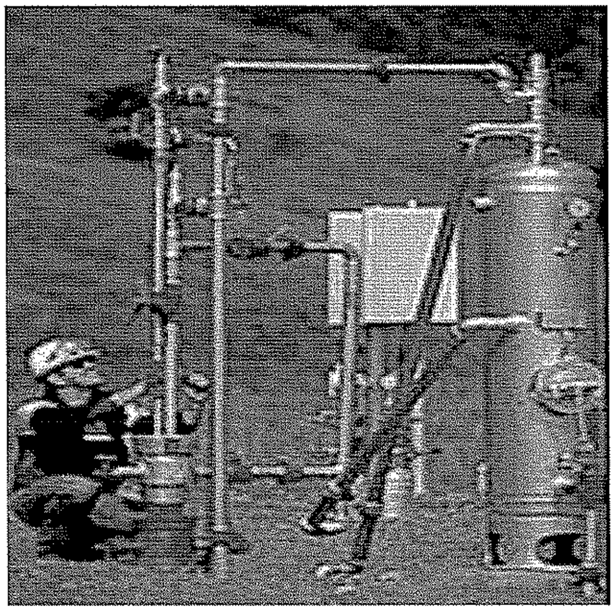
OKLAHOMA CORPORATION COMMISSION

OIL AND GAS CONSERVATION DIVISION
2ND Floor, Jim Thorpe Building
2101 N Lincoln Blvd
Oklahoma City, OK 73105



MANUAL OF BACK PRESSURE TESTING OF GAS WELLS

PART I
Field Testing Procedures

PART II
Basic Calculations with Examples

7/9/84

(THIS PAGE INTENTIONALLY LEFT BLANK)

<u>INTRODUCTION</u>

Recognizing the need for improved gas well testing and calculating procedures, the Oklahoma Corporation Commission and the Interstate Oil and Gas Compact Commission (IOGCC) prepared this **<u>Manual of Back Pressure testing of Gas Wells</u>**. The IOGCC Manual presents recommended testing, calculating, and reporting procedures for various types of gas well tests. The procedures herein are modeled after the IOGCC Manual, but deviate when dictated by State requirements or where past practices have indicated other procedures to be more applicable to well conditions existing in Oklahoma.

The testing, calculating, and reporting procedures contained in the Oklahoma Manual; Parts I and II, are to be substituted for the procedures contained in the IOGCC Manual. <u>Whenever a conflict of procedures exists between the Oklahoma Manual and the IOGCC Manual, the procedures in the Oklahoma Manual shall take precedence</u>.

All factors and constants necessary in the calculation of gas well tests shall be obtained from the IOGCC Manual. Reference is made in the basic calculations and examples contained herein to the appropriate tables in the IOGCC Manual. The terminology of the IOGCC Manual has been used throughout the Oklahoma Manual except where specifically noted.

(THIS PAGE INTENTIONALLY LEFT BLANK)

OKLAHOMA CORPORATION COMMISSION

MANUAL OF BACK PRESSURE TESTING OF GAS WELLS

Part I: **Field Testing Procedures**

Part II: **Basic Calculations with Examples**

Part III: **Interstate Oil and Gas Compact Commission Manual Of Back Pressure Testing of Gas Wells***

* The complete Oklahoma Manual of Back Pressure Testing of Gas Wells consists of three parts as listed above. Parts I and II are issued by the Oklahoma Corporation Commission, while the Interstate Manual is published by the IOGCC and may be obtained from them: 900 NE 23rd St, Oklahoma City, OK 73105.

RULES AND PROCEDURES

I. General Instructions

A. All back pressure tests required by the Oklahoma Corporation Commission, unless otherwise specified by applicable special pool rules, shall be conducted in accordance with the procedures set forth in this manual.

B. All well tests required by and submitted to the Oklahoma Corporation Commission shall not be performed until the well is connected to a gas transmission facility.

C. Unofficial well tests, for the use of the operator or purchaser only, may be made prior to connection to a gas transmission facility. The volume of gas vented during testing shall be the minimum required to obtain an accurate test and prior approval must be granted by the appropriate District Manager.

D. The initial test of a gas well must be witnessed by Corporation Commission personnel unless exempted by OAC 165:10-17-7(b)(1) of the General Rules.

E. Flow measurements shall be obtained by the use of an orifice meter or a gas turbine meter. The orifice shall be calibrated and the diameter of the orifice plate and meter run verified as to size, condition, and compliance with acceptable standards.

F. The specific gravity of the separator gas, the produced liquid, and the gas/liquid hydrocarbon ratio shall be determined.

G. The temperature of the gas column must be accurately known to obtain correct test results; therefore, a thermometer well shall be installed in the wellhead. Under shut-in or low flow rate conditions, the observed wellhead temperatures may be distorted by the external temperature. Whenever a thermometer well is not available, or when the wellhead temperature has been obviously distorted by the external temperature, a temperature of 60° F shall be used.

H. Calculations shall be made in the manner prescribed in the appropriate test example. All constants and factors utilized in the calculations shall be obtained from the IOGCC **Manual of Back Pressure Testing of Gas Wells**.

I. For increased accuracy the stepwise procedure for computing static column pressures shall be used for all wells having a wellhead shut-in pressure of 2,000 psig or greater.

J. All tests and calculations shall be subject to the review and approval of the Oklahoma Corporation Commission.

K. All surface pressure readings shall be taken with either a dead-weight or an electronic digital gauge. Pressure readings taken with a spring gauge will not be accepted.

II. Shut-In Pressures

A. Wells shall be produced for at least 24 hours prior to the shut-in at a flow rate large enough to clear the Wellbore of accumulated liquids. If the Wellbore cannot be cleared of accumulated liquids while producing into a pipeline, the well may be blown to the atmosphere to remove these liquids, with prior approval from the appropriate District Manager.

B. The shut-in pressure shall be recorded after the well has been shut in for a 24-hour period.

C. When multiple-completion wells are being tested, all zones shall be shut in at the same time for the purpose of obtaining the shut-in pressure on the zone that is to be tested. This procedure will eliminate any effect that a flowing column of gas may have on a static column of gas, due to temperature differentials, which may exist between the gas columns. The recording of pressures on all zones while shut in and during flow will indicate whether or not communication exists.

D. In the event liquid accumulation in the Wellbore during the shut-in period appreciably affects the surface pressure, a correction of the indicated surface pressure shall be made by calculating the surface pressure from an accurately determined sub-surface pressure. Refer to Test Example 3, page II-21; Test Example 4, page II-24; or Test Example 5, page II-29, whichever is applicable.

III. One-Point Stabilized Back Pressure Test Procedure

A. Flow Test

1. The wellhead flowing pressure and flow rate data shall be recorded at any time stabilization has been reached. The well shall be considered stabilized when the decrease in wellhead flowing pressure is less than 0.1 percent of the previously observed wellhead flowing pressure, psig, during any 15 minute period. If stabilization at the end of 24 hours may be utilized.

2. The static column wellhead pressure shall be no more than 90 percent of the wellhead shut-in pressure. If data cannot be obtained in accordance with the fore-going provisions, an assumed static column wellhead pressure of 90 percent of the wellhead shut-in pressure shall be used to calculate the results of the test.

3. At the end of the flow period, the flowing information shall be recorded:

   (a) flowing wellhead pressure
   (b) static column wellhead pressure, if obtainable
   (c) amount of liquid production
   (d) flowing wellhead temperature
   (e) duration of flow
   (f) all data pertinent to the gas metering device:
      (1) line size and orifice size
      (2) meter pressure
      (3) differential
      (4) temperature at point of measurement
      (5) type and size of meter

4. The rate at which the well is producing at the end of the flow period shall be considered the stabilized producing rate corresponding to the static column wellhead pressure existing at that time, provided such rate is not greater than the average producing rate for the entire flow period.

5. The initial test of any gas well shall be flowed for 24 hours and must be witnessed by Oklahoma Corporation Commission personnel unless exempted by OAC 165:10-17-7(b)(1).

B. Wellhead Calculations

1. The wellhead absolute open flow potential (WHAOF) will be determined from the equation:

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

2. The value 0.85 shall be used for the exponent "n" for all well tests except when otherwise specified by special pool rules requiring a four-point test to determine the value of the exponent "n".

3. The static column wellhead pressure is to be obtained, if possible.

4. When a well has been completed in such a manner that the static column wellhead pressure cannot be obtained, it shall be calculated as shown in Test Example 1 through 4, as applicable.

5. The average barometric pressure shall be assumed to be 14.40 psia.

6. All pressures used in the calculations shall be corrected to pounds per square inch absolute by adding the average barometric pressure of 14.40 psia to the metered gauge pressures.

IV. Multi-Point Back Pressure test Procedures – Special Pool Rules Only

When so required by special pool rules, multi-point back pressure tests shall be taken for the purpose of determining the wellhead open-flow potential and exponent "n".

A. Flow Tests

1. After recording the shut-in pressure, a series of at least four flow rates of the same duration and the pressures corresponding to each flow rate shall be taken. Each flow shall extend for a maximum period of two hours. If the decrease in wellhead flowing pressure is less than 0.1 percent of the previously observed wellhead flowing pressure, psig, during any 15-minute period prior to the end of the first two hour flow period, the pressure may be recorded and the next flow started. All subsequent flow periods shall be of the same duration as the first flow period.

2. All rates shall be run in the increasing flow rate sequence. In the case of high liquid ratio wells, or unusual temperature conditions, a decreasing flow rate sequence may be used if the increasing sequence method did not result in the alignment of points. If the decreasing sequence method is used, a statement giving the reason why the use of such method was necessary, together with a copy of the data taken by the increasing sequence method, shall be furnished to the Oklahoma Corporation Commission.

3. The lowest flow rate shall be sufficient to keep the Wellbore clear of all liquids.

4. In order to obtain a good alignment of points, the static column wellhead pressure, psig, at the lowest flow rate should be equal to or less than 95 percent of the shut-in pressure, psig, and at the highest flow rate, equal to or greater than 75 percent of the shut-in pressure, psig.

One criterion as to the acceptability of the test is a good spread of data points within the above limits. If data cannot be obtained in accordance with the fore-going provisions, an explanation shall be furnished to the Oklahoma Corporation Commission.

5. At the end of each flow rate, the following information shall be recorded:

   (a) flowing wellhead pressure
   (b) static column wellhead pressure, if obtainable
   (c) amount of liquid production
   (d) flowing wellhead temperature
   (e) duration of flow
   (f) all data pertinent to the gas metering device:
      (1) line size and orifice size
      (2) meter pressure
      (3) differential
      (4) temperature at point of measurement
      (5) type and size of meter

6. The stabilized one-point test data may be obtained by continuation of the last flow rate in the manner prescribed for Flow Test in the One-Point Stabilized Back Pressure Test Procedure. See Section III, IOGCC Manual.

B. Wellhead Calculations

1. The static column wellhead pressure must be obtained, if possible, at the end of each flow rate.

2. When a well has been completed in such a manner that the static wellhead pressure cannot be obtained, it shall be calculated as shown in Test Example 1 through 4, Part II, as applicable.

3. The average barometric pressure shall be assumed to be 14.40 psia. All pressures shall be in pounds per square inch absolute.

C. Plotting

1. The points for the back pressure curve shall be accurately and neatly plotted on equal-scale log-log paper of a minimum of three inches per cycle and a straight line drawn through the best average of three or more points. When no reasonable relationship can be established between three or more points, the well shall be retested.

2. The cotangent of the angle this line makes with the volume coordinate is the exponent "n" which is used in the back pressure equation:

$$Q = C(P_c^2 - P_w^2)^n$$

   The exponent "n" shall be calculated as shown in Section V, Basic Calculations, No. 5, page V-3, IOGCC Manual.

3. If the exponent "n" is greater than 1.000 or less than 0.500, the well shall be retested.

4. If, after retesting a well, a satisfactory test is not obtained, the Oklahoma Corporation Commission may grant an exception and assign a value of the exponent "n" to the well.

D. Calculation of Wellhead Open-Flow Potential

Using the pressure and volume corresponding with the highest rate of flow, which falls on the curve, calculate the wellhead open-flow potential from the equation:

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

V. Reporting

All required potential tests and production tests should be reported on Form 1016; original only to be filed.

(THIS PAGE INTENTIONALLY LEFT BLANK)

PART II – BASIC CALCULATIONS WITH EXAMPLES (SUPPLEMENT TO IOGCC TEST MANUAL

All constants and factors utilized in the calculations shall be obtained from the IOGCC **Manual of Back Pressure Testing of Gas Wells**. The nomenclature is given in the IOGCC Manual on Page II-1.

NUMBER 1. DETERMINATION OF COMPRESSIBILITY FACTOR (Z) AND SUPER-COMPRESSIBILITY FACTOR (F_{pv}) :

Using the data from the Field Data Sheet Test Example 1,

G_g (gravity of gas)	= 0.625
Carbon Dioxide	= 2%
Nitrogen	= 3%

From Table IX, determine P_{cr} and T_{cr} and make appropriate corrections for carbon dioxide and nitrogen content as determined from Table X, thus:

$$P_{cr} = 671 + 8 - 5 = 674$$
$$T_{cr} = 365 - 3 - 9 = 353$$

Using the two-hour data obtained from the first flow,

$$P_r = P_m / P_{cr} = 735.4 / 674 = 1.09$$
$$T_r = T_m / T_{cr} = 526 / 353 = 1.49$$

From Table XI for $P_r = 1.09$ and $T_r = 1.49$

$$Z = 0.891$$

From Table XII for $Z = 0.891$

$$F_{pv} = 1.059$$

NUMBER 2. CALCULATION OF THE RATE OF FLOW USING METER DATA:

$$Q = F_b * \sqrt{(h_w)(P_m)} * F_t * F_g * F_{pv}$$

Using the two-hour data obtained from the first flow,

$$Q = (17.23) * \sqrt{(8.3)(735.4)} * (0.9943)(1.265)(1.059)$$
$$= (17.23)(78.13)(0.9943)(1.265)(1.059)$$
$$= 1793 \text{ MCF/day}$$

Source of factors:

$F_b = 17.23$ (from Table II for 4-inch (4.026 ID) meter run and 1.750-inch orifice).

Note: Use Table I for flange tap meters.

$$\sqrt{(8.3)(735.4)} = \sqrt{6103.8} = 78.13$$

$F_t = 0.9943$ (from Table VII for temperature of 66° F)
$F_g = 1.265$ (from Table VIII for $G_g = 0.625$)
$F_{pv} = 1.059$ (from Basic Calculation No. 1, page II-1)

NUMBER 3. CALCULATION OF THE RATE OF FLOW USING CRITICAL FLOW PROVER DATA:

$$Q = F_p * P_m * F_t * F_g * F_{pv}$$

Source of factors:

F_p (from Table V for appropriate prover size and orifice diameter)
P_m (prover pressure, psia)

Note: Other factors are determined in the same manner as in Basic Calculation Number 2.

NUMBER 4. DETERMINATION OF THE EXPONENT n OF THE BACK PRESSURE EQUATION:

The exponent of the back pressure equation (n) shall be determined as follows:

$$n = \frac{\log Q_2 - \log Q_1}{\log (P_c^2 - P_w^2)_2 - \log (P_c^2 - P_w^2)_1}$$

If $(P_c^2 - P_w^2)_2$ is selected from the back pressure curve at a point one cycle greater than $(P_c^2 - P_w^2)_1$, then

$$n = \log Q_2 - \log Q_1, \text{ or}$$
$$n = \log (Q_2 / Q_1)$$

Using the back pressure curve in Test Example 1, (page II-10)

at $(P_c^2 - P_w^2)_2 = 3000$, $Q_2 = 10400$, and $\log Q_2 = 4.01703$
at $(P_c^2 - P_w^2)_1 = 300$, $Q_1 = 2000$, and $\log Q_1 = 3.30103$
$n = 4.01703 - 3.30103 = 0.716$

<u>NUMBER 5</u>. CALCULATION OF THE GAS GRAVITY OF THE FLOWING FLUID:

When the specific gravity of the well fluid is not known, but the specific gravity of the separator gas "G_g", the API gravity of the separator liquid, and the gas / liquid hydrocarbon ratio are known, the gas gravity of the flowing fluid "G" should be calculated as outlined in page C-1 of the IOGCC Manual. Example calculations are shown below:

Specific gravity of separator gas (G_g)	= 0.625
API gravity of separator liquid	= 50.2 @ 60° F
Gas / liquid hydrocarbon ration (GOR)	= 193 MCF / bbl
Specific gravity of separator liquid (G_1)	= 0.7787 (See Table XIII)
Cubic feet of vapor equivalent to one bbl of hydrocarbon liquid (V_1)	= 721 (See Page C-1)

$$G = \frac{0.625 + \frac{(4595)(0.7787)}{193{,}000}}{1 + \frac{721}{193{,}000}}$$

$= 0.641$

TEST EXAMPLE 1

FOUR-POINT BACK PRESSURE TEST

Calculation of Static Column Wellhead Pressure (P_w)
Corresponding to Wellhead Flowing Pressure (P_t)
Using Average Temperature and Compressibility Factors

NOTE: Test Example 1 is an example of a four-point back pressure test, to be used only when required by special pool rules for the purpose of determining the value of the exponent "n" in an initial testing situation. A four-point test must always be accompanied by an appropriate one-point test (which uses the value of "n" derived from the four-point test) to determine the absolute open flow potential of the well. Thereafter, as specific pool rules dictate, this four-point value of "n" will be used on all future annual one-point tests.

For those wells not under special pool rules and/or annual-status tests, please refer to Test Example 2 procedures.

Given a well flowing at a rate of 1793 MCF/day through 2 3/8-inch, 4.70 lb.-tubing, with a tubing working pressure, P_t of 1786.4 psia, H = 8130 feet, L = 8130 feet, L / H = 1.000, and flowing fluid gravity = 0.641, CO_2 = 2.0 percent, and N_2 = 3.0 percent, wellhead temperature = 74° F, reservoir temperature = 155° F @ 8130 feet, calculate the static column pressure P_w.

Step 1.

a. Enter well data as shown at the top of Form 1016b.

b. Obtain P_{cr} and T_{cr} from Table IX for a gas with a specific gravity of 0.641; obtain corrections for carbon dioxide = 2.0 percent, and nitrogen = 3.0 percent from Table X.

   Correct P_{cr} and T_{cr} as follows:

   $P_{cr} = 670 + 8 - 5 = 673$
   $T_{cr} = 372 - 3 - 9 = 360$

   (If the composition of the gas is known, P_{cr} and T_{cr} may be calculated directly from critical pressure and temperature data, Table A, Appendix E.)

c. Determine H, the vertical distance from the bottom of the flow string to the wellhead, for the well. Calculate L / H, the length of the flow string divided by the vertical distance. In most gas wells, L / H is one as H is equal to L. However, L / H is greater than one for directionally drilled wells. In this example, L / H is equal to 1.000.

d. GH = 0.641 * 8130 = 5211

Step 2.

a. Enter 1.793 rate of flow in line 1. (line references are indicated in parentheses following each step.)

b. T_w = Wellhead temperature, R = 74 + 460 = 534 (line 2).
T_b = Bottom-hole temperature, R = 155 + 460 = 615 (line 3).

The bottom-home temperature should be measured or estimated from reliable data on other wells in the area.

c. $T = (T_w + T_b) / 2 = (534 + 615) / 2 = 574.5$ (line 4).

Step 3.

Estimate effective compressibility factor. In this example, Z was estimated to be 0.825 (line 5).

Step 4.

a. TZ = 574.5 * 0.825 = 474.0 (line 6).

b. GH / TZ = 5211 /474/0 = 10.994 (line 7).

c. For GH / TZ = 10.994 read e^s and $(1-e^{-s})$ in table XIV.
$e^s = 1.510$ (line 8) and $(1-e^{-s}) = 0.338$ (line 9).

Step 5.

a. Flowing wellhead pressure, $P_t = 1786.4$ (line 10).

b. $P_t^2 = (1786.4)^2 / 1000 = 3191.2$ (line 11).

Step 6.

For flow string with d = 1.995 inches, F_r from Table XV is 0.017777 (line 12).

Step 7.

a. $F_c = F_r TZ = (0.017777)\ (474.0) = 8.426$ (line 13).

b. $F_c Q_m = (8.426)\ (1.793) = 15.11$ (line 14).

c. $L / H(F_c Q_m)^2 = (1.000)\ (15.11)^2 = 228.3$ (line 15).

d. $F_w = L / H(F_c Q_m)^2\ (1\text{-}e^{-s}) = (228.3)\ (0.338) = 77.2$ (line 16).

e. $P_w^2 = P_t^2 + F_w = 3191.2 + 77.2 = 3268.4$ (line 17).

Step 8.

a. $P_s^2 = e^s\ P_w^2 = (1.510)\ (3268.4) = 4935.3$ (line 18).

b. $P_s = \sqrt{P_s^2} = \sqrt{(14935.3)\ (1000)} = 2221.6$ (line 19).

c. $P = (P_t + P_s) / 2 = (1786.4 + 2221.6) / 2 = 2004.0$ (line 20).

d. $P_r = P / P_{cr} = 2004.0 / 673 = 2.98$ (line 21).

e. $T_r = T / T_{cr} = 574.5 / 360 = 1.60$ (line 22).

Step 9.

Enter in line 23 the compressibility factor from Table XI corresponding to a P_r of 2.98 and a T_r of 1.60. In this example, Z = 0.826 (line 23).

Step 10.

Since Z (line 23) is not equal to Z (line 5), enter Z = 0.826 on line 5, second trial, and repeat steps 4 through 9.

Step 11.

Since the final value of Z (line 23, second trail) is equal to the assumed value of Z (line 5, second trial), the value of $P_w^2 = 3268.5$ (line 17, second trial) is then used in the back pressure computations Form 1016 (page II-9).

FORM 1016a
1975

OKLAHOMA CORPORATION COMMISSION — OIL & GAS CONSERVATION DIVISION

380 Jim Thorpe Building — Oklahoma City, Oklahoma 73105

BACK-PRESSURE TEST FOR NATURAL GAS WELLS

(RULE 2-308)

TYPE TEST: 4-point [X] INITIAL [ ] ANNUAL [ ] SPECIAL		TEST DATE 7/7/83		OKLAHOMA TAX COMMISSION ASSIGNED LEASE NO.
COMPANY Test Example 1	CONNECTION (Name of Purchaser)			059-000000-0
FIELD Mocane-LaVerne	RESERVOIR Morrow (Pool #93)	LOCATION SW/4 NE/4		UNIT
COMPLETION DATE 4/5/83	TOTAL DEPTH 8320	PLUG BACK TO 8250	ELEVATION 2025	FARM OR LEASE NAME Test Example
CSG. SIZE 7" OD	WT. 23.00 # d 6.366	SET AT 8293	PERFORATIONS: FROM 8112 TO 8148	WELL NO. #1
TBG. SIZE 2 3/8" OD	WT. 4.70 # d 1.995	SET AT 8134	PERFORATIONS: FROM 8127 TO 8132	SEC. 5 TWP. 28N RGE. 26W
TYPE COMPLETION (DESCRIBE) Single Gas			PACKER SET AT 8100	COUNTY Harper
PRODUCING THRU Tubing	RESERVOIR TEMP. F 155 @ 8130	MEAN GROUND TEMP. F 60	BARO. PRESS.— Pa 14.4	STATE Oklahoma

L	H	G_g	%CO_2	%N_2	%H_2S	PROVER	METER RUN	TAPS
8130	8130	0.625	2.0	3.0	0.0		4"	Pipe

DATE Time of Reading	ELAP. TIME Hrs.	WELLHEAD WORKING PRESSURE Tbg. Psig	Csg. Psig	Temp. F	METER OR PROVER Pressure Psig	Diff.	Temp. F	Orifice	REMARKS (Include liquid production data: Type — API Gravity — Amount)
7/7/83									St Tk 3' 7 1/8" 60F
7:45A		1864.0	Packer						72 hour shut-in pressure
8:00A									Start 1st Flow
8:30A		1809.0		74	718.0	7.0	60	1.75	
9:00A		1793.0		74	720.0	8.0	59		
9:30A		1779.0		74	721.0	8.4	64		
10:00A		1772.0		74	721.0	8.3	66		St Tk 3' - 7 1/2" 60F
10:00A									Increased Rate for 2nd Flow
10:30A		1765.0		74	719.0	15.0	54	1.75	
11:00A		1742.0		74	719.0	15.5	54		
11:30A		1728.0		74	722.0	15.7	55		
12:00N		1698.0		74	729.0	17.5	56		St Tk 3' - 8 1/4" 60F
12:00N									Increased Rate for 3rd Flow
12:30P		1705.0		74	739.0	24.0	43	1.75	
1:00P		1672.0		74	740.0	25.5	46		
1:30P		1633.0		74	742.0	27.5	50		
2:00P		1608.0		74	744.0	29.3	54		St Tk 3' - 9 1/8" 60F
2:00P									Increased Rate for 4th Flow
2:30P		1630.0		74	745.0	38.0	44	1.75	
3:00P		1587.0		74	746.0	39.3	46		
3:30P		1539.0		74	749.0	41.5	52		API - 50.2° at 60F
4:00P		1512.0		74	759.0	41.5	55		
									Tank Size - 12' Diameter
									1.68 Barrels/inch

PAGE 1 OF 1 DATA BY ____

FORM 1016b
(1975)

OKLAHOMA CORPORATION COMMISSION – OIL & GAS CONSERVATION DIVISION
380 JIM THORPE BUILDING, OKLAHOMA CITY, OKLAHOMA 73105
WORK SHEET FOR CALCULATION OF STATIC COLUMN WELLHEAD PRESSURES (P_c or P_w)

COMPANY ABC Oil Company LEASE Test Example WELL NO. #1 DATE 7/7/83

L 8130 M 8130 L/H 1.000 G 0.641 %CO_2 2.0 %N2 3.0 %H_2S 0.0

d 1.995" F_r 0.017777 GH 5211 P_{cr} 673 T_{cr} 360

LINE		1st Rate 1st trial	1st Rate 2nd trial	2nd Rate 1st trial	2nd Rate 2nd trial	3rd Rate 1st trial	3rd Rate 2nd trial	4th Rate 1st trial	4th Rate 2nd trial		
1.	Q_m	1.793	1.793	2.659	2.659	3.488	3.488	4.192	4.192		
2.	Tw	534	534	534	534	534	534	534	534		
3.	Ts	615	615	615	615	615	615	615	615		
4.	T	574.5	574.5	574.5	574.5	574.5	574.5	574.5	574.5		
5.	Z	0.825	0.826	0.833	0.829	0.833	0.832	0.833	0.835		
6.	TZ	474.0	474.5	478.6	476.3	478.6	478.0	478.6	479.7		
7.	GH/TZ	10.994	10.982	10.888	10.941	10.888	10.902	10.888	10.863		
8	e^s	1.510	1.510	1.504	1.507	1.504	1.505	1.504	1.503		
9.	$1-e^{-s}$	0.338	0.338	0.335	0.336	0.335	0.336	0.335	0.335		
10.	P_c OR P_t	1786.4	1786.4	1712.4	1712.4	1622.4	1622.4	1526.4	1526.4		
11.	P_c^2 OR P_t^2	3191.2	3191.2	2932.3	2932.3	2632.2	2632.2	2329.9	2329.9		
12.	Fr	0.017777	0.017777	0.017777	0.017777	0.017777	0.017777	0.017777	0.017777		
13.	$F_c = F_r TZ$	8.426	8.435	8.508	8.467	8.508	8.497	8.508	8.528		
14.	$F_c Q_m$	15.11	15.12	22.62	22.51	29.68	29.64	35.67	35.75		
15.	$L/H (F_c Q_m)^2$	228.3	228.6	511.7	506.7	880.9	878.5	1272.3	1278.1		
16.	$F = L/H (F_c Q_m)^2 (1-e^{-s})$	77.2	77.3	171.4	170.3	295.1	295.2	426.2	428.2		
17.	$P_w^2 = P_t^2 + F_w$	3268.4	3268.5	3103.7	3102.6	2927.3	2927.4	2756.1	2758.1		
18.	P_f^2 or $P_s^2 = e^s P_c^2$ or $e^s P_w^2$	4935.3	4935.4	4668.0	4675.6	4402.7	4405.7	4145.2	4145.4		
19.	P_f or P_s	2221.6	2221.6	2160.6	2162.3	2098.3	2099.0	2036.0	2036.0		
20.	P	2004.0	2004.0	1936.5	1937.4	1860.4	1860.7	1781.2	1781.2		
21.	P_r	2.98	2.98	2.88	2.88	2.76	2.76	2.65	2.65		
22.	Tr	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60		
23.	Z	0.826	0.826	0.829	0.829	0.832	0.832	0.835	0.835		

FORM 1016
(1982) REV.

BACK — PRESSURE TEST FOR NATURAL GAS WELLS
(RULE 2-308)

TYPE TEST: 4-Point	INITIAL X	ANNUAL	RETEST	TEST DATE 7/7/83
COMPANY Test Example 1		CONNECTION (Name of Purchaser)		DATE OF 1ST SALES 5/20/83
FIELD Mocane-LaVerne	ALLOCATED POOL NO. 93	RESERVOIR Morrow		LOCATION SW/4 NE/4
COMPLETION DATE 4/5/83	TOTAL DEPTH 8320	PLUG BACK TO 8250		ELEVATION 2025

OKLAHOMA TAX COMMISSION ASSIGNED LEASE NO. 059-99999

UNIT

FARM OR LEASE NAME Test Example

WELL NO. #1

SEC. 5 TWP. 28N RGE. 26W

COUNTY Harper

STATE Oklahoma

	WT.	d	SET AT	PERFORATIONS: FROM	TO
CSG. SIZE 7" OD	23.00#	6.366	8293	8112	8148
TBG. SIZE 2 3/8" OD	4.70	1.995	8134	8127	8132

TYPE COMPLETION (DESCRIBE) Single gas — PACKER SET AT 8100

PRODUCING THRU Tubing — RESERVOIR TEMP. F 155 @ 8130 — MEAN GROUND TEMP. F 60 — BARTO. PRESS.-P_a 14.4

L	H	G_g	% CO_2	% N_2	% H_2S	PROVER	METER RUN	TAPS
8130	8130	0.625	2.0	3.0	0.0		4"	Pipe

NO.	FLOW DATA: (PROVER) (LINE) X ORIFICE SIZE SIZE	PRESS. PSIG	DIFF. (INCHES)	TEMP. F	TUBING DATA: PRESS. PSIG	TEMP. F	CASING DATA: PRESS. PSIG	TEMP. F	DURATION OF FLOW HR.
SI					1864.0		Packer		72
1.	4 x 1.750	721.0	8.3	66	1772.0	74			2
2.	4 x 1.750	729.0	17.5	56	1698.0	74			2
3.	4 x 1.750	744.0	29.3	54	1608.0	74			2
4.	4 x 1.750	759.0	41.5	55	1512.0	74			2
5.									

RATE OF FLOW CALCULATIONS

NO.	COEFFICIENT (24-HOUR)	$\sqrt{h_w P_m}$	PRESSURE P_m	FLOW TEMP. FACTOR F_t	GRAVITY FACTOR F_g	SUPER COMPRESS. FACTOR F_{pv}	RATE OF FLOW Q. MCFD
1.	17.23	78.13	735.4	0.9943	1.265	1.059	1793
2.	17.23	114.1	743.4	1.004	1.265	1.065	2659
3.	17.23	149.1	758.4	1.006	1.265	1.067	3488
4.	17.23	179.2	773.4	1.005	1.265	1.068	4192
5.							

NO.	P_r	TEMP. R	T_r	Z
1.	1.09	526	1.49	0.891
2.	1.10	516	1.46	0.882
3.	1.13	514	1.46	0.879
4.	1.15	515	1.46	0.877
5.				

GAS LIQUID HYDROCARBON RATIO 193 MCF/BBL

API GRAVITY OF LIQUID HYDROCARBONS 50.2 DEG.

SPECIFIC GRAVITY SEPARATOR GAS 0.625 | XXXXXXXXXXXX

SPECIFIC GRAVITY FLOWING FLUID XXXXXXXXXXXXX | 0.641

CRITICAL PRESSURE 674 PSIA | 673 PSIA

CRITICAL TEMPERATURE 353 R | 360 R

P_C 1878.4 P_C^2 3528.4

NO.	P_w	P_w^2	$P_C^2 - P_w^2$
1.	1807.4	3268.5	259.9
2.	1761.4	3102.5	425.9
3.	1711.0	2927.5	600.9
4.	1660.7	2757.9	770.5
5.			

(1) $\frac{P_C^2}{P_C^2 - P_w^2} = 4.579$ (2) $\left[\frac{P_C^2}{P_C^2 - P_w^2}\right]^n = 2.972$

$$\text{WHAOF} = Q\left[\frac{P_C^2}{P_C^2 - P_w^2}\right]^n = 12460$$

CALCULATED WELLHEAD OPEN FLOW 12460 MCFD @ 14.65 | ANGLE OF SLOPE 54° | SLOPE, n .716

REMARKS:

APPROVED BY COMMISSION:	CONDUCTED BY:	CALCULATED BY:	CHECKED BY:

(OVER)

HAS THE ALLOWABLE FOR THIS WELL BEEN ADJUSTED BY COMMISSION ORDER? ________

IF SO STATE ORDER NUMBER ________________

I, ______________________, BEING FIRST DULY SWORN ON OATH, STATE THAT I AM FAMILIAR WITH FACTS AND FIGURES SET FORTH IN THIS REPORT, AND THAT THE REPORT IS TRUE AND CORRECT.

____

SIGNATURE AND TITLE OF AFFIANT

____

COMPANY

SUBSCRIBED AND SWORN TO BEFORE ME THIS ________ DAY OF ________________, 19 ____

MY COMMISSION EXPIRES

____

NOTARY PUBLIC

PC = SHUT - IN PRESSURE, PSIA (LENGTH OF SHUT - IN MINIMUM OF 24 HOURS).
PW = STATIC COLUMN WELLHEAD PRESSURE CORRESPONDING TO THE FLOWING WELLHEAD PRESSURE, PSIA (TO BE RECORDED AT END OF EACH FLOW RATE.)

Gg = SPECIFIC GRAVITY OF SEPARATOR GAS (AIR = 1.000).

L = LENGTH OF HE FLOW STRING FROM THE MIDDLE OF THE PRODUCING FORMATION TO THE PRESSURE POINT AT WELL HEAD, FEET.

H = VERTICAL DEPTH CORRESPONDING TO L, FEET.

Q = 24 HOUR RATE OF FLOW, MCFD.

d = INSIDE DIAMETER, INCHES.

R = DEGREES, RANKINE (DEGREES FAHRENHEIT ABSOLUTE).

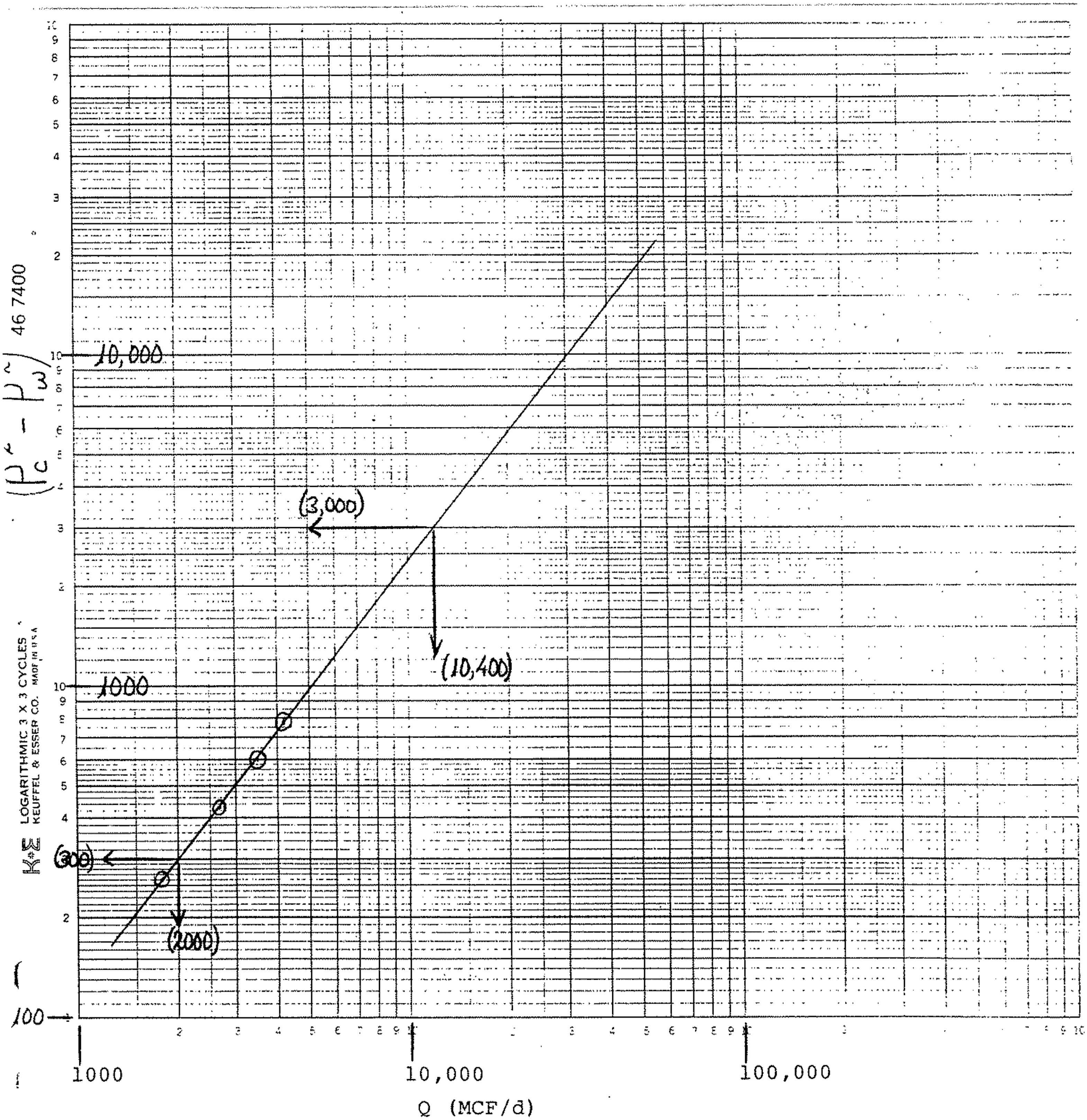
Pr = REDUCED PRESSURE, DIMENSIONLESS.

Tr = REDUCED TEMPERATURE, DIMENSIONLESS.

z = COMPRESSIBILITY FACTOR, DIMENSIONLESS.

TEST EXAMPLE 1

NOTE: COMPLETELY IDENTIFY WELL (COMPANY, WELL NAME, NUMBER)



$(P_c^2 - P_{w^2}^2)_2 = 3000$ $\quad Q_2 = 10400$ $\quad \text{Log } Q_2 = 4.01703$

$(P_c^2 - P_\omega^2)_1 = 300$ $\quad Q_1 = 2000$ $\quad \text{Log } Q_1 = 3.30103$

0.7161

TEST EXAMPLE 2

Calculation of Static Column Wellhead Pressure (P_w)
Corresponding to Wellhead Flowing Pressure (P_t)
USING STEPWISE PROCEDURE

Given a wellhead flowing pressure of 1689.4 psia at a flow rate of 843.4 MCF/day, calculate the equivalent static column pressure at the wellhead (P_w).

Flow string: 22,120 feet of 2 7/8-inch, 6.50-lb. tubing. The flow string is vertical, H = L.

Computations are given on Form 1016c (in the example) which solves the equation D-20 by trial and error. The steps in the computation are as follows:

Step 1.

Obtain the inside diameter and corresponding F_r values from Table XV and enter at the top of Form 1016c:

$d = 2.441 \qquad F_r = 0.010495$

$$L / H(F_r Q_m)^2 = 1.0000\ (0.010495 * 0.8434)^2 = 0.000078$$

Step 2.

Determine the temperature gradient applicable to the problem. In this example, the flowing temperature of the gas at the wellhead was 60° F and the subsurface temperature at 22,120 feet was 290° F. The temperature was assumed to be a straight-line relationship between 60° F at H = 0 and 290° F at H = 22120 feet. The temperature at the midpoint of the 2 7/8-inch tubing string (22,120 ft/2 = 11,060 ft) is :

$$(290 - 60)\frac{11{,}060}{22{,}120} + 60 = 175° \text{ F}$$

or

$$175° \text{ F} + 460 = 635° \text{ R}$$

STEP 3.

Enter H = 0 in line 1, column 1. (Line references are indicated in parentheses following each step, column references unchanged unless indicated).

a. Line 1, 2, and 3 in column 1 = 0.

b. P_t = 1689.4 psia which is the measured wellhead pressure (line 4).

c. P_r = wellhead pressure divided by the critical pressure; 1689.4 / 680 = 2.4844 (line 5). Use 2.48.

d. T = wellhead temperature, 60° F + 460 = 520° R (line 6).

e. T_r = wellhead temperature (R) divided by the critical temperature, 520 / 340 = 1.5294 (line 7). Use 1.53.

f. Z = compressibility factor of gas at a P_r of 2.48 and a T_r of 1.53 (line 8). From Table XI, Z = 0.810.

g. P / Z = 1689.4 / 0.810 = 2086 (line 9).

h. P / TZ = 2086 / 520 = 4.0115 (line 10).

i. $(P / TZ)^2 / 1000 = (4.0115)^2 / 1000 = 0.016092$ (line 11).

j. $(1 / H) (F_rQ_m)^2 = 0.000078$ (line 12).

k. Add (line 11) and (line 12), 0.016092 + 0.000078 = 0.016170 (line 13).

l. I_t = (line 10) / (line 13) = 4.0115 / 0.016170 = 248.083 (line 14).

Step 4.

Make first trial calculation for the pressure at H / 2, 22,120 / 2 = 11,060 feet (line 1, column 2):

a. Compute GH and 37.5GH. GH = 0.579 * 11,060 = 6403.74 (line 2).
37.5 GH = 37.5 * 6403.74 = 240,140 (line 3)

b. Estimate value of M as follows: 37.5GH / (2 * I) = 240,140 / (2 * 248.083) = 484 (line 15, column 2).

c. $P_1 = M + P_t$ = 484 + 1689.4 = 2173.4 psia (line 4).

d. Compute P_r and T_r, enter appropriate Z (line 8); compute P / Z, P / TZ, and $(P / TZ)^2 / 1000$; enter appropriate values in (lines 9, 10, and 11 respectively).

e. Since L / H = 1.000 and neither F_r nor Q_m have changed, $(L / H)(F_rQ_m)^2$ = 0.000078 (line 12).

f. (Line 11 + line 12) = 0.014147 + 0.000078 + 0.014225 (line 13).

g. I_1 = (line 10) / (line 13) = 3.7612 / 0.014225 = 264.408 (line 14).

h. N = I_t + trial I_1 = 248.083 + 264.408 = 512.491 (line 16).

i. Divide 37.5GH by N, 240,140 / 512.491 = 469 (line 15, column 3).

j. When M has been estimated correctly, the value determined under (i) equals M estimated under (b).

k. Enter 469 under M (line 15, column 3) and repeat items (c) through (i) until a correct value of M is determined in accordance with item (j).

l. Multiply final values of M and N, 467 * 514.564 = 240,301 (line 17).

m. Enter value of M * N under ∑(M * N) (line 18).

Step 5.

Make first trial calculation for the pressure at H = 22,120 feet (line 1, column 5).

a. Compute GH and 37.5GH: GH = 0.579 * 22,120 = 12,807.48 (line2) and 37.5GH = 37.5 * 12,807.48 = 480,281 (line 3).

b. Estimate value of M by dividing N (line 16, column 4) into the difference, 37.5GH (line 3, column 5) minus (M * N), (line 17, column 4). Thus (480,281 – 240,301) / 514.564 = 466.

c. $P_2 = M + P_1$ = 466 + 2156.4 = 2622.4 (line 4).

d. Compute P_r and T_r, enter appropriate Z (line 8); compute P / Z and $(P / TZ)^2 / 1000$, enter appropriate values in (lines 9, 10 and 11 respectively).

e. $L / H(F_rQ_m)^2$ = 0.000078 (line 12).

f. (Line 11 + line 12) = 0.013152 (line 13).

g. I_2 = (line 10) / (line 13) = 3.6159 / 0.013152 = 274.932 (line 14).

h. N = I_1 + trial I_2 = 266.481 + 274.932 = 541.413 (line 16).

i. Divide N (line 16) into the difference, 37.5GH (line 3) minus (M * N) (line 17, column 4), thus 480,281 − 240,301 / 541.413 = 443 (line 15, column 6).

j. When M has been estimated correctly, the value determined under (i) equals M estimated under (b).

k. Enter 443 under M (line 15, column 6) and repeat items (c) through (i) until a correct value of M is determined in accordance with item (j).

l. Add M * N (line 17, column 7) and ∑(M * N) (line 18, column 4); 239,914 + 240,301 = 480,215 (line 18, column 7).

Step 6.

Using equation D-22, calculate ΔP by substituting 248.083 (line 14, column 1) for I_t, 266.481 (line 14, column 4) for I_1, and 277.542 (line 14, column 7) for I_2 as indicated by the calculations listed below. By equation D-21, the result is $P_s = P_t + \Delta P$:

D-22: $$\Delta P = \frac{3(37.5GH)}{I_t + 4I_1 + I_2} = \frac{3(480{,}281)}{248.083 + 4(266.481) + 277.542} = 905.3$$

D-21: $$P_s = P_t + \Delta P = 1689.4 + 905.3 = 2594.7 \text{ psia}$$

The flowing pressure at 22,120 feet is 2594.7 psia which is the required pressure for the next major step in the calculations. The following steps are the calculations for converting this pressure to a static column pressure at the wellhead.

Step 7.

From page 1 of Form 1016c, transfer the following information from the last column to column 1, page 2 of Form 1016c: H = 22,120, GH = 12,807.48, 37.5GH = 480,281, P_n = 2594.7, P_r = 3.82, T = 750, T_r = 2.21, Z = 0.967, P / Z = 2686, and P / TZ = 3.5814.

a. Lines 11, 12 and 13 can be omitted in the static column case. Where $Q_m = 0$, $L / H(F_dQ_m)^2$ must also be zero, therefore, I_n resolves:

$$I_n = (P / TZ) \Big/ \left[\frac{(P / TZ)^2}{1000} + L / H(F_rQ_m)^2\right] = \frac{1000}{(P / TZ)}$$

$I_s = 1000 / 3.5814 = 279.220$

b. Enter value of 37.5Gh = 480,281 from line 3 to line 18.

Step 8.

Make first trial calculation for the pressure at H / 2 = 22,120 / 2 = 11,060 (line 1, column 2) as follows:

a. H = 11,060 (line 1).

b. GH = (0.579) (11,060) = 6403.74 (line 2).

c. 37.5GH = (37.5) (6403.74) = 240,140 (line 3).

d. Estimate the value of M by dividing $2I_s$ (line 14, column 1) into the difference between $\Sigma(M * N)$ (line 18, column 1) and 37.5GH (line 3, column 2): (480,281 – 240,140 / 2 * 279.220 = 430 (line 15), then $P_1 = P_s - M$ = 2594.7 – 430 = 2164.7 (line 4).

e. P_r = 2164.7 / 680 = 3.18 (line 5).

f. T = estimated temperature at 11,060 feet = (60 + 290) / 2 + 460 = 635 (line 6).

g. T_r = 635 / 340 = 1.87 (line 7).

h. Z = compressibility factor of a gas at a P_r of 3.18 and a T_r of 1.87 = 0.911 (line 8).

i. P / Z = 2164.7 / 0.911 = 2376 (line 9).

j. P / TZ = 2376 / 635 = 3.7420 (line 10).

k. I_1 = 1000 / (P / TZ) = 267.237 (line 14).

l. N = I_s (column 1) + I_1 Trial 1 (column 2) = 279.220 + 267.237 = 546.457 (line 16).

m. M = 37.5GH / N = 240,140 / 546.457 = 439. When M has been correctly estimated, the value determined under this step will be equal to M as estimated under (d).

n. Enter M = 439 (line 15, column 3). P_1 (line 4, column 3) is then $P_s - M$ = 2594.7 – 439 = 2155.7.

o. Repeat steps (d) through (m) until the correct value of M is determined in accordance with (m).

p. Multiply final values of M and N: 439 * 547.568 = 240,382 (line 17, column 3).

q. Subtract (M * N) (line 17) from Σ(M * N) (line 18, column 1): 480,281 – 240,382 = 239,899 (line 18).

<u>Step 9</u>.

Make first trial calculation for the pressure at H = 0 (line 1, column 4).

a. GH = 0 (line 2).

b. 37.5GH = 0 (line 3).

c. Estimate M by dividing N (line 16, column 3) into line 18, column 3 = 239,899 / 547.568 = 438 (line 15, column 4)

d. Subtract M from P_1 value found at H = 11,060. 2155.7 – 438 = 1717.7 (line 4, column 4).

e. P_r = 1717.7 / 680 = 2.53 (line 5).

f. T = 60 + 460 = 520 (line 6).

g. T_r = 520 / 340 = 1.53 (line 7).

h. Z = compressibility factor of gas at a P_r of 2.53 and a T_r of 1.53 = 0.807 (line 8).

i. P / Z = 1717.7 / 0.807 = 2129 (line 9).

j. P / TZ = 2129 / 520 = 4.0942 (line 10).

k. I_c = 1000 / 4.0942 = 244.248 (line 14).

l. N = 244.248 + 268.348 = 512.596 (line 16).

m. Divide (M * N) (line 18, column 3) by N (line 16, column 4) = 239,899 / 512.596 = 468. When M has been estimated correctly, the value determined under this step will be equal to M as estimated under (c).

n. Enter M = 468 (line 15, column 5). Trial P_w (line 4, column 5) is then P_1 = M = 2155.7 – 468 = 1687.7 (line 4, column 5).

o. Repeat items (c) through (m) until the correct value of M is determined in accordance with item (m).

p. Multiply final values of M and N: 464 * 517.030 = 239,902 (line 17, column 7).

<u>Step 10</u>.

Using equation D-19, calculate ΔP by substituting 248,682 (line 14, column 7) for I_c, 268.348 (line 14, column 3) for I_1, and 279.220 (line 14, column 1) for I_2 as indicated by calculations below:

D-19: $$\Delta P = \frac{3(37.5GH)}{I_c + 4I_1 + I_2} = \frac{3(480{,}281)}{248.682 + 4(268.348) + 279.220}$$

$$= 899.8$$

D-20: $$P_w = P_s - \Delta P = 2594.7 - 899.8$$

$$= 1694.9 \text{ psia}$$

The static column wellhead pressure (P_w) is 1694.9 psia, which is the final factor needed to determine the absolute open flow potential of the well. Use this value of P_w along with P_c to determine coefficients (steps 1 and 2 near bottom of Form 1016). The absolute open flow potential is derived by multiplying the coefficient in step 2 by the rate of flow Q.

In this example, WHAOF = 1.516 * 843.4 = 1279 MCF / day.

FORM 1016c
1975

OKLAHOMA CORPORATION COMMISSION — OIL & GAS CONSERVATION DIVISION
380 JIM THORPE BUILDING, OKLAHOMA CITY, OKLAHOMA 73105
WORK SHEET FOR CALCULATION OF STATIC COLUMN WELLHEAD PRESSURES (P_c or P_w)

COMPANY Test Example 2 LEASE (Farm Name) WELL NO. #2 DATE 1/9/84

L 22120 H 22120 L/H 1.000 G 0.579 $\%CO_2$ 1.89 $\%N_2$ 0.39 $\%H_2S$ 0.0

d 2.441 F_r .010495 Q_m 843.4 M^2cfd $(L/H)(F_rQ_m)^2$ .000078 P_{cr} 680 T_{cr} 340

LINE	ITEM	SOURCE	1	2	3	4	5	6	7	8	9	10
1.	H		0	11060			22120					
2.	GH		0	6403.74			12807.48					
3.	37.5GH		0	240140			480281					
4.												
4.	P_n		1689.4	2173.4	2158.4	2156.4	2622.4	2599.4	2597.4			
5.	P_r		2.48	3.20	3.17	3.17	3.86	3.82	3.82			
6.	T		520	635	635	635	750	750	750			
7.	T_r		1.53	1.87	1.87	1.89	2.21	2.21	2.21			
8.	Z		0.810	0.910	0.910	0.910	0.967	0.967	0.967			
9.	P/Z	$\overline{4} \div \overline{8}$	2086	2388	2372	2370	2712	2688	2686			
10.	P/T·Z	$\overline{9} \div \overline{6}$	4.0115	3.7612	3.7352	3.7318	3.6159	3.5841	3.5814			
11.	$(P/TZ)^2$ 1000	$(\overline{10})^2/1000$	.016092	.014147	.013952	.013926	.013074	.012846	.012826			
12.	$L/H\,(F_rQ_m)^2$		.000078	.000078	.000078	.000078	.000078	.000078	.000078			
13.		$\overline{11} + \overline{12}$	.016170	.014225	.014030	.014004	.013152	.012924	.012904			
14.	In	$\overline{10} \div \overline{13}$	248.083	264.408	266.230	266.481	274.932	277.321	277.542			
15.	$M = P_n - P_{n-1}$			484	469	467	466	443	441			
16.	$N = I_n + I_{n-1}$			512.491	514.313	514.564	541.413	543.802	544.023			
17.	M X N	$\overline{15} \times \overline{16}$				240301			239914			
18.	$\sum (M \times N)$	$\sum \overline{17}$				240301			480215			

$\Delta P = (3(37.5GH))/(I_t + 4I_1 + I_2)$

$P_s = P_t + \Delta P$

$P_s = 2594.7$

FORM 1016c
1975

OKLAHOMA CORPORATION COMMISSION — OIL & GAS CONSERVATION DIVISION
380 JIM THORPE BUILDING, OKLAHOMA CITY, OKLAHOMA 73105
WORK SHEET FOR CALCULATION OF STATIC COLUMN WELLHEAD PRESSURES (P_c or P_w)

COMPANY Test Example 2 LEASE (Farm Name) WELL NO. #2 DATE 1/9/84

L 22120 H 22120 L/H 1.000 G 0.579 $\%CO_2$ 1.89 $\%N_2$ 0.39 $\%H_2S$ 0.0

d 2.441 F_r .010495 Q_m 843.4 M^2cfd $(L/H)(F_rQ_m)^2$ .000078 P_{cr} 680 T_{cr} 340

LINE	ITEM	SOURCE	1	2	3	4	5	6	7	8	9	10
1.	H		22120	11060		0						
2.	GH		12807.48	6403.74		0						
3.	37.5GH		480281	240140		0						
4.												
4.	P_n		2594.7	2164.7	2155.7	1717.7	1687.7	1692.7	1691.7			
5.	P_r		3.82	3.18	3.17	2.53	2.48	2.49	2.49			
6.	T		750	635	635	520	520	520	520			
7.	T_r		2.21	1.87	1.87	1.53	1.53	1.53	1.53			
8.	Z		0.967	0.911	0.911	0.807	0.810	0.809	0.809			
9.	P/Z	$\overline{4} \div \overline{8}$	2686	2376	2366	2129	2084	2092	2091			
10.	P/TZ	$\overline{9} \div \overline{6}$	3.5814	3.7420	3.7265	4.0942	4.0077	4.0231	4.0212			
11.	$(P/TZ)^2$ 1000	$(\overline{10})^2/1000$										
12.	$L/H\,(F_r Q_m)^2$											
13.		$\overline{11} + \overline{12}$										
14.	In	$\overline{10} \div \overline{13}$	279.220	267.237	268.348	244.248	249.520	248.565	248.682			
15.	$M = P_n - P_{n-1}$			430	439	438	468	463	464			
16.	$N = I_n + I_{n-1}$			546.457	547.568	512.596	517.868	516.913	517.030			
17.	M X N	$\overline{15} \times \overline{16}$			240382				239902			
18.	$\sum (M \times N)$	$\sum \overline{17}$	480281		239899							

$\Delta P = (3(37.5GH))/(I_c + 4I_1 + I_2)$ $P_w = P_s - \Delta P$ $P_w = 1694.9$

FORM 1016
(1982) REV.

BACK — PRESSURE TEST FOR NATURAL GAS WELLS
(RULE 2-308)

TYPE TEST: One-point	INITIAL X	ANNUAL	RETEST	TEST DATE 1/9/84	OKLAHOMA TAX COMMISSION ASSIGNED LEASE NO. 109-99999
COMPANY Test Example 2		CONNECTION (Name of Purchaser)		DATE OF 1ST SALES 11/25/83	
FIELD Oklahoma City	ALLOCATED POOL NO. Unalloc	RESERVOIR Viola		LOCATION NE/4 SE/4	UNIT
COMPLETION DATE 10/4/83	TOTAL DEPTH 22884	PLUG BACK TO 22746		ELEVATION 1223	FARM OR LEASE NAME Test Example
CSG. SIZE 9 5/8	WT. 53.5	d 8.535	SET AT 22884	PERFORATIONS: FROM TO	WELL NO. #2
TBG. SIZE 2 7/8	WT. 6.50	d 2.441	SET AT 22120	PERFORATIONS: FROM TO 22284-22346	SEC. 27 TWP. 12N RGE. 3W
TYPE COMPLETION (DESCRIBE) Single				PACKER SET AT 22120	COUNTY Oklahoma
PRODUCING THRU Tubing	RESERVOIR TEMP. F 290 @ 22120	MEAN GROUND TEMP. F 60		BARTO. PRESS.-P_a 14.4	STATE Oklahoma

L	H	G_g	% CO_2	% N_2	% H_2S	PROVER	METER RUN	TAPS
22120	22120	.579	1.89	0.39	0.0		4.026	Flange

	FLOW DATA				TUBING DATA		CASING DATA		
NO.	(PROVER) (LINE) X ORIFICE SIZE SIZE	PRESS. PSIG	DIFF. (INCHES) X (ROOTS)	TEMP. F	PRESS. PSIG	TEMP. F	PRESS. PSIG	TEMP. F	DURATION OF FLOW. HR.
SI					2710	60	0	60	
1.	4.0 x 1.000	689.44	22.56	65	1675	60	0	60	24.0
2.									
3.									
4.									
5.									

RATE OF FLOW CALCULATIONS

NO.	COEFFICIENT (24-HOUR)	$\sqrt{h_w P_m}$	PRESSURE P_m	FLOW TEMP. FACTOR F_t	GRAVITY FACTOR. F_g	SUPER COMPRESS. FACTOR, F_{pv}	RATE OF FLOW Q, MCFD
1.	4.874	126.02	703.84	.9952	1.314	1.050	843.4
2.							
3.							
4.							
5.							

NO.	P_r	TEMP. R.	T_r	Z
1.	1.04	525	1.54	.907
2.				
3.				
4.				
5.				

GAS LIQUID HYDROCARBON RATIO 0.0 MCF/BBL

API GRAVITY OF LIQUID HYDROCARBONS 0.0 DEG.

SPECIFIC GRAVITY SEPARATOR GAS .579 | XXXXXXXXXXXX

SPECIFIC GRAVITY FLOWING FLUID XXXXXXXXXXXXX | .579

CRITICAL PRESSURE 680 PSIA | 680 PSIA

CRITICAL TEMPERATURE 340 R | 340 R

P_c 2724.4 P_c^2 7422.4

NO.	P_w	P_w^2	$P_c^2 - P_w^2$
1.	1694.9	2872.7	4549.7
2.			
3.			
4.			
5.			

$$(1)\ \frac{P_c^2}{P_c^2 - P_w^2} = 1.631 \qquad (2)\ \left[\frac{P_c^2}{P_c^2 - P_w^2}\right]^n = 1.516$$

$$\text{WHAOF} = Q\left[\frac{P_c^2}{P_c^2 - P_w^2}\right]^n = 1279$$

CALCULATED WELLHEAD OPEN FLOW 1279 MCFD @ 14.65 | ANGLE OF SLOPE 49.6 | SLOPE, n .85

REMARKS:

APPROVED BY COMMISSION:	CONDUCTED BY:	CALCULATED BY:	CHECKED BY:

(OVER)

HAS THE ALLOWABLE FOR THIS WELL BEEN ADJUSTED BY COMMISSION ORDER? ________

IF SO STATE ORDER NUMBER ________________

I, ____________________________, BEING FIRST DULY SWORN ON OATH, STATE THAT I AM FAMILIAR WITH FACTS AND FIGURES SET FORTH IN THIS REPORT, AND THAT THE REPORT IS TRUE AND CORRECT.

____

SIGNATURE AND TITLE OF AFFIANT

____

COMPANY

SUBSCRIBED AND SWORN TO BEFORE ME THIS ________ DAY OF ____________________, 19 ____

MY COMMISSION EXPIRES

____

NOTARY PUBLIC

PC = SHUT - IN PRESSURE, PSIA (LENGTH OF SHUT - IN MINIMUM OF 24 HOURS).
PW = STATIC COLUMN WELLHEAD PRESSURE CORRESPONDING TO THE FLOWING WELLHEAD PRESSURE, PSIA (TO BE RECORDED AT END OF EACH FLOW RATE.)

Gg = SPECIFIC GRAVITY OF SEPARATOR GAS (AIR = 1.000).

L = LENGTH OF HE FLOW STRING FROM THE MIDDLE OF THE PRODUCING FORMATION TO THE PRESSURE POINT AT WELL HEAD, FEET.

H = VERTICAL DEPTH CORRESPONDING TO L, FEET.

Q = 24 HOUR RATE OF FLOW, MCFD.

d = INSIDE DIAMETER, INCHES.

R = DEGREES, RANKINE (DEGREES FAHRENHEIT ABSOLUTE).

Pr = REDUCED PRESSURE, DIMENSIONLESS.

Tr = REDUCED TEMPERATURE, DIMENSIONLESS.

z = COMPRESSIBILITY FACTOR, DIMENSIONLESS.

TEST EXAMPLE 3

Calculation of Wellhead Pressure (P_c or P_w)
When the Observed Wellhead Pressure is
Affected by Liquids in the Wellbore
(Corresponding to Test Example 1, Page II-4)

In some cases, it may be necessary to calculate the wellhead pressure which would have existed had there been no liquid column in the Wellbore. This calculation depends upon a known bottom-hole pressure, which has been determined by a bottom-hole pressure bomb.

With the known bottom-hole pressure, the adjusted wellhead pressure is determined by carrying out the normal static column calculation in reverse, i.e., by starting with the pressure at the sandface and calculating the wellhead pressure.

If, in Test Example 1, the bottom-hole pressure (the pressure used in the test example happens to be shut-in pressure (P_f)) had been determined to be 2309.0 psia and it had been desired to calculate the wellhead pressure, the necessary calculations would be carried out as follows:

<u>Steps 1 through 3</u>.

Same as in Test Example 1. This time, Z is initially estimated at 0.860.

<u>Step 4</u>.

a. TZ = 574.5 * 0.860 = 494 (line 6).

b. GH / TZ = 5211 / 494 = 10.549 (line 7).

c. For GH / TZ = 10.549, read e^s in Table XIV: $e^s = 1.485$ (line 8).

<u>Step 5</u>.

a. Enter reservoir pressure (P_f) = 2309.0 (line 19).

b. $P_f^2 = (2309.0)^2 / 1000 = 5331.5$ (line 18).

c. $P_c^2 = 5331\text{-}5 / 1.485 = 3590.2$ (line 11).

d. $P_c = \sqrt{(3590.2)\,(1000)} = 1894.8$ (line 10).

Step 6.

a. $P = (P_c + P_f) / 2 = (1894.8 + 2309.0) / 2 = 2101.9$ (line 20).

b. $P_r = 2101.9 / 673 = 3.12$ (line 21).

c. $T_r = 574.5 / 360 = 1.60$ (line 22).

Step 7.

Enter in line 23 the compressibility factor from Table XI corresponding to a P_r of 3.12 and a T_r of 1.60. In this example, $Z = 0.822$ (line 23).

Step 8.

Since Z (line 23) is not equal to Z (line 5), enter $Z = 0.822$ on line 5, second trial and repeat steps 4 through 7.

Step 9.

Since the final value of Z (line 23, second trial) is equal to the assumed value of Z (line 5, second trial), the value of $P_c = 1877.2$ (line 10, second trial) is used in the back pressure computations.

FORM 1016b
(1975)

OKLAHOMA CORPORATION COMMISSION — OIL & GAS CONSERVATION DIVISION
380 JIM THORPE BUILDING, OKLAHOMA CITY, OKLAHOMA 73105
WORK SHEET FOR CALCULATION OF STATIC COLUMN WELLHEAD PRESSURES (P_c or P_w)

COMPANY Test Example 3 LEASE ______ WELL NO. ______ DATE 11/3/83

L 8130 M 8130 L/H 1.000 G 0.641 $\%CO_2$ 2.0 %N2 3.0 $\%H_2S$ ---

d 1.995 F_r 0.017777 GH 5211 P_{cr} ______ T_{cr} ______

LINE		1st trial	2nd trial								
1.	Q_m	0	0								
2.	Tw	534	534								
3.	Ts	615	615								
4.	T	574.5	574.5								
5.	Z	0.860	0.822								
6.	TZ	494.0	472.2								
7.	GH/TZ	10.549	11.036								
8	e^s	1.485	1.513								
9.	$1-e^{-s}$										
10.	P_c OR P_t	1894.8	1877.2								
11.	P_c^2 OR P_t^2	3590.2	3523.6								
12.	Fr										
13.	$F_c = F_r TZ$										
14.	$F_c Q_m$										
15.	$L/H (F_c Q_m)^2$										
16.	$F = L/H (F_c Q_m)^2 (1-e^{-s})$										
17.	$P_w^2 = P_t^2 + F_w$										
18.	P_f^2 or $P_s^2 = e^s P_c^2$ or $e^s P_w^2$	5331.5	5331.5								
19.	P_f or P_s	2309.0	2309.0								
20.	P	2101.9	2093.1								
21.	P_r	3.12	3.11								
22.	Tr	1.60	1.60								
23.	Z	0.822	0.822								

TEST EXAMPLE 4

Calculation of Wellhead Pressure (P_c or P_w)
When the Observed Wellhead Pressure is
Affected by Liquids in the Wellbore
(Stepwise Procedure Corresponding to Test Example 2, Page II-11)

In the event it is desirable to utilize the stepwise procedure described in Test Example 2 to calculate the static column wellhead pressure, the necessary calculations would be carried out as follows:

Step 1.

a. Enter well information as shown at the top of Form 1016c.

b. Enter H = 22,120 (line 1, column 1). (Line references are indicated in parentheses following each step; column references remain unchanged unless indicated).

c. GH = (0.579) (22,120) = 12,807 (line 2)

d. 37.5GH = (37.5) (12,807) = 480,263 (lines 3 and 18).

Step 2.

a. Assume that the bottom-hole pressure bomb measured a bottom-hole flowing pressure of 2678.2 psia (this example uses a flowing pressure, but a bottom-hole shut-in pressure could have been substituted if the wellhead shut-in pressure was to be calculated). Enter P_n = 2678.2 (line 4).

b. P_r = 2678.2 / 680 = 3.94 (line 5).

c. Enter T = 750 (line 6).

d. T_r = 750 / 340 = 2.21 (line 7).

e. Z = compressibility of gas at a P_r of 3.94 and a T_r of 2.21: Z = 0.968 (line 8).

f. P / Z = 2678.2 / 0.968 = 2767 (line 9).

g. P / TZ = 2767 / 750 = 3.6893 (line 10).

h. Lines 11, 12 and 13 may be omitted in the static column case (see Step 2 of test Example 2 for explanation).

i. $I_2 = 1000 / (P / TZ) = 271.054$ (line 14).

Step 3.

Make first trial calculation for the pressure at H / 2 = 22,120 / 2 = 11,060 (line 1, column 2) as follows:

a. H = 11,060 (line 1).

b. GH = (0.579) (11,060) = 6404 (line 2).

c. 37.5GH = (37.5) (6404) = 240,150 (line 3).

d. Estimate value of M by dividing $2I_2$ (line 14, column 1) into the difference between $\sum(M * N)$ (line 18, column 1) and 37.5GH (line 3, column 2): (480,263 – 240,150) / 2 * (271.054) = 443 (line 15). Then, $P_1 = P_f - M$ = 2678.2 – 443 = 2235.2 (line 4).

e. $P_r = 2235.2 / 680 = 3.29$ (line 5).

f. T = estimated temperature at 11,060 ft. = (60 + 290) / 2 + 460 = 635 (line 6).

g. $T_r = 635 / 340 = 1.87$ (line 7).

h. Z = compressibility factor of a gas at a P_r of 3.29 and a T_r of 1.87 = 0.909 (line 8).

i. P / Z = 2235.2 / 0.909 = 2459 (line 9).

j. P / TZ = 2459 / 635 = 3.8724 (line 10).

k. $I_1 = 1000 / (P / TZ) = 258.238$ (line 14).

l. $N = I_2$ (column 1) + I_1 (column 2) = 271.054 + 258.238 = 529.292 (line 16).

m. M = 37.5GH / N = 240,150 / 529.292 = 454. When M has been estimated correctly, the value determined under this step will be equal to M as estimated under (d).

n. Enter M = 454 (line 15, column 3). P_1 (line 4, column 3) is then $P_f - M$ = 2678.2 – 454 = 2224.2.

o. Repeat steps (e) through (m) until the correct value of M is determined. In this example, three more trials were made.

p. Multiply final values of M and N: (461) (521.669) = 240,489 (line 17, column 5).

q. Subtract (M * N) (line 17, column 5) from $\sum$(M * N) (line 18, column 1). 480,263 – 240,489 = 239,774 (line 18, column 5).

Step 4.

Make first trial calculation for the pressure at H = 0 (line 1, column 6).

a. GH = 0 (line 2).

b. 37.5GH = 0 (line 3).

c. Estimate M by dividing N (line 16, column 5) into line 18, column 5 = 239,774 / 521.669 = 460 (line 15, column 6).

d. Subtract M from P_n value found at H = 11,060: 2217.2 – 460 = 1757.2 (line 4, column 6).

e. P_r = 1757.2 / 680 = 2.58 (line 5).

f. T = 60 + 460 = 520 (line 6).

g. T_r = 520 / 340 = 1.53 (line 7).

h. Z = compressibility factor of gas at a P_r of 2.58 and a T_r of 1.53 = 0.806 (line 8).

i. P / Z = 1757.2 / 0.806 = 2180 (line 9).

j. P / TZ = 2180 / 520 = 4.1923 (line 10).

k. I_c = 1000 / 4.1923 = 238.533 (line 14).

l. N = 260.675 + 238.533 = 499.208 (line 16).

m. Divide $\sum$(M * N) (line 18, column 5) by N (line 16, column 6) = 239,774 / 499.208 = 480. When M has been estimated correctly, the value determined under this step will be equal to M as estimated under (c).

n. Enter M – 480 (line 15, column 7). P_w (line 4, column 7) is then P_1 – M = 2217.2 – 480 = 1737.2 (line 4, column 7).

o. Repeat steps (e) through (m) until the correct value of M is determined. Again, repeated trials are presented for this example on the 1016c worksheet.

p. Multiply final values of M and N: (491) (487.122) = 239,177 (line 17, column 10).

q. Subtract line 17, column 10 from line 18, column 5: 239,774 – 239,177 = 597 (line 18, column 10).

Step 5.

Using equation D-19, calculate ΔP by substituting 243.445 (line 14, column 10) for I_c, 260.675 (line 14, column 5) for I_1, and 271.054 (line 14, column 1) for I_2. The result is that $\Delta P = 925.2$, and by using equation D-20, $P_w = 2678.2 - 925.2 = 1753.0$ psia.

D-19: $$\Delta P = \frac{3(37.5)\,(GH)}{I_c + 4I_1 + I_2}$$

D-20: $$P_w = P_s - \Delta P$$

FORM 1016c
1975

OKLAHOMA CORPORATION COMMISSION — OIL & GAS CONSERVATION DIVISION
380 JIM THORPE BUILDING, OKLAHOMA CITY, OKLAHOMA 73105
WORK SHEET FOR CALCULATION OF STATIC COLUMN WELLHEAD PRESSURES (P_c or P_w)

COMPANY Test Example 4 LEASE (Farm Name) WELL NO. #4 DATE 7/6/84

L 22120 H 22120 L/H 1.000 G 0.579 %CO_2 1.89 %N_2 0.39 %H_2S 0.0

d 2.441 F_r .010495 Q_m 843.4 M^2cfd (L/H) $(F_r Q_m)^2$ .000078 P_{cr} 680 T_{cr} 340

LINE	ITEM	SOURCE	1	2	3	4	5	6	7	8	9	10
1.	H		22120	11060				0				
2.	GH		12807	6404				0				
3.	37.5GH		480263	240150				0				
4.												
4.	P_n		2678.2	2235.2	2224.2	2214.2	2217.2	1757.2	1737.2	1718.2	1724.2	1726.2
5.	P_r		3.94	3.29	3.27	3.26	3.26	2.58	2.55	2.53	2.54	2.54
6.	T		750	635	635	635	635	520	520	520	520	520
7.	T_r		2.21	1.87	1.87	1.87	1.87	1.53	1.53	1.53	1.53	1.53
8.	Z		0.968	0.909	0.910	0.910	0.910	0.806	0.806	0.807	0.808	0.808
9.	P/Z	$\bar{4} \div \bar{8}$	2767	2459	2444	2433	2436	2180	2153	2126	2134	2136
10.	P/TZ	$\bar{9} \div \bar{6}$	3.6893	3.8724	3.8488	3.8315	3.8362	4.1923	4.1404	4.0885	4.1038	4.1077
11.	$(P/TZ)^2$ 1000	$(\overline{10})^2/1000$										
12.	$L/H\,(F_r Q_m)^2$											
13.		$\overline{11} + \overline{12}$										
14.	In	$\overline{10} \div \overline{13}$	271.054	258.238	259.821	260.994	260.675	238.533	241.523	244.588	243.677	243.445
15.	$M = P_n - P_{n-1}$			443	454	464	461	460	480	499	493	491
16.	$N = I_n + I_{n-1}$			529.292	518.059	520.815	521.669	499.208	480.056	486.111	488.265	487.122
17.	M X N	$\overline{15} \times \overline{16}$					240489					239177
18.	$\sum$ (M × N)	$\sum \overline{17}$					239774					597

TEST EXAMPLE 5

Calculation of Wellhead Pressure (P_c)
When the Observed Wellhead Shut-In Pressure is
Affected by Liquids in the Wellbore
(Adjusting Pressure by Knowing Height of Liquid Column)

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 and adding to this figure the weight of the liquid column above the desired datum plane. The formation pressure is then used to calculate an adjusted wellhead pressure based on the assumption that no liquid column exists.

The calculations are done in three major steps:

Step 1.

Compute the pressure at the gas / liquid interface by the Average Temperature and Compressibility Method or the Two-Step Method, whichever is applicable.

A. Average Temperature and Compressibility Method

1. H is the vertical distance from the gas / liquid interface to the wellhead.
2. Enter zero rate of flow on line 1, Form 1016b.
3. T_s is the temperature at the gas / liquid interface (line 3).
4. Enter wellhead shut-in pressure (P_c) on line 10.
5. Lines 12 through 17 are not used.
6. Whenever the final value of Z is equal to the assumed value of Z, line 19 will be the pressure at the gas / liquid interface.

B. Two-Step Method

Follow Steps 1 through 6 in Test Example 2 except for the following differences:

1.H is the vertical distance from the gas / liquid interface to the wellhead.
2.The rate of flow (Q_m) is equal to zero.

Step 2.

Calculate the weight of the liquid column:

$$Psia = h * G_l * 0.4333$$

Where:

H = Length of liquid column in Wellbore above datum.
G_l = Specific gravity of liquid (water = 1.000).

Formation pressure = pressure at the gas / liquid interface as determined in Step 1, plus the pressure of the liquid column).

Step 3.

A. Average Temperature and Compressibility Method

Using pressure as determined in Step 2, compute the surface pressure as outlined in Test Example 3.

B. Two-Step Method

Using pressure as determined in Step 2, compute the surface pressure as outlined in Test Example 4.