INTERNATIONAL STANDARD

ISO 17078-2

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Petroleum and natural gas industries — Drilling and production equipment —

Part 2: **Flow-control devices for side-pocket mandrels**

Industries du pétrole et du gaz naturel — Équipement de forage et de production —

Partie 2: Dispositifs de régulation de la vitesse d'écoulement pour raccords à poche latérale

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 17078-2 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 4, *Drilling and production equipment*.

ISO 17078 consists of the following parts, under the general title *Petroleum and natural gas industries — Drilling and production equipment*:

— *Part 1: Side-pocket mandrels*

— *Part 2: Flow-control devices for side-pocket mandrels*

— *Part 3: Running, pulling and kick-over tools, and latches for side-pocket mandrels*

A part 4 dealing with practices for side-pocket mandrels and related equipment is under development.

Introduction

This part of ISO 17078 has been developed by users/purchasers and suppliers/manufacturers of subsurface flow-control devices used in side-pocket mandrels (hereafter called flow-control devices) intended for use in the worldwide petroleum and natural gas industry. This part of ISO 17078 is intended to provide requirements and information to all parties who are involved in the specification, selection, manufacture, testing and use of flow-control devices. Further, this part of ISO 17078 addresses supplier/manufacturer requirements that set the minimum parameters with which suppliers/manufacturers shall comply to claim conformity with this part of ISO 17078.

This part of ISO 17078 has been structured to support varying requirements in environmental service classes, design validation, product functional testing and quality control grades. These variations allow the user/purchaser to select the grade for a specific application.

Well environmental service classes. There are four environmental service classes for flow-control devices that provide the user/purchaser with a range of choices from which to select products to meet varying environmental conditions.

Design validation grades. There are three design validation grades for flow-control devices that provide the user/purchaser with a range of technical and performance requirements. This ensures that the products supplied according to this part of ISO 17078 meet the requirements and that the user/purchaser is able to compare these requirements with its preference or application and determine whether additional requirements are placed on the supplier/manufacturer.

It is important that users of this part of ISO 17078 be aware that requirements in addition to those outlined herein can be needed for individual applications. This part of ISO 17078 is not intended to inhibit a supplier/manufacturer from offering, or the user/purchaser from accepting, alternative equipment or engineering solutions. This can be particularly applicable where there is innovative or developing technology. Where an alternative is offered, it is the responsibility of the supplier/manufacturer to identify any variations from this part of ISO 17078 and provide details.

Product functional testing grades. There are three product functional testing grades for flow-control devices that provide the user/purchaser with a range of choices for confirming that individual products manufactured under this part of ISO 17078 meet the design specifications.

Quality control grades. There are two quality control grades that provide the user/purchaser with the choice of requirements to meet specific preferences or applications. Additional quality upgrades can be specified by the user/purchaser as supplemental requirements.

In addition to this document, ISO 17078-1 provides requirements for side-pocket mandrels used in the petroleum and natural gas industry. ISO 17078-3, to be published, is intended to provide requirements for running, pulling and kick-over tools, and latches used in conjunction with side-pocket mandrel flow-control devices.

Petroleum and natural gas industries — Drilling and production equipment —

Part 2:
Flow-control devices for side-pocket mandrels

1 Scope

This part of ISO 17078 provides requirements for subsurface flow-control devices used in side-pocket mandrels (hereafter called flow-control devices) intended for use in the worldwide petroleum and natural gas industry. This includes requirements for specifying, selecting, designing, manufacturing, quality-control, testing and preparation for shipping of flow-control devices. Additionally, it includes information regarding performance testing and calibration procedures.

The installation and retrieval of flow-control devices is outside the scope of this part of ISO 17078. Additionally, this part of ISO 17078 is not applicable to flow-control devices used in centre-set mandrels or with tubing-retrievable applications.

This part of ISO 17078 does not include requirements for side-pocket mandrels, running, pulling, and kick-over tools, and latches that might or might not be covered in other ISO specifications. Reconditioning of used flow-control devices is outside of the scope of this part of ISO 17078.

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.

ISO 9000, *Quality management systems — Fundamentals and vocabulary*

ISO 15156 (all parts), *Petroleum and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production*

ISO 17078-1:2004, *Petroleum and natural gas industries — Drilling and production equipment — Part 1: Side-pocket mandrels*

ANSI/NCSL Z540-1, *Calibration Laboratories and Measuring and Test Equipment General Requirements*[1)]

ASME Boiler and Pressure Vessel Code, Section IX, *Welding and Brazing Qualifications*[2)]

ASTM A370, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*[3)]

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1) NCSL International, 2995 Wilderness Place, Suite 104, Boulder, Colorado 80301-5404, USA.

2) American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA.

3) ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA, 19428-2959.

ASTM D1415, *Standard Test Method for Rubber Property — International Hardness*

ASTM D2240, *Standard Test Method for Rubber Property — Durometer Hardness*

BS 2M 54, *Specification for temperature control in the heat treatment of metals*[4)]

MIL-STD-1916, *DOD Preferred Methods for Acceptance of Product*[5)]

MIL-STD-413C, *Visual Inspection Guide for Elastomeric O-rings*[5)]

SAE AMS-H-6875, *Heat Treatment of Steel Raw Materials*[6)]

SAE AS568B, *Aerospace Size Standard for O-Rings*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9000 (for quality-system-related terms not given below) and the following apply.

3.1
acceptance
flow-control device component(s) and/or assembly(s) accepted for use without restriction

3.2
ager
pressure device used to apply an external pressure to a flow-control device for a specified period of time and/or number of cycles

3.3
balanced injection-pressure-operated
injected gas pressure-operated flow-control device with no spread, that is, for which the opening and closing pressures are the same

3.4
certificate of conformance
documentation declaring that a specific flow-control device meets the requirements of this part of ISO 17078 and the requirements of the functional specification

3.5
coating
application of a thin film of one material on the surface of another material for different purposes

3.6
date of manufacture
date of manufacturer's final acceptance of finished products

NOTE The date is day-month-year in the format DD-MM-YYYY.

3.7
design family
group of products whose configurations, sizes, materials and applications are sufficiently similar that identical design methodologies can be used to establish the design parameters for each product within the family

4) British Standards Institute, Customer Services, 389 Chiswick High Road, London W4 4AL, UK.

5) US military/Department of Defense standard.

6) SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, USA.

3.8
design method
method, procedure or equations used by the supplier/manufacturer to design a flow-control device product

3.9
design validation
process of proving a design by testing to demonstrate conformity of the product to design requirements

3.10
design verification
process of examining the premise of a given design by calculation, comparison or investigation to substantiate conformity with specified requirements

3.11
differential flow-control device
flow-control device that opens and closes on differential pressure between the injected gas and production pressures

3.12
dome
chamber that contains an internal pressure that is applied to the responsive element that may be a bellows or piston

3.13
dome charge maximum
supplier/manufacturer's maximum recommended pressure charge in the dome at recommended operating temperature

3.14
dummy flow-control device
blank device that is installed in a side-pocket mandrel to prevent flow or pressure communication between the casing annulus and the tubing

3.15
dump/kill flow-control device
flow-control device that is initially closed; once it is open, it cannot be closed again

NOTE These valves have very large ports and no reverse-flow check to allow a high injection rate to kill the well.

3.16
dynamic flow testing
flow testing of an operable flow-control device to determine the flow characteristics as a function of changes in either upstream or downstream pressures

3.17
end connections
thread or other mechanism providing a connection between the flow-control device and other equipment

3.18
flow coefficient testing
testing that is performed on a modified flow-control device to determine the flow capacity as a function of fixed stem travel

3.19
full life cycle
expected period of time over which the product shall function according to the manufacturer's specifications

3.20
functional test
test performed to confirm proper operation of equipment

3.21
functionality
definition or description of the performance with associated properties, characteristics and limits of a flow-control device

3.22
gas passage undercut
clearance between the flow-control device and the pocket of the side-pocket mandrel through which injected media flows

3.23
heat
⟨cast lot⟩ material originating from a final melt or cast lot

NOTE For re-melted alloys, a heat is defined as the raw material originating from a single re-melted ingot.

3.24
informative
information that is meant to inform the user/purchaser or supplier/manufacturer without containing requirements

3.25
injection-pressure-operated
injected gas pressure-operated flow-control device

3.26
injection-pressure-operated with choke
injected gas pressure-operated flow-control device with a choke installed downstream of the port

3.27
job lot
group or quantity of piece parts, subassemblies or assemblies that are grouped or processed together during the manufacturing process

3.28
latch
retention mechanism for a flow-control device that is landed in a side-pocket mandrel

3.29
manufacturing
process(es) and action(s) performed by an equipment supplier/manufacturer that are necessary to provide finished component(s), assemblies and related documentation that fulfil the requests of the user/purchaser, and to meet the standards of the supplier/manufacturer

NOTE Manufacturing begins when the supplier/manufacturer receives the order and is completed at the moment the component(s), assembly(ies) and related documentation are transferred to a transportation provider.

3.30
model
side-pocket mandrel flow-control device that has unique components and functional characteristics that differentiate it from other products of the same type

3.31
normative
information or procedures that shall be used by the user/purchaser or supplier/manufacturer as they comply with this part of ISO 17078

3.32
nozzle venturi flow-control device
flow-control device that cannot be closed, but is intended to restrict flow to a desired rate

NOTE The port is in the shape of a venturi nozzle.

3.33
operating environment
set of environmental conditions to which the product is exposed during its service life

NOTE This includes such environmental variables as temperature, pressure, liquid composition and properties, gas composition and properties, solids, etc.

3.34
orifice flow-control device
flow-control device that cannot be closed but is intended to restrict flow to a desired rate

3.35
perceptible leak
any leak during a test that can be detected

3.36
pilot flow-control device
injected gas pressure-operated flow-control device with a primary opening section that activates the full-opening flow section

3.37
production-pressure-operated
production-well fluid pressure-operated flow-control device

3.38
production-pressure-operated with choke
production well fluid pressure-operated flow-control device with a choke installed upstream of the port

3.39
qualified design family
design family whereby the validation of one or more representative design(s) and product(s) permits the entire family to be treated as validated by association in accordance with 6.4

3.40
quality control
process and/or method(s) used by the supplier/manufacturer to ensure the quality of the materials and manufacturing process(es)

3.41
rated pressure
maximum pressure at the rated temperature for which the flow-control device is designed in normal operation

3.42
rated temperature
maximum temperature at the rated pressure for which the flow-control device is designed in normal operation

3.43
shear orifice flow-control device
flow-control device that is initially closed; once it is opened, it cannot then be reclosed

NOTE It is equipped with a back-check valve.

3.44
side-pocket mandrel
tubing-mounted device that accepts a flow-control or other device in a bore that is offset from, and essentially parallel with, the through-bore of the tubing product

NOTE This bore includes sealing surfaces and latching profiles.

3.45
supplier/manufacturer
company, organization or entity that designs, manufactures and/or markets flow-control device products

3.46
technical specifications
requirements of the equipment necessary for compliance with the functional specification

3.47
test pressure
pressure, based upon all relevant design criteria, at which the equipment is tested

NOTE Each test pressure has a related test temperature, as specified by the pertinent test procedure.

3.48
test temperature
temperature, based upon all relevant design criteria, at which the equipment is tested

3.49
traceability
⟨job lot⟩ ability for individual components to be designated as originating from a job lot that identifies the included heat(s)

3.50
type
flow-control device equipment with unique characteristics that differentiate it from other functionally similar flow-control device equipment

3.51
user/purchaser
company, organization or entity that purchases, installs and uses flow-control device products

3.52
welding
method for joining two metallic substances through a process of melting and re-solidification

NOTE The term “welding” covers welding, brazing, or soldering operations.

3.53
well environmental service grade
well environmental service grade refers to the service in which the flow-control device is used

3.54
wireline
equipment and associated technique(s) used to install and retrieve flow-control devices in a well using a continuous length of solid line (slick line) or stranded wire, appropriate spooling equipment at the surface and weight and specialized tools attached to the well (downhole) end of the wire

3.55
yield strength
stress level measured at test temperature, beyond which material plastically deforms and does not return to its original dimensions

NOTE The yield strength is expressed in units of force per unit of area.

4 Symbols and abbreviated terms

4.1 Abbreviations

ANSI	American National Standards Institute
AQL	acceptable quality level
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing Materials
AWS	American Welding Society
CIPT	constant injection pressure test
CPPT	constant production pressure test
ECV	equalizing control flow-control device
FCD	flow-control device
GST	geometric stem travel for fully opened condition
ID	internal diameter
IPO	injection-pressure-operated
ISA	Instrument Society of America
LST	maximum effective stem travel from the probe test
MSCFD	thousands of standard cubic feet per day
MSCMD	thousands of standard cubic metres per day
NDE	non-destructive testing method
OD	external diameter
PPO	production-pressure-operated
PQR	procedure qualification record
RP	recommended practice
SC	standard conditions, assumed to be 101 kPa (14,73 psia) and 15,5 °C (60 °F)
SCFD	standard cubic feet per day
SCMD	standard cubic meters per day
VST	flow-control device stem travel
WPQ	welder/welding operator performance qualification
WPS	welding procedure specification

4.2 Symbols and engineering terms

A_{b}	effective bellows area, expressed in square centimetres (square inches)
A_{p}	area based on the nominal port diameter, expressed in square centimetres (square inches)
A_{s}	area based on the diameter where the stem contacts the seat, expressed in square centimetres (square inches)
B_{lr}	bellows assembly load rate, expressed in kilopascals per centimetre (pounds per square inch per inch)
C_{v}	flow coefficient
$\mathrm{d}P$	differential pressure, expressed in kilopascals (pounds per square inch)

d_{st} distance stem has moved from seat, expressed in centimetres (inches)

d_{LST} distance of maximum effective stem travel from probe test

d_{VST} distance of flow-control device stem travel

F_x specific heat factor, equal to k/1,40

H factor determined by the manufacturer to calculate the upstream test procedure for the constant injection pressure test

k ratio of specific heats of lift gas

m_{bf} slope of the best-fit straight line

P_1 upstream gauge pressure of test section, expressed in gauge kilopascals (pounds per square inch)

P_2 downstream gauge pressure of test section, expressed in gauge kilopascals (pounds per square inch)

P_{iod} operating injection gauge pressure at flow-control device depth, expressed in gauge kilopascals (pounds per square inch)

P_o upstream gauge pressure for a constant downstream pressure

P_{pd} flowing production gauge pressure at flow-control device depth, expressed in gauge kilopascals (pounds per square inch)

P_{ox} measured or calculated pressure applied over the area (A_b minus A_s), required to initiate flow through a flow-control device with zero gauge pressure downstream at the supplier/manufacturer's reference temperature

NOTE Referred to as flow-control device opening pressure at the supplier/manufacturer's reference temperature, expressed in gauge kilopascals (pounds per square inch).

P_{tro} measured or calculated gauge pressure applied over the area (A_b minus A_s), required to initiate flow through a flow-control device with zero gauge pressure downstream at 15,5 °C (60 °F)

NOTE Referred to as flow-control device opening pressure at standard temperature, expressed in gauge kilopascals (pounds per square inch).

P_{vc} measured or calculated upstream gauge pressure when the downstream pressure is equal to the upstream pressure and near zero gas flow rate at 15,5 °C (60 °F)

NOTE Referred to as flow-control device closing pressure at standard temperature, expressed in gauge kilopascals (pounds per square inch).

P_{vcT} measured or calculated upstream gauge pressure when the downstream pressure is equal to the upstream pressure and near zero gas flow rate at a known temperature

NOTE Referred to as flow-control device closing pressure at a known temperature, expressed in gauge kilopascals (pounds per square inch).

P_{vo} valve opening pressure

P_{voT} measured or calculated gauge pressure applied over the area (A_b minus A_s), required to initiate flow through a flow-control device with zero gauge pressure downstream at a known temperature

NOTE Referred to as flow-control device opening pressure at a known temperature, expressed in gauge kilopascals (pounds per square inch).

P_{vst} pressure at maximum stem travel

q measured flow rate at standard conditions, expressed in cubic metres per hour or standard cubic feet per hour

q_{gi} measured flow rate at standard conditions, expressed in thousands of standard cubic metres per day or thousands of cubic feet per day

R_{tef} ratio that expresses the "tubing effect factor" of flow-control devices, as given by Equation (1) or the alternative form given in Equation (2):

$$R_{tef} = \left(\frac{A_s}{A_b}\right) \Big/ \left(1 - \frac{A_s}{A_b}\right) \quad (1)$$

$$R_{tef} = \left(P_{voT} - P_{vcT}\right) / P_{vcT} \quad (2)$$

Ra roughness, expressed in micrometres (micro-inches)

S_g specific gravity of gas (the value for air equals 1,0)

t time, expressed in seconds

T_1 upstream gas temperature, expressed in either degrees Celsius (degrees Fahrenheit) or kelvin (degrees Rankine)

T_v temperature of flow-control device at depth, expressed in either degrees Celsius (degrees Fahrenheit) or kelvin (degrees Rankine)

R_p pressure ratio; the measured differential pressure across the test section divided by the absolute upstream pressure, expressed as $\mathrm{d}P / (P_1 + 100)$ kPa $[\mathrm{d}P / (P_1 + 14{,}7)\ \mathrm{psi}]$

$R_{p,crt}$ critical pressure ratio factor; the pressure ratio factor at which the velocity of fluid exceeds the local speed of sound

NOTE Critical flow occurs when $F_k \times R_{p,crt}$ equals or exceeds the pressure ratio. The value is determined as specified in Clause 5.

F_Y expansion factor

Z_1 upstream compressibility factor

5 Functional specification

5.1 General

The purpose of the functional specification is to allow the user/purchaser to specify and define the functional requirements for flow-control device(s).

The user/purchaser shall prepare a functional specification for products that conform to this part of ISO 17078. The specification shall specify the following requirements and operating conditions, as appropriate, and/or identify the supplier/manufacturer's specific product. These requirements and operating conditions may be conveyed by means of a dimensional drawing, a data sheet, a functional specification form or other suitable documentation.

5.2 Functional characteristics

A flow-control device is a device that is landed by wireline or other means and secured in a side-pocket mandrel bore. The flow-control device acts to control the flow or communication of gas and/or liquid between the pressure-retaining areas of the well (e.g. annulus-to-tubing flow of gas, tubing-to-annulus flow of injection fluid, etc.).

The user/purchaser shall specify, as applicable, the following functional characteristics.

a) Flow-control device functions, including the specific function for which the flow-control device is used, e.g. gas lift, chemical injection, water flood injection, etc.;

b) Functions, which the user/purchaser may define by specifying either a specific flow-control device or functional items such as the following:

   — flow-control device type: IPO, PPO, seat material, elastomers, packing type, TRO/PVC range and special coating;

   — nominal flow-control device size, e.g. 2,54 cm (1 in), 3,81 cm (1,5 in), etc.;

   — port size;

   — port type: square-edged, bevelled, tapered, venturi, cross-over;

   — maximum bellows pressure;

   — bellows protection;

   — maximum spring load rate;

   — minimum flow-control device stem travel;

   — minimum/maximum flow rate when fully open;

   — back-check flow-control device(s);

   — choke size and type, if applicable;

c) Latch, the size and/or type and/or model(s) of which may be used to install, secure and retrieve the flow-control device in a side-pocket mandrel;

d) Seal bore, either the nominal size and configuration with which to accommodate the flow-control or other device, or the model(s) of the side-pocket mandrel in which the flow-control or other device for installation;

e) Communication ports, either the location and configuration of both inlet and outlet ports on the flow-control device, and/or the model of the flow-control device for installation;

f) Conduit ports, the connection size and configuration for side-pocket mandrel external ports and outlets to which a side-string, control, or injection conduit is to connect. This is for reference to validate that the specified flow-control device communication and internal port sizes are compatible.

5.3 Well parameters

5.3.1 Well fluid parameters

The following well fluid parameters to which the flow-control device is exposed during its full life cycle shall be provided:

a) fluid composition, chemical composition, specific gravity, etc., of

   — produced fluids (liquid, hydrocarbon gas, CO_2, H_2S, etc.),

   — injection gas (e.g. hydrocarbon gas, CO_2, etc.),

— injection fluids (e.g. water, steam, CO_2, chemicals, etc.),

— completion fluids,

— treatment/stimulation fluids/chemicals;

b) description of extraneous components (e.g. paraffin, sand, scale, corrosion products, etc.).

5.3.2 Allowable well operations

Expected well intervention(s) including its (their) parameters, such as the following, shall be stated:

a) acidizing, including acid composition, pressure, temperature and acidizing velocity, as well as exposure time and any other chemicals used during well stimulation;

b) fracturing, including proppant description, fracture fluid velocity, proppant/fluid ratio;

c) sand consolidation operations.

5.3.3 Corrosion information

If the user/purchaser has access to the corrosion property data of the operating environment based on historical data and/or research, this information shall be made available to the supplier/manufacturer. The user/purchaser may indicate to the supplier/manufacturer which material(s) has/have the ability to perform as required within the subject well's corrosion environment.

5.4 Operational parameters

The user/purchaser shall specify specific appropriate installation, testing and operational parameters to which the flow-control devices are subjected. These shall include, but are not limited to,

a) expected hydrostatic head at flow-control device depth,

b) expected minimum and maximum operating injection pressures,

c) expected minimum and maximum operating production pressures,

d) expected minimum and maximum operating temperatures,

e) expected minimum and maximum gas or liquid injection rates,

f) expected minimum and maximum fluid production rates,

g) expected maximum differential pressure across the back-check,

h) expected maximum internal-to-external differential pressure across the flow-control device,

i) expected pressure/differential at which a dump/kill or shear orifice opens,

j) expected installation, testing and operational procedures,

k) expected flow-control device deployment and retrieval method(s).

Exceptional operating conditions can require flow-control devices that are outside of the scope of this part of ISO 17078. In such cases, the user/purchaser and the supplier/manufacturer shall develop a mutually acceptable design and evaluation program that meets the intent and spirit of this part of ISO 17078.

5.5 Compatibility with well-related equipment

The user/purchaser, where applicable, shall specify the interface connection designs and material requirements, free-passage requirements and external/internal dimensional limitations needed to ensure that the product conforms to their application.

An example list is as follows:

a) size, type, material, configuration and interface dimensions of the connection between the product and other well equipment.

b) internal/external receptacle profile(s)/securing mechanism(s), sealing dimensions and their respective locations.

ISO 17078-1:2004, Table 1, details the polished bore dimensions required for side-pocket mandrels built to ISO 17078-1 specifications. The flow-control devices shall be selected to match the dimensions in accordance with ISO 17078-1. If there are occasions when the design of the side-pocket mandrel requires polished bore dimensions other than those listed, agreement between user/purchaser and supplier/manufacturer shall be documented.

5.6 Environmental service classes

The user/purchaser shall specify one of the following environmental service classes. If no class is specified, class E4 is deemed acceptable. This part of ISO 17078 provides for the following four environmental service classes as stipulated in 6.3. See Annex B for definitions.

— E4: Standard service;

— E3: H_2S or sour service;

— E2: CO_2 service;

— E1: Unique service, the characteristics of which are specified by the user/purchaser.

5.7 Design validation grades

The user/purchaser shall specify one of the following design validation grades. If no design validation grade is specified, grade V3 shall be deemed acceptable. This part of ISO 17078 provides the following three design validation grades as stipulated in 6.5. See Annex C for definitions.

— V3: Basic level of design validation;

— V2: Intermediate level of design validation;

— V1: Highest level of design validation.

5.8 Product functional testing grades

The user/purchaser shall specify one of the following product functional testing grades. If no product functional testing grade is specified, grade F3 shall be deemed acceptable. This part of ISO 17078 provides the following three product functional testing grades as stipulated in 6.6. See Annex D for definitions.

— F3: Basic level of product functional testing;

— F2: Intermediate level of product functional testing;

— F1: Highest level of product functional testing.

5.9 Quality control grades

The user/purchaser shall specify one of the following quality control grades. If no quality control grade is specified, grade Q2 shall be provided. This part of ISO 17078 provides two design quality control grades as stipulated in 7.4.

— Q2: Basic level of quality control;

— Q1: Highest level of quality control.

5.10 Additional required testing

The user/purchaser may specify additional design validation testing, product functional testing and/or quality control that is deemed necessary for a specific application. These requirements shall be in addition to those included herein.

6 Technical specification

6.1 General requirements

6.1.1 Purpose

The purpose of the technical specification is to guide the supplier/manufacturer to specify and define the technical requirements that shall be met by the flow-control device product(s) that are designed and manufactured to meet the functional specifications produced by the user/purchaser.

The supplier/manufacturer shall prepare the technical specification to meet the requirements defined in the user/purchaser's functional specification as defined in Clause 5. The supplier/manufacturer shall also provide the product data as defined in 7.2 to the user/purchaser.

6.1.2 Flow-control device groups

There are many possible types and permutations of flow-control devices. For purposes of simplification in flow-control device design validation testing and product functional testing, the various flow-control device types are classified into groups as shown in Table 1. See Clause 3 for definitions.

Table 1 — Flow-control device descriptions

Flow-control device group	Flow-control device types	Flow-control device description
I	IPO	Injection-pressure-operated flow-control device
	Balanced IPO	Injection-pressure-operated flow-control device with no “spread”, that is the opening and closing pressures are the same
	IPO with choke	Injection-pressure-operated flow-control device, with a choke installed downstream of the port
II	PPO	Production-pressure-operated flow-control device
	PPO with choke	Production-pressure-operated flow-control device, with a choke installed upstream of the port
III	Pilot	Injection-pressure-operated flow-control device with a pilot section and a full-opening primary flow section
	Differential	Flow-control device that opens and closes depending on the difference between the injection and production pressures
IV	Orifice	Flow-control device that cannot be closed
	Nozzle venturi	Flow-control device that cannot be closed, having a port in the shape of a venturi nozzle
	Shear orifice	Flow-control device that is initially closed; once it is opened, it cannot then be reclosed
	Dump/kill	Flow-control device that is initially closed; once it is opened, it cannot then be reclosed. These valves have very large ports and no reverse-flow check to allow a high-injection rate to kill the well.
V	Dummy	Blank device that is installed in a side-pocket mandrel to prevent flow or pressure communication between the casing annulus and the tubing
VI	Chemical injection	Injection-pressure-operated flow-control device used for injection of chemical from a special injection line into the tubing
	Chemical injection – spring loaded	Spring-operated flow-control device used for injection of chemical from a special injection line into the tubing
VII	Surface controlled – hydraulic	Flow-control device that is opened or closed by use of hydraulic pressure actuated from the surface
	Surface controlled – electric	Flow-control device that is opened or closed by use of an electrical signal actuated from the surface
	“Smart”	Flow-control device that contains on-board logic that can be used to regulate its degree of open/close
VIII	Liquid injection	Flow-control device used to control the rate of liquid injection within desired ranges
IX	Other	Devices that are not intended to control flow but may be installed in side-pocket mandrels, such as devices for pressure measurement, temperature measurement, monitoring corrosion, measuring flow, connecting to other devices and providing control logic

6.2 Technical characteristics

6.2.1 General

The supplier/manufacturer shall design and manufacture the flow-control device product to meet the functional criteria in 6.2.2 through 6.2.6.

6.2.2 Flow-control device installation

The flow-control device shall be positioned and seal at the specified location and remain so until human intervention defines otherwise.

6.2.3 Functional requirements

While located in the side-pocket mandrel, the flow-control device shall perform as in accordance with its specific technical specification.

6.2.4 Tool passage

The flow-control device, where applicable, shall not interfere with the safe passage through the side-pocket mandrel of tools, as specified in the functional specification.

6.2.5 Corrosion and chemical resistance requirements

Should the supplier/manufacturer determine that another material can equally or better meet the user/purchaser's specified corrosion-prevention requirements for the application (see 5.3.3), the user/purchaser shall be notified that this material has performance characteristics suitable for all parameters specified in the well and production/injection parameters (see 5.4). This applies to metallic and non-metallic components. Agreement shall be obtained before any change in materials from those indicated by the user/purchaser.

6.2.6 Operating parameters

The flow-control device shall perform in accordance with the operating parameters and characteristics as stated in the functional specification.

6.3 Design criteria

6.3.1 General

The supplier/manufacturer shall use the design criteria in 6.3.2 through 6.3.11 in designing the flow-control device(s).

6.3.2 Material environmental service grades

The supplier/manufacturer shall meet the environmental service requirements as specified by the user/purchaser. The required design requirements associated with each environmental service grade are detailed in Annex B.

6.3.3 Performance rating

The supplier/manufacturer shall state the pressure, temperature and other operational characteristics of the flow-control device.

6.3.4 Polished bore dimensions

ISO 17078-1:2004, Table 1, details the polished bore dimensions required for side-pocket mandrels built to ISO 17078-1 specifications. The flow-control device shall be designed to be compatible with dimensions in accordance with ISO 17078-1. However, there may be occasions when the design of the flow-control devices requires polished bore dimensions other than those listed. In those cases, agreement between user/purchaser and supplier/manufacturer shall be documented.

6.3.5 Interchangeability

Components and subassemblies of each type, model and size of flow-control device shall be designed, manufactured and identified to provide interchangeability within the product line of any one manufacturer. Stems and seats lapped to form matched sets are considered a single component for the purposes of this subclause.

6.3.6 Compatibility

The supplier/manufacturer shall provide documentation of specific side-pocket mandrels and latches that are compatible with the flow-control device. The level of documentation depends on the design validation grade and/or product functional test grade selected by the user/purchaser.

6.3.7 Dimensions

Dimensional tolerances of components or subassemblies shall be such that cumulative tolerances do not preclude proper operation as described in the design validation requirements. The assumptions, calculations and/or other design criteria shall be detailed in the design file for that product.

6.3.8 Packing, O-rings and seals

6.3.8.1 Allowable elastomeric materials

The supplier/manufacturer shall provide elastomeric materials that are compatible with the environmental service grade specified by the user/purchaser. Where applicable, consider the effects on elastomeric materials of the presence of aromatics and the proportion of hydrocarbons with a molecular weight of less than 120. The supplier/manufacturer shall document the process used for selecting compatible elastomeric materials.

6.3.8.2 Packing polished bore dimensions

The diameters of the external packing on all flow-control devices shall be designed using the polished bore dimensions as listed in ISO 17078-1 or upon special agreement between user/purchaser and supplier/manufacturer.

6.3.8.3 Design validation testing

Packing, O-rings and seal design validation testing shall be conducted as detailed in 7.4.8.2.

6.3.9 Good design practice

Good design practices, such as the following, shall be used.

- Locate the gas passage entry port of the flow-control device in the gas passage undercut of the side-pocket mandrel pocket.

- Provide rounded or bevelled exterior surfaces to prevent handing difficulties as the flow-control devices are lowered into or retrieved from the well.

- Design to prevent possible unseating of the flow-control device from the side-pocket mandrel as other devices are pulled through the side-pocket mandrel.

6.3.10 Design methods

Flow-control devices shall be designed using all or some of the following:

- finite element analysis for strength of material issues;
- computational fluid dynamics for flow characteristics;
- proprietary equations;
- standard equations;
- experimental stress analyses;
- experimental flow analyses;
- proof test analysis.

This part of ISO 17078 does not dictate the methods, equations or procedures for design purposes. The design method(s) that are used shall be documented in written supplier/manufacturer procedures.

All pressure-containing parts shall be designed to satisfy the supplier/manufacturer’s test pressures and to meet the conditions defined in the functional specification. The assumptions, calculations and/or other design criteria shall be detailed in the design file for that product.

All flow characteristics pertinent to the design that are calculated by computational fluid dynamics shall be validated through testing, the use of appropriate equations, flow analysis modelling or other means in accordance with this part of ISO 17078 and recognized industry practices in regard to flow validations.

6.3.11 Scaling of design

6.3.11.1 Qualified design families

For the purpose of design scaling, scaling is allowed to scale only between maximum and minimum port sizes on a specific flow-control device design family.

Products may be grouped into design families if they have interchangeable parts and if their configurations, sizes and applications are sufficiently similar to utilize a common methodology for establishing their design limits.

If requested by user/purchaser, the supplier/manufacturer shall provide the following documentation with products that have been verified by association:

- summary of all records of validated designs and/or products from the family;
- trend analyses or scatter diagrams, as appropriate, to demonstrate that the performance generated by the design methodology and analysis are sufficiently consistent to permit other designs to be validated by association;
- defined limits to the design variables within the validated family, outside of which similar designs cannot be considered to be validated by association and are, therefore, not part of the validated family.

6.3.11.2 New design variations

New designs may be added to existing design families if their configurations, materials and applications are documented and approved by the supplier/manufacturer’s assigned approval agent, as sufficiently similar to utilize the common methodology for establishing the design performance for products in that family. These designs are considered to be variations within the scope of the existing product family. If the design family is a qualified design family, the new designs may be considered qualified by association.

6.4 Allowable design changes

6.4.1 General

Under certain circumstances, design changes are allowed. Any changes in the design of a flow-control device shall be made following the procedures listed in 6.4.2 and 6.4.3.

6.4.2 Design changes

Design changes to existing products within a design family that meet the following requirements do not change their status as part of the design family and do not change their qualification by association within a qualified design family.

- The design changes do not require a change in the common methodology for establishing design performance envelopes within the design family.
- The operational parameters for the product(s) experiencing a design change are consistent with the operational parameters for the design family.
- A change in seat size is not considered a change in flow-control device design for the purposes of this subclause unless it also changes the calculated stem travel and bellows position from the initial starting position to the mechanical stop by more than 5 %.

A design that undergoes a substantive change becomes a new design requiring design validation. Justifications for design changes identified as non-substantive shall be documented.

For flow-control devices with unique or multiple features that do not constitute a substantive change of the design configuration of the product, the new feature(s) are tested in accordance with the supplier/manufacturer's documented requirements for design validation of that feature. Acceptance criteria and results shall be documented.

6.4.3 Supplemental features validation test

Flow-control devices with unique or multiple supplemental features that do not change the design of the product are to be tested in accordance with the supplier/manufacturer's documented requirements that validate proper operation of that feature. Acceptance criteria and results shall be documented.

6.5 Design verification and validation requirements

6.5.1 General

The supplier/manufacturer shall use these design verification and validation procedures to ensure that each flow-control device design family fulfils the applicable functional requirements that it is intended to meet.

6.5.2 Design verification

Design verification shall be performed on each design family of flow-control device to ensure that the device meets the supplier/manufacturer's technical specifications. Design verification includes activities such as design reviews, design calculations and comparison with similar designs and historical records of defined operating conditions.

6.5.3 Design validation

6.5.3.1 Testing

Design validation testing shall be performed on each design family of flow-control devices to ensure that the device meets the supplier/manufacturer's technical specifications. Design validation test requirements are specified in the normative Annexes A to M.

6.5.3.2 Design validation grade table

The design validation grade table specifies the design validation process(es), procedure(s) and test(s) that shall be followed for each design validation grade. See Table A.2.

6.5.4 Optional design validation testing

Some applications can require additional design validation testing. These additional design validation tests shall be specified by the user/purchaser in the functional specification.

6.6 Product functional testing requirements

6.6.1 General

The supplier/manufacturer shall use the following test(s) and/or process(es) to demonstrate that each flow-control device that is produced fully meets the design specifications.

6.6.2 Product functional testing grade table

The product functional testing grade table specifies the process(es) or procedure(s) that shall be followed for each product functional testing grade. See Table A.2.

6.6.3 Optional product functional testing

Some applications can require additional product functional testing. These shall be specified by the user/purchaser in the functional specification.

7 Supplier/manufacturer requirements

7.1 General

The supplier/manufacturer shall meet the following requirements in designing, manufacturing, testing, and delivering the flow-control device product(s) that are covered by this part of ISO 17078.

Clause 7 contains the detailed requirements to ensure that each product manufactured meets the requirements of the functional specifications in Clause 5 and the technical specifications in Clause 6. As a minimum, each of the topics discussed in 7.2 to 7.9 shall be addressed.

7.2 Documentation and data control

7.2.1 General

The supplier/manufacturer shall establish and maintain documented procedures to control all documents and data that relate to the requirements, including normative annexes of this part of ISO 17078. These documents and data shall be maintained to demonstrate conformance to specified requirements. All documents and data shall be legible and shall be sorted and retained in such a way that they are readily retrievable in facilities that provide a suitable environment to prevent damage or deterioration and to prevent loss. Documents and data may be in the form of any type of media, such as hard copy or electronic media. All documents and data shall be available and auditable by the user/purchaser.

7.2.2 Documentation requirements

The supplier/manufacturer shall have available a completed design file containing all the supplier/manufacturer's required design validation testing procedures and design validation grade testing records, with verified acceptance of each. The file shall further contain test results and/or calculations that validate the design. The design packet shall be properly reviewed and approved by a qualified person other than the originator.

7.2.3 Documentation requirements for specific product design validation testing

There are three sets of requirements for the documentation of product design validation tests, one for each product design validation grade: V3, V2 and V1. These are identified in Table A.2 and the test requirement annexes to which Table A.2 refers. In some cases, the requirements in 7.2 are sufficient. In other cases, special documentation is required and is specified in the appropriate annexes.

7.2.4 Devices tested prior to date of publication of this part of ISO 17078

The requirements for documentation may be met for flow-control device products that existed before the publication of this part of ISO 17078 if the supplier/manufacturer can document that they successfully performed the required tests on these devices to meet the equivalent validation testing requirements, and that these tests have been approved by a qualified person. If the procedures are not the same as defined in this part of ISO 17078, the supplier/manufacturer shall provide written evidence of the suitability of the previous test procedure(s) to ensure that they meet or exceed these requirements.

7.2.5 Design documentation

The design validation test results shall be clearly identified as grade V3, V2 or V1.

The product functional test results shall be clearly identified as grade F3, F2 or F1.

All design documents, data, design validation test results and initial product functional test results in the following list shall be maintained for five years after the date of last manufacture:

a) functional and technical specifications;

b) supplier/manufacturer's quality manual;

c) required grade of QC (quality control) documentation as specified in 5.8;

d) one complete set of drawings, written specifications and design calculations and standards;

e) instructions providing methods for the safe installation and use of the flow-control device. This document shall state the operations that are permitted and shall preclude those operations that can lead to failure and/or non-compliance with the functional and performance requirements;

f) material type, yield strength and connection identification for the actual end connection(s) provided with the flow-control device (where applicable);

g) welding procedure specification (WPS);

h) weld procedure qualification record (PQR);

i) welder/welding operator performance qualification (WPQ).

7.2.6 Product functional testing documentation

7.2.6.1 Test file

The supplier/manufacturer shall have available a complete test file containing all the supplier/manufacturer's required product functional testing procedures and product functional test grade testing records, with verified acceptance of each. The file shall further contain test results and/or calculations that confirm the performance of the product(s) that have been tested.

7.2.6.2 Documentation requirements for specific product functional testing

There are three sets of requirements for documentation of product functional tests, one for each product functional testing grade: F3, F2 and F1. These are identified in Table A.2 and the test requirement annexes to which Table A.2 refers.

7.2.7 User/purchaser documentation

A product data sheet for each line item on each order shall be supplied upon delivery of the order to the user/purchaser, as required in the quality control grade.

NOTE The intent of this is to require a separate product data sheet for each unique product or set of products that is part of a specific design family.

The product sheet shall contain at least the following, as applicable:

a) name and address of supplier/manufacturer;

b) supplier/manufacturer assembly number;

c) supplier/manufacturer product name;

d) product type;

e) operational parameters as specified in 5.4;

f) metallic materials;

g) non-metallic materials;

h) overall length;

i) temperature range for rated pressure;

j) rated pressure;

k) top connection(s);

l) conveyance method;

m) maximum conveyance OD, inclusive of running equipment, as applicable;

n) retrieval method;

o) quality control grade;

p) design validation grade;

q) product functional testing grade;

r) technical/operations manual reference number.

7.2.8 Technical/operations manual

A technical/operations manual shall be available for products supplied in accordance with this part of ISO 17078 and shall contain at least the following information:

a) manual reference number and revision level;

b) product data sheet;

NOTE An example product data sheet will be shown in ISO 17078-4, which is under development as of the date of publication of this part of ISO 17078.

c) operational procedures;

d) pre-installation inspection procedures;

e) storage recommendations;

f) representative drawing showing major dimensions (ODs, IDs, and lengths);

g) special precautions and handling;

h) list of all devices with which compatibility is claimed for the flow-control device.

7.3 Product identification requirements

7.3.1 General

The supplier/manufacturer shall clearly identify and mark each flow-control device according to the requirements of 7.3.

7.3.2 Product identification

Each product furnished to this part of ISO 17078 shall be permanently identified using low-stress marking devices, which include interrupted-dot or rounded cold die-stamp, vibratory method or laser etching. Supplier/manufacturer specifications shall define the method(s) and location of the markings. The following information, as a minimum, shall be marked on each flow-control device:

a) supplier/manufacturer's name or mark;

b) date (month and year) of manufacture;

c) supplier/manufacturer's part number and unique traceable serial number.

7.4 Quality control requirements

7.4.1 General

This part of ISO 17078 provides for two quality control grades. Requirements for each of these grades are specified in 7.4.6.

7.4.2 Quality control personnel qualifications

All personnel performing quality control activities directly affecting material and product quality shall be qualified in accordance with the supplier/manufacturer's documented requirements.

7.4.3 Manufacturing non-conformance

The supplier/manufacturer shall establish and maintain documented procedures to ensure that an assembly or component that does not conform to specified requirements is prevented from unintended use or installation. This control shall provide for identification, documentation, evaluation, segregation (when applicable) and disposition of non-conforming assemblies or components.

The responsibility for review and authority for the disposition of non-conforming assemblies or components shall be defined by the supplier/manufacturer. Non-conforming assemblies or components may be

— reworked to meet the specified requirements,

— accepted, with or without repair, by concession of the supplier/manufacturer's authorized personnel, if the assembly or component does not violate design validation requirements, or

— rejected or scrapped.

Repaired and/or reworked assemblies or components shall be inspected in accordance with the appropriate quality control grade.

7.4.4 Component dimensional examination

Components and assemblies shall be dimensionally inspected to ensure proper function and compliance with design criteria and technical specifications. The frequency of these examinations shall be performed as detailed in the supplier/manufacturer’s written requirements.

7.4.5 Traceability

The supplier/manufacturer is responsible for traceability, documentation and the product condition at time of shipment to the user/purchaser.

All components, weldments, subassemblies and assemblies of equipment supplied in accordance with this part of ISO 17078 shall be traceable to a job lot, for which components and weldments shall also identify the heat(s) or batch lot(s) included. All components and weldments in a multi-heat or batch job lot shall be rejected if any heat or batch does not comply with specified requirements. Individual component identification shall be maintained to facilitate traceability until the supplier/manufacturer’s final inspection is completed.

7.4.6 Quality control grade selection

7.4.6.1 General

This part of ISO 17078 provides two grades of quality control for flow-control devices. The user/purchaser shall specify, in the functional specification, the grade of quality control and/or additional requirements when desired. The documentation of quality control shall be presented to the user/purchaser on request.

7.4.6.2 Grade Q2 — Basic grade of flow-control device quality control

The documentation shall include a certificate of conformance for the flow-control devices in the flow-control device job lot, at the request of the user/purchaser.

7.4.6.3 Grade Q1 — Highest level of flow-control device quality control

The documentation shall include a certificate of conformance for the flow-control devices in the flow-control device job lot. It shall also contain mill certification for all components, except common hardware items, as specified in this subclause. In addition, it shall contain the results of all product functional tests run on this flow-control device job lot.

The following are examples of common hardware items that may be excluded:

— roll pins;

— copper gaskets;

— snap rings;

— coating materials;

— valve cores.

Products shall be supplied to quality control grade Q2 unless the user/purchaser specifies grade Q1.

The user/purchaser may also specify an additional quality/certification system to apply to equipment supplied to this part of ISO 17078.

Each quality control grade requires appropriate documentation. This documentation shall be maintained in manufacturing or quality control files. It shall be presented to the user/purchaser if requested.

7.4.7 Measuring/testing equipment

7.4.7.1 General

Measuring and testing equipment shall meet or exceed the measurement accuracy required by the acceptance criteria for that evaluation or test.

7.4.7.2 Calibration

7.4.7.2.1 General

Measuring and testing equipment used for acceptance (including annex acceptance criteria) shall be identified, inspected, calibrated and adjusted at specific intervals in accordance with documented specifications, ANSI/NCSL Z540-1 and this part of ISO 17078.

7.4.7.2.2 Pressure-measuring devices

Pressure-measuring devices shall

a) be readable to at least ± 0,5 % of full-scale range, or better, as required to perform the specified measurement;

b) be calibrated to maintain ± 2 % accuracy of full-scale range, or better, as required to perform the specified measurement.

Pressure-measuring devices shall be used only within the calibrated range.

Pressure-measuring devices shall be calibrated with a master pressure-measuring device or a dead weight tester. Calibration intervals for pressure-measuring devices shall be a maximum of three months until a documented calibration history can be established. Calibration intervals shall then be established based on repeatability, degree of usage and documented calibration history.

7.4.8 Elastomeric materials and seal design

7.4.8.1 Inspection requirements for packing, O-rings and seal materials

7.4.8.1.1 General

All flow-control device packing, O-rings and seal materials shall be inspected according to the requirements of 7.4.

7.4.8.1.2 Elastomeric materials

Each elastomeric component shall comply with the supplier/manufacturer's written specifications. Supplier/manufacturers providing equipment to this specification shall be responsible for the following.

a) Tolerances

The tolerances of O-rings shall be in compliance with SAE AS 568A. Other packing elements shall meet the dimensional tolerances of the supplier/manufacturer's written specifications. Sampling procedures for inspection and the basis for acceptance or rejection of a batch lot shall be in accordance with MIL-STD-1916, General Inspection Level II, at a 2.5 AQL for O-rings and at a 1.5 AQL for other packing elements.

b) Hardness

The durometer hardness of O-rings shall be measured in accordance with ASTM D2240 or ASTM D1415. The preferred method is to conduct the hardness test on a test specimen from each batch and cure cycle rather than test individual seals. In the event that such tests are conducted on individual seals, sampling procedures for inspection and the basis for acceptance or rejection of a batch lot shall be in accordance with those cited in 7.4 for O-rings or other packing elements.

c) Visual inspection

O-rings shall be visually inspected in accordance with MIL-STD-413C. Other packing elements shall be visually inspected according to the manufacturer's written inspection procedures. The inspection shall include such items as lip damage, flashing, breaks, cracks or other visible damage.

d) Handling and storage

Materials used for sealing devices such as O-rings or other packing elements require special handling and storage procedures. The supplier/manufacturer shall have written specifications that include handling and storage requirements, including the shelf life appropriate for each specific material compound.

7.4.8.1.3 Other materials

Non-metals other than elastomers shall comply with the supplier/manufacturer's written specifications.

7.4.8.1.4 Traceability

Traceability requirements shall be documented by the supplier/manufacturer and shall be sufficient to ensure that all piece parts are manufactured from materials that satisfy the supplier/manufacturer's written specifications. Traceability of piece parts is required until the parts are used in subassemblies or assemblies. The traceability of subassemblies or assemblies is not required for the purposes of this subclause.

7.4.8.2 Sealing device design validation testing

7.4.8.2.1 General

The supplier/manufacturer shall perform and document design validation testing for each size, design and material of sealing device used in each flow-control device. Once a sealing device has successfully passed design validation testing, it is qualified for use on multiple products of similar dimensional requirements within the temperature and pressure differentials tested. All sealing devices shall be tested by pressurization in the direction(s) of the seal's intended use and design requirements. Sealing devices that qualified to ISO 10432 or ANSI/API Spec 14A, prior to the publication of this part of ISO 17078, may be considered as meeting the design validation test requirements of this part of ISO 17078, providing that the documentation of these tests confirms conformance to test requirements of this part of ISO 17078.

7.4.8.2.2 Required characteristics for the apparatus

The apparatus shall meet the following requirements.

a) The tested sealing device and the gland, mandrel and sealing bore surfaces shall be of the identical configuration, dimension and tolerances as used for the production products.

b) When a test fixture is used, it shall be designed to apply the pressures, temperatures and loads in a manner comparable to that of the production products.

c) Testing components/fluids shall be designed to perform the test procedure within the required parameters.

d) The sealing device design, materials, test results and all test pressures, test temperatures and fluid descriptions shall be documented.

7.4.8.2.3 Test procedure

The test shall be carried out as outlined below.

a) Install the sealing device in the test apparatus following the supplier/manufacturer’s procedures. Verify that all equipment and fluids can safely meet the required pressures, temperatures and accuracy.

b) Adjust and stabilize the assembled test apparatus to within ${}^{+10}_{\ 0}$ % of the sealing device’s maximum rated temperature. Adjust and stabilize the differential pressure on the sealing device to (25 ± 2) % of the maximum rated pressure. Hold and continuously record the temperature and pressure for a minimum of 15 min. The pressure and temperature measurement shall remain within the tolerances for a successful test. If there are concerns with low-temperature service, this shall be addressed with a special separate written test procedure.

c) Repeat step (b) at (100 ± 2) % of the maximum rated pressure with all other parameters unchanged.

d) Release the pressure.

e) Repeat step (b) at the maximum rated temperature ${}^{+10}_{\ 0}$ % with all other parameters unchanged.

f) Repeat step (e) at (100 ± 2) % of the maximum rated pressure.

g) Release the pressure.

7.4.8.2.4 Acceptance criteria

Acceptance criteria are listed below.

a) The sealing device shall successfully meet the test requirements and remain within the required limits.

b) A visual inspection of the sealing device following this testing shall confirm that it meets the supplier/manufacturer’s written acceptance criteria.

7.4.9 Material certifications

7.4.9.1 Test certificates

A supplier/manufacturer's mill test certificate of the original heat of the material or a supplier/manufacturer's certification of test results are acceptable if the certifications include test results for mechanical properties and chemical composition for that heat of material. If the material is altered by subsequent processes that change its properties, then acceptance is based on either hardness or mechanical properties as specified in ASTM A370 from the heat of the material in question. These tests are completed using the heat treat cycle for which the material is being qualified. If the initial test specimen fails, two new, additional tests shall be successfully performed to qualify the material. The material shall be rejected if the results of either of two additional tests do not meet specified requirements. If hardness is used for final acceptance, then the supplier/manufacturer shall document the hardness-strength correlations.

Acceptance of all materials shall be indicated either on the materials or in the records traceable to the materials.

Raw material used in the manufacture of components shall meet the following requirements:

a) certificate of conformance stating that the raw material meets the supplier/manufacturer’s documented specifications;

b) material test report showing that the supplier/manufacturer can verify that the raw material meets the supplier/manufacturer’s documented specifications.

7.4.9.2 Mechanical properties

Material mechanical properties shall be as follows.

a) Mechanical property test procedures and practices for metallic materials shall be in accordance with ASTM A370 for the metallic materials used for traceable components.

b) Mechanical property test procedures for elastomeric and non-metallic compound types shall be in accordance with 7.4 of this part of ISO 17078.

7.4.9.3 Inspection requirements

Inspection requirements for packing, O-ring and seal materials shall be conducted as detailed in 7.4, as applicable.

7.5 Heat-treating-equipment qualification

Heat-treating-equipment shall meet the following qualifications.

a) Heat treating of production parts shall be performed with heat-treating equipment that has been calibrated and surveyed.

b) Each furnace shall be surveyed within one year prior to heat-treating operations. When a furnace is repaired or rebuilt, a new survey shall be required before heat treating.

c) Batch-type and continuous-type heat-treating furnaces shall be calibrated in accordance with one of the following procedures:

    1) procedures specified in SAE AMS-H-6875;

    2) procedures specified in BS 2M 54;

    3) supplier/manufacturer's written specifications, including acceptance criteria that are not less stringent than the procedures identified above.

7.6 Welding requirements

7.6.1 General

The supplier/manufacturer's welding control system shall include requirements for monitoring, updating and controlling the qualifications of welders/welding operators and the use of welding procedure specifications. Instruments utilized to verify temperature, voltage and amperage shall be serviced and calibrated in accordance with the flow-control device supplier/manufacturer’s written procedures.

All welding procedures, welders and welding operators shall be qualified in accordance with ASME Boiler and Pressure Vessel Code Section IX. Base metals that are not classified under the ASME P-number grouping shall be qualified as unassigned metals in accordance with QW-424.1 in ASME Boiler and Pressure Vessel Code Section IX.

7.6.2 Welding consumables

Welding consumables shall conform to AWS or supplier/manufacturer’s written specifications. The supplier/manufacturer shall have a written procedure for selection, storage and control of welding consumables. Materials of low-hydrogen type shall be stored and used as recommended by the consumable manufacturer to retain their original low-hydrogen properties.

7.6.3 Welding procedures/qualification records

Welding shall be performed in accordance with welding procedure specifications written and qualified in accordance with Article II of ASME Boiler and Pressure Vessel Code Section IX. The WPS shall describe all the essential and nonessential variables as defined in ASME Boiler and Pressure Vessel Code Section IX. The procedure qualification record shall record all essential variables as defined in ASME Boiler and Pressure Vessel Code Section IX of the weld procedure used for the qualification test(s).

The test weldment for hardness testing shall have the same type of post-weld heat treatment as the final product. For flow-control device environmental service class E3, hardness tests across the weld, base material and heat-affected zone (HAZ) cross-section shall be performed in accordance with ASTM E18 and recorded as part of the PQR. Maximum hardness values for environmental grade E3 service shall not exceed the requirements of ISO 15156 (all parts).

NOTE For the purposes of this provision, NACE MR0175 is equivalent to ISO 15156 (all parts).

7.6.4 Welder/welding operator performance qualification

Welders and welding operators shall be qualified in accordance with Article III of ASME Boiler and Pressure Vessel Code Section IX. Records of WPQ test shall include all welding parameters as detailed in ASME Boiler and Pressure Vessel Code Section IX.

7.7 Non-destructive examination requirements

Non-destructive examinations (NDE) are not required as part of this part of ISO 17078, except as indicated in this subclause. If NDE examinations are conducted for supplier/manufacturer’s internal procedures or because of user/purchaser written requests, the NDE procedures defined in ISO 17078-1 shall be followed.

Where NDE is used on flow-control devices, the supplier/manufacturer shall prepare written specifications for allowable relevant indications.

7.8 Storage and shipping preparation

7.8.1.1 General

The supplier/manufacturer shall comply with the requirements specified in 7.8.1.2 to 7.8.1.5 for storage and shipping of flow-control device products.

7.8.1.2 Draining, cleaning and/or drying

The processes for draining, cleaning and/or drying of flow-control device products after they have been tested shall be specified in the supplier/manufacturer's written procedures. The minimum standard shall be that the products be free of any foreign liquids and/or matter.

7.8.1.3 Threaded connections and packing

All threaded connections and packing shall be protected as specified in the supplier/manufacturer's written procedures.

7.8.1.4 Permanent marking prior to coating

Prior to coating, all permanent marking that is required by this part of ISO 17078 shall be completed. No marking may affect the operation of any component of a flow-control device. All markings shall be made and located according to supplier/manufacturer’s written procedures. No coating is allowed on or in active threads or on the sealing surface other than coating, plating or other surface treatments that are specified by the supplier/manufacturer for these surfaces.

7.8.1.5 Shipping of pressurized flow-control devices

Shipping of pressurized flow-control devices shall conform with applicable transportation regulations.

7.9 Allowable changes after manufacturing

Any reconfiguration of, or change to, a previously validated and tested product, over and above settings and adjustments, shall require full design validation and product functional testing to qualify it to this part of ISO 17078.

7.10 Reconditioning of flow-control devices

Reconditioning of used flow-control device products is outside of the scope of this part of ISO 17078. However, this process is used in industry. See ISO 17078-4, which is under preparation as of the date of publication of this part of ISO 17078, for a discussion of this topic.

Annex A
(normative)

Design validation and product functional testing requirements

A.1 General

Table A.1 is an index of the annexes and their purpose.

Table A.1 — Purpose of normative and informative annexes

Annex	Annex title	Purpose of annex[a]
A	Design validation and product functional testing requirements	List purpose of each annex List all required design validation and product functional test requirements
B	Environmental service classes	Tests required for four environmental service grades: E4, E3, E2 and E1
C	Design validation grades	Tests required for three design validation grades: V3, V2 and V1
D	Product functional testing grades	Tests required for three product functional testing grades: F3, F2 and F1
E	Interface testing requirements	Design validation testing of all interfaces between flow-control devices and other related devices such as side-pocket mandrels
F	Insertion testing requirements	Design validation testing of insertion and retrieval of flow-control devices into and from side-pocket mandrels
G	Probe and travel testing and load rate determination	Design validation testing of maximum travel and load rate Product functional testing of maximum travel and load rate
H	Dynamic flow testing and flow coefficient, C_v, calculation	Design validation testing of flow and flow coefficient, C_v Product functional testing of flow and flow coefficient, C_v
I	Back-check testing	Design validation testing of back-check devices Product functional testing of back-check devices
J	Opening and closing pressure testing	Design validation testing of opening and closing Product functional testing of opening and closing
K	Bellows actuation life cycle testing	Design validation testing of bellows life cycles
L	Erosion testing requirements	Design validation testing of effects of erosion
M	Shelf (bellows integrity) testing requirements for nitrogen-pressure-charged flow-control devices	Design validation shelf (bellows integrity) testing Product functional shelf (bellows integrity) testing
N	Conducting port/seat leakage rate testing	Design validation testing of port/seat leakage rates Product functional testing of port/seat leakage rates
O	Performance testing — Recommendations for a flow-control device performance test facility	Recommended practices for facilities for performance testing of flow-control devices
P	Performance testing — Prediction correlations using a simplified flow-control device performance model	Tests to develop performance correlations Recommended practices for performance testing of flow-control devices

[a] The purpose of the normative Annexes A to M is to define design validation and product functional test requirements for flow-control devices.

A.2 Design validation and product functional testing requirements

The following table summarizes the design validation and product functional testing requirements that shall be performed for each flow-control device group and type (see 6.1.2 and Table 1 for a definition of each flow-control device and type). There are several categories of tests, for example interface testing, insertion testing, probe or travel testing, etc. However, the open and close test is only pertinent for design validation testing and the separate open and close tests are only pertinent for product functional testing.

The specific requirements for each category of test are defined in one of the normative Annexes E through M. For each group and type of flow-control device there are three design validation grades (V3, V2 and V1) and three product functional test grades (F3, F2 and F1). There can be a separate test required for each grade or a single test can be used for more than one grade.

If a cell in the following table contains a dash, no test is required. If a specific test is not listed for a specific flow-control device group and type, it is not required.

In Table A.2, the specific test for each grade is identified. For example, the interface testing requirements for flow-control device type IPO are defined in Annex E. The design validation test specified in E.2.1 is required for grades V3 and V2. The design validation test specified in E.2.2 is required for grade V1. No product functional tests are required for interface testing for this flow-control device type.

As another example, the back-check testing requirements for flow-control device type IPO are defined in Annex I. The design validation test specified in I.2.1 is required for grade V3. The design validation test specified in I.2.2 is required for grade V2. The design validation test specified in I.2.3 is required for grade V1. The product functional test specified in I.3.1 is required for grade F3. The product functional test specified in I.3.2 is required for grade F2. The product functional test specified in I.3.3 is required for grade F1.

Open and close testing are conducted together for design validation. Separate open and close tests are required for production functional testing. Therefore, these tests are listed separately in Table A.2.

Table A.2 — Testing requirements

Flow-control device group and type (See 6.1.2)		Design validation test and/or product functional test	Annex	Design validation and product functional test requirements for each flow-control device grade					
				V3 Basic grade	V2 Intermediate grade	V1 Highest grade	F3 Basic grade	F2 Intermediate grade	F1 Highest grade
I	IPO Balanced IPO IPO w/ choke	Interface	E	E.2.1	E.2.1	E.2.2	-	-	-
		Insertion	F	F.2	F.2	F.2	-	-	-
		Probe or travel	G	G.2	G.2	G.2	-	G.4.2	G.4.3
		Load rate	G	G.3	G.3	G.3	-	G.5.2	G.5.3
		Flow	H	-	H.2.2	H.2.3	-	-	H.3.4
		Back-check	I	I.2.1	I.2.2	I.2.3	I.3.1	I.3.2	I.3.3
		Open and close	J	J.1.2	J.1.2	J.1.2	-	-	-
		Open	J	-	-	-	J.2	J.2	J.2
		Close	J	-	-	-	-	J.3.2	J.3.3
		Actuation life cycle	K	-	-	K.2.2	-	-	-
		Erosion	L	-	L.2.2	L.2.2	-	-	-
		Shelf	M	M.2.1	M.2.1	M.2.1	M.3.2	M.3.2	M.3.2
		Port/seat leakage rate	N	N.2.1	N.2.1	N.2.1	N.3.1	N.3.1	N.3.1
II	PPO PPO w/choke	Interface	E	E.2.1	E.2.1	E.2.2	-	-	-
		Insertion	F	F.2	F.2	F.2	-	-	-
		Probe or travel	G	G.2	G.2	G.2	-	G.4.2	G.4.3
		Load rate	G	G.3	G.3	G.3	-	G.5.2	G.5.3
		Flow	H	-	H.2.2	H.2.3	-	-	H.3.4
		Back-check	I	I.2.1	I.2.2	I.2.3	I.3.1	I.3.2	I.3.3
		Open and close	J	J.1.2	J.1.2	J.1.2	-	-	-
		Open	J	-	-	-	J.2	J.2	J.2
		Close	J	-	-	-	-	J.3.2	J.3.3
		Actuation life cycle	K	-	-	K.2.2	-	-	-
		Erosion	L	-	L.2.2	L.2.2	-	-	-
		Shelf	M	M.2.1	M.2.1	M.2.1	M.3.2	M.3.2	M.3.2
		Port/seat leakage rate	N	N.2.1	N.2.1	N.2.1	N.3.1	N.3.1	N.3.1

Table A.2 (*continued*)

Flow-control device group and type (See 6.1.2)		Design validation test and/or product functional test	Annex	Design validation and product functional test requirements for each flow-control device grade					
				V3 Basic grade	V2 Intermediate grade	V1 Highest grade	F3 Basic grade	F2 Intermediate grade	F1 Highest grade
III	Pilot Differential	Interface	E	E.2.1	E.2.1	E.2.2	-	-	-
		Insertion	F	F.2	F.2	F.2	-	-	-
		Flow	H	-	H.2.2	H.2.3	-	-	H.3.4
		Back-check	I	I.2.1	I.2.2	I.2.3	I.3.1	I.3.2	I.3.3
		Open and close	J	J.1.2	J.1.2	J.1.2	-	-	-
		Open	J	-	-	-	J.2	J.2	J.2
		Close	j	-	-	-	-	J.3.2	J.3.3
		Actuation life cycle	K	-	-	K.2.2	-	-	-
		Erosion	L	-	L.2.2	L.2.2	-	-	-
		Shelf	M	M.2.1	M.2.1	M.2.1	M.3.2	M.3.2	M.3.2
		Port/seat leakage rate	N	N.2.1	N.2.1	N.2.1	N.3.1	N.3.1	N.3.1
IV	Orifice Nozzle venturi Shear orifice Dump/kill	Interface	E	E.2.1	E.2.1	E.2.2	-	-	-
		Insertion	F	F.2	F.2	F.2	-	-	-
		Flow	H	-	H.2.2	H.2.3	-	-	H.3.4
		Back-check	I	I.2.1	I.2.2	I.2.3	I.3.1	I.3.2	I.3.3
		Open and close	J	J.1.2	J.1.2	J.1.2	-	-	-
		Erosion	L	-	L.2.2	L.2.2	-	-	-
		Shelf	M	M.2.1	M.2.1	M.2.1	-	-	-
		Port/seat leakage rate	N	-	-	-	N.3.1	N.3.1	N.3.1
V	Dummy	Interface	E	E.2.1	E.2.1	E.2.2	-	-	-
VI	Chemical injection Chemical injection, spring-loaded	Interface	E	E.2.1	E.2.1	E.2.2	-	-	-
		Insertion	F	F.2	F.2	F.2	-	-	-
		Probe or travel	G	-	-	-	-	G.4.2	G.4.3
		Load rate	G	-	-	-	-	G.5.2	G.5.3
		Flow	H	-	H.2.2	H.2.3	-	-	-
		Back-check	I	I.2.1	I.2.2	I.2.3	I.3.1	I.3.2	I.3.3
		Open and close	J	J.1.2	J.1.2	J.1.2	-	-	-
		Open	J	-	-	-	J.2	J.2	J.2
		Close	J	-	-	-	-	J.3.2	J.3.3
		Actuation life cycle	K	-	-	K.2.2			-
		Erosion	L	-	L.2.2	L.2.2			-
		Shelf	M	M.2.1	M.2.1	M.2.1	M.3.2	M.3.2	M.3.2
		Port/seat leakage rate	N	N.2.1	N.2.1	N.2.1	N.3.1	N.3.1	N.3.1

Table A.2 (*continued*)

Flow-control device group and type (See 6.1.2)		Design validation test and/or product functional test	Annex	Design validation and product functional test requirements for each flow-control device grade					
				V3 Basic grade	V2 Intermediate grade	V1 Highest grade	F3 Basic grade	F2 Intermediate grade	F1 Highest grade
VII	Surface-controlled hydraulic Surface-controlled electric "Smart"	Interface	E	E.2.1	E.2.1	E.2.2	-	-	-
		Insertion	F	F.2	F.2	F.2	-	-	-
		Flow	H	H.2.1	H.2.2	H.2.3	-	H.3.3	H.3.4
		Back-check	I	I.2.1	I.2.2	I.2.3	I.3.1	I.3.2	I.3.3
		Open and close	J	J.1.2	J.1.2	J.1.2	-	-	-
		Open	J	-	-	-	J.2	J.2	J.2
		Close	J	-	-	-	J.3.1	J.3.2	J.3.3
		Erosion	L	-	L.2.2	L.2.2	-	-	-
		Port/seat leakage rate	N	N.2.1	N.2.1	N.2.1	N.3.1	N.3.1	N.3.1
VIII	Liquid injection	Interface	E	E.2.1	E.2.1	E.2.2	-	-	-
		Insertion	F	F.2	F.2	F.2	-	-	-
		Load rate	G	-	-	-	-	G.5.2	G.5.3
		Flow	H	-	H.2.2	H.2.3	-	-	-
		Back-check	I	I.2.1	I.2.2	I.2.3	I.3.1	I.3.2	I.3.3
		Open and close	J	J.1.2	J.1.2	J.1.2	-	-	-
		Open	J	-	-	-	J.2	J.2	J.2
		Close	J	-	-	-	-	J.3.2	J3.3
		Actuation life cycle	K	-	-	K.2.2	-	-	-
		Erosion	L	-	L.2.2	L.2.2	-	-	-
		Shelf	M	M.2.1	M.2.1	M.2.1	M.3.2	M.3.2	M.3.2
IX	Other: Measure pressure Measure temperature Monitor corrosion Connect to other devices Provide control logic	Interface	E	E.2.1	E.2.1	E.2.2	-	-	-
		Insertion	F	F.2	F.2	F.2	-	-	-

Annex B
(normative)

Environmental service classes

B.1 General

This annex provides detailed requirements for each of the four environmental service classes for flow-control devices that are specified in this part of ISO 17078. The supplier/manufacturer shall establish criteria and select materials to meet the requirements of the environmental service classes as listed in Table B.1, or materials agreed by the user/purchaser shall be used.

Table B.1 — Environmental service (E) classes

Environmental service (E) classes Grades	Characteristics
Class E4 — Standard service (see Clause B.2)	Environments not subject to stress cracking or CO_2 corrosion
Class E3 — Stress-cracking service (see Clause B.3)	Stress-cracking environments [a]
Class E2 — CO_2 service (see Clause B.4)	CO_2 corrosion environments
Class E1 — Unique service (see Clause B.5)	Unique service requirements defined by the user/purchaser that are not covered by Classes E4, E3, or E2

[a] As specified in ISO 15156 (all parts).

B.2 Class E4 — Standard service

This is the service in fluids that have an H_2S partial pressure less than those listed for sulfide stress cracking in ISO 15156 (all parts) and no CO_2 content. The standard materials used for this service shall be 303 stainless steel, 304 stainless steel, 316 stainless steel and 17/4 PH stainless steel. Carbon and low-alloy steels and 200 series stainless steels shall not be used. Other materials may be acceptable for this service if proposed by the supplier/manufacturer and approved by the user/purchaser.

NOTE For the purposed of this provision, NACE MR0175 is equivalent to ISO 15156.

B.3 Class E3 — Stress-cracking service

This is the service in fluids that have an H_2S partial pressure greater than those listed for sulfide stress cracking in ISO 15156 (all parts) and no CO_2 content. Materials used for this service shall be compatible with ISO 15156 (all parts). Carbon and low-alloy steels and 304 stainless steel shall not be used. Other materials may be acceptable for this service if proposed by the supplier/manufacturer and approved by the user/purchaser. Welding processes used for this service shall meet ISO 15156 (all parts) requirements.

Within this service class, there are two sub-classes: E3S for sulfide stress-cracking service and stress-corrosion-cracking service where chlorides are present in a sour environment and E3C for stress-corrosion-cracking service in a non-sour environment. Metallic materials suitable for a E3S environment shall be in accordance with ISO 15156 (all parts). Metallic materials suitable for class E3C non-sour service are dependent on specific well conditions; no national standard or International Standard exists for the application of metallic materials for this class of service.

NOTE For the purposes of this provision, NACE MR0175 is equivalent to ISO 15156 (all parts).

B.4 Class E2 — CO_2 service

This class of equipment is intended for use in wells where corrosive agents can be expected to cause CO_2 corrosion. Class E2 equipment shall be manufactured from materials that are resistant to CO_2 corrosion. Metallic materials suitable for Class E2 service are dependent on specific well conditions; no national standard or International Standard exists for the application of metallic materials for this class of service.

This service may be in fluids that have an H_2S partial pressure less than those listed for sulfide stress cracking in ISO 15156 (all parts) but do have CO_2 present.

NOTE For the purposes of this provision, NACE MR0175 is equivalent to ISO 15156 (all parts).

B.5 Class E1 — Unique service (to be defined by user/purchaser)

This class may be used by the user/purchaser to specify unique service requirements that are not otherwise covered in classes E4, E3, or E2 of this part of ISO 17078. The user/purchaser and supplier/manufacturer may define and agree on requirements for environments that contain both H_2S and CO_2 and for other unique environments. As a minimum, the requirements of Class E4 shall be met.

Annex C
(normative)

Design validation grades

C.1 General

C.1.1 General requirements

Flow-control devices of each design, type and size shall be validation tested before the product design may be presented for sale to user/purchaser as meeting the requirements of this part of ISO 17078. This design validation testing shall be performed as specified by the requirements stated in this annex. All validation testing shall conform to the requirements of Clause 7.

Each design validation grade requires a number of individual validation procedure(s), process(s) or test(s). The results of the validation evaluations shall be maintained in a design validation file that shall be legible and retrievable. All products tested shall be fully detailed and the procedures and detailed testing results shall become a component of the permanent record of that product design documentation. The file shall contain test results or calculations that validate the design. The design file shall be reviewed and approved by a qualified person other than the originator. This review shall verify that, as a minimum, all of the requirements of this part of ISO 17078 have been met. The appropriate design validation tests (see 6.5) and the records of these tests (see Clause C.2) shall be documented as required.

The required procedures for each design validation test shall be documented by the supplier/manufacturer. All pressure, temperature and load test results shall be recorded on a continuous, time-based data collection system and shall be maintained in the validation test file for that specific product. Pressure measurements shall be accurate to within 0,25 % of the full scale of the pressure measurement system.

Testing may be combined to provide results that encompass several of the individual requirements. The supplier/manufacturer shall demonstrate and document that the test results meet the requirements as outlined in the design-validation-test annexes.

C.1.2 Products selected for design validation testing

Several of the specified flow-control device design validation tests require more than one flow-control device for evaluation, as detailed in the specific annexes described in Annex A. This is to ensure consistency and repeatability across the product design, type and/or size. The specific products that are tested shall be manufactured within the nominal manufacturing system and processes; it is not permitted to select special specimens for testing. During each series of tests, the individual devices shall not be repaired or serviced in any way. If (a) specific component(s) of a flow-control device fails a specific test, the cause of the failure shall be analysed and documented. The cause of the failure shall be corrected and the test repeated from the beginning.

C.1.3 Design validation grades

This part of ISO 17078 provides multiple grades of design validation evaluations. These grades are designated as V3, V2 and V1. As the numerical rating decreases, the extent and/or depth of the requirements increases. These grades are specified by the user/purchaser when the product is ordered.

C.2 Design validation test requirements

Design validation test requirements for flow-control devices are identified in Table A.2.

Annex D
(normative)

Product functional testing grades

D.1 General

D.1.1 Functional testing

This annex describes the product functional testing requirements for flow-control devices. All functional testing shall conform to the requirements of Clauses 6 and 7.

D.1.2 General requirements

The user/purchaser shall specify the grade of product functional tests to be conducted on the flow-control device(s). The specific requirements for each product functional test grade are defined in this annex. Each product functional test grade requires a number of individual functional test procedure(s), process(s) or test(s) to demonstrate conformance with the requirements in this part of ISO 17078. The procedures and results shall be maintained in manufacturing or quality control files and shall be traceable to the individual product(s).

Product functional tests, pertinent test pressures, temperatures, flow rates, etc. shall be recorded on a continuous, time-based data collection system. Pressure measurements shall be accurate to within 0,25 % of the full scale of the pressure measurement device.

Other types of functional test procedures can produce a combination of results with a single test process. The supplier/manufacturer shall demonstrate and document that the test results meet the requirements as outlined in the product functional test annexes.

D.1.3 Product selection for functional testing

Several flow-control device functional tests require that a sample of one or more flow-control device(s) from a job lot be evaluated to ensure consistency across the job lot. The products shall be randomly selected from the specific job lot. It is not permitted to manufacture or select special specimens for testing. The supplier/manufacturer shall have a written procedure defining the random selection process.

D.1.4 Procedure if a device fails a test

If any device fails a test, it may be repaired and re-tested. Additionally, two more devices shall be randomly selected from the job lot and tested. If the test criteria are not fully met by both units, the entire job lot shall be tested and pass all the test requirements. Only devices that meet the test requirements shall be accepted and provided under this part of ISO 17078.

D.1.5 Product functional test grades

This part of ISO 17078 provides multiple grades of product functional testing evaluations. These grades are designated as F3, F2 and F1. As the numerical rating decreases, the extent and/or depth of the requirements increase. These grades shall be specified by the user/purchaser when the product is ordered.

D.2 Product functional test requirements

Product functional test requirements for flow-control devices are identified in Table A.2.

Annex E
(normative)

Interface testing requirements

E.1 General

The interface (compatibility) testing requirements for each design validation grade are presented in this annex. Interface testing is conducted to demonstrate that a specific flow-control device is compatible with and/or successfully fits within the side-pocket mandrel(s), running/pulling tools, kick-over tools and latches with which it is intended to be used. This statement of compatibility shall be presented in the supplier/manufacturer's operating manual or data sheet for this device. Successful completion of this testing permits a supplier/manufacturer to claim and demonstrate compatibility with equipment manufactured by others.

E.2 Requirements for design validation

The design validation testing requirements for grades V3, V2 and V1 are defined in this clause.

E.2.1 Requirements for design validation, grades V3 and V2

E.2.1.1 Number of test specimens

Design information for the subject flow-control device and measurements for devices where compatibility is claimed shall be used for the tolerance accumulation studies for grades V3 and V2.

One set of devices for which compatibility is claimed shall be used for the physical test. The possible combination of devices is too large to attempt to achieve statistical significance. Successful testing of one set of devices shall demonstrate compatibility.

It is permitted, if necessary, to redress the external packing of the test specimen to complete the requirements of E.2.1.2 step b).

E.2.1.2 Test procedure

The interface (compatibility) test requirements for design validation grades V3 and V2 shall be as outlined below.

a) Conduct the following tolerance accumulation study.

   Use a mandrel pocket and a latch to develop a scaled drawing and perform a tolerance accumulation study comparing the scaled drawing and the tolerances of the flow-control device.

b) Testing for the design validation grades V3 and V2 shall be carried out as follows.

   1) Attach the flow-control device to an associated latch/running tool/kick-over tool.

   2) Insert the flow-control device into the pocket bore of a side-pocket mandrel.

   3) Shear the running tool from the flow-control device. The latch-locking ring shall be fully engaged under/in the mandrel-locking lug/profile.

4) Connect an associated pulling tool/kick-over tool to the latch and/or running head on the flow-control device.

5) Retrieve the flow-control device from the pocket bore of the side-pocket mandrel.

6) Repeat this test with each combination of side-pocket mandrel, running tool, pulling tool, kick-over tool and latch that is claimed to be compatible with the flow-control device.

7) Conduct this test with the smallest side-pocket mandrel of the mandrel type for which compatibility with the flow-control device is claimed.

E.2.1.3 Acceptance criteria

To pass the grades V3 and V2 test tolerance accumulation study, demonstrate, in the worst cases of both the "go" and the "no-go" positions, that the full lengths of both seal stacks are no closer than 0,16 cm (1/16 in) to the edge of the seal bores of the side-pocket mandrel.

To pass the design validation test the following criteria shall be met.

a) All test steps defined above (see E.2.1.2) shall be completed successfully.

b) The flow-control device, external packing and latch shall not be damaged in a way that precludes their intended operation.

c) Insertion and retrieval forces shall not exceed those recommended by the supplier/manufacturer.

E.2.1.4 Documentation

The following additional specific documentation is required. (See 7.2 for design validation documentation requirements.)

a) Identify the supplier/manufacturer, part number and serial number for the side-pocket mandrel pocket used for the scaled drawing or tolerance accumulation study.

b) Identify the supplier/manufacturer, part number and serial number of each test component.

c) Record the jarring forces required for each insertion and retrieval test.

d) Record the visual evidence of the condition of each test specimen after completion of the test.

E.2.2 Requirements for design validation, grade V1

E.2.2.1 Number of test specimens

No new test specimen is required for these tests.

E.2.2.2 Test procedure

The interface (compatibility) test requirements for design validation grade V1 shall be as outlined below:

a) meet all test requirements for design validation grades V3 and V2, as defined in E.2.1.2;

b) conduct a tolerance accumulation study with all required tolerances, including the specific design tolerances of the side-pocket mandrel, the flow-control device and the latch.

E.2.2.3 Acceptance criteria

To pass the grade V1 test, demonstrate, in the worst cases of both the “go” and the “no-go” positions, that the full lengths of both seal stacks are no closer than 0,16 cm (1/16 in) to the edge of the seal bores of the side-pocket mandrel.

E.2.2.4 Documentation

The following specific documentation is required. (See 7.2 for design validation documentation requirements.) Identify and record the name of the supplier/manufacturer, unique part number for the side-pocket mandrel, flow-control device, and latch used for the tolerance accumulation study.

Annex F
(normative)

Insertion testing requirements

F.1 General

The insertion test requirements for the three design validation grades are indicated below. The test shall demonstrate that installation of a flow-control device into a side-pocket mandrel shall not significantly change the flow-control device's set pressure or operating characteristics. The insertion test shall be conducted using the following methods, fixtures, and procedures.

F.2 Requirements for design validation

F.2.1 General

The insertion test requirements for design validation grades V3, V2 and V1 are defined in F.2.2 to F.2.5.

F.2.2 Number of test specimens

This test shall be conducted on a minimum of seven flow-control devices of each type. This is required to ensure that the bellows pressure is maintained and consistent in the design.

F.2.3 Test procedure

In this procedure, only steps e) through i) shall be followed for the following flow-control devices:

— shear orifice and dump kill devices of class IV;

— class VI;

— class VII;

— class VIII;

— class IX.

While the device is in the test fixture, validate that the device performs as required in accordance with its documented design parameters. The insertion test requirements for design validation grades V3, V2 and V1 shall be as follows.

a) Set the flow-control device at a minimum of 75 % of its maximum rated pressure, at standard reference temperature.

b) Allow the flow-control device and test fixture to stabilize to ambient temperature.

c) Record the test rack open pressure, P_{tro}, of the flow-control device and the ambient temperature of the device and its test fixture.

d) Attach the flow-control device to the proper latch.

e) Prepare the test stand as defined by Figure F.1.

f) Attach the flow-control device and latch to the specific running tool, using the appropriate pin.

g) Attach the flow-control device, latch and running tool to the mechanical jars as defined by Figure F.1.

h) Using the full jar stroke and free fall of the weight bar, drive the flow-control device into the pocket with a minimum of five wireline-activated blows. If the latch is not engaged in the “no-go” position, continue jarring until engaged.

i) Jar upwards to release the running tool from the latch, leaving the latch and the flow-control device in the test fixture.

j) Measure and record the P_{tro} and the ambient temperature with the flow-control device in the test fixture pocket.

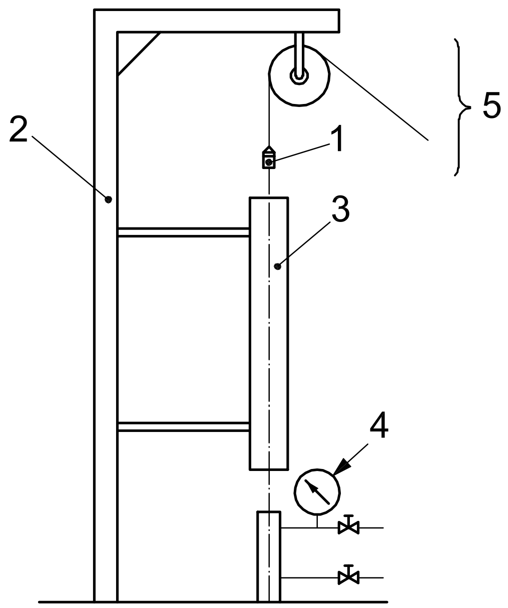
k) Record the difference between the original P_{tro} and the P_{tro} after the insertion test. Insertion testing form 1 (Figure F.2) or insertion testing form 2 (Figure F.3) may be used to record these results.

l) Evaluate the P_{tro} acceptance criteria. If successful, proceed to step o).

m) Measure and record P_{vc} and the ambient temperature with the flow-control device in the test fixture pocket.

n) Evaluate the P_{vc} acceptance criteria.

o) Remove the flow-control device from the tester.



Key

1 rope socket

2 gin pole

3 1,83 m (6 ft) section of 6,03 cm (2 3/8 in) OD tubing for guide for spang jars and weight bar

4 simulated pocket with test connections for checking valve set pressure

5 tool string with

- 1,52 m (5 ft) of 38,1 mm (1 1/2 in) OD stem
- 50,8 cm (20 in) stroke of 38,1 mm (1 1/2 in) spang jar
- appropriate running tool

Figure F.1 — Typical vertical valve insertion test stand

F.2.4 Acceptance criteria

All seven flow-control devices shall satisfy the following criteria.

a) P_{tro} shall not change by more than 1 % of the original P_{tro} when corrected to the ambient temperature. For this test to be accepted, P_{tro} shall meet this criterion, or the P_{vc} criterion in step b) shall be met.

b) P_{vc} shall not change by more than 2,0 % of the design P_{vc} as corrected to the same ambient temperature.

c) If more than one device of the original seven test devices fails the test, an additional seven devices shall be selected and the entire test process shall be performed on the new devices. Device failures shall be documented and corrective actions recorded.

F.2.5 Documentation

The following additional specific documentation is required. (See 7.2 for design validation documentation requirements.) Record the results of the insertion tests on insertion testing form 1 (Figure F.2) or insertion testing form 2 (Figure F.3), as appropriate.

Insertion testing form 1											
	Valve serial number	Initial test data				Final test data (FCD in fixture)				Change in P_{tro} gauge kPa (psig)	Change in FCD temperature °C (°F)
		P_{tro} gauge kPa (psig)	Ambient temperature °C (°F)				Ambient temperature °C (°F)				
			Air	FCD	Fixture	TRO	Air	FCD	Fixture		
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

Figure F.2 — Insertion testing form 1 for P_{tro} test results

Insertion testing form 2											
	Valve serial number	Initial test data				Final test data (FCD in fixture)				Change in P_{vc} gauge kPa (psig)	Change in FCD temperature °C (°F)
		P_{vc} gauge kPa (psig)	Ambient temperature °C (°F)			P_{vc} kPa (psi)	Ambient temperature °C (°F)				
			Air	FCD	Fixture		Air	FCD	Fixture		
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

Figure F.3 — Insertion testing form 2 for P_{vc} test results

Annex G
(normative)

Probe and travel testing and load rate determination

G.1 General

This annex provides requirements for probe and travel testing and load rate determination of flow-control devices.

G.2 Probe or travel test requirements for design validation

G.2.1 General

The probe or travel test requirements for design validation grades V3, V2 and V1 are defined in this annex.

G.2.2 Number of test specimens

This test shall be conducted on a minimum of seven flow-control devices of each type.

G.2.3 Test procedure

The test procedure determines the maximum effective travel distance for each device. See Clause G.8.

G.2.4 Acceptance criteria

All seven flow-control devices shall meet the following criteria. The minimum travel distance of each device shall be large enough to provide a flow area between the stem/seat interface that is greater than the flow area of the port.

G.2.5 Documentation

Documentation of the results of the insertion tests is also required. (See 7.2 for design validation documentation requirements.) Record the maximum effective travel distance of each device using the probe test data form 1 (see Figure G.3), or an equivalent.

G.3 Load rate determination requirements for design validation

G.3.1 General

The load requirements for design validation grades V3, V2 and V1 are defined in G.3.2 to G.3.5.

G.3.2 Number of test specimens

This test shall be conducted on a minimum of seven flow-control devices of each type.

G.3.3 Test procedure

Determine the load rate of each device. The test procedure shall be as defined in Clause G.8. The test data shall be analysed using the procedures in Clause G.9.

G.3.4 Acceptance criteria

All seven flow-control devices shall meet the following criteria. The load rate of each sampled flow-control device shall be within ± 10 % of the average of the seven load rates.

G.3.5 Documentation

Documentation of the results of the insertion tests is also required. (See 7.2 for design validation documentation requirements.) Record the load rate of each device using the probe test data form 1 (see Figure G.3) or an equivalent.

G.4 Probe or travel test requirements for product functional testing

G.4.1 Requirements for product functional testing, grade F3

There are no probe or travel test requirements for product functional testing grade F3.

G.4.2 Requirements for product functional testing, grade F2

G.4.2.1 General

The probe or travel test requirements for product functional testing grade F2 shall be as defined below. For flow-control device group VI, this test is required only for chemical injection devices.

G.4.2.2 Number of test specimens

This test shall be performed on a minimum of 5 % of any job lot or three flow-control devices, whichever is greater. If a job lot consists of three or fewer devices, they shall all be tested

G.4.2.3 Test procedure

The maximum effective travel of the flow-control device shall be tested in accordance with the procedure defined in Clause G.8, with exceptions, if needed. The load rate shall be determined in accordance with the procedure defined in Clause G.9.

G.4.2.4 Acceptance criteria

The maximum effective travel shall be within the ± 10 % tolerance of the maximum effective travel established during the design validation test procedure.

G.4.2.5 Documentation

Documentation of the results of the insertion tests is also required. (See 7.2 for design validation documentation requirements.) Record the maximum effective stem travel.

G.4.3 Requirements for product functional testing, grade F1

The probe or travel test requirements for product functional testing grade F1 shall be the same as for grade F2. This test shall be performed on 100 % of the flow-control devices in any job lot.

G.5 Load rate determination requirements for product functional testing

G.5.1 Requirements for product functional testing, grade F3

There are no load rate test requirements for product functional testing grade F3.

G.5.2 Requirements for product functional testing, grade F2

G.5.2.1 General

The load rate test requirements for product functional testing grade F2 shall be as defined below. For flow-control device type VI, this test is required only for non-spring-loaded chemical injection devices.

G.5.2.2 Number of test specimens

This test shall be performed on a minimum of 5 % of any job lot or three flow-control devices, whichever is greater. If a job lot consists of three or fewer devices, they shall all be tested.

G.5.2.3 Test procedure

The load rate of the flow-control device shall be tested in accordance with the procedure defined in Clause G.8, with exceptions, if needed. The load rate shall be calculated in accordance with the procedure defined in Clause G.9.

G.5.2.4 Acceptance criteria

The load rate shall be within the ± 10 % tolerance of the average load rate established during the design validation test procedure.

G.5.2.5 Documentation

Record the load rate. (See 7.2 for product functional testing documentation requirements.)

G.5.3 Requirements for product functional testing, grade F1

The load rate test requirements for product functional testing grade F1 shall be the same as for grade F2. This test shall be performed on 100 % of the flow-control devices in any job lot.

G.6 Introduction to flow-control device probe and travel testing

The purpose of this test is to determine the relative stiffness of a flow-control device and to determine the maximum effective travel of the stem. When gas pressure is applied to the test system, it shall act on the full area of the flow-control device bellows to lift the stem off the seat. When this pressure is increased, the stem lifts further from the seat. By using the flow-control device probe tester (see Figure G.1), measurement of the stem travel versus pressure can be determined and the results tabulated and plotted. The flow-control device probe test equipment shown in Figure G.1 is an example.

When the pressure is plotted as the ordinate (vertical axis) and the stem travel as the abscissa (horizontal axis), a relatively straight line is generated for the effective stem travel. The slope of this line is an indication of the stiffness of the flow-control device. The numerical value of the slope is called the “bellows assembly load rate”, B_{lr}, and is measured in kilopascals per centimetre (pounds per square inch per inch). In this context, the bellows assembly includes the bellows and the flow-control device mechanism that applies a load to hold the flow-control device stem on the seat. The higher the load rate, the stiffer the flow-control device.

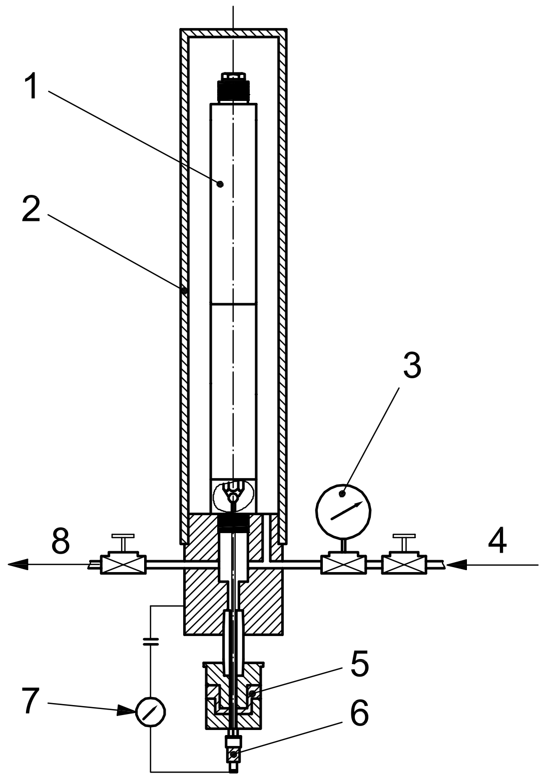
If the above test is conducted with the same flow-control device, except that the opening pressure (dome charge or spring setting) is varied, then the effect of the dome charge pressure or spring setting on the bellows assembly load rate may be compared for the same type of flow-control device when set for different opening pressures.

The maximum effective stem travel and bellows assembly load rate are values used to compare different types of flow-control devices or when evaluating the same flow-control device under different load conditions and when designing the installation.

G.7 Equipment required for probe and travel testing

G.7.1 Test stand

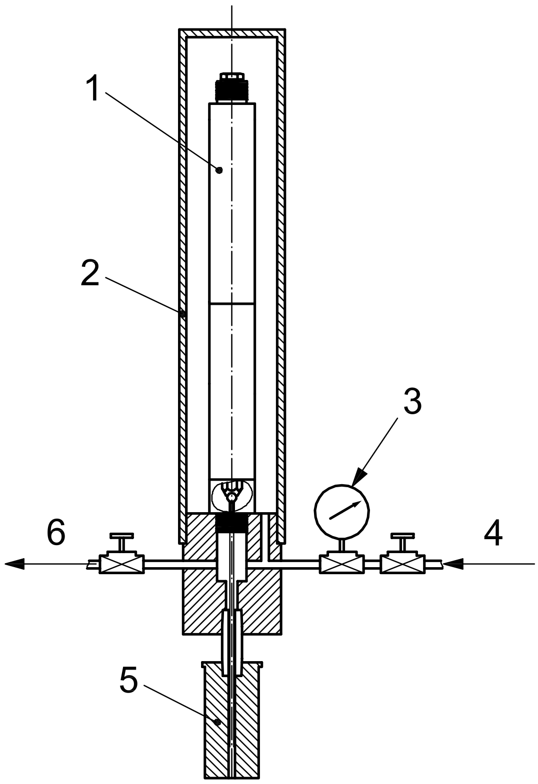
The test stand shall have a means for controlling and measuring the pressure applied to the flow-control device sleeve. The apparatus shown in Figure G.1 is an example of a suitable test stand for the probe test. The apparatus shown in Figure G.2 is an alternative device using a linear variable differential transducer (LVDT) for measuring the position.



Key

1	flow-control device	5	insulated bushing
2	tester	6	micrometer
3	pressure gauge	7	ohmmeter
4	tester gas	8	bleed

Figure G.1 — Typical flow-control device probe tester



Key

1 flow-control device
2 tester
3 pressure gauge
4 tester gas
5 LVDT
6 bleed

Figure G.2 — Typical flow-control device probe tester with LVDT

G.7.2 Flow-control device sleeve

The sleeve shall communicate pressure from a source to the flow-control device without perceptible leaks. The source pressure shall be communicated both above and below the flow-control device seat when the flow-control device is closed.

G.7.3 Flow-control device position measurement

For the manual method, the position measurement device shown in Figure G.1 is a micrometer designed to accurately measure the stem travel. The measurement method shall be capable of determining the stem position within $\pm$ 0,127 mm (0,005 in).

For the automatic method, the position measurement device shown in Figure G.2 is an LVDT designed to accurately measure the stem travel.

G.8 Probe test procedure

G.8.1 Requirements

The supplier/manufacturer shall prepare a written test procedure for conducting the probe test. The items in G.8.2 to G.8.4 shall, as a minimum, be addressed in the procedure.

G.8.2 Prepare the flow-control device for testing

Nitrogen-charged flow-control devices and combination flow-control devices (spring-loaded and nitrogen-charged) shall be probe tested at opening pressures, P_{voT}, of 5 515 gauge kPa (800 psig), 8 274 gauge kPa (1 200 psig) and at the supplier/manufacturer's maximum recommended pressure rating.

Spring-loaded flow-control devices shall be probe tested at the supplier/manufacturer's maximum recommended opening pressure, P_{vo}, or closing pressure, P_{vc}.

G.8.3 Assemble test equipment

Assemble the test equipment in accordance with the written test procedures.

G.8.4 Perform probe test

Steps for conducting the probe test with a test fixture are shown in Figure G.1. If an automated test procedure is used in accordance with Figure G.2, or a similar method, this shall be defined in the written test procedure and each of the items defined below shall be addressed. All applied pressures, temperatures and measurements shall be recorded in the test report.

The test procedure is as follows.

a) Increase the pressure slowly to the test sleeve until the position measurement device indicates the stem is no longer touching the seat. This is the pressure at which the flow-control device just opens when test pressure is applied across the full area of the bellows, P_{vcT}.

b) Adjust the position measurement device to determine the new stem position. Advance the probe with the micrometer barrel until it contacts the tip of the flow-control device stem. This is noted by a significant decrease in the ohmmeter resistance reading.

c) Record the pressure and the stem position using the probe test data form 1 (see Figure G.3) or an equivalent electronic data storage method. (See 7.2 for design validation documentation requirements.)

d) Repeat steps a) and b) using the same pressure increment. These pressure increments shall yield at least five recordings within the range of the maximum effective stem travel.

   If the test pressure drops to a value less than the target pressure, do not increase the pressure; continue with the test using the pressure recorded.

e) Decrease the pressure to the test sleeve in increments such as 69 kPa (10 psi), 103 kPa (15 psi), 138 kPa (20 psi) or 172 kPa (25 psi).

   Before decreasing the pressure, retract the probe rod by reversing the measurement tool to prevent stem tip contact during pressure decrease. If the test pressure drops to a value less than the target pressure, do not increase the pressure; continue with the test using the pressure recorded.

f) Adjust the stem position measurement device to determine the new stem position.

   Advance the probe with the micrometer barrel until it contacts the tip of the flow-control device stem. This can be noted by a significant decrease in the ohmmeter resistance reading.

g) Record the pressure and the stem position using the probe test data form 1 (see Figure G.3).

   Repeat e) through g) using the same pressure increments until the flow-control device stem is back on its seat [initial micrometer reading ± 0,127 mm (0,005 in)]. At least five stem positions shall be recorded within the range of the maximum effective stem travel.

If the test pressure drops to a value less than the target pressure, do not increase the pressure; continue with the test using the pressure recorded.

Probe test data form 1		
1	Attach assembly drawing of probe test apparatus	
2	Type of pressure measurement device	
	— Accuracy	
3	ISO designation of flow-control device	
	Supplier/manufacturer’s part number of flow-control device	
	Attach a dated assembly drawing of flow-control device	
4	Test data: flow-control device set pressure, gauge kPa (psig)	
	— P_{vo} or P_{vc}	
5	Attach graph showing test pressures, stem positions, best-fit straight line and maximum effective stem travel	
6	Bellows assembly load rate, B_{lr}, kPa/cm (psi/in)	
7	Date test was performed	
8	Person who performed test	
Test No.	**Test pressure** gauge kPa (psig)	**Actual stem measurement**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Figure G.3 — Probe test data form 1

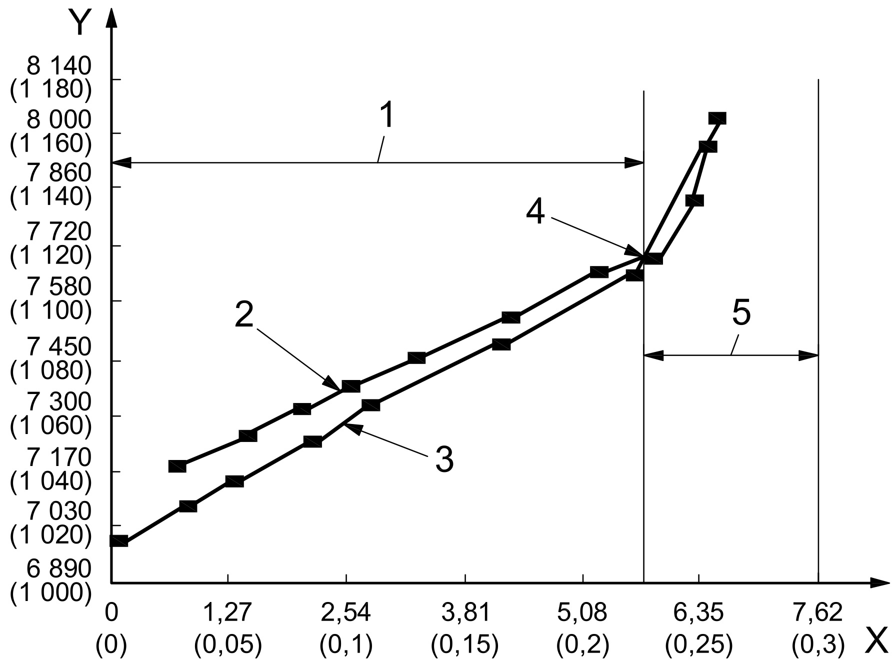
G.9 Determine flow-control device load rate

G.9.1 Plot the data

Plot the data on linear coordinate paper with the pressure readings on the vertical axis and the stem position readings on the horizontal axis as shown in Figure G.4.

Note, on Figure G.4, that there are two distinct regions of the plot where the slopes are different. The region identified as slope A is the effective usable travel range of the flow-control device. The region identified as slope B is the travel range where the bellows have met a substantial resistance to travel and represents travel that is not normally usable. This additional resistance to travel can be the result of many different factors, but is usually the result of bellows stacking or reaching a bellows stop.

The region of slope A shall extend from zero stem travel to the point where the slope of the load rate data turns sharply upward. This point shall be visually determined. Draw the best-fit straight line to the data of the region corresponding to slope A. See Figure G.5 for an example.



■ data points

Key

X stem travel, millimetres (inches)

Y test pressure, gauge kilopascals (pounds per square inch gauge)

1 region of slope A

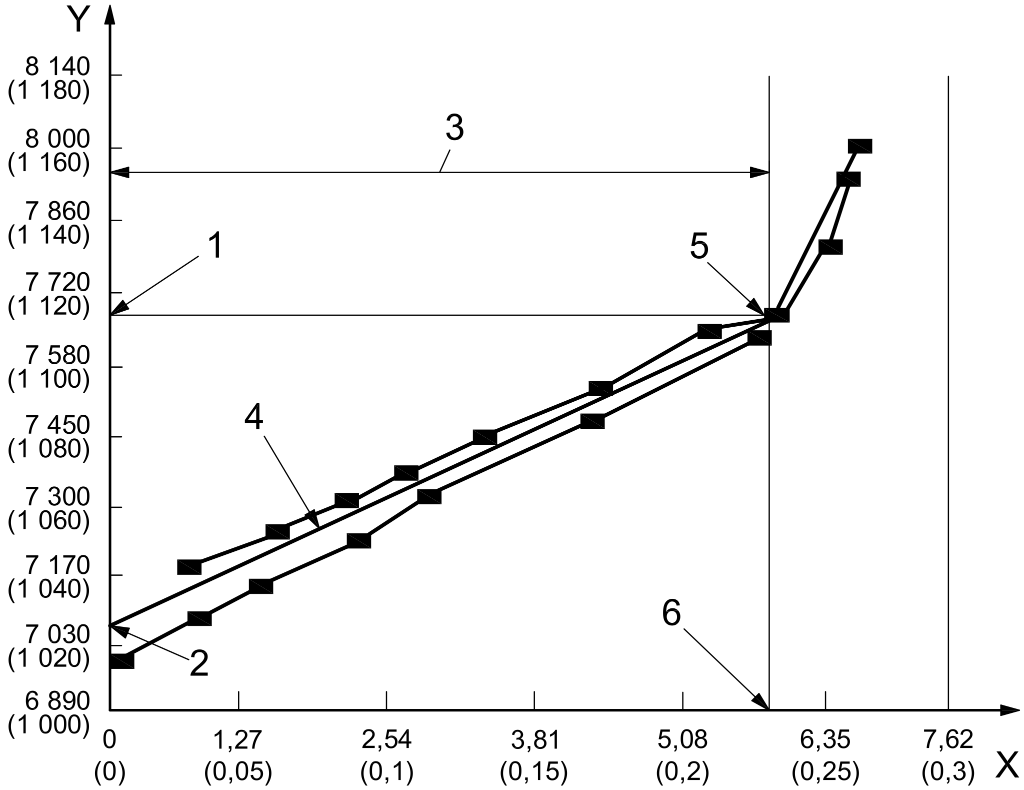
2 increasing test pressure

3 decreasing test pressure

4 point at which the slope changes

5 region of slope B

Figure G.4 — Example plot of stem travel data



■ data points

Key

X stem travel, millimetres (inches)

Y test pressure, gauge kilopascals (pounds per square inch gauge)

1 point where $y = P_1$

2 point where $y = P_2$

3 region of slope A

4 best-fit straight line of data in region of slope A

5 visually determined point at which slope changes

6 maximum effective stem travel, d_{LVT}

NOTE Load rate, B_{lr}, is equal to $(P_1 - P_2)/d_{st}$.

Figure G.5 — Example chart to determine bellows load rate

G.9.2 Calculate the slope

NOTE See Figure G.5.

Calculate the slope, m_{bf}, of this best-fit straight line as given in Equation (G.1):

$$m_{bf} = \frac{(P_1 - P_2)}{dx} \tag{G.1}$$

where

P_1 is the upstream gauge pressure of test section, expressed in gauge kilopascals (pounds per square inch);

P_2 is the downstream gauge pressure of test section, expressed in gauge kilopascals (pounds per square inch).

The slope of this line is the bellows assembly load rate, B_{lr}, of the flow-control device.

The bellows assembly load rate, B_{lr}, documentation shall include a graph showing all the data points, the best-fit straight line and the B_{lr} calculation.

G.10 Determine maximum effective stem travel

The maximum effective stem travel is the greatest travel obtainable within the region of slope A as shown in Figure G.5.

NOTE See Clause G.9 for a detailed explanation of the load-rate and maximum effective stem travel calculation.

G.11 Probe test documentation

The following minimum data shall be documented. The probe test data form 1 (see Figure G.3) is a recommended method for recording these data.

a) assembly drawing of the probe test equipment;

b) type and accuracy of the pressure gauge or transducer;

c) ISO type of tested flow-control device, supplier/manufacturer's flow-control device designation and part number and dated assembly drawing of flow-control device;

d) test data including

    1) flow-control device set pressure,

    2) test pressures,

    3) stem positions,

e) graph showing

    1) tested pressures and stem positions,

    2) best-fit straight line,

f) bellows assembly load rate, B_{lr};

g) maximum effective stem travel;

h) date test performed;

i) person in charge of the test.

Annex H
(normative)

Dynamic flow testing and flow coefficient calculation

H.1 General

This annex provides requirements for flow coefficient, C_v, testing and dynamic flow testing of flow-control devices.

H.2 Requirements for design validation

H.2.1 Requirements for design validation, grade V3

H.2.1.1 General

Requirements for design validation grade V3 are given in Clause H.2. For grade V3, only surface-controlled flow-control devices, type VII, shall be tested.

H.2.1.2 Number of test specimens

This test shall be conducted on a minimum of one flow-control device. The purpose of this test is to validate the flow coefficient, C_v, of the device.

H.2.1.3 Test procedure

Each flow-control device shall be tested to determine the flow coefficient, C_v, of the device using the test procedures defined in Clause H.5.

H.2.1.4 Acceptance criteria

The flow coefficient shall meet the supplier/manufacturer's written engineering specifications.

H.2.1.5 Documentation

The flow coefficient, C_v, shall be reported as a function of the valve stem travel distance from the fully closed position. (See 7.2 for design validation documentation requirements.)

H.2.2 Requirements for design validation, grade V2

H.2.2.1 Number of test specimens

The flow test shall be conducted on a minimum of one flow-control device of each type that is tested. The purpose of this test is to validate the flow coefficient, C_v, of the device at various port sizes.

H.2.2.2 Test procedure

Each flow-control device shall be tested to determine its flow coefficient, C_v, using the test procedures defined in Clause H.5.

The common port diameters [commonly expressed as nominal sizes in inches as 3,17 cm (1/8 in); 4,76 cm (3/16 in); 6,35 cm (1/4 in); 7,94 cm (5/16 in); 9,53 cm (3/8 in); 11,11 cm (7/16 in) and 12,70 cm (1/2 in)] shall be tested. As a minimum, the minimum and maximum port sizes shall be tested. If the difference between the minimum and maximum port size is greater than 3,17 cm (1/8 in), an additional test shall be conducted for each 3,17 cm (1/8 in) of incremental port size. A procedure specified by the supplier/manufacturer shall be used for interpolation of C_{v}s for the intermediate port sizes.

Flow-control devices designed to accept the installation of chokes (i.e. flow-control device types I or II), shall have additional flow, C_{v}, tests and flow dynamic tests conducted, for each port size that is tested, using the minimum and maximum choke sizes that can be installed.

H.2.2.3 Acceptance criteria

The test results from the flow coefficient, C_{v}, test shall meet the supplier/manufacturer's written specifications.

H.2.2.4 Documentation

Record the C_{v} for each flow-control device and/or flow-control device/choke combination that is tested. (See 7.2 for design validation documentation requirements.)

H.2.3 Requirements for design validation, grade V1

H.2.3.1 General requirements

Requirements for design validation grade V1 are specified in H.2.3. Record the flow coefficient, C_{v}, that is calculated from test data. (See 7.2 for product functional testing documentation requirements.)

H.2.3.2 Number of test specimens

The flow test shall be conducted on a minimum of one flow-control device of each type that is tested. The purpose of this test is to conduct a dynamic flow test of the device at various port sizes.

H.2.3.3 Test procedure

Each flow-control device

a) shall meet all flow, C_{v}, test requirements for design validation grade V2,

b) shall be subject to a dynamic flow test using the test procedures defined in Clause H.6.

H.2.3.4 Acceptance criteria

The test results from the dynamic test shall meet the supplier/manufacturer's written specifications.

H.3 Requirements for product functional testing

H.3.1 General

Requirements for the three product functional testing grades are specified in H.3.2 and H.3.3. A flow coefficient, C_{v}, test is required for flow-control device type VII. Dynamic tests shall be required, depending on the functional testing grade, for other flow-control device types. Performance of the dynamic test is described in Clause H.11 and Annex P.

H.3.2 Requirements for product functional testing, grade F3

There are no flow test requirements for product functional testing grade F3.

H.3.3 Requirements for product functional testing, grade F2

H.3.3.1 Flow test

The flow test for product functional testing grade F2 is only required on type VII flow-control devices.

H.3.3.2 Number of test specimens

This test shall be conducted on 100 % of any job lot.

H.3.3.3 Test procedure

The flow-control device shall be tested to determine the flow coefficient, C_v, using the test procedures defined in Clause H.5.

H.3.3.4 Acceptance criteria

The flow coefficient, C_v, of each flow-control device shall be within ± 10 % of the value established during design validation testing.

H.3.4 Requirements for product functional testing, grade F1

H.3.4.1 Flow test

The flow test for product functional testing grade F1 shall be as defined in H.3.4.2 to H.3.4.4.

H.3.4.2 Number of test specimens

This test shall be performed on 100 % of any job lot.

H.3.4.3 Test procedure

The flow-control device shall be dynamically flow-tested in accordance with Clause H.6 to determine the flow-control device's flow rate.

H.3.4.4 Acceptance criteria

The flow-control device's flow rate shall be within ± 15 % of the test result determined during the design validation test for the same test conditions.

H.4 Discussion of flow coefficient testing

H.4.1 General

This procedure determines a flow-control device's flow capacity as a function of its stem travel. The data from this test allow the accurate calculation of the gas and/or liquid flow rate at any pressure conditions. The flow-control device's flow rate as a function of pressure is dependent on the geometry of the flow-control device, and, therefore, it is appropriate only for the particular configuration of the test specimen.

The flow coefficient, C_v, test method requires control of both upstream and downstream pressure. Tests have shown that slow and steady changes in pressure (ramp method) require less gas and yield more accurate results than when the pressures are changed abruptly (traditional method). Therefore, only the ramp method is presented in this part of ISO 17078. However, other methods, including the traditional method, may be used, if the supplier/manufacturer can demonstrate that their accuracy is equal to, or better than, that of the ramp method.

The ramp method requires that the system time constant be determined and that the data be collected by transducers and data acquisition equipment. Determination of the system time constant is defined in Clause H.11. When these tests are conducted as specified in this part of ISO 17078, the maximum error associated with calculation of the flow coefficients, C_v, is less than 10 % and the maximum error associated with calculation of the critical pressure ratio factor is less than 12 %.

H.4.2 Test specimen for conducting flow tests

The test specimen shall include the following components.

a) A flow-control device shall be modified for this testing to include a feature that allows positive mechanical adjustment of the flow-control device stem with respect to its seat. This feature shall not affect the normal flow path through the flow-control device. If the flow-control device normally includes a reverse flow-control device, the supplier/manufacturer's recommended reverse flow-control device shall be part of the flow-control device assembly. Refer to Figure H.1.

b) A compatible latch shall be securely threaded to the flow-control device. The latch may be modified to allow easy access to the stem adjustment feature as long as the modification does not impair the ability of the latch to be threaded securely to the flow-control device or to anchor securely the latch/flow-control device assembly to the compatible receptacle.

c) The flow-control device and latch shall be inserted into a compatible receptacle.

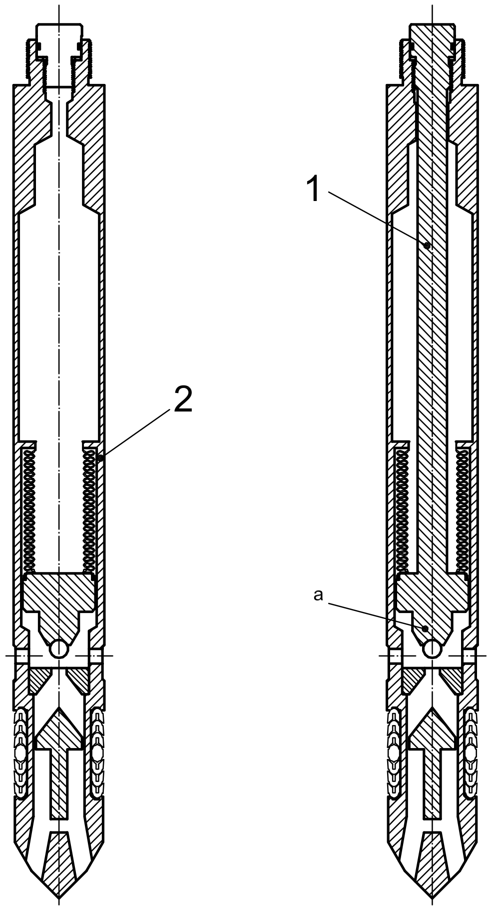
H.4.3 Stem position measurement

The stem adjustment feature shall permit measurement of the position of the stem with respect to the seat within ± 0,076 mm (± 0,003 in). The position of the stem with respect to the seat shall be defined as fully closed when the flow rate through the flow-control device is less than 5,66 SCMD (200 SCFD) at test pressure conditions. When the device is fully closed, the measurement of the stem position with respect to the seat shall be 0 cm (0 in).

H.4.4 Required stem test positions

At least five stem positions shall be tested for each specific flow-control device design and stem/seat configuration. At least one test shall be conducted with the stem no more than 10 % of its maximum effective travel from the seat and at least one test shall be conducted with the stem at 100 % of maximum effective travel. Refer to Clause G.10 for a definition of maximum effective travel.

A minimum of three more stem position tests shall be conducted at stem positions of approximately 30 %, 50 %, and 70 % of their maximum effective travel. Additional or different intermediate stem positions may be chosen if the supplier/manufacturer can demonstrate that more accurate flow capacity data can be obtained in the range of travel where flow rate is changing significantly.



Key

1 valve modified with adjustable stem

2 standard valve with a reverse flow valve

[a] Internal flow passage shall not be modified from standard configuration.

Figure H.1 — Standard and modified test configuration

H.5 Flow coefficient tests

H.5.1 General

The following procedures shall be used to determine flow coefficients, C_v, for flow-control devices.

H.5.2 Flow testing

Refer to Clause H.10 for flow rate calculations.

H.5.3 Test pressure range

For each stem position, a minimum of five well spaced pressure ratios, R_p, shall be tested. The pressure ratio, R_p, is equal to the measured differential pressure across the test section divided by the absolute upstream pressure $\mathrm{d}P/(P_1+100)$ kPa $[\mathrm{d}P/(P_1+14{,}7)$ psi$]$. Analysis of the test data can require additional tests. Refer to Clause H.4 for clarification of the potential need for additional tests.

H.5.4 Measurement

For each pressure ratio, R_p, measure the flow rate; the upstream test section gas temperature, T_1; the upstream pressure, P_1; the downstream pressure, P_2; and the stem position. Stem position measurements shall be made as defined in Clause H.4.

H.5.5 Test procedure

The following test method shall be used to determine flow coefficients for flow-control devices.

a) Both upstream and downstream test section pressures, P_1 and P_2, shall be equalized to a pressure greater than 689 kPa (100 psi) before each test. Both upstream and downstream pressure measurement devices shall read within 2 % of each other, and the flow measurement device shall show a flow rate of less than 5,66 SCMD (200 SCFD).

b) Initiate flow through the flow-control device so that the pressure ratio, R_p, is less than 0,05. Record the test data.

c) The pressure ratio, R_p, shall be increased until critical flow is observed. Critical flow occurs when the flow rate no longer increases for a constant upstream pressure and a decreasing downstream pressure. This is accomplished by holding the upstream pressure constant while slowly and continuously reducing the downstream pressure. (See Clause H.11 for information concerning the rate of pressure change.) Record the data in accordance with Clause H.12.

d) At least three pressure ratios, R_p, in the range of 10 % to 90 % of the pressure ratio, R_p, observed for critical flow shall be recorded in accordance with Clause H.12.

H.6 Dynamic performance testing

H.6.1 General

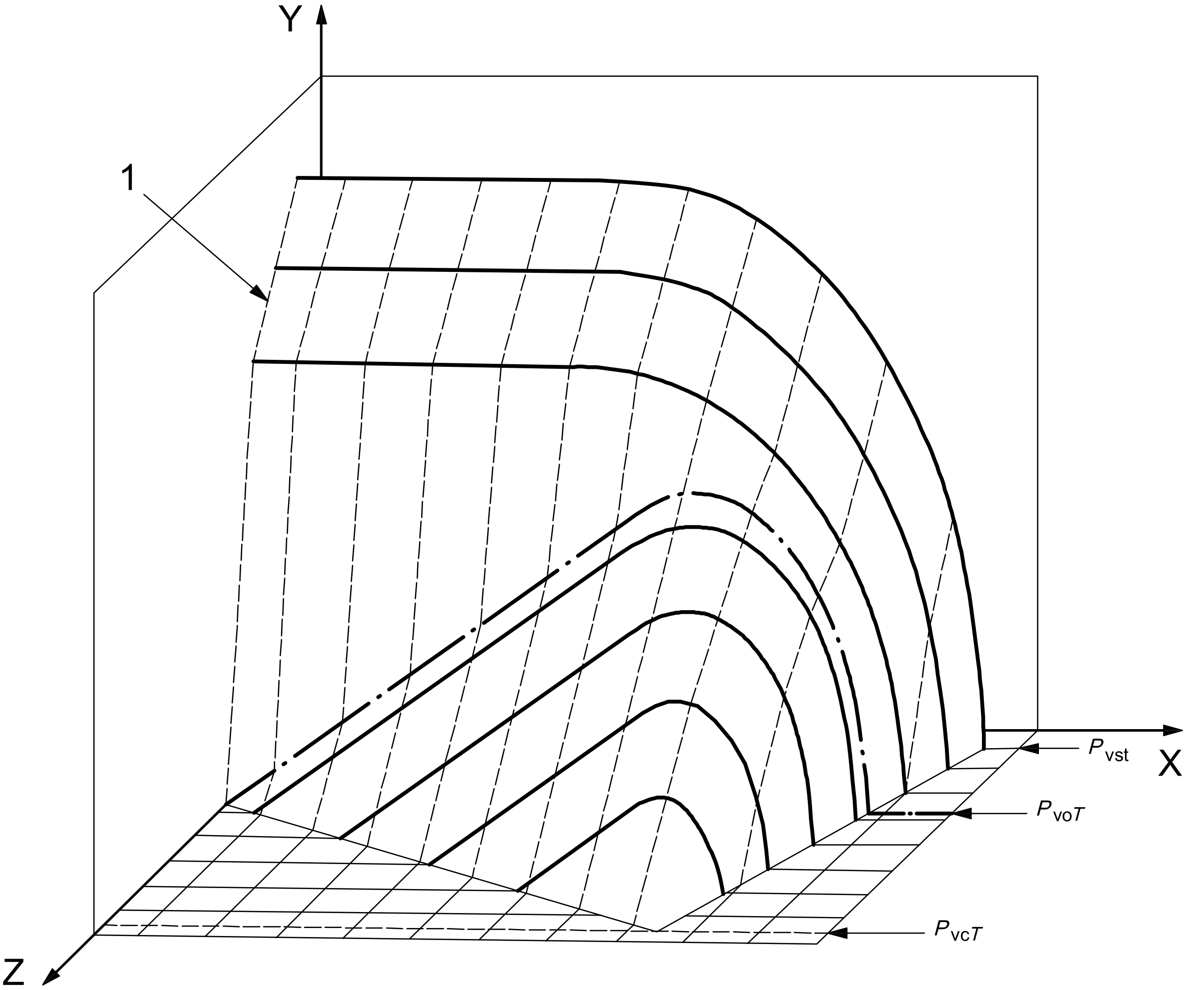
There are two methods for dynamic performance testing of flow-control devices. They are the constant-production-pressure and the constant-injection-pressure methods. The preferred technique should be selected based on the type of device to be tested. Application of the method is not limited to any specific valve type.

In the first method, the production pressure is held constant at several values. At each value, the injection pressure is adjusted to determine how the flow-control device performs with changes in injection pressures. This is referred to as the constant production pressure test (CPPT).

In the second method, the injection pressure is held constant at several values. At each value, the production pressure is adjusted to determine how the flow-control device performs with the changes in production pressures. This is referred to as the constant injection pressure test (CIPT).

See Figure O.1 for a diagram of basic flow test systems. These tests should be performed in a facility that is the same or similar to the one described in Annex O. The flow-control device to be tested may be nitrogen-charged, spring-loaded or a combination spring-loaded/nitrogen-charged device. It may be injection-pressure-operated (IPO) or production-pressure-operated (PPO). It shall comply with the test specimen in O.2.3.

Figure H.2 shows typical flow-control-device dynamic performance characteristics on a three-dimensional graph of upstream pressure, P_1, downstream pressure, P_2, and flow rate, q_{gi}. Data from either a constant-injection-pressure test or a constant-production-pressure test may be plotted on the same three dimensional graph. Figure H.2 illustrates how the flow through a flow-control device moves from the throttling flow regime, through a regime of transition, to the orifice flow regime as P_1 is increased. When q_{gi} and P_2 are considered to be a vertical plane, that vertical plane has a specific value of P_1. Likewise, when q_{gi} and P_1 are considered to be a vertical plane, that vertical plane has a specific value of P_2. This value may be visualized as one of the dashed isobar lines.



Key

X P_2, expressed in gauge kilopascals (pounds per square inch gauge)

Y q_{gi}, expressed in MSCMD (MSCFD)

Z P_1, expressed in gauge kilopascals (pounds per square inch gauge)

1 isobars

Figure H.2 — Three-axis plot of upstream pressure, downstream pressure and flow rate

In summary, Figure H.2 shows the results of a constant production pressure test using the dashed isobar lines as constant production pressure, P_2, and changing the injection pressures, P_1. It also shows the results of a constant injection pressure test using the solid line curves as isobars for constant injection pressure, P_1, as the production pressures, P_2, are changed.

As with flow coefficient, C_v, testing, the ramp method is described in this part of ISO 17078. The supplier/manufacturer may use other methods if the results can be shown to be equal or better than those from the ramp method. The ramp method requires that the system time constant be determined (see Clause H.11) and that the data be collected by transducers and electronic data acquisition equipment.

H.6.2 Preparation for constant production pressure test

The following steps shall be accomplished prior to conducting the test described in Clause H.7.

a) Establish the maximum flow-control device stem travel (VST) of the flow-control device. This is used to calculate the increase in injection pressure for the constant production pressure tests. Maximum VST is the lesser of either the maximum effective stem travel from the probe (LST) or the geometric stem travel for fully opened condition (GST). LST is determined from the probe test of the flow-control device (see Clause G.4). GST is based on the physical geometry of the flow-control device stem tip (usually a carbide ball) and its seat as described in step d). GST is the VST required to attain an equivalent area (surface area of the fustum of a right circular cone generated by the stem tip moving away from its seat) that is equal to the valve port area.

b) Calculate the required maximum increase, $\mathrm{d}P_{max}$, in the upstream test section pressure, P_1, above the initial valve opening pressure, P_o, to achieve maximum VST for a constant downstream test section pressure, P_2. This maximum increase in the injection pressure, $\mathrm{d}P_{max}$, is constant for a given flow-control device and for all values of P_2. If the maximum VST is equal to, or greater than, the LST, the $\mathrm{d}P_{max}$ increase above the valve closing pressure, P_{vc}, to attain the LST from the probe test is calculated according to Equation (H.1):

$$\mathrm{d}P_{max} = 1{,}2\left(\mathrm{d}P_{pr}\right) \Big/ \left[1-\left(A_s / A_b\right)\right] \tag{H.1}$$

where

$\mathrm{d}P_{pr}$ is the change in probe pressure;

A_b is the effective bellows area, expressed in square centimetres (square inches);

A_s is the area based on the diameter where the stem contacts the seat, expressed in square centimetres (square inches).

If the VST is equal to, or greater, than the GST, the maximum $\mathrm{d}P$ increase is calculated from the load rate, B_{lr}, the probe test and the GST as given in Equation (H.2):

$$\mathrm{d}P_{max} = 1{,}2 d_{VST} B_{lr} \tag{H.2}$$

where d_{VST} is the distance of the flow-control device stem travel.

c) Calculate the incremental pressure, $\mathrm{d}P$, values above the upstream initial valve opening pressure, P_o, for the constant downstream test section pressure, P_2, tests. A minimum of four equally spaced test $\mathrm{d}P$ values over the full range, including the maximum, $\mathrm{d}P_{max}$, calculated in step b), is required. For example, use 25 %, 50 %, and 75 % of the maximum, $\mathrm{d}P_{max}$, and the minimum, $\mathrm{d}P_{min}$.

d) Install the flow-control device in the test fixture and determine the opening pressure, P_{voT}, at the temperature of the test fixture, with a downstream test section pressure, P_2, equal to 0 gauge kPa (0 psig). Record the P_{voT}.

e) It can be difficult to measure the flow-control device closing pressure, P_{vcT}, accurately in the test fixture. Therefore, calculate the P_{voT} for selecting the values of downstream test section pressures, P_2, in step f) using Equation (H.3):

$$P_{vcT} = P_{voT}\left[1-\left(A_s / A_b\right)\right] \tag{H.3}$$

f) Calculate at least four equally spaced values for downstream test section pressures, P_1, based on the flow-control device closing pressure, P_{vcT}. Suggested values of P_1 for the full range of operation are 20 %, 40 %, 60 % and 80 % of P_{vcT}.

H.7 Constant production pressure test procedure

The test procedure is as follows.

a) Adjust the upstream and downstream control valves for a near zero gas flow rate through the flow-control device for the calculated downstream test section pressure, P_1. Record the upstream initial opening pressure, P_o, and its corresponding P_2.

b) Calculate the upstream test section pressure, P_1, based on the upstream initial valve opening pressure, P_o, for the set constant downstream test section pressure, P_2, from step a) and the value of the pressure difference, dP, from step c) as given in Equation (H.4):

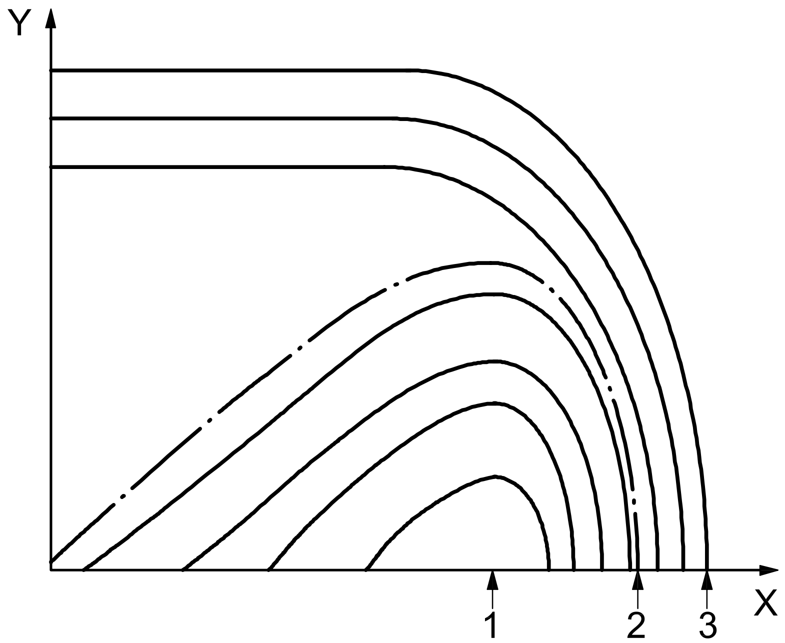
$$P_1 = P_o + \mathrm{d}P \tag{H.4}$$

c) Increase the upstream test section pressure, P_1, from P_o to $P_1 = P_o + \mathrm{d}P_{max}$ in a slow and continuous ramp. The length of time for the test shall be greater than five time constants and the slope of the increase in P_1 should be as constant as possible. See Clause H.11 for discussion of this method.

d) Check the flow-control device's opening pressure with zero downstream pressure, P_{voT}, following the final highest upstream pressure test based on the maximum, dP_{max}, for the constant test downstream pressure, P_2, expressed in centimetres (inches). If P_{voT} varies by more than 0,5 % percent from the P_{voT} tested in step d) of H.6.2 repeat the test beginning at step c) for the last P_2.

e) Select the next downstream pressure, P_2, and repeat step a) through step d) until the final constant P_2 test series has been concluded.

f) Plot the upstream initial flow-control device opening pressure, P_o, from step a), and calculate the gas flow rate, q_{gi}, for each test and graph the data with the upstream pressure, P_1, as a function of q_{gi} for each constant downstream pressure, P_2. The curves appear as shown in Figure H.3.



Key

X P_1,expressed in gauge kilopascals (pounds per square inch gauge)

Y q_{gi}, expressed in MSCMD (MSCFD)

1 P_{vcT}

2 P_{voT}

3 P_{vst}

Figure H.3 — Example flow rate vs pressure through a flow-control device

H.8 Constant injection pressure test procedure

The test procedure is as follows.

a) Place the test specimen in the test section. Measure the flow-control device opening pressure, P_{voT}, at temperature. Record P_{voT} and the temperature. The flow-control device's closing pressure, P_{vcT}, can be difficult to measure accurately in the test fixture. Therefore, calculate P_{vcT} as given in Equation (H.5) and record the calculated P_{vcT}.

$$P_{vcT} = P_{voT}\left[1-\left(A_s/A_b\right)\right] \quad \text{(H.5)}$$

b) Charge the flow test system with the flow-control device opening pressure, P_{voT} at temperature. Close the equalizing control flow-control valve (ECV) after charging the system. The flow-control device is open with P_{voT} upstream and downstream.

1) Adjust the upstream pressure, P_1, to equal $\left[P_{voT} - 0{,}1\left(P_{voT} - P_{vcT}\right)\right]$ while reducing downstream pressure, P_2, from P_{voT} to 0,9 P_1. Stabilize P_2 at 0,9 P_1. Record the proper values as indicated on the dynamic test data form 1 (see Figure H.4).

2) Decrease the downstream test section pressure, P_2, from P_1 to 0 in a slow and continuous ramp. The length of time for the test shall be greater than five time constants and the slope of the decrease in P_2 should be as constant as possible. Record at least six flow rates during the ramp test.

3) The upstream pressure, P_1, shall be maintained within 34,5 kPa (5 psi) of the target value while testing at the downstream pressures, P_2, specified in item H.8 b) 2).

4) Check P_{voT} after the test. It shall be within 0,5 % of initial P_{voT}. Record this P_{voT} and the temperature at the end of the test.

5) Recharge the flow test system to an upstream pressure, P_1, equal to $\left[P_{voT} - 0{,}25\left(P_{voT} - P_{vcT}\right)\right]$. Reduce the downstream pressure, P_2, to 0,9 P_1 and stabilize. Record the proper values as indicated on the dynamic test data form 1 (see Figure H.4). Repeat steps H.8 b) 2) through H.8 b) 4).

6) Recharge the flow test system to an upstream pressure, P_1, equal to $\left[P_{voT} - 0{,}5\left(P_{voT} - P_{vcT}\right)\right]$. Reduce downstream pressure, P_2, to 0,9 P_1 and stabilize. Record the proper values as indicated on the dynamic test data form 1. Repeat steps H.8 b) 2) through H.8 b) 4).

7) Recharge the flow test system to an upstream pressure, P_2, equal to $\left[P_{voT} - 0{,}65\left(P_{voT} - P_{vcT}\right)\right]$. Reduce the downstream pressure, P_2, to 0,9 P_1 and stabilize. Record the proper values as indicated on the dynamic test data form 1 (see Figure H.4). Repeat steps H.8 b) 2) through H.8 b) 4).

c) Test the flow-control device at upstream pressures, P_1, greater than the opening pressure, P_{voT}, (the orifice flow regime). Calculate the maximum dP_{max} above P_{voT} using H.10.2.

1) Recharge the flow test system to an upstream pressure, P_1, equal to $P_{voT} + \mathrm{d}P_{max}$. Reduce the downstream pressure, P_2, to 0,9 P_1 and stabilize. Record the proper values as indicated on the dynamic test data form 1 (see Figure H.4). Repeat steps H.8 b) 2) through H.8 b) 4). Obtain at least two P_2s that are less than half the upstream pressure.

2) Recharge the flow test system to an upstream pressure, P_1, equal to $P_{voT} + 0{,}5\ \mathrm{d}P_{max}$. Reduce the downstream pressure, P_2, to 0,9 P_1 and stabilize. Record the proper values as indicated on the dynamic test data form 1 (see Figure H.4). Repeat steps H.8 b) 2) through H.8 b) 4). Obtain at least two P_2s that are less than half the upstream pressure.

3) If the flow-control device supplier/manufacturer intends for the device to be used in a well only in the throttling flow regime, only a small fraction of the maximum, dP_{max}, might be used in step H.8 c) 1).

d) Plot the data. The plot has the form shown in Figure H.7. Include the valve closing pressure, P_{vcT}, as an integral part of the plotted data.

e) Data accumulation: if data is accumulated manually, use the dynamic test data form 1 (see Figure H.4) to record the data.

Dynamic test data form 1		
Information required		
1	ISO designation of flow-control device	
	Supplier/manufacturer's name	
	Supplier/manufacturer's part number of flow-control device	
	Flow-control device description	
	Intended operating flow regime: fully open, throttling, or combination	
2	Flow-control device information	
	Set pressure, P_{vo}, expressed in gauge kilopascals at 15,6 °C (pounds per square inch gauge at 60 °F)	
	Bellows area, expressed in square centimetres (square inches)	
	Stem-seat area, expressed in square centimetres (square inches)	
	Port bore diameter, expressed in centimetres (inches)	
	Probe test data	
	Maximum effective stem travel, expressed in centimetres (inches)	
	Differential pressure for maximum stem travel, expressed in kilopascals (pounds per square inch)	
	Average bellows assembly load rate, expressed in kilopascals per centimetre (pounds per square inch per inch)	
	Name of technician performing test	
	Performance test date	
	Meter tube ID, expressed in centimetres (inches)	
	Gas gravity	
	Time test began	
	Beginning P_{voT}, expressed in gauge kilopascals (pounds per square inch gauge)	
	Beginning temperature, expressed in degrees Celsius (degrees Fahrenheit)	
	Time test ended	
	Ending P_{voT}, expressed in gauge kilopascals (pounds per square inch gauge)	
	Ending temperature, expressed in degrees Celsius (degrees Fahrenheit)	

Data

Test no.	Gas orifice meter tube data					Flow-control device fixture data			
	Orifice bore ID	**Press**	**Diff. press.**	**Flowing temp.**	**Computer gas rate**	**Upstream press.**	**Down-stream press.**	**Inlet temp.**	**dP across FCD**
	cm (in)	gauge kPa (psig)	cm (in H_2O)	°C (°F)	m^3/day (MSCFD)	gauge kPa (psig)	gauge kPa (psig)	°C (F)	kPa (psi)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									

Figure H.4 — Dynamic test data form 1

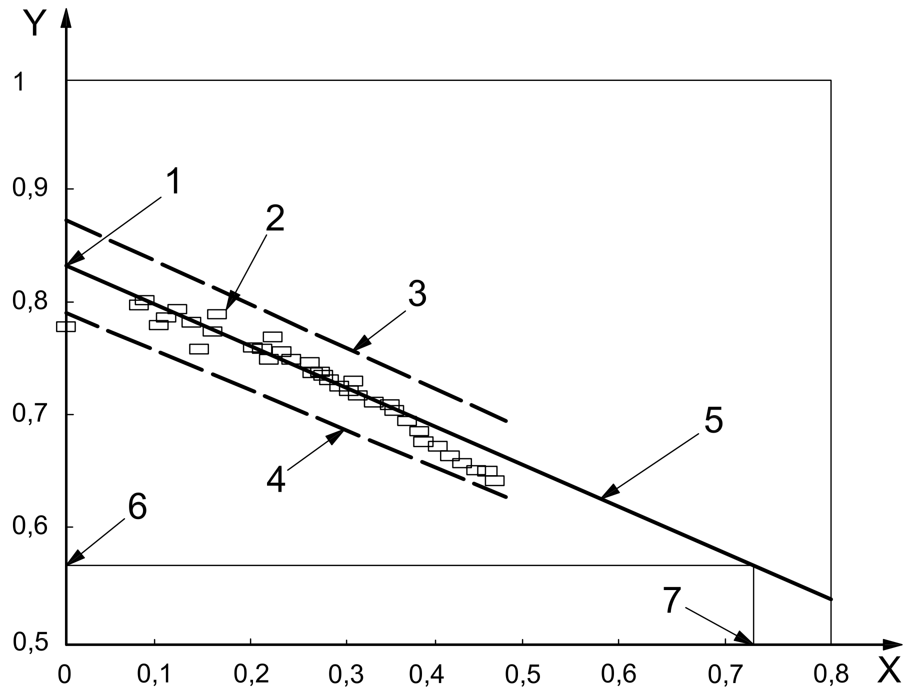
H.9 Data evaluation of flow coefficient data

H.9.1 Introduction

Clause H.9 describes the procedure for evaluating the test data collected as described in Clause H.6. This procedure determines the flow coefficient, C_v, and the pressure drop ratio factor, $R_{p,crt}$, for a given value at a given stem travel, d_{st}. Refer to Figure H.5, which is constructed as follows.

a) After the data are collected, the best-fit straight line is fitted.

b) Two additional lines are plotted such that one has ($F_Y \times C_v$) values 5 % greater and the other ($F_Y \times C_v$) values 5 % less than the best-fit straight line. All the data points shall fit between these upper and lower limit lines.



▢ data points

Key

X pressure ratio, $R_{p,crt}$

Y $F_Y \times C_v$

1 point A for the flow coefficient, C_v

2 upper 5 % limit line: $y = F_Y \times C_v \times 1{,}05$

3 lower 5 % limit line: $y = F_Y \times C_v \times 0{,}95$

4 best-fit straight line: $y = m_{bf} \times R_{p,crt} + C_V$

5 point where $F_Y \times C_v = 0{,}667 \times C_v$

6 point B for the pressure drop ratio factor, $R_{p,crt}$

Figure H.5 — Example of typical C_v data

H.9.2 Calculation

For each pressure ratio, $R_{p,crt}$, find the product of ($F_Y \times C_v$), in SI units using Equation (H.6) or in USC units using Equation (H.7).

$$F_Y \times C_v = q \times \left[\frac{\left(S_g \times T_1 \times Z_1 \frac{1}{R_p} \right)^{\frac{1}{2}}}{4{,}17 P_1} \right] \tag{H.6}$$

where

q is the flow rate, expressed in standard cubic metres per hour;

S_g is the specific gravity of gas (the value for air equals 1,0);

T_1 is the upstream gas temperature, expressed in kelvin;

P_1 is the upstream gauge pressure of the test section, expressed in gauge kilopascals;

Z_1 is the upstream compressibility factor;

R_p is the pressure ratio.

$$F_Y \times C_v = q \times \left[\frac{\left(S_g \times T_1 \times Z_1 \frac{1}{R_p} \right)^{\frac{1}{2}}}{1\,360 P_1} \right] \tag{H.7}$$

where

q is the flow rate, expressed in standard cubic feet per hour;

T_1 is the upstream gas temperature, expressed in degrees Rankine;

P_1 is the upstream gauge pressure of the test section, expressed in pounds per square inch absolute.

H.9.3 Analysis

The values calculated as ($F_Y \times C_v$) shall be plotted on linear coordinate paper with ($F_Y \times C_v$) on the vertical axis and the pressure ratio, $R_{p,crt}$, on the horizontal axis. A best-fit straight line shall be fitted to the data. If any test data point deviates by more than 5 % from the straight line, additional test data shall be taken near that pressure ratio, $R_{p,crt}$, to ascertain if the specimen truly exhibits anomalous behaviour.

The accuracy of data collected at very low pressure ratios and small stem displacements is suspect. These data points may be ignored if at least five additional data points meet the criteria described above.

H.9.4 Determination of flow coefficient

The value of the flow coefficient, C_v, shall be read as the point on the vertical axis where the fitted straight line intersects the vertical axis. This is designated as point A on Figure H.5.

H.9.5 Determination of pressure drop ratio factor

The pressure drop ratio factor, $R_{p,crt}$, is determined by projecting a horizontal line from the vertical axis at a value of $F_Y \times C_v = 0{,}667 C_v$ until it intersects the fitted straight line. A vertical line is then drawn from this intersection to the horizontal axis. The value of $R_{p,crt}$ is read on the horizontal axis as the point of intersection of the vertical line and the horizontal axis. This is designated as point B on Figure H.5.

Alternatively, Equation (H.8) may be used to determine $R_{p,crt}$ if the slope, m_{bfl}, of the straight line is known.

$$R_{p,crt} = \frac{\left[0{,}667\left(F_Y \times C_v\right) - C_v\right]}{m_{bfl}} \tag{H.8}$$

H.9.6 Calculating the expansion factor

The value of the expansion factor, F_Y, is as given in Equation (H.9).

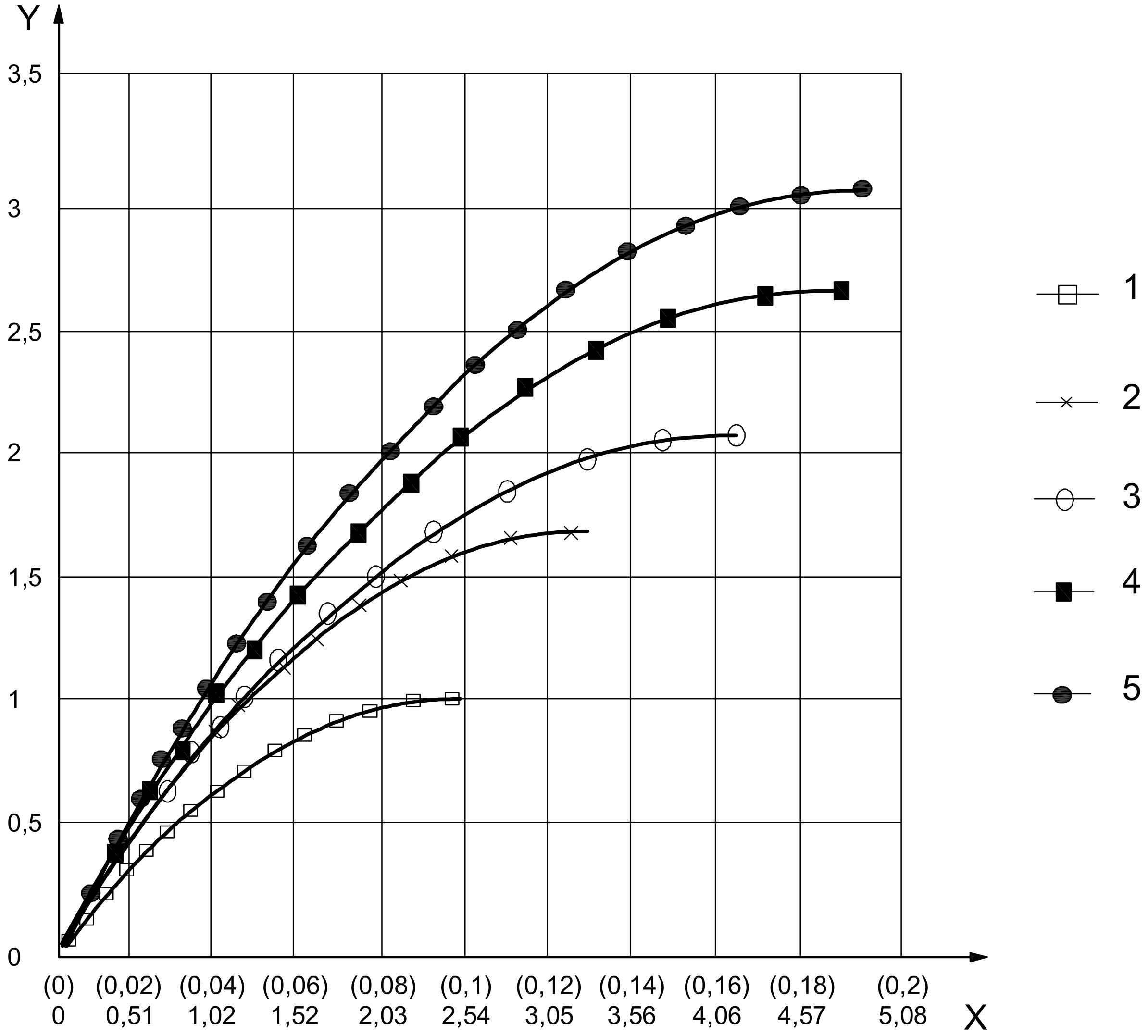
$$F_Y = 1 - \left(\frac{R_p}{3F_k R_{p,crt}}\right) \tag{H.9}$$

The computed value of the expansion factor, F_Y, shall be greater than or equal to 0,667 and less than or equal to 1,0. In addition, if R_p is greater than $F_k R_{p,crt}$, the value which shall be used for R_p is $F_k R_{p,crt}$.

H.9.7 Record flow coefficient versus stem travel

A graph of the flow coefficient, C_v, versus stem travel shall be made on linear coordinates with C_v on the vertical axis and stem travel on the horizontal axis. The range of the stem travel axis shall begin at 0,000 and extend to the maximum effective travel of the stem as determined in Clause G.10.

Each of the tested points shall be identified with a symbol. A curve shall be fitted to the data points using any method suggested by the supplier/manufacturer to obtain flow coefficients not tested. See Figure H.6 for an example of flow coefficients plotted versus stem travel in millimetres (inches) for different port sizes in millimetres (inches).



Key

X stem travel, expressed in millimetres (inches)

Y flow coefficient

1 port size: 4,76 mm (3/16 in)

2 port size: 6,35 mm (1/4 in)

3 port size: 7,94 mm (5/16 in)

4 port size: 9,53 mm (3/8 in)

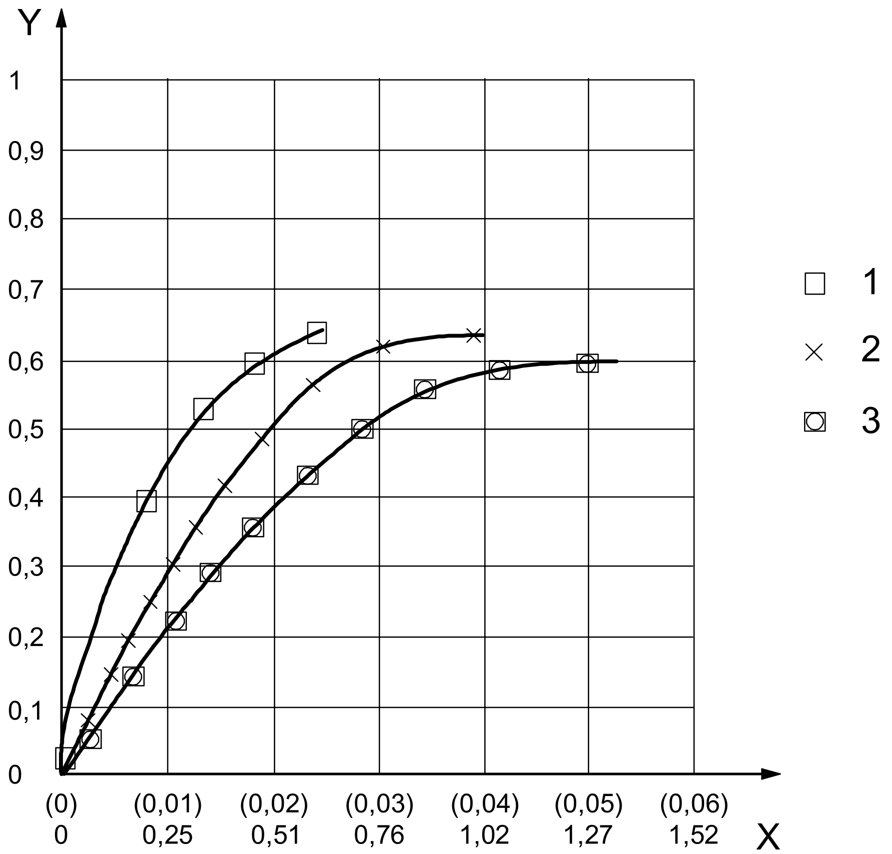
5 port size: 11,11 mm (7/16 in)

Figure H.6 — C_v vs stem travel

H.9.8 Record pressure drop ratio factor versus stem travel

A graph of the pressure drop ratio factor, $R_{p,crt}$, versus stem travel shall be made on linear coordinates with $R_{p,crt}$ on the vertical axis and stem travel on the horizontal axis. The range of the stem travel axis shall begin at 0,00 mm (0,00 in) and extend to the maximum effective travel of the stem as determined in Clause G.10.

Each of the tested points shall be identified with a symbol. A curve shall be fitted to the data points using a method recommended by the supplier/manufacturer to obtain pressure drop ratio factors not tested. See Figure H.7 for an example of critical pressure ratios plotted versus travel in inches, for different port sizes in inches.



Key

X stem travel, expressed in millimetres (inches)

Y critical pressure ratio

1 port size: 3,18 mm (1/8 in)

2 port size: 4,76 mm (3/16 in)

3 port size: 6,35 mm (1/4 in)

Figure H.7 — Critical pressure ratio vs stem travel

H.10 Use of C_v and $R_{p,crt}$ test data

H.10.1 Use of the flow coefficient

The flow coefficient, C_v, can be used to compute flow rate, q_{gi}, as given in Equation (H.10) for SI units and in Equation (H.12) for USC units.

$$q_{gi} = 0{,}1 \times C_v \left(P_{iod} + 100{,}0\right) \times F_Y \left(\frac{R_p}{S_g T_v Z_1}\right)^{\frac{1}{2}} \tag{H.10}$$

where

$$R_p = \frac{P_{iod} - P_{pd}}{P_{iod} + 100}; \tag{H.11}$$

P_{iod} and P_{pd} are pressures expressed in gauge kilopascals;

S_g is the specific gravity of gas (the value for air equals 1,0);

T_v is the temperature of the flow-control device at depth, expressed in kelvin;

q_{gi} is the measured flow rate at standard conditions, expressed in MSCMD.

$$q_{gi} = 32,64 \times C_v \left(P_{iod} + 14,7\right) \times F_Y \left(\frac{R_p}{S_g T_v Z_1}\right)^{\frac{1}{2}} \quad \text{(H.12)}$$

where

$$R_p = \frac{P_{iod} - P_{pd}}{P_{iod} + 14,7}; \quad \text{(H.13)}$$

P_{iod} and P_{pd} are pressures, expressed in pounds per square inch gauge;

T_v is the temperature of the flow-control device at depth, expressed in degrees Rankine;

q_{gi} is the measured flow rate at standard conditions, expressed in MSCFD.

In the above equation, use the actual pressure ratio, R_p, if it is less than $F_k P_{p,crt}$; otherwise, use $F_k P_{p,crt}$ as the value of R_p.

H.10.2 Example for using C_v and $R_{p,crt}$ to compute flow rate

H.10.2.1 General

To calculate the flow rate through a flow-control device using this equation, it is necessary to know the amount of stem travel for the pressure conditions. This can be determined using either the simplified method (see P.3.5) or any other correlation that calculates stem travel. It is also necessary to know the ratio of the specific heats of the media used to test the flow coefficients. Example calculations follow.

H.10.2.2 Data

Figure H.6 is a graph of C_v versus stem travel for this flow-control device.

Figure H.7 is a graph of $R_{p,crt}$ versus stem travel for this flow-control device.

Test media ratio of specific heats equals 1,4.

Upstream pressure, P_{oid}, equals 6 895 kPa (1 000 psig).

Downstream pressure, P_{pd}, equals 5 860 kPa (850 psig).

Natural gas specific gravity, S_g, equals 0,65.

Temperature, T_v, equals 65,6 °C (150 °F).

The flow-control device stem travel equals 0,635 mm (0,025 in).

The fow-control device port size equals 6,350 mm (1/4 in).

H.10.2.3 Calculation

Using the above data, the calculation is performed as follows.

a) Calculate the pressure ratio, R_p:

$$R_p = \frac{6\,895 - 5\,860}{6\,895 + 100} = 0{,}148 \qquad \left(R_p = \frac{1\,000 - 850}{1\,000 + 14{,}7} = 0{,}147\,8 \right)$$

b) From Figure H.7, determine the $R_{p,crt}$ for the flow-control device at a travel of 0,635 mm (0,025 in). Read $R_{p,crt} = 0{,}45$.

c) Determine the ratio F_k. The test media used a gas with a specific heat ratio of 1,4. Natural gas has a specific heat ratio of 1,3; therefore, $F_k = \frac{1{,}3}{1{,}4} = 0{,}929$.

d) Determine whether the flow-control device is in critical flow. If R_p is greater than $R_{p,crt} F_k$, then the flow-control device is in critical flow and $R_{p,crt} F_k$ shall be used rather than R_p to compute flow rate.

$$R_{p,crt} F_k = 0{,}45 \times 0{,}928 = 0{,}418 \qquad R_{p,crt} F_k = 0{,}45 \times 0{,}928 = 0{,}418$$

The actual pressure ratio, 0,148 (0,147 8), is less than the critical pressure ratio factor, 0,417; therefore, the flow-control device is not in critical flow and the actual pressure ratio factor can be used to compute flow and the expansion factor.

e) Compute the expansion factor, F_Y:

$$F_Y = 1 - \left(\frac{R_p}{3 F_k R_{p,crt}} \right) = 1 - \frac{0{,}147\,8}{3(0{,}929)(0{,}45)} = 0{,}882 \qquad \left[F_Y = 1 - \frac{0{,}147\,8}{3 \times (0{,}929)(0{,}45)} = 0{,}882 \right]$$

f) From Figure H.6, determine the C_v for the flow-control device at a travel of 0,635 mm (0,025 in). Read $C_v = 0{,}60$.

g) Compute the compressibility factor for pressure equal to 6 900 kPa (1 000 psig) and temperature, T_v, equal to 65,6 °C (150 °F). The resultant value of Z_1 is 0,95.

h) Compute the flow rate:

$$q_{gi} = 0{,}1 \times 0{,}60 (6\,900 + 100{,}0) \times 0{,}882 \left[\frac{0{,}147\,8}{0{,}65 \times (65{,}6 + 273{,}15) \times 0{,}95} \right]^{\frac{1}{2}} = 9{,}846 \text{ MSCMD}$$

$$\left\{ q_{gi} = 32{,}64 \times 0{,}60 (1\,000 + 14{,}7) \times 0{,}882 \left[\frac{0{,}147\,8}{0{,}65 \times (150 + 460) \times 0{,}95} \right]^{\frac{1}{2}} = 347{,}25 \text{ MSCFD} \right\}$$

H.11 Description of use of a ramp function in a dynamic test of a flow-control device

H.11.1 General

Clause H.11 describes how to design and use a constant pressure change (ramp method) for flow coefficient and dynamic flow tests. This method ensures that the data accurately represents the behaviour of the flow-control device at steady state conditions. Data collected during the ramp tests shall be electronically recorded. Data recorded manually are not accurate enough to apply the ramp method.

H.11.2 Background and theory of approach

A discussion of "steady state" and "system time constant" follows.

a) Steady state

— The components of a flow-control device test system, e.g. flow-control device, pressure measurement devices, lengths of pipe, etc., do not react instantaneously to changes in system pressure. For these components, there is a measurable lag between the time an external step change in pressure is applied and the time required for the system to reach "steady state".

— Theoretically, a system reaches "steady state" only after waiting an infinite amount of time. However, for practical purposes, a flow-control device test system is assumed to reach "steady state" when values of P_1 (upstream injection pressure), P_2 (downstream production pressure) and flow rate are changing by only small random fluctuations. It is assumed that this random error does not significantly affect the calculations. To determine whether these random fluctuations are important, a sensitivity analysis on the specific flow-control device design calculations can be required.

b) System time constant

— A study done using an actual flow-control device and test section showed that the transient behaviour of this system can be approximated by a first-order response. The governing equation for a first-order response is given as Equation (H.14) for a discharging system, i.e. for constant injection pressure tests.

$$P_2(t) = P_{1,\text{max}} \times e^{\left(\frac{-t}{C_\text{t}}\right)} \tag{H.14}$$

where

$P_2(t)$ is the downstream system pressure, expressed in gauge kilopascals (pounds per square inch gauge) as a function of time;

$P_{1,\text{max}}$ is the maximum upstream system pressure, expressed in kilopascals (pounds per square inch);

t is the time, expressed in seconds;

C_t is the system time constant, expressed in seconds.

— The system time constant, C_t, is a physical parameter that varies with system geometry and the physical properties of the gas. This time constant can be used to determine how close the measured values are to steady state. For example, after an elapsed time of 1 s, 2 s, 3 s, 4 s and 5 s, the test system has reached 63,2 %, 85,6 %, 95 %, 98 % and 99 % of steady state, respectively.

— The accuracy of the calculations can be improved by fitting the experimental data to a second-order response. This analysis requires a curve fit of the experimental data and the calculation of several empirical constants. For example, in the case of the discharging test system, the second-order equation given as Equation (H.15) applies.

$$P_2(t) = C_1 \times e^{\left(\frac{-t}{C_{\text{t},1}}\right)} + C_2 \times e^{\left(\frac{-t}{C_{\text{t},2}}\right)} \tag{H.15}$$

where

$P_2(t)$ is the downstream system pressure, expressed in gauge kilopascals (pounds per square inch gauge) as a function of time;

C_1 and C_2 are the empirical constants determined by curve-fitting data, expressed in kilopascals (pounds per square inch);

t is the time, expressed in seconds;

$C_{t,1}$ and $C_{t,2}$ are the system time constants found by curve-fitting the data, expressed in seconds.

— Increasing the capacity of surge tanks and overall pipe volume in the test system helps dampen fluctuations in system pressure. This makes it easy for the operator to control the system pressures and read the pressure measurement devices and flow meters during a dynamic test. However, the trade-off for increasing the system volume is that it also acts to increase the system time constant(s). As this time constant increases, longer periods of time are required to ensure that measured data represent steady-state conditions. The end result is an increase in the time and the gas volume required.

H.11.3 Measuring system time constant

H.11.3.1 General

H.11.3 defines the measurement of the system time constant for a typical discharging test system. This example assumes a first-order response. This test shall be performed on the test system configuration for flow-control device testing. Do not install a flow-control device in the test section for this test. Close the bypass valve before beginning.

The procedure is carried out as follows.

a) Close the downstream valve in the test system.

b) Open the upstream valve so that both upstream and downstream pressures are equal at 5 860 kPa (850 psig), i.e. $P_{1\,\mathrm{max}} = P_2(t)$ at $t = 0$.

c) Start the data acquisition equipment and collect data at frequencies of no more than 2 s intervals. Open the downstream valve as rapidly as possible.

d) When $P_2(t)$ is at atmospheric pressure or is changing by only small random fluctuations, the test is complete.

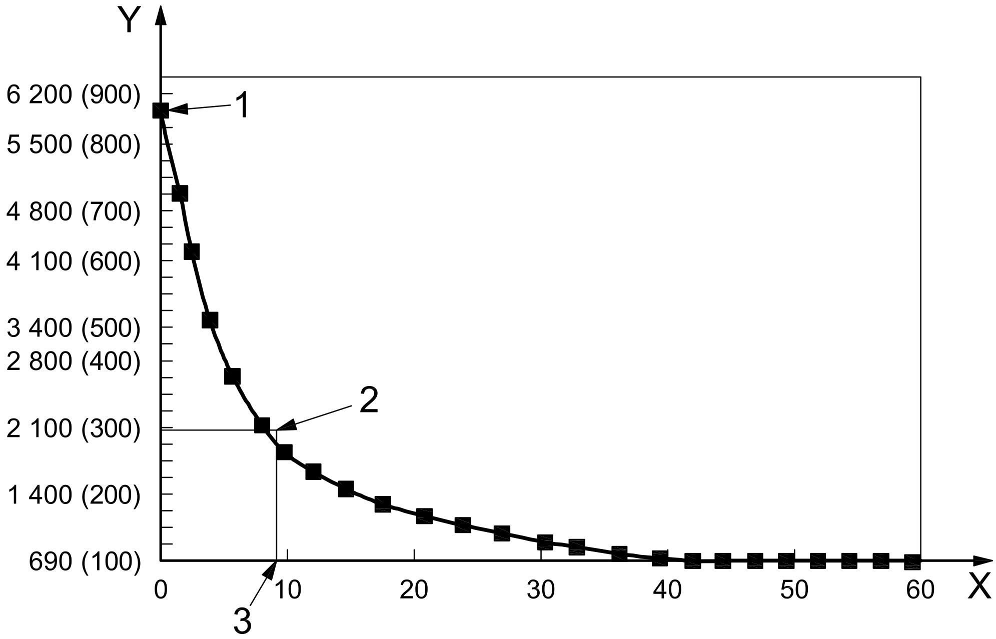
e) Plot P_2 as a function of time as shown in Figure H.8.

Calculate the first-order time constant, C_t, by finding the time required to decrease from an initial value of $P_2 = P_{1,\mathrm{max}}$ at $t = 0$ to $P_2\left(t\right) = \frac{100 - 63{,}2}{100} \times P_{1,\mathrm{max}} - P_{2,\mathrm{min}}\left(t\right)$.

EXAMPLE $P_2(t) = \frac{100 - 63{,}2}{100} \times \left(5\ 860 - 0\right) = 2\ 227$ gauge kPa;

$[P_2(t) = \frac{100 - 63{,}2}{100} \times \left(850 - 0\right) = 313$ psig].

As an alternative, the data can be curve-fit using Equation (H.15). Pressures are expressed in gauge kilopascals (pounds per square inch gauge).



Key

X time, expressed in seconds

Y downstream pressure, expressed in gauge kilopascals (pounds per square inch gauge)

1 $P_{1,\max} = P_2$ = 5 860 gauge kPa (850 psig)

2 P_2 = 227 gauge kPa (323 psig)

3 one (1) time constant, equal to 9 s

Figure H.8 — Example test system response

H.11.3.2 Using the system time constant to design a ramp for the dynamic test

Use the system time constant developed in accordance with H.11.3.1. It can be used to design a ramp function for the flow coefficient test or the dynamic flow test. The ramp function is basically a constant rate linear decrease in downstream pressure, $P_2(t)$, over time as upstream pressure, $P_{1,\max}$, is held constant. It is necessary that the duration of this ramp be at least five time constants to ensure that the data recorded are within 99 % of steady state. Generally, the longer the duration of this ramp, the more conservative and the better the assurance that the data represent the system at steady state. Figure H.8 illustrates a ramp function design where the time constant is 9 s.

Deviations from linearity in the ramp function can be caused by a failure to maintain upstream pressure, $P_{1,\max}$, constant or by rapid changes in the downstream pressure. These deviations in linearity can cause an error in the test data. To reduce this error, design a longer ramp with a gentler slope.

H.12 Documentation

H.12.1 General

The documentation in the following list shall be produced to record the execution of the flow coefficient, C_v, test. The flow coefficient data form 2 (Figure H.9) is a convenient method to record the data. (See 7.2 for design validation documentation requirements.)

a) supplier/manufacturer's flow-control device type, identification and part number, and dated assembly drawing;

b) drawing of the modified flow-control device;

c) maximum effective stem travel of flow-control device (see Clause G.10);

d) type and accuracy of flow rate measurement;

e) type and accuracy of pressure measurement;

f) type and accuracy of temperature measurement;

g) stem travel;

h) test data to include the following at each test point:

   1) upstream pressure, P_1;

   2) downstream pressure, P_2;

   3) upstream temperature, T_1;

   4) flow rate;

i) calculation of the following variables:

   1) pressure ratio for each test point, R_p;

   2) product of $F_Y \times C_v$ for each test point as specified in Clause I.9;

   3) coefficients of best-fit straight line (i.e. coefficients A and B of the equation $y = m\,x + b$ that best fits data);

   4) $+$ 5 % limit of each data point using the best-fit straight line as reference;

   5) $-$ 5 % limit of each data point using the best-fit straight line as reference;

j) graph of data points and best-fit straight line;

k) flow coefficient, C_v;

l) pressure drop ratio factor, $P_{p,crt}$;

m) graph of flow coefficient, C_v, versus stem travel;

n) graph of pressure drop ratio factor, $P_{p,crt}$, versus stem travel;

o) location of test facility and test facility operator;

p) media used for testing;

q) date tested and person in charge of testing.

Flow coefficient data form 2 — Information required		
1	ISO designation of flow-control device	
	Supplier/manufacturer's part number of flow-control device	
	Dated assembly drawing of flow-control device attached	
2	Drawing of modified flow-control device attached	
3	Maximum effective travel of flow-control device	
4	Type of flow measurement device:	
	Accuracy:	
5	Upstream pressure measurement device:	
	Accuracy:	
	Downstream pressure measurement device:	
	Accuracy:	
	Differential pressure measurement device:	
	Accuracy:	
6	Upstream temperature measurement device:	
	Accuracy:	
7	Stem travel	
8	Coefficient A of best-fit straight line:	
	Coefficient B:	
9	Graph showing data points and best-fit straight line	
10	Flow coefficient, C_v	
11	Pressure drop ratio factor, $P_{p,crt}$	
12	Graph of flow coefficient vs stem travel	
13	Graph of pressure drop ratio factor vs stem travel	

Test no.	Upstream pressure	Downstream pressure	Differential pressure	Upstream temperature	Flowrate
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Calculation number	Pressure ratio R_p	$F_Y \times C_v$	+ 5 % limit	− 5 % limit
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Figure H.9 — Flow coefficient data form 2

H.12.2 Flow performance test documentation

This subclause defines the required flow performance test documentation. The following information shall be recorded.

a) Record the valve description, including the supplier/manufacturer's name and an assembly or part number designation for the tested flow-control device. Include the version number of the flow-control device or date of manufacture.

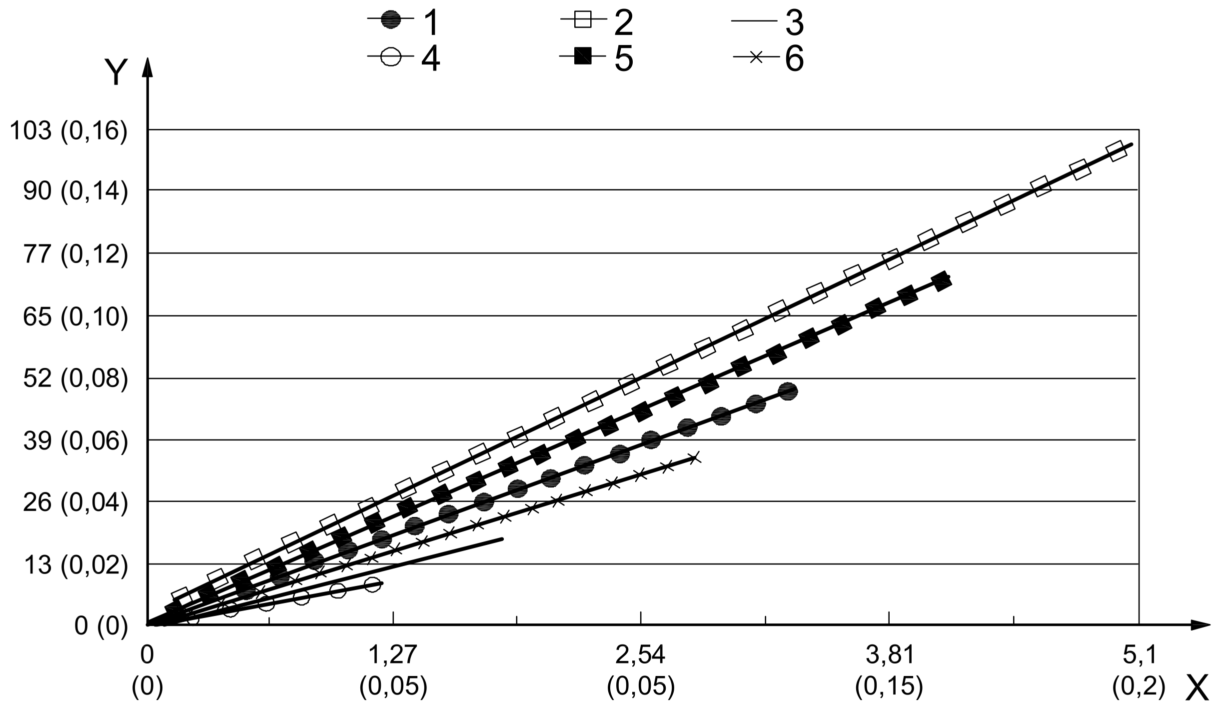
b) Record the stem, seat, and bellows dimensions, including the effective bellows area, port ID, stem-tip description and seat-bevel configuration.

c) Record the valve specifications, including the ratio of stem-seat contact area to effective bellows areas (A_s/A_b).

d) Define a profile of equivalent flow area versus stem travel as a curve representing equivalent flow area versus stem travel on the basis of the surface area of the frustum of a right circular cone for the stem and seat geometry from zero stem travel to a maximum equivalent flow area equal to the port area. This curve defines the fully open stem travel. Figure H.10 is an example of the equivalent flow area versus stem travel, for port sizes expressed in inches.

e) The test rack set pressure of the valve shall be defined in pounds per square inch gauge at 15,5 °C (60 °F). The valve set pressure may be the P_{vo} or P_{vc} as designated by the supplier/manufacturer.

f) A probe test of the valve as defined in Annex H shall be performed and a copy of the dynamic test data form 1 (Figure H.4) included with the documentation.



Key

X stem travel, expressed in millimetres (inches)

Y test pressure, expressed in gauge kilopascals (pounds per square inch gauge)

1 port size: 7,9 mm (5/16 in)

2 port size: 11,11 mm (7/16 in)

3 port size: 4,8 mm (3/16 in)

4 port size: 3,2 mm (1/8 in)

5 port size: 9,5 mm (3/8 in)

6 port size: 6,4 mm (1/4 in)

Figure H.10 — Example of equivalent flow area vs stem travel

Annex I
(normative)

Back-check testing

I.1 General

The following tests are defined for reverse flow or back-check valves in flow-control devices. These valves may be tested as a subassembly. These devices are designed and intended to prevent reverse flow through a flow-control device. They are not designed nor intended to be a part of the safety system, nor to provide a tight shut-off pressure safety seal.

There are four types of tests to be performed to fully qualify a back-check for use in a gas-lift installation. Each succeeding test further qualifies the back-check as a reverse-flow device. The four tests are: mechanical function, hydraulic integrity, activation and erosion.

- The mechanical function test (Clause I.4) ensures that the check dart or closing mechanism is capable of mating with the seating surface and unseating without human intervention.
- The backflow integrity test (Clause I.5 with water and Clause I.6 with gas) ensures that the back-check can act as a reverse flow check when subjected to hydraulic or gas pressures applied from the reverse direction of normal flow.
- The activation test (Clause I.7 and Clause I.8) determines the minimum amount of reverse flow required to cause the closing mechanism to activate and impede the flow of fluid from the reverse direction of normal flow.
- The erosion test (Clause I.9) subjects the back-check mechanism to hydraulic flow in the normal direction of flow (as in the unloading process of a gas-lift well) and determines the ability of the back-check to function as originally intended.

I.2 Requirements for design validation

I.2.1 Requirements for design validation, grade V3

I.2.1.1 General

The test requirements for design validation, grade V3, shall be as described in I.2.1.2 to I.2.1.5.

I.2.1.2 Number of test specimens

This test shall be conducted on a minimum of seven flow-control devices of each type.

I.2.1.3 Test procedure

The following test procedure shall be performed to satisfy the design validation requirement.

a) A mechanical function test shall be conducted in accordance with Clause I.4.

b) A backflow integrity test shall be conducted at maximum rated pressure in accordance with Clause I.5.

I.2.1.4 Acceptance criteria

Acceptance criteria are as follows.

a) Acceptance criteria for the mechanical function test are defined in Clause I.4.

b) Acceptance criteria for the backflow integrity test are defined in Clause I.5.

I.2.1.5 Documentation

Record the results of each mechanical function testing and the results of each backflow integrity test. (See 7.2 for design validation documentation requirements.)

I.2.2 Requirements for design validation, grade V2

I.2.2.1 General

The test requirements for design validation, grade V2, shall be as described in I.2.2.2 to I.2.2.5.

I.2.2.2 Number of test specimens

This test shall be conducted on a minimum of seven flow-control devices of each type.

I.2.2.3 Test procedure

The following test shall be performed to satisfy the design validation requirement.

a) Meet all test requirements for design validation, grade V3.

b) A backflow integrity test using gas shall be performed in accordance with Clause I.6.

c) The minimum liquid flow rate and differential-pressure activation test shall be performed in accordance with Clause I.7.

d) For spring-loaded back-check valves, determine the pressure differential required to open the valve in accordance with Clause I.8.

e) For both flow-activated and spring-loaded check valves, ensure that the check dart does not stick to the valve seat. Do this by repeating the mechanical function test defined in Clause I.4 after the above tests.

I.2.2.4 Acceptance criteria

Acceptance criteria for the backflow integrity test using gas are defined in Clause I.6, those for the minimum liquid flow rate and differential-pressure activation test using gas are defined in Clause I.7, those for tests of spring-loaded back-check valves are defined in Clause I.8, and those for the back-check dart test are defined in Clause I.4.

I.2.2.5 Documentation

Record the results for each

a) backflow integrity test,

b) minimum liquid flow rate and differential-pressure activation test,

c) test of spring-loaded back-check valves,

d) repetition of mechanical function rest.

NOTE See 7.2 for design validation documentation requirements.

I.2.3 Requirements for design validation, grade V1

I.2.3.1 General

The test requirements for design validation, grade V1, shall be as described in I.2.3.2 to 1.2.3.5.

I.2.3.2 Number of test specimens

The requirements for test specimens are as follows.

a) This test shall be conducted on a minimum of seven flow-control devices of each type. If more than one device of the original seven test devices fails the test, an additional seven devices shall be selected and the entire test process shall be performed on the new devices.

b) The back-check erosion test shall be conducted on one flow-control device.

I.2.3.3 Test procedure

The following shall be accomplished to satisfy the design validation requirement.

a) Meet all test requirements for design validation, grade V2.

b) Repeat the backflow integrity test defined in Clause I.5 at the maximum rated temperature $^{+5}_{0}$ % of the flow-control device. The test shall be conducted at a low differential pressure of (689 ± 34,5) kPa [(100 ± 5) psi].

c) Conduct the minimum liquid flow rate and differential pressure activation test defined in Clause I.7 at the supplier/manufacturer's rated pressure $^{+5}_{0}$ %.

d) Conduct a back-check erosion test as defined in Clause I.9 on one flow-control device.

I.2.3.4 Acceptance criteria

Acceptance criteria are as follows.

a) For acceptance of the backflow integrity test, each test result shall meet the test requirements specified in the supplier/manufacturer's written test procedures. If one or more devices fail, the test fails.

b) For acceptance of the minimum liquid flow rate and differential-pressure activation test, each test result shall meet the test requirements specified in the supplier/manufacturer's written test procedures. If one or more devices fail, the test fails.

c) For acceptance of the back-check erosion test, the back-check shall maintain at least 90 % of the differential pressure required to activate it after a 10 min time span; if not, the backflow check fails the erosion test.

I.2.3.5 Documentation

Record the results of each. (See 7.2 for design validation documentation requirements.)

For the backflow integrity test, record the minimum liquid flow rate and differential-pressure activation test and back-check erosion test.

I.3 Requirements for product functional testing

I.3.1 Requirements for product functional testing, grade F3

I.3.1.1 General

The test requirements for product functional testing, grade F3, shall be as defined in I.3.1.2 to 1.3.1.5.

I.3.1.2 Number of test specimens

This test shall be performed on 100 % of any job lot.

I.3.1.3 Test procedure

The following test shall be performed to satisfy the design validation and functional test requirements.

a) A mechanical function test as defined in Clause I.4 shall be performed.

b) A nitrogen gas (N_2) back-check leak test in accordance with Clause I.6 shall be conducted.

I.3.1.4 Acceptance criteria

The acceptance criteria are as follows.

a) For acceptance of the mechanical function test, the check dart shall move freely from the open to the closed position and from the closed to the open position without human intervention. If the check dart fails to move as required, the test fails.

b) For acceptance of the N_2 back-check leak test, the leak rate shall not exceed 1 SCMD (35 SCFD) with a (689 ± 69) kPa [(100 ± 10) psi] differential pressure across the reverse-flow valve. If the leak rate exceeds this amount, the test fails.

I.3.1.5 Documentation

The following items are required as documentation:

a) recorded results of each test (see 7.2 for design validation documentation requirements);

b) description of the mechanical function test and N_2 back-check leak test.

I.3.2 Requirements for product functional testing, grade F2

The test requirements for product functional testing, grade F2, shall be the same as for product functional grade F3.

I.3.3 Requirements for product functional testing, grade F1

I.3.3.1 General

The test requirements for product functional testing, grade F1, shall be as defined in I.3.3.2 to I.3.3.5.

I.3.3.2 Number of test specimens

This test shall be performed on 100 % of any job lot.

I.3.3.3 Test procedure

The following test shall be performed to satisfy the functional test requirement.

a) Meet all product functional testing test requirements for product functional testing, grade F3.

b) The minimum and maximum back-check activation rates/pressures shall be determined as defined in Clause I.7.

I.3.3.4 Acceptance criteria

For acceptance of the minimum and maximum back-check activation rates/pressures test, these values shall be within the supplier/manufacturers' specified tolerance.

I.3.3.5 Documentation

Record the minimum and maximum back-check activation rates and pressures and the additional documentation that is required. (See 7.2 for design validation documentation requirements.)

I.4 Mechanical function test

I.4.1 General

Two types of back-checks are commonly used in flow-control devices: spring-loaded darts and hydraulically activated darts. Spring-activated darts are held against the seat by a spring. Hydraulically activated darts require flow to seat the dart. The mechanical test for each is explained in I.4.2 and I.4.3, respectively.

I.4.2 Spring-activated darts

I.4.2.1 General

This dart activation method is used for chemical injection valves. This type of back-check valve is normally closed.

I.4.2.2 Test procedure

The following shall be performed to satisfy the mechanical function test requirements for spring-activated darts.

a) The flow-control device shall be tested in a test fixture similar to the fixture used for open and close pressure tests (see Figure J.1).

b) The hydraulic pressure acting on the bellows shall be increased to the activation pressure of the flow-control device.

c) The flow of the hydraulic test fluid shall be evident at the outlet of the flow-control device.

d) The pressure acting on the bellows shall be reduced to atmospheric and a visual inspection of the dart should indicate seating of the dart.

I.4.2.3 Acceptance criteria

For acceptance of the mechanical function test, the check dart shall move freely from the open to the closed position and from the closed to the open position without human intervention. If any device fails to move as required, the test fails.

I.4.3 Hydraulically activated darts

I.4.3.1 General

This back-check valve is normally open. Some hydraulically activated darts have weak springs that hold the dart close to the seat. This minimizes the reverse flow necessary to activate the back-check valve. All flow-control devices that require reverse flow for activation are tested as specified in I.4.3.2.

I.4.3.2 Test procedure

The following shall be performed to satisfy the mechanical function test requirements for hydraulically activated darts.

a) Hold the flow-control device in the normal manner in which it is positioned in the side-pocket mandrel.

b) Visually inspect the outlet of the flow-control device and verify that the check dart is located in its lowermost position.

c) Invert the flow-control device and visually inspect that the check dart has properly mated with the sealing surface.

I.4.3.3 Acceptance criteria

Acceptance criteria are as follows.

a) For acceptance of the mechanical function test, the check dart shall move freely from the open to the closed position and from the closed to the open position without human intervention. If any device fails to move as required, the test fails.

b) For acceptance of the repeat mechanical function test required in I.2.2.3, the check dart shall move freely from the open to the closed position and from the closed to the open position without human intervention. If one or more devices fail to move as required, the test fails.

I.5 Backflow integrity test

I.5.1 Test procedure

The following shall be performed to satisfy the backflow integrity test requirements.

a) Apply hydraulic pressure to the reverse-flow or back-check valve of the flow-control device, in the opposite direction to normal flow through the device.

b) Test to the supplier/manufacturer's maximum rated pressure ${}^{+10}_{\ 0}$ %.

c) Hold the pressure for a minimum of 1 min.

d) For flow-activated reverse-flow check valves, ensure that the reverse-flow check does not stick to the primary/secondary seal after completion of the backflow integrity test.

I.5.2 Acceptance criteria

For acceptance of the backflow integrity test, each test result shall meet the test requirements specified in the supplier/manufacturer's written test procedures. As a minimum, the device shall exhibit no pressure drop over the 1 min period.

I.6 Gas test

I.6.1 Test procedure

The following shall be performed to satisfy the gas test requirements.

a) Apply air, nitrogen, helium or another compressed gas at (689 ± 34,5) kPa [(100 ± 10) psi] differential pressure to the reverse-flow or back-check valve of the flow-control device, in the opposite direction to normal flow through the device.

b) Test in accordance with the supplier/manufacturer's written specifications.

I.6.2 Acceptance criteria

The acceptance criteria are as follows.

a) For acceptance of the backflow integrity test using gas, each test result shall meet the test requirements specified in the supplier/manufacturer's written test procedures.

b) The leak rate shall not exceed 1 SCMD (35 SCFD).

For safety considerations, non-flammable gases, such as the ones suggested, shall be used for all valve testing.

I.7 Flow test for flow-activated reverse-flow or back-check activation

I.7.1 General

The purpose of this test is to determine the minimum hydrostatic flow rate needed to activate (close) the reverse-flow or back-check valve for flow-activated valves.

I.7.2 Test procedure

The following shall be performed to satisfy the flow-activated reverse-flow/back-check activation requirements.

a) Conduct a flow test, in the direction opposite to normal flow through the flow-control device.

b) This test may be conducted on an assembled flow-control device or on a disassembled flow-control device with the necessary components for the reverse-flow or back-check assembly.

c) The minimum flow rate and differential pressure that are necessary to close the reverse-flow or back-check valve shall be within the supplier/manufacturers written specification limits.

I.7.3 Acceptance criteria

For acceptance of the minimum liquid flow rate and differential-pressure activation test, each test result shall meet the test requirements specified in the supplier/manufacturer's written test procedures.

I.8 Pressure differential test for spring-loaded reverse-flow or back-check activation

I.8.1 General

The purpose of this test is to determine the minimum differential pressure needed to activate (open) the reverse-flow or back-check valve for normally closed spring-loaded back-check valves.

I.8.2 Test procedure

The following shall be performed to satisfy the spring-loaded reverse-flow/back-check activation requirements.

a) This test is conducted in the direction of normal flow through the flow-control device.

b) This test may be conducted on an assembled flow-control device or on a disassembled flow-control device with the necessary components for the reverse flow or back-check assembly.

c) The minimum differential pressure that is necessary to open the reverse-flow or back-check valve shall be within the supplier/manufacturer's written specification limits.

I.8.3 Acceptance criteria

For acceptance of the test of spring-loaded back-check valves, the pressure differential to open the valve shall be within the supplier/manufacturer's specified tolerances.

I.9 Erosion testing of reverse-flow check

I.9.1 General

The purpose of this test is to determine the ability of the reverse-flow check to function properly after being subjected to an erosive flow.

I.9.2 Test procedure

Refer to Annex L for erosion test methods and acceptance criteria.

Annex J
(normative)

Opening and closing pressure testing

J.1 Testing

J.1.1 Purpose

The following tests shall be successfully performed to determine the flow-control device opening and closing pressures. These tests verify that the mechanical performance of the flow-control device is consistent with the theoretical calculated performance parameters as determined by the supplier/manufacturer.

J.1.2 General

J.1.2.1 Defining tests

The open and close test requirements for design validation grades V3, V2 and V1 shall be as defined in J.1.2.2 to J.4.5.

J.1.2.2 Number of test specimens

This test shall be conducted on a minimum of seven flow-control devices of each type. If more than one device of the original seven test devices fails the test, an additional seven devices shall be selected and the entire test process shall be performed on the new devices.

J.1.2.3 Test procedure

The following shall be performed for opening and closing pressure requirements.

a) Conduct the open and close pressure tests as specified in J.4.4 and J.4.5; sample test apparatus are shown in Figures J.1 and J.2. Conduct the tests a minimum of five times.

b) Calculate the R_{tef} value according to Equation (J.1) using the measured open and close pressures determined in J.4.4 and J.4.5:

$$R_{\text{tef}} = \left(\frac{P_{\text{vo}T} - P_{\text{vc}T}}{P_{\text{vc}T}} \right) \quad \text{(J.1)}$$

where

$P_{\text{vc}T}$ is the measured or calculated upstream gauge pressure when the downstream pressure is equal to the upstream pressure and near zero gas flow rate, at a known temperature;

$P_{\text{vo}T}$ is the measured or calculated gauge pressure applied over the area, $(A_{\text{b}} - A_{\text{s}})$, required to initiate flow through a flow-control device with zero gauge pressure downstream, at a known temperature.

J.1.2.4 Acceptance criteria

Acceptance criteria are as follows.

a) For acceptance of the calculated R_{tef} value using the measured open and close pressures, the calculated R_{tef} value of each test shall be within ± 5 % of the average of all test results.

b) The calculated R_{tef} value based on the measured pressures shall be within ± 5 % of the published R_{tef} value that is based on the mechanical dimensions, as given in Equation (J.2):

$$R_{tef} = \left(\frac{A_s / A_b}{1 - A_s / A_b} \right) \tag{J.2}$$

where

A_b effective bellows area, expressed in square centimetres (square inches);

A_s area based on the diameter where the stem contacts the seat, expressed in square centimetres (square inches).

J.1.2.5 Documentation

The following specific additional documentation is required. (See 7.2 for design validation documentation requirements.) Record the R_{tef} value calculated from measured pressures and the R_{tef} value calculated from the mechanical dimensions.

J.2 Open test requirements for product functional testing

J.2.1 Defining tests

The open test requirements for product functional testing, grades F3, F2 and F1, shall be as defined in J.2.2 to J.2.5.

J.2.2 Number of test specimens

This test shall be conducted on 100 % of any job lot.

J.2.3 Test procedure

Conduct an open test at a "known" opening pressure, as defined in J.4.4.

J.2.4 Acceptance criteria

For acceptance of the open test, the flow-control device shall open with 5 % of the known opening pressure.

J.2.5 Documentation

Record the test rack opening pressure, P_{tro}, value.

J.3 Close test requirements for product functional testing

J.3.1 Requirements for product functional testing, grade F3

J.3.1.1 General

The close test requirements for product functional testing, grade F3, shall be as given in J.3.1.2 to J.3.1.5. This test is only required for type VII flow-control devices.

J.3.1.2 Number of test specimens

This test shall be conducted on 100 % of any job lot.

J.3.1.3 Test procedure

The following test shall be performed to satisfy the close test requirements.

a) Send a “close” signal to the flow-control device and verify that the device closes.

b) Conduct a leakage rate test (see Clause N.4) to verify that the flow device is fully closed.

J.3.1.4 Acceptance criteria

If the flow rate through the flow-control device is greater than 1 SCMD (35 SCFD), the test has failed.

J.3.1.5 Documentation

Record the flow rate through the flow-control device.

J.3.2 Requirements for product functional testing, grade F2

J.3.2.1 General

The close test requirements for product functional testing, grade F2, shall be as defined in J.3.2.2 to J.3.2.5.

J.3.2.2 Number of test specimens

This test shall be conducted on 5 % of any job lot or three flow-control devices, whichever is greater. If a job lot consists of one or two devices, all devices shall be tested.

J.3.2.3 Test procedure

This test shall be conducted as follows.

a) Open the flow-control device.

b) Close the downstream port on the flow-control device.

c) Increase the upstream pressure to above the P_{tro} of the device.

d) Equalize the upstream and downstream pressures.

e) Bleed the downstream pressure slowly until the flow-control device closes.

f) Measure the closing pressure at $P_{\text{vc}T}$.

J.3.2.4 Acceptance criteria

The closing activation point shall be within 5 % of the activation point determined from the defined opening pressure, P_{vcT}, and the R value determined by the design validation test. If it is not, the test fails.

J.3.2.5 Documentation

Record the closing activation point of the flow-control device. (See 7.2 for design validation documentation requirements.)

J.3.3 Requirements for product functional testing grade F1

J.3.3.1 General

The close test requirements for product functional testing grades F1 and F6 shall be as defined in J.3.3.2 to J.3.3.5. Note that this test is not required on flow-control device type IV, dump/kill and water injection devices.

J.3.3.2 Number of test specimens

This test shall be conducted on 100 % of any job lot.

J.3.4 Test procedure

The test shall be conducted as follows.

a) All close test requirements for product functional testing grade F2 shall be met.

b) Using the open pressure test results from Clause J.2 and the close pressure results from product functional grade F2, calculate and report the R_{tef} value, using Equation (J.3).

$$R_{tef} = \frac{P_{voT} \times P_{vcT}}{P_{vcT}} \tag{J.3}$$

J.3.4.1 Acceptance criteria

The R_{tef} value calculated from the measured pressures shall be within ± 5 % of the published R_{tef} value that is based on the mechanical dimensions:

$$\left[R_{tef} = \left(\frac{A_s / A_b}{1 - A_s / A_b} \right) \right]$$

If it is not, the test fails.

J.3.4.2 Documentation

Record the R_{tef} value based on the measured pressure and the R_{tef} value based on the mechanical dimensions for the flow-control device. (See 7.2 for design validation documentation requirements.)

J.4 Open and close test procedure

J.4.1 General requirements

The procedure to perform open and close tests is contained in Clause J.4. To perform these tests, a test block is used. The test blocks can be divided into two basic concepts: the typical donut fixture, and the typical encapsulated fixture.

When performing these tests, the requirements listed hereafter shall be met.

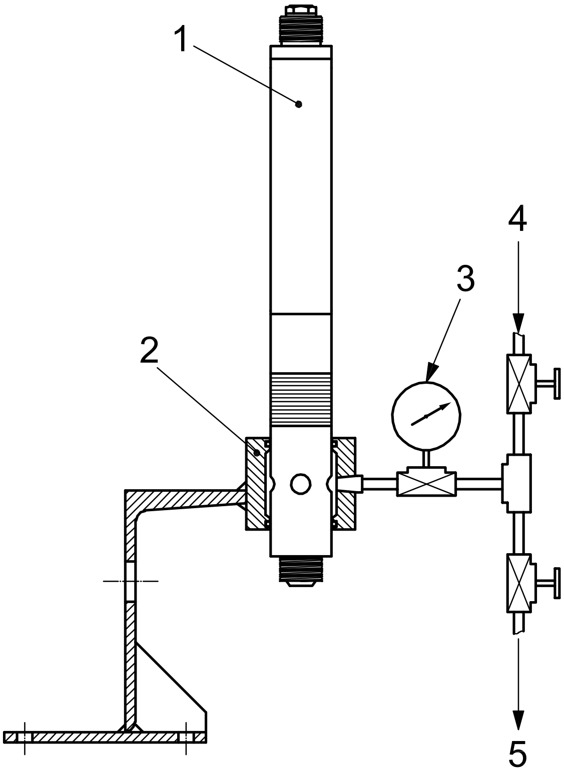
a) For these tests, the flow-control device shall be set up as defined in Clause G.7.

b) The test block calibration pressure measuring device shall be calibrated as defined in 7.4.7.

c) The opening and closing tests shall be performed consecutively in a manner that best maintains the flow-control device's reference temperature.

d) Consecutive cycling and a long test duration can lead to a temperature change and a flow-control device calibration change.

Separate procedures are provided for injection-pressure-operated (IPO) and production-pressure-operated (PPO) flow-control devices. When testing an IPO flow-control device, pressure is applied to the normal input port of the device. When testing a PPO flow-control device, pressure is applied to the normal exit port of the device.



Key

1 flow-control device

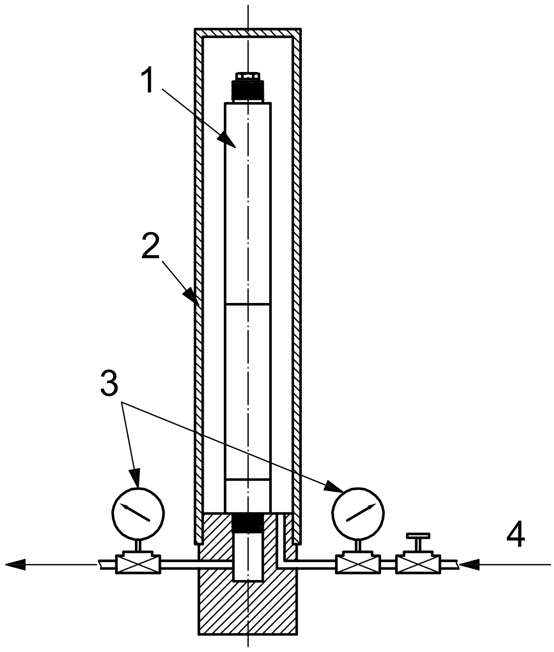
2 donut tester

3 pressure gauge

4 supply line

5 bleed

Figure J.1 — Typical donut test fixture



Key

1 flow-control device
2 tester
3 pressure gauge
4 supply line

Figure J.2 — Typical encapsulated test fixture

J.4.2 Opening test for injection pressure operated flow-control devices

The following test shall be performed.

a) Apply gas pressure to the gas entrance of the flow-control device. The flow-control device's exit shall not be obstructed and it shall be exposed to atmospheric pressure.

b) Apply the pressure slowly so that pressure enters the flow-control device's inlet ports in a slow but steady manner. It is important that pressure increases at a slow, steady rate to ensure that an accurate opening pressure measurement is obtained. Opening the gas pressure source too quickly can cause the pressure to override the opening pressure resulting in a faulty opening pressure reading. The pressure rises to a point at which the flow-control device opens, as indicated by a slow, steady flow (a hissing sound) of gas exiting the flow-control device.

c) The pressure at which this gas flow starts, as indicated by the gas-source test block pressure-measuring device, is the flow-control device's opening pressure.

J.4.3 Closing test for injection-pressure-operated flow-control devices

The following test shall be performed.

a) Once the flow-control device is in the open position, close the flow-control device's exit test block control valve, thus blocking the test flow-control device's outlet port.

b) Continue to supply gas through the inlet test block control valve until pressure equalization occurs at a pressure equal to, or greater than, the calculated opening pressure.

c) Close the inlet test block control valve. The inlet and exit pressures within the flow-control device can equalize and be monitored by both the inlet and exit test block pressure measurement devices.

d) Slowly open the exit test block control valve to allow a slow, steady flow of gas to the exit. Exhausting the gas pressure source too quickly can cause the pressure to override the closing pressure, resulting in a faulty closing pressure reading. As the gas is exhausted from the test fixture, the pressure declines on both the inlet and exit test block pressure-measuring devices until the flow-control device stem contacts the seat.

e) The pressure at which the inlet pressure stops declining and the exit pressure continues to decrease, as measured by the inlet test block pressure-measuring device, is the flow-control device’s closing pressure.

J.4.4 Opening test for production-pressure operated flow-control devices

The following test shall be performed.

a) Apply gas pressure to the gas entrance of the flow-control device. The flow-control device’s exit shall not be obstructed and it shall be exposed to atmospheric pressure.

b) Apply the pressure slowly so that pressure enters the flow-control device’s exit ports in a slow but steady manner. It is important that pressure increases at a slow, steady rate to ensure that an accurate opening pressure measurement is obtained. Opening the gas pressure source too quickly can cause the pressure to override the opening pressure, resulting in a faulty opening pressure reading. The pressure rises to a point at which the flow-control device opens, as indicated by a slow, steady flow (a hissing sound) of gas exiting the flow-control device’s entrance.

c) The pressure at which this gas flow starts, as indicated by the gas source test block pressure-measuring device, is the flow-control device’s opening pressure.

J.4.5 Closing test for production-pressure-operated flow-control devices

The following test shall be performed.

a) Once the flow-control device is in the open position, close the flow-control device’s entrance test block control valve, thus blocking the test flow-control device’s inlet port.

b) Continue to supply gas through the exit test block control valve until pressure equalization occurs at a pressure equal to, or greater than, the calculated opening pressure.

c) Close the exit test block control valve. The inlet and exit pressures within the flow-control device can equalize and be monitored by both the inlet and exit test block pressure measuring devices.

d) Slowly open the inlet test block control valve to allow a slow, steady flow of gas to the inlet. Exhausting the gas pressure source too quickly can cause the pressure to override the closing pressure, resulting in a faulty closing pressure reading. As the gas is exhausted from the test fixture, the pressure declines on both the inlet and exit test block pressure-measuring devices until the flow-control device stem contacts the seat.

e) The pressure at which the exit pressure stops declining and the inlet pressure continues to decrease, as measured by the exit test block pressure-measuring device, is the flow-control device’s closing pressure.

Annex K
(normative)

Bellows actuation life cycle testing

K.1 General

This annex provides procedures that shall be followed for life-cycle testing of flow-control device bellows.

K.2 Requirements for design validation

K.2.1 Requirements for design validation, grades V3 and V2

There are no actuation life cycle test requirements for design validation, grades V3 and V2.

K.2.2 Requirements for design validation, grade V1

K.2.2.1 General

The actuation life cycle test requirements for design validation, grade V1, shall be as defined in K.2.2.2 to K.2.2.5. The following shall be successfully achieved:

a) manufacturer's defined testing and acceptance criteria;

b) requirements of Clauses K.3 and K.4 for the intended service life.

NOTE This test is applicable only to bellows-operated flow-control devices.

K.2.2.2 Number of test specimens

This test shall be conducted on a minimum of seven flow-control devices of each type. If more than one device of the original seven test devices does not meet the requirements of Clause K.4, an additional seven devices shall be selected and the entire test process shall be performed on the new devices.

K.2.2.3 Test procedure

This test shall be conducted in accordance with the procedures defined in Clause K.3.

K.2.2.4 Performance criteria

Each flow-control device shall be tested until the bellows fails. Failure shall be as defined in Clause K.4.

K.2.2.5 Documentation

The following specific additional documentation is required. (See 7.2 for design validation documentation requirements.)

a) The results of the test on all seven flow-control devices shall be reported. The average number of cycles to failure and the standard deviation shall be determined by calculating the average of the seven flow-control devices tested.

b) The minimum number of cycles to failure shall be determined by the flow-control device that failed with the fewest number of cycles. The number of cycles prior to failure for this flow-control device becomes the minimum number of cycles to failure.

c) The maximum number of cycles to failure shall be determined by using the flow-control device that failed with the greatest number of cycles. The number of cycles prior to failure for this flow-control device becomes the maximum number of cycles to failure.

K.3 Procedure for bellows actuation life cycle testing

K.3.1 Cycle test pressures

Determine the cycle pressures to ensure full open and full close. A probe test and load rate test in accordance with Annex H shall have previously been conducted at the supplier/manufacturer's maximum rated pressure. These data are used to determine the upper and lower test pressures.

K.3.2 Upper test pressure

The upper test pressure is determined by using the reciprocal of the load rate multiplied by the maximum total travel of the flow-control device. The load rate shall be determined based on the supplier/manufacturer's dome charge maximum. This value is then multiplied by 1,25 and added to a flow-control device dome set pressure of 6 895 kPa (1 000 psi). This value then becomes the minimum upper pressure that is applied during the life cycle test.

K.3.3 Lower test pressure

The lower test pressure is determined by multiplying the closing pressure of the flow-control device being tested by 0,75. This value then becomes the maximum lower pressure that is applied during the life cycle test.

K.4 Test measurements

K.4.1 General

The items in K.4.2 to K.4.5 shall be monitored and recorded in an electronic data acquisition system during the test.

K.4.2 Dome pressure failure criteria

The dome pressure shall be continuously recorded during the test. This pressure shall be used as an indicator of failure of the bellows. A change in the upper or lower dome pressure by more than 25 % of the initial values indicates that the bellows of the flow-control device in test have failed and shall be removed from the cycling test.

K.4.3 Cycle duration recording

The duration of each cycle shall be continuously recorded during the test. The duration of each cycle shall be a minimum of 30 s and a maximum of 120 s.

K.4.4 Operating pressure

The operating pressure shall be continuously recorded during the test. The pressure cycles between the minimum upper test pressure and the maximum lower test pressure.

K.4.5 Number of cycles

The number of cycles until failure shall be recorded.

K.5 Presentation of results

K.5.1 Average number of cycles to failure and standard deviation

The results on all seven flow-control devices shall be reported. The average number of cycles to failure and the standard deviation shall be determined by calculating the average of the seven flow-control devices tested.

K.5.2 Minimum number of cycles to failure

The minimum number of cycles to failure shall be determined by the flow-control device that failed with the fewest number of cycles. The number of cycles prior to failure for this flow-control device becomes the minimum number of cycles to failure.

K.5.3 Maximum number of cycles to failure

The maximum number of cycles to failure shall be determined by using the flow-control device that failed with the greatest number of cycles. The number of cycles prior to failure for this flow-control device becomes the maximum number of cycles to failure.

K.6 Test fixture

K.6.1 Data recording

The test fixture shall allow for data recording of the dome pressure, the operating pressure, the duration of each cycle and the number of cycles to failure. These data shall be recorded directly using an electronic data acquisition system.

K.6.2 Application of operating pressure

The operating pressure shall be cyclically applied by the use of hydraulic pressure within the range of the minimum operating pressure to the maximum operating pressure. The operating pressure shall be applied both above and below the seat simultaneously.

Annex L
(normative)

Erosion testing requirements

L.1 General

L.1.1 Erosion testing

This annex defines the requirements, procedures, and acceptance criteria for erosion testing of flow-control devices. Since erosion testing is a destructive test, it is required only for design validation.

L.1.2 Erosion test scope and method

The liquid flow test is conducted to determine the ability of the reverse-flow check and/or the flow-control device port to function properly after being subjected to a potentially erosive liquid flow. This testing requires facilities that can generate and record a liquid flow rate through the reverse-flow check or device port in the direction of nominal flow. This testing demonstrates that the device can withstand the erosion forces that can occur during normal unloading conditions.

The erosion testing facility requires a pump that can generate a sustained flow rate of 0,16 m^3/min (1 bbl/min). Any method of accomplishing this is acceptable. Upstream of the reverse-flow check, a flow rate meter and pressure-measuring device are required. The flow rate meter shall be capable of measuring the flow rate at an accuracy of ± 2 % with continuous readings at intervals not exceeding 10 s per reading.

L.2 Requirements for design validation

L.2.1 Requirements for design validation, grade V3

There are no erosion test requirements for design validation, grade V3.

L.2.2 Requirements for design validation, grades V2 and V1

L.2.2.1 General

The erosion test requirements for design validation, grades V2 and V1, shall be as defined below.

This test is not required if the flow-control device, once opened, is not intended to close and it has no reverse-flow check valve. This pertains, for example, to dump/kill valves.

Testing is performed in an open system with fresh water and no temperature constraints.

L.2.2.2 Number of test specimens

Testing shall be conducted on one flow-control device. This test does not establish where the device will fail. It demonstrates that the device can withstand the erosion forces that can occur during normal unloading conditions.

L.2.2.3 Test procedure

Conduct testing as specified in Clauses L.3 and/or L.4, as applicable.

L.2.2.4 Acceptance criteria

For acceptance, the flow-control device shall meet the acceptance criteria defined in Clause N.4.

L.2.2.5 Documentation

Report the results of the testing. (See 7.2 for design validation documentation requirements.)

L.3 Reverse-flow check erosion test

L.3.1 General

The reverse-flow check erosion test is conducted to determine the ability of the reverse flow check to function properly after being subjected to an erosive liquid flow. This test shall be conducted on one or more of the flow-control devices that passed the back-check leak test (see Annex I).

a) Prior to erosion testing, the reverse-flow check shall be tested to determine the ability to impede flow from the reverse direction. This is accomplished by performing the activation test in accordance with Clause I.7.

b) The reverse flow check shall be installed in the test fixture such that flow is initiated through the reverse-flow check in the direction that allows free flow.

c) The erosion test shall be conducted by initiating a flow of fresh water and adjusting the control valves or the pump such that a steady and continuous flow rate of 0,16 m^3/min (1 bbl/min) is achieved and maintained.

d) This flow rate shall be maintained until a total of at least 63,6 m^3 (400 bbls) of liquid has passed through the reverse-flow check.

e) The reverse-flow check shall be tested again to determine the ability to impede flow from the reverse direction. This is accomplished by performing the activation test in accordance with Clause I.7.

f) Maintain the differential pressure required to activate the reverse-flow check and record the pressure loss after a 10 min time span.

L.3.2 Erosion testing acceptance criteria

If the reverse-flow check is unable to maintain at least 90 % of the differential pressure required to activate it after the 10 min time span, the reverse-flow check fails the erosion test.

L.4 Port erosion test

L.4.1 General

The port erosion test is conducted to determine the ability of the flow-control device port/stem seat interface to function properly after being subjected to an erosive liquid flow. This test shall be conducted on one or more of the flow-control devices that passed the flow-control device port leak test following the steps below.

a) Prior to erosion testing, the flow-control device port shall be leak-tested in accordance with Clause N.4.

b) The flow-control device shall be installed in the test fixture such that flow is initiated through the port in the direction that allows free flow.

c) The erosion test shall be conducted by initiating a flow of fresh water and adjusting the control valves or the pump such that a steady and continuous flow rate of 0,16 m^3/min (1 bbl/min) is achieved and maintained.

d) This flow rate shall be maintained until a total of at least 63,6 m^3 (400 bbls) of liquid has passed through the flow-control device port.

e) The flow-control device port shall be leak-tested again in accordance with Clause N.4.

L.4.2 Erosion testing acceptance criteria

The flow-control device shall meet the acceptance criteria defined in N.4.5.

Annex M
(normative)

Shelf (bellows integrity) testing requirements for nitrogen-pressure-charged flow-control devices

M.1 General

The test described in this annex is defined for nitrogen-pressure-charged flow-control devices to determine the integrity of the pressure-containing element(s).

M.2 Requirements for design validation

M.2.1 Shelf testing requirements

M.2.1.1 General

The shelf test requirements for design validation grades V3, V2 and V1 shall be as defined in M.2.1.2 to M.2.1.5.

M.2.1.2 Number of test specimens

This test shall be conducted on a minimum of seven flow-control devices of each type.

M.2.1.3 Test procedure

The shelf test shall be conducted as defined in Clause M.3.

M.2.1.4 Acceptance criteria

The opening pressure shall not change by more than 1 %. If it changes by more than this amount, the test fails.

M.2.1.5 Documentation

Report the opening pressure at the beginning and conclusion of the test. (See 7.2 for design validation documentation requirements.)

M.3 Requirements for product functional testing

M.3.1 General

Before delivery to the user/purchaser, each pressure-charged flow-control device shall be tested according to the procedure as defined in M.3.2.

M.3.2 Requirements for product functional testing

M.3.2.1 General

The shelf test requirements for product functional testing grades F3, F2 and F1 shall be as defined in M.3.2.2 to M.3.2.5. Note that, for flow-control device VIII, this test is required only on chemical injection devices.

M.3.2.2 Number of test specimens

This test shall be conducted on 100 % of any job lot.

M.3.2.3 Test procedure

The shelf test shall be conducted as follows.

a) The test shall be conducted only on flow-control devices with pressure-charged bellows. There are no requirements for conducting shelf tests for flow-control devices with non-charged bellows. For these devices, the bellows integrity is determined during the ageing test as defined in Clause M.4.

b) Conduct the bellow stabilization procedure as defined in Clause M.4, with the flow-control device set to a minimum test-rack opening pressure of 5 516 gauge kPa (800 psig) at the supplier/manufacturer’s specified reference temperature.

c) The test-rack opening pressure and shelf date shall be recorded and the flow-control device shall then be placed on the shelf for a minimum of 5 days.

d) After 5 days on the shelf, the set pressure of each flow-control device shall be checked at the supplier/manufacturer's reference temperature.

M.3.2.4 Acceptance criteria

The opening pressure shall not change by more than 1 %. If it changes by more than this amount, the test fails.

M.3.2.5 Documentation

Report the opening pressure at the beginning and the conclusion of the test. (See 7.2 for design validation documentation requirements.)

M.3.3 Test equipment

The equipment used to set the opening pressure of the pressure-charged flow-control device shall be as defined in Annex J.

M.4 Flow-control device setting and bellows stabilization

M.4.1 Initial preparation

Remove the tail plugs and charge the bellows to a pressure charge of 344,7 gauge kPa (50 psig) greater than the supplier/manufacturer’s recommended pressure, P_{tro}, with a minimum P_{tro} of 5 516 gauge kPa (800 psig). Do not exceed the rated pressure of the flow-control device. Place the flow-control device in a constant temperature water bath for 15 min.

M.4.2 Initial pressure setting

Remove the flow-control device from the constant temperature water bath and insert it in a fixture.

CAUTION — Do not hold the flow-control device by the dome as that heats the dome and causes incorrect set pressures.

Apply gas pressure to open the flow-control device. Measure the pressure required to open the flow-control device. If it takes longer than 30 s to apply and measure the opening pressure, remove the flow-control device from the tester and return it to the constant temperature water bath to stabilize the temperature, and repeat this process.

M.4.3 Inspect/replace tail plug seals

Inspect all elastomeric seals used for pressure sealing of the tail plug. If metallic gaskets are used, replace the gaskets if required by supplier/manufacturer specifications. Inspect the sealing surfaces of the tail plug to ensure that all surfaces are smooth and free of debris. Install tail plugs to ensure proper sealing of the dome area.

M.4.4 First ageing sequence of the flow-control device

Place the flow-control device in the vertical position in the pressure chamber or ageing fixture with the tail-plug end up. Increase the pressure on the chamber to 34 473,8 gauge kPa (5 000 psig) and hold for a minimum of 5 min. Release the pressure and repeat the pressure/hold cycle two more times. Bleed down the chamber and remove the flow-control device. Remove the tail plug from the flow-control device and place it in the constant temperature water bath for a minimum period of 15 min.

M.4.5 Stage 2 — Set flow-control device pressure

Remove the flow-control device from the water bath and insert it in the tester. Do not hold the flow-control device by the dome as that heats the dome and causes incorrect set pressures. Apply gas pressure to open the flow-control device. Compare the initial recorded pressure to the new opening pressure. If the pressure declines by more than 172,4 kPa (25 psi), repeat the ageing cycle described in M.4.4. If it increases by more than 172,4 kPa (25 psi), the flow-control device could be defective and should be replaced and inspected.

Adjust the dome pressure to achieve the proper opening pressure, $P_{\mathrm{vo}T}$. If it takes longer than 30 s to obtain the desired opening pressure, remove the flow-control device from the tester and return it to the constant temperature water bath.

M.4.6 Inspect/replace tail plug seals

Inspect all elastomeric seals used for pressure sealing of the tail plug. If metallic gaskets are used, replace the gaskets if required by supplier/manufacturer specifications. Inspect the sealing surfaces of the tail plug to ensure all surfaces are smooth and free of debris. Install tail plugs to ensure the proper sealing of the dome area.

M.4.7 Age the flow-control device

Place the flow-control device in the vertical position in the pressure chamber or ageing fixture with the tail-plug end up. Increase the pressure on the chamber to 34 473,8 gauge kPa (5 000 psig) and hold it for a minimum of 5 min. Release the pressure and repeat the pressure/hold cycle two more times. Bleed down the chamber and remove the flow-control device. Remove the tail plug from the flow-control device and place it in the constant temperature water bath for a minimum period of 15 min.

M.4.8 Fine tune pressure setting

Remove the flow-control device from the constant temperature water bath, install it in a tester and check the opening pressure. If the opening pressure has changed by more than 34,5 kPa (5 psi), repeat the steps described in M.4.5 through M.4.7 until the pressure does not change by more than 34,5 kPa (5 psi).

M.4.9 Final flow-control device assembly and marking

Place a new copper gasket on the tail plug whenever the tail plug has been removed. Install the lower packing and inspect the flow-control device housing for any sharp surfaces. Inspect the reverse-flow check and check seal for proper fit, smooth movement and to ensure that it is free of debris. Assemble the checked flow-control device as specified in the supplier/manufacture's recommended procedure. Install the upper packing.

Annex N
(normative)

Conducting port/seat leakage rate testing

N.1 General

This annex contains requirements, procedures and acceptance criteria for conducting port and stem/seat interface leakage tests on flow-control devices.

N.2 Requirements for design validation

N.2.1 Port/seat leakage testing

N.2.1.1 General

The port and stem/seat interface leakage rate test requirements for design validation grades V3, V2 and V1 shall be as defined below.

N.2.1.2 Number of test specimens

This test shall be conducted on a minimum of seven flow-control devices of each type.

N.2.1.3 Test procedure

This test shall be conducted in accordance with the procedure defined in Clause N.4 and the following.

a) This test shall be conducted on the minimum and maximum port sizes of each type of device to be tested.

b) The leakage rates shall be determined and averaged.

N.2.1.4 Acceptance criteria

If the flow rate through any of the flow-control devices is greater than 1 SCMD (35 SCFD), the test has failed.

N.2.1.5 Documentation

The following specific additional documentation is required. (See 7.2 for design validation documentation requirements.)

Report the leak rate through each flow-control device and report the average leak rate of all devices tested.

N.3 Requirements for product functional testing

N.3.1 Port/seat leakage testing

N.3.1.1 General

The leakage rate test requirements for product functional testing grades F3, F2 and F1 shall be as defined in N.3.1.2 to N.3.1.5.

N.3.1.2 Number of test specimens

This test shall be conducted on 100 % of any job lot.

N.3.1.3 Test procedure

This test shall be conducted in accordance with the procedure defined in Clause N.4.

N.3.1.4 Acceptance criteria

If the flow rate through the flow-control device is greater than 1 SCMD (35 SCFD), the test has failed.

N.3.1.5 Documentation

The following specific additional documentation is required. (See 7.2 for design validation documentation requirements.)

Report the leak rate through each flow-control device.

N.4 Valve leakage test

N.4.1 Introduction

The test rack for this test shall have provisions for measuring low gas flow rates on the downstream side of the flow-control device. Figures N.1 and N.2 are examples of two such devices.

N.4.2 Test temperature

This test shall be conducted at ambient temperature.

N.4.3 Seat preparation

No visible oil, grease, water or other lubricating or sealing material shall be allowed on the stem and/or seat.

N.4.4 Conduct leakage test

The test shall be conducted per the following steps.

a) Determine the flow-control device opening pressure, $P_{\text{vo}T}$, with atmospheric pressure applied beneath the port of the device.

b) Calculate the flow-control device closing pressure, $P_{\text{vc}T}$.

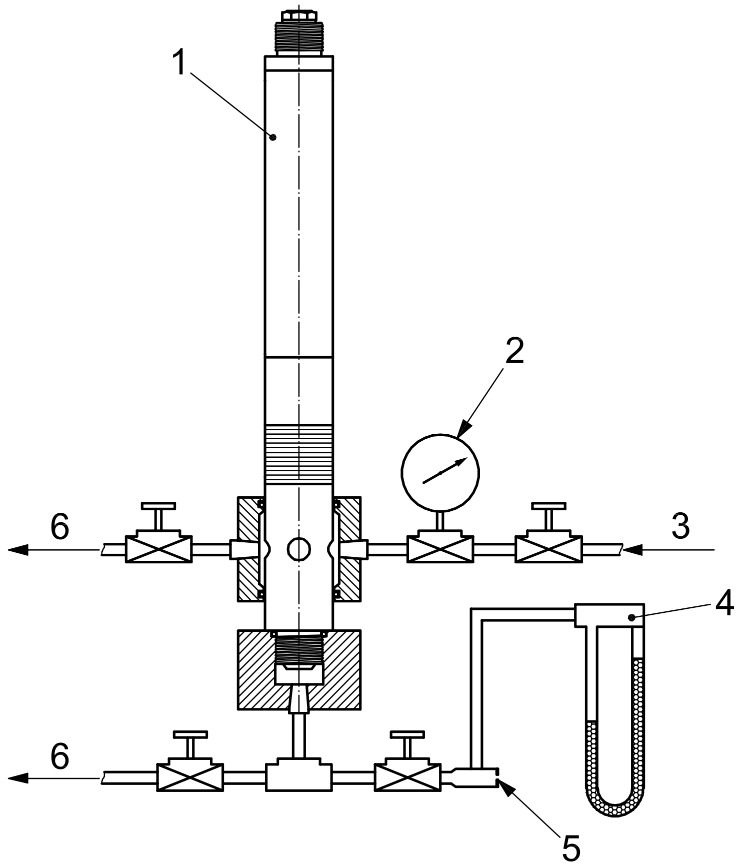
c) Open the flow-control device by applying an upstream pressure equal to $P_{\text{vo}T}$.

d) Close the flow-control device by reducing the upstream pressure equal to, or greater than, P_{vcT}.

e) Direct the downstream outlet of the flow-control device to a flow measurement device.

N.4.5 Acceptance criteria

If the flow rate through the flow-control device is greater than 1 SCMD (35 SCFD), the test has failed and the stem and seat shall be rejected.



Key

1 flow-control device

2 pressure gauge

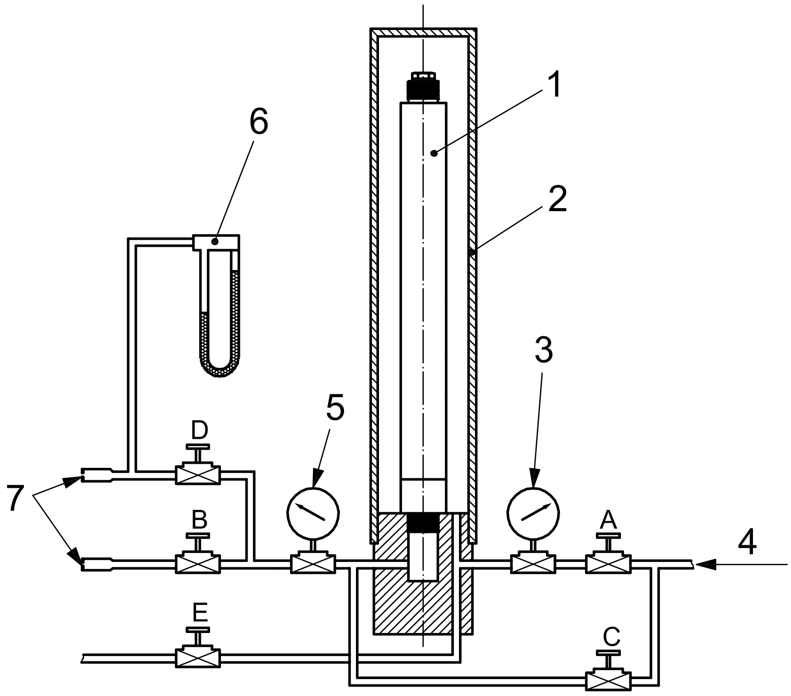
3 supply line

4 manometer

5 bleed orifice

6 bleed

Figure N.1 — Valve leakage test device — Option 1



Key

1 flow-control device

2 hood

3 pressure gauge (gas)

4 supply line

5 pressure gauge (production)

6 manometer

7 bleed orifice

Figure N.2 — Valve leakage test device — Option 2

Annex O
(informative)

Performance testing — Recommendations for a flow-control device performance test facility

O.1 General

This annex provides information for performance testing of flow-control devices. Specifically, it contains recommendations for a flow-control device performance test facility.

O.2 Test site recommendations

O.2.1 Introduction

Clause O.2 describes the equipment needed for testing flow-control devices to determine

a) the flow-control device flow coefficients, C_v,

b) the pressure drop ratio factor, $R_{p,crt}$,

c) the gas-lift flow-control device performance curves.

The type of testing defined here requires a high-volume, high-pressure source of gas. It is suggested that the gas storage device be at least 2,83 m^3 (100 ft^3) and the pressure be at least 10 432 gauge kPa (1 500 psig).

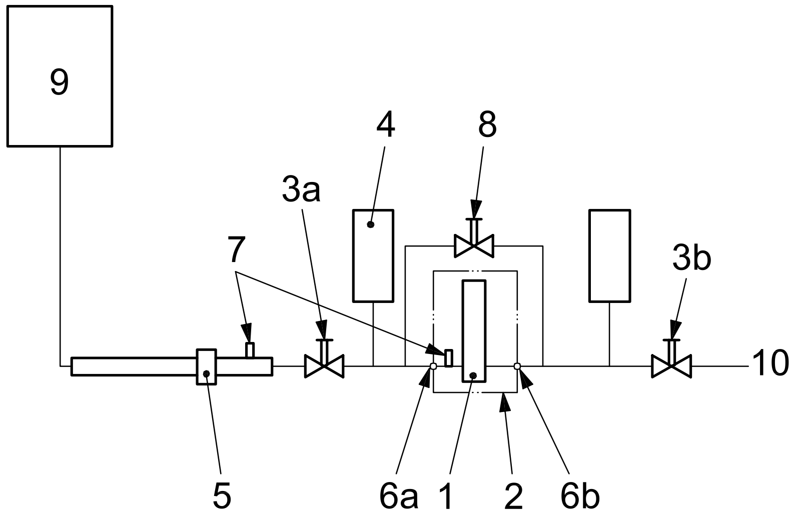
Applicable codes and practices shall be followed when constructing the test facility; the fabrication, testing and flow-control device selections shall comply with the codes governing piping systems and vessels. Surge or other vessels with diameters exceeding 152 mm (6 in) should adhere to the ANSI/ASME Boiler and Pressure Vessel Code, Section VIII. These rules provide requirements for the 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. Piping material should be specified as Grade B. Flanges should adhere to ANSI/ASME B16.5; flow-control devices are covered by ANSI/ASME B16.34. Note that API flow-control devices and flanges can be used but are covered by API Spec 6D (ISO 14313:2007). These API flanges might not be interchangeable with ANSI/ASME flanges.

The design pressure for piping, flow-control devices, flanges or pressure vessels is at least 20 % greater than the highest pressure anticipated during the tests. When tests are conducted using a test stand as described in this section, the maximum error associated with the calculation of the flow rate is 6 %.

O.2.2 General description

The flow test system includes, as a minimum, items shown in Figure O.1.



Key

1	test specimen	6a	upstream pressure tap
2	test section	6b	downstream pressure tap
3a	upstream control valve	7	temperature taps
3b	downstream control valve	8	equalizing control valve
4	pressure surge protection	9	source
5	flow meter	10	exhaust

Figure O.1 — Flow test system schematic

O.2.3 Test specimen — Wireline retrievable flow-control devices

The test specimen consists of the components listed in O.2.4 and shown in Figure O.2.

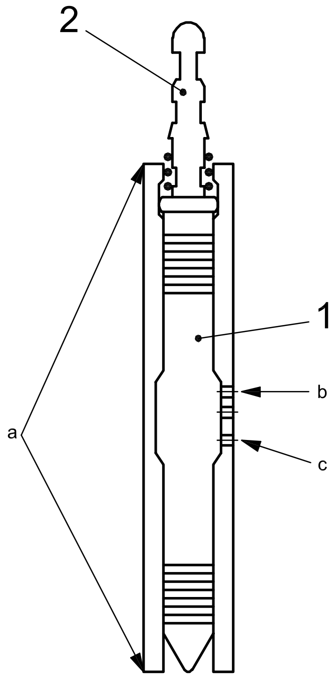
The specimen includes the fully assembled test flow-control device including the supplier/manufacturer's recommended reverse check valve. It includes a latch that is compatible with the receptacle and flow-control device. It is installed and latched in a compatible receptacle. Replacement of the external V-ring packing stacks with an alternate sealing means is permissible.

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

O.2.4 Test section

O.2.4.1 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 shall not pass through any chokes, close radius elbows or tees, and it shall be free of internal obstructions. Elbows shall have a minimum 10,16 cm (4 in) radius. Figure O.3 shows an example of a test section that complies with these requirements.



Key

1 fully assembled test valve

2 standard latch securely threaded to assembly valve

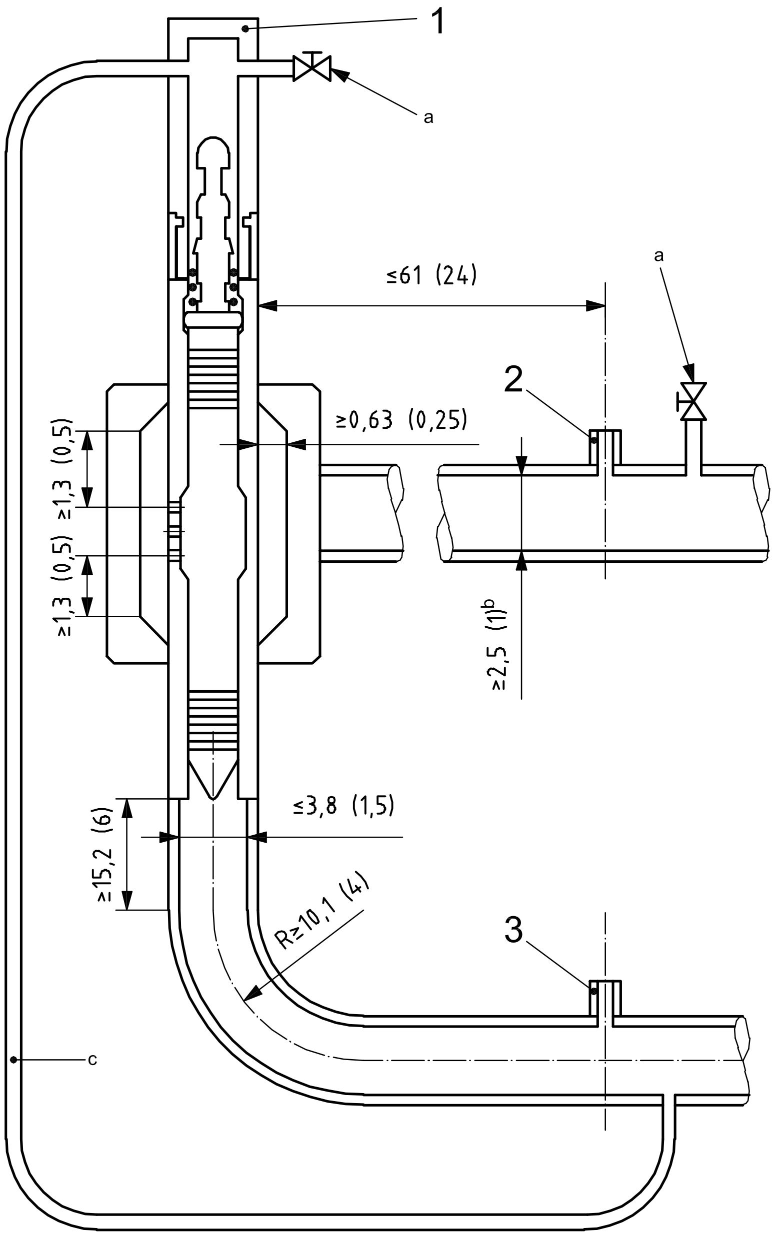
[a] Upper and lower end of pocket section may be modified.

[b] Record inlet-port area.

[c] Record annular-flow area.

Figure O.2 — Test specimen components

Dimensions in centimetres (inches)



Key

1 safety cap

2 upstream pressure and temperature sensors

3 downstream pressure and optional temperature sensors

a Bleed to atmosphere before removing valve (test specimen).

b ⩽ 61 cm (24 in) from test specimen.

c A pressure-equalizing line is recommended when using the safety cap.

Figure O.3 — Flow-control device performance test section — Example for wireline retrievable valves

O.2.4.2 Upstream test section

The test section upstream of the test specimen shall extend no more than 60,96 cm (24 in) from the test specimen and shall have a minimum inside flow diameter of at least 2,54 cm (1 in). The upstream test section shall be plumbed to the test specimen such that an unobstructed annular chamber exists surrounding the inlet ports of the test specimen. This chamber shall extend no less than 1,27 cm (1/2 in) above and below the inlet ports of the test specimen and should have an annular width of at least 0,64 cm (1/4 in).

O.2.4.3 Downstream test section

The test section downstream of the test specimen shall extend no more than 60,96 cm (24 in) from the test specimen and shall have an inside diameter of at least 3,81 cm (1,5 in). The downstream test section shall be aligned such that the centrelines of the specimen and section are parallel and concentric. The downstream test section should have a straight extension of at least 15,24 cm (6 in) in length beginning at the test specimen.

O.2.5 Throttling control valves

O.2.5.1 General

O.2.5 recommends procedures for performance testing of throttling flow-control devices.

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 valve.

O.2.5.2 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.

O.2.6 Pressure surge protection

O.2.6.1 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 can occur as a result of flow-control device performance. Pressure surge can cause serious damage to pressure measurement devices and transducers and seriously hamper the ability to control and monitor a test.

O.2.6.2 Surge tanks

Surge tanks shall be used to gain an adequate amount of surge protection. These tanks shall 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 can be placed in the plumbing connecting the pressure surge tanks to the test system.

The volume of the pressure surge tanks shall be no less than 0,057 m^3 (2 ft^3). It is recommended that the downstream pressure surge tank have twice the volume of the upstream pressure surge tank.

O.2.6.3 Alternative methods

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

O.2.7 Flow measurement methods and accuracy

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

Flow rate shall be determined within an error not exceeding ± 6 % of actual flow rate. The resolution and repeatability of the method shall be within ± 1 % of actual flow rate. These are satisfied by AGA Report No.8 methods of flow rate calculation, along with a certified meter run.

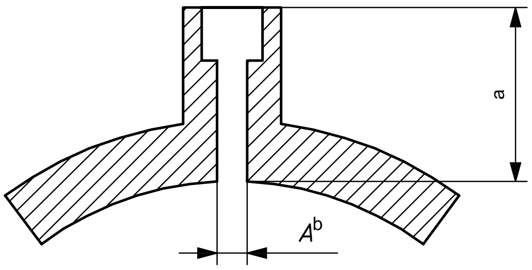
NOTE AGA Report No. 8 is equivalent to API MPMS, Chapter 14.2, and GPA 8185-90.

O.2.8 Pressure taps

O.2.8.1 General

O.2.8 recommends pressure tap locations and orientation.

Two pressure taps are required to measure 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 O.4. The edge hole shall be clean and sharp or slightly rounded, and free from burrs, wire edges or other irregularities. In no case shall any fitting protrude inside the pipe.



[a] Minimum distance, 2,5*A*; recommended distance, 5*A*.

[b] Dimensions of *A* as a function of pipe size:

Size of pipe cm (in)	*A*
< 5,08 (2)	0,063 5 ⩽ *A* ⩽ 0,317 5 (1/4 ⩽ *A* ⩽ 1/8)
5,08 to < 10,16 (2 to < 4)	0,952 5 ⩽ *A* ⩽ 0,317 5 (3/8 ⩽ *A* ⩽ 1/8)
10,16 to 20,32 (4 to 8 in)	1,27 ⩽ *A* ⩽ 0,317 5 (1/2 ⩽ *A* ⩽ 1/8)

Figure O.4 — Pressure tap geometry

O.2.8.2 Location and orientation

The upstream and downstream pressure taps should be located as near as possible to the test specimen but should be no more than 60,96 cm (24 in) from the test specimen.

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

O.2.9 Pressure measurement, accuracy, and reporting requirements

O.2.9 recommends pressure measurement requirements and reporting.

All pressure and differential pressure measurements shall be selected so that measurement errors do not exceed ± 1 % of actual value. Pressure-measuring devices shall be calibrated at least once every three months, or more frequently, if required, to maintain specified accuracy. The upstream and downstream test section pressure measurements shall be displayed continuously to the operators controlling the test pressures.

A hardcopy report of the pressures measured at both the upstream and downstream pressure taps of the test section shall be produced. The pressures shall be within an accuracy of ± 2 % of the pressure measurement devices.

O.2.10 Temperature taps, location, and orientation

O.2.10.1 General

O.2.10 recommends the location and orientation of temperature measurement taps. Two temperature taps are required, one on the upstream side of the test section and the other for the flow rate measurement device. An optional downstream temperature tap may be located on the downstream side of the test section.

O.2.10.2 Location and orientation

The upstream temperature tap shall be located on the upstream side of the test section. The temperature tap used for flow rate measurement shall be located as recommended by the supplier/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.

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

O.2.11 Temperature measurement, accuracy, and reporting requirements

Temperature measurements shall be accurate to ± 1,1 °C (± 2 °F) of actual value. The gas temperature shall be measured at the flow rate measurement device and on the upstream portion of the test section. Temperatures measured at both the flow rate measurement device and the upstream portion of the test section shall be reported to an accuracy of ± 2 % of the temperature being measured.

O.2.12 Equalizing valves

The upstream and downstream pressures shall be equalized prior to testing. The equalizing valve shall be positioned between the upstream and downstream test sections and shall provide the ability to bypass the test specimen.

O.2.13 Gas supply

Air or some other compressible gas shall be used as the fluid in this test procedure. Vapours that can approach their condensation points at the vena contracta of the test specimen are not acceptable. Avoid formation of liquids or solids in the gas supply during the test.

O.2.14 Documentation

The information listed below is required and shall be available to demonstrate compliance with the test results. Flow skid documentation form 1 can be used for this purpose. Test documentation shall meet the requirements of 7.2.

The information includes the following:

a) schematic identifying the layout and location of key items 1 to 10 in Figure O.1 and signed by the person in charge of the testing;

b) detailed drawing of the test section showing

    1) the distance from upstream test section to test specimen,

    2) the distance from downstream test section to test specimen,

    3) the number and size of receptacle inlet ports and annular flow area between flow-control device and receptacle for wireline retrievable fixtures,

    4) the location and size of annular chamber around test specimen,

c) type and capacity of throttling control valves;

d) type and size of surge protection;

e) type and accuracy of flow measurement device;

f) type and accuracy of pressure measurement devices;

g) type and accuracy of pressure recording hardcopy device;

h) type and accuracy of temperature measurement devices;

i) type and accuracy of temperature recording hardcopy device.

Flow skid documentation form 1		
Information required		
1	Provide schematic of test apparatus	
	Identify key items 1 to 10 in Figure O.1	
2	Attach detailed drawing of test section	
	Distance from test specimen to upstream pressure measurement device, expressed in centimetres (inches)	
	Distance from test specimen to downstream pressure measurement device, expressed in centimetres (inches)	
	Number of receptacle inlet ports	
	Diameter of receptacle inlet ports, expressed in centimetres (inches)	
	Annular flow area between FCD and receptacle, expressed in square centimetres (square inches)	
	Distance from OD of test specimen to ID of annular chamber around test specimen, expressed in centimetres (inches)	
	Distance from test specimen inlet ports to annular chamber seal, expressed in centimetres (inches)	
3	Upstream control valve description	
	Flow capacity of upstream control valve at full open position, expressed in cubic metres per day (thousands of cubic feet per day)	
	Downstream control valve description	
	Flow capacity of downstream control valve at full open position, expressed in cubic metres per day (thousands of cubic feet per day)	
4	Type of upstream pressure surge protection	
	Type of downstream pressure surge protection	
5	Type of flow measurement device	
	Accuracy of flow measurement device	
6	Upstream pressure measurement device	
	Accuracy	
	Downstream pressure measurement device	
	Accuracy	
	Differential pressure measurement device	
	Accuracy	
7	Method for reporting and recording pressure measurements	
	Accuracy for pressure measurement recording device	
8	Upstream temperature measurement device	
	Accuracy	
	Downstream temperature measurement device	
	Accuracy	
9	Method for reporting and recording temperature measurements	
	Accuracy of temperature measurement recording device	

Figure O.5 — Flow skid documentation form 1

Annex P
(informative)

Performance testing — Prediction correlations using a simplified flow-control device performance model

P.1 General

This annex contains recommended tests for developing flow-control device performance prediction correlations (see Clause P.2), a simplified flow-control device performance model (see Clause P.3), and a method for analysing probe test data (see Clause P.4).

P.2 Tests to develop performance correlations

P.2.1 General

The use of test data to predict flow-control device performance at conditions other than those tested requires the development of models or correlations. This annex describes the required tests and the performance of the tests. All or part of these tests can be used to develop a model. Suggestions on the quantity of tests required to develop a model are given in P.2.2 to P.2.5.

P.2.2 Probe tests

Annex G describes the procedure to determine a flow-control device's bellows assembly load rate, B_{lr}, and its maximum effective valve stem travel. Annex G also describes the number of tests and the set pressures to be tested.

P.2.3 Flow coefficient tests

Annex H describes the procedures to determine a flow-control device's flow coefficient, C_{v}, and pressure drop ratio factor, $R_{\mathrm{p,crt}}$, as a function of the maximum effective stem travel. The number of tests required to determine a flow-control device's full range of operation is recommended in Annex H. Annex H provides data applicable to any range of pressure and for any type of gas.

P.2.4 Performance tests

Annex H describes the procedures to obtain the dynamic performance characteristics of a flow-control device with a given set pressure. To obtain sufficient data to develop a model, additional tests are required at different set pressures. The test procedures described in Annex H shall be performed on a flow-control device at a minimum of three set pressures. Two of these set pressures shall be the supplier/manufacturer's minimum and maximum, which shall be separated by at least 1 379 gauge kPa (200 psig). For example, a flow-control device recommended for operation between 4 137 gauge kPa (600 psig) and 12 410 gauge kPa (1 800 psig) shall be tested at 4 137 gauge kPa (600 psig), 8 274 gauge kPa (1 200 psig), and 12 410 gauge kPa (1 800 psig) set pressures.

P.2.5 Use of test data

The test procedures described in the previous sections yield sufficient data to develop a model of flow-control device performance that can be used to predict gas passage at conditions other than those tested. An example model is presented in Clause P.3. Additional models are also possible.

The simplified model presented in Clause P.3 uses the test data collected as specified in Annex G. This model makes several assumptions concerning the stem position during flowing conditions and might not be appropriate for gas passage prediction under all circumstances. This simplified model does not require data collected in accordance with Annex H. If data are collected as described in Annex H, they can be used to modify the simplified model to account for the dynamic pressures occurring inside the valve and, thus, produce a more accurate model. A method for using data collected as described in Annex H to modify the simplified model is not presented in this part of ISO 17078.

P.3 Simplified flow-control device performance model

P.3.1 Simplified model

Clause P.3 presents a simplified flow-control device performance model. The model uses data collected as described in Annex G. It is based on the following assumptions.

a) The measured downstream pressure at the test section is assumed to work on the ball/seat interface contact area.

b) The areas acted upon by both upstream and downstream pressures remain constant.

c) The static force balance equation is used to determine the stem position.

The amount of error in calculated stem position increases as the port size increases. Accuracy of flow rate prediction is within approximately ± 30 % for ports of 0,48 cm (3/16 in) or less. This statement of accuracy is based on a limited comparison of tested flow-control devices from a 2,54 cm (1 in) IPO valve.

The simplified model can be improved by including data collected as described in Annex H to define more accurately the dynamic stem position during flowing conditions.

P.3.2 Determine stem position

Determine the flow-control device's static stem position, d_{st}, for the anticipated subsurface pressure and temperature conditions, using the static force balance equation as given in Equations (P.1) and (P.2), which include a term for the travel and load rate of the flow-control device. For example, the static force balance equation for a nitrogen- or spring-loaded flow-control device would be as follows:

$$P_{\mathrm{vc}T} \times A_{\mathrm{b}} + B_{\mathrm{lr}} \times A_{\mathrm{b}} \times d_{\mathrm{st}} = P_{\mathrm{iod}}\left(A_{\mathrm{b}} - A_{\mathrm{s}}\right) + P_{\mathrm{pd}} \times A_{\mathrm{s}} \qquad \text{(P.1)}$$

$$d_{\mathrm{st}} = \frac{P_{\mathrm{iod}}\left(A_{\mathrm{b}} - A_{\mathrm{s}}\right) + \left(P_{\mathrm{pd}} \times A_{\mathrm{s}}\right) - \left(P_{\mathrm{vc}T} \times A_{\mathrm{b}}\right)}{B_{\mathrm{lr}} \times A_{\mathrm{b}}} \qquad \text{(P.2)}$$

Equations (P.1) and (P.2) are valid for either metric (SI) or USC units.

P.3.3 Determine C_{v} and $R_{\mathrm{p,crt}}$

From the graph of C_{v} versus stem travel (see Figure H.6), read the flow coefficient, C_{v}, for the static stem travel computed in Clause H.9. From the graph of $R_{\mathrm{p,crt}}$ versus stem travel (see Figure H.7), read the pressure drop ratio factor, $R_{\mathrm{p,crt}}$, for the static stem travel computed in Clause H.9.

P.3.4 Calculate flow rate

Use Equation (P.3) to calculate flow rate, q_{gi}, expressed in SI units.

$$q_{gi} = 0{,}1 \times C_V \times \left(P_{iod} + 100{,}0\right) \times \left(F_Y\right) \times \left(\frac{R_p}{T_V \times S_g \times Z_1}\right)^{\frac{1}{2}} \tag{P.3}$$

where

q_{gi} is the flow rate, expressed in MSCMD;

P_{iod} is the operating injection gauge pressure at flow-control device depth, expressed in gauge kPa;

T_V is the temperature of flow-control device at depth, expressed in kelvin;

R_p is equal to the lesser of $\frac{P_{iod} - P_{pd}}{P_{iod} + 100{,}0}$ or $F_k R_{p,crt}$;

F_Y is equal to $1 - \left(\frac{R_p}{3F_k R_{p,crt}}\right)$ where $F_k = \frac{k}{1{,}40}$;

k is the ratio of specific heat of lift gas.

Use Equation (P.4) to calculate flow rate, q_{gi}, expressed in USC units.

$$q_{gi} = 32{,}64 \times C_V \left(P_{iod} + 14{,}7\right) \times F_Y \times \left(\frac{R_p}{T_V S_g Z_1}\right)^{\frac{1}{2}} \tag{P.4}$$

where

q_{gi} is the flow rate, expressed in MSCFD;

P_{iod} is the operating injection gauge pressure at flow-control device depth, expressed in pounds per square inch;

T_V is the temperature of flow-control device at depth, expressed in degrees Rankine;

R_p is equal to the lesser of $\frac{P_{iod} - P_{pd}}{P_{iod} + 100{,}0}$ or $F_k R_{p,crt}$;

F_Y is equal to $1 - \left(\frac{R_p}{3F_k R_{p,crt}}\right)$ where $F_k = \frac{k}{1{,}40}$;

k is the ratio of specific heat of lift gas.

P.3.5 Example of use of simplified method

P.3.5.1 General

Assume a 2,54 cm (1 in) IPO valve with a 0,476 cm (3/16 in) port and the following parameters:

- upstream pressure: $P_{\text{iod}} = 6\,378$ gauge kPa (925 psig);
- downstream pressure: $P_{\text{pd}} = 3\,103$ gauge kPa (450 psig);
- $P_{\text{tro}} = 5\,688$ gauge kPa (825 psig);
- temperature at depth: $T_{\text{v}} = 65{,}6$ °C (150 °F);
- specific gravity of the gas: $k = 0{,}65$;
- load rate at 65,6 °C (150 °F) per manufacturer/supplier data: $B_{\text{lr}} = 2\,538$ kPa/cm (935 psig/in).

Figure H.6 can be used as the flow coefficient curve and Figure H.7 can be used for the critical pressure ratio curve. The example calculations in P.3.5.2 to P.3.5.4 are for illustration purposes only.

P.3.5.2 Determine stem position

Compute $P_{\text{vo}T}$ at a temperature of 65,6 °C (150 °F), using the approximation given in Equation (P.5).

$$P_{\text{vo}T} = \frac{P_{\text{tro}}(Z_1)(\text{T}_{\text{v}} + 273{,}15)}{15{,}6 + 273{,}15} \qquad \left[P_{\text{vo}T} = \frac{P_{\text{tro}}(Z_1)(\text{T}_{\text{v}} + 460)}{60 + 460}\right] \tag{P.5}$$

$$= \frac{5\,688 \times 0{,}95 \times (65{,}6 + 273{,}15)}{15{,}6 + 273{,}15} \qquad \left[= \frac{825 \times 0{,}95 \times (150 + 460)}{60 + 460}\right]$$

$$= 6\,339 \text{ gauge kPa} \qquad (= 919 \text{ psig})$$

Alternatively, if a supplier/manufacturer's temperature correction chart is available, this can be used rather than the approximation given in Equation (P.5). Also, a chart of the compressibility factor for nitrogen can be used to determine Z_1.

$P_{\text{vc}T}$ at a temperature of 65,6 °C (150 °F) can be calculated using Equation (P.6) and the results of the approximation from Equation (P.5):

$$P_{\text{vc}T} = \frac{P_{\text{vo}T}(A_{\text{b}} - A_{\text{s}})}{A_{\text{b}}} \qquad \left[P_{\text{vc}T} = \frac{P_{\text{vo}T}(A_{\text{b}} - A_{\text{s}})}{A_{\text{b}}}\right] \tag{P.6}$$

$$= \frac{6\,339\,(2 - 0{,}178)}{2} \qquad \left[= \frac{919\,(0{,}31 - 0{,}027\,6)}{0{,}31}\right]$$

$$= 5\,775 \text{ gauge kPa} \qquad (= 837{,}5 \text{ psig})$$

Use the static force balance equation to compute a stem position. At a $P_{\text{vc}T}$ of 5 775 gauge kPa (837,5 psi), this flow-control device has a load-rate of 2 538 gauge kPa/cm (935 psig/in). Use the flow-control device supplier/manufacturer's tested load rate at temperature. This flow-control device has an effective stem travel of 0,216 cm (0,085 in).

Using Equation (P.2):

$$d_{st} = \frac{6\,378(2-0{,}178)+(3\,103\times 0{,}178)-(5\,775\times 2)}{2\,538\times 2} \quad \left[= \frac{925(0{,}31-0{,}027\,6)+(450\times 0{,}027\,6)-(837{,}5\times 0{,}31)}{935\times 0{,}31} \right]$$

$$= 0{,}123 \qquad (= 0{,}048)$$

The computed stem travel, d_{st}, equal in this case to 0,123 cm (0,048 in), cannot exceed the maximum effective stem travel, LST, equal to 0,216 cm (0,085 in). However, when the computed stem travel is greater than the LST, then the LST should be used instead of d_{st} in the equations given in P.3.5.3 and P.3.5.4.

P.3.5.3 Determination of C_v and $R_{p,crt}$

To determine the flow coefficient, C_v, use the supplier/manufacturer curves in Figure H.6 for a stem travel as calculated above of 0,123 cm (0,048 in).

Read $C_v = 0{,}7$.

To determine the critical pressure ratio factor curve, $R_{p,crt}$, use the curve in Figure H.7 for a stem travel as calculated above of 0,123 cm (0,048 in).

Read $R_{p,crt} = 0{,}63$.

P.3.5.4 Determination of the flow rate, q_{gi}

P.3.5.4.1 Calculate the pressure ratio, R_p

$$R_p = \frac{(P_1 - P_2)}{(P_1 + 100)} \qquad \left[R_p = \frac{(P_1 - P_2)}{(P_1 + 14{,}7)} \right] \tag{P.7}$$

$$= \frac{6\,378 - 3\,103}{6\,378 + 100} \qquad \left(= \frac{925 - 450}{925 + 14{,}7} \right)$$

$$= 0{,}505 \qquad (= 0{,}505)$$

P.3.5.4.2 Determine whether the flow-control device is critical

If R_p is greater than $R_{p,crt}$, then the flow-control device is in critical flow and $R_{p,crt}$ shall be used rather than R_p to compute flow rate. In this example, $R_{p,crt} = 0{,}63$, which is greater than the actual pressure ratio, R_p, which is equal to 0,505. Therefore, the valve is not in critical flow and R_p shall be used in Equations (P.8) and (P.9).

P.3.5.4.3 Compute the expansion factor, F_Y

$$F_Y = 1 - \frac{R_p}{3 F_k R_{p,crt}} \qquad \left[F_Y = 1 - \frac{R_p}{3 F_k R_{p,crt}} \right] \tag{P.8}$$

$$= 1 - \frac{0{,}505}{3\times\left(\frac{1{,}3}{1{,}4}\right)\times 0{,}63} \qquad \left[= 1 - \frac{0{,}505}{3\times\left(\frac{1{,}3}{1{,}4}\right)\times 0{,}63} \right]$$

$$= 0{,}712 \qquad (= 0{,}712)$$

P.3.5.4.4 Determine the compressibility factor, Z_1

Determine the compressibility factor for natural gas at 6 378 gauge kPa (925 psig) and 65,5 °C (150 °F), either by calculation or from a chart.

$$Z_1 = 0{,}95$$

P.3.5.4.5 Calculate the flow rate, q_{gi}

The flow rate is calculated as given in Equation (P.9). If R_p is greater than $R_{p,crt}$, then $R_{p,crt}$ shall be used to compute the flow rate. Otherwise, use R_p.

$$q_{gi} = 0{,}1 \times C_v \times \left(P_{iod} + 100\right) \times F_Y \times \sqrt{\frac{R_p}{\left(T_v + 273{,}15\right) S_g Z_1}} \tag{P.9}$$

$$= 0{,}1 \times 0{,}70 \times \left(6\,378 + 100\right) \times 0{,}712 \times \sqrt{\frac{0{,}505}{\left(65{,}6 + 273{,}15\right) \times 0{,}65 \times 0{,}95}}$$

$$= 17{,}72 \text{ MSCMD}$$

$$\left[q_{gi} = 32{,}64 \times C_v \times \left(P_{iod} + 14{,}7\right) \times F_Y \times \sqrt{\frac{R_{p,crt}}{\left(T_v + 460\right) S_g Z_1}}\right]$$

$$\left[= 32{,}64 \times 0{,}70 \times \left(925 + 14{,}7\right) \times 0{,}712 \times \sqrt{\frac{0{,}505}{\left(150 + 460\right) \times 0{,}65 \times 0{,}95}}\right]$$

$$\left(= 625 \text{ MSCFD}\right)$$

P.4 Method to analyse probe test data

P.4.1 General

A simple calculation technique is given for determining load rate and LST for a flow-control device. The data values needed to perform this calculation are measured during the probe test as described in Annex G. Applying this technique yields a consistent, reproducible value for load rate and LST. Also, this technique can be programmed to run on a computer.

P.4.2 Assumptions

The following assumptions are utilized.

a) At least four data points of measured values are required.

b) Each data point in the set shall consist of a unique stem-travel value/system-pressure-value pair.

NOTE Ignore early data point in the set of measured data if these points show a large (almost infinite) increase in slope at the smallest values of stem travel.

c) Starting at the smallest value of stem travel and system pressure, all points in the data set shall continually increase.

d) All data below the point of LST are fit to a linear relationship ($y = m_A x + b_A$). Also all data above this point are fit to a separate linear relationship ($y = m_B x + b_B$), where m_A and m_B are the slopes of these two lines and b_A and b_B are the y intercepts.

e) The measured slopes and intercepts shall be unique, i.e. m_A shall not equal m_B, and b_A shall not equal b_B.

P.4.3 Hysteresis

Data measured from both increasing and decreasing system pressures commonly show some hysteresis in the data. Possible cause(s) have not been documented by the industry. A suggested way to handle multiple data sets is to analyse each data set separately and calculate average values for load rate and LST.

P.4.4 Calculation procedure

The probe test data are graphed using a linear x-y plot. The values of system pressure are plotted on the vertical (y) axis and the values of stem travel are plotted on the horizontal (x) axis. Assume that there are n data points in the set.

a) Sort data from lowest to highest values for valve stem travel. Data point 1 has the lowest value of stem travel and point n has the highest.

b) Use the last two data points to define an initial approximation for line B. Calculate the slope and intercept as given in Equations (P.10) and (P.11), respectively.

$$m_B = \frac{y_n - y_{n-1}}{x_n - x_{n-1}} \quad \text{(P.10)}$$

$$b_B = y_n - (m_B x_n) \quad \text{(P.11)}$$

where n is the number of data points in the set.

c) If the data set contains only four data points, then calculate the slope and intercept of line A as given in Equations (P.12) and (P.13), respectively.

$$m_A = \frac{y_2 - y_1}{x_2 - x_1} \quad \text{(P.12)}$$

$$b_A = y_1 = (m_A x_1) \quad \text{(P.13)}$$

d) If there are more than four data points, determine to which line the next (n – 2) data point belongs. Perform linear regression on data points (n – 2, n – 3, n – 4, ... 1) to calculate m_A and b_A for the line A defined as $y = m_A x + b_A$.

e) Calculate the shortest distance from point (n – 2) to lines A and B using the following equations, where i = A for line A and i = B for line B, as given in Equations (P.14) to (P.19):

$$x_i = \frac{y_{n-2} - b_i}{m_i} \quad \text{(P.14)}$$

$$y_i = m_i x_{n-2} + b_i \quad \text{(P.15)}$$

$$x = |x_i - x_{n-2}| \quad \text{(P.16)}$$

$$y = |y_i - y_{n-2}| \quad \text{(P.17)}$$

$$a = \tan^{-1}\left(\frac{y}{x}\right) \qquad \text{(P.18)}$$

$$d = x \sin(a) \qquad \text{(P.19)}$$

where d is the shortest distance between point $(n-2)$ and line i.

f) If the distance between line B and point $(n-2)$ is less than the distance between line A and point $(n-2)$, assume $(n-2)$ belongs to line B. Otherwise assume point $(n-2)$ belongs to line A.

g) Perform linear regression analysis again to re-compute the slope and intercept of lines A and B. Include the $(n-2)$ data point in the appropriate line as determined in step f).

h) Repeat steps d), e), f) and g) for data points $(n-3, n-4, n-5, \ldots 3)$ in place of the $(n-2)$ data point until a point belonging to line A is found.

NOTE In most cases the number of data points used to define line B is smaller than the points used to define line A. By starting with the $(n-2)$ data point and working backwards towards data point 3, the total number of required calculations can be minimized.

i) Calculate the x value for the point of intersection between lines A and B using Equation (P.20) (see also Figure G.5):

$$d_{\mathrm{LST}} = \frac{b_{\mathrm{B}} - b_{\mathrm{A}}}{m_{\mathrm{A}} - m_{\mathrm{B}}} \qquad \text{(P.20)}$$

where the value of the slope, m_{A}, of line A is the load rate.

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