

INTERNATIONAL STANDARD

ISO
13628-3

First edition
2000-12-15

Petroleum and natural gas industries — Design and operation of subsea production systems

Part 3: Through flowline (TFL) systems

*Industries du pétrole et du gaz naturel — Conception et exploitation des
systèmes de production sous-marins*

Partie 3: Systèmes d'injection TFL



Reference number
ISO 13628-3:2000(E)

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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 3.

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 part of ISO 13628 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 13628-3 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum and natural gas industries*, Subcommittee SC 4, *Drilling and production equipment*.

ISO 13628 consists of the following parts, with the general title *Petroleum and natural gas industries — Design and operation of subsea production systems*:

- *Part 1: General requirements and recommendations*
- *Part 2: Flexible pipe systems for subsea and marine applications*
- *Part 3: Through flowline (TFL) systems*
- *Part 4: Subsea wellhead and tree equipment*
- *Part 5: Subsea control umbilicals*
- *Part 6: Subsea production control systems*
- *Part 7: Workover/completion riser systems*
- *Part 8: Remotely Operated Vehicle (ROV) interfaces on subsea production systems*
- *Part 9: Remotely Operated Tool (ROT) intervention systems*

Annex A forms a normative part of this part of ISO 13628. Annexes B, C and D are for information only.

Introduction

This part of ISO 13628 is based on API RP 17C:1991 [5].

The TFL systems and tools described herein permit both horizontal transport and vertical entry into the wellbore.

Users of this part of ISO 13628 should be aware that further or differing requirements may be needed for individual applications. This part of ISO 13628 is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This may be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this part of ISO 13628 and provide details.

Petroleum and natural gas industries — Design and operation of subsea production systems

Part 3: Through flowline (TFL) systems

1 Scope

This part of ISO 13628 specifies requirements and gives recommendations for the design, fabrication and operation of TFL equipment and systems.

The procedures and requirements presented are for the hydraulic servicing of downhole equipment, subsea tree and tubing hanger, and flowlines and equipment within the flowlines.

This part of ISO 13628 primarily addresses TFL systems for offshore, subsea applications but it may also be used in other applications such as highly-deviated wells or horizontally-drilled wells.

Subsea separation, boosting, metering and downhole pumps are outside the scope of this part of ISO 13628.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 13628. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 13628 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 3183-1, *Petroleum and natural gas industries — Steel pipe for pipelines — Technical delivery conditions — Part 1: Pipes of requirement class A.*

ISO 11960, *Petroleum and natural gas industries — Steel pipes for use as casing or tubing for wells.*

ISO 13628-4:1999, *Petroleum and natural gas industries — Design and operation of subsea production systems — Part 4: Subsea wellhead and tree equipment.*

API RP 14E, *Design and Installation of Offshore Production Platform Piping Systems.*

API Std 1104, *Welding of Pipelines and Related Facilities.*

3 Terms, definitions and abbreviated terms

For the purposes of this part of ISO 13628, the following terms, definitions and abbreviated terms apply.

3.1 Terms and definitions

3.1.1

bend radius

radius of curvature as measured to the centreline of a conduit

3.1.2

circulation control valve

valve normally placed across the circulation point to allow isolation of the tubing strings or tubing/casing during production

3.1.3

circulation point

location where communication is established between supply and return fluids for TFL servicing

3.1.4

diverter

device used to direct tools at a branch connection

NOTE Used generically, it refers to that category of equipment which includes deflectors, diverters and selectors.

3.1.5

drift

gauge used to check the minimum radius of curvature and minimum ID of loops, flowline and nipples

3.1.6

H-member

nipple assembly that provides fluid communication and circulation between strings of tubing in the wellbore

3.1.7

loop

curved section of pipe allowing change in direction of TFL flowlines

3.1.8

lubricator

tube and valve assembly that permits tool-strings to be inserted into and removed from a pressurized system

3.1.9

parking system

system whereby tools/equipment for a particular tubing size are transported through a flowline of a larger size by a transport (carrier) piston string which is left behind or "parked" outside the well while the remaining equipment continues into the tubing

3.1.10

profile

internal conduit configuration (receptacle) used to engage tools

3.1.11

recess

enlargement in conduit bore, normally concentric with the bore

3.1.12

sealing bore

polished section of conduit that receives a packing element

3.1.13

flowline

service line

line from a platform or land facility to a subsea facility used for TFL servicing

NOTE It may also be used for production or other testing of the well.

3.1.14**flowline signature****service line signature**

particular set of pressure pulses (spikes) read or recorded at the surface that identifies a certain point in the service/flowline or well as tools are pumped past

3.1.15**subsea tree**

christmas tree placed at the seabed

3.1.16**TFL piping system**

all piping from the surface lubricator through the flowline and tubing to the deepest point in the well to which TFL tools can be circulated

3.1.17**tubing-retrievable safety valve**

downhole safety valve run in the well on tubing

NOTE It is normally surface-controlled and has an ID close to the size of the tubing bore, thereby providing an almost unrestricted bore.

3.1.18**wye spool**

piping section of a subsea tree where the loop joins the vertical tubing bore

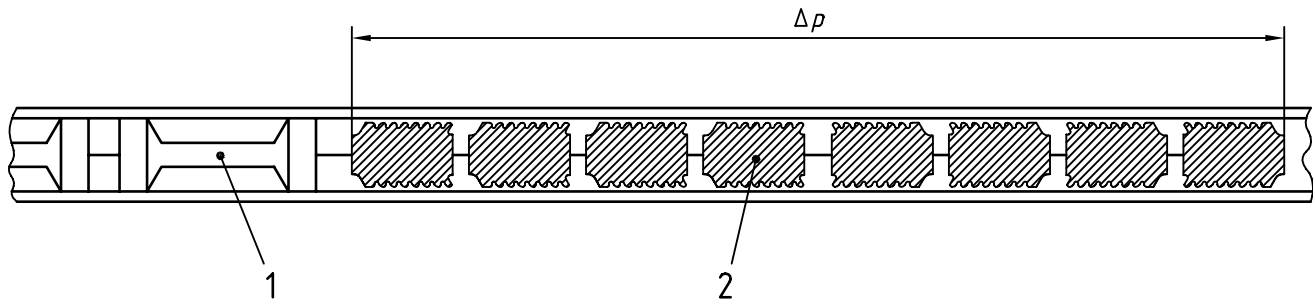
3.2 Abbreviated terms

BHP	bottom-hole pressure
CCV	circulation control valve
EUE	external upset end
ID	inside diameter
OD	outside diameter
SDC	side door choke
SCSSV	surface-controlled subsurface safety valve
SVLN	safety valve landing nipple
TFL	through flowline
TRSV	tubing-retrievable safety valve
TMD	total measured depth
TVD	true vertical depth

4 TFL system

4.1 Description of system

The TFL method allows various well servicing operations to be performed by utilizing fluid to transport tools through flowlines and loops into and out of tubing strings. The differential pressure of the transport fluid across the tool-string provides the force required to perform the various operations as shown in Figure 1.



Key

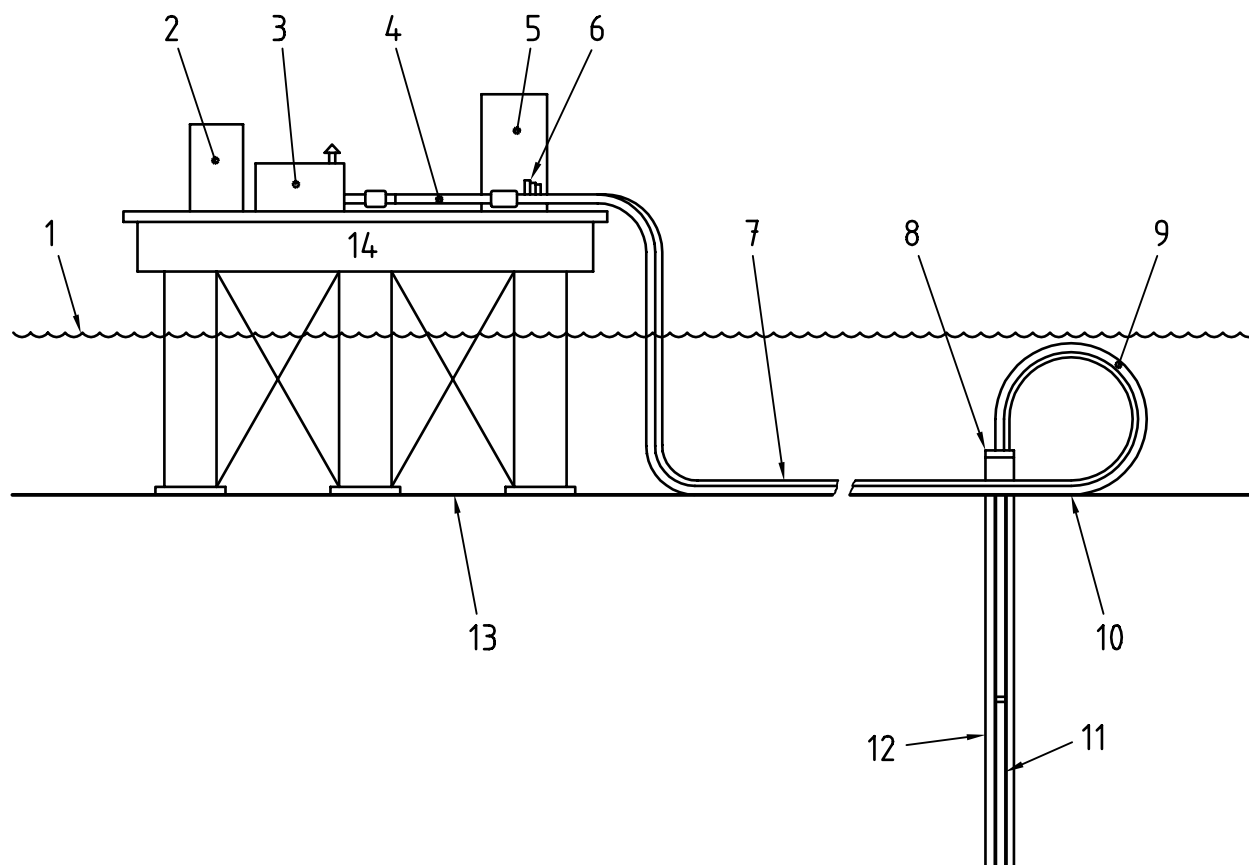
- 1 Tools
- 2 Pistons

Figure 1 — Differential pressure, Δp

4.2 TFL components

Figure 2 is a representation of a typical TFL system. The basic components of a system include the surface equipment, flowlines, subsea tree, TFL service tools and associated downhole equipment. The function of this system is to provide the means of transport and control of TFL tools. The transportation of tools is provided by the pumping equipment while the control of these tools is provided by the pumping rate, instrumentation and TFL control manifold. The basic criteria of a TFL system are

- to have an appropriate pressure rating for the system;
- to provide necessary volumes of fluid required by the TFL operations;
- to control the equipment within operating specifications.



Key

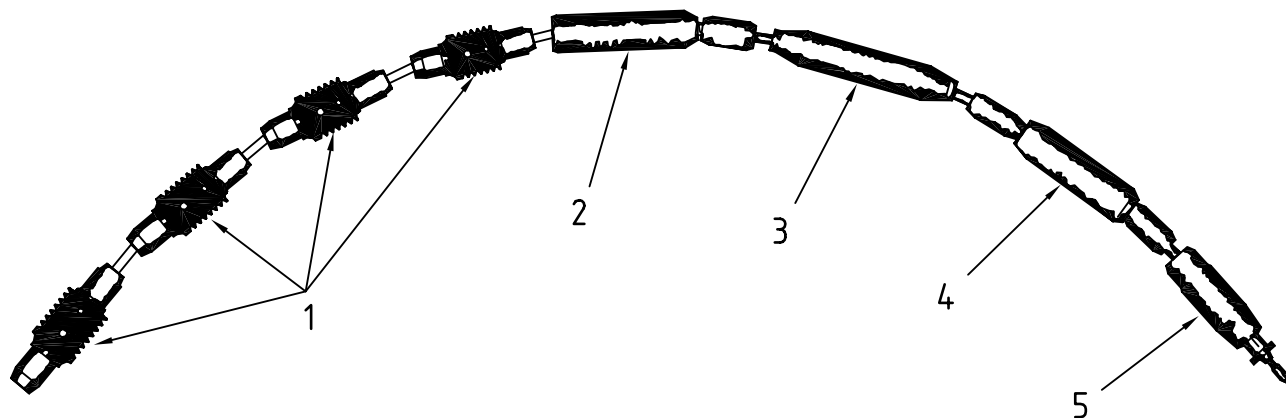
1	Water	8	Subsea tree
2	Tank	9	TFL bends
3	Pump	10	Subsea wellhead
4	Lubricator	11	Circulation point (H-member)
5	Manifold and instrumentation	12	Well
6	Pressure transducers	13	Mudline
7	Flowline/service line	14	Platform

Figure 2 — Typical offshore TFL installation

4.3 System/equipment design

TFL tools (see Figure 3) have been designed to operate in various tubing sizes commonly used in subsea wells. TFL tool design is dependent upon the tubing ID and the minimum radius of curvature of tube bends. The design of a TFL piping system shall take into account the internal diameters of the conduit and receptacles and the pressure ratings of the pipe and tubing. The ID of the service line should be the same as the ID of the downhole tubing strings, otherwise it should incorporate a parking system. If the ID is too large, fluid will bypass the tool-string piston units, reducing their force capability and resulting in inaccurate measurement of tool position. Conversely, if the ID is too small it can prevent tool passage, can cause excessive drag or can damage and wear the tool, seals and piston units.

Annex A specifies the requirements for TFL pipe and Table A.1 lists pipe ID dimensions that are compatible with tubing sizes.



Key

- 1 Piston units
- 2 Accelerator
- 3 Stem
- 4 Hydraulic jar
- 5 Pulling tool

Figure 3 — Typical TFL service string

4.4 Pressure rating

The pressure rating of a TFL system shall be greater than the maximum pressure to be encountered during TFL operations throughout the life of the installation. As a guide, consideration should be given to practical combinations of the following:

- maximum static bottom-hole pressure of the well, minus the hydrostatic pressure of the fluids in the TFL system;
- pressure to overcome frictional losses when circulating fluids and tool-strings;
- pressure required to operate all the TFL devices. This includes not only service tools but also downhole isolation and plugging equipment;
- hydraulic shocks or surges in the system which may occur during operations such as jarring;
- pressure required to kill the well if the TFL system is to be used to pump well kill fluids into the producing formation.

Multiple-well systems shall consider the effect of the higher pressure wells in the system.

Additional information about the system pressure rating and TFL fluids is provided in clause 9 and annex B.

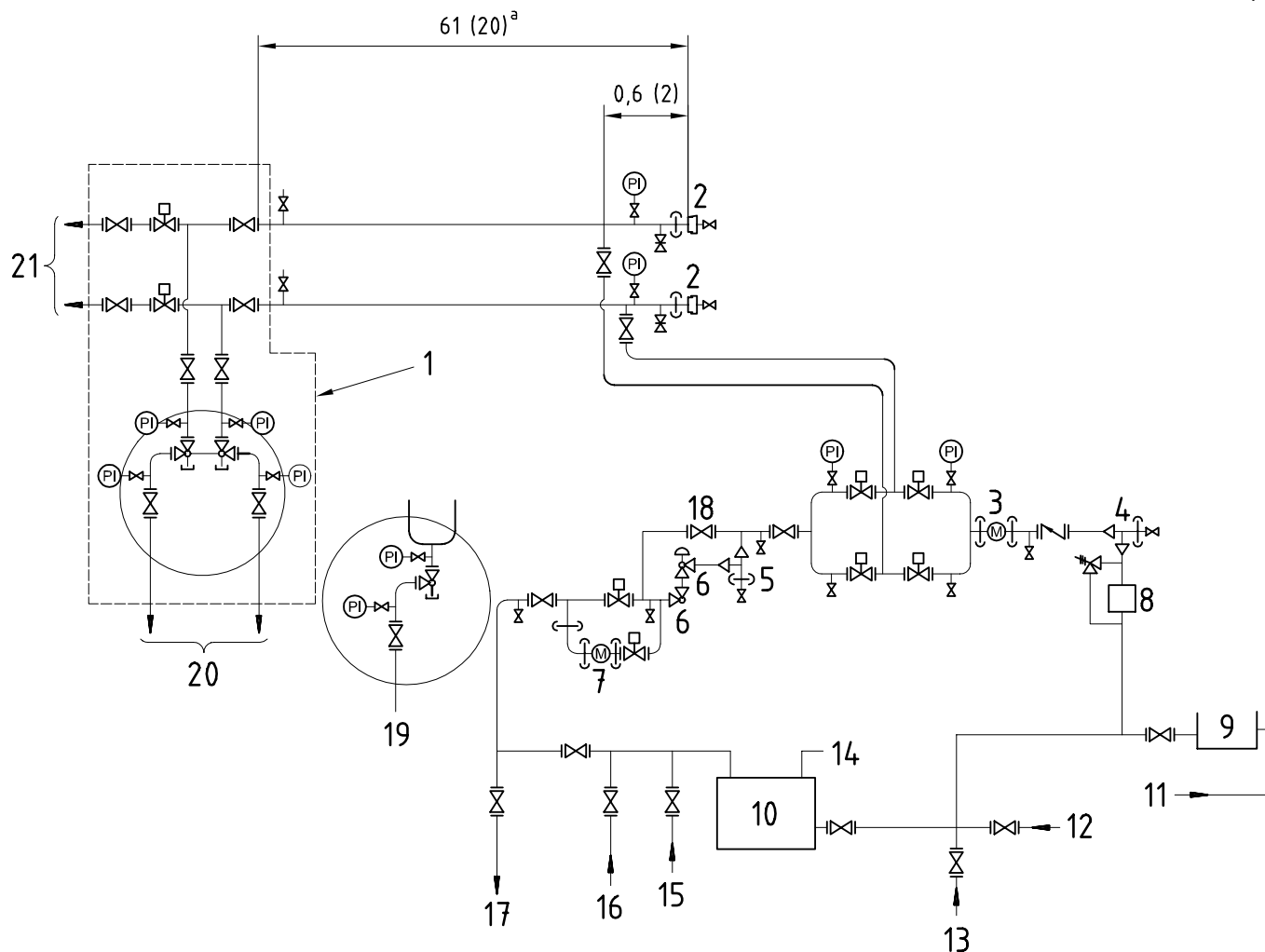
5 TFL surface equipment

5.1 General

TFL surface equipment (see Figure 4) includes a service pump, TFL control manifold, TFL control console, lubricator, fluid storage, separator and piping system. The pump pressure and flow rating should be compatible with the design of the system, taking into account the tool transport speeds referenced in clause 9 (see Table 1), tool-string actuation pressures and the fluid bypass that may occur during these operations. Sufficient volume (see 5.6) should be provided in the tanks and tubing strings to assure that all operations can be handled effectively. The surface facility (see Figure 5) should provide space to accommodate the TFL facilities, and the equipment

layout should be arranged with due regard to the proximity of the control console, pump, manifolding and lubricator, and the space needed to easily insert and remove extended-length tool-strings. If this equipment is located on a drilling/production platform, the use of basic platform equipment (such as high-volume mud pump or kill pump) may eliminate the need for dedicated equipment.

Dimensions in metres (ft)

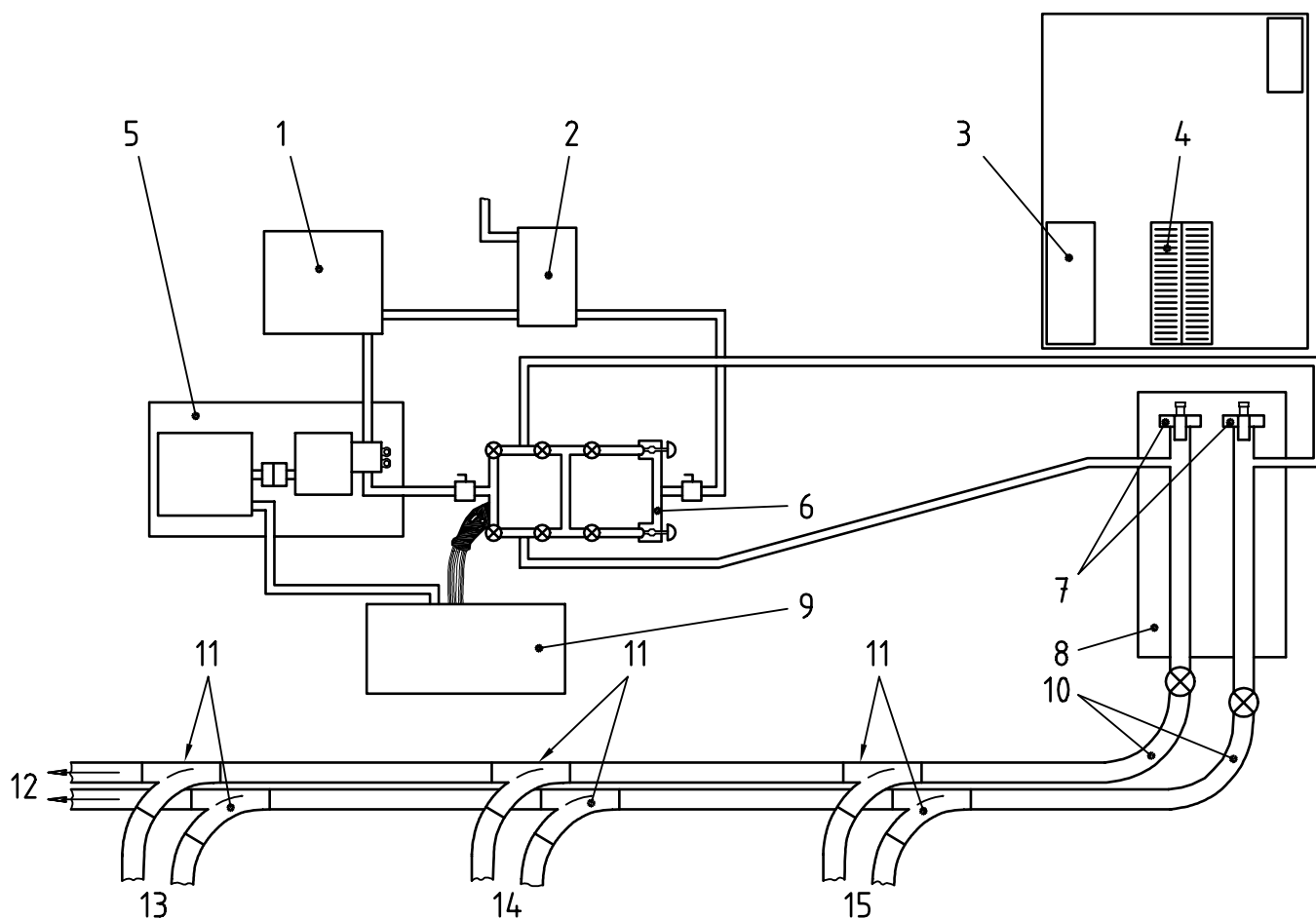


Key

- | | | | |
|----|---|----|------------------------------------|
| 1 | Production control manifold | 12 | From mixing tank |
| 2 | Threaded quick connection with plug | 13 | From dry oil tank (optional) |
| 3 | Flowmeter | 14 | Gas blanket |
| 4 | High pressure strainer | 15 | Fill-up line |
| 5 | High pressure strainer | 16 | From separator liquid dump |
| 6 | Choke | 17 | To separator |
| 7 | Flowmeter | 18 | Optional valve |
| 8 | High pressure/high volume triplex pump | 19 | Optional surface choke arrangement |
| 9 | 795 l (5 BBL) open tank | 20 | To production manifold |
| 10 | Working tank | 21 | To well |
| 11 | From platform saltwater system (optional) | | |

^a Recommended minimum straight level section.

Figure 4 — Example of TFL platform piping



Key

- | | |
|------------------------------|-----------------------------|
| 1 Fluid mixing tank | 9 Control console |
| 2 Storage tank | 10 Entry loops |
| 3 Work table | 11 Diverters |
| 4 Roller table | 12 To other wells in system |
| 5 Pump unit | 13 Well 3 |
| 6 Surface control manifold | 14 Well 2 |
| 7 Tool feeders | 15 Well 1 |
| 8 Dual horizontal lubricator | |

Figure 5 — Typical surface equipment arrangements for installations

Table 1 — Recommended flow rates for TFL tools

Feature	Nominal tubing ID				
	mm (in)				
	50,8 (2)	63,5 (2 1/2)	76,2 (3)	101,6 (4)	127 (5)
	Flow rate				
	l/min (bbl/min)				
Tool transport	318 (2,0)	477 (3,0)	636 (4,0)	795 (5,0)	954 (6,0)
Restricted line (max.)	159 (1,0)	159 (1,0)	318 (2,0)	318 (2,0)	318 (2,0)
Locating and landing (max.)	79,5 (0,5)	79,5 (0,5)	159 (1,0)	159 (1,0)	159 (1,0)

5.2 Service pump

Generally, triplex-type positive displacement pumps have been used for TFL operations although slow speed duplex and high-pressure multi-stage centrifugal pumps have also been successfully used by some operators. The primary recommendations for the pumps are as follows:

- pressure and flow rate capability should be in accordance with clause 9;
- a relief valve should be provided on the pump discharge to protect the pump and piping system against over-pressure or hydraulic shocks and surges;
- pump suction piping should have connections for auxiliary tanks or mixing facilities;
- the TFL pump drive should be designed to allow smooth changes to be made over the range of operating conditions described in clause 9.

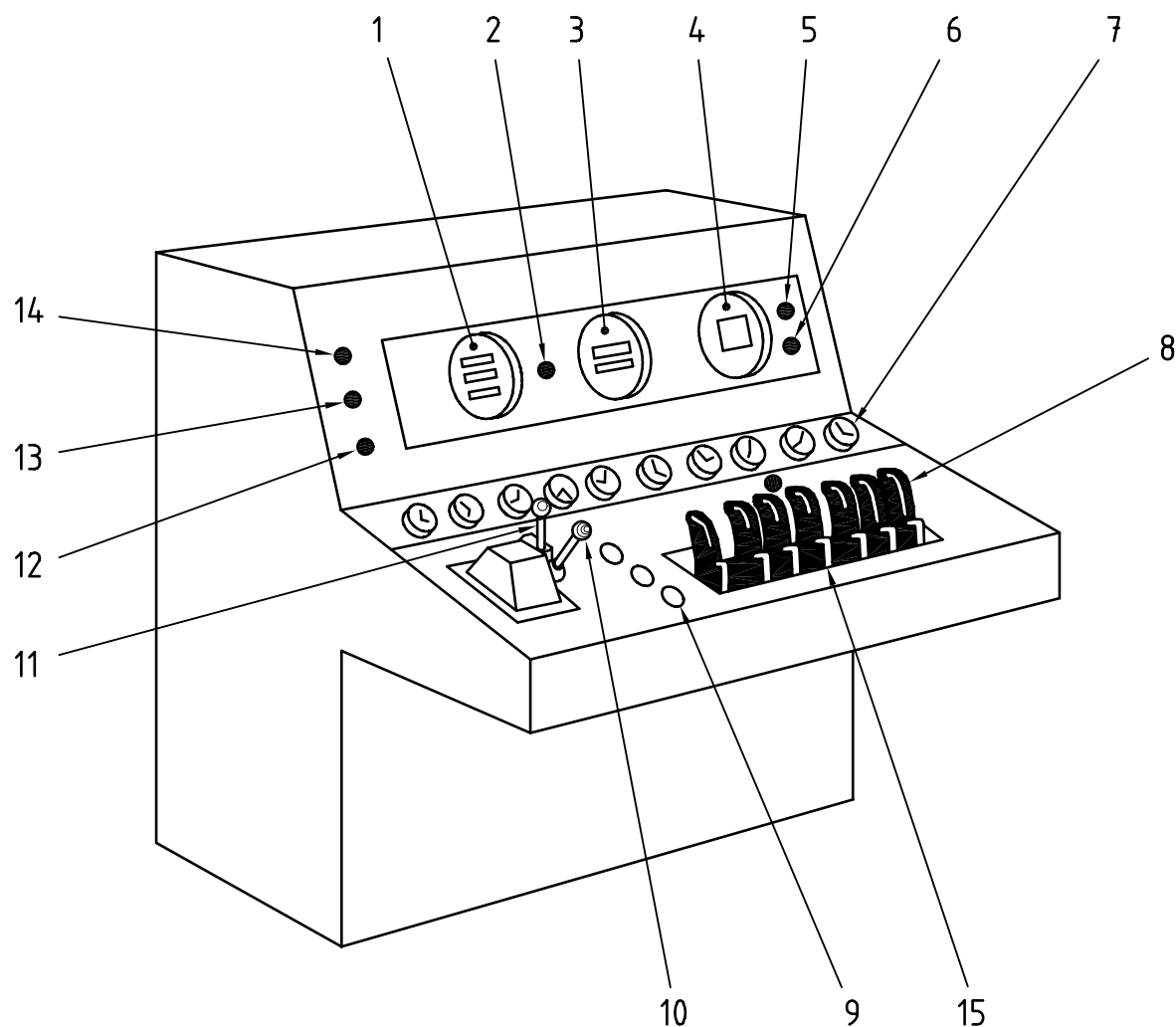
5.3 TFL control manifold

Valving arrangements shall be designed to direct pump flow and fluid return to the service lines, tanks, separators, etc., as needed to perform TFL operations. Piping and valves should be capable of handling the maximum working pressure of the system. Valves and actuators should be selected to permit rapid line switching (i.e. within 2 s or less). Valving should provide for return of fluids through an adjustable back pressure regulator or choke and through flow meters. The regulator or choke is used to regulate back pressure on the return line to control inflow from the well or fluid loss to the formation during downhole TFL operations.

5.4 TFL control console and instrumentation

Figure 6 shows a typical TFL instrumentation/control console. This instrumentation enables the monitoring of tool progress, tool operation and well fluid gain or loss. Instrumentation generally includes pressure gauges with strip chart recorders, pressure transducers located on the lubricator or manifold, and flow rate meters and volume totalizers on both the pump discharge and return lines. The instrumentation should be designed to withstand the vibrations and pressure surges that can occur. High-pressure screens or filters should be installed upstream of turbine flow meters to minimize damage to the meters by debris. Other types of meter may be used without the need for such filters.

In addition to control console instrumentation, pressure transducers with surface readout may be installed at the wellhead to assist in monitoring the tool location. Other special tool detection systems may be installed to monitor the location of a tool as it moves through the TFL system.



Key

- | | | | |
|---|---|----|---|
| 1 | Dual flow meters and totalizers | 8 | Hydraulic choke and manifold – control valves |
| 2 | Explosion-proof instrumentation box (Class 1 Div 1 Grp 0) | 9 | Engine – start, stop and emergency kill |
| 3 | Dual pressure gauges | 10 | Engine – throttle |
| 4 | Two-pen strip-chart recorder | 11 | Transmission – gear selector |
| 5 | Chart recorder on/off switch | 12 | Totalizer reset |
| 6 | Power-off switch | 13 | Power-on switch |
| 7 | Monitoring gauges (engines, pumps and transmission) | 14 | Totalizer reset |
| | Pump – oil temperature | 15 | Back-pressure control |
| | Pump – oil pressure | | |
| | Back-pressure signal | | |
| | Transmission – oil temperature | | |
| | Transmission – oil pressure | | |
| | Engine – water temperature | | |
| | Engine – oil pressure | | |
| | Engine – tachometer | | |
| | System hydraulic pressure | | |
| | System air pressure | | |

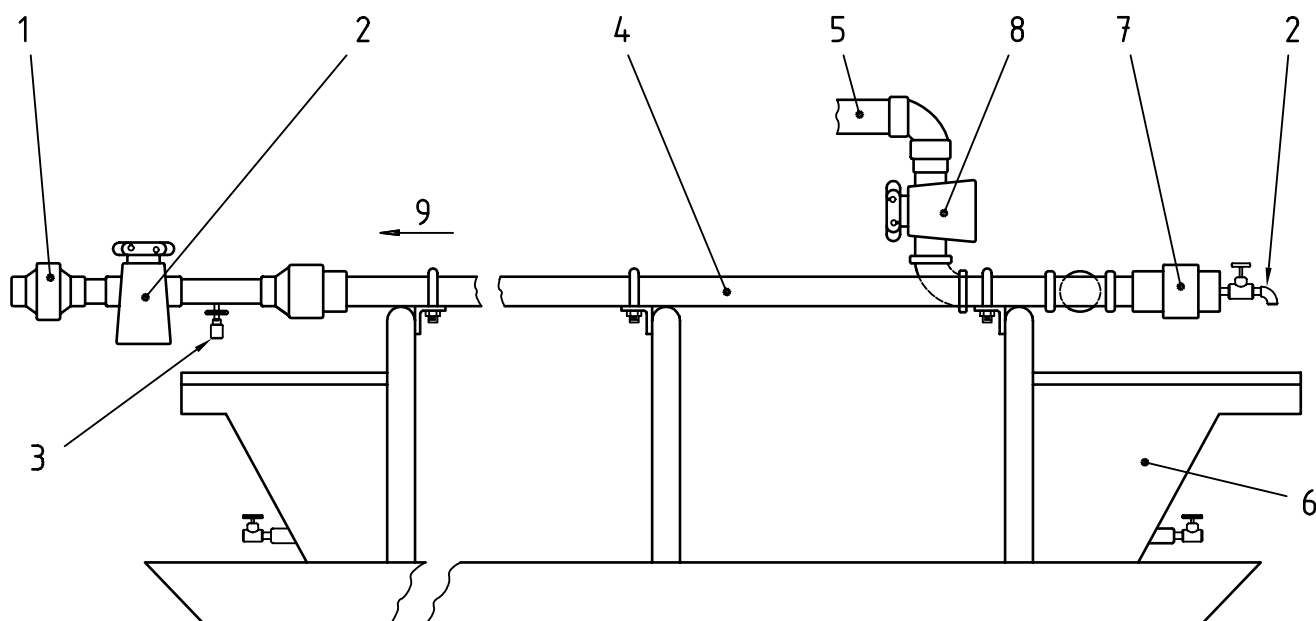
Figure 6 — Typical TFL instrumentation control console

5.5 Lubricator

5.5.1 General

A lubricator allows tool-strings to be inserted into and removed from a pressurized system. Generally, a TFL lubricator consists of a horizontal launch tube section 6 m to 18 m (20 ft to 60 ft) long with quick-connecting unions at the ends, a full-opening block valve, bleed valves and a connection for pumping fluid into the lubricator. Figure 7 shows the principal features of the lubricator.

During some fishing and remedial operations that need extended-length tool-strings, it may be necessary to use the service line to the subsea tree as part of the lubricator. The line pressure shall be bled off during each use.



Key

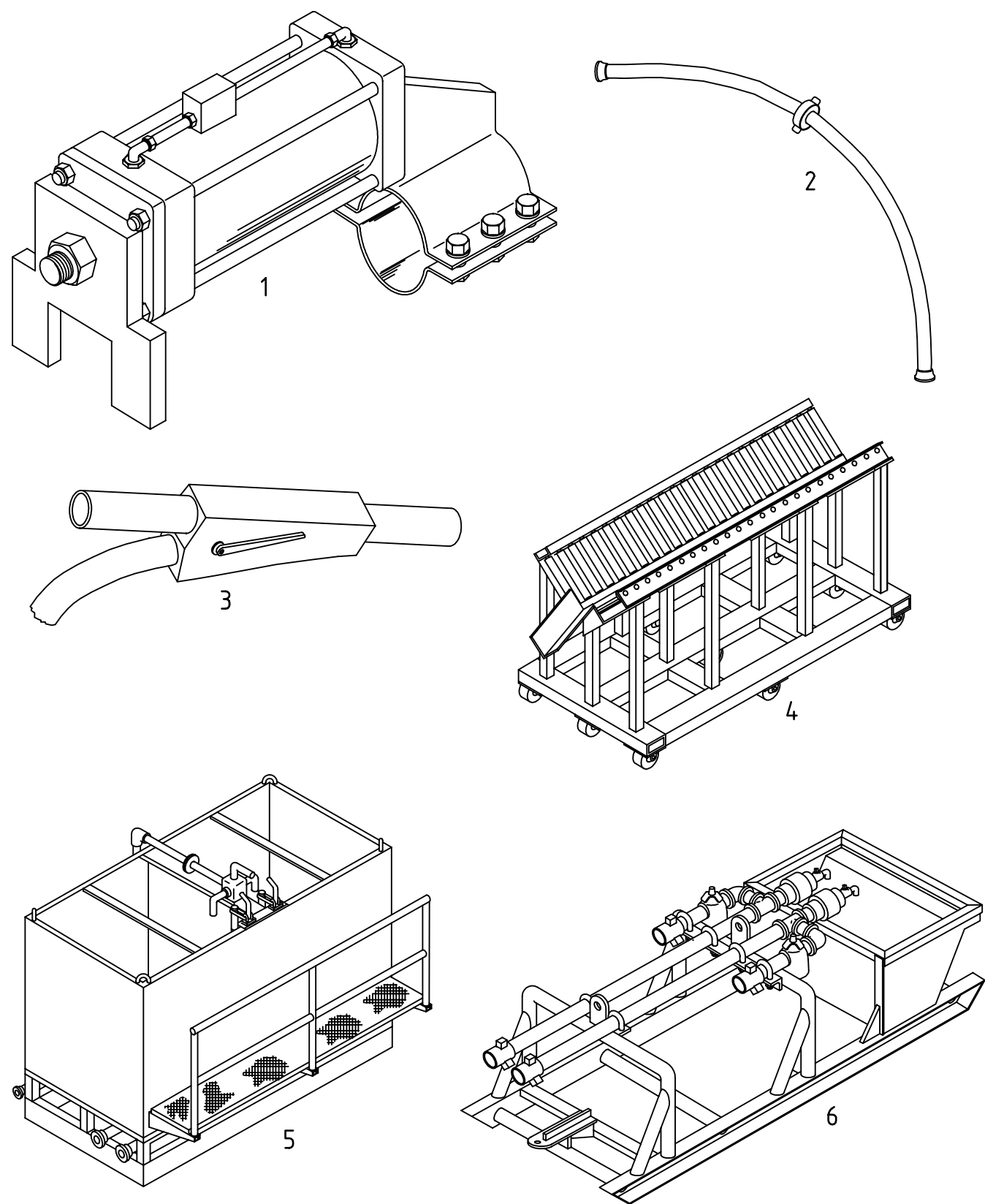
- | | |
|-------------------------|---------------------------------------|
| 1 Quick union or flange | 6 Sumps |
| 2 Bleed valve | 7 Bull plug assembly with quick union |
| 3 Full-opening valve | 8 Valve |
| 4 Oversized tube | 9 Tool direction |
| 5 Pipeline | |

Figure 7 — Typical lubricator skid

5.5.2 Design

A primary consideration in designing a TFL lubricator is preventing ID reductions or misalignments that could impede tool passage or cause seal damage or other tool damage. The lubricator ID should be sufficiently larger than the flowline ID, in order to permit the tools to be loaded and removed easily, but not so oversized that a high pump rate would be required to move the tools from the lubricator into the flowline. In general, if the lubricator ID is 1,6 mm to 4,8 mm (1/16 in to 3/16 in) larger than the service line nominal ID, these criteria will be satisfied.

As a safety feature, pressure bleed-off valves should be provided at both ends of the lubricator launch tube to ensure blow-down of pressure on both sides of the tool-string before removing the tool from the lubricator. The design should allow collection of excess fluids from the lubricator. Branch connections should be located so as to ensure the tool-string can be launched and will not slam into the lubricator end when it returns to the surface. A power-assisted tool feeder (providing push/pull) and work tables may be necessary for loading and/or removing larger/longer tool-string sizes (see Figure 8).



Key

- | | | | |
|---|-----------------------|---|-----------------------|
| 1 | Hydraulic tool feeder | 4 | Roller table |
| 2 | Entry loops | 5 | Working tank |
| 3 | Diverters | 6 | Horizontal lubricator |

Figure 8 — TFL surface equipment

5.5.3 Fabrication

The lubricator piping shall be designed and fabricated in accordance with API RP 14E and clause 6.

5.6 Fluid storage and working tank

A working tank or other fluid storage vessel should be provided in the surface facilities. The storage capacity should be at least equal to the volume of the flowlines and tubing strings. However, if the available space restricts the size of the tank, and if make-up liquid is available, and if excess fluids can be safely disposed of, smaller tanks may be used. A working tank is very useful for keeping track of allowances for lost circulation or well fluid influx. A split 6,3 m³ (40 bbl) tank (see Figure 8) has been found to be a workable size for this function. The working fluid type may vary (diesel, dead crude, inhibited water or brine, etc.) and suitable connections should be available to access these sources. Special precautions shall be taken to satisfy the relevant area classification when using crude oil or handling fluid returns.

5.7 Separator

A separator is generally required to remove gas from the return stream. Removal of the gas helps to obtain repeatable performance in tool operations and tool location and is covered further in clause 9.

The separator should be sized and pressure-rated as appropriate to handle the well fluids, the maximum pumping rate and any fluid surges when switching flow paths during TFL operations.

5.8 Testing

The entire TFL platform facility assembly (see Figure 4) should be pressure tested in accordance with API RP 14E. In addition, the ID of the piping through which TFL tools are to pass should be gauged using the tests described in clause 6.

6 TFL piping system

6.1 General

The TFL piping system consists of the following:

- a) the surface piping between the lubricator and the top of riser;
- b) the riser from the seabed;
- c) a relatively straight flowline section;
- d) the preformed TFL loops or bends used to change tool direction in restricted spaces;
- e) the subsea tree;
- f) the tubing string, downhole accessories and their end connections.

All piping connectors and connecting methods shall provide free, unrestricted passage of tools and shall not cause damage to either metallic seals or non-metallic seals on the TFL tools, TFL pistons or other TFL tool-string components.

6.2 Design

6.2.1 Piping

6.2.1.1 General

TFL pipe shall be either a rigid metallic tubular or a flexible tubular, the latter being constructed of composites of metallic and non-metallic materials.

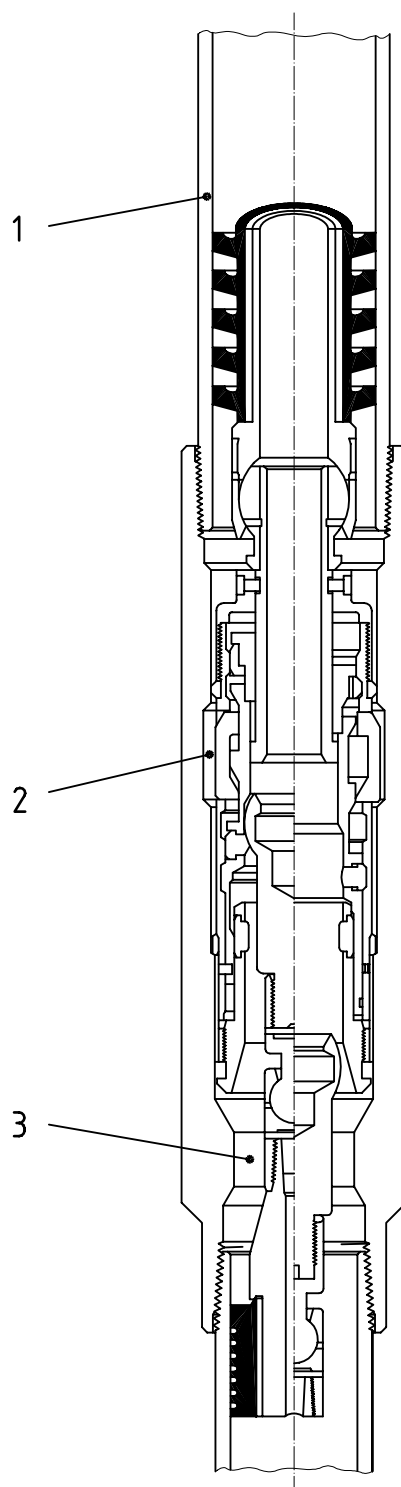
6.2.1.2 Materials

Various metal grades have been used for TFL piping, including carbon steel (ISO 3183-1 and ISO 3183-2 [6]), austenitic-ferritic ("duplex") stainless steel, martensitic stainless steel ("13-chrome"), and others.

More detailed information on the appropriate materials can be found in API RP 17A [4] and ISO 13628-1 [8] for subsea production control systems and in ISO 10420 [7] for flexible pipe.

6.2.1.3 Diameters

Except as noted below, the flowline(s) and other straight portions of the piping system shall have the same minimum ID and maximum ID as the well tubing string(s) (see Table A.1); this practice minimizes the amount of fluid bypassing between the TFL pistons and the pipe wall and improves TFL tool-positioning control. There are situations, however, when the flowline ID must be larger than the well tubing. This occurs when flowlines are particularly long, and large IDs are needed in order to reduce the pressure drop along the line. For this case, a parking system should be employed as is shown in Figure 9. A large diameter TFL tool carrier transports the downhole service tool-string to the subsea wellhead and releases or picks up the smaller diameter downhole tool-string.

**Key**

- 1 Carrier string
- 2 Parking latch
- 3 Service tool-string

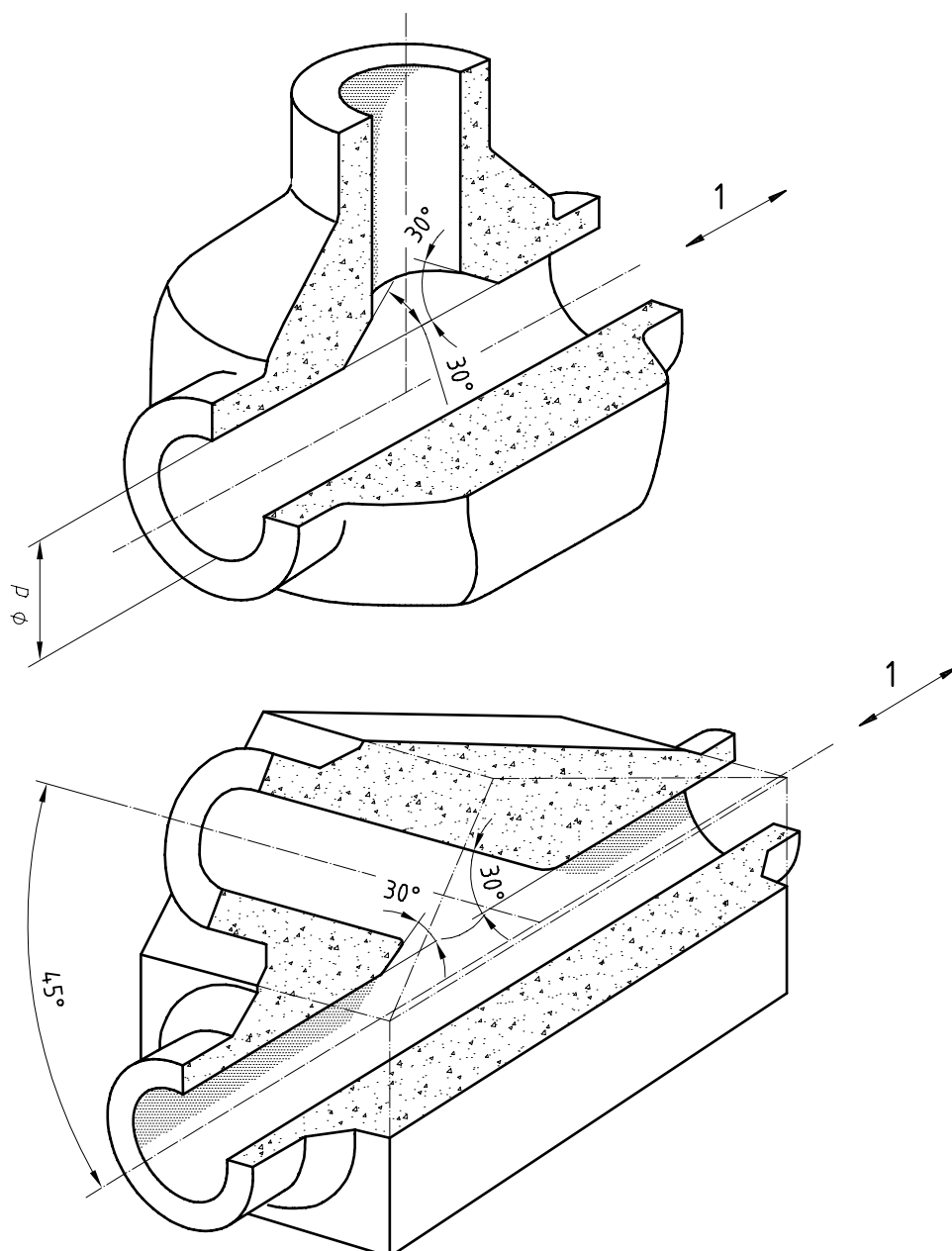
Figure 9 — Parking system

6.2.1.4 Pressure ratings

TFL piping systems shall have a working pressure compatible with the TFL system design pressure. Wall thickness and material strength shall be selected so that all the piping system components comply with the design codes applicable in the country of operation or with those specified by the operator.

6.2.1.5 Side-entry ports

In straight portions of the piping system, side-entry ports should intersect the TFL flowline at an angle of 90° . However, if this is not achievable, the angle shall be at least 45° to the longitudinal axis of the TFL flowline. This minimizes the exposed side-port opening. The intersection should be higher than the longitudinal axis of the TFL flowline. All corners of the intersecting bore should be bevelled as shown in Figure 10 to prevent interference with the TFL tool or damage to its components.



Key

1 Tool travel

Figure 10 — Bore junction configuration for a non-TFL pipe intersecting TFL piping

6.2.1.6 Position locator devices

Restrictions in the flowline or tubing which cause momentary pressure increases during passage of the TFL pistons are useful for locating the TFL service string. The restrictions may be introduced intentionally, as with a specially-manufactured, short, heavy-walled section of pipe, or they may be restrictions that normally occur in any flowline (flowline signature). These restrictions typically cause a 1,4 MPa to 2,1 MPa (200 psi to 300 psi) pressure increase at normal tool transport velocity. Blast joints and flow couplings have been used successfully for this purpose.

If these restriction devices are intentionally introduced downhole to identify the tool-string location, sufficient distance should be provided between the devices and any landing nipple to allow the tool position to be identified and the tool to be slowed down before it reaches the landing nipple. The required distance between such a device and a landing nipple depends on the pumping rate, the fluid volume and the flow rate response time at the pump (i.e. these parameters govern the ability to slow down the tool to the proper speed for the appropriate operation). Since the pressure pulse in the fluid travels at sonic speed, the speed of detection is affected by the fluid properties, the temperature and pressure, and the distance between the pressure detector and the restriction device. Spacing of these restriction devices should ensure that the piston elements are not positioned within the device while the tool is being actuated or force is being generated. This is to prevent difficulties in fishing operations due to reduced fluid bypass.

6.2.1.7 Ovality

Installation methods shall consider the effects of installation forces and stresses causing ovality that would restrict drifting and tool passage.

6.2.2 Bends (loops)

6.2.2.1 Bend radius

Bend loops shall have a bend radius of not less than 1524 mm (60,0 in). If space and geometry allow, a larger bend radius should be used to reduce fabrication and/or operating problems. The minimum bend radius applies to both rigid and flexible pipe.

6.2.2.2 Bend diameters

Table 2 specifies, for some typical tubing sizes, the maximum ID of loop material prior to bending and the minimum ID of loop material after bending. Minimizing the pipe ID in the bend should be considered in order to increase the efficiency of the TFL tool.

Table 2 — Loop material dimensions

Tubing OD mm (in)	Maximum loop material ID before bending mm (in)	Minimum ID after bending mm (in)
60,3 (2 3/8)	52,37 (2,062)	50,3 (2,000)
73,0 (2 7/8)	66,68 (2,625)	63,5 (2,500)
88,9 (3 1/2)	79,38 (3,125)	76,2 (3,000)
101,6 (4)	92,08 (3,625)	88,9 (3,500)
114,3 (4 1/2)	104,78 (4,125)	101,6 (4,000)
139,7 (5 1/2)	123,83 (4,875)	120,65 (4,750)