

Gas-lift Valve Performance Testing

API RECOMMENDED PRACTICE 11V2
SECOND EDITION, MARCH 2001

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Gas-lift Valve Performance Testing

Upstream Segment

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Gas-lift Valve Performance Testing

0 Introduction

This Recommended Practice (RP) covers the test procedures for flow performance testing of wireline retrievable and tubing retrievable IPO (injection pressure operated), and PPO (production pressure operated) gas-lift valves. Injection pressure operated means that the largest force causing the ball and stem to move is supplied by injection pressure and production pressure is the major force for moving the ball and stem for PPO valves.

The 11V2 RP contains sections which:

- a. Briefly describes each section (Section 1).
- b. Provide Definitions and Abbreviations (Section 2).
- c. Recommend dynamic test facility requirements (Section 3).
- d. Recommend the test equipment and describe the test procedure necessary to determine bellows assembly load rate and maximum effective travel for a given valve (Section 4).
- e. Describe the test procedure necessary to determine valve flow coefficients for the full range of stem travel (Section 5).
- f. Describe two methods of obtaining the gas-lift valve performance curves (Section 6).
- g. Recommend the number of tests required to develop a model or correlation to predict valve performance (Section 7).
- h. Describe two methods that use the test data to predict performance at conditions other than those tested (Appendix A and B).
- i. Describe a method for the analysis of probe test data obtained from Section 4 (Appendix C).
- j. Describe a test procedure which yields the time constant of the test system described in Section 3 (Appendix D).

1 Scope

Test site recommendations (Section 3): This section outlines the equipment needed for testing valves to determine the following:

- a. Valve flow coefficients (C_v).
- b. Pressure drop ratio factor (X_t).
- c. Gas-lift valve performance curves.

Gas-lift valve probe tests (Section 4): This test method is outlined for determining the stem travel as pressure is applied over the bellows area. The test results are combined with analysis (Appendix C) to allow the user to approximate the valve load rate over the range of expected practical application conditions. The test also defines the maximum effective valve stem travel.

Flow coefficient test procedure (Section 5): The test procedure recommends test methods required to determine the flow coefficient (C_v) as a function of stem travel. The test results, combined with analysis, allow the user to approximate the

valve flow coefficient (C_v) and pressure drop ratio factor (X_t) over the range of expected practical application conditions.

Gas-lift valve performance test methods (Section 6): This test procedure lists the test methods recommended to measure valve performance (flow) for upstream and downstream pressures and other controlled conditions.

Use of test data (Section 7): This section recommends the number of tests which should be performed in order to acquire sufficient data to develop a model or correlation describing valve performance at conditions other than those tested. Reference is made to methods described in Appendices A and B.

Simplified flow performance model (Appendix A): This appendix describes a method of analysis of test data that will predict flow at conditions other than those tested. The model makes several simplifying assumptions concerning valve dynamics.

TUALP flow performance model (Appendix B): This appendix describes a method of analysis of test data that will predict flow at conditions other than those tested. The model was developed and is supported by the Tulsa University Artificial Lift Projects research program at the University of Tulsa.

Method to analyze probe test data (Appendix C): This appendix describes a mathematical method of analysis to determine loadrate and maximum effective travel when data is collected per Section 4.

Determination of test system time constant (Appendix D): This appendix gives the supporting explanation for the use of "ramp" functions in the test methods and describes how to determine a test systems time constant.

2 Definitions and Abbreviations

2.1 DEFINITIONS

2.1.1 A_b : Effective bellows area (in.²) [cm²].

2.1.2 A_p : Area based on the nominal port diameter (in.²) [cm²].

2.1.3 A_s : Area based on the diameter where the stem contacts the seat (in.²) [cm²].

2.1.4 B_l : Bellows assembly load rate as per Section 4 (psi/in.) [kPa/cm].

2.1.5 C_v : Flow Coefficient as per Section 5.

2.1.6 dP : Differential pressure as defined in context (psi) [kPa].

2.1.7 dx : Distance stem has moved from seat (in.) [cm].

2.1.8 F_k : Specific heats factor equal to $k/1.40$.

2.1.9 H: A factor determined by the manufacturer to calculate the upstream test pressure for the Constant Injection Pressure Test

2.1.10 k: Ratio of specific heats of lift gas.

2.1.11 P₁: Upstream gage pressure of test section (psig) [kPag].

2.1.12 P₂: Downstream gage pressure of test section (psig) [kPag].

2.1.13 P_{vst}: Pressure required to achieve LST of GLV.

2.1.14 P_{iod}: Operating injection gage pressure at valve depth (psig) [kPag].

2.1.15 P_o: Upstream gage pressure for a constant downstream gage pressure and near zero gas flow rate (psig) [kPag].

2.1.16 P_{pd}: Flowing production gage pressure at valve depth (psig) [kPag].

2.1.17 P_{vc}: Measured or calculated upstream gage pressure when the downstream pressure is equal to the upstream pressure and near zero gas flow rate at 60°F (15.5°C) (psig) [kPag]. Referred to as Valve Closing Pressure at 60°F.

2.1.18 P_{vcT}: Measured or calculated upstream gage pressure when the downstream pressure is equal to the upstream pressure and near zero gas flow rate at a known temperature (psig) [kPag]. Referred to as Valve Closing Pressure at temperature.

2.1.19 P_{vo}: Measured or calculated gage pressure applied over the area A_b minus A_s required to initiate flow through a valve with zero gage pressure downstream at 60°F (15.5°C) (psig) [kPag]. Referred to as Valve Opening Pressure at 60°F.

2.1.20 P_{voT}: Measured or calculated gage pressure applied over the area A_b minus A_s required to initiate flow through a valve with zero gage pressure downstream at a known temperature (psig) [kPag]. Referred to as Valve Opening Pressure at Temperature.

2.1.21 q: Measured flow rate in cubic feet per hour at SC (SCF/hr) [m³/hr].

2.1.22 q_{gi}: Measured flow rate in thousands of cubic feet per day at SC (MSCFD) [SCMD].

2.1.23 S_g: Specific gravity of gas (Air = 1.0).

2.1.24 T₁: Upstream gas temperature of test section (°F) [°C].

2.1.25 T_v: Temperature of valve at depth (°F) [°C].

2.1.26 x: Pressure ratio. The measured differential pressure across the test section divided by the absolute upstream pressure ($dP/(P_1 + 14.7)$).

2.1.27 X_f: Pressure drop ratio factor. The largest pressure ratio (x) for a given upstream pressure at which a decrease in downstream pressure will not increase the flow rate. Critical flow occurs when $F_k \cdot X_f$ equals or exceeds the pressure ratio. Determined as per Section 5.

2.1.28 Y: Expansion factor.

2.1.29 Z₁: Upstream compressibility factor.

2.2 ABBREVIATIONS

ASME	American Society of Mechanical Engineers
ANSI	American National Standards Institute
API	American Petroleum Institute
CIPT	Constant injection pressure test
CPPT	Constant production pressure test
DCV	Downstream control valve
ECV	Equalizing control valve
GLV	Gas-lift valve
GST	Geometric Stem Travel for full opened condition
IPO	Injection pressure operated
ISA	Instrument Society of America
LST	Maximum effective stem travel from probe test
MSCFD	Thousands of standard cubic feet per day
PPO	Production pressure operated
RP	Recommended Practice
SC	Standard Conditions assumed to be 14.73 psia (101 kPa) and 60°F (15.5°C)
SCFD	Standard cubic feet per day
SCMD	Standard cubic meters per day
UCV	Upstream control valve
VST	Valve stem travel

3 Test Site Recommendations

3.1 INTRODUCTION

This section outlines the testing facility necessary to perform gas-lift valve testing. The type testing anticipated will require a high-volume, high-pressure source of gas. It is suggested that the gas storage device be at least 100 ft³ (cubic meter) and the pressure be at least 1500 psig (kPa).

Local, state, and national codes and practices should be followed when constructing the facility. The piping, valves, and surge vessels comprising the gas-lift valve testing system will be subjected to high pressure gas. As such, the fabrication, testing, and valve selections should adhere to the established codes governing piping systems and vessels.

Surge or other vessels with diameters exceeding 6 in. (152 mm) should adhere to ANSI/ASME Sec VIII D1-89, *Rules for Construction of Pressure Vessels Division 1* or Sec VIII D2-89, *Rules for Construction of Pressure Vessels Division 2*. Alter



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native Rules. These rules provide requirements for design, fabrication, inspection, and certification of applicable vessels.

The piping consisting of materials, wall thickness, and related pressure ratings, should adhere to ANSI/ASME B31.8-89, *Gas Transmission and Distribution Piping Systems* and subsequent addenda. Piping material should be specified as Grade B. Flanges should adhere to ANSI/ASME B16.5-88, *Pipe Flanges and Flanged Fittings* and errata; valves are covered by ANSI/ASME B16.34-88, *Valves—Flanged, Threaded, and Welded End*.

Note: API valves and flanges could be used but are covered by API Spec 6D *Specification for Pipeline Valves (Steel Gate, Plug, Ball, and Check Valves)*. These API flanges may not be interchangeable with ANSI/ASME flanges.

The design pressure for piping, valves, flanges, or pressure vessels should be at least 20% greater than the highest pressure anticipated during the gas-lift valve tests.

When tests are conducted using a test stand as described in this section, the maximum possible error associated with the calculation of the flow rate will be approximately 6% and could be less.

3.2 GENERAL DESCRIPTION

The flow test system includes, as a minimum, items shown in Figure 1 and listed below:

1. Test specimen.
2. Test section.

3. Throttling control valves.
4. Pressure surge tanks.
5. Flow measuring device.
6. Pressure sensors.
7. Temperature sensors.
8. Equalizing valves.

3.3 TEST SPECIMEN

3.3.1 Wireline Retrievable Valves

The test specimen consists of the components as listed below and shown in Figure 2.

1. The fully assembled test valve including the manufacturers recommended reverse flow valve.
2. With a compatible latch.
3. Installed and latched in a compatible receptacle.

3.3.1.1 Test Valve

The valve should be in the fully assembled condition as suggested by the manufacturer. Replacement of the external V-ring packing stacks with an alternate sealing means is permissible.

3.3.1.2 Latch

The latch should be compatible with the receptacle and valve.

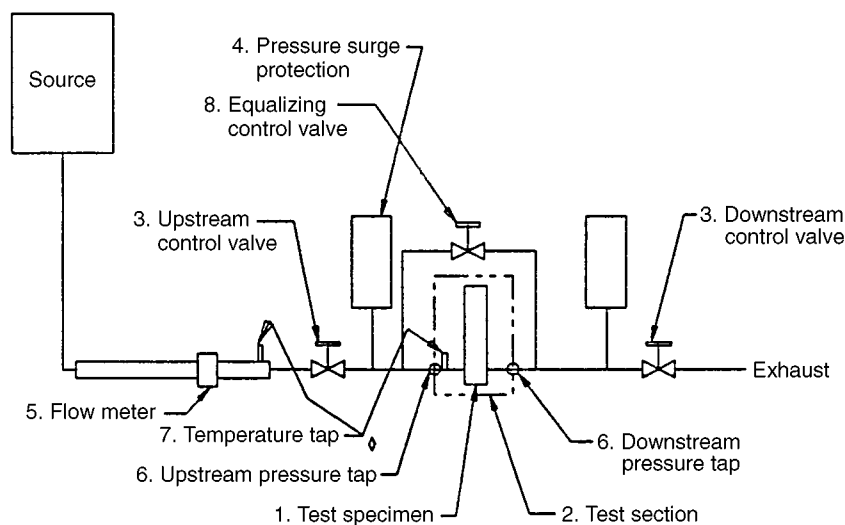


Figure 1—Basic Flow Test System Schematic

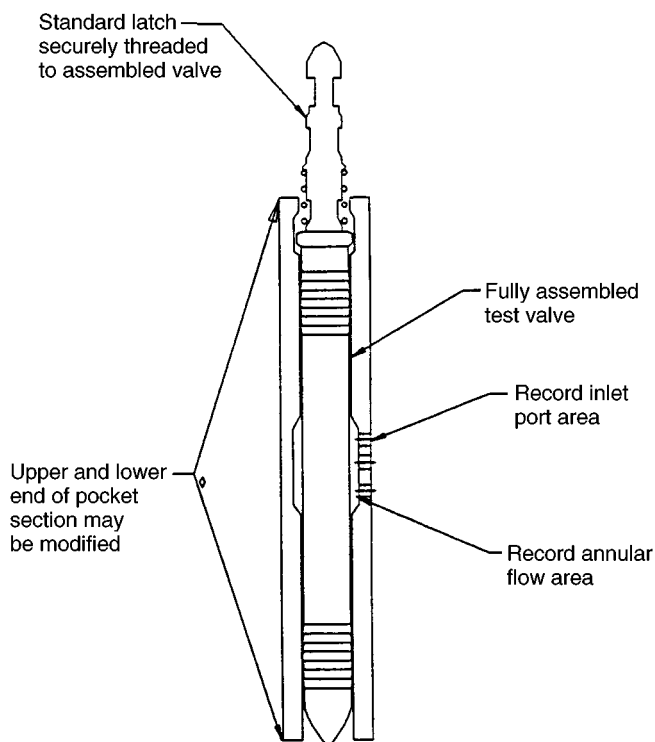


Figure 2—Wireline Retrievable Test Specimen

3.3.1.3 Valve Receptacle

The valve receptacle should be compatible with the valve and latch and should provide means to seal above and below the valve inlet ports. The inlet port area of the receptacle and the minimum annular flow area between the receptacle and valve inlet port should be recorded.

3.3.2 Tubing Retrievable Valves

The test specimen consists of the components as listed below and shown in Figure 3.

1. The fully assembled test valve including the manufacturers recommended reverse flow valve.
2. Threaded to a compatible receptacle for attachment to the test facility.

3.4 TEST SECTION

3.4.1 General

The test section includes the test specimen and all fixtures located between the upstream and downstream pressure measurement devices. The flow path through the test section should not pass through any chokes, close radius elbows or tees and be free of internal obstructions. Elbows should have a minimum 4 in. (10.16 cm) radius. Figures 4 and 5 show examples of test sections which comply with these recommendations.

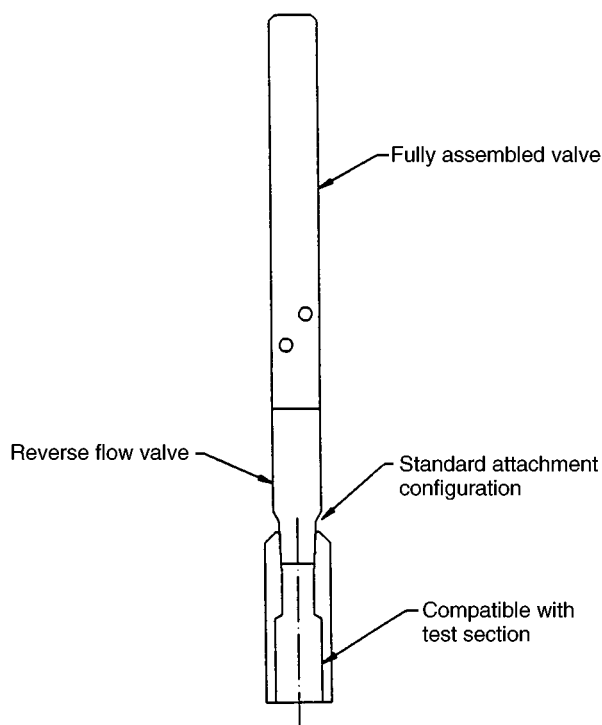


Figure 3—Tubing Retrievable Test Specimen

3.4.2 Upstream Test Section

The test section upstream of the test specimen may extend no more than 24 in. (60.96 cm) from the test specimen and should have a minimum inside flow diameter of at least 1 in. (2.54 cm). The upstream test section should be plumbed to the test specimen such that an unobstructed annular chamber exists surrounding the inlet ports of the test specimen. This chamber should extend no less than 1/2 in. (1.27 cm) above and below the inlet ports of the test specimen and should have an annular width of at least 1/4 in. (0.64 cm).

3.4.3 Downstream Test Section

The test section downstream of the test specimen may extend no more than 24 in. (60.96 cm) from the test specimen and should have an inside diameter of at least 1.5 in. (3.81 cm). The downstream test section should be aligned such that the centerlines of the specimen and section are parallel and concentric. The downstream test section should have a straight extension of at least 6 in. (15.24 cm) length beginning at the test specimen.

3.5 THROTTLING CONTROL VALVES

3.5.1 General

Upstream and downstream throttling control valves are used to control the pressures acting on the test section. There is no restriction as to the style of these valves.

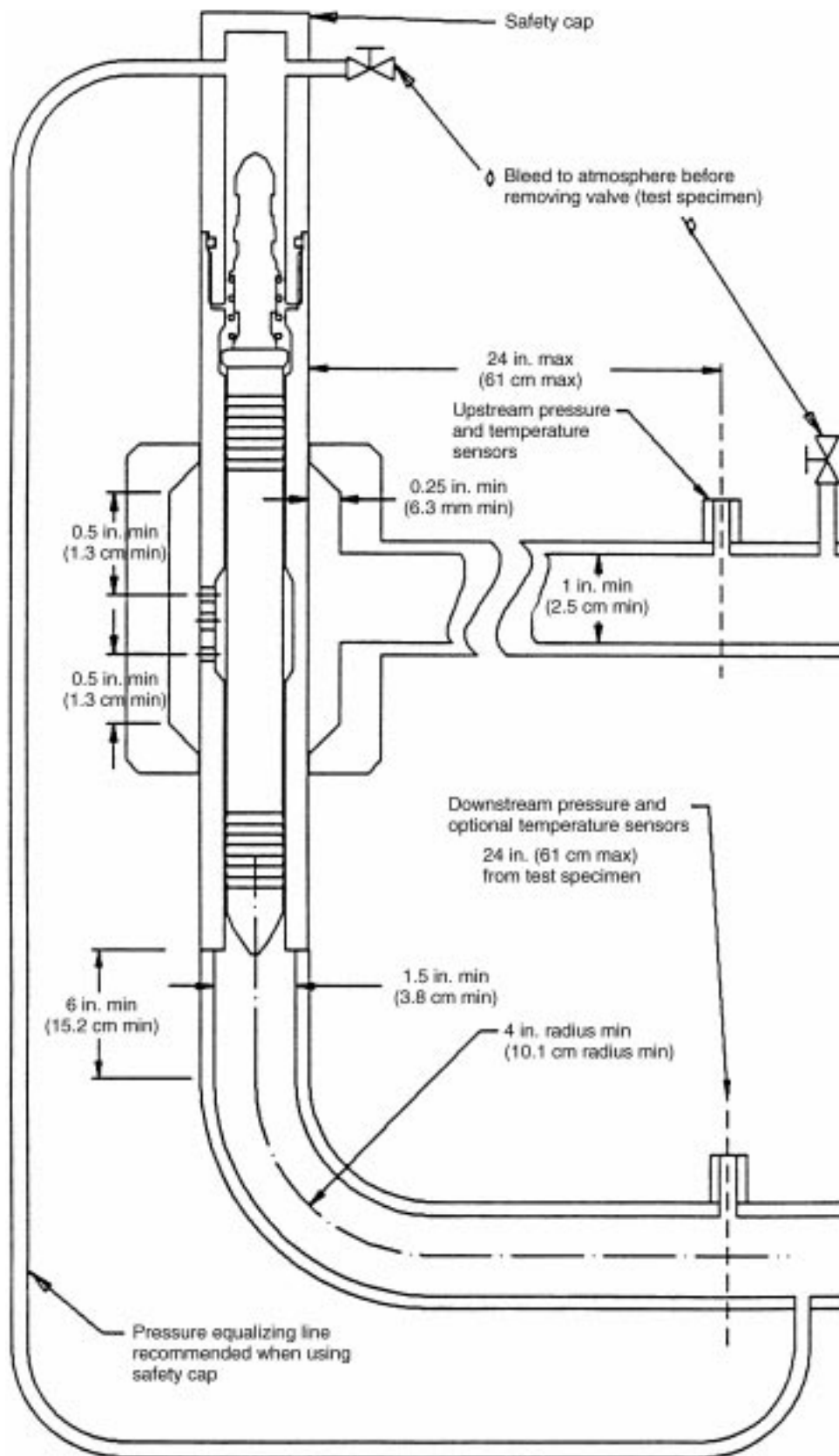


Figure 4—Test Section Example for Wireline Retrievable Valves

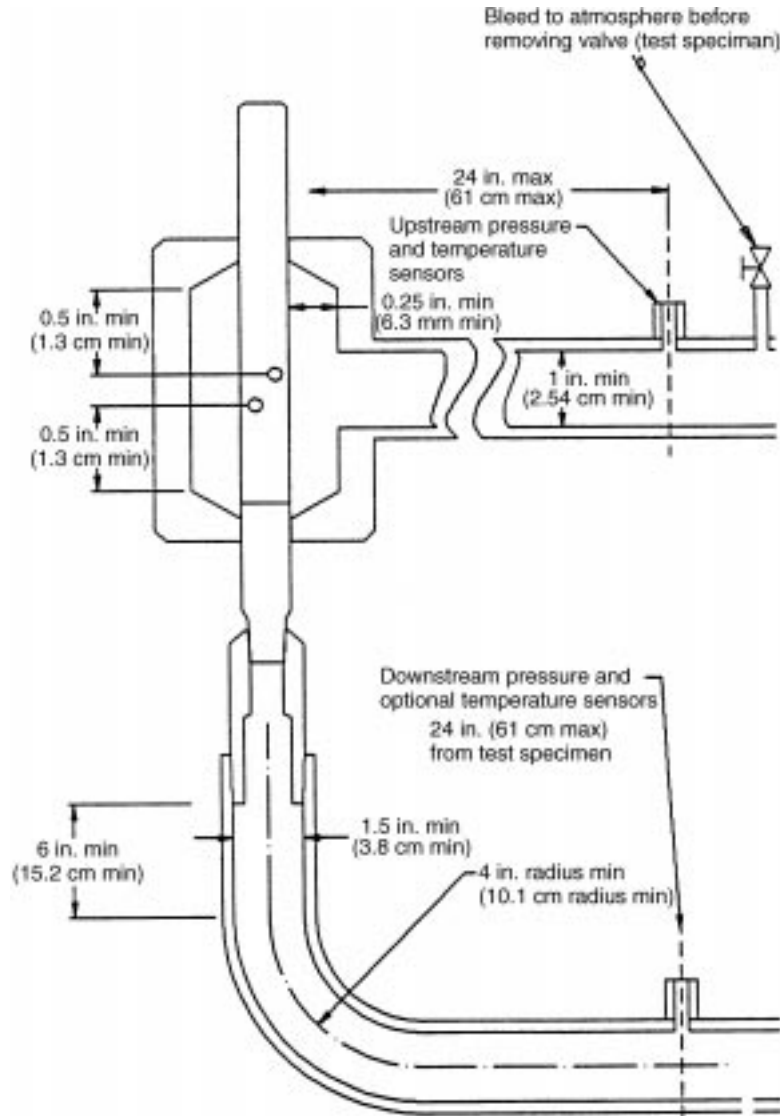


Figure 5—Test Section Example for Tubing Retrieval Valves

3.5.2 Capacity

Both control valves should be of sufficient flow rate and pressure capacity to exceed the flow rate and pressure capacity of the test specimen.

3.6 PRESSURE SURGE PROTECTION

3.6.1 General

Pressure surge protection is recommended on both the upstream and downstream side of the test section. The purpose of the pressure surge protection is to dampen the effects of a pressure surge that might occur as a result of valve performance. Pressure surge may cause serious damage to pres-

sure gages and transducers and seriously hamper the ability to control and monitor a test.

3.6.2 Surge Tanks

Surge tanks can be used to gain an adequate amount of surge protection. These tanks should be plumbed into the test system outside of the test section such that they are each independently in full pressure communication with the upstream and downstream pressures acting on the test section. Optional control valves may be placed in the plumbing connecting the pressure surge tanks to the test system.

The volume of the pressure surge tanks should be no less than 2 ft³ (0.057 m³). It is preferred that the downstream pres-

sure surge tank have twice the volume of the upstream pressure surge tank.

3.6.3 Alternative Methods

Alternative surge protection systems that reduce pressure surges in the test specimen to no more than 10 psig/sec (69 kPa/sec) are also permitted.

3.7 FLOW MEASUREMENT

3.7.1 Methods

The flow measurement instrument and/or method may be any device which meets the specified accuracy.

3.7.2 Accuracy

Flow rate should be determined within an error not exceeding $\pm 6\%$ of actual flow rate. The resolution and repeatability of the method should be within $\pm 1\%$ of actual flowrate. The measuring instrument should be selected and maintained to achieve the specified accuracy. The AGA Report No. 3, ANSI/API MPMS 14.31-1990, or GPA 8185-90 Part 1 methods of flowrate calculation along with a certified meter run will satisfy these recommendations.

3.8 PRESSURE TAPS

3.8.1 General

Two pressure taps are required. The location of these two pressure taps will define the upstream and downstream pressures acting on the test specimen. The location of these two taps define the beginning and end of the test section. The

geometry of the tap should conform to the dimensions given in Figure 6.

3.8.2 Location

The upstream and downstream pressure taps should be located as near as possible to the test specimen but should be no more than 24 in. (60.96 cm) from the test specimen.

3.8.3 Orientation

When located on a horizontal run, the upstream and downstream taps should be located above a horizontal plane extending through the centerline of the pipe. The tap centerline should be perpendicular to the pipe centerline.

3.9 PRESSURE MEASUREMENT

3.9.1 Accuracy

All pressure and pressure differential measurements should be selected with an accuracy such that any errors do not exceed $\pm 1\%$ of actual value. Pressure measuring devices should be calibrated as frequently as necessary to maintain specified accuracy.

3.9.2 Pressure Reporting Requirements

The upstream and downstream test section pressure measurement should be visually displayed continuously to the operators controlling the test pressures at the test section.

A means should be provided to produce a hardcopy report of the pressures measured at both the upstream and downstream pressure taps of the test section. This means should report pressures within an accuracy of $\pm 2\%$ of the pressure measurement devices.

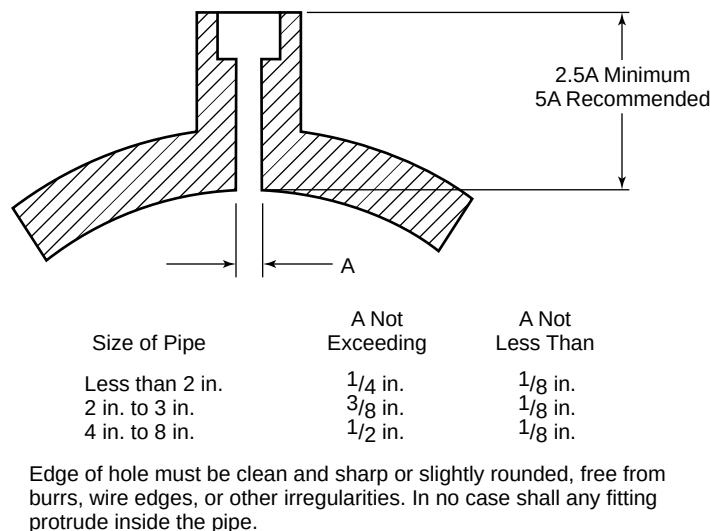


Figure 6—Recommended Pressure Taps

3.10 TEMPERATURE TAPS

3.10.1 General

Two temperature taps are required. One temperature tap is required on the upstream side of the test section and another is required for the flow rate measurement device. An optional downstream temperature tap may be located on the downstream side of the test section.

3.10.2 Location

The upstream temperature tap should be located within the upstream side of the test section. The temperature tap used for flow rate measurement should be located as recommended by the manufacturer of the flow rate measurement device. There is no requirement for the location of the optional downstream temperature tap, however, it is recommended that if one is used, it be located within the downstream side of the test section.

3.10.3 Orientation

When located on a horizontal run, the temperature taps should be located above a horizontal plane extending through the centerline of the pipe.

3.11 TEMPERATURE MEASUREMENT

3.11.1 Accuracy

The devices used to measure gas temperature should not have an error exceeding $\pm 2^{\circ}\text{F}$ ($\pm 1.1^{\circ}\text{C}$) of actual value.

3.11.2 Measurement Requirements

The gas temperature should be measured at the flow rate measurement device and on the upstream portion of the test section.

3.11.3 Temperature Reporting Requirements

A means should be provided to produce a hardcopy report of the temperatures measured at both the flow rate measurement device and at the upstream portion of the test section. This means should report temperatures within an accuracy of $\pm 2\%$ of the temperature being measured.

3.12 EQUALIZING VALVES

The method of accomplishing the tests may require that the upstream and downstream pressures be equalized prior to testing. The equalizing valve is positioned between the upstream and downstream test section and allows the ability to bypass the test specimen.

3.13 GAS SUPPLY

Air or some other compressible gas should be used as the basic fluid in this test procedure. Vapors which may approach their condensation points at the vena contracta of the specimen are not acceptable. Care should be taken to avoid formation of liquids or solids in the gas supply during the test.

3.14 DOCUMENTATION

The following information should be available as a means for demonstrating the compliance of the test apparatus with this recommendation. Data Form 1 is a convenient form that may be used for this purpose.

1. Schematic identifying the layout and location of items 1–8 of 3.2 and signed by the person in charge of testing.
2. Detail drawing of the test section showing:
 - a. distance from upstream test section to test specimen.
 - b. distance from downstream test section to test specimen.
 - c. number and size of receptacle inlet ports and annular flow area between valve and receptacle for wireline retrievable fixtures.
 - d. location and size of annular chamber around test specimen.
3. Type and capacity of throttling control valves.
4. Type and size of surge protection.
5. Type and accuracy of flow measurement device.
6. Type and accuracy of pressure measurement devices.
7. Type and accuracy of pressure recording hardcopy device.
8. Type and accuracy of temperature measurement devices.
9. Type and accuracy of temperature recording hardcopy device.

4 Gas-lift Valve Probe Test

4.1 INTRODUCTION

The purpose of the Gas-lift Valve Probe Test is to determine the relative “stiffness” of a gas-lift valve and to determine the maximum effective travel of the stem. When gas pressure is admitted to the tester, it must act on the full area of the valve bellows to lift the stem off the seat. When this pressure is increased, the stem lifts further from the seat. By using the Valve Probe Tester (see Figure 7), an accurate measure of the stem travel versus pressure can be determined and the results tabulated and plotted. The valve probe tester shown in Figure 7 is an example and is not intended to restrict the many possible devices which may be used to accomplish the test.

When the pressure is plotted as the ordinate and the stem travel as the abscissa, a relatively straight line will be generated for the effective stem travel. The slope of this line is an indication of the “stiffness” of the valve. The numerical value