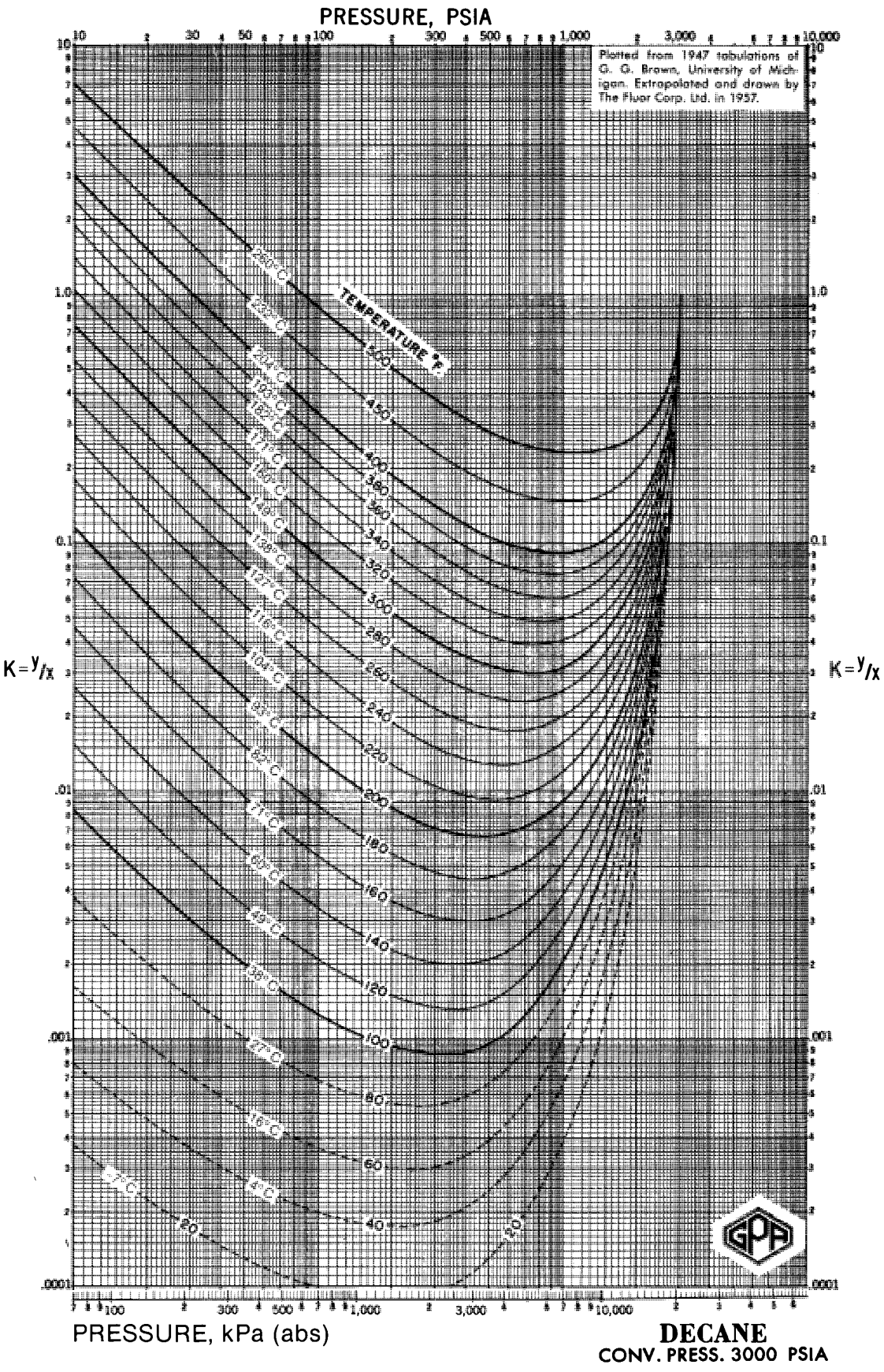
PILOT EXHIBIT 2027 PAGE 064
SCOUT/CHEVRON v. PILOT - IPR2024-00385



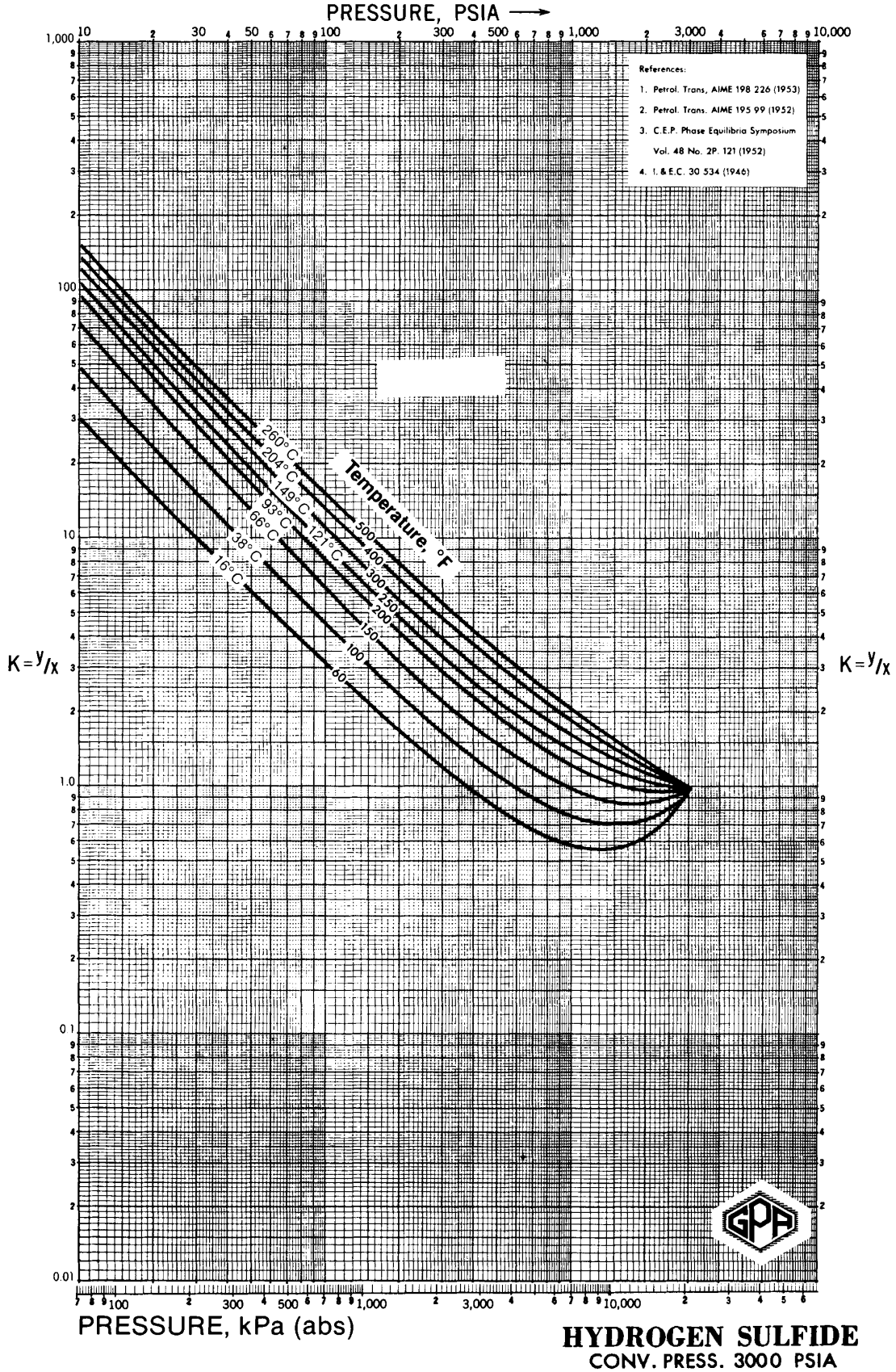
PILOT EXHIBIT 2027 PAGE 065
SCOUT/CHEVRON v. PILOT - IPR2024-00385



PILOT EXHIBIT 2027 PAGE 066
SCOUT/CHEVRON v. PILOT - IPR2024-00385



PILOT EXHIBIT 2027 PAGE 067
SCOUT/CHEVRON v. PILOT - IPR2024-00385



PILOT EXHIBIT 2027 PAGE 068
SCOUT/CHEVRON v. PILOT - IPR2024-00385

NOTES:

PILOT EXHIBIT 2027 PAGE 069
SCOUT/CHEVRON v. PILOT - IPR2024-00385

SECTION 26

Members

Gas Processors Suppliers Association

6526 East 60th Street
Tulsa, Oklahoma 74145
Phone: 918-493-3872
Fax: 918-493-3875
e-mail: gpsa@gasprocessors.com

The following is a listing of the members of GPSA. Please contact them directly for further information. Behind this listing of members, the GPSA companies are classified by the type of services and supplies that they provide to the industry. Services begin on page 26-10; Supplies begin on page 26-21.

Company & Address	Phone	Fax
3M Company 2465 Lexington Ave. So. Mendota Heights, MN 55120 www.mmm.com	651-737-0065	651-733-9525
ABB Inc. – Totalflow 431 N. Park Central Dr., Suite 100 Houston, TX 77073 www.abb.com/totalflow	281-869-5211	281-869-5203
ACS Industries, LP Separations Division - Tower & Vessel Internals 14211 Industry Rd. Houston, TX 77053 www.acsseparations.com	800-231-0077	713-433-6201
Advanced Extraction Technologies, Inc. 2 Northpoint Dr., Suite 820 Houston, TX 77060 www.aet.com	281-447-0571	281-447-5601
Afton Pumps Inc. 7335 Ave. No. Houston, TX 77011 www.aftonpumps.com	713-923-9731	713-923-3902
Aggreko LLC 12000 Areospace Ave., Suite 300 Houston, TX 77034-5588 www.aggreko.com	713-852-4500	713-852-4591
Air Products and Chemicals, Inc. 7201 Hamilton Blvd. Allentown, PA 18195-1501 www.airproducts.com	610-481-4544	610-481-3406
air-x-changers 5215 Arkansas Rd. Catoosa, OK 74105 www.airx.com	918-266-1850	918-266-4512
Air-x-hemphill 2230 E. 49th St. Tulsa, OK 74105 www.airxhemphill.com	918-712-8268	918-712-8269

Company & Address	Phone	Fax
Aker Kvaerner, Inc. 7909 Parkwood Circle Dr. Houston, TX 77036 www.akerkvaerner.com	713-988-2002	713-772-4673
Albert Garaudy and Associates, Inc. 3500 No. Causeway Blvd., Suite 600 Metairie, LA 70002 www.aga-engineers.com	504-846-6400	504-838-8955
Alcoa World Chemicals, Adsorbents and Catalysts 15333 JFK Blvd., Suite 425** Houston, TX 77032 www.adcats.alcoa.com	281-590-7856	281-590-3294
Allesco 740 W. Elgin Broken Arrow, OK 74012 www.allesco.com	800-331-4018, 918-258-3556	918-251-4582
Alliance Wood Group Engineering, L.P. 16340 Park Ten Place Dr. Houston, TX 77084 www.alliance-engineering.com	713-647-9701	713-647-9696
Amercool Manufacturing, Inc. 6312 So. 39th W. Ave. Tulsa, OK 74132 www.amercool.com	918-445-5366	918-445-2857
American Measurement Services P. O. Box 37, 105 No. Frisco Ames, OK 73718	580-753-4387	580-753-4388
Ariel Corporation 35 Blackjack Rd. Mount Vernon, OH 43050 www.arielcorp.com	740-397-0311	740-397-3856
Aspen Technology, Inc. Ten Canal Park Cambridge, MA 02141 www.aspentech.com	617-949-1000	617-949-1030

PILOT EXHIBIT 2027 PAGE 070
SCOUT/CHEVRON v. PILOT - IPR2024-00385

Company & Address	Phone	Fax
Atofina Chemicals, Inc., (Adsorbents Group) 2000 Market St. Philadelphia, PA 19103 www.siliporite.com	215-419-7152	215-419-5230
Atofina Chemicals Inc., Technical Polymers Division 2000 Market St. Philadelphia, PA 19103 www.atofinachemicals.com	215-419-7329	215-419-7497
Baker Energy 16340 Park Ten Place, Suite 320 Houston, TX 77084 www.mbakercorp.com	281-579-7850	281-579-4577
Barry D. Payne & Associates, Inc. P. O. Box 1159 Stafford, TX 77497 www.bdpayne.com	281-240-4488	281-240-3913
Bartlett Equipment Company, Inc. P. O. Box 470246 Tulsa, OK 74147 www.bartlettequipment.com	918-627-7040	918-665-8469
BASF Corporation 15710 JFK Blvd., Suite 550 Houston, TX 77032 www.amdea.com	281-985-2416	281-985-2401
BCCK Engineering, Inc. 2500 No. Big Spring Midland, TX 79705 www.bcck.com	432-685-6095	432-685-7021
BE&K Construction - Houston 14701 St. Mary's Lane, Suite 500 Houston, TX 77079-2924 www.bek.com	832-486-4556	832-486-4580
Bechtel 3000 Post Oak Blvd. Houston, TX 77056 www.bechtel.com	713-235-2000	713-960-9031
Bexar Energy Holdings, Inc. 105 So. Saint Mary's, Suite 1922 San Antonio, TX 78205	210-342-7106	210-308-7250
Bill Spitzer & Associates 11530 Brittmoore Park Dr. Houston, TX 77041 www.spitzer-assoc.com	713-937-8977	713-937-1856
Black & Veatch Pritchard, Inc. Black & Veatch-Gas, Oil & Chemicals Division 11401 Lamar Overland Park, KS 66211 11111 Richmond Ave., Suite 300 Houston, TX 77082 www.bv.com	913-458-2000 713-260-0454	913-458-6098 713-260-0460
Boots & Coots, Inc. 11615 No. Houston-Rosslyn Rd. Houston, TX 77086 www.bncg.com	281-931-8884, 800-BLOWOUT	281-931-8302
Bowden Construction Co., Ltd. P. O. Box 12308 Odessa, TX 79768	432-366-8877	432-366-0936
Brice Equipment Company P. O. Box 7945 Midland, TX 79708	432-697-3111	432-697-6805
Bryan Research & Engineering, Inc. P. O. Box 4747 Bryan, TX 77805 www.bre.com	979-776-5220	979-776-4818
C3 Resources 2050 No. Loop W., Suite 227 Houston, TX 77018-8111 www.c3resources.com	713-476-9958	713-476-9975

Company & Address	Phone	Fax
CAP-HIS Emissions Reduction Systems 9837 Whithorn Dr. Houston, Texas 77095 www.cleanairpartners.com	281-463-8883	281-463-8951
Cardinal Gas Services, LLC 1700 Pacific Ave., Suite 2950 Dallas, TX 75201	214-468-0700	214-468-0701
Caterpillar, Inc. - Global Petroleum Group 13105 NW Freeway, Suite 1010 Houston, TX 77040 www.cat.com	713-329-2207	713-329-2211
CB&I Howe-Baker Process & Technology 3102 E. 5th St. Tyler, TX 75701 www.cbiepc.com	903-595-7911	903-595-7751
CCR Technologies Inc. 11375 W. Sam Houston Parkway So. Suite 201 Houston, TX 77031 www.reclaim.com	281-988-5800	281-988-5858
Chandler Engineering Company, LLC 2001 No. Indianwood Ave. Broken Arrow, OK 74012 www.chandlereng.com	918-250-7200	918-459-0165
Chart Heat Exchangers 2191 Ward Ave. La Crosse, WI 54601 www.chart-ind.com	608-787-3333	608-787-2141
Chart Inc. - Process Systems Division 20 Walkup Dr. Westborough, MA 01581 www.chart-ind.com	508-898-0361	—
Chiyoda Corporation 2-12-1, Tsurumichuo, Tsurumi-ku Yokohama 230-8601, JAPAN	81-45-506-7337	81-45-506-7085
City Pipe & Supply Corp. 2108 W. 2nd Odessa, TX 79763 www.citypipe.com	800-688-7473, 432-332-1541	432-333-2300
Clayton Hamm, Cryogenic Specialist 1104 Red Oak Rd. W. Red Oak, TX 75154	972-576-0329, 214-704-9831	—
CLOUGH Limited Level 6, 251 St. Georges Terrace Perth, 6000 WESTERN AUSTRALIA www.clough.com.au	618-9281-9281	618-9481-6699
Coastal Chemical Co., LLC 5300 Memorial Dr., Suite 250 Houston, TX 77007-8250 www.coastalchem.com	713-865-8787	713-865-8788
Coastal Flow Measurement, Inc. 2222 Bay Area Blvd., Suite 200 Houston, TX 77058 www.coastalflow.com	281-282-0622, 800-231-9741	281-282-0792
Comau Pico 120 W. Virginia St., Suite 211 McKinney, TX 75069	972-562-0087	503-214-5598
Compressor Controls Corporation 4725 121st St Des Moines, IA 50323 www.cccglobal.com	515-270-0857	515-270-1331
Compressor Engineering Corporation 5440 Alder Houston, TX 77081-1798 www.ceconet.com	800-879-2326	713-664-6444

PILOT EXHIBIT 2027 PAGE 071
SCOUT/CHEVRON v. PILOT - IPR2024-00385

Company & Address	Phone	Fax
Compressor Systems, Inc. P. O. Box 60760 Midland, TX 79711 www.compressor-systems.com	432-563-1170	432-563-0760
CompressorTech Two 20855 Watertown Rd., Suite 220 Waukesha, WI 53186 www.dieselpub.com	262-832-5000	262-832-5075
Connelly-GPM, Inc. 3154 So. California Ave. Chicago, IL 60608-5112 www.connellygpm.com	773-247-7231	773-247-7239
Continental Products of Texas P. O. Box 3627 Odessa, TX 79760 www.cptonline.com	432-337-4681	432-337-4685
Control Microsystems 3914 Cypresswood Dr. Spring, TX 77388 www.controlmicrosystems.com	281-651-6300	—
Cook Compressor Group 5411 So. 125th E. Ave., Suite 305 Tulsa, OK 74146 www.cookcompressor.com	800-767-6689	918-252-0380
Cooper Energy Services 714 Darnel Mesquite, TX 75149-5328 www.coopercameron.com	972-602-6810	972-285-5855
Cosa Instrument Corporation 84 Horseblock Rd., Unit G Yaphank, NY 11980 www.cosa-instrument.com	631-345-3434	631-345-5349
Criterion Catalyst & Technologies, LP Two Greenspoint Plaza 16825 Northchase Dr., Suite 1000 Houston, TX 77060 www.criterioncatalysts.com	281-875-7899	281-874-2474
CrystaTech, Inc. 4616 W. Howard Lane, No. 2500 Austin, TX 78728-6302 www.crystatech.com	512-371-0649	512-248-6301
Daniel Measurement and Control 9720 Old Katy Rd. Houston, TX 77055 www.daniel.com	713-827-3874	713-827-3886
DCG Partnership 1, Ltd. 4170 A Main Pearland, TX 77581 www.dcgpartnership.com	281-648-1894	281-648-1895
Dickson & Tryer Engineering Co., Ltd. P. O. Box 60478 Midland, TX 79711-0478 www.dicksontryer.com	432-561-8594	432-561-8990
Domain Engineering Inc. 406 So. Boulder, Suite 234 Tulsa, OK 74103 www.domain-engineering.com	918-582-4280	918-582-4283
Drake Controls, LLC 5227 Langfield Rd. Houston, TX 77040 www.drakecontrols.com	713-996-0190	713-996-0195
Dresser-Rand Company P. O. Box 560 Paul Clark Drive Olean, NY 14760 www.dresser-rand.com	716-375-3000, 713-935-3484	716-375-3178
Dufour Petroleum Inc. P. O. Box 1184 Petal, MS 39465-1184	601-583-9991	601-583-9881

Company & Address	Phone	Fax
Eaton Metal Products Company 4800 York St. Denver, CO 80216 www.eatonmetal.com	303-296-4800	303-296-5736
Elkhorn Construction, Inc. 71 Allegiance Circle Evanston, WY 82930 www.elkhornconstruction.com	307-789-1595	307-789-7145
Elliott Turbomachinery Co. Inc. P. O. Box 4366 Houston, TX 77210-4366 www.elliott-turbo.com	713-984-3800	713-984-3905
Ellipsys, Inc. 6750 W. Loop So., Suite 840 Bellaire, TX 77401 www.ellipsys.com	713-852-9595	713-667-9010
eLynx Technologies, LLC 6655 So. Lewis Ave. Tulsa, OK 74136 www.elynxtech.com	918-496-8500	918-496-8615
Energy Dynamics, Ltd. (EnDyn, Ltd.) 300 W. First St. Alice, TX 78332 www.endyn.com	361-668-8311	361-668-3906
Energy Compression Systems 1319 So. Padre Island Dr. Corpus Christi, TX 78416 www.energycompression.qpg.com	361-882-7900	361-888-6497
Engelhard Corporation 101 Wood Ave. Iselin, NJ 08830 www.engelhard.com	732-205-6979	732-205-5915
Entero Corporation 440 - 2nd Ave. SW, Suite 1500 Calgary, AB, CANADA, T2P 5E9 www.entero.com	403-261-1820, 877-261-1820	403-261-2816
EPC, Inc. 14128 Hwy. 110 So. Whitehouse, TX 75791	903-939-1555	903-939-1566
eSimulation, Inc. 14102 Champion Village Dr. Houston, TX 77069 www.esimulation.com./	713-962-3107	—
Eurecat US Inc. 13100 Bay Park Rd. Pasadena, TX 77507	281-218-0669	—
Exline, Inc. 3256 E. Country Club Rd. Salina, KS 67401 www.exline-inc.com./	800-255-0111	785-826-4425
Fairfield Energy Consultants 10915 Holly Springs Houston, TX 77042	713-780-2767	713-266-7049
Fesco Ltd. 1408 E. Main Alice, TX 78332 www.fescoinc.com	361-664-3479	361-664-3157
Fisher Controls International Inc. P. O. Box 190 Marshalltown, IA 50158 www.emersonprocess.com/ fisher/index.html	641-754-3011	641-754-2903
Fluor Enterprises, Inc. Oil and Gas Group One Fluor Daniel Drive Aliso Viejo, CA 92698 www.fluor.com	949-349-4486	949-349-5458
Ford, Bacon & Davis 7825 Park Place Blvd. Houston, TX 77087	713-845-4345, 713-645-4141	713-645-4240

PILOT EXHIBIT 2027 PAGE 072
SCOUT/CHEVRON v. PILOT - IPR2024-00385

Company & Address	Phone	Fax
ForeRunner Corporation 411 No. Sam Houston Parkway E. Suite 250 Houston, TX 77060 www.forerunnercorp.com	832-327-0442	832-327-0447
Foster Wheeler USA Corporation 2020 Dairy Ashford Houston, TX 77077 www.fwc.com	281-597-3000	281-597-3028
FWMurphy 5311 So. 122nd E. Ave. Tulsa, OK 74146 www.fwmurphy.com	918-317-4100	918-371-4266
GARZO, Incorporated 4430 Steffani Lane Houston, TX 77041 www.garzoproducts.com	713-466-8679	713-466-8686
Gas Analytical Solutions, Inc. P. O. Box 131147 Tyler, TX 75113-1147	903-581-0017	903-581-5036
Gas Packagers, Inc. 1609 E. 58th Ave. Denver, CO 80216 www.thecompressorcompany.com	303-297-8100	303-297-2765
Gas Technology Corporation 1425 Greenway Dr., Suite 450 Irving, TX 75038 www.gastech.net	972-255-7800	972-550-0071
Gas Technology Products LLC 846 E. Algonquin Rd., Suite A100 Schaumburg, IL 60173	847-285-3850	847-285-3888
GasTech Engineering Corporation 1007 E. Admiral Blvd. Tulsa, OK 74120 www.gastecheng.com	918-663-8383	918-599-9846
Gateway Energy Corporation 500 Dallas St., Suite 2615 Houston, TX 77002 www.gatewayenergy.com	713-336-0844 xt 102	713-336-0855
GE Oil & Gas 540 E. Rosecrans Ave. Gardena, CA 90248	310-329-8447	310-329-8708
Glaucon Capital Partners, LLC 21 Carlton Dr. Mt. Kisco, NY 10549	914-666-4789	435-604-8437
GPM Solutions, Inc. 202 Madison Square Colleyville, TX 76034	817-821-8107	—
GRACE Davison Process Adsorbents 20333 State Hwy. 249, Suite 200 Houston, TX 77070 www.gracedavison.com	281-378-1591	281-378-1593
Graves Analytical Services LLC P. O. Box 253 Hugoton, KS 67951 www.gaspeak.com	620-428-6053, 620-420-2277	620-428-6069
Gregg Industrial Insulators, Inc. 201 Estes Dr. Longview, TX 75603-1726	903-757-5754	903-757-8864
Gulf Coast Chemical, Inc. 220 Jacqulyn St. Abbeville, LA 70510	337-898-0213	337-893-1563
Gulf Coast Dismantling P. O. Box 5249 Pasadena, TX 77508-5249	281-487-0595	281-487-0597
Gulsby Engineering, Inc. P. O. Box 549 Humble, TX 77347	281-446-4230	281-446-5445

Company & Address	Phone	Fax
H. J. Baker, P.E. 1511 Rock Ridge Dr. Cleveland, OK 74020	918-358-5286	425-928-2637
H & S Valve Inc. 6704 No. County Rd. West Odessa, TX 79764	432-362-0486	432-368-5052
Hammco, Inc. 6900 No. 115th E. Ave. Owasso, OK 74055 www.hammco-aircoolers.com	918-272-9575	918-272-9585
Hanover Compression, L.P. 20602 E. 81st St. Broken Arrow, OK 74015	918-259-2338	918-259-2856
Harris Group Inc. 1999 Broadway, Suite 1500 Denver, CO 80202 www.harrisgroup.com	303-291-0355	303-291-0136
Hart's Gas Processors Report 800 Wilcrest Dr., #125 Houston, TX 77042	713-975-7590	713-975-9029
Hawkins Filtration Products Inc. 1401 W. Detroit Broken Arrow, OK 74012 www.westernfilterco.com	918-258-5528	918-258-5520
HOAD Inc. P. O. Box 168 Ft. Lipton, CO 80621	303-857-0956	303-857-9415
Holloman Corporation 5257 W. I-20, P.O. Box 69410 Odessa, TX 79768	432-381-2000	432-381-6200
HPF Consultants, Inc. 601 No. Marienfeld, Suite 107 Midland, TX 79701 www.hpfconsultants.com	432-685-4143	432-685-4145
HPT Inc. 6202 So. Lewis, Suite N Tulsa, OK 74136	918-749-9993	918-745-2471
HT Engineering, Inc. 802 Merritt St. SE Grand Rapids, MI 49507-3398 www.htengineering.com	616-452-3279	616-452-3290
Hudson Products Corporation 1307 Soldiers Field Sugar Land, TX 77479 www.hudsonproducts.com	281-275-8100	281-275-8211
Huntsman Corporation 3040 Post Oak Blvd. Houston, TX 77056 www.huntsmangastreating.com	713-235-6000	713-235-6977
Huzyk Energy Management, Inc. 2118 So. Milwaukee St. Denver, CO 80210 www.huzykenergy.com	303-692-9113	303-692-8992
Hy-Bon Engineering Company, Inc. 2404 Commerce Drive Midland, TX 79704 www.hy-bon.com	432-697-2292	432-697-2310
Hydrocarbon Technology Engineering P.O. Box 7347 Grand Rapids, MI 49510-7347 www.htengineering.com	616-452-3279	616-452-3290
Ignition Systems & Controls, LP P. O. Box 60372 Midland, TX 79711 www.ignition-systems.com	432-697-6472	432-697-0563
INEOS Oxide 2925 Briarpark Dr., Suite 870 Houston, TX 77042 www.gastreating.com/	713-243-6200	713-243-6220

PILOT EXHIBIT 2027 PAGE 073
SCOUT/CHEVRON v. PILOT - IPR2024-00385

Company & Address	Phone	Fax
Ingenieros Consultores y Asociados, CA Edif. Residencias Las Americas, Local No. 4, Calle Cecilio Acosta entre Av. Santa Rita y Bellas Vista Maracaibo, Venezuela www.gas-training.com	613-823-4683	—
Inspectorate America Corporation 131 No. Pasadena Blvd. Pasadena, TX 77506	713-477-1567	713-477-4032
Intertek Caleb Brett 2200 W. Loop So. Houston, TX 77027 www.itscb.com	713-407-3600	713-407-3612
Invensys Foxboro 33 Commercial St. Foxboro, MA 02035-2099 www.foxboro.com	866-746-6477	508-549-4999
IPSI LLC P. O. Box 2166 Houston, TX 77252-2166 www.ipsi.com	713-235-2400	713-235-1612
J-W Measurement Company 20612 So. Hwy. 75 Mounds, OK 74047 www.metrongas.com	918-827-5770	918-827-5773
J-W Operating Company (J-W Power Co., Compression Services; J-W Measurement Co., Measurement Services) P. O. Box 226406 Dallas, TX 75222 www.jwoperating.com	972-233-8191	972-991-0704
J. W. Williams, Inc. P. O. Box 2106 Casper, WY 82602 www.jwwilliams-flint.com	307-237-8345	307-234-1530
Jacobs Engineering Group Inc. 5995 Rogerdale Rd. Houston, TX 77072	832-351-6000	832-351-7701
Jet Specialty 1208-A North Council Rd. Oklahoma City, OK 73127	405-789-5260	405-499-9840
JFE Engineering Corporation 2-1, Suehiro-cho, Tsurumi-Ku Yokohama 230-8611, Japan www.jfe-eng.co.jp	81-45-505-7772	81-45-505-8941
JGC Corporation 2-3-1 Minato Mirai, Nishi-ku Yokohama 220-6001 Japan 10370 Richmond Ave., Suite 800 Houston, TX 77024, USA www.jgc.co.jp	81-45-682-1111 713-789-1441	81-45-682-1112 713-789-1348
JHF Safety Consulting LLC P. O. Box 1725 Brownwood, TX 76804 jhfsafetyconsultingllc@hotmail.com	915-784-8540	—
John M. Campbell & Company 1215 Crossroads Blvd. Norman, OK 73072 www.jmcampbell.com	405-321-1383	405-321-4533
Johnson Filtration Products, Inc. P. O. Box 30010 Amarillo, TX 79120-0010 www.johnsonfiltration.com	806-371-8033	806-372-5257
Johnson Matthey Catalysts (formerly Synetix) 1100 Hercules Ave., Suite 200 Houston, TX 77058-2759 www.jmcatalysts.com	713-528-8064	713-528-8103

Company & Address	Phone	Fax
Kams, Inc. 1831 NW 4th Dr. Oklahoma City, OK 73106 www.kamsinc.com	405-232-2636, 800-228-KAMS	405-232-3107
Kane Environmental Engineering, Inc. 5307 Oakdale Creek Court Spring, TX 77379	281-370-6580	281-379-3935
KBR 601 Jefferson Ave. Houston, TX 77002-7990 P. O. Box 3 Houston, TX 77001-0003 www.kbr.com	713-753-2000	713-753-3877
Kimray, Inc. P. O. Box 18949, 52 NW 42nd Oklahoma City, OK 73154 www.kimray.com	405-525-6601	405-525-7520
KnightHawk Engineering 17625 El Camino Real, Suite 412 Houston, TX 77058 www.knighthawk.com	281-282-9200	281-282-9333
Koch-Glitsch LP 4111 E. 37th No. Wichita, KS 67220-3203 www.kochglitsch.com	316-828-5110	316-828-5263
Krause, Inc. Engineers - Architects 10 So. Briar Hollow Lane, Suite 93 Houston, TX 77027	713-552-1200	713-552-1201
Krueger Engineering & Mfg. Co., Inc. P. O. Box 11308 Houston, TX 77293-1308 www.kemco.net	281-442-2537	281-442-6668
Kvaerner Process Systems US 7909 Parkwood Circle, 6th Flr. Houston, TX 77036	281-820-1171	281-820-1174
Linde BOC Process Plants LLC 8522 E. 61st St. Tulsa, OK 74133 www.lindebocpp.com	918-250-8522	918-250-6915
Loco Energy Company, LLC 1001 McKinney, Suite 520 Houston, TX 77002 www.locoenergy.com	713-655-9500	713-655-1281
Lomic, Inc. 100 N. Patterson, Suite 202 State College, PA 16801 www.lomic.com	814-238-5225	814-238-5315
Louisiana Chemical Equip. Co. LLC P. O. Box 1490 La Porte, TX 77572-1490	281-471-4900	281-471-2968
M & H Enterprises, Inc. 2900 Wilcrest, Suite 300 Houston, TX 77042	713-268-2193	713-974-0711
Mafi-Trench Corporation 3037 Industrial Parkway Santa Maria, CA 93455 www.mafi-trench.com	805-928-5757	805-925-3861
Manley Gas Testing, Inc. 120 Dock Road Odessa, TX 79762	432-367-3024	432-367-1166
Marlboro Enterprises, Inc. 5959 Shallowford Rd., Suite 511 Chattanooga, TN 37421-2240	423-308-3000	423-308-3040
Marsau Enterprises 1209 N. 30th Enid, OK 73701	580-233-3910	580-233-5063
Martin Energy Consultants P. O. Box 8064 The Woodlands, TX 77387	281-367-9401	281-367-0540

PILOT EXHIBIT 2027 PAGE 074
SCOUT/CHEVRON v. PILOT - IPR2024-00385

Company & Address	Phone	Fax
Master Corporation P. O. Box 831, Odessa, TX 79760-0831 4682 E. University, Suite A Odessa, TX 79762-8104 www.mastercorporation.com	432-550-2197	432-362-5166
Maxxam Analytics Inc. 9331 - 48 St Edmonton, AB, CANADA, T6B 2R4 www.maxxamanalytics.com	780-468-3500	780-468-3560
McJunkin Corporation P. O. Box 4395 Odessa, TX 79762 www.mcjunkin.com	432-332-8131	432-332-8132
Mechanical Equipment, Inc. 2525 E. I-20 Midland, TX 79701	432-687-0601	432-687-0810
Mid Continent Measurement Co. P. O. Box 49 Bristow, OK 74010	918-367-5517	918-367-9392
Miratech Corp. 4224 So. 76th E. Ave. Tulsa, OK 74145 www.miratechcorp.com	918-622-7077	918-663-5737
Mitsubishi Heavy Industries, Ltd 3-3-1, Minatomirai, Nishi-ku Yokohama 220-8401, JAPAN www.mhi.co.jp	045-224-9393	045-224-9948
Mobile Analytical Laboratories, Inc. P. O. Box 69210 Odessa, TX 79769 www.mobilelabs.com	432-337-4744	432-337-8781
Moore Control Systems, Inc. 1435 Katy Flewellen Katy, TX 77494 www.moore-control.com	281-392-7747	281-392-7727
Morgan Advanced Materials & Technology 1212 Milby Houston, TX 77023	713-224-9015	713-224-7527
MPR Services, Inc. 1201 FM 646 Dickinson, TX 77539-3014 www.mprserve.com	281-337-7424	281-337-6534
Multiphase Solutions, Inc. Two Park Ten, 16300 Katy Freeway, Suite 300 Houston, TX 77094 www.multiphase.com	281-646-1515	281-646-8700
Mustang Engineering, LP 16001 Park Ten Place Houston, TX 77084 www.mustangeng.com	713-215-8000	713-215-8506
Myers-Aubrey Co. 7477 E. 46th Pl. Tulsa, OK 74145	918-622-3500	918-628-0349
NATCO Group Inc. 2950 No. Loop W., Suite 750 Houston, TX 77092 www.natcogroup.com	713-683-9292	713-683-6768
National Petroleum & Energy Services, Inc. 105A W. Washington St. Rockwall, TX 75087 www.npesi.com	972-463-8225	972-463-8226
Natural Gas Liquids, Inc. 1415 Eldridge, #617 Houston, TX 77077 www.ngliquids.com	281-759-4700	281-759-4898
Nicholas Consulting Group, Inc. 600 No. Marienfeld, Suite 390 Midland, TX 79701 www.thencg.com	437-570-8093	432-683-1993

Company & Address	Phone	Fax
Nicol & Associates, Inc. 331 Melrose Dr., Suite 121 Richardson, TX 75080 www.nicolandassoc.com	972-437-9136	972-437-5443
Nomis Venture, LLC 7722 E. 102nd St. Tulsa, OK 74133 www.nomis.com	918-369-5773	918-369-5773
NORIT Americas Inc. 5775 Peachtree Dunwoody Rd., Building C, Suite 250 Atlanta, GA 30342 www.norit-americas.com	404-256-6150	404-256-6199
Nowata Filtration, Division of NMW, Inc. P.O. Box 678 Nowata, OK 74048 www.nowata.com	800-259-2204	918-273-2101
Oilphase - DBR 9419 - 20 Ave. Edmonton, AB, T6N 1E5, Canada www.oilphase-dbr.com	780-463-8638	780-450-1668
ONDEO Nalco Energy Services, L.P. 2307 Quarterpath Dr. Richmond, TX 77469	281-263-7716	281-263-7154
OPIS Energy Group 1255 Rte. 70, Suite 32N Lakewood, NJ 08701	732-901-8800	732-901-9632
Optimized Gas Treating, Inc. 15638 Whitewater Lane Houston, TX 77079 www.ogtrt.com	281-496-2729	281-496-2729
Optimized Pipeline Solutions, Inc. 1220 W. Cleburne Rd. Crowley, TX 76036 www.ops-services.com	817-297-3811	817-297-2859
Optimized Process Designs 25610 Clay Rd. Katy, TX 77493 www.opd-inc.com	281-371-7500	281-371-0132
Optimized Process Furnaces 3995 So. Santa Fe Chanute, KS 66720 www.firedheater.com	620-431-1260	620-431-6631
Orbit Valve Co. P. O. Box 193520 Little Rock, AR 72219-3520 7200 Interstate 30 Little Rock, AR 72209 www.orbitvalve.com	501-568-6000, 800-643-6544	501-570-5700
Ormat Technologies, Inc. 980 Greg Street Sparks, NV 87431 www.ormat.com	775-356-9029	775-356-9039
Ortloff Engineers, Ltd. 415 W. Wall, Suite 2000 Midland, TX 79701 www.ortloff.com	432-685-0277	432-685-0258
Pantechs Laboratories, Inc. P. O. Box 64489 Lubbock, TX 79464-4489 www.pantechs.com	800-687-6346	806-797-4474
Paragon Engineering Services, Inc. 10777 Clay Rd. Houston, Texas 77041-5497 www.paraengr.com	713-570-1000	713-570-8922
Parker Hannifin Corporation Finite Filter Operation 500 Glaspie St. Oxford, MI 48371 www.finitefilter.com	800-521-4357	248-628-1850

PILOT EXHIBIT 2027 PAGE 075
SCOUT/CHEVRON v. PILOT - IPR2024-00385

Company & Address	Phone	Fax
Parsons Energy & Chemicals Group Inc. 125 W. Huntington Dr. Arcadia, CA 91007 www.parsonsec.com	626-294-3582	626-294-3311
Pasadyn, Inc. 4411 Bluebonnet Dr., Suite 103 Stafford, TX 77477 www.pasadyn.com	281-240-7404	281-240-7409
Pearl Development Company 460 Park County Rd. 43 Bailey, CO 80421 www.pearldc.com	303-838-8090	303-838-1630
Peerless Mfg. Co. 2819 Walnut Hill Lane Dallas, TX 75229 www.peerlessmfg.com	214-357-6181	214-351-0194
Perry Equipment Corporation P. O. Box 640 Mineral Wells, TX 76068 www.pecousa.com	800-877-7326, 940-325-2575	940-325-4622
Petroleum Extension Service (PETEX), The University of Texas at Austin One University Station, MC: R8100 Austin, TX 78712-1100 www.utexas.edu/cee/petex	512-471-3150, 903-984-8689	512-471-9410, 903-984-8483
Pioneer Pipe 1660 Lincoln, Suite 2300 Denver, CO 80264	303-824-2224	303-289-6381
Porous Media 4301 W. Davis Conroe, TX 77304 www.porous.com	936-788-1000	936-788-1220
Premier Measurement Services 19302 Allview Lane Houston, TX 77094	281-492-1002	281-492-0541
Prosernat Tour Framatome 92084 Paris La Defense Cedex, France www.prosernat.com	33-147-9601-80	33-147-9602-50
Puffer-Sweiven Co. P. O. Box 2000 Stafford, TX 77477	713-274-1873	713-274-6438
Q. B. Johnson Mfg., Inc. P. O. Box 95129 Oklahoma City, OK 73143	405-677-6676	405-670-3270
Q2 Technologies P. O. Box 2927 Conroe, TX 77305 www.q2technologies.com	936-588-2242	936-588-2298
Quadra Chemicals P. O. Box 12430 Ogden, UT 84412 www.quadrachemicals.com	801-392-5950	801-392-5951
Questar Energy Services 1210 D St. Rock Springs, WY 82901 www.questenergy.com	888-777-0262, 307-352-7292	307-352-7326
Quorum & Associates P.O. Box 1144 Bridgeport, TX 76426-1144 www.quorumandassociates.com	940-575-4951	940-575-4961
Quorum Business Solutions, Inc. 2929 Briarpark Dr., Suite 215 Houston, TX 77042 www.qbsol.com	713-430-8604	713-430-8699
R & R Engineering Co. Inc. P.O. Box 700005 Tulsa, OK 74170	918-252-2571	—

Company & Address	Phone	Fax
Randall & Dewey, Inc. 16800 Greenspoint Park Dr. Suite 300-S Houston, TX 77060 www.randew.com	281-774-2000	281-774-2050
Randall Gas Technologies - ABB Lummus Global Inc. 3010 Briarpark Houston, TX 77042 www.randallgastech.com	713-821-4100	713-821-3538
Ref-Chem L.P. P.O. Box 2588 Odessa, TX 79760 www.ref-chem.com	432-332-8531	432-332-3325
Regard Resources Co., Inc. 330 Marshall St., Suite 700 Shreveport, LA 71101	318-425-2533	318-425-1014
Rhine Ruhr Pty Ltd. 19-21 Industrial Dr. Sunshine, Victoria 3020, Australia www.rhineruhr.com.au	03-9300-5000	03-9300-5001
Rike Service, Inc. Box 13786 New Orleans, LA 70185	504-827-0161	504-822-7599
River City Engineering, Inc. 1202 E. 23rd St., Suite B Lawrence, KS 66046 www.rivercityeng.com	785-842-4783	785-842-1450
Robert L. Rowan & Associates, Inc. 3816 Dacoma St. Houston, TX 77092	713-681-5811	—
Rockwell Automation 1221 So. 11th St. Kingfisher, OK 73750	405-375-4970	—
Rolls-Royce Energy Business 105 No. Sandusky St. Mount Vernon, OH 43050 www.rolls-royce.com	740-393-8888	740-393-8336
Rotor-Tech, Inc. 10613 Stebbins Circle Houston, TX 77043 www.rotor-tech.com	713-984-8900	713-984-9425
Rouly, Inc. 1506 W. Broadway Pl. Hobbs, NM 88240	505-393-4254	505-393-1886
Royal Filter Manufacturing Co., Inc. 4327 South 4th St. Chickasha, OK 73018 www.royalfilter.com	800-256-2559	405-224-9174
RW Beck Inc. 1801 California St., Suite 2800 Denver, CO 80202 www.rwbeck.com	303-299-5216	303-297-2811
RSC International 11931 Wickchester, Suite 201 Houston, TX 77043 www.rsc-gc.com	281-531-0001	281-531-0011
S & B Engineers and Constructors 7825 Park Pl. Blvd Houston, TX 77087 www.sbec.com	713-845-4345, 713-645-4141	713-645-4240
S-Con, Inc. 2925 FM 1960 E. Humble, TX 77338 www.sconinc.com	281-540-7266	281-540-1568
Saulsbury Industries 5308 Andrews Hwy. Odessa, TX 79762 www.si-tx.com	432-366-3686	432-368-0081

PILOT EXHIBIT 2027 PAGE 076
SCOUT/CHEVRON v. PILOT - IPR2024-00385

Company & Address	Phone	Fax
SCFM Compression Systems Co. 3701 So. Maybelle Ave. Tulsa, OK 74107-5708 www.scfm.com	918-663-1309	918-663-6140
Scott Specialty Gases 9810 Bay Area Blvd. Pasadena, TX 77507	281-909-3105	281-474-2127
Select Engineering, Inc. 324 So. Main, Suite 510 Tulsa, OK 74103-3679 www.select-engineering.com	918-592-1133	918-592-1134
Separation Systems, Inc. 100A Nightingale Lane Gulf Breeze, FL 32561	904-932-1433	904-934-8642
SGS Minerals Services (formerly Commercial Testing & Engineering) 1212 No. 39th St., Suite 323 Tampa, FL 33605 www.sgs.com	813-248-6566	813-247-2562
Shamrock Gas Analysis 1100 So. Madden Shamrock, TX 79079	806-256-3249	806-256-3159
Sherry Laboratories/LA 2129 W. Willow St. Scott, LA 70583 www.sherrylabs.com	337-232-3568	337-232-3621
Siemens Demag Delaval 840 Nottingham Way Trenton, NJ 08638 www.pg.siemens.com	609-890-5000	609-890-9180
Simms Machinery International Inc. 2035 No. Preisker Lane, Unit C Santa Maria, CA 93454	805-349-2540	805-349-9959
Sivalls, Inc. 2200 E. 2nd St. Odessa, TX 79761	915-337-3571	915-337-2624
SME Associates 11211 Katy Freeway, Suite 380 Houston, TX 77079	713-932-7611	713-932-7623
Smithco Engineering, Inc. 6312 So. 39th W. Ave. Tulsa, OK 74132 www.smithco-eng.com	918-446-4406	918-445-2857
Solar Turbines, Incorporated 13105 NW Freeway, Suite 400 Houston, TX 77040 www.solarturbines.com	713-895-2300	713-895-4270
SolArc, Inc. 320 So. Boston Ave., Suite 600 Tulsa, OK 74103 www.solarc.com	918-594-7320	918-594-7330
South-Tex Treaters, Inc. P. O. Box 60480 Midland, TX 79711 www.southtex.com	432-563-2766	432-563-1729
Southern Flow Companies P. O. Box 51475 Lafayette, LA 70505-1475	318-233-2066	318-233-0314
SPL, Inc. 8880 Interchange Dr. Houston, TX 77054 www.spl-inc.com	713-660-0901	713-660-6035
SulfaTreat 17998 Chesterfield Airport Rd. Suite 215 Chesterfield, MO 63005 www.sulfatreat.com	800-726-SOUR	636-532-2764

Company & Address	Phone	Fax
Sulzer Chemtech 4106 New W. Dr. Pasadena, TX 77507 4019 So. Jackson Tulsa, OK 74107 www.sulzerchemtech.com	281-604-4100 918-446-6672	281-291-0207 918-446-5321
Sundyne Corporation 14845 W. 64th Ave. Arvada, CO 80007 www.sundyne.com	303-425-0800	303-425-0896
Surface Production Systems 580 Westlake Park Blvd., Suite1501 Houston, TX 77079	281-589-1808	281-589-2638
T. F. Hudgins, Inc. 4405 Directors Row Houston, TX 77092 www.tfhudgins.com	713-682-3651	713-682-1109
Technip USA Corporation 1990 Post Oak Blvd., Suite 200 Houston, TX 77056 www.technip-coflexip.com	281-249-2300	281-249-2321
Technology Trade International, Inc. P. O. Box 821341 Houston, TX 77282-1341 www.tti-usa.com	281-920-0648	281-920-0638
TECNA ESTUDIOS Y PROYECTOS DE INGENIERIA SA Encarnacion Ezcurra 365, C1107CLA Buenos Aires, Argentina www.tecna.com	[54-11] 4347-0300	[54-11] 4347-0800
Texas Turbine Inc. 624 Profit Street Azle, TX 76020 www.txturbine.com	817-444-5528	817-444-3925
The ADEPT Group, Inc. 10866 Wilshire Blvd., Suite 350 Los Angeles, CA 90024 www.adept@adeptgroup.net/	310-441-4404	310-441-3001
The Arrington Corporation P. O. Box 131749 Tyler, TX 75713-1749 www.arringtoncompanies.com	903-894-6157	903-894-7428
The Hanover Company 12001 No. Houston Rosslyn Houston, TX 77086 www.hanover-co.com	800-950-8428	281-447-8790
The Lubrizol Corporation 29400 Lakeland Blvd. Wickliffe, OH 44092-2298 www.lubrizol.com	440-347-6721	440-347-6587
The Propane Market Strategy Letter P. O. Box 691976 Houston, TX 77269-1976 www.thepropaneletter.com	281-583-0656	281-583-0656
Thermo Electron Cooperation 2215 Grand Avenue Pkwy Austin, TX 78728	512-251-1400, 512-251-1597	—
Third Coast Terminals 1871 Mykawa Pearland, TX 77581 www.3cterminals.com	281-412-0275	281-412-0073
Thomas Petroleum Ltd. P. O. Box 1876 Victoria, TX 77902 www.thomaspetro.com	361-573-7662, Ext. 122	928-395-8374
Thomas Russell Co. 7050 So. Yale, Suite 210 Tulsa, OK 74136 www.thomasrussellco.com	918-481-5682	918-481-7427

PILOT EXHIBIT 2027 PAGE 077
SCOUT/CHEVRON v. PILOT - IPR2024-00385

Company & Address	Phone	Fax
Thomason Mechanical Corp. 2150 E. 37th St. Vernon, CA 90058 www.thomasonmech.com	800-639-3523	310-639-8217
Thurmond-McGlothlin Inc. P. O. Box 806 Woodward, OK 73802 www.tm-ems.com	580-256-9849	580-256-5909
TIC-The Industrial Company Wyoming, Inc. 1474 Willer Drive Casper, WY 82604, P.O. Box 3800 Casper, WY 82602 www.tic-inc.com	307-235-9958	307-266-2053
Tomcej Engineering Inc. P. O. Box 1274 Station Main Edmonton, AB T5J 2M8, Canada www.tomcej.com	780-483-0248	780-483-0248
Toromont Process Systems, Inc. 10815 Telge Rd. Houston, TX 77095 www.toromontprocess.com	281-345-9300	281-345-7434
Total Energy Corp. P.O. Box 757 Croton Falls, NY 10519 www.totalenergy.com	914-276-0490	914-276-0229
Toyo Engineering Corporation 8-1 Akanehama 2-chome Narashino, Chiba, 275-0024 Japan www.toyo-eng.co.jp	47-454-1113	47-454-1160
Trinity Industries, Inc. P. O. Box 568887 Dallas, TX 75356-8887 www.trinitylpg.com	888-558-8529	214-589-8553
Tru-Tec Services Inc. 11005 W. Fairmont Parkway LaPorte, TX 77571 www.tru-tec.com	281-471-8970	281-471-4871
Turnbow Engineering P. O. Box 1604 Bartlesville, OK 74005	918-333-8475	918-331-9639
Unichem, A Div. of BJ Services 707 N. Leech, POB 1499 Hobbs, NM 88240	505-393-7751	505-393-0377
United/Wells P. O. Box 4575 Odessa, TX 79760	432-362-2361	432-381-5000
Univar USA, Inc. 777 Brisbane St. Houston, TX 77061 www.univarusa.com	713-644-1601	713-664-3171
Universal Compression 4444 Brittmore Road Houston, TX 77041 www.universalcompression.com	713-335-7000	713-335-7771
UOP LLC 13105 NW Frwy, Suite 600 Houston, TX 77040 www.uop.com	713-744-2860	713-744-2881
Valve Maintenance Corporation 2234 No. FM 1936 Odessa, TX 79763	432-381-3221	432-381-4010
Vanco Engineering Co. 7033 E. 40 Tulsa, OK 74145	918-627-1920	918-627-6742
Vanson Engineering Co. 1240 No. Van Buren St., Suite 212 Anaheim, CA 92807	714-630-3344	714-630-0384

Company & Address	Phone	Fax
Veco Rocky Mountain, Inc. 9000 E. Nichols Ave., Suite 250 Englewood, CO 80112 www.veco.com	303-792-2211	303-792-2212
Vera & Associates 8327 S. 76th E. Ave. Tulsa, OK 74133	918-254-1422	918-252-9150
Vinson Process Controls 1432 Wainwright Way Carrollton, TX 75007 www.vppco.com	972-389-5700	888-201-6518
W. H. Linder & Associate Inc. 3330 W. Esplanade Ave. So., Suite 300 Metairie, LA 70002 www.whlinder.com	504-835-2577	504-837-5924
W. L. Hamilton Engineering P.C. 1949 Sugarland Dr., Suite 134 Sheridan, WY 82801	307-672-0743	307-672-5118
Walco Recycling Services LLC P. O. Box 5270 Houston, TX 77262	713-926-9277	713-926-9342
Washington Group International, Inc. 7800 E. Union Ave., Suite 100 Denver, CO 80237 www.wgint.com	303-843-2000	303-843-2008
Wasson-ECE Instrumentation 101 Rome Court Ft. Collins, CO 80524 www.wasson-ece.com	970-221-9179	970-221-9364
Waukesha Engine 1000 W. St. Paul Ave. Waukesha, WI 53188 www.waukeshaengine.dresser.com	281-775-4000	281-775-4010
Waukesha-Pearce Industries, Inc. 12320 So. Main Houston, TX 77035 www.wpi.com	713-723-1050	713-551-0799
Welker Engineering Co. P. O. Box 138 Sugar Land, TX 77478-0138 www.welkereng.com	281-491-2331	281-491-8344
Western Filter Co., Inc. 8330 No. County Rd. W. Odessa, TX 79764 www.westernfilterco.com	432-550-9006	432-550-9007
Westfield Engineering & Services, Inc. 8310 McHard Rd. Houston, TX 77053 www.westfieldengineering.com	281-438-2047	281-438-0459
Winn-Marion Barber, LLP 2009 So. Cherokee St. Denver, CO 80223 www.winn-marion.com	303-778-6767	303-733-9836
WinSim Inc. P. O. Box 1885 Houston, TX 77251 13333 SW Fwy, Suite 130 Sugar Land TX 77478 www.winsim.com	281-565-6700	281-565-7593
Yokogawa Corporation of America 5010 Wright Rd., Suite 100 Stafford, TX 77477 www.us.yokogawa.com	281-340-3868	281-340-3838
York Process Systems 5692 E. Houston St. San Antonio, TX 78220 www.york.com	210-661-9191 Ext. 235	210-662-6591

PILOT EXHIBIT 2027 PAGE 078
SCOUT/CHEVRON v. PILOT - IPR2024-00385

Classification of Members

Gas Processors Suppliers Association

6526 East 60th Street
Tulsa, Oklahoma 74145
Phone: 918-493-3872
Fax: 918-493-3875
email: gpsa@gasprocessors.com

SERVICES

The following is a listing of GPSA member companies classified by the type of services that they provide to the industry.

ADVANCED PROCESS CONTROL

Aker Kvaerner, Inc.
Aspen Technology, Inc.
Barry D. Payne & Associates, Inc.
BCCK Engineering, Inc.
BE&K Construction - Houston
CB&I Howe-Baker Process & Technology
Domain Engineering Inc.
Fluor Enterprises, Inc.
ForeRunner Corporation
FWMurphy
Ignition Systems & Controls, LP
Invensys Foxboro
KBR
KnightHawk Engineering
Marlboro Enterprises, Inc.
Master Corporation
Moore Control Systems, Inc.
Mustang Engineering, LP
NATCO Group Inc.
Nicholas Consulting Group, Inc.
Pearl Development Company
Quorum & Associates
SCFM Compression Systems Co.
Thomas Russell Co.
Tru-Tec Services Inc.
W. L. Hamilton Engineering P.C.
Washington Group International, Inc.
Wasson-ECE Instrumentation
Yokogawa Corporation of America

AMINE CLEANING

MPR Services, Inc.

ANALYTICAL LABORATORIES

American Measurement Services
Atofina Chemicals, Inc.
Coastal Flow Measurement, Inc.
DCG Partnership 1, Ltd.
Engelhard Corporation
Fesco Ltd.
Gas Analytical Solutions, Inc.
Graves Analytical Services LLC
Inspectorate America Corporation
Intertek Caleb Brett
J-W Measurement Company
Jet Specialty
Manley Gas Testing, Inc.
Maxxam Analytics Inc.
Mobile Analytical Laboratories, Inc.
MPR Services, Inc.
Pantechs Laboratories, Inc.
Porous Media
Questar Energy Services
SGS Minerals Services
Sherry Laboratories/LA
SPL, Inc.
The Lubrizol Corporation
Thurmond-McGlothlin Inc.
Wasson-ECE Instrumentation

AUDITS

Martin Energy Consultants
SPL, Inc.

CIVIL/STRUCTURAL CONSTRUCTION

Aker Kvaerner, Inc.
BE&K Construction - Houston
Bowden Construction Co., Ltd.
CB&I Howe-Baker Process & Technology
Elkhorn Construction, Inc.
Fluor Enterprises, Inc.
ForeRunner Corporation
Holloman Corporation
KBR

PILOT EXHIBIT 2027 PAGE 079
SCOUT/CHEVRON v. PILOT - IPR2024-00385

CIVIL/STRUCTURAL CONSTRUCTION (Cont'd.)

Linde BOC Process Plants LLC
Master Corporation
National Petroleum & Energy Services, Inc.
Nicholas Consulting Group, Inc.
Optimized Process Designs
Pasadyn, Inc.
Pearl Development Company
Ref-Chem L.P.
S & B Engineers and Constructors
Saulsbury Industries
Technology Trade International, Inc.
TIC-The Industrial Company Wyoming, Inc.
Washington Group International, Inc.
Westfield Engineering & Services, Inc.

COMPRESSOR FOUNDATION REPAIR

Bowden Construction Co., Ltd.
Energy Compression Systems
Exline, Inc.
GE Oil & Gas
Holloman Corporation
Master Corporation
Ref-Chem L.P.
SCFM Compression Systems Co.
Thomason Mechanical Corp.
United/Wells

COMPRESSOR RENTAL, LEASING, & CONTRACT O&M

Compressor Systems, Inc.
Energy Dynamics, Ltd. (EnDyn, Ltd.)
Energy Compression Systems
J-W Measurement Company
J-W Operating Company
Questar Energy Services
Rolls-Royce Energy Business
SCFM Compression Systems Co.
The Hanover Company
Universal Compression

COMPUTER SYSTEM CONSULTANTS (for Software see Industry Software)

Barry D. Payne & Associates, Inc.
Dresser-Rand Company
Ellipsys, Inc.
Master Corporation
Moore Control Systems, Inc.
Mustang Engineering, LP
Quorum Business Solutions, Inc.

CONSULTANT

Entero Corporation
SCFM Compression Systems Co.

CORROSION CONSULTING

Aker Kvaerner, Inc.
Continental Products of Texas
Domain Engineering Inc.
Fluor Enterprises, Inc
HT Engineering, Inc.
Mustang Engineering, LP
National Petroleum & Energy Services, Inc.
Questar Energy Services
Quorum & Associates
Toyo Engineering Corporation

CRITICAL INCIDENT/EMERGENCY RESPONSE

Black & Veatch Pritchard, Inc.
Boots & Coots, Inc.
National Petroleum & Energy Services, Inc.
Quorum & Associates

DEHYDROGENATION SYSTEMS

Aker Kvaerner, Inc.
CB&I Howe-Baker Process & Technology
Fluor Enterprises, Inc.
Pearl Development Company
Ref-Chem L.P.
Westfield Engineering & Services, Inc.

DISMANTLING

Bowden Construction Co., Ltd.
Domain Engineering Inc.
Fluor Enterprises, Inc.
Gulf Coast Dismantling
Holloman Corporation
Marlboro Enterprises, Inc.
Marsau Enterprises
Master Corporation
Optimized Process Designs
Pearl Development Company
Quorum & Associates
Ref-Chem L.P.
Rouly, Inc.
S-Con, Inc.
Technology Trade International, Inc.
United/Wells
Walco Recycling Services LLC
Washington Group International, Inc.

DRAFTING

Aker Kvaerner, Inc.
Albert Garaudy and Associates, Inc.
BCCK Engineering, Inc.
BE&K Construction - Houston
Black & Veatch Pritchard, Inc.
CB&I Howe-Baker Process & Technology
Domain Engineering Inc.
Fluor Enterprises, Inc.
ForeRunner Corporation

PILOT EXHIBIT 2027 PAGE 080
SCOUT/CHEVRON v. PILOT - IPR2024-00385

DRAFTING (Cont'd.)

Gas Packagers, Inc.
GE Oil & Gas
Gulsby Engineering, Inc.
Harris Group Inc.
HPF Consultants, Inc.
HPT Inc.
KnightHawk Engineering
Marlboro Enterprises, Inc.
Master Corporation
Moore Control Systems, Inc.
Mustang Engineering, LP
Natural Gas Liquids, Inc.
Nicholas Consulting Group, Inc.
Nicol & Associates, Inc.
Pasadyn, Inc.
Pearl Development Company
Ref-Chem L.P.
S-Con, Inc.
Saulsbury Industries
Vanson Engineering Co.
Vera & Associates
W. L. Hamilton Engineering P.C.
Washington Group International, Inc.

E-COMMERCE

eLynx Technologies, LLC
Toyo Engineering Corporation

EMISSIONS TESTING

Mechanical Equipment, Inc.

ENGINEERING & DESIGN

Aggreko LLC
Air Products and Chemicals, Inc.
Aker Kvaerner, Inc.
Albert Garaudy and Associates, Inc.
Atofina Chemicals, Inc.
Barry D. Payne & Associates, Inc.
BCCK Engineering, Inc.
BE&K Construction - Houston
Black & Veatch Pritchard, Inc.
CB&I Howe-Baker Process & Technology
Chandler Engineering Company, LLC
Chiyoda Corporation
Compressor Systems, Inc.
Continental Products of Texas
CrystaTech, Inc.
Domain Engineering Inc.
Ellipsys, Inc.
Engelhard Corporation
EPC, Inc.
Fairfield Energy Consultants
Fluor Enterprises, Inc.
Ford, Bacon & Davis
ForeRunner Corporation
Foster Wheeler USA Corporation
Gas Packagers, Inc.
Gas Technology Corporation
Gas Technology Products LLC
GE Oil & Gas
GPM Solutions, Inc.
Gulsby Engineering, Inc.
Harris Group Inc.
Holloman Corporation
HPF Consultants, Inc.
HPT Inc.
HT Engineering, Inc.
Huzyk Energy Management, Inc.
IPSI LLC
J. W. Williams, Inc.
Jacobs Engineering Group Inc.
JFE Engineering Corporation
JGC Corporation
Kams, Inc.
KBR
KnightHawk Engineering
Krause, Inc. Engineers - Architects
Linde BOC Process Plants LLC
Marlboro Enterprises, Inc.
Martin Energy Consultants
Master Corporation
Miratech Corp.
Mitsubishi Heavy Industries, Ltd.
Moore Control Systems, Inc.
Mustang Engineering, LP
National Petroleum & Energy Services, Inc.
Natural Gas Liquids, Inc.
Nicholas Consulting Group, Inc.
Nicol & Associates, Inc.
Optimized Process Designs
Ortloff Engineers, Ltd.
Parsons Energy & Chemicals Group Inc.
Pasadyn, Inc.
Pearl Development Company
Peerless Mfg. Co.
Porous Media
Prosernat
Quorum & Associates
R & R Engineering Co. Inc.
Randall Gas Technologies - ABB Lummus Global Inc.
Ref-Chem L.P.
River City Engineering, Inc.
Rouly, Inc.
S & B Engineers and Constructors
SCFM Compression Systems Co.
S-Con, Inc.
Saulsbury Industries
Select Engineering, Inc.
Technip USA Corporation
Technology Trade International, Inc.
TECNA ESTUDIOS Y PROYECTOS DE INGENIERIA SA
The Arrington Corporation
Thomas Russell Co.
Toyo Engineering Corporation

PILOT EXHIBIT 2027 PAGE 081
SCOUT/CHEVRON v. PILOT - IPR2024-00385

ENGINEERING & DESIGN (Cont'd.)

UOP LLC
Vanson Engineering Co.
Vera & Associates
W. H. Linder & Associate Inc.
W. L. Hamilton Engineering P.C.
Washington Group International, Inc.
Wasson-ECE Instrumentation
Welker Engineering Co.
Westfield Engineering & Services, Inc.
Zeochem, LLC

ENGINEERING CONSULTANTS

Air Products and Chemicals, Inc.
Aker Kvaerner, Inc.
Albert Garaudy and Associates, Inc.
Barry D. Payne & Associates, Inc.
BCCK Engineering, Inc.
BE&K Construction - Houston
Black & Veatch Pritchard, Inc.
Boots & Coots, Inc.
Bryan Research & Engineering, Inc.
CB&I Howe-Baker Process & Technology
Compressor Systems, Inc.
CrystaTech, Inc.
Domain Engineering Inc.
Ellipsys, Inc.
Fairfield Energy Consultants
FESCO Ltd.
Fluor Enterprises, Inc.
ForeRunner Corporation
Foster Wheeler USA Corporation
GE Oil & Gas
GPM Solutions, Inc.
Gulsby Engineering, Inc.
H. J. Baker, P.E.
HPF Consultants, Inc.
HPT Inc.
HT Engineering, Inc.
Huzyk Energy Management, Inc.
IPSI LLC
Jacobs Engineering Group Inc.
JGC Corporation
John M. Campbell & Company
KBR
KnightHawk Engineering
Krause, Inc. Engineers - Architects
Lomic, Inc.
Marlboro Enterprises, Inc.
Martin Energy Consultants
Master Corporation
Mustang Engineering, LP
Natural Gas Liquids, Inc.
Nicholas Consulting Group, Inc.
Nicol & Associates, Inc.
Nomis Venture, LLC
Optimized Process Designs
Ortloff Engineers, Ltd.
Paragon Engineering Services, Inc.
Parsons Energy & Chemicals Group Inc.
Pasadyn, Inc.
Pearl Development Company
Prosernat
Quadra Chemicals
Quorum & Associates
Randall Gas Technologies - ABB Lummus Global Inc.
Ref-Chem L.P.
River City Engineering, Inc.
Rouly, Inc.
RW Beck Inc.
Select Engineering, Inc.
Simms Machinery International Inc.
Technip USA Corporation
Technology Trade International, Inc.
TECNA ESTUDIOS Y PROYECTOS DE INGENIERIA SA
The Arrington Corporation
Tomcej Engineering Inc.
Tru-Tec Services Inc.
Turnbow Engineering
Vanson Engineering Co.
Vera & Associates
W. H. Linder & Associate Inc.
W. L. Hamilton Engineering P.C.
Washington Group International, Inc.
Westfield Engineering & Services, Inc.

ENGINEERING, PROCUREMENT & CONSTRUCTION

Air Products and Chemicals, Inc.
Aker Kvaerner, Inc.
Barry D. Payne & Associates, Inc.
BCCK Engineering, Inc.
BE&K Construction - Houston
Black & Veatch Pritchard, Inc.
CB&I Howe-Baker Process & Technology
Chiyoda Corporation
CLOUGH Limited
Domain Engineering Inc.
Elkhorn Construction, Inc.
EPC, Inc.
Fluor Enterprises, Inc.
Ford, Bacon & Davis
ForeRunner Corporation
Foster Wheeler USA Corporation
Gas Technology Corporation
Gulsby Engineering, Inc.
Holloman Corporation
HPT Inc.
Huzyk Energy Management, Inc.
Jacobs Engineering Group Inc.
JFE Engineering Corporation
JGC Corporation
KBR
KnightHawk Engineering
Krause, Inc. Engineers - Architects
Linde BOC Process Plants LLC

PILOT EXHIBIT 2027 PAGE 082
SCOUT/CHEVRON v. PILOT - IPR2024-00385

ENGINEERING PROCUREMENT & CONSTRUCTION (Cont'd.)

Marlboro Enterprises, Inc.
Master Corporation
Mitsubishi Heavy Industries, Ltd.
Mustang Engineering, LP
National Petroleum & Energy Services, Inc.
Natural Gas Liquids, Inc.
Nicholas Consulting Group, Inc.
Nicol & Associates, Inc.
Optimized Pipeline Solutions, Inc.
Optimized Process Designs
Parsons Energy & Chemicals Group Inc.
Pasadyn, Inc.
Pearl Development Company
Quorum & Associates
Ref-Chem L.P.
Rouly, Inc.
S & B Engineers and Constructors
S-Con, Inc.
Saulsbury Industries
Select Engineering, Inc.
Technip USA Corporation
Technology Trade International, Inc.
TECNA ESTUDIOS Y PROYECTOS DE INGENIERIA SA
The Hanover Company
Thomas Russell Co.
TIC-The Industrial Company Wyoming, Inc.
Toyo Engineering Corporation
United/Wells
Vanson Engineering Co.
W. H. Linder & Associate Inc.
W. L. Hamilton Engineering P.C.
Washington Group International, Inc.
Westfield Engineering & Services, Inc.
ZAP Engineering & Construction Services, Inc.

ENVIRONMENTAL SERVICES

Aker Kvaerner, Inc.
Black & Veatch Pritchard, Inc.
C3 Resources
CAP-HIS Emissions Reduction Systems
CCR Technologies, Inc.
CrystaTech, Inc.
Fluor Enterprises, Inc.
HPT Inc.
Ignition Systems & Controls, LP
KBR
Miratech Corp.
National Petroleum & Energy Services, Inc.
Nicol & Associates, Inc.
Pantechs Laboratories, Inc.
Pearl Development Company
Questar Energy Services
Quorum & Associates
RW Beck Inc.
SGS Minerals Services
Sherry Laboratories/LA
SPL, Inc.
Technology Trade International, Inc.
The Arrington Corporation
Washington Group International, Inc.
Wasson-ECE Instrumentation

EXPANDER CRYOGENIC PROCESS SERVICES & TRAINING

Clayton Hamm, Cryogenic Specialist
GE Oil & Gas
HPT Inc.
Mafi-Trench Corporation
Ortloff Engineers, Ltd.
Simms Machinery International Inc.
Texas Turbine Inc.
Washington Group International, Inc.

EXPERT WITNESS

Fairfield Energy Consultants
Optimized Pipeline Solutions, Inc.
Quorum & Associates
SCFM Compression Systems Co.

FAILURE ANALYSIS/FORENSIC ENGINEERING

Exline, Inc.
Fluor Enterprises, Inc.
GE Oil & Gas
HT Engineering, Inc.
IPSI LLC
Kams, Inc.
KnightHawk Engineering

FCC OFFGAS RECOVERY

Air Products and Chemicals, Inc.
Black & Veatch Pritchard, Inc.
CB&I Howe-Baker Process & Technology
Domain Engineering Inc.
Fluor Enterprises, Inc.
Gulsby Engineering, Inc.
Linde BOC Process Plants LLC
Nomis Venture, LLC
Parsons Energy & Chemicals Group Inc.
Technip USA Corporation
Thomas Russell Co.
Tru-Tec Services Inc.
Washington Group International, Inc.

GAS & LIQUIDS PURIFICATION

Johnson Matthey Catalysts (formerly Synetix)

GAS COMPRESSING & PROCESSING

Air Products and Chemicals, Inc.
Ariel Corporation

PILOT EXHIBIT 2027 PAGE 083
SCOUT/CHEVRON v. PILOT - IPR2024-00385

GAS COMPRESSING & PROCESSING (Cont'd.)

BASF Corporation
BCCK Engineering, Inc.
BE&K Construction - Houston
Bexar Energy Holdings, Inc.
Bowden Construction Co., Ltd.
Cardinal Gas Services, LLC
CB&I Howe-Baker Process & Technology
CLOUGH Limited
Compressor Systems, Inc.
Domain Engineering Inc.
Dresser-Rand Company
Elliott Turbomachinery Co. Inc.
Energy Compression Systems
Fluor Enterprises, Inc.
Ford, Bacon & Davis
ForeRunner Corporation
Gas Packagers, Inc.
GE Oil & Gas
Gulsby Engineering, Inc.
HPT Inc.
Hy-Bon Engineering Company, Inc.
IPSI LLC
J-W Operating Company
Linde BOC Process Plants LLC
Loco Energy Company, LLC
Marlboro Enterprises, Inc.
Mitsubishi Heavy Industries, Ltd
National Petroleum & Energy Services, Inc.
Nicholas Consulting Group, Inc.
Optimized Process Designs
Ortloff Engineers, Ltd.
Parsons Energy & Chemicals Group Inc.
Pearl Development Company
Peerless Mfg. Co.
Prosernat
Quorum & Associates
Ref-Chem L.P.
Regard Resources Co., Inc.
Rolls-Royce Energy Business
RSC International
S & B Engineers and Constructors
SCFM Compression Systems Co.
S-Con, Inc.
Solar Turbines, Incorporated
South-Tex Treaters, Inc.
Technip USA Corporation
Technology Trade International, Inc.
The Hanover Company
Thomas Petroleum Ltd.
Thomas Russell Co.
United/Wells
Universal Compression
Vanson Engineering Co.
Vera & Associates
W. L. Hamilton Engineering P.C.
Washington Group International, Inc.
Westfield Engineering & Services, Inc.
York Process Systems

GAS CONTAMINATION TESTING

CrystaTech, Inc.
National Petroleum & Energy Services, Inc.
Pantechs Laboratories, Inc.
Perry Equipment Corporation
Porous Media
SPL, Inc.

GAS PLANT LEASING

BCCK Engineering, Inc.
Cardinal Gas Services, LLC
Dickson & Tryer Engineering Co., Ltd.
Gas Technology Corporation
Select Engineering, Inc.
South-Tex Treaters, Inc.
The Hanover Company
W. L. Hamilton Engineering P.C.

GAS TREATING

Washington Group International, Inc.

INDUSTRY RESEARCH

Aker Kvaerner, Inc.
Black & Veatch Pritchard, Inc.
CrystaTech, Inc.
IPSI LLC
KBR
Lomic, Inc.
Oilphase - DBR
Quorum & Associates
Randall & Dewey, Inc.

INSPECTION SERVICES

Aker Kvaerner, Inc.
BE&K Construction - Houston
HPF Consultants, Inc.
Hudson Products Corporation
Intertek Caleb Brett
J-W Measurement Company
KBR
Marlboro Enterprises, Inc.
Master Corporation
Moore Control Systems, Inc.
National Petroleum & Energy Services, Inc.
Natural Gas Liquids, Inc.
Nicholas Consulting Group, Inc.
Optimized Pipeline Solutions, Inc.
Pantechs Laboratories, Inc.
Parsons Energy & Chemicals Group Inc.
Quorum & Associates
Rouly, Inc.
SCFM Compression Systems Co.
SGS Minerals Services
SPL, Inc.
Technology Trade International, Inc.
Thurmond-McGlothlin Inc.

PILOT EXHIBIT 2027 PAGE 084
SCOUT/CHEVRON v. PILOT - IPR2024-00385

INSPECTION SERVICES (Cont'd.)

Tru-Tec Services Inc.
Washington Group International, Inc.

INSTRUMENT AND ELECTRICAL CONSTRUCTION

Barry D. Payne & Associates, Inc.
CB&I Howe-Baker Process & Technology
Chandler Engineering Company, LLC
Fluor Enterprises, Inc.
GE Oil & Gas
Ignition Systems & Controls, LP
Invensys Foxboro
Jet Specialty
KBR
Marlboro Enterprises, Inc.
Master Corporation
Moore Control Systems, Inc.
NATCO Group Inc.
Nicholas Consulting Group, Inc.
Optimized Process Designs
Pasadyn, Inc.
Pearl Development Company
Questar Energy Services
S & B Engineers and Constructors
S-Con, Inc.
Saulsbury Industries
Technip USA Corporation
Technology Trade International, Inc.
Thomas Russell Co.
TIC-The Industrial Company Wyoming, Inc.
Washington Group International, Inc.

INSULATION

Elkhorn Construction, Inc.
Fluor Enterprises, Inc.
Jet Specialty
KBR
Marlboro Enterprises, Inc.
National Petroleum & Energy Services, Inc.
Pasadyn, Inc.
Washington Group International, Inc.

INVESTMENT BANKING

Glaucon Capital Partners, LLC

LICENSED PROCESSES

Advanced Extraction Technologies, Inc.
Air Products and Chemicals, Inc.
Aker Kvaerner, Inc.
BASF Corporation
BCCK Engineering, Inc.
Black & Veatch Pritchard, Inc.
CB&I Howe-Baker Process & Technology
CCR Technologies, Inc.
CrystaTech, Inc.
Engelhard Corporation
Fluor Enterprises, Inc.
Ford, Bacon & Davis
Foster Wheeler USA Corporation
Gateway Energy Corpoartion
IPSI LLC
Jacobs Engineering Group Inc.
JGC Corporation
KBR
Krause, Inc. Engineers - Architects
Linde BOC Process Plants LLC
Master Corporation
MPR Services, Inc.
Ortloff Engineers, Ltd.
Parsons Energy & Chemicals Group Inc.
Porous Media
Prosernat
Randall Gas Technologies - ABB Lummus Global Inc.
South-Tex Treaters, Inc.
Technip USA Corporation
Toyo Engineering Corporation
UOP LLC
Washington Group International, Inc.
Westfield Engineering & Services, Inc.

LNG PROCESSES

Air Products and Chemicals, Inc.
Holloman Corporation
Marlboro Enterprises, Inc.
Ortloff Engineers, Ltd.

MACHINING & REPAIR

Afton Pumps, Inc.
Compressor Engineering Corporation
Elliott Turbomachinery Co. Inc.
Energy Dynamics, Ltd. (EnDyn, Ltd.)
Exline, Inc.
GE Oil & Gas
H & S Valve Inc.
Hy-Bon Engineering Company, Inc.
Jet Specialty
Kams, Inc.
Marsau Enterprises
National Petroleum & Energy Services, Inc.
Simms Machinery International Inc.
Texas Turbine Inc.
Thomason Mechanical Corp.
United/Wells
Universal Compression
Valve Maintenance Corporation

MEASUREMENT SERVICES

American Measurement Services
Atofina Chemicals, Inc.
Coastal Flow Measurement, Inc.
DCG Partnership 1, Ltd.
Daniel Measurement and Control

PILOT EXHIBIT 2027 PAGE 085
SCOUT/CHEVRON v. PILOT - IPR2024-00385

MEASUREMENT SERVICES (Cont'd.)

eLynx Technologies, LLC
Engelhard Corporation
Fesco Ltd.
Gas Analytical Solutions, Inc.
GE Oil & Gas
Graves Analytical Services LLC
Intertek Caleb Brett
J-W Measurement Company
J-W Operating Company
Jet Specialty
Pearl Development Company
Questar Energy Services
Quorum & Associates
Quorum Business Solutions, Inc.
SPL, Inc.
Technology Trade International, Inc.
Thurmond-McGlothlin Inc.
Turnbow Engineering
Winn-Marion Barber, LLP

MECHANICAL CONSTRUCTION

Aker Kvaerner, Inc.
BE&K Construction - Houston
Bowden Construction Co., Ltd.
CB&I Howe-Baker Process & Technology
Elkhorn Construction, Inc.
Fluor Enterprises, Inc.
ForeRunner Corporation
Foster Wheeler USA Corporation
Holloman Corporation
Jet Specialty
KBR
Linde BOC Process Plants LLC
Marlboro Enterprises, Inc.
Master Corporation
National Petroleum & Energy Services, Inc.
Nicholas Consulting Group, Inc.
Optimized Process Designs
Pasadyn, Inc.
Pearl Development Company
Ref-Chem L.P.
S & B Engineers and Constructors
Saulsbury Industries
South-Tex Treaters, Inc.
Technip USA Corporation
Technology Trade International, Inc.
TECNA ESTUDIOS Y PROYECTOS DE INGENIERIA SA
The Hanover Company
TIC-The Industrial Company Wyoming, Inc.
United/Wells
Washington Group International, Inc.
Westfield Engineering & Services, Inc.

NITROGEN REJECTION AND HELIUM RECOVERY TECHNOLOGY

Air Products and Chemicals, Inc.
Aker Kvaerner, Inc.
BCCK Engineering, Inc.
Black & Veatch Pritchard, Inc.
CB&I Howe-Baker Process & Technology
Domain Engineering Inc.
Engelhard Corporation
Gateway Energy Corpoartion
GE Oil & Gas
Gulsby Engineering, Inc.
HPT Inc.
IPSI LLC
Krause, Inc. Engineers - Architects
Linde BOC Process Plants LLC
Pasadyn, Inc.
Pearl Development Company
Randall Gas Technologies - ABB Lummus Global Inc.
Ref-Chem L.P.
Technip USA Corporation
Thomas Russell Co.
UOP LLC
Washington Group International, Inc.

OILFIELD SERVICES

Aggreko LLC
CB&I Howe-Baker Process & Technology
Coastal Chemical Co., LLC
eLynx Technologies, LLC
Energy Dynamics, Ltd. (EnDyn, Ltd.)
FESCO Ltd.
GE Oil & Gas
Graves Analytical Services LLC
Gulf Coast Chemical, Inc.
Jet Specialty
KBR
Marsau Enterprises
Master Corporation
NATCO Group Inc.
National Petroleum & Energy Services, Inc.
Nicholas Consulting Group, Inc.
Oilphase - DBR
Ref-Chem L.P.
Technology Trade International, Inc.
Washington Group International, Inc.

OPERATIONS & MAINTENANCE

Air Products and Chemicals, Inc.
Aker Kvaerner, Inc.
Baker Energy
CLOUGH Limited
Compressor Systems, Inc.
Dresser-Rand Company
Elliott Turbomachinery Co. Inc.
Ellipsys, Inc.
Energy Dynamics, Ltd. (EnDyn, Ltd.)
Energy Compression Systems
Exline, Inc.

PILOT EXHIBIT 2027 PAGE 086
SCOUT/CHEVRON v. PILOT - IPR2024-00385

OPERATIONS & MAINTENANCE (Cont'd.)

Fluor Enterprises, Inc.
ForeRunner Corporation
Foster Wheeler USA Corporation
GE Oil & Gas
Graves Analytical Services LLC
Jet Specialty
JHF Safety Consulting LLC
KBR
NATCO Group Inc.
National Petroleum & Energy Services, Inc.
Natural Gas Liquids, Inc.
Optimized Process Designs
Quorum & Associates
Ref-Chem L.P.
Rolls-Royce Energy Business
SCFM Compression Systems Co.
South-Tex Treaters, Inc.
Technology Trade International, Inc.
TECNA ESTUDIOS Y PROYECTOS DE INGENIERIA SA
The Arrington Corporation
The Hanover Company
TIC-The Industrial Company Wyoming, Inc.
Toyo Engineering Corporation
United/Wells

PAINTING

Bowden Construction Co., Ltd.
Elkhorn Construction, Inc.
Fluor Enterprises, Inc.
GE Oil & Gas
Marsau Enterprises
National Petroleum & Energy Services, Inc.

PERFORMANCE ANALYSIS

Air Products and Chemicals, Inc.
Aker Kvaerner, Inc.
Ariel Corporation
Atofina Chemicals, Inc.
BCCK Engineering, Inc.
CB&I Howe-Baker Process & Technology
Compressor Engineering Corporation
Domain Engineering Inc.
Exline, Inc.
Fisher Controls International Inc.
Fluor Enterprises, Inc.
GE Oil & Gas
GPM Solutions, Inc.
Gulsby Engineering, Inc.
Hudson Products Corporation
KBR
KnightHawk Engineering
Linde BOC Process Plants LLC
Marlboro Enterprises, Inc.
Martin Energy Consultants
Nomis Venture, LLC
Optimized Pipeline Solutions, Inc.
Ortloff Engineers, Ltd.
Pantechs Laboratories, Inc.
Pasadyn, Inc.
Pearl Development Company
Quorum & Associates
SCFM Compression Systems Co.
SGS Minerals Services
T. F. Hudgins, Inc.
The Arrington Corporation
The Hanover Company
The Lubrizol Corporation
Thomas Petroleum Ltd.
Thomas Russell Co.
Tru-Tec Services Inc.
Vanson Engineering Co.
W. L. Hamilton Engineering P.C.
Washington Group International, Inc.
Westfield Engineering & Services, Inc.

PIPELINE CONSTRUCTION

CB&I Howe-Baker Process & Technology
CLOUGH Limited
Fluor Enterprises, Inc.
ForeRunner Corporation
Gateway Energy Corpoartion
Holloman Corporation
HT Engineering, Inc.
KBR
Lomic, Inc.
Marsau Enterprises
Master Corporation
National Petroleum & Energy Services, Inc.
Nicholas Consulting Group, Inc.
Optimized Pipeline Solutions, Inc.
Pearl Development Company
Technology Trade International, Inc.

PIPELINE INSPECTION

Optimized Pipeline Solutions, Inc.

PIPELINE MAPS & DATA

CB&I Howe-Baker Process & Technology
Domain Engineering Inc.
Master Corporation
Mustang Engineering, LP
Nicholas Consulting Group, Inc.
Pearl Development Company

PROCUREMENT SERVICES

Aker Kvaerner, Inc.
BE&K Construction - Houston
Black & Veatch Pritchard, Inc.
Bowden Construction Co., Ltd.
CB&I Howe-Baker Process & Technology
Domain Engineering Inc.

PILOT EXHIBIT 2027 PAGE 087
SCOUT/CHEVRON v. PILOT - IPR2024-00385

PROCUREMENT SERVICES (Cont'd.)

Fluor Enterprises, Inc.
ForeRunner Corporation
Foster Wheeler USA Corporation
Harris Group Inc.
Jet Specialty
JGC Corporation
KBR
Marlboro Enterprises, Inc.
Master Corporation
Moore Control Systems, Inc.
Mustang Engineering, LP
National Petroleum & Energy Services, Inc.
Natural Gas Liquids, Inc.
Nicholas Consulting Group, Inc.
Optimized Process Designs
Pasadyn, Inc.
Pearl Development Company
Quorum & Associates
SCFM Compression Systems Co.
Technip USA Corporation
Technology Trade International, Inc.
Toyo Engineering Corporation
Vanson Engineering Co.
Washington Group International, Inc.
Westfield Engineering & Services, Inc.

PVT PHASE BEHAVIOR LAB. SERVICES

Chandler Engineering Company, LLC
Fesco Ltd.
Oilphase - DBR

SAFETY CONSULTANTS

Boots & Coots, Inc.
C3 Resources
Compressor Engineering Corporation
Domain Engineering Inc.
Elkhorn Construction, Inc.
IPSI LLC
JHF Safety Consulting LLC
KBR
Marlboro Enterprises, Inc.
Nomis Venture, LLC
Pearl Development Company
Quorum & Associates
Technip USA Corporation
TECNA ESTUDIOS Y PROYECTOS DE INGENIERIA SA
The Arrington Corporation
Washington Group International, Inc.

STRATEGY PLANNING

Aker Kvaerner, Inc.
Domain Engineering Inc.
Fluor Enterprises, Inc.
ForeRunner Corporation
GPM Solutions, Inc.
IPSI LLC
Martin Energy Consultants
Mustang Engineering, LP
National Petroleum & Energy Services, Inc.
Natural Gas Liquids, Inc.
Nomis Venture, LLC
Ortloff Engineers, Ltd.
Pearl Development Company
Quorum & Associates
Randall & Dewey, Inc.
SCFM Compression Systems Co.
The Propane Market Strategy Letter
Vanson Engineering Co.
Washington Group International, Inc.

SULFUR REMOVAL/RECOVERY

Washington Group International, Inc.

TECHNICAL PUBLICATIONS

Atofina Chemicals, Inc.
Foster Wheeler USA Corporation
IPSI LLC
John M. Campbell & Company
Ortloff Engineers, Ltd.
Petroleum Extension Service (PETEX), The
Prosernat
The Propane Market Strategy Letter
University of Texas at Austin

TRAINING

Air Products and Chemicals, Inc.
Atofina Chemicals, Inc.
Baker Energy
Barry D. Payne & Associates, Inc.
Boots & Coots, Inc.
C3 Resources
Compressor Engineering Corporation
Compressor Systems, Inc.
Domain Engineering Inc.
Drake Controls, LLC
Dresser-Rand Company
Ellipsys, Inc.
Exline, Inc.
Fisher Controls International Inc.
GE Oil & Gas
Graves Analytical Services LLC
IPSI LLC
Jet Specialty
JHF Safety Consulting LLC
John M. Campbell & Company
KBR
Lomic, Inc.
Marlboro Enterprises, Inc.
Miratech Corp.
Moore Control Systems, Inc.
NATCO Group Inc.
Natural Gas Liquids, Inc.

PILOT EXHIBIT 2027 PAGE 088
SCOUT/CHEVRON v. PILOT - IPR2024-00385

TRAINING (Cont'd.)

Ortloff Engineers, Ltd.
Pasadyn, Inc.
Pearl Development Company
Petroleum Extension Service (PETEX), The
Prosernat
Quorum & Associates
River City Engineering, Inc.
SCFM Compression Systems Co.
SPL, Inc.
T. F. Hudgins, Inc.
Technology Trade International, Inc.
The Arrington Corporation
The Hanover Company
Thomas Petroleum Ltd.
University of Texas at Austin
Vanson Engineering Co.
W. L. Hamilton Engineering P.C.
Washington Group International, Inc.
Welker Engineering Co.

UNDERGROUND STORAGE FACILITIES

Black & Veatch Pritchard, Inc.
Boots & Coots, Inc.
CB&I Howe-Baker Process & Technology
Domain Engineering Inc.
ForeRunner Corporation
Holloman Corporation
Marlboro Enterprises, Inc.
Master Corporation
SCFM Compression Systems Co.
Technip USA Corporation
Washington Group International, Inc.

PILOT EXHIBIT 2027 PAGE 089
SCOUT/CHEVRON v. PILOT - IPR2024-00385

Gas Processors Suppliers Association

6526 East 60th Street
Tulsa, Oklahoma 74145
Phone: 918-493-3872
Fax: 918-493-3875
email: gpsa@gasprocessors.com

SUPPLIES

The following is a listing of GPSA member companies classified by the type of services that they provide to the industry.

AIR COOLERS

air-x-changers
Air-x-hemphill
Amercool Manufacturing, Inc.
Bartlett Equipment Company, Inc.
Brice Equipment Company
Gulf Coast Dismantling
Hammco, Inc.
Hudson Products Corporation
KnightHawk Engineering
R & R Engineering Co. Inc.
Rouly, Inc.
Smithco Engineering, Inc.
South-Tex Treaters, Inc.

AMINE CLEANING EQUIPMENT

MPR Services, Inc.

AUTOMATION AND PROCESS CONTROLS

ABB Inc. – Totalflow
Barry D. Payne & Associates, Inc.
CB&I Howe-Baker Process & Technology
Control Microsystems
Drake Controls, LLC
eLynx Technologies, LLC
Energy Dynamics, Ltd. (EnDyn, Ltd.)
EPC, Inc.
FWMurphy
GE Oil & Gas
Ignition Systems & Controls, LP
Invensys Foxboro
Jet Specialty
Kimray, Inc.
KnightHawk Engineering
Miratech Corp.
Moore Control Systems, Inc.
NATCO Group Inc.
Peerless Mfg. Co.
Rolls-Royce Energy Business
Siemens Demag Delaval
TECNA ESTUDIOS Y PROYECTOS DE INGENIERIA SA
The Lubrizol Corporation
Wasson-ECE Instrumentation
Winn-Marion Barber, LLP
Yokogawa Corporation of America

BOILERS

Aggreko LLC
Bartlett Equipment Company, Inc.
Foster Wheeler USA Corporation
KnightHawk Engineering
Mitsubishi Heavy Industries, Ltd.
National Petroleum & Energy Services, Inc.
Rouly, Inc.

BUILDINGS

Elkhorn Construction, Inc.
Moore Control Systems, Inc.
National Petroleum & Energy Services, Inc.
Thurmond-McGlothlin Inc.

CHEMICALS/CATALYSTS/ MOLE SIEVES/ADSORBENTS

Alcoa World Chemicals, Adsorbents and Catalysts
Atofina Chemicals, Inc.
BASF Corporation
CAP-HIS Emissions Reduction Systems
CCR Technologies, Inc.
Coastal Chemical Co., LLC
Continental Products of Texas
Criterion Catalyst Company, LP
Engelhard Corporation
Gas Technology Products LLC
GRACE Davison Process Adsorbents
Gulf Coast Chemical, Inc.

PILOT EXHIBIT 2027 PAGE 090
SCOUT/CHEVRON v. PILOT - IPR2024-00385

CHEMICALS/CATALYSTS/ MOLE SIEVES/ADSORBENTS (Cont'd.)

Huntsman Corporation
INEOS Oxide
Jet Specialty
Miratech Corp.
MPR Services, Inc.
NORIT Americas Inc.
Q2 Technologies
Quadra Chemicals
SulfaTreat
The Lubrizol Corporation
Third Coast Terminals
Thomas Petroleum Ltd.
UOP LLC
Waukesha-Pearce Industries, Inc.
Western Filter Co., Inc.
Zeochem, LLC

CHROMATOGRAPH CALIBRATION STANDARDS

DCG Partnership 1, Ltd.
Daniel Measurement and Control
Jet Specialty
Sherry Laboratories/LA

COLD BOXES FOR GAS PROCESSING APPLICATIONS

Air Products and Chemicals, Inc.
BCCK Engineering, Inc.
CB&I Howe-Baker Process & Technology
Chart Heat Exchangers
Jet Specialty
Linde BOC Process Plants LLC
National Petroleum & Energy Services, Inc.

COMPRESSORS AND PARTS

Aggreko LLC
Ariel Corporation
Bexar Energy Holdings, Inc.
Compressor Engineering Corporation
Compressor Systems, Inc.
Cook Compressor Group
Drake Controls, LLC
Dresser-Rand Company
Elliott Turbomachinery Co. Inc.
Energy Dynamics, Ltd. (EnDyn, Ltd.)
Energy Compression Systems
Exline, Inc.
Gas Packagers, Inc.
GE Oil & Gas
Gulf Coast Dismantling
H & S Valve Inc.
Hawkins Filtration Products Inc.
Hy-Bon Engineering Company, Inc.
J-W Measurement Company
J-W Operating Company
Marsau Enterprises
Mitsubishi Heavy Industries, Ltd
Peerless Mfg. Co.
Rolls-Royce Energy Business
RSC International
SCFM Compression Systems Co.
Siemens Demag Delaval
Simms Machinery International Inc.
Solar Turbines, Incorporated
Sundyne Corporation
T. F. Hudgins, Inc.
The Hanover Company
Thomas Petroleum Ltd.
Toromont Process Systems, Inc.
Total Energy Corp.
United/Wells
Universal Compression
Valve Maintenance Corporation
Vanco Engineering Co.
Waukesha-Pearce Industries, Inc.
York Process Systems

CONTINGENCY PLANS & TRAINING

Aggreko LLC
Boots & Coots, Inc.
Domain Engineering Inc.
eSimulation, Inc.
Peerless Mfg. Co.

CONTROL VALVES/REGULATORS

Allesco
Bartlett Equipment Company, Inc.
Daniel Measurement and Control
Drake Controls, LLC
Fisher Controls International Inc.
GARZO, Incorporated
GE Oil & Gas
J-W Measurement Company
Jet Specialty
Kimray, Inc.
Marsau Enterprises
Miratech Corp.
Myers-Aubrey Co.
NATCO Group Inc.
Peerless Mfg. Co.
SCFM Compression Systems Co.
Vinson Process Controls
Welker Engineering Co.
Winn-Marion Barber, LLP

COOLING TOWERS

Aggreko LLC
Eaton Metal Products Company
Gulf Coast Dismantling
National Petroleum & Energy Services, Inc.
Rouly, Inc.

PILOT EXHIBIT 2027 PAGE 091
SCOUT/CHEVRON v. PILOT - IPR2024-00385

DEHYDRATION EQUIPMENT

Aggreko LLC
Air Products and Chemicals, Inc.
Alcoa World Chemicals, Adsorbents and Catalysts
CB&I Howe-Baker Process & Technology
Chart Heat Exchangers
Dickson & Tryer Engineering Co., Ltd.
Engelhard Corporation
Gas Technology Corporation
GasTech Engineering Corporation
GRACE Davison Process Adsorbents
Gulf Coast Dismantling
Hawkins Filtration Products Inc.
J. W. Williams, Inc.
Jet Specialty
Kimray, Inc.
Linde BOC Process Plants LLC
Marsau Enterprises
Mitsubishi Heavy Industries, Ltd
NATCO Group Inc.
Prosernat
Rhine Ruhr Pty Ltd.
Rotor-Tech, Inc.
Rouly, Inc.
Select Engineering, Inc.
TECNA ESTUDIOS Y PROYECTOS DE INGENIERIA SA
The Hanover Company
Thomas Russell Co.
Welker Engineering Co.
Westfield Engineering & Services, Inc.
Zeochem, LLC

ELECTRIC MOTORS

Gas Packagers, Inc.
GE Oil & Gas
Gulf Coast Dismantling
Siemens Demag Delaval
The Hanover Company

EMISSION CONTROL EQUIPMENT

Mechanical Equipment, Inc.

ENGINES & PARTS

Caterpillar, Inc. - Global Petroleum Group
Compressor Engineering Corporation
Cook Compressor Group
Drake Controls, LLC
Energy Dynamics, Ltd. (EnDyn, Ltd.)
Energy Compression Systems
Exline, Inc.
Gas Packagers, Inc.
Gulf Coast Dismantling
Hawkins Filtration Products Inc.
Ignition Systems & Controls, LP
Kams, Inc.
Marsau Enterprises
Mitsubishi Heavy Industries, Ltd
SCFM Compression Systems Co.
T. F. Hudgins, Inc.
The Hanover Company
Toromont Process Systems, Inc.
United/Wells
Universal Compression
Valve Maintenance Corporation
Waukesha Engine
Waukesha-Pearce Industries, Inc.
Western Filter Co., Inc.

FILTERS

3M Company
ACS Industries, LP
Allesco
Bartlett Equipment Company, Inc.
Coastal Chemical Co., LLC
Compressor Engineering Corporation
Continental Products of Texas
Dickson & Tryer Engineering Co., Ltd.
Energy Dynamics, Ltd. (EnDyn, Ltd.)
Hawkins Filtration Products Inc.
Jet Specialty
Johnson Filtration Products, Inc.
Marsau Enterprises
NATCO Group Inc.
Nowata Filtration, Division of NMW, Inc.
Parker Hannifin Corporation
Perry Equipment Corporation
Porous Media
Rotor-Tech, Inc.
Royal Filter Manufacturing Co., Inc.
SCFM Compression Systems Co.
South-Tex Treaters, Inc.
The Lubrizol Corporation
Waukesha-Pearce Industries, Inc.
Welker Engineering Co.
Western Filter Co., Inc.

FIRED HEATERS

CB&I Howe-Baker Process & Technology
Foster Wheeler USA Corporation
GasTech Engineering Corporation
Gulf Coast Dismantling
NATCO Group Inc.
National Petroleum & Energy Services, Inc.
Optimized Process Furnaces
Prosernat
Rouly, Inc.
South-Tex Treaters, Inc.
TECNA ESTUDIOS Y PROYECTOS DE INGENIERIA SA
The Hanover Company

FLARES

CB&I Howe-Baker Process & Technology
Gulf Coast Dismantling

PILOT EXHIBIT 2027 PAGE 092
SCOUT/CHEVRON v. PILOT - IPR2024-00385

FLARES (Cont'd.)

National Petroleum & Energy Services, Inc.
SCFM Compression Systems Co.
Total Energy Corp.

GAS FILTER SEPARATORS, COALESCERS

Brice Equipment Company

GAS PURIFYING MATERIALS

ACS Industries, LP
Alcoa World Chemicals, Adsorbents and Catalysts
BASF Corporation
CAP-HIS Emissions Reduction Systems
CB&I Howe-Baker Process & Technology
Coastal Chemical Co., LLC
Connelly-GPM, Inc.
Engelhard Corporation
Gas Technology Products LLC
Hawkins Filtration Products Inc.
INEOS Oxide
Jet Specialty
Porous Media
Quadra Chemicals
SulfaTreat
Thomas Petroleum Ltd.
UOP LLC
Zeochem, LLC

GENERATORS

Aggreko LLC
Caterpillar, Inc. - Global Petroleum Group
Drake Controls, LLC
GE Oil & Gas
Gulf Coast Dismantling
Marsau Enterprises
Mitsubishi Heavy Industries, Ltd.
Solar Turbines, Incorporated
The Hanover Company
Total Energy Corp.
Waukesha-Pearce Industries, Inc.

HEAT EXCHANGERS

Aggreko LLC
Air-x-hemphill
Amercool Manufacturing, Inc.
Bartlett Equipment Company, Inc.
BCCK Engineering, Inc.
Bexar Energy Holdings, Inc.
Brice Equipment Company
Chart Heat Exchangers
Eaton Metal Products Company
Foster Wheeler USA Corporation
Gas Packagers, Inc.
GE Oil & Gas
J. W. Williams, Inc.
KnightHawk Engineering
Krueger Engineering & Mfg. Co., Inc.
Linde BOC Process Plants LLC
Marsau Enterprises
NATCO Group Inc.
National Petroleum & Energy Services, Inc.
Rouly, Inc.
Smithco Engineering, Inc.
South-Tex Treaters, Inc.
The Hanover Company
Toromont Process Systems, Inc.
United/Wells

HEAT PIPES

Hudson Products Corporation
Jet Specialty
Rouly, Inc.

INDUSTRIAL & SPECIALTY GASES

DCG Partnership 1, Ltd.
Jet Specialty
Linde BOC Process Plants LLC
National Petroleum & Energy Services, Inc.

INDUSTRY SOFTWARE

Aspen Technology, Inc.
Bryan Research & Engineering, Inc.
Coastal Flow Measurement, Inc.
Ellipsys, Inc.
eLynx Technologies, LLC
Entero Corporation
Lomic, Inc.
Oilphase - DBR
Optimized Gas Treating, Inc.
Quorum Business Solutions, Inc.
River City Engineering, Inc.
SolArc, Inc.
The Arrington Corporation
Tomcej Engineering Inc.
WinSim Inc.

INSTRUMENTS, CONTROLS & ANALYZERS

Allesco
Barry D. Payne & Associates, Inc.
Chandler Engineering Company, LLC
Control Microsystems
DCG Partnership 1, Ltd.
Daniel Measurement and Control
Drake Controls, LLC
Elliott Turbomachinery Co. Inc.
Energy Dynamics, Ltd. (EnDyn, Ltd.)
Exline, Inc.
Fisher Controls International Inc.
FWMurphy
GE Oil & Gas
Graves Analytical Services LLC

PILOT EXHIBIT 2027 PAGE 093
SCOUT/CHEVRON v. PILOT - IPR2024-00385

INSTRUMENTS, CONTROLS & ANALYZERS (Cont'd.)

Ignition Systems & Controls, LP
Invensys Foxboro
Jet Specialty
Miratech Corp.
Moore Control Systems, Inc.
Myers-Aubrey Co.
Quorum & Associates
Rolls-Royce Energy Business
T. F. Hudgins, Inc.
The Lubrizol Corporation
Thermo Electron Cooperation
Vinson Process Controls
Wasson-ECE Instrumentation
Welker Engineering Co.
Winn-Marion Barber, LLP
Yokogawa Corporation of America

LAB SUPPLIES

Graves Analytical Services LLC
Jet Specialty
Thomas Petroleum Ltd.

LIGHTNING SUPPRESSION

Jet Specialty

LIQUID NATURAL GAS EQUIPMENT

Afton Pumps, Inc.
Air Products and Chemicals, Inc.
CB&I Howe-Baker Process & Technology
Chart Heat Exchangers
Elliott Turbomachinery Co. Inc.
JGC Corporation
KBR
Linde BOC Process Plants LLC
Mitsubishi Heavy Industries, Ltd
Peerless Mfg. Co.
Sundyne Corporation
The Hanover Company
Total Energy Corp.
Trinity Industries, Inc.

LIQUID NATURAL GAS PROCESSING PLANTS

JGC Corporation

MEASUREMENT EQUIPMENT

ABB Inc. – Totalflow
Allesco
American Measurement Services
Barry D. Payne & Associates, Inc.
Chandler Engineering Company, LLC
Coastal Flow Measurement, Inc.
Control Microsystems
DCG Partnership 1, Ltd.
Daniel Measurement and Control
eLynx Technologies, LLC
FWMurphy
GARZO, Incorporated
Gas Analytical Solutions, Inc.
GE Oil & Gas
Graves Analytical Services LLC
Gulf Coast Dismantling
J-W Measurement Company
J-W Operating Company
J. W. Williams, Inc.
Jet Specialty
Kimray, Inc.
SPL, Inc.
Thurmond-McGlothlin Inc.
Vinson Process Controls
Wasson-ECE Instrumentation
Welker Engineering Co.
Winn-Marion Barber, LLP
Yokogawa Corporation of America

MEMBRANES

ACS Industries, LP
Air Products and Chemicals, Inc.
CB&I Howe-Baker Process & Technology
Continental Products of Texas
NATCO Group Inc.
NORIT Americas Inc.
Porous Media
Randall Gas Technologies - ABB Lummus Global Inc.
Sulzer Chemtech
UOP LLC
Wasson-ECE Instrumentation
Welker Engineering Co.

MIXERS

Allesco
Sulzer Chemtech

MODULAR GAS PROCESSING PLANTS

Alcoa World Chemicals, Adsorbents and Catalysts
BCCK Engineering, Inc.
CB&I Howe-Baker Process & Technology
CrystaTech, Inc.
Dickson & Tryer Engineering Co., Ltd.
Engelhard Corporation
EPC, Inc.
Gas Technology Corporation
GasTech Engineering Corporation
HPT Inc.
J. W. Williams, Inc.
Krause, Inc. Engineers - Architects
Linde BOC Process Plants LLC
Mitsubishi Heavy Industries, Ltd,
NATCO Group Inc.
Optimized Process Designs
Pearl Development Company

PILOT EXHIBIT 2027 PAGE 094
SCOUT/CHEVRON v. PILOT - IPR2024-00385

MODULAR GAS PROCESSING PLANTS (Cont'd.)

Prosernat
Saulsbury Industries
Select Engineering, Inc.
South-Tex Treaters, Inc.
TECNA ESTUDIOS Y PROYECTOS DE INGENIERIA SA
The Hanover Company
Thomas Russell Co.
Vanson Engineering Co.
Westfield Engineering & Services, Inc.

NITROGEN GENERATORS

Air Products and Chemicals, Inc.
CB&I Howe-Baker Process & Technology
Linde BOC Process Plants LLC
Parker Hannifin Corporation

ODOR CONTROL PRODUCTS

JGC Corporation
SulfaTreat

ODORIZATION

Peerless Mfg. Co.
Welker Engineering Co.

OPTICAL PIPELINE VIEWING EQUIPMENT

Welker Engineering Co.

PACKAGED REFRIGERATION SYSTEMS

Aggreko LLC
CB&I Howe-Baker Process & Technology
Dickson & Tryer Engineering Co., Ltd.
Energy Compression System
Gas Packagers, Inc.
Gulf Coast Dismantling
HPT Inc.
Mitsubishi Heavy Industries, Ltd.
NATCO Group Inc.
RSC International
Saulsbury Industries
Select Engineering, Inc.
Toromont Process Systems, Inc.
W. L. Hamilton Engineering P.C.
York Process Systems

PIGGING EQUIPMENT

Western Filter Co., Inc.

PIPELINE MARKER & TEST STATION

Western Filter Co., Inc.

PIPES, VALVES, FITTINGS

CB&I Howe-Baker Process & Technology
City Pipe & Supply Corp.
Daniel Measurement and Control
GE Oil & Gas
J-W Measurement Company
Jet Specialty
Marsau Enterprises
McJunkin Corporation
Myers-Aubrey Co.
Orbit Valve Co.
Peerless Mfg. Co.
Welker Engineering Co.

POLYMERS

Atofina Chemicals Inc., Technical Polymers Division

PRODUCTION EQUIPMENT

CB&I Howe-Baker Process & Technology
Control Microsystems
Gas Technology Corporation
Gulf Coast Dismantling
Hy-Bon Engineering Company, Inc.
J. W. Williams, Inc.
Jet Specialty
Mitsubishi Heavy Industries, Ltd.
NATCO Group Inc.
National Petroleum & Energy Services, Inc.
Peerless Mfg. Co.
Prosernat
Rouly, Inc.
The Hanover Company
United/Wells
W. L. Hamilton Engineering P.C.
Westfield Engineering & Services, Inc.

PROPRIETARY CRYOGENIC PROCESS EQUIPMENT

Air Products and Chemicals, Inc.
BCCK Engineering, Inc.
CB&I Howe-Baker Process & Technology
Chart Heat Exchangers
Pasadyn, Inc.
Sundyne Corporation

PUMPS

Afton Pumps, Inc.
Brice Equipment Company
Rotor-Tech, Inc.
SCFM Compression Systems Co.
Sundyne Corporation
Vanco Engineering Co.

RAILCAR PARTS

Walco Recycling Services LLC

PILOT EXHIBIT 2027 PAGE 095
SCOUT/CHEVRON v. PILOT - IPR2024-00385

RECONDITIONED GAS PLANTS & EQUIPMENT

CB&I Howe-Baker Process & Technology
Bexar Energy Holdings, Inc.
Dickson & Tryer Engineering Co., Ltd.
Energy Compression Systems
Gas Technology Corporation
Gulf Coast Dismantling
HPT Inc.
NATCO Group Inc.
Optimized Process Designs
Pasadyn, Inc.
Pearl Development Company
Rouly, Inc.
Saulsbury Industries
South-Tex Treaters, Inc.
The Hanover Company
Thomas Russell Co.
Total Energy Corp.
Vanson Engineering Co.
W. L. Hamilton Engineering P.C.
Westfield Engineering & Services, Inc.

REFURBISHED TREATING EQUIPMENT

Bexar Energy Holdings, Inc.
CB&I Howe-Baker Process & Technology
Dickson & Tryer Engineering Co., Ltd.
Gas Technology Corporation
Gulf Coast Dismantling
HPT Inc.
Marsau Enterprises
NATCO Group Inc.
Pearl Development Company
Saulsbury Industries
South-Tex Treaters, Inc.
The Hanover Company
Thomas Russell Co.
Westfield Engineering & Services, Inc.

RELIEF VALVES

Brice Equipment Company
Fisher Controls International Inc.
GE Oil & Gas
Jet Specialty
Marsau Enterprises
Myers-Aubrey Co.
NATCO Group Inc.
Total Energy Corp.
Welker Engineering Co.

SAFETY EQUIPMENT

3M Company
Boots & Coots, Inc.
Fisher Controls International Inc.
Invensys Foxboro
Jet Specialty

SAMPLING SYSTEMS

Chandler Engineering Company, LLC
Jet Specialty
SPL, Inc.
Welker Engineering Co.

SEPARATORS

ACS Industries, LP
CB&I Howe-Baker Process & Technology
Dickson & Tryer Engineering Co., Ltd.
Dresser-Rand Company
Eaton Metal Products Company
Gas Packagers, Inc.
GasTech Engineering Corporation
Gulf Coast Dismantling
Hawkins Filtration Products Inc.
J-W Measurement Company
KnightHawk Engineering
Marsau Enterprises
NATCO Group Inc.
Nowata Filtration, Division of NMW, Inc.
Peerless Mfg. Co.
Perry Equipment Corporation
Porous Media
Prosernat
Rhine Ruhr Pty Ltd.
South-Tex Treaters, Inc.
The Hanover Company
United/Wells
Westfield Engineering & Services, Inc.

SKID MOUNTED EQUIPMENT

Afton Pumps, Inc.
Alcoa World Chemicals, Adsorbents and Catalysts
BCCK Engineering, Inc.
CB&I Howe-Baker Process & Technology
Continental Products of Texas
CrystaTech, Inc.
Daniel Measurement and Control
Dickson & Tryer Engineering Co., Ltd.
Elkhorn Construction, Inc.
Elliott Turbomachinery Co. Inc.
Engelhard Corporation
EPC, Inc.
Gas Packagers, Inc.
Gas Technology Corporation
GasTech Engineering Corporation
GE Oil & Gas
Gulf Coast Dismantling
HPT Inc.
Hy-Bon Engineering Company, Inc.
J-W Measurement Company
Jet Specialty
Johnson Filtration Products, Inc.
KnightHawk Engineering
Linde BOC Process Plants LLC
Marsau Enterprises

PILOT EXHIBIT 2027 PAGE 096
SCOUT/CHEVRON v. PILOT - IPR2024-00385

SKID MOUNTED EQUIPMENT (Cont'd.)

Mitsubishi Heavy Industries, Ltd.
NATCO Group Inc.
National Petroleum & Energy Services, Inc.
Pasadyn, Inc.
Pearl Development Company
Peerless Mfg. Co.
Prosernat
Ref-Chem L.P.
RSC International
Saulsbury Industries
Select Engineering, Inc.
Simms Machinery International Inc.
TECNA ESTUDIOS Y PROYECTOS DE INGENIERIA SA
The Hanover Company
Thomas Russell Co.
Thurmond-McGlothlin Inc.
Toromont Process Systems, Inc.
United/Wells
Universal Compression
Vanson Engineering Co.
W. L. Hamilton Engineering P.C.
Welker Engineering Co.
Westfield Engineering & Services, Inc.
York Process Systems

SURPLUS EQUIPMENT

Bexar Energy Holdings, Inc.
Energy Compression Systems
Gas Technology Corporation
Gulf Coast Dismantling
Jet Specialty
NATCO Group Inc.
Pearl Development Company
South-Tex Treaters, Inc.
The Hanover Company
W. L. Hamilton Engineering P.C.
Westfield Engineering & Services, Inc.

TOWER PACKING/INTERNALS/ TRAYS/MIST ELIMINATORS

CB&I Howe-Baker Process & Technology
Koch-Glitsch LP
NATCO Group Inc.
National Petroleum & Energy Services, Inc.
Rhine Ruhr Pty Ltd.
Rouly, Inc.
Sulzer Chemtech

TURBINES

Dresser-Rand Company
Elliott Turbomachinery Co. Inc.
GE Oil & Gas
Gulf Coast Dismantling
Mitsubishi Heavy Industries, Ltd
Rolls-Royce Energy Business
Siemens Demag Delaval
Solar Turbines, Incorporated

TURBOCHARGERS

Exline, Inc.
Hawkins Filtration Products Inc.
Mitsubishi Heavy Industries, Ltd
Waukesha-Pearce Industries, Inc.

TURBOEXPANDERS

Dresser-Rand Company
Elliott Turbomachinery Co. Inc.
GE Oil & Gas
Mafi-Trench Corporation
Simms Machinery International Inc.
Texas Turbine Inc.

VAPOR RECOVERY UNITS

Air Products and Chemicals, Inc.
Dickson & Tryer Engineering Co., Ltd.
Gas Packagers, Inc.
Hy-Bon Engineering Company, Inc.
JGC Corporation
NATCO Group Inc.
SCFM Compression Systems Co.
Texas Turbine Inc.
The Hanover Company
Toromont Process Systems, Inc.
Westfield Engineering & Services, Inc.

VESSELS/INTERNALS/TANKS

Bartlett Equipment Company, Inc.
CB&I Howe-Baker Process & Technology
Dickson & Tryer Engineering Co., Ltd.
Eaton Metal Products Company
Gulf Coast Dismantling
Hawkins Filtration Products Inc.
Johnson Filtration Products, Inc.
KnightHawk Engineering
Linde BOC Process Plants LLC
Marsau Enterprises
NATCO Group Inc.
National Petroleum & Energy Services, Inc.
Rouly, Inc.
Saulsbury Industries
SulfaTreat
The Hanover Company
Total Energy Corp.
Trinity Industries, Inc.
United/Wells

WASTE HEAT RECOVERY UNITS

Bartlett Equipment Company, Inc.
CB&I Howe-Baker Process & Technology

PILOT EXHIBIT 2027 PAGE 097
SCOUT/CHEVRON v. PILOT - IPR2024-00385

WASTE HEAT RECOVERY UNITS (Cont'd.)

Gulf Coast Dismantling
JGC Corporation
KnightHawk Engineering
Mitsubishi Heavy Industries, Ltd
Optimized Process Furnaces
Rouly, Inc.
Thomas Russell Co.

WATER TREATING

Bartlett Equipment Company, Inc.

PILOT EXHIBIT 2027 PAGE 098
SCOUT/CHEVRON v. PILOT - IPR2024-00385

NOTES:

PILOT EXHIBIT 2027 PAGE 099
SCOUT/CHEVRON v. PILOT - IPR2024-00385