Low Pressure Air Testing of Sewers

Acceptance tests are included in sewer contract documents to assure the necessary combination of good workmanship and materials is obtained during construction of the project. This Design Data describes the application and limitations of low pressure air testing of installed concrete pipe sewers and provides information and guidelines for proper application of the test and interpretation of results.

No correlation has been found between air loss and water leakage from sewers. Although such relationships exist for an orifice of known dimensions, in concrete sewers, the orifices are generally of capillary tube size, or smaller, and surface tension may stop the flow of water while dry air may pass through the openings. Experience has demonstrated this and has shown a sewer line passing the air test should pass the water infiltration or exfiltration test specified in *ASTM C969, Practice for Infiltration and Exfiltration Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines*. It should also be noted that there is no relationship between the criteria and results of low-pressure air testing of sewer lines and that of low-pressure air testing of individual joints.

GENERAL

Precast concrete pipe is plant tested prior to acceptance and delivery to the job site. Since plant leakage testing is a check on the pipes performance, field leakages test demonstrates the quality of construction procedures and integrity of the installation. The leakage tests applicable to pipe installations are the water infiltration, water exfiltration and low-pressure air tests of the sewer line, and individual joints.

In the infiltration test the amount of water leakage into the sewer line is measured. This test is generally applicable only when the groundwater level is a minimum of two feet above the crown of the pipe for the entire length of the test section. In some areas, the trench may be flooded to simulate groundwater conditions for the infiltration test. In the exfiltration test, the sewer line is filled with water and the amount of water loss is measured. The exfiltration test can be used if the groundwater level is less than two feet above the crown of the pipe at the highest elevation of the sewer. Procedures and test criteria for water infiltration and exfiltration tests of concrete pipe sewer lines are prescribed in *ASTM C969*.

In the low-pressure air test, the sewer line to be tested is plugged at both ends, air is introduced at low pressure into the plugged line and the amount of air loss during a specified time period is measured. Test procedures and criteria are prescribed in *ASTM Standard C924, Testing Concrete Pipe Sewer Lines by Low Pressure Air Test Method*. This Design Data discusses the development and use of low-pressure air test.

AIR TEST DEVELOPMENT

The low-pressure air test was developed to detect damaged pipe or improper jointing and is a test to determine the rate at which air, under pressure, escapes from an isolated section of sewer. Initially water testing, the air rest is now a common method of testing installed sewer lines for acceptance by demonstrating the integrity of the pipe and joints and a quality of construction methods.

Due to the physical differences between air and water, and the difference in behavior of gases and fluids under pressure conditions, there is no direct correlation between air loss and water infiltration and exfiltration. In most cases the air test is a "go" or "no go" situation, and, if the sewer passes the test, it should perform satisfactory under an infiltration or exfiltration test. In the event of failure to pass the air test, the sewer line should be subjected to a water infiltration or exfiltration test as prescribed by *ASTM C696* before rehabilitation or reconstruction is considered.

METHOD

ASTM C924 specifies the test method, criteria and procedures, and limits the size of the pipe that can be tested to 4-inch through 24-inch diameters. The lower limit of 4-inch diameter is the smallest concrete pipe currently produced in some areas of North America. The upper limit of 24-inch diameter was primarily for safety reasons, and the fact that larger diameters can be more readily tested by visual inspection or testing individual joints. The criteria, pressures, holding times and procedures are not applicable to air testing of individual joints.

The Time Pressure Drop Method (on page 8) is the most commonly used air test method. The section of sewer to be tested is isolated, and the internal air pressure is raised to a specific level. If the drop in pressure is one pound per square inch, or less, within a specified time interval, the line is acceptable.

For safety reasons, and to prevent damage to joint integrity, under no circumstances should the sewer line and laterals be subjected to more than six pounds per square inch.

CRITERIA

Allowable air loss rates were established for different diameters of concrete pipe to identify significant losses. Field experience with testing sewer lines, combined with other test observations, indicate that any defect of significance will result in losses which exceed the allowable air loss rates. To pass the air test, the sewer being tested must not lose a total volume of air greater than the product of the allowable rate of air loss and the test time, which is expressed as:

$$V_L = Q_L + T_T \qquad (1)$$

where:

V_L = total volume of air loss, cubic feet
Q_L = allowable rate of air loss, cubic feet per minute
T_T = required test time, minute

The required test time is a function of the total volume of air loss divided by the allowable rate of air loss which can be expressed by rearranging terms:

$$T_T = \frac{V_L}{Q_L} \qquad (2)$$

The volume of air loss is a function of the volume of the test section which, in turn, is a function of the test section length and pipe diameter. By substituting these relationships into Equation [2] the required test time (on page 8) can be stated as:

$$T_T = 0.00037 \left[\frac{D^2 L}{Q_L} \right] \qquad (3)$$

where:

D = Inside diameter of main sewer line in test section, inches
L = Length of main sewer line in test section, feet

From Equation [3], required air test times can be calculated for any combination of length and diameter of pipe. *ASTM C924* includes a table of the allowable air loss rates for concrete pipe diameters from 4 to 24 inches. *Table 1* establishes the allowable air loss rate as a constant rate for each pipe diameter, regardless of the length of the test section. This concept, and the loss rate values, were based on experience and results obtained from many field air tests. To calculate the required test time, use Equation [3] and the allowable air loss rate from *Table 1* for the pipe diameter.

Table 1	Allowable Air Loss Rates		
Pipe Diameter, Inches	Q_L cubic feet per minute	Pipe Diameter, Inches	Q_L cubic feet per minute
4	2	15	4
6	2	18	5
8	2	21	5.5
10	2.5	24	6
12	3		

To simplify the calculation process, the total required test time for a specific pipe diameter can converted to a test time per unit length of pipe. *ASTM C924* includes a table of test times per 100 feet of sewer line for pipe diameters from 4 through 24 inches. *Table 2* was developed using Equation [3] and the allowable air loss rates in *Table 1*. This is represented by Equation [4].

$$T_T = \left(\frac{L}{100}\right) T \qquad (4)$$

where:

T   = Required test time, minutes per 100 feet of pipe

Table 2	Minimum Test Times		
Pipe Diameter, Inches	T Minutes per 100 Feet	Pipe Diameter, Inches	T Minutes per 100 Feet
4	0.3	15	2.1
6	0.7	18	2.4
8	1.2	21	3.0
10	1.5	24	3.6
12	1.8		

To test a sewer system involving multiple diameter pipe, the volume of each size of pipe must be converted to an equivalent length of main sewer line, which length is then added to the test length of the main sewer line. Equivalent length is determined by:

$$L_e = \sum \frac{d^2 \ell}{D^2} \qquad (5)$$

where:

L_e = Total value of all laterals connected to the main sewer line expressed as an equivalent length of the mail sewer line, feet

d   = inside diameter of lateral, inches

ℓ = Total length of each diameter lateral, feet

To obtain the required total test time for a multiple diameter system, add the equivalent length of laterals to the main sewer line length, divide by 100, and then multiply by the appropriate test time value from *Table 2* for the main sewer pipe diameter, as follows:

$$T_T = \left(\frac{L + L_e}{100}\right) T \qquad (6)$$

From *Table 3* for *Figure 1*, the required holding times may be directly selected for the specified length and diameter of multiple and single diame-

Table 3	Time Holding Chart: Minimum Required Test Time in Minutes and Seconds for Pressure Drop from 3.5 to 2.5 psi								
Length in Feet	Pipe Diameter in Inches								
	4	6	8	10	12	15	18	21	24
50	0-09	0-20	0-36	0-44	0-53	1-02	1-12	1-29	1-47
75	0-13	0-30	0-53	1-07	1-20	1-34	1-48	2-14	2-40
100	0-18	0-40	1-11	1-29	1-47	2-05	2-24	2-58	3-33
125	0-22	0-50	1-29	1-51	2-13	2-36	3-00	3-43	4-26
150	0-27	1-00	1-47	2-13	2-40	3-07	3-36	4-27	5-20
175	0-31	1-10	2-04	2-36	3-06	3-39	4-12	5-12	6-13
200	0-36	1-20	2-22	2-58	3-33	4-10	4-48	5-56	7-06
225	0-40	1-30	2-40	3-20	4-00	4-41	5-24	6-41	8-00
250	0-44	1-40	2-58	3-42	4-26	5-12	6-00	7-25	8-53
275	0-49	1-50	3-15	4-04	4-53	5-43	6-36	8-10	9-46
300	0-53	2-00	3-33	4-26	5-20	6-15	7-12	8-54	10-39
325	0-58	2-10	3-51	4-49	5-46	6-46	7-48	9-39	11-33
350	1-02	2-20	4-09	5-11	6-13	7-17	8-23	10-23	12-26
375	1-07	2-30	4-26	5-33	6-40	7-48	8-39	11-08	13-19
400	1-11	2-40	4-44	5-55	7-06	8-20	9-35	11-52	14-12
425	1-15	2-50	5-02	6-18	7-33	8-51	10-11	12-37	15-06
450	1-20	3-00	5-20	6-40	8-00	9-22	10-47	13-21	15-59
475	1-24	3-10	5-37	7-02	8-26	9-53	11-23	14-06	16-52
500	1-29	3-20	5-55	7-24	8-53	10-24	11-59	14-50	17-46
525	1-33	3-30	6-13	7-46	9-19	10-56	12-35	15-35	18-39
550	1-38	3-40	6-31	8-08	9-46	11-27	13-11	16-19	19-32
575	1-42	3-50	6-48	8-31	10-13	11-58	13-47	17-04	20-25
600	1-47	4-00	7-06	8-53	10-39	12-29	14-23	17-48	21-19

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ter pipe systems. The required holding times in *Table 3* and *Figure 1* were calculated using Equation [3] and the minimum test times, T, given in *Table 2*. To use *Table 3*, simply select the required holding time for the specified diameter and the length or equivalent length of the sewer system. To use *Figure 1*, project a horizontal line from the length or equivalent length to the pipe diameter line, and then vertically to the horizontal scale to obtain the value for the required holding time.

PROCEDURE

Before conducting any leakage test, determine the groundwater conditions surrounding the sewer to be tested and select the type of test to be conducted. The requirements and limitations for each test are summarized in *Table 4*. The first step in each such procedures is to stop all dewatering operations and allow the groundwater to return to it's normal level.

If groundwater pressure is equal to or greater than the test pressure and the installed sewer is not leaking, the sewer line is acceptable and no additional testing is required. If one or more joints are leaking, but the total amount of leakage in the sewer line being tested is equal to or less than the allowable leakage rate established in accordance with *ASTM C969*, the line is acceptable and no additional testing is required.

If the groundwater level is two feet, or more, above the crown of the pipe at the upstream end, or if the test pressure required is greater than six pounds per square inch gage, the air test should not be used, since damage to unrestrained laterals is possible. If the groundwater level is two feet or more, above the crown of the pipe, for the entire length of the test section, the infiltration test, or visual inspection, should be used depending on the size of the pipe. If the groundwater level is less than two feet above the crown of the pipe at upstream end of the test section, the low-pressure air test, exfiltration test, and individual joint tests and visual inspection are all appropriate depending on the size of the pipe. If the air test is appropriate and selected, the proper procedures are presented in the following paragraphs.

Line Preparation

Where practical, the section of sewer line to be tested should be flushed and cleaned prior to conducting the low-pressure air test. This serves to clean out any debris and produce more consistent test results, since air may escape through the walls of dry concrete pipe.

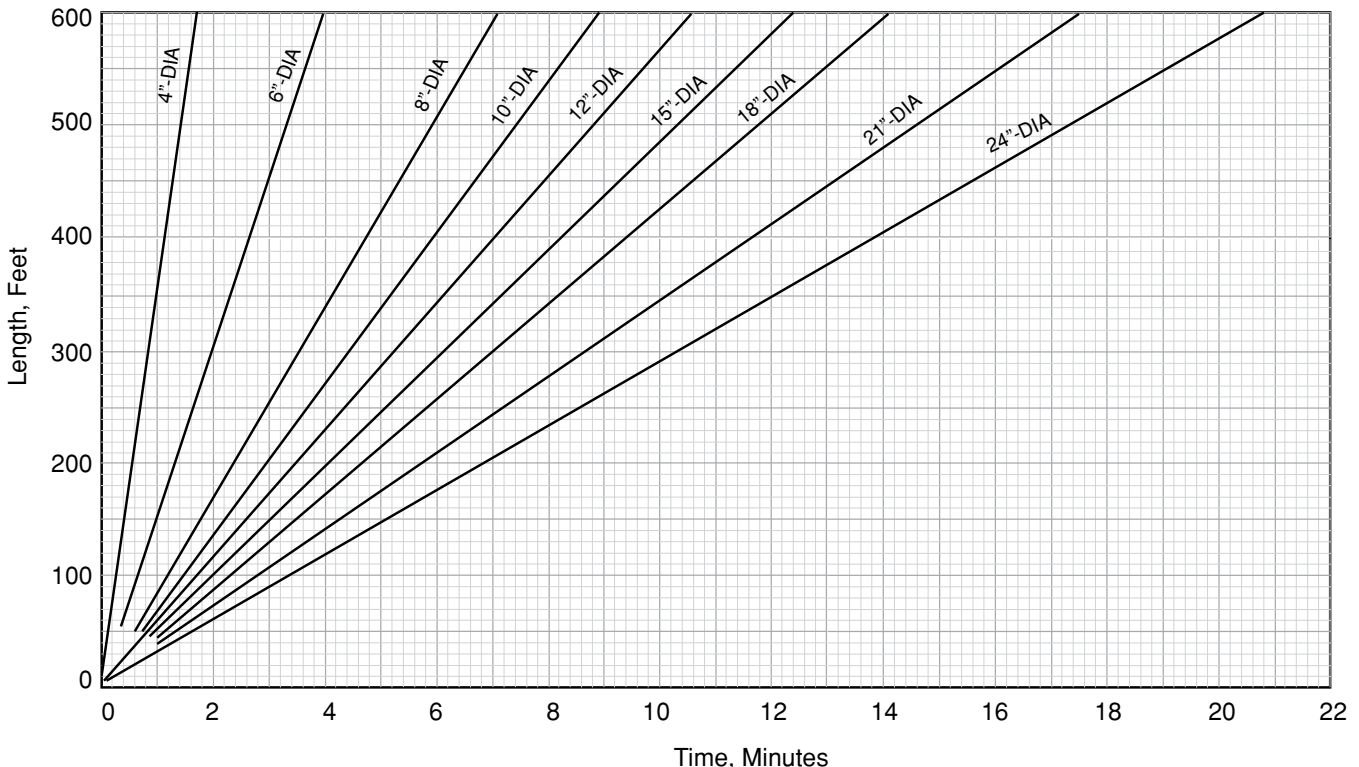**Figure 1   Low Pressure Air Testing by the Time Pressure Drops Method**

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Table 4 Applicable Leakage Tests for Sewer Lines

Pipe	Groundwater Condition	Applicable Tests				Comments
		Infiltration	Exfiltration	Air	Visual Inspection	
All	Groundwater pressure is greater than test pressure				X	If there is no visual leakage, or leakage at one or more joints that is less than allowable, the sewer line is acceptable without any additional testing,
	Groundwater is either: • Two feet or greater above the crown of the sewer lines at inlet • Two feet above the sewer line's crown along its entire length.	X			X	Do not air test. Air testing may result in damage to the unrestrained laterals.
4" to 24"	Groundwater is two feet or less above the highest point of the crown of the sewer line.	X	X	X	X	All test are appropriate. Note: Air test pressure is restricted to a maximum of 6 psi.
Greater Than 24"	All groundwater conditions				X	Do not air test. Testing should be limited to visual inspection of the sewer line or testing of individual joints.

Isolate the section of sewer line to be tested by inflatable plugs or other suitable means. The ends of all branches, laterals, tees, wyes and stubs to be included in the test should be plugged. Securely anchor and brace all plugs to prevent blow-out due to the internal air pressure.

Safety

The materials, equipment and operation of the air test may be hazardous, and this Design Data does not purport to address all of the safety problems associated with its use. It is the responsibility of the user to consult and establish appropriate safety and health practices and to determine the applicability of regulatory limitation prior to use.

No one should be allowed in the trench or manhole during pressurization, testing, or depressurization. Pressurizing a 24-inch diameter pipe to 4.0 pounds per square inch gage results in a total force of over 1800 pounds on the 24-inch plug. Such force could cause the violent expulsion of an improperly installed plug, and the energy of the plug released air could injure persons within the manhole or manhole opening.

Air Supply

Connect the air compressor to the inlet tap. The air supply system should include the necessary valves and gages to control the rate at which air flows into the test section and to enable monitoring the air pressure within the test section. The system should be equipped with a six pound per square inch pressure relief valve to reduce hazards and avoid possible damage to the sewer and unrestrained laterals. The system should have a bleeder valve to depressurize the sewer at the completion of the air test.

To provide realistic test results, the air compressor should be capable of pressurizing the test section in the required test time, or less. The minimum compressor capacity required is equal to the rate necessary to fill the sewer line to the desired pressure plus the allowable air loss rate:

$$C = \frac{0.17L}{T_T} \left[\frac{D}{12} \right]^2 + Q_L \qquad (7)$$

where:
C = Compressor capacity, cubic feet per minute

Test Pressure

If the test section is below groundwater level, determine the height of the groundwater above the crown of the pipe at each end of the test section. Compute the average groundwater height and increase the gage test pressure by 0.43 pounds per square inch for each foot of groundwater above the pipe crown. Under no circumstances should

the test pressure be allowed to exceed six pounds per square inch. Test pressures above six pounds per square inch are unsafe and may damage unrestrained laterals.

Initial Pressurization

Slowly add air to the test section until the pressure inside the pipe is raised to 4.0 pounds per square inch gage. Regulate the air supply so that pressure is maintained between 3.5 and 4.0 pounds per square inch gage for a period of time to allow the air and pipe wall temperatures to stabilize. The pressure will drop slightly until equilibrium is reached, which normally takes about five minutes. If the air and pipe wall temperatures are greatly different, equilibrium may take longer to reach.

During initial pressurization, the plugs should be checked to determine if there is any air leakage from the plugs. This can be accomplished by listening at the top of the open manhole for the sound of air leakage.

Testing

Disconnect the air supply, decrease the pressure to about 3.5 pounds per square inch gage, and begin timing the test. Experience has shown that the low pressure air test usually is a "go" or "no go" test and borderline cases are rarely encountered. If the gage holds steady, or has a low steady drop, the sewer line will usually pass the test. A sewer line with significant leaks will be indicated by an immediate or rapid drop in gage pressure.

Acceptance

If the pressure holds between 3.5 to 2.5 pounds per square inch gage for the required test time, the line is acceptable.

If the air pressure drops more than one pound per square inch in less than the test time, stop the test. Either conduct the air test again to check equipment, plugs, procedures and results, or use other methods to test the sewer line for leakage. If the sewer line still fails, the following courses of action should be considered:

- Segmentally test the line and compare the time-air loss values in each segment.
- If the values in each segment are compa-

rable, air losses are probably distributed throughout the line, and further analyses and tests should be made.
- If the values in each segment are significantly different, each segment should be evaluated and further tests made to determine the location of the air losses.

Again, it is important to emphasize that the low-pressure air test is an acceptable test which detects pipe damaged during installation or improper jointing and is not intended to be an indicator of possible water leakage under service conditions. Use or failure of this air test should not preclude acceptable by water test or other methods.

Disconnection

Upon completion of the test, the bleeder valve is opened to reduce the pressure to atmospheric. it is imperative that all pressure in the pipe be eliminated completely before any plug is loosed for removal.

EXAMPLES

The following examples have been prepared to demonstrate the techniques applied to determine minimum test times.

EXAMPLE 1

Given: A sewer system consists of 342 feet of 24-inch diameter concrete pipe between manholes A and B, and 135 feet of 18-inch diameter pipe between manholes B and C.

Find: The minimum test times required to demonstrate the integrity of the installed lines.

Solution: For the main sewer between manholes A and B, use Equation [4], and from *Table 2*, T=3.6 minutes per 100 feet for 24-inch pipe:

$$T_T = \left[\frac{L}{100}\right]T$$

$$T_T = \left[\frac{342}{100}\right]3.6$$

$$T_T = 12.3 \text{ minutes}$$

For the main sewer between manholes B and C, use Equation [4], and *Table 2*, T=2.4 minutes per 100 feet for 18-inch pipe:

$$T_T = \left[\frac{135}{100}\right]2.4$$

$$T_T = 3.2 \text{ minutes}$$

To calculate the required compressor capacity for the main sewer between manholes A and B, use Equation [7] and from *Table 1*, Q_L=6 cubic feet per minute for 24-inch diameter pipe:

$$C = \frac{0.17L}{T_T}\left[\frac{D}{12}\right]^2 + Q_L$$

$$C = \frac{0.17(342)}{12.3}\left[\frac{24}{12}\right]^2 + 6$$

$$C = 24.9 \text{ cubic feet per minute}$$

For the main sewer between manholes B and C, from Table 1, Q_L=5 cubic feet per minute for 18-inch diameter pipe:

$$C = \frac{0.17(135)}{3.2}\left[\frac{18}{12}\right]^2 + 5$$

$$C = 21.1 \text{ cubic feet per minute}$$

EXAMPLE 2

Given: The 342 feet of 24-inch diameter concrete pipe between manholes A and B in Example 1 has several 6-inch laterals with a total length of 900 feet connected to the main.

Find: The test time required to demonstrate the integrity of the installed lines.

Solution: Use Equation [5] to convert the total volume of 6-inch laterals to an equivalent length of main sewer:

$$L_e = \sum \frac{d^2\ell}{D^2}$$

$$L_e = \frac{(6)^2 \times 900}{(24)^2}$$

$$L_e = 56 \text{ feet}$$

For the total system, use Equation [6] from Table 2, T=3.6 minutes per 100 feet for 24-inch pipe:

$$T_T = \left[\frac{L + L_e}{100}\right]T$$

$$T_T = \left[\frac{342 + 56}{100}\right]3.6$$
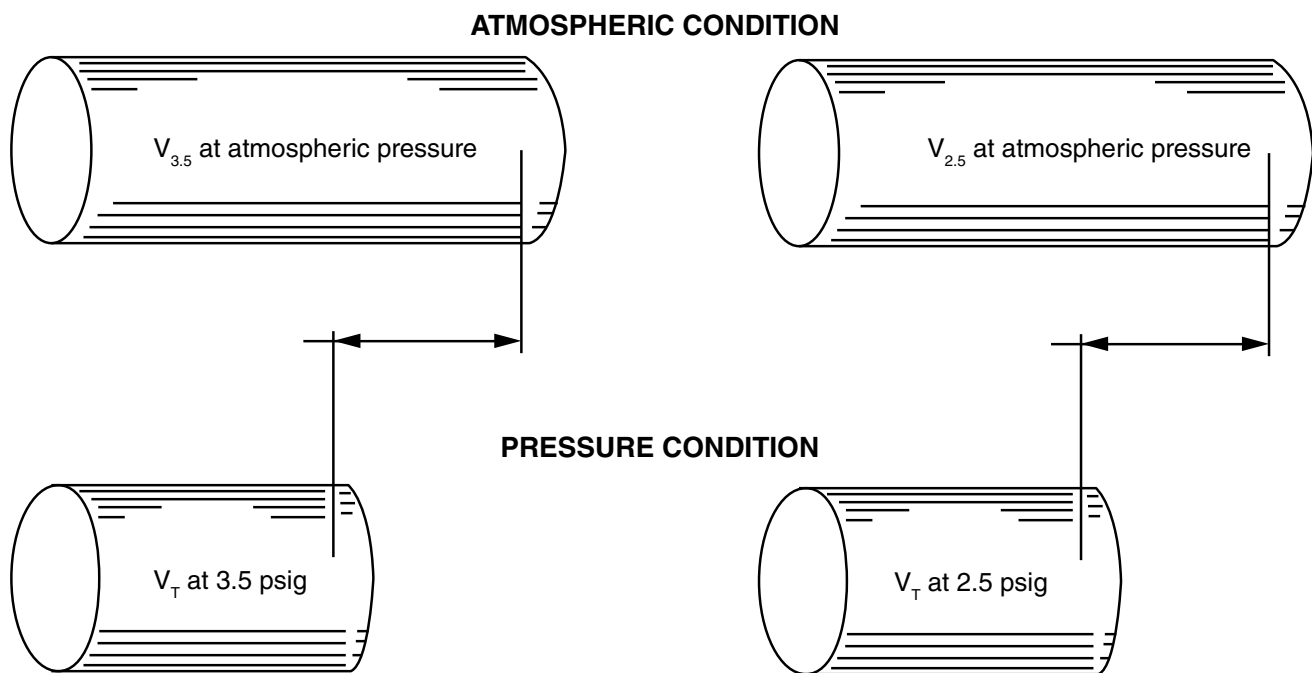
$$T_T = 14.3 \text{ minutes}$$

To calculate the compressor capacity for the equivalent system, use Equation [7] and from *Table 1*, Q_L=6 cubic feet per minute for 24-inch diameter pipe:

$$C = \frac{0.17L}{T_T}\left[\frac{D}{12}\right]^2 + Q_L$$

$$C = \frac{0.17(342 + 56)}{14.3}\left[\frac{24}{12}\right]^2 + 6$$

$$C = 24.9 \text{ cubic feet per minute}$$

Figure A-1

ATMOSPHERIC CONDITION

$V_{3.5}$ at atmospheric pressure

$V_{2.5}$ at atmospheric pressure

PRESSURE CONDITION

V_T at 3.5 psig

V_T at 2.5 psig

APPENDIX - TIME PRESSURE DROP METHOD

The time pressure Drop Method is derived from Boyle's Law, which states that the product of absolute pressure intensity and specific volume of any given mass of air is constant for any compression or expansion at constant temperature. Expressed in equation form:

$$P_1 V_1 = P_2 V_2 \qquad \text{[A.1]}$$

where:

P_1 = pressure at point 1, pounds per square inch or foot

V_1 = volume at point 1, cubic inches or feet

P_2 = pressure at point 2, pounds per square inch or foot

V_2 = volume at point 2, cubic inches or feet

To determine the volume of air loss within a pipe test section for a pressure drop from 3.5 pounds per square inch gage (18.2 psia) to 2.5 pounds per square inch gage (17.2 psia), it is necessary to evaluate the pressure-volume relationship at both of these pressure conditions. Referring to Figure A-1 and applying Boyle's law:

$$14.7 V_{3.5} = 18.2 V_T \quad \& \quad 14.7 V_{2.5} = 17.2 V_T$$

where:

14.7 = atmospheric pressure at sea level, pounds per square inch

$V_{3.5}$ = volume of air at atmospheric pressure required to be compressed into the volume of the test section to develop a gage pressure of 3.5 psig, cubic feet

18.2 = absolute pressure corresponding to 3.5 psi gage pressure within the test section, pounds per square inch

V_T = volume of pipe test section, cubic feet

$V_{2.5}$ = volume of air at atmospheric pressure required to be compressed into the volume of the test section to develop a gage pressure of 2.5 psig, cubic feet

17.2 = absolute pressure corresponding to 2.5 psi gage pressure within the test section, pounds per square inch

The volume of air loss (V_L) for the pressure drop from 3.5 to 2.5 pounds per square inch gage is expressed as:

$$
\begin{aligned}
V_L &= V_{3.5} - V_{2.5} \\
&= \frac{18.2 V_T - 17.2 V_T}{14.7} \\
&= \frac{V_T}{14.7}
\end{aligned}
$$

substituting

$$V_T = \frac{\pi D^2 L}{4} \times \frac{1}{144}$$

where:

π = 3.1416

D = diameter, inches

L = length of test section, feet

therefore:

$$V_L = 0.00037 \, D^2 L \qquad \text{[A.2]}$$

The time in which the volume of air is lost is equal to the volume of air loss divided by the rate of air loss.

$$
\begin{aligned}
T_T &= \frac{V_L}{Q_L} \\[6pt]
&= \frac{0.00037 D^2 L}{Q_L} \qquad \text{[A.3]}
\end{aligned}
$$

where:

T_T = test time, minutes

Q_L = rate of air loss, cubic feet per minute

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Technical data herein is considered reliable, but no guarantee is made or liability assumed.