

Recommended Practice for Design, Testing, and Qualification of Subsea Chemical Injection Delivery Systems

API RECOMMENDED PRACTICE 17Y
FIRST EDITION, APRIL 2022



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Introduction

Subsea chemical injection delivery systems (SCIDS) are designed to deliver chemicals to a specified point into the subsea production to mitigate flow assurance, corrosion risks, pressure testing, pressure management, and other operational purposes. SCIDS are highly integrated systems that require collaboration across multiple disciplines without which the systems may not perform as intended during operations.

This recommended practice (RP) provides guidance for the design, testing, qualification, commissioning, and operations of SCIDS and its associated equipment. This includes system and equipment specifications, performance requirements, functional specifications, testing specifications, hardware and software interfaces, chemical management, in-house and in-field calibration methods, commissioning and start-up, system maintenance, field modifications, system and equipment reliability, qualification and testing requirements, and operational requirements.

Specific recommendations are provided where a standard design or operating principles have been adopted and are accepted as standard industry practice. The intention is to facilitate and complement the decision process rather than replace individual engineering judgment and to provide positive guidance for the design selection of an optimum solution and the operating and maintaining practices.

This standard is under the jurisdiction of API Subcommittee 17 on Subsea Production Systems.

Recommended Practice for Design, Testing, and Qualification of Subsea Chemical Injection Delivery Systems

1 Scope

This RP is for the design, specification, testing, qualification, installation, commissioning, and operation of SCIDS (excluding workover and subsurface equipment). It covers SCIDS from chemical storage tank located on host facility (onshore or offshore) to injection points subsea with a holistic approach. It discusses interfaces between topsides, subsea, and subsurface scopes as well as between engineering, mechanical equipment, and controls.

This RP does not supersede or eliminate any requirement imposed by any other industry specification.

2 Normative References

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

API Recommended Practice 1FSC, *Facilities Systems Completion Planning and Execution*

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

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

API Recommended Practice 17A, *Design and Operation of Subsea Production Systems-General Requirements and Recommendations*

API Specification 17D, *Specification for Subsea Wellhead and Tree Equipment*

API Specification 17E, *Specification for Subsea Umbilicals*

API Standard 17F, *Standard for Subsea Production Control Systems*

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

API Recommended Practice 17N, *Recommended Practice on Subsea Production System Reliability, Technical Risk, and Integrity Management*

API Recommended Practice 17P, *Recommended Practice for Subsea Structures and Manifolds*

API Recommended Practice 17Q, *Recommended Practice on Subsea Equipment Qualification*

API Recommended Practice 17S, *Recommended Practice for the Design, Testing, and Operation of Subsea Multiphase Flow Meters*

API Technical Report 17TR5, *Avoidance of Blockages in Subsea Production Control and Chemical Injection Systems*

API Technical Report 17TR6, *Attributes of Production Chemicals in Subsea Production Systems*

API Recommended Practice 17V, *Recommended Practice for Analysis, Design, Installation, and Testing of Safety Systems for Subsea Applications*

API Specification 19AC, *Specification for Completion Accessories*

API Specification 19CI, *Downhole Chemical Injection Devices and Related Equipment*

API Recommended Practice 75, *Safety and Environmental Management System for Offshore Operations and Assets*

API Standard 520 (all parts), *Sizing, Selection, and Installation of Pressure-relieving Devices*

API Standard 521, *Pressure-relieving and Depressuring Systems*

API Standard 674, *Positive Displacement Pumps—Reciprocating*

API Standard 675, *Positive Displacement Pumps—Controlled Volume for Petroleum, Chemical, and Gas Industry Services*

API Standard 2000, *Venting Atmospheric and Low-pressure Storage Tanks*

ASME ¹ *Boiler and Pressure Vessel Code*, Section V

EN 10204 ², *Metallic products—Types of inspection documents*

ISO ³/IEC ⁴ Guide 98-3:2008, *Uncertainty of measurement—Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/TR 10949, *Hydraulic fluid power—Component cleanliness—Guidelines for achieving and controlling cleanliness of components from manufacture to installation*

ISO 23936-2/NORSOK ⁵ M-710, *Qualification of non-metallic materials and manufacturers—Polymers*

ISO 28300, *Petroleum, petrochemical and natural gas industries—Venting of atmospheric and low-pressure storage tanks*

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

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

3.1.1

chemical injection unit (topside)

CIU

The mechanical elements of the SCIDS installed on topsides including tanks, pumps, piping, and flow control valves.

3.1.2

deadband

The range through which an input can be varied, in a control system, without initiating an observable response.

¹ American Society of Mechanical Engineers, 2 Park Avenue, New York, NY 10016, www.asme.org.

² European Committee for Standardization (CEN-CENELEC), Rue de la Science 23, B-1040 Brussels, Belgium, www.cen.eu.

³ International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org.

⁴ International Electrotechnical Commission, 3 rue de Varembe, 1st Floor, PO Box 131, CH-1211 Geneva 20, Switzerland, www.iec.ch.

⁵ Standards Norway, Lilleakerveien 2a, NO-0283 Oslo, Norway, www.standard.no/en/.

3.1.3**design life**

Specified operational life of system after pre-delivery test.

3.1.4**design pressure**

Maximum pressure at which a system (or an individual component) is designed to operate continuously. Also known as rated working pressure (RWP).

3.1.5**electronic control module (metering valve)****ECM**

The electronic control module (ECM) is typically responsible for processing and controlling all signals and functions in the chemical injection metering valve (CIMV).

3.1.6**flying lead**

Single or multiple composite grouping of hydraulic, chemical, electrical power, electrical signal, and/or optical signal carrying conduits used to interconnect various items of subsea equipment.

3.1.7**hunting**

When a valve or control system cycles around a point for an extended duration or indefinitely while trying to control to a fixed value.

3.1.8**injection rate control device****IRCD**

Flow-control components of distributed systems installed on topsides.

3.1.9**operating pressure**

System operational characteristic; the nominal pressure at which the system is actually operated in normal conditions.

3.1.10**operator**

Person, group, or organization who is the client/customer of the supplier; also a person who operates equipment or a machine.

3.1.11**redundancy**

Existence of more than one means of performing a required function or representing information.

3.1.12**subsea chemical injection delivery system****SCIDS**

System designed to deliver chemicals to a specified point into the subsea production to mitigate flow assurance and/or corrosion risks.

3.1.13**turndown**

The ratio of the highest controllable flowrate to the lowest controllable flowrate.

3.2 Acronyms and Abbreviations

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

AISI	American Iron and Steel Institute
ALARP	as low as reasonably practical
AWV	annulus wing valve
BPCS	basic process control system
BPR	back pressure regulator
CIMV	chemical injection metering valve
CIU	chemical injection unit
CIV	chemical isolation valve
CP	cathodic protection
D&C	drilling & completions
DH	down hole
ECM	electronic control module (part of CIMV)
EFAT	extended factory acceptance test
ESP	electrical submersible pump
ESS	environmental stress screening
FA	flow assurance
FAT	factory acceptance test
HIPPS	high integrity pressure protection system
HMI	human machine interface
HSE	health, safety, and environment
ICSS	integrated control and safety system
ID	inner diameter
IR	insulation resistance
IRCD	injection rate control device
KPI	key performance indicator
LDHI	low-dosage hydrate inhibitor

MCS	master control station
MTBF	mean time between failure
NPSH	net positive suction head
OD	outer diameter
OEM	original equipment manufacturer
PCS	production control system
PCV	pressure control valve
pH	acidity measure
PI	pressure indicator
PLEM	pipeline end manifold
PLET	pipeline end termination
PMV	production master valve
ppm	parts per million
ppmv	parts per million by volume
PSE	pressure safety element
PSHL	pressure safety high/low
PSL	product specification level
PSV	pressure safety valve
PT	pressure transmitter
PWV	production wing valve
RMS	root mean square
ROV	remote operating vehicle
RWP	rated working pressure
SCIDS	subsea chemical injection delivery system
SCM	subsea controls module
SCSSV	surface controlled subsurface safety valve
SDS	safety data sheet
SDU	subsea distribution unit

SOP	standard operating procedure
SPCS	subsea production control system
SS	stainless steel
SSIV	subsea isolation valve
SUT	subsea umbilical termination
TRL	technology readiness level
TUTA	topsides umbilical termination assembly
VPCI	vapor phase corrosion inhibitor
v/v	volume to volume

4 System Configuration

4.1 General

4.1.1 Introduction

The SCIDS spans from chemical storage located on the host facility (onshore or offshore) to injection points in subsea and/or subsurface equipment. The system can be split into three major subsystems: topsides/surface equipment, subsea equipment, and subsurface equipment. Interfaces are usually defined along similar lines with the exception that the topsides umbilical termination assembly (TUTA) is located on topsides/surface. TUTA could be delivered by topsides/surface or subsea. The “topsides to subsea” interface could be upstream or down stream of TUTA.

Figure 1 illustrates three typical SCIDS architectural configurations: point-to-point, distributed, and service. The “point-to-point” architecture is the simplest architectural configuration that requires individual dedicated tubes in the umbilical for each injection point. A “distributed” system architecture injects a chemical at multiple points using subsea distribution via CIMVs from a common chemical line. “Service” chemical injection systems are generally used for intermittent injection, batch injection, or pressure control supporting operations like valve testing, pressure balancing, chemical displacement, annulus management, etc. Other configurations may be possible or necessary to address specific requirements. If used, they should be evaluated to ensure they provide comparable isolation and functional protections as the typical systems.

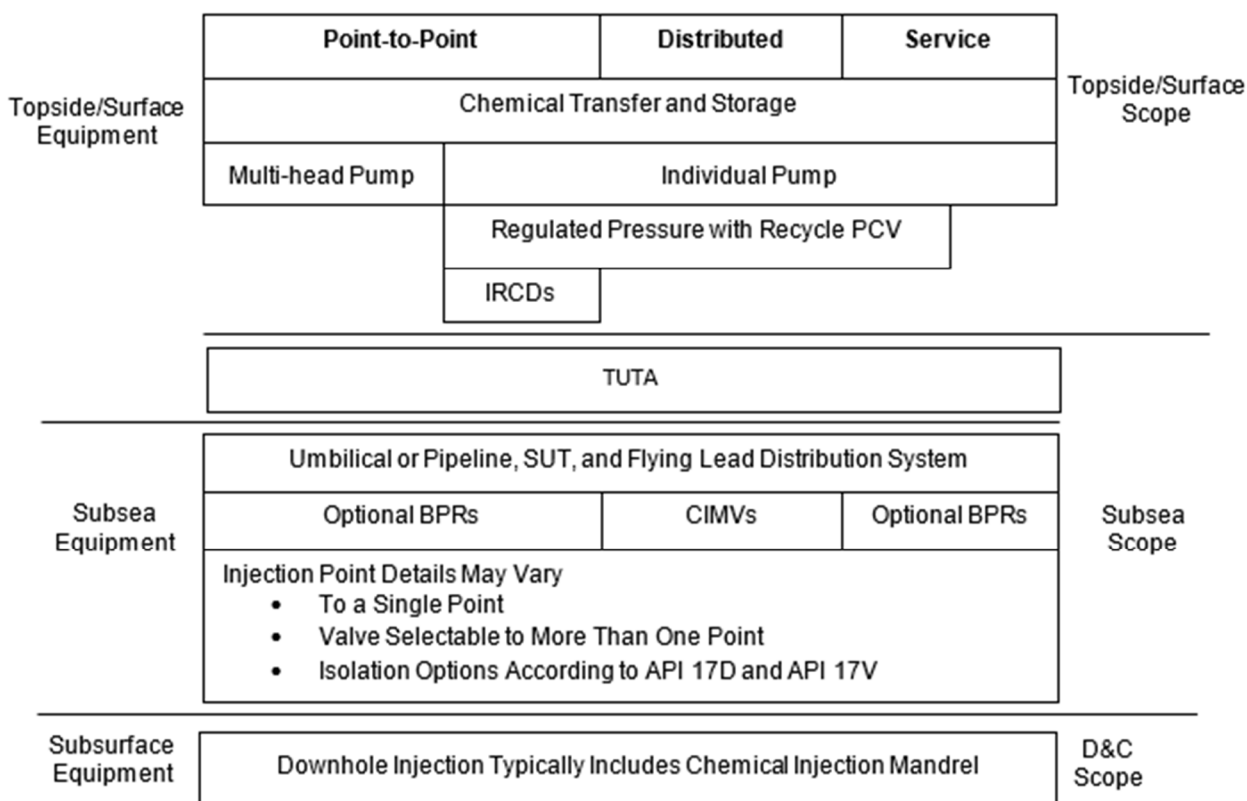


Figure 1—Typical SCIDS Architectural Configurations

4.1.2 Surface Equipment

Surface equipment of the SCIDS, placed either onshore or on an offshore facility, stores and pumps the chemicals at the required injection rate, pressure, and cleanliness for a specified duration or number of operations. Chemical usage along with replenishment frequency determines the minimum storage volume.

This subsystem includes the chemical transfer system for chemical loading, storage (temporary and permanent), piping, filtering, pumping, pressure control/relief, distribution, metering, and TUTA. This system is generally designed as a part of the process system and may be integrated with equipment for injection of chemicals into the topsides process. The topsides chemical injection system typically is monitored and controlled by the production control system (PCS), which also transfers data to other control systems such as subsea production control system (SPCS). Topsides SCIDS equipment, either standalone or integrated in facilities' chemical injection system, shall comply with API 14C requirements in addition to host facility requirements and local legislation. Detail requirements for topside equipment can be found in Section 7.

4.1.3 Subsea Equipment

Subsea equipment is a delivery and distribution system that ensures injection of chemicals at specific locations. The SCIDS's subsea system includes the umbilical, the subsea umbilical termination (SUT), flying leads, connectors, and injection equipment (valves, connectors, etc.). Subsea equipment is monitored and controlled by SPCS in communication with PCS. Subsea equipment shall comply with API 17D, API 17E, and API 17F requirements as applicable for equipment type. Detail requirements for the subsea equipment can be found in Section 8.

4.1.4 Subsurface Equipment

Equipment for subsurface chemical injection points in the well below the tubing hanger (tubing, connectors, and chemical injection mandrel) are provided and installed by Drilling & Completions (D&C). Typically, individual chemical lines are run from the tubing hanger to injection points deep in the well or around the surface controlled subsurface safety valve (SCSSV). Connection systems may offer external pressure testing. Subsurface chemical injection equipment is outside the scope of this document; refer to API 19AC and API 19CI for completion design specifications.

4.2 System Architecture

4.2.1 General

The architecture of the SCIDS should be defined for each chemical to be used to address storage, umbilical functionality, chemical delivery method, distribution, injection rate control, and injection isolation and barriers. Depending on the specific chemical service needs, criticality, and umbilical design considerations, different system architectures may be selected for each chemical. In architecture value comparisons, the installed cost, complexity, and reliability of competing systems should be considered along with total life cycle cost inclusive of operation, maintenance, spares, and decommissioning. Strategies for pressure testing, commissioning, mitigations and contingencies for lost injection lines (permanently blocked), leak detection, well additions, expansion beyond current design limits, and abandonment should also be considered.

4.2.2 Point-to-Point

The “point-to-point” architecture is the simplest architectural configuration for subsea chemical injection, but it requires individual dedicated tubes in the umbilical for each injection point. This type of system is typically used for continuous chemical injection.

Chemical is injected at a controlled flowrate and pressure into a subsea or subsurface injection point. In point-to-point injection systems, chemical distribution from storage to injection points is done at the host facility, either by typically multi-head pumps, which have a single drive mechanism coupled in parallel with multiple pumping chambers (Figure 2) or injection rate control devices (IRCDs) (Figure 3).

In a point-to-point system using multi-head pumps, injection rates may be controlled at each pump. In a system with IRCDs, single pump is used, and injection rate is controlled by an IRCD on each line. In either variation, the chemical is directed through a single line to one injection point, which may be selected by chemical isolation valves (CIVs). The system with a multi-head pump does not require a recycle line. The system with IRCDs requires a PCV and recycle line to manage pressure to the IRCDs. IRCDs are similar in function to CIMVs but located topsides. They draw the chemical from a constant pressure header and regulate the flowrate of the chemical for each line. The system should be capable of measuring flowrate either through IRCD or separate device. Additionally, back pressure regulators (BPRs) may be installed subsea to protect against vacuum conditions in chemical lines if injection depth and low injection point pressures cause vacuum conditions or siphoning of chemical. The following are considerations for point-to-point system architecture.

- a) Due to direct flow path from the host to the injection point, leak testing and detection is relatively easier. Efforts can be focused on flow path through the equipment.
- b) Easier to commission. When adding new wells to an existing system, fluid compatibility can be managed from the host. If buffer fluids are required, they can be pumped before production chemicals and displaced into the production system.
- c) Individual line failures generally only affect one well. If one line fails or becomes blocked, remaining lines may be repurposed to mitigate and work around the problem. In some cases, depending on the chemical, adequate treatment of bulk comingled fluids may be obtained by compensating with higher injection rates in other wells.

- d) If needed, individual lines may be repurposed. In principle, chemicals can be customized by well.
- e) Lines may also be displaced for special chemical treatments and then displaced back to production chemical without affecting other well services. It is easier to manage fluid compatibility issues with buffer fluids in a line that does not have branches to multiple injection points.
- f) The full flow area of the line is available for injection. Umbilical tube capacity is not shared with other injection points. Commissioning or other fluid displacements can be performed at a maximum rate because flow is not restricted by CIMVs.
- g) Limitations on umbilical design will impose constraints on point-to-point systems with long offset distances and high well counts.
- h) Point-to-point lines will generally inject a slug of fluid when a CIV is opened, as pressures equalize. In addition, changes to flowing pressure can be expected to impact injection rates until umbilical and injection point pressures adjust to new flow conditions. Both of these issues will be aggravated by low injection rates and increasing umbilical tube length/volume.

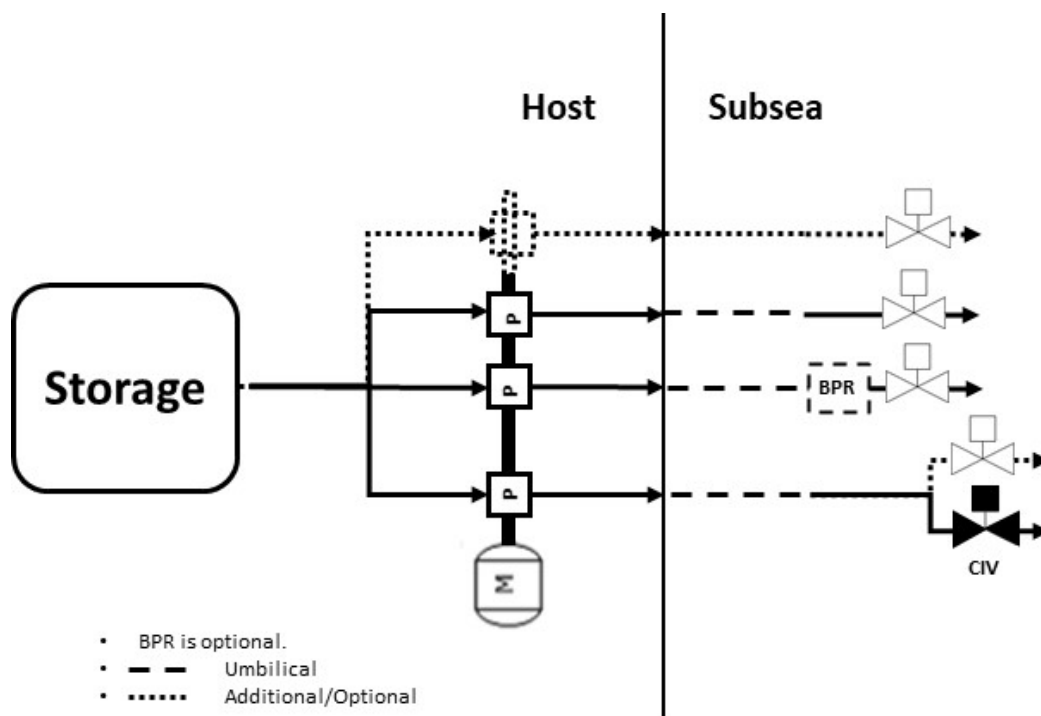


Figure 2—Point-to-Point Architecture with Multi-Head Pump

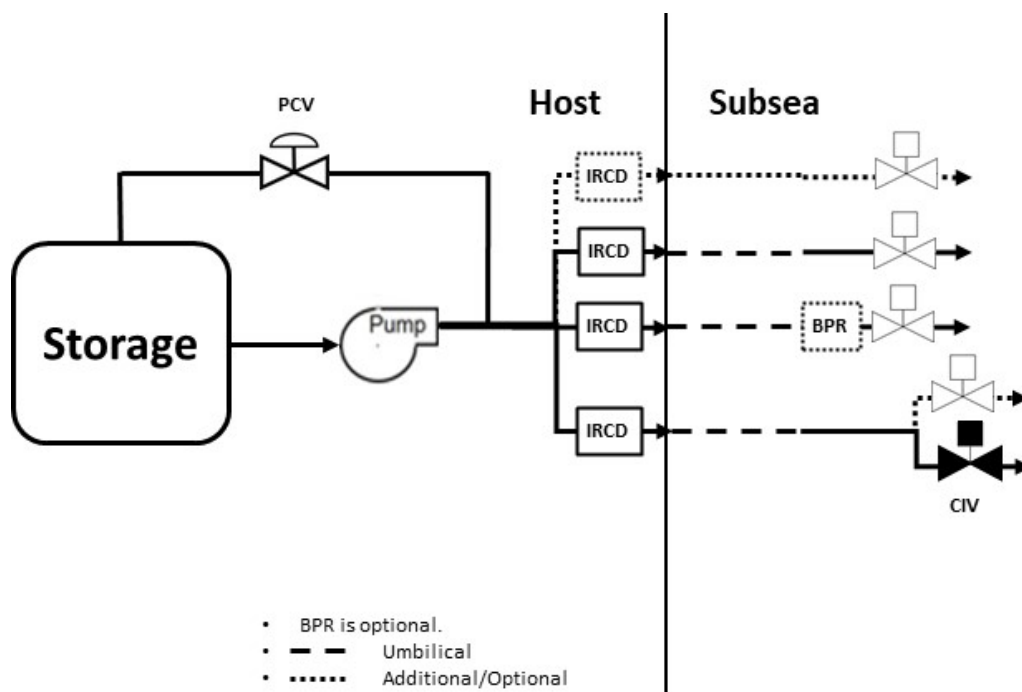


Figure 3—Point-to-Point Architecture with IRCDs

4.2.3 Distributed

A “distributed” system architecture (Figure 4) injects a chemical at multiple points using subsea distribution via CIMVs from a common chemical line (could be multiple parallel umbilical lines if high rates are required or a separate larger diameter service line). This system reduces the number of tubes required in an umbilical and pumps needed. The CIMVs control and monitor the rate of chemical through the valve going to each injection point. CIVs control which injection points are open. This configuration can provide continuous injection of a chemical at several injection points at the same time.

Distributed systems are frequently used for corrosion inhibitor, scale inhibitor, low-dosage hydrate inhibitor (LDHI), or mono-ethylene glycol. Distributed systems use a pump(s) with pressure control (such as PCV and recycle line) to maintain a steady topsides pressure. The CIMVs in a subsea distribution system allow sufficient back pressure to be maintained in the umbilical to prevent vacuum conditions. CIMVs cannot be considered as a barrier for isolation purposes.

Consideration should be given to commissioning and decommissioning of distributed systems. Conventional storage fluids are often incompatible with production chemicals and should be displaced with intermediate “buffer” fluids. Initial commissioning can be done much like with point-to-point systems, but adding in future wells may require the strategic placement of buffer fluids in new flying leads and downhole injection lines to manage interfaces between incompatible fluids. In some cases, large elements of the system may need to be displaced to a buffer fluid to add new equipment to the system. In general:

- distributed systems can have challenges when injecting into multiple points with wide range of injection pressures;
- a failure (such as leak or blockage) in a distributed system generally affects the whole well cluster/field;
- distributed systems have CIMVs that may fail and need to be replaced—CIMVs need power and interface with control system and hardware in which they are installed;
- locating a leak in a distributed system could be challenging due to increased number of leak paths through connections and equipment.

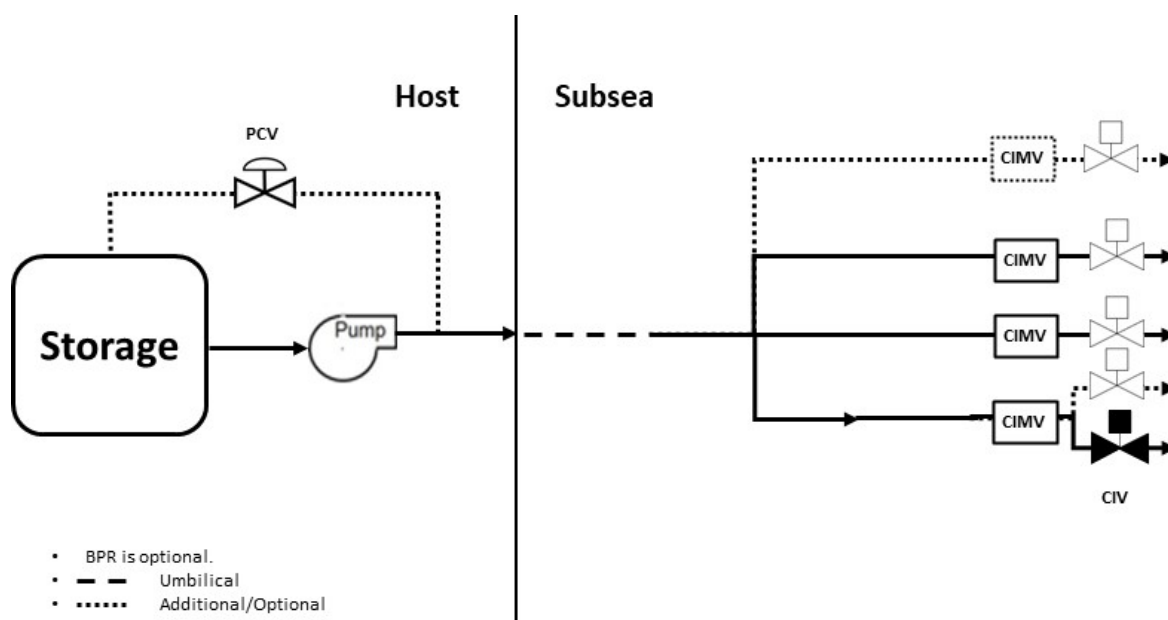


Figure 4—Distributed Architecture

4.2.4 Service

“Service” chemical injection systems are generally used for intermittent injection, batch injection, or pressure control supporting operations like valve testing, pressure balancing, chemical displacement, annulus management, etc.

A service chemical line is usually connected to multiple injection points but injected into only one point at a time by opening the appropriate CIV. They can also be used for continuous injection to one point as a contingency injection. Chemical may be provided by a single pump, through a single umbilical tube (could be multiple if high rates required). There may be a recycle loop with a PCV to regulate injection pressure topsides. BPRs may be used to protect against vacuum conditions in the bulk chemical line if water depth and low system pressures cause insufficient back pressure to keep the line fluid filled. The full flow area of the service line is available to maximize flow to a single injection point, and a service line may be displaced and repurposed for specialty treatments.

The annulus monitor line is designed to manage annulus pressure, which requires bidirectional flow in service (Figure 5). If annulus monitor line is used for other services, risk assessment shall be completed prior to use.

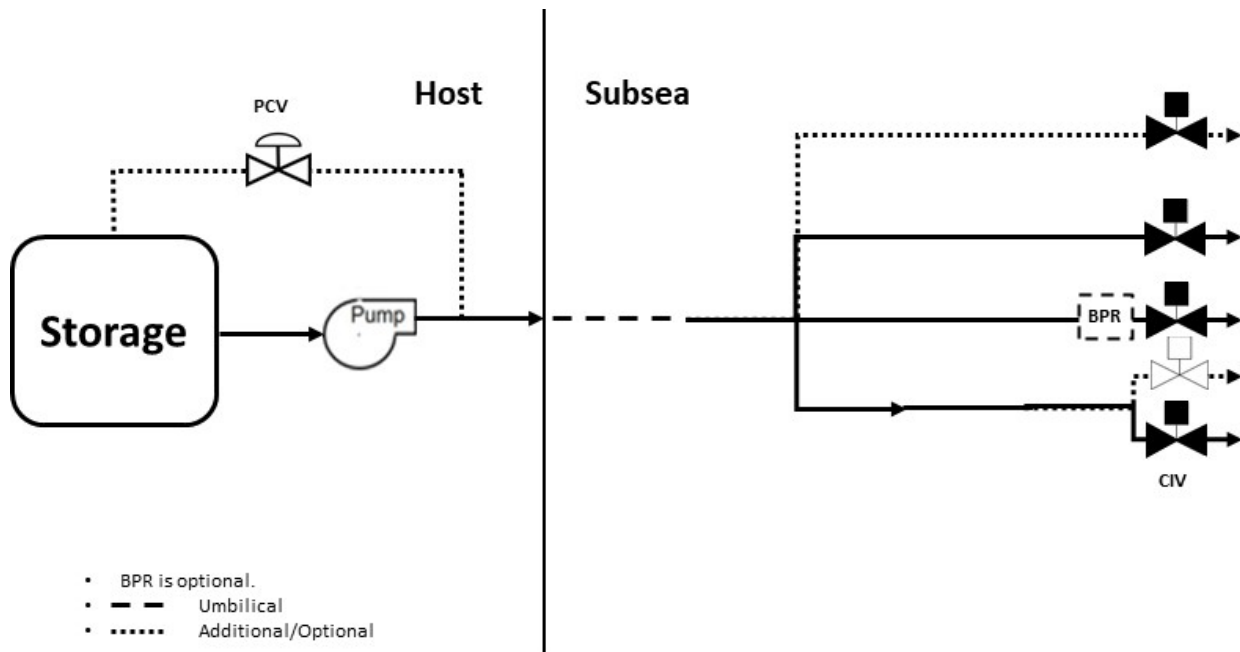


Figure 5—Service Architecture

4.2.5 Barrier and Isolation

Valving at subsea tree and equipment for chemical injection is governed by API 17D and API 17V. Pressure barrier and isolation requirements change with the location of the injection point with respect to the production master valve (PMV). API 17D and API 17V provide details of barrier and isolation requirements and exceptions. In addition to these requirements, a minimum of one CIV shall be used to isolate injection to each injection point. CIMV is not a well barrier nor an isolation.

5 System Design

5.1 Chemical Injection System Design Process

It is the intent of this RP to take a system-wide approach when designing and implementing a SCIDS. The SCIDS should be designed as a complete system from storage to point of injection. The configuration of the SCIDS's distribution and controls system, including the physical arrangement of piping systems and injection point placement, can affect injection delivery performance and chemical treatment effectiveness.

The design, configuration, and operation of the SCIDS directly impacts the life cycle operation for the subsea production system. To obtain a safe and optimized chemical injection solution, it is important to maintain good coordination between the subsea production system design and the chemical injection system design. The SCIDS should be designed in conjunction with the subsea facilities to achieve the desired operational performance.

Goals for the chemical injection system design include:

- ensure that the integrity of the system is maintained,
- ensure the system performs as required,
- ensure that issues of technical conflict/gaps are identified and tracked to closure,
- ensure that awareness of new technology in the system and associated risks are understood.