

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

API RECOMMENDED PRACTICE 17Y
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BALLOT DRAFT



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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 and/or corrosion risks. There have been instances when the systems did not perform as intended during operations. This is due to poor system design and lack of a system ownership during design and operations. SCIDS are highly integrated systems that require collaboration across multiple disciplines.

This recommended practice (RP) provides recommended practice and guidance for the design, commissioning, operations and maintenance of SCIDS and its associated equipment. This include 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 has 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.

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1 Scope

This RP is for the design, specification, testing, qualification, installation, commissioning and operation of SCIDS. It covers SCIDS from chemical storage tank located on host facility (onshore or offshore) to injection points subsea with a holistic approach. SCIDS interfaces are categorized in three main groups: 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 Specification 17D, *Design and Operation of Subsea Production Systems—Subsea Wellhead and Tree Equipment*

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 17Q, *Recommended Practice on Subsea Equipment Qualification*

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

API 17TR6, *Attributes of Production Chemicals in Subsea Production Systems*".

API Std 2000, *Venting Atmospheric and Low-Pressure Storage Tanks*

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

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 & Definition

3.1.1

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

3.1.2

component

All elements of the bill of materials (BoM) such as electronic components, mechanical components, product, tooling, processes, software, and firmware.

3.1.3

design life

Specified operational life of system after pre-delivery test.

3.1.4

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.

3.1.5

operating pressure

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

3.1.6

operator

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

3.1.7

design pressure

maximum pressure at which a system (or an individual component) is designed to operate continuously.

3.1.8

redundancy

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

3.1.9

Subsea Chemical Injection Delivery Systems (SCIDS)

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

3.1.10

Turn down

The ratio of the highest, repeatable measurement to the smallest

3.1.11

umbilical system

Umbilical, complete with end terminations and other ancillary equipment.

3.2 Acronyms and Abbreviations

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

ALARP As low as reasonably practical

AISI	American Iron and Steel Institute
API	American Petroleum Institute
BPR	back pressure regulator
CAPEX	capital expenditure
CIMV	chemical injection metering valve
CIV	chemical injection valve
CIU	Chemical Injection Unit
CP	Cathodic Protection
D&C	drilling and completions
ECM	Electronic Control Module
EFAT	Extended Factory Acceptance Test
ESD	emergency shut down
ESS	Environmental Stress Screening
FAT	factory acceptance test
FT	flow transmitter
HSC	Hydrogen Stress Cracking
HSE	health, safety, and environment
ICSS	Integrated Control and Safety System
IR	Insulation Resistance
IRCD	injection rate control device
KPI	Key Performance Indicator
LDHI	Low-Dosage Hydrate Inhibitor
MTBF	Mean Time Between Failure
MCS	Master Control Station
MoC	management of change
NPSH	Net Positive Suction head
pH	Acidity measure
PI	pressure indicator

PPE	Personal Protective Equipment
ppm	parts per million
PSD	process shut down
PSE	pressure safety element
PSV	pressure safety valve
PT	pressure transmitter
RMS	Root Mean Square
ROV	remote operating vehicle
RP	recommended practice
SCM	Subsea Controls Module
SCIDS	subsea chemical injection delivery system
SDS	safety data sheet
SEM	Subsea Electronic Module
SIIS	Subsea Instrumentation Interface Standardization
SOP	Standard Operating Procedure
SS	Stainless Steel
SUTA	Subsea Umbilical Termination Assembly
TRL	Technology Readiness Level
TUTA	Topsides Umbilical Termination Assembly
v/v	volume to volume
VPCI	Vapor Phase Corrosion Inhibitor
Xmass	Christmas tree

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 generally supplied as part of the subsea scope with connections to the TUTA being the “topsides to subsea” interface.

Figure 1 illustrates 3 typical SCIDS architectural configurations, Point to Point, Distributed and Service. 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.

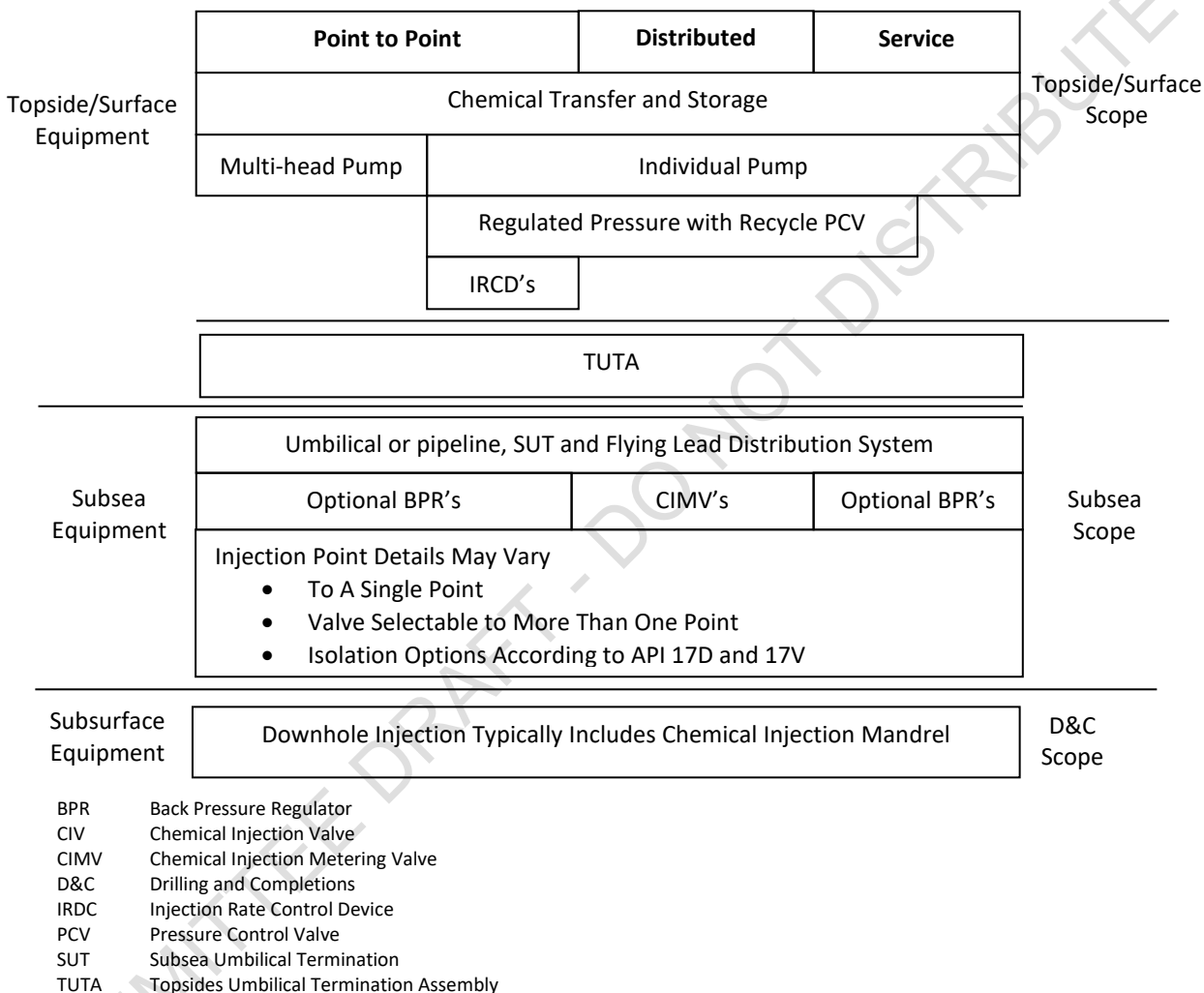


Figure 1—Typical SCIDS Architectural Configurations

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 and metering. 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) in communication with the subsea production control system (SPCS). Topsides SCIDS equipment, either standalone or integrated in facilities chemical injection, system shall comply with API 14C requirements. Topside equipment details are covered in Section 7.

4.1.3 Subsea Equipment

Subsea Equipment is mainly a delivery and distribution system which ensures injection of chemicals at specific locations. The SCIDS's subsea system includes the TUTA, 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 details are covered in Section 7.

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 RP19AC and API RP 19 CI for Completion Design Specifications.

4.2 System Architecture

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. There are three typical SCIDS architecture configurations namely, Point to Point, Distributed and Service.

Generally, some combination of architecture is required to meet all field needs. Each chemical service can be examined independently to determine which architecture suits its function best. Some compromises may be necessary to manage umbilical size, cost and topsides chemical system capabilities. The distributed system minimizes cost and weight by reducing the number of umbilical tubes and pumps needed but has challenges when considering deliverability across systems with widely varying injection pressures. The higher the number of injection locations for a given chemical, the more savings that can be realized through the distributed system relative to the discrete system.

4.2.1 Point to Point

The "Point to Point" Architecture is the simplest and offers the most reliable 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 flow rate 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 multi head pumps, Figure 2, or Injection Rate Control Devices (IRCDs), Figure 3.

Multi head pumps have a single drive mechanism coupled in parallel with multiple pumping chambers.

Injection rate is controlled by individual chamber's stroke setting. 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 CIV's. 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 IRDC's. IRDC's are similar in function to CIMV's but located topsides. They draw the chemical from a constant pressure header and regulate the flow rate of the chemical for each line. IRDCs should include a means of determining flow rate. 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. Following should be considered if point to point architecture is selected:

- 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 pump 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 doesn't 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 CIMV's.
- g) The cost of point to point systems increases with offset distances and 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.

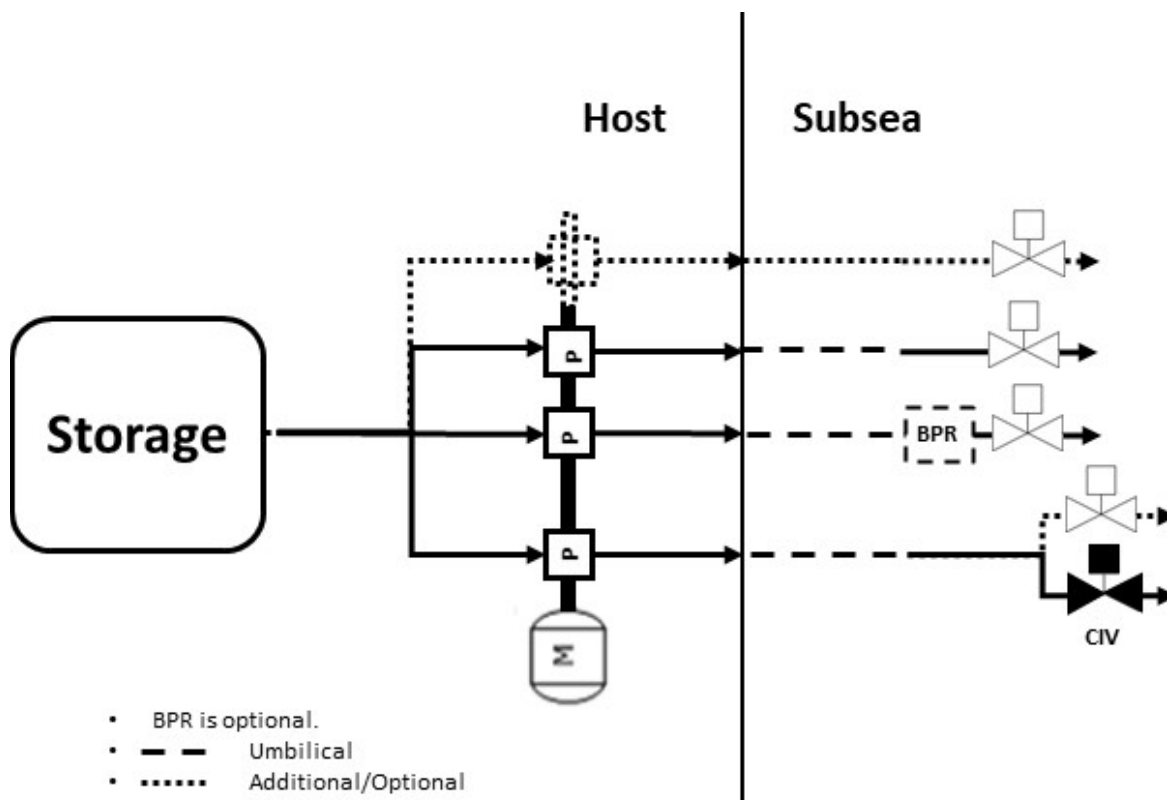


Figure 2— Point to Point Architecture with Multi-Head Pump

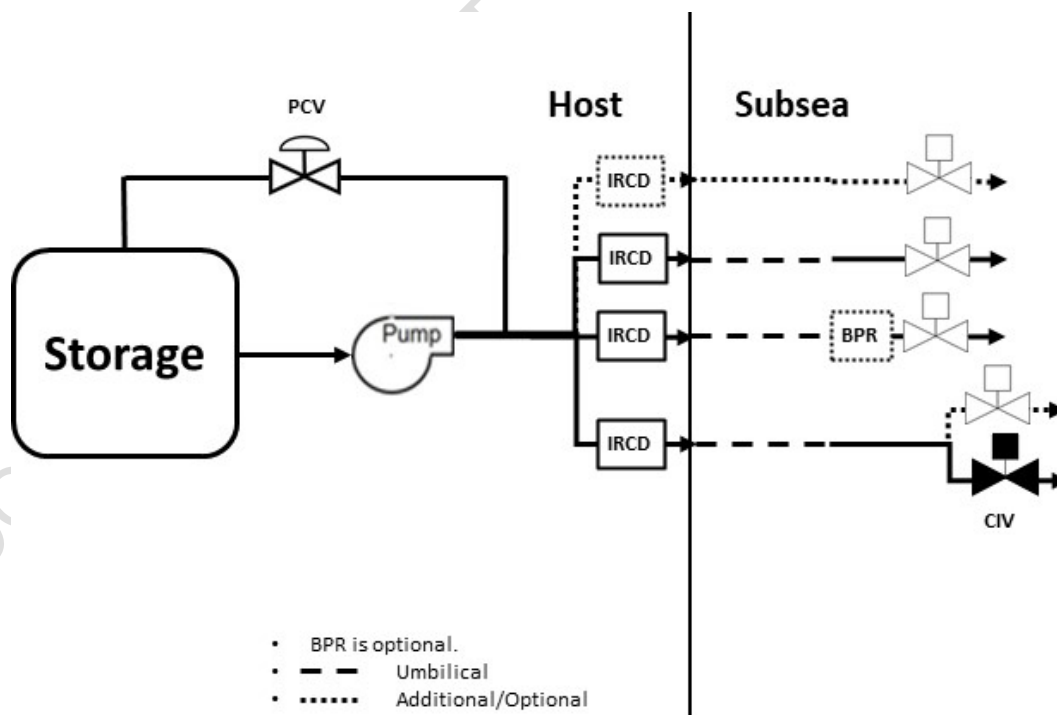


Figure 3— Point to Point Architecture with IRCsDs

4.2.2 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 umbilical tubes required in an umbilical. 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, LDHI, or mono-ethylene glycol. Distributed systems use a single pump with 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. CIMV’s 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 minimize system costs for longer offset developments and the costs are less sensitive to increasing well count.
- If a distributed line is out of service, it generally affects the whole well cluster/field.
- Distributed systems are more complex and CIMVs may fail and need to be replaced, which requires management of spare parts. 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 leak paths through connections and equipment. Distributed systems typically branch out to multiple wells through individual well flying leads, this increases the number of components that might leak or fail.

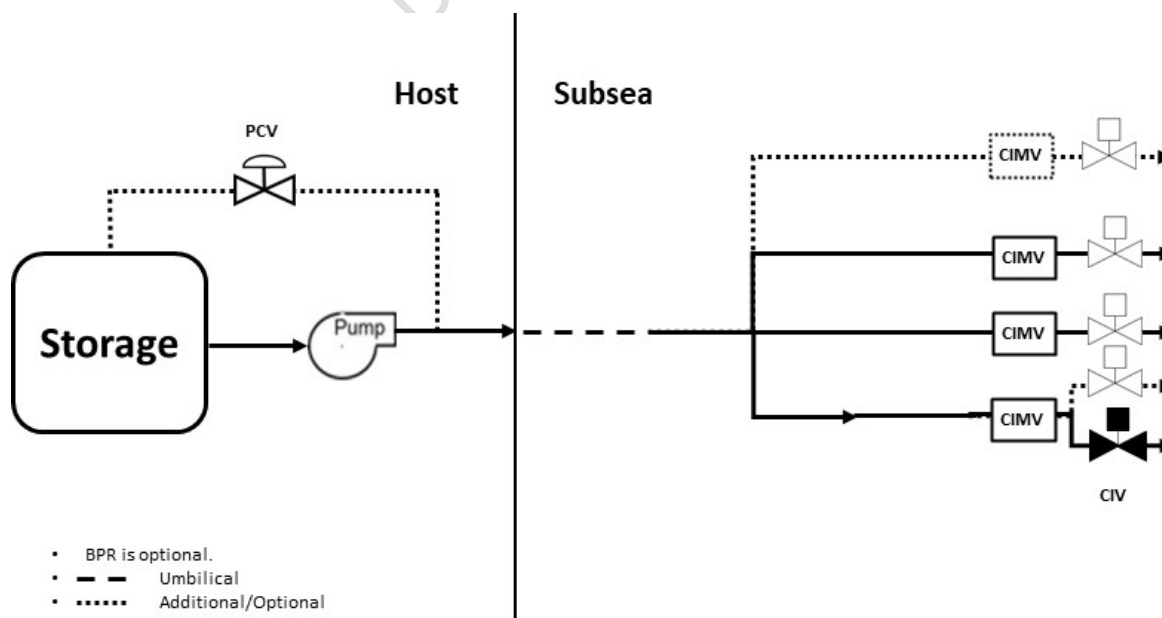


Figure 4— Distributed Architecture

4.2.3 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, and 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 chemical injection valve (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. BPR’s 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.

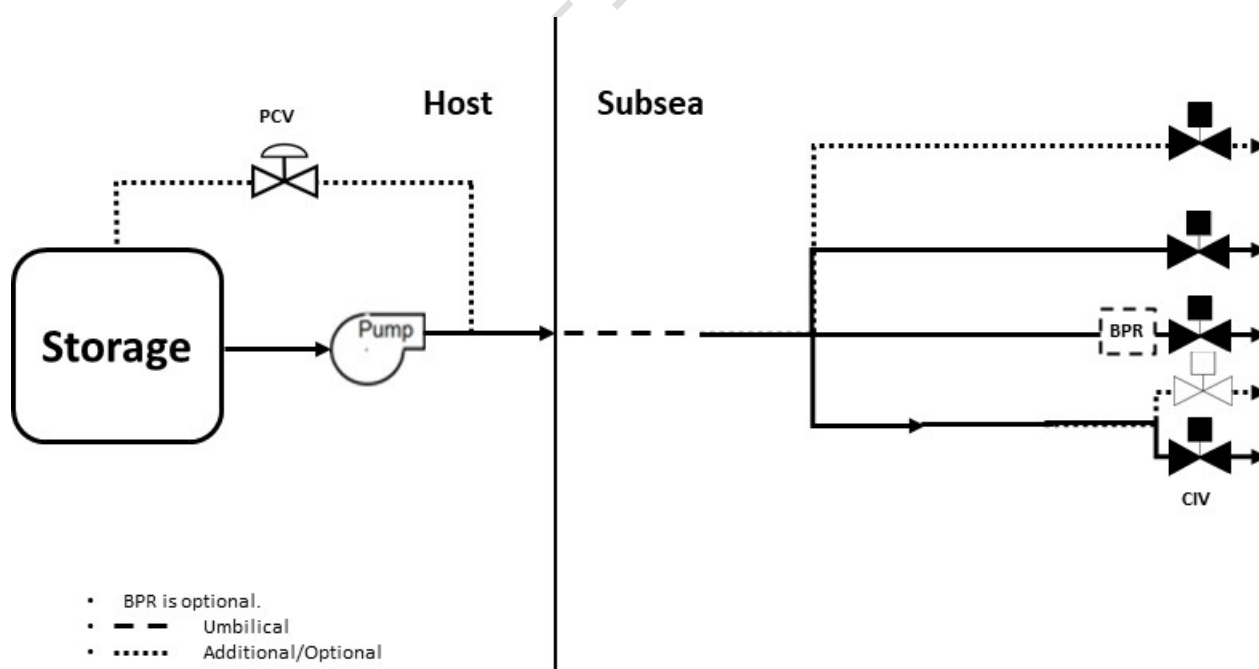


Figure 5— Service Architecture

4.2.4 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 control injection for each injection point, and CIMV is not a well barrier nor an isolation.

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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 and chemical effectiveness.

The design, configuration and operation of the SCIDS directly impacts the life cycle cost for the entire subsea production system. To obtain a safe and cost-effective 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,
- Ensure that the SCIDS can be operated and maintained per design and operating limits.

When designing a SCIDS, a chemical injection philosophy should be established which supports facility flow assurance and mechanical integrity strategies. The philosophy should address the chemicals required for injection, injection locations, target injection dosages and rates, estimated topsides storage volume required, and estimated injection pressures.

A chemical injection system concept/configuration should be selected (see Section 4) based on the project drivers and in alignment with the chemical injection philosophy. Different configuration solutions may be selected for each chemical.

A chemical evaluation may be conducted with chemical suppliers to survey potential chemical products and identify if new product or formulation needs to be developed.

When selecting an SCIDS solution the following should be considered:

- a) Chemical injection philosophy
- b) Chemicals selected to be injected
- c) Redundancy requirements
- d) Continuous or intermittent injection
- e) Injection rate
- f) Pressure drop
- g) Injection pressure
- h) Potential for backflow
- i) Potential for vacuum conditions
- j) Commissioning requirements
- k) start-up/shut-in (planned and unplanned)
- l) design life of the field

Input to the design should be documented in an SCIDS basis of design. The SCIDS basis of design typically includes the following:

1. A description and function of the chemical to be injected,
2. A dosage (concentration) range for the chemical to be injected, including the dosage (concentration) units e.g. ppm v/v for continuous chemical injection,
3. An injection rate range for the chemical to be injected that is consistent with the required dosage covering field life,

4. Operating and environmental conditions that the individual component parts of the chemical injection system will experience, including environmental temperature extremes that chemicals can be exposed to while in outside storage or transport on-shore and/or during offshore logistics movements,
5. The density, compressibility, and viscosity of the chemical over the range of temperature and pressure that the chemical will experience in all parts of the chemical injection system,
6. The chemical specification to be achieved and maintained during storage and injection,
7. Chemical sampling requirements, and
8. Chemicals and materials compatibility.

The SCIDS basis of design should be updated as the design advances through project phases.

During the design, design data will come from multiple sources; such as chemical and equipment manufacturers. Data to be considered includes chemical properties (chemical OEM), equipment specifications, operating conditions (operator, systems engineer), and lessons learned (operator, SCIDS OEM, systems engineers). Basic chemical injection flow modeling may be conducted for the selected injection concept. Flow modeling may include a review of pressure drops, potential for backflow or vacuum conditions, start-up/shut-in (planned and unplanned) across the SCIDS for the life of the field. Detailed design should be conducted with the selected chemical vendors input.

During the design the following are typically developed:

- a) Specifications for the chemical injection skids on host (including materials, the scope of supply, and testing.
- b) Number and size of chemical injection tubes
- c) Types of chemical injection connections
- d) Number and types of flying leads and tubes in flying leads
- e) Metering requirements
- f) Chemical performance indicators
- g) Testing and commissioning philosophy and procedures
- h) Selection of a chemical vendor
- i) Operating procedures

During commissioning startup and early operation, it is recommended that:

- Operator training be finalized
- SCIDS performance should be verified
- Injection rates and pressure to be monitored and optimized.

5.2 Material Selection

Material selection for the system and individual components, including seal materials, should meet the recommendations listed in API 17A. SCIDS materials selection should consider the combined effect of equipment exposure to anticipated injected chemicals for all operational considerations, including commissioning, operating pressure and operating temperature.

Subsea chemical isolation valves, check valves and downhole injection mandrels that are exposed to production fluids (i.e. production, completion, drilling, chemical injection fluids) shall comply with materials classes as indicated by API 6A/API 17D including Sour Service, where applicable.

The materials selected should consider testing chemical compatibility if it is not already known. When selecting materials of construction, it is important to look at the life of field aspects of chemical injection, in that a chemical used for a specific application may be changed after several years of operation, due to production fluid or conditions changing in wells or flowlines, new wells.

The selection of metals and elastomers with a broad range of chemical compatibilities may allow easier chemical change outs in later years. Refer to "Technical Report 17TR5, and "Technical Report 17TR6.

Compatibility between different chemicals being injected into the same system should be verified.

5.3 System Design Recommendations

5.3.1 General

The SCIDS should be designed with flexibility to meet various production scenarios. Any requirements for future expansion should be addressed during the design phase. Future expansion functionality should be documented along with any requirements for implementation.

The following recommendations are related to the SCIDS and should be addressed during the design and operating phases:

- a) HSE issues related to injected chemical properties, including the storage location, and the potential requirement for gas blanketing
- b) SCIDS should be designed to minimize any chemical exposure risk to personnel working on and maintaining the system. SDS should be consulted for necessary controls
- c) Pumps should be selected to deliver the designed flow rate against the highest possible injection point backpressure that is expected through the life of the field, including frictional pressure drop and net positive suction head
- d) Chemicals injection pressures should not exceed the pressure rating of a flowline segment or design rating of subsea equipment (e.g. tree, SDU) to which it is connected
- e) Determine the maximum allowable operating pressure considering the specific gravity of the chemical and how it is connected to the subsea system, including pump pressure.
- f) Operating temperatures and pressures in the production system and in SCIDS (topsides, subsea, and downhole) should be considered during chemical selection to ensure that temperature is not detrimental to the properties and effectiveness of the chemicals being injected.
- g) Chemical storage size and location should consider local environmental conditions as well as nearby external heat sources (e.g. sunlight, flares, heat exchangers, well production)
- h) Consider potential excessive fluid temperature buildup in the chemical system storage/recirculation loop due to excess flow and Joule -Thomson (J-T) heating potentially leading to fluid property changes and/or the failure of components
- i) Chemical selection that is compatible with SCIDS materials in the flow path
- j) System design should consider fluid properties under operating pressures and temperatures. Viscosity can increase significantly at high pressure and low temperature.
- k) Avoid large pressure drops, and high velocities
- l) Avoid small diameter tubing when possible as this increase plugging risk
- m) Flow area changes due to tube size and/or number of tubes should be minimized
- n) Chemical injection system thermal hydraulic analysis should be conducted to determine the effect of pressure and temperature on chemical properties
- o) When chemicals are integrated into an umbilical with high voltage electric power, the thermal effects of the electric power should be evaluated, in particular the non-submerged sections of umbilical,
- p) Chemical line sizes should be adequate for the specified flow rates as well as for other considerations such as:
 - Subsurface chemical lines are generally 1/4" to 1/2" OD (larger tubes are difficult to fit in the well annulus)
 - Subsea tree and equipment lines are generally 1/2" to 1" OD.
 - Chemical injection umbilical line sizes of 1/2" ID to 1" ID are preferred. Larger tubes have been used, but there is limited hardware available to connect to the lines at SUT's

- Flying leads may use of two or more smaller tubes in parallel as a substitute for a larger tube due to stiffness. The difficulty of handling and making up metal tube flying leads grows geometrically with tube size due to the torsional stiffness of tubes. ½" to ¾" OD tubes are generally manageable.
- q) Pressure drops and the effects on the system operating pressures when an IRCD or CIMV or BRP should be included in the design
- r) Designed to have a minimal required maintenance for topsides installed equipment and maintenance free for the subsea installed equipment.
- s) All remediation and intervention methods should be considered in the design phase to ensure sufficient chemical injection points are available to execute the remediation and intervention procedures
- t) Chemicals should be selected and tested to verify that there are no serious incompatibility issues when they are all mixed into the production stream, including low flow and no flow conditions
- u) Availability and redundancy should be considered in the SCIDS design based on the criticality of each chemical

5.3.2 Codes and Standards

The requirements for each type of equipment are defined by equipment function, location and interfaces including local codes and standards.

The design, testing and operation requirements for SCIDS components are covered by the following standards:

Application	Applicable Standard
Subsea and downhole equipment that is normally exposed to production fluids	API 17D/API 6A, API 19AC/API 19CI
Subsea controls equipment interfacing with and controlling subsea elements of the chemical injection system and interfacing with topsides controls equipment.	API 17F
Topsides and subsea equipment included in TUTA, Subsea Umbilical's and SUTA	API 17E
Topside safety systems for chemical injection	API 14C
Subsea safety systems for chemical injection (including overpressure protection)	API 17V

5.3.3 Pressure Ratings

The SCIDS system design pressure is based on the chemical injection pressure required to ensure design flow rates at the injection points with the appropriate safety devices and interlocks to prevent the system from pressurizing subsea production equipment above its design rating. SCIDS design shall meet the pressure ratings defined by API 17V, API 17F, API 17E and API 17D, as applicable. Topsides CIU or other subsea components not covered by one of the indicated standards should conform to API 17F pressure requirements.

5.3.4 Temperature Ratings

The subsea chemical injection equipment shall conform with API 17F, API 17E, and API 17D temperature rating as applicable for the respective equipment installation. Special SCIDS components as subsea chemical injection valves, check valves upstream of chemical isolation valves and downhole injection mandrels shall follow the temperatures classes defined by API 6A/API 17D.

5.3.5 Injection Point Considerations

Chemical injection system design is a part of the overall facility design. The locations of chemical injection points should be selected in accordance with flow assurance, production chemistry and operational

requirements. Chemicals such as; corrosion inhibitor and scale inhibitor, require injection points upstream of the risk location to ensure mixing of the chemical to be effective.

Chemicals such as, methanol and glycol, are typically injected at the risk location for hydrate management. Chemical injection locations are typically selected for operational functionality (e.g. valve testing, leak testing, pressure balancing, and displacement).

The chemical treatment of piping dead legs should be considered. The length and number of dead legs should be limited. High alloy materials can be used where it is difficult to deliver corrosion inhibitors.

if it is desired to treat comingled fluid stream instead of treating individually, the injection point should be downstream of the mixing point to simplify system configuration. If the fluid streams are incompatible, treatment may be required prior to the mixing of the two streams.

Common injection points include:

- a) Production tubing deep in the well near the formation and below ESP
- b) Production tubing above the SCSSV
- c) Subsea tree
 - between the PWV and PMV
 - Subsea tree at the AWV
 - Subsea tree downstream of the production choke
- d) Subsea Equipment
 - Manifold, PLET, PLEM
 - subsea gas lift injection
 - SSIV
 - HIPPS
 - Subsea pig launcher
- e) Subsea Processing
 - Separation
 - Boosting
 - Compression

5.3.6 Product Level Specification

The SCIDS equipment that is exposed to production fluids and/or perform subsea chemical isolation functions such as chemical isolation valves shall meet the respective subsea equipment or downhole completion PSL classification requirements per API 6A/API 17D.

The rest of topsides and subsea SCIDS equipment being part of the subsea chemical storage, pumping and distribution is not subject of PSL requirements per API 17D/6A. This equipment should be manufactured and tested according with API 17F and/or API 17E.

5.4 System Functional Requirements

Chemical injection systems can be characterized in two main categories for their function: continuous and intermittent injection. Continuous injection systems provide chemical continuously during production, such as inhibitors for scale, corrosion, asphaltene, emulsion, and wax. Chemical injection stops when production ceases. These inhibitors are not typically injected during shutdowns and are typically only injected at one point in the system.

Intermittent injection systems are generally designed to inject chemicals temporarily, either to deliver a specified volume, a specified pressure or for a limited duration to cover a transient condition. These chemicals can be injected during shutdowns, restarts, and to support utility operations and interventions. Chemicals associated with intermittent injection may be injected at various locations, for example, downhole, wellhead, manifold. Chemical injection systems can also be used to equalize and increase pressure within the subsea well annulus to maintain well integrity.

Injection rates should be determined based on the required concentration of the injected chemical in the treated fluid. Typically, this is a chemical dose concentration in either water or hydrocarbon liquid in ppmv. The injection rate of continuously injected chemicals to treat production fluids is based on the production profiles. The treatment rate for each chemical should be specified as a range. The basis for the rate, such as oil rate, water rate should also be provided.

The Injection rate range should consider all production cases including normal, turndown and contingency production scenarios. The turn-down ratio can be large in some cases. The turn-down ratio can be limited by the CIMV, and / or check valves in chemical injection mandrels. Injection chemical can be diluted to allow better management of the injection rate. It may be useful to select a small and middle-range chemical injection pump, to accommodate a larger turndown than a single pump can provide.

For some chemicals, the maximum injection rate will be set to provide a specific injection volume in a specified duration at several injection points simultaneously to meet operational requirements. When specifying injection rates, uncertainties in measurements and injection rate control should be considered for both production fluids and injection chemicals. If the chemical injection rate is critical, multiple rate monitoring and controlling methods may be required. Injection rates, pressure and associated ranges should be consistent with design limits of equipment used in the injection system.

The following functional requirements for the SCIDS and should be addressed during the design phase:

- a) Chemicals shall be stored per manufacturer's instructions and monitored to ensure that the chemicals do not go outside their chemical specifications (e.g. evaporation of chemicals, condensation of water).
- b) Potential contamination of the chemical by airborne solids onshore, nearby shot blast or painting to avoid chemical solidification, thermal degradation, and chemical phase separation
- c) SCIDS should be designed to maintain the specified chemical cleanliness.
 - a. NOTE: Cleanliness standard of AE AS 4059, Class 6, or ISO 4406, Class -/15/12 for new chemical systems is recommended.
- d) There should be provisions for cleaning chemical injection tanks and systems, for potentially changing chemicals and eventually decommissioning. This includes providing for low-point drains or draw-offs, and a means to flush solvent and drain the flushing fluids used.
- e) Consideration should be given to human factors and managing interface hardware for refilling chemical tanks to minimize the potential to contaminate a chemical by accidentally adding the wrong chemical to a tank.
- f) Functionality for testing, flushing, commissioning, intervention, leak detection, and decommissioning of itself and associated systems should be provided
- g) Reasonable access should be available to umbilical lines and umbilical spares for replumbing to bypass blocked or leaking umbilical lines, as well as for possible repair and re-installment
- h) Consider and plan for the use buffer fluids between incompatible fluids during commissioning displacements.
 - NOTE: Future branches in distributed and shared chemical systems pose difficulties when displacing incompatible fluids. Strategically spotting buffer fluids in key components before they are installed, as part of a commissioning plan, can mitigate these difficulties.
- i) Design and operate to avoid hydrocarbon backflow into the system
- j) Use check valves or control of valve closure timing to control backflow
- k) CIMV may provide back flow detection

- l) Operating procedures may include maintaining a positive pressure in the chemical system when it is out of service to reduce backflow risk
- m) Controls interlock, permissive and valve sequences for chemical injection
- n) Chemical isolation valves may be closed when tree valves are closed, even if chemical pumps are still running, depending on injection rates and system volumes
- o) Chemical injection valves should not be opened until chemical line pressures are sufficiently high to flow into the injection point to reduce backflow risk
- p) Chemical injection system is typically be monitored at the host facility, including injection rate and pressure, if the system has a CIMV, subsea monitoring is possible
- q) A means should be provided for metering of the injected chemicals with a known accuracy and precision. This may be continuous with a meter or intermittent with a pump calibration cylinder, or by other generally equivalent means.
- r) Periodic calibration of chemical injection metering equipment is recommended
- s) Chemical fluids material balances are recommended to ensure that there are no significant deviations in fluid usage from planned that might indicate a leak or unexplained fluid usage caused by equipment malfunction
- t) "Flushing plates" or dummy chemical valve inserts without CIMV's fitted, may be outfitted with pressure transmitters and other instruments to monitor chemical line conditions at the injection point
- u) Poppetted connectors typically used on chemical lines will hold high internal pressure and prevent chemical leakage to the sea. However, they can function as a spring check valve and allow seawater ingress into the umbilical, which can displace contents in the line towards the host facility. Topsides pressure management of chemical lines is important during intervention operations. Positive pressure may be maintained on the system to prevent the ingress of seawater based on respective chemical specific gravity.
- v) Chemical storage capacity should be designed to meet the required rates and an adequate number of days of operation to safeguard against prolonged adverse weather conditions. However, storage volumes may be limited by safety considerations.
- w) Intermittent chemical storage volumes should be determined based on expected number of planned and unplanned operations between chemical deliveries. Chemical storage should consider chemical shelf life from its production to delivery to injection point.

5.5 Installation and Retrievalability

Most elements of the chemical injection system are integrated with the subsea control system, subsea trees or other subsea structures. Installation and retrievalability requirements for system components can be found in API SPEC 17D, API RP 17F, API RP 17H, API RP 17P, API RP 17R, and API RP 17S. The system design should include, as appropriate.

- a) An effective means and strategy for displacement of fluids in the system to production chemicals during installation/commissioning.
- b) A strategy for leak testing and fluid displacements to support future planned system expansions and adding planned new wells to the system.
- c) A method to minimize discharges to the environment during intervention work.
- d) A barrier philosophy that meets the requirements in API RP 17A during intervention operations.
- e) A strategy to manage fluid compatibility issues when replacing elements of the system.
- f) A method allowing for the controlled depressurization of any recovered equipment.

6 Interfaces

6.1 General

The SCIDS is an integration of several sub-systems that requires collaboration across multiple disciplines. As SCIDS spans from host facility (onshore or offshore facility) to injection points subsea and subsurface, the system will interface with a large range of equipment and other systems. The design, function, performance and operating limits of each element of equipment and sub-system will greatly influence the final SCIDS' design, effectiveness, availability and performance.

The SCIDS interfaces may be viewed and categorized in three main groups:

- Engineering.
- Mechanical Equipment.
- Controls.

6.2 Engineering Discipline Interfaces

A key aspect of engineering interface management is the ability to effectively communicate across all involved engineering disciplines, and all the details related to an interface, including requirements, technical specifications, and potential issues.

Table A.1 in Annex A shows an example of a typical responsibility matrix for each discipline involved in SCIDS development.

Table A.2 in Annex A shows an example of the typical interface activities for each discipline involved in SCIDS development.

Note: Depending on each project and operation teams is organized, some engineering disciplines and specialists listed in the Tables A.1 and A.2 might have different job titles. In some projects, roles and responsibilities of the discipline and specialists might be combined.

To ensure that SCIDS performed as intended, the following engineering disciplines and specialists are suggested to be involved in various stages of SCIDS development in projects and in operations:

- reservoir and production.
- flow assurance, production chemistry, and process and process safety.
- topside controls and facilities.
- subsea controls, umbilical, tree, manifold and pipeline.
- wellheads and completion.
- equipment designer.
- commissioning and operations.

It is essential that the roles and responsibilities of each discipline in SCIDS development are well defined at the beginning of projects.

It is essential that the communication channel is promptly established, and the proper information is exchanged so that they can proceed with their scope of work. A responsibility matrix between disciplines may be used as a tool to communicate engineering activities in SCIDS development.

Each of the engineering disciplines and specialists has specific roles in SCIDS development. For example, the subsea controls engineer ensures the chemical injection-related interlocks and controls are implemented in the controls system, and the controls system has the capability to detect and monitor process and chemical injection conditions prior to executing any subsea chemical injection commands.

Another example is that flow assurance, and process engineers should provide process conditions over the life of the field as inputs to the SCIDS design. The operations engineer should then ensure the conditions are operable and not exceed other systems' operating limits.

The systems engineer responsible for SCIDS (i.e. SCIDS component/system design and interface management) should be aware where the code breaks are within the system.

6.3 Mechanical Interfaces

SCIDS mechanical interfaces are physical interfaces between its hardware, the SCIDS, and the external hardware/sub-system.

Typical mechanical interfaces between major components in SCIDS can be found in Fig 1, and should be depending on how the SCIDS architecture is configured.

The typical mechanical interfaces on topside are:

- The interface between the chemical injection unit and the topside utility services equipment. These interfaces may include CIU weight, dimensions, electrical power requirements, utilities (air, drains, etc.).
- The interface between the chemical injection unit and the topside distribution piping/tubing that cover tubing sizes, materials, pressure ratings, test requirements, etc.
- The interface between topside distribution piping/tubing and the TUTA.

The distribution interface between the topside chemical injection supply system and the subsea equipment for SCIDS is at TUTA where filtered, pressurized, and possibly metered chemicals are delivered to individual umbilical tubes for subsea injection.

The TUTA is generally designed within the subsea equipment scope by the subsea systems engineering team. The TUTA provides connections to each chemical injection tube with proper valves for sampling, isolation, depressurization, and displacement for different operational purposes and may also be used to separate topsides and subsea pressure testing and commissioning work.

The typical mechanical interfaces managed within the topsides system scope are:

- Chemical conduit connections between the chemical injection unit and the chemical injection distribution system.
- Chemical conduit connections between the chemical injection distribution system and the TUTA.
- Topside Chemical Metering Valves.

The typical mechanical interfaces managed within the subsea system scope are:

- Chemical conduit connections between SUT and umbilical.
- Chemical conduit connections between SUT or other distributions and flying leads.
- CIMV and ROV docking mechanism.
- Chemical conduit connections between the CIMV and subsea distributions, flying leads, or injection conduit.
- Chemical conduit connections between the subsea tree and the tubing hanger.
- Chemical conduit connections in flowlines terminations and end terminations structures.

- Subsea tree and manifold (injection valves and check valves).
- The interface between subsea and sub-surface.

The typical mechanical interfaces managed within the sub-surface system scope are:

- Well completion system.
- Chemical injection tubing connections at the tubing hanger and the DH injection mandrel.
- Tree and DH tubing sizes, materials, pressure ratings, and test requirements.

Mechanical interfaces to subsurface are the chemical injection tubing connections at the tubing hanger and to DH injection mandrel when SCIDS requires downhole chemical injections. The interfaces include tubing sizes, materials, pressure ratings and test requirements.

The mechanical interfaces typically include code breaks at natural equipment interface breaks within the SCIDS system as defined by the subsea systems team referenced in section 6.2 (Engineering Discipline Interfaces) above. Each code break will influence operating limits and SCIDS performance.

6.4 Controls Interfaces

The typical controls interfaces for SCIDS can be divided into three sub-interfaces:

- Topside CIU to ICSS, BPCS, and MCS
- MCS to Topside CIU, ICSS, and BPCS
- MCS to Subsea CIU

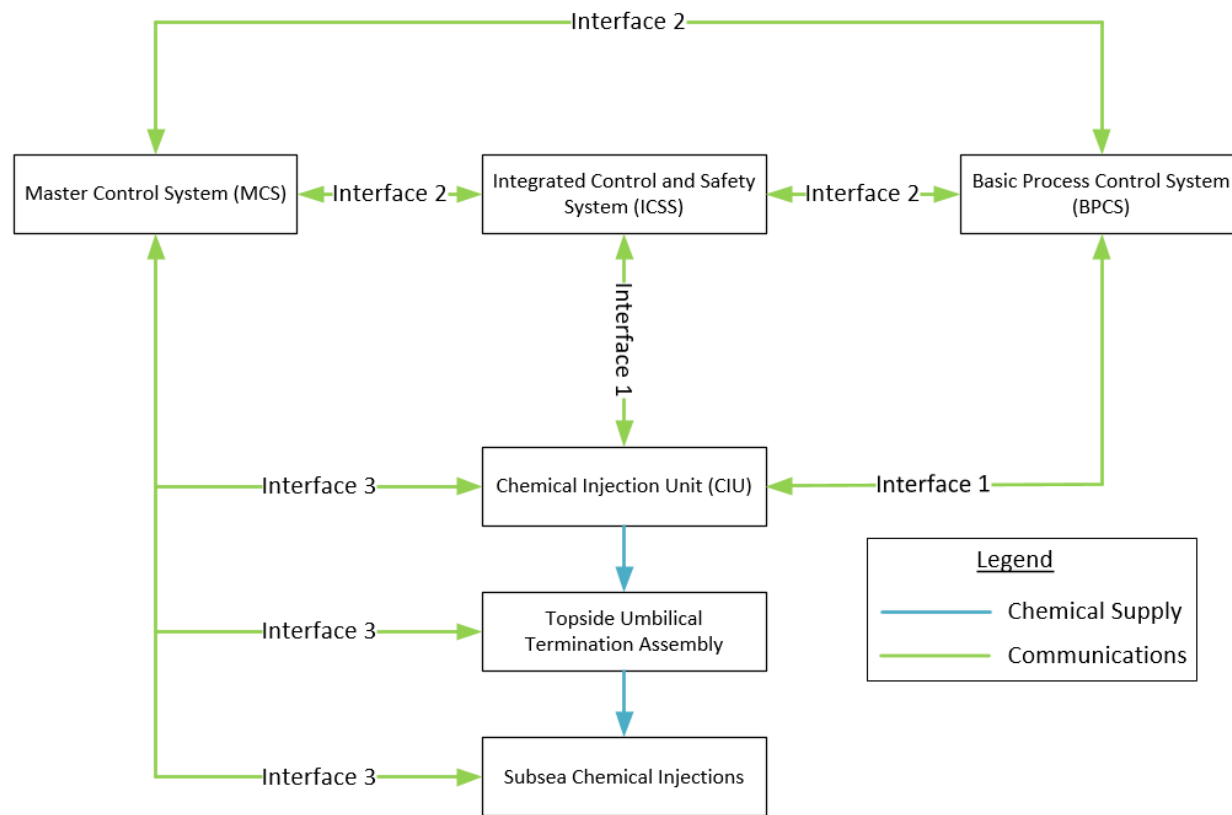


Figure 6 - SCIDS typical interface

As shown in Fig 6, the typical Controls interfaces for SCIDS:

- The Interface 1 is between the topside Chemical Injection Unit (CIU), the Integrated Control and Safety System (ICSS), and the Basic Process Control System (BPCS). This interface provides ICSS and BPCS controlling and monitoring of the CIU at surface facilities. CIU overpressure protection by the safety system and the isolation of the CIU during a safety shutdown event are part of this interface.
- The Interface 2 is between ICSS, BPCS, and MCS. This interface provides CIU status reporting and monitoring to the MCS. It also contains controls and commands to the MCS for SCIDS command executions, chemical injection-related statuses, and condition data retrieval from subsea. This interface also actively monitors topside and subsea chemical injection pressures, flow conditions, valve commands, subsea interlocks and other monitoring data points to ensure proper chemical injection conditions.
- The Interface 3 is between the MCS and subsea chemical injection system. This interface contains monitoring and controlling of status and condition of chemical injection on topside and in subsea. For examples, monitoring and controls of CIMV and chemical injection isolation valves in tree and manifold.

7 Topsides Equipment

7.1 General

The purpose of this clause is to provide functional requirements and equipment-specific requirements for the topside (onshore, offshore) equipment of SCIDS to ensure safety, environmental protection, and SCIDS effectiveness.

This section is not intended to provide comprehensive design guidance, but rather to support the management of interfaces necessary to achieve an effective SCIDS system.

In general, all topside equipment should meet all material and fabrication requirements described in Section 10. All wetted components of the SCIDS should be checked for chemical compatibility.

The system should be monitored and controlled by the process control system in communication with the subsea control system.

7.2 System Monitoring

The surface streams on the SCIDS should be monitored to ensure integrity, safety and successful delivery of the chemical. A well-implemented monitoring strategy should ensure these are met.

- a) Monitor the flow to each injection point either continuously or via periodic checks;
- b) Monitor for low- and high-pressure excursions that could result in equipment damage and/or release to environment;
- c) Monitor temperatures, particularly if temperature excursions are possible that could exceed the system temperature ratings;
- d) Monitor pressure drop across filters;
- e) Monitor chemical storage tank level; and,
- f) Monitor for chemical cleanliness and quality.

7.3 Control and Safeguarding

7.3.1 Pressure Rating, Control and Safeguarding and Pressure Surge Control

The pressure rating of the surface equipment potentially exposed to subsea operating pressure should be consistent with the pressure rating of the subsea equipment items. Extra care should be taken to avoid over-pressuring subsea equipment. The pressure at the surface may have to be controlled at a pressure that protects subsea equipment. The elevation head between the surface and subsea elevation should be considered when determining the surface pressure limits. (Ref Sections 5.3.3 and 5.3.4)

Injection pumps are positive displacement pumps and should conform to either API 674 or 675. These systems generate pressure pulses. The pulses are minimized via pulsation dampeners. The design should include the appropriate design and placement of pulsation dampeners at pump discharge and/or pump suction.

7.3.2 Pressure Control

Pressure control at the discharge of injection pumps can be achieved via recycle valves that route some or all the pump flow back to storage. This can be achieved via a PCV or pressure control loop.

Recycle valves often experience very large pressure drops and hence are subject to erosion failures and vibration induced failures.

There is frequently a significant temperature increase across the injection pump and across the recycle valve (Joules-Thompson heating). If there is significant temperature increase across the pump and/or recycle valve, overheating is possible if dissipation of this heat is not accounted for in the design.

If the flow is routed to storage, heat loss from the storage tank may be adequate.

If the flow is routed back to pump suction a cooler and a high temperature safeguard system may be required to protect against pump overheating or degradation of the fluid.

7.3.3 Pressure Safeguarding

Safeguarding shall be provided by Pressure Safety Valves (PSVs) and/or Pressure-Safety Elements (PSEs) used at the discharge of the injection pumps and by Safety Instrumented Functions that take appropriate actions such as shutting down the pump consistent with requirements of API RPs 14C, 520 and 521..

When PSVs relieve pressure, they experience a very large differential pressure and very high fluid velocity. This can result in cutting of the seats.

7.3.4 Pulsation Dampeners

Positive Displacement pumps generate pressure pulsations. Pulsation dampeners may be needed on either suction or discharge of pumps, or both, to mitigate these pulsations.

Three types of pulsation dampener include:

- Gas-charged: A volume of pressurized gas provides the dampening. Usually a bladder is provided to separate the gas from the chemical. The dampener is charged with a pressure that is a specified fraction of the operating pressure. For systems with widely varying operating pressure the gas charge pressure may need to be adjusted for different operating conditions. If that is impractical, another dampening option should be selected.
- Liquid volume: Liquid compressibility is used for dampening. These are much larger than gas-charged dampeners. They have the advantage of not requiring a pressure charge and dampen surges in any pressure range.
- Liquid volume and pressure drop (acoustic filters): Combinations of liquid volume and pressure drop can be designed to reduced surges at specified frequencies.

The quality of the inert gas used for bladder systems needs to be confirmed to avoid corrosion and/or flammable mixtures.

7.4 Equipment Items

7.4.1 Storage Tanks

There are three types of chemical storage tanks – permanent, day, and temporary tanks. The type used depends on the use and criticality of the chemical and the type of platform. Temporary tanks are typically those used to transport the chemical, such as tote tanks. Permanent tanks are large volume tanks.

Injection pumps may take suction from permanent tanks, or the chemical may be transferred in batches to day tanks from which the injection pumps take suction. A common example of this is a large methanol tank in the hull of a floating platform with a smaller methanol day tank on topsides. Usually

- Critical or continuous use chemicals should use permanent or day tanks;
- Batch or infrequent use chemicals may use day or temporary tanks; and,
- Temporary use chemicals may use temporary tanks.

Storage tanks should be sized considering the volume of chemical use and typical replenishment times. Non-volatile chemicals should be stored in atmospheric vented tanks while volatile chemicals should be stored in blanketed tanks. The blanketing is provided by using either fuel gas or nitrogen as applicable.

Chemical storage tote tanks and loading hose connections should be clearly labeled, color-coded and/or mechanically unique to prevent cross-contamination risks.

The storage tank design shall be consistent with the requirements of the chemical SDS.

The storage tanks should be designed with the following safety systems:

- high- and low-level alarms;
- high- and low-pressure alarms;
- fire and gas detection systems with alarms when the chemical is flammable
- flame arrestors on atmospheric vents when the chemical is flammable;
- PSVs and vents to safe locations; venting practices should follow API 2000 and ISO 28300; the PSVs should be sized according to API 5251; and,
- overflow drains.

7.4.2 Chemical Loading

Facilities are provided for chemical loading into permanent storage tanks. Chemicals may be delivered via:

- portable containers such as tote tanks; and,
- permanent tanks in service vessels.

Chemicals from portable tanks may be gravity drained or pumped into permanent topsides tanks.

Chemicals delivered via permanent tanks in service vessels are pumped to permanent topsides tanks. Since it is difficult to maintain cleanliness standards in service vessel tanks, filtration should be provided in the offloading system.

Care should be taken to ensure that all products entering the tank meet chemical composition and cleanliness specifications.

7.4.3 Filters and Strainers

Chemicals delivered subsea should meet the applicable project cleanliness requirements of Umbilicals and subsea equipment items.

The filters and/or strainers should be placed:

- upstream of the storage tank to maintain cleanliness of the stored chemical;
- upstream of a charge pump (if there is a charge pump) to protect the pump; and,
- upstream of the injection pump to protect the pump and to provide chemical cleanliness to subsea chemical specifications.

Additional filter(s) may be positioned downstream of the pump. These are usually provided to catch mechanical debris from pump or flowmeter breakage.

A 'pump-around' filter may be used to filter fluid and return the filtered fluid to the storage tank. This filter allows for cleanup of contaminated chemical in the storage tank.

Bypasses should not be installed around filters unless there is a valid scenario in which filters can be bypassed without risk of system contamination.

7.4.4 Charge Pumps

Charge pumps are used for pressure boosting when necessary to meet the Net Positive Suction Head (NPSH) requirement of the injection pumps.

Redundancy should be considered to ensure pump availability.

7.4.5 Injection Pumps

Injection pumps are positive displacement pumps and should conform to either API 674 or 675. NPSH design calculations should include both friction losses and acceleration losses.

Check valves should be installed immediately downstream of each injection pump. Refer to API 14C.

Redundancy should be considered to ensure pump availability.

7.4.6 Flow meters and Flow Control

7.4.6.1 General

Chemicals are delivered in either a discrete or a distributed architecture as described in Section 4.

Distributed control is accomplished on topsides either via flow control loops which include flow meters and a control valves or via injection rate control devices (IRCDs)

7.4.6.2 Flow meters

Appropriate chemical metering should be provided. This may take the form of continuous flowmeters, continuous flow control devices or periodic calibration of pump output. As a minimum, the impact of the following factors should be used when deciding on a metering option:

- meter reliability;
- inherent risk with using the meter for operation and installation;

- complexity of the meter; and,
- weight and space available on the surface.

Additionally, it should be ensured that the flowmeter does not decrease the pressure to below the vapor pressure of the chemical due to low injection back pressure.

There are multiple types of flow meters and flow control devices available for chemical systems. Because the flowrates are frequently very low, specialized devices may be required.

Systems featuring typical flow control loops are available (flowmeter, controller and control valve).

Specialized devices which contain both flow measurement and flow control elements are commonly used.

7.4.6.3 IRCDs

Injection rate control devices (IRCDs) are the flow-control components of distributed systems installed on topsides. Conceptually they are similar to CIMVs installed subsea, but there are additional challenges in controlling flowrate with topsides control valves or IRCDs.

They control the chemical flowrate by controlling the flowrate across a fixed or variable orifice. IRCD behavior is influenced significantly by downstream system frictional pressure drop. If the downstream pressure drop is large compared to the IRCD pressure drop, then the IRCD may have little impact on the flowrate. A system model is required to fully understand this behavior.

IRCDs have a performance curve available from the vendor. In general, the vendor should provide a minimum pressure drop and a maximum pressure drop. Flow control may be poor if inadequate pressure drop is available to the unit. Vibration may occur if the unit is forced to consume too much pressure drop.

Dynamic behavior of the Umbilicals can affect calibration of IRCD systems. Long-offset delivery systems may take a significant amount of time to adjust to a changed setting prior to arriving at a new steady state.

Pump dynamics (pressure pulses) may impact IRCD performance. Effective pulsation dampening may be necessary to achieve accurate flow control.

8 Subsea Equipment

8.1 General

The subsea chemical injection system typically consists of a topside TUTA, umbilical, subsea umbilical termination, subsea distribution system, flying leads, non-return valves, check valves, hydraulic couplers, chemical valves (both controlling with measurement and on/off) and connections into the injection point.

API 17D details the requirements of designing injection points, tubing and interfaces on subsea trees which can be applied to other structures, where required.

API 17E details the requirements of the subsea umbilical system for the transmission of fluids, power and communications from topside to the relevant subsea structure (tree, manifold, inline structure, pump or PLET).

API 17F provides limited guidelines to subsea injection systems and associated equipment and instrumentation.

API 17V provides guidance on subsea pressure ratings and safety systems.

The primary scope of this section is to provide guidance on the equipment that is not currently covered within the API 17 group of Standards and Recommended Practices and predominantly focuses on the CIMV.

In general, subsea equipment used in the SCIDS should:

- Be designed and qualified through qualification processes in conformance with API 17N and API 17Q.
- Have validated product reliability data in the form of MTBF in conformance to API 17N.
- Be evaluated through TRL assessments to establish and document the technology readiness level (TRL) of the product and/or systems in conformance to API 17N.

8.2 CIMV Hardware Functional Requirements

8.2.1 Basic Functional Requirements

A CIMV should conform to the following basic functional description;

- Provided as an independently retrievable module with receptacle, or integrated into a retrievable module;
- May be suitable for mounting in either the vertical or horizontal orientation;
- Retrievable by a standard work class ROV. If specialized tooling or orientations are required, this should be advised by the supplier;
- Have a failsafe or redundant means of retrieval such that receptacle and adjacent structure are not compromised;
- Interface to the subsea production control system via a wet mate electrical connector, in either stab-plate or ROV-mate configuration, for power and communications, if applicable;
- May be Controlled via the topside MCS through the SCM, or by other means;
- Able to independently regulate the flow of chemicals to a specified rate, entered by a user via the MCS, or by other means;
- Connected to the chemical distribution system via fluid couplers;
- Constructed of materials suitable for chemical service.

8.2.2 Material Map and Compatibility

A detailed and complete material map of all wetted and pressure containing materials, both metallic and non-metallic, used in the CIMV should be made available for review.

Materials of construction should be suitable for use in their specific fluid environment (chemical, dielectric, seawater, etc.). Chemical suppliers conduct compatibility testing on subsea chemicals (including storage and commissioning fluids) and the CIMV material map should be used to determine suitability for the specific application.

To minimize the compatibility screening process, materials of construction should be limited to the standard materials used for compatibility testing by the chemical suppliers. This should in no way exclude special alloys or engineered elastomers which may be necessary for specific working conditions. Material design considerations should be documented for review.

8.2.3 Coatings

The external sea water wetted components of the CIMV should be suitably coated or otherwise designed to address marine growth and cathodic protection design. Exposed surface areas should be defined by equipment manufacturer to aid sizing of cathodic protection system

Coatings which provide lubricity for moving parts should be rated for the design life and should not degrade in the environment they are exposed to e.g. sea water, chemicals or fluids used for pressure compensation systems etc.

8.2.4 Cathodic Protection

The CIMV should be considered as part of the tree or host structure CP system and additional anodes are not required on the receptacle or CIMV. Electrical continuity between the CIMV and receptacle should be confirmed to be below an agreed upon limit during FAT.

Materials that are isolated from the CP system should be chosen to maintain their integrity for the given design life of the project.

Titanium alloys should be isolated from the CP system where applicable.

8.2.5 Sealing

All elastomeric seals and materials should be decompression resistant and industry accepted for chemical applications. Some guiding specifications for carrying out the elastomer material review include ISO 23936-2/NORSOK M-710.

If a dual barrier principle applies for the chemical seal design, both sealing solutions should be individually qualified. All sealing solutions used in a CIMV design should be documented by detailed design, qualification, testing data or service history.

All seal systems should be designed to prevent ingress of sea water at the design water depth with atmospheric internal pressure during operation.

Attention should be made to corrosive, abrasive and erosion wear of the valve components and seals. All seal materials should be suitable for exposure to all intended fluids. Any metallic seals should be galvanically compatible with the seal areas.

8.2.6 CIMV Flow Meter

The flow meter or flow measurement device contained within the CIMV should conform to the following definitions and recommendations:

- a) The required accuracy of measurement should be expressed across the measurement flow range. Uncertainty should be expressed as either independent or dependent on the properties of the chemical being measured and the process conditions i.e. the uncertainty should account for changes in viscosity and pressure, if applicable. Variation in the regulation system may create flowrates in excess of the user set point and this is not reflected in uncertainty values. The user may request that the reported flowrate accounts for both uncertainty and variation due to the regulation system.
- b) The flowmeter should be capable of meeting the stated accuracy of measurement across its specified flow range, pressure rating and pressure drop. Any variance across this range due to a tertiary parameter should be clearly defined. Variations in accuracy of measurements across the range should be clearly indicated.
- c) The flowmeter turndown ratio (being the ratio of the highest, repeatable measurement to the smallest) should be clearly stated. The flowmeter may have different turndowns in different configurations.
- d) The flowmeter should be able to produce a continuous real time measurement of flow rate when requested.

The flow meter should be tolerant to particles and the acceptable tolerance range defined by the equipment supplier. This requirement should be communicated to the topside facilities and incorporated into the design of the injection system.

The CIMV may be able to identify a reverse flow condition and communicate this to the MCS to allow alarms to alert the operator.

Failure of the primary flow measurement device should not prevent the injection of chemical through the CIMV.

The CIMV may provide a secondary flow measurement system. The achievable accuracy of this secondary flow measurement should be stated.

8.2.7 Control Valve and Actuator

If a control valve is used as part of the CIMV device, the following items should be considered. For this Recommended Practice, any device that controls the chemical flow rate is considered as a control valve.

- a) The turndown ratio of the CIMV control valve should be defined.
- b) The control valve should be capable of taking the full design pressure drop rating across it. This may occur during field commissioning when injecting into flow lines or at ambient conditions.
- c) The control valve should be capable of operating “open” to “close” against a pressure differential range defined by the manufacturer and at maximum rated operating pressure.
- d) The control valve design should be cavitation resistant.
- e) The control valve should be particle tolerant and should be designed to flush through any blockages that may occur due to large particles or buildup of small particles. The acceptable particle range and volume is defined by the equipment supplier.

- f) The valve actuator and control system should be capable of concise positioning such that the CIMV does not hunt or modulate around a set point. Hunting may also be managed by filtering of measurements, delaying movements or other techniques that should be included in the determination of uncertainty.
- g) The control valve or flow rate control device should fail-as-is such that chemical can still be injected even if flow control is not possible. If flow control is lost due to loss of power, the fail-fixed mechanism should not prevent normal operation and flow control on return of power.
- h) The control valve and actuator should be qualified for the design life of the CIMV. The potential number of cycles should be defined by the equipment supplier and a suitable qualification program completed to quantify the devices design life.

8.2.8 Regulation Device

Some CIMVs use pressure regulators to maintain a constant differential pressure across the control valve to maintain a specific flowrate. Other CIMVs maintain flowrate using control valve stem position which adjusts based on upstream and downstream pressures. Both arrangements are considered regulation devices and are designed to maintain a set flowrate, provided by the user.

The regulation device should ensure that a stable flowrate is maintained regardless of pressure drop and flowrate setting. This means the CIMV should not release batches of chemical but will maintain a stable flow rate while adjusting for pressure changes.

If the regulation device can be adjusted or turned off by the operator, the following recommendations assume that the device is in the regulate mode and will operate as such throughout its design life.

There are several different regulation devices available and currently no universal norm for specification. It is recommended that the regulation device comply with the following functional requirements:

- a. Pressure fluctuations across the CIMV can occur due to decreases in reservoir pressure, operational actions like shut-ins and start-ups, changes in flow rate from adjacent wells being fed from the same umbilical tube and slugging. The period of the pressure fluctuation is dependent on the nature of the change. The regulation device should be designed to respond to changes in pressures upstream and downstream of the CIMV.
- b. The regulation device, whether an independent system or incorporated as part of the control system, should be qualified for the design life of the CIMV. As such, the potential number of regulation cycles should be defined by the supplier and a suitable qualification program completed to quantify the devices design life.
- c. Regulation should not result in intermittent dosing of chemical. The CIMV should be capable of continuously injecting chemical at the required rate throughout its regulation cycle.

The SCIDS should consider the possibility of seabed or downhole injection creating sub-ambient/ high differential pressure conditions and how it is affected by the CIMV.

8.2.9 Lock-down Connector

The lock-down connector that attaches the CIMV to the receptacle should conform to the following:

- a) The lock-down connector should be operable by a standard work class ROV with a standard API 17H torque tool or manipulator arm
- b) The lock-down, running and breakout torques should be clearly identified on project documentation and the product, if applicable
- c) A visual indicator, which can be read by a ROV, should be provided. It should indicate the CIMV is locked in place and hydraulically connected to the chemical system. The indicator should also indicate when the CIMV is unlocked from the chemical system and safe to retrieve.
- d) The lock-down connector should soft mate both the hydraulic and electrical interfaces. In some instances, the electrical connector may be a separate connection made by an ROV.
- e) The lock-down connector should be designed such that there is a redundant over-ride or secondary retrieval means or retrieval plan in case of failure. Failure of the lock-down connector in any mode should not result in a stuck or non-retrievable CIMV.
- f) The operations of means of secondary retrieval or retrieval plan should not cause any damage to the adjacent structures.

8.2.10 Couplers

The fluid couplers should be sized for the entire range of flow and be considered as part of the native pressure drop across the CIMV. Coupler to coupler sealing arrangements for chemical injection systems should utilize metal to metal primary seals with non-metallic backups to provide a seal to the environment.

Coupler design should eliminate hydraulic lock directly or if not, the system design should accommodate this. Chemical loss / contamination with seawater during CIMV insert retrieval and replacement should be minimized.

8.2.11 Filter

A subsea filter may be provided within the CIMV to prevent clogging or damage to its internal components.

The umbilical is typically installed with a buffer fluid that may be passed through the CIMV during commissioning. Larger particles of debris from umbilical installation may be present post commissioning and could be transferred into the CIMV as part of normal operation.

Any filter in the CIMV should be suitable for limiting the size and volume of particles to within an acceptable range for the CIMV, as determined by the equipment supplier. If fitted, the filter should be suitably sized for the design life of the CIMV insert.

If fitted, Filters should have a bypass and alarm which indicates when the filter is operating and when it has been bypassed due to blockage with an excessive amount of particulate.

8.3 CIMV Controls Functional Requirements

8.3.1 General Requirements

The design, qualification and testing of electronics, communication and electrical components used in subsea chemical injection systems should conform to API 17F. The ECM is typically responsible for processing and controlling all signals and functions in the CIMV.

Software and software configurations should be able to be updated remotely and independently from each other. Software and configurations should have checksums or similar to confirm that all information has been transferred successfully and accepted by the CIMV.

8.3.2 Firmware and Data

Firmware installations should be uniquely identifiable by version number. CIMV communications interface should allow upgrading of software, firmware and calibration tables to the CIMV after installation. Portable diagnostic tools should interface with the topsides subsea controls system. The following are the typical data that may be transmitted from a CIMV:

- current flow rate
- flow measurement device fail
- reverse flow
- no flow
- modes of operation
- flow restriction position
- total cycle
- flow restriction in action
- pressure (upstream)
- pressure (downstream)
- pressure transmitter fail
- flow restriction device current draw alarm
- serial numbers
- software version
- input voltage
- ECM current

- device currents
- device comm status/error rate
- internal devices comm status

8.3.3 Power Requirements

Power consumption for each electrical control module should be medium power as specified API 17F. Average inrush current should not exceed the limit specified in API 17F.

8.3.4 Communication

Communication protocol should be an industry-standard recognized protocol to communicate with SCM. The most common protocols are Modbus over serial line, Modbus over Ethernet and CiA 443 CANopen profile for SIIIS level-2 devices. The communication protocol should be capable of transparent link mode to facilitate diagnostics and upload of software or firmware upgrades. API 17F should be followed for standards on communications.

8.4 CIMV Qualification Tests

8.4.1 General

The following tests are typically completed during CIMV qualification. CIMV qualification plans will vary depending on the technology and operator availability requirements. Additional qualification tests related to the specific CIMV design may be required. Where no recommended test procedures exist, manufactures should use their best practice. Refer to API 17Q

8.4.2 Quantify Turndown Ratio

CIMV turndown is the ratio of the highest controllable flowrate to the lowest controllable flowrate. As a CIMV may consist of both a control valve and flow meter both turndown ratios should be considered. The measurable range may be different to the controllable range.

Controllability requires stability of flowrate at both the lowest and highest flow rates. The turndown ratio may be affected by fluid viscosity and pressure drop across the control valve (laminar to turbulent flow) and valve actuator movement sensitivity. If any of these factors or others affects the functional turndown ratio they should be clearly identified.

The turndown ratio should be determined during qualification and given for the fixed set of parameters at which it was measured, and any sensitivity noted.

8.4.3 Measurement Uncertainty

Flow meter uncertainty should be determined using an accepted industry practice (e.g. ISO/IEC Guide 98-3:2008- Guide to the expression of uncertainty in measurement (GUM:1995)). The verification hardware / process should have a measurement scale at least ten times more refined than the parameter being measured. Measurements should be recorded over a sufficient period of time and at regular intervals to

identify any flow instability. A minimum of three separate measurements should be taken at each recording point to ensure repeatability. These measurements do not have to be taken consecutively.

Any meter correction factors should be clearly identified as being directly measured or derived from flow modeling.

8.4.4 Uncertainty Determination

An uncertainty calculation should be provided, where necessary, to quantify the cumulative effects of all components used to derive the flow measurement. All measurements should include the effects of uncertainty across the operating range.

Uncertainty is typically associated with derived flow measurements but can be related to accuracy measurement techniques or limited information on injection fluids (viscosity-pressure-temperature relationships). This calculation may require input from the operator to provide the range of operating parameters for the SCIDS and the chemical supplier for the chemical properties at those conditions.

8.4.5 Firmware Qualification

Firmware for CIMVs should be designed and qualified in accordance with a proven international standard or practice. A rigorous, formal firmware qualification test program should be developed and completed as part of qualification. Changes to the firmware may require to be re-qualified using the formal qualification test program. A record of all firmware changes and revisions should be maintained.

8.4.6 CIMV Communications and Monitoring

If any onboard diagnostics are available for the CIMV a functional test should be performed on each routine. As some diagnostics relate to extended service measurements, multiple tests may be required throughout the qualification duration. Some common test may involve motor starts, current draw, sensor drift and reverse flow indication.

8.4.7 Extended Duration Testing

Extended duration tests should be conducted to determine the long-term functionality of measurement, flow control, actuation and communication components, as applicable. Extended test requirements are generally based on availability targets or reliability measurement determined for a specific application. The extended duration testing may vary depending on the operators' needs and application.

For extended duration tests the following considerations should be addressed:

- Flow rate measurements should be conducted over the operational range of the CIMV, as given in its functional specification.
- Extended testing of a complete CIMV may be done in addition to subcomponent reliability tests which may require protracted test periods.
- The intent of extended testing is to focus on certain elements of the system that affect functional and fatigue life. A series of defining characteristics may be established for each component of the CIMV

that are required to be maintained to ensure operation. It is expected that these characteristics will change across the technologies used. Some potential characteristics may include sensor accuracy / repeatability / drift, dynamic seal stability, valve controllability under harsh conditions, software and controls integrity over long periods, motor life and actuator assembly life.

A suitable extended performance test may contain the following elements:

- a. Isolation of individual components and defining their potential failure mode. For flow meters this could be sensors or mechanical fatigue (static seals), for valves this could be pressure loss, for actuators this could be fatigue / galling etc.
- b. The use of multiple units across operational ranges to establish inherent characteristics (such as stability, drift, pressure loss, fatigue damage) and to reduce statistical uncertainty.
- c. Intermittent or continued measurement of the defining characteristic to develop an appropriate service history.
- d. Running components to failure or accelerating wear to determine performance limits.

8.4.8 Integrated Component Testing

There is no universal procedure that can be applied, and a manufacturer should define a suitable CIMV assembly testing procedure based on their products functional specification.

Guidelines are provided to help determine the scope of an integrated CIMV assembly test and not the specific of the test itself.

1. Full integrated CIMV assembly tests should be conducted to prove integrated functionality of all components. Extensive tests across operating ranges should be completed. This may include varying the fluid properties, if it has an effect on the metering or control characteristic of the CIMV.
2. Testing duration should be defined to provide statistically significant data for the system reliability prediction. Data from multiple test articles provide a higher degree of certainty. Periodic full-range performance tests at intervals during the system-level testing should be performed.

8.5 CIMV Factory Acceptance Testing (FAT)

8.5.1 General

FAT (factory acceptance test) are conducted on each production unit.

Extended Factory Acceptance Tests (EFAT) may be performed on the first unit of a production run or for a project.

8.5.2 CIMV ECM Test

The electronic control module (ECM) for the CIMV (also known as CIMV controller) should pass Environmental Stress Screening (ESS) test as defined in API 17F. ESS testing may be performed as a part of the CIMV ECM fabrication and testing is typically prior to pressure testing.

The electronic canister(s) should pass helium leak testing using a quantitative testing method according to ASME V with a helium leak rate $\leq 5 \cdot 10^{-8}$ mbar-l/s after being sealed or pass a hyperbaric test on individual units at design water depth. The leak testing may be performed on a subassembly of the CIMV prior to final assembly.

8.5.3 Hydrostatic Test

All CIMV's should be hydrostatically tested prior to shipping from the manufacturer's facility. Hydrostatic testing of CIMV's should as a minimum be performed per the requirements of API 17F.

The CIMV can be considered separate from the tree system due to the barriers provided by the isolation and check valves.

8.5.4 Functional Test

The scope of functional testing typically ensures all sensors, transmitters, receivers, software and communications are functioning within the given range of the CIMVs Functional Specification. Before flow testing starts each component in the uncertainty calculation for the CIMV flow meter should be proven to be operating within specified limits.

The functional testing generally includes, but is not limited to, the following activities:

- power-up test of the CIMV
- CIMV boot test
- check software version
- CIMV electronic redundancy test, if applicable (consists of turning each redundant electronic off while verifying communication with transmitters)
- electrical continuity test and insulation resistance test
- power consumption test
- instrumentation tests (testing of all internal instrumentation including internal diagnostic sensors)
- Physical verification of all operating modes. This may be combined with communication tests. Functional testing may be done under flowing conditions with automatic flow regulation, manual flow regulation, flushing strokes, reverse flow indication, valve break-out, fail safe by-passes, end-stops and all applicable functions tested.
- Verification that the software version and software image installed on the CIMV is according with the CIMV specific software report for the product. In addition, all old software versions should be deleted from the CIMV.

The CIMV should demonstrate that it can operate at the maximum defined pressure differential at nominal, minimum and maximum defined supply voltages without stalling or exceed maximum defined power consumption. The test should be performed at maximum power consumption which may require auxiliary functions to be in operation. Power consumption (Watt RMS) should be continuously recorded during this test. If applicable, valve actuation time from fully closed to fully open and vice versa should be recorded during this test. The valve should demonstrate the ability to stop automatically when reaching end points.

8.5.5 Flow Test Fluid

CIMV FAT can be performed with actual chemicals or a suitable test fluid. This may be dependent on the flowrate measurement technology used. Test fluid properties may mimic known chemical properties in field conditions e.g. viscosity. Testing may be performed using a standardized test fluid providing that CIMV behavior is known and translatable to actual chemical performance. The test fluid to be used should be clarified with the end user before test initiation.

Test fluid cleanliness should be controlled before and after FAT and both measurements should be within defined cleanliness requirements for the CIMV.

8.5.6 Flowrate Measurement Performance Test

This test should demonstrate that project specific flow rates can be obtained and measured with the specified uncertainty of measurement, using project specific fluid properties, at the specified pressure differentials. This applies both to minimum and maximum defined flow rates. The calculated flow rate should be controlled against a calibrated flow meter or other device capable of determining flow rate with a higher accuracy than the CIMV. A series of measurements across the meter range should be made with an expectation of at least ten points. At each point three measurements can be made to confirm stability of measurement.

Flowrate performance testing should be performed for all flowrate calculation methods incorporated into the CIMV. A graph or table can be used to present the test records showing deviations between actual flowrate and calculated flowrate for points across the range. Variations in uncertainty of measurement due to fluid properties or pressure drop should also be shown.

Flow regulation functionality should be demonstrated at a low flow setting, medium flow setting and high flow setting in relation to specified flowrates. The CIMV should automatically adjust the flowrate, using its proprietary technology, to obtain the flowrate set point within a defined deadband. The defined deadband may be a percentage of flowrate set point or a fixed flowrate value. Input pressure to the CIMV should be manipulated to force the flowrate outside the set deadband, and the CIMV should demonstrate the ability to automatically regulate the flow valve position to reclaim the set flowrate within the defined deadband. The CIMV should be able to reach the minimum defined flow rate at maximum defined pressure differential and the maximum defined flow rate at minimum defined pressure differential, or other flow rate / pressure differential combinations specified by the end user.

8.5.7 Lock-down Functional Test

This section is only applicable for ROV retrievable CIMVs. It is preferable to use a receptacle from the production run for the tests. A representative receptacle could be used if agreed with the client. The intent is to confirm the CIMV receptacle interface, establish a baseline for required torque and number of turns, and to verify operation.

The CIMV should be installed into the receptacle according to defined procedures. Hydraulic and electric connection should be verified once installed. The installation and removal processes should be performed within stated installation and removal torque limits. Applied torque and number of rotations (if applicable) should be recorded.

The CIMV should be pressurized to product defined maximum working pressure before being fully unlocked from the receptacle and reinstalled according to procedure. Applied torque should be recorded. Coupling seals should preferably be engaged during the entirety of this test to avoid potential hazards from pressurized test fluid escaping the hydraulic couplers. There should be no damage to CIMV or receptacle couplings and connectors.

8.5.8 Electric Continuity Test

The CIMV is intended to be under cathodic protection when installed, electric continuity between the receptacle earth point or hydraulic coupling and the furthest uncoated component of the CIMV body should be measured to have a maximum electrical resistance of 0.1 Ohm or as agreed with interface owner. Preferably, electric continuity should be measured between all bolted or welded components of the CIMV body.

This test maybe performed while the CIMV is installed in the receptacle in the lock-down test.

8.5.9 Insulation resistance Test

IR testing should be performed with 50 VDC and the reading recorded 60 seconds after application of the test voltage with acceptance criteria as defined in API 17F. Power and communication should be disconnected from the CIMV during IR testing. The IR test leads should be connected to an earth point or ground on receptacle and all the conductors coupled together for power supply and communication from the CIMV.

8.5.10 Hyperbaric Test

CIMV assemblies should be hyperbaric tested at least 1.1 times the project-specific ambient pressure per API 17F. CIMV pressure and external hyperbaric pressure should be monitored for the hyperbaric test duration. The test data should be analyzed to ensure that the rate of pressure change internally or external to the CIMV is not increasing during the test period. The recorded hyperbaric test pressure should not fall below the nominal test pressure at any time during the test period

Before the hyperbaric pressure test (external pressure), the CIMV should be installed into a receptacle in a test setup that allows measurement of insulation resistance (IR) between the CIMV body and electric connections used for communication and power supply. The IR should be measured and recorded before and after the hyperbaric test with acceptance criteria as defined in API 17F.

9 Materials and Fabrication

9.1 General

Material selection for the system and individual components, including seal materials, should meet the recommendations listed in API 17A. SCIDS materials selection should consider the combined effect of equipment exposure to anticipated injected chemicals for all operational considerations, including commissioning, operating pressure and operating temperature.

Subsea chemical isolation valves, check valves and downhole injection mandrels that are exposed to production fluids (i.e. production, completion, drilling, chemical injection fluids) shall comply with materials classes as indicated by API 6A/API 17D including Sour Service, where applicable.

The materials selected should consider testing chemical compatibility if it is not already known. When selecting materials of construction, it is important to look at the life of field aspects of chemical injection, in that a chemical used for a specific application may be changed after several years of operation, due to production fluid or conditions changing in wells or flowlines, new wells. The selection of metals and elastomers with a broad range of chemical compatibilities may allow easier chemical change outs in later years. Refer to "Technical Report 17TR5, Avoidance of Blockages in Subsea Production Control and Chemical Injection Systems" and "Technical Report 17TR6, Attributes of Production Chemicals in Subsea Production Systems".

Compatibility between different chemicals being injected into the same system should be verified.

All materials used in the subsea chemical injection system should be qualified per requirements of API 17N. Chemical injection systems should be evaluated with respect to material class and temperature rating, independently of the production system

9.2 Materials

Materials selected for use in chemical injection system applications should be capable of being cleaned to a specified cleanliness level.

Corrosion protection through material selection, based upon a marine and process environment, should consider the following issues, where applicable:

- external fluids / environment;
- internal fluids;
- weldability;
- crevice corrosion / pitting corrosion;
- corrosion under insulation
- dissimilar metals effects;
- CP effects (including calcification in carbonate-rich environment and CP over protection);
- the impact of breakdown of coatings due to damage and disbandment;
- bacterial effects / microbially-induced corrosion;
- marine growth.

All wetted surfaces should be verified compatible with the control fluid, storage / buffer fluid, chemical-injection fluid, and/or wellbore fluids. Resilient seal materials should be selected to ensure compatibility with wetting fluids at temperature and pressure. Materials should be selected considering compatibility with specified fluids that they could potentially contact. This should be managed by the operator, using the material map as outlined in 9.3. Fluids that may be encountered during product life include:

- cleaning fluid(s);
- grease(s) and lubricant(s);
- subsea control fluid(s);
- dielectric fluid(s);
- storage fluids, e.g. for umbilical lines;
- seawater;
- production chemical(s);
- completion fluid(s).

Emphasis should be placed on anticipation and identification of unexpected or unconventional material/fluid combinations that could potentially be experienced during all phases of a project.

All pressure containing materials should be per EN 10204, clause 3.1. Non-pressure containing materials (excluding electronic components) should as a minimum be per EN 10204, clause 2.2. Refer to API 17A for additional material requirements.

Fillet and socket welds are not recommended.

AISI 316L or higher alloys such as duplex, and other austenitic SS or nickel-chrome-molybdenum alloys are acceptable for chemical injection tubing.

9.3 Fabrication

9.3.1 Fittings and Connections

Where practical, the same type (style) of fitting should be used for each pressure class throughout the system.

For topside equipment and interconnections, the same type (style) of tubing and/or piping fitting should be used throughout for each service and pressure class.

For subsea equipment, butt-welded joints and flanges should be used in preference to tubing and/or threaded piping fittings.

Structural-load-bearing welds should be treated as non-pressure-containing welds and should comply with a documented structural welding code, e.g. AWS D1.1.

All pressure-containing welds should be in accordance with API 17F.

9.3.2 Cleanliness

All SCIDS components should be handled in accordance with the requirements of ISO/TR 10949. Equipment should be cleaned to the specified cleanliness standard prior to assembly. Flushing as the sole method is generally not effective as the means to achieve system and component cleanliness, as turbulent flow may not be possible in an injection system.

10 Integration, Commissioning and Operation

10.1 General

The purpose of this section is to provide general recommendations for the installation, commissioning, and operation of SCIDS to ensure safety, environmental protection, and effectiveness.

10.2 Host Facility-Integration

Host facility components of the SCIDS are usually skid mounted as complete pumping systems with storage tanks either located on or off skid. Interconnecting piping between the skid and off-skid storage tanks and between the skid and the TUTA is provided during construction and/or hook-up. This stage includes hydrostatic testing, preservation, tubing joint management, and systems completion. In general, the following should be accounted for:

- Hydrostatic pressure testing or hydrotesting should be performed on manufactured components by the manufacturer at or before FAT, skid mounted piping by the skid fabricator prior to assembly, and field run piping by the contractor responsible for the interconnection lines.
- Where pressure testing is conducted on installed systems, care should be taken to protect vulnerable equipment (e.g. flow meters, PSVs, PIs, rupture disks). If these items are removed to prevent damage, then the temporary replacement spools should be designed for full system pressure.
- Hydrotest water should be thoroughly drained and the system dried following the test. This is especially critical if the service fluid is incompatible with water. Where the service fluid is incompatible with water, consideration should be given to using an alternative medium for the pressure test.
- A detailed preservation plan should be developed and implemented to protect equipment in the period between installation and startup. The plan should consider long-term preservation if the equipment will not be immediately used. Refer to API RP-17P.
- The facility should have an overall tubing joint management plan that addresses the requirements for all types of joints including flanged, welded and specialized joints, which are tubing joints required by high operating pressures (> 5,000 psi). Refer to API 17 RP-17E/F as required. At a minimum the overall joint management plan should identify specialty joints.
- A process should be developed to prevent use of the wrong tubing joint components, especially if multiple specialized joints are used on the facility. Procedures will be in place for the make-up of specialty joints.
- Systems completion philosophy should be developed and implemented for the entire host facility scope including the chemical system per API 1FSC.

10.3 Host Facility Pre-commissioning

The pre-commissioning of the host facility equipment includes static checkout of individual components to verify they operate as designed. This stage will also include verification of de-preservation, cleaning/flushing to the required specifications, pulsation dampener charging (if required), leak testing and point to point checks to verify piping/tubing routing, installation of ship loose items, and safety devices. In general, there should be a plan in place that takes into account the following:

- De-preservation should be completed per the procedures provided as part of the overall project preservation plan. The De-preservation plan should consider lubricating oil levels in rotating equipment, shipping plugs / breathers, sea fastening, temporary motor heaters, desiccant or VPCI (Vapor phase corrosion inhibitor), and positive pressure gas blanketing or preservation fluids.
- Verification should be obtained prior to the leak test that all mechanical joints have been installed per procedure and by a qualified technician and that a hydrostatic pressure test of all components has been conducted prior to the leak test.
- Leak test acceptance criteria should be established prior to leak testing.
- The leak test pressure should not exceed the design pressure of the system and the system should be protected from overpressure during the leak test. Where overpressure is possible, a risk management process should be implemented to ensure that the system is not over-pressured.
- Leak test are normally executed using nitrogen or demineralized water, but other liquid media can be utilized. If a liquid media is to be used, compatibility with the service fluid should be considered as well as any potential environmental impacts should an unplanned release occur.
- Loop checks and preliminary function tests should be done end to end from the instrument/individual component to the display point on the MCS with the proper log in mode applied.
- Leak test fluids should be selected to help maintain fluid cleanliness, avoid internal corrosion, avoid environment issues if there is a leak and to facilitate the transition to production chemicals during commissioning.
- During pre-commissioning, all safety devices (e.g. rupture discs, PSVs, etc.) should be inspected to confirm set pressures and to verify required certifications are current. Re-test components as necessary.

10.4 Subsea Pre-Commissioning

Subsea pre-commissioning is carried out on the system prior to progression into dynamic commissioning activities. These activities are described in API 17A. Subsea pre-commissioning should include verification of routing. Namely, verify that when a particular CIV is commanded and a particular supply line is used to pump down that these are all lined up correctly and that the system is connected as per drawings.

10.5 Host Facility Commissioning

10.5.1 First Fills

Some chemical systems may not be used at initial startup and may not be used for a significant period after initial production. For example, chemicals used for produced water treating may not be required until water breakthrough.

First fill chemicals are those required at initial startup.

Some chemicals may be required only during commissioning and/or at initial startup such as buffer fluids for umbilical commissioning.

Where chemicals used at initial startup are different than those used during normal operation, plans should be made to either use existing chemical delivery systems or to use temporary systems. In either case, the systems will have to be commissioned for the chemical used and cleaned and re-preserved, as necessary, after use.

First fill chemicals should be checked for the following prior to being introduced into the chemical system:

- correct chemical delivered;
- Cleanliness to the project specification; and,
- Compatibility with system materials and chemicals.

10.5.2 Pulsation Dampener Charging

Pulsation dampeners are often used to dampen the pulsating effects of high-pressure positive displacement pumps commonly used in chemical injection applications. Where dampeners using pressurized gas are employed, it is essential to charge these prior to dynamic pump runs. If the pulsation dampeners have been charged at the factory and left under pressure for delivery, the charge pressure should be re-verified prior to operating the pumps.

Charging of pulsation dampeners is potentially hazardous. It is critical to verify the correct charge pressure range to ensure that overcharging does not occur.

10.5.3 Dynamic Commissioning

Commissioning establishes the functionality of the system as a whole. This will generally involve running the pumps in recycle (dynamic pump runs) on the host facility at normal operating pressures and flowrates and confirming that all system components, especially the flow meters and control systems function per the design.

The operator may choose not to perform dynamic commissioning on systems that will not be used at initial production. Where such systems are commissioned, re-preservation may be required.

Commissioning runs should be performed with water or storage fluid unless contraindicated by compatibility issues or system functionality issue. Water may be contraindicated if the service chemical is highly incompatible with water and/or the system is difficult to drain and dry. Problems discovered during the pump runs may require that the system be drained for repair. For this reason, the service chemical should not be used unless it is benign from both safety and environmental perspectives.

Particular attention should be paid to system cleanliness during the Dynamic Pump Runs. Circulation of fluid in recycle is an opportunity to filter out particulates. All system filters should be in place and should be checked periodically until the system is confirmed clean.

High pressure pumps are usually positive displacement such as piston or diaphragm types. These generate pressure pulses that may result in vibration and/or overpressure. These systems should be operated in recycle prior to startup. Pressure pulsation and resulting vibration should be monitored during the pump runs.

All safeguarding systems should be fully commissioned and in service.

10.5.4 Re-preservation

Where commissioning is completed on a system (or part of a system) that is not going to be used for extended periods of time, re-preservation may be necessary to prevent equipment degradation.

Any re-preservation required should be determined during the detailed commissioning planning phase. Procedures for conducting the preservation should be developed, executed and handed over as part of the final system Turnover Completion Package.

Any required periodic preservation check or reapplication should be captured in the facility maintenance system.

10.6 Subsea Commissioning

10.6.1 Umbilical Displacement/Flushing

10.6.1.1 General

Umbilical chemical lines are typically installed with a storage fluid, however water based hydraulic fluid, diesel, special buffer fluids or other fluids may be used. These fluids are generally displaced with production chemical, and sometime intermediate buffer fluids are required to avoid fluid incompatibility issues. Displacement can occur before startup, shortly after startup or be deferred until the chemical service is needed. Refer to API 17D, 17E, 17F, and 17P as required.

The key consideration when displacing one fluid with another is chemical compatibility. If the service fluid is not compatible with the storage fluid, one or more buffer fluids may be required. In this case the storage fluid is displaced first with a buffer fluid that is compatible with both the storage fluid and the service fluid. If no suitable single buffer fluid is found, then more than one buffer fluid may be required.

As some axial mixing will occur in the umbilical a suitable amount of over flush is required to ensure service fluid is available at the injection point when needed. The over-flush volume required may be calculated via axial mixing methods or estimated via previous results in similar systems.

Similarly, the volume of buffer fluid may be determined by the amount of axial mixing that is tolerable during the displacement.

Special attention should be paid to chemicals containing surface active chemicals that may leave a chemical residue on the walls of the chemical injection system. Numerous flushing volumes using the base solvent of the chemical may be required to remove the residue. Verify the impact of displacement on topsides system (e.g., water quality, phase separation, methanol-in-crude content, etc.) if displacing fluids into the wellbore or a live production system.

Verify if dead legs in the subsea distribution system could contain significant incompatible chemicals.

10.6.1.2 Procedures

Detailed displacement plans, and procedures should account for the following:

- Ensure that no incompatible fluids will mix during the displacement;

- Ensure that adequate displacement flowrates are possible. Consider the restriction imposed by CIMVs in particular. If the required flowrate cannot be achieved with the chemical service pumps, temporary pumps may be required for displacement;
- Perform fluid checks prior to introduction into umbilical, particularly if buffer fluid(s) are being used.
- During displacement, slowly increase chemical flow in a controlled manner. If possible, close the CIMV prior to opening isolation valves to prevent sudden increases in flow and associated demand on the chemical injection system;
- Equalize pressure across subsea valves before opening them where possible;
- Minimize the flowrate across subsea valves prior to closing. It may be necessary to close some subsea injection valves under flowing conditions to prevent backflow.
- Maintain pressure control and pressure safeguarding to avoid over-pressuring subsea systems.

10.6.1.3 Types of Displacements

Umbilicals may be displaced:

- To surface by creating a temporary loop of umbilical tubes.
- To the flowline
- To temporary subsea equipment designed to receive fluids
- To the wellbore. Reservoir damage is possible if chemicals are forced into the reservoir. Avoid displacing chemicals into the wellbore prior to well startup unless approval is given by reservoir specialists.

Looped displacements should ensure that the chemical will be routed properly to the host facility, collected, and disposed of according to all regulations.

If displaced into the flowline or wellbore, consideration should be given to how the displaced fluid will be handled when it eventually is returned to the surface facility.

For displacements to the flowline: If displacing into hydro-test water, the chemical should be rated to be discharged overboard. If it is not, appropriate measures should be taken to ensure environmental regulations are followed.

Displacements to the wellbore are usually done following well startup.

10.7 Operations

10.7.1 General

Operation of the SCIDS should be governed by the system Standard Operating Procedures (SOPs) and the Chemical Management Plan.

10.7.2 SOPs and Operating Guidelines

The SOPs should conform to API 75.

Important considerations of subsea SCIDS procedures include:

- the SOPs should specify operation so as to prevent backflow of produced fluids into umbilical tubes as applicable.
- differential pressure across injection valves should be equalized prior to opening the valves to prevent valve damage and to minimize unwanted backflow.
- flowrate through Chemical injection valves should be minimized prior to closing the valves to prevent valve erosion for high flowrate fluids such as MeOH.
- monitor system cleanliness based on required cleanliness levels, testing methods, and testing frequency.

10.7.3 Chemical Management Plan

A Chemical Management Plan should be developed and continuously updated. It should include information on:

- chemicals selected for use and their operation condition / production conditions under which the chemical use is applicable;
- key chemical parameters such as viscosity, density, composition, and pH;
- confirmation of chemical compatibility with the chemically wetted materials and other chemicals in the system;
- the recommended dosing levels;
- the availability requirements (fraction of the time the chemical system is available for use);
- allowed duration of operation when a chemical system is out-of-service;
- specified/required cleanliness levels of chemicals;
- key performance Indicators (KPIs);
- impact of the chemicals on separation, produced water treating and other downstream systems;
- chemical logistics;
- any other information required for effective chemical injection; and,
- records of the current chemical in each line throughout the system, including step-outs or parts of the system, which could include a different chemical.

11 Maintenance

11.1 General

The primary purpose of this section is to provide general recommendations for maintenance and field modification of the SCIDS to ensure its integrity and chemical delivery performance.

Recommendations provided in this clause are not intended to supersede any previous industry guidelines and recommendations. If there are any field modifications occurring, please refer to industry guidelines and the guidelines outlined in previous sections.

SCIDS maintenance should be part of the overall facility maintenance plan and should focus on reducing risk as low as reasonably possible (ALARP). It should include input from all various users and should refer to all applicable industry standards (e.g. API 75, API 18LCM, etc.) and vendor guidelines.

In general, maintenance of the SCIDS should include the following:

- routine cleanings and inspections of appropriate components;
- defining key performance indicators (KPIs) as required;
- monitoring the defined KPIs and if there is any noncompliance identified with the KPIs, developing action item(s) to solve it when applicable;
- retrieving and repairing of retrievable components as required;
- accessing non-retrievable components for repair in an appropriate manner.

11.2 Chemical Injection Pumps

Maintenance of the chemical injection pump and its pertinent components should reference API 674 and 675 and applicable vendor guidelines.

11.3 CIMVs

CIMV's are generally run to failure. Monitoring may indicate a progressive fault, and this may offer an opportunity to modify operations, arrange for replacement or allow for other options. Some items that may be monitored are around the following KPIs:

- monitoring the flowrate if flowrate measurement is available. Loss of low flow control may indicate wear of seats;
- monitoring the number of installation connection cycles against the lifetime limit of the particular design;
- monitoring CIMV diagnostic parameters, trends, and status indicators if available;
- pressure sensors can be evaluated at zero flow against other transmitters sensing the same pressure, adjusted for fluid heads; and,
- monitor the CP of the system that the CIMV is mounted in.

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Annex A (Informative)

SCIDS DEVELOPMENT RESPONSIBILITY AND ACTIVITY MATRIX

A.1 Development Responsibility Matrix

A matrix may be created to assist managing multi discipline involved activities in SCIDS development. Table A.1 is a typical SCIDS development responsibility matrix that identities each discipline responsibility during the development.

Table A.1—SCIDS Development Responsibility Matrix

		Activity								
		<u>Chemical injection strategy, requirements and operating plan</u>	<u>Injection location & chemical selection</u>	<u>Chem Flow Analysis</u>	<u>Process Flow Analysis</u>	<u>Subsea hardware qualification, design, functional definitions and hardware interface</u>	<u>Chemical controls, alarm, interlocks, permissive, and HMI and topside controls interface</u>	<u>Operating Procedure and maintenance plan</u>	<u>D&C Equipment design, functional definition and hardware interface</u>	<u>Topsides Equipment associated with SCIDS</u>
Discipline	FA Engr	I / In/ C	In/ C	R	R	I / In	I / In	I / In/ C	In	In
	Subsea Controls Engr	I / In	I / In/ C	In/ C	In	I / In/ C	R	I / In/ C	In	I / In/ C
	Chemist	R	R	I / C	I / In	I / In	I / In	I / In/ C	I / In/ C	I / In/ C
	Operations Engr	I / In/ C	In/ C	I / C	I / In	I / In	I / In	R	In	I / In/ C
	Topside Facilities Engr	I / In/ C	In/ C	In	In	In	I / In	I / In/ C	In	R
	Topside - Controls	In	In	In	In	In	I / In	I / In/ C	In	I / In/ C
	Completion Engr	In	In/ C	I	I / In	I / In	In	In/ C	R	In
	Reservoir / Production Engr	I / In/ C	In/ C	I	I	In	In	In	I / In/ C	In
	Subsea hardware, flowline and umbilical Engr	I / In/ C	I / In/ C	I / In	In	R	I / In	I / In/ C	In	I / In/ C
FOOTNOTES "In" - To be informed - Discipline will be provided information in regard to activity and its outcomes. "I" - Provide Input - Discipline is required to provide inputs for activity. "R" - Responsible - Discipline is responsible to perform or to lead activity. "C" - To be consulted - Discipline will be consulted for advice or opinions on activity.										

A.2 Development Activity Matrix

Another matrix can be created to detail engineering activities for each involved discipline in SCIDS development. Table A.2 shows typical SCIDS development activities for each discipline.

Table A.2—Typical SCIDS Development Activity Matrix

		Activities						
		<u>Chem Flow Analysis / Engineering</u>	<u>Injection location & chemical selection</u>	<u>Chemical injection strategy, requirements and operating plan</u>	<u>Process FA engineering</u>	<u>Subsea hardware qualification, design, functional definitions and hardware interface</u>	<u>Chemical controls, alarm, interlocks, permissive, and HMI and topside controls interface</u>	<u>Operating Procedure and maintenance plan</u>
Disciplines	<u>FA Engr</u>	Responsible for this activity	Input for definition of injecting location	Input for - life of field production profile	Responsible for this activity	Provide -Conduit size, hardware performance/ functional requirement and injection locations	Input for cause and effects development	Input for - life of field production profile
	<u>Subsea Controls Engr</u>	Provide hardware and controls equipment data	Provide hardware and controls equipment data	Provide hardware and controls equipment data	Provide hardware and controls equipment data	Controls and hardware interface	Responsible for this activity	Provide hardware and controls equipment data
	<u>Chemist</u>	Chemical properties, rates, accuracy, injecting location and availability requirements	Chemical properties, rates, accuracy, injecting location and availability requirements	Responsible for this activity	Chemical properties, rates, accuracy, injecting location and availability requirements	Chemical properties, rates, accuracy, injecting location and availability requirements	Input for cause and effects development	Chemical properties, rates, accuracy, injecting location and availability requirements
	<u>Operations Engr</u>	Provide operational limits and requirements	Provide operational limits and requirements	Provide operational limits and requirements	Provide operational limits and requirements.	Provide operational limits and requirements.	Provide operational limits and requirements, and Input for cause and effects development.	Responsible for this activity
	<u>Topside Facilities Engr</u>	Informed	Informed	Provide topside operational limits and requirements	Informed	Input for subsea controls interface	Input for cause and effects development	Provide topside operational limits and requirements, and maintenance inputs.
	<u>Topside - Controls</u>	Informed	Informed	Informed	Informed	Informed	Input for cause and effects development and implementation as needed	Informed
	<u>Completion Engr</u>	Provide completion equipment data	Provide completion equipment data	Provide completion equipment data	Provide completion equipment data	Provide completion equipment data and interface details	Provide completion equipment data and interface details	Provide completion equipment data

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	<u>Reservoir / Production Engr</u>	Provide produce fluid properties and life of field requirements	Provide produce fluid properties and life of field requirements	Provide produce fluid properties and life of field requirements	Provide produce fluid properties and life of field requirements	Provide produce fluid properties and life of field requirements	Informed	Provide produce fluid properties and life of field requirements
	<u>Subsea hardware, flowline and umbilical Engr</u>	Provide hardware equipment data	Provide hardware equipment data	Provide hardware equipment data	Provide hardware equipment data	Responsible for this activity	Input for cause and effects development	Provide hardware equipment data

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