Tablica 1. - SVOJSTVA UGLJIKOVODIKA I DRUGIH SASTOJAKA PRIRODNOG PLINA, NAFTE I KONDENZATA (*)

							Kritične konstante						Gustoća tekuće faze			Idealni plin, @15℃, 1.01325 bar(abs)			
Br.	Spoj	Formula	Molarna masa	Vrelište, ℃ @ 1.013250 bar (abs)	Tlak para, bar (abs) @ 40 ℃	Ledište, ℃ @ 1.01325 bar (abs)	Kritični tlak, bar (abs)	Kritična temperatura, K	Kritični volumen, m^3/kg	Z_c	Acentrični faktor, ω	Z-faktor realnog plina, @ 15℃, 1.01325 bar (abs)	Relativna gustoća ("specifična težina"), 15℃/15℃	Gustoća, kg/m^3 (u vakuumu)	$m^3/kmol$	Relativna gustoća ("specifična težina"), zrak=1	m^3 plina/kg	Volumetrijski omjer plin- tekućina	Br.
1	Metan	CH_4	16.043	-161.51	350	-182.45*	45.99	190.56	0.00617	0.2873	0.0108	0.998	(0.3)*	(300.)*	(0.05)*	0.55392	1.4738	(442.15)*	1
2	Etan	C_2H_6	30.070	-88.59	60	-182.79*	48.80	305.41	0.00489	0.2826	0.0972	0.9918	0.35808*	357.76*	0.084051 *	1.0382	0.78635	281.32*	2
3	Propan	C_3H_8	44.097	-42.07	13.698	-187.62*	42.40	369.77	0.00454	0.2761	0.1515	0.9824	0.50776*	507.30*	0.086925*	1.5226	0.53619	272.01*	3
4	Izobutan	C_4H_{10}	58.123	-11.79	5.3089	-159.59	36.40	407.82	0.00446	0.2783	0.1852	0.9709	0.56349*	562.98*	0.10324*	2.0068	0.4068	229.02*	4
5	n-Butan	C_4H_{10}	58.123	-0.51	3.7961	-138.35	37.84	425.1	0.00439	0.2732	0.1981	0.9664	0.58459*	584.06*	0.099515*	2.0068	0.4068	237.60*	5
6	Izopentan	C_5H_{12}	72.150	27.83	1.5131	-159.89	33.81	460.35	0.00427	0.2721	0.2286	-	0.62491	624.35	0.11556	2.4912	0.32772	204.61	6
7	n-Pentan	C_5H_{12}	72.150	36.05	1.147	-129.71	33.65	469.65	0.00434	0.2698	0.251	-	0.63157	631	0.11434	2.4912	0.32772	206.79	7
8	Neopentan	C_5H_{12}	72.150	9.5	2.7	-16.58	31.99	433.71	0.0042	0.2688	0.1965	0.9579	0.59724*	596.70*	0.12092*	2.4912	0.32772	195.55*	8
9	n-Heksan	C_6H_{14}	86.177	68.72	0.37297	-95.31	30.30	506.4	0.00429	0.2661	0.299	0.9881	0.66449	663.89	0.12981	2.9755	0.27438	182.15	9
10	2-Metilpentan	C_6H_{14}	86.177	60.24	0.5068	-153.67	30.10	497.46	0.00426	0.2672	0.278	0.9848	0.65834	657.75	0.13102	2.9755	0.27438	180.47	10
11	3-Metilpentan	C_6H_{14}	86.177	63.26	0.4573	-162.89	31.20	504.4	0.00426	0.2731	0.2736	0.9863	0.66953	668.93	0.12883	2.9755	0.27438	183.54	11
12	Neoheksan	C_6H_{14}	86.177	49.72	0.7341	-99.825	30.80	488.66	0.00417	0.2724	0.2334	0.9798	0.65455	653.96	0.13178	2.9755	0.27438	179.43	12
13	2,3-Dimetilbutan	C_6H_{14}	86.177	57.96	0.5534	-128.53	31.30	499.86	0.00415	0.2693	0.2481	0.984	0.66675	666.15	0.12937	2.9755	0.27438	182.78	13
14	n-Heptan	C_7H_{16}	100.204	98.37	0.12342	-90.55	27.40	539.2	0.00426	0.2609	0.3483	0.9948	0.68846	687.84	0.14568	3.4598	0.23597	162.3	14
15	2-Metilheksan	C_7H_{16}	100.204	90.03	0.17226	-118.26	27.30	530.06	0.0042	0.2607	0.3312	0.9931	0.68359	682.97	0.14672	3.4598	0.23597	161.16	15
16	3-Metilheksan	C_7H_{16}	100.204	91.85	0.16155	-	28.10	535.16	0.00403	0.2550	0.3231	0.9935	0.69206	691.44	0.14492	3.4598	0.23597	163.16	16
17	3-Etilpentan	C_7H_{16}	100.204	93.47	0.15265	-118.58	28.90	540.46	0.00415	0.2674	0.3111	0.9939	0.70327	702.64	0.14261	3.4598	0.23597	165.8	17
18	2,2-Dimetilpentan	C_7H_{16}	100.204	79.17	0.2632	-123.78	27.70	520.36	0.00415	0.2662	0.287	0.9903	0.67884	678.23	0.14774	3.4598	0.23597	160.04	18
19	2,4-Dimetilpentan	C_7H_{16}	100.204	80.47	0.2485	-119.21	27.40	519.66	0.00417	0.2650	0.3035	0.9907	0.67763	677.02	0.14801	3.4598	0.23597	159.75	19
22	n-Oktan	C_8H_{18}	114.231	125.65	0.04146	-56.76	24.90	568.4	0.0042	0.2528	0.3978	0.9977	0.70718	706.54	0.16168	3.9441	0.20699	146.25	22
23	Diizobutil	C_8H_{18}	114.231	109.08	0.08417	-91.16	24.90	549.96	0.00422	0.2625	0.3571	0.9959	0.69845	697.82	0.1637	3.9441	0.20699	144.44	23
24	Izooktan	C_8H_{18}	114.231	99.21	0.12966	-107.35	25.70	543.86	0.0041	0.2662	0.3043	0.9941	0.69669	696.06	0.16411	3.9441	0.20699	144.08	24
25	n-Nonan	C_9H_{20}	128.258	150.78	0.01358	-53.48	22.80	594.7	0.00433	0.2561	0.4425	0.999	0.72231	721.66	0.17773	4.4284	0.18436	133.04	25
26	n-Dekan	$C_{10}H_{22}$	142.285	174.11	0.00481	-29.63	21.00	617.7	0.00439	0.2554	0.4881	0.9996	0.73452	733.86	0.19389	4.9127	0.16618	121.95	26
60	Dušik	N_2	28.0134	-195.798	-	-209.997*	33.98	126.21	0.00318	0.2885	0.037	0.9997	0.80933*	808.60*	0.034644*	0.96723	0.84402	682.48*	60
53	Ugljikov dioksid	CO_2	44.010	-78.464*	-	-56.56*	73.74	304.11	0.00214	0.2747	0.2667	0.9964	0.82268*	821.94*	0.053544*	1.5196	0.53726	441.59*	53
54	Vodikov sulfid	H_2S	34.082	-60.266	28.597	-85.48*	89.63	373.37	0.00288	0.2834	0.0948	0.9845	0.80262*	801 90*	0.042499*	1.1767	0.69382	556.37*	54
57	Zrak	N_2+O_2	28.9625	-194.34	-	-	37.71	132.43	0.00323	0.3204		0.9996	0.87469*	873.90*	0.033142*	1	0.81639	713.45*	57
59	Kisik	O_2	31.9988	-182.954*	-	-218.792*	50.43	154.59	0.00229	0.2875	0.0216	0.9992	1.1420*	1141.0*	0.028045*	1.1048	0.73893	843.12*	59
62	Voda	H_2O	18.0153	99.974*	0.07385	0.000	220.64	647.1	0.003106	0.2295	0.3445	-	1.0000	999.1	0.018032	0.62202	1.3125	1311.3	62
63	Helij	He	4.0026	-268.95	-		2.28	5.2	0.01436	0.3024	0	1.0005	0.12509*	124.98*	0.032026*	0.1382	5.9074	738.30*	63

(*) Preuzeto i adaptirano iz "*Engineering Data Book*" , 11th Edition-SI , Vol.2, Gas Processors Suppliers Association, Tulsa (1998).

Tablica 2 - VRIJEDNOSTI OPĆE PLINSKE KONSTANTE

p	*T*	*V*	*n*	*R*
atm	K	L	gmol	0.0820575
atm	K	cm^3	gmol	82.0575
bar	K	L	gmol	0.083145
bar	K	m^3	kgmol	0.083145
kPa	K	m^3	gmol	0.0083145
Pa	K	m^3	gmol	8.3145
kPa	K	m^3	kgmol	8.3145
kg/cm^2	K	L	gmol	0.084784
	T	*Energija*	*n*	*R*
	K	cal	gmol	1.9859
	K	joule	gmol	8.3145
	K	joule	kgmol	8314.5

KONVERZIJE JEDINICA I VELIČINA

Duljina:

1 inch (in.; također: 1*”)*= 2.54 *cm* = 0.0254 *m*
1 foot (ft) = *12”* = 30.48 *cm* = 0.3048 *m*

Površina:

1 square inch = $(1'')^2 = 6.4516\ cm^2 = 0.00064516\ m^2$

1 square foot = $ft^2 = 144\ in.^2 = 929.0304\,cm^2 = 0.09290304\,m^2$

Volumen:

1 cubic inch = $(1'')^3 = 16.38706\,cm^3 = 16.38 \times 10^{-6}\,m^3$

1 cubic foot = $1\,cuft = 1\,ft^3 = 28316.85\,cm^3 = 0.02831685\,m^3$

1 barrel (bbl) = $0.15898\,m^3$, *1 STB* = barrel pri s.c.

1 gallon = $3.785412\ dm^3 = 3.785412 \times 10^{-3} m^3$

Masa:

1 pound (lb) = $0.4535924\,kg$

Relativna gustoća:

API gravity: $\rho_{API} = \dfrac{141.5}{\gamma} - 131.5$, $\gamma_o = \dfrac{\rho_o}{(\rho_w)_{s.c.}}$, $\gamma_g = \dfrac{\rho_g}{(\rho_{zrak})_{s.c.}}$

Tlak:

1 *atm* = 760 *mmHg* = 1.01325 *bar*
1 *at* = 735.559 *mm Hg* = 0.980665 *bar*
1 *bar* = 750.0617 *mmHg*
1 *bar* = $10^5\,Pa$ = 100 *kPa*
1 *pound per square inch* (***psi***)

$$= \left(\frac{lb}{in^2}\right) = \frac{(0.4535924\,kg \times 9.80665\ m/s^2)}{(0.00064516\ m^2)} = 6.894757\,kPa = 0.06894757\ bar$$

Temperatura:

$$1^\circ\,Rankine\,(^\circ R) = \frac{9}{5}K$$

$0^\circ\,Fahrenheit\ (^\circ F) = 459.67\ ^\circ R$; $0^\circ C = 273.15\,K$

$$K = {}^\circ C + 273.15$$

$${}^\circ C = \frac{5}{9}({}^\circ F - 32)$$

$${}^\circ C = \frac{5}{9}({}^\circ F - 32)$$

$${}^\circ R = {}^\circ F + 459.67$$

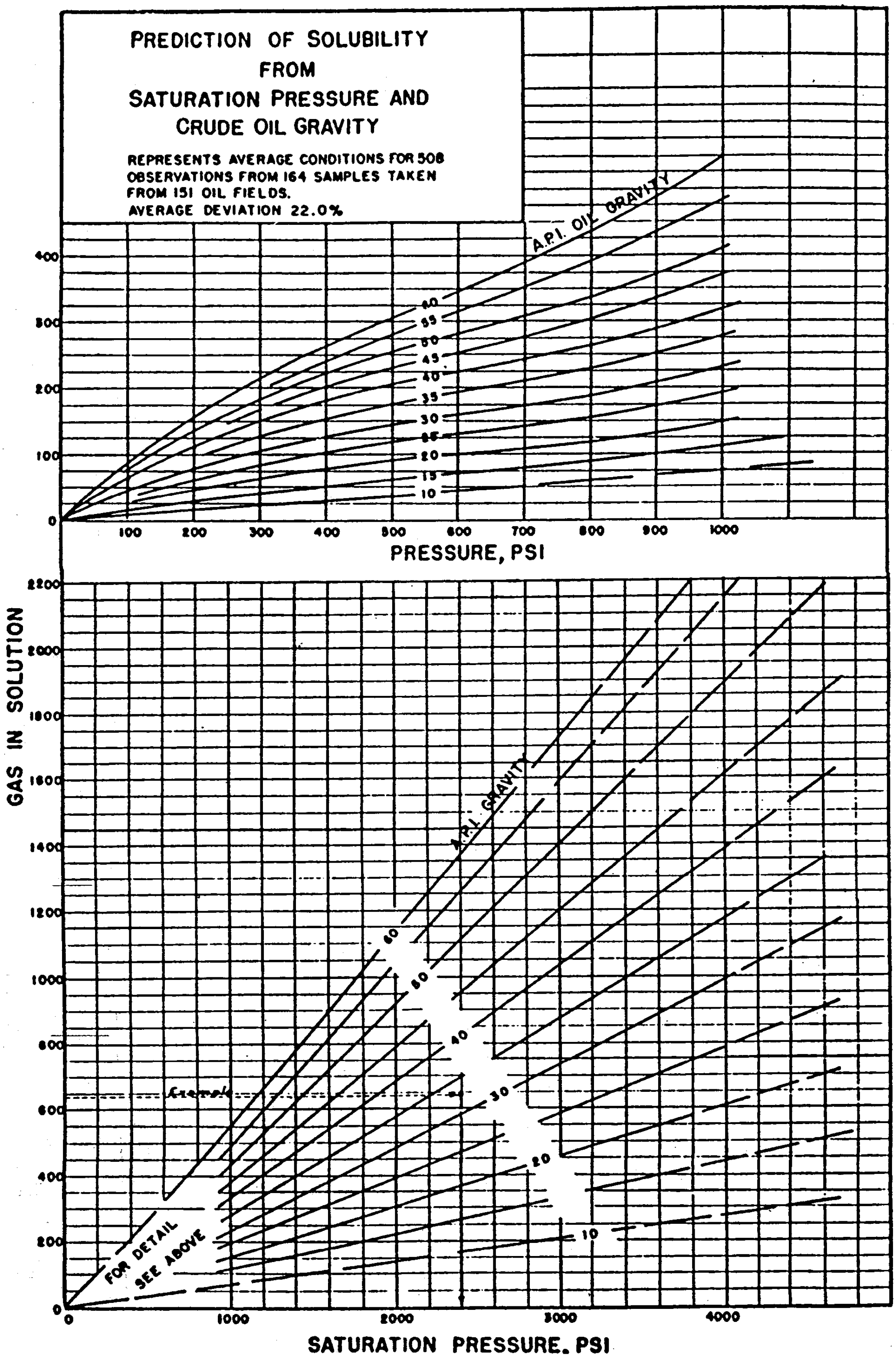
$${}^\circ F = {}^\circ R - 459.67$$

$${}^\circ F = \frac{9}{5}{}^\circ C + 32$$

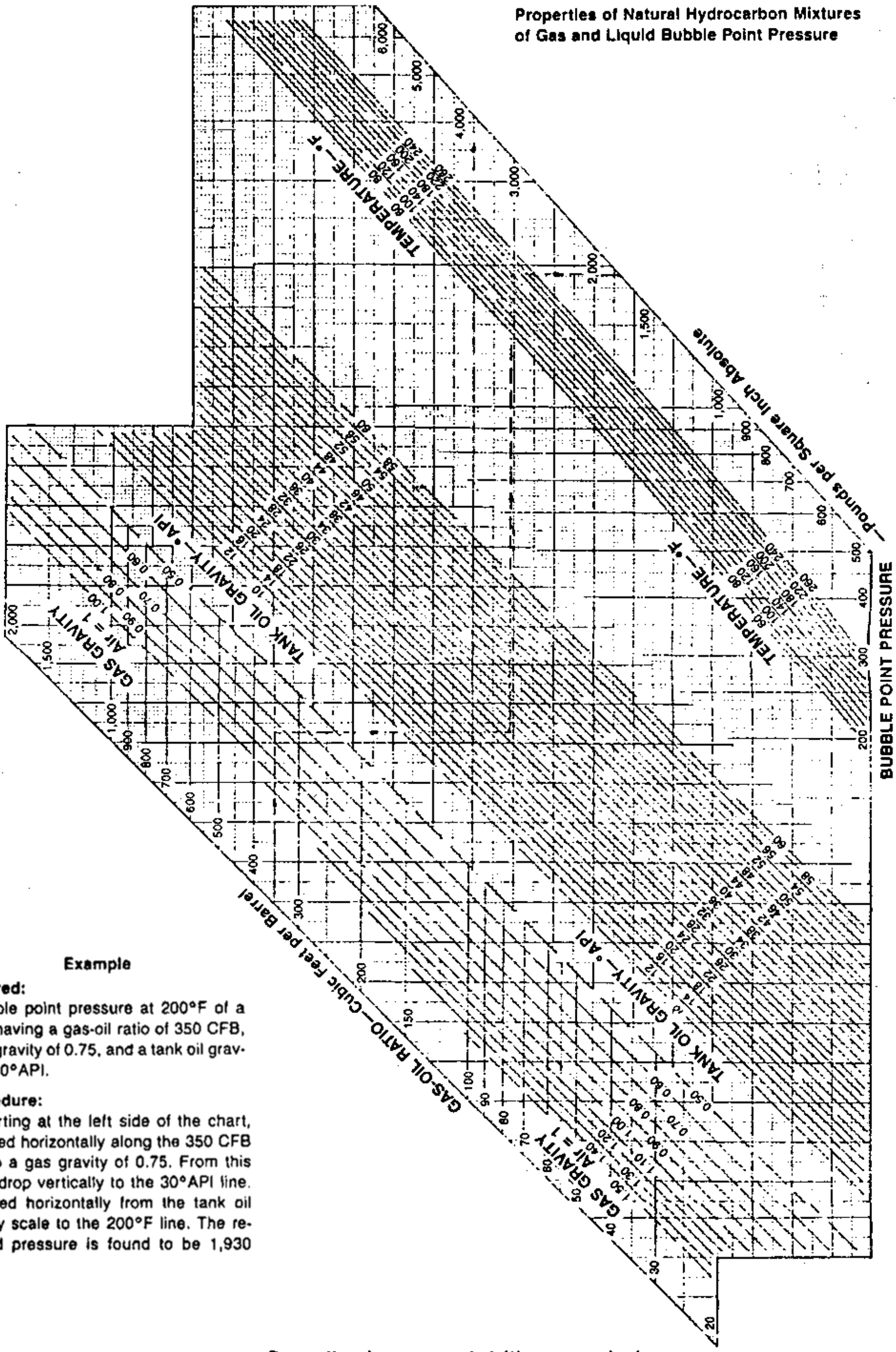
Viskoznost

1 *centiPoise* (*cP*) $= 1\,mPa \cdot s$ *(milipascal sekunda)*

DIJAGRAMI



Beal's correlation for determining R_s. Permission to publish by the Society of Petroleum Engineers of AIME. Copyright SPE-AIME.



Example

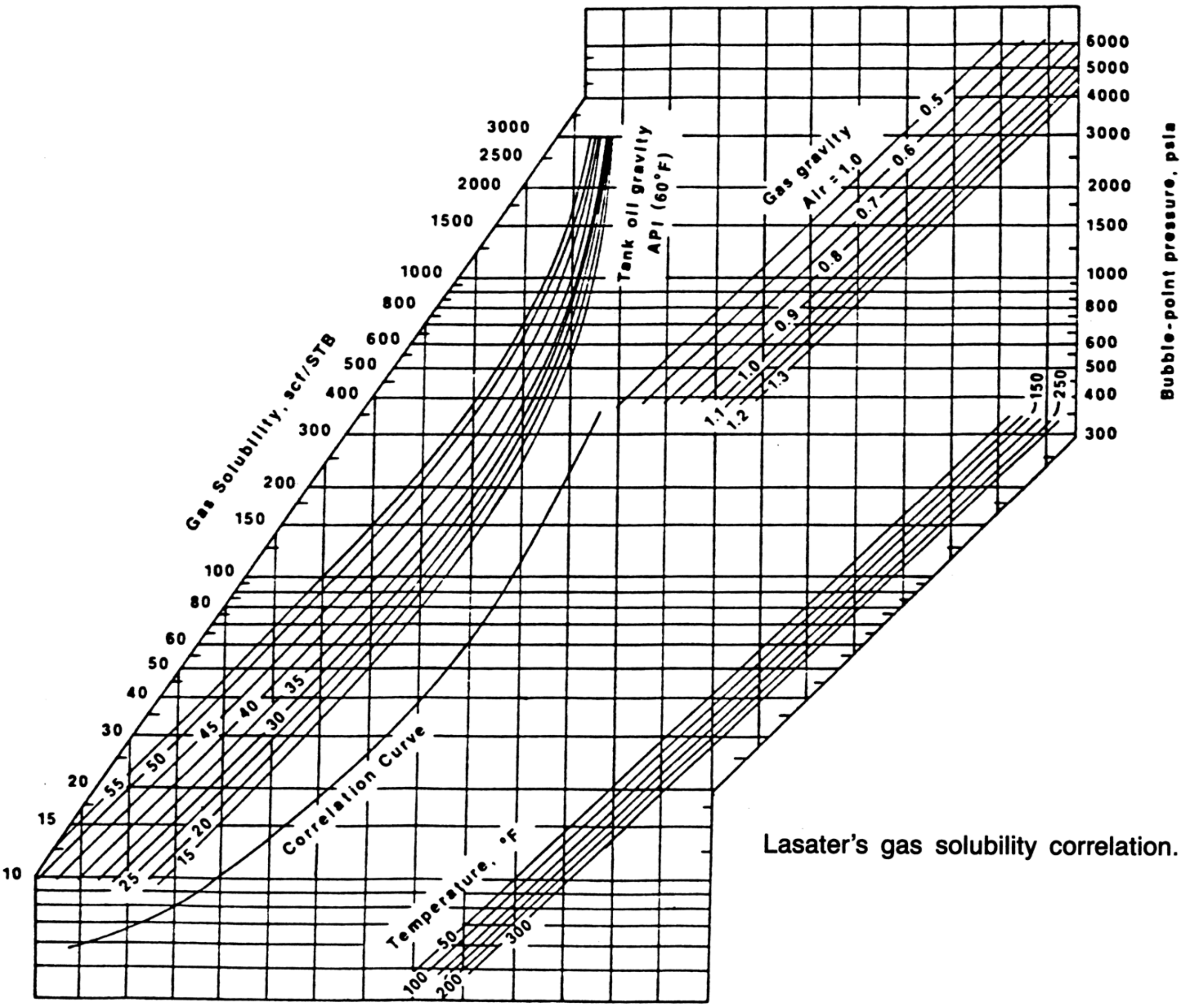
Required:

Bubble point pressure at 200°F of a liquid having a gas-oil ratio of 350 CFB, a gas gravity of 0.75, and a tank oil gravity of 30°API.

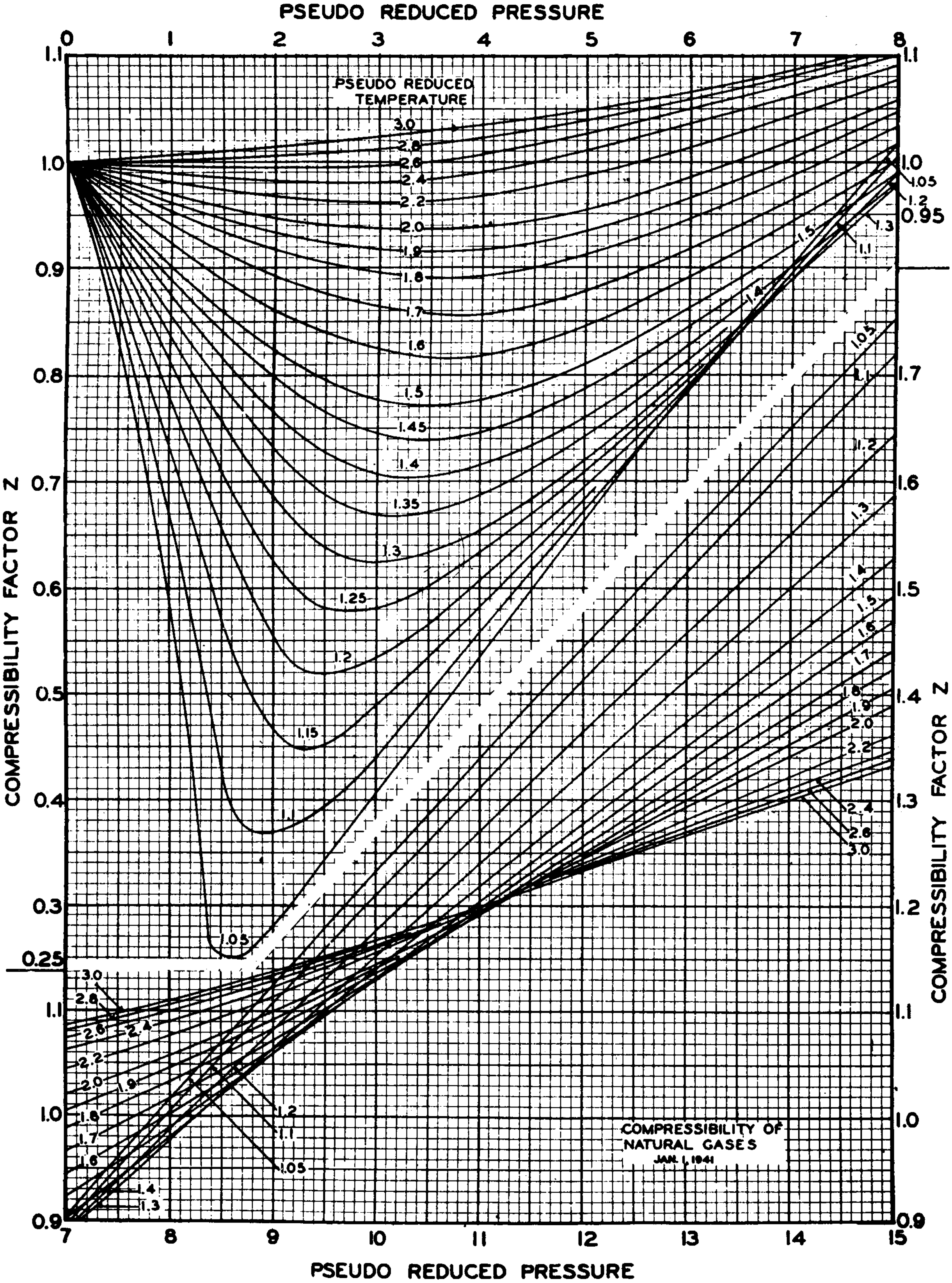
Procedure:

Starting at the left side of the chart, proceed horizontally along the 350 CFB line to a gas gravity of 0.75. From this point drop vertically to the 30°API line. Proceed horizontally from the tank oil gravity scale to the 200°F line. The required pressure is found to be 1,930 PSIA.

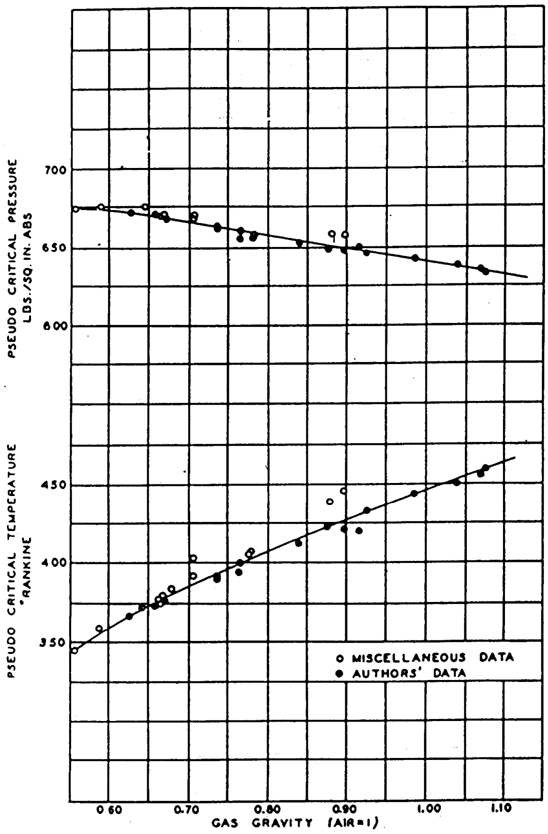
Standing's gas solubility correlation.



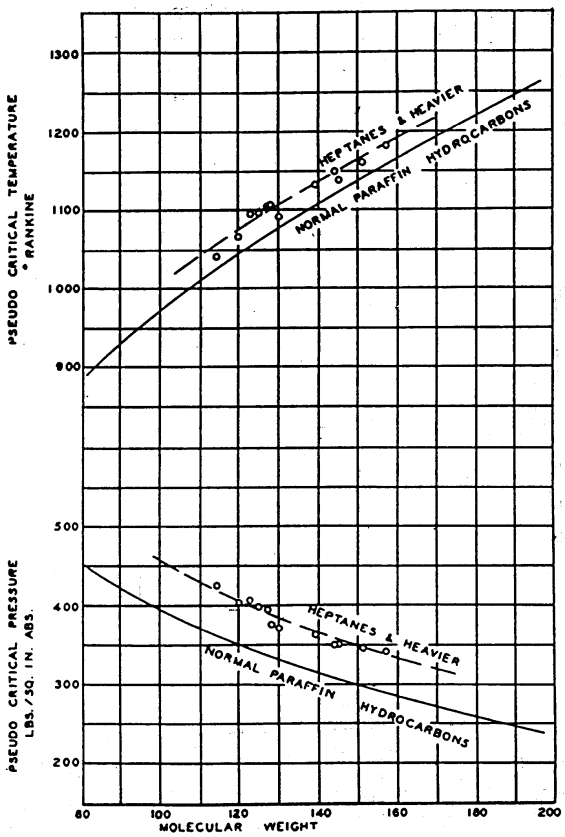
Lasater's gas solubility correlation.



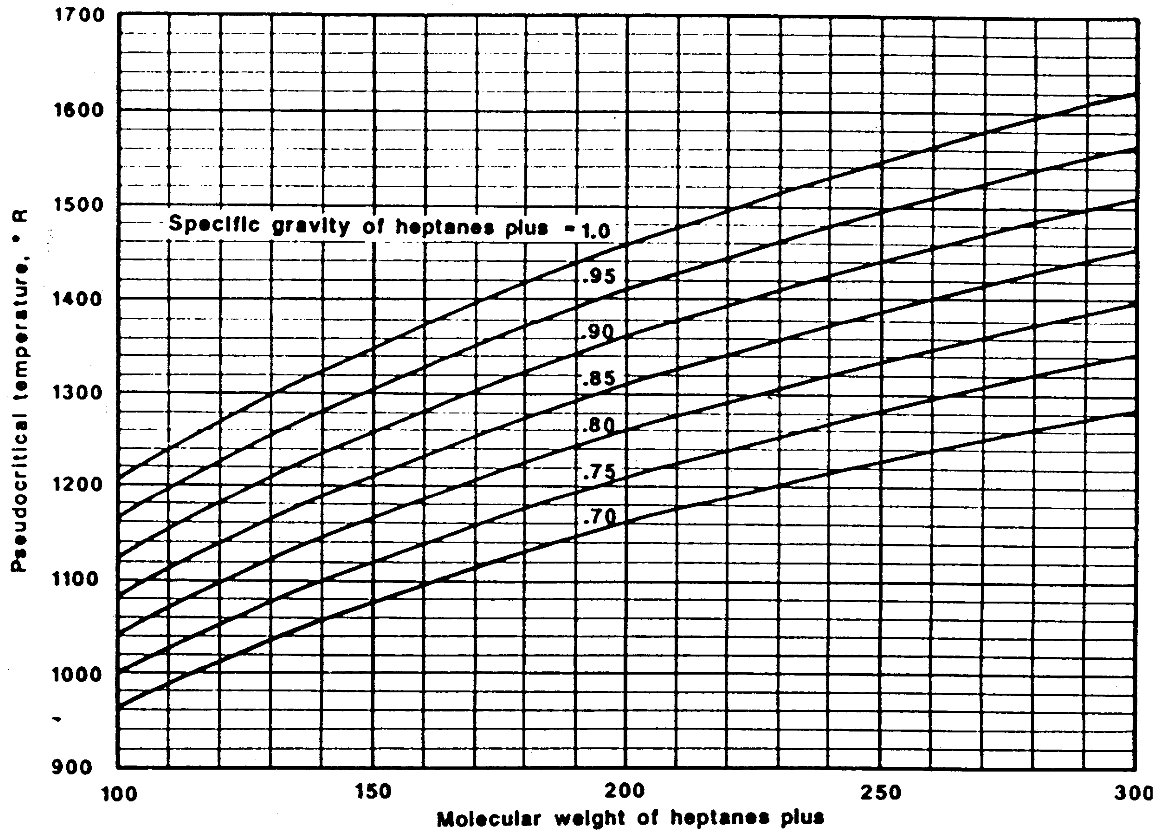
Compressibility Factors for Natural Gases (After Standing and Katz, Trans. AIME, 1942)

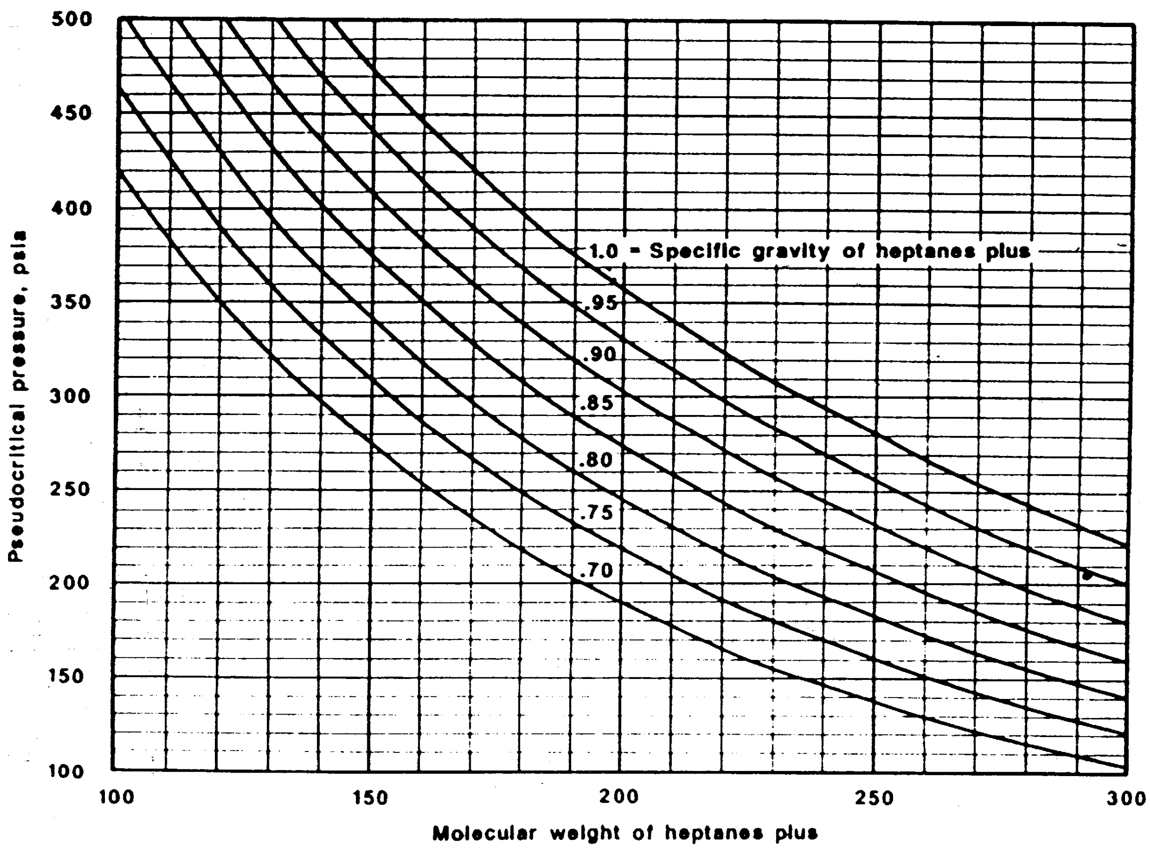


Variation Of Pseudocriticals With Gas Gravity

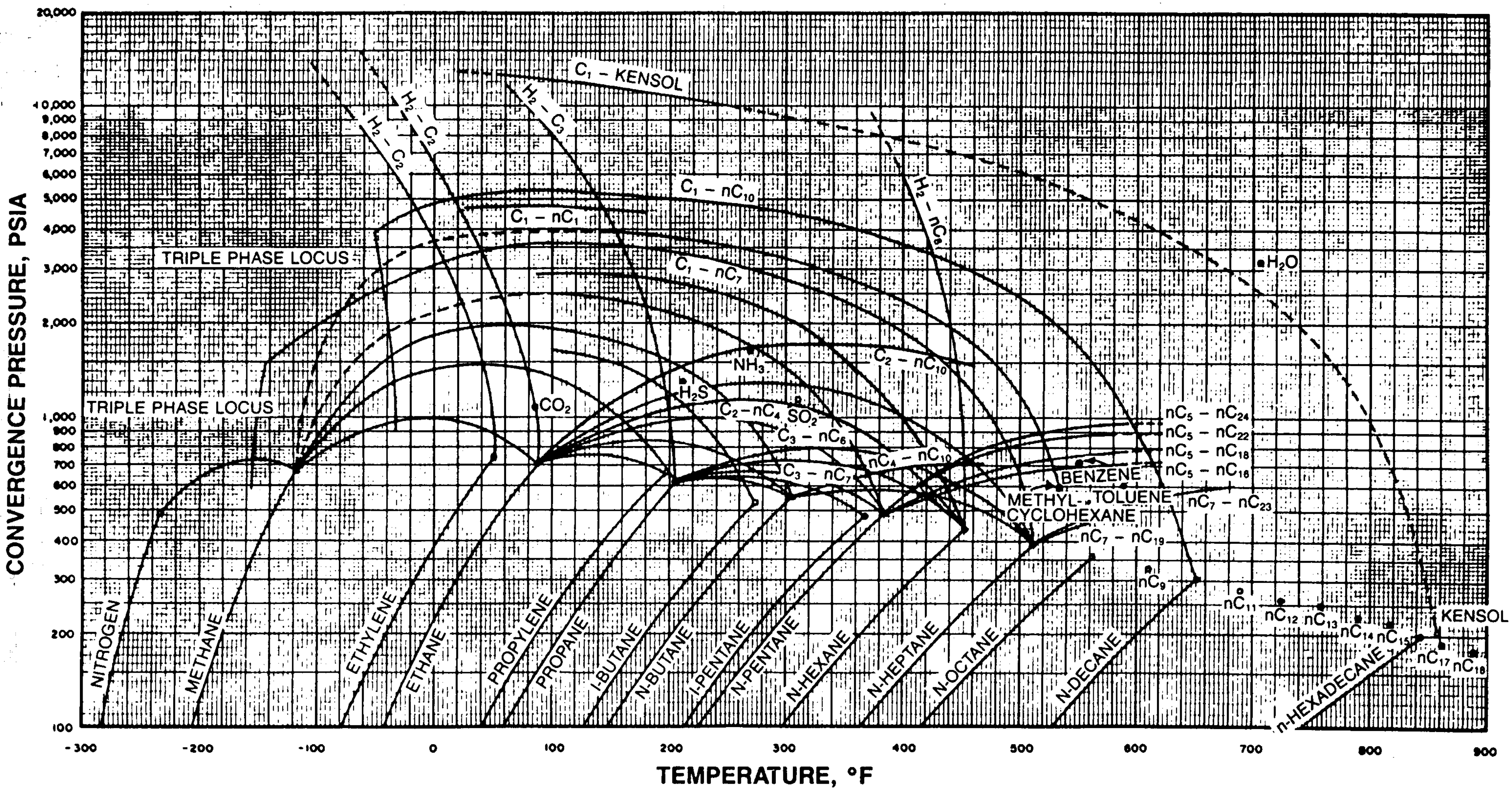


Variation Of Pseudocriticals With Molecular Weight





Pseudocritical properties of heptanes plus



Convergence pressures for binary systems. Courtesy of the Gas Processors Suppliers Association. Published in the GPSA Engineering Data Book, Tenth Edition, 1987.

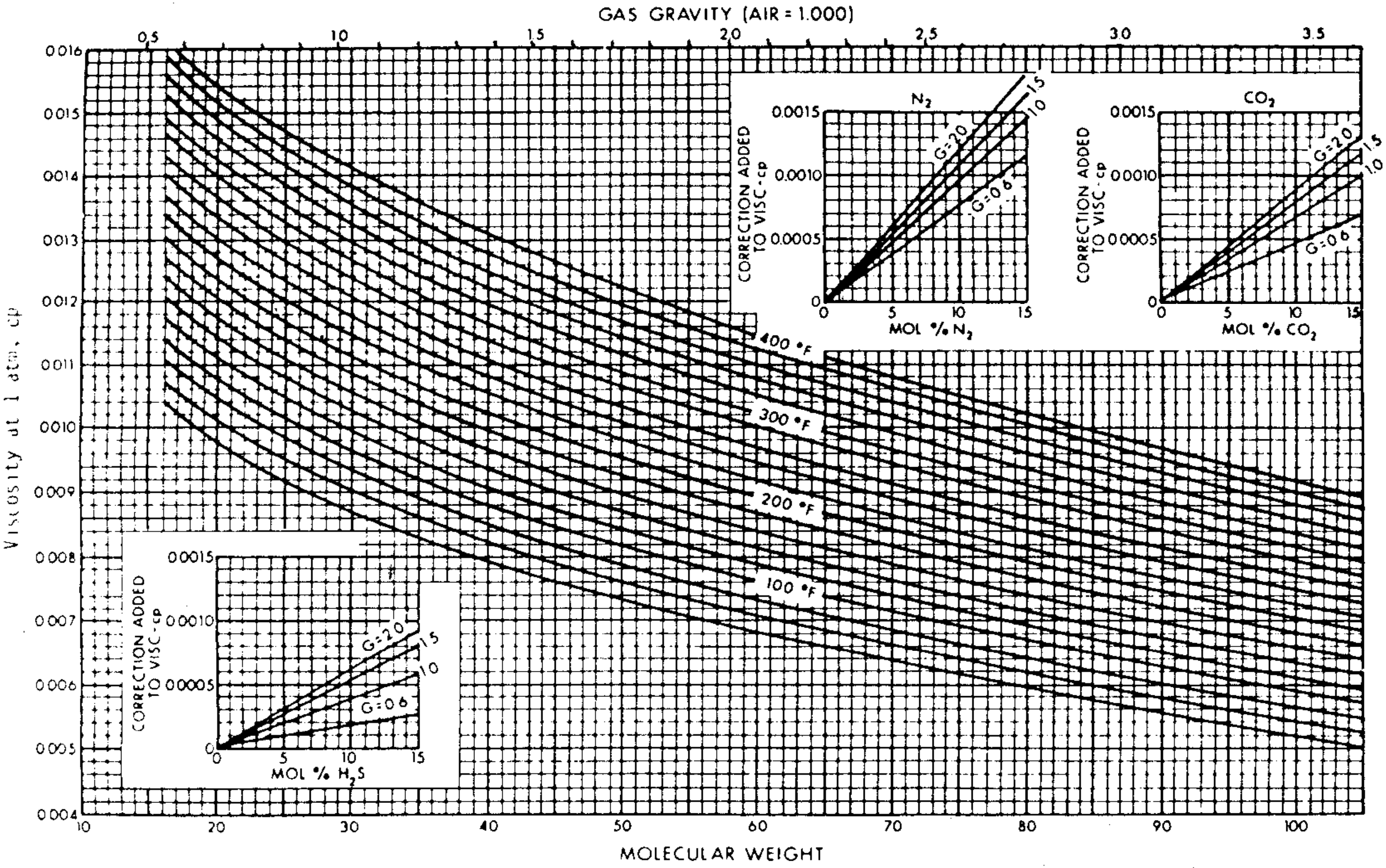
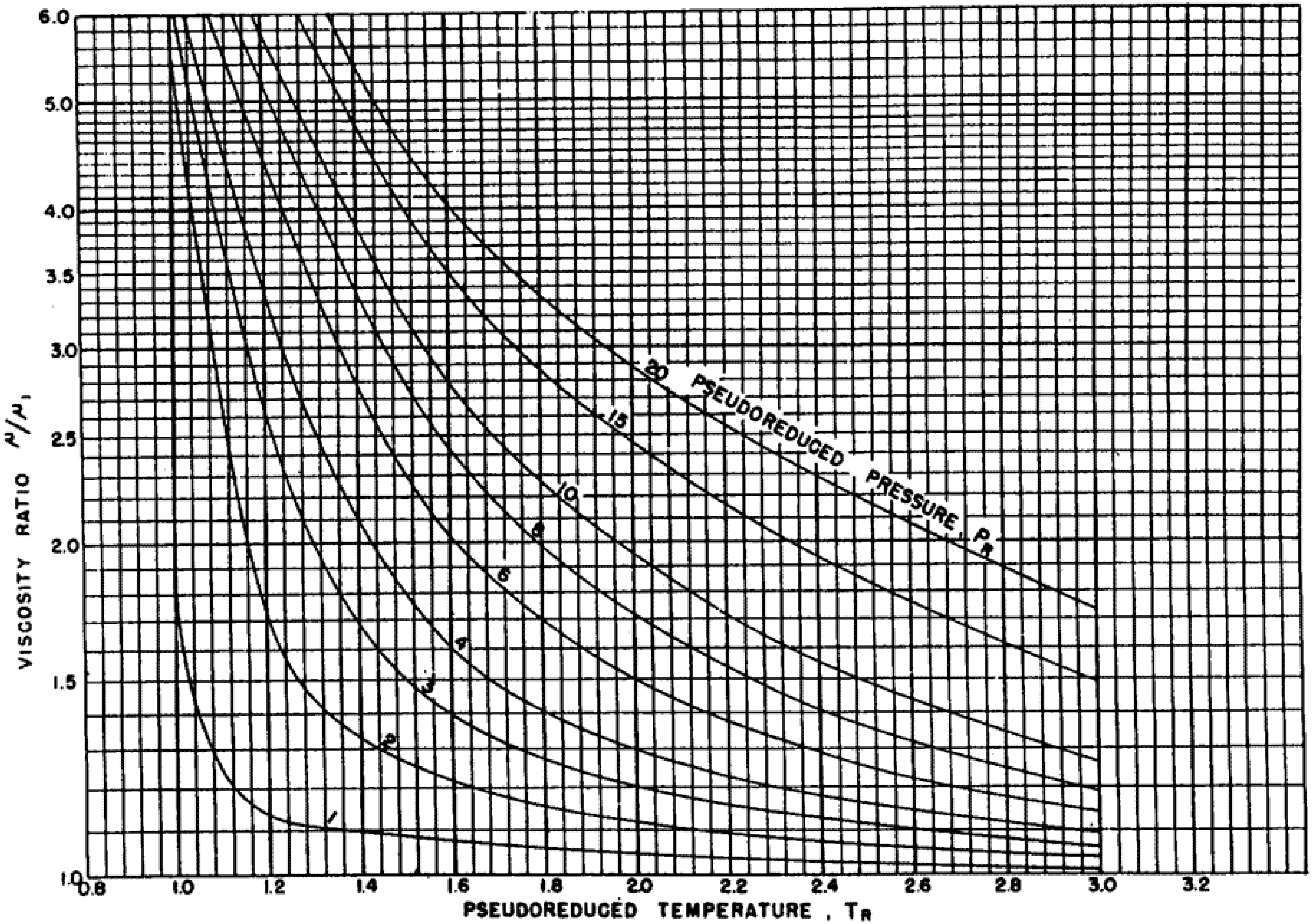


Figure 3-10. Carr's atmospheric gas viscosity correlation. Permission to publish by the Society of Petroleum Engineers of AIME. Copyright SPE-AIME.



RATIO OF GAS VISCOSITY AT ELEVATED PRESSURE TO VISCOSITY AT ATMOSPHERIC PRESSURE
VS. PSEUDOREDUCED TEMPERATURE AND PRESSURE
(After Carr, Kobayashi and Burrows, Trans AIME, 1954)

FORMULE I KORELACIJE ZA RAČUNANJE SVOJSTAVA FLUIDA

-molarni udjel komponente i ($i = 1,N$) u smjesi:

$$\sum_{i=1}^{N} y_i = \sum_{i=1}^{N} \frac{n_i}{n} = 1$$

n_i = broj molova komponente i u smjesi,
n = ukupni broj molova smjese

$$y_i = \frac{n_i}{\sum_{i=1}^{N} n_i} \text{ odnosno } y_i = \frac{n_i}{n}$$

-broj molova:

$$n = \frac{m}{M} \text{ odnosno } m = nM \quad \text{i} \quad M = \frac{m}{n}$$

m = masa tvari
M = molekularna masa
-molekularna masa smjese

$$M = \sum_{i=1}^{N} y_i M_i$$

-maseni udjel (w_i) komponente u smjesi:

$$w_i = m_i \Big/ \sum_{i=1}^{N} m_i$$

-Boyle-Marriotteov zakon: $p_1V_1 = p_2V_2 = p_3V_3$, $T = const.$

-Charlesov zakon:

$$V_1T_2 = V_2T_1 \text{ , pri } p = const. \text{ odnosno } V_2 = \frac{V_1T_2}{T_1}$$

-Gay-Lussacov zakon:

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}, \text{ pri } V = const. \text{ odnosno } p_2 = \frac{T_2 p_1}{T_1}$$

-jednadžba stanja idealnog plina:

$$pV = nRT = \frac{m}{M} RT$$

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

-Daltonov zakon o parcijalnim tlakovima $p_i = y_i \times p$.

-gustoća plina $\rho = \frac{m}{V} = \frac{pM}{RT}$

-relativna gustoća nafte(*specifična težina*)

$$\gamma_o = \frac{\rho_{o_{(p,T)}}}{\rho_{w_{(p,T)}}} \text{ , } \rho_{w_{(s.c.)}} = 0.999 g/cm^3$$

-gustoća u °API ima:

$$\rho_{API} = \frac{141.5}{\gamma_o} - 131.5 \text{ odnosno } \gamma_o = \frac{141.5}{\rho_{API} + 131.5}$$

-volumni faktor nafte:

$$B_o = \frac{V_{o_{(r.c.)}}}{V_{o_{(s.c.)}}} = \frac{\text{volumen nafte pri ležišnim uvjetima}}{\text{volumen nafte pri standardnim uvjetima}}$$

-plinski faktor (faktor otopljenog plina):

$$R_s = \frac{V_{g_{(s.c.)}}}{V_{o_{(s.c.)}}} \text{ , } V_{g_{(s.c.)}} = \text{volumen plina pri standardnim uvjetima}$$

-relativna gustoća plina:

$$\gamma_g = \frac{\rho_{g_{(p,T)}}}{\rho_{zraka_{(p,T)}}} \text{ , } \rho_{zraka(s.c.)} = 1.225 \, kg/m^3$$

-prosječni koeficijent izotermičke kompresibilnosti fluida:

$$c = -\frac{1}{V_{poč}} \times \frac{V_{o_2} - V_{o_1}}{p_2 - p_1}$$

-Standingova korelacija za računanje faktora otopljenog plina:

$$R_s = \gamma_g \left[\left(\frac{p_b}{18.2} + 1.4 \right) \times 10^{0.0125\rho_{API} - 0.00091\times T} \right]^{1.2048}$$

$$\left(T \text{ u } F \text{ , } p_b \text{ u psia , } R_s \text{ u } \frac{scf}{STB} \right)$$

-Glasøva korelacija za računanje faktora otopljenog plina:

$$R_s = \gamma_g \left[\frac{\rho_{API}^{0.989}}{T^{0.172}} \times p_b^* \right]^{1.225}$$

$$\text{korekcioni broj } p_b^* = 10^{2.8869 - (14.1811 - 3.3093 \times \log p_b)^{0.5}}$$

$$\left(T \text{ u } F \text{ , } p_b \text{ u psia , } R_s \text{ u } \frac{scf}{STB} \right)$$

-Standingova korelacija za računanje volumnog faktora nafte:

$$B_{o_{Standing}} = 0.9759 + 0.00012 \times \left[R_s \times \left(\frac{\gamma_g}{\gamma_o} \right)^{0.5} + 1.25 \times T \right]^{1.2}$$

-Glasøva korelacija za računanje volumnog faktora nafte:

$$B_{o_{Glaso}} = 1 + 10^A$$

$$A = -6.58511 + 2.91329 \times \log(B_{ob})^* - 0.27683 \times \log^2(B_{ob})^*$$

$(B_{ob})^*$ je "*korelacijski broj*" *definiran kao*:

$$(B_{ob})^* = R_s \left(\frac{\gamma_g}{\gamma_o} \right)^{0.526} + 0.968 \times T$$

-Marhounova korelacija za računanje volumnog faktora nafte:

$$B_{o_{Marhoun}} = 0.497069 + 0.862963 \times 10^{-3} \times (T + 460) +$$
$$+ 0.182594 \times F \times 10^{-2} + 0.318099 \times 10^{-5} \times F^2$$

$$F = R_s^{\,a} \times \gamma_g^{\,b} \times \gamma_o^{\,c}$$

$a = 0.74239$

$b = 0.323294$

$c = -1.20204$

-Arpova korelacija za računanje volumnog faktora nafte:

$$B_{o_{Arp}} = 1.05 + 0.0005R_s$$

-Standingova korelacija za računanje tlaka zasićenja nafte:

$$p_b = 18.2\left[\left(R_s / \gamma_g\right)^{0.83} \times 10^a - 1.4\right] \qquad [psia]$$

$$a = 0.00091 \times T - 0.0125 \times {}^{\circ}API$$

-Glasøva korelacija za računanje tlaka zasićenja nafte:

$$\log p_b = 1.7669 + 1.7447 \log p_{b*} - 0.30218 \log^2 p_{b*}$$

p_{b*} je korelacijski broj

$$p_{b*} = \left(\frac{R_s}{\gamma_g}\right)^a \times T^b \times \left(\rho_{o_{(API)}}\right)^c$$

$$a = 0.816,\ b = 0.172,\ c = -0.989$$

– u svim korelacijama za računanje volumnog faktora nafte i tlaka zacićenja su :

T = *ležišna temperatura u F*

R_s = *omjer otopljenog plina i nafte* $\left[\frac{scf}{STB}\right]$

γ_o = *relativna gustoća nafte*

γ_g = *relativna gustoća naftnog plina*

-reducirani tlak, volumen i temperatura:

$$p_r = \frac{p}{p_c}\ ,\quad V_r = \frac{V}{V_c}\ ,\quad T_r = \frac{T}{T_c}$$

p_c, V_c, T_c = *kritični tlak, volumen, temperatura*

-pseudokritični tlak i temperatura:

$$P_{pc} = \sum y_i \cdot P_{ci}$$

$$T_{pc} = \sum y_i \cdot T_{ci}$$

P_{ci}, T_{ci} = *kritični tlak i temperatura komponente i*

-pseudoreducirani tlak i temperatura:

$$P_{pr} = \frac{P}{P_{pc}},\ T_{pr} = \frac{T}{T_{pc}}$$

-Standingova korelacija za računanje ravnotežnih omjera:

$$K_i = \frac{1}{p} \times 10^{a + c \times F_i}\ ,\quad F_i = b_i \times \left(\frac{1}{T_{bi}} - \frac{1}{T}\right)$$

$$a = 1.2 + 0.00045p + 15 \times 10^{-8} \times p^2$$

$$c = 0.89 - 0.00017p - 3.5 \times 10^{-8} \times p^2$$

p = *tlak u psia*

T = *temperatura u* $^{\circ}R$

F_i = *faktor karakterizacije komponente i*

T_{bi} = *normalno vrelište komponente* ^{o}R

b_i = *korelacijski parametar, ukoliko nije zadan*:

$$b_i = \frac{\log \frac{p_{ci}}{14.7}}{\frac{1}{T_{bi}} - \frac{1}{T_{ci}}}$$

T_{ci}, p_{ci} = *kritična temperatura* $[{}^{\circ}R]$ *i tlak* $[psia]$ *komponente*

-Standingova metoda za određivanje konvergentnog tlaka:

$$P_k = 60M_{Wc_{7+}} - 4200\,[psia]$$

-Rzasova metoda za određivanje konvergentnog tlaka:

$$P_k = -2381.8542 + 46.341487 M_{wC_{7+}} \times \gamma_{C_{7+}} + \sum_{i=1}^{3} a_i \left[\frac{M_{wC7+} \times \gamma_{C7+}}{T}\right]^i$$

$$a_1 = 6124.3049\ ,\ a_2 = -2753.2538\ ,\ a_3 = 415.42049$$

T – *temperatura u* $^{\circ}F$, $P_k = [psia]$

-Haddenova metoda:

$$w_i = \frac{x_i \times M_i}{\sum x_i \times M_i}$$

-Newton-Raphsonove metode iteracije za određivanje količine kapljive faze u separatoru i sastava plinske i kapljive faze na izlazu iz separatora:

$$\sum_i \frac{z_i}{V \times K_i + L} = 1\ ,\ x_i = \frac{z_i}{L + V \times K_i}\ ,\ y_i = K_i \times x_i$$

-tlak rosišta (Newton-Raphsonove metode iteracije):

$$\sum_i \frac{z_i}{K_i} = 1$$

-tlak zasićenja smjese (Newton-Raphsonove metode iteracije):

$$\sum z_i \times K_i = 1$$

-viskoznost pomoću korelacije Carr-Kobayashi-Burrows:

$$\mu = \mu'_1 + \mu_{cor}$$

$$\mu = \frac{\mu}{\mu_1} \times \mu_1$$