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INTERPRETING API RP 553 ON EMERGENCY BLOCK VALVES

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Abstract

Insurance companies are increasingly requiring refineries to show capability of remote isolation of flammable and toxic process streams to minimize a spill or release during a process emergency. API Recommended Practice 553, Refinery Valves and Accessories for Control and Safety Instrumented Systems, Section 8, provides guidance regarding the installation of Emergency Block Valves (EBVs), actuator selection, fireproofing, and control stations. The guidelines include consideration of characteristics of the contents of the process equipment and piping, such as toxicity and flammability of those contents. This paper discusses requirements of Section 8.1 – EBV General Installation Guidelines and reviews additional industry information that can be used to aid in interpreting or using some of the API RP 553 definitions.

Introduction

Insurance companies have been increasingly requiring refineries to install isolation valves that can be remotely operated to avoid major losses during emergency events such as liquid hydrocarbon spills, flammable or toxic gas releases, and fires. Investigations into some major industrial accidents have found that the ability to remotely isolate sources of the release would significantly reduce the impact of fires, which would otherwise cause massive damage and personnel exposure to toxic material. An example where the impact could have been reduced by EBVs follows.

In February 2007, the Valero-McKee refinery in Sunray, Texas experienced an estimated $50 million in direct losses due to a liquefied petroleum gas (LPG) fire in their propane deasphalting (PDA) unit. A failure of an out-of-service dead leg caused a release of 4,500 pounds per minute of liquid propane, and operators could not access the manual isolation valves located inside the battery limits. The U.S. Chemical Safety and Hazard Investigation Board (CSB) concluded that remote EBVs could have significantly reduced the amount of propane allowed to leak out, and in turn, reduced the size and time of the fire [1].

The Valero-McKee incident is not an isolated event. For example, on April 2, 2019, an incident at the KMCO LLC facility in Crosby, TX resulted in a worker fatality and 30 injuries, two of which were serious injuries. One of the three safety issues listed in the CSB investigation report was the inability for workers to close the actuated block valve upstream of the release point from a safe location [2].

After the Valero-McKee incident in 2007, updates were made to the API Recommended Practices regarding Remotely Operated Shutoff Valves (ROSVs) and later, the API Recommended Practice 553, Second Edition, in October 2012, which provided guidelines for installation of EBVs for equipment containing flammables and toxic materials.

This paper reviews Section 8.1 of API RP 553, which focuses on emergency block valves and their purpose. Subsequent sections of this paper supplement the API RP 553 guidelines, address potential questions, and provide interpretation of definitions. Flowcharts summarizing the results of the analysis in this paper can be found at the end.

Emergency Block Valve Definition and Intended Functionality

In different industry standards, valves used to isolate hazardous materials are referred to by different names, such as Emergency Isolation Valves (EIVs), safety shutoff valves, cutoff valves, SIS valves, etc. For consistency, this paper will refer to these valves as Emergency Block Valves (EBVs).

EBVs are designed to control a hazardous incident [3] by isolating the flow of flammable or toxic substances in the event of a process upset or emergency, such as a leak or fire [1,2]. EBVs can be different types of valves, such as a gate, butterfly, or ball, and may or may not have an actuator (for remote operation) depending on the type and situation. For example, a valve located outside of the battery limits of a unit may be safe for manual operation in the event of a fire.

This paper discusses Type D EBVs, which are remotely controlled from a minimum distance of 40 feet from the source of the leak, located outside the fire zone, and designed for safe operation in the event of loss of containment.

Emergency Block Valve Location Requirements

The location recommendations of EBVs can be determined by the following guidelines in Section 8.1 of API RP 553 [3]. Subsequent portions of this paper will provide supplementary information to get a more concrete idea of the recommended locations for EBVs.

Compressors – Section 8.1.1

- EBVs required on 200 HP or larger compressors handling flammable or toxic materials.
- EBVs required on all suction and discharge lines.

- EBVs required in between stages and inter-stage equipment if the inter-stage equipment holds more than 1000 gallons of liquid.

Pumps – Section 8.1.2

- EBV required upstream of the pump if the upstream vessel contains more than 2000 gallons of light ends or hydrocarbons above their auto ignition point or above 600 °F.
- EBV required upstream of the pump if the upstream vessel contains more than 4000 gallons of liquid hydrocarbons.
- EBV required downstream of the pump spillback in the case of high discharge pressures for reverse flow overpressure protection.

Vessels – Section 8.1.3

- EBV required for vessels containing light ends or toxic materials. Flow from these vessels should be isolated from potential leak sources such as pumps, compressors, heat exchangers, and fired equipment.
- An EBV is needed for vessels containing liquids heavier than light ends, but above the flash point.

Heaters – Section 8.1.4

- An EBV is required for each fuel gas or fuel oil line to fired heaters and boilers. At least one EBV outside battery limits for each fuel gas or oil line is typically specified.
- An EBV is needed for each process side feed line to a fired heater that contains flammable fluid.

Applying the Recommended Practice

It is necessary to understand the sentiment of API RP 553 Chapter 8 and the goal to prevent a large loss of containment leading to ignitable vapor clouds / large pool fires or exposure to acutely toxic materials.

During a recent refinery evaluation to determine locations for EBVs, some guidelines and recommendations needed further definition to determine if an EBV was recommended by API 553. In the following sections, situations where further definition was needed in order to develop the EBV installation recommendations are discussed.

Compressors

Section 8.1.1 – The compressors section leaves room for interpretation of the recommendations. The second bullet point under “Compressors” above is written as an independent guideline and implies that EBVs would be recommended on the inlet and outlet of any compressor regardless of size or type of material handled. Application of this bullet point is actually dependent on the first bullet point being true. The meaning of the first two bullet points together becomes “EBVs are required on all suction and outlet lines for compressors 200 horsepower or larger, handling flammable materials”. This issue was not found in the other equipment recommendations, as each bullet point is independent of others.

An issue not discussed in this section is the potential problem of having an EBV on the suction line to a compressor. For example, if the fail position of an EBV on the suction of a compressor is designated as fail-closed, the action could cause significant and costly damage by surging a compressor. Before EBVs are placed into any location, a process hazard analysis should be performed to determine the risks and benefits.

Pumps

The language in the pumps section of API RP 553 Chapter 8 is straightforward except for a definition of "light ends" and "high discharge pressures". The term "light ends" is discussed in the "Vessels" section below.

High discharge pressure that may cause reverse-flow and an overpressure scenario cannot be given a blanket definition. An analysis should be performed on the system, looking at upstream equipment to determine if reverse flow due to a pump failure or other cause, can lead to an overpressure, mechanical failure, and loss of containment. Trimeric knows of parties that, based on their internal analyses and standards, define high discharge pressure as a few hundred to several hundred psi above the suction pressure.

Vessels

The vessels section of Chapter 8 is less defined than the other sections and may lead to difficulty in determining if an EBV is needed. This will be the subject of much of the discussion and examples in this paper.

Light Ends

The first bullet point in Chapter 8 contains the term "light ends". While this term is not defined in Chapter 3 Terms & Definitions of API RP 553, research, including consultation with industry professionals, resulted in a working definition that light ends are generally defined as flammable hydrocarbons having boiling points equal to or lower than that of normal pentane [97 ^{0}F]. This definition is consistent with the one provided in The *Handbook of Petroleum Refining Processes* which defines light ends as hydrocarbons with equivalent boiling points ranging from C1 to C5 [4].

Toxic Materials

The first bullet point in Chapter 8 also mentions "toxic materials," a term defined in Chapter 3, Terms & Definitions, of API RP 553 as:

> "A liquid or vapor that can cause harm to humans, with an established exposure limit (either Material Threshold Limit Value [TLV] or Occupational Exposure Limit [OEL]) set by a relevant regulatory agency (e.g., the US EPA). These substances can lead to significant negative effects (such as severe inflammation, shock, collapse, or even sudden death) if humans are exposed to sufficiently high concentrations for extended periods. Examples include, but are not limited to: Benzene, Xylene, Butadiene, Chlorine, Ammonia, Hydrogen Sulfide, and Hydrogen Fluoride." [3]

It is important to note that specific concentration limits within the process are not provided. Therefore, the impact of potential leak sources and the volume of toxic materials that may leak should be assessed through a process safety analysis. For instance, a Pasquill-Gifford dispersion model can be applied to evaluate the formation of a vapor cloud containing hazardous levels of H_2S during a leak. The results of such an analysis should also be reviewed—while a vapor cloud with a maximum H_2S concentration of 15 ppmv may not be lethal, it still exceeds the OEL, and a risk-ranking of this scenario in a process hazard analysis may result in no actions being taken.

Additionally, itis essential to differentiate between the concentration of a toxic material in a process stream and the concentration personnel might be exposed to during a spill. The 2018 paper “PHA Guidance for Correlating H_2S Concentrations in Process Streams to Severity of Adverse Health Outcomes in the Event of a Leak,” from the Mary Kay O’Connor Process Safety Center, states that large liquid leaks (2” or greater) may result in personnel being exposed to at least 140% of the H_2S concentration in the process stream. This higher H_2S concentration from a liquid leak is due to H_2S evolving at a higher rate than hydrocarbons and due to liquid leaks having a larger mass flowrate than vapor leaks, leading to more H_2S in the air. This analysis was performed with a mixture of n-hexane and H_2S [5]. This is dependent on what liquid is leaking, and the vapor / liquid equilibrium of the process fluid should be modeled to determine the concentration of H_2S that will be present in the vapor space above the liquid leak – in general, assuming a constant weight % H_2S is present, the heavier the hydrocarbon, the higher the concentration of H_2S present due to a leak, as less of the hydrocarbon will flash.

The paper from the Mary Kay O'Connor Process Safety Center also provided examples of H_2S concentrations in process streams and the corresponding H_2S concentrations in nearby breathing zones. For instance, consider a vessel that contains 5,000 gallons of n-hexane, with a concentration of 1,000 ppmw of H_2S and a 2” liquid outlet line. In the example given, a leak in this 2” line, either at a pump or fin-fan exchanger, would result in > 700 ppmv of H_2S in the immediate breathing zone, which could result in fatalities should any personnel be near the leak [5]. Because of the severity of a leak, an EBV may be recommended on the liquid outlet line.

Inventory Levels

The next point involves the material inventory within vessels. Since API RP 553 does not specify an inventory threshold for requiring EBVs in Section 8.1.3 - Vessels, the guidelines provided in Section 8.1.2 - Pumps may be applied by extension. Thus, according to those guidelines, vessels containing fewer than 2,000 gallons of: light ends, toxic materials, or hydrocarbons above their flash point, or fewer than 4,000 gallons of other hydrocarbons are not required to have an EBV.

This brings up a key distinction between normal inventory versus maximum inventory. API RP 553 does not specify whether the total vessel volume or normal liquid inventory is the basis when determining if an EBV is needed. However, the language in bullet points 1 and 2 of the pumps section, again, may be used. The first and second bullet points in the pumps section state that EBVs are recommended when a “vessel contains more than X gallons”. Based on the use of the word “contains”, it can be inferred that normal inventory is the relevant measure. For instance, a distillation column that contains hydrocarbons above their flash point, may have a shell with a total volume of 5,000 gallons but has a normal liquid level such that the vessel contains only 800 gallons; an EBV would not be recommended for this case.

This same principle applies to pump arounds and side strippers. Pump arounds, in the event of a seal leak or other leak at the pump, have only a small inventory of hydrocarbons that can be released. In many distillation columns, the volume of liquid hydrocarbons in the tray at and above the pump around or side stripper draw is well under the 2,000 (or 4,000) gallon limit.

Heaters

The language in Section 8.1.3 - Heaters, like the pumps section, is generally well defined; however, there is some ambiguity in second bullet point, which states that “an EBV is needed for each process side feed line to a fired heater that contains flammable fluid." But, this may not always hold true. Based on the inventory guidelines in the pump section (then applied by extension to the vessels section), which recommend EBVs for vessels containing more than 2,000 gallons of light-end hydrocarbons or more than 4,000 gallons of other hydrocarbons, a similar approach can be applied to heaters. Specifically, heaters that are fed by vessels with hydrocarbon volumes below these thresholds would not require an EBV on the process inlet. For example, a fixed-bed platforming unit containing three reactors and three heaters in series were analyzed for potential need of EBVs. The volume of the reactor (each located upstream of a heater) had volumes less than the 2,000-gallon threshold, suggesting that EBVs on the process feed lines to the heaters were not necessary in this case.

Preventative Maintenance

While API RP 553 does not specifically address it, insurance companies and refining clients have highlighted the importance of establishing a preventative maintenance (PM) and testing schedule for EBVs. Operators must have confidence that these valves will function properly to prevent significant losses of containment. To ensure this, a consistent PM schedule should be implemented for each EBV to verify that the valves and actuators are operating effectively. Valve testing should also be a part of this PM schedule, where operators remotely actuate the EBV and verify its function. To allow for this, EBVs should be installed with bypasses and double block and bleed valves, to avoid any disruption to normal operation.

Conclusions

In summary, the implementation of emergency block valves (EBVs) plays a critical role in minimizing the risk associated with hazardous material releases in refineries. As detailed in API RP 553, Section 8, these valves help prevent large-scale containment losses and fires (such as the Valero-McKee refinery), or toxic exposures. And, while API RP 553 provides clear guidelines for EBV installation, there are some instances where further clarification or analysis is necessary. The flowcharts below incorporate the above sections and provide a streamlined process for determining if an EBV is recommended. As mentioned previously in this article, a process hazard analysis for assessing risks should be conducted prior to adding or discounting EBVs in a process unit.

Table 1: Supplemented API RP 553 Guidelines

Equipment	Recommendation
Compressors	EBV recommended on all suction and discharge lines IF Compressor is 200 HP or larger AND Handling flammable or toxic materials
	EBV recommended between stages IF Interstage equipment holds more than 1000 gallons of liquid AND Compressor is handling flammable or toxic materials
Pumps	EBV recommended upstream of pump IF Upstream vessel contains more than 2000 gallons[1] of Light ends (boiling point of 97 ^{0}F or lower), OR Hydrocarbons above their auto ignition point, OR Hydrocarbons above 600 ^{0}F OR Upstream vessel contains more than 4000 gallons[1] of liquid hydrocarbons
	EBV recommended downstream of pump spillback IF Pump has a high discharge pressure[2]
Vessels	EBV recommended on liquid outlet lines IF Vessel contains more than 2000 gallons[1] of: light ends, toxic materials[3], or hydrocarbons above their flash point OR Vessel contains more than 4000 gallons[1] of liquid hydrocarbons AND Liquid outlet lines go to a potential leak source such as a pump, compressor, heat exchanger, or fired equipment
Heaters	An EBV is recommended on each fuel gas or fuel oil line to fired heaters and boilers
	An EBV is recommended for each process side feed line to a fired heater that contains a flammable fluid IF The upstream vessel contains more than 2000 gallons of light ends OR The upstream vessel contains more than 4000 gallons of liquid hydrocarbons

Notes:

1. EBV recommendations are based on if vessel contains more than X gallons at its normal liquid level.
2. A high discharge pressure should be determined in a HAZOP etc.; a few hundred to several hundred psi above the suction pressure has sometimes been used by some parties based on their internal risk analyses and/or standards.
3. As discussed above, an evaluation to determine the concentration of toxic materials in the event of a leak should be completed, prior to deciding if an EBV should be recommended due to the presence of toxic materials.

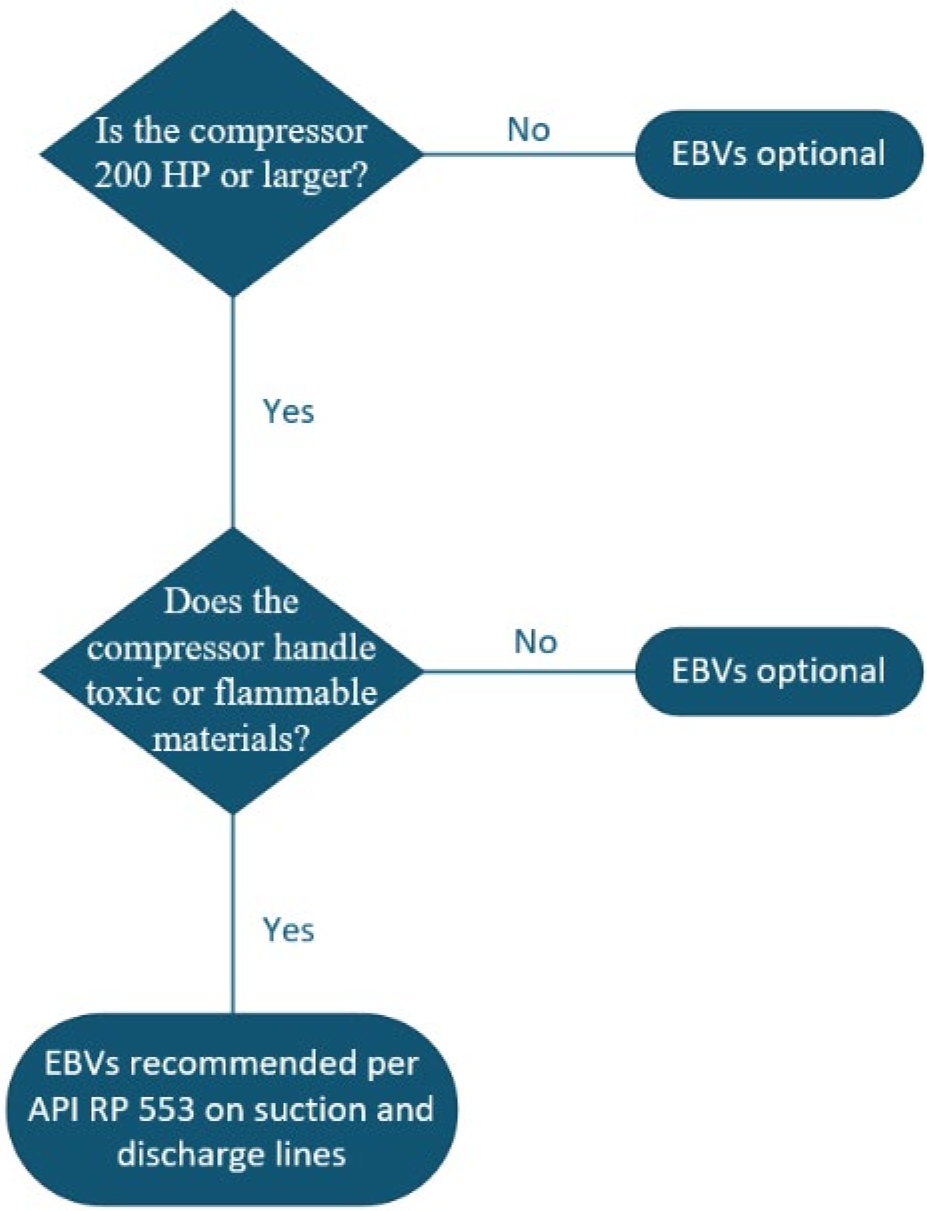

Figure 1: Emergency Block Valve Flowchart for Compressor Suction and Discharge

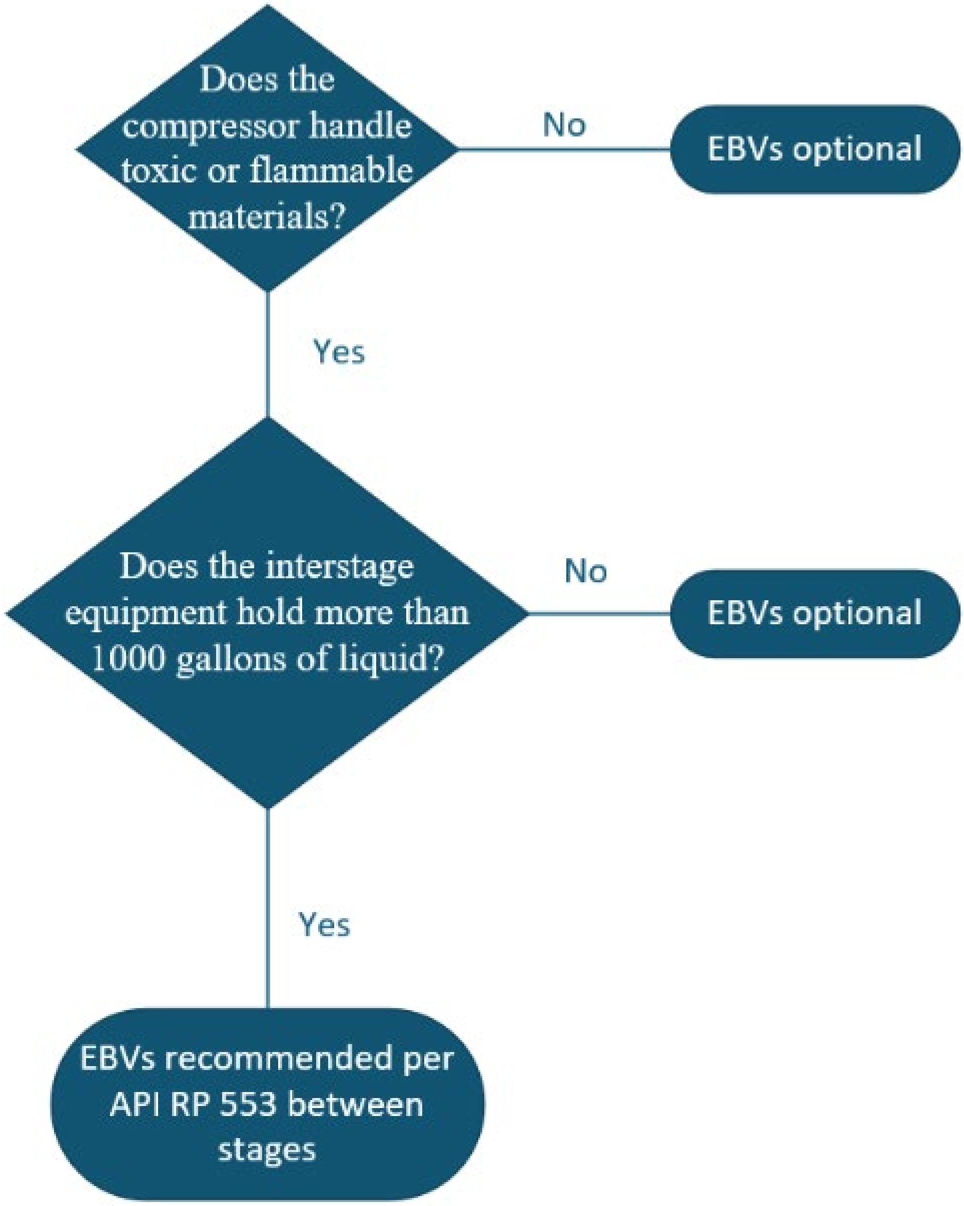

Figure 2: Emergency Block Valve Flowchart for Compressor Interstage Locations

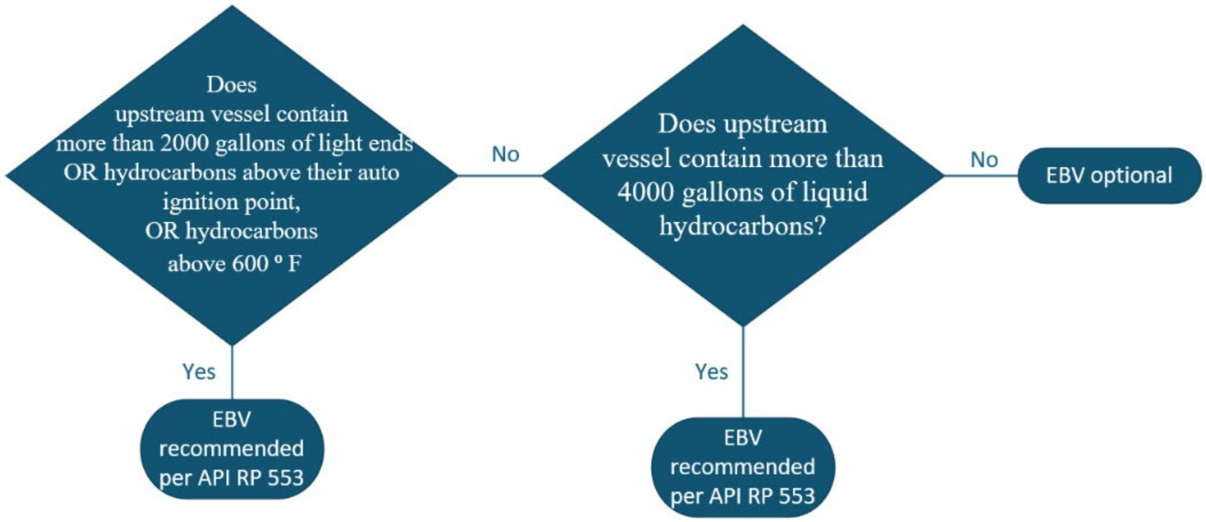

Figure 3: Emergency Block Valve Flowchart for Upstream of Pumps

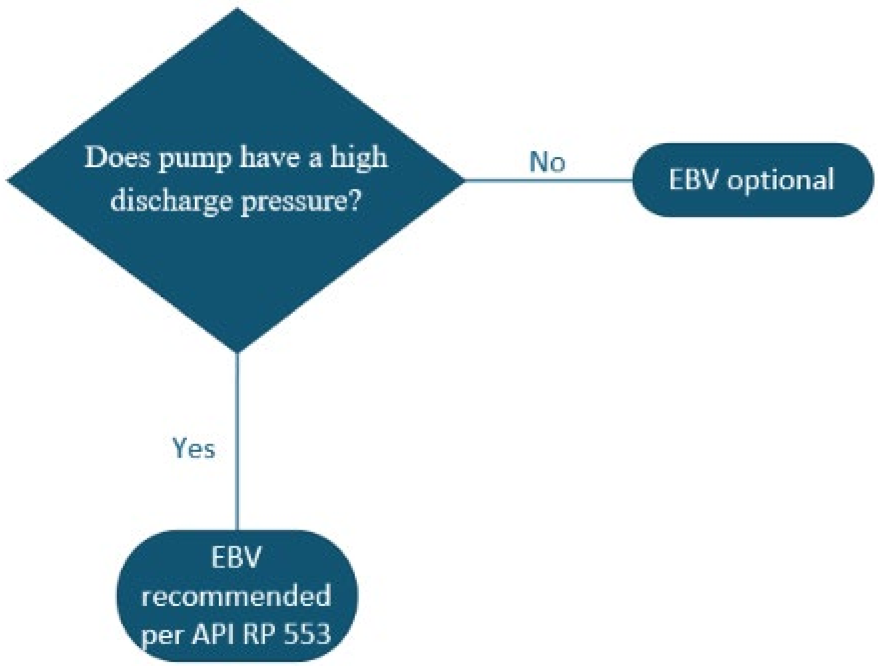

Figure 4: Emergency Block Valve Flowchart for Downstream of Pump Spillback

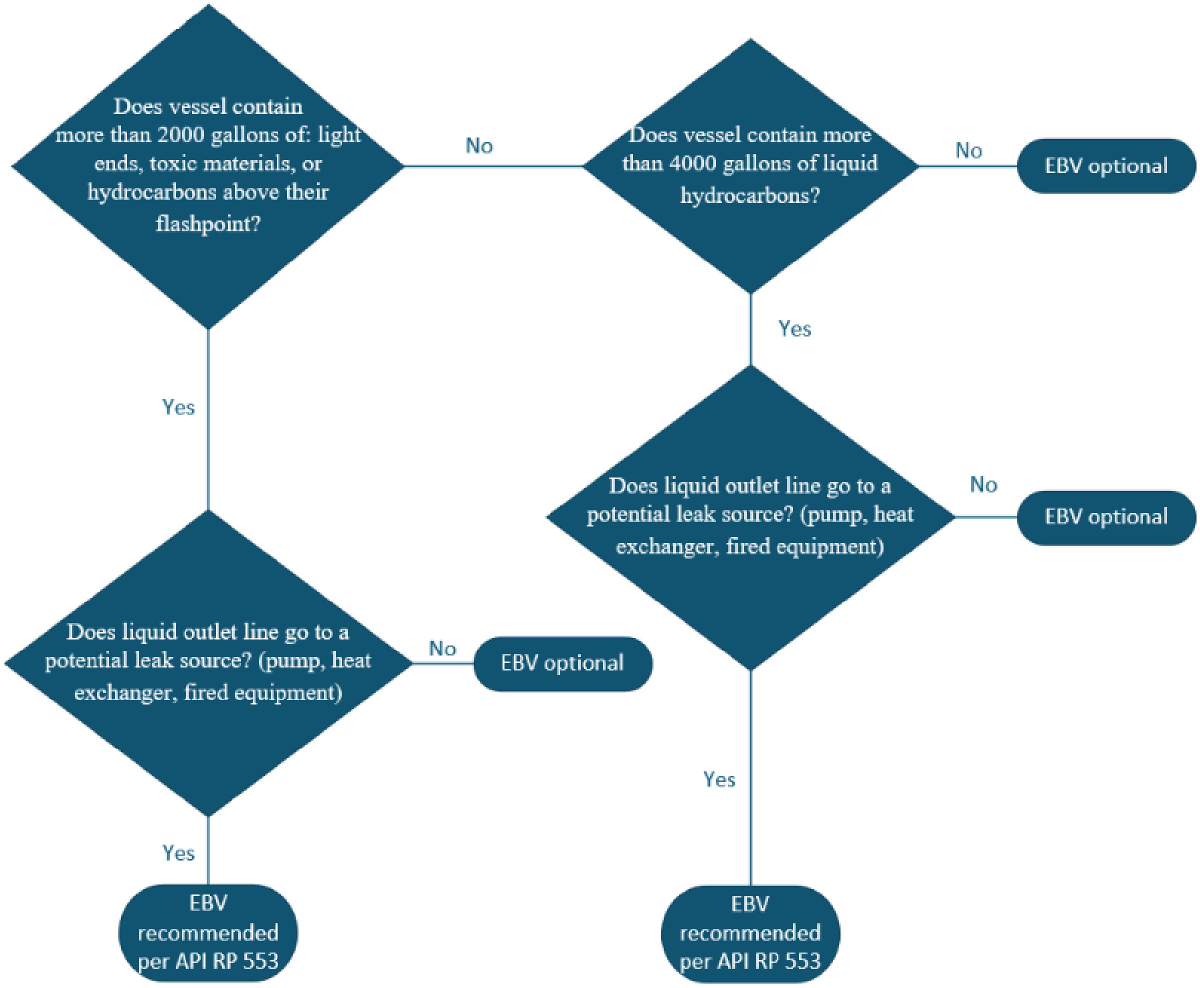

Figure 5: Emergency Block Valve Flowchart for Vessel Liquid Outlet Lines

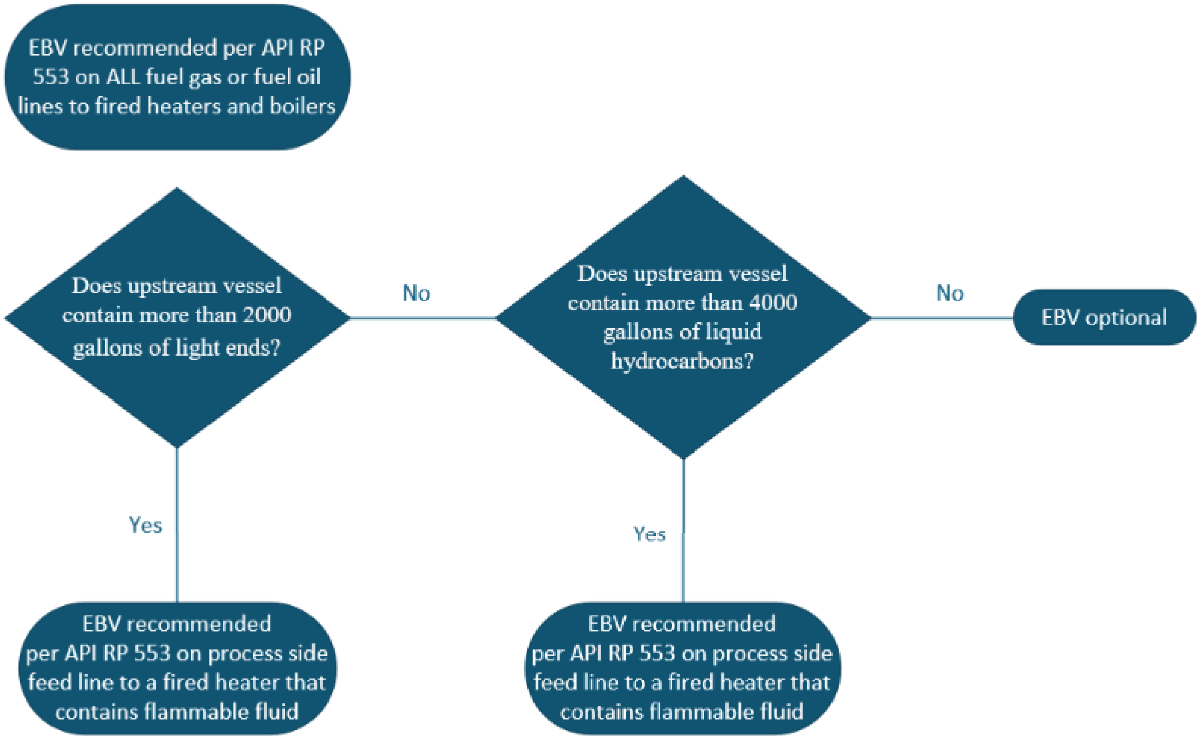

Figure 6: Emergency Block Valve Flowchart for Heaters

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