Burns

CHEMICALS

INDUSTRIES

INTEROFFICE / LAKE CHARLES

TO. (See Distribution)

DATE September 19, 1968

FROM Charles Breedlove

SUBJECT Chlorine to Conoco Meter Manual - Supercompressibility Factor

The calculations enclosed herein are the basis for concluding that the supercompressibility factor, F_{pv}, used in calculating the gaseous chlorine flow to Conoco, need not include the effects of each of the minute quantities of inert gases found in the gas.

In lieu of this, the effects of all the inert gases on F_{pv} are approximated by multiplying the number, one (1), by the percent by volume value of the inert gases. This value is then added to the Z value determined for the percent chlorine in the gas, the square root is taken of this sum, and this value is divided into 1 to give the supercompressibility factor, F_{pv}.

$F_{pv} = Z_b / \sqrt{Z_f}$ Eq 5Ø Spink 8TH ED.

$$F_{pv} = \frac{1}{\sqrt{Z_{Cl_2}(\%\ Cl_2) + (100\% - \%\ Cl_2)\ 1.0}}$$

CB/JS

$\rho = \frac{PM}{ZRT}$

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$= \frac{14.73 \times 70.92}{1.0 \times 10.73 \times 520}$

$= 0.1872269$

$\rho = \frac{14.73 \times 70.914}{1.0 \times 10.73 \times 520} = .1872113$

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OBJECT

The object of the following calculations is to determine if the effect of each of the inert gases found in the gaseous chlorine flow to Conoco need be considered individually when calculating the supercompressibility flow factor, (creating a very difficult series of calculations in view of varying percentages of the five prominent inerts), or if the inert supercompressibility factor may be approximated (a) by using the supercompressibility of air or (b) by using the inert volume percentage multiplied by one(1).

BASIS OF CALCULATIONS AND CONCLUSION

The following calculations and conclusion are based on the following considerations:

a) The PPG/Conoco chlorine gas sales contract specifies that the supercompressibility factor, F_{pv}, must not contribute an error of more than 0.25% of the total daily flow.

b) The percent by volume values of inerts used are correct and representative of a "worse" condition (verified by Liquefaction); therefore, the supercompressibility factor determined for these inerts will be assumed to be correct.

c) Compressibility information on the inerts found in the chlorine gas is not available over the ranges of pressure and temperature that Liquefaction may operate.

PROCEDURE

a) Assume the following percent by volume values.

Cl_2	-	95.80%	O_2	-	0.90%
CO_2	-	1.60%	H_2	-	0.34%
N_2	-	1.30%	CO	-	0.06%

4.8% fuel

b) Determine the supercompressibility factor F_{pv} (inerts), by using the tables on pages 6 and the following formulas:

1) $$Z_{inerts} = Z_{Cl_2}(\%Vol.) + Z_{CO_2}(\%Vol.) + Z_{N_2}(\%Vol.) + Z_{O_2}(\%Vol.) + Z_{H_2}(\%Vol.) + Z_{CO}(\%Vol.)$$

2) $$F_{pv}(\text{inerts}) \quad \frac{1}{\sqrt{Z_{inerts}}}$$ (See Calculations, page 4)

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c) Determine the supercompressibility factor F_{pv}(air) by using the tables on pages 6 and the following formulas:

1) $Z_{air_T} = Z_{Cl_2}(\% \text{ Vol.}) + Z_{air}(100\% - \%Cl_2)$

2) $F_{pv}(\text{air}) = \dfrac{1}{\sqrt{Z_{air}}}$ (See calculations, page 4)

d) Determine the supercompressibility factor F_{pv} (one), by using the table on page 6 and the following formulas:

1) $Z_{one} = Z_{Cl_2}(\% \text{ Vol.}) + 1.0(100\% - \%Cl_2)$

2) $F_{pv}(\text{one}) = \dfrac{1}{\sqrt{Z_{one}}}$ (See calculations, page 5)

e) Using F_{pv} (inerts) as the correct value, determine the % error caused by approximating the inerts (a) by using air and (b) by using a percent of one(1) by using the following formulas:

a) $\% \text{ error (air)} = \dfrac{F_{pv}(\text{inerts}) - F_{pv}(\text{air})}{F_{pv}(\text{inerts})} \times 100\%$

b) $\% \text{ error (one)} = \dfrac{F_{pv}(\text{inerts}) - F_{pv}(\text{one})}{F_{pv}(\text{inerts})} \times 100\%$

(See Calculations, page 5)

CONCLUSION

Since the PPG/Conoco sales contract specifies that the error caused by reading the supercompressibility factor, F_{pv}, must not contribute more than 0.25% error in calculating chlorine gas flow to Conoco, and since the above calculations indicate the error between the F_{pv}(inerts) factor (determined for a percent by volume mixture of chlorine and inerts) and the F_{pv}(one) factor (determined for a percent by volume of chlorine and $(100\% - \%Cl_2)1.0$) to be 0.0147%, then it is to be concluded that the supercompressibility factor used in the chlorine to Conoco meter manual will be determined by approximating the effect of the inerts with a percentage of the number one (1.0) as follows:

$$F_{pv} = \frac{1}{\sqrt{Z_{Cl_2}(\% \text{ Vol.}) + 1.0(100\% - \%Cl_2)}}$$

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The smaller percentage of error between F_{pv}(inerts) and F_{pv}(air) of 0.0127% was not sufficient in terms of accuracy to warrant the increased difficulties of calculation if F_{pv}(air) had been chosen to approximate F_{pv}(inerts) instead of F_{pv}(one).

CALCULATIONS

The following calculations are made using the percent volumes listed in part (a) of the procedure and under the following conditions of temperature and pressure.

Temp. = 558°R   Pressure = 58.92 PSIA

1) Supercompressibility factor F_{pv}(inerts):

$$Z_{inerts} = Z_{cl_2}(\%\ Vol.) + Z_{CO_2}(\%\ Vol.) + Z_{N_2}(\%\ Vol.) + Z_{O_2}(\%\ Vol.) + Z_{H_2}(\%\ Vol.) + Z_{CO}(\%\ Vol.)$$

See table 1, page 6, for the Z factors inserted below.

$$\begin{aligned} Z_{inerts} &= (0.91970)(95.8\%) + (0.98190)(1.6\%) + (0.99961)(1.3\%) \\ &+ (0.99799)(0.9\%) + (1.00240)(0.34\%) \\ &+ (0.99904)(0.06\%) \\ &= (0.91778) + (0.01571) + (0.01299) + (0.00898) \\ &+ (0.00341) + (0.00060) \\ &= (0.91778) + (0.04169) = 0.95947 \end{aligned}$$

$$\begin{aligned} F_{pv}(\text{inerts}) &= \frac{1}{\sqrt{Z_{inerts}}} \\ &= \frac{1}{\sqrt{0.95947}} \\ &= \underline{\underline{1.02088}} \end{aligned}$$

2) Supercompressibility factor F_{pv}(air):

$$\begin{aligned} Z_{air_T} &= Z_{Cl_2}(\%\ Vol.) + Z_{air}(\%\ Vol.) \\ &= (0.9197)(95.8\%) + (0.99912)(4.2\%) \\ &= (0.91778) + (0.04196) = 0.95964 \end{aligned}$$

$$\begin{aligned} F_{pv}(\text{air}) &= \frac{1}{\sqrt{Z_{air_T}}} \\ &= \frac{1}{\sqrt{0.95964}} \\ &= \underline{\underline{1.02075}} \end{aligned}$$

3) Supercompressibility factor, $F_{pv}(one)$:

$$Z_{one} = Z_{Cl_2}(\%\ Vol.) + (100\% - \%Cl_2)\ 1.0$$

$$= (0.91970)(95.8\%) + (4.2\%)\ 1.0$$

$$= 0.91778 + 0.04200$$

$$= 0.95978$$

$$F_{pv}(one) = \frac{1}{\sqrt{Z_{one}}}$$

$$= \frac{1}{\sqrt{0.95978}}$$

$$= \underline{\underline{1.02073}}$$

4) Since F_{pv}(inerts) is assumed to be the correct supercompressibility factor for the given conditions, the error caused by allowing "air" or "one" to approximate the inerts can be determined. Also, since F_{pv} is a linear multiple in the equation used to determine the tons/day value of flow to Conoco, the error determined will be the percentage error in flow caused by the F_{pv} factor chosen, F_{pv}(air) or F_{pv}(one). The percentage error are determined as follows:

a) $$\%\ error(air) = \frac{F_{pv}(inerts) - F_{pv}(air)}{F_{pv}(inerts)} \times 100\%$$

$$= \frac{1.02088 - 1.02075}{1.02088}$$

$$= \underline{\underline{0.0127\%}}$$

b) $$\%\ error(one) = \frac{F_{pv}(inerts) - F_{pv}(one)}{F_{pv}(inerts)}$$

$$= \frac{1.02088 - 1.02073}{1.02088}$$

$$= \underline{\underline{0.0147\%}}$$

Table 1: Compressibility Factors for Air, CO_2, CO, N_2, O_2 and H_2
From: Tables of Thermodynamics & Transport Properties

	°R	Pressure (PSIA) 14.73 (1 atm)	58.92 (4 atm)	103.11 (7 atm)
Air	504.0	0.99949	0.99798	0.99656
	522.0	0.99960	0.99841	0.99732
	540.0	0.99970	0.99879	0.99797
	558.0	0.99978	0.99912	0.99855
	576.0	0.99985	0.99940	0.99905
CO_2	504.0	0.99372	0.9746	0.9550
	522.0	0.99441	0.9774	0.9600
	540.0	0.99501	0.9798	0.9644
	558.0	0.99553	0.9819	0.9681
	576.0	0.99598	0.9838	0.9714
CO	504.0	0.99942	0.99773	0.99610
	522.0	0.99955	0.99823	0.99697
	540.0	0.99966	0.99866	0.99772
	558.0	0.99975	0.99904	0.99838
	576.0	0.99984	0.99938	0.99896
N_2	504.0	0.99963	0.99854	0.99749
	522.0	0.99973	0.99895	0.99820
	540.0	0.99982	0.99930	0.99882
	558.0	0.99990	0.99961	0.99936
	576.0	0.99996	0.99988	0.99983
O_2	504.0	0.99915	0.99661	0.99408
	522.0	0.99928	0.99713	0.99500
	540.0	0.99939	0.99759	0.99580
	558.0	0.99949	0.00799	0.99650
	576.0	0.99958	0.99834	0.99712
H_2	504.0	1.0006	1.0024	1.0042
	522.0	1.0006	1.0024	1.0042
	540.0	1.0006	1.0024	1.0042
	558.0	1.0006	1.0024	1.0041
	576.0	1.0006	1.0024	1.0041

	[illegible]		[illegible]
	Δ -		
	9	9.76	10
54	0.98541	0.982816	0.9822
54.9		0.98[illegible]120	
56	0.9860	0.983492	0.98[illegible]7

96%

	50	54.9	60
53	1.0192		1.0224
54	1.01915	1.021835	1.0223
40	1.0191		1.0222

95%

53	1.0190		1.0231
54	1.0159[illegible]	1.02093[illegible]	1.0230
[illegible]	1.0189		1.0229

1.0209385 1.02108270 1.0211835

$$R = 0.010296\ (ATM)(FT^3)/(Lb)(°R)$$

$$R = 0.010296 \frac{(\cancel{ATM})(FT^3)}{(\cancel{LB})(°R)} \times 14.696 \frac{LBf/IN^2}{\cancel{ATM}} \times 70.914 \frac{\cancel{LBm}}{LB\ MOLE}$$

$$= 10.729998 \approx 10.73\ PSI\ FT^3/LBMOL\ °R$$

$$Z_b = P_b M / \rho_b R T_b$$

$$= 14.73 \times 70.914 / 0.18961 \times 10.73 \times 520$$

$$= 0.987352$$

8/20/71
JOM

Computer Errors or Question

1) Use 459.6°R not 460°R as T in °R
2). What schedule pipe is used at flange - is specified to be Sched 40
(Sched 40 to Sched 30 = 0.202% decrease
Base conditions must be 60°F + 14.73 psia
$F_b = 338.17 K_0 d^2$
Have a Robinson H-104 orifice fitting - 10.020" I.D.

3). Manometer fluid may be bad - also manometer is not accurate to better than 0.
0.2" = 0.2% error approx.

4). Check actual temps + pressure as recorded.
1°F ≅ 0.1% error   1 psig ≅ 7% error
0.1 psia = 0.7% error.

need a temp std of about 80°F
Actual gages are 0-60 psig and 0 to 100°F

5). Crisco's changes amount to a 0.547% increase in weight flow

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CONTINENTAL OIL COMPANY
CALCULATION SHEET

MADE BY
CHECKED BY
DATE
PAGE OF
TITLE
JOB NO
FIELD
STATE