Form 23-85B (10-56)

EL PASO NATURAL GAS COMPANY

BOTTOM HOLE PRESSURE REPORT

Company EPNG W.O. No.

Field Blanco SW Sec. 32-31-9

Lease Walker Well No. 2

Date 2-28-62 Time Status of Well Shut-in 21 days

Pay MV Top 4780 ft. Bottom 5435 ft. T.D. 5435 ft. Datum ft.

Tubing 2.375 Depth 5380 ft. B.H.C. ft. Plug or Pin Packer ft.

Casing 7 Depth 4755 ft. Perfs. open ft. Liner Tree Connection

Depth Feet	Pressure lbs. sq. in.	Pressure	Gradient
Lube	893		
1000	924		.031
2000	952		.028
3000	979		.027
5200	1035		.025
5250	1036		.020
5280	1038		.067
5300	1038		----
5320	1038		---
5340	1038		---
5360	1039		.050
5380	1043		.200

Casing Press. 896 D.W.T.
Tubing Press. 880 D.W.T.
Oil Level none ft.
Water Level ft.
Hours Shut In
Temp. 5380 165
Last Test Date
Press. Last Test Psig
Loss
Choke Size
Oil Bbls./day
Water Bbls./day
Gas Sp. Gr. .673
GOR
GLR

PRODUCTIVITY INDEX BBLS./DAY LBS. DROP

Last Cumulative Production | Present Cumulative Production | Production Between Tests

Instrument Humble Number 1222 Recovery Factor Bbls. pound Loss

Run by T. B. Grant Calibration No. 30862 Calculated Ex

Calculations and Remarks:

Calculated BHP = 1043 psig

Form 23-85R (10-56

EL PASO NATURAL GAS COMPANY

BOTTOM HOLE PRESSURE REPORT

Company EPNG W.O. No.

Field Blanco NE Sec. 9-30-8

Lease Woodriver Well No. 2

Date 2-28-62 Time Status of Well Shut-in 21 days

Pay MV Top 4865 ft. Bottom 5424 ft. T.D. 5482 ft. Datum ft.

Tubing 2.375 Depth 5398 ft. B.H.C. ft. Plug or Pin Packer ft.

Casing 5.500 Depth 5482 ft. Perfs. 4865 - 5424 ft. Liner Free Connection

Depth Feet	Pressure lbs. sq. in.	Pressure Gradient lbs. ft.
Lube	803	
1000	830	.027
2000	852	.022
3000	875	.023
5200	918	.020
5300	920	.020
5320	921	.050
5340	921	----
5360	921	----
5409	921	----

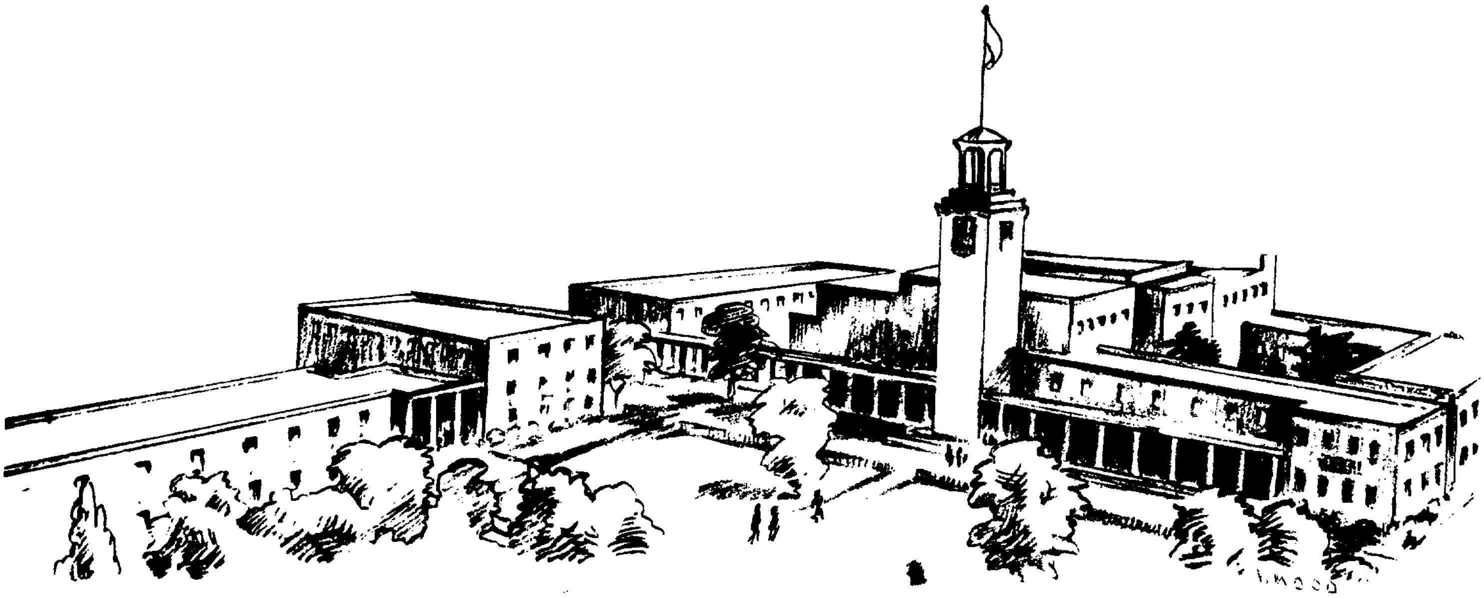
Casing Press. 807 P.S.I.
Tubing Press. 805 P.S.I.
none
Fluid Level
Hours Shut In Flowing
5409 158
Last Test Date
Press. Last Test
B.H.P. Change
Loss
Choke Size
Oil Bbls. day
Water Bbls. day
Total Bbls. day
Orifice
Static Differential
Gas Sp. Gr. .646
Cu. ft. day
GOR cu. ft. Bbl.

PRODUCTIVITY INDEX BBLS. DAY LBS. DROP

Last Cumulative Production	Present Cumulative Production	Production Between Tests
Instrument Humble	Number 1222	Recovery Factor Bbls. pound Loss
Run by T. B. Grant	Calibration No. 30862	Calculated by

Calculations and Remarks:

Calculated BHP = 934 psia



NEW MEXICO OIL CONSERVATION COMMISSION

MANUAL FOR

BACK PRESSURE TEST FOR NATURAL GAS WELLS

STATE OF NEW MEXICO

MANUAL FOR

BACK PRESSURE TEST FOR NATURAL GAS WELLS

STATE OF NEW MEXICO

Compiled

by

Elvis A. Utz

Gas Engineer

February 1, 1956

I N D E X

ACKNOWLEDGEMENT

We wish to express our appreciation to Mr. M. H. Cullender and Mr. C. W. Binkley, Phillips Petroleum Company, for contributing the basic data and tables for calculating pressure loss due to friction and the method of calculating Static Column Pressures as well as their invaluable counsel and advice.

We also express appreciation to Mr. F. Norman Woodruff, Chairman of the Industry Committee appointed by the Commission to study gas well testing in Southeastern New Mexico, and the following committee members for their invaluable counsel and advice, as well as their willing and effective work in making special well tests and analyzing various material used in this manual:

Mr. W. G. Abott, Amerada Petroleum Corporation
Mr. J. W. Cole, Jr., Gulf Oil Corporation
Mr. H. M. Purkaple, Shell Oil Company
Mr. M. H. Cullender, Phillips Petroleum Company
Mr. C. L. Quast, Sinclair Oil and Gas Company
Mr. Dave Nichols, Southern Union Gas Company
Mr. Max Curry, Buffalo Oil Company
Mr. D. L. Henry, Gulf Oil Corporation
Mr. William Randolph, Continental Oil Company
Mr. Robert E. Cook, Continental Oil Company
Mr. G. L. Tribble, Permian Basin Pipeline Company
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Mr. C. W. Binkley, Phillips Petroleum Company
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Mr. J. A. Moore, Continental Oil Company

W. B. MACEY, Secretary-Director

ELVIS A. UTZ, Gas Engineer

FOREWORD

The staff of the New Mexico Oil Conservation Commission has prepared this manual as a result of considerable study in cooperation with a committee composed of engineers from the industry.

The purpose of this manual is to assist the gas operators of the State to comply with the Commission's Rules and Regulations, and to standardize gas testing procedure.

W. B. MACEY
Secretary-Director

INTRODUCTION

This manual is written in compliance with Rule 401 of the Commission's Rules and Regulations of January 1, 1953 and Orders R-368-A through R-376-A, inclusive. Rule 401 requires back pressure tests on all gas wells in the State to be filed once each year. Orders R-368-A through R-376-A, inclusive, are proration orders for the designated dry gas pools of Southeast New Mexico. Reference is made to Paragraph (7) of the findings of each of the above-mentioned orders which states:

> (7) That an adequate gas well testing procedure should be adopted as soon as possible so that operators, purchasers and the Commission can determine the fairness and feasibility of an allocation factor for the pool which employs the factors of deliverability, pressure, or any other factor relating to gas well productivity.

RULES OF PROCEDURES
MULTI-POINT BACK PRESSURE TEST FOR
NATURAL GAS WELLS IN STATE
OF NEW MEXICO

The New Mexico Oil Conservation Commission has adopted the following procedure for taking of Back Pressure Tests on gas wells in the State, except those wells in pools where special testing orders are applicable. This procedure has been adopted to standardize back pressure testing and should be followed closely so that the test be acceptable to the Commission's engineering department.

1. If the well being tested has a pipeline connection it should be flowed for at least 24 hours prior to the shut-in period at a rate high enough to clear the well of liquids.

   If the well cannot be cleared of liquids by producing into the pipeline or if the well has no pipeline connection an attempt shall be made to clear the well by blowing to the atmosphere prior to the shut-in period.

2. The well shall be shut-in for 72 hours plus or minus 6 hours. This shut-in pressure shall be considered stabilized unless deadweight readings taken at a lessor period are higher, in which event the highest recorded pressure shall be used as the shut-in pressure.

   In the event liquid accumulation in the wellbore during the shut-in period appreciably effects the surface pressure, appropriate correction of the surface pressure shall be made in order to account for the pressure due to the liquid column. This correction shall be made in the manner shown in examples No. 6 and No. 7 pages 28 and 34.

3. All shut-in and flowing pressure readings shall be taken with a deadweight gauge. The use of spring gauges is not acceptable because of their inaccuracy.

4. The lowest rate of flow on the test shall be at a rate high enough to keep the well clear of liquids.

5. The test shall be run in the increasing flow rate sequence except in the case of high liquid ratio wells where a decreasing flow rate sequence may be used after the increasing sequence method will not give point alignment. When the decreasing sequence method is used, a statement giving the reasons why the use of such method is necessary shall be furnished with the Form C-122.

6. If possible the working wellhead pressure on the low rate of flow should be drawn down at least 5% of the well's shut-in pressure and at least 30% of the well's shut-in pressure on the highest rate of flow. One criterian as to the acceptability of the test shall be a good spread of data points. If data cannot be obtained in accordance with the above provisions an explanation shall be furnished with Form C-122.

7. An orifice meter, critical flow prover, or a positive choke are the only acceptable metering devices. Gas shall not be vented however, except where absolutely necessary.

8. The diameter of the orifice plate in the meter run and the inside diameter of the run should be checked.

9. The meter pens should be checked and verified correct.

10. a. The absolute potential herein referred to shall be the potential as determined from the 24-hour back pressure curve. The 24-hour back pressure curve shall be determined by either of the following means.

(1) The data obtained from at least four flow rates of 20 to 28-hour duration each or;

(2) By the application of the slope of the back pressure curve, as determined from data obtained from at least four flow rates of lesser duration, to the data obtained from a one-point test of 20 to 28 hours duration. Each flow rate of a test taken for the purpose of establishing only the slope of the back pressure curve shall be of approximately the same duration and not less than three hours unless stabilization is obtained in a lesser time. A constant working pressure for a period of one hour shall constitute stabilization. The one-point test referred to above may be a separate one-point test after shut-in or a continuation after the fourth rate of flow of the multipoint test.

This later procedure shall be used when gas is being vented to the atmosphere except that in the case of information tests taken in the process of completing the well, the operator may utilize such method as is necessary to evaluate the well.

b. The slope herein referred to is the exponent (n) in the back pressure equation $Q = C\ (P_c^2 - P_w^2)^n$ and shall be determined as outlined in example No. 1 page 7.

c. When the back pressure curve cannot be drawn through at least three of the plotted points, the well shall be re-tested. If upon retest a curve cannot be drawn through at least three of the plotted points, an average curve shall be drawn through the points of such test provided, however, that the slope of said curve will not be more than 1.0 nor less than 0.5.

d. If the curve drawn through at least 3 points of the back pressure test has a slope greater than 1.0 or less than 0.5, the well should be retested.

(1) If upon retest the slope of the curve is greater than 1.0, a curve with a slope of 1.0 shall be drawn through the data point corresponding to the highest rate of flow.

(2) If upon retest the slope of the curve is less than 0.5, a curve with a slope of 0.5 shall be drawn through the data point corresponding to the lowest rate of flow.

11. Correction for the compressibility of flowing gas shall be made in accordance with the Simplified Supercompressibility (F_{pv}) tables published by the Commission.

In the event the gas contains carbon dioxide or nitrogen in excess of 2% by volume, the F_{pv} factor shall be determined through use of the appropriate California Natural Gasoline Association (510 W. Sixth Street, Los Angeles 14, California) bulletins TS402 or TS461.

12. Where the static wellhead working pressure reading cannot be obtained due to packer or dual completion said pressure shall be calculated by using the tables in this manual and as shown in example No. 5 page 25 .

13. The average Barometric Pressure shall be assumed to be 13.2 psia in Southeastern New Mexico and 12.0 psia in Northwestern New Mexico.

14. Upon completion of the test, all the calculations shall be shown on New Mexico Oil Conservation Commission Form No. C-122 and shall be accompanied by a back pressure curve neatly plotted on equal scale log-log paper of at least 3 inch cycles. Three copies of both the data sheet and back pressure curve shall be mailed to the Commission office in Santa Fe, New Mexico.

CALCULATION EXAMPLE NO. 1

BACK PRESSURE TEST ON A GAS WELL PRODUCING THROUGH THE TUBING WITH CASING PRESSURES AVAILABLE.

Step (1) After filling in the General Data at the top of Form C-122 and Observed Data for each rate of flow on Form C-122, the calculation may begin.

Step (2) Flow Rate Calculations

Formula for calculating orifice meter flow:

$$Q = C \sqrt{(h_w)\ (p_f)} \times F_t \times F_g \times F_{pv}$$

Where:

Q = rate of flow, MCFD @ 15.025 psia. 60°F.

C = basic orifice factor (Flange Taps)

h_w = Differential meter pressure. (inches of water)

p_f = static meter pressure. psia

F_t = flowing temperature factor

F_g = specific gravity factor

F_{pv} = supercompressibility factor

Calculating first rate of flow:

General and observed data.

Barometric Pressure	-	13.2 psia
Gas Gravity	-	.675
Testing Device	-	Meter Run
Type Taps	-	Flange
Meter Run	-	4"
Orifice size	-	1.500"

Observed Field Data and Table Factors

C = 13.99 (Table I Page 38)

h_w = 12.00 in wtr. (Field Data)

p_f = 767.2 psia (Field Data)

F_t = .9868 (Table V Page 42)

F_g = .9427 (Table VI Page 43)

F_{pv} = 1.084 (NMOCC Simplified Supercompressibility Tables)

Substituting above data into formula

$$Q = 13.99 \sqrt{(12.0)\quad(767.2)} \times .9868 \times .9427 \times 1.084$$

$$Q_1 = 1353 \text{ MCFD}$$

In like manner the other three flow rates are found to be: (see Form C-122, page 13)

2nd rate	-	Q_2	= 1838	MCFD
3rd rate	-	Q_3	= 2031	MCFD
4th rate	-	Q_4	= 2421	MCFD

Step (3)

PRESSURE CALCULATIONS

Since this is a dry gas well and the static wellhead working pressures are measured the liquid column or pressure loss due to friction calculations (P_w) are not necessary.

Data for plotting back pressure curve.

Q vs. $(P_c^2 - P_w^2)$

Where:

Q = rate of flow, MCFD @ 15.025 psia 60°F.

P_c = wellhead shut-in pressure, casing or tubing whichever is higher.

P_w = static wellhead working pressure at the termination of each flow period. (casing if flowing through tubing, tubing if flowing through casing) All squared pressures in thousands.

Then:

	Q MCFD	P_c (Psia)	P_c^2 (Thsnds)	P_w (Psia)	P_w^2 (Thsnds)	$P_c^2 - P_w^2$ (Thsnds)
(1)	1353	999.2	998.4	855.2	731.4	267.0
(2)	1838	999.2	998.4	795.2	632.3	366.1
(3)	2031	999.2	998.4	767.2	588.6	409.8
(4)	2421	999.2	998.4	711.2	505.8	492.6

The above data shall then be plotted on log log paper of at least three inch cycles in accordance with item 10 of the Rules of Procedures. Q shall be plotted on the horizontal axis and $(P_c^2 - P_w^2)$ on the vertical axis as shown in the example on page 13 .

Enter values of P_c, P_c^2, P_w, P_w^2 and $(P_c^2 - P_w^2)$ on Form C-122.

Step (5) Determining the value of slope n of the back pressure curve.

The numerical value of the slope n is the cotangent of the angle formed by the back pressure curve and the horizontal axis of the log log plot.

However, a more convenient and accurate method shall be used to determine the value of n. The difference of the logarithm of two values of Q which are exactly one vertical cycle apart shall be determined in the following manner. (see example on page 13)

Value of Q where curve intersects the $(P_c^2 - P_w^2)$ scale exactly one cycle higher than the $(P_c^2 - P_w^2)$ value used for Q_1. In this example this value is 2000 (thousands)	Q_2 = 8910; Log Q_2 = 3.949878
Value of Q where curve intersects the lowest convenient value of $(P_c^2 - P_w^2)$. In this example this value is 200 (thousands)	Q_1 = 1045; Log Q_1 = 3.019116
	Slope n .930762

Rounded off to two decimals the slope n is then .93. This value shall be entered on Form C-122.

Step (6) Determining Absolute Potential

The absolute potential is defined as the calculated rate of flow at the wellhead after flowing for a 24 hour flow period against atmospheric pressure if there were no pressure loss due to friction in the flow string. The rate of flow shall be expressed at New Mexico Oil Conservation Commission base conditions of 15.025 psia and 60° Farenheit. This is sometimes called a wellhead absolute potential.

The error caused in the value of the absolute potential, when atmospheric pressure is ignored in the determination of absolute potential, is insignificant when shut-in pressure is below 100 psia. Because of this fact, atmospheric pressure will not be considered in the following explanations.

The absolute potential shall be determined by plotting the value of $(P_c^2 - P_w^2)$ on the back pressure curve when P_w equals 0 absolute. The absolute potential is read on the Q or horizontal scale of the log log plot directly under the plotted point where the $(P_c^2 - P_w^2)$ value intersects the back pressure curve.

In this example P_c^2 equals 998.4 (thousands). When plotted on the back pressure curve, the value of (AP) the absolute potential is 4670 MCFD. Record this value on Form C-122.

The values of AP and slope n should be checked by substituting test data in the following formula. If a data point does not fall on the curve as drawn, then any convenient value of Q and $(P_c^2 - P_w^2)$ from the curve should be used in the following formula.

$$AP = Q \left[\frac{P_c^2}{(P_c^2 - P_w^2)} \right]^n$$

where:

AP = absolute potential

Q = rate of flow from test data point, or from B. P. curve.

P_c = shut-in pressure psia.

P_w = static wellhead working pressure psia.

Note: Where data is taken from curve $(P_c^2 - P_w^2)$ is read from the Back Pressure Plot.

Substituting values in equation:

$$AP = 2421 \left[\frac{998.4}{(998.4 - 505.8)} \right]^{.93}$$

$$AP = 2421 \; (2.02679)^{.93}$$

$$AP = 2421 \; (1.9288)$$

$$AP = 4669.6$$

The Calculation checks the value of 4670 as read from the Back Pressure Curve and is correct.

Form C-122 should be checked for accuracy and to be sure that all necessary data has been filled in. The Form should then be signed and filed in triplicate with the Commission Office, Box 871, Santa Fe, New Mexico.

EXAMPLE NO. 1

NEW MEXICO OIL CONSERVATION COMMISSION

Form C-122
Revised 12-1-55

MULTI-POINT BACK PRESSURE TEST FOR GAS WELLS

Pool Eumont Formation Queen County Lea

Initial X Annual ____ Special ____ Date of Test 12-1-55

Company Blowe Gas Company Lease H.I. Test Well No. 6

Unit A Sec. 36 Twp. 22S Rge. 35E Purchaser Blowe Gas Company

Casing 5.5 Wt. 15.5 I.D. 4.950 Set at 3573 Perf. 3550 To 3560

Tubing 2.375 Wt. 4.7 I.D. 1.995 Set at 3573 Perf. None To ____

Gas Pay: From 3550 To 3580 L 3573 xG .675 -GL 2412 Bar.Press. 13.2

Producing Thru: Casing ____ Tubing x Type Well Single
Single-Bradenhead-G. G. or G.O. Dual

Date of Completion: 6-4-50 Packer None Reservoir Temp. 130 F.

OBSERVED DATA

Tested Through ~~(Prover)~~ ~~(Choke)~~ (Meter) Type Taps Flange

No.	Flow Data					Tubing Data		Casing Data		Duration of Flow Hr.
	~~(Prover)~~ (Line) Size	~~(Choke)~~ (Orifice) Size	Press. psig	Diff. h_w	Temp. °F.	Press. psig	Temp. °F.	Press. psig	Temp. °F.	
SI	4 in.	1.5 in.				986	75	984	75	72 hr. S. I.
1.	"	"	754	12.0	74	754	74	842	75	24
2.	"	"	652	26.0	71	652	72	782	75	24
3.	"	"	598	35.0	71	598	71	754	75	24
4.	"	"	401	77.0	71	401	71	698	75	24
5.	"	"								

FLOW CALCULATIONS

No.	Coefficient (24-Hour)	$\sqrt{h_w p_f}$	Pressure psia	Flow Temp. Factor F_t	Gravity Factor F_g	Compress. Factor F_{pv}	Rate of Flow Q-MCFPD @ 15.025 psia
1.	13.99	95.94	767.2	.9868	.9427	1.084	1353
2.	"	131.49	665.2	.9896	"	1.071	1838
3.	"	146.23	611.2	.9896	"	1.064	2031
4.	"	177.89	414.2	.9896	"	1.043	2421
5.							

PRESSURE CALCULATIONS

Gas Liquid Hydrocarbon Ratio Dry Gas cf/bbl.
Gravity of Liquid Hydrocarbons ____ deg.
F_c P_w measured $(1-e^{-s})$ ____

Specific Gravity Separator Gas ____
Specific Gravity Flowing Fluid ____
P_c 999.2 P_c^2 998.4

No.	P_w P_t (psia)	P_t^2	F_cQ	$(F_cQ)^2$	$\frac{(F_cQ)^2}{(1-e^{-s})}$	P_w^2	$P_c^2-P_w^2$	Cal. P_w	$\frac{P_w}{P_c}$
1.	855.2					731.4	267.0		85.6
2.	795.2					632.3	366.1		79.6
3.	767.2					588.6	409.8		76.6
4.	711.2					505.8	492.6		71.2
5.									

Absolute Potential: 4670 MCFPD; n .93
COMPANY Blowe Gas Company
ADDRESS 4600 Broadway, Jal, New Mexico
AGENT and TITLE John Doe, Gas Engineer
WITNESSED I. M. Goode
COMPANY North Gas Company

REMARKS

INSTRUCTIONS

This form is to be used for reporting multi-point back pressure tests on gas wells in the State, except those on which special orders are applicable. Three copies of this form and the back pressure curve shall be filed with the Commission at Box 871, Santa Fe.

The log log paper used for plotting the back pressure curve shall be of at least three inch cycles.

NOMENCLATURE

Q = Actual rate of flow at end of flow period at W. H. working pressure (P_w). MCF/da. @ 15.025 psia and 60° F.

P_c = 72 hour wellhead shut-in casing (or tubing) pressure whichever is greater. psia

P_w = Static wellhead working pressure as determined at the end of flow period. (Casing if flowing thru tubing, tubing if flowing thru casing.) psia

P_t = Flowing wellhead pressure (tubing if flowing through tubing, casing if flowing through casing.) psia

P_f = Meter pressure, psia.

h_w = Differential meter pressure, inches water.

F_g = Gravity correction factor.

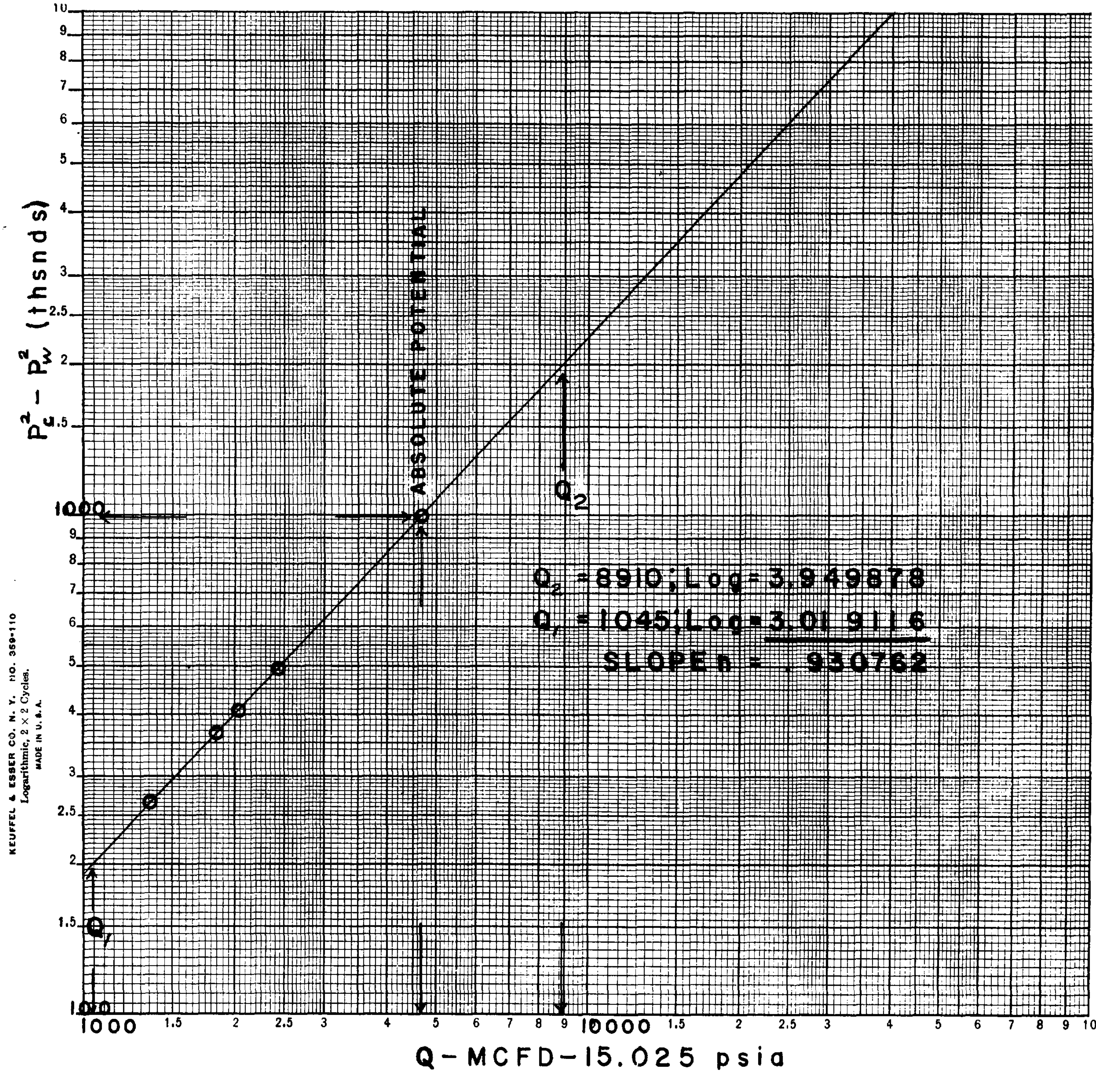
F_t = Flowing temperature correction factor.

F_{pv} = Supercompressability factor.

n = Slope of back pressure curve.

Note: If P_w cannot be taken because of manner of completion or condition of well, then P_w must be calculated by adding the pressure drop due to friction within the flow string to P_t.

COMPANY	Blowe Gas Company
WELL	H. I. Test No. 6
LOCATION	A 36-22S-35E
COUNTY	Lea
DATE	12-1-55



CALCULATION EXAMPLE NO. 2

BACK PRESSURE TEST ON A HIGH PRESSURE DUALLY COMPLETED GAS WELL PRODUCING THROUGH THE ANNULUS.

This Example will show the method of calculating G_{mix} and static wellhead working pressure when they cannot be measured.

Step (1) After filling in the General Data at the top of Form C-122 and the Observed Data on same Form, the calculations may begin.

Step (2) Flow Rate Calculations

Since this well was tested through an Orifice Meter refer to the procedure for calculating the flow rates in Example 1.

The rates of flow are calculated to be:

1st rate	-	2584 MCFD	or	2.584 M^2CFD
2nd rate	-	3570 MCFD	or	3.570 M^2CFD
3rd rate	-	4859 MCFD	or	4.859 M^2CFD
4th rate	-	6493 MCFD	or	6.493 M^2CFD

Step (3) Pressure Calculations

Since this well is a dual completion the static wellhead working pressure must be calculated. In order to accurately calculate this pressure it is first necessary to determine the gravity of the flowing fluid or the G_{mix}:

G_{mix} calculation.

Formula:

$$G_{mix} = \frac{G_1 + \frac{4591\ (G_2)}{R}}{1 + \frac{1123}{R}}$$

Where:

G_{mix} = specific gravity of flowing fluid (Air = 1.0)

G_1 = specific gravity of separator gas (Air = 1.0)

G_2 = specific gravity of separator liquid hydrocarbons (water = 1.0)

R = gas-liquid ratio (cu. ft. per bbl.)

Then:

G_1 = .680 from data on Form C-122

G_2 = .6988 from Table IX page 52.

R = 76,859 from data on Form C-122

Substituting data into formula:

$$G_{mix} = \frac{.680 + \frac{(4591)\ (.6988)}{76,859}}{1 + \frac{1123}{76,859}}$$

G_{mix} = .711

Static Wellhead Working Pressure Calculation: *

Formula:

$$P_w^{\ 2} = P_t^{\ 2} + (F_c Q)^2 \ (1-e^{-s})$$

Where:

$P_w^{\ 2}$ = Static wellhead working pressure, psia squared, expressed in thousands.

$P_t^{\ 2}$ = flowing wellhead pressure psia. squared, expressed in thousands.

F_c = Flow string factor Table VII C page 50.

Q = Rate of flow M^2CFD from Form C-122

$(1-e^{-s})$ = GL factor. Table VIII page 48.

In order to determine the value of F_c and $(1-e^{-s})$ we must first determine:

O.D. of Tubing = 2.375 in.
I.D. of Casing = 4.392 in.
GL = G_{mix} gravity x length of flow string from top of perforations = 3831 ft.

* Tables VII A (Southeast), VII B (Southeast), VII C (Southeast) and VIII (Southeast) are based on average conditions existing in Southeastern New Mexico. For friction loss calculations in San Juan Basin (Northwestern New Mexico) the appropriate tables for that area should be obtained from the Commission.

Taken from Data on Form C-122 for 1st. rate of flow:

P_{t1} = 1691.2 psia

Q_1 = 2.584 M^2CFD

F_c = 1.812 (2.375" OD tubing and 4.892" ID casing from Table VII C page 47.)

$(1-e^{-s})$ = .232 (GL of 3831 from Table VIII page 48.)

Substituting in formula:

$P_{w1}^2 = (1691.2)^2 + \left[(1.812 \times 2.584)^2 \ (.232)\right]$

P_{w1}^2 = 2865.08

P_{w1} = 1692.6

Second rate of flow:

P_{t2} = 1610.2

Q_2 = 3.570 M^2CFD

$P_{w2}^2 = (1610.2)^2 + \left[(1.812 \times 3.570)^2 \ (.232)\right]$

P_{w2}^2 = 2602.4

P_w = 1613.2

Third rate of flow:

P_{t3} = 1509.2

Q_3 = 4.859 M^2CFD

$P_{w3}^2 = (1509.2)^2 + \left[(1.812 \times 4.859)^2 \ (.232)\right]$

P_{w3}^2 = 2296

P_{w3} = 1515

Fourth rate of flow:

P_{t4} = 1340.2

Q_4 = 6.493 M^2CFD

$P_{w4}^2 = (1340.2)^2 + \left[(1.812 \times 6.493)^2 \ (.232)\right]$

P_{w4}^2 = 1828.2

P_{w4} = 1352.1

Step (4) Data for Plotting Back Pressure Curve

	Q (MCFD)	P_c (psia)	P_c^2 (Thsnds)	P_w (psia)	P_w^2 (Thsnds)	$P_c^2 - P_w^2$ (Thsnds)
1	2584	1876	3519.0	1692.6	2865.0	654.0
2	3570	1876	3519.0	1613.2	2602.4	916.6
3	4859	1876	3519.0	1515.1	2295.6	1223.4
4	6493	1876	3519.0	1352.1	1828.2	1690.8

The above plotting data should be plotted on log log paper, then the slope of the back pressure curve and the absolute potential determined as explained in Example No. 1 under "Determining the value of slope n" and "Determining absolute potential" respectively.

The slope "n" is determined to be .97.

The absolute potential is read from the log log plot as 13,200 MCFD.

When checking the accuracy of the absolute potential of 13,200 MCFD, as determined from the plot, we calculate this to be 13,219 when using data for the first plotting point and 13,225 when using data for the fourth plotting point. The absolute potential of 13,200 MCFD is therefore considered correct.

The above data should be recorded on Form C-122 under "Pressure Calculations".

The Form C-122 should be checked carefully for accuracy, signed and filed in triplicate with the Commission Office, Box 871, Santa Fe.

EXAMPLE NO. 2

NEW MEXICO OIL CONSERVATION COMMISSION

Form C-122
Revised 12-1-55

MULTI-POINT BACK PRESSURE TEST FOR GAS WELLS

Pool Undesignated Formation Blinebry County Lea

Initial X Annual ____ Special ____ Date of Test 1-31-56

Company Doe Gas Company Lease Deer Well No. 1

Unit C Sec. 10 Twp. 24S Rge. 36E Purchaser American Pipeline Company

Casing O.D. 5½ Wt. 17# I.D. 4.892 Set at 6484 Perf. 5388 To 5494

Tubing 2 3/8 Wt. 4.7# I.D. 1.995 Set at 6469 Perf. 6460 To 6463

Gas Pay: From 5388 To 5494 L 5388 xG mix .711 -GL 3831 Bar.Press. 13.2

Producing Thru: Casing X Tubing ____ Type Well G. O. Dual

Single-Bradenhead-G. G. or G.O. Dual

Date of Completion: 12-15-55 Packer 6410 Reservoir Temp. 110°F

OBSERVED DATA

Tested Through ~~(Prover)~~ ~~(Choke)~~ (Meter) Type Taps Pipe Taps

No.	Flow Data (Prover) (Line) Size	(Choke) (Orifice) Size	Press. psig	Diff. h_w	Temp. °F.	Tubing Data Press. psig	Temp. °F.	Casing Data Press. psig	Temp. °F.	Duration of Flow Hr.
SI	4"	2.50						1863	60	72 hrs.
1.	"	"	459	5.0	70			1678	72	24
2.	"	"	464.8	9.2	63			1597	65	24
3.	"	"	461.4	17.3	66			1496	68	24
4.	"	"	473	29.5	58			1327	60	24
5.										

FLOW CALCULATIONS

No.	Coefficient (24-Hour)	$\sqrt{h_w p_f}$	Pressure psia	Flow Temp. Factor F_t	Gravity Factor F_g	Compress. Factor F_{pv}	Rate of Flow Q-MCFPD @ 15.025 psia
1.	54.44	48.58		.9905	.9393	1.050	2584
2.	"	66.31		.9971	"	1.056	3570
3.	"	90.65		.9943	"	1.054	4859
4.	"	119.78		1.0019	"	1.058	6493
5.							

PRESSURE CALCULATIONS

Gas Liquid Hydrocarbon Ratio 76,859 cf/bbl.

Gravity of Liquid Hydrocarbons 71° deg.

F_c 1.812 $(1-e^{-s})$ .232

Specific Gravity Separator Gas .680

Specific Gravity Flowing Fluid .711

P_c 1876 P_c^2 3519

No.	P_w P_t (psia)	P_t^2	F_cQ	$(F_cQ)^2$	$(F_cQ)^2 (1-e^{-s})$	P_w^2	$P_c^2-P_w^2$	Cal. P_w	$\frac{P_w}{P_c}$
1.	1691.2	2860	4.682	21.92	5.09	2865	654	1692.6	90.2
2.	1610.2	2593	6.468	41.83	9.71	2602.4	916.6	1613.2	85.9
3.	1509.2	2277	8.804	77.51	17.98	2295.6	1223.4	1515.1	80.7
4.	1340.2	1796	11.77	138.53	32.11	1828.2	1690.8	1352.1	72.0
5.									

Absolute Potential: 13,200 MCFPD; n .97

COMPANY Doe Gas Company

ADDRESS 9670 Main Street, Hobbs, New Mexico

AGENT and TITLE I. M. Lowe, Gas Engineer

WITNESSED J. R. Neal

COMPANY Best Oil Company

REMARKS

INSTRUCTIONS

This form is to be used for reporting multi-point back pressure tests on gas wells in the State, except those on which special orders are applicable. Three copies of this form and the back pressure curve shall be filed with the Commission at Box 871, Santa Fe.

The log log paper used for plotting the back pressure curve shall be of at least three inch cycles.

NOMENCLATURE

Q = Actual rate of flow at end of flow period at W. H. working pressure (P_w). MCF/da. @ 15.025 psia and 60° F.

P_c = 72 hour wellhead shut-in casing (or tubing) pressure whichever is greater. psia

P_w = Static wellhead working pressure as determined at the end of flow period. (Casing if flowing thru tubing, tubing if flowing thru casing.) psia

P_t = Flowing wellhead pressure (tubing if flowing through tubing, casing if flowing through casing.) psia

P_f = Meter pressure, psia.

h_w = Differential meter pressure, inches water.

F_g = Gravity correction factor.

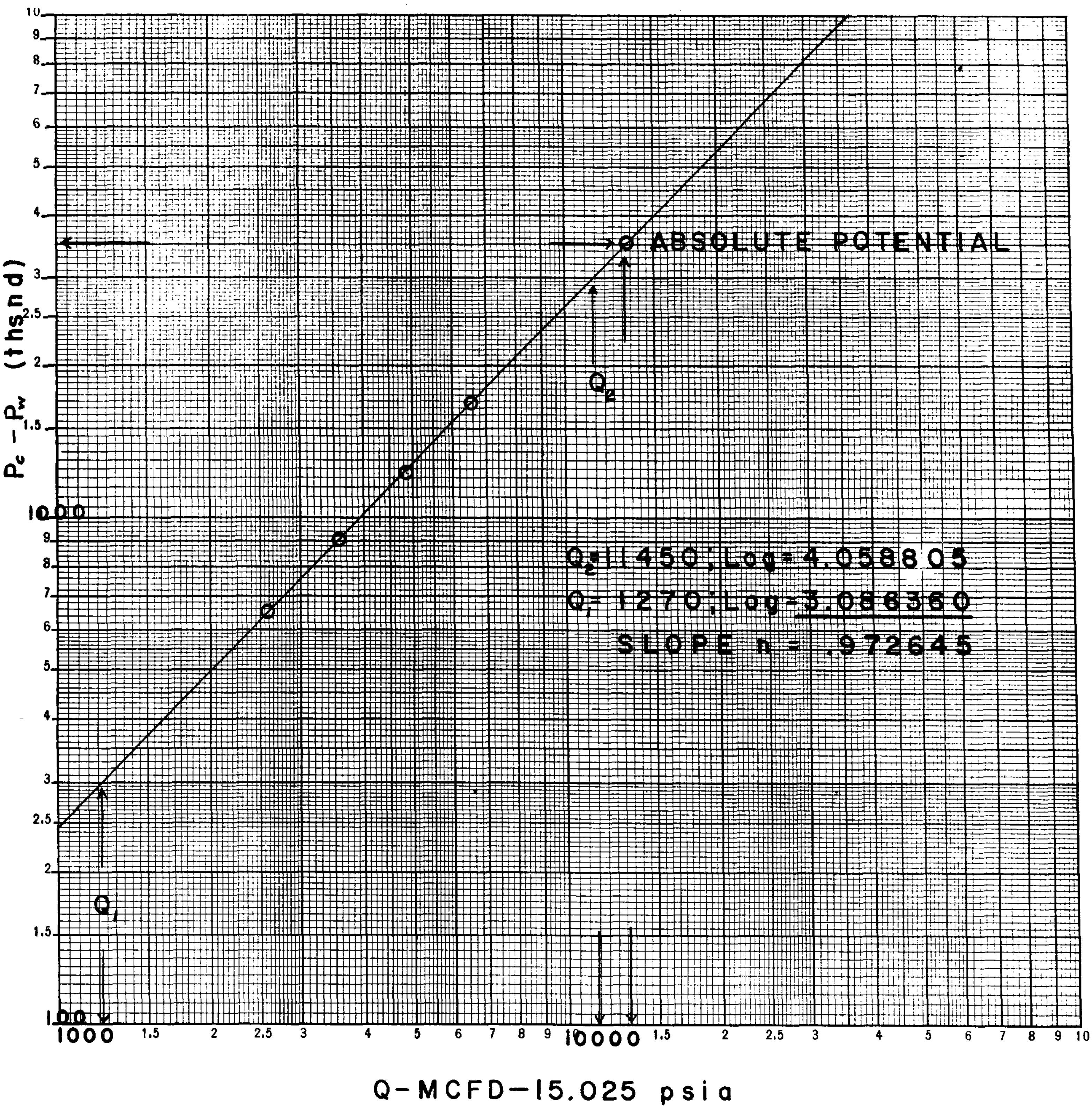
F_t = Flowing temperature correction factor.

F_{pv} = Supercompressability factor.

n = Slope of back pressure curve.

Note: If P_w cannot be taken because of manner of completion or condition of well, then P_w must be calculated by adding the pressure drop due to friction within the flow string to P_t.

COMPANY	Doe Gas Company
WELL	Deer No. 1
LOCATION	C-10-24S-36E
COUNTY	Lea
DATE	1-31-56



PROCEDURES TO FOLLOW FOR WELLS COMPLETED IN MANNERS OTHER THAN THOSE CONSIDERED IN EXAMPLE NO. 1 AND 2.

I. A single completion producing through the tubing but where P_w cannot be measured due to packer, no pressure connection on casing, etc.

Follow the procedures of Example No. 1, steps 1, 2, 5 and 6.

Since P_w cannot be measured we will use the procedure of step 3, Example No. 2 to complete the calculation. The value of F_c used will be for the proper size tubing from Table VII A page 44 .

If the well produced dry gas the G_{mix} calculation shown in this example shall be eliminated and the actual measured gravity of the flowing gas used in its place.

II. A single Completion with no tubing in well.

Follow the procedures of Example 2, steps 1 through 4. The procedure of step 4 is changed only in that the F_c factor is determined for the proper size casing from Table VII B.

If the well produces dry gas the G_{mix} calculation shown in step 3 of this Example shall be eliminated and the actual measured gravity of the flowing gas used in its place.

III. Bradenhead well (a well producing gas from exposed zones in the annular area between the outside of the production casing and the well-bore or outside of the production string and inside the intermediate or surface casing.)

The wells where flow is for the most part between the outside of the production casing and the well bore (i.e., no intermediate casing in well), no attempt shall be made to calculate the pressure drop due to friction. The value of P_t shall be used in place of P_w in plotting the Back Pressure curve.

The wells where flow is mostly from the annular area between the outside of the production string and the inside of the intermediate string, the procedure shall be the same as used in Example No. 2, step 3. The friction loss shall be calculated only for flow between the two strings of casing and any loss due to flow between the production casing and the well bore shall be ignored.

IV. <u>Dual Completions with two paralled tubing strings.</u>

(a) Where P_w can be measured use procedures in Example No. 1.

(b) Where P_w cannot be measured use the procedures outlined in I above for that particular tubing size.

EXAMPLE NO. 3

VOLUME CALCULATIONS FOR FLOW THROUGH ORIFICE METER, CRITICAL FLOW PROVER AND POSITIVE CHOKES.

Orifice Meter

Refer to flow calculations in Example No. 1, Page 7

CRITICAL FLOW PROVER
(Two and Four Inch)

Formula:

$$Q = C \times P_t \times F_t \times F_g \times F_{pv}$$

where:

Q	=	Rate of flow MCFD, 15.025 psia 60° F.
C	=	Coefficient of orifice plate.
P_t	=	Flowing gas pressure on prover psia.
F_t	=	Flowing gas temperature factor.
F_g	=	Flowing gas gravity factor
F_{pv}	=	Supercompressibility factor

Observed data:

2" critical flow prover - 1/2" plate
Pressure of flowing gas on prover - 915 psig
Temperature of flowing gas - 70°F
Gravity of flowing gas - .675
Barometric pressure - 13.2 psia

Determining values of factors for formula:

C	=	5.523 Table III, page 40.
P_t	=	928.2 psia from observed data.
F_t	=	.9905 Table V, page 42.
F_g	=	.9427 Table VI, page 43.
F_{pv}	=	1.104 New Mexico Oil Conservation Commission. Simplified Supercompressibility Tables. (915 psig, .675 gravity and 70°F.)

Then:

Q = 5.523 x 928.2 x .9905 x .9427 x 1.104

Q = 5285. MCFD

Positive Chokes

(Including Thornhill-Craver positive flow-beans)

Formula:

$$Q = C \times P_t \times F_t \times F_g \times F_{pv}$$

where:

Q = Rate of flow MCFD, 15.025 psia, 60°F.

C = Positive choke coefficient.

P_t = Pressure of flowing gas on choke, psia.

F_t = Flowing gas temperature factor.

F_g = Flowing gas gravity factor.

F_{pv} = Supercompressibility factor of flowing gas.

Observed data:

Positive choke size - 13/64 in.
Pressure of flowing gas on prover - 915 psig.
Temperature of flowing gas - 70°F
Gravity of flowing gas - .675 (Air = 1.0)
Barometric Pressure - 13.2 psia

Determining factors for formula:

C = .8731 Table IV page 41.
Column (1) for Thornhill-Craver chokes.

P_t = 928.2 psia from observed data.

F_t = .9905 Table V page 42.

F_g = .9427 Table VI, page 43.

F_{pv} = 1.104 New Mexico Oil Conservation Commission Simplified Supercompressibility tables. .675 gravity, 915 psig, 70°F.

Then:

Q = .8731 x 928.2 x .9905 x .9427 x 1.104

Q = 835 MCFD

EXAMPLE NO. 4

PROCEDURE FOR DETERMINING THE GRAVITY OF FLOWING WET GAS IN THE FLOW STRING.

In cases where the gravity of flowing wet gas is not known this procedure may be used to determine the gravity.

When this method is used we must know the

(1) Specific gravity of the separator gas,

(2) The specific, or A.P.I. gravity of the separator Hydrocarbon Liquids, and

(3) The Gas-Liquid ratio.

If only the A.P.I. gravity of the separator liquids is known we must determine the specific gravity by referring to Table IX, Page 52, or by calculating using the following equation:

$$\text{Specific gravity} = \frac{141.5}{131.5 + \text{Degrees A.P.I.}}$$

The specific gravity may then be calculated as follows:

Formula:

$$\text{Flowing wet gas gravity} = \frac{G_1 + \frac{4591\ G_2}{R}}{1 + \frac{1123}{R}}$$

Where:

G_1 = Separator gas specific gravity. (Air = 1.00)

G_2 = Separator Hydrocarbon Liquid Specific gravity. (Water = 1.0)

R = Gas - Liquid Ratio. (cu. ft./bbl.)

and

G_1 = .680

G_2 = .6988 for 71° A.P.I.

R = 76,859 cu. ft./bbl.

Substituting values in formula:

$$\text{Flowing Gravity of wet gas } (G_{mix}) = \frac{.680 + \frac{(4591)(.6988)}{76,859}}{1 + \frac{1123}{76,859}}$$

EXAMPLE NO. 5

METHOD OF DETERMINING PRESSURE LOSS DUE TO FRICTION IN FLOW STRINGS FOR GAS WELLS.

Nomenclature

Q	=	M²cfd @ 15.025 psia and $60^\circ F$.
P_c	=	Shut-in wellhead pressure, psia.
P_w	=	Static wellhead working pressure, psia
P_t	=	Flowing wellhead pressure, psia
F_c	=	Factor dependent upon size of flow string, pressure base, temperature and compressibility factor. (See Tables VII A, B and C of F_c values)
$(1-e^{-s})$	=	Factor dependent upon GL, temperature and compressibility factor. (See Table VIII of $(1-e^{-s})$. values)
G	=	Specific gravity (Air = 1.00)
L	=	Length of flowing gas column, ft.

Procedure

1. From the Table VII A, B or C, obtain the value of F_c corresponding to the internal diameter of the pipe.
2. From the Table VIII, obtain the value of $(1-e^{-s})$ corresponding to the value of GL.
3. From the test data, obtain the rate of flow (Q) and the corresponding flowing pressure. (P_t)
4. Multiply F_c (Table VII A, B or C value) times Q.
5. Square the term F_cQ.
6. Multiply $(F_cQ)^2$ by $(1-e^{-s})$ (Table VIII value)
7. Add the value of $(F_cQ)^2$ $(1-e^{-s})$ to P_t^2 to obtain P_w^2.
8. Extract square root of P_w^2 to obtain P_w.

Calculations

Test data from Form C-122 (revised 12-1-55) necessary for P_w calculation.

1. 1.995" = Size of Flow String I.D. (If not known I. D. may be determined from Table VII A by referring to O.D. and #/ft. columns.)

2. L = 4000' = Length of Flowing String (If lower sections of tubing is perforated, the top of the perforations shall determine L. Where the flow is through the casing and casing is set above the producing formation the casing shoe shall determine L. Where flow is through casing and casing is set through the producing formation and slotted or perforated the top of the perforations shall determine L.)

3. G = .651 = Specific Gravity of Flowing Gas. (Air = 1.0.)

4. P_t = 835 psia = Wellhead flowing tubing or casing pressure.

5. Q = 2.500 M^2CF = Rate of Flow (Volume shown under "Flow Calculations" expressed in million cu. ft. per day.)

Begin calculation as follows:

6. Determine Table VII A Value (F_c) for 1.995 Tubing. This is 9.936. Show this value in space provided for friction calculations on Form C-122.

7. Multiply G x L; GL = 2604, shown at top of Form C-122.

8. Determine Table VIII value ($1-e^{-s}$) for GL of 2604. This is .164. Show this value in space provided for "Pressure Calculations" Form C-122.

9. Multiply Table VII A value 9.936 (F_c) by 2.500 (Q) and square the product. $(9.936 \times 2.500)^2 = 617.0$ (thousands).

10. Multiply 617.0 by Table VIII value of .164 ($1-e^{-s}$). $617.0 \times .164 = 101.2$ (thousands).

11. Square 835 (P_t); $(835)^2 = 697.2$ (thousands). Item 4 above from Form C-122.

12. Add 697.2 $(P_t)^2$ to 101.2 $(F_c Q^2)(1-e^{-s})$ and extract the square root of the sum.
$697.2 + 101.2 = 798.4$ (thousands).

$(798.4)^{.5} = 893.5 = P_w$ (Calculated static wellhead working pressure).

13. This is the P_w to be used in the $(P_c^2 - P_w^2)$ calculation when P_w cannot be measured accurately because of dual completion, liquids in well-bore and etc.

14. The above data should be entered in the space provided under Pressure Calculations on Form C-122.

15. The simplified formula for the above calculation is:

$$P_w = \left(P_t^2 + \left[(F_cQ)^2 \quad (1-e^{-s})\right]\right)^{.5}$$

EXAMPLE NO. 6

DETERMINING STATIC COLUMN PRESSURES IN GAS WELLS

The determination of subsurface static column pressures shall be accomplished through the use of the following procedure and the "Calculation Sheet for Static Column Pressures". *

Observed data:

Specific gravity of gas	.725 (Air = 1.0)
Measured Wellhead Pressure	1350 Psia
% CO_2	0
% N	0
Wellhead temperature	80° F (540° Rankine)
Reservoir Temperature	128° F (588° Rankine)

Using the "Calculation Sheet for Static Column Pressures", Case I.

1. Enter specific gravity of gas (G) and the composition of gas at top of calculation sheet.

2. Determine critical pressure and temperature of gas from CNGA Bulletin No. TS 461.

$$P_{cr} = 688; \ T_{cr} = 398$$

If the gas contains carbon dioxide or Nitrogen the P_{cr} and T_{cr} should be corrected at this time by using Table II of CNGA TS 461.

Enter values of T_{cr} and F_{cr} at top of calculation sheet.

* In cases where extremely accurate calculated pressures are required the Procedures outlined on page 66 of appendix C should be used.

3. Enter initial depth (zero wellhead) on line 1, column 1.

4. Enter wellhead pressure (P_n) on Line 1, Column 2. (1350 psia)

5. Determine reduced pressure. (P_r)

$$\frac{P_n}{P_{cr}} = \frac{1350}{668} = 2.02 = P_r$$

Enter on Line 1, Column 3.

6. Enter wellhead temperature (absolute) on Line 1, Column 4. (540° R.)

7. Determine reduced temperature (T_r)

$$\frac{T}{T_{cr}} = \frac{540}{398} = 1.36 = T_r$$

Enter on Line 1, Column 5.

8. Using P_r and T_r determine supercompressibility factor (F_{pv}) from Table V, CNGA Bulletin TS 461.

$$F_{pv} = 1.165$$

Enter on Line 1, Column 6.

9. From F_{pv} determine Z factor.

$$\frac{1}{(F_{pv})^2} = \frac{1}{(1.165)^2} = .737 = Z$$

Enter on Line 1, Column 7.

10. Determine value of TZ.

$$540 \times .737 = 397.98 = TZ$$

Enter on Line 1, Column 8.

11. Determine value of $\frac{TZ}{P_n}$

$$\frac{397.98}{1350} = .29480 = \frac{TZ}{P_n}$$

Enter on Line 1, Column 9.

12. H is the length of the static gas column being evaluated in each step of the calculation (see page 33.)

Enter H (Total Depth) for which pressure is being determined on Line 2, Column 1.

$$H = 4800 \text{ ft.}$$

13. Determine value of .0375 GH

$$.0375 \times .725 \times 4800 = 130.497$$

Enter on Line 2, Column 14.

14. Determine first trial value of weight of gas column (0-4800 ft.)

$$\frac{\frac{1}{2}(.0375\ GH)}{\frac{TZ}{P_n}} = \frac{\frac{1}{2}(130.479)}{.29480} = 221.3$$

where:

$$H = 4800 \text{ ft.}$$

$$\frac{TZ}{P_n} = \frac{TZ}{P_n} \text{ where } H = 0 \text{ ft.}$$

Enter on Line 2, Column 10.

15. Determine first trial value P_n of pressure at total depth. (4800 ft.)

$$1350 + 221.3 = 1571.3 \text{ psia} = P_n$$

Enter on Line 2, Column 2.

16. Determine absolute bottom hole temperature (T)

$$128^oF + 460\ ^oR = 588\ ^oR. = T$$

Enter on Line 2, Column 4.

17. Determine values of P_r, T_r, F_{pv}, Z, TZ, and $\frac{TZ}{P_n}$ as shown in steps 5, 7, 8, 9, 10 and 11.

$$P_r = 2.35;\ T_r = 1.48;\ F_{pv} = 1.124;\ Z = .792;$$

$$TZ = 465.696; \text{ and } \frac{TZ}{P_n} \text{ or } I = .296376$$

Enter on Line 2, Columns 3, 5, 6, 7, 8, and 9 respectively.

18. Determine value of N.

I where H = 0 ft. + Trial I where H = 4800 ft. =

Trial N where H = 4800 ft.

.294800 + .296376 = .591176 = N

Enter on Line 2, Column 11.

19. Determine value of M x N where H = 4800 ft.

221.3 x .591176 = 130.827

Enter on Line 2, Column 12 and 13.

When Column 13 is equal to Column 14 then the proper value of M, where H = 4800 ft., has been determined. A check should be made by dividing Column 14 by Column 11 as follows:

$$\frac{.0375\ GH}{N} = \frac{130.497}{.591176} = 220.7$$

Since the check value of M (220.7) is only .4 psia more than the first trial value of M (221.3 psia) we shall consider the check value of 220.7 to be correct.

Since the check value of M is considered correct it follows that the value of P_f is:

$$P_f = P_c + \frac{.0375\ GH}{N}$$

where:

P_f = Bottom Hole Pressure psia

P_c = Wellhead shut-in pressure, psia

G = Specific gravity of the gas (Air = 1.0)

H = Total length of gas column

and

$$P_f = 1350 + \frac{130.497}{.591176}$$

$$P_f = 1350 + 220.7$$

$$P_f = 1571 \text{ psia}$$

If the check value of M had been different than trial value of M by more than 1 psia we would have entered this value on Line 3, Column 10 and repeated steps 15 through 19 until Column 13 was as close to column 14 as possible.

CALCULATION SHEET FOR STATIC COLUMN PRESSURES

COMPANY________ LEASE________ WELL NO.________ DATE________

G= .725 %CO_2= 0 %N= 0 Cr. Pressure (P_{cr})= 668 Cr. Temp. (T_{cr})= 398 .0375G = .027187

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		P_r		T_r		Z		I	M	N			
H	P_n	$\frac{P_n}{P_{cr}}$	T	$\frac{T}{T_{cr}}$	F_{pv}	$\frac{1}{(F_{pv})^2}$	TZ	$\frac{TZ}{P_n}$	$P_n P_{n-1}$	$I_n - I_{n-1}$	M x N	Σ(MxN)	.0375GH
						CASE I							
0	1350	2.02	540	1.36	1.165	.737	397.98	.294800				0	0
4800	1571.3	2.35	588	1.48	1.124	.792	465.696	.296376	221.3	.591176	130.827	130.827	130.497
	1671								221				
						CASE II							
6000	1955	2.93	600	1.51	1.128	.786	471.600	.241227				163.122	163.122
0	1616.9	2.42	540	1.36	1.195	.700	378.0	.233780	338.1	.475007	160.509	2.523	0
0	1611.6	"	"	"	"	"	"	.234570	343.4	.475707	163.388	+ .266	0
	1612								343				

EXAMPLE NO. 7

DETERMINING THE ADJUSTED WELLHEAD SHUT-IN PRESSURE ON GAS WELLS, WITH LIQUID COLUMNS IN WELLBORE, UNDER STATIC CONDITIONS.

In some cases the observed wellhead shut-in pressures of a gas well is effected by accumulated liquids in the wellbore and will not reflect the true conditions of the well. When the height of liquid column and specific gravity of the liquids are known, the formation (Bottom Hole) pressure may be determined by calculating the pressure at the gas-liquid interface as explained in Example No. 6 and adding to this figure the weight of the liquid column above the desired datum plane.

When it is necessary to determine the wellhead pressure which would exist if the liquid column were not present, the formation pressure determined as explained above may be used to calculate an adjusted wellhead pressure based on the assumption that no liquid column exists.

Observed data:

H = 6000 ft. (Length of wellbore to datum point. Datum point used shall be that determined by the Commission).

G_1 = .725 (Gravity of Gas, Air = 1.00)

G_2 = .7389 (Specific gravity of liquids, water = 1.00, 60°API, Table IX, page 52.)

h 1200 ft. (Length of the liquid column above the datum)

Wellhead Temperature = 540°R.

Formation Temperature = 600°R.

1 ft. column of water = .4333 psia

Weight of liquid column above datum expressed as psia.

$$psia = h \times G_2 \times .4333$$

$$psia = 1200 \times .7389 \times .4333 = 384.2$$

Pressure at Gas-Liquid Interface as determined in Example No. 6 =	1571 psia
Pressure of Liquid Column =	384 psia
Formation pressure (P_f @ 6000 ft.)	1955 "

Since we desire the adjusted wellhead pressure and we now have the formation pressure at the well's datum point we must calculate the pressure due to the weight of column of gas by beginning with datum point conditions.

Using the "Calculation sheet for Static Column Pressures" shown with Example No. 6, Case II.

1. The values of G, P_{cr} and T_{cr} will be the same as shown for Case I, Example No. 6.

2. Enter length of column (H), formation pressure (P_n) and absolute formation temperature (T) on Line 3, Columns 1, 2 and 4, respectively.

3. Determine P_r, T_r, F_{pv}, Z, TZ and $\frac{TZ}{P_n}$ or I

   and enter on Line 3, Columns 3, 5, 6, 7, 8 and 9 respectively.

$$P_r = \frac{P_n}{P_{cr}} = \frac{1955}{668} = 2.93$$

$$T_r = \frac{T}{T_{cr}} = \frac{600}{398} = 1.51$$

$$F_{pv} = 1.128 \text{ (CNGA TS-461, Table V)}$$

$$Z = \frac{1}{(F_{pv})^2} = \frac{1}{1.272} = .786$$

$$TZ = 600 \times .786 = 471.600$$

$$\frac{TZ}{P_n} = \frac{471.600}{1955} = .241227$$

4. Determine value of .0375 GH where H = 6000 ft.

$$.0375 \times .725 \times 6000 = 163.122$$

   Enter on Line 3, Column 13 and 14.

5. Enter (H) where H = 0 (wellhead) on Line 4, Column 1.

6. Enter value of .0375 GH where H = 0 on Line 4, Column 14.

$$.0375 \text{ GH} = 0$$

7. Determine the first trial value of the weight of the column from 6000 to wellhead.

$$\frac{\frac{1}{2}\,(.0375\text{ GH})}{\frac{TZ}{P_n}} = \frac{\frac{1}{2}\,(163.122)}{.241227} = 338.1$$

Where:

$H = 6000$ ft. and $\frac{TZ}{P_n} = \frac{TZ}{P_n}$ where $H = 6000$ ft.

Enter on Line 4, Column 10.

8. Determine first trial value of the pressure at the wellhead.

P_n (where H = 6000 ft.) - Trial M (where H = 0) =

Trial P_n (where H = 0)

1955 - 338.1 = 1616.9 psia.

Enter on Line 4, Column 2.

9. Enter absolute wellhead temperature (T) on Line 4, Column 4.

$T = 540^{\circ}R.$

10. Determine values of P_r, T_r, F_{pv}, Z, TZ and $\frac{TZ}{P_n}$ and enter on Line 4, Columns 3, 5, 6, 7, 8 and 9.

$P_r = 2.42$; $T_r = 1.36$; $F_{pv} = 1.195$; $Z = .700$;

$TZ = 378.0$; $\frac{TZ}{P_n}$ or $I = .233780$

11. Determine Trial N where H = 0.

I where H = 6000 ft. + I where H = 0 =

Trial N where H = 0 ft.

.241227 + .233780 = .475007

Enter on Line 4, Column 11.

12. Determine trial value of M x N where H = 0 ft.

M x N = 338.1 x .475007 = 160.599

Enter on Line 4, Column 12.

13. Determine trial value of Σ(M x N) where H = 0

Trial Σ(M x N) where H = 6000 - Trial M x N where H = 0 = Trial Σ(M x N) where H = 0.

163.122 - 160.599 = 2.523

Enter on Line 4, Column 13.

When Column 13 is equal to Column 14 the proper value of M, where H = 0, has been determined. A check should be made by determining again the weight of the column of gas as follows:

$$\frac{(M \times N) \text{ where } H = 6000}{\text{Trial } (N) \text{ where } H = 0} = \text{check value of M where } H = 0.$$

$$\frac{163.122}{.475007} = 343.4$$

Since this check value is 5.3 psia higher than the first trial value of M we must enter this value on Line 5, Column 10 and repeat steps 8, 9. $\frac{TZ}{P_n}$ part of 10, 11, 12 and 13.

then:

$$P_n = 1611.6; \ \frac{TZ}{P_n} = .234570; \ N = .475797;$$

$$M \times N = 163.388; \ \sum(M \times N) = -.266$$

and

$$\text{Check value of } M = 342.8$$

Since the check value of M is only .6 psia lower than the second trial value of 343.4 the check value of 343 psia is considered correct. Also the adjusted wellhead pressure is:

$$1955 - 343 = 1612 \text{ psia}$$

TABLE I

NEW MEXICO OIL CONSERVATION COMMISSION

BASIC ORIFICE FACTORS - MCF 24/ HOURS F_b

FLANGE TAPS

Base Temperature	60^oF	Base Flowing Temp. 60^oF.
Base Pressure	15.025 Psia	Specific Gravity .600

Pipe Sizes - Nominal and Actual Diameters

Orifice Diameter Inches	2" Std. 2.067	3" Std. 3.068	4" Std. 4.026	6" Std. 6.065
.250	.3860	.3858	.3852	- - -
.375	.8634	.8618	.8607	- - -
.500	1.535	1.528	1.525	1.524
.625	2.409	2.388	2.382	2.378
.750	3.497	3.449	3.435	3.424
.875	4.814	4.713	4.686	4.664
1.000	6.386	6.182	6.135	6.100
1.125	8.253	7.868	7.786	7.732
1.250	10.48	9.781	9.643	9.559
1.375	13.16	11.94	11.71	11.58
1.500	16.47	14.36	13.99	13.80
1.625- - -	- - - - - - -	- 17.08	16.51	16.23
1.750- - -	- - - - - - -	- 20.15	19.27	18.86
1.875- - -	- - - - - - -	- 23.60	22.28	21.69
2.000- - -	- - - - - - -	- 27.52	25.58	24.74
2.125- - -	- - - - - - -	- 31.97	29.17	27.99
2.250- - -	- - - - - - -	- 37.15	33.10	31.47
2.375- - -	- - - - - - -	- - - - - - -	- 37.41	35.18
2.500- - -	- - - - - - -	- - - - - - -	- 42.13	39.13
2.625- - -	- - - - - - -	- - - - - - -	- 47.33	43.31
2.750- - -	- - - - - - -	- - - - - - -	- 53.05	47.75
2.875- - -	- - - - - - -	- - - - - - -	- 59.39	52.47
3.000- - -	- - - - - - -	- - - - - - -	- 66.67	57.46
3.125- - -	- - - - - - -	- - - - - - -	- - - - - - -	- - 62.75
3.250- - -	- - - - - - -	- - - - - - -	- - - - - - -	- - 68.36
3.375- - -	- - - - - - -	- - - - - - -	- - - - - - -	- - 74.32
3.500- - -	- - - - - - -	- - - - - - -	- - - - - - -	- - 80.64
3.625- - -	- - - - - - -	- - - - - - -	- - - - - - -	- - 87.35
3.750- - -	- - - - - - -	- - - - - - -	- - - - - - -	- - 94.50
3.875- - -	- - - - - - -	- - - - - - -	- - - - - - -	- 102.1

TABLE II

NEW MEXICO OIL CONSERVATION COMMISSION

BASIC ORIFICE FACTORS - MCF 24/HOURS - F_b

PIPE TAPS

Base Temperature 60°F
Base Pressure 15.025 psia

Base Flowing Temp. 60°F
Specific Gravity .600

Pipe Sizes - Nominal and Actual Diameters

Orifice Diameter Inches	2" Std. 2.067	3" Std. 3.068	4" Std. 4.026	6" Std. 6.065
.250	.3887	.3872	.3864	---
.375	.8810	.8712	.8682	---
.500	1.594	1.557	1.546	1.538
.625	2.554	2.455	2.425	2.405
.750	3.797	3.584	3.515	3.469
.875	5.379	4.961	4.828	4.735
1.000	7.390	6.607	6.375	6.209
1.125	9.963	8.556	8.174	7.897
1.250	13.30	10.85	10.24	9.807
1.375	17.74	13.54	12.59	11.94
1.500		16.70	15.26	14.32
1.625		20.44	18.28	16.95
1.750		24.88	21.69	19.84
1.875		30.19	25.55	23.00
2.000		36.62	29.92	26.45
2.125		44.50	34.88	30.21
2.250			40.53	34.29
2.375			47.00	38.72
2.500			54.44	43.52
2.625			63.05	48.73
2.750			73.11	54.38
2.875				60.51
3.000				67.17
3.125				74.42
3.250				82.31
3.375				90.92
3.500				100.33
3.675				110.63
3.750				121.95
3.875				134.41

TABLE III

CRITICAL FLOW COEFFICIENTS FOR TWO AND FOUR INCH CRITICAL FLOW PROVERS

MCF Per day; Pressure Base: 15.025 psia; Specific Gravity: 0.60; Base and Flowing Temperature: 60 Degrees Fahrenheit.

TWO INCH PROVER		FOUR INCH PROVER	
Orifice Dia., Inches	Coefficient	Orifice Dia, Inches	Coefficients
1/16	.0827	1/4	1.352
3/32	.1820		
1/8	.3418	3/8	3.039
3/16	.7851		
7/32	1.0834		
1/4	1.4030	1/2	5.436
3/16	2.1577	5/8	8.469
3/8	3.0691	3/4	12.137
7/16	4.3997	7/8	16.504
1/2	5.5233	1	21.501
5/8	8.3555	1 1/8	27.085
3/4	12.2023	1 1/4	33.444
7/8	16.7816	1 3/8	40.264
1	22.0662	1 1/2	47.979
1 1/8	28.2569	1 3/4	65.542
1 1/4	35.6738	2	86.594
1 3/8	43.8286	2 1/4	111.009
1 1/2	54.3653	2 1/2	139.223
		2 3/4	172.374
		3	211.818

TABLE IV

SIX INCH POSITIVE CHOKE NIPPLE COEFFICIENTS

MCF/da./ Psia: Pressure Base: 15.025; Specific Gravity: .60;
Base and Flowing Temperature: 60° Fahrenhiet.

Nominal Choke Size. Inches	Inside Diameter inches	Coefficient (1)	Coefficient (2)
1/8	.1250	.3261	.3393
9/64	.1406	.4140	.4329
5/32	.1563	.5133	.5392
11/64	.1719	.6224	.6572
3/16	.1875	.7425	.7839
13/64	.2031	.8731	.9321
7/32	.2188	1.0155	1.0881
15/64	.2344	1.1678	1.2558
1/4	.2500	1.3309	1.4382
17/64	.2656	1.5049	1.6254
9/32	.2813	1.6907	1.8379
19/64	.2969	1.8865	2.0573
5/16	.3125	2.0930	2.3674
21/64	.3281	2.3105	2.5361
11/32	.3438	2.5404	2.7945
23/64	.3594	2.7796	3.0655
3/8	.3750	3.0300	3.3210
25/64	.3906	3.2911	3.6467
13/32	.4063	3.5650	3.9616
27/64	.4219	3.8481	4.2843
7/16	.4531	4.1423	4.6188
29/64	.4531	4.4476	4.9737
15/32	.4688	4.7659	5.3374
31/64	.4844	5.0931	5.7157
1/2	.5000	5.4315	6.1155
9/16	.5625	6.8979	7.8101
5/8	.6250	8.5417	9.7524
11/16	.6875	10.3640	11.8721
3/4	.7500	12.3650	14.1605

(1) For standard six inch Thornhill-Craver positive flow-beans. Calculated from test data of Texas College of Arts and Industries.

(2) Calculated from data appearing in United States Bureau of Mines Monograph 7, for choke nipples as illustrated below.

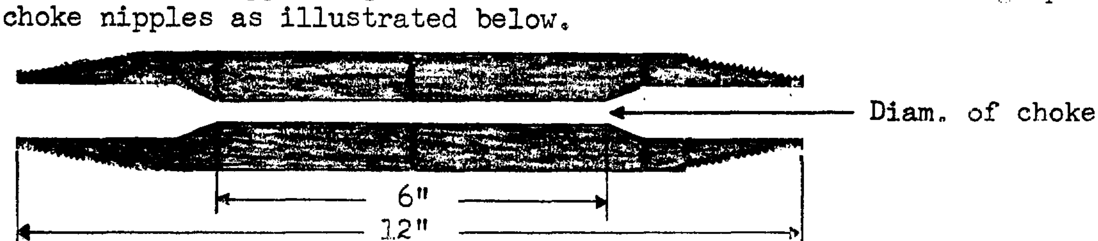


TABLE V

FLOWING TEMPERATURE FACTORS

$$\text{Factor} = \frac{520}{460^{\circ} + T}$$

°F	Factor	°F	Factor	°F	Factor	°F	Factor	°F	Factor	°F	Factor
0	1.0632	35	1.0249	70	0.9905	105	0.9592	140	0.9309	175	0.9048
1	1.0620	36	1.0239	71	0.9896	106	0.9585	141	0.9301	176	0.9042
2	1.0609	37	1.0229	72	0.9887	107	0.9576	142	0.9293	177	0.9035
3	1.0598	38	1.0219	73	0.9877	108	0.9568	143	0.9284	178	0.9028
4	1.0586	39	1.0208	74	0.9868	109	0.9559	144	0.9279	179	0.9020
5	1.0574	40	1.0198	75	0.9859	110	0.9551	145	0.9271	180	0.9014
6	1.0563	41	1.0188	76	0.9850	111	0.9543	146	0.9263	181	0.9007
7	1.0552	42	1.0178	77	0.9840	112	0.9534	147	0.9255	182	0.9000
8	1.0540	43	1.0168	78	0.9831	113	0.9526	148	0.9247	183	0.8992
9	1.0529	44	1.0157	79	0.9822	114	0.9518	149	0.9240	184	0.8985
10	1.0518	45	1.0147	80	0.9813	115	0.9510	150	0.9233	185	0.8979
11	1.0507	46	1.0137	81	0.9804	116	0.9501	151	0.9225	186	0.8972
12	1.0496	47	1.0127	82	0.9795	117	0.9493	152	0.9217	187	0.8965
13	1.0485	48	1.0117	83	0.9786	118	0.9485	153	0.9210	188	0.8958
14	1.0474	49	1.0107	84	0.9777	119	0.9477	154	0.9202	189	0.8951
15	1.0463	50	1.0098	85	0.9768	120	0.9469	155	0.9195	190	0.8944
16	1.0452	51	1.0088	86	0.9759	121	0.9460	156	0.9187	191	0.8937
17	1.0441	52	1.0078	87	0.9750	122	0.9452	157	0.9180	192	0.8931
18	1.0430	53	1.0068	88	0.9741	123	0.9444	158	0.9173	193	0.8923
19	1.0419	54	1.0058	89	0.9732	124	0.9436	159	0.9165	194	0.8916
20	1.0408	55	1.0048	90	0.9723	125	0.9428	160	0.9158	195	0.8910
21	1.0398	56	1.0039	91	0.9715	126	0.9420	161	0.9150	196	0.8903
22	1.0387	57	1.0029	92	0.9706	127	0.9412	162	0.9143	197	0.8896
23	1.0376	58	1.0019	93	0.9697	128	0.9404	163	0.9135	198	0.8889
24	1.0365	59	1.0010	94	0.9688	129	0.9396	164	0.9128	199	0.8882
25	1.0355	60	1.0000	95	0.9680	130	0.9388	165	0.9121		
26	1.0344	61	0.9990	96	0.9671	131	0.9380	166	0.9112		
27	1.0333	62	0.9981	97	0.9662	132	0.9372	167	0.9106		
28	1.0323	63	0.9971	98	0.9653	133	0.9364	168	0.9099		
29	1.0312	64	0.9962	99	0.9645	134	0.9356	169	0.9092		
30	1.0302	65	0.9952	100	0.9636	135	0.9348	170	0.9085		
31	1.0291	66	9.9943	101	0.9627	136	0.9341	171	0.9077		
32	1.0281	67	0.9933	102	0.9618	137	0.9333	172	0.9069		
33	1.0270	68	0.9924	103	0.9610	138	0.9325	173	0.9063		
34	1.0260	69	0.9915	104	0.9602	139	0.9317	174	0.9055		

TABLE VI

SPECIFIC GRAVITY FACTORS

$$\text{Factor} = \frac{0.60}{\text{Sp. Gr.}}$$

Sp. Gr.	Factor	Sp. Gr.	Factor	Sp. Gr.	Factor
0.500	1.0954	0.650	0.9608	0.800	0.8660
0.505	1.0900	0.655	0.9571	0.805	0.8635
0.510	1.0847	0.660	0.9535	0.810	0.8607
0.515	1.0794	0.665	0.9498	0.815	0.8580
0.520	1.0742	0.670	0.9463	0.820	0.8554
0.525	1.0690	0.675	0.9427	0.825	0.8528
0.530	1.0640	0.680	0.9393	0.830	0.8502
0.535	1.0590	0.685	0.9359	0.835	0.8476
0.540	1.0541	0.690	0.9325	0.840	0.8452
0.545	1.0492	0.695	0.9292	0.860	0.8353
0.550	1.0445	0.700	0.9258	0.880	0.8257
0.555	1.0398	0.705	0.9225	0.900	0.8165
0.560	1.0351	0.710	0.9193	0.920	0.8076
0.565	1.0304	0.715	0.9161	0.940	0.7989
0.570	1.0260	0.720	0.9129	0.960	0.7906
0.575	1.0215	0.725	0.9097	0.980	0.7825
0.580	1.0171	0.730	0.9066	1.000	0.7746
0.585	1.0127	0.735	0.9035	1.020	0.7669
0.590	1.0084	0.740	0.9005	1.040	0.7595
0.595	1.0041	0.745	0.8974	1.060	0.7523
0.600	1.0000	0.750	0.8944	1.080	0.7453
0.605	0.9958	0.755	0.8914	1.100	0.7385
0.610	0.9918	0.760	0.8885	1.120	0.7319
0.615	0.9877	0.765	0.8856	1.140	0.7255
0.620	0.9837	0.770	0.8827	1.160	0.7192
0.625	0.9798	0.775	0.8793	1.180	0.7131
0.630	0.9759	0.780	0.8771	1.200	0.7071
0.635	0.9721	0.785	0.8743	1.220	0.7013
0.640	0.9682	0.790	0.8715	1.240	0.6956
0.645	0.9645	0.795	0.8687	1.260	0.6901

TABLE VII A
(SOUTHEASTERN NEW MEXICO)

Values of F_c for Various Tubing Sizes

(Use only for internal diameters less than 4.277 in.)

Note: $$F_c = \frac{0.10797}{d^{2.612}} \quad \frac{P_b}{14.65} \quad (T) \quad (Z)$$

Values shown based on P_b = 15.025

T = 545

Z = 1.00

Nominal Size, In.	O.D. In.	#/Ft.	I.D. In.	F_c
1	1.315	1.80	1.049	53.26
1 1/4	1.660	2.40	1.380	26.02
1 1/2	1.990	2.75	1.610	17.40
2	2.375	4.70	1.995	9.936
2 1/2	2.875	6.50	2.441	5.866
	3.500	9.30	2.992	3.447
	4.000	11.00	3.476	2.330
	4.500	12.70	3.958	1.660
	4.750	16.25	4.082	1.532
	4.750	18.00	4.000	1.615
	5.000	18.00	4.276	1.357
	5.000	21.00	4.154	1.463

TABLE VII B
(SOUTHEASTERN NEW MEXICO)

Values of F_c for Various Casing Sizes

(Use only for internal diameters greater than 4.277 in.)

Note: $$F_c = \left(\frac{0.10337}{d^{2.582}}\right) \left(\frac{P_b}{14.65}\right) (T) \quad (Z)$$

Values shown based on P_b = 15.025
T = 545
Z = 1.00

O.D. In.	#/Ft.	I.D. In.	F_c
5.000	13.00	4.494	1.193
5.000	15.00	4.408	1.254
5.500	14.00	5.012	0.9002
5.500	15.00	4.976	0.9171
5.500	17.00	4.892	0.9583
5.500	20.00	4.778	1.018
5.500	23.00	4.670	1.080
5.500	25.00	4.580	1.136
6.000	15.00	5.524	0.7003
6.000	17.00	5.450	0.7251
6.000	20.00	5.352	0.7599
6.000	23.00	5.240	0.8025
6.000	26.00	5.140	0.8435
6.625	20.00	6.049	0.5539
6.625	22.00	5.989	0.5684
6.625	24.00	5.921	0.5854
6.625	26.00	5.855	0.6026
6.625	28.00	5.791	0.6199
6.625	31.80	5.675	0.6532
6.625	34.00	5.595	0.6776
7.000	20.00	6.456	0.4682
7.000	22.00	6.398	0.4792
7.000	24.00	6.336	0.4915
7.000	26.00	6.276	0.5037
7.000	28.00	6.214	0.5168
7.000	30.00	6.154	0.5299
7.000	40.00	5.836	0.6076
7.625	26.40	6.969	0.3843
7.625	29.70	6.875	0.3980
7.625	33.70	6.765	0.4150
7.625	38.70	6.625	0.4380
7.625	45.00	6.445	0.4703
8.000	26.00	7.336	0.3308
8.125	28.00	7.485	0.3196
8.125	32.00	7.385	0.3309

TABLE VII B (continued)
(SOUTHEASTERN NEW MEXICO)

Values of F_c for Various Casing Sizes

O.D. IN.	#/FT.	I.D. In.	F_c
8.125	35.50	7.285	0.3427
8.125	39.50	7.185	0.3552
8.625	17.50	8.249	0.2487
8.625	20.00	8.191	0.2532
8.625	24.00	8.097	0.2609
8.625	28.00	8.003	0.2689
8.625	32.00	7.907	0.2774
8.625	36.00	7.825	0.2850
8.625	38.00	7.775	0.2897
8.625	43.00	7.651	0.3020
9.000	34.00	8.290	0.2455
9.000	38.00	8.196	0.2528
9.000	40.00	8.150	0.2565
9.000	45.00	8.032	0.2664
9.625	36.00	8.921	0.2031
9.625	40.00	8.835	0.2083
9.625	43.50	8.755	0.2132
9.625	47.00	8.681	0.2180
9.625	53.50	8.535	0.2277
9.625	58.00	8.435	0.2348
10.000	33.00	9.384	0.2329
10.000	55.50	8.908	0.2039
10.000	61.20	8.790	0.2111
10.750	32.75	10.192	0.1440
10.750	35.75	10.136	0.1461
10.750	40.00	10.050	0.1493
10.750	45.50	9.950	0.1532
10.750	48.00	9.902	0.1552
10.750	54.00	9.784	0.1600

TABLE VII C
(SOUTHEASTERN NEW MEXICO)

Values of F_c for various casing-tubing combinations. (Annular Flow)

CASING			TUBING			
O.D. In.	I.D. In.	#/Ft.	O.D. In.	I.D. In.	#/Ft.	F_c
7.625	6.625	39	2.375	1.995	4.7	.651
7.000	6.366	23	2.375	1.995	4.7	.740
7.000	6.276	26	2.375	1.995	4.7	.744
7.000	6.366	23	2.875	2.441	6.5	.865
6.625	6.049	20	2.375	1.995	4.7	.875
7.000	6.276	26	2.875	2.441	6.5	.910
6.625	6.049	20	2.875	2.441	6.5	1.041
6.625	5.921	24	3.500	2.992	9.3	1.540
5.500	4.892	17	2.375	1.995	4.7	1.812
5.500	4.892	17	3.000			2.735
5.500	4.976	15.5	2.375	1.995	4.7	1.758
5.500	5.012	14.0	2.375	1.995	4.7	1.712
6.625	6.049	20.0	4.000	3.476	11.0	1.889
6.625	6.049	20.0	3.500	2.992	9.3	1.399
5.500	4.950	15.5	2.375	1.995	4.7	1.793
7.000	6.456	20.0	2.375	1.995	4.7	0.707
5.5	4.892	17.0	2.875	2.441	6.5	2.507
5.0	4.408	15.0	2.375	1.995	4.7	2.834
5.50	4.892	17.0	3.500	2.992	9.3	4.220
4.50	4.090	9.5	2.375	1.995	4.7	3.912

Formula 1.

$$F_c \text{ (for Annulus)} = \left(\frac{\dfrac{0.10797}{1.612}}{(d_1 + d_2)\ (d_1 - d_2)} \right) \left(\frac{P_b}{14.65} \right) (T) \quad (Z)$$

d_1 = I.D. of casing-in.
d_2 = O.D. of tubing-in.

Formula 2.

$$F_c \text{ (for Annulus)} = \left(\frac{\dfrac{0.10337}{1.582}}{(d_1 + d_2)\ (d_1 - d_2)} \right) \left(\frac{P_b}{14.65} \right) (T) \ (Z)$$

d_1 = I.D. of casing-in.
d_2 = O.D. of tubing-in.

NOTE: When calculating F_c factors for d_1, d_2, T, or Z values not listed in these tables use above formula 1, for annular flow. If the answer is less than 1.357 then the above formula 2 for annular flow is the proper formula to use to calculate F_c.

TABLE VIII
(SOUTHEASTERN NEW MEXICO)

Values of $(1-e^{-s})$ for Various Vaules of GL

Note: $S = \frac{0.0375 \ GL}{TZ}$

Values shown based on T = 545
Z = 1.00

From	To	$(1-e^{-s})$	From	To	$(1-e^{-s})$
1000	1015	0.067	1559	1571	0.102
1016	1031	0.068	1572	1587	0.103
1032	1046	0.069	1588	1604	0.104
1047	1062	0.070	1605	1620	0.105
1063	1078	0.071	1621	1636	0.106
1079	1093	0.072	1637	1653	0.107
1094	1109	0.073	1654	1669	0.108
1110	1124	0.074	1670	1684	0.109
1125	1141	0.075	1685	1700	0.110
1142	1156	0.076	1701	1716	0.111
1157	1172	0.077	1717	1734	0.112
1173	1188	0.078	1735	1751	0.113
1189	1203	0.079	1752	1767	0.114
1204	1218	0.080	1768	1783	0.115
1219	1235	0.081	1784	1800	0.116
1236	1251	0.082	1801	1816	0.117
1252	1267	0.083	1817	1832	0.118
1268	1283	0.084	1833	1849	0.119
1284	1298	0.085	1850	1876	0.120
1299	1314	0.086	1877	1882	0.121
1315	1329	0.087	1883	1899	0.122
1330	1346	0.088	1900	1915	0.123
1347	1362	0.089	1916	1932	0.124
1363	1378	0.090	1933	1949	0.125
1379	1394	0.091	1950	1965	0.126
1395	1410	0.092	1966	1982	0.127
1411	1426	0.093	1983	1998	0.128
1427	1441	0.094	1999	2015	0.129
1442	1458	0.095	2016	2032	0.130
1459	1474	0.096	2033	2049	0.131
1475	1490	0.097	2050	2065	0.132
1491	1507	0.098	2066	2082	0.133
1508	1523	0.099	2083	2099	0.134
1524	1539	0.100	2100	2116	0.135
1540	1558	0.101	2117	2132	0.136

Values of $(1-e^{-s})$ for Various Values of GL

GL From	GL To	$(1-e^{-s})$	GL From	GL To	$(1-e^{-s})$
2133	2149	0.137	2876	2893	0.180
2150	2166	0.138	2894	2910	0.180
2167	2183	0.139	2911	2928	0.182
2184	2200	0.140	2929	2946	0.183
2201	2217	0.141	2947	2964	0.184
2218	2234	0.142	2965	2982	0.185
2235	2251	0.143	2983	2999	0.186
2252	2268	0.144	3000	3017	0.187
2269	2285	0.145	3018	3035	0.188
2286	2302	0.146	3036	3053	0.189
2303	2319	0.147	3054	3071	0.190
2320	2336	0.148	3072	3089	0.191
2337	2353	0.149	3090	3107	0.192
2354	2370	0.150	3108	3125	0.193
2371	2387	0.151	3126	3144	0.194
2388	2404	0.152	3145	3161	0.195
2405	2422	0.153	3162	3179	0.196
2423	2439	0.154	3180	3197	0.197
2440	2456	0.155	3198	3215	0.198
2457	2473	0.156	3216	3234	0.199
2474	2490	0.157	3235	3252	0.200
2491	2508	0.158	3253	3270	0.201
2509	2525	0.159	3271	3288	0.202
2526	2542	0.160	3289	3306	0.203
2543	2560	0.161	3307	3325	0.204
2561	2577	0.162	3326	3343	0.205
2578	2594	0.163	3344	3361	0.206
2595	2611	0.164	3362	3379	0.207
2612	2629	0.165	3380	3398	0.208
2630	2646	0.166	3399	3416	0.209
2647	2664	0.167	3417	3435	0.210
2665	2681	0.168	3436	3453	0.211
2682	2699	0.169	3454	3471	0.212
2700	2716	0.170	3472	3490	0.213
2717	2734	0.171	3491	3507	0.214
2735	2751	0.172	3508	3526	0.215
2752	2769	0.173	3527	3545	0.216
2770	2787	0.174	3546	3564	0.217
2788	2804	0.175	3565	3582	0.218
2805	2822	0.176	3583	3601	0.219
2823	2840	0.177	3602	3620	0.220
2841	2857	0.178	3621	3638	0.221
2858	2875	0.179	3639	3657	0.222

Values of $(1-e^{-s})$ for Various Values of GL

GL			GL		
From	To	$(1-e^{-s})$	From	To	$(1-e^{-s})$
3658	3676	0.223	4505	4524	0.267
3677	3695	0.224	4525	4544	0.268
3696	3713	0.225	4545	4563	0.269
3714	3732	0.226	4564	4583	0.270
3733	3751	0.227	4584	4603	0.271
3752	3770	0.228	4604	4623	0.272
3771	3789	0.229	4624	4643	0.273
3790	3807	0.230	4644	4663	0.274
3808	3826	0.231	4664	4683	0.275
3827	3845	0.232	4684	4703	0.276
3846	3864	0.233	4704	4723	0.277
3865	3883	0.234	4724	4743	0.278
3884	3902	0.235	4744	4764	0.279
3903	3921	0.236	4765	4784	0.280
3922	3940	0.237	4785	4804	0.281
3941	3960	0.238	4805	4824	0.282
3961	3979	0.239	4825	4845	0.283
3980	3998	0.240	4846	4865	0.284
3999	4017	0.241	4866	4885	0.285
4018	4036	0.242	4886	4906	0.286
4037	4055	0.243	4907	4926	0.287
4056	4074	0.244	4927	4946	0.288
4075	4094	0.245	4947	4967	0.289
4095	4113	0.246	4968	4987	0.290
4114	4132	0.247	4988	5008	0.291
4133	4151	0.248	5009	5028	0.292
4152	4171	0.249	5029	5049	0.293
4172	4190	0.250	5050	5070	0.294
4191	4210	0.251	5071	5090	0.295
4211	4229	0.252	5091	5111	0.296
4230	4249	0.253	5112	5131	0.297
4250	4268	0.254	5132	5152	0.298
4269	4288	0.255	5153	5173	0.299
4289	4307	0.256	5174	5194	0.300
4308	4327	0.257	5195	5214	0.301
4328	4346	0.258	5215	5235	0.302
4347	4366	0.259	5236	5256	0.303
4367	4386	0.260	5257	5277	0.304
4387	4405	0.261	5278	5298	0.305
4406	4425	0.262	5299	5319	0.306
4426	4444	0.263	5320	5340	0.307
4445	4464	0.264	5341	5361	0.308
4465	4484	0.265	5362	5382	0.309
4485	4504	0.266	5383	5403	0.310

Values of $(1-e^{-s})$ for Various Values of GL

GL From	GL To	$(1-e^{-s})$	GL From	GL To	$(1-e^{-s})$
5404	5424	0.311	5832	5852	0.331
5425	5445	0.312	5853	5874	0.331
5446	5466	0.313	5875	5896	0.333
5467	5488	0.314	5897	5918	0.334
5489	5509	0.315	5919	5940	0.335
5510	5530	0.316	5941	5962	0.336
5531	5551	0.317	5963	5984	0.337
5552	5573	0.318	5985	6005	0.338
5574	5594	0.319	6006	6028	0.339
5595	5615	0.320	6029	6049	0.340
5616	5637	0.321	6050	6071	0.341
5638	5658	0.322	6072	6093	0.342
5659	5679	0.323	6094	6116	0.343
5680	5701	0.324	6117	6138	0.344
5702	5723	0.325	6139	6160	0.345
5724	5744	0.326	6161	6182	0.346
5745	5766	0.327	6183	6205	0.347
5767	5787	0.328	6206	6227	0.348
5788	5809	0.329	6228	6249	0.349
5810	5831	0.330	6250	6272	0.350

TABLE IX

CONVERSION OF °A. P. I. TO SPECIFIC GRAVITY

Degrees API at 60°F	Specific Gravity	Degrees API at 60°F	Specific Gravity	Degrees API at 60°F	Specific Gravity
0	1.076	34	.8550	68	.7093
1	1.068	35	.8498	69	.7057
2	1.060	36	.8448	70	.7022
3	1.052	37	.8398	71	.6988
4	1.044	38	.8348	72	.6953
5	1.037	39	.8299	73	.6919
6	1.029	40	.8251	74	.6886
7	1.022	41	.8203	75	.6852
8	1.014	42	.8155	76	.6819
9	1.007	43	.8109	77	.6787
10	1.000	44	.8063	78	.6754
11	.9930	45	.8017	79	.6722
12	.9861	46	.7972	80	.6690
13	.9792	47	.7927	81	.6659
14	.9725	48	.7883	82	.6628
15	.9659	49	.7839	83	.6597
16	.9593	50	.7796	84	.6566
17	.9529	51	.7753	85	.6536
18	.9465	52	.7711	86	.6506
19	.9402	53	.7669	87	.6476
20	.9340	54	.7628	88	.6446
21	.9279	55	.7587	89	.6417
22	.9218	56	.7547	90	.6388
23	.9159	57	.7507	91	.6360
24	.9100	58	.7467	92	.6331
25	.9042	59	.7428	93	.6303
26	.8984	60	.7389	94	.6275
27	.8927	61	.7351	95	.6247
28	.8871	62	.7313	96	.6220
29	.8816	63	.7275	97	.6193
30	.8762	64	.7238	98	.6166
31	.8708	65	.7201	99	.6139
32	.8654	66	.7165	100	.6112
33	.8602	67	.7128		

$$\text{SP. GR.} = \frac{141.5}{131.5 + {}^{\circ}\text{A. P. I.}}$$

TABLE X

METER FACTORS, M, FOR L-10 CHARTS

Defferential Range of (R_h) Meter, Inches	Maximum Pressure Range of Meter in Pounds absolute; for gas or air at varying pressure (R_s)						
	24.7	50	100	250	500	1000	1500
2 1/2	0.0786						
10	0.1572	0.2236					
20	0.2223	0.3162	0.4472	0.7071	1.0000		
50	0.3514	0.5000	0.7071	1.1180	1.5810	2.2360	2.7390
100		0.7071	1.0000	1.5810	2.2360	3.1620	3.8730

$$M = 0.01 \quad (R_h \times R_s)^{1/2}$$

R_h = is maximum differential range, inches

R_s = is maximum static range, pounds

TABLE OF SQUARE ROOTS

N	$\sqrt{N}$	N	$\sqrt{N}$	N	$\sqrt{N}$	N	$\sqrt{N}$	N	$\sqrt{N}$
		50	7.071	100	10.000	150	12.247	200	14.142
1	1.000	51	7.141	101	10.050	151	12.288	201	14.177
2	1.414	52	7.211	102	10.100	152	12.329	202	14.213
3	1.732	53	7.280	103	10.149	153	12.369	203	14.248
4	2.000	54	7.348	104	10.198	154	12.410	204	14.283
5	2.236	55	7.416	105	10.247	155	12.450	205	14.318
6	2.449	56	7.483	106	10.296	156	12.490	206	14.353
7	2.646	57	7.550	107	10.344	157	12.530	207	14.387
8	2.828	58	7.616	108	10.392	158	12.570	208	14.422
9	3.000	59	7.681	109	10.440	159	12.610	209	14.457
10	3.162	60	7.746	110	10.438	160	12.649	210	14.491
11	3.317	61	7.810	111	10.536	161	12.689	211	14.526
12	3.464	62	7.874	112	10.533	162	12.728	212	14.560
13	3.606	63	7.937	113	10.630	163	12.767	213	14.595
14	3.742	64	8.000	114	10.677	164	12.806	214	14.629
15	3.873	65	8.062	115	10.724	165	12.845	215	14.663
16	4.000	66	8.124	116	10.770	166	12.884	216	14.697
17	4.123	67	8.185	117	10.817	167	12.923	217	14.731
18	4.243	68	8.246	118	10.863	168	12.961	218	14.765
19	4.359	69	8.307	119	10.909	169	13.000	219	14.799
20	4.472	70	8.367	120	10.954	170	13.038	220	14.832
21	4.583	71	8.426	121	11.000	171	13.077	221	14.866
22	4.690	72	8.485	122	11.045	172	13.115	222	14.900
23	4.796	73	8.544	123	11.091	173	13.153	223	14.933
24	4.899	74	8.602	124	11.136	174	13.191	224	14.967
25	5.000	75	8.660	125	11.180	175	13.229	225	15.000
26	5.099	76	8.718	126	11.225	176	13.266	226	15.033
27	5.196	77	8.775	127	11.269	177	13.304	227	15.067
28	5.292	78	8.832	128	11.314	178	13.342	228	15.100
29	5.385	79	8.888	129	11.358	179	13.379	229	15.133
30	5.477	80	8.944	130	11.402	180	13.416	230	15.166
31	5.568	81	9.000.	131	11.446	181	13.454	231	15.199
32	5.657	82	9.055	132	11.439	182	13.491	232	15.232
33	5.745	83	9.110	133	11.533	183	13.528	233	15.264
34	5.831	84	9.165	134	11.576	184	13.565	234	15.297
35	5.916	85	9.220	135	11.619	185	13.601	235	15.330
36	6.000	86	9.274	136	11.662	186	13.638	236	15.362
37	6.083	87	9.327	137	11.705	187	13.675	237	15.395
38	6.164	88	9.381	138	11.747	188	13.711	238	15.427
39	6.245	89	9.434	139	11.790	189	13.748	239	15.460
40	6.325	90	9.487	140	11.832	190	13.784	240	15.492
41	6.403	91	9.539	141	11.874	191	13.820	241	15.524
42	6.481	92	9.592	142	11.916	192	13.856	242	15.556
43	6.557	93	9.644	143	11.958	193	13.892	243	15.588
44	6.633	94	9.695	144	12.000	194	13.928	244	15.620
45	6.708	95	9.747	145	12.042	195	13.964	245	15.652
46	6.782	96	9.798	146	12.083	196	14.000	246	15.684
47	6.856	97	9.849	147	12.124	197	14.036	247	15.716
48	6.928	98	9.899	148	12.166	198	14.071	248	15.748
49	7.000	99	9.950	149	12.207	199	14.107	249	15.780

TABLE OF SQUARE ROOTS

N	√N	N	√N	N	√N	N	√N	N	√N
250	15.811	300	17.321	350	18.708	400	20.000	450	21.213
251	15.843	301	17.349	351	18.735	401	20.025	451	21.237
252	15.875	302	17.378	352	18.762	402	20.050	452	21.260
253	15.906	303	17.407	353	18.788	403	20.075	453	21.284
254	15.937	304	17.436	354	18.815	404	20.100	454	21.307
255	15.969	305	17.464	355	18.841	405	20.125	455	21.331
256	16.000	306	17.493	356	18.868	406	20.149	456	21.354
257	16.031	307	17.521	357	18.894	407	20.174	457	21.378
258	16.062	308	17.550	358	18.921	408	20.199	458	21.401
259	16.093	309	17.578	359	18.947	409	20.224	459	21.424
260	16.125	310	17.607	360	18.974	410	20.248	460	21.448
261	16.155	311	17.635	361	19.000	411	20.273	461	21.471
262	16.186	312	17.664	362	19.026	412	20.298	462	21.494
263	16.217	313	17.692	363	19.053	413	20.322	463	21.517
264	16.248	314	17.720	364	19.079	414	20.347	464	21.541
265	16.279	315	17.748	365	19.105	415	20.372	465	21.564
266	16.310	316	17.776	366	19.131	416	20.396	466	21.587
267	16.340	317	17.804	367	19.157	417	20.421	467	21.610
268	16.371	318	17.833	368	19.183	418	20.445	468	21.633
269	16.401	319	17.861	369	19.209	419	20.469	469	21.656
270	16.432	320	17.889	370	19.235	420	20.494	470	21.679
271	16.462	321	17.916	371	19.261	421	20.518	471	21.703
272	16.492	322	17.944	372	19.287	422	20.543	472	21.726
273	16.523	323	17.972	373	19.313	423	20.567	473	21.749
274	16.553	324	18.000	374	19.339	424	20.591	474	21.772
275	16.583	325	18.028	375	19.365	425	20.616	475	21.794
276	16.613	326	18.055	376	19.391	426	20.640	476	21.817
277	16.643	327	18.083	377	19.416	427	20.664	477	21.840
278	16.673	328	18.111	378	19.442	428	20.688	478	21.863
279	16.703	329	18.138	379	19.468	429	20.712	479	21.886
280	16.733	330		380	19.494	430	20.736	480	21.909
281	16.763	331	18.193	381	19.519	431	20.761	481	21.932
282	16.793	332	18.221	382	19.545	432	20.785	482	21.954
283	16.823	333	18.248	383	19.570	433	20.809	483	21.977
284	16.852	334	18.276	384	19.596	434	20.833	484	22.000
285	16.882	335	18.303	385	19.621	435	20.621	485	22.023
286	16.912	336	18.330	386	19.647	436	20.881	486	22.045
287	16.941	337	18.358	387	19.672	437	20.905	487	22.068
288	16.971	338	18.385	388	19.698	438	20.928	488	22.091
289	17.000	339	18.412	389	19.723	439	20.952	489	22.113
290	17.029	340	18.439	390	19.748	440	20.976	490	22.136
291	17.059	341	18.466	391	19.774	441	21.000	491	22.159
292	17.088	342	18.498	392	19.799	442	21.024	492	22.181
293	17.117	343	18.520	393	19.824	443	21.048	493	22.204
294	17.146	344	18.547	394	19.849	444	21.071	494	22.226
295	17.176	345	18.574	395	19.875	445	21.095	495	22.249
296	17.205	346	18.601	396	19.900	446	21.119	496	22.271
297	17.234	347	18.628	397	19.925	447	21.142	497	22.293
298	17.263	348	18.655	398	19.950	448	21.166	498	22.316
299	17.292	349	18.682	399	19.975	449	21.190	499	22.338

TABLE OF SQUARE ROOTS

N	√N	N	√N	N	√N	N	√N	N	√N
500	22.361	550	23.452	600	24.495	650	25.495	700	26.458
501	22.383	551	23.473	601	24.515	651	25.515	701	26.476
502	22.405	552	23.495	602	24.536	652	25.534	702	26.495
503	22.428	553	23.516	603	24.556	653	25.554	703	26.514
504	22.450	554	23.537	604	24.576	654	25.573	704	26.533
505	22.472	555	23.558	605	24.597	655	25.593	705	26.552
506	22.494	556	23.580	606	24.617	656	25.612	706	26.571
507	22.517	557	23.601	607	24.637	657	25.632	707	26.589
508	22.539	558	23.622	608	24.658	658	25.652	708	26.608
509	22.561	559	23.643	609	24.678	659	25.671	709	26.627
510	22.583	560	23.664	610	24.698	660	25.690	710	26.646
511	22.605	561	23.685	611	24.718	661	25.710	711	26.665
512	22.627	562	23.707	612	24.739	662	25.729	712	26.683
513	22.650	563	23.728	613	24.759	663	25.749	713	26.702
514	22.672	564	23.749	614	24.779	664	25.768	714	26.721
515	22.694	565	23.770	615	24.799	665	25.788	715	26.739
516	22.716	566	23.791	616	24.819	666	25.807	716	26.758
517	22.738	567	23.812	617	24.839	667	25.826	717	26.777
518	22.760	568	23.833	618	24.800	668	25.846	718	26.796
519	22.782	569	23.854	619	24.880	669	25.865	719	26.814
520	22.804	570	23.875	620	24.900	670	25.384	720	26.833
521	22.825	571	23.896	621	24.920	671	25.904	721	26.851
522	22.847	572	23.917	622	24.940	672	25.923	722	26.870
523	22.869	573	23.937	623	24.960	673	25.942	723	26.889
524	22.891	574	23.958	624	24.980	674	25.962	724	26.907
525	22.913	575	23.979	625	25.000	675	25.981	725	26.926
526	22.935	576	24.000	626	25.020	676	26.000	726	26.944
527	22.956	577	24.021	627	25.040	677	26.019	727	26.963
528	22.978	578	23.042	628	25.060	678	26.038	278	26.981
529	23.000	579	24.062	629	25.080	679	26.058	729	27.000
530	23.022	580	24.083	630	25.100	680	26.077	730	27.019
531	23.043	581	24.104	631	25.120	681	26.096	731	27.037
532	23.065	582	24.125	632	25.140	682	26.115	732	27.055
533	23.087	583	24.145	633	25.159	683	26.134	733	27.074
534	23.108	584	24.166	634	25.179	684	26.153	734	27.092
535	23.130	585	24.187	635	25.199	685	26.173	735	27.111
536	23.152	586	24.207	636	25.219	686	26.192	736	27.129
537	23.173	587	24.228	637	25.239	687	26.211	737	27.148
538	23.195	588	23.249	638	25.259	688	26.230	738	27.166
539	23.216	589	23.269	639	25.278	689	26.249	739	27.185
540	23.238	590	24.290	640	25.298	690	26.268	740	27.203
541	23.259	591	24.310	641	25.318	691	26.287	741	27.221
542	23.281	592	24.331	642	25.338	692	26.306	742	27.240
543	23.302	593	24.352	643	25.357	693	26.325	743	27.258
544	23.324	594	24.372	644	25.377	694	26.344	744	27.276
545	23.345	595	24.393	645	25.397	695	26.363	745	27.295
546	23.367	596	24.413	646	25.417	696	26.382	746	27.313
547	23.388	597	24.434	647	25.436	697	26.401	747	27.331
548	23.409	598	24.454	648	25.456	698	26.420	748	27.350
549	23.431	599	24.474	649	25.475	699	26.439	749	27.368

TABLE OF SQUARE ROOTS

N	√N	N	√N	N	√N	N	√N	N	√N
750	27.386	800	28.284	850	29.155	900	30.000	950	30.822
751	27.404	801	28.302	851	29.172	901	30.017	951	30.838
752	27.423	802	28.320	852	29.189	902	30.033	952	30.854
753	27.441	803	28.337	853	29.206	903	30.050	953	30.871
754	27.459	804	28.355	854	29.223	904	30.067	954	30.887
755	27.477	805	28.373	855	29.240	905	30.083	955	30.903
756	27.495	806	28.390	856	29.257	906	30.100	956	30.919
757	27.514	807	28.408	857	29.275	907	30.116	957	30.935
758	27.532	808	28.425	858	29.292	908	30.133	958	30.952
759	27.550	809	28.443	859	29.309	909	30.150	959	30.968
760	27.568	810	28.460	860	29.326	910	30.166	960	30.984
761	27.586	811	28.478	861	29.343	911	30.183	961	31.000
762	27.604	812	28.496	862	29.360	912	30.199	962	31.016
763	27.622	813	28.513	863	29.377	913	30.216	963	31.032
764	27.641	814	28.531	864	29.394	914	30.232	964	31.048
765	27.659	815	28.548	865	29.411	915	30.249	965	31.064
766	27.677	816	28.566	866	29.428	916	30.265	966	31.081
767	27.695	817	28.583	867	29.445	917	30.282	967	31.097
768	27.713	818	28.601	868	29.462	918	30.299	968	31.113
769	27.731	819	28.618	869	29.479	919	30.315	969	31.129
770	27.749	820	28.636	870	29.496	920	30.332	970	31.145
771	27.767	821	28.653	871	29.513	921	30.348	971	31.161
772	27.785	822	28.671	872	29.530	922	30.364	972	31.177
773	27.803	823	28.688	873	29.547	923	30.381	973	31.193
774	27.821	824	28.705	874	29.563	924	30.397	974	31.209
775	27.839	825	28.723	875	29.580	925	30.414	975	31.225
776	27.857	826	28.740	876	29.597	926	30.430	976	31.241
777	27.875	827	28.758	877	29.614	927	30.447	977	31.257
778	27.893	828	28.775	878	29.631	928	30.463	978	31.273
779	27.911	829	28.792	879	29.648	929	30.480	979	31.289
780	27.928	830	28.810	880	29.665	930	30.496	980	31.305
781	27.946	831	28.827	881	29.682	931	30.512	981	31.321
782	27.964	832	28.844	882	29.698	932	30.529	982	31.337
783	27.982	833	28.862	883	29.715	933	30.545	983	31.353
784	28.000	834	28.879	884	29.732	934	30.561	984	31.369
785	28.018	835	28.896	885	29.749	935	30.578	985	31.385
786	28.036	836	28.914	886	29.766	936	30.594	986	31.401
787	28.054	837	28.931	887	29.783	937	30.610	987	31.417
788	28.071	838	28.948	888	29.799	938	30.627	988	31.432
789	28.089	839	28.965	889	29.816	939	30.643	989	31.448
790	28.107	840	28.983	890	29.833	940	30.659	990	31.464
791	28.125	841	29.000	891	29.850	941	30.676	991	31.480
792	28.142	842	29.017	892	29.866	942	30.692	992	31.496
793	28.160	843	29.034	893	29.883	943	30.708	993	31.512
794	28.178	844	29.052	894	29.900	944	30.725	994	31.528
795	28.196	845	29.069	895	29.917	945	30.741	995	31.544
796	28.213	846	29.086	896	29.933	946	30.757	996	31.559
797	28.231	847	29.103	897	29.950	947	30.773	997	31.575
798	28.249	848	29.120	898	29.967	948	30.790	998	31.591
799	28.267	849	29.138	899	29.983	949	30.806	999	31.607

APPENDIX A

SOURCE OF THE TERM F_c USED IN THE CALCULATION OF EQUIVALENT STATIC COLUMN WELLHEAD PRESSURES

The calculation of the equivalent static column wellhead pressure corresponding to a flowing wellhead pressure is carried out through use of the following equation:

$$P_w^2 = P_t^2 + F^2T^2Z^2 \ (1-e^{-s}) \text{------------------} (1)$$

where:

$$F^2 = \frac{2.6665 \ f \ Q^2}{d^5}$$

$$S = \frac{0.0375 \ GL}{TZ}$$

G = Specific gravity (air = 1.00)

L = Length of flow string, ft.

P = Pressure, psia (P^2 in thousands)

Q = Rate of flow, M^2cfd @ 14.65 psia, and 60°F.

T = Effective absolute temperature, °R.

Z = Effective compressibility factor.

d = Internal diameter of flow string, in.

f = Coefficient of friction, dimensionless.

Through use of the complete turbulence portion of the curves published by Lewis F. Moody in November 1944, Transactions of the A.S.M.E., it is possible to determine the value of (f) for various sizes of pipe at a constant absolute roughness of 0.0006 in., which value is considered valid for clean pipe.

Using the values of (f) so determined, it is possible to arrive at a correlation of friction coefficient (f) vs. internal diameter (d) which is reasonably correct. It was found for an absolute roughness of 0.0006 in. that the value of (f) could be expressed as follows:

$$f = \frac{4.372 \times 10^{-3}}{d^{0.224}} \quad \text{for diameters less than 4.277 in.}$$

and

$$f = \frac{4.007 \times 10^{-3}}{d^{0.164}} \quad \text{for diameters greater than 4.277 in.}$$

If the expression $(F_cQ)^2$ is allowed to represent the expression $(F^2T^2Z^2)$ in equation (1), then the value of F_c can be shown to be those given in Table VII, A, B and C.

APPENDIX B

THE GENERAL FLOW EQUATION AND THE DEVELOPMENT OF VARIOUS FORMULAS FOR THE FLOW OF GAS IN PIPES

If it is assumed that the change in kinetic energy due to the flow of gas is negligable, the general equation for the flow of gas in pipes may be expressed as follows:

General Flow Equation

$$\frac{1000\ GL}{53.33} = \int_{P_2}^{P_1} \frac{P/TZ \quad d\ (P)}{\frac{2.6665\ fQ^2}{d^5} + \frac{H}{L}\ (\bar{P}/TZ)^2} \text{ ------------------ (1).}$$

G = Specific gravity (Air = 1.00)

H = Difference in elevation, ft.

L = Length, ft.

P = Pressure, psia ($\bar{p}^2$ in thousands)

Q = Rate of flow, M^2cfd @ 14.65 psia and 60°F.

T = Absolute temperature, °R.

Z = Compressability factor, dimensionless.

d = Internal diameter, inches.

f = Coefficient of friction, dimensionless.

If we let

$$F^2 = \frac{2.6665\ fQ^2}{d^5} \text{ ---------------------------- (2).}$$

then

$$\frac{1000\ GL}{53.33} = \int_{P_2}^{P_1} \frac{P/TZ \quad d\ (P)}{F^2 + \frac{H}{L}\ (P/TZ)^2} \text{ ---------------------- (3).}$$

INCLINED STATIC COLUMN

In a static column of gas Q = 0, consequently F^2 = 0, then EQ. (3) may be expressed as follows:

$$\frac{GH}{53.33} = \int_{P_c}^{P_f} \frac{TZ}{P} \, d \, (P) \text{ ----------------------------------(4)}$$

where,

P_c = Shut-in wellhead pressure, psia.

P_f = Formation pressure, psia

Without making certain assumptions with respect to T and Z, EQ. (4) does not lend itself to mathmatical integration; however, an evaluation of the integral over definite limits can be accomplished by numerical means.

In order to evaluate the expression

$$\int_{P_o}^{P_n} \frac{TZ}{P} \, d \, (P) \text{ --------------------------------(5)}$$

it is necessary to calculate the value of $\frac{TZ}{P}$ for P_o and appropriate values of P_i where i = (0, 1, 2, 3 -------n)

If we let,

$$I = \frac{TZ}{P} \text{ ---(6)}$$

then

$$\int_{P_o}^{P_n} \frac{TZ}{P} \, d \, (P) = 1/2 \quad (P_1-P_o)\ (I_1-I_o) + (P_2-P_1)\ (I_2 + I_1) + \text{----}$$
$$\text{---------} + (P_n-P_{n-1})\ (I_n+I_{n-1}) \quad \text{--------(7)}$$

Where the variation of temperature with depth is known, it is necessary to assume appropriate values for the depth; determine the temperature (T) and determine P_i by trial and error so that

$$\frac{2\ GH_1}{53.33} = \left[(P_1-P_0)\ (I_1+I_0) + (P_2-P_1)\ (I_2+I_1)\right],$$

$$\frac{2\ GH_2}{53.33} = \left[(P_1-P_0)\ (I_1+I_0) + (P_2-I_1) + (P_3-P_2)\ (I_3+I_2)\right],$$

and

$$\frac{2GH}{53.33} = \left[(P_1-P_0)(I_1+I_0) + (P_2-P_1)\ (I_2+I_1) + \text{------} + (P_n-P_{n-1})(I_n+I_{n-1})\right]$$

The method is rather tedious if a large number of increments are chosen for (H); however, in many cases the total depth may be considered in one increment without causing appreciable error.

A two increment calculation may also be made with Simpson's Rule being applied to the result obtained to minimize the error in the final result.

An example of each method is shown in the attached tables.

CALCULATION SHEET FOR STATIC COLUMN PRESSURES

COMPANY__________ LEASE__________ WELL NO.__________ DATE__________

G 0.850 %CO_2 28 % N__________ Cr. Press. 788 Cr. Temp. 393

H	P_n	P_r	T	T_r	Z	TZ	I TZ/P	M P_n-P_{n-1}	N I_n-I_{n-1}	MxN	Σ(MxN)	0.0375 x GH
0	4465	5.67	564	1.44	0.821	463.044	.103705					
1000	4619	5.86	571	1.45	0.837	477.927	.103470	154	.207175	31.905	31.905	31.875
2000	4773	6.06	577	1.47	0.856	493.912	.103480	154	.206950	31.870	63.775	63.750
3000	4927	6.25	584	1.49	0.873	509.832	.103477	154	.206957	31.871	95.646	95.625
4000	5081	6.45	591	1.50	0.889	525.399	.103405	154	.206882	31.860	127.506	127.500
5000	5236	6.64	597	1.52	0.897	535.509	.102274	155	.205679	31.880	159.386	159.375
6000	5391	6.84	604	1.54	0.921	556.284	.103188	155	.205462	31.847	191.233	191.250
7000	5546	7.04	611	1.55	0.935	571.285	.103008	155	.206196	31.960	223.193	223.125
8000	5700	7.23	618	1.57	0.952	588.336	.103217	154	.206225	31.759	254.952	255.000
9000	5855	7.43	624	1.59	0.967	603.408	.103058	155	.206275	31.973	286.925	286.875
10000	6010	7.63	631	1.60	0.980	618.380	.102892	155	.205950	31.922	318.847	318.750
11000	6164	7.82	638	1.62	0.994	634.172	.102883	154	.205775	31.689	350.536	350.625
12000	6319	8.02	644	1.64	1.009	649.796	.102832	155	.205715	31.886	382.422	382.500
13148	6497	8.24	652	1.66	1.024	667.648	.102762	178	.205594	36.596	419.018	419.093

T @ H = 0 = 104°F = 564°R
T @ H = 13148 = 192° F = 652°R

$\frac{88}{13148} \times 1000 = 6.69°/1000$ ft

CASE I

Numerical Evaluation of the Definite Integral

$$\int_{P_c}^{P_f} \frac{TZ}{P} d(P)$$ using 1000 ft. intervals

CALCULATION SHEET FOR STATIC COLUMN PRESSURES

COMPANY ________ LEASE ________ WELL NO. ________ DATE ________

G 0.850 % CO_2 28 %N ________ Cr. Press. 788 Cr. Temp. 393

H	P_n	P_r	T	T_r	Z	TZ	I TZ/P	M P_n-P_{n-1}	N I_n+I_{n-1}	MxN	(MxN)	0.0375 xGH
0	4465	5.67	564	1.44	0.821	463.044	.103705				0	0
13148	6494	8.24	652	1.66	1.024	667.648	.102810	2029	.206515	419.019	419.019	419.09

T @ H = 0 = 104°F = 564° R
T @ H = 13148 = 192°F = 652 °R

CASE II

Numerical Evaluation of the Definite Integral

$$\int_{P_s}^{P_f} \frac{TZ}{P} d(P) \text{ by One Interval}$$

CALCULATION SHEET FOR STATIC COLUMN PRESSURES

COMPANY ________ LEASE ________ WELL NO. ________ DATE ________

G 0.850 $\%CO_2$ 28 %N ________ Cr. Press. 788 Cr. Temp. 393

							I	M	N			
H	P_n	P_r	T	T_r	Z	TZ	TZ/P	P_n-P_{n-1}	I_n+I_{n-1}	MxN	(MxN)	0.0375 x GH
0	4465	5.67	564	1.44	0.821	463.044	.103705				0	0
6574	5478	6.95	608	1.55	0.930	565.44	.103220	1013	.206925	209.615	209.615	209.546
13148	6495	8.24	652	1.66	1.024	667.648	.102794	1017	.206014	209.516	419.131	419.093

By Simpson's Rule

$$\frac{2\ P}{3}(0.103705 + 4(0.103220) + 0.102794) = 419.093$$

$$2\ P = 2030$$

$$P_s = P_w + 2\ P$$

$$P_s = 6495$$

Note: Although in this particular case there is no difference in the values determined for P_s before and after the application of Simpson's Rule; there is usually some difference between the two values and the final value is considered to be more nearly correct.

CASE III

Numerical Evaluation of the Definite Integral $\int_{P_c}^{P_f} \frac{TZ}{P} d(P)$ by Two Equal Intervals and Simpson's Rule

APPENDIX C

DETERMINING STATIC COLUMN PRESSURES IN GAS WELLS

The determination of subsurface static column pressures by the "Two Step" Simpson's Rule may be accomplished through the use of the following procedure and the "Calculation Sheet for Static Column Pressures".

Observed data:

Specific Gravity of Gas	.725 (Air= 1.00)
Measured Wellhead Pressure	1350 psia
% CO_2	0
% N	0
Wellhead Temperature	80°F
Reservoir Temperature	128°F

Using "Calculation Sheet for Static Column Pressures", Case I.

1. Enter specific gravity (G) and composition of gas at top of calculation sheet.

2. Determine critical pressure (P_{cr}) and critical temperature (T_{cr}).

   $P_{cr} = 668$ CNGA TS-461, Table I.

   $T_{cr} = 398$ CNGA TS-461, Table I.

If gas contains carbon dioxide or nitrogen P_{cr} and T_{cr} should be corrected at this time by using Table II of CNGA TS 461. Enter these values at top of Calculation Sheet.

3. Enter initial depth (zero wellhead) on Line 1, Column 1.

4. Enter wellhead pressure (P_n) on Line 1, Column 2. (1350 psia)

5. Determine reduced pressure. (P_r)

$$\frac{P_n}{P_{cr}} = \frac{1350}{668} = 2.02 = P_r$$

   Enter on Line 1, Column 3.

6. Enter Wellhead Temperature (absolute) on Line 1, Column 4.

7. Determine reduced temperature. (T_r)

$$\frac{T}{T_{cr}} = \frac{540}{398} = 1.36$$

   Enter on Line 1, Column 5.

8. Using P_r and T_r determined supercompressibility factor (F_{pv})

   $F_{pv} = 1.165$ (AGA-TS-461 Table V)

   Enter on Line 1, Column 6.

9. From F_{pv} determine Z factor.

$$\frac{1}{(F_{pv})^2} = \frac{1}{(1.165)^2} = .737$$

Enter on Line 1, Column 7.

10. Determine value of TZ.

$$540 \times .737 = 397.98$$

Enter on Line 1, Column 8.

11. Determine value of $\frac{TZ}{P_n}$.

$$\frac{TZ}{P_n} = \frac{397.98}{1350} = .29480$$

Enter on Line 1, Column 9.

12. H is the length of the static gas column being evaluated in each step of the calculation (see page 71).

Enter H (1/2 of total depth) for which the pressure is being determined on Line 2, Column 1.

13. Determine value of .0375 GH.

$$.0375 \times .725 \times 2400 = 65.249$$

Enter on Line 2, Column 14.

14. Determine first trial value of weight of gas column at midpoint of gas column.

$$\frac{\frac{.0375GH}{2}}{\frac{TZ}{P_n}} = \frac{\frac{65.249}{2}}{.29480} = 110.66 \text{ or } 110.7$$

Enter on Line 2, Column 10.

15. Determine first trial value of pressure at midpoint of gas column.

$$1350 + 110.7 = 1460.7 \text{ psia}$$

Enter on Line 2, Column 2.

16. Determine the average absolute temperature between the wellhead and Bottom Hole.

$$\frac{80 + 128}{2} + 460\ R^{o} = 564\ {}^{o}R \text{ (Rankine)}$$

Enter on Line 2, Column 4.

17. Determine values of P_r, T_r, F_{pv}, Z, TZ and $\frac{TZ}{P_n}$ as shown in steps 5, 7, 8, 9, 10 and 11.

$P_r = 2.18$, $T_r = 1.42$, $F_{pv} = 1.143$, $Z = .765$.

$TZ = 431.46$ and $\frac{TZ}{P_n}$ or $I = .295318$

Enter on Line 2, Columns 3, 5, 6, 7, 8 and 9, respectively.

18. Determine value of N.

I @ 0 ft. + trial I @ 2400 ft. = Trial N @ 2400 ft.

.29480 + .295318 = .590118

Enter on Line 2, Column 11.

19. Determine value of M x N.

M x N = MN

110.7 x .590118 = 65.348

Enter on Line 2, Column 12 and 13.

When Column 13 is equal to Column 14 then the proper value of P_n @ 2400 ft. has been determined. A check should be made by dividing column 14 by column 11, as follows:

$$\frac{.0375\ GH}{N} = \frac{65.249}{.590118} = 110.57$$

Since this value is only .13 psi less 110.7 we shall consider 110.7 as correct. If the value of M in this check had been different than 110.7 by more than .5 psi. then we would have entered this value on line 3, column 10 and repeated steps 15 through 19 until column 13 was as close to column 14 as possible.

20. Enter total depth for which pressure is being calculated on line 3, column 1.

21. Determine value of .0375 GH as in step 13.

.0375 GH = 130.497

22. Determine trial value of the weight of the gas column (M) at this depth. (4800 ft.)

$$\frac{.0375\ GH - \Sigma(MxN)\ @\ 2400\ ft.}{N\ @\ 2400\ ft.} = \text{Trial (M) @ 4800 ft.}$$

$$\frac{130.497 - 65.348}{.590118} = 110.40$$

Enter on Line 3, Column 10.

23. Determine trial value of pressure at desired depth of 4800 ft.

(P_n) at 2400 ft. + trial (M) @ 4800 ft. = trial ($P_{n'}$) @ 4800 ft.

$1460.7 + 110.4 = 1571.1$ psia

Enter on Line 3, Column 2.

24. Enter absolute bottom hole temperature at 4800 ft.

$128 + 460\ R^o = 588\ R^o$

Enter on Line 3, Column 4.

25. Determine values of P_r, T_r, F_{pv}, Z, TZ and $\frac{TZ}{P_n}$ at 4800 ft. as shown in steps 5, 7, 8, 9, 10 and 11.

$P_r = 2.35$, $T_r = 1.48$, $F_{pv} = 1.124$, $Z = .791$, TZ -465.11, $\frac{TZ}{P_n}$ or I= .296040.

Enter on Line 3, Columns 3, 5, 6, 7, 8 and 9, respectively.

26. Determine trial value of N for 4800 ft.

I @ 2400 + trial I @ 4800 ft. = trial N @ 4800 ft.

$.295318 + .296040 = .591358$

Enter on Line 3, Column 11.

27. Determine Trial M x N @ 4800 ft.

Trial M @ 4800 ft. x trial N @ 4800 = trial M x N @ 4800 ft.

$110.4 \times .591358 = 65.285$

28. Determine trial value of Σ(M x N) 4800 ft.

Σ(M x N) @ 2400 ft. + Trial M x N @ 4800 ft. =Trial Σ(M x N) at 4800 ft. $65.348 + 65.285 = 130.633$

Enter on Line 3, Column 13.

When column 13 is equal to column 14 the proper value of P_n @ 4800 ft. has been determined. A check must be made by determining again the value of the weight of the column of gas @ 4800 ft. as in step 22, except that the value of N is the trial value @ 4800 ft.

$$\frac{.0375 \text{ GH @ 4800 ft.} - \Sigma(\text{M x N}) \text{ @ 2400 ft.}}{\text{Trial N @ 4800 ft.}} = 110.16$$

Since this value is only .24 psi less than the trial M @ 4800 ft. of 110.4 we shall consider 110.4 as correct and the value of P_{n1} (1571.1) on line 3, column 2, as correct. If the value of M in this check had been different than 110.4 by more than .5 psi., then we would have entered this value on line 4, column 10 and repeat steps 22, 23, the $\frac{TZ}{P_n}$ of 25, 26, 27, and 28 until Column 13 is as near equal to Column 14 as possible.

29. Determine Pressure at Total Depth (4800 ft.)

Now that the proper values of P_n for 2400 and 4800 ft. have been determined we can calculate the pressure at 4800 ft. by the following formula.

$$P_f = P_c + 2\,\Delta P$$

where: $$2\,\Delta P = \frac{3\,(.0375\ GH)\ @\ 4800\ ft.}{I_1 + 4I_2 + I_3}$$

P_f = Bottom Hole Pressure psia.

P_c = Wellhead shut-in pressure. psia.

G = Specific gravity of gas. (Air = 1.0)

H = Length of gas column to gas liquid inter-face.

I_1 = Value of I where H = 0 ft.

I_2 = Value of I where H = 2400 ft.

I_3 = Value of I where H = 4800 ft.

then:

$$P_f = 1350 + \frac{3\ (130.497)}{.294800 + 4\ (.295318) + .296040}$$

$$P_f = 1350 + 220.92$$

$$P_f = 1570.92 \text{ or } 1571 \text{ psia}$$

CALCULATION SHEET FOR STATIC COLUMN PRESSURES

COMPANY________ LEASE________ WELL NO.________ DATE________

G= .725 %CO_2= 0 %N= 0 Cr. Pressure (P_{cr})= 668 Cr. Temp. (T_{cr})= 398 .0375G = .027187

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
			P_r		T_r		Z		I	M	N			
	H	P_n	$\frac{P_n}{P_{cr}}$	T	$\frac{T}{T_{cr}}$	F_{pv}	$\frac{1}{(F_{pv})^2}$	TZ	$\frac{TZ}{P_n}$	$P_n P_{n-1}$	$I_n - I_{n-1}$	M x N	Σ(MxN)	.0375
							CASE I (Wellhead to Gas-Liquid Interface)							
1	0	1350	2.02	540	1.36	1.165	.737	397.98	.294800				0	0
2	2400	1460.7	2.18	564	1.42	1.143	.765	431.46	.295318	110.7	.590118	65.348	65.348	65.249
3	4800	1571.1	2.35	588	1.48	1.124	.791	465.11	.296040	110.4	.591358	65.285	130.633	130.497
							CASE II (Datum Point to Wellhead)							
4	6000	1955	2.93	600	1.51	1.128	.786	471.60	.241227				163.122	163.122
5	3000	1786	2.67	570	1.43	1.161	.742	422.93	.236808	169.0	.478035	80.788	82.334	81.561
6	3000	1784.4	"	"	"	"	"	"	.237020	170.6	.478247	41.589	81.533	"
7	0	1613.9	2.42	540	1.36	1.195	.700	378.00	.234215	170.5	.471235	80.346	1.187	0
8	0	1611.4	"	"	"	"	"	"	.234578	173.0	.471598	81.586	.053	

CASE I

$$2\ AP = \frac{3\ (.0375\ GH)}{I_1 + 4I_2 + I_3} = \frac{3\ (130.487)}{.294800 + 4\ (.295318) + .296040}$$

$= 220.9$

$Pf = 1350 + 220.9 = 1570.9$

CASE II

$$2\ AP = \frac{3\ (.0375\ GH)}{I_1 + 4I_2 + I_3} = \frac{3\ (163.122)}{.241227 + 4\ (.237020) + .234578}$$

$= 343.7$

$P_c = 1955 - 343.7 = 1611.3$

DETERMINING THE ADJUSTED WELLHEAD SHUT-IN PRESSURE ON GAS WELLS WITH LIQUID COLUMNS IN WELLBORE UNDER STATIC CONDITIONS.

In some cases, the observed wellhead shut-in pressure of a gas well is effected by accumulated liquids in the wellbore and will not reflect the true conditions of the well. When the height of the liquid column and the specific gravity of the liquids are known, the formation (Bottom Hole) pressure may be determined by calculating the pressure at the gas-liquid interface as explained in Example No. 6 and adding to this figure the weight of the liquid column above the desired datum plane.

When it is necessary to determine the wellhead pressure which would exist if the liquid column were not present, the formation pressure determined as explained above may be used to calculate an adjusted wellhead pressure based on the assumption that no liquid column exists. The following example explains the same method and procedure as shown in Appendix C, except that it is used to determine wellhead pressure from a known bottom hole pressure while Appendix C shows the procedure for determining bottom hole pressure when the wellhead pressure is known.

Observed data:

H = 6000 ft. (Length of wellbore to datum point. Datum Point used shall be that determined by the Commission)

G_1 = .725 (Gravity of Gas, Air = 1.00)

G_2 = .7389 (Specific gravity (water = 1.00)60° API, Table IX, Page 52 .)

h = 1200 ft. (Length of Liquid Column in wellbore above Datum)

Wellhead Temperature = 540 °R

Formation Temperature = 600 °R

1 ft. of water = .4333 psia.

Weight of liquid column expressed as psia.

$$\text{psia} = h \times G_2 \times .4333$$

$$\text{psia} = 1200 \times .7389 \times .4333 = 384.2$$

Pressure at gas-liquid interface as determined in Appendix C	= 1571 psia
Pressure of liquid column	= 384 "
Formation Pressure (P_f @ 6000 ft.)	1955 psia

Since we desire the adjusted wellhead pressure and we have the Formation pressure at the well datum point we must calculate the pressure due to the weight of the column of gas by beginning with datum point conditions.

Using "Calculation Sheet for static column pressures" shown with Example of Appendix C, Case II.

1. The values of G, P_{cr}, and T_{cr} will be the same as shown for Case I, (Appendix C).

2. Enter length of column (H), Formation Pressure (P_n) and absolute formation temperature T on Line 4, Columns 1, 2 and 4, respectively.

3. Determine P_r, T_r, F_{pv}, Z, TZ and $\frac{TZ}{P_n}$ or I and enter on line 4, Columns 3, 5, 6, 7, 8 and 9 respectively.

$$P_r = \frac{P_n}{P_{cr}} = \frac{1955}{668} = 2.93$$

$$T_r = \frac{T}{T_{cr}} = \frac{600}{398} = 1.51$$

$$F_{pv} = 1.128 \text{ CNGA TS - 461, Table V.}$$

$$Z = \frac{1}{(F_{pv})^2} = \frac{1}{1.272} = .786$$

$$TZ = 600 \times .786 = 471.600$$

$$\frac{TZ}{P_n} = \frac{471.600}{1955} = .241227$$

4. Determine value of .0375 GH. for 6000 ft.

$$.0375 \times .725 \times 6000 = 163.122$$

Enter on Line 4, Columns 13 and 14.

5. Enter H (1/2 of total depth) on Line 5, Column 1.

$$\frac{6000}{2} = 3000 \text{ ft.} = H$$

6, Determine value of .0375 GH @ 3000 ft.

$$.0375 \text{ GH} \times .725 \times 3000 = 81.561$$

Enter on Line 5, Column 14.

7. Determine first trial value of the weight of the lower half of the gas column (from 3000 to 6000 ft.)

$$\frac{\frac{.0375 \text{ GH @ 3000 ft.}}{2}}{\frac{TZ}{P_n}} = \frac{40.780}{.241227} = 169.0$$

Enter on Line 5, Column 10.

8. Determine first trial value of pressure at mid-point of gas column.

$$P_n \text{ @ } 6000 \text{ ft} - \text{Trial M} = \text{Trial } P_n \text{ @ } 3000 \text{ ft.}$$

$$1955 - 169 = 1786 \text{ psia.}$$

Enter on Line 5, Column 2.

9. Determine the average absolute temperature at mid-column.

$$\frac{540 + 600}{2} = 570\ ^{o}R$$

Enter on Line 5, Column 4.

10. Determine values of P_r, T_r, F_{pv}, Z, TZ and $\frac{TZ}{P_n}$ for 3000 ft. and enter on line 5, Columns 3, 5, 6, 7, 8 and 9 as shown in step 3 above.

$P_r = 2.67$; $T_r = 1.43$; $F_{pv} = 1.161$; $Z = .742$; $TZ = 422.94$;

$$\frac{TZ}{P_n} = .236808$$

11. Determine value of N @ 3000 ft.

I @ 6000 ft + trial I @ 3000 ft. = trial N @ 3000 ft.

$$.241227 + .236808 = .478035$$

Enter on Line 5, Column 11.

12. Determine trial value of M x N @ 3000 ft.

$$169.0 \times .478035 = 80.788$$

Enter on Line 5, Column 12.

13. Determine trial value of Σ(M x N) @ 3000 ft.

Σ(M x N) @ 6000 ft. - Trial (M x N) @ 3000 ft. =

Trial (M x N) @ 3000 ft.

$$163.122 - 80.788 = 82.334$$

Enter on Line 5, Column 13.

When column 13 is equal to Column 14 the proper value of P_n @ 3000 has been determined. A check must be made by determining the value of the pressure due to the weight of the column of gas from 3000 ft. to 6000 ft. as follows:

Σ(M x N) @ 6000 ft. - .0375 GH @ 3000 ft. = Check value of M @ 3000 ft.

$$\frac{163.122 - 81.561}{.478035} = 170.6$$

14. Since this value is more than .5 psia different than the first trial value of M we must enter this value on Line 6, Column 10 and repeat steps 8, the $\frac{TZ}{P_n}$ part of 10, 11, 12 and 13.

then:

$$P_n = 1784.4$$

$$\frac{TZ}{P_n} = .237020$$

$$N = .478247$$

$$(M \times N) = 81.589$$

$$\Sigma(M \times N) = 81.533$$

and:

Check value of M = 170.5

Since the check value of M is different than the trial value of M by only .1 psia the second trial value of M (170.5) and the second trial value of P_n (1784.4) is considered correct.

15. Enter depth at which next pressure is to be calculated (zero wellhead) on Line 7, Column 1.

16. The value of .0375 GH is now 0.
Enter on Line 7, Column 14.

17. Determine the first trial value of the pressure due to the weight of the gas column from 3000 to wellhead (0).

$$\frac{\Sigma(M \times N) \text{ @ 3000 ft.} - .0375 \text{ GH @ 0 ft}}{N \text{ @ 3000 ft.}} = \text{First Trial M @ 0 ft.}$$

$$\frac{81.533 - 0}{.478247} = 170.5 \text{ psia}$$

Enter on Line 7, Column 10.

18. Determine first trial value of pressure at wellhead.

P_n @ 3000 ft. - M @ 0 ft. = P_n @ 0 ft.
1784.4 - 170.5 = 1613.9 psia

19. Enter wellhead absolute temperature on Line 7, Column 4.

20. Determine P_r, T_r, F_{pv}, Z, TZ, and $\frac{TZ}{P}$ for 0 ft.

P_r = 2.42; T_r = 1.36; F_{pv} = 1.195; Z = .700;

TZ = 378.00; $\frac{TZ}{P}$ = .234215

Enter on Line 7, Column 3, 5, 6, 7, 8 and 9 respectively.

21. Determine value of N @ 0 ft.

I @ 3000 ft. + trial I @ 0 ft. = trial N @ 0 ft.

.237020 + .234215 = .471235

Enter on Line 7, Column 11.

22. Determine M x N @ 0 ft.

Trial M @ 0 ft. x Trial N @ 0 ft. = Trial M x N @ 0 ft.

170.5 x .471235 = 80.346

Enter on Line 7, Column 12.

23. Determine Σ(M x N) @ 0 ft.

Σ(M x N) @ 3000 ft. - trial M x N @ 0 ft. = Trial Σ(M x N) @ 0 ft.

81.533 - 80.346 = 1.187

Column 13 is not equal to Column 14 so a check must be made to determine how close we are to the proper value of M @ 0 ft. The check is made as in step 13 above.

$$\frac{81.533 - 0}{.471235} = \text{Check value of M} = 173.0$$

24. Since the check value of M is different than the first trial value of M by 2.5 psia we must enter this value on Line 8, Column 10 and repeat steps 18, the $\frac{TZ}{P}$ part of 20, 21, 22, and 23 until Column 13 is as close to Column 14 as possible.

$\frac{TZ}{P}$ = .234578

N = .471598

M x N = 81.586

Σ(M x N) = .053

Check value of M = 172.8

Since the check value of M is different from the second trial value by only .2 psia the second trial value of M (173.0) and the second trial value of P_n (1611.4) is considered correct.

25. Now that the proper values of P_n for 6000, 3000 and 0 ft. have been determined we can calculate the adjusted wellhead pressure by using the following formula:

$$P_c = P_f - 2\Delta P$$

where:

$$2\,\Delta P = \frac{3\,(.0375\text{ GH})\text{ @ 6000 ft.}}{I_1 + 4I_2 + I_3}$$

P_f = Bottom Pressure psia

P_c = Adjusted wellhead pressure psia

G = Specific gravity of gas column (air = 1.00)

H = Length of gas column to datum point.

I_1 = Value of I where H = 6000 ft.

I_2 = Value of I where H = 3000 ft.

I_3 = Value of I where H = 0 ft.

Then:

$$P_c = 1955 - \frac{3\ (163.122)}{.241227 + 4\ (.237020) + .234578}$$

$$P_c = 1955 - 343.7$$

$$P_c = 1611.3 \text{ or } 1611 \text{ psia}$$