2017/1/30 流量計測クラブ

気体流量測定における物性値

石橋雅裕

産総研・気体流量標準G

気体流量・・・圧縮性（流れに沿う密度変化）のある流れ

- 流速によって密度が変化する。

  ✓ 流路断面積が変わると流速が変化して密度が変化し、定常流であっても、場所によって体積流量が変わる。（質量流量は不変）

  ✓ 面積が一定であっても、圧損（管壁摩擦）によって体積流量が変化。

- 条件を指定しないと体積が決まらない。

  ✓ 指定状態が決まると、密度を使って換算。

  ✓ たとえば、「標準状態での」体積流量、通過体積の計算。

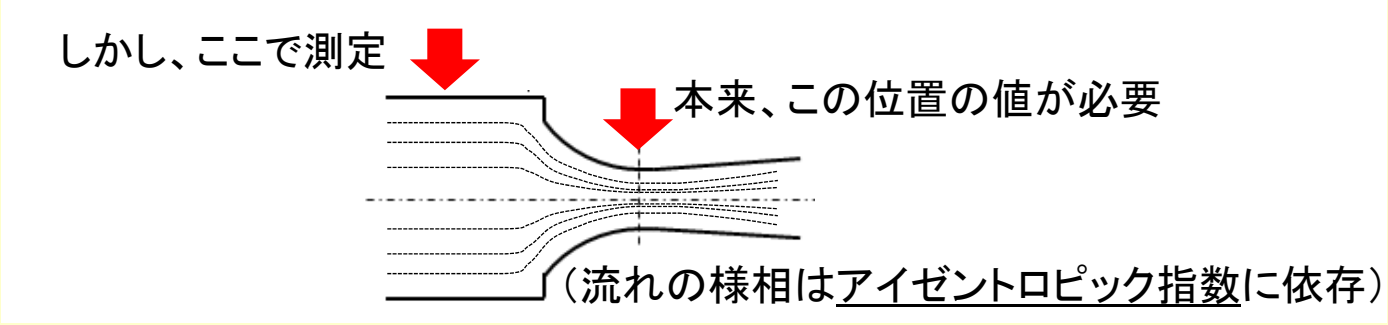
- 密度は？
  - 状態方程式：$PV = nRT = \frac{M}{N}RT \Rightarrow \rho = \frac{M}{V} = \frac{N}{R}\frac{P}{T}$
  - 測定：　高精度は難しい。

気体流量・・・圧縮性のある流れの流量

- 密度が変化するが故に、
  - ✓ 流量を求める式に物性値が必要。

    ⇧

    本来必要な位置（スロート位置、オリフィス孔位置）で温度圧力が測定できない。



  - ✓ そもそも、流量の計算に密度が使われている。

$$q_V = A \cdot c$$

臨界ノズル

$$c = \sqrt{\frac{\kappa p}{\rho}}$$

すべてこれを基礎とする

$$\frac{u^2}{2} + \int \frac{dp}{\rho} = const$$

気体流量・・・圧縮性のある流れの流量

- オリフィス流量計
  - ✓ 元が非圧縮の式である。（非圧縮のベルヌーイの式から出発。）

⇩

圧縮性流体では、圧力が下がると膨張するため、補正が必要となる。

⇩

膨張補正係数： アイゼントロピック指数を使用して補正。

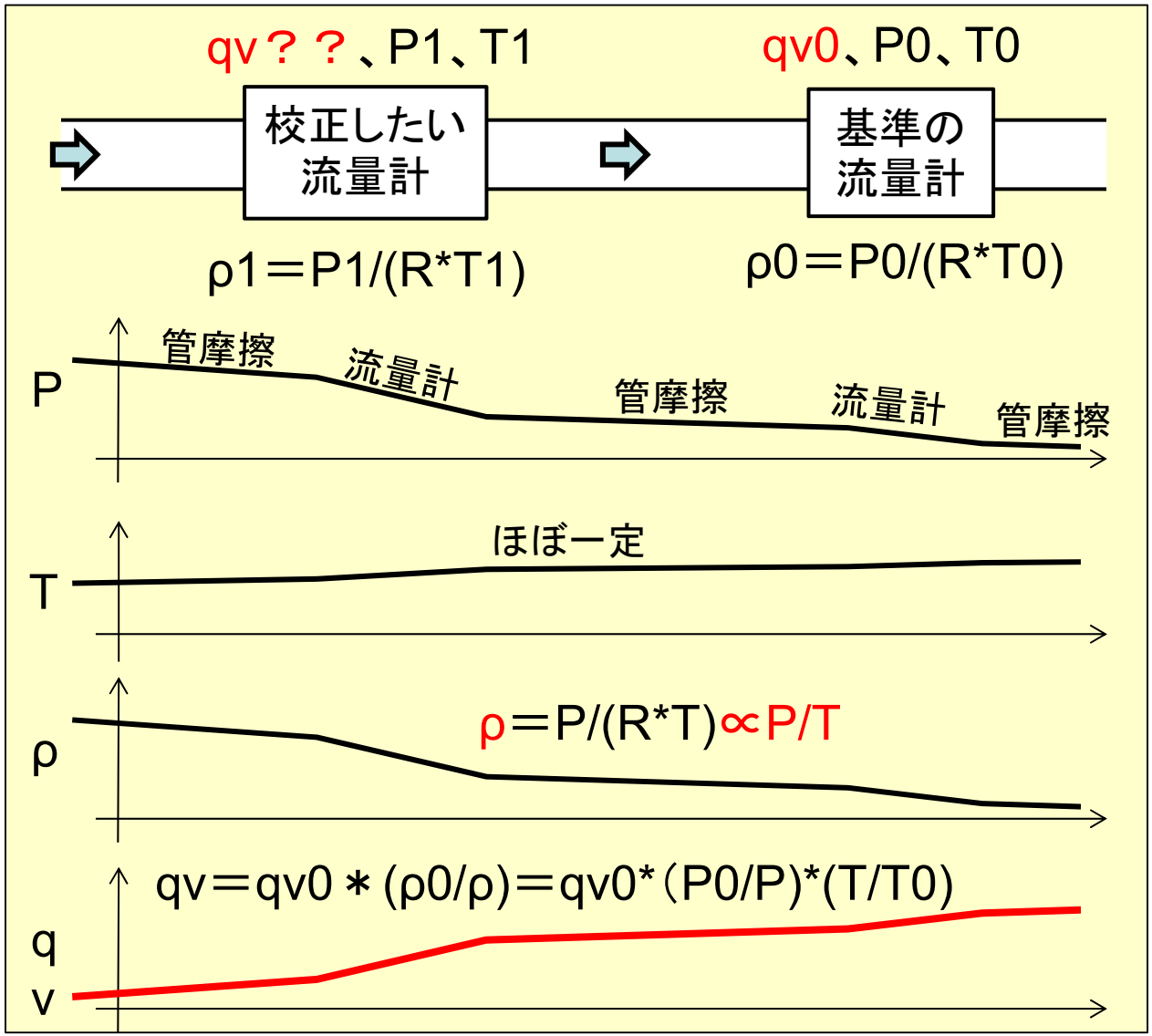
$$\varepsilon = 1 - \left(0{,}351 + 0{,}256\beta^4 + 0{,}93\beta^8\right)\left[1 - \left(\frac{p_2}{p_1}\right)^{1/\kappa}\right]$$

ISO 5167-2: 2003

圧縮性が無くても・・・レイノルズ数←粘度

$$R_e = \frac{4q_m}{\pi D \mu}$$

流量計の校正



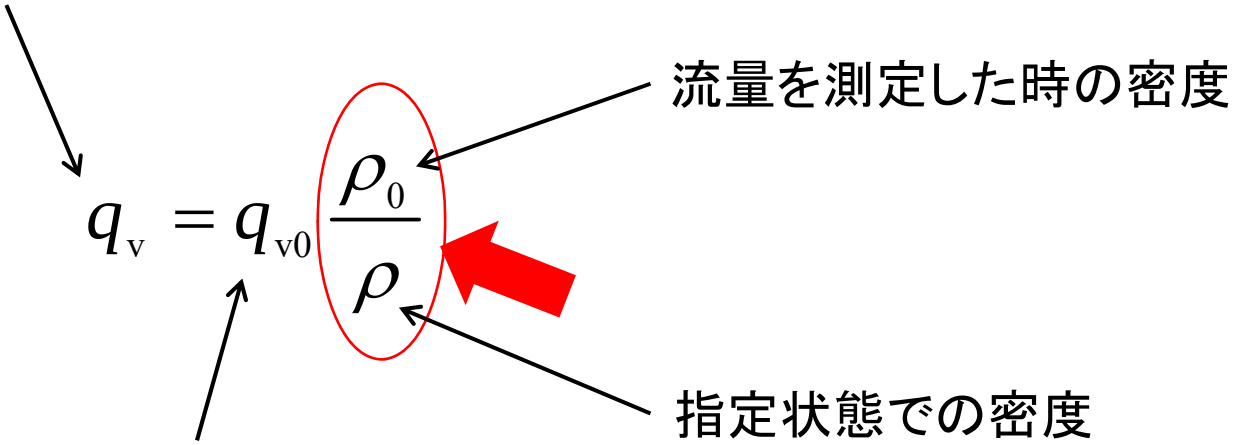
流量計の体積流量
（求める流量）

$$q_v = q_{v0}\frac{\rho_0}{\rho}$$

基準流量計が
測定した体積流量
（測定された流量）

指定状態での体積(流量)

知りたい状態での体積流量



密度の比

圧縮性があると、常に
密度の比が付きまとう

$$q_v = q_{v0}\frac{\rho_0}{\rho}$$

状態方程式より:

$$PV = nRT$$

これは理想気体の式

$$\rho = \frac{P}{RT}$$

$$\left(\frac{\rho_0}{\rho}\right) = \left(\frac{P_0}{P}\right)\left(\frac{T}{T_0}\right)$$

簡単
？？

実際には

圧縮係数 compression factor
compressibility factor

$$PV = nZRT$$

実在気体の状態方程式

実際の密度の比は・・・

$$q_v = q_{v0}\frac{\rho_0}{\rho}$$

状態方程式より:

$$PV = nZRT$$

圧縮係数

$$\rho = \frac{P}{RT}$$

$$\left(\frac{\rho_0}{\rho}\right) = \left(\frac{P_0}{P}\right)\left(\frac{T}{T_0}\right)\left(\frac{Z}{Z_0}\right)$$

圧縮係数の比が必要

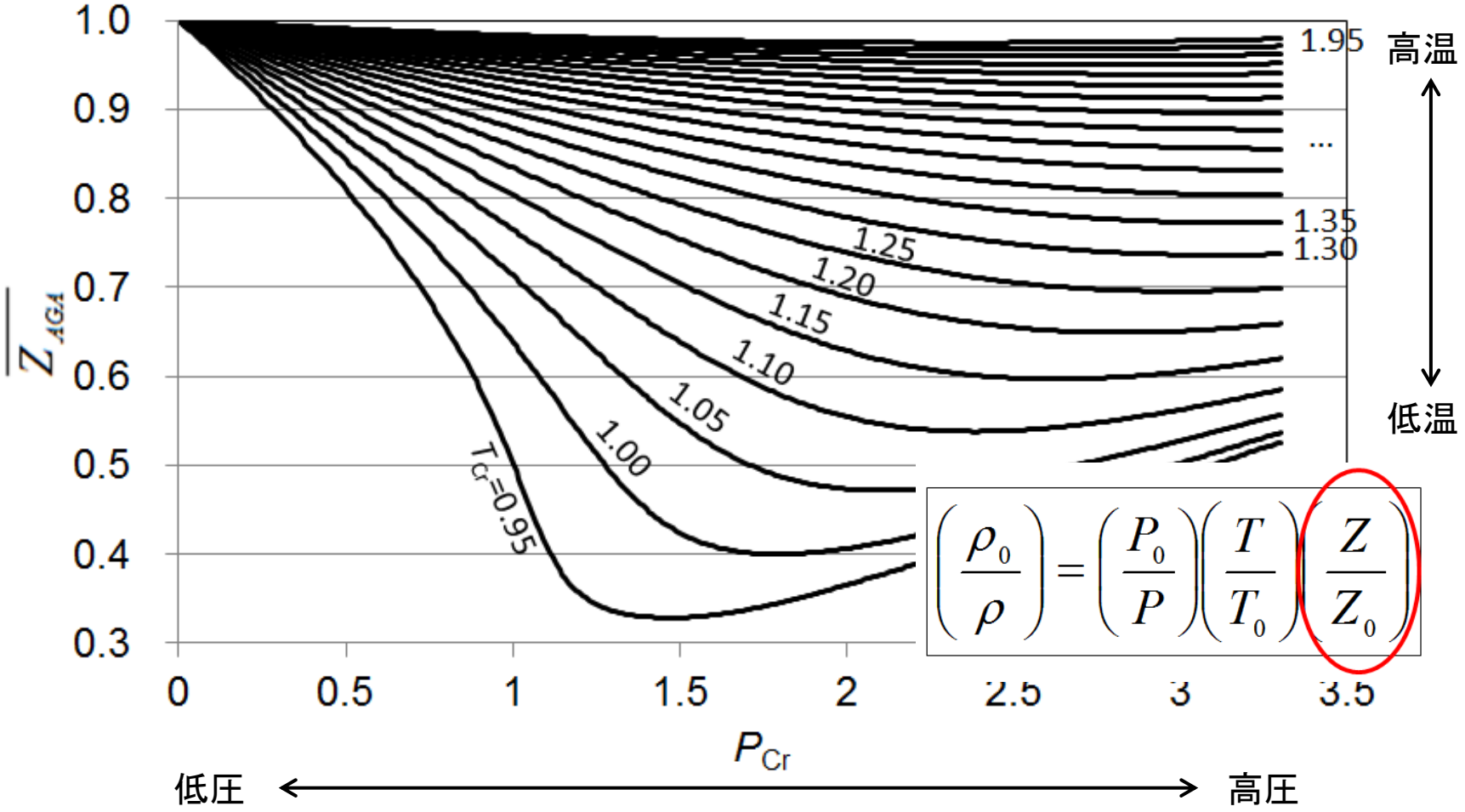
Zは、、、

- ✓ 低圧、常温ではほとんど1
- ✓ 高圧、低温で大きく変わる

Zの例（天然ガス）

$$q_v = q_{v0}\left(\frac{\rho_0}{\rho}\right)$$

1～100気圧程度、－20～＋80℃程度の範囲、各種ガスの代表値



注： 非現実的な成分を持つガスも含まれている

Zの例（天然ガス、ISO 12213-2のサンプル）

Table C.1 — Gas analysis in mole fractions

	Gas 1	Gas 2	Gas 3	Gas 4	Gas 5	Gas 6
x_{CO_2}	0,006	0,005	0,015	0,016	0,076	0,011
x_{N_2}	0,003	0,031	0,010	0,100	0,057	0,117
x_{H_2}	0,00	0,00	0,00	0,095	0,00	0,00
x_{CO}	0,00	0,00	0,00	0,010	0,00	0,00
x_{CH_4}	0,965	0,907	0,859	0,735	0,812	0,826
$x_{C_2H_6}$	0,018	0,045 0	0,085	0,033	0,043	0,035
$x_{C_3H_8}$	0,004 5	0,008 4	0,023	0,007 4	0,009	0,007 5
$x_{iso\text{-}C_4H_{10}}$	0,001 0	0,001 0	0,003 5	0,001 2	0,001 5	0,001 2
	0,001 0	0,001 5	0,003 5	0,001 2	0,001 5	0,001 2

Gas1～Gas6

成分

Conditions		Gas 1	Gas 2	Gas 3	Gas 4	Gas 5	Gas 6
p bar	*t* °C						
60	– 3,15	0,840 53	0,833 48	0,793 80	0,885 50	0,826 09	0,853 80
60	6,85	0,861 99	0,855 96	0,822 06	0,901 44	0,849 69	0,873 70
60	16,85	0,880 06	0,874 84	0,845 44	0,915 01	0,869 44	0,890 52
60	36,85	0,908 67	0,904 66	0,881 83	0,936 74	0,900 52	0,917 23
60	56,85	0,930 11	0,926 96	0,908 68	0,953 18	0,923 68	0,937 30
120	– 3,15	0,721 33	0,710 44	0,641 45	0,810 24	0,695 40	0,750 74
120	6,85	0,760 25	0,750 66	0,689 71	0,837 82	0,737 80	0,785 86
120	16,85	0,793 17	0,784 75	0,731 23	0,861 37	0,773 69	0,815 69
120	36,85	0,845 15	0,838 63	0,796 97	0,899 13	0,830 22	0,863 11
120	56,85	0,883 83	0,878 70	0,845 53	0,927 66	0,872 11	0,898 62

Zの値

60気圧 -3℃ ↕ +60℃

120気圧 -3℃ ↕ +60℃

0.72　0.71　0.64　0.79～0.91（60気圧）：　10～20%の補正

Zの計算

AGA8 1992

DCM
直接計算法
ダイレクトメソド

GCM
総量？計算法
グロスメソド

AGA Report No.8

Detailed **C**haracterization **M**ethod

AGA8-92DC法

成分をベース

Gross **C**haracterization **M**ethod

GERG法、sGERG法

SGERG-88、SGERG-02、SGERG-04、SGERG-08、、

熱量をベース

DCMを補完する方法として開発

極限状態（非常な高圧、非常な低温）で正確、やや複雑

現在

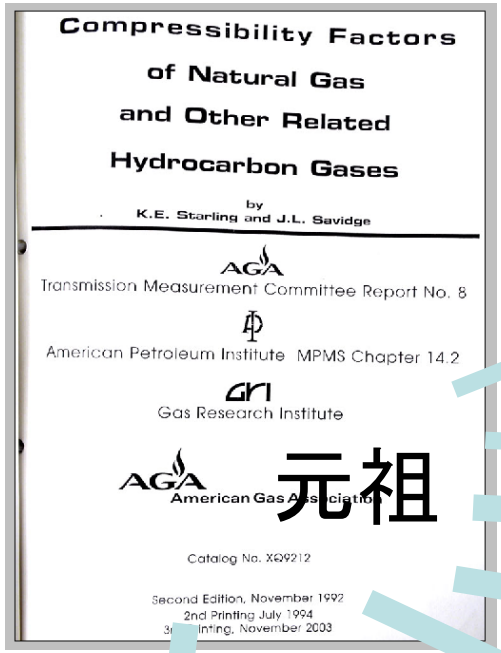
ISO 12213-2
ISO 20765-1
AGA8改定中

ISO 12213-3
ISO 20765-2作成中

AGA＝アメリカガス協会

GERG＝ヨーロッパのガス研究グループ

規格たち



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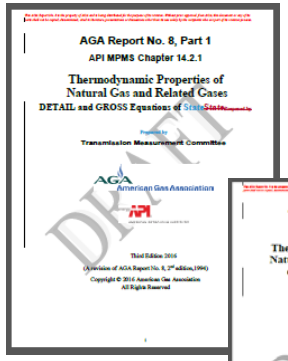
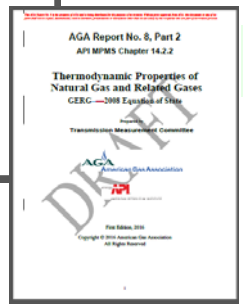


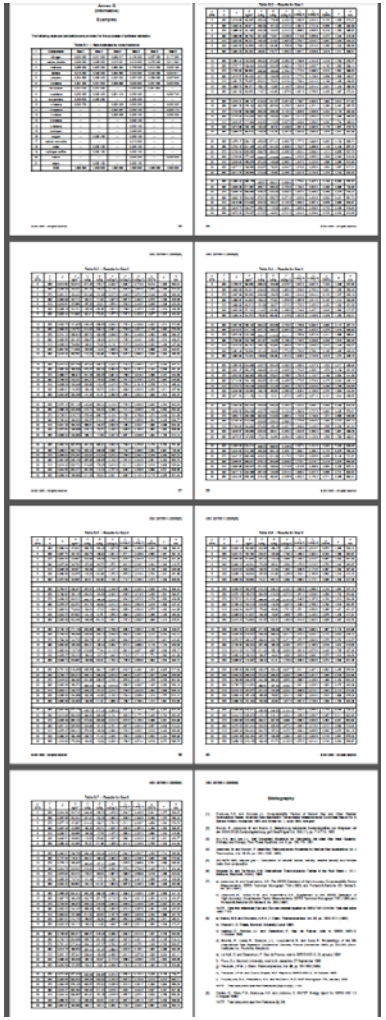


2分冊に

元祖(改)
改訂中(出版直前)

Lemmonさん座長

式の山に
テーブルの山

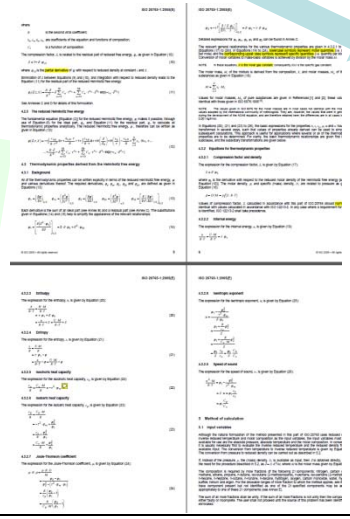


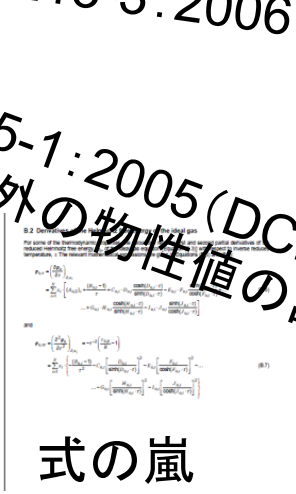
数値テーブルの山

ISO 12213-2:2006(DCM)

ISO 12213-3:2006(GCM)

ISO 20765-1:2005(DCM)
粘性以外の物性値の計算





式の嵐

ISO 20765-2(多分GCM)作成中

Lemmonさん座長

アーティスト

アイゼントロピック指数

ISO 20765-1

INTERNATIONAL STANDARD

ISO 20765-1

First edition
2005-09-15

Natural gas — Calculation of thermodynamic properties —

Part 1:
Gas phase properties for transmission and distribution applications

Gaz naturel — Calcul des propriétés thermodynamiques —

Partie 1: Propriétés de la phase gazeuse utilisée pour des applications de transport et de distribution

4.3.2.8 Isentropic exponent

The expression for the isentropic exponent, κ, is given by Equation (25):

$$\kappa = \frac{\varphi_1 - \frac{\varphi_2^2}{\tau^2 \cdot \varphi_{\tau\tau}}}{\delta \cdot \varphi_\delta + \frac{R}{\ldots}}$$

B.2 Derivatives of the Helmholtz free ener

For some of the thermodynamic properties, the calcul
reduced Helmholtz free energy, φ_o, of the ideal gas e
temperature, τ. The relevant mathematical expression

$$\varphi_{o,\tau} = \left(\frac{\partial \varphi_o}{\partial \tau}\right)_{\delta,x_i}$$

$$= \sum_{i=1}^{N} x_i \cdot \left[(A_{o,2})_i + \frac{(B_{o,i}-1)}{\tau} + C_{o,i} \cdot D_{o,i} \frac{\cosh(\ldots}{\sinh(\ldots} \right.$$

$$\left. \ldots + G_{o,i} \cdot H_{o,i} \frac{\cosh(H_{o,i} \cdot \tau)}{\sinh(H_{o,i} \cdot \tau)} \right]$$

and

$$\varphi_{o,\tau\tau} = \left(\frac{\partial^2 \varphi_o}{\partial \tau^2}\right)_{\delta,x_i} = -\tau^{-2}\left(\frac{c_{o,p}}{R} - 1\right)$$

$$= \sum_{i=1}^{N} x_i \cdot \left[\frac{(B_{o,i}-1)}{\tau^2} - C_{o,i} \left[\frac{D_{o,i}}{\sinh(D_{o,i} \cdot \tau)} \right]^2 \right.$$

$$\left. \ldots - G_{o,i} \left[\frac{H_{o,i}}{\sinh(H_{o,i} \cdot \tau)} \right] \right]$$

The Helmholtz free energy of the ideal gas

$$\varphi_o = \sum_{i=1}^{N} x_i \cdot \left\{ (A_{o,1})_i + (A_{o,2} \right.$$

$$\ldots + G_{o,i} \cdot \ln\left[\sinh(H_o\right.$$

C.1 Calculation of the Helmholtz free energy

The reduced Helmholtz free energy for the specified gas n

$$\varphi = \varphi_o + \frac{B \cdot \delta}{K^3} - \delta \sum_{n=13}^{18} C_n \cdot \tau^{u_n} + \sum_{n=13}^{58} C_n \cdot \tau^{u_n} \cdot \delta^{b_n} \exp($$

The Helmholtz free energy of the ideal gas

B.1 Calculation of the Helmholtz free energy of the ideal gas

a) The ideal isobaric heat capacity of a single component [3, 4] may be written as in Eq

$$\frac{(c_{o,p})_i}{R} = B_{o,i} + C_{o,i}\left[\frac{D_{o,i}\cdot\tau}{\sinh(D_{o,i}\cdot\tau)}\right]^2 + K_{o,i}\left[\frac{F_{o,i}\cdot\tau}{\cosh(F_{o,i}\cdot\tau)}\right]^2 + G_{o,i}\left[\frac{H_{o,i}\cdot\tau}{\sinh(H_{o,i}\cdot\tau)}\right]^2$$

$$\ldots I_{o,i}\left[\frac{J_{o,i}\cdot\tau}{\cosh(J_{o,i}\cdot\tau)}\right]^2$$

Equation (B.1) may be generalized to the case of an N-component mixture by use of Eq

$$\frac{c_{o,p}}{R} = \sum_{i=1}^{N} x_i \frac{(c_{o,p})_i}{R}$$

b) This formulation for the ideal isobaric heat capacity, $c_{o,p}$, may be inserted int
reduced Helmholtz free energy, φ_o. The integrations in Equation (6) may then b
Equation (B.3):

$$\varphi_o = \sum_{i=1}^{N} x_i \cdot \left\{ (A_{o,1})_i + (A_{o,2})_i \cdot \tau + B_{o,i} \cdot \ln\tau + C_{o,i} \cdot \ln\left[\sinh(D_{o,i}\cdot\tau)\right] - E_{o,i} \cdot \ln\left[\cosh(\right.\right.$$

$$\left.\left. \ldots + G_{o,i} \cdot \ln\left[\sinh(H_{o,i}\cdot\tau)\right] - I_{o,i} \cdot \ln\left[\cosh(J_{o,i}\cdot\tau)\right] + \ln(x_i) + \ln\left(\frac{\delta}{\ldots}\right) + \ln\left(\frac{\tau_0}{\ldots}\right) \right.\right.$$

It is important to observe, in Equation (B.3), that φ_o is a function of the reduced molar
gas (i.e. not the reduced molar density of the ideal gas) and, therefore, cannot be comp
value for δ is available (see Annex D). Equation (B.3) shall be used for the calcu
Helmholtz free energy of the ideal gas.

c) The best available values in the scientific literature for the ideal isobaric heat capaci
been taken as source data and re-correlated[4] so as to provide numerical values of
for the 21 pure component gases considered in this part of ISO 20765.

Values of the constants $(A_{o,1})_i$ and $(A_{o,2})_i$ and constants $B_{o,i}$ to $J_{o,i}$ for use in Equa
Table B.1.

ISO 20765-1:2005(E)

B.2 Derivatives of the Helmholtz free energy of the ideal gas

For some of the thermodynamic properties, the calculation requires first and second partial de
reduced Helmholtz free energy, φ_o, of the ideal gas equation [Equation (B.3)] with respect to
temperature, τ. The relevant mathematical expressions are given in Equations (B.6) and (B.7):

$$\varphi_{o,\tau} = \left(\frac{\partial \varphi_o}{\partial \tau}\right)_{\delta,x_i}$$

$$= \sum_{i=1}^{N} x_i \left[(A_{o,2})_i + \frac{(B_{o,i}-1)}{\tau} + C_{o,i} \cdot D_{o,i} \frac{\cosh(D_{o,i}\cdot\tau)}{\sinh(D_{o,i}\cdot\tau)} - E_{o,i} \cdot F_{o,i} \frac{\sinh(F_{o,i}\cdot\tau)}{\cosh(F_{o,i}\cdot\tau)} + \ldots \right.$$

$$\left. \ldots + G_{o,i} \cdot H_{o,i} \frac{\cosh(H_{o,i}\cdot\tau)}{\sinh(H_{o,i}\cdot\tau)} - I_{o,i} \cdot J_{o,i} \frac{\sinh(J_{o,i}\cdot\tau)}{\cosh(J_{o,i}\cdot\tau)} \right]$$

and

$$\varphi_{o,\tau\tau} = \left(\frac{\partial^2 \varphi_o}{\partial \tau^2}\right)_{\delta,x_i} = -\tau^{-2}\left(\frac{c_{o,p}}{R} - 1\right)$$

4.3.2.9 Speed of sound

The expression for the speed

$$\frac{w^2 \cdot M}{R \cdot T} = \varphi_1 - \frac{\varphi_2^2}{\tau^2 \cdot \varphi_{\tau\tau}}$$

$$= Z \cdot \kappa = \varphi_1 \frac{c_p}{\ldots}$$

$$w = \sqrt{\kappa Z R T}$$

$$\kappa = \frac{w^2}{ZRT}$$

アイゼントロピック指数（サンプル値）

ISO 20765-1

INTERNATIONAL STANDARD **ISO 20765-1**

First edition 2005-09-15

Natural gas — Calculation of thermodynamic properties —

Part 1:
Gas phase properties for transmission and distribution applications

Table G.1 — Gas analyses by mole fractions

i	Component	Gas 1	Gas 2	Gas 3	Gas 4	Gas 5	Gas 6
1	nitrogen	0,003 000	0,031 000	0,009 617	0,100 000	0,057 000	0,117 266
2	carbon dioxide	0,006 000	0,005 000	0,015 021	0,016 000	0,076 000	0,011 093
3	methane	0,965 000	0,907 000	0,859 284	0,735 000	0,812 000	0,825 198
4	ethane	0,018 000	0,045 000	0,084 563	0,033 000	0,043 000	0,034 611
5	propane	0,004 500	0,008 400	0,023 022	0,007 400	0,009 000	0,007 645
6	n-butane	0,001 000	0,001 500	0,006 985	0,000 800	0,001 500	0,002 539
7	iso-butane	0,001 000	0,001 000	—	0,000 800	0,001 500	—
8	n-pentane	0,000 300	0,000 400	0,001 218	0,000 400	—	0,000 746

Table G.2 — Results for Gas 1

p MPa	*T* K	*Z*	*D* kg/m³	*U* kJ/kg	*H* kJ/kg	*S* kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	μ K/MPa	κ	*w* m/s
5	250	0,819 96	49,295	−280,49	−179,06	−2,422 3	1,690 6	2,834 2	6,153	1,366	372,27
5	260	0,845 44	45,971	−260,09	−151,32	−2			,658	1,360	384,59
5	270	0,866 43	43,196	−240,26	−124,51	−2			,219	1,354	395,93
5	290	0,898 88	38,764	−201,60	−72,61	−2			,473	1,344	416,29
5	310	0,922 62	35,331	−163,45	−21,93	−1			,861	1,333	434,32

p MPa	*T* K	κ
5	250	1,346
5	260	1,335
5	270	1,327
5	290	1,314
5	310	1,303
5	330	1,293
5	350	1,283
10	250	2,113
10	260	1,818
10	270	1,665
10	290	1,518
10	310	1,448
10	330	1,405
10	350	1,374

Z 圧縮係数
D 密度
U 内部エネルギー
H エンタルピー
S エントロピー
Cv 定積比熱
Cp 低圧比熱
m ジュールトムソン係数
k アイゼントロピック指数
w 音速

（参考）簡易な計算方法、解説
JIS M 8010（改定中）
天然ガスの計量

		Gas1	Gas2	Gas3 ・・・
p MPa	*T* K	κ		
20	250	4,102	4,254	5,499
20	260	3,439	3,552	4,420
20	270	2,965	3,048	3,658
20	290	2,380	2,425	2,727
20	310	2,060	2,085	2,238
20	330	1,867	1,882	1,961
20	350	1,742	1,750	1,790
30	250	5,600	5,753	7,038
30	260	4,865	4,991	5,975
30	270	4,276	4,380	5,148
30	290	3,421	3,492	3,976
30	310	2,860	2,909	3,220
30	330	2,488	2,521	2,721
30	350	2,233	2,256	2,386

粘度

AGA8系には
粘度は含まれない

独自に相当数の研究、1950年代より

ガス粘度の算定式について

	提唱者（または算定式・方法）	提唱年	適用範囲、
1	Carr, Kobayashi, and Burrow correlation	1954	Absolute error : 1.5% データ点数 : 30 ケ ガス比重 : 0.55～1.5 温　度 : 100F～300F 圧　力 : 不明？【1ケ 【Carr については 1 に低度範囲 21～121 の記述あり。）
	Dempsey の圧力補正	1965	Carr et al の算定式 圧する。 条件としては、 1.2≦Tr≦3.0 1.0≦Pr≦20.0
2	Jossi, Stiel, and Thodos Correlation (JST) correlation	1962	Reduced density 関 からの算定式 Reduced density 2.0 AAE(Average Absolu
3	Lee, Gonzalez, and Eakin (LGE) correlation	1966	データ点数 : 254 da 温度 : 100～340F 圧力 : 100～8000psia AAE=2% for low pr AAE=4% for high p 但し、比重 1.0 以下 下の場合で、比重 1 gases については 2 る場合がある。また いては Carr の方法 度は？） HPHT にならない条 われる。
6	Sutton correlation	2005	Tpc, Ppc, Tpr を使用 発
7	Viswanathan correlation	2007	高低圧条件につい 使用、1964 年の Lee 式を提発 【温度 :100～400 F、 の範囲にある NIST 式を修正）
8	SUPERTRAP	2010	NIST【National Ins Technology) 炭化水素流体の粘性 圧力 : 44,100psia ま 温度 : 1,340F まで
9	HYSYS (Simulation Soft)		Mod Ely & Hanley (NBS の方法)

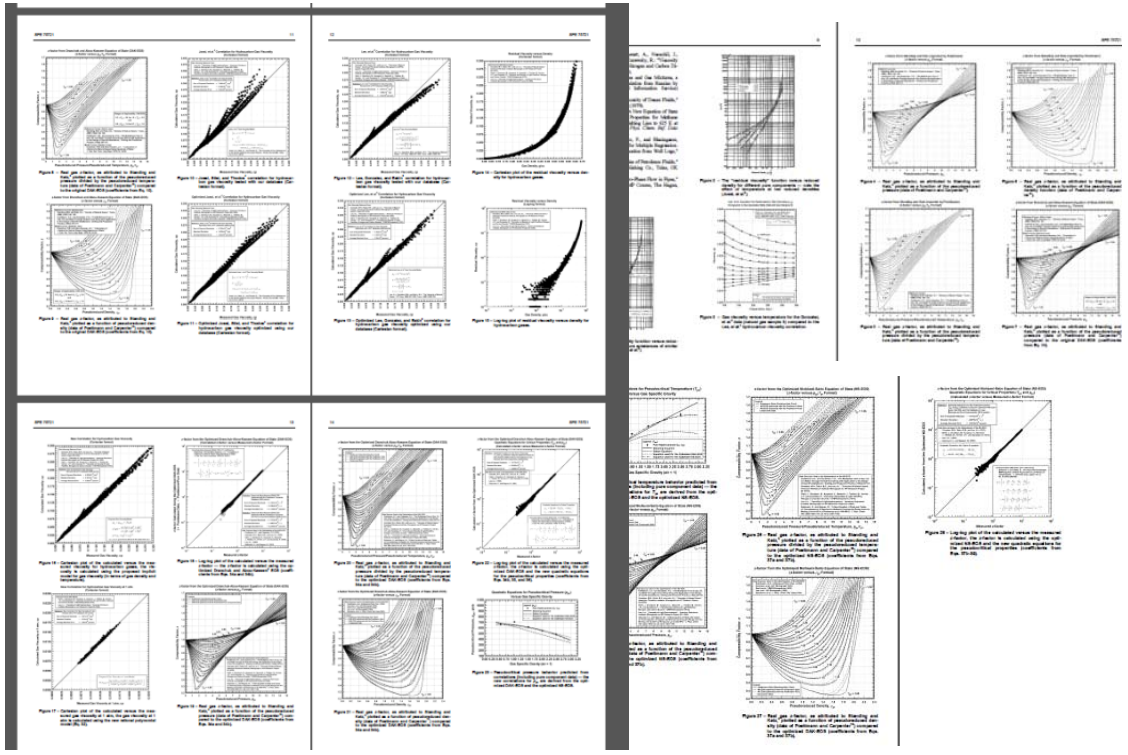
			注記： 1947 年 : Born and 1964 年 : Starling x 発 1964 年 : Lee et al 1966 年 : Lee et al 【比較】 2001 年 : Londono 最低式提発 2005 年 : Sutton 新 2007 年 : Viswanah 算定式提発
4	the Optimized LGE (Londono correlation) Texas A&M University	2001	13,636 ケのデータで 最低 AAE= 8.26% for JST AAE= 3.34% for LG データの再フィッティ AAE= 4.43% for JST AAE= 2.29% for LG に改善とのこと。 (the Optimized LGE 使用。2,494 ケの g 2,415 ケの gas mixtu 上)
5	Implicit Model Texas A&M University	2002	1 気圧での Viscosity 関数で求め、密度に 数で）を行って、圧 を算出する。 AAE=3.05% [4,909 ケ AAE=1.36% 【1 気圧 のデータで検証】 CO2 濃度 : 0.19～ N2 濃度 : 0.04～15.8 He 濃度 : 0.05～0.8 のサンプルガスを含む

これでもごく一部

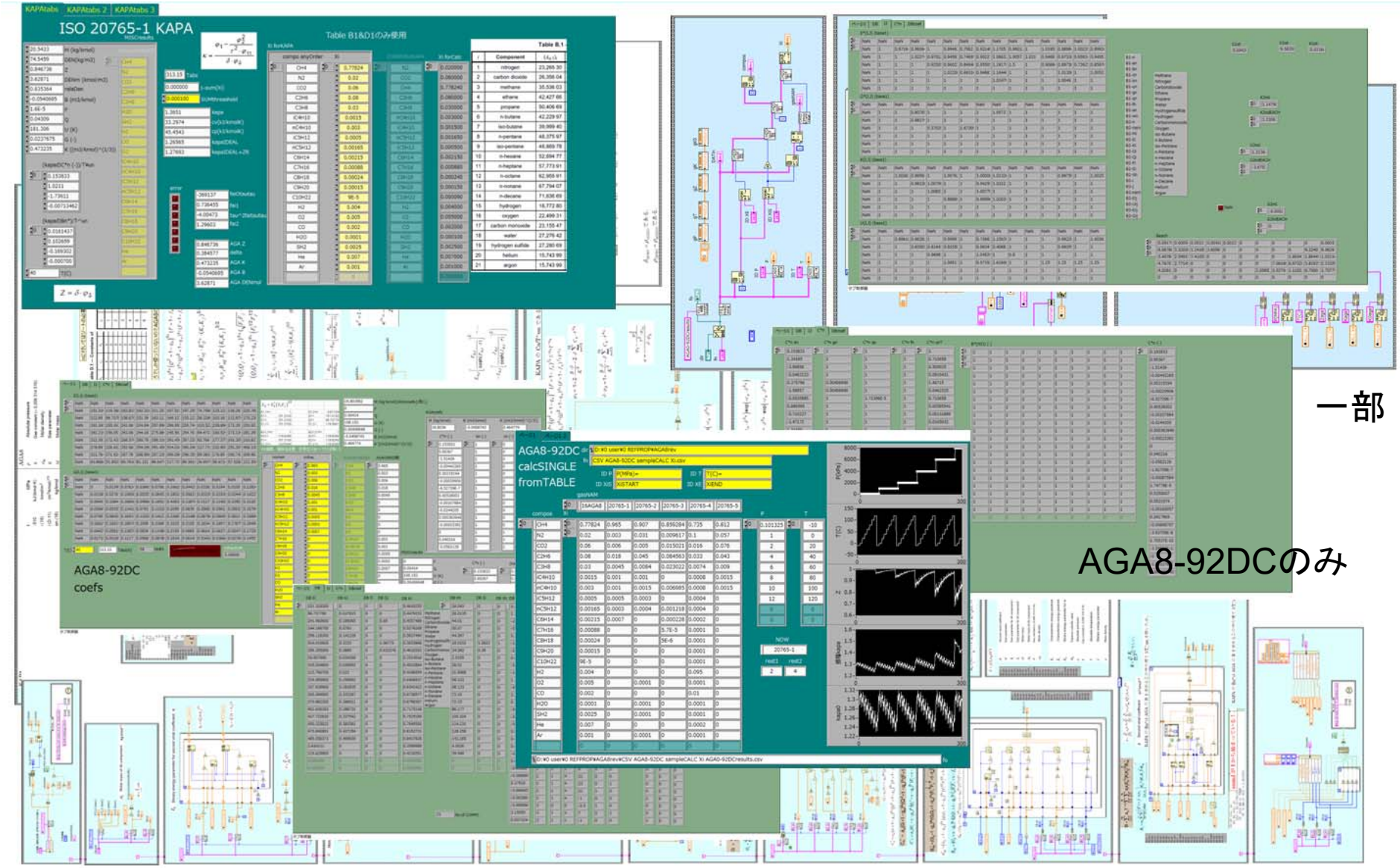
SPE 75721 例えば

Simplified Correlations for Hydrocarbon Gas Viscosity and Gas Density — Validation and Correlation of Behavior Using a Large-Scale Database

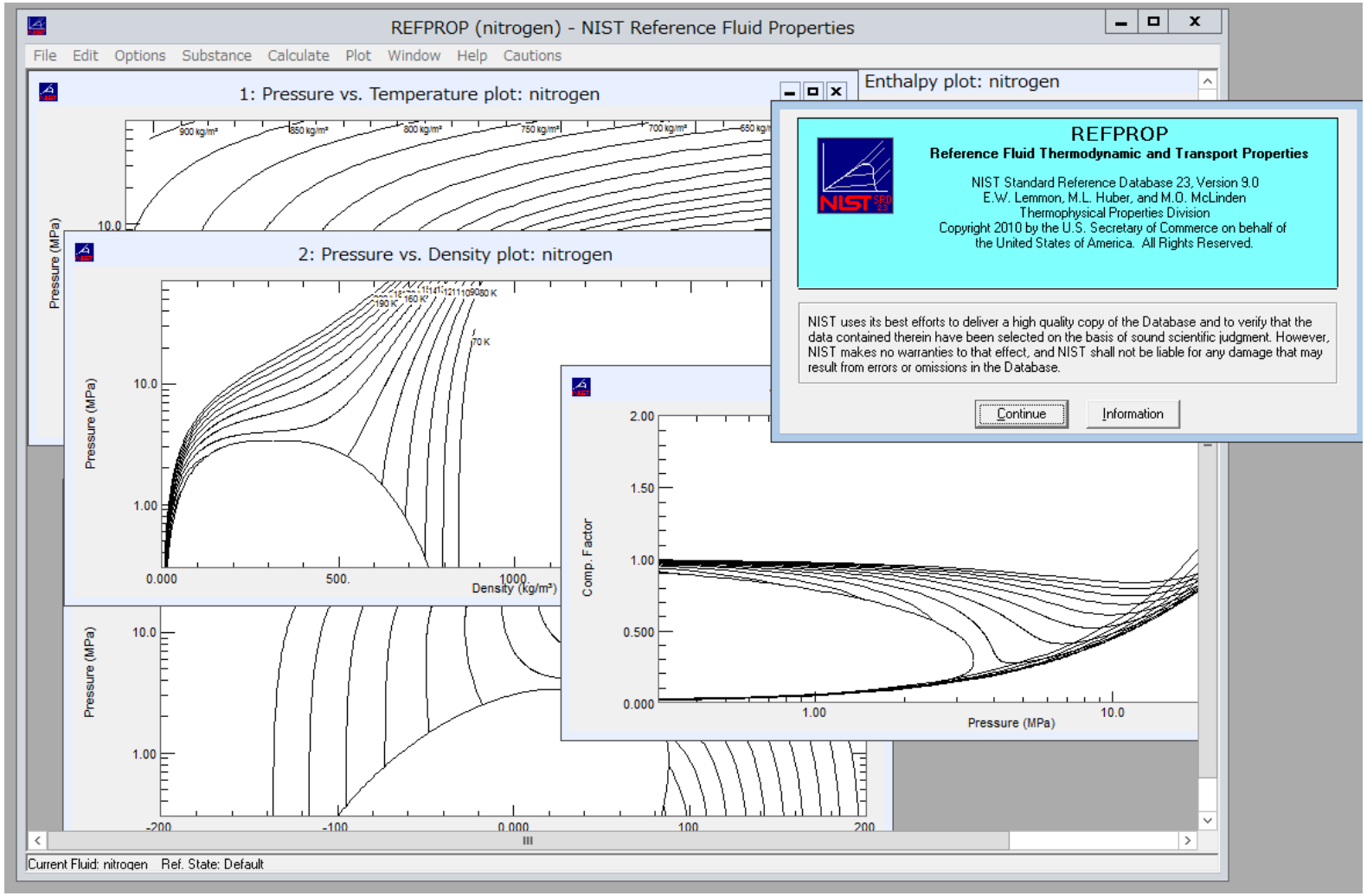
F.E. Londono, R.A. Archer, and T. A. Blasingame, Texas A&M U.



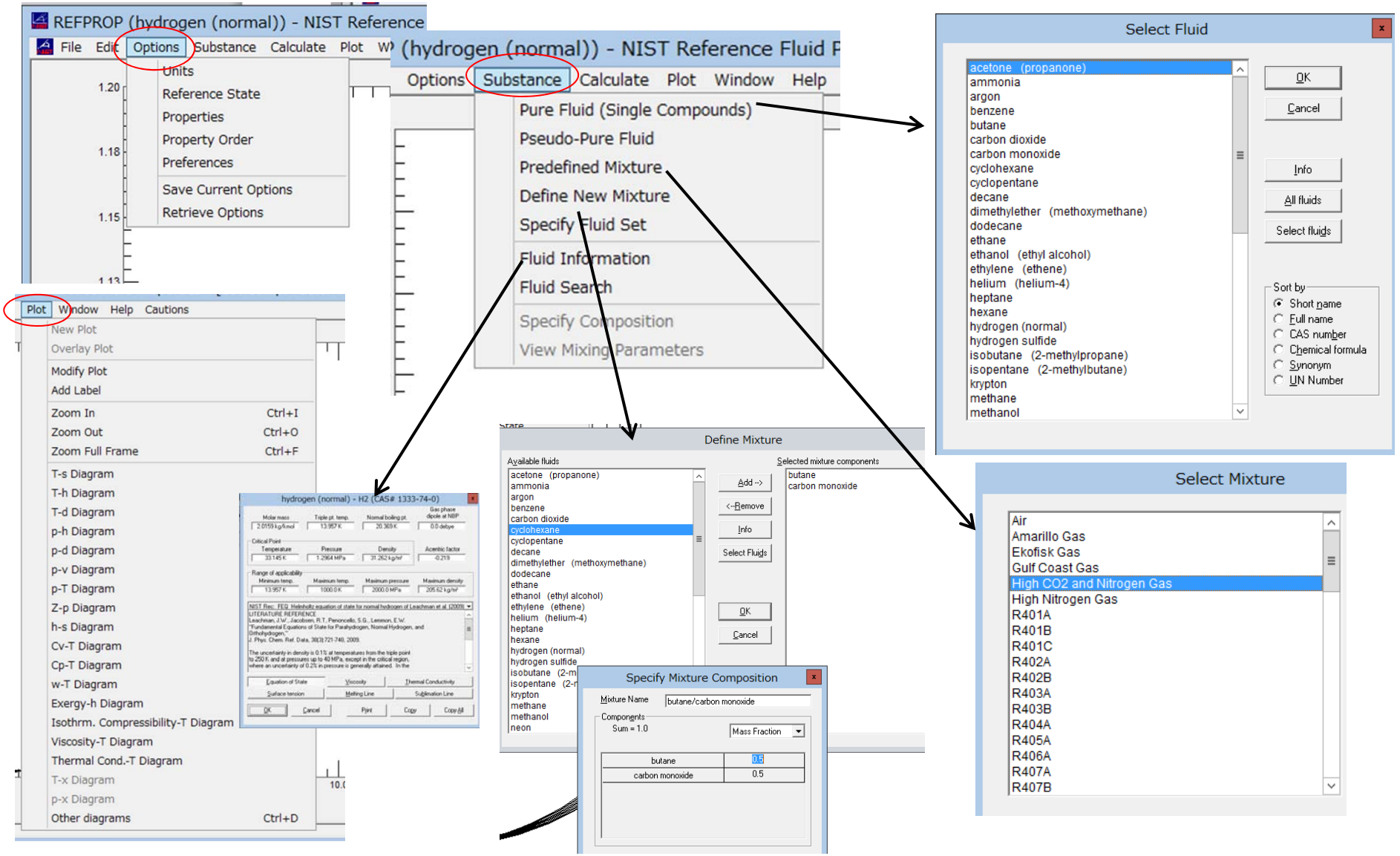
自前プログラムも可ではあるが・・・



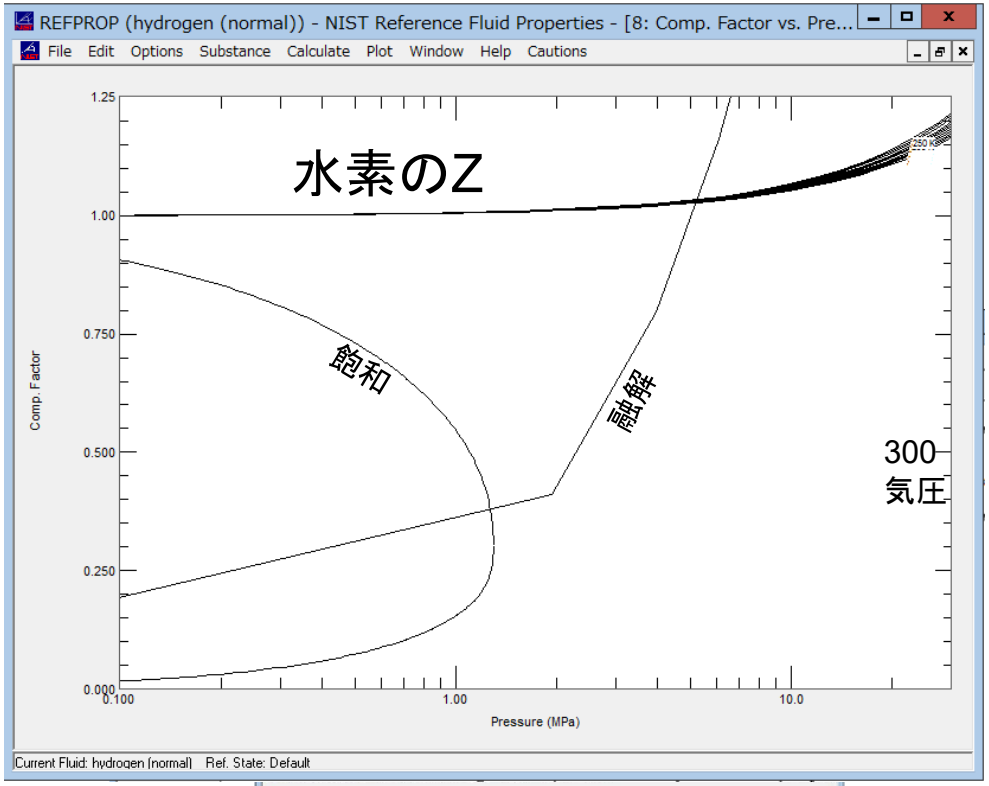
REFPROP

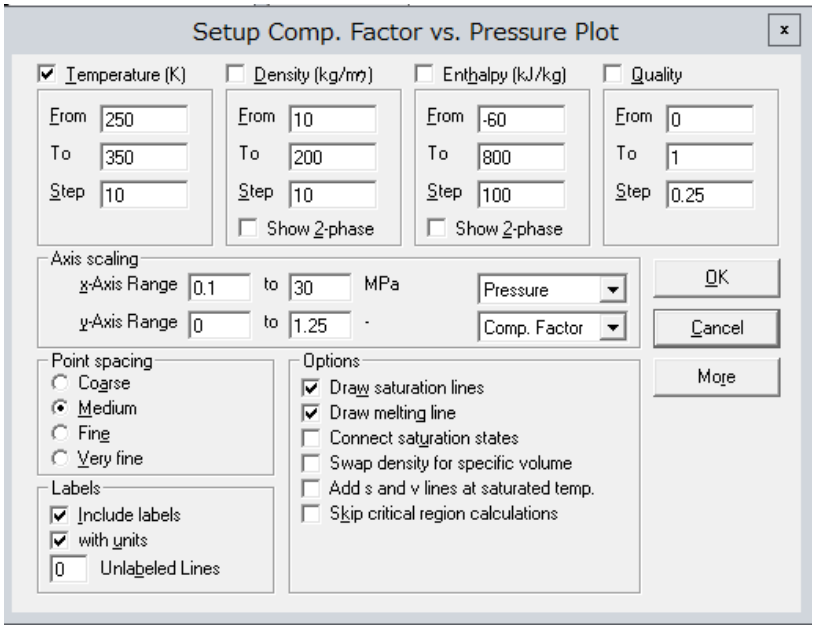

REFPROP (nitrogen) - NIST Reference Fluid Properties
File Edit Options Substance Calculate Plot Window Help Cautions
1: Pressure vs. Temperature plot: nitrogen
Pressure (MPa)
2: Pressure vs. Density plot: nitrogen
Density (kg/m³)
Enthalpy plot: nitrogen
Comp. Factor
Pressure (MPa)
REFPROP
Reference Fluid Thermodynamic and Transport Properties
NIST Standard Reference Database 23, Version 9.0
E.W. Lemmon, M.L. Huber, and M.O. McLinden
Thermophysical Properties Division
Copyright 2010 by the U.S. Secretary of Commerce on behalf of the United States of America. All Rights Reserved.
NIST uses its best efforts to deliver a high quality copy of the Database and to verify that the data contained therein have been selected on the basis of sound scientific judgment. However, NIST makes no warranties to that effect, and NIST shall not be liable for any damage that may result from errors or omissions in the Database.
Continue
Information
Current Fluid: nitrogen Ref. State: Default

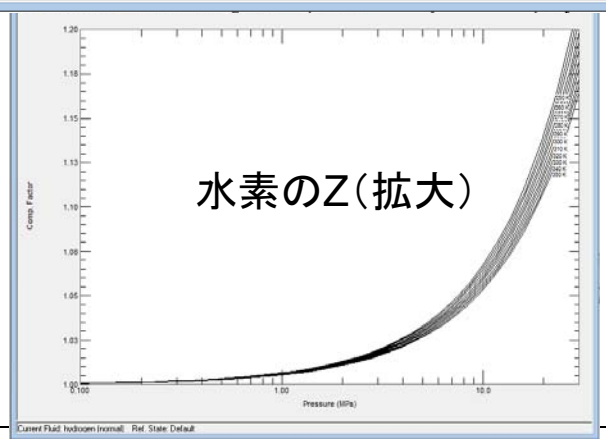
REFPROP

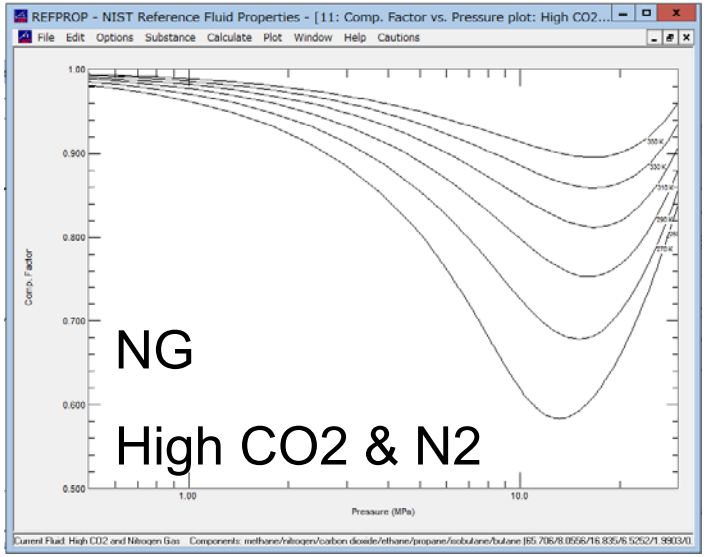

REFPROP (hydrogen (normal)) - NIST Reference
File Edit Options Substance Calculate Plot W
Units
Reference State
Properties
Property Order
Preferences
Save Current Options
Retrieve Options
(hydrogen (normal)) - NIST Reference Fluid P
Options Substance Calculate Plot Window Help
Pure Fluid (Single Compounds)
Pseudo-Pure Fluid
Predefined Mixture
Define New Mixture
Specify Fluid Set
Fluid Information
Fluid Search
Specify Composition
View Mixing Parameters
Select Fluid
acetone (propanone)
ammonia
argon
benzene
butane
carbon dioxide
carbon monoxide
cyclohexane
cyclopentane
decane
dimethylether (methoxymethane)
dodecane
ethane
ethanol (ethyl alcohol)
ethylene (ethene)
helium (helium-4)
heptane
hexane
hydrogen (normal)
hydrogen sulfide
isobutane (2-methylpropane)
isopentane (2-methylbutane)
krypton
methane
methanol
OK
Cancel
Info
All fluids
Select fluids
Sort by
Short name
Full name
CAS number
Chemical formula
Synonym
UN Number
Plot Window Help Cautions
New Plot
Overlay Plot
Modify Plot
Add Label
Zoom In Ctrl+I
Zoom Out Ctrl+O
Zoom Full Frame Ctrl+F
T-s Diagram
T-h Diagram
T-d Diagram
p-h Diagram
p-d Diagram
p-v Diagram
p-T Diagram
Z-p Diagram
h-s Diagram
Cv-T Diagram
Cp-T Diagram
w-T Diagram
Exergy-h Diagram
Isothrm. Compressibility-T Diagram
Viscosity-T Diagram
Thermal Cond.-T Diagram
T-x Diagram
p-x Diagram
Other diagrams Ctrl+D
hydrogen (normal) - H2 (CAS# 1333-74-0)
Define Mixture
Available fluids
Selected mixture components
butane
carbon monoxide
Add -->
<--Remove
Info
Select Fluids
OK
Cancel
Specify Mixture Composition
Mixture Name
butane/carbon monoxide
Components
Sum = 1.0
Mass Fraction
butane 0.5
carbon monoxide 0.5
Select Mixture
Air
Amarillo Gas
Ekofisk Gas
Gulf Coast Gas
High CO2 and Nitrogen Gas
High Nitrogen Gas
R401A
R401B
R401C
R402A
R402B
R403A
R403B
R404A
R405A
R406A
R407A
R407B

REFPROP

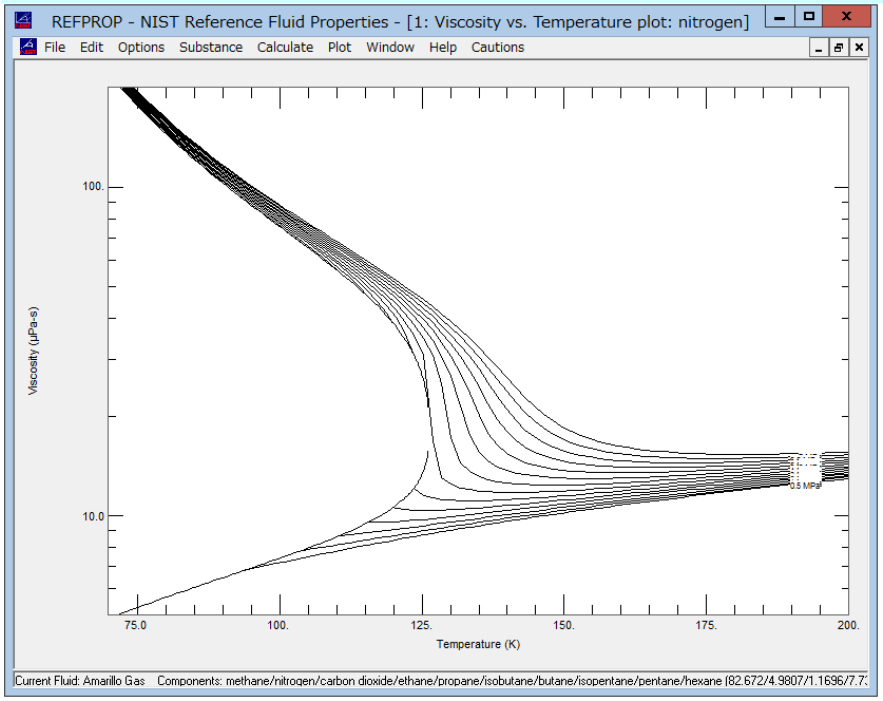

REFPROP (hydrogen (normal)) - NIST Reference Fluid Properties - [8: Comp. Factor vs. Pre...
File Edit Options Substance Calculate Plot Window Help Cautions
水素のZ
飽和
融解
300
気圧
Comp. Factor
Pressure (MPa)
Current Fluid: hydrogen (normal) Ref. State: Default


Setup Comp. Factor vs. Pressure Plot
Temperature (K)
Density (kg/m³)
Enthalpy (kJ/kg)
Quality
From 250
To 350
Step 10
From 10
To 200
Step 10
Show 2-phase
From -60
To 800
Step 100
Show 2-phase
From 0
To 1
Step 0.25
Axis scaling
x-Axis Range 0.1 to 30 MPa
Pressure
y-Axis Range 0 to 1.25
Comp. Factor
OK
Cancel
More
Point spacing
Coarse
Medium
Fine
Very fine
Options
Draw saturation lines
Draw melting line
Connect saturation states
Swap density for specific volume
Add s and v lines at saturated temp.
Skip critical region calculations
Labels
Include labels
with units
0 Unlabeled Lines

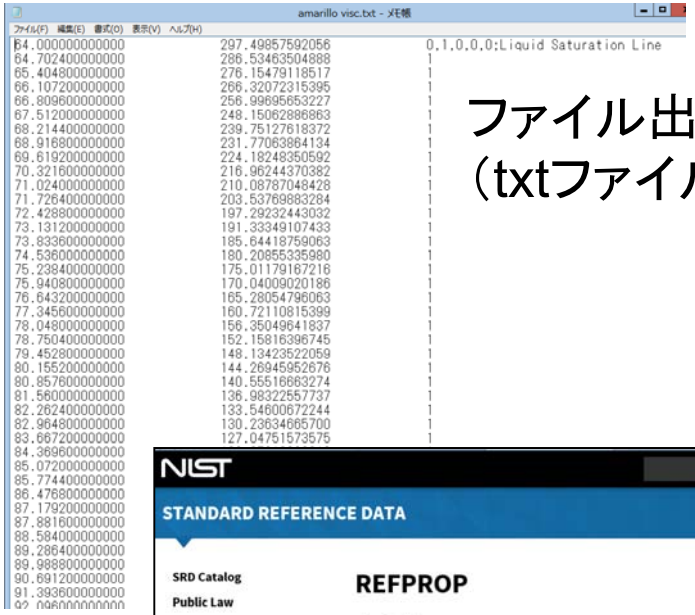

水素のZ（拡大）


REFPROP - NIST Reference Fluid Properties - [11: Comp. Factor vs. Pressure plot: High CO2...
NG
High CO2 & N2
Comp. Factor
Pressure (MPa)

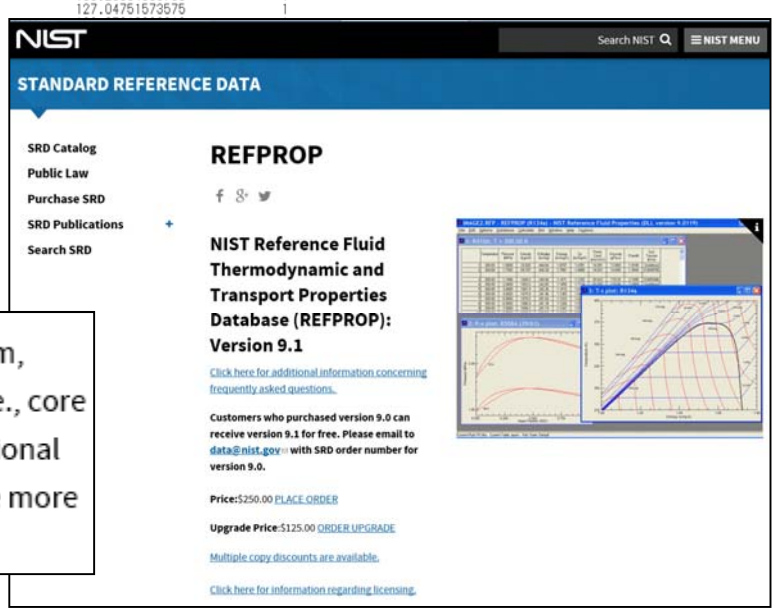
REFPROP



例：Amarilloガスの粘度



ファイル出力
（txtファイル）



Enhancements have been made to most areas of the NIST REFPROP program, including the graphical interface, the Excel spreadsheet, the Fortran files (i.e., core property routines), the sample programs in C++, MatLab, VB, etc., and additional fluids. The number of enhancements has been substantial, with some of the more important ones listed below:

Welcome Eric!

The top of Google search results