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
INTRODUCTION

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 Manual of Back Pressure testing of Gas Wells. 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. Whenever a conflict of procedures exists between the Oklahoma Manual and the IOGCC Manual, the procedures in the Oklahoma Manual shall take precedence.

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.
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 

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 
fails on the curve, calculate the wellhead open-flow potential from the equation:

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

V. Reporting

All required potential tests and production tests should be reported on Form 1016; 
original only to be filed.
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-COMPRESSION FACTOR (Fpv):

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

\[ G_g \text{ (gravity of gas)} = 0.625 \]
\[ \text{Carbon Dioxide} = 2\% \]
\[ \text{Nitrogen} = 3\% \]

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:

\[ Q = F_b * \sqrt{h_m} * (P_m) * F_t * F_g * F_{pv} \]
Using the two-hour data obtained from the first flow,

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

**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.

\[ \sqrt{8.3 \times (735.4)} = \sqrt{6103.8} = 78.13 \]

\( F_t = 0.9943 \) (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:**

\[ Q = F_p \times P_m \times F_t \times F_g \times F_{pv} \]

**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:

\[ n = \frac{\log Q_2 - \log Q_1}{\log (P_2^2 - P_w^2) - \log (P_1^2 - P_w^2)} \]

If \( (P_2^2 - P_w^2)_2 \) is selected from the back pressure curve at a point one cycle greater than \( (P_1^2 - P_w^2)_1 \), 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)

\[
\begin{align*}
\text{at } (P_e^2 - P_w^2)_2 &= 3000, Q_2 = 10400, \text{ and } \log Q_2 = 4.01703 \\
\text{at } (P_e^2 - P_w^2)_1 &= 300, Q_1 = 2000, \text{ and } \log Q_1 = 3.30103 \\
n &= 4.01703 - 3.30103 = 0.716
\end{align*}
\]

**NUMBER 5. 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 ratio (GOR) = 193 MCF / bbl  
Specific gravity of separator liquid \((G_l)\) = 0.7787 (See Table XIII)  
Cubic feet of vapor equivalent to one bbl of hydrocarbon liquid \((V_l)\) = 721 (See Page C-1)

\[
G = \frac{0.625 + (4595)(0.7787)}{193,000}
\]

\[
= \frac{0.625 + 721}{193,000}
\]

\[
= 0.641
\]
**TEST EXAMPLE 1**

**FOUR-POINT BACK PRESSURE TEST**

Calculation of Static Column Wellhead Pressure \( (P_w) \)
Corresponding to Wellhead Flowing Pressure \( (P_l) \)
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.

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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\(^\circ\) F, reservoir temperature = 155\(^\circ\) 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 \( \frac{L}{H} \), the length of the flow string divided by the vertical distance. In most gas wells, \( \frac{L}{H} \) is one as H is equal to L. However, \( \frac{L}{H} \) is greater than one for directionally drilled wells. In this example, \( \frac{L}{H} \) is equal to 1.000.

d. \( GH = 0.641 \times 8130 = 5211 \)

**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-hole temperature should be measured or estimated from reliable data on other wells in the area.

c. \( T = \frac{T_w + T_b}{2} = \frac{534 + 615}{2} = 574.5 \) (line 4).

**Step 3.**

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

**Step 4.**

a. \( TZ = 574.5 \times 0.825 = 474.0 \) (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. \( F_e = F_e T_z = (0.017777) (474.0) = 8.426 \) (line 13).

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

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

d. \( F_w = L / H(F_e Q_m)^2 \left(1 - e^{-x}\right) = (228.3) (0.338) = 77.2 \) (line 16).

e. \( P_w^2 = P_r^2 + F_w = 3191.2 + 77.2 = 3268.4 \) (line 17).

Step 8.

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

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

c. \( P = (P_r + P_s) / 2 = (1786.4 + 2221.6) / 2 = 2004.0 \) (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 trial) 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).
### Back-Pressure Test for Natural Gas Wells

**OKLAHOMA CORPORATION COMMISSION — OIL & GAS CONSERVATION DIVISION**
300 Jim Thorpe Building — Oklahoma City, Oklahoma 73105

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

### Test Example 1

**Location:** Mocane-LaVerne, Morrow (Pool #93) SW/4 NE/4

**Completion Date:** 4/5/83

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Date</th>
<th>Size 1</th>
<th>Depth 1</th>
<th>Size 2</th>
<th>Depth 2</th>
<th>Elevation</th>
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<tbody>
<tr>
<td></td>
<td>7&quot;</td>
<td>OD 23.00</td>
<td>6.366</td>
<td>8293</td>
<td>8112 8148</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8&quot; 3/8&quot;</td>
<td>OD 4.70</td>
<td># 1.995</td>
<td>8134</td>
<td>8127 8132</td>
<td></td>
</tr>
</tbody>
</table>

**Type:** Single Gas

**Reservoir Temp.:** 8100

**Mean Ground Temp.:** 60

**Barrels Pressure (Psia):** 14.4

**State:** Oklahoma

**PRODUCING FLD:**

<table>
<thead>
<tr>
<th>Date</th>
<th>Wellhead Working Pressure</th>
<th>Meter or Prover</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/7/83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:45A</td>
<td>1864.0</td>
<td>Packer</td>
</tr>
<tr>
<td>8:00A</td>
<td></td>
<td>72 hour shut-in pressure</td>
</tr>
<tr>
<td>8:30A</td>
<td>1809.0</td>
<td>Start 1st Flow</td>
</tr>
<tr>
<td>9:00A</td>
<td>1793.0</td>
<td></td>
</tr>
<tr>
<td>9:30A</td>
<td>1779.0</td>
<td></td>
</tr>
<tr>
<td>10:00A</td>
<td>1772.0</td>
<td></td>
</tr>
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<td>10:00A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:30A</td>
<td>1765.0</td>
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<td>11:30A</td>
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<tr>
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<td></td>
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<tr>
<td>12:30N</td>
<td>1705.0</td>
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<td>1633.0</td>
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<tr>
<td>2:00P</td>
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<tr>
<td>2:30P</td>
<td>1630.0</td>
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</tr>
<tr>
<td>3:00P</td>
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<td>1539.0</td>
<td></td>
</tr>
<tr>
<td>4:00P</td>
<td>1512.0</td>
<td></td>
</tr>
</tbody>
</table>

**Remainder:**

- 4" Pipe

**Remarks:**

- St Tk 3' - 7 1/2" 60F
- Increased Rate for 2nd Flow
- St Tk 3' - 8 1/4" 60F
- Increased Rate for 3rd Flow
- St Tk 3' - 9 1/8" 60F
- Increased Rate for 4th Flow
- Tank Size - 12' Diameter 1.68 Barrels/inch

**API - 50.2° at 60F**
<table>
<thead>
<tr>
<th>COMPANY</th>
<th>ABC Oil Company</th>
<th>LEASE</th>
<th>Test Example</th>
<th>WELL NO.</th>
<th>#1</th>
<th>DATE</th>
<th>7/7/83</th>
</tr>
</thead>
<tbody>
<tr>
<td>8130</td>
<td>8130</td>
<td>1.000</td>
<td>0.641</td>
<td>2.0</td>
<td>3.0</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

| d | 1.995" | f | 0.017777 | gh | 5211 |

\[ P_{or} = 673 \quad T_{cr} = 360 \]

<table>
<thead>
<tr>
<th>LINE</th>
<th>1st Rate</th>
<th>2nd Rate</th>
<th>3rd Rate</th>
<th>4th Rate</th>
</tr>
</thead>
</table>

| Qm   | 1.793    | 1.793    | 2.659    | 3.488    | 3.488    | 4.192    | 4.192    |
| Tw   | 534      | 534      | 534      | 534      | 534      | 534      | 534      |
| Tq   | 615      | 615      | 615      | 615      | 615      | 615      | 615      |
| T    | 574.5    | 574.5    | 574.5    | 574.5    | 574.5    | 574.5    | 574.5    |
| Z    | 0.825    | 0.826    | 0.833    | 0.829    | 0.833    | 0.832    | 0.833    | 0.835    |
| Yz   | 474.0    | 474.5    | 478.6    | 476.3    | 478.0    | 478.6    | 479.7    |
| \( e^8 \) | 1.510 | 1.510    | 1.504    | 1.507    | 1.504    | 1.505    | 1.504    | 1.503    |
| \( 1-e^{-a} \) | 0.338 | 0.338    | 0.335    | 0.336    | 0.335    | 0.336    | 0.335    | 0.335    |
| \( P_{c \text{ or } P_t} \) | 1786.4 | 1786.4   | 1712.4   | 1712.4   | 1622.4   | 1622.4   | 1526.4   | 1526.4   |
| \( P_{c \text{ or } P_t}^2 \) | 3191.2 | 3191.2   | 2932.3   | 2932.3   | 2632.2   | 2632.2   | 2329.9   | 2329.9   |
| \( F_r \) | 0.017777 | 0.017777 | 0.017777 | 0.017777 | 0.017777 | 0.017777 | 0.017777 | 0.017777 |
| \( F_c = F_r Tz \) | 8.426 | 8.435    | 8.508    | 8.467    | 8.508    | 8.497    | 8.508    | 8.528    |
| \( F_{c Q_m} \) | 15.11  | 15.12    | 22.62    | 22.51    | 29.68    | 29.64    | 35.67    | 35.75    |
| \( L/H (F_c Q_m)^2 \) | 228.3 | 228.6    | 511.7    | 506.7    | 880.9    | 878.5    | 1272.3   | 1278.1   |
| \( F = L/H (F_c Q_m^2 (1-e^{-a})) \) | 77.2 | 77.3     | 171.4    | 170.3    | 295.1    | 295.2    | 426.2    | 428.2    |
| \( P_{c \text{ or } P_t}^2 \) | 3268.4 | 3268.5   | 3103.7   | 3102.6   | 2927.3   | 2927.4   | 2756.1   | 2758.1   |
| \( P_{c \text{ or } P_t}^2 \) | 4935.3 | 4935.4   | 4668.0   | 4675.6   | 4402.7   | 4405.7   | 4145.2   | 4145.4   |
| \( P_{c \text{ or } P_t}^2 \) | 2221.6 | 2221.6   | 2160.6   | 2162.3   | 2098.3   | 2099.0   | 2036.0   | 2036.0   |
| \( P \) | 2004.0 | 2004.0   | 1936.5   | 1937.4   | 1860.4   | 1860.7   | 1781.2   | 1781.2   |
| \( P \) | 2.98   | 2.98     | 2.88     | 2.88     | 2.76     | 2.76     | 2.65     | 2.65     |
| \( T \) | 1.60   | 1.60     | 1.60     | 1.60     | 1.60     | 1.60     | 1.60     | 1.60     |
| \( Z \) | 0.826  | 0.826    | 0.829    | 0.829    | 0.832    | 0.832    | 0.835    | 0.835    |
# BACK — PRESSURE TEST FOR NATURAL GAS WELLS

**RULE 2-308**

**TYPE TEST:** 4-Point  
**INITIAL X**  
**ANNUAL**  
**RETEST**  
**TEST DATE:** 7/7/83  
**OKLAHOMA TAX COMMISSION**  
**ASSIGNED LEASE NO:** 059-99999

**COMPANY**  
**NAME:** Test Example 1  
**CONNECTION:**  
**DATE OF 1ST SALES:** 5/20/83  
**FIELD**  
**ALLOCATED POOL NO:** Mocane-LaVerne  
**RESEVOIR**  
**LOCATION:** SW/4 NE/4  
**UNIT**  
**COMPLETION DATE**  
**TOTAL DEPTH**  
**PLUG BACK TO**  
**ELEVATION**  
**FARM OR LEASE NAME:** Test Example

**CSG. SIZE**  
**WT.**  
**SET AT**  
**PERFORATIONS:** FROM TO  
**WELL NO.**  
**SEC.** Twp. Rge.  
**COUNTY**  
**PRODUCING THRU**  
**RESEVOIR TEMP. F**  
**MEAN GROUND TEMP. F**  
**BARTO. PRESS. Ps**  
**STATE**  
**PROVER**  
**METER RUN**  
**TAPS**  
**FLOW DATA**  
**TUBING DATA**  
**CASING DATA**  
**DURATION OF FLOW HR.**

<table>
<thead>
<tr>
<th>No.</th>
<th>(PROVER LINE) ORIFICE SIZE</th>
<th>PRESS. PSIG</th>
<th>DIFF (INCHES)</th>
<th>TEMP. F</th>
<th>PRESS. PSIG</th>
<th>TEMP. F</th>
<th>PRESS. PSIG</th>
<th>TEMP. F</th>
<th>DURATION OF FLOW HR.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td>721.0</td>
<td>8.3</td>
<td>66</td>
<td>1772.0</td>
<td>74</td>
<td></td>
<td></td>
<td>2</td>
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<tr>
<td>2.</td>
<td></td>
<td>729.0</td>
<td>17.5</td>
<td>56</td>
<td>1698.0</td>
<td>74</td>
<td></td>
<td></td>
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<tr>
<td>3.</td>
<td></td>
<td>744.0</td>
<td>29.3</td>
<td>54</td>
<td>1608.0</td>
<td>74</td>
<td></td>
<td></td>
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<tr>
<td>4.</td>
<td></td>
<td>759.0</td>
<td>41.5</td>
<td>55</td>
<td>1512.0</td>
<td>74</td>
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<td></td>
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</table>

**RATE OF FLOW CALCULATIONS**

<table>
<thead>
<tr>
<th>NO.</th>
<th>COEFFICIENT (24-HOUR)</th>
<th>$\sqrt{h_\text{w}P_\text{m}}$</th>
<th>PRESSURE $P_\text{m}$</th>
<th>FLOW TEMP. FACTOR $F_1$</th>
<th>GRAVITY FACTOR $F_\text{g}$</th>
<th>SUPER COMPRESS. FACTOR $F_\text{py}$</th>
<th>RATE OF FLOW Q, MCFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>17.23</td>
<td>78.13</td>
<td>735.4</td>
<td>0.9943</td>
<td>1.265</td>
<td>1.059</td>
<td>1793</td>
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<tr>
<td>2.</td>
<td>17.23</td>
<td>114.1</td>
<td>743.4</td>
<td>1.004</td>
<td>1.265</td>
<td>1.065</td>
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<tr>
<td>3.</td>
<td>17.23</td>
<td>149.1</td>
<td>758.4</td>
<td>1.006</td>
<td>1.265</td>
<td>1.067</td>
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<tr>
<td>4.</td>
<td>17.23</td>
<td>179.2</td>
<td>773.4</td>
<td>1.005</td>
<td>1.265</td>
<td>1.068</td>
<td>4192</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NO.</th>
<th>$P_\text{r}$</th>
<th>TEMP. R</th>
<th>$T_\text{r}$</th>
<th>Z</th>
<th>$G_\text{LH}$</th>
<th>API GRAVITY OF LIQUID HYDROCARBONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>1.09</td>
<td>526</td>
<td>1.49</td>
<td>0.891</td>
<td></td>
<td>50.2</td>
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<tr>
<td>2.</td>
<td>1.10</td>
<td>516</td>
<td>1.46</td>
<td>0.882</td>
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<tr>
<td>3.</td>
<td>1.13</td>
<td>514</td>
<td>1.46</td>
<td>0.879</td>
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<td></td>
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<tr>
<td>4.</td>
<td>1.15</td>
<td>515</td>
<td>1.46</td>
<td>0.877</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$P_c = 1878.4 \times c^2 = 3528.4$

CALCULATED WELLHEAD OPEN FLOW 12460 MCFD @ 14.65 ANGLE OF SLOPE 54° SLOPE m .716

**REMARKS:**

**APPROVED BY COMMISSION:**

**CONDUCTED BY:**

**CALCULATED BY:**

**CHECKED BY:**

(OVER)

II-9
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)

\[
\begin{align*}
\left( P_r^2 - P_w^2 \right)_2 &= 3000 & Q_2 &= 10400 & \log Q_2 &= 4.01703 \\
\left( P_r^2 - P_w^2 \right)_1 &= 300 & Q_1 &= 2000 & \log Q_1 &= 3.30103 \\
\end{align*}
\]
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:

\[
\begin{align*}
  d &= 2.441 \\
  F_r &= 0.010495 \\
  \frac{L}{H(F_r Q_m)^2} &= 1.0000 \ (0.010495 \times 0.8434)^2 \\
  &= 0.000078
\end{align*}
\]

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 \( 22,120 \text{ ft/2 = 11,060 ft} \) is:

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

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. \( P_t = 1689.4 \text{ psia} \) which is the measured wellhead pressure  (line 4).

c. \( P_t = \) wellhead pressure divided by the critical pressure; \( \frac{1689.4}{680} = 2.4844 \) (line 5). Use 2.48.

d. \( T = \) wellhead temperature, \( 60^\circ \text{F} + 460 = 520^\circ \text{R} \) (line 6).

e. \( T_r = \) wellhead temperature \((\text{R})\) divided by the critical temperature, \( \frac{520}{340} = 1.5294 \) (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. \(\frac{P}{Z} = \frac{1689.4}{0.810} = 2086 \) (line 9).

h. \( \frac{P}{TZ} = \frac{2086}{520} = 4.0115 \) (line 10).

i. \( \left(\frac{P}{TZ}\right)^2 / 1000 = \left(\frac{4.0115}{1000}\right)^2 = 0.016092 \) (line 11).

j. \( \left(\frac{1}{H}\right)(F_rQ_m)^2 = 0.000078 \) (line 12).

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

l. \( I_t = \frac{\text{line 10}}{\text{line 13}} = \frac{4.0115}{0.016170} = 248.083 \) (line 14).

**Step 4.**

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

a. Compute \( GH \) and \( 37.5GH \). \( GH = 0.579 \times 11,060 = 6403.74 \) (line 2). \( 37.5 \text{ GH} = 37.5 \times 6403.74 = 240,140 \) (line 3)

b. Estimate value of \( M \) as follows: \( 37.5GH / (2 \times 1) = 240,140 / (2 \times 248.083) = 484 \) (line 15, column 2).

c. \( P_t = M + P_t = 484 + 1689.4 = 2173.4 \text{ psia} \) (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. \((\text{Line 11} + \text{line 12}) = 0.014147 + 0.000078 + 0.014225 \) (line 13).

g. \(I_1 = (\text{line 10}) / (\text{line 13}) = 3.7612 / 0.014225 = 264.408 \) (line 14).

h. \(N = I_t + \text{trial } I_1 = 248.083 + 264.408 = 512.491 \) (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, \(467 \times 514.564 = 240,301 \) (line 17).

m. Enter value of \(M \times N \) under \(\sum(M \times N) \) (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: \(GH = 0.579 \times 22,120 = 12,807.48 \) (line 2) and \(37.5GH = 37.5 \times 12,807.48 = 480,281 \) (line 3).

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

c. \(P_2 = M + P_t = 466 + 2156.4 = 2622.4 \) (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. \((\text{Line 11} + \text{line 12}) = 0.013152 \) (line 13).

g. \(I_2 = (\text{line 10}) / (\text{line 13}) = 3.6159 / 0.013152 = 274.932 \) (line 14).

h. \(N = I_t + \text{trial } I_2 = 266.481 + 274.932 = 541.413 \) (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 \(\sum(M * N)\) (line 18, column 4); 239,914 + 240,301 = 480,215 (line 18, column 7).

**Step 6.**

Using equation D-22, calculate \(\Delta P\) by substituting 248.083 (line 14, column 1) for \(I_0\), 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 \(P_s = P_t + \Delta P\):

\[
\Delta P = \frac{3(37.5GH)}{3(480.281)} = \frac{3(248.083)}{3(266.481) + 277.542} = 905.3
\]

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, \(P_n = 2594.7\), \(P_r = 3.82\), \(T = 750\), \(T_r = 2.21\), \(Z = 0.967\), \(P / TZ = 2686\), 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:

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

\[
I_s = 1000 / 3.5814 = 279.220
\]

II-14
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 $\Sigma(M \times N)$ (line 18, column 1) and $37.5GH$ (line 3, column 2): $(480,281 - 240,140 / 2 * 279.220 = 430$ (line 15), then $P_t = P_t - M = 2594.7 - 430 = 2164.7$ (line 4).

e. $P_t = 2164.7 / 680 = 3.18$ (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 $P_t$ 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). $P_t$ (line 4, column 3) is then $P_t - M = 2594.7 - 439 = 2155.7$.
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: \[ 439 \times 547.568 = 240,382 \] (line 17, column 3).

q. Subtract \((M \times N)\) (line 17) from \(\Sigma(M \times N)\) (line 18, column 1): \[ 480,281 - 240,382 = 239,899 \] (line 18).

**Step 9.**

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 \((M \times N)\) (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 \( N \): \( 464 \times 517.030 = 239,902 \) (line 17, column 7).

Step 10.

Using equation D-19, calculate \( \Delta P \) 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:

\[
\begin{align*}
\text{D-19:} & \quad \Delta P = \frac{3(37.5G)I_c + 4I_1 + I_2}{3(480.281)} \\
& = \frac{3(37.5\times 248,682) + 4(268.348) + 279.220}{3(480.281)} \\
& = 899.8 \\
\text{D-20:} & \quad P_w = P_s - \Delta P = 2594.7 - 899.8 \\
& = 1694.9 \text{ psia}
\end{align*}
\]

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 \( P_e \) 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 \times 843.4 = 1279 MCF / day.
**OKLAHOMA CORPORATION COMMISSION – OIL & GAS CONSERVATION DIVISION**

386 JIM THORPE BUILDING, OKLAHOMA CITY, OKLAHOMA 73105

**WORK SHEET FOR CALCULATION OF STATIC COLUMN WELLHEAD PRESSURES (P_C or P_W)**

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>Test Example 2</th>
<th>LEASE (Farm Name)</th>
<th>WELL NO.</th>
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<td>(P/TZ)^2/1000</td>
<td>(T/5)^2/1000</td>
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<td>467</td>
<td>467</td>
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</table>

\[ ΔP = 3(37.5GĦ)/\left(\frac{I_1}{1} + 4I_1 + I_2\right) \]

\[ P_S = P_t + ΔP \]

\[ P_S = 2594.7 \]
## WORK SHEET FOR CALCULATION OF STATIC COLUMN WELLHEAD PRESSURES ($P_c$ or $P_w$)

### Test Example 2  
**COMPANY:**  
**LEASE:**  
**WELL NO.:**  
**DATE:** 1/9/84  
**Gh**  
**37.5Gh**  
**H**  
**L/H F_r q_m**  
**%CO_2**  
**%N_2**  
**%H_2S**  
**1.000**  
**0.579**  
**1.89**  
**0.39**  
**0.00078**  
**680.0**  
**340**  

<table>
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<th>ITEM</th>
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<th>4</th>
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<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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<tr>
<td>4.</td>
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<tr>
<td>8.</td>
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<td>0.807</td>
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<td>468</td>
<td>463</td>
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<tr>
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<td>$T_1 + T_2$</td>
<td>546.457</td>
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<td>512.596</td>
<td>517.868</td>
<td>516.913</td>
<td>517.030</td>
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<tr>
<td>14.</td>
<td>$\ln (I_1 + I_2)$</td>
<td>240382</td>
<td>239902</td>
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<tr>
<td>15.</td>
<td>$M = P_n - P_n - 1$</td>
<td>480281</td>
<td>239899</td>
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\[ \Delta P = \frac{(3(37.5Gh))}{(I_1 + 4I_1 + I_2)} \]

\[ P_w = P_s - \Delta P \]

\[ P_w = 1694.9 \]
## BACK — PRESSURE TEST FOR NATURAL GAS WELLS
### (RULE 2-308)

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<th>INITIAL</th>
<th>ANNUAL</th>
<th>RETEST</th>
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<th>ALLOCATED POOL NO.</th>
<th>RESERVOIR</th>
<th>LOCATION</th>
<th>UNIT</th>
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<td>Oklahoma City</td>
<td>Unalloc</td>
<td>Viola</td>
<td>NE/4 SE/4</td>
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<th>COMPLETION DATE</th>
<th>TOTAL DEPTH</th>
<th>PLUG BACK TO</th>
<th>ELEVATION</th>
<th>FARM OR LEASE NAME</th>
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<td>10/7/83</td>
<td>22884</td>
<td>1223</td>
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<th>CSG. SIZE</th>
<th>WT.</th>
<th>d</th>
<th>SET AT</th>
<th>PERF. FROM TO</th>
<th>WELL NO.</th>
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<td>9 5/8</td>
<td>53.5</td>
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<td>8.535</td>
<td>22884</td>
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<th>SEC TWP RGE</th>
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<td>2 7/8</td>
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<th>TYPE COMPLETION (DESCRIPTION)</th>
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<th>MEAN GROUND TEMP. F</th>
<th>BARTO. PRESS. P_b</th>
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<th>L</th>
<th>H</th>
<th>G_m</th>
<th>% CO_2</th>
<th>% N_2</th>
<th>% H_2S</th>
<th>PROVER</th>
<th>METER RUN</th>
<th>TAPS</th>
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<td>22120</td>
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<td>579</td>
<td>1.89</td>
<td>0.39</td>
<td>0.0</td>
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### FLOW DATA

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<tr>
<th>NO.</th>
<th>[PROVER] X ORIFICE SIZE</th>
<th>PRESS. PSIG</th>
<th>DIFF. (INCHES) X [INCHES]</th>
<th>TEMP. F</th>
<th>PRESS. PSIG</th>
<th>TEMP. F</th>
<th>PRESS. PSIG</th>
<th>TEMP. F</th>
<th>DURATION OF FLOW HR.</th>
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<td>1.</td>
<td>4.0 x 1.000</td>
<td>689.44</td>
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### RATE OF FLOW CALCULATIONS

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<th>NO.</th>
<th>COEFFICIENT (24-HOUR)</th>
<th>\sqrt{h_{wm}}</th>
<th>\text{PRESSURE} \text{P}\text{m}</th>
<th>FLOW TEMP. FACTOR \text{F}_1</th>
<th>GRAVITY FACTOR \text{F}_9</th>
<th>SUPER COMPRESS. FACTOR \text{P}_{PV}</th>
<th>RATE OF FLOW Q MCF/D</th>
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<tr>
<td>1.</td>
<td>4.874</td>
<td>126.02</td>
<td>703.84</td>
<td>.9952</td>
<td>1.314</td>
<td>1.050</td>
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<tr>
<th>NO.</th>
<th>\text{P}_1</th>
<th>TEMP R.</th>
<th>\text{T}_f</th>
<th>Z</th>
<th>\text{P}_C</th>
<th>\text{P}_{C^2}</th>
<th>\text{P}<em>{C^2-P</em>{gw}}</th>
<th>\text{P}<em>{C^2-P</em>{gw}}</th>
<th>\text{P}<em>{C^2-P</em>{gw}}</th>
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<td>1.54</td>
<td>.907</td>
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<td>7422.4</td>
<td>1.631</td>
<td>1.516</td>
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\[
\text{WHAOF} = \left[ \frac{\text{P}_{C^2}}{\text{P}_{C^2-P_{gw}}} \right]^n = 1279
\]

### CALCULATED WELLHEAD OPEN FLOW

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>\text{P}_W</th>
<th>\text{P}_{W^2}</th>
<th>\text{P}<em>{C^2-P</em>{gw}}</th>
<th>\text{P}<em>{C^2-P</em>{gw}}</th>
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<tr>
<td>1.</td>
<td>1694.9</td>
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\[
\text{P}_{C^2-P_{gw}} = \frac{\text{P}_{C^2}}{\frac{\text{P}_{C^2}}{\text{P}_{C^2-P_{gw}}}} = 1.631
\]

\[
\text{WHAOF} = \left[ \frac{\text{P}_{C^2}}{\text{P}_{C^2-P_{gw}}} \right]^n = 1279
\]

### REMARKS:

- Gas Liquid Hydrocarbon Ratio = 0.0 MCF/BBL
- API Gravity of Liquid Hydrocarbons = 0.0 Deg.
- Specific Gravity Separator Gas = 0.579
- Specific Gravity Flowing Fluid = 0.579
- Critical Pressure = 680 PSIA
- Critical Temperature = 340 R

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

(OVDP)
II-20
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 ($P_d$)) 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:

**Steps 1 through 3.**

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

**Step 4.**

a. $TZ = 574.5 \times 0.860 = 494$ (line 6).

b. $\frac{GH}{TZ} = \frac{5211}{494} = 10.549$ (line 7).

c. For $\frac{GH}{TZ} = 10.549$, read $e^8$ in Table XIV: $e^8 = 1.485$ (line 8).

**Step 5.**

a. Enter reservoir pressure ($P_r$) = 2309.0 (line 19).

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

c. $P_c^2 = 5331.5 / 1.485 = 3590.2$ (line 11).

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

II-21
Step 6.

a. \[ P = \frac{(P_c + P_t)}{2} = \frac{(1894.8 + 2309.0)}{2} = 2101.9 \text{ (line 20).} \]

b. \[ P_r = \frac{2101.9}{673} = 3.12 \text{ (line 21).} \]

c. \[ T_r = \frac{574.5}{360} = 1.60 \text{ (line 22).} \]

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.
**OKLAHOMA CORPORATION COMMISSION - OIL & GAS CONSERVATION DIVISION**

**300 JIM THORPE BUILDING, OKLAHOMA CITY, OKLAHOMA 73105**

**WORK SHEET FOR CALCULATION OF STATIC COLUMN WELLHEAD PRESSURES (P_c or P_w)**

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<th>LEASE</th>
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<td>m 8130</td>
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<td>11/3/83</td>
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<td>t 1.995</td>
<td>f 0.017777</td>
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<td>9. l-e^-s</td>
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<td>12. F_r</td>
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<td>13. F_c = F_r Tz</td>
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<td>14. F_c Q_m</td>
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<td>15. L/H (P_c Q_m)^2</td>
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<tr>
<td>16. F = L/H (P_c Q_m)^2 (1-e^-s)</td>
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<tr>
<td>17. P_w^2 + P_c^2 + F</td>
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<tr>
<td>18. P_t^2 or P_w^2 = e<em>a^2 + e</em>b^2 + e*c</td>
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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).

II-24
i. \( I_2 = \frac{1000}{P / TZ} = 271.054 \) (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 \( \Sigma(M * N) \) (line 18, column 1) and \( 37.5GH \) (line 3, column 2):
   \[
   \frac{(480,263 - 240,150)}{2} \times (271.054) = 443 \quad \text{(line 15)}.
   \] Then, \( P_t = P_t - M = 2678.2 - 443 = 2235.2 \) (line 4).

e. \( P_t = \frac{2235.2}{680} = 3.29 \) (line 5).

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

g. \( T_r = \frac{635}{340} = 1.87 \) (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. \( I_1 = \frac{1000}{P / TZ} = 258.238 \) (line 14).

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

m. \( M = \frac{37.5GH}{N} = 240,150 / 529.292 = 454. \) 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). \( P_t \) (line 4, column 3) is then \( P_t - M = 2678.2 - 454 = 2224.2 \).

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

II-25
p. Multiply final values of M and N: $(461)(521.669) = 240,489$ (line 17, column 5).

q. Subtract $(M \times N)$ (line 17, column 5) from $\sum(M \times N)$ (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 $\sum(M \times N)$ (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 ΔP = 925.2, and by using equation D-20, P_w = 2678.2 – 925.2 = 1753.0 psia.

\[ \Delta P = I_c + 4I_1 + I_2 \]

\[ D-19: \quad \Delta P = \frac{3(37.5)(GH)}{I_c} \]

\[ D-20: \quad P_w = P_s - \Delta P \]
**Test Example 4**

**LEASE (Farm Name)**

L 22120  H 22120  L/H 1.000  G 0.579

**WELL NO.**  #4

**DATE**  7/6/84

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**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:

$$Psia = h \times G_l \times 0.4333$$
Where:

\[ H = \text{Length of liquid column in Wellbore above datum.} \]
\[ G_l = \text{Specific gravity of liquid (water = 1.000).} \]

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.