Code of Practice

Upstream Polyethylene Gathering Networks – CSG Industry

Companion Paper CP-08-001

Pressure testing: Alternatives for exclusion zone reduction

Rev 1

April 2025

Contents

Acknowledgements

This Companion Paper has been prepared by the Australian Pipelines and Gas Association (APGA) CSG Committee working group. The working group members contributed significant time and resources at the working group level in developing and reviewing this companion paper and their support is acknowledged.

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Preface

Companion Papers have been developed by the Working Group responsible for the *APGA Code of Practice for Upstream PE Gathering Networks – CSG Industry* (the Code) as a means to document technical information, procedures and guidelines for good industry practice in the coal seam gas (CSG) industry.

Since 2008, the development of the LNG export industry based in Gladstone, Queensland, with its related requirement for a large upstream CSG supply network of pipelines and related facilities presented the impetus for significant improvements in design and best practice approach.

The principal motivation for the initial development of the APGA Code of Practice was safety and standardisation in design and procedures and to provide guidance to ensure that as low as reasonably practicable (ALARP) risk-based requirements were available to the whole CSG industry. Accordingly, the Code is focused solely on this industry and the gathering networks using locally-manufactured PE100 pipeline. The Code is a statutory document within Queensland.

The incorporation of Companion Papers in Version 4 of the Code is intended to provide information and best practice guidelines to the Industry, allowing the Code to be limited to mandating essential safety, design, construction and operation philosophies and practices.

These documents form part of the suite of documents together with the Code and are intended to:

a) be used in the design, construction and operation of upstream PE gathering networks
b) provide an authoritative source of important principles and practical guidelines for use by responsible and competent persons or organisations.

These documents should be read in conjunction with the requirements of the Code to ensure sound principles and practices are followed. These documents do not supersede or take precedence over any of the requirements of the Code.

A key role of the Companion Papers is to provide the flexibility to incorporate endorsed industry practices and emerging technologies expeditiously, as/when necessary.

A related benefit is that the Companion Papers can be referenced by the wider resources industry which uses similar PE gathering networks for gas or water handling, including coal bed methane (CBM) in underground coal mines; mine de-watering; or the emerging biogas industries (agricultural, landfill, etc.).

1 Scope

The scope of this Companion Paper is related to the pressure testing of the relevant gathering network component, and should be considered as supplementary to the general construction requirements in Section 5, and pressure testing requirements in Section 8 of the APGA Code of Practice.

CSG construction activity shall normally conform to the resources industry's health safety and environment (HSE) standards based on 'golden rules, 'lifesavers', or the equivalent, which recognise the major hazards implicit in this industry. Specifically, these include:

- driving
- excavation
- lifting [and handling]
- electrical safety
- working in confined spaces
- retained (stored) energy
- safe systems of work (permitting, etc.).

The latter two rules predominate in relation to the scope of works covered by this paper.

An essential feature is that all staff involved in the testing, supervision and approval of such exclusion zones are experienced and competent in these tasks, including the technicians and traffic controllers enforcing the zone.

Additionally, normal mandatory procedures to achieve ALARP such as risk assessments, HAZOPs, work permit systems and endorsed work procedures are used.

2 Introduction

Until V6 of the code of practice, pressure testing exclusion zone determination was based on pre-2018 editions of ASME PCC-2. This method directly linked the volume of test sections to the required exclusion zone size.

During recent years, the size of the larger trunk or header PE pipes in the gathering system has increased to achieve operating and construction benefits

When conventional pneumatic pressure testing methods were used, the quantity of stored energy was accordingly increased, resulting in requirements for larger exclusion zones in accordance with the pre-2018 editions of ASME PCC-2. This presented challenges

in the following locations in particular:

- road and rail crossings and;
- locations where header/trunk lines run parallel to roads or rail lines, normally within 20–30 metres of adjoining property boundaries.

The previous revision of this companion paper addressed these challenges, and discussed the results of significant independent research conducted during 2013 which could be used in risk assessments where required.

Version 6 of the Code of Practice has been updated to align with the 2022 edition of ASME PCC-2, under which it is only required to consider the volume of 8 pipe diameters when calculating the stored energy for pressure tests. This is in recognition of the fact that it is only the stored energy local to the point of release that meaningfully contributes to the size of the initial blast wave.

Due to this change, some of the options for exclusion zone reduction discussed in the previous revision of this paper are no longer applicable (such as the use of loop over hoses or orifices between test section, with the purpose of effectively reducing the test section volume).

Under version 6 of the code, it is now the case that designers / constructors / operators are required to consider all hazards associated with pressure testing, and determine an appropriate exclusion zone on the basis of an informed risk assessment of all of these hazards (e.g. stored energy and the potential for rock or fragment throw). A separate companion paper has been produced to provide further quantitative guidance on theoretical potential rock throw distances.

3 Options for exclusion zone reduction

3.1 Hydraulic testing

Hydraulic (or also commonly known as hydrostatic) testing is the most commonly used method in association with trenchless construction techniques for road/rail/other crossings. The PE pipes are welded in a suitable length along the right-of-way in a location near the entry pit or bell hole, capped and strength pressure tested above-ground.

For large diameter pipes and tests at higher pressures, and provided adequate test water sources are available, this method is preferably adopted due to its reduced exclusion zone requirements compared to pneumatic testing methods (by virtue of having both reduced stored energy, and a lessor potential rock throw distance). If water sources are not adequately available, several separate sections of welded pipe can be tested consecutively by re-using the test water, and these sections then (golden) welded together.

In brownfield situations, when new PE pipe is to be installed with limits inhibiting the use of pneumatic testing (eg. installing a new gas header/trunkline into a compression facility) a similar construction and testing process can be used.

Comment: The above applications are neither unique nor controversial, but as with most of CSG field development, simply require a risk-based fit-for-purpose adaption of proven methodology, rather than adopting a one size fits all single pneumatic testing only approach. Designers should consult with experienced field project testing staff to develop the optimum (normally the simplest) solution.

3.2 Methods of reducing the amount of pneumatic stored energy in the pipeline test section

The former Section 8.2.8 of the Code of Practice (Version 3) detailed the following solutions which are reproduced below.

"The methods in sections 3.2.1 and 3.2.2 were viable options under the previous version of the code to reduce the effective stored energy volume in a test section, however under the updated ASME PCC-2, requiring only 8 pipe diameters of the test section volume to be considered, these methods are not likely to be required for typical pressure tests. Under some specific circumstances, it may be the case that these options provide for a safer pressure test, and hence the options are left in this revision of the companion paper, for the consideration of pressure test designers."

3.2.1 Loop over hose

The diagram below details a test section broken into two smaller sections and connected by a small diameter hose. The hose will limit the rate of energy that can be transferred from one section of the test section to the other in the event of a rupture.

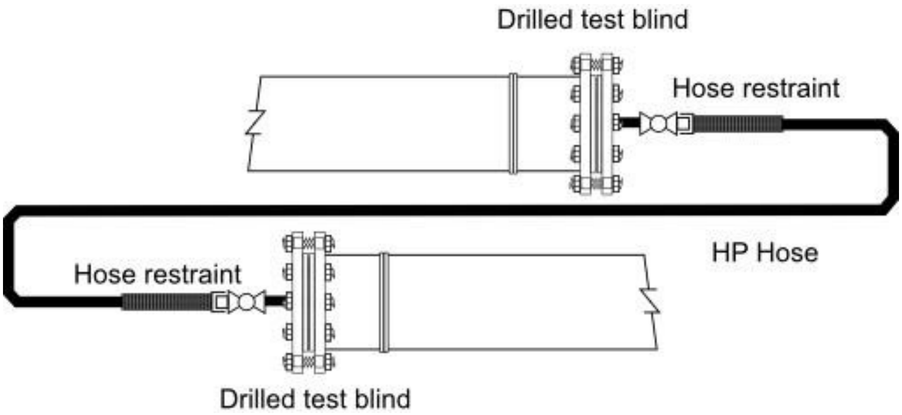

Figure 3.1 Interconnecting pipes with use of loop over hose.

3.2.2 Orifice plate

An alternative means would be to insert an orifice plate as shown below. The plate would have a smaller diameter hole drilled through the centre of the plate that would be inserted into a mechanical joint. The orifice plate will limit the amount of energy that can be transferred from one section of test section to the other in the event of a rupture.

The diameter of the orifice shall be calculated to limit the amount of energy transferred from one section to the other in the event of a failure.

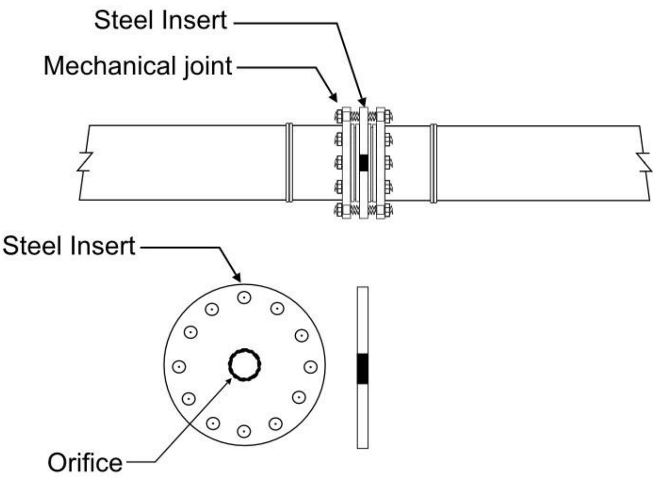

Figure 3.2 Interconnecting pipes with use of orifice plate.

The above methods (loop over hoses and orifice plates) for reducing stored energy are suitable for pipes of all sizes, but for PE pipe of DN450 and above, the size and weight of the orifice plates and related fittings can represent significant challenges. The need for additional bell holes with lifting and personnel safety risks in addition to costs are factors that need to be considered before their use.

3.2.3 Blast mats

Blast mats are well-known technology initially developed within the trenching industry to consume stored energy and prevent fragmentation or missile propagation during blasting when required in hard rock easements.

Mats can be used for both hydraulic and pneumatic testing, as an additional control where required by the risk assessment.

Mats are available in various forms ranging from interlocking wire mesh, recycled rubber, aramid fibre and heavy duty woven matting, with new materials also emerging from the resources industry. Their use shall always conform to manufacturer's recommendations for the duty involved.

Mats should be used to supplement other control measures as identified in a risk assessment and calculation sheet containing details of:

- the stored energy in the pipe section
- depth of cover
- type of backfill
- surrounding areas such as landowner/wellsite tracks, residences or nearby council roads.

The risk assessment should be informed by the details in this section, and identify specific points of possible rupture such as buried valve installations, electrofusion couplings, 'golden' weld locations, joints and junctions. The installation of blast mats at these specific locations can be considered a control measure to limit the quantity of any debris throw in the event of a rupture under test. In such circumstances, exclusion zones can be met even with significant site restrictions, as detailed below.

A key application for blast mat usage is where trunk/header lines adjoin major in-field roads used on a 24-hour basis by drilling rigs and associated vehicles. For brownfield locations, these roads are used by a myriad of operations, maintenance and construction staff during daylight hours; coupled with risk-based other controls, travel disruption can be minimised.

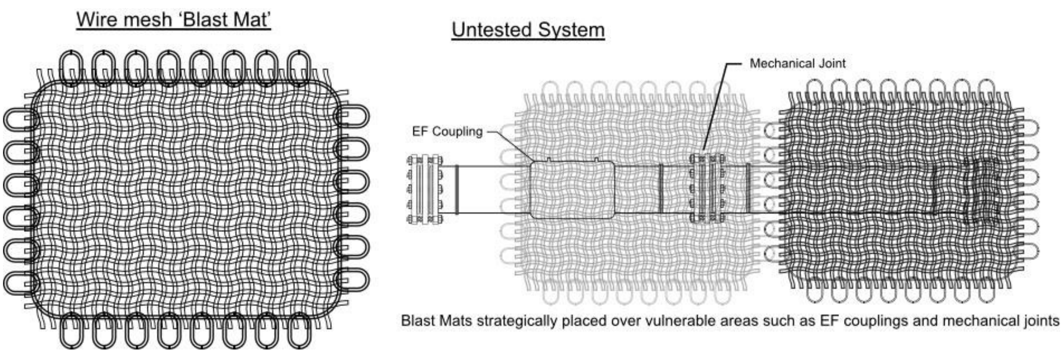

Figure 3.3 Blast matting over vulnerable joints

4 Industry testing and technical review

Section 8.2.9 of the Code of Practice allows the Operator to use an alternate calculation methodology for 'safe distance calculations' subject to independent qualification and third party verification.

During 2012-2013, DNV GL was commissioned by QGC to review the exclusion zone distances for pneumatic testing of buried PE pipe and relevant extracts from their reports are detailed below.

Extracts from the literature review by Connor et al (2013) included:

"As a result of the above literature review it has been established that the approach used in ASME PCC-2 is based upon materials, installation conditions, failure characteristics, and energy release rates that differ from those expected for a situation of buried PE pipes under pressure."

"The theoretical approach of equating stored energy to TNT contains a number of assumptions and steps that indicate it would be a cautious approach when applied in the vicinity of the event, including instantaneous energy release and 100% efficiency of equivalence between stored energy and TNT. The finite rate of propagation of the failure and the effect of the overlying soil would also tend to make these values cautious. Experimental evidence from the controlled failure of a large diameter HP gas pipeline some kilometres long suggest that in this case a 22% TNT equivalence for the pressurised volume involved in the failure would be more appropriate (even without overlying soil). It would take some distance for the finite rise time wave to shock-up and over this distance the front-loading on structures and people would be less significant..."

"The approach adopted in ASME PCC-2 does not consider the potential damage or harm from the projection of fragments (in this case, predominantly soil particles) as a result of the loss of containment..."

"Therefore, it is concluded that it would be prudent to undertake experimental work to establish actual energy release and, equally importantly, to establish credible distances of debris throw."

Subsequently, field testing was conducted at the (then) GL Noble Denton Spadeadam test site in the UK.

The main scope of the tests was to simulate complete circumferential failures of butt fusion and electrofusion (EF) coupling joints in a 400 metre length of DN315 SDR11 PE100 pipe pressurised to 12.5 barg.

These field test results confirmed that both the butt and EF joints failed as predicted, with butt fusion weld failures producing the longest debris throw.

Extracts from the trial report by Faragher et al. (2013) included the following conclusions:

- "The magnitude of recorded over-pressures suggests that the stored energy which contributes to the over-pressurisation after a release, is that contained in a volume of pipeline 5 diameters either side of the release point...
- "For the scenario modelled (DN 315 SDR11 PE100 pipe at 12.5 barg), the observed debris throw distances did not exceed 30 metres, was reasonably constant for all tests in line with predicted throw distances.

- "At the limit of debris throw for this scenario (30m), the predicted over-pressures are below the levels that would give rise to structural damage or human harm, being of the order of 1-2kPa."
- "The exclusion zones required to avoid harm during pressure testing will therefore be defined by the limit of debris throw rather than the effects of over-pressure."

The test results and conclusions support the notion that the number of pneumatic strength tests conducted in the field do not necessarily have to be constrained by the total stored energy in the pipeline and that the actual overpressures observed at the 30m debris cloud boundary would more than satisfy the minimum requirements for the Scaled consequence factor (R_{scaled}) of 20 when calculating the primary exclusion zone.

It must be noted that further testing is still required to validate the conclusions for larger PE100 pipeline sizes that are greater than DN315 and at higher test pressures than 1250 kPa.

NOTE: These reports (see References) can be accessed on the APGA website in the same location as this Companion Paper.

These reports were conducted under the light of previous editions of ASME PCC-2 which required consideration of the whole test section volume stored energy. The findings (e.g. that magnitude of recorded over-pressures suggests that the stored energy which contributes to the over-pressurisation after a release, is that contained in a volume of pipeline 5 diameters either side of the release point) are somewhat consistent with the changed PCC-2 methodology, albeit with a minor variance on the number of pipe diameters to consider.

As version 6 of the code requires the consideration of rock throw distances, the findings of this study may additionally be used to inform a risk assessment for exclusion zone size determination. Refer to CP-08-004 for further information on the topic of theoretical rock throw distances, and methods for minimising potential rock throw distances (such as ensuring large rocks are not contained within the backfill).

4.1 Effects of fragmentation

Effects of fragmentation were not considered in the testing done by Faragher et al. (2013) as at the time, ASME PCC-2-2011 did not provide guidance for throw distances if vessel**s** or piping were at risk of producing fragments. Part 5 – Article 5.1 Mandatory Appendix III of ASME PCC-2-2015 now includes a table (Table III-2) of minimum distances for fragment throw considerations.

When testing PE gathering systems, the pipe is normally buried, and in these instances typically you would not need to increase the exclusion zone (in addition to the blast wave distance calculation) to account for fragments from the pipe. However, there will still be debris throw in the form of soil and rock.

It must be noted that most, if not all, industry pressure testing incidents that have eventuated in fatalities have been due to the failure of an exposed pipe end where the person should not have been in the line of fire within the primary exclusion zone. It is therefore highly recommended and industry best practice to have additional controls in place for pipelines at the end of a test section where they typically have exposed blind flanges, connection points and end caps. Options for additional controls include thrust restraints and blast mitigation (in the form of overburden or blast mats as per section 3.2.3) to prevent missile or debris spread in the event of a full open ended failure.

5 Summary

Following over ten years of intensive construction activity in the CSG province with tens of thousands of kilometers of PE pipe being successfully pressure tested and installed, various field methods and techniques to design and enforce exclusion zones have been developed. Optimised planning has ensured that in most cases, public road closures have been able to be avoided, or restricted to night times only.

Control measures have included:

- Scheduling of the strength testing period to nights, as required;
- Manned traffic control on appropriate public and field roads, with instances of escorted vehicle movements to strictly enforce 'remain in vehicle' permit requirements;
- Community and stakeholder liaison;
- Selective use of hydraulic/hydrostatic testing, as appropriate; and
- Use of blast matting and other listed methods to reduce/retard stored energy.

The results and conclusions from the field testing experiments conducted during 2012-2013 by DNV GL and QGC and summarised in Section 4 (above) can be used to support the inform the nomination of exclusion zone distances.

In summary, a mix of hydraulic and pneumatic pressure testing should be used during most CSG field development, especially where sensitive locations are involved.

Selection criteria is well defined in the Section 8.4 of the Code of Practice and most operating companies (OPCOs) and construction/testing companies have defined test plans suitable for the specific geographic locations of their proposed operations.

The Code of Practice mandates that these test plan provisions shall be formally considered in the design phase for both gathering networks and related transfer pipelines.

6 References

The DNV GL/QGC reports can be accessed by APGA members via a link on the APGA website in the same location as this Companion Paper.

O'Connor, C., Faragher, E., Cleaver, R.P. and Graham, I. (2013), Report number 13457: Review of Proximity Distances for Pneumatic Testing of Buried PE Pipe. Loughborough,UK: DNV GL and QGC Pty Ltd

Faragher, E., and Graham, I. (2013), Report number 13590: Review of Pressure Test Exclusion Zones, Phase 1 Tests. Loughborough,UK: DNV GL and QGC Pty Ltd

Faragher, E., Chester, A., Cleaver, R.P. and Graham, I. (2013), Report number 14110: Review of Pressure Test Exclusion Zones, Phase 2 Tests. Loughborough,UK: DNV GL and QGC Pty Ltd