Installation, Maintenance, and Repair of Surface Safety Valves and Underwater Safety Valves Offshore

API STANDARD 6AV2
FIRST EDITION, MARCH 2014

AMERICAN PETROLEUM INSTITUTE

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This standard is the result of the revisions of API 14H, *Recommended Practice for Installation, Maintenance and Repair of Surface Safety Valves and Underwater Safety Valves Offshore*, 5th Edition. The document was revised with additional requirements and re-classified as a "standard." Even though this document (API 6AV2) is the First Edition, it is a revision of and supersedes API 14H, 5th Edition, and is the next in the evolution of the document.

This standard shall become effective on the date printed on the cover.

Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

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1 Scope

This standard provides requirements for installing and maintaining surface safety valves (SSV) and underwater safety valves (USV). Included are requirements for receiving inspection, installation and maintenance, field and off-site repair, testing procedures with acceptance criteria, failure reporting, and documentation. Power and control systems for SSVs/USVs are not included. This document is applicable to SSVs/USVs used or intended to be used as part of a safety system, as defined by documents such as API 14C.

NOTE SSV/USV system architecture and power/control systems for SSVs/USVs are addressed in safety system documents such as API 14C.

This standard is the revision of and supersedes API 14H, Fifth Edition.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Specification 6A, *Specification for Wellhead and Christmas Tree Equipment*

API Recommended Practice 14C*, Analysis, Design, Installation, and Testing of Basic Surface Safety Systems for Offshore Production Platforms*

API Recommended Practice 17A/ISO 13628-1:2005, *Design and Operation of Subsea Production Systems—General Requirements and Recommendations*

API Specification 17D, *Design and Operation of Subsea Production Systems—Subsea Wellhead and Tree Equipment*

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

For the purposes of this standard, the following terms and definitions apply.

3.1.1
choked flow
Flow condition in which the fluid flow velocity and mass-flow rate are insensitive to the pressure differential across the flow restriction and occurs when the pressure drop across the flow restriction is higher than the critical pressure differential.

3.1.2
christmas tree
Assembly of equipment, including tubing-head adapters, valves, tees, crosses, top connectors, and chokes attached to the uppermost connection of the tubing head, used to control well production (as defined in API 6A and API 17D).

3.1.3
critical pressure differential
Pressure drop resulting from a pressure ratio below the critical pressure ratio.

3.1.4
critical pressure ratio
Ratio of pressure downstream of the flow restriction to pressure upstream of the flow restriction below which choked flow occurs.

3.1.5
direct measurement device
Instrument/equipment whose output is the measurement of flow rate (leakage) across the pressure-controlling components of the SSV/USV.

3.1.6
failure
Improper performance of a device or equipment item that prevents completion of its in-service design function.

3.1.7
indirect measurement method
Use of equipment whose output is the measurement of one or more thermodynamic properties of the fluid moving across the SSV/USV, and the methodology used to convert the measured quantities into the equivalent flow rate (leakage) across the pressure-controlling components of the SSV/USV.

3.1.8
maintenance
Routine actions defined in the manufacturer's operation and maintenance manual that keep the device in working order.

NOTE Maintenance does not include repair/remanufacture.

3.1.9
manufacturer
The principal agent in the design, fabrication, and furnishing of a SSV/USV actuator and/or SSV/USV valve.

NOTE The SSV/USV valve and SSV/USV actuator define functional entities and do not necessarily represent the units as supplied.

3.1.10
non-choked flow
Fluid flow resulting when the pressure drop across the flow restriction is lower than the critical pressure differential.

3.1.11
OPD part supplier
Entity that has supplied the original product definition (OPD) components for use on SSVs/USVs.

3.1.12
operating manual
The publication issued by the manufacturer containing detailed data and instructions related to the design, installation, operation, and maintenance of SSV/USV equipment.

3.1.13
operator
The user of a SSV/USV who is in conformance with the requirements of this standard.

3.1.14
original product definition
OPD
Complete definition of the requirements for the original assembled equipment, single equipment unit, or component part, including specified limits and tolerances, health, safety, and environmental requirements, limitations of use, customer specific requirements, design acceptance criteria, materials of construction, materials processing requirements and physical properties, physical dimensions, and requirements for manufacturing process controls, inspection, assembly and testing, marking, handling, storage, maintenance, and records requirements (as defined in API 6A).

3.1.15
pressure-containing part
Part whose failure to function as intended results in a release of retained fluid to the atmosphere.

NOTE Examples of pressure-containing parts include bodies, bonnets, one-piece stems, and that segment of multi-piece stems that passes through the pressure boundary.

3.1.16
pressure-controlling part
Part intended to control or regulate the movement of pressurized fluids.

NOTE An example of pressure-controlling parts includes valve-bore sealing mechanisms.

3.1.17
qualified personnel
Individual with characteristics or abilities gained through training, experience, or both, as measured against the established requirements of the manufacturer/purchaser/this document. (As defined in 6A.)

3.1.18
remanufacture
Activity involving disassembly, reassembly, and testing of the SSV/USV, with or without the replacement of parts other than bodies, where machining, welding, heat treating, or other manufacturing operations are employed.

NOTE Remanufacture does not include the replacement of bodies, in order to retain traceability.

3.1.19
repair
Activity involving disassembly, reassembly, and testing of SSVs/USVs, with or without the replacement of parts other than bodies, which restores the equipment to its original performance meeting or exceeding the requirements of the edition of API 6A, API 14D, and ASME SPPE 1 that were in effect at the time of original manufacture.

NOTE Repair does not include machining, welding, heat treating, other manufacturing operations, or the replacement bodies.

3.1.19.1
field repair
Repair activity performed in accordance with this standard by qualified personnel using components that meet or exceed OPD requirements at the equipment installation site.

NOTE Field repair does not include replacement of the SSV/USV valve body.

3.1.19.2
off site repair
Repair that occurs at a location other than the equipment installation site and performed in conformance with API 6A.

3.1.20
service provider
Entity and its designated qualified personnel contracted to perform installation, field maintenance, and/or repair.

3.1.21
SSV/USV actuator
The device that causes the SSV/USV valve to open when power is supplied and to automatically close when power is lost or released.

3.1.22
SSV lock-open device
A device installed on a SSV actuator to maintain the SSV valve in a full open position until exposed to sufficient heat to cause the device to release and allow the SSV valve to close.

3.1.23
SSV/USV valve
The portion of the SSV/USV that contains the well-stream and shuts off flow when closed.

3.1.24
surface safety valve
SSV
An automatic wellhead valve assembly that will close upon loss of power supply.

NOTE When used in this standard it includes the SSV valve, SSV actuator, and SSV lock-open device.

3.1.25
sustained leak rate
Leak rate representative of current field performance of the SSV/USV valve-bore sealing mechanism.

3.1.26
underwater safety valve
USV
Automatic valve assembly installed at an underwater wellhead location, which closes on loss of power supply.

NOTE Where used in this standard, the term is understood to include a USV valve and USV actuator (as defined in API 6A).

3.2 Acronyms and Abbreviations

For the purposes of this specification, the following abbreviations shall apply.

NORM	naturally occurring radioactive material
OEM	original equipment manufacturer
OPD	original product definition
PPB	parts per billion
PPM	parts per million
PSL	product specification level (as defined in API 6A)

RL	repair and remanufacture level (as defined in API 6A)
SITP	shut-in tubing pressure
SSV	surface safety valve
USV	underwater safety valve

4 Receiving Inspection

Prior to installation of the SSV/USV on the well, the SSV/USV documentation shall be checked to verify the following:

a) the serial numbers on the SSV/USV correspond to those recorded on the accompanying shipping report;

b) the SSV/USV valve and SSV/USV actuator are the proper size, PSL/RL, material class, temperature, and pressure rating for the intended service;

c) the SSV/USV valve is marked with the appropriate service class (e.g. API 6A Class II for Sandy Service).

The SSV/USV shall be visually inspected by qualified personnel for damage that might impair its proper operation.

If disassembly is required as part of the visual inspection of the SSV/USV, it shall be performed by qualified personnel and shall be in accordance with the manufacturer's operating manual and the requirements set in Section 6 of this document.

Tools and operational equipment (e.g. SSV lock-open device) associated with the SSV/USV should be identified and inspected for proper operation/condition, according to user's and manufacturer's written procedures.

5 Installation and Maintenance

5.1 Location in System

The SSV should be located in the tree architecture in accordance with API 14C, and the location shall be specified in the operator's procedure.

NOTE The SSV is typically the second valve in the flow stream of the wellhead and christmas tree.

The USV should be located in the tree architecture in accordance with API 17A, API 17D, and API 14C. The location shall be specified in the operator's procedure.

NOTE Typical subsea tree architecture is specified in API 17D. General barrier system philosophy is described in 17A. In the event that the primary designated USV is found to not conform to the operational test specification, then an alternate may be designated as the primary USV.

5.2 Installation and Maintenance

5.2.1 General

Installation and maintenance of SSVs/USVs shall be performed by qualified personnel.

5.2.2 Work Procedures

Operator's work procedures utilized with SSV/USV equipment should be performed in accordance with manufacturer's operating manual. If an SSV lock-open device or a manual override is required, it shall comply with the requirements of API 6A. Prior to its use, the SSV lock-open device or manual override shall be inspected in accordance with the manufacturer's procedures.

Operator's work procedures shall address condition and cleanliness of all supply lines and control fluids prior to hook-up.

The SSV/USV actuator supply medium (gas or liquid) shall meet or exceed the manufacturer-specified cleanliness requirements and be compatible with actuator materials of construction. If supply medium is a gas, it shall be free from solids, liquid hydrocarbons, and water or vapor that would impact the performance of the SSV/USV actuator. If supply medium is liquid, fluid shall be free from gases and solids that would impact the performance of the SSV/USV actuator. Prior to installation, the SSV/USV actuator supply medium shall be confirmed compatible with the fluid contained in equipment received on site.

5.2.3 Installation

The field installation of SSV/USV end connections, bolting, nuts, and seal rings shall meet the manufacturer's original requirements.

After installation, but prior to application of any well-stream fluid or pressure, the SSV/USV valve shall be operated a minimum of three full open/close cycles to ensure smooth operation. Proper continuity shall be verified between the control system and SSV/USV to ensure proper operation of the complete system. Proper functionality of any status indicators shall be verified.

NOTE Control systems are out of the scope of this document. Testing and operation of control system is defined in the control system operating manuals.

5.2.4 Testing

After installation on the well, the SSV/USV shall be tested in accordance with 7.3.

Each SSV/USV shall be inspected, maintained, and tested at specified regular intervals. Operator's policy should consider field experience, manufacturer's recommendations, and governmental regulations. The test shall consist of an operating and pressure holding test in accordance with 7.2.

If maximum wellhead shut-in tubing pressure (SITP) increases as a result of well stimulation or other production-enhancing process, then the valve shall be revalidated to the new SITP in accordance with 7.2, prior to resuming normal production activities.

5.2.5 Maintenance

Maintenance shall be performed in accordance with the manufacturer's operating manual. The SSV shall be lubricated as recommended in the manufacturer's operating manual, as dictated by field experience. Lubricants and sealants used shall be as prescribed in the manufacturer's operating manual or a manufacturer-approved alternate.

Maintenance and testing performed off site are not considered repair. Records of off-site maintenance shall be kept in accordance with Section 9 of this document.

The operator shall verify that the control system has the necessary controls, power (including safety factors), and fluids required to open and close the SSV/USV. The operator shall verify the USV is rated for the intended installation depth as determined by design methodologies in API 17D.

NOTE USV operations can be affected by installation depth and control fluid densities.

6 Repair and Remanufacture

6.1 Field Repair of SSVs/USVs

Field repair shall be accomplished by qualified personnel, and in accordance with OPD.

Replacement parts shall meet or exceed OPD requirements and shall be documented on the SSV/USV Repair Record Sheet (Table 2).

Testing after field repair shall be performed in accordance with 7.3.

Completed copies of the SSV/USV Repair Record Sheet (Table 2) and the SSV/USV Functional Test Datasheet for Field Repairs (Table 3) shall be retained by the operator as documentation of the repair. Documentation shall be maintained for the possession period of the equipment and shall accompany the equipment during transfer of ownership.

6.2 Off-site Repair/Remanufacture of SSVs/USVs

Off-site repair/remanufacture shall be performed in accordance with API 6A. Off-site repair/remanufacture records shall be retained in accordance with Section 9 of this document. The minimum RL of a SSV/USV repaired off site/remanufactured shall be RL 2. Maintenance and testing, as defined in the manufacturer written procedures/instructions, performed off site are not considered repair. Records of off-site maintenance shall be kept in accordance with Section 9 of this document. Off-site maintenance and testing occur at a location other than the equipment installation site.

7 Testing Procedures

7.1 General

The requirements for testing minimally include the following:

a) Owner/operator shall have a written work procedure. The testing process outlined in the work procedure shall be performed by qualified personnel and be in compliance with government regulations, the requirements of Section 7, and should be performed in accordance with manufacturer procedures.

b) Pressure upstream of SSV/USV should be stabilized. Stabilization is achieved when upstream pressure is not varying by more than 5 % or 3.45 MPa (500 psi) per hour, whichever is less, after well is shut in.

   A stable pressure source upstream of the SSV/USV during the test is required to correctly interpret test results.

   For shut-in pressures at or below 600 psi, pressure shall be considered stabilized when the upstream pressure is not varying by more than 30 psi per hour after the well is shut in.

   NOTE Upstream temperature variation impacts test results conditions by affecting upstream pressure. By imposing stabilized conditions in upstream pressure prior to the start of the test, the effects of temperature variation are mitigated. For indirect measurement methods, the choked flow condition is primarily dependent on upstream pressure.

c) Upstream conditions shall be stabilized in accordance with 7.1 b) when determining sustained leak rate.

d) Grease, lubricant, or sealant materials shall not be injected into the valve during pressure testing.

e) Direct or indirect measurement methods can be used to evaluate SSV/USV performance and compliance with test acceptance criteria.

f) Records of SSV/USV testing shall be maintained in accordance with Section 9 that identify the valve that was tested. The results of the test shall be documented using a method that compiles all of the information specified in Table 3, for testing after installation/field repairs, and Table 4, for periodic testing, which includes:

1) measured test parameter(s):

a) for direct measurement device: leakage rate;

b) for indirect measurement methods: properties being monitored such as pressure, temperature, and starting/ending times, as well as related calculations, etc., shall be documented.

2) determination of pass/fail;

3) the company and person performing the test and test date;

4) the company, person accepting the test results, and his/her functional role.

g) The first downstream block valve should have a pressure rating comparable to that of the SSV/USV. However, if equipment through the first downstream block valve cannot withstand full wellhead SITP, then the test shall be conducted using the working pressure of the limiting downstream equipment.

7.2 SSV /USV Operating/Pressure Holding Test

7.2.1 General

Periodic testing of SSV/USV shall be in accordance to the procedure outlined in 7.2.2. All requirements outlined in 7.1 shall be observed. The test results shall be documented on an SSV/USV Functional Test Datasheet for Periodic Testing per the example shown in Table 4.

7.2.2 Testing

Testing requirements are outlined as follows:

a) Shut in well.

NOTE System capabilities may be used to minimize pressure differential across SSV/USV.

b) Close SSV/USV.

c) Open SSV/USV.

d) Repeat Steps b) and c) two additional times.

e) Close SSV/USV.

f) Ensure wing and flowline valves are positioned to allow pressure to bleed off downstream of SSV/USV.

g) Verify system stability per 7.1 b).

h) If an indirect measurement method such as pressure buildup is used, close valves downstream of the SSV/USV to create the test cavity and immediately begin the pressure monitoring period. The pressure monitoring period, test cavity volume, pressure change, temperature change, and sensitivity of pressure measuring devices shall be sufficient to demonstrate compliance to the acceptance criteria.

NOTE Annex A contains an example of and guidelines for a specific pressure buildup method of indirect leakage measurement. Other indirect measurement methodologies may be used if these methods have the accuracy needed in order to discern compliance with acceptance criteria.

i) Monitor pressures and/or leakage using direct measurement or other indirect measurement methods. The duration of the monitoring period shall be a minimum of 5 minutes for the direct measurement method. If using an indirect method, the monitoring period shall be the longer of 5 minutes or time sufficient to demonstrate compliance to the acceptance criteria.

NOTE Determination of sufficient time is dependent on many factors, including but not limited to: test cavity volume, critical pressure, and the sensitivity of pressure measuring devices.

j) Compare SSV/USV leakage to the following acceptance criteria:

— pressure-containing parts: no leakage;

— pressure-controlling parts:

  — liquid leakage: sustained leak rate shall be less than 0.106 gpm (400 cc/min),

  — gas leakage: sustained leak rate shall be less than 15 scfm (0.42 m^3/min).

If an indirect measurement method such as pressure buildup is used, a decrease in test cavity downstream temperature shall be considered in the determination of compliance with the volume leakage acceptance criteria.

If the SSV/USV leak rate is higher than the acceptance criteria, the valve fails the test and shall be repaired or replaced, or an alternate SSV/USV may be designated as the SSV/USV.

k) Upon successful completion of test, return well to production using valve opening sequence that minimizes pressure differential across SSV/USV valve.

l) If the SSV/USV fails the test, it shall be repaired or replaced.

7.3 SSV/USV Testing After Installation/Field Repairs

7.3.1 General

Upon installation and/or after field repair, a SSV/USV shall be subjected to the appropriate test(s) listed in 7.3.2 and 7.3.3 to demonstrate proper assembly and operation. All requirements outlined in 7.1 shall be observed. The test results shall be documented on an SSV/USV Functional Test Datasheet for Installation/Field Repairs per the example shown in Table 3.

7.3.2 Testing

Required tests for SSVs/USVs following installation and/or field repairs are stated below. Actual test procedure performed depends on the extent of repair, and as specified below, may be limited to a reduced number of steps.

For field repairs affecting actuator seals, the SSV/USV actuator shall be, at a minimum, tested for leakage using the SSV/USV actuator media. Test pressure shall be the normal field operating supply pressure. Duration of the test shall be 15 minutes minimum. The acceptance criterion is zero leakage.

For field repairs affecting the alignment of the gate and seats with the conduit bore, alignment shall be verified, at a minimum, with a drift mandrel, unless it can be verified through other means.

For field repairs that require breaking or disturbing a pressure-containing seal in the SSV/USV valve, the SSV/USV valve pressure-containing seals shall be tested for leakage with the SSV/USV in a fully or partially open position and with the SSV/USV valve body exposed to maximum wellhead SITP. The test duration shall be a minimum of 5 minutes with no leakage.

For field repairs affecting valve pressure-controlling/containing operation of the SSV/USV assembly, perform testing per 7.3.3 incorporating the test prescribed for field repairs that require breaking or disturbing a pressure-containing seal, above.

7.3.3 Test Procedure

Testing requirements are outlined as follows:

a) Shut in well.

   NOTE System capabilities may be used to minimize pressure differential across SSV/USV.

b) Close SSV/USV.

c) Open SSV/USV.

d) Repeat Steps b) and c) two additional times.

e) Close SSV/USV.

f) Ensure wing and flowline valves are positioned to allow pressure to bleed off downstream of SSV/USV.

g) Verify system stability per 7.1 b).

h) If an indirect measurement method such as pressure buildup is used, close valves downstream of the SSV/USV to create the test cavity and immediately begin the pressure monitoring period. The pressure monitoring period, test cavity volume, pressure change, temperature change, and sensitivity of pressure measuring devices shall be sufficient to demonstrate compliance to the acceptance criteria.

   NOTE Annex A contains an example of and guidelines for a specific pressure buildup method of indirect leakage measurement. Other indirect measurement methodologies may be used if these methods have the accuracy needed in order to discern compliance with acceptance criteria.

i) Monitor pressures and/or leakage using direct measurement or other indirect measurement methods. The duration of the monitoring period shall be a minimum of 5 minutes for the direct measurement method. If using an indirect method, the monitoring period shall be the longer of 5 minutes or time sufficient to demonstrate compliance to the acceptance criteria.

   NOTE Determination of sufficient time is dependent on many factors, including but not limited to: test cavity volume, critical pressure, and the sensitivity of pressure measuring devices.

j) Compare SSV/USV leakage to the following acceptance criteria:

   — pressure-containing parts: no leakage;

   — pressure-controlling parts:

      — liquid leakage: sustained leak rate shall be less than 0.053 gpm (200 cc/min),

      — gas leakage: sustained leak rate shall be less than 7.5 scfm (0.21 m^3/min).

NOTE The acceptance criteria for tests after a field repair are one-half of the values used for periodic testing. These values reflect higher performance requirements for repaired valves.

If an indirect measurement method such as pressure buildup is used, a decrease in test cavity downstream temperature shall be considered in the determination of compliance with the volume leakage acceptance criteria.

If the SSV/USV leak rate is higher than the acceptance criteria, the valve fails the test and shall be repaired or replaced, or an alternate SSV/USV may be designated as the SSV/USV.

k) For field repaired valves, cycle valve. Equalization of pressure across SSV/USV before cycling valve is acceptable for safety and environmental reasons.

l) For field repaired valves, repeat Steps f) through j) one additional time.

m) Upon successful completion of test, return well to production using valve opening sequence that minimizes pressure differential across SSV/USV valve.

n) If the SSV/USV fails the test, it shall be repaired or replaced.

8 Failure Reporting

8.1 General

The operator of SSV/USV equipment covered by this standard shall provide a written report of equipment failure to the manufacturer and, as applicable, to the provider(s) of associated goods and services. Table 1 through Table 3 list the information required but do not preclude the operator from compiling and reporting this information in other formats.

NOTE Nonconforming products are reported by the manufacturer to the operator in accordance with API Q1.

One or more entities are involved in the maintenance and repair of these products in the field. The reporting forms consider the specific roles that are involved in the maintenance and repair of these products. When one entity executes multiple roles in this process, then that entity shall be responsible for the information related to those roles in the failure report.

8.2 Failure Report

A complete failure report shall consist of the information in Table 1, Table 2, and Table 3:

— Table 1: Failure Checklist,

— Table 2: Field Repair Record Sheet,

— Table 3: Functional Test Datasheet.

8.3 Reporting Responsibilities

Operator—Circulate completed Sections 1, 2, and 3 of Table 1 to manufacturer, service provider, and OPD part supplier (as applicable). Request detailed part descriptions of OPD/original equipment manufacturer (OEM) parts from supplier and forward them to manufacturer and service provider. Circulate Table 2 and Table 3 to manufacturer and service provider (as applicable). Circulate all previous repair records, including certificates of repair per Annex J of API 6A to the manufacturer. Determine and document root cause (Table 1, Section 5), after considering all feedback from manufacturer, service provider, and OPD part supplier (as outlined below).

Manufacturer—Review~~s~~ completed Sections 1, 2, and 3 of Table 1 and provide~~s~~ recommendations and feedback of suspected root cause per the reporting requirements of API 6A.

Service Provider—Review~~s~~ completed Sections 1, 2, and 3 of Table 1 and provide~~s~~ recommendations and feedback to the operator within six weeks from time of receipt of request.

OPD Part Supplier—Review~~s~~ completed Sections 1, 2, and 3 of Table 1, and provide~~s~~ detailed part description to the operator within six weeks from time of receipt of request.

9 Documentation Requirements

For SSVs/USVs purchased in accordance with API 6A or API 14D specifications, an operator seeking to comply with this standard shall maintain or have access to the following documentation for equipment in continued service:

a) operating manual,

b) shipping report and/or traceability records,

c) failure reports,

d) field repair record sheets,

e) functional test datasheets,

f) off-site repair/remanufacture records in accordance with API 6A,

g) maintenance records.

Documentation shall be traceable to equipment and accompany the equipment during transfer of ownership.

Equipment documentation records in conformance with previous editions of API 14H shall be satisfactory to meet the document records for installation, maintenance, and repair occurring prior to the effective date of this standard.

Table 1—Failure Checklist for Surface Safety Valves and Underwater Safety Valves

Reference/tracking number:	

To be completed by operator:

1. Identification:	
Operator name:	
Date of occurrence:	
Field and/or area:	
Lease name/platform/well number:	
Equipment identification	
SSV/USV actuator data	
Vendor:	
Model:	
Size:	
Part number:	
Serial number:	
Control operating pressure:	
SSV/USV actuator control fluid:	
Actual, installed water depth (USV):	
SSV/USV valve data	
Vendor:	
Model:	
Size, pressure rating:	
Temperature rating:	
Part number:	
Serial number:	
SSV lock-open device (if applicable)	
Vendor:	
Model:	
Part number:	
ROV lock-open device (if applicable)	
Vendor:	
Model:	
Part number:	

2. Well data:	
Flow (as applicable to failure mode):	
Percent/flow rate Gas:	
Percent/flow rate Oil:	

2. Well data (Continued):	
Percent/flow rate H_2O:	
Partial pressure H_2S:	
Partial pressure CO_2:	
Percent sand:	
PPM chloride:	
PPB oxygen:	
PPM mercury:	
PPM elemental sulfur:	
NORM (Yes/No):	
Well pressures and temperatures:	
SSV (at surface):	
Flowing:	
Shut-in:	
USV (at depth):	
Flowing:	
Shut-in:	

3. Description of failure:	
Failure mode:	
Valve pressure containment (Yes/No) :	
Valve pressure control (Yes/No) :	
Estimated leak rate (If applicable):	
Valve/actuator operation	
Failure to open (Yes/No) :	
Failure to close (Yes/No) :	
Actuator pressure containment	
Piston seal (Yes/No) :	
Stem seal (Yes/No) :	
Lock-open device (Yes/No) :	
Suspected cause of failure (i.e. product defect, excessive wear, erosion, maintenance, corrosion):	
Include pictures of damaged areas on parts, and provision to list any information the operator deems important.	

4. To be completed by the original equipment manufacturer (OEM)/service provider/OPD part supplier:
(Information shall be furnished by the party/parties associated with the failure/repair)

Identification of failed component(s) (e.g. gate, seat): (Completed by manufacturer and service provider)	
Component name/description:	
OPD equipment (Yes/No/Unable to confirm):	
Vendor:	
Model:	
Size:	
Suspected cause of failure (i.e. product defect, excessive wear, erosion, maintenance, corrosion):	

5. Determined root cause (completed by operator; attach root cause analysis, if performed)	

Table 2—SSV/USV Field Repair Record Sheet

1. Identification:

Operator name:			**SSV/USV valve data**	
Date of occurrence:			Vendor:	
Field and/or area:			Model:	
Lease name/platform/well number:			Size, pressure rating:	
Equipment identification			Temperature rating:	
			Part number:	
SSV/USV actuator data			Serial number:	
Vendor:			**SSV lock-open device (if applicable)**	
Model:			Vendor:	
Size:			Model:	
Part number:			Part number:	
Serial number:			**ROV lock-open device (if applicable)**	
Control operating pressure:			Vendor:	
SSV/USV actuator control fluid:			Model:	
Actual, installed water depth (USV):			Part number:	

2. Replaced component list:

Part No. and Serial Number of Replaced Part(s)	Manufacturer of Replaced Part(s)	Qty.	Description	Part No. and Serial Number of New Part(s)	Manufacturer of New Part(s)

3. Entity/persons performing repair:

Name:	
Title:	
Company:	
Signature:	
Date:	

Table 3—SSV/USV Functional Test Datasheet for Installation/Field Repairs

1. Identification:			
Operator name:		**SSV/USV valve data**	
Date of occurrence:		Vendor:	
Field and/or area:		Model:	
Lease name/platform/Well number:		Size, pressure rating:	
Equipment identification		Temperature rating:	
		Part number:	
SSV/USV actuator data		Serial number:	
Vendor:		**SSV lock-open device (if applicable)**	
Model:		Vendor:	
Size:		Model:	
Part number:		Part number:	
Serial number:		**ROV lock-open device (if applicable)**	
Control operating pressure:		Vendor:	
SSV/USV actuator control fluid:		Model:	
Actual, installed water depth (USV):		Part number:	

2. Test information:	
2.1 Functional test date:	
2.2 SSV/USV actuator seal test	
2.2.1 Normal operating pressure:	
2.2.2 Actual test pressure:	
2.2.3 Test media:	
2.3 Drift test	
2.3.1 Drift test (Pass/Fail):	
Measured diameter of drift mandrel/bar/tool (if applicable):	
2.3.2 Visual inspection (Pass/Fail):	
2.4 Pressure-containing test	
2.4.1 Leakage observed (Yes/No):	
2.5 SSV/USV operation test	
2.5.1 Number of cycles completed with SSV/USV valve body at atmospheric pressure (per 5.8):	
2.5.2 Number of cycles completed with SSV/USV valve body exposed to SITP [per 7.3.3 d]):	
2.6 SSV/USV valve leakage test (per 7.3.2.5):	
2.6.1 Well SITP:	
2.6.2 Test pressure:	
2.6.3 Test start time:	
2.6.4 Test end time:	
2.6.5 Pressure-containing Components	
Met acceptance criteria (Yes/No):	
2.6.6 Pressure-controlling Components	
Leakage observed (Yes/No):	
Leakage rate/method:	
Measured property (e.g. pressure, for indirect method):	
Met acceptance criteria (Yes/No):	

3. Entity/persons performing test/preparing document:	
Name:	
Title:	
Company:	
Signature:	
Date:	

Table 4—SSV/USV Functional Test Datasheet for Periodic Testing

1. Identification:

Operator name:			**SSV/USV valve data**	
Date of occurrence:			Vendor:	
Field and/or area:			Model:	
Lease name/platform/well number:			Size, pressure rating:	
Equipment identification			Temperature rating:	
			Part number:	
SSV/USV actuator data			Serial number:	
Vendor:			**SSV lock-open device (if applicable)**	
Model:			Vendor:	
Size:			Model:	
Part number:			Part number:	
Serial number:			**ROV lock-open device (if applicable)**	
Control operating pressure:			Vendor:	
SSV/USV actuator control fluid:			Model:	
Actual, installed water depth (USV):			Part number:	

2. Test information:

2.1 Functional test date:	
2.2 SSV/USV Operation Test	
Number of cycles completed with SSV/USV [per 7.2.2 d)]:	
2.3 SSV/USV valve leakage test [per 7.2.2 j)]:	
2.3.1 Well SITP:	
2.3.2 Test pressure:	
2.3.3 Test start time:	
2.3.4 Test end time:	
2.3.5 Pressure-containing components	
Met acceptance criteria (Yes/No):	
2.3.6 Pressure-controlling components	
Leakage observed (Yes/No):	
Leakage rate/method:	
Measured property (e.g. pressure, for indirect method):	
Met acceptance criteria (Yes/No):	

3. Entity/Persons Performing Test/Preparing Document:

Name:	
Title:	
Company:	
Signature:	
Date:	

Annex A
(informative)

Pressure Buildup Calculation

A.1 General

SSV/USV installed in configurations that do not allow for direct leakage measurement require alternate means of determining leakage. One indirect evaluation method is to use pressure buildup in a closed chamber downstream from the SSV/USV. Two examples of the pressure buildup method are provided in this annex for consideration. One example (A.6) uses a long flowline, while another (A.7) uses a christmas tree for the test chamber. In both cases, leakage may be indirectly measured by closing the SSV/USV, bleeding the pressure downstream of the SSV/USV, and then closing the first convenient isolation valve downstream of the SSV/USV. Pressure in the isolated test chamber can then be monitored over a given time. If the SSV/USV is leaking, a pressure increase in the test chamber will result. If the resulting pressure increase is higher than the allowable increase determined by calculation, the SSV/USV does not meet the leakage acceptance criteria.

Other indirect measurement approaches are acceptable if their accuracy to discern compliance with the acceptance criteria is equal to or better than the method presented in this annex.

This method does not apply to equipment in applications with gas-to-liquid ratio of 0 at actual flow conditions seen by SSV/USV, such as liquid injection wells. A method that takes the compressibility of the fluid into account may be required for these applications.

A.2 Assumptions of Method

The assumptions of the method are as follows.

a) Upstream pressure and temperature have stabilized prior to isolating test cavity and beginning pressure-holding period.

b) Upstream pressure does not change as a result of leakage across SSV/USV valve bore sealing mechanism.

c) Effects of temperature are accounted for in the stabilization requirements for upstream pressure.

d) Choked flow across the SSV/USV valve bore sealing mechanism is maintained throughout test duration, ensuring a constant leak rate into the cavity.

e) During pressure hold, only gas phase will cross the SSV/USV valve bore sealing mechanism.

f) Integrity of test cavity is intact. Observed flow into and out of test cavity occurs only across SSV/USV valve bore sealing mechanism.

g) Liquid or gas trapped in the test cavity during the hold period does not change phase.

h) Instrumentation used to conduct the test is sufficient to determine test success or failure.

i) Ideal gas law, modified with compressibility factors to more closely simulate real gas behavior, applies to the behavior of gases during testing.

A.3 Nomenclature

Variable	Description
k	Specific heat ratio of gas
n_t	Maximum allowable number of moles in test cavity at end of test
n_1	Initial number of moles
n_2	Allowable number of moles leaking into test cavity
P_a	Allowable test cavity pressure (starting conditions)
P_f	Allowable test cavity pressure (at actual conditions)
P_{std}	Standard pressure (P_{std} = 14.696 psia = 101,325 Pa)
P_{up}	Pressure upstream of SSV/USV
P_1	Initial pressure in test cavity
P_2	Pressure in test cavity at end of pressure hold
Q	Allowable leakage rate [maximum of 15 scfm (0.42 m^3/min) for periodic testing, per 7.2, or a maximum of 7.5 scfm (0.21 m^3/min) for testing after installation/field repair, per 7.3]
Q_{act}	Computed leakage rate based on test method
$\overline{R}$	Universal Gas Constant $\left(\overline{R} = 1545 \dfrac{\text{ft-lb}}{\text{°R} \cdot \text{mole}} = 518 \dfrac{\text{J}}{\text{K} \cdot \text{kg}}\right)$
R_{gl}	Produced gas liquid ratio in standard atmospheric conditions
R_{gl}'	Produced gas liquid ratio in monitored volume (actual conditions)
T_{std}	Standard temperature [T_{std} = 520 °R (60 °F) = 288 K (15.6 °C)]
T_1	Temperature in test cavity at start of test
T_2	Temperature in test cavity at end of pressure hold
t	Test duration time
V_{lq}	Initial volume of liquid in test cavity
V_m	Total volume of test cavity
V_1	Initial volume of gas in test cavity
x_c	Critical pressure ratio
Z_1	Assumed initial dimensionless compressibility factor
Z_2	Final actual dimensionless compressibility factor

A.4 Flow Diagram

NOTE Please refer to A.3 for the nomenclature used in the flow diagram.

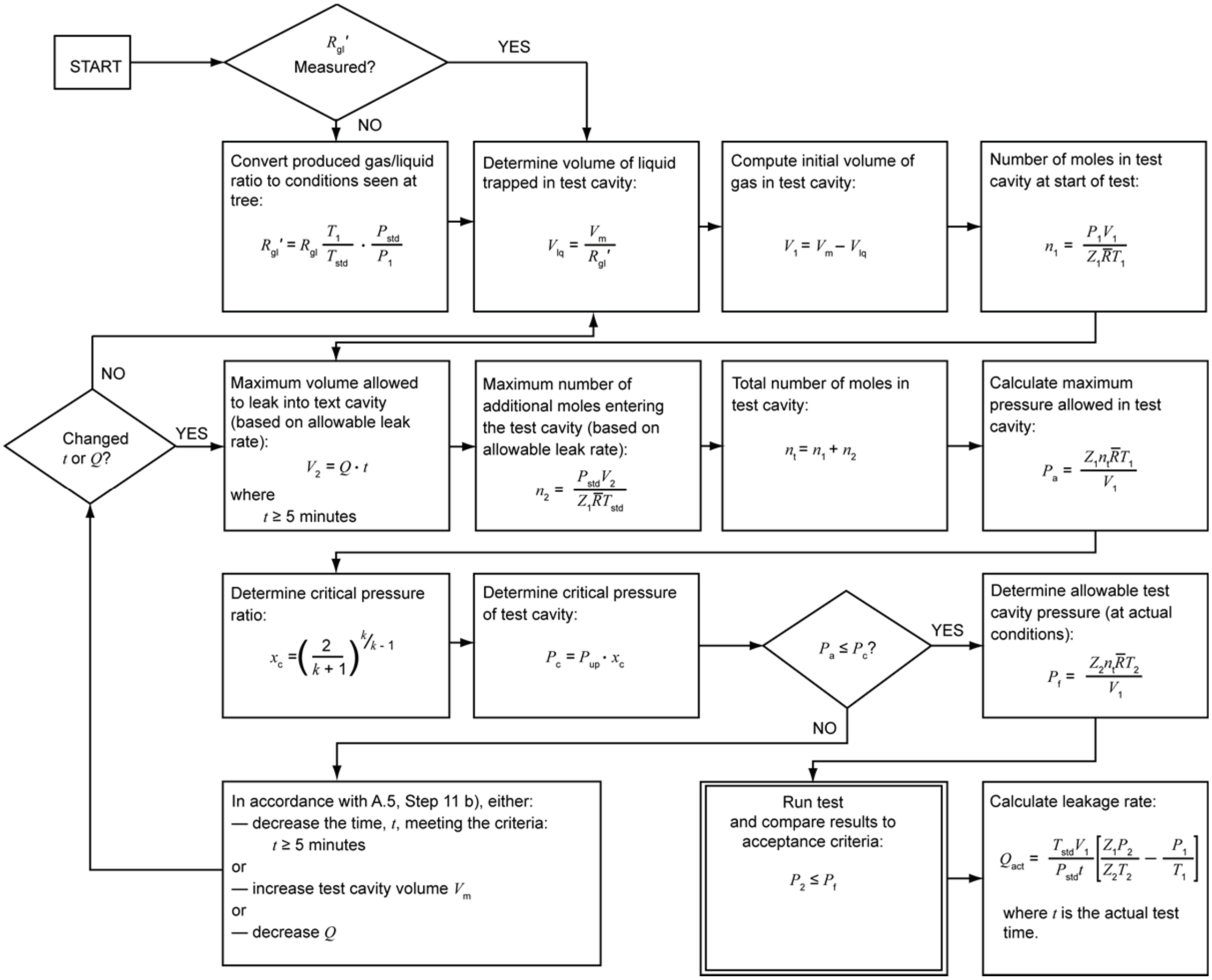

Figure A.1—Calculation Flow Diagram

A.5 Procedure

NOTE Steps 1) through 11) should be carried-out prior to the execution of the test, minimizing equipment downtime. Steps 8) through 11) determine the validity of the test volume and duration of test to ensure the methodology presented in this annex accurately determines compliance with the allowable leakage rate.

1) If gas/liquid ratio is measured at actual conditions seen at SSV/USV, skip to Step 2). If gas/liquid ratio is measured at standard conditions, convert produced gas/liquid ratio to conditions seen at test cavity:

$$R_{gl}' = R_{gl} \frac{T_1}{T_{std}} \cdot \frac{P_{std}}{P_1}$$

2) Determine volume of liquid trapped in test cavity:

$$V_{lq} = \frac{V_m}{R_{gl}'}$$

3) Compute initial volume of gas in test cavity:

$$V_1 = V_m - V_{lq}$$

4) Number of moles in test cavity at start of test:

$$n_1 = \frac{P_1 V_1}{Z_1 \bar{R} T_1}$$

NOTE P_1 is the pressure to which the fluid trapped in the monitor volume is vented prior to pressure-rise monitoring step.

5) Maximum volume allowed to leak into test cavity (based on allowable leakage rate):

$$V_2 = Q \cdot t$$

6) Maximum number of additional moles entering the test cavity (based on allowable leakage rate):

$$n_2 = \frac{P_{std} V_2}{Z_1 \bar{R} T_{std}}$$

7) Total number of moles allowed in test cavity at end of pressure-holding period:

$$n_t = n_1 + n_2$$

8) Maximum pressure allowed in test cavity for this method to be valid:

$$P_a = \frac{Z_1 n_t \bar{R} T_1}{V_1}$$

9) Determine critical pressure ratio:

$$x_c = \frac{P_c}{P_{up}} = \left(\frac{2}{k+1}\right)^{k/k-1}$$

NOTE In the event that it is not known, the value of k can be assumed to be k = 1.293 (that of methane).

10) Calculate critical pressure:

$$P_c = P_{up} \cdot x_c$$

11) Compare P_a to P_c:

a) If $P_a \leq P_c$: proceed to Step 12).

b) If $P_a > P_c$: test may result in non-choked flow conditions [in violation of assumption A.2 d)]. Either:

i) adjust/reduce the test time, t, observing the criteria $t \geq 5$ minutes, or

ii) increase the test-cavity volume V_m, or

iii) decrease Q.

NOTE 1 Selecting the "Decrease Q" option may provide passing results in conformance the acceptance criteria of Section 7.

NOTE 2 A failing result with the "Decrease Q" option does not conclusively determine the SSV/USV is out of conformance with the acceptance criteria of Section 7.

And go back to Step 1).

12) Perform test.

13) At end of test, compare the resulting test cavity pressure, P_2, to the acceptance criteria:

$$P_2 \leq P_f$$

where

$$P_f = \frac{Z_2 n_t \bar{R} T_2}{V_1}$$

14) Calculate the flow rate based on test method:

$$Q_{act} = \frac{T_{std} V_1}{P_{std}\, t}\left[\frac{Z_1 P_2}{Z_2 T_2} - \frac{P_1}{T_1}\right]$$

A.6 Example 1—Periodic Test: Flowline Used as Test Cavity

NOTE The following example is based on U.S. customary units. Other systems of units may be applied.

- 2 $^1/_{16}$ in. 5000 psi WP API 6A SSV:
  - 2.375 in. (0.1979 ft) OD,
  - 1.996 in. (0.1663 ft) ID.
- Flowline:
  - 2.375 in. (0.1979 ft) OD,
  - 1.996 in. (0.1663 ft) ID,
  - 2583 ft long.

For the purposes of illustrating all computations in this example, the following values were utilized.

- Total test volume capacity, V_m = 56.13 cu ft.
- Production temperature, T_1 = 80 °F or 540 °R.
- Standard temperature, T_{std} = 60 °F or 520 °R.
- Standard pressure, P_{std} = 14.696 psia = 2116 psfa.
- Shut-in pressure, P_{up} = 3000 psig = 3014.7 psia or 434,117 psfa.
- Initial test cavity pressure, P_1 = 0 psig = 14.7 psia or 2117 psfa.
- Produced gas liquid ratio, R_{gl} = 1500 scf/bbl or 267.1 scf/cu ft.
- Gas is methane.

  k = 1.293;

  $Z_1 = Z_2$ = 1.0, dimensionless compressibility factor.
- Final test cavity pressure, P_2 = 100 psig.
- Final test cavity temperature, $T_2 = T_{std}$.

Calculations:

1) Convert produced gas/liquid ratio to conditions seen at test cavity:

$$R_{gl}' = R_{gl} \frac{T_1}{T_{std}} \cdot \frac{P_{std}}{P_1} = \left(\frac{267.1 \text{ scf gas}}{1 \text{ cu ft liquid}} \right) \cdot \frac{540 \ ^\circ\text{R}}{520 \ ^\circ\text{R}} \cdot \frac{2116 \text{ psfa}}{2117 \text{ psfa}} = \frac{277.2 \text{ cu ft gas}}{1 \text{ cu ft liquid}}$$

267.1 cu ft of gas at standard conditions occupies 277.2 cu ft at 80 °F.

2) Determine volume of liquid trapped in test cavity:

$$V_{\text{lq}} = \frac{V_{\text{m}}}{R_{\text{gl}}{}'} = 56.13 \text{ cu ft} \cdot \frac{1 \text{ cu ft liquid}}{277.2 \text{ cu ft gas}} = 0.20 \text{ cu ft liquid}$$

3) Compute initial volume of gas in test cavity:

$$V_1 = V_{\text{m}} - V_{\text{lq}} = 56.13 \text{ cu ft} - 0.20 \text{ cu ft liquid} = 55.93 \text{ cu ft gas}$$

4) Number of moles in test cavity at start of test:

$$n_1 = \frac{P_1 V_1}{Z_1 \bar{R} T_1} = \frac{(2117 \text{ psfa})\left(55.93 \text{ ft}^3\right)}{(1)\left(1545 \frac{\text{ft-lb}}{°\text{R} \cdot \text{mole}}\right)(540\ °\text{R})} = 0.142 \text{ moles}$$

5) Maximum volume allowed to leak into test cavity (based on allowable leakage rate and assumed test length of 1 hour):

$$V_2 = Q \cdot t = \frac{15 \text{ scf}}{\text{min}} \cdot 60 \text{ min} = 900 \text{ scf}$$

NOTE This example assumes a duration of 60 minutes. This test time may vary down to a minimum of 5 minutes provided that conformance to the acceptance criteria as defined in 7.2 and 7.3 is demonstrated.

6) Maximum number of additional moles entering the test cavity (based on allowable leakage rate):

$$n_2 = \frac{P_{\text{std}} V_2}{Z_1 \bar{R} T_{\text{std}}} = \frac{(2116 \text{ psfa})\left(900 \text{ ft}^3\right)}{(1)\left(1545 \frac{\text{ft-lb}}{°\text{R} \cdot \text{mole}}\right)(520\ °\text{R})} = 2.370 \text{ moles}$$

7) Total number of moles in test cavity:

$$n_{\text{t}} = n_1 + n_2 = 0.142 + 2.370 = 2.512 \text{ moles}$$

8) Pressure allowed in test cavity at end of test:

$$P_{\text{a}} = \frac{Z_1 n_{\text{t}} \bar{R} T_1}{V_1} = \frac{(1)(2.512 \text{ moles})\left(1545 \frac{\text{ft-lb}}{°\text{R} \cdot \text{mole}}\right)(540\ °\text{R})}{55.93 \text{ ft}^3}$$

$$P_{\text{a}} = 37{,}471.2 \text{ psfa} = 260.2 \text{ psia} = 245.5 \text{ psig}$$

9) Determine critical pressure ratio:

$$x_{\text{c}} = \left(\frac{2}{k+1}\right)^{k/k-1} = \left(\frac{2}{2.293}\right)^{1.293/0.293} = 0.547$$

10) Calculate critical pressure:

$$P_c = P_{up} \cdot x_c = 434{,}117 \text{ psfa} \cdot 0.547 = 237{,}462 \text{ psfa} = 1649 \text{ psia} = 1634.3 \text{ psig}$$

NOTE If P_c is significantly larger than P_a, the test time may be shortened.

11) Compare P_a to P_c: Since $P_a \le P_c$ (245.5 psig ≤ 1634.3 psig), proceed to Step 12).

12) Perform test. Monitor pressure for one hour [per Step 5)]. Record pressure, P_2.

13) At end of test, compare the resulting test cavity pressure, P_2, to the acceptance criteria:

$$P_2 \le P_f$$

where, assuming $T_2 = T_{std}$:

$$P_f = \frac{Z_2 n_t \bar{R} T_2}{V_1} = \frac{(1)(2.514 \text{ moles})\left(1545 \dfrac{\text{ft-lb}}{°\text{R} \cdot \text{mole}}\right)(520\ °\text{R})}{55.93 \text{ ft}^3}$$

$$P_f = 36{,}112.1 \text{ psfa} = 250.8 \text{ psia} = 236.1 \text{ psig}$$

Given the assumed measured value of P_2 = 100 psig, the valve passes the test.

14) Compute the leakage rate based on test method:

$$Q_{act} = \frac{T_{std} V_1}{P_{std} t}\left[\frac{Z_1 P_2}{Z_2 T_2} - \frac{P_1}{T_1}\right] = \frac{520\ °\text{R}\ \left(55.93 \text{ ft}^3\right)}{14.696 \text{ psig}\ (60 \text{ min})}\left[\frac{(1)100 \text{ psig}}{(1)520\ °\text{R}} - \frac{14.7 \text{ psig}}{540\ °\text{R}}\right] = 5.44 \text{ scfm}$$

A.7 Example 2—Periodic Test: Christmas Tree Used as Test Cavity

NOTE The following example is based on U.S. customary units. Other systems of units may be applied.

— 3 1/16 in. 5000 psi WP API 6A loose component surface christmas tree:

  — total test cavity length (including wetted length of swab, and wing valves, and cross): 88 in. (7.33 ft);

  — bore: 3 in. (0.25 ft).

For the purposes of illustrating all computations in this example, the following values were utilized.

— Total test volume capacity, V_m = 0.360 cu ft.

— Production temperature, T_1 = 80 °F or 540 °R.

— Standard temperature, T_{std} = 60 °F or 520 °R.

— Standard pressure, P_{std} = 14.696 psia = 2116 psfa.

— Shut-in pressure, P_{up} = 3000 psig = 3014.7 psia or 434,117 psfa.

— Initial test cavity pressure, P_1 = 0 psig = 14.7 psia or 2117 psfa.

— Produced gas liquid ratio, R_{gl} = 1500 scf/bbl or 267.1 scf/cu ft.

— Properties of gas are not known. Assumed gas is methane.

k = 1.293;

$Z_1 = Z_2$ = 1.0, dimensionless compressibility factor (change negligible if ideal gas is assumed).

— Final test cavity pressure, P_2 = 1000 psig.

— Final test cavity temperature, $T_2 = T_{std}$.

Calculations:

1) Convert produced gas/liquid ratio to conditions seen at test cavity:

$$R_{gl}' = R_{gl}\frac{T_1}{T_{std}}\cdot\frac{P_{std}}{P_1} = \left(\frac{267.1\text{ scf gas}}{1\text{ cu ft liquid}}\right)\cdot\frac{540\ ^\circ\text{R}}{520\ ^\circ\text{R}}\cdot\frac{2116\text{ psfa}}{2117\text{ psfa}} = \frac{277.2\text{ cu ft gas}}{1\text{ cu ft liquid}}$$

267.1 cu ft of gas at standard conditions occupies 277.2 cu ft at 80 °F.

2) Determine volume of liquid trapped in test cavity:

$$V_{lq} = \frac{V_m}{R_{gl}'} = 0.360\text{ cu ft}\cdot\frac{1\text{ cu ft liquid}}{277.2\text{ cu ft gas}} = 0.001\text{ cu ft liquid}$$

3) Compute initial volume of gas in test cavity:

$$V_1 = V_m - V_{lq} = 0.360\text{ cu ft} - 0.001\text{ cu ft liquid} = 0.359\text{ cu ft gas}$$

4) Number of moles in test cavity at start of test:

$$n_1 = \frac{P_1V_1}{Z_1\bar{R}T_1} = \frac{(2117\text{ psfa})\left(0.359\text{ ft}^3\right)}{(1)\left(1545\frac{\text{ft-lb}}{^\circ\text{R}\cdot\text{mole}}\right)(540\ ^\circ\text{R})} = 0.001\text{ moles}$$

5) Maximum volume allowed to leak into test cavity (based on allowable leakage rate and assumed test length of 5 minutes):

$$V_2 = Q\cdot t = \frac{15\text{ scf}}{\text{min}}\cdot(5\text{ min}) = 75\text{ scf}$$

6) Maximum number of additional moles entering the test cavity (based on allowable leakage rate):

$$n_2 = \frac{P_{std}V_2}{Z_1\bar{R}T_{std}} = \frac{(2116\text{ psfa})(75\text{ ft}^3)}{(1)\left(1545\frac{\text{ft-lb}}{°\text{R}\cdot\text{mole}}\right)(520\ °\text{R})} = 0.198\text{ moles}$$

7) Total number of moles in test cavity:

$$n_t = n_1 + n_2 = 0.001 + 0.198 = 0.199\text{ moles}$$

8) Pressure allowed in test cavity at end of test:

$$P_a = \frac{Z_1 n_t \bar{R} T_1}{V_1} = \frac{(1)(0.199\text{ moles})\left(1545\frac{\text{ft-lb}}{°\text{R}\cdot\text{mole}}\right)(540\ °\text{R})}{0.359\text{ ft}^3}$$

$$P_a = 462{,}467.1\text{ psfa} = 3211.6\text{ psia} = 3196.9\text{ psig}$$

9) Determine critical pressure ratio:

$$x_c = \left(\frac{2}{k+1}\right)^{k/k-1} = \left(\frac{2}{2.293}\right)^{1.293/0.293} = 0.547$$

10) Calculate critical pressure:

$$P_c = P_{up} \cdot x_c = 434{,}117\text{ psfa} \cdot 0.547 = 237{,}462\text{ psfa}$$

11) Compare P_a to P_c: Since P_a > P_c, test volume and/or duration is not acceptable, as non-choked flow conditions may occur. Since the test duration is already at the shortest allowed, either a larger test cavity volume is required, or a reduced allowable leak rate is used in the calculations.

a) If the test cavity volume is modified, ensure the pressure rating of the equipment used to create the test volume is not exceeded (e.g. if using a flow line valve downstream of the choke to create the test volume). The following equation (derived from those presented above) can be used to approximate the minimum test volume required:

$$V_1 = \frac{P_{std}V_2T_1}{T_{std}\left[P_c - P_1\right]} = \frac{(2116\text{ psfa})(75\text{ cu ft})(540\ °\text{R})}{(520\ °\text{R})\left[237{,}462\text{ psfa} - 2117\text{ psfa}\right]} = 0.700\text{ cu ft}$$

For a 3 in. bore, this means a test cavity length of roughly 14.25 ft.

For a 4 in. bore, this means a test cavity length of roughly 8 ft.

b) Assuming the test volume cannot be changed, the leak-rate used in the calculations can be reduced. The following equation (derived from those presented above) can be used to approximate the upper limit for the leak-rate:

$$Q = \frac{T_{\text{std}} V_1}{T_1 P_{\text{std}} t}\left[P_{\text{c}} - P_1\right] = \frac{(520\ ^{\circ}\text{R})0.359\ \text{ft}^3}{(540\ ^{\circ}\text{R})(2116\ \text{psfa})(5\ \text{min})}\left[237{,}462\ \text{psfa} - 2117\ \text{psfa}\right] = 7.7\ \text{scfm}$$

After selecting an acceptable leak rate, for example, Q = 7.5 scfm, repeat Steps 5) through 8):

i) $V_2 = Q \cdot t = \frac{7.5\ \text{scf}}{\text{min}} \cdot (5\ \text{min}) = 37.5\ \text{scf}$

ii) $n_2 = \frac{P_{\text{std}} V_2}{Z_1 \bar{R} T_{\text{std}}} = \frac{(2116\ \text{psfa})(37.5\ \text{ft}^3)}{(1)\left(1545 \frac{\text{ft-lb}}{^{\circ}\text{R} \cdot \text{mole}}\right)(520\ ^{\circ}\text{R})} = 0.099\ \text{moles}$

iii) $n_{\text{t}} = n_1 + n_2 = 0.001 + 0.099 = 0.100\ \text{moles}$

iv) $P_{\text{a}} = \frac{Z_1 n_{\text{t}} \bar{R} T_1}{V_1} = \frac{(1)(0.100\ \text{moles})\left(1545 \frac{\text{ft-lb}}{^{\circ}\text{R} \cdot \text{mole}}\right)(540\ ^{\circ}\text{R})}{0.359\ \text{ft}^3}$

$$= 232{,}395.5\ \text{psfa} = 1613.9\ \text{psia} = 1599.2\ \text{psig}$$

NOTE Although the method outlined in Step 11 b) allows the use of a small volume, it will result in the evaluation of the SSV using a more stringent acceptance criterion. This, in turn, may result in an inconclusive test if the actual leak rate across the valve bore sealing mechanism exceeds that used in the calculations.

12) Perform test. For this example, we follow process outlined in Step 11 b) above.

13) At end of test, compare the resulting test cavity pressure, P_2, to the acceptance criteria:

$$P_2 \le P_{\text{f}}$$

where, assuming $T_2 = T_{\text{std}}$:

$$P_{\text{f}} = \frac{Z_2 n_{\text{t}} \bar{R} T_2}{V_1} = \frac{(1)(0.100\ \text{moles})\left(1545 \frac{\text{ft-lb}}{^{\circ}\text{R} \cdot \text{mole}}\right)(520\ ^{\circ}\text{R})}{0.359\ \text{ft}^3}$$

$$P_{\text{f}} = 223{,}788.3\ \text{psfa} = 1554.1\ \text{psia} = 1539.4\ \text{psig}$$

Given the assumed measured value of P_2 = 1000 psig, the valve passes the test.

14) Compute the leakage rate based on test method:

$$Q = \frac{T_{\text{std}} V_1}{P_{\text{std}} t}\left[\frac{Z_1 P_2}{Z_2 T_2} - \frac{P_1}{T_1}\right] = \frac{520\ °\text{R}\left(0.359\ \text{ft}^3\right)}{14.696\ \text{psig}(5\ \text{min})}\left[\frac{(1)1000\ \text{psig}}{(1)520\ °\text{R}} - \frac{14.7\ \text{psig}}{540\ °\text{R}}\right] = 4.81\ \text{scfm}$$

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