Table 2—Actuated Valve Safety Device Symbols

Service	Common Symbols			
Wellhead surface safety valve or underwater safety valve (USV)	SSV	SSV	N/A	N/A
Blowdown valve	BDV	BDV	BDV	M BDV
All other shutdown valves	SDV	SDV	SDV	M SDV
Boarding shutdown valves	BSDV	BSDV	BSDV	N/A

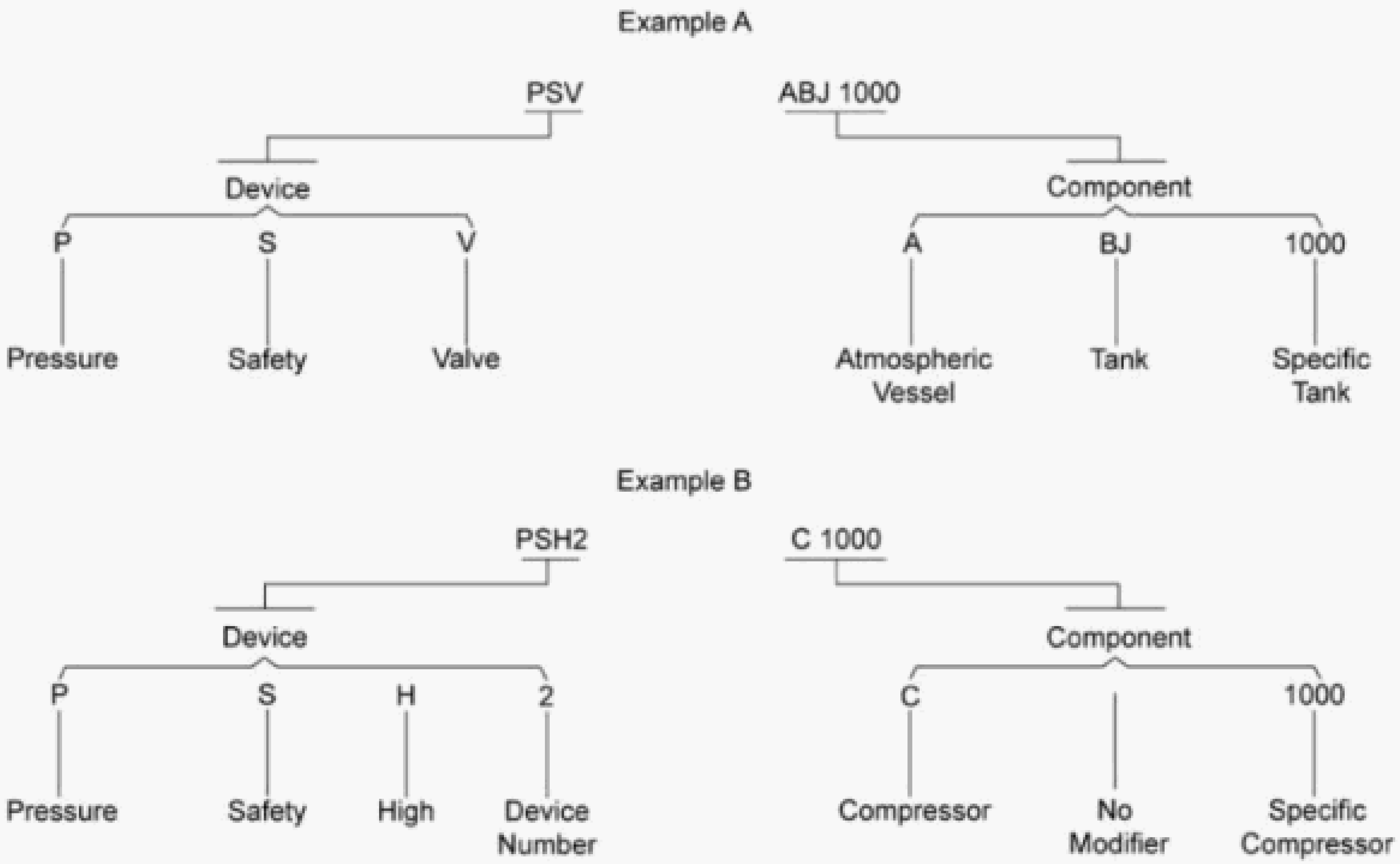


Figure 2—Examples of Safety Device Identification

Table 3—Component Identification

First Letter			Second Letter		Succeeding Characters
Code	**Component Type**	**Common Modifiers**	**Code**	**Component Modifier**	
A	Atmospheric vessel (ambient temperature)	BH,BJ,BM	AA	Bidirectional	User assigned identification unique to equipment at location
B	Atmospheric vessel (heated)	AP,BC,BK,BM	AB	Blowcase	
C	Compressor	NONE	AC	Boiler	
D	Enclosure	AE,AN,AU,BB	AD	Coalescer	
E	Fired or exhaust-heated component	AL,AW,BN	AE	Compressor	
F	Flowline	A1–A9	AF	Contactor	
G	Header	AR,AS,AT,AY,AZ	AG	Control unit	
H	Heat exchanger	BG, AP	AH	Departing	
J	Injection line	AR,AS,AT	AJ	Filter	
K	Pipeline	AA,AH,AQ	AK	Filter-separator	
L	Platform	AG	AL	Forced draft	
M	Pressure vessel (ambient temperature)	AB,AD,AF,AJ,AK,AM, AV,BD,BF,BH,BJ,BL,BM	AM	Freewater knockout	
N	Pressure vessel (heated)	AC,AF,AM,AP,BC,BD, BG,BJ,BK	AN	Generator	
P	Pump	AX,BA,BE	AP	Heater	
Q	Wellhead	AR,AT,AY,AZ	AQ	Incoming	
Z	Other		AR	Injection, gas	
			AS	Injection, gas lift	
			AT	Injection, water	
			AU	Meter	
			AV	Metering vessel	
			AW	Natural draft	
			AX	Pipeline	
			AY	Production, hydrocarbon	
			AZ	Production, water	
			A1-A9	Flowline segment	
			BA	Process, other	
			BB	Pump	
			BC	Reboiler	
			BD	Separator	
			BE	Service	
			BF	Scrubber	
			BG	Shell and tube, cooler	
			BH	Sump	
			BJ	Tank	
			BK	Treater	
			BL	Volume bottle	
			BM	Water treating	
			BN	Exhaust heated	
			ZZ	Other	

5 Safety Analysis and System Design

5.1 Purpose and Objectives

5.1.1 The purpose of a production facility safety system is to protect personnel, the environment, and the facility from threats to safety caused by the production process. The purpose of a safety analysis is to identify undesirable events that can pose a threat to safety or the environment, and define reliable protective measures that prevent such events or minimize their effects if they occur. Potential threats to safety and/or the environment are identified through proven systems analysis techniques that have been adapted to the production process. Recommended protective measures are common industry practices proven through long experience. The systems analysis and protective measures have been combined into a safety analysis for offshore production facilities.

5.1.2 The content of this document establishes a firm basis for designing and documenting a production facility safety system for a process composed of components and systems normally used offshore. It also establishes guidelines for analyzing components or systems that are new or significantly different from those covered in this document. However, it is incumbent on the user to apply appropriate additional hazardous analysis methodologies to ensure that hazards are identified and mitigated.

5.1.3 Before a production facility safety system is placed in operation, procedures should be established to ensure continued system integrity. Annex B may be used for this purpose.

5.2 Safety Flow Chart

5.2.1 Figure 3 is a safety flow chart depicting the manner in which undesirable events could result in personnel injury, environmental impact, or facility damage. It also shows where safety devices or procedures should be used to prevent the propagation of undesirable events. As shown on the chart, the release of hydrocarbons is a factor in virtually all threats to safety. Thus, the major objective of the safety system should be to prevent the release of hydrocarbons from the process and to minimize the adverse effects of such releases if they occur.

5.2.2 Referring to Figure 3, the overall objectives may be enumerated as follows:

a) prevent undesirable events that could lead to a release of hydrocarbons;

b) shut in the process or affected part of the process to stop the flow of hydrocarbons to a leak or overflow if it occurs;

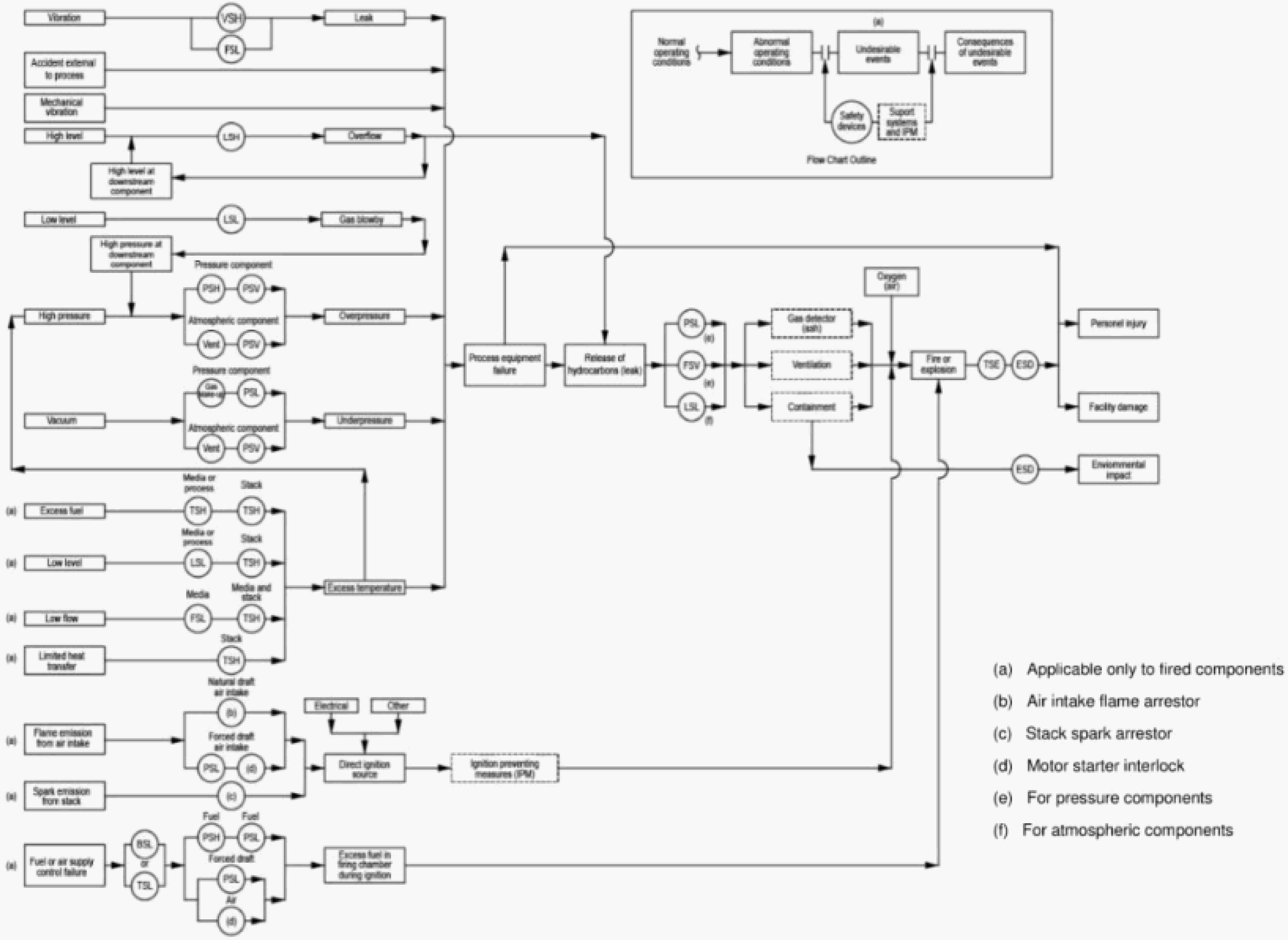
c) accumulate and recover hydrocarbon liquids and safely disperse gases that escape from the process;

d) prevent ignition of released hydrocarbons;

e) shut in the process in the event of a fire;

f) prevent undesirable events that could cause the release of hydrocarbons from equipment other than that in which the event occurs.

5.2.3 Accidents occurring external to the process on a production facility are not self-propagating unless they affect the process. If an external accident can affect the process, the safety system should shut down the process or affected part of the process. The firefighting and emergency response systems shall be maintained in operation. Such accidents may be caused by natural phenomenon, ship or helicopter collision, failure of tools and machinery, or mistakes by personnel. These types of accidents can be prevented or minimized through safe design of tools and machinery, safe operating procedures for personnel and equipment, and personnel training. Figure 3 indicates the manner in which external accidents may affect the process.



NOTE TSE designations are symbolic and are not intended to reflect actual location or quantity.

Figure 3—Offshore Production Facility Safety Flow Chart

5.3 Safety System Operation

The safety system provides protection in all of the following ways:

a) automatic monitoring and automatic protective action if an abnormal condition indicating an undesirable event can be detected by a sensor,

b) protective action manually actuated by personnel who observe or are alerted to an unsafe condition by an alarm,

c) continuous protection by support systems that minimize the effects of escaping hydrocarbons.

The emergency shutdown (ESD) system is required for all offshore facilities. These ESD systems are required for those facilities that are not continuously occupied, because many accidents and failures are caused by human error and can occur on normally unoccupied facilities during those times when personnel are aboard and conducting maintenance or other activities. Thus, personnel may be available to actuate the ESD system.

A system to remotely control the facility safety system and process control system may be installed to monitor, control, open, close, and restart specific wells, pipelines, and process components remotely. See Annex C for further details on remote operations.

5.4 Premises for Basic Analysis and Design

5.4.1 The analysis and design procedures for a platform safety system are based on the premises described in 5.4.2 through 5.4.10.

5.4.2 The process facility shall be designed for safe operation in accordance with good engineering practices.

5.4.3 The safety system provides two levels of protection to prevent or minimize the effects of an equipment failure within the process. In general, the two levels should be provided by functionally different types of safety devices for a wider spectrum of coverage. Two identical devices would have the same characteristics and might have the same inherent weaknesses.

5.4.4 The two levels of protection should be the highest order (primary) and next highest order (secondary) available. Judgment is required to determine these two highest orders for a given situation. Preference shall be given to prevention as opposed to mitigation measures. As an example, two levels of protection from a rupture due to overpressure would be provided by a PSH and a PRD. The PSH prevents the rupture by shutting in affected equipment before pressure becomes excessive, and a PRD is selected because it prevents the rupture by relieving excess volumes to a safe location. In this case the PSH would be the primary device because it prevents the overpressure at a level below the set point of the PRD. In some cases a PRD's fast response can prevent a rupture in situations where the PSH might not effect corrective action fast enough.

5.4.5 The safety devices shall be independent of and in addition to the control devices used in normal process operation. Process connections between control and safety devices should be independent to eliminate common cause failures. For example, the LSH and the level control device would have separate process connections for high level in a vessel.

5.4.6 The use of proven systems analysis techniques, such as those provided in 6.4, will determine the minimum safety requirements for a process component. If such an analysis is applied to the component as an independent unit, assuming worst-case conditions of input and output, the analysis is valid for that component in any process configuration.

5.4.7 All temporary and permanent process components, associated with a production facility, comprise the entire process from the wellhead to the most downstream discharge point; thus, all process equipment and functions are incorporated into the safety system.

5.4.8 When fully protected process components are combined into a facility, no additional threats to safety are expected. Therefore, if all process component safety devices are logically integrated into a safety system, the entire facility should be protected. However, it is incumbent on the user to apply appropriate additional hazardous analysis methodologies to ensure that hazards are identified and mitigated.

5.4.9 The analysis procedure should provide a standard method to develop a safety system and provide supporting documentation.

5.4.10 The safety system should be designed to limit the amount of time and frequency that safety functions are bypassed and to automate start-up bypasses where practical to minimize human error. Bypasses shall be classified and applied in accordance with Annex C.

6 Protection Concepts and Safety Analysis

6.1 Introduction

Section 5.1 emphasizes that most threats to safety from the production process involve the release of hydrocarbons. Thus, the analysis and design of a production facility safety system should focus on preventing such releases, stopping the flow of hydrocarbons to a leak if it occurs, and minimizing the effects of hydrocarbons that are released. A hazard analysis should be utilized to identify the causes.

Section 6.2 explains the basic concepts of protection used in the analysis. These concepts are repeated in Annex A, as applicable to individual component analysis.

Section 6.3 discusses methods of analyzing the process and establishing design criteria for an integrated safety system covering the entire production process. These methods are exemplified in the example analysis illustrated in Annex B.

Section 6.4 is a step-by-step summary for performing a safety analysis in accordance with this document. It is pointed out that this method initially considers each component independently from the rest of the process and can recommend safety devices that are not required after larger segments of the process are considered. For example, many safety devices initially considered on headers are not normally required because their safety function is performed by devices on other components.

6.2 Protection Concepts

6.2.1 General

The basic protection concepts used in the safety system analysis are discussed in this paragraph. Section 6.2.2 describes each undesirable event that could affect a process component and considers its cause, effect, and protective measures. Section 6.2.3 discusses safety device selection criteria. Section 6.2.4 discusses protective shut-in action for isolating a process component. Section 6.2.5 discusses ignition preventing measures (IPMs) that can be used to minimize the possibility of combustible concentrations of hydrocarbons contacting an ignition source. Section 6.2.6 discusses protective measures to prevent accidental contact of hot surfaces by personnel. Section 6.2.7 discusses the function of the ESS. Section 6.2.8 discusses the function of other support systems.

6.2.2 Undesirable Events

6.2.2.1 General

An undesirable event is an adverse occurrence in a process component that can pose a threat to personnel, the environment, and the facility. The undesirable events discussed in this paragraph are those that might develop in a process component under worst-case conditions of input and output. An undesirable event may be indicated by one or more process variables ranging out of operating limits. These abnormal operating conditions can be detected by sensors that initiate shutdown action to protect the process component. Each undesirable event that can affect a process component is discussed according to the following format:

a) cause,

b) effect and detectable abnormal condition,

c) primary and secondary protection that should prevent or react to its occurrence,

d) location of safety device.

6.2.2.2 Overpressure

6.2.2.2.1 General

Overpressure is pressure in a process component in excess of the MAWP.

6.2.2.2.2 Cause

Overpressure can be caused by various scenarios that develop a pressure that is in excess of the MAWP of the component. Typical causes of overpressure include, but are not limited to, the following.

a) An input source that develops pressure in excess of a process component's MAWP if inflow exceeds outflow. Inflow can exceed outflow if an upstream flow rate control device fails, if there are restrictions or blockage in the component's outlets, or if overflow or gas blow-by from an upstream component occurs.

b) Backflow occurs from a downstream source with a higher operating pressure than the MAWP of the component. Backflow can occur when forward flow is stopped, allowing reverse flow to the upstream components. Typical examples include centrifugal pumps and compressors where the suction side has an MAWP lower than the downstream operating pressure. Check valves should not be assumed to prevent such backflow as they are subject to leaking and failing open on demand. Careful consideration should also be given to side streams feeding into the system.

c) Settle-out pressure after compressor shutdown results in a pressure exceeding the MAWP of any component in the system. This scenario can occur when the MAWP of the suction side of a compressor is lower than the resulting settle-out pressure.

d) In the event of tube leakage or rupture in a heat exchanger where the higher pressure side operates at a pressure in excess of the MAWP of the lower pressure side.

e) Thermal expansion of fluids within a component if heat is added while the inlets and outlets are closed. The heat source can be from other process streams, ambient conditions, or solar radiation.

f) Heating of component contents by an external fire.

g) Misdirected flow resulting from a high-pressure source being inadvertently routed to a component having a lower MAWP.

Causes of overpressure can vary between sites and depends on the facility design and operating conditions. API 521 provides information on additional causes that should be considered and additional guidance on evaluating the scenarios listed above.

6.2.2.2.3 Effect and Detectable Abnormal Condition

The effect of overpressure can be a sudden rupture and leak of hydrocarbons. High pressure is the detectable abnormal condition that indicates that overpressure may occur.

6.2.2.2.4 Primary Protection

Primary protection from overpressure in a pressure component should be provided by a PSH sensor to shut off inflow. If a vessel is heated, the PSH sensor should also shut off the fuel or source of heat. Primary protection for atmospheric components should be provided by an adequate vent system.

6.2.2.2.5 Secondary Protection

6.2.2.2.5.1 Secondary protection from overpressure in a pressure component should be provided by a PRD. Secondary protection for atmospheric components should be provided by a second vent. The second vent may be identical to the primary vent, a gauge hatch with a self-contained PRD, or an independent PRD.

6.2.2.2.5.2 Establishment of required PRD or vent capacities should include consideration of operating conditions and failure modes during all modes of operation capable of creating overpressure, including start-up, shutdown, trip, and maintenance, and should consider common modes of failure, such as electrical, instrument control system, mechanical, human, and procedural. Guidance regarding potential causes of overpressure to be considered in sizing of PRDs is provided in API 521.

6.2.2.2.5.3 While the preferred second layer of protection against overpressure is a mechanical PRD such as a pressure-relief valve, provision of a PRD and the associated vent/flare system in accordance with the requirements contained within API 521 may not be technically or economically practical. In such cases, use of an alternative high-integrity instrumented system [high-integrity pressure protection system (HIPPS)] for overpressure protection may be applied. Where implemented, the high-integrity instrumented system shall conform to the requirements set forth in Annex E. Such a system is typically referred to as an HIPPS. While HIPPS has been presented as an option for overpressure protection of multiple components, HIPPS shall only be used after consideration of other alternatives. Caution should be applied when using HIPPS given the rigorous design, testing, and maintenance requirements for the system.

6.2.2.2.5.4 For applications involving a well flowing in a flowline to a manifold, a similar level of protection can be achieved by adding a second SDV to the well (in addition to the well SSV) and a second independent PSH sensor connected to a separate logic solver (see Annex F) and sensing point. Use of this alternative approach should be used with caution after consideration of the potential risks and other alternative means of overpressure protection. Design of this alternative system should ensure that the volume upstream of any block valves, chokes, or control valves located downstream of the pressure specification break is adequate to allow sufficient time for the SDVs to close before exceeding the MAWP of the protected system. This response time and leakage rates shall be established as performance criteria for the protection layer and shall be periodically verified through testing. Consideration should also be given to installing a small PSV in addition to the protective layer to protect against overpressure from leakage through the SSVs. Operations personnel shall be trained regarding the operation, testing, and maintenance of the protective layer.

6.2.2.2.6 Location of Safety Devices

In a process component with a liquid and a gas section, the PSH sensor, PRD, or vent should be installed to sense or relieve pressure from the gas or vapor section. The sensing connections for the safety devices should be located at the highest practical location on the component to minimize the chance of fouling by flow stream contaminants. The installation of PRDs and vents on atmospheric tanks should be in accordance with API 2000 or other applicable standards.

6.2.2.3 Leak

6.2.2.3.1 General

A leak is the accidental escape of fluids from a process component to atmosphere. In this document, "leak" implies that the escaping fluids are hydrocarbons, flammable, toxic, or hazardous chemicals.

6.2.2.3.2 Cause

A leak can be caused by deterioration from corrosion, erosion, mechanical failure, vibration, or excess temperature; by rupture from overpressure; or by accidental damage from external forces.

6.2.2.3.3 Effect and Detectable Abnormal Conditions

The effect of a leak is the release of hydrocarbons to the atmosphere. Low pressure and low level are the abnormal conditions that, when detected, can indicate that a leak has occurred.

6.2.2.3.4 Primary Protection

Primary protection from leaks of sufficient rate to create an abnormal operating condition within a pressure component should be provided by a PSL sensor to shut off flow and a flow safety valve (FSV) to minimize backflow. Primary protection from leaks from the liquid section may also be provided by an LSL sensor to shut off flow. On an atmospheric component, primary protection from liquid leaks should be provided by an LSL sensor to shut off flow. A containment system should provide primary protection from small liquid leaks that cannot be detected by the safety devices on a process component. Primary protection from small gas leaks that occur in an inadequately ventilated area and cannot be detected by component sensing devices should be provided by a combustible gas detection system.

6.2.2.3.5 Secondary Protection

Secondary protection from all detectable leaks and small gas leaks in an inadequately ventilated area shall be provided by the ESSs. Secondary protection from small liquid leaks should be provided by an LSH sensor installed on the sump tank to shut in all components that can leak into the sump.

6.2.2.3.6 Location of Safety Devices

In a process component with both a liquid and a gas section, the PSL sensor should be connected to sense pressure from the gas or vapor section. The PSL sensor should be installed at the highest practical location on the component to minimize the chances of fouling by flow stream contaminants. FSVs should be installed in each component operating outlet line subject to significant backflow. The LSL sensor should be located a sufficient distance below the lowest operating liquid level to avoid nuisance shutdowns, but with adequate volume between the LSL sensor and liquid outlet to prevent gas blow-by before shutdown is accomplished.

6.2.2.4 Liquid Overflow

6.2.2.4.1 General

Liquid overflow is the discharge of liquids from a process component through a gas or vapor outlet or the relief system.

6.2.2.4.2 Cause

Liquid overflow can be caused by liquid input in excess of liquid outlet capacity. This may be the result of failure of an upstream flow rate control device, failure of the liquid level control system, or blockage of a liquid outlet.

6.2.2.4.3 Effect and Detectable Abnormal Condition

The effects of liquid overflow can be overpressure or excess liquids in a downstream component, or release of hydrocarbons to the atmosphere. High level is the detectable abnormal condition that indicates that overflow may occur.

6.2.2.4.4 Primary Protection

Primary protection from liquid overflow should be provided by an LSH sensor to shut off inflow into the component.

6.2.2.4.5 Secondary Protection

Secondary protection from liquid overflow to the atmosphere should be provided by the containment system as defined by the ESSs in 6.2.7 b). Secondary protection from liquid overflow to a downstream component should be provided by safety devices on the downstream component.

6.2.2.4.6 Location of Safety Devices

The LSH sensor should be located a sufficient distance above the highest operating liquid level of a component to prevent nuisance shutdowns, but with adequate volume above the LSH sensor to prevent liquid overflow before shutdown is accomplished.

6.2.2.5 Gas Blow-by

6.2.2.5.1 General

Gas blow-by is the discharge of gas from a process component through a liquid outlet.

6.2.2.5.2 Cause

Gas blow-by can be caused by failure of a liquid level control system or inadvertent opening of a bypass valve around a level control valve.

6.2.2.5.3 Effect and Detectable Abnormal Condition

The effect of gas blow-by can be overpressure in a downstream component. Low level is the detectable abnormal condition that indicates gas blow-by may occur.

6.2.2.5.4 Primary Protection

Primary protection from gas blow-by should be provided by an LSL sensor to shut off the liquid outlet or shut off inflow when closure of the inflow valve does not exceed the downstream vessel MAWP caused by gas blow-by.

6.2.2.5.5 Secondary Protection

Secondary protection from gas blow-by to a downstream component should be provided by over pressure protection on the downstream component.

6.2.2.5.6 Location of Safety Devices

The LSL sensor should be located a sufficient distance below the lowest operating liquid level to avoid nuisance shutdowns, but with an adequate volume between the LSL sensor and liquid outlet to prevent gas blow-by before shutdown is accomplished.

6.2.2.6 Underpressure

6.2.2.6.1 General

Underpressure is pressure in a process component less than the design collapse pressure.

6.2.2.6.2 Cause

Underpressure can be caused by fluid withdrawal in excess of inflow that may be the result of failure of an inlet or outlet control valve, blockage of an inlet line during withdrawal, or thermal contraction of fluids when the inlets and outlets are closed.

6.2.2.6.3 Effect and Detectable Abnormal Condition

The effect of underpressure can be collapse of the component and a leak. Low pressure is the detectable abnormal condition that indicates underpressure may occur.

6.2.2.6.4 Primary Protection

Primary protection from underpressure in an atmospheric component should be provided by an adequate vent system. Primary protection for a pressure component subject to underpressure should be provided by a gas makeup system.

6.2.2.6.5 Secondary Protection

Secondary protection for an atmospheric component should be provided by a second vent or by a PVRV. Secondary protection for a pressure component subject to underpressure should be provided by a PSL sensor to shut off inflow and outflow.

6.2.2.6.6 Location of Safety Devices

The PSL sensor should be installed at the highest practical location on the component to minimize the chances of fouling by flow stream contaminants. Vents and PVRVs should be installed in accordance with API 2000 or other applicable standards.

6.2.2.7 Excess High Temperature (Fired and Exhaust-heated Components)

6.2.2.7.1 General

Excess temperature is temperature above that in which a process component is designed to operate. This undesirable event in fired and exhaust-heated components is categorized as excess medium or process fluid temperature and excess stack temperature. Excess temperature in unfired components is discussed in individual component analyses in Annex A.

6.2.2.7.2 Cause

Excess medium or process fluid temperature can be caused by excess fuel or heat input due to failure or inadvertent bypassing of the fuel or exhaust gas control equipment, extraneous fuel entering the firing chamber through the air intake, or a leak of combustible fluids into the fired or exhaust-heated chamber; insufficient volume of heat transfer fluid due to low flow in a closed heat transfer system (where the heated medium is circulated through tubes located in the firing or exhaust-heated chamber); or low liquid level in a fired component with an immersed fire or exhaust gas tube. Excess stack temperature in a fired component can be caused by any of the above or by insufficient transfer of heat because of accumulation of foreign material (sand, scale, etc.) in the heat transfer section. Excess stack temperature in an exhaust-heated component can result from ignition of a combustible medium leak into the exhaust-heated chamber.

6.2.2.7.3 Effect and Detectable Abnormal Condition

The effects of high medium or process fluid temperature can be a reduction of the working pressure and subsequent leak or rupture of the affected component and/or overpressure of the circulating tubes in a closed heat transfer system, if the medium is isolated in the tubes. The effect of high stack temperature can be a direct ignition source for combustibles coming in contact with the stack surface. High temperature, low flow, and low level are the detectable abnormal conditions that indicate that excess temperature may occur.

6.2.2.7.4 Primary Protection

Primary protection from excess medium or process fluid temperature resulting from excess or extraneous fuel, heat, or medium leaks into the fired or heated chamber should be provided by a TSH sensor. If caused by low liquid level, protection should be provided by an LSL sensor. The TSH and LSL sensors on fired components should shut off fuel supply and inflow of combustible fluids. The TSH and LSL sensors on exhaust-heated components should divert or shut off the fuel or heat source. If excess medium temperature is due to low flow in a closed heat transfer system containing combustible fluid, primary protection should be provided by an FSL sensor to shut off fuel supply to a fired component or to divert the exhaust flow from an exhaust-heated component. Primary protection from excess stack temperature should be provided by a TSH (stack) sensor to shut off the fuel or exhaust gas source and inflow of combustible fluids.

6.2.2.7.5 Secondary Protection

Secondary protection from excess medium or process fluid temperature in a fired component, if caused by excess or extraneous fuel, should be provided by a TSH (stack) sensor and, if caused by low flow, by a TSH (medium) sensor and TSH (stack) sensor. If caused by low level, secondary protection should be provided by a TSH (medium or process fluid) sensor and TSH (stack) sensor. Secondary protection from excess medium or process fluid temperature in an exhaust-heated component, if caused by low level or low flow, should be provided by a TSH (medium) sensor. These TSH sensors should perform the same function as the primary protection. Secondary protection for excess stack temperature should be provided by the ESSs and an FSV, where applicable.

6.2.2.7.6 Location of Safety Devices

Temperature sensors, other than fusible or skin contact types, should be placed in a thermowell for ease of removing and testing. In a two-phase (gas/liquid) system, the TSH sensor should be located in the liquid section. In a tube-type heater, where the heated medium flows through tubes located in the firing or heating chamber, the TSH sensor should be located in the tube outlet as close as is practical to the heater. An FSL sensor should be located in the medium circulating tube piping. An FSV installed on medium tube outlet piping is used to prevent backflow from downstream components in the event of tube rupture. See A.6.3.2 for additional guidance.

6.2.2.8 Excess Low Temperature (Pipe Embrittlement)

6.2.2.8.1 General

Excess low temperature is temperature below the minimum allowable working temperature of a process component. This type of low temperature results in loss of ductility, or embrittlement, of the process component material. Embrittled materials can mechanically fail even at pressures far below the process component's MAWP. Piping is more commonly associated with the effects of this type of low temperature since the process cause of the low temperature often occurs in the piping between process components. Pipe can experience failure first because of its smaller relative mass to the downstream process component.

6.2.2.8.2 Causes

Excessive pressure drop of gases can produce a Joule-Thomson (JT) effect. This effect can create extremely low temperatures in the downstream piping after the pressure drop and can cause the low temperature limit of the piping to be exceeded. Flashing liquids may also cause low temperatures.

6.2.2.8.3 Conditions

Extremely low temperature in the downstream piping can result in brittle fracture and failure of the piping. "Low temperature" in the downstream section is the detectable condition.

6.2.2.8.4 Primary Protection

Primary protection from low-temperature embrittlement should be through system design such that the process component materials are suitable for all credible low temperatures considering both abnormal and normal operations. A TSL located downstream of the pressure drop should be installed as primary protection from low-temperature embrittlement when system design is impracticable. The use of a TSL as a layer of protection should not apply to blowdown piping and relief systems because stopping relief flow to prevent a low temperature could cause a more dangerous event.

If low temperatures only result from a high pressure drop, then a high differential pressure monitor can give a quicker response time and may be considered as an alternative. The monitoring devices should shut off the process flow.

6.2.2.8.5 Secondary Protection

Secondary protection shall be required when the system cannot be designed to avoid low-temperature embrittlement during normal operating conditions even if temperature-based operating constraints are implemented, e.g. the system shall be allowed to warm up following a low-temperature event before repressurization can occur. A second TSL located downstream of the pressure drop should be installed and not associated with the primary protection monitoring device to take appropriate action.

6.2.2.8.6 Location of Safety Devices

TSL sensors installed as insertion elements should be protected by thermowells in the downstream piping no more than five diameters from the source of pressure drop. TSL sensors installed as skin-type elements should be insulated to protect against ambient temperature effects.

6.2.2.9 Direct Ignition Source (Fired Components)

6.2.2.9.1 General

A direct ignition source is an exposed surface, flame, or spark at sufficient temperature and heat capacity to ignite combustibles. Direct ignition sources discussed in this paragraph are limited to fired components. Electrical systems and other ignition sources are discussed in 6.2.5.

6.2.2.9.2 Cause

Direct ignition sources can be caused by flame emission from the air intake due to the use of improper fuel (e.g. liquid carry-over in a gas burner), reverse draft from a natural draft burner, or extraneous fuel entering the air intake, spark emission from the exhaust stack, or hot surfaces resulting from excess temperature.

6.2.2.9.3 Effect and Detectable Abnormal Condition

The effect of a direct ignition source can be a fire or explosion if contacted by a combustible material. High temperature and low airflow (forced draft burners only) are the detectable abnormal conditions that indicate a direct ignition source can occur.

6.2.2.9.4 Primary Protection

Primary protection from flame emission through the air intake of a natural draft burner should be provided by a flame arrestor to contain the flame in the firing chamber. Primary protection from flame emission through the air intake of a forced draft burner should be provided by a PSL (air intake) sensor to detect low airflow and shut off the fuel and air supply. A stack arrestor should provide primary protection from exhaust stack spark emission. Primary protection from hot surfaces due to excess temperature should be provided by a TSH (medium or process fluid) sensor and TSH (stack) sensor. The TSH sensor should shut off fuel supply and inflow of combustible fluids.

6.2.2.9.5 Secondary Protection

Secondary protection from flame emission through the air intake of a natural draft burner should be provided by the ESS. Secondary protection from flame emission through the air intake of a forced draft burner should be provided by a blower motor interlock to detect blower motor failure and to initiate a signal to shut off the fuel and air supply. Secondary protection from exhaust stack spark emission and hot surfaces should be provided by the ESSs and an FSV where applicable.

6.2.2.9.6 Location of Safety Devices

The location of air intake flame arrestors and exhaust stack spark arrestors is fixed. These items should be installed to facilitate inspecting and cleaning. TSH (stack, media, process fluids) sensors should be installed as discussed in 6.2.2.7. A PSL (air intake) sensor should be installed downstream of the blower fan inside the air intake on a forced draft burner. Forced draft burners should have starter interlocks installed on the blower motor starter. An FSV should also be installed in medium tube outlet piping.

6.2.2.10 Excess Combustible Vapors in the Firing Chamber (Fired Component)

6.2.2.10.1 General

Excess combustible vapors in the firing chamber are combustible vapors in addition to those required for normal ignition of either the pilot or main burner.

6.2.2.10.2 Cause

Accumulation of excess combustible vapors in the firing chamber can be caused by a failure of the fuel or air supply control equipment or improper operating procedures.

6.2.2.10.3 Effect and Detectable Abnormal Condition

The effect of excess combustible vapors in the firing chamber, on ignition, can be an explosion and possible rupture of the component. Flame failure and high or low fuel supply pressure are detectable abnormal conditions that can indicate excess combustible vapors in the firing chamber. Low air supply pressure and blower failure can also indicate this condition in forced draft burners.

6.2.2.10.4 Primary Protection

Primary protection from excess combustible vapors in the firing chamber caused by a mechanical failure of the fuel control equipment should be provided by a flame failure sensor (BSL). The sensor should detect a flame insufficient to ignite the entering vapors and shut off the fuel.

6.2.2.10.5 Secondary Protection

Secondary protection from excess combustible vapors in the firing chamber due to fuel control failure should be provided by a PSH and PSL (fuel) sensor to shut off the fuel. On a forced draft burner, a PSL (air) sensor and motor starter interlock should be installed to detect an inadequate air supply and initiate a signal to shut off the fuel and air. An FSL sensor may be installed in place of a PSL sensor in the air intake to sense low airflow. In addition to the above safety devices, safe operating procedures should also be followed to prevent firebox explosions during ignition of the pilot or main burner. Recommended safe operating procedures are shown in A.6.4. Additionally, automated burner start-up procedures should be considered.

6.2.2.10.6 Location of Safety Devices

A BSL sensor should be installed in the firing chamber to monitor the pilot and/or main burner flame. PSH and PSL sensors in the fuel supply should be installed downstream of all fuel pressure regulators. A PSL (air intake) sensor should be installed in the air intake downstream of the forced draft blower.

6.2.3 Safety Device Selection

6.2.3.1 The required safety device protection is categorized into primary and secondary protective devices. The primary device will react sooner, safer, or more reliably than the secondary device. The primary device will provide the highest order of protection, and the secondary device should provide the next highest order of protection.

6.2.3.2 A single safety device may not provide complete primary or secondary protection because the results of a failure can vary by degree or sequence. Thus, several devices or systems may be shown, the combination of which will provide the necessary level of protection. For example, a PSL sensor and an FSV can be required to stop flow to a leak. These two devices can provide the primary level of protection.

6.2.3.3 The protection devices determined in the SAT, in conjunction with necessary SDVs or other final control devices, protect the process component in any process configuration. It is important that the user understand the SAT logic and how the SATs are developed.

6.2.3.4 The location of SDVs and other final control devices shall be determined from a study of the detailed flow schematic(s) [e.g. safety analysis flow diagram, process flow diagram (PFD), and P&ID] and from a knowledge of operating parameters. When an undesirable event is detected in a process component, the component can be isolated from all input process fluids, heat, and fuel, by either shutting in the primary sources of input or diverting the inputs to other components where they can be safely handled.

6.2.3.5 All safety devices shown in the figures in Annex A for each component should be considered and should be installed unless conditions exist whereby the function normally performed by a safety device is not required or is performed adequately by another safety device(s). The safety analysis checklists (SACs) in Annex A list equivalent protection methods, thereby allowing the exclusion of some devices.

6.2.3.6 If a process component is used that is not covered in Annex A, an SAT for that component should be developed as discussed in 6.2.3.2 and 6.2.3.3.

6.2.4 Protective Shut-in Action

6.2.4.1 When an abnormal condition is detected in a process component by a safety device or by personnel, all input sources of process fluids, heat, and fuel should be shut off or diverted to other components where they can be safely handled. If shutoff is selected, process inputs should be shut off at the primary source of energy (wells, pump, compressor, etc.). It is not advisable to only close the process inlet to a component if this can create an abnormal condition in the upstream component, causing its safety devices to shut it in. This would be repeated for each component back through the process until the primary source is shut in. Each component would therefore be subjected to abnormal conditions and shall be protected by its safety devices every time a downstream component shuts in. This cascading effect depends on the operation of several additional safety devices and can place undue stress on the equipment.

There can be special cases where shut-in by cascading is acceptable; the following are examples.

a) The source of input to a separator is frequently changed as wells are periodically switched into the separator. If the well(s) producing to the separator is to be directly shut in when an abnormal condition is detected, the safety system logic shall be changed each time different wells are switched into the unit. This creates the possibility of oversight in changing the logic. In this case, it may be preferable to close the separator inlet and let the resulting high flowline pressure cause the well(s) to shut in by action of the flowline PSH sensor. The header and the flowline should be rated for the maximum pressure that can be caused by this action.

b) A platform receives production through a flowline from a satellite well. Although the source of energy to the system is the satellite well, detection of an abnormal condition on the platform should cause activation of an SDV on the incoming flowline. If it is desired to shut in the satellite well following closure of the flowline SDV at the platform, this may be accomplished by use of a flowline PSH sensor installed at the satellite location.

c) A compressor installation is equipped with an automatic divert valve that permits production to be maintained from wells capable of producing against pipeline pressure when a compressor shutdown occurs. In this case, wells incapable of producing against pipeline pressure may be shut in by action of the individual flowline PSH sensors to minimize potential safety system logic problems as discussed in Item a) above

6.2.4.2 Where subsea trees are the source of pressure, a boarding shutdown valve (BSDV) shall be installed and assumes the role of the surface safety valve (SSV) required for a traditional dry tree. This protects the production facility from the subsea flowline inventory.

6.2.4.3 The BSDV shall be designed to meet the following requirements.

a) The BSDVs shall be rated to at least the riser MAOP.

b) BSDV shall meet the requirements of API 6A and API 6AV1 and be fire rated for a minimum of 30 minutes.

c) BSDVs shall be located as close to the water line as practical while providing adequate access for operation, maintenance, and testing. The piping outboard of the BSDV shall be protected from all credible hazards.

d) A temperature safety element (TSE) or other fire detection device shall be installed to allow detection of fire at each BSDV.

6.2.4.4 Where pipelines are a potential source of pressure or backflow (e.g. gas pipelines or where pipelines have multiple downstream input sources), the pipeline-tested SDV/FSV should have a leakage rate as specified per I.4.10 to ensure that leakage through a closed valve will not lead to significant escalation from an ignited release. This ensures the maximum level of safety for the production facility and the people aboard the facility.

6.2.4.5 A TSE or other fire detection device shall be installed to allow detection of fire on pipeline-tested SDV/FSV.

6.2.4.6 It may be desirable or necessary to shut in the inlet to a process component for additional protection or to prevent upstream components from equalizing pressure or liquid levels after the primary source is shut in. If this option is selected, the primary source of energy should be shut in simultaneously with or prior to closing of the component inlet valve.

6.2.5 Ignition Preventing Measures

6.2.5.1 General

The safety flow chart shown in Figure 3 illustrates that the principal threat to platform safety is the release of hydrocarbons. However, if ignition of released hydrocarbons can be prevented, the consequences of the hydrocarbon release can be reduced. Thus, prevention of ignition is another protection method that shall be considered along with safety devices and ESSs. Ignition of hydrocarbons can be caused by electric arcs, flame, sparks, and hot surfaces. Protection from these sources is provided by design considerations that decrease the possibility of hydrocarbons contacting an ignition source or preventing gaseous hydrocarbons from reaching a combustible concentration. Collectively, these methods are referred to in this document as IPMs and include

— ventilation,

— application of electrical codes and standards,

— location of potential ignition sources,

— protection of hot surfaces.

6.2.5.2 Ventilation

Ignition of a combustible gas requires that the concentration of the gas mixed with air (oxygen) reaches the lower explosive limit (LEL). The safety system is designed to minimize the amount of hydrocarbon released by shutting off the hydrocarbon source on detecting an abnormal condition. Another method for preventing a combustible mixture is to provide a volume of air sufficient to maintain the hydrocarbon concentration below the LEL. To prevent the accumulation of combustible mixtures, process areas should be as open as practicable to allow the free movement of air. Enclosed areas containing hydrocarbon handling or fueled equipment should have adequate ventilation so that the gases or vapors will dissipate before reaching the LEL. Refer to G.2.3 for requirements related to combustible gas detector installation.

6.2.5.3 Electrical Codes and Standards

6.2.5.3.1 Protection from ignition by electrical sources should be provided by designing, installing, and maintaining electrical equipment in accordance with API 14F or API 14FZ or other applicable standards and by classification of platform areas according to API 500 or API 505.

6.2.5.3.2 API 14F and API 14FZ define criteria for electrical equipment and wiring methods that can be used safely in classified and unclassified areas on offshore production facilities.

6.2.5.3.3 API 500 and API 505 presents methods for classifying areas surrounding drilling rigs and production facilities on land and on marine fixed and mobile platforms for safe installation of electrical equipment.

6.2.5.4 Location

Potential ignition sources, such as fired process components and certain rotating machinery, are normally equipped to minimize the possibility of igniting released hydrocarbons. Additional protection can be provided by locating equipment in areas where exposure to inadvertently released hydrocarbons is minimized. API 14J provides guidance for locating equipment. Some other potential ignition sources are those related to housekeeping such as boilers, water heaters, stoves, clothes dryers, etc. These should be located in electrically unclassified locations. If such equipment is gas fueled and installed in an inadequately ventilated building, a combustible gas detector (ASH) should be installed to close the fuel SDV(s) located outside the building.

6.2.5.5 Hot Surface Protection

Any surface including portable equipment with a temperature in excess of 400 °F (204 °C) should be protected from exposure to hydrocarbon liquids due to spillage or leakage. Surfaces including portable equipment with a temperature in excess of 725 °F (385 °C) should be protected from exposure to accumulations of combustible gases and vapors. Methods of protection can be insulation, barriers, water cooling, etc. Some mechanical components such as turbochargers, exhaust manifolds and the like (including associated piping) that cannot be insulated without causing mechanical failure should be protected by other means.

6.2.6 Hot Equipment Shielding

Any surface with a temperature in excess of 160 °F (71 °C) should have protection when accidental contact of the hot surface could be made by personnel within normal work or walk areas. Protection may be in the form of guards, barriers, or insulation. Some mechanical components such as turbochargers, exhaust manifolds, compressor heads, expansion bottles, and the like (including associated piping) are exceptions; in these cases, warning signs are acceptable.

6.2.7 Emergency Support Systems

To minimize the effects of escaped hydrocarbons on offshore production facilities, the ESSs shall be designed in accordance with Annex G. The ESS includes:

a) the combustible gas detection system to sense the presence of escaped hydrocarbons and initiate alarms and facility shutdown before gas concentrations reach the LEL;

b) the containment system to collect escaped liquid hydrocarbons and initiate facility shutdown on high level in the collective containment system;

c) the fire detection system to sense a fire and initiate facility shutdown;

d) the ESD system to provide a method to manually initiate facility shutdown by personnel observing abnormal conditions or undesirable events;

e) the SSSVs that may be self-actuated [subsurface-controlled subsurface safety valves (SSCSVs)] or activated by an ESD system and/or fire detection system [surface-controlled subsurface safety valves (SCSSVs)];

f) systems for discharging gas to the atmosphere are installed to provide a means for conducting discharged gas from process components to safe locations for final release to the atmosphere.

6.2.8 Other Support Systems

The integrity of a facility surface safety system depends on proper operation of several other support systems. These ancillary support systems carry the same degree of importance as other portions of the facility safety system and should be equally as well maintained. Those discussed in Annex G are the pneumatic supply system and the hydraulic supply system.

The pneumatic and hydraulic supply systems are installed to provide power for actuators. The pneumatic system also provides supply for instruments.

6.3 Safety Analysis

6.3.1 Safety Analysis Table

6.3.1.1 Safety analysis tables (SATs) for the basic process components of a production facility are presented in Annex A. The SATs are applicable to a component regardless of its position in the process flow. The boundaries of each process component include the inlet piping, control devices, and the outlet piping to another component. Every outlet pipe and pipe branch should be included up to the point where safety devices on the next component provide protection.

6.3.1.2 The safety analysis of each process component highlights undesirable events (effects of equipment failures, process upsets, accidents, etc.) from which protection should be provided, along with detectable abnormal conditions that can be monitored for safety surveillance. These detectable conditions are used to initiate action through automatic controls to prevent or minimize the effect of undesirable events. The tables present the logical sequence of safety system development, including undesirable events that could be created in downstream process components because of failures in the equipment or safety devices of the component under consideration.

6.3.1.3 The generic causes of each undesirable event are listed. The primary causes are equipment failures, process upsets, and accidental, but all primary causes in a category will create the same undesirable event. Thus, a blocked line could be due to plugging, freezing, or other failure of a control valve or the inadvertent closing of a manual valve. The undesirable events should be determined from a detailed investigation of the failure modes of the component and its ancillary equipment. These failure modes are grouped under causes, according to the manner in which they can generate the undesirable event.

6.3.1.4 The protective safety devices and ESSs that prevent or react to minimize the effects of undesirable events shall be designed in accordance with 6.2.

6.3.2 Safety Analysis Checklist

Individual SACs are shown in Annex A as an aid for discussing the application of the safety analysis to each individual component. The SAC lists the safety devices that would be required to protect each process component if it were viewed as an individual unit with the worst probable input and output conditions. Listed under each device are certain conditions that eliminate the need for that particular device when the component is viewed in relation to other process components. This action is justified because safety devices on other components can provide the same protection, or because in a specific configuration, the abnormal condition that the device detects cannot lead to a threat to safety.

6.3.3 SAFE Chart

The SAFE chart, shown in Figure B.2, is used to relate all sensing devices, SDVs, shutdown devices, and ESSs to their functions. The SAFE chart should list all process components and ESSs with their required safety devices and should list the functions to be performed by each device. If the device is not needed, the reason shall be listed on SAFE by referring to the appropriate SAC item number. The SAC references are defined by the item and procedure numbers from the appropriate SAC table for the equipment referenced. If the reason for eliminating a device is that a device on another component provides equivalent protection, this alternate device should also be shown on SAFE. The relation of each safety device with its required function can be documented by checking the appropriate box in the chart matrix. Completion of the SAFE chart provides a means of verifying the design logic of the safety system.

6.4 Analysis and Design Procedure Summary

The analysis and design of a facility surface safety system should include the following steps.

1. A description of the process in a detailed flow schematic(s) (e.g. safety analysis flow diagram, PFDs, and P&IDs) that establishes the operating parameters. The flow schematic(s) and operating parameters should be developed based on equipment design and process requirements.

2. Verification from the SATs of the need for basic safety devices to protect each process component viewed as an individual unit. The SAC for individual components is then used to justify the elimination of any safety device when each process component is analyzed in relation to other process components. The SAC lists specific conditions under which some safety devices may be eliminated when larger segments of the process are considered.

3. Develop an SAT and an SAC table for process components that differ from those covered in this document.

4. Logically integrate all safety devices and self-protected equipment into a complete facility safety system using the SAFE chart. List on the SAFE chart all process components and their required safety devices. Enter the functions the devices perform and relate each device to its function by checking the appropriate box in the chart matrix.

5. If designing a new facility, show all devices to be installed on the P&IDs.

6. If analyzing an existing facility, compare SAFE chart with the detailed flow schematic(s) and add the devices required but not shown.

The analyses should define the monitoring devices (sensors) and self-actuating safety devices needed for a process facility. They also establish the safety function required (shutdown, diverting the input, pressure-relief, etc.).

Annex A
(normative)

Process Component Analysis

A.1 General

This annex presents a complete safety analysis of each basic process component normally used in a facility production process system. The component analysis includes the following.

a) A description of each process component.

b) A typical drawing of each process component showing safety devices that should be considered based on individual component analysis. A discussion of each process component is included outlining recommended safety device locations.

c) An SAT for each process component analyzing the undesirable events that could affect the component.

d) An SAC for each process component listing safety devices and showing conditions under which particular safety devices may be excluded. A discussion of the rationale for including or excluding each safety device is presented.

A.2 Wellheads and Flowlines

A.2.1 Description

Wellheads provide surface control (manual and automatic) and containment of well fluids and provide downhole access for well servicing. Flowlines transport well fluids from the wellhead to the first downstream process component.

For analysis purposes and assignment of safety devices, flowlines are divided into flowline segments. A flowline segment is any portion of a flowline that has an assigned operating pressure different from other portions of the same flowline. These flowline segments can be classified as either initial (beginning at wellhead), intermediate, or final (terminating at another process component) segments. Thus, a flowline that experiences a reduction in operating pressure due to some inline pressure-reducing device, such as a choke, and has two different assigned operating pressures will have an initial and final segment. A flowline that experiences no reduction in operating pressure due to a pressure-reducing device will have only one segment. In this case, the initial and final flowline segment will be the same. Each flowline segment shall be analyzed to determine appropriate safety devices. Recommended safety devices for typical wellheads and flowlines are shown in Figures A.1, A.2, and A.3.

A.2.2 Safety Analysis

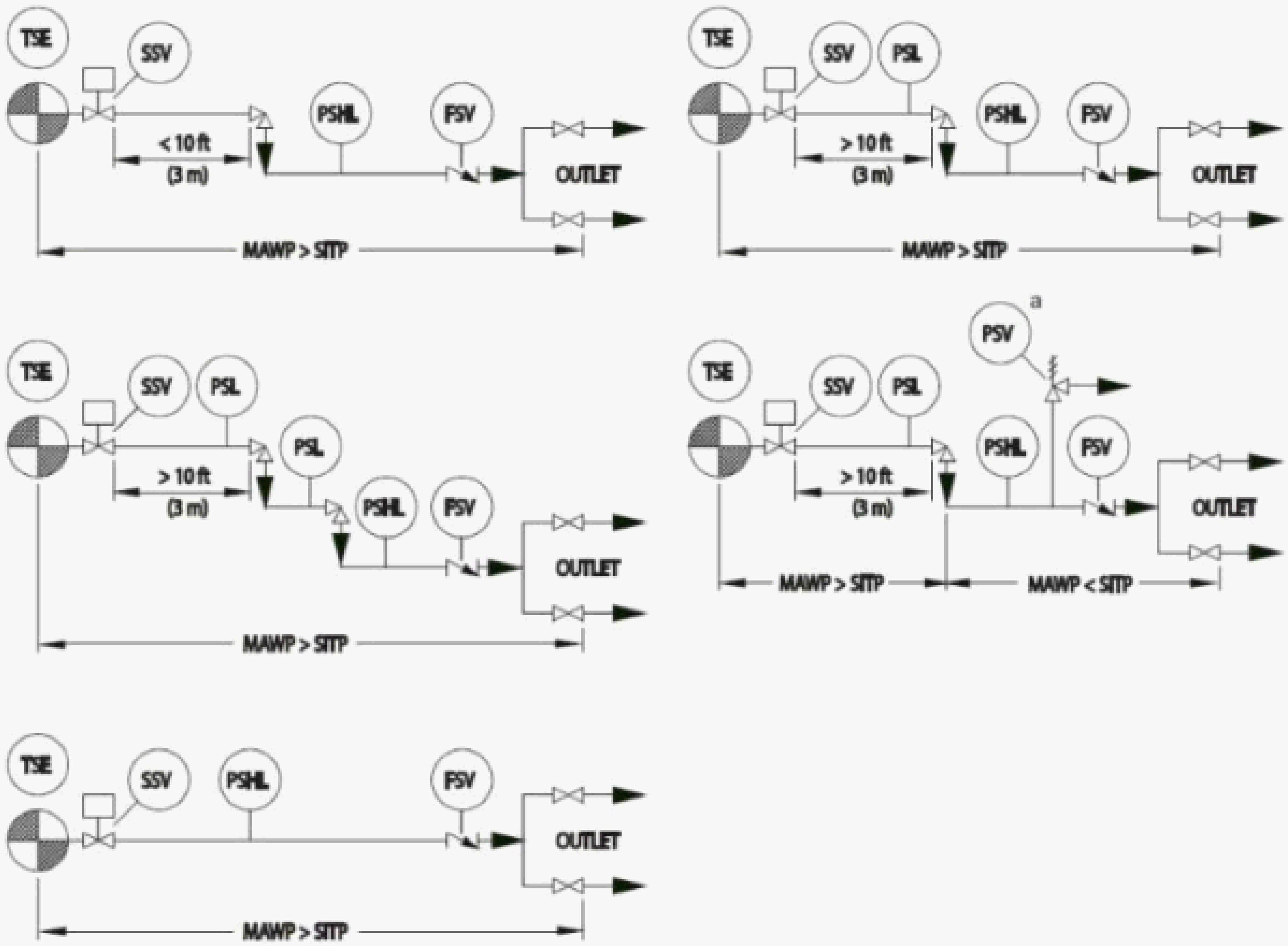
A.2.2.1 Safety Analysis Table

The SAT for a flowline segment is presented in Table A.1. The undesirable events that can affect a flowline segment are overpressure and leak.

A.2.2.2 Safety Analysis Checklist

A.2.2.2.1 General

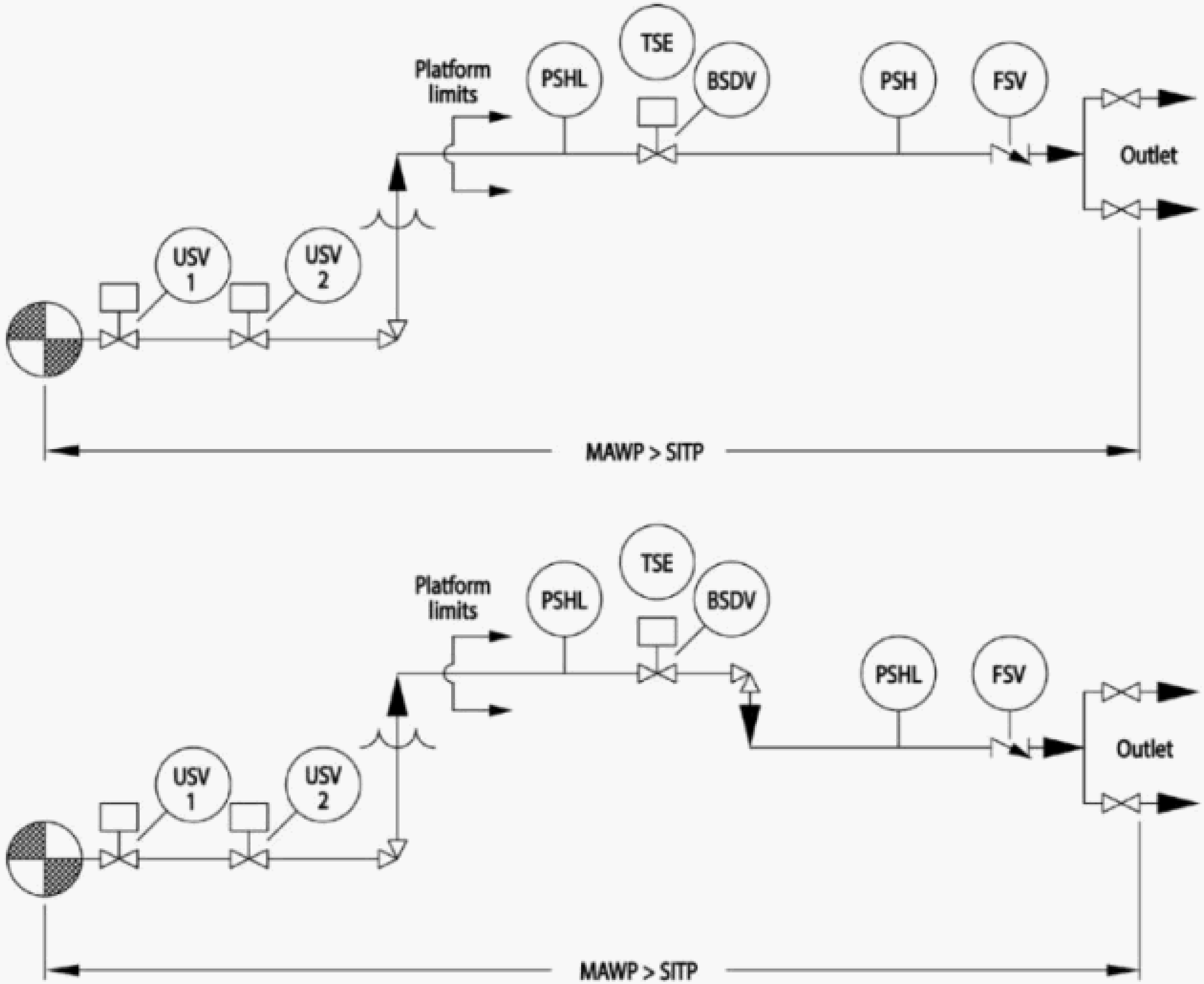
The SAC for a flowline segment is presented in Table A.2.



NOTE The TSE designations are symbolic and are not intended to reflect actual location or quantity.

[a] The PSV location can be upstream or downstream of the FSV.

Figure A.1—Safety Devices: Dry Tree Wellhead Flowlines

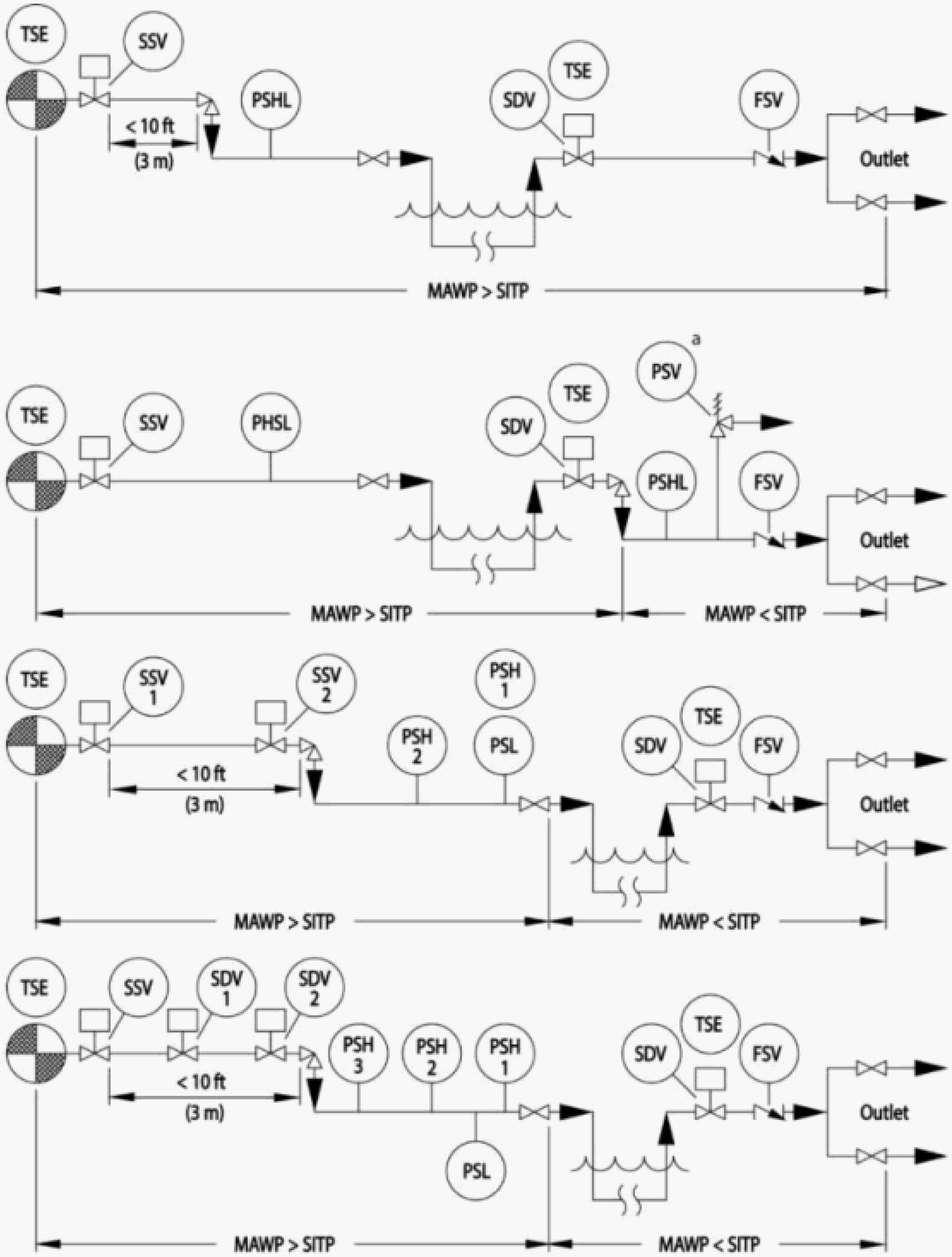


Key

SITP shut-in tubing pressure

MAWP maximum allowable working pressure (rated)

Figure A.2—Safety Devices: Underwater Wellhead Flowlines



NOTE 1 TSE designations are symbolic and are not intended to reflect actual location or quantity.

NOTE 2 Numbers used on safety devices are provided as reference for this drawing and are not required to be used as actual tagging requirements.

[a] PSV location can be upstream or downstream of the FSV.

Figure A.3—Satellite Well

Table A.1—Flowline Segment Safety Analysis Table

Undesirable Event	Cause	Detectable Abnormal Condition at Component
Overpressure	Blocked or restricted line	High pressure
	Downstream choke plugged	
	Hydrate plug	
	Upstream flow control failure	
	Changing well conditions	
	Closed outlet valve	
Leak	Deterioration	Low pressure
	Erosion	
	Corrosion	
	Impact damage	
	Vibration	

Table A.2—Flowline Segment Safety Analysis Checklist

Item	Description
A.1a.	High-pressure sensor (PSH). 1) PSH installed. 2) Flowline segment has a maximum allowable working pressure (MAWP) greater than maximum shut-in pressure and is protected by a PSH on a downstream flowline segment.
A.1b.	Low-pressure sensor (PSL). 1) PSL installed. 2) Flowline segment is between the well and the first choking device and is less than 10 ft (3 m) in length.
A.1c.	Pressure safety valve (PSV). 1) PSV installed. 2) Flowline segment has an MAWP greater than the maximum shut-in tubing pressure. 3) Two shutdown valves (SDVs) [one of which being the original surface safety valve (SSV)] with independent PSHs, logic solvers, and sensing points are installed where there is adequate flowline volume upstream of any block valves to allow sufficient time for the SDVs to close before exceeding the MAWP. NOTE See additional design requirements in 6.2.2.2.5. 4) Flowline segment is protected by a pressure-relief device (PRD) on upstream segment. 5) Flowline segment is protected by a PRD on downstream component that cannot be isolated from the flowline segment and there are no chokes or other restrictions between the flowline segment and the PRD. 6) Flowline segment is protected by a high-integrity pressure protection system (HIPPS) meeting the requirements in Annex E.
A.1d.	Flow safety valve (FSV). 1) FSV installed. 2) Flowline segment is protected by FSV in final flowline segment.

A.2.2.2.2 Pressure Safety Devices (PSH, PSL, and PSV)

Because wells are the primary source of pressure, a PSH sensor to shut in the well shall be provided on each flowline to detect abnormally high pressure. A PSH sensor to shut in the well should be installed on the final flowline segment and on any other segment that has an MAWP less than the maximum SITP of the well. A PSL sensor to shut in the well should be provided on each flowline segment, except the initial segment if the first choking device is less than 10 ft (3 m) from the wellhead.

A PSV is not required on a flowline under the following conditions:

a) the MAWP of a flowline segment is greater than the maximum SITP of the well;

b) the flowline is protected by a PRD located on an upstream flowline segment;

c) an SDV (in addition to the SSV) with an independent PSH sensor connected to a separate logic solver and sensing point is an acceptable alternate to a PSV, providing the flowline volume upstream of block valve is adequate to allow sufficient time for the SDVs to close before exceeding the MAWP;

d) the flowline is protected by an HIPPS meeting the requirements Annex E.

The use of an SDV and SSV or HIPPS in lieu of a PSV should be approached with caution after consideration of other alternatives. In some cases, installation of a PSV in addition to an SDV and SSV or HIPPS might be desirable even at locations having no containment system.

A.2.2.2.3 Flow Safety Device (FSV)

A check valve (FSV) is only necessary in the final flowline segment to minimize backflow to the flowline.

A.2.3 Safety Device Location

A.2.3.1 Pressure Safety Devices (PSH, PSL, and PSV)

The PSH and PSL sensors should be located for protection from damage due to vibration, shock, and accidents. The sensing point should be located on top of a horizontal run or in a vertical run. Independent sensing points should be provided for all required PSHs used with an SDV or HIPPS as alternate protection for a PSV. The PSV should be located upstream of the first blocking device in the flowline segment and should not be set higher than the rated working pressure of the segment.

A.2.3.2 Flow Safety Device (FSV)

The check valve (FSV) should be located in the final flowline segment so that the entire flowline is protected from backflow.

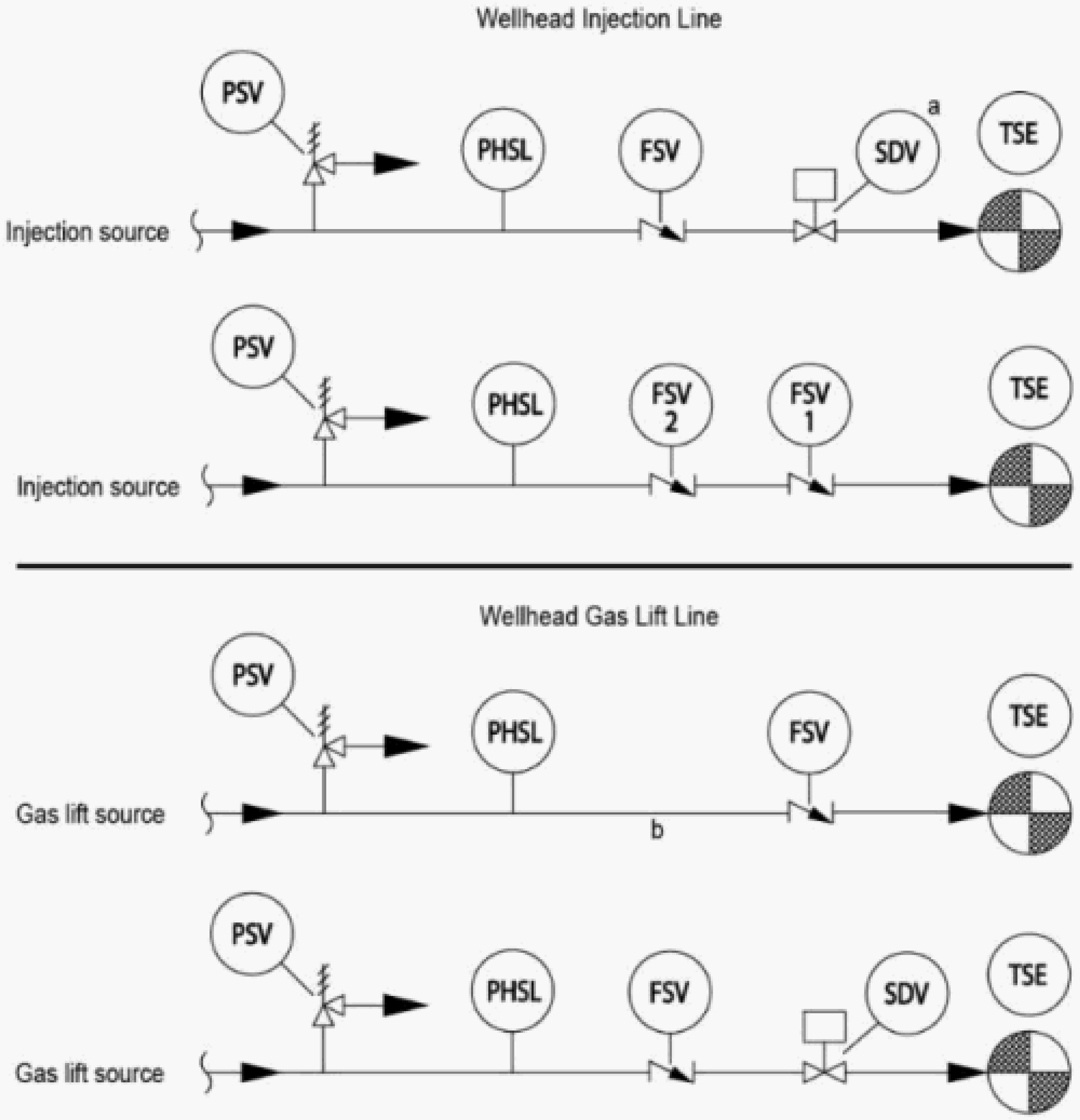
A.2.3.3 Shutdown Devices (SSV or USV)

The SSV should be located on the wellhead as the first automatically actuated valve in the flow stream from the wellbore. The SSV should be actuated by the flowline pressure sensors, ESD system, fire detection system, and sensors on downstream process components. An SDV (in addition to the SSV) may be installed on the wellhead. If an SDV is installed, it may be actuated, in lieu of the SSV, by the flowline pressure sensors and sensors on downstream process components. The USV should be actuated by the flowline pressure sensors located upstream of the BSDV, by the ESD system, and by the fire detection system.

A.3 Wellhead Injection Lines

A.3.1 Description

Injection lines transfer fluids to the wellbore for artificial lift or reservoir injection. Recommended safety devices for wellhead injection lines are shown in Figure A.4.



NOTE 1 TSE designations are symbolic and are not intended to reflect actual location or quantity.

NOTE 2 Numbers used on safety devices are provided as reference for this drawing and are not required to be used as actual tagging requirements.

[a] In the event of hydrocarbon injection, the SDV shall be an SSV.

[b] Producing formation not capable of backflow.

Figure A.4—Safety Devices: Dry Tree Wellhead Injection Lines

A.3.2 Safety Analysis

A.3.2.1 Safety Analysis Table

The SAT for wellhead injection lines is presented in Table A.3. The undesirable events that can affect an injection line are overpressure and leak.

A.3.2.2 Safety Analysis Checklist

A.3.2.2.1 General

The SAC for wellhead injection lines is presented in Table A.4.

Table A.3—Safety Analysis Table: Dry Tree Wellhead Injection Lines

Undesirable Event	Cause	Detectable Abnormal Condition at Component
Overpressure	Blocked or restricted outlet Hydrate plug Upstream flow control failure Plugged formation Backflow from formation	High pressure
Leak	Deterioration Erosion Corrosion Impact damage Vibration	Low pressure

Table A.4—Safety Analysis Checklist: Dry Tree Wellhead Injection Lines

Item	Description
A.2a.	High-pressure sensor (PSH). 1) PSH installed. 2) Line and equipment are protected by an upstream PSH.
A.2b.	Low-pressure sensor (PSL). 1) PSL installed. 2) Line and equipment are protected by an upstream PSL.
A.2c.	Pressure safety valve (PSV). 1) PSV installed. 2) Line and equipment have a maximum allowable working pressure (MAWP) greater than the maximum pressure that can be imposed by the injection source. 3) Line and equipment are protected by an upstream pressure-relief device (PRD). 4) Line and equipment are protected by a high-integrity pressure protection system (HIPPS) meeting the requirements in Annex E.
A.2d.	Check valves (FSV). 1) FSV(s) installed.

A.3.2.2.2 Pressure Safety Devices (PSH, PSL, and PSV)

Pressure protection is usually provided by a PSH and a PSL sensor on the injection source, such as a compressor or pump, to shut off inflow. If the PSH and PSL sensors also protect the injection line, wellhead, and other equipment, these devices are not required on the injection line. A PSV is not necessary if the injection line is designed to withstand the maximum pressure that can be imposed by the injection source. Usually, a PRD is provided on the injection source that will also protect the injection line, wellhead, and other equipment.

A.3.2.2.3 Flow Safety Device (FSV)

A check valve (FSV) should be provided on each injection line to minimize backflow.

A.3.3 Safety Device Location

A.3.3.1 Pressure Safety Devices (PSH, PSL, and PSV)

The PSH and PSL sensors should be located upstream of the FSV, and the sensing point should be on top of a horizontal run or in a vertical run. The PSV should be located so that it cannot be isolated from any portion of the injection line.

A.3.3.2 Flow Safety Device (FSV)

The check valve (FSV) should be located on each injection line as near the wellhead as is practical so that the entire line is protected from backflow.

A.3.3.3 Shutdown Devices (SDV)

Injection line SDVs to prevent backflow should be located as near the wellhead as is practical to minimize the amount of line exposed to piping failure. SDVs are not required on gas lift lines if they are protected at an upstream component and if they are not subject to backflow from the producing formation. SDVs are not required if the injection line is for the purpose of injecting water and the subsurface formation is incapable of backflowing hydrocarbons. If closing an SDV could cause rapid pressure buildup in the injection line, consideration should be given to shutdown of the injection source and/or use of a second FSV in lieu of an SDV.

A.4 Headers

A.4.1 Description

Headers receive production from two or more flow streams and distribute production to the required process systems, such as the low-, intermediate-, or high-pressure production and test separation facilities. Recommended safety devices for typical headers are shown in Figure A.5.

A.4.2 Safety Analysis

A.4.2.1 Safety Analysis Table

The SAT for headers is presented in Table A.5. The undesirable events that can affect a header are overpressure and leaks.

A.4.2.2 Safety Analysis Checklist

A.4.2.2.1 General

The SAC for headers is presented in Table A.6.

A.4.2.2.2 Pressure Safety Devices (PSH, PSL, and PSV)

PSH and PSL sensors are not required on headers if each input source is equipped with a PSH and a PSL sensor and the PSH sensor is set less than the rated working pressure of the header. Also, a PSH sensor is not required if the header is protected by a PSH sensor on a downstream process component and the header cannot be isolated, from either pluggage or by a manual isolation valve, from the downstream component. A PSL is not required if the header is for flare, relief, vent, or atmospheric service. If the header requires a PSH and a PSL sensor, the signal from each should shut off all input sources to the header.

A PSV is not required on a header under the following conditions.

a) The MAWP is greater than the maximum shut-in pressure of any connected input source.

b) Pressure-relief protection is provided on all connected input sources that have a maximum shut-in pressure greater than the MAWP of the header.

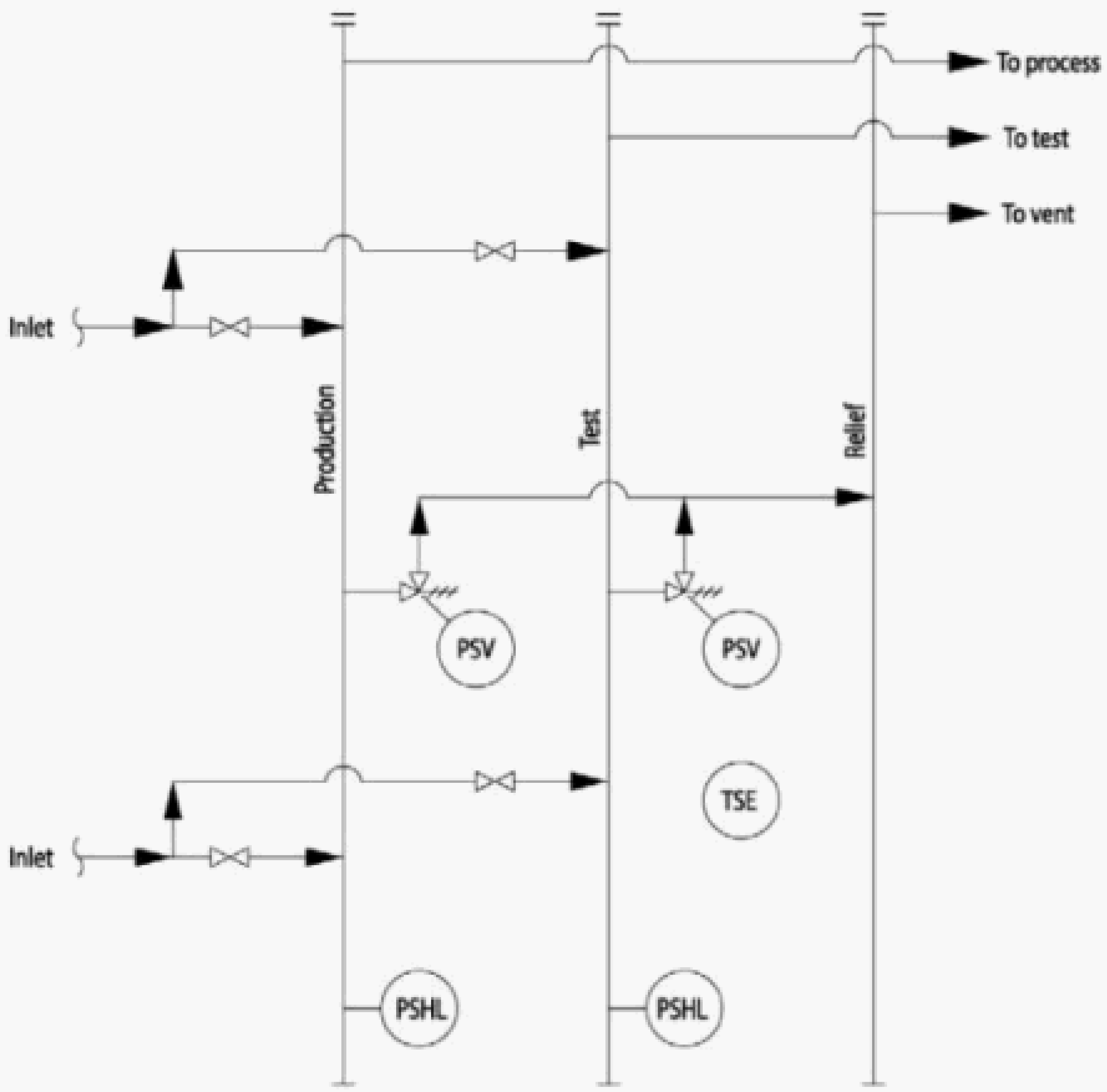
c) The header is protected by a PRD on a downstream process component that cannot be isolated from the header.

d) The header is for flare, relief, vent, or atmospheric service and has no valving in the outlet piping.

e) Input sources include well(s) having a pressure greater than the MAWP of the header and that well is equipped with two SDVs (one of which may be the original SSV) controlled by independent PSHs connected to separate logic solvers and sensing points. This design shall provide adequate flowline volume to allow sufficient time for the SSVs to close before exceeding the MAWP. See additional design requirements in 6.2.2.2.5. Other input sources having a pressure greater than the MAWP of the header are protected by PSVs.

f) Input source is a well(s) having a pressure greater than the MAWP of the header and is protected by an HIPPS meeting the requirements in Annex E.

The use of two SSVs or HIPPS in lieu of a PSV should be approached with caution after consideration of other alternatives. In some cases, installation of a PSV in addition to two SSVs or HIPPS might be desirable even at locations having no containment system.



NOTE TSE designations are symbolic are not intended to reflect actual location or quantity.

Figure A.5—Safety Devices: Headers

A.4.3 Safety Device Location

Pressure safety devices, PSH and PSL sensors or a PSV, if required, should be located to sense pressure throughout the header. If different pressure conditions exist in separate sections of the header, each section should have the required protection.

Table A.5—Safety Analysis Table: Headers

Undesirable Event	Cause	Detectable Abnormal Condition at Component
Overpressure	Blocked or restricted outlet Hydrate plug Upstream flow control failure Excess inflow	High pressure
Leak	Deterioration Erosion Corrosion Impact damage Vibration	Low pressure

Table A.6—Safety Analysis Checklist: Headers

Item	Description
A.3a.	High-pressure sensor (PSH). 1) PSH installed. 2) Each input source is equipped with a PSH set less than the maximum allowable working pressure (MAWP) of the header. 3) Header is protected by downstream PSH that cannot be isolated from the header. 4) Header is for flare, relief, vent, or atmospheric service and has no valving in the outlet piping.
A.3b.	Low-pressure sensor (PSL). 1) PSL installed. 2) Each input source is protected by a PSL and there are no pressure control devices or restrictions between the PSL and the header. 3) Header is for flare, relief, vent, or atmospheric service.
A.3c.	Pressure safety valve (PSV). 1) PSV installed. 2) Header has an MAWP greater than the maximum shut-in pressure of any connected well. 3) Pressure-relief protection is provided on each input source having a maximum shut-in pressure greater than the MAWP of the header. 4) Header is protected by downstream pressure-relief device (PRD) that cannot be isolated from the header. 5) Header is for flare, relief, vent, or atmospheric service and has no valving in the outlet piping. 6) Input sources is a well(s) having a pressure greater than the MAWP of the header and that well is equipped with two shutdown valves (SDVs) [one of which may be the original surface safety valve (SSV)] controlled by independent PSHs connected to separate logic solver and sensing points and there is adequate volume upstream of any block valves to allow sufficient time for the SSVs to close before exceeding the MAWP. Other input sources having a pressure greater than the MAWP of the header are protected by PSVs. NOTE See additional design requirements in 6.2.2.2.5. 7) Input source is a well(s) having a pressure greater than the MAWP of the header and is protected by a high-integrity pressure protection system (HIPPS) meeting the requirements Annex E.

A.5 Pressure Vessels

A.5.1 Description

Pressure vessels handle hydrocarbons under pressure such as for separation, dehydration, storage, and surge. Some pressure vessel applications require heat input. This discussion covers only the effects of temperature to the process section of vessel. Electric heaters installed within process vessels are covered by this section. Heat exchangers transferring heat between fluids are covered in A.6 and A.10. Pressure vessels associated with compressors, other than compressor cylinders, should be protected in accordance with this section. Compressor cylinders and cases are covered in A.8. Recommended safety devices for typical pressure vessels are shown in Figure A.6.

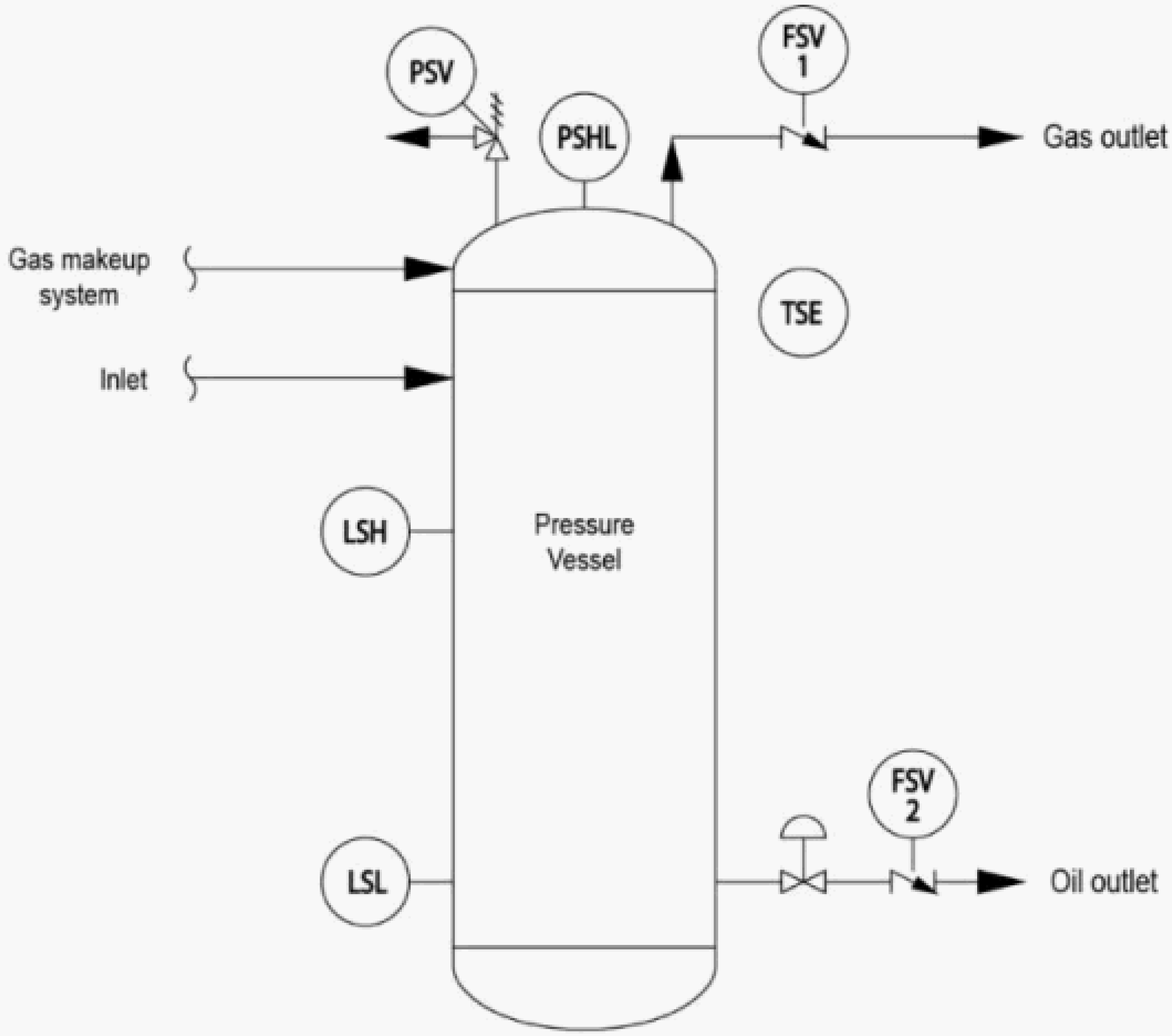
A.5.2 Safety Analysis

A.5.2.1 Safety Analysis Table

The SAT for pressure vessels is presented in Table A.7. The undesirable events that can affect a pressure vessel are overpressure, underpressure, overflow, gas blow-by, leak, and excess temperature.

Table A.7—Safety Analysis Table: Pressure Vessels

Undesirable Event	Cause	Detectable Abnormal Condition at Component
Overpressure	Blocked or restricted outlet Inflow exceeds outflow Gas blow-by (upstream component) Pressure control system failure Thermal expansion Excess heat input Fire	High pressure
Underpressure (vacuum)	Withdrawals exceed inflow Thermal contraction Open outlet Pressure control system failure	Low pressure
Liquid overflow	Inflow exceeds outflow Liquid slug flow Blocked or restricted liquid outlet Level control system failure	High liquid level
Gas blow-by	Liquid withdrawals exceed inflow Open liquid outlet Level control system failure	Low liquid level
Leak	Deterioration Erosion Corrosion Impact damage Vibration	Low pressure, low liquid level
Excess temperature (high)	Temperature control system failure High inlet temperature	High temperature
Excess temperature (low)	Temperature control system failure Low inlet temperature Low ambient temperature Blowdown or rapid depressurization	Low temperature



NOTE 1 TSE designations are symbolic and are not intended to reflect actual location or quantity.

NOTE 2 If pressure vessel is subject to high temperature, TSH should be installed.

NOTE 3 If the vessel is subject to temperature lower than design a TSL must be installed. See A.4.2.2.4.

NOTE 4 Numbers used on safety devices are provided as reference for this drawing and are not required to be used as actual tagging requirements.

Figure A.6—Safety Devices: Pressure Vessels

A.5.2.2 Safety Analysis Checklist

A.5.2.2.1 General

The SAC for pressure vessels is presented in Table A.8.

A.5.2.2.2 Pressure Safety Devices (PSH, PSL, and PSV)

A.4.2.2.2.1 A pressure vessel that receives fluids from a well or from other sources that can cause overpressure should be protected by a PSH sensor to shut off inflow to the vessel. The PSH sensor need not be provided on the vessel if a PSH sensor on other process components will sense vessel pressure and shut off inflow to the vessel, and the PSH sensor cannot be isolated from the vessel; or if the vessel is the final scrubber in a flare, relief, or vent system and is designed to withstand maximum built-up back pressure; or if the vessel operates in atmospheric service and has an adequate vent system. A vessel receiving fluids from a well shall be protected by a PSH sensor because the pressure potential of a well may increase due to changes in reservoir conditions, artificial lift, workover activities, etc.

Table A.8—Safety Analysis Checklist: Pressure Vessels

Item	Description
A.4a.	High-pressure sensor (PSH). 1) PSH installed. 2) Input is from a pump or compressor that cannot develop pressure greater than the maximum allowable working pressure (MAWP) of the vessel. 3) Input source is not a wellhead flowline(s), production header, or pipeline and each input source is protected by a PSH that protects the vessel. 4) Adequately sized piping without block or regulating valves connects gas outlet to downstream equipment protected by a PSH that also protects the upstream vessel. 5) Vessel is the final scrubber in a flare, relief, or vent system and is designed to withstand maximum built-up back pressure. 6) Vessel operates in atmospheric service and has an adequate vent system.
A.4b.	Low-pressure sensor (PSL). 1) PSL installed. 2) Minimum operating pressure is atmospheric pressure when in service. 3) Each input source is protected by a PSL and there are no pressure control devices or restrictions between the PSL(s) and the vessel. 4) Vessel is scrubber or small trap, is not a process component, and adequate protection is provided by downstream PSL or design function (e.g. vessel is gas scrubber for pneumatic safety system or final scrubber for flare, relief, or vent system). 5) Adequately sized piping without block or regulating valves connects gas outlet to downstream equipment protected by a PSL that also protects the upstream vessel.
A.4c.	Pressure safety valve (PSV). 1) PSV installed. 2) Each input source is protected by a pressure-relief device (PRD) set no higher than the MAWP of the vessel and a PSV is installed on the vessel for fire exposure and thermal expansion. 3) Each input source is protected by a PRD set no higher than the vessel's MAWP and at least one of these PRDs cannot be isolated from the vessel and the PRD is adequately sized for thermal expansion and fire exposure for the vessels being protected. 4) PRDs on downstream equipment can satisfy relief requirement of the vessel and cannot be isolated from the vessel. 5) Vessel is the final scrubber in a flare, relief, or vent system, is designed to withstand maximum built-up back pressure, and has no internal or external obstructions, such as mist extractors, back pressure valves, or flame arrestors. 6) Vessel is the final scrubber in a flare, relief, or vent system, is designed to withstand maximum built-up back pressure, and is equipped with a PRD to bypass any internal or external obstructions, such as mist extractors, back pressure valves, or flame arrestors. 7) Vessel is protected by a high-integrity pressure protection system (HIPPS) installed at the component or on all input sources that may exceed the MAWP of the vessel, meeting the requirements in Annex E, and is protected by a PSV for any other credible overpressure source the HIPPS is not designed to protect against, to include those listed in 6.2.2.2.2 and HIPPS leakage.
A.4d.	High-level sensor (LSH). 1) LSH installed. 2) Equipment downstream of gas outlet is not a flare or vent system and can safely handle maximum liquid carry-over. 3) Vessel function does not require handling separated fluid phases. 4) Vessel is a small trap from which liquids are manually drained.

Table A.8—Safety Analysis Checklist: Pressure Vessels (Continued)

A.4e.	Low-level sensor (LSL). 1) LSL installed to protect each liquid outlet. 2) Liquid level is not automatically maintained in the vessel, and the vessel does not have an immersed heating element subject to excess temperature or the heating element is located in the gas phase. 3) For vessels controlling a gas-liquid interface, equipment downstream of liquid outlet(s) can safely handle maximum gas rates that can be discharged through the liquid outlet(s), and vessel does not have an immersed heating element subject to excess temperature. Restrictions in the discharge line(s) may be used to limit the gas flow rate. 4) For vessels controlling a hydrocarbon/water interface, equipment downstream of liquid outlet(s) can safely handle maximum hydrocarbon gas or liquid rates that can be discharged through the liquid outlet(s) and vessel does not have an immersed heating element subject to excess temperature.
A.4f.	Check valve (FSV). 1) FSV installed on each outlet. 2) The maximum volume of hydrocarbons that could backflow from downstream equipment is insignificant. 3) A control device in the line will effectively minimize backflow.
A.4g.	High-temperature sensor (TSH). NOTE TSHs are applicable only to vessels having a heat source. 1) TSH installed. 2) (Deleted in Second Edition.) 3) Heat source is incapable of causing excess temperature.
A.4h.	Low-temperature sensor (TSL). NOTE Low-temperature sensors are applicable only to vessels subject to cooling. 1) TSL installed. 2) Materials suitable for all credible low temperatures considering both abnormal and normal operations.

A.4.2.2.2.2 A pressure vessel should be provided with a PSL sensor to shut off inflow to the vessel when leaks large enough to reduce pressure occur, unless PSL sensors on other components will provide necessary protection and the PSL sensor cannot be isolated from the vessel when in service. A PSL sensor should not be installed if the vessel normally operates at atmospheric pressure or frequently varies to atmospheric while in service.

A.4.2.2.2.3 A pressure vessel shall be protected by one or more PSVs with sufficient capacity to discharge maximum vessel input rates. At least one PSV should be set no higher than the MAWP of the vessel. API 521 may be used as a guide in determining set pressures of multiple relief valve installations. A PSV need not be provided on a vessel if the vessel is the final scrubber in a flare, relief, or vent system; is designed so that back pressure, including inertial forces, developed at maximum instantaneous flow conditions will not exceed the working pressure of the lowest pressure rated element; and has no internal or external obstructions, such as mist extractors, back pressure valves, or flame arrestors. If obstructions exist, a PSV, or other PRD, should be installed to bypass the restriction. A PSV need not be provided on a vessel if PRDs on other process components provide adequate relief capacity, relieve at or below vessel MAWP, and cannot be isolated from the vessel when in service. If such PRDs are located on downstream components, they shall not be isolated from the vessel at any time. Moreover, if upstream PRDs provide necessary protection when the vessel is in service, but can be isolated when the vessel is shut in, a PSV should be installed on the vessel for pressure relief due to thermal expansion or fire exposure.

For vessels with an overpressure scenario that cannot be practicably protected by a PRD, an HIPPS may be used. HIPPS installation shall be in accordance with Annex E. Where an HIPPS is installed, a PSV can be required to protect against other credible overpressure scenarios, including those listed in 6.2.2.2.2 and HIPPS leakage.

A.4.2.2.2.4 If a pressure vessel is subject to underpressure that can cause it to collapse, the vessel should be provided with a gas makeup system that will maintain adequate pressure in the vessel.

A.5.2.2.3 Level Safety Devices (LSH and LSL)

A pressure vessel that discharges to flare should be protected from liquid overflow by an LSH sensor to shut off inflow to the vessel. Vessels that do not discharge to flare should also be protected by an LSH sensor unless downstream process components can safely handle maximum liquids that could overflow. Normal response to an LSH is to shut off inflow to the vessel. Downstream components (e.g. compressors) may require shutdown to prevent equipment failure. A pressure vessel should be protected from gas blow-by by an LSL sensor to shut off the liquid outlet or shut off inflow when closure of the inflow valve alone prevents the downstream vessel from exceeding the MAWP caused by gas blow-by. The LSL sensor is not required if a liquid level is not maintained in the vessel during normal operation or downstream equipment can safely handle any gas that could blow-by without venting flammable vapors to an unsafe area. An LSL sensor to shut off the heating source should be provided in a heated vessel if the heating element is immersed. Level devices are not required on pressure vessels that are not designed for liquid-gas separation or on small traps from which liquids are manually drained. This includes such vessels as pressure-surge bottles, de-sanders, gas volume bottles, gas meter drip traps, fuel gas filters, etc.

A.5.2.2.4 Temperature Safety Devices (TSH and TSL)

If a pressure vessel is heated, a TSH sensor should be provided to shut off the source of heat when process fluid temperature becomes excessive.

If process vessel, pipe or equipment is exposed to JT effect cooling, a TSL sensor should be provided to shut off JT effect cooling flow. If the JT effect cooling is the result of a shutdown-blowdown operation, the TSL should activate a permissive that does not allow the equipment to be pressurized until the actual temperature exceeds the minimum design temperature. The TSL is not required if the equipment is designed for the minimum credible JT effect temperature. This requirement excludes blowdown piping and relief headers.

A.5.2.2.5 Flow Safety Devices (FSV)

An FSV should be installed in each gas and liquid discharge line if significant fluid volumes could backflow from downstream components in the event of a leak. An FSV is not required if a control or safety device in the line will effectively minimize backflow. Whether backflow is significant is a judgment decision. If a line discharges to a pressure vessel at a point above the liquid level range, the backflow of liquids should be insignificant. Whether or not the gas volume is insignificant should depend on the size and pressure of the gas section and the conditions where a leak might occur.

A.5.3 Safety Device Location

A.5.3.1 Pressure Safety Devices (PSH, PSL, and PSV)

The PSH and PSL sensors and the PSV should be located to sense or relieve pressure from the gas or vapor section of the vessel. This is usually on or near the top. However, such devices may be located on the gas outlet piping if the pressure drop from the vessel to the sensing point is negligible and if the devices cannot be isolated from the vessel. Such isolation could be caused externally (e.g. by blocked valves on gas outlet) or internally (e.g. by plugged mist extractors).

For vessels with an overpressure scenario that cannot be practicably protected by a PRD, an HIPPS may be used. HIPPS installation shall be in accordance with Annex E. Where an HIPPS is installed, a PSV can be required to protect against other credible overpressure scenarios, including those listed in 6.2.2.2.2 and HIPPS leakage.

A.4.2.2.2.4 If a pressure vessel is subject to underpressure that can cause it to collapse, the vessel should be provided with a gas makeup system that will maintain adequate pressure in the vessel.

A.5.2.2.3 Level Safety Devices (LSH and LSL)

A pressure vessel that discharges to flare should be protected from liquid overflow by an LSH sensor to shut off inflow to the vessel. Vessels that do not discharge to flare should also be protected by an LSH sensor unless downstream process components can safely handle maximum liquids that could overflow. Normal response to an LSH is to shut off inflow to the vessel. Downstream components (e.g. compressors) may require shutdown to prevent equipment failure. A pressure vessel should be protected from gas blow-by by an LSL sensor to shut off the liquid outlet or shut off inflow when closure of the inflow valve alone prevents the downstream vessel from exceeding the MAWP caused by gas blow-by. The LSL sensor is not required if a liquid level is not maintained in the vessel during normal operation or downstream equipment can safely handle any gas that could blow-by without venting flammable vapors to an unsafe area. An LSL sensor to shut off the heating source should be provided in a heated vessel if the heating element is immersed. Level devices are not required on pressure vessels that are not designed for liquid-gas separation or on small traps from which liquids are manually drained. This includes such vessels as pressure-surge bottles, de-sanders, gas volume bottles, gas meter drip traps, fuel gas filters, etc.

A.5.2.2.4 Temperature Safety Devices (TSH and TSL)

If a pressure vessel is heated, a TSH sensor should be provided to shut off the source of heat when process fluid temperature becomes excessive.

If process vessel, pipe or equipment is exposed to JT effect cooling, a TSL sensor should be provided to shut off JT effect cooling flow. If the JT effect cooling is the result of a shutdown-blowdown operation, the TSL should activate a permissive that does not allow the equipment to be pressurized until the actual temperature exceeds the minimum design temperature. The TSL is not required if the equipment is designed for the minimum credible JT effect temperature. This requirement excludes blowdown piping and relief headers.

A.5.2.2.5 Flow Safety Devices (FSV)

An FSV should be installed in each gas and liquid discharge line if significant fluid volumes could backflow from downstream components in the event of a leak. An FSV is not required if a control or safety device in the line will effectively minimize backflow. Whether backflow is significant is a judgment decision. If a line discharges to a pressure vessel at a point above the liquid level range, the backflow of liquids should be insignificant. Whether or not the gas volume is insignificant should depend on the size and pressure of the gas section and the conditions where a leak might occur.

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A.5.3.1 Pressure Safety Devices (PSH, PSL, and PSV)

The PSH and PSL sensors and the PSV should be located to sense or relieve pressure from the gas or vapor section of the vessel. This is usually on or near the top. However, such devices may be located on the gas outlet piping if the pressure drop from the vessel to the sensing point is negligible and if the devices cannot be isolated from the vessel. Such isolation could be caused externally (e.g. by blocked valves on gas outlet) or internally (e.g. by plugged mist extractors).

For vessels with an overpressure scenario that cannot be practicably protected by a PRD, an HIPPS may be used. HIPPS installation shall be in accordance with Annex E. Where an HIPPS is installed, a PSV can be required to protect against other credible overpressure scenarios, including those listed in 6.2.2.2.2 and HIPPS leakage.

A.4.2.2.2.4 If a pressure vessel is subject to underpressure that can cause it to collapse, the vessel should be provided with a gas makeup system that will maintain adequate pressure in the vessel.

A.5.2.2.3 Level Safety Devices (LSH and LSL)

A pressure vessel that discharges to flare should be protected from liquid overflow by an LSH sensor to shut off inflow to the vessel. Vessels that do not discharge to flare should also be protected by an LSH sensor unless downstream process components can safely handle maximum liquids that could overflow. Normal response to an LSH is to shut off inflow to the vessel. Downstream components (e.g. compressors) may require shutdown to prevent equipment failure. A pressure vessel should be protected from gas blow-by by an LSL sensor to shut off the liquid outlet or shut off inflow when closure of the inflow valve alone prevents the downstream vessel from exceeding the MAWP caused by gas blow-by. The LSL sensor is not required if a liquid level is not maintained in the vessel during normal operation or downstream equipment can safely handle any gas that could blow-by without venting flammable vapors to an unsafe area. An LSL sensor to shut off the heating source should be provided in a heated vessel if the heating element is immersed. Level devices are not required on pressure vessels that are not designed for liquid-gas separation or on small traps from which liquids are manually drained. This includes such vessels as pressure-surge bottles, de-sanders, gas volume bottles, gas meter drip traps, fuel gas filters, etc.

A.5.2.2.4 Temperature Safety Devices (TSH and TSL)

If a pressure vessel is heated, a TSH sensor should be provided to shut off the source of heat when process fluid temperature becomes excessive.

If process vessel, pipe or equipment is exposed to JT effect cooling, a TSL sensor should be provided to shut off JT effect cooling flow. If the JT effect cooling is the result of a shutdown-blowdown operation, the TSL should activate a permissive that does not allow the equipment to be pressurized until the actual temperature exceeds the minimum design temperature. The TSL is not required if the equipment is designed for the minimum credible JT effect temperature. This requirement excludes blowdown piping and relief headers.

A.5.2.2.5 Flow Safety Devices (FSV)

An FSV should be installed in each gas and liquid discharge line if significant fluid volumes could backflow from downstream components in the event of a leak. An FSV is not required if a control or safety device in the line will effectively minimize backflow. Whether backflow is significant is a judgment decision. If a line discharges to a pressure vessel at a point above the liquid level range, the backflow of liquids should be insignificant. Whether or not the gas volume is insignificant should depend on the size and pressure of the gas section and the conditions where a leak might occur.

A.5.3 Safety Device Location

A.5.3.1 Pressure Safety Devices (PSH, PSL, and PSV)

The PSH and PSL sensors and the PSV should be located to sense or relieve pressure from the gas or vapor section of the vessel. This is usually on or near the top. However, such devices may be located on the gas outlet piping if the pressure drop from the vessel to the sensing point is negligible and if the devices cannot be isolated from the vessel. Such isolation could be caused externally (e.g. by blocked valves on gas outlet) or internally (e.g. by plugged mist extractors).

For vessels with an overpressure scenario that cannot be practicably protected by a PRD, an HIPPS may be used. HIPPS installation shall be in accordance with Annex E. Where an HIPPS is installed, a PSV can be required to protect against other credible overpressure scenarios, including those listed in 6.2.2.2.2 and HIPPS leakage.

A.4.2.2.2.4 If a pressure vessel is subject to underpressure that can cause it to collapse, the vessel should be provided with a gas makeup system that will maintain adequate pressure in the vessel.

A.5.2.2.3 Level Safety Devices (LSH and LSL)

A pressure vessel that discharges to flare should be protected from liquid overflow by an LSH sensor to shut off inflow to the vessel. Vessels that do not discharge to flare should also be protected by an LSH sensor unless downstream process components can safely handle maximum liquids that could overflow. Normal response to an LSH is to shut off inflow to the vessel. Downstream components (e.g. compressors) may require shutdown to prevent equipment failure. A pressure vessel should be protected from gas blow-by by an LSL sensor to shut off the liquid outlet or shut off inflow when closure of the inflow valve alone prevents the downstream vessel from exceeding the MAWP caused by gas blow-by. The LSL sensor is not required if a liquid level is not maintained in the vessel during normal operation or downstream equipment can safely handle any gas that could blow-by without venting flammable vapors to an unsafe area. An LSL sensor to shut off the heating source should be provided in a heated vessel if the heating element is immersed. Level devices are not required on pressure vessels that are not designed for liquid-gas separation or on small traps from which liquids are manually drained. This includes such vessels as pressure-surge bottles, de-sanders, gas volume bottles, gas meter drip traps, fuel gas filters, etc.

A.5.2.2.4 Temperature Safety Devices (TSH and TSL)

If a pressure vessel is heated, a TSH sensor should be provided to shut off the source of heat when process fluid temperature becomes excessive.

If process vessel, pipe or equipment is exposed to JT effect cooling, a TSL sensor should be provided to shut off JT effect cooling flow. If the JT effect cooling is the result of a shutdown-blowdown operation, the TSL should activate a permissive that does not allow the equipment to be pressurized until the actual temperature exceeds the minimum design temperature. The TSL is not required if the equipment is designed for the minimum credible JT effect temperature. This requirement excludes blowdown piping and relief headers.

A.5.2.2.5 Flow Safety Devices (FSV)

An FSV should be installed in each gas and liquid discharge line if significant fluid volumes could backflow from downstream components in the event of a leak. An FSV is not required if a control or safety device in the line will effectively minimize backflow. Whether backflow is significant is a judgment decision. If a line discharges to a pressure vessel at a point above the liquid level range, the backflow of liquids should be insignificant. Whether or not the gas volume is insignificant should depend on the size and pressure of the gas section and the conditions where a leak might occur.

A.5.3 Safety Device Location

A.5.3.1 Pressure Safety Devices (PSH, PSL, and PSV)

The PSH and PSL sensors and the PSV should be located to sense or relieve pressure from the gas or vapor section of the vessel. This is usually on or near the top. However, such devices may be located on the gas outlet piping if the pressure drop from the vessel to the sensing point is negligible and if the devices cannot be isolated from the vessel. Such isolation could be caused externally (e.g. by blocked valves on gas outlet) or internally (e.g. by plugged mist extractors).

For vessels with an overpressure scenario that cannot be practicably protected by a PRD, an HIPPS may be used. HIPPS installation shall be in accordance with Annex E. Where an HIPPS is installed, a PSV can be required to protect against other credible overpressure scenarios, including those listed in 6.2.2.2.2 and HIPPS leakage.

A.4.2.2.2.4 If a pressure vessel is subject to underpressure that can cause it to collapse, the vessel should be provided with a gas makeup system that will maintain adequate pressure in the vessel.

A.5.2.2.3 Level Safety Devices (LSH and LSL)

A pressure vessel that discharges to flare should be protected from liquid overflow by an LSH sensor to shut off inflow to the vessel. Vessels that do not discharge to flare should also be protected by an LSH sensor unless downstream process components can safely handle maximum liquids that could overflow. Normal response to an LSH is to shut off inflow to the vessel. Downstream components (e.g. compressors) may require shutdown to prevent equipment failure. A pressure vessel should be protected from gas blow-by by an LSL sensor to shut off the liquid outlet or shut off inflow when closure of the inflow valve alone prevents the downstream vessel from exceeding the MAWP caused by gas blow-by. The LSL sensor is not required if a liquid level is not maintained in the vessel during normal operation or downstream equipment can safely handle any gas that could blow-by without venting flammable vapors to an unsafe area. An LSL sensor to shut off the heating source should be provided in a heated vessel if the heating element is immersed. Level devices are not required on pressure vessels that are not designed for liquid-gas separation or on small traps from which liquids are manually drained. This includes such vessels as pressure-surge bottles, de-sanders, gas volume bottles, gas meter drip traps, fuel gas filters, etc.

A.5.2.2.4 Temperature Safety Devices (TSH and TSL)

If a pressure vessel is heated, a TSH sensor should be provided to shut off the source of heat when process fluid temperature becomes excessive.

If process vessel, pipe or equipment is exposed to JT effect cooling, a TSL sensor should be provided to shut off JT effect cooling flow. If the JT effect cooling is the result of a shutdown-blowdown operation, the TSL should activate a permissive that does not allow the equipment to be pressurized until the actual temperature exceeds the minimum design temperature. The TSL is not required if the equipment is designed for the minimum credible JT effect temperature. This requirement excludes blowdown piping and relief headers.

A.5.2.2.5 Flow Safety Devices (FSV)

An FSV should be installed in each gas and liquid discharge line if significant fluid volumes could backflow from downstream components in the event of a leak. An FSV is not required if a control or safety device in the line will effectively minimize backflow. Whether backflow is significant is a judgment decision. If a line discharges to a pressure vessel at a point above the liquid level range, the backflow of liquids should be insignificant. Whether or not the gas volume is insignificant should depend on the size and pressure of the gas section and the conditions where a leak might occur.

A.5.3 Safety Device Location

A.5.3.1 Pressure Safety Devices (PSH, PSL, and PSV)

The PSH and PSL sensors and the PSV should be located to sense or relieve pressure from the gas or vapor section of the vessel. This is usually on or near the top. However, such devices may be located on the gas outlet piping if the pressure drop from the vessel to the sensing point is negligible and if the devices cannot be isolated from the vessel. Such isolation could be caused externally (e.g. by blocked valves on gas outlet) or internally (e.g. by plugged mist extractors).

For vessels with an overpressure scenario that cannot be practicably protected by a PRD, an HIPPS may be used. HIPPS installation shall be in accordance with Annex E. Where an HIPPS is installed, a PSV can be required to protect against other credible overpressure scenarios, including those listed in 6.2.2.2.2 and HIPPS leakage.

A.4.2.2.2.4 If a pressure vessel is subject to underpressure that can cause it to collapse, the vessel should be provided with a gas makeup system that will maintain adequate pressure in the vessel.

A.5.2.2.3 Level Safety Devices (LSH and LSL)

A pressure vessel that discharges to flare should be protected from liquid overflow by an LSH sensor to shut off inflow to the vessel. Vessels that do not discharge to flare should also be protected by an LSH sensor unless downstream process components can safely handle maximum liquids that could overflow. Normal response to an LSH is to shut off inflow to the vessel. Downstream components (e.g. compressors) may require shutdown to prevent equipment failure. A pressure vessel should be protected from gas blow-by by an LSL sensor to shut off the liquid outlet or shut off inflow when closure of the inflow valve alone prevents the downstream vessel from exceeding the MAWP caused by gas blow-by. The LSL sensor is not required if a liquid level is not maintained in the vessel during normal operation or downstream equipment can safely handle any gas that could blow-by without venting flammable vapors to an unsafe area. An LSL sensor to shut off the heating source should be provided in a heated vessel if the heating element is immersed. Level devices are not required on pressure vessels that are not designed for liquid-gas separation or on small traps from which liquids are manually drained. This includes such vessels as pressure-surge bottles, de-sanders, gas volume bottles, gas meter drip traps, fuel gas filters, etc.

A.5.2.2.4 Temperature Safety Devices (TSH and TSL)

If a pressure vessel is heated, a TSH sensor should be provided to shut off the source of heat when process fluid temperature becomes excessive.

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If process vessel, pipe or equipment is exposed to JT effect cooling, a TSL sensor should be provided to shut off JT effect cooling flow. If the JT effect cooling is the result of a shutdown-blowdown operation, the TSL should activate a permissive that does not allow the equipment to be pressurized until the actual temperature exceeds the minimum design temperature. The TSL is not required if the equipment is designed for the minimum credible JT effect temperature. This requirement excludes blowdown piping and relief headers.

A.5.2.2.5 Flow Safety Devices (FSV)

An FSV should be installed in each gas and liquid discharge line if significant fluid volumes could backflow from downstream components in the event of a leak. An FSV is not required if a control or safety device in the line will effectively minimize backflow. Whether backflow is significant is a judgment decision. If a line discharges to a pressure vessel at a point above the liquid level range, the backflow of liquids should be insignificant. Whether or not the gas volume is insignificant should depend on the size and pressure of the gas section and the conditions where a leak might occur.

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For vessels with an overpressure scenario that cannot be practicably protected by a PRD, an HIPPS may be used. HIPPS installation shall be in accordance with Annex E. Where an HIPPS is installed, a PSV can be required to protect against other credible overpressure scenarios, including those listed in 6.2.2.2.2 and HIPPS leakage.

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