

Operator and Mounting Kits for Subsea Pipeline Valves

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Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, standards@api.org.

Contents

	Page
1 Scope.....	1
2 Normative References	1
3 Terms, Definitions, Acronyms, Abbreviations, Symbols, and Units	3
3.1 Terms and Definitions	3
3.2 Acronyms, Abbreviations, Symbols, and Units	8
4 Operator Types and Configurations	9
4.1 General	9
4.2 Action on Loss of Supply Energy	10
4.3 Actuator Types	10
4.4 Actuator Configuration	10
4.5 Gearboxes	10
5 Design.....	11
5.1 Design Input.....	11
5.2 Design Standards and Calculations.....	13
5.3 Design Requirements	14
5.4 Pressure-containing Parts	15
5.5 Pressure Boundary Bolting and Tie Rod Design	15
5.6 Mechanically Loaded Parts.....	16
5.7 Springs and Spring Modules.....	16
5.8 Mounting Kit.....	17
5.9 Drive Trains.....	17
5.10 Design Documents	18
5.11 Sealing.....	19
5.12 Fluid Requirements.....	20
5.13 Compensation System.....	21
5.14 Lubrication	24
5.15 Retrievable Operators.....	24
5.16 Operator Override	28
5.17 Mechanical Advantage.....	29
5.18 Lifting Arrangements.....	29
5.19 Remotely Operated Tool System	31
5.20 Input Interface Operation Strength	32
5.21 Handwheels and Levers	33
5.22 Location and Orientation.....	33
5.23 Environmental and Operational Conditions	34
5.24 Actuator Hydraulic Input	34
5.25 Water Depth Performance	34
5.26 Corrosion Resistant Overlay.....	34
5.27 Cathodic Protection	34
5.28 Overpressure Protection.....	35
5.29 Hydraulic Connections.....	35
5.30 Electrical Connections	35
5.31 Wet and Dry Thermal Insulation	35
5.32 Instrumentation and Accessories.....	35
5.33 Position Indication.....	36
5.34 Travel Stops.....	36
5.35 Assembly Practice	37

Contents

	Page
6 Materials	37
6.1 Material Specification	37
6.2 Tensile Test Requirements	38
6.3 Service Compatibility	38
6.4 Cast Material	38
6.5 Forged Material	38
6.6 Composition Limits	38
6.7 Impact Test Requirements	40
6.8 Pressure Boundary Bolting	41
6.9 Cathodic Protection	41
6.10 Hydrogen-induced Cracking	42
6.11 Heat-treating Equipment Qualification	42
7 Welding	43
7.1 Welding Consumables	43
7.2 Welding Procedure and Welder/Welding Operator Qualifications	43
7.3 Impact Testing	44
7.4 Hardness Testing	45
7.5 Repairs	46
7.6 Repair of Welds	46
7.7 Structural Welding	46
8 Quality Control	47
8.1 Conformance with Standard	47
8.2 Processes Requiring Validation	47
8.3 Quality Control Procedures	47
8.4 NDE Requirements	47
8.5 Measuring and Test Equipment	48
8.6 Qualification of Personnel	49
8.7 Welding Inspectors	50
8.8 NDE of Repairs	50
8.9 Production Material Hardness Testing on Critical Parts	50
8.10 Marking, Age Control, and Storage for Nonmetallic Seals	50
9 Sizing Methodology	51
9.1 Sizing Method	51
9.2 Design and Sizing Output Data	52
10 Testing	53
10.1 Validation	53
10.2 Effect of Changes in Product	54
10.3 Factory Acceptance Test	54
10.4 Certification	58
11 Surface Protection	58
12 Marking	58
13 Preparation for Shipment	59
14 Documentation	60

Contents

	Page
14.1 Provided to Purchaser	60
14.2 Documentation Provided with the Operator	60
Annex A (informative) Optional Documentation.....	61
Annex B (normative) Purchasing Guidelines.....	62
Annex C (normative) Record Retention.....	64
Annex D (informative) Design Validation—Actuator	65
Annex E (informative) Design Validation—Gearbox.....	74
Annex F (informative) Hyperbaric Validation Testing.....	81
Annex G (normative) Requirements for Nondestructive Examination	84
Annex H (informative) Castings and Forgings.....	89
Annex I (normative) Qualification of Heat-treating Equipment	90
Bibliography.....	93

Figures

1	Relationship Between Design, Rated and Supply Pressures	14
2	Retrievable Actuator Types	25
3	Part-turn Retrievable Operator Terminology	26
4	Type 1 Lifting	30
5	Type 2 Lifting	30
6	Type 3 Lifting	31
7	Handwheel Interface	33
8	Charpy V-notch Weld Metal Specimen Location.....	45
9	Charpy V-notch Heat-affected Zone Specimen Location.....	45
D.1	Test Procedure for Pressure Temperature Cycle	72
E.1	Test Procedure for Temperature Cycle	80
I.1	Temperature Sensor Location—Rectangular Furnace (Working Zone).....	91
I.2	Temperature Sensor Locations—Cylindrical Furnace (Working Zone).....	91

Tables

1	Description and Functionality of Mechanical Override Systems	28
2	Handwheel Interface Applied Forces	33
3	Minimum V-notch Impact Requirements for Carbon and Low-alloy Steels (Full-size Specimen).....	40
4	Minimum V-notch Impact Requirements for Duplex and Super Duplex Stainless Steel (Full-size Specimen).....	40

Contents

	Page
5 Chemical Composition of Nickel-based Alloy UNS N06625	44
6 Marking of Electric Actuators	59
7 Marking of Hydraulic Actuators	59
8 Marking of Gearbox	59
B.1 Actuator Data Sheet	62
C.1 Record Retention	64
D.1 Design Validation for Actuator	68
E.1 Design Validation for Gearbox	77
F.1 Hyperbaric Qualification Test	81
G.1 NDE Requirements	87
G.2 Extent, Method, and Acceptance Criteria of NDE/Item Examination Code	87

Introduction

It is necessary that users of this document be aware that further or differing requirements can be needed for individual applications. This document is not intended to inhibit a vendor from offering or the purchaser from accepting alternative equipment or engineering solutions for the individual application. This can be particularly applicable where there is innovative or developing technology. Where an alternative is offered, it is the responsibility of the vendor to identify any variations from this document and provide details.

Units of measurement

In this specification, data are expressed in both SI and USC units.

Rounding

Except as otherwise required by this specification, to determine conformance with the specified requirements, observed or calculated values are rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding method of ASTM E29 or ISO 80000–1.

Operator and Mounting Kits for Subsea Pipeline Valves

1 Scope

This standard defines the requirements for design, mechanical integrity, and sizing of operators and related components used on subsea pipeline valves that conform to API Specification 6DSS.

This standard is applicable to the following:

- electric actuators;
- electro-hydraulic actuators;
- hydraulic actuators;
- actuator override systems;
- diver and remotely operated tool (ROT)-operated gearboxes;
- other actuators, by agreement;
- mounting kit;
- pressure and volume compensation and associated systems;
- pressure caps;
- protection covers; electrohydraulic
- position indication systems.

This standard is not applicable to the following:

- manual or powered torque tools not permanently mounted;
- actuator control system equipment/components;
- remote-located units.

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies.

API Specification 6DSS, *Specification for Subsea Pipeline Valves*

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

API Recommended Practice 17H, *Remotely Operated Tools and Interfaces on Subsea Production Systems*

API Recommended Practice 17U, *Recommended Practice for Wet and Dry Thermal Insulation of Subsea Flowlines and Equipment*

ASME. *Boiler and Pressure Vessel Code (BPVC)*,¹ Section V: Nondestructive Examination

ASME. *Boiler and Pressure Vessel Code (BPVC)*, Section VIII: Rules for Construction of Pressure Vessels; Division 1: Rules for Construction of Pressure Vessels

ASME. *Boiler and Pressure Vessel Code (BPVC)*, Section VIII: Rules for Construction of Pressure Vessels; Division 2: Alternative Rules

ASME. *Boiler and Pressure Vessel Code (BPVC)*, Section IX: Welding and Brazing Qualifications

ASNT SNT-TC-1A,² *Recommended Practice No. SNT-TC-1A—Personnel Qualification and Certification in Non-Destructive Testing*

ASTM A320,³ *Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service*

ASTM A370, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM A578/A578M, *Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications*

ASTM A609/A609M, *Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof*

AWS QC1,⁴ *Standard for AWS Certification of Welding Inspectors*

EN 287-1,⁵ *Qualification test of welders—Fusion welding—Part 1: Steels*

ISO 4406,⁶ *Hydraulic fluid power—Fluids—Method for coding the level of contamination by solid particles*

ISO 148-1, *Metallic materials—Charpy pendulum impact test—Part 1: Test method*

ISO 5817, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded)—Quality levels for imperfections*

ISO 6892-1, *Metallic materials—Tensile testing—Part 1: Method of test at room temperature*

ISO 9606-1, *Approval testing of welders—Fusion welding—Part 1: Steels*

ISO 9712, *Non-destructive testing—Qualification and certification of personnel*

ISO 15156 (all parts), *Petroleum and natural gas industries—Materials for use in H₂S-containing environments in oil and gas production*

ISO 15607, *Specification and qualification of welding procedures for metallic materials—General rules*

ISO TR 15608:2013, *Welding—Guidelines for a Metallic Materials Grouping System*

¹ American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990, www.asme.org.

² American Society for Nondestructive Testing International Service Center, PO Box 28518, 1711 Arlingate Lane, Columbus, OH, 43228-0518, www.asnt.org.

³ ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, www.astm.org.

⁴ American Welding Society, 8669 NW 36 Street, # 130, Miami, Florida 33166-6672, www.aws.org.

⁵ European Committee for Standardization, CEN-CENELEC Management Centre, Rue de la Science 23, B-1040 Brussels, Belgium, www.cen.eu.

⁶ International Organization for Standardization, ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org.

ISO 15609 (all parts), *Specification and qualification of welding procedures for metallic materials—Welding procedure specification*

ISO 15614-1, *Specification and qualification of welding procedures for metallic materials—Welding procedure test—Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys*

ISO 15614-7, *Specification and qualification of welding procedures for metallic materials—Welding procedure test—Part 7: Overlay welding*

SAE AS4059,⁷ *Aerospace Fluid Power—Cleanliness Classification for Hydraulic Fluids*

MSS SP-55,⁸ *Quality Standard for Steel Castings for Valves, Flanges, Fittings and Other Piping Components, Visual Method for Evaluation of Surface Irregularities*

MSS SP-101, *Part-Turn Valve Actuator Attachment, FA Flange and Driving Component Dimensions and Performance Characteristics*

MSS SP-102, *Multi-Turn Valve Actuator Attachment, Flange and Driving Component Dimensions and Performance Characteristics*

NACE MR0175 (all parts),⁹ *Petroleum and natural gas industries—Materials for use in H₂S-containing environments in oil and gas production*

3 Terms, Definitions, Acronyms, Abbreviations, Symbols, and Units

3.1 Terms and Definitions

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

3.1.1

actuator

Electric or hydraulic device bolted or otherwise attached to the valve for powered opening and closing of the valve.

3.1.2

actuator (linear)

Actuator that transmits thrust to the valve for a defined linear stroke.

3.1.3

actuator (multi-turn)

Actuator that transmits torque to the valve for a rotation for at least one revolution.

3.1.4

actuator (part-turn)

Actuator that transmits torque to the valve for a rotation of less than one revolution.

3.1.5

breakaway angle

breakaway percent of stroke

Point at which the closure member breaks/makes sealing contact with the seat.

⁷ Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096, www.sae.org.

⁸ Manufacturers Standardization Society of the Valve and Fittings Industry, Inc, 127 Park St. NE | Vienna, VA, 22180-4602, msshq.org.

⁹ NACE International, 15835 Park Ten Place, Houston, Texas 77084, www.nace.org

3.1.6**by agreement**

Agreed between manufacturer and/or supplier and/or purchaser.

3.1.7**compensation**

Design feature that provides pressure balance to environment and allows volume change resulting from one or more of the following: valve actuator movement, temperature change, and relative densities of seawater vs compensation fluid during deployment.

3.1.8**compensation fluid**

Medium that is used in the compensation system at the design temperature range and ambient temperature range.

3.1.9**coupling**

Driven component (drive adapter, drive tube, drive shaft) that allows transmission of torque and/or thrust from an operator driving component to the valve shaft/stem.

3.1.10**critical parts**

Minimally, those defined in 5.4 (pressure-containing) and 5.5 (pressure boundary bolting).

3.1.11**cycle**

Operation from the fully closed to fully open and return to the closed position or operation from the fully open to fully closed and return to the open position.

3.1.12**drive train**

Parts in the operator and mounting kit designed to provide the transmission of torque/thrust, not including the valve stem.

3.1.13**gearbox**

Mechanical torque and/or thrust multiplying/reducing device used to operate a valve.

3.1.14**gearbox, multi-turn**

Gearbox that transmits torque to the valve for at least one revolution.

3.1.15**gearbox, part-turn**

Gearbox that transmits torque to the valve for less than one revolution.

NOTE A part-turn gearbox does not have to be capable of withstanding thrust.

3.1.16**intermediate support (mounting spool)**

Structural component (e.g. bracket, pipe, adapter flange) that connects the actuator to the valve.

3.1.17**manufacturer**

Organization that produces equipment that meets the requirement of this standard.

3.1.18

maximum allowable stem torque/thrust

MAST

Maximum torque/thrust that is permissible to apply to the valve drive train without risk of damage, as defined by the valve manufacturer or supplier of the valve.

3.1.19

mechanically loaded parts

Operator parts that are designed to generate, multiply, and/or transmit torque or thrust.

3.1.20

mounting kit

Components that may be made of combinations of the following: mounting spool, drive shaft, drive key, dowel pin, and bolting.

3.1.21

closure member

Part of a valve, such as a ball, clapper, disc, gate, or plug, that is positioned in the flow stream to permit or prevent flow.

NOTE Other documents may use the term “obturator” as synonymous to closure member.

3.1.22

operator

Device (or assembly) for opening or closing a valve; includes gearbox, actuator, and direct drive devices.

EXAMPLE Direct mount handwheel or lever.

3.1.23

pressure cap

Pressure-containing part designed to contain internal pressure and withstand external pressure to prevent water ingress.

3.1.24

pressure-containing parts

Parts that are designed to contain pressurized process fluid and/or pressurized subsea control fluid, whose failure would result in a release of the fluid.

3.1.25

pressure-controlling parts

Parts that are designed to control or regulate the movement of pressurized fluids.

3.1.26

pressure, design

Pressure defined for the design of the actuator pressure-containing and mechanically loaded parts, as defined by the actuator manufacturer.

3.1.27

pressure, hold

Minimum pressure to balance the spring thrust of a spring return actuator; used to hold the spring in the fully compressed position.

3.1.28

pressure, maximum operating/working

Maximum allowable pressure to supply at the actuator pressure port, as defined by the actuator manufacturer or supplier of the actuator.

3.1.29**pressure, minimum operating/working**

Minimum pressure at which the actuator provides the torque/thrust to operate the valve, inclusive of safety factor, as defined by the actuator manufacturer.

3.1.30**pressure, maximum rated**

Maximum pressure permissible into the actuator for pressure-containing or mechanically loaded parts, as defined by the actuator manufacturer.

3.1.31**pressure, maximum supply**

Maximum pressure to be supplied at the actuator, as defined by the purchaser.

3.1.32**pressure, minimum supply**

Minimum pressure to be supplied at the actuator, as defined by the purchaser.

3.1.33**protection cap**

Cap designed to protect the mechanical interface between the valve and the operator when the operator is removed.

NOTE Protection caps do not need to be pressure-containing.

3.1.34**remotely operated tool system****ROT system**

Dedicated, unmanned, subsea tools used for installation and inspection, maintenance, and repair tasks that require lift and/or handling capacity beyond that of free-swimming ROV systems.

NOTE 1 The ROT system comprises wire-suspended tools with control system and support-handling system for performing dedicated subsea intervention tasks.

NOTE 2 ROT systems are usually deployed on lift wires or a combined lift wire/umbilical. Lateral guidance may be via guidelines, dedicated thrusters, or ROV assistance.

3.1.35**remotely operated vehicle****ROV**

Free-swimming or tethered submersible craft used to perform tasks such as inspection, valve operations, hydraulic functions, and other general tasks.

3.1.36**running tool**

Tool used to run, retrieve, position, or connect subsea equipment remotely from the surface.

3.1.37**stall torque**

Maximum torque/thrust that an electric actuator or torque tool will develop when the motor is energized, and the output drive is locked.

3.1.38**stem/shaft**

Valve part that connects the closure member to the operator.

3.1.39

stroke

Movement of the operator from the fully closed to the fully open positions, or vice versa.

3.1.40

subsea

Situated or occurring beneath the surface of the sea.

3.1.41

swept volume

Volume of fluid displaced during one stroke of the operator.

3.1.42

swept volume system

Compensation system that transfers fluid between cavities of the operator or spool piece or bladder, e.g. change in volume due to hydraulic cylinder piston stroke.

3.1.43

temperature, maximum ambient

Maximum temperature the operator will experience during storage, transport, installation, in-service, commissioning, and maintenance.

3.1.44

temperature, maximum design

Maximum temperature at which the operator is capable of operating.

3.1.45

temperature, minimum ambient

Minimum temperature the operator will experience during storage, transport, installation, in-service, commissioning, and maintenance.

3.1.46

temperature, minimum design

Minimum temperature at which the operator is capable of operating.

3.1.47

torque/thrust, break-to-close

BTC

Torque or thrust necessary to operate the valve from the fully open position.

3.1.48

torque/thrust, break-to-open

BTO

Torque or thrust required to operate a valve from the seated position.

3.1.49

torque/thrust, design

Highest torque/thrust of an operator without the use of torque/thrust limiting or pressure-reducing protection devices.

3.1.50

torque/thrust, end-to-close

ETC

Torque or thrust necessary at the end of the stroke to operate a valve to the seated (closed) position.

3.1.51**torque/thrust, end-to-open****ETO**

Torque or thrust necessary at the end of the stroke to operate a valve to the open position.

3.1.52**torque/thrust, maximum**

Highest torque/thrust of an operator at specified voltage/pressure or input torque/thrust with torque/thrust-limiting or pressure-reducing protection devices active.

3.1.53**torque/thrust, run**

Torque or thrust necessary to maintain movement of the valve, at operating condition; occurs in the intermediate positions between the open (RTO) or closed (RTC) position.

3.1.54**unless otherwise agreed**

Modification of the requirements of this specification when the manufacturer and purchaser agree on a deviation.

3.1.55**valve, multi-turn**

Valve with a stem rotation of more than one revolution.

3.1.56**valve, part-turn**

Valve with a stem rotation of one revolution or less.

3.1.57**voltage, maximum supply**

Maximum available voltage to be supplied at the actuator.

3.1.58**voltage, minimum supply**

Minimum available voltage to be supplied at the actuator.

3.2 Acronyms, Abbreviations, Symbols, and Units

For the purposes of this document, the following acronyms, abbreviations, symbols, and units apply.

ac	alternating current
BM	base metal
BTC	break-to-close
BTO	break-to-open
CE	carbon equivalent
CP	cathodic protection
CRA	corrosion resistant alloy
dc	direct current
ETC	end-to-close
ETO	end-to-open
FAT	factory acceptance test
HAZ	heat affected zone

HBW	Brinell hardness, tungsten ball indenter
HRC	Rockwell C hardness
HPU	hydraulic power unit
lbf	pound-force
MAST	maximum allowable stem torque/thrust
Mpa	megapascal
MT	magnetic maximum allowable stem torque/thrust -particle testing
NDE	nondestructive examination
N	Newton
PLEM	pipeline end manifold
PLET	pipeline end termination
PQR	procedure qualification record
psi	pounds per square inch
PT	penetrant testing
PWHT	postweld heat treatment
QL	quality level
QTC	qualified test coupon
ROV	remotely operated vehicle
ROT	remotely operated tool
rpm	revolutions per minute
RT	radiographic testing
RTC	run-to-close
RTO	run-to-open
SMYS	specified minimum yield strength
TC	test coupon
UT	ultrasonic testing
WPQ	welder performance qualification
WPS	weld procedure specification
WM	weld metal
C_v	flow coefficient in USC units
K_v	flow coefficient in metric units
S_m	design stress intensity value
Ω	ohms

4 Operator Types and Configurations

4.1 General

Operators shall be part-turn, multi-turn, or linear in action, and include the following types.

- a) electric actuator;

- b) hydraulic actuator;
- c) gearbox;
- d) handwheel or lever.

4.2 Action on Loss of Supply Energy

Upon loss of supply energy or receiving a “fail-to” signal from the control system, the operator shall automatically drive the valve to, or remain in, a predetermined position as defined by the purchaser.

NOTE These positions are commonly known as fail-open; fail-closed; or fail-last/fail-in-place.

4.3 Actuator Types

4.3.1 Hydraulic

Hydraulic actuators shall consist of a hydraulic cylinder or fluid motor that uses hydraulic power to facilitate mechanical operation. The mechanical motion provides an output in terms of linear or rotary motion.

4.3.2 Electric

Electric actuators shall be self-contained units and consist of a motor that uses ac or dc electric source to facilitate mechanical operation. The mechanical motion provides an output in terms of linear or rotary valve operation.

4.4 Actuator Configuration

4.4.1 Single-acting

Single-acting actuators shall be of the electric or hydraulic type and shall have either part-turn or linear action to operate in one direction only, with the return stroke being powered by an alternative form of stored energy.

NOTE Single-acting actuators are generally associated with fail-position applications.

4.4.2 Double-acting

Double-acting actuators shall be of the electric or hydraulic type and shall have either part-turn, multi-turn, or linear action. The design shall require the application of supply energy to operate the actuator output in both directions.

4.5 Gearboxes

Gearboxes shall consist of the following:

- a) housing;
- b) gearing; and
- c) appropriate travel stops, when necessary based on valve type.

If provided, pressure and volume compensation shall be in accordance with 5.13.

5 Design

5.1 Design Input

5.1.1 General

The entity responsible for integration of the operator onto the valve shall compare the valve maximum allowable stem torque/thrust (MAST) and operator maximum output torque/thrust to ensure the valve MAST is not exceeded.

The following information shall be documented for operator design:

- a) minimum and maximum operating temperatures;
- b) minimum and maximum ambient temperatures;
- c) minimum and maximum temperatures encountered from the time of shipment from the factory to time of installation;
- d) safety factors in addition or supplementing those specified in 9.1.2;
- e) design water depth;
- f) valve type (see API 6DSS);
- g) minimum and maximum required time of operation (seconds) in the open and closed directions;
- h) location and orientation of position indicator in relation to the valve stem and/or the ROT interface;
- i) required orientation for installation;
- j) need for subsea retrieval (must specify diver or remotely operated vehicle [ROV] retrievable);
- k) type of compensation system in conformance with 5.13.3; and
- l) environmental and operational conditions (see 5.23).

If a mechanical override system is requested, the following shall be provided:

- 1) method of operation in conformance with 5.3.1 and:
 - ROT interface type and class;
 - rpm of ROT;
 - minimum and maximum ROT input torque; and
 - ROV reaction loads (see API 6DSS).
- 2) axial configuration of ROT interface, i.e. orientation of input shaft in relation to valve stem.

5.1.2 Installation Details

The following information shall be documented for operator design:

- a) maximum rate of deployment (e.g. meters/hour [feet/hour])

- b) connection condition of umbilical (i.e. connected or disconnected)
- c) type of umbilical
- d) deployment method

5.1.3 Valve Torque and/or Thrust Data

The following information shall be documented for operator design:

- a) valve top works dimensions,
- b) break-to-open (BTO) torque or thrust at zero and operating water depth,
- c) break-to-close (BTC) torque or thrust at zero and operating water depth,
- d) valve breakaway angle or breakaway percent of stroke,
- e) run-to-open (RTO) torque or thrust,
- f) run-to-close (RTC), torque or thrust
- g) end-to-open (ETO) torque or thrust,
- h) end-to-close (ETC) (reseal) torque or thrust,
- i) valve drive train MAST,
- j) length and direction of stroke to open and closed for linear valves,
- k) angle and direction of rotation for part-turn or check valves,
- l) direction of rotation and number of turns for multi-turn valves,
- m) thrust necessary to enable valve to maintain position, if applicable,
- n) any other specific torque or thrust conditions of the valve, and
- o) number of cycles expected during the service life of the equipment (end-user provided).

NOTE The breakaway angle or percent of stroke can be significant to actuator sizing when more than 5° or 5 % respectively.

5.1.4 Hydraulic Actuator Data Input

The following information shall be documented for operator design as applicable:

- a) control fluid type,
- b) compensation fluid type and data sheet,
- c) minimum and maximum supply pressure,
- d) minimum hold open/closed pressure,
- e) actuator configuration (single or double acting),

- f) action on loss of supply energy (closed, open, or fail-last/fail-in-place),
- g) number of strokes from stored-power source,
- h) hydraulic supply connection type and size,
- i) end of stroke damping feature, when required,
- j) bore diameter and length of the umbilical, and
- k) hydraulic control fluid pressure and flow rate supplied to and returning from the actuator to achieve operating times.

5.1.5 Electric Actuator Data Input

The following information shall be documented for operator design as applicable:

- a) voltage, phase, frequency, current (for ac systems),
- b) voltage, current (for dc systems),
- c) voltage variation and frequency variation,
- d) number of consecutive valve strokes,
- e) required opening and closing minimum and maximum time,
- f) number of starts per hour,
- g) action on loss of supply energy (closed, open, or fail-last/fail-in-place),
- h) number of strokes from stored-power source, and
- i) communication protocol between operating system and actuator.

5.1.6 Gearbox Data

The following information shall be documented for gearbox design as applicable:

- a) axial configuration of gearbox, i.e. orientation of input shaft in relation to valve stem
- b) limits on input shaft number of turns to complete one stroke
- c) part-turn or multi-turn gearbox
- d) method of operation in accordance with 5.3.1

Purchaser shall specify whether self-locking capability shall be provided by the operator or the valve.

5.2 Design Standards and Calculations

Pressure-containing parts, including bolting, shall be designed with materials specified in Section 6.

Design and calculations for pressure-containing elements shall be in accordance with requirements specified in 5.4.

Design and calculations for mechanical loaded parts shall be in accordance with requirements specified in 5.5.

Design and calculations for drive train components shall be in accordance with requirements specified in 5.9.

The allowable stress values shall be consistent with the selected design code or standard (see 5.4).

5.3 Design Requirements

5.3.1 General

Design validation, including a design review/verification, shall be performed in accordance with manufacturer's procedures.

For hydraulic actuators:

- a) the pressure used for the design of the pressure-containing parts, including bolting, shall be specified by the actuator manufacturer, and shall be at least 1.1 times the maximum rated pressure;
- b) the maximum rated pressure shall be defined by the actuator manufacturer and shall be less than the design pressure and greater than or equal to the maximum operating pressure.

NOTE Actuator pressure relationships are illustrated in Figure 1.

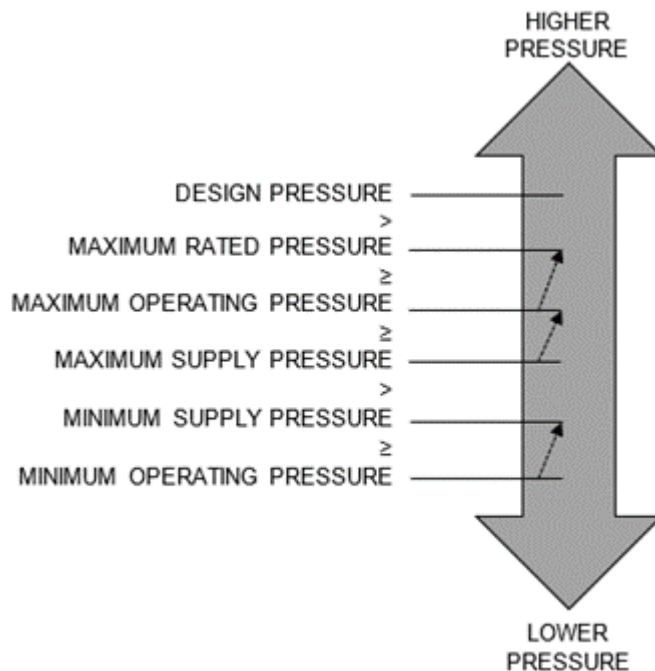


Figure 1—Relationship Between Design, Rated and Supply Pressures

All metallic and nonmetallic pressure-containing and pressure-controlling parts shall be designed to meet the applicable pressures and temperatures encountered during storage, transport, installation, in-service, commissioning and maintenance.

Gearboxes and mechanical override systems shall be part-turn or multi-turn. Purchaser shall specify the method of operation as one of the following:

Method of operation shall be:

- Manual/diver operated: for a gearbox, lever or mechanical override with an input interface suitable for manual operation, the maximum force applied at the handwheel shall not exceed 180 N (40 lbf). The handwheel

diameter shall not exceed the face-to-face or end-to-end dimension of the valve or 800 mm (31.5 in.) whichever is smaller. If the gearbox/override is not fitted with a handwheel, the maximum torque required at the input drive to apply the breakaway torque or thrust shall be 68 Nm (50 ft-lb).

- ROT Operated: for a gearbox/mechanical override with an input interface suitable for ROT operation the interface shall be in accordance with API 17H or as specified by the purchaser.

5.3.2 Design Basis

The design shall be either stress-based or based on satisfactory documented previous experience including validation.

When a pressure limiting device (e.g. relief valve) is used to limit the supply pressure, the maximum thrust or torque shall be determined at a minimum of 1.1 times the relief valve set pressure.

5.3.3 Allowable Deflections

Deflections of the operator, including the mounting kit, shall not prevent the closure member from reaching the fully closed or fully open position.

NOTE Adherence to allowable stress limits alone may still result in a design that produces deflections that prevents the operator from reaching the fully closed or open positions.

5.3.4 Bolting

Bolting of mechanically loaded parts and drive train components shall be designed to accommodate the direct loading applied by the operator design torques/thrust and, if applicable, loads from pressure and purchaser defined external loads.

Bolting shall not be subjected to direct shear.

5.4 Pressure-containing Parts

Pressure-containing parts, such as the cylinder heads, cylinder and noncompensated parts, shall be designed in accordance with one of the following:

- ASME *BPVC* Section VIII, Div. 1 or Div. 2;
- other internationally recognized design codes or standards by agreement.
- proprietary design methodology, calculations, acceptance criteria and satisfactory documented previous experience including validation testing shall be by agreement.

If the selected design code or standard specifies a test pressure less than 1.5 times the design pressure, the design pressure for the body calculation shall be increased such that the hydrostatic test pressure in 10.3.3.4 can be applied

NOTE Associated fittings and actuator control equipment are not within the scope of this document.

5.5 Pressure Boundary Bolting and Tie Rod Design

Bolting and tie rod design for pressure-containing parts shall be in accordance with the selected design code (see 5.4), unless otherwise agreed.

5.6 Mechanically Loaded Parts

Mechanically loaded parts shall be designed to accommodate the maximum anticipated in-service load, including design torque/thrust, and shall use the following data:

- torque/thrust generated at maximum rated pressure, for hydraulic actuators;
- torque/thrust generated by maximum spring force, for spring return actuators;
- torque/thrust at maximum supply voltage;
- torque/thrust at stall condition, for electric actuators.

Mechanically loaded parts shall be designed to transmit, to the valve stem, only those forces required to operate the valve. Any forces other than those required to operate the valve shall be prevented by the design.

Design stress intensity value, S_m , shall be taken as 67 % of SMYS. In addition, the average primary shear stress across a section loaded under design conditions in pure shear (e.g. keys, shear rings, screw threads, etc.) shall be limited to $0.6 S_m$.

The maximum primary shear under design conditions, exclusive of stress concentration at the periphery of a solid section in torsion, shall be limited to $0.8 S_m$.

The average bearing stress for resistance to crushing under the maximum design load shall be limited to the yield strength, SMYS.

When bearing loads are applied on parts having free edges, such as at a protruding edge or a keyway, the possibility of a shear failure shall be considered. In the case of load stress, only the average shear stress shall be limited to $0.6 S_m$.

NOTE These stress limits do not apply to the components of rolling-element or other proprietary bearings or high bearing strength capable materials that are included in the drive train where manufacturer's recommendations or limits derived from tests and service experience apply.

These limits shall be justified in design documents.

The drive train shall be designed such that the weakest component is outside the pressure boundary.

A strength efficiency factor of 0.75 shall be used for fillet welds.

NOTE Examples of these loads are lateral, side or axial loads.

5.7 Springs and Spring Modules

The spring on spring return actuators shall be designed and verified for a minimum of 5000 cycles, in accordance with internationally recognized design codes or standards. If no equations exist for the spring type, a proprietary equation may be used provided it has been validated by cycle testing.

NOTE An example of an internationally recognized design code or standard is EN 13906 or EN 16984.

The spring shall be type tested by compressing to a length that represents maximum travel during usage, a minimum of 600 times to validate the performance characteristics.

The manufacturer shall perform a test on all springs by full load cycling a minimum of five times followed by load testing to validate the actuator spring design data.

5.8 Mounting Kit

The mounting kit shall be designed to transfer all the loads from the operator to the valve and to react to them, including loads of 1.1 times or more the maximum torque/thrust output, and it shall use the following data:

- torque/thrust generated at maximum supply pressure or as limited by relief valve or another pressure-limiting device;
- torque/thrust generated by maximum spring force, for spring return actuators;
- torque/thrust at stall condition or 100 % torque/thrust switch setting, for electric actuators;
- ROT torque output loads.

The maximum torque/thrust output shall be less than or equal to the design torque/thrust.

5.8.1 Interface with the Valve

Unless otherwise agreed, the operator portion of the interface shall be in accordance with the following:

- For part-turn operators: ISO 5211 or MSS SP-101
- For multi-turn operators: ISO 5210 or MSS SP-102

If alternative dimensions are used that are outside the scope of ISO 5210 or ISO 5211 or MSS SP-101 or MSS SP-102, they shall follow the design methodology and acceptance criteria of these International Standards unless otherwise agreed.

NOTE 1 The environmental seal between the valve and the operator is provided by the valve manufacturer (see API 6DSS).

NOTE 2 The output drive of operators may be an integral part or a removable component to allow it, when necessary, to be machined to suit the driven component of the valve.

The material of the drive component shall clearly be indicated in the mounting kit manufacturer's or supplier of the mounting kit documentation and shall at a minimum define mechanical properties.

5.9 Drive Trains

Allowable stresses in the drive train components shall not exceed the following limits at the maximum rated input pressure or input torque/thrust:

- a) 67 % of SMYS for tensile stresses (excluding pressure-containing bolting);
- b) 40 % of SMYS for shear stresses;
- c) 54 % of SMYS for torsional shear stresses;
- d) 100 % of SMYS for bearing stresses.

Design of springs and spring modules shall be in accordance with 5.7.

A strength efficiency factor of 0.75 shall be used for fillet welds.

For pressure-containing components that are part of the drive train, the rules for pressure-containing parts shall apply (see 5.4).

Records shall be maintained of the calculations used to demonstrate that the allowable stress limits have been satisfied.

NOTE Stress limits required on the above-mentioned sections do not apply to third party or proprietary designed components (rolling elements or other proprietary bearings, high bearing strength capable materials, gearing assembly or other shelf products) where manufacturer's recommendations or limits derived from tests and service experience apply.

The weakest component of the drive train shall remain outside the pressure boundary.

Torque or thrust transmitting parts between the intermediate coupling and the operator shall be considered part of the drive train.

5.10 Design Documents

5.10.1 Design File Documentation

The design shall be documented in a retrievable and reproducible form.

Design documentation shall be reviewed and verified by competent personnel other than the person who performed the original design.

Design documents shall be retained for a minimum of 10 years following the date of manufacture.

When the following features form part of the design, the design file shall include:

- a) critical parts calculations,
- b) drive train calculations,
- c) bolting calculations,
- d) material specifications,
- e) mounting kit design calculations,
- f) compensator and swept volume sizing calculation,
- g) sizing calculation of lifting points, and
- h) design basis/methodology.

5.10.2 Data Sheet Information

The following information shall be provided by the manufacturer:

- a) back pressure (equivalent pressure of the spring during the fail stroke), checked with actuator alone, not installed on the valve;
- b) pre-charge pressures and volumes from any back-up equipment;
- c) pressure relief setting of compensation system, when applicable;
- d) swept volume of the hydraulic pressure cylinder;
- e) compensation fluid type and volume;
- f) method of calculation used to determine operating times;

- g) number of turns to complete one stroke;
- h) length of stroke of linear stroke actuator;
- i) maximum actuator output at maximum supply pressure;
- j) maximum actuator output at minimum supply pressure; and
- k) maximum input torque for ROT interface, when applicable.

5.11 Sealing

5.11.1 General

The seal material shall be specified by the purchaser.

Seals shall be designed to:

- a) prevent seawater ingress
- b) prevent internal fluid egress
- c) isolate internal fluids, where required
- d) ensure performance at the specified water depth
- e) be resistant to premature aging and embrittlement
- f) ensure material compatibility with exposed fluids
- g) maintain compression/squeeze during full range of deployment and design conditions
- h) maintain performance requirements through the design temperature range
- i) Swelling and shrinkage over time shall be minimal and within acceptable values that shall not infringe on the intended performance expectations of the specific actuator type

NOTE These requirements are intended to describe the minimum requirements for both dynamic and static seal configurations used for various operator types and designs for submerged applications. These requirements are not intended to inhibit a subsea operator manufacturer or supplier from offering alternative seals, equipment and engineering solutions for individual applications.

5.11.2 Dynamic Seals

Type and material selection of dynamic seals shall be from materials with low friction and high wear resistance.

Dynamic sealing surfaces shall resist corrosion when exposed to seawater.

Dynamic seals on the hydraulic power system shall:

- a) Perform without failure up to and including the design pressure at the minimum operating time.
- b) Exhibit no permanent deformation or seal failure when exposed to the design pressure x 1.5 during factory acceptance testing in a static condition.

5.11.3 Dual Seal Design

A dual seal is a double barrier where each seal is designed to create a seal, independent of the other seal.

Operator shall incorporate a dual seal:

- a) between pressurized operating fluid and compensating fluid,
- b) between pressurized operating fluid and seawater, excluding the operating fluid supply connection port,
- c) between compensating fluid and seawater, when the seal is dynamic.

Dual seal design shall minimize the void between the two seals.

NOTE Dual seal design does not apply to the compensator membrane, bladder or bellows.

5.11.4 Redundant Seal Design

A redundant seal is a double barrier where a second seal is provided in the event the primary seal fails.

The redundant seal shall meet all requirements of the primary seal.

5.12 Fluid Requirements

5.12.1 Hydraulic Control Fluid

5.12.1.1 General

The hydraulic fluid shall be defined by the purchaser and the manufacturer shall ensure chemical compatibility with internal actuator parts and lubricants and environmental conditions. For self-contained fluid power units (i.e. units not intended for in situ fluid replenishment) the fluid shall be defined by the manufacturer and approved by the purchaser.

5.12.1.2 Cleanliness

Actuator shall be flushed to a minimum cleanliness according to SAE AS4059 class 6 or ISO 4406 class -/15/12 unless otherwise specified by the purchaser.

5.12.2 Compensation Fluid

5.12.2.1 Operator

The compensation fluid for the operator shall be defined by the operator manufacturer and approved by the purchaser. The manufacturer shall ensure fluid compatibility with all wetted parts (including sealing barriers) and lubricants and environmental conditions. Grease shall not be used as a compensation fluid.

5.12.2.2 Cavities between the Valve and the Operator

The compensation fluid of the cavities between the valve and the operator shall be defined by the operator manufacturer and approved by the purchaser and by the valve manufacturer. The valve manufacturer shall ensure fluid compatibility with all wetted parts (including sealing barriers) and lubricants and environmental conditions.

For operator and valve manufactured by a single manufacturer, the above approval is not required.

5.12.3 Cavity Filling Fluid

Direct mounted actuators that form a noncompensated cavity between the valve and actuator, the cavity shall be filled with compensation fluid.

5.13 Compensation System

5.13.1 General

Compensation systems, when provided, shall be designed to accommodate the temperature range specified, fluid compressibility (including residual trapped air), operational volume change, anticipated special requirements (e.g. fast closing, rapid deployment, etc.) and life cycle expectation.

The compensation system is made of elements that by design shall:

- a) provide compensation for:
 - 1) operator swept volume (if applicable)
 - 2) thermal expansion of system fluid
 - 3) compressibility of system fluid
- b) provide over-pressure protection of the operator, e.g. an emergency relief valve,
- c) balance pressure between unpressurized internal cavity(ies) and external seawater pressure,
- d) be sized to account for residual entrapped gas remaining after filling,
- e) be designed to minimize entrapped gas,
- f) not be dependent on entrapped gas to assist the functionality,
- g) be sized to ensure required performance at design conditions (e.g. coincident depth, pressure, temperature and speed of operation),
- h) include safety factor for entire system volume (see 5.13.6),
- i) minimize or prevent sediment or marine growth on sea water breathers, and
- j) maintain system functionality in the presence of sediment, scale or marine growth.

All internal cavities of the same compensation system shall be connected by communication channels, (e.g. orifice holes, slots or passageways), and shall permit efficient fluid transfer.

NOTE A pressure increase due to rapid deployment to in situ position is a possibility.

All cavities not included in the compensation system shall be designed to sustain an equivalent hydrostatic pressure of 1.1 times the installed water depth.

5.13.2 Swept Volume System

Operator and compensation system design shall be such that structural integrity of the operator is maintained and the relief valve shall not open during normal operation.

The design shall prevent potential of a sub-ambient pressure condition in the system.

The manufacturer shall include an internal relief valve to break vacuum and prevent hydraulic lock.

5.13.3 Types of Compensation Systems

5.13.3.1 Open

An open compensation system shall:

- a) be open to the marine environment,
- b) use a compensation fluid that:
 - 1) provides corrosion inhibition,
 - 2) is heavier than seawater,
 - 3) shall have properties that minimize or prevent dilution in seawater,
- c) be designed to prevent loss of oil during storage, transport, installation and commissioning, and
- d) maintain system functionality in the presence of sediment, scale or marine growth.

The maximum allowable angles from the installed orientation the operator may tilt to prevent leakage of compensation fluid shall be provided by the manufacturer to the purchaser.

5.13.3.2 Closed

A closed compensation system shall be self-contained and prevent the exchange or contact between the compensation fluid and seawater.

Closed compensation system shall:

- a) include a device to provide over-pressure protection, and
- b) for swept volume operators, provide a means to break vacuum.

NOTE Closed compensation systems commonly include piston/cylinder, bladder, membrane or metallic bellows design.

5.13.4 Central Compensation System

When connecting to a central compensation system, the operator manufacturer shall provide the following information to the purchaser:

- a) swept volume,
- b) compensated volume,
- c) allowance for entrapped gas,
- d) minimum and maximum flow rate required for proper operation,
- e) minimum recommended connection size,
- f) maximum allowable differential pressure between the operator cavity and ambient external pressure,

The purchaser shall provide the following information to the manufacturer: