Engineering Design Practice

Process

Gas Breakthrough and RO Sizing Liquid Lines

Owner		GM Infrastructure Engineering		**Next Review Date**	Aug-28
Document No		ATP-EDP-Q-0019		**Classification**	Public
Rev	**Date**	**Status**	**Originated**	**Checked**	**Approved**
1	15-Aug-23	IFU	Christine Nicholson Digitally signed by Christine Nicholson Date: 2023.08.16 15:36:48 +10'00'	Snell, Matthew 2023.08.17 11:42:50+10'00'	Caroline Button Digitally signed by Caroline Button Date: 2023.08.17 08:33:11 +10'00'

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1 INTRODUCTION

The APA Technical Practice (ATP) aims to achieve sound engineering and design practice through standardisation. We endeavour to make ATP sufficiently flexible to allow engineers to adapt the information in the ATP to project, asset, or customer conditions and requirements. This is of particular importance where the standard may not cover all situations or needs of use.

APA staff and its Contractors shall be solely responsible for applying ATP in the context of legal, statutory and approvals requirements to achieve the required engineering design and quality of work. For those requirements not specifically covered, the designer shall use a recognised engineering practice or standard to accomplish as a minimum the same level of integrity as reflected in the ATP. If in doubt, the Contractor shall, without detracting from their responsibility, consult APA.

Refer to APA's Engineering Glossary [Ref.1] for terms and abbreviations not listed in the appendices.

1.1 CONFLICTS AND WAIVERS

Conflicts between this standard and other applicable ATP or international, national standards, codes and industry practices shall be resolved in writing by the APA Standards and Assurance team.+

Requests for waivers from this standard shall follow the ATP Waiver procedure in [Ref.2].

1.2 ORDER OF PRECEDENCE

Refer to the order of precedence of standards in ATP Development, Use and Management Procedure [Ref.3].

2 PURPOSE AND SCOPE

Gas breakthrough during drainage of liquid from vessels operating at high pressure is a special concern that has the potential to exceed the minimum design temperature or the maximum design pressure of the drainage system leading to a loss of containment. This effect is most significant in vessels discharging liquids into a low pressure drain header. This EDP sets out the requirements and suggested strategies to protect against adverse impacts of gas breakthrough.

Note the automatic and manual draining of high vapour pressure liquids such as propane has a similar effect to gas breakthrough and the same principles apply to the design.

APA Climate Transition Plan outlines the company's commitment to achieving net-zero greenhouse gas emissions by 2050. The plan includes a range of strategies to reduce emissions, including increasing the use of renewable energy sources, transitioning to lower-emission fuels, and improving energy efficiency. APA aims to reduce its methane emissions, through the implementation of the Methane Guiding Principles and is committed to ensuring that all opportunities to reduce emissions are in line with the relevant Australian Federal, State, and Territory legislation.

For all greenfield and brownfield projects, the Net Zero requirements shall be considered to eliminate or reduce any risk of harm from Scope 1 and 2 GHG emissions i.e., avoid or minimise Scope 1 and Scope 2 emissions or where and so far as is reasonably practicable. The designer(s) shall apply to the commercial decision-making processes in APA’s Internal Carbon Pricing Procedure, [Ref.18], to determine the best options to avoid or abate emissions. See also the Climate Change Standard [Ref.16] and The Methane Guiding Principles [Ref.20].

3 GAS BREAKTHROUGH

Gas breakthrough occurs when a failure in either process equipment or procedure(s) designed to control liquid level leads to gas unexpectedly flowing into the downstream system. Typically, the gas is released into the downstream system via a level control valve or manual drain valve(s). If the downstream system has not been designed to safely handle gas breakthrough, possible risks and consequences include:

- Process interruption of the downstream or upstream equipment
- Minimum temperature excursion of downstream equipment
- Overpressure of the downstream equipment
- Waste of process gas*
- Uncontrolled GHG emissions
- Loss of containment*
- Ignition of gas cloud
- Possible injury or fatality of on-site personnel

*This release of these gases is direct GHG emissions

4 DESIGN OF DRAIN SYSTEMS

The principals of Inherently Safer Design, [Ref.9], and the Process Design Guideline, [Ref.8], shall be followed.

The full possible operating envelope of the drain system shall be assessed, including potential failures of equipment and/or controls. The unmitigated (worst case) consequence of these failure scenarios shall be determined. The system design shall mitigate the risk of these potential consequences as per the Risk Assessment Techniques, [Ref.12].

All systems shall be designed for the failure open flow of all possible gas breakthrough scenarios, including ensuring safe dispersion of gas from the liquids drum receiver. The system shall be designed so that in the event of gas breakthrough, and in the event it ignites, then the heat will not be sufficient to seriously injure on-site personnel. See Flares and Vents, [Ref.5], and Plume Dispersion and Radiation Analysis, [Ref.6].

Consideration shall be taken to minimise any GHG emissions resulting from gas breakthrough, as per the direction in APA's Climate Transition Plan [Ref.17] and Climate Change Standard [Ref.16].

4.1 BASIS OF DESIGN

The design of the drain system shall be sized based on the liquid rates required through the system. Where possible, a Level Control Valve (LCV) should be selected so that the failure open case does not significantly exceed the maximum normal liquid rate.

The LCV sizing shall be suitable for the design of gas breakthrough. Where the rate of gas breakthrough exceeds what is allowable for the design (i.e., due to the backpressure), the installation of a restriction orifice (RO) can be used to significantly restrict the gas rate without causing a major additional restriction for the liquid.

Generally, only a single gas breakthrough event (single LCV failure) should be considered to occur at any one time. Common causes should be considered in the design including concurrent operation of manual drain valves (e.g., both manual drain valves for upper and lower chamber of filter coalescers, and other drain valves in the same area).

Where multiple upstream systems dispose into the same downstream drain system, drain system sizing shall consider the likelihood of coincident failures, where more than one upstream system may fail.

Gas breakthrough from an automated LCV is generally considered an unlikely event.

Note: with manual drain points it is common for operators to use the gas breakthrough event to signify that the vessel is fully drained, and the valve should be closed.

The following calculations will generally be required to establish a suitable design:

- Size the liquid lines based on liquid flow per the Line Sizing Guide [Ref.4].
- Determine the gas breakthrough maximum downstream backpressure based on two-phase flow. Note that this may not be the same as the maximum gas rate per the restrictions of the level control valve.
- Consider also maximum backpressure based on an LCV fail open and manual drain valve(s) open at maximum normal upstream pressure.
- If the maximum pressure exceeds the design pressure, an RO should be sized to restrict the gas flow to the allowable rate. The inlet pressure to the RO should be equal to the outlet pressure of the LCV at the allowable gas rate. Control valve sizing can be calculated with the Control Valve Sizing, [Ref.15], and RO sizing can be calculated with the RO Sizing, [Ref.14].
- Check that the LCV-RO combination still has an adequate liquid flow rate. If an acceptable LCV-RO combination cannot be established, increase the drain line size, increase the drain system design pressure or add a PSV to the design.
- Confirm that the minimum calculated temperatures are acceptable for the selected design.
- Confirm the backpressure generated in the drain system will not overpressure other systems that drain to the same drain lines at each junction in the drain line.
- As far as practically possible, incorporate a blowdown recovery system, to capture and recompress any released gas. See Climate Transition Plan, [Ref.17].
- References to documents with examples of a previous solution for a drain system design at an existing APA asset are listed in Appendix A.

4.2 DESIGN PRESSURE AND TEMPERATURES

Design conditions shall be selected in accordance with the Process Design Guideline, [Ref.8].

The drain piping material selection shall be suitable for the minimum operating temperature experienced during service including ambient or upset conditions.

Several options are available for designing to address the risk of overpressure of drain systems, which are listed in order of preference:

1. Set the design pressure of the drain system equal to the design pressure of the upstream system. In general, this will mean designing the system equal to the flange rating of the upstream system. In most cases, this eliminates the requirement for any additional pressure protection systems, this needs to be confirmed during the design.
2. If the drain system is an open-ended system, the design pressure may be lower than the design pressure of the upstream system. The design pressure shall be at least higher than the maximum anticipated backpressure calculated by a suitable hydraulic model including a suitable design margin.
3. If the drain system is designed to a lower pressure than the maximum backpressure, appropriately sized pressure relief valves shall be provided to accommodate for gas breakthrough.

In any case, the design pressure shall be consistent with the Overpressure Protection Philosophy, [Ref.7]. Note that piping systems permit design pressure excursions for limited periods of time.

Given that gas breakthrough is an unlikely event, credit for the allowable pressure excursions may be used in accordance with the Managing MAOP & MOP Limitations for AS 2885 Pipelines, [Ref.10] and ASME B31.3, [Ref.19].

To eliminate the risk of minimum design temperature excursions, several options are also available, listed in order of preference:

1. Set the minimum design temperature of the drain system equal to the minimum temperature anticipated based on letdown of the upstream gas to atmospheric pressure.
2. If there is another natural limit to the minimum pressure, set the minimum design temperature of the drain system equal to the minimum temperature anticipated based on letdown of the upstream gas to the natural limit. The natural limit may be the minimum normal operating pressure of the downstream system.
3. If the downstream system pressure will rapidly increase to the relieving pressure, set the minimum design temperature of the drain system equal to the minimum temperature anticipated based on letdown of the upstream gas to the drain system design pressure.

4.3 HYDRAULIC CONSIDERATIONS

4.3.1 Liquids and two-phase flow

During gas breakthrough, in most cases the liquid will continue to flow along with the gas. This liquid can significantly increase the backpressure relative to the gas flowing alone in a pipe. Liquid may also continue to enter the vessel being drained and will leave with the breakthrough gas. This liquid should be considered when assessing the hydraulics and/or gas dispersion. All hydraulic calculations shall be performed with an appropriate two-phase correlation. See the Line Sizing Guide [Ref.4].

Avoid releasing any gas to the atmosphere, as per the Net Zero principals of reducing all GHG emissions and consider all possible solutions for capturing and recovery. If any remaining gas needs to be released from the system – prioritise recycling or flaring over venting, as per the Flares and Vents, [Ref.5].

4.3.2 Restriction Orifices

A Restriction Orifice (RO) may be used to restrict the flow of gas in a breakthrough event to:

- avoid over-pressure of the drain system.
- limit the size of the gas cloud at the vent as part of disposal system.

If the RO is relied upon to prevent a Major Accident Event (MAE), it is a Safety Critical Element (SCE). Design and placement of restriction orifices shall conform with the relevant and applicable Safety Case Standards.

Care shall be taken when choosing a location for a restriction orifice in a pipe. The fluid is accelerated as it passes through the orifice, reaching the maximum velocity a short distance downstream of the orifice itself (the Vena Contracta). This high localised velocity can result in vibration and damage to intrusive fittings (e.g. thermowells, sample probes), as well as pulsation within susceptible branch lines. To avoid these consequences, there shall be a minimum straight run distance of 6 diameters of piping downstream of the RO location where there are no intrusive fittings and no side branches.

If there is a design need to insert intrusive fittings < 6 pipe diameters downstream of an RO, refer to the Piping Design Criteria, [Ref.13], for AIV risk assessment criteria.

4.4 GAS DISPOSAL AND DISPERSION

After a gas breakthrough, the gas that enters the drain system shall be disposed of in a safe manner. All drain residues shall be appropriately and safely disposed of, and to follow all applicable legislation and regulations.

It is possible for a large gas cloud to develop at the drain system outlet. If the gas is released to atmosphere, dispersion and thermal radiation analysis shall be conducted per the Plume Dispersion and Radiation Analysis, [Ref.6], to confirm that the gas disperses safely, even if ignited. Avoid or reduce venting. If gas needs to be released, use vapor recovery or flaring rather than venting if possible. Monitor vents and evaluate for further improvements and control. See the Methane Guiding Principles' Best Practice Guides – Venting [Ref.21].

To ensure no entrained liquids are included in the gas cloud, suitable liquid slug and droplet management shall be included in drain system and liquid drain drum design, sized for the worst-case vent with a suitable margin. If liquids disposal is via the flare/vent knock-out drum, then gravity separation to 300 µm per the typical design is adequate. All residues shall be appropriately and safely disposed of, and to follow all applicable legislation and regulations.

If the liquid drain drum vent is located close to operating personnel or plant such that there is a risk of entrained liquids causing harm or damage respectively, then a mesh pad on the vent outlet should be provided. A flame arrestor shall also be provided with any tanks not designed to contain detonation (design pressure < 700 kPag for natural gas, see Flares and Vents [Ref.5]). Without this, ignition of the vent may damage the liquid drain drum.

Wherever possible incorporate a blowdown recovery system, to capture and recompress the released gas. See Climate Transition Plan, [Ref.17].

4.5 INSTRUMENTATION AND CONTROL

For drainage systems, the following controls are recommended. At a minimum the LCV (i.e. on off valve for Transmission separators) shall be closed at a low-level alarm / shutdown point and be designed spring-to-close (fail safe closed). Due to the tendency of LCVs to leak, particularly at high pressures, a shutdown valve in series with the LCV should be considered. If gas breakthrough presents a minimum design temperature excursion risk, a low temperature alarm and shutdown shall be provided with an appropriate safety rating. Protective measures including the LCV and/or shut down function to be assessed in LOPA workshop to confirm the design is adequate and determine the SIL rating of any protective function (and need for independent low-level trip and shutdown valve).

Some complex systems cannot rely fully on pressure relief valves to maintain the required integrity of the downstream system. Failed closed SDVs coupled with dedicated level control can be used, with SIL integrated loops. This is then the last resort and the process safety time to close the valve shall be calculated and compared to the time it takes to pressurise the downstream system. Such a system shall be consistent with the Functional Safety Management for Projects, [Ref.11].

Details on emissions shall be identified, analysed and documented, along with plans for measuring and monitoring. This to identify and enable reduction of GHG emissions in accordance with APA's Climate Transition Plan [Ref.17] and Climate Change Standard [Ref.16].

5 REVISION CHANGE RECORD

Table 1 Revision Change Record

Rev	Description	Date	Author
1	Document content based on 530-EDP-Q-0019 Rev 3, re-templated and general updates to text and references. Net Zero and environmental considerations added. Inherently Safer Design (paragraphs 1-3) added. Asset drawings and specifications removed from the Appendix and a list of references to these documents added in Appendix A	15.08.2023	C. Nicholson

6 TERMS[1]

Item	Definition
Gas breakthrough	The event when liquid level is lost in a vessel and pressurised gas passes through a normally liquid-flooded valve into the downstream line.
Greenhouse Gas	A Greenhouse Gas (GHG) is a gas that absorbs and emits radiant energy within the thermal infrared range, causing the greenhouse effect. The primary Greenhouse gases in Earth's atmosphere are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3).
Net Zero	A target of completely negating the amount of greenhouse gases produced by human activity, to be achieved by reducing emissions and implementing methods of absorbing carbon dioxide from the atmosphere.
Safety Critical Element	Any item of equipment, system, process, procedure or other control measure the failure of which can contribute to a Major Accident Event
Vena Contracta	The point in a fluid stream with the least diameter and maximum fluid velocity (e.g., through a gas nozzle).

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[1] Definitions should be accompanied by a reference using the "Citations & Bibliography" APA style. Terms listed in the APA Engineering Glossary need not be repeated in this list.

7 ABBREVIATIONS[2]

Item	Definition
AIV	Acoustic Induced Vibration
ASME	American Society of Mechanical Engineers
CHAZOP	Control Hazard and Operability
EDP	Engineering Design Practice
GHG	Greenhouse Gas
HAZOP	Hazard and Operability
LCV	Level Control Valve
LOPA	Layers of Protection Analysis
MOC	Management of Change
MOP	Maximum Operating Pressure
PSV	Pressure Safety Valve
RO	Restriction Orifice
SCE	Safety Critical Element
SDV	Shut Down Valve
SIL	Safety Integrity Level

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[2] Any abbreviation (acronym) used more than once in the body of the document shall be listed in this table. An abbreviation/acronym used once only, must be written out in full in parentheses after the abbreviation/acronym, for example WIP (Work in Progress).

8 REFERENCES

All work performed in accordance with this document shall be in conformance with the current issue, including amendments, of those national and international standards, codes of practice, guidelines and APA document/s listed below.

APA Technical Practices

Ref. No.	Doc. No.	Description
1.	530-LI-QM-0001	APA Engineering Glossary
2.	530-PR-EM-0002	Engineering Standards Waivers
3.	530-PR-EM-0003	APA Engineering Standards
4.	530-EDP-Q-0002	Line Sizing Guide
5.	530-EDP-Q-0003	Flares and Vents
6.	530-EDP-Q-0005	Plume Dispersion and Radiation Analysis
7.	530-EDP-Q-0006	Overpressure Protection Philosophy
8.	530-EDP-Q-0028	Process Design Guideline
9.	530-EDP-R-0001	Inherently Safer Design
10.	530-GD-Q-0005	Managing MAOP & MOP Limitations for AS 2885 Pipelines
11.	530-PL-FS-0001	Functional Safety Management for Projects
12.	530-PR-R-0001	Risk Assessment Techniques
13.	530-SP-P-096	Piping Design Criteria
14.	530-TP-Q-0009	RO Sizing
15.	530-TP-Q-0014	Control Valve Sizing
16.	APA Group Standard	Climate Change Standard
17.	APA Group	Climate Transition Plan
18.	APA Group Procedure	Internal Carbon Pricing

Superseded Documents

Ref. No.	Doc. No.	Description
	530-EDP-Q-0019	Gas Breakthrough and RO Sizing Liquid Lines, Rev 3

Australian Standards

Ref. No.	Doc. No.	Description
-	-	-

International Standards and Other References

Ref. No.	Doc. No.	Description
19.	ASME B31.3	American Standard: Process Piping
20.	Methane Guiding Principles	The Methane Guiding Principles
21.	Methane Guiding Principles	Best Practice Guides – Venting

9 LISTS

9.1 TABLES

9.2 FIGURES

No table of figures entries found.

Appendix A APA ASSET EXAMPLE

Table 2 References to documents with examples of solutions for existing APA assets.

System	Doc. No.	Doc. Name
Compressor Station	ECS-DS-M-007	Mechanical/Process Data Sheet
	1400-PB-141	Liquid Drains Drum
	1400-PB-123	Filter Separator P&ID
	1400-PB-139	Fuel Gas Skid P&ID
	1400-MB-110	Liquid Drains Drum and Pipe Track elevations and Sections

Note: Contact your APA representative if you need access to any of the above documents.