Australian Pipeline Industry Association

APIA Code of Practice

UPSTREAM PE GATHERING NETWORKS – CSG INDUSTRY

Version 3.0 Supplementary

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(Including May 2015 Supplementary Updates)
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APIA CODE OF PRACTICE - UPSTREAM PE GATHERING NETWORKS

CSG INDUSTRY

• ACKNOWLEDGEMENTS

This Code of Practice has been prepared on behalf of the Australian Pipeline Industry Association (APIA) by members of the Association who are associated with the Coal Seam Gas (CSG) industry. Representative members of all sections of the industry were active participants, including all major CSG producing companies, constructors, manufacturers of polyethylene (PE) resin, pipelines and fittings as well as CSG engineers.

APIA gratefully acknowledges the assistance and support of the Plastics Industry Pipe Association of Australia Ltd (PIPA) and its various technical members, who provided invaluable assistance during all stages of this Code’s preparation. Many PIPA guidelines are referenced in the Code and all are available on the PIPA website www.PIPA.com.au.

In addition, many industry members contributed significant time and resources at the sub-committee working level in developing and reviewing individual sections of this Code and its subsequent revisions.

The support of the APIA Board and the APIA Secretariat led by Chief Executive Cheryl Cartwright is also acknowledged.
PREFACE

The provision of clean energy is of vital interest to all members of the Australian community. Gas-fired power generation is widely acknowledged as a significant part of the solution to meeting carbon pollution reduction guidelines, as the emissions released from modern gas fired power stations are much less than those from coal-fired power generation.

During the past decade, sufficient coal seam gas (CSG) reserves have been identified from the extensive coal formations in Queensland and New South Wales to support the widespread utilisation of gas fired power stations throughout eastern Australia. In addition, a CSG to LNG export industry is being developed by several major resource companies. Polyethylene (PE) has been used widely throughout Australia for several decades in water reticulation and in the oil and gas industries, especially in metropolitan gas distribution networks. Within the CSG industry, PE has been utilised as the material of choice for gas flowlines upstream of field compression stations and for water flowline systems. It provides a cost effective solution with a long service life and is not subject to corrosion.

For the initial decade of CSG field development, common industry practice, based on various water and gas industry standards and codes, was followed for installing the gathering networks throughout the predominantly rural environment of the CSG fields. However, as the industry matured and larger diameter PE pipelines were installed, requirements of the existing standards were seen as less appropriate. In particular, design factors needed review and temperature de-rating emerged as a significant issue due to some observed fluid temperatures above 40 °C. Existing standards provided differing interpretations for this aspect.

Most importantly, several safety incidents were recorded during PE pressure testing and commissioning, and the industry jointly recognised that further guidance was needed relating to jointing procedures, especially electrofusion, pressure testing and commissioning, specifically to meet the “as low as reasonably practicable” (ALARP) risk-based requirements of the CSG industry.

This Code has been developed to provide guidance to all industry participants. It is intended to encapsulate the best techniques and methods currently available and is cross-referenced against relevant Australian and international standards wherever possible.

It is an evolving document, and APIA proposes that it be used as the basis for the future development of an appropriate Australian Standard.

1 Unless otherwise defined, the term “fluid” includes both liquid and gaseous substances – See Appendix I
This Code of Practice has been developed by APIA in consultation with its membership, PIPA, the gas industry and regulatory authorities, particularly those in Australian jurisdictions with a current CSG industry. APIA Members in all States are encouraged to adopt this Code and to provide feedback on its application. Other interested parties are also invited to provide feedback on this initiative.

Comments may be forwarded to APIA at –

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1 SCOPE

1.1 INTRODUCTION

This Code of Practice has been specifically designed to be, as far as possible, a single reference source for the Coal Seam Gas (CSG) industry in working with polyethylene pipe and fittings. It needs to be read in conjunction with the Standards referenced in Appendix I and relevant legislation.

The Code does not specifically detail environmental requirements, it needs to be read in conjunction with the respective State’s Environmental Protection legislation, the Operator’s Environmental License and the APIA Code of Environmental Practice.

The maximum design pressure for pipelines covered by this Code is 1000 kPa for gas and 2500 kPa for water. The Operator may in accordance with the ‘Fit for Purpose’ Design requirements of this Code design pipelines with higher design pressures. Note that, unless otherwise stated, all references to pressure in this Code refer to gauge pressure.

The Code addresses safety performance, design, construction and testing of pipeline systems and places particular emphasis on jointing techniques and pressure test methods.

This version also provides more explicit guidance on the obligations, and process required, to undertake and validate Safety Management Studies (SMS) and the requirement to demonstrate ALARP where risks are considered intolerable and have to be addressed by the implementation of additional risk reduction measures.

Jointing, particularly of large diameter PE pipe, presents challenges and the Code recognises this by proposing mandatory and ongoing training and accreditation of all relevant personnel involved in PE welding including PE welders, QA/QC and supervisory personnel.

Pneumatic pressure testing in PE networks is expected to be used for most of the network. It is acknowledged, however, that significant hazards need to be carefully addressed, primarily by exclusion zone design and careful planning. Again, training forms a pivotal role in safety management. Several options for leak testing are listed including tracer gas for CSG nodes or networks.

In Section 5 - Construction several PE pipe installation methods are provided, including horizontal directional drilling and thrust boring. Some emerging NDT technologies are available; however the Code does not endorse the use of NDT due to the lack of proven and verified techniques and acceptance criteria. For more information refer to PIPA technical note TN016 “Non Destructive Examination of PE welds – Emerging Techniques”.

The Code recognises the importance of good engineering design in providing appropriate isolation and segregation within the gathering network. Good engineering design establishes the basis for the proper construction of the pipeline, allowing an extended pipeline life and reducing the risk of future faults or emergencies. The Code also considers technical requirements such as temperature re-rating and other design factors, as well as special
considerations to be made when pipe systems are in close proximity to populated areas, roads etc.

The Code also sets out the requirements for commissioning and operation of the network systems including the requirement to review and approve important matters related to safety, engineering design, inspection and operation. This version also clarifies requirements related to pipeline suspension and abandonment.

1.2 SCOPE

The Code applies to CSG water and gas pipelines and associated piping and components of all diameters which are manufactured to the PE100 specification that transmit CSG, PFW, permeate, saline water and treated water.

Figure 1.1 and 1.2 shows the scope of gas and water pipelines covered by this Code. The break between the pipeline and the plant or lease facility shall be defined for each facility. The break should preferably be at, or adjacent to, the first isolation valve, off the pipeline, on the side of the valve remote from the pipeline.

Where the pipeline includes carbon or stainless steel components, or components manufactured from other materials (eg risers, high point vents, low point drains, isolation valves or manifolds) the requirements of Section 4.15 of this Code shall apply.

The Code also applies to modifications to a pipeline constructed to a previous version of this Code or alternate Standard.

1.2.1 Exclusions

The Code does not apply to the following installations:

a) Material selection for pipelines constructed of materials other than PE e.g. Polyamide or Fibre Reinforced Plastic;

b) Potable or drinking water pipelines.
Figure 1.1 Limitations of a Gas Pipeline System

_____________________ indicates pipeline / facility included in the scope of this Code
_____________________ indicates pipeline / facility excluded from the scope of this Code
Figure 1.2 Limitations of a Water Pipeline System

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1.3 RETROSPECTIVE APPLICATION

The Code of Practice is subject to continuous improvement, and when a revision of part of the Code of Practice is published, the revision should be reviewed by the Operator to identify opportunities for improvement of existing systems.

Publication of a new Code of Practice or revision of the Code of Practice does not, of itself, require modification of the existing physical assets constructed to a previous Standard or a previous edition of this Code of Practice.

Operation of the assets should comply with the requirements of the Network Management System and Safety (Section 2) and Operations (Section 11) of the most recent edition of this Code of Practice.

Where the changes in the latest edition of the Code of Practice are considered significant, the existing network system shall be assessed against these requirements and where technical or safety non-compliances are deemed to exist, mitigation measures determined by risk assessment shall be applied in accordance with the Code of Practice.
2 NETWORK MANAGEMENT SYSTEM AND SAFETY

2.1 BASIS OF SECTION

This Section describes the requirements of the management system to be in place before commissioning and operation, and to ensure an existing network remains fit for operation.

Networks shall have a documented and approved Network Management System (NMS).

The NMS shall address the Operator’s approach to the following areas –

a) Management;
b) Planning;
c) Implementation;
d) Measurement and evaluation;
e) Consultation, communication and reporting;
f) Safety Management;
g) Environmental Management;
h) Construction and Commissioning;
i) Site Safety.

The NMS shall include a description of the flowline(s) covered by the NMS including suitable maps (alignment sheets and/or GIS) showing the route of the flowline(s), the location of associated facilities such as compressor and pump stations, low point drains, high point vents and valve stations.

NOTE: In some jurisdictions there are special requirements for Safety Management Systems/Plans and these will need to be addressed in the NMS.

2.2 NETWORK MANAGEMENT SYSTEM ELEMENTS

2.2.1 General

Each element of the NMS is described below and supports each other. The NMS shall comply with those requirements. Much of the responsibility for creating and implementing the NMS lies with the Operator.

NOTES:

1. In this Code, the term “Operator” refers to the person in overall charge of the project. It should not be confused with the term “operator” (lower case) which refers to a person carrying out a defined task. Depending on the process being undertaken (e.g. construction, commissioning, operation), the title Operator may be held by different individuals.

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2 For the definition of the term “approved” see Appendix I
2. The term “Operator” used in this Code should also not be confused with the same term used in the Queensland Petroleum and Gas (Production and Safety) Act 2004 that has specific obligations and responsibilities imposed on the incumbent.

How the Operator chooses to structure its NMS is flexible, but should address the criteria specified in Sections 2.2.2.1 to 2.2.2.6.

2.2.2 Management

The policy towards the various aspects of operating the network shall be defined by the Operator. These include, but are not limited to, integrity management, environmental management and occupational health and safety management.

2.2.2.1 Management Structure

A defined management structure for the network shall be established to identify key positions and personnel. An appropriate management structure shall be maintained.

2.2.2.2 Responsibilities, accountabilities and authorities

The responsibilities, accountabilities and authority levels of personnel and or contractors with respect to the various aspects of the operation and maintenance of the network shall be detailed in the NMS.

2.2.2.3 Training and competency

Personnel shall be competent to perform the specific tasks and functions they are responsible for conducting.

The Operator shall establish and maintain procedures for identifying and providing the training needs of all personnel performing functions covered by the NMS.

As a minimum, personnel responsible for the operation and maintenance of the network shall, as applicable to their position –

a) be trained and experienced in all aspects of the equipment in their control;

b) be trained in the obligations of the NMS and briefed in the requirements of the actions identified during the safety management study (see Section 2.7);

c) be aware of properties of the fluid, including its hazards (see AS 4343);

d) ensure the safe disposal of any accidentally discharged fluid; and

e) be capable of arranging for damaged flowlines to be repaired.

NOTE: Operators can be assisted in assessing, training and developing the competency of personnel for the specific tasks and functions by use of relevant Competency Standards. In the case of:

1. Operators and technicians, the relevant competency standards are maintained by E-OZ in UEG-11 The Gas Industry Training Package which can be found at www.training.gov.au/Training/Details/UEG11;
2. Pipeline Engineers, the relevant competency standards are published by the Australian Pipeline Industry Association and can be found in the members only area of the APIA website at www.apia.net.au/training/pipeline-engineer-training-project.

2.2.2.4 Resourcing

The Operator shall identify the resourcing, equipment and material requirements for the network’s operation and maintenance, including whether specially trained personnel are required to ensure the appropriate development, implementation and review of the NMS.

2.2.2.5 Change Management

The Operator shall establish procedures for managing changes to the NMS and procedures to ensure they are made in a controlled and authorised manner.

The change management procedures shall also ensure that any changes to the network’s design or operation are managed in a controlled and authorised manner.

Any significant change to the network or its operating context shall be reviewed and approved. Significant change shall be considered to have taken place if the engineering design has been upgraded or modified, or if any event initiates an operational, technical or procedural change in the measures in place to —

a) protect the network and associated installations;
b) promote public awareness of the network;
c) operate and maintain the network safely;
d) respond to emergencies;
e) prevent and minimise product leakage;
f) carry out inspections; or
g) ensure that the plans and procedures continue to comply with the engineering design.

The change management procedures shall address implementation of any resulting NMS changes including notification and training of staff impacted by the change, and responsibilities for any identified actions as well as timelines for completion of those actions.

2.2.2.6 Management Review

The Operator shall establish procedures for regular management review of the effectiveness and appropriateness of the NMS.

The NMS shall be monitored, reviewed and, if necessary updated, at least every 2 years or in the event of any significant change to the network.
2.3 PLANNING

2.3.1 General
The Operator shall have appropriate planning processes and procedures for the network for any situations that may result from normal and abnormal operations including emergencies. This planning process must include a comprehensive Safety Management Study to ensure that risks to the pipeline and personnel are as low as reasonably practicable. Prior to installation, additional controls can be designed where identified.

2.3.2 Planning for normal operations
When developing the policies and procedures of the NMS, the Operator shall utilise the safety management studies and risk assessments undertaken under this Code of Practice.

Control measures required to eliminate risks or reduce them to an acceptable level, including risks to the environment as a result of network operation activities, shall be incorporated into the appropriate procedures.

The Operator shall also establish a process for the identification of Occupational Health, Safety and Environment (OHS&E) hazards and mitigation of OHS&E risks prior to the commencement of any activity.

2.3.3 Planning and preparation for abnormal operations
The Operator shall plan and prepare for operation of the network in circumstances that are different from those initially considered during the design of the network. These circumstances may include the following –

   a) Operating under emergency power supplies;
   b) Operating without key assets such as wells or compressors;
   c) Operating at low flow or pressure;
   d) Operating where key areas of the gathering system or access roads are subject to flooding or inundation;
   e) Operating where key areas of the gathering system could be directly exposed to, or in the vicinity of, bushfires.

The Operator shall develop contingency plans and procedures for actions that may be required in situations of significant disruption to normal operations.

2.3.4 Emergency planning and preparation
The Operator shall plan and prepare for emergency events resulting from the network’s operation and maintenance and also from external events that may affect the safe and reliable operation of the network.

In the event of an emergency, the Operator shall ensure that there is an approved Emergency Plan in place and it is followed.
NOTES:

1. Liaison with relevant Emergency Services and stakeholders may assist the Operator to be adequately prepared for an emergency event.
2. Emergency response exercises are an excellent way of testing preparedness.

2.4 IMPLEMENTATION

The Operator shall implement the plans and procedures of the NMS covering at least the following –

a) Testing;
b) Commissioning;
c) Operations;
d) Network integrity management including –
   - External interference management;
   - Change of operating conditions and remaining life review;
e) Emergency response; and
f) Records management.

2.5 MEASUREMENT AND EVALUATION

2.5.1 General

The NMS shall incorporate procedures that ensure the following elements are measured and evaluated appropriately.

2.5.2 Data acquisition and analysis

The Operator shall establish procedures for identifying, collecting and analysing network operational, maintenance and reliability data to identify trends in the network’s operation and performance.

NOTE: Analysis of this data should ensure operation of the network continues as planned. It should also identify any negative trend that may result in an event adversely impacting the safe and reliable operation of the network.

2.5.3 Accident/incident investigation and reporting

The Operator shall establish procedures for identifying, notifying, recording, investigating and reporting accidents, near misses or incidents resulting from the operation and maintenance of the network. This shall cover any event that either causes or has the potential to cause —

a) injury or death to network personnel or the public;
b) significant damage to the environment or property;
c) impact on the network’s operation or integrity; and/or
d) Uncontrolled gas or water release.

Reporting shall include notification to relevant regulatory authorities including OH&S and environmental regulators as required.
2.5.4 System audits

The Operator shall establish procedures for planning and implementing audits of the NMS to determine compliance with and effectiveness of the plans and procedures. System audits should also assess compliance with legal and regulatory requirements and ensure the NMS adequately address these issues.

The Operator shall consider the threats identified and risks evaluated in the safety management study to ensure that audits address —

a) the effectiveness of the NMS in managing the risks identified; and

b) the effectiveness of the monitoring procedures in place to identify new or changed risks.

Audits shall be performed by competent personnel who preferably are independent of the section of the NMS being audited. The audit procedures shall cover the timing of audits, including the conduct of external independent audits where chosen to be undertaken or where required by regulatory authorities.

Audit procedures shall cover arrangements for verifying the implementation and effectiveness of corrective and preventive actions designed to address any non-conformances identified during the audit.

The outcomes of audits shall be subject to management review. See ISO/AS/NZS 9001 for more information.

NOTE: The results of audit, review and monitoring processes should be utilised for the purpose of management review of the NMS.

2.5.5 Corrective and preventative actions

Corrective actions are taken to deal with an existing issue while preventative actions address potential issues. The Operator shall develop and implement procedures for determining, approving and implementing corrective and preventative actions.

The proposed actions shall be appropriate and commensurate to the risks encountered or identified. The proposed actions shall be recorded and their effectiveness determined by audit.

The basis for any action taken shall be documented and the outcomes of actions taken along with their effectiveness and timeliness shall be subject to management review.

2.6 CONSULTATION, COMMUNICATION AND REPORTING

The Operator shall identify external people and organisations with a legitimate interest in the safe operation and maintenance of the network. These will include landowners, local and emergency authorities, regulatory authorities and government agencies.
The Operator shall establish procedures for regular consultation with, as well as communication and reporting to, these identified stakeholders. These procedures shall include statutory reporting requirements.

2.7 SAFETY MANAGEMENT PROCESS

2.7.1 General
The pipeline network safety management process consists of the following –
   a) Threat identification;
   b) Application of physical, procedural and design measures to identified risks;
   c) Review and control of failure threats;
   d) Assessment of residual risk.

2.7.2 Threats
2.7.2.1 General
The underlying principal of threat identification is that a threat exists at a location. A threat is any activity or condition that can adversely affect the pipeline if not adequately controlled.

Threats may exist –
   • at a specific location (e.g. excavation risk at a particular road crossing);
   • at specific sections of a pipeline (e.g. farming, forestry); or
   • over the entire length of the pipeline network.

The same safety management process applies to both location-specific and non-location-specific threats.

2.7.2.2 Threat Identification
Threat identification shall be undertaken for the full length of the pipeline network, including stations and pipeline facilities. The threats to be considered shall include, at least –
   a) natural events;
   b) operations and maintenance activities;
   c) construction defects;
   d) design defects;
   e) material defects;
   f) intentional damage; and
   g) third party activities.

The threat identification shall consider all threats with the potential to damage the pipeline network and cause –
• interruption to service;
• release of liquid or gas from the pipeline network;
• harm to pipeline operators, the public, property or the environment.

NOTE: Typical data sources used to conduct the risk identification include –
- alignment survey data to determine basic geographical information;
- land user surveys in which liaison officers gather information from land users on the specific activities carried out on the land, and obtain any other local knowledge;
- third-party spatial information (GIS type data) on earthquakes, drainage, water tables, soil stability, near-surface geology, environmental constraints, etc;
- land planning information.

The threat identification shall generate sufficient information about each threat to allow external interference protection and engineering design to take place.

For each identified threat, at least the following information shall be recorded –

a) What is the risk to the pipeline network?
b) Where does it occur? (the location of the risk)
c) Who (or what) is responsible for the activity?
d) What is done? (e.g. depth of excavation)
e) When is it done? (e.g. frequency of the activity, time of year)
f) What equipment is used? (if applicable, e.g. power of plant, characteristics of the excavator teeth, etc.)

2.7.2.3 Threats to typical designs

The pipeline network design process involves the development and application of typical designs to locations where there is a common range of design conditions and identified threats. Threats common to typical designs shall be documented and controlled.

Each typical design shall be subjected to the safety management process in accordance with this Code to demonstrate that the design provides effective control for the identified threats and their associated risks.

2.7.2.4 Other threats at typical design locations

Prior to construction, each location at which a typical design is applied shall be assessed to determine whether threats other than the threats common to that design exist at that location.

Where other threats are identified, effective controls shall be applied to each of these additional location specific risks.
2.7.2.5 **Non-credible threats**

Each threat identified as being non-credible shall be documented. The reason for it being declared non-credible shall also be documented. The validity of this decision shall be considered at each review of the safety management study.

Non-credible threats do not require controls.

2.7.3 **Controls**

2.7.3.1 **General**

Effective controls for each credible threat shall be identified and applied using a systematic process.

Physical and procedural controls shall be applied to all credible external interference threats.

Design and/or procedures shall be applied to other threats.

Control is achieved by the application of multiple independent protective measures in accordance with this Code.

Controls are considered effective when failure as a result of that threat has been removed for all practical purposes at that location.

Where controls are determined to be not effective for a particular threat, that threat shall be subject to potential failure analysis.

2.7.3.2 **Control by external interference protection**

The pipeline network shall be protected from external interference by a combination of physical and procedural controls at the location of each identified threat. All reasonably practicable controls shall be applied.

The physical and procedural controls applied shall be appropriate to protect the pipeline network from the specified threat. Where physical or procedural controls are not sufficient, other design and/or procedures shall be applied.

NOTE: Re-routing is an example of a design change decision that may be taken if external interference protection is not sufficient.

2.7.3.3 **Control by design and/or procedures**

a) Design and/or procedures shall be applied to threats other than external interference threats in accordance with this Code;

b) Materials shall be specified, qualified and inspected in accordance with Section 3;

c) Pipeline network design shall be carried out in accordance with Section 4;

d) Erosion protection for the full length of the pipeline network shall be designed in accordance with Section 4;

e) Protection against stress and strain shall be designed in accordance with Section 4 and 5;
f) Protection against construction related defects shall be in accordance with Section 5;
g) Operational controls shall be designed in accordance with Section 11.

2.7.4 Residual risk assessment

Assessment of risks shall be undertaken in accordance with AS/NZS ISO 31000.

There are circumstances where risk estimation using quantitative methods may be required to enable comparison of alternative mitigation measures as a basis for demonstration of ALARP, and in some jurisdictions, to satisfy planning criteria.

2.7.5 Safety Management Validation

Each detailed safety management study shall be validated by a properly constituted workshop, which shall critically review each aspect of the safety management study. Appendix H provides guidance for conducting the safety management study and shall be considered in the validation workshop.

The safety management study shall be completed at Design and then reviewed and validated as a result of any of the following changes:

a) At pre-commissioning for Operation;
b) At any review for changed operating conditions;
c) Before recommencement of operation following a flowline failure where such failure has resulted from a mechanism not previously included in preceding studies;
d) At any time when new or changed threats including land use occur;
e) At any time where there is a change of knowledge affecting the safety of the flowline or network;
f) At any review for extension of design life;
g) Where a part of the network is suspended;
h) At abandonment.

The SMS review and validation shall be completed at a minimum of five yearly intervals, where none of the above changes occur.

Where the issue relates to a specific part of the network, a specific location or specific safety issue, the safety management study may be restricted to only that part of the network for which the issue applies.

Where an extension to an existing network is proposed, for which a safety management study exists, the safety management study for the extension may be restricted to specific new location threats provided the non-specific location threats are reviewed and deemed to adequately cover the threats associated with the network extension.
The safety management study shall:

- be completed at the Maximum Allowable Operating Pressure (MAOP) of the Network;
- have an evaluation of the threats in accordance with an appropriate radiation intensity contour;
- be subject to a risk assessment; and
- have all risks reduced to ALARP.

In addition the assessment shall consider the impact of the failure occurring due to a failure of all controls where the maximum pressure exceeds that able to be achieved under the Overpressure Protection design for the network. An assessment of the implementation and effectiveness of all threat controls shall be made at each review.

2.8 ENVIRONMENTAL MANAGEMENT

Risks to the environment from each part of the life cycle of the pipeline network shall be identified and control measures implemented so that these risks are reduced to an acceptable level. Preference shall be given to ensuring environmental risks are managed by avoidance (route selection) and, where necessary, specific construction techniques.

The requirements of this Code complement the requirements of regulatory authorities in assessment and management of environmental risk, and are intended to be used during planning, construction and operational phases of a pipeline network to ensure that –

a) environmental management effort is concentrated on significant risks;

b) environmental management methods are assessed holistically for their contribution to minimising the impact to the environment; and

c) there is a basis for assessing alternative construction and management methods to minimise the impact to the environment.

An analysis of the impacts of construction techniques and design at sensitive locations shall be considered.

Risk of damage to the environment from operational maintenance and abandonment activities shall be identified and control measures developed.

The environmental management plan shall include approved procedures for protecting the environment from construction, operation, maintenance and abandonment activities. The environmental management plan shall also address emergency situations.

NOTE: The APIA Code of Environmental Practice provides industry accepted guidance on management for the environment through the design, construction and operational phases of a project.
The following data shall be obtained prior to conducting the environmental safety assessment –

a) Basic environmental data (including cultural heritage and archaeological data);
b) Stakeholder survey information;
c) Constructability and safety constraints;
d) Emergency response capabilities;
e) Legislative requirements.

The environment severity classes that apply to the pipeline project shall be defined and approved. Specification of environmental impacts shall, as far as practicable, be expressed in quantified terms.

2.9 CONSTRUCTION AND COMMISSIONING

2.9.1 Construction safety

Construction of pipelines shall be carried out in a safe manner.
The safety of the public, construction personnel, adjacent property, equipment and the pipeline shall be maintained and not compromised.

A construction safety plan shall be prepared, reviewed by appropriate personnel, and approved. This review shall take the form of a construction safety plan workshop.

Specific construction safety requirements exist in each regulatory jurisdiction. The more stringent of the regulatory requirements and the requirements of this Section shall apply.

NOTES:

1. Review by appropriate personnel should include designers, construction personnel, OH&S personnel, certified environmental practitioners and the approval authority.
2. The construction safety plan details should be consistent with the nature of the work being undertaken. It may be a component of an integrated construction safety system, a construction safety case (where the regulatory jurisdiction requires this), or a project or activity specific safety plan.

As a minimum the following shall be addressed:

a) Approved fire protection shall be provided and local bushfire and other fire regulations shall be observed;
b) Where the public could be exposed to danger or where construction operations are such that there is the possibility that the pipeline could be damaged by vehicles or other mobile equipment, suitable physical and/or procedures measures shall be implemented;
c) Where a power line is in close proximity to the route, safe working practices shall be established;
d) Adequate danger and warning signs shall be installed in the vicinity of construction operations, to warn of dangers including those from mobile equipment and the presence of excavation, overhead power lines and overhead telephone lines;

e) Unattended excavations in locations accessible to the public shall be suitably barricaded or fenced off and, where appropriate, traffic hazard warning lamps shall be operated during the hours of darkness;

f) Procedures to be followed for lifting pipes both from stockpile and into trench after welding;

g) Procedures for safe use and handling of chemicals and solvents;

h) Frequency and provision of safety talks (tool box meetings);

i) Accident reporting and investigation procedures;

j) Appointment of safety supervisor and specification of duties;

k) Travel associated with attending the worksite;

l) Statutory obligations;

m) Traffic management plan.

NOTE: The APIA document Onshore Pipeline Projects, Construction Safety Guidelines provides guidance on construction safety for the Australian Pipeline Industry.

2.9.2 Testing safety

The construction safety plan shall address safety through all phases of testing of the pipeline during construction.

2.9.3 Commissioning safety

The commissioning plan shall consider the safety of the activities undertaken through all phases of commissioning and, where required, develop specific procedures to manage the safety during commissioning of the pipeline.

Commissioning safety shall comply with Section 10.

2.10 SITE SAFETY

The safety of the public and maintenance personnel, repair personnel, the integrity of equipment and the pipeline network shall not be compromised.

Control processes shall be established for all personnel to ensure that risks are kept to as low as reasonably practicable (ALARP) and, where necessary, risk mitigation measures are implemented.

A permit to work process shall be required for site works involving high levels of risk, when working with any pipeline or its facilities, to ensure that high levels of OHS&E are maintained.

As a key requirement of the system, a job safety analysis (JSA) shall be carried out to ensure that all on site OHS&E hazards are identified and addressed prior to work commencing.
A permit to work should always be issued for –

- Work in pipe trenches;
- Pressure testing;
- Commissioning;
- Work on existing operating network including tie-ins;
- All other high risk tasks.
3 MATERIALS AND COMPONENTS

3.1 GENERAL

Polyethylene was first used for pipelines in the 1950’s in water supply applications. Since then, the production and manufacturing technology of polyethylene resins has improved enormously and the polyethylene resins of today bear little resemblance to the first generation of polyethylene resins.

Polyethylene is a thermoplastic and behaves differently from metals. However these properties are well known and are embraced in Australian and other International standards.

PE100 resins used in today’s pipelines have high toughness, excellent resistance to slow crack growth and to rapid crack propagation. They also have an inherent resistance to water and many chemicals. Polyethylene is now the material of choice for many water, waste-water, gas and other pipeline applications.

The following information details the minimum material requirements for PE resins and PE pipe and fitting materials for use in coal seam gas projects.

3.2 QUALIFICATION OF MATERIALS AND COMPONENTS

Materials and components shall be fit for purpose for the conditions under which they are to be stored, transported and used, including construction. They shall have the composition, pressure rating (PN number) or Standard Dimension Ratio (SDR), temperature rating and design life specified by the engineering design.

3.3 COMPOUND

PE pipes used in upstream gathering networks shall be manufactured from PE100 fully pre-compounded material complying with AS/NZS 4131 and listed in PIPA Guideline POP 004.

NOTE: The test results for compounds listed in POP 004 have been independently scrutinised and are acknowledged to meet the requirements of AS/NZS 4131 and satisfy the temperature re-rating factors listed in this code.

Materials not listed in POP 004, but for which compliance with AS/NZS 4131 is claimed, may be used provided a full assessment of independent test reports by an appropriately qualified and experienced scientist or engineer confirms compliance.

3.3.1 Pipes

PE pipes shall be manufactured in accordance with AS/NZS 4130 and shall be third-party certified by a JAS-ANZ accredited certifier under the StandardsMark, GasMark or WaterMark schemes or equivalent. Marking and product traceability shall be in accordance with the Standard. Appendix A of AS/NZS 4130 shall be used as the basis for demonstrating compliance.
Pipes for water applications shall be Series 1 as per AS/NZS 4130 and identified with coloured stripes or jackets and markings as defined in Table 3.3.1. For gas service the Series 1 pipe shall be classified in terms of SDR and not PN.

NOTES:
1. For CSG applications, Series 1 pipe is to be used for gas service
2. Stripes shall be applied in accordance with AS/NZS 4130 Polyethylene (PE) Pipes for Pressure Applications.

Table 3.3.1 Colour Specification

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Colour</th>
<th>Colour Specification</th>
<th>Additional Pipe Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>Yellow</td>
<td>No darker than RAL 1018</td>
<td>none</td>
</tr>
<tr>
<td>Saline Water</td>
<td>None</td>
<td></td>
<td>Saline water</td>
</tr>
<tr>
<td>Produced Formation Water</td>
<td>Purple</td>
<td>AS/NZS4130</td>
<td>PFW</td>
</tr>
<tr>
<td>Permeate Water</td>
<td>Green</td>
<td>AS1345 in the range G13, G21, G23</td>
<td>RO Water</td>
</tr>
</tbody>
</table>

NOTE: Information on the RAL colour range may be obtained from RAL Deutsches Institut für Gütesicherung und Kennzeichnung, www.ral.de

Examples of mandatory markings (See AS/NZS 4130):

Gas
TRADEMARK S1 DN315 SDR 11 GAS PE100 100930 F1 AS/NZS4130 CERTMARK

Saline Water
TRADEMARK S1 DN315 PN10 SDR17 PE100 100930 F1 AS/NZS4130 CERTMARK BRINE

Produced Formation Water
TRADEMARK S1 DN315 PN10 SDR17 PE100 100930 F1 AS/NZS4130 CERTMARK PFW

Permeate Water
TRADEMARK S1 DN315 PN10 SDR17 PE100 100930 F1 AS/NZS4130 CERTMARK RO WATER

NOTE: An explanation of the nomenclature used in the marking examples is provided in AS/NZS 4130. CERTMARK refers to the certification marking required by the third-party certifier.

3.3.2 Fittings

3.3.2.1 Marking

Fittings shall be marked in accordance with the requirements of the Standard to which they are manufactured. For all other fittings the following minimum marking requirements shall apply.
All fittings shall be legibly marked or labelled using lettering of 5mm minimum height, with the following information:

(a) The manufacturer’s name or registered trademark.
(b) The fitting type in the form of ‘PE-Steel Transition’, as appropriate.
(c) The grade of PE material in the form ‘PE100’, as appropriate.
(d) Nominal size in the form ‘DN315’, as appropriate.
(e) Classification in the form ‘SDR11’, as appropriate.
(f) Traceability data in either of the two following formats –
   A unique batch number; or
   The date of manufacture of the fitting and the identification of place of manufacture.

NOTE: The branding requirements for PE Pipe do not apply to fittings manufactured from the PE pipe.

3.3.2.2 De-rating requirements for fittings
Pressure fittings manufactured from Polyethylene which are not covered by AS 1463 or AS/NZS 4129 or an equivalent International Standard, and which are intended for use with polyethylene pipes made to AS/NZS 4130 should comply with PIPA guideline POP 006.

3.3.2.3 Electrofusion Fittings
Electrofusion fittings shall comply with AS/NZS 4129 and shall be third party certified by a JAS-ANZ accredited certifier under the StandardsMark, GasMark or WaterMark schemes or equivalent. Fittings for above-ground applications shall be black.

3.3.2.4 Fabricated PE Fittings
Fabricated fittings shall be manufactured from PE100 pipes complying with Section 3.3.1. Butt welding or electrofusion welding shall be the only welding processes used to connect segments or components. Fillet, extrusion or rod welding shall not be used.

3.3.2.5 Mechanical Compression fittings
Mechanical fittings shall comply with AS/NZS 4129.

3.3.2.6 Mechanical Couplings
Mechanical couplings shall comply with Section 6.

3.3.3 Tracer wire
Tracer wire shall be metallic, electrically insulated and have a minimum diameter of 14 gauge. Tracer wire shall be resistant to corrosion damage either by use of coated copper wire or by other means.

3.3.4 Previously used pipe
Pipe that has been exhumed after being taken out or removed from service shall not be re-used in upstream gathering networks.
NOTE: PE100 is a thermoplastic material and can be reprocessed. The pipe manufacturer should be consulted regarding options for collecting reclaimed pipes and off-cuts for recycling into other products.

3.4 VALVES

3.4.1 Valve material

Materials used in the manufacture of valves shall be appropriate for the specific fluid being transported and shall be suitable for installation above or below ground as appropriate.

Metallic valves that are subject to corrosion shall be manufactured from a corrosion resistant material such as stainless steel or be provided with a suitable protective surface coating such as thermal bonded coating or painting. The grade of stainless steel shall be selected based on the specific fluids properties. Where protective coatings are used, requirements for coating type, surface preparation and thickness shall be determined and specified. Thermal bonded coating shall be in accordance with AS/NZS 4158. Valve bodies manufactured from PE shall use a conforming PE100 material.

3.4.2 Pressure rating of valves

The pressure rating of a valve shall be not less than the pressure rating of the piping system within which it operates.

3.5 TRANSITION FITTINGS FOR PE PIPE TO CARBON STEEL PIPE

3.5.1 Fitting materials

A transition fitting is to be manufactured from PE 100 pipe or carbon steel pipe of the same or higher specification to that of the pipes to which it is being joined.

3.5.2 Pressure rating of transition fittings

All fittings shall have a pressure rating not less than that of the piping system within which they operate and comply with the following test requirements for Mechanical Compression Joint Fittings specified in AS/NZS 4129 –

- Pressure test for assembled joints;
- Pull-out test.

3.6 STORAGE AND TRANSPORTATION

Storage and transportation shall be in accordance with AS/NZS 2033 and Section 5 of this code.

Pipe and fittings shall be assessed for transportation damage prior to acceptance.

NOTE: Further information on storage and transportation of PE pipe can be found in PIPA Guideline POP 005 which recommends a maximum of 2 year exposure to heat and sunlight for other than black PE pipe.
4 DESIGN

4.1 BASIS OF SECTION

This section sets out requirements for the design of pipelines, gathering lines, and related components such as isolation valves, branch connections, and connections to above-ground facilities. Materials are limited to pipe and fittings as detailed in Section 3.

Designs for pipelines shall use performance based material properties resulting from established PE industry test results as provided in this Code of Practice. Installation designs shall use service/design factors from established PE industry experience as provided in this Code of Practice. The design shall use established engineering principles to determine stress, strain and creep resulting from the applied loads and ensure that these remain within acceptable limits for the intended life of the pipeline. The design shall satisfy the criteria for risk mitigation identified in relevant Risk Assessment(s).

A structured design process, appropriate to the requirements of the specific pipeline, shall be carried out to ensure that all safety, performance and operational requirements can be met during the design life of the pipelines.

4.2 DESIGN PRINCIPLES

System design uses a mechanism called the “Design Basis” which is detailed below and is pivotal to any design procedure.

This Code of Practice also sets out the methodology for the design of PE100 systems, prescribing a minimum design through the use of design factors as set out in this Section, subject only to the use of risk assessment. There are two mechanisms which can be used either individually or in conjunction to complete a design.

The first and preferred mechanism is “Prescribed Design” and uses a series of formulae and tables derived from theoretical considerations and industry practice.

The second mechanism is called the “Fit for Purpose Design” and relies on a study of a real and present situation and the use of a rigorous risk assessment process to derive one or more of the factors used in the Prescribed Design case.

There is an overarching requirement that the use of the “Fit for Purpose” case is not to be used in any way which would compromise the safety of people, plant or the environment.

4.3 SYSTEM DESIGN

4.3.1 Design Basis

The basis for design of the pipeline, and for each modification to the pipeline, shall be documented in the Design Basis.
The purpose of the Design Basis is to document both principles and philosophies that will be applied during the development of the detailed design, and specific design criteria that will be applied throughout the design.

The Design Basis shall be approved.

The Design Basis is usually an output of the planning and preliminary design phase of a project.

The Design Basis shall be revised during the development of the project to record changes required as a result of additional knowledge of the project requirements as the detailed design is developed and approved.

The Design Basis shall be revised at the completion of the project to reflect the as-built design.

The design process shall be undertaken in parallel with, and as an integrated part of, the safety management process and shall reflect the obligation to provide protection for people, property, the pipeline, and the environment.

As a primary requisite, every pipeline shall be leak tight and have the capability to safely withstand all reasonably predictable influences to which it may be exposed during the whole of its design life.

The design requirements to be considered shall include, but are not limited to the following –

a) Safety of the public, property and pipelines is paramount;

b) Design is specific to the nominated fluid(s);

c) Route selection considers existing land use and allows for known future land planning requirements and the environment, and the presence/location of existing pipelines and facilities;

d) The fitness for purpose of the pipeline and associated equipment;

e) Engineering calculations for known load cases and probable conditions;

f) Nominated limits for pressure, temperature and capacity;

g) Pipeline design shall include provision for maintaining the integrity by —
   • external interference and external loading protection;
   • operation and maintenance in accordance with defined plans;

h) Consideration of the types of changes which would prompt a design review.

The design basis also needs to address the following specific issues –

i) The pipe dimensions shall be in accordance with AS/NZS 4130 Series 1. The Standard provides details of pipe diameters, wall thickness and tolerances and matches pipes to a preferred number SDR series. The SDR shall be selected ensuring that it is no less than that required for pressure containment determined from the design pressure fluid, temperature, installation method.
and location design factors applicable for CSG or PFW (Produced Formation Water) and is suitable for any special construction at all locations along the pipeline length;
j) The pipeline shall be assigned a Maximum Allowable Operating Pressure (MAOP) which shall account for elevation changes, the fluid being carried, the design temperature, the installation method and the location (population density or land use) at all locations along the pipeline length and all pipeline fittings and appurtenances. The MAOP shall not be greater than the maximum determined in Section 8;
k) The design factors are based on a design life of 50 years unless otherwise limited by the material properties and/or temperature design factor table;
l) Extra protection shall be provided where necessary, particularly to prevent damage from unusual conditions such as may arise at road, rail or river crossings, bridges, areas of heavy traffic, from vibration, or the possibility of ground subsidence or other abnormal forces or any other condition that may impact on the integrity of the pipeline;
m) The pipeline shall be pressure tested in accordance with Section 8 to verify that it has the required strength and is leak tight;
n) The battery limits between this Code and design to other standards shall be documented.

4.3.2 Design Basis recording
The Design Basis shall record, as a minimum, the following –
a) A description of the project covered by the Design Basis;
b) Statutory legislation and industry codes and Standards applicable to the pipeline and facilities;
c) Specific physical criteria to be used in the design including at least –
   • design capacity of the pipeline, and, where applicable, the pressure and temperature conditions at which this applies – including initial and final capacity where this is significant to the design;
   • design life of pipeline system as applicable;
   • design pressure(s), internal and external;
   • design temperature(s);
   • fluids to be carried;
   • where required, the maximum fluid property excursion and the duration of any excursion beyond which the fluid must be excluded from the pipeline (e.g. temperature or composition);
d) Materials;
e) Minimum design and installation criteria for the pipeline;
f) Specific process and maintenance criteria to be used in the design including, as a minimum, the following –
   • Operating and maintenance philosophy;
   • Performance requirements for pipeline depressurisation, re-pressurisation, and isolation valve bypass;
   • Pipeline pressure/flow regime established for the pipeline system;
   • Isolation principles;
   • Limiting conditions.
g) Design principles established as the basis of detailed design;
h) Design philosophies established to guide development of the detailed design;
i) The location of facilities and their functionality;
j) Communications and control principles;
k) Inspection and testing principles;
l) System reliability principles.

4.3.3 System design considerations

The design of an overall gathering system shall take into account factors such as –
   • Location;
   • Land usage;
   • Existing pipelines and facilities;
   • Future pipelines and facilities;
   • Licensed pipelines and access requirements.

NOTE: Appendix A provides guidelines on system design layout.

4.3.4 Process design

Process design of the pipeline shall be undertaken in accordance with the system requirements detailed in the Design Basis, and shall include as a minimum –
   • Process Flow Diagrams (PFD’s) and Process and Instrumentation Drawings (P&ID’s);
   • Hydraulic calculations;
   • Transient calculations;
   • Hazops and risk assessments.
The designer may include further activities as deemed necessary for completeness of the pipeline design.

4.3.5 **MAOP\(^3\) and Design Pressure for pipelines**

The actual MAOP of a PE pipeline shall be no greater than the lesser of –

a) the design pressure of the pipeline network;

b) the pneumatic strength test pressure divided by 1.25;

c) for water pipelines hydraulically tested, the lesser of –
   - the hydraulic strength test pressure at the low point divided by 1.25; or
   - the hydraulic strength test pressure at the high point.

d) for gas pipelines hydraulically tested –
   - the hydraulic strength test pressure at the high point divided by 1.25.

The MAOP shall be determined, or calculated, and recorded for each pipeline and/or pressure system.

In the case of PFW pipes, the MAOP shall take into account the effect of the static head of the water due to changes in elevation of the pipeline.

4.3.5.1 **Design Pressure Calculation**

The Design Pressure for the pipe shall be calculated from the following equation –

\[
P \leq \frac{2 \times MRS}{C \times (SDR - 1)}
\]

Where MRS = Minimum Required Strength for the material in MPa.

C = Design Factor (See 4.3.6)

SDR = Standard Dimension Ratio as per AS/NZS 4130 Series 1

NOTE: The MRS for PE compounds is determined in accordance with AS/NZS 4131 and is expressed as a hoop stress in Mega Pascals. The MRS for PE100 is 10.0 MPa. Pipeline Hoop Stress, \(\sigma_h\), is calculated using the following formula:

\[
\sigma_h = \frac{P \times (D - t)}{(2 \times t)} = \frac{P \times (SDR - 1)}{2} \text{MPa}
\]

where: 
P = Design Pressure in MPa

D = Outside Diameter in mm

t = Pipeline Wall Thickness (minimum) in mm

SDR = Standard Dimension Ratio

---

\(^3\) Maximum Allowable Operating Pressure
4.3.6 **Design Factor - general**

The minimum design factor for PE gathering pipelines is based on Appendix B of AS/NZS 4645.3 using the values nominated below.

The Design Factor, C, shall be calculated as follows:

\[ C = f_0 \times f_1 \times f_2 \times f_3 \times f_4 \]

where:

- \( f_0 \) is the material factor
- \( f_1 \) is the operating temperature factor
- \( f_2 \) is the installation method factor
- \( f_3 \) is the risk factor
- \( f_4 \) is the fluid factor

### 4.4 **PREScribed DESIGN**

#### 4.4.1 Other Design Factors

##### 4.4.1.1 Design Factor for Material (\( f_0 \))

The design factor for material is included in the calculation of the overall design factor, “C”. This factor is independent of the fluid and is 1.25 for all fluids.

##### 4.4.1.2 Design Factor for Temperature (\( f_1 \))

The design factor for the associated pipe temperatures shall be in accordance with Table 4.4.1.2.

**Table 4.4.1.2 Design Factor for Temperature**

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>Design Factor, ( f_1 )</th>
<th>Min. potential service life (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤20</td>
<td>1.0</td>
<td>100</td>
</tr>
<tr>
<td>25</td>
<td>1.1</td>
<td>100</td>
</tr>
<tr>
<td>30</td>
<td>1.1</td>
<td>100</td>
</tr>
<tr>
<td>35</td>
<td>1.2</td>
<td>50</td>
</tr>
<tr>
<td>40</td>
<td>1.2</td>
<td>50</td>
</tr>
<tr>
<td>45</td>
<td>1.3</td>
<td>35</td>
</tr>
<tr>
<td>50</td>
<td>1.4</td>
<td>22</td>
</tr>
<tr>
<td>60</td>
<td>1.5</td>
<td>7</td>
</tr>
</tbody>
</table>

At continuous service temperatures above 20°C it shall be assumed the service life will not exceed the minimum potential service lives listed in this Code.

**NOTE:** Definition of minimum potential service life is the expected life when operated at a single temperature. The above values are supported by current test data and should be used in establishing design life.
4.4.1.3 **Design Factor for Installation (f₂)**

The design factor corresponding with the following installation methods shall be in accordance with Table 4.4.1.3

The installation factor shall not be less than 1.0. For installations other than open trench, the factor may be reduced taking into account surface damage and installation loads. Trials may be used to provide guidance to the factor.

<table>
<thead>
<tr>
<th>Installation Method</th>
<th>Installation Factor f₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Trench</td>
<td>1.0</td>
</tr>
<tr>
<td>Plough-in(^1)</td>
<td>1.1</td>
</tr>
<tr>
<td>Directional Drilling(^2)</td>
<td>1.2</td>
</tr>
</tbody>
</table>

**NOTES:**

1. Pipes may be ploughed in by pulling the pipe into the soil cavity behind the plough. Alternatively the pipe can be placed into the soil cavity as the plough moves along thereby minimising damage to the pipe.

2. The appropriate value to be determined by assessing the magnitude of surface damage and longitudinal strain caused by proprietary methods. There are other possible factors to be considered when selecting the installation factor \(f₂\) including tensile loads, critical buckling pressures, long term soil loads and the as-built hydraulic grade. Lower values might be appropriate in some circumstances depending upon, for example, the soil conditions, the equipment being used and the length of the drilling operation. For pipes designed and installed in accordance with "Polyethylene Pipe for Horizontal Directional Drilling - PPI" a design factor of 1.0 may be used.

4.4.1.4 **Design Factor for Risk Classification (f₃)**

The design factor corresponding with the location classifications detailed in Section 4.7.2 shall be in accordance with Table 4.4.1.4.

<table>
<thead>
<tr>
<th>Location Classification</th>
<th>Risk Factor, f₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>PFW, Permeate, Treated Water</td>
</tr>
<tr>
<td>Rural (R1)</td>
<td>1.28</td>
</tr>
<tr>
<td>Rural Residential (R2)</td>
<td>1.40</td>
</tr>
</tbody>
</table>

**NOTE:** Saline water is defined as having > 40,000 mg/TDS (Total Dissolved Salts as determined by laboratory analysis in accordance with CAS number GIS-210-010).

In addition to the above location classification other high risk locations need to be assessed for a suitable risk factor \(f₃\).
These high risk locations can be defined as the following locations within 250 D (a distance of 250 times the nominal diameter of the pipeline) of:

- road and rail crossings;
- creek and river crossings;
- dwellings, plant, buildings, or locations where people gather.

4.4.1.5 Design Factor for Fluid \( f_d \)
The design factor for the fluid transported shall be 1.0 for gas and all water types.

4.5 FIT FOR PURPOSE DESIGN

Subject to the exclusions detailed below, the Code of Practice allows the Operator to design and construct a system to a ‘Fit for Purpose’ design as detailed in this section of the Code of Practice.

4.5.1 Basis for Fit for Purpose Design

This Section sets out the basis for a ‘Fit for Purpose’ design of the flowline or network, which subject to the conditions below, shall be deemed to comply with this Code of Practice. However, nothing in this process is to place any personnel, community, plant or the environment at increased risk.

Fit for Purpose design does not apply to and cannot be used for –:

- the use of the option where it has been excluded by legislation;
- the design of plant piping;
- above ground gas lines;
- the design of above ground PFW lines; or
- the design for toxic fluids.

Examples of where fit for purpose design could be used, subject to the above exclusions, include –

a) PE piping other than PE100;

b) Operating Conditions - pressures and or temperatures outside the scope of this Code of Practice;

c) Fluids other than those covered by the Code of Practice (hydrocarbon fluids with C3+, or hypersaline water);

d) Residential (T1) locations as defined in Section 4.7.2.

4.5.2 Minimum requirements

The minimum conditions under which a ‘Fit for Purpose’ design may be undertaken, and deemed to comply with this Code of Practice are –

a) Where it is inappropriate to use a prescribed design as there are unusual threats, complications or land-use requirements. The
areas of unsuitability shall be documented and included in the design;
b) The fit for purpose design shall be based upon a demonstrated methodology, that complies with international standards, Australian or International experience or research;
c) The design shall be fully documented in a ‘design book approach’ incorporating but not limited to –
   an overview (reason for use);
   basis of design as per (b);
   design calculations;
   threat assessments;
   risk assessments and mitigations;
   construction and test methodology including test factors;
   Operational and Integrity Management Plans.
d) The design shall be approved;
e) The design shall comply with the requirements of the Network Management System and Safety (Section 2), Records Management (Section 9), Commissioning (Section 10) and Operations (Section 11) of the most recent edition of this Code of Practice;
f) The design shall be constructed and tested in accordance with the most recent edition of this Code of Practice;
g) Where appropriate, the design shall be based upon activity agreements with other entities. For example an activity agreement may be considered to contribute to the safety or environmental performance of the design (and the network system) where the owners of adjacent assets are party to the agreement and they have systems in place to comply with the provisions of the agreement.

4.5.3 System Design – Fit for Purpose method

The design factor(s) shall be evaluated subject to the conditions detailed in Section 4.3.5 and 4.4.1. These factor(s) shall not be less than 1.0.

The process for evaluating the design factors shall involve a detailed risk and engineering assessment on the proposed operating and design conditions of the gathering system and be subject to a third party review by a competent designer or assessor. This process needs to be formally approved by the Operator of the CSG gathering network.

The different design factors require specialist evaluation skills. Relevant personnel shall be competent in the specialist subject matter pertinent to the design factor under consideration as detailed in Table 4.5.3.
Table 4.5.3

<table>
<thead>
<tr>
<th>Design Factor</th>
<th>Competency/ Skill to include appropriate tertiary qualifications and relevant expertise</th>
<th>Minimum Personnel involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Factor (f_0)</td>
<td>Resin and pipe manufacturing characteristics</td>
<td>Designers, resin manufacturers, construction personnel</td>
</tr>
<tr>
<td>Temperature factor (f_1)</td>
<td>Resin characteristics</td>
<td>Designers, resin experts</td>
</tr>
<tr>
<td>Installation factor (f_2)</td>
<td>Construction methodology</td>
<td>Designers, pipe/resin experts, construction personnel</td>
</tr>
<tr>
<td>Risk factor (f_3)</td>
<td>Risk management</td>
<td>Designers, EHS personnel, stakeholders</td>
</tr>
<tr>
<td>Fluid factor (f_4)</td>
<td>Resin characteristics, chemistry</td>
<td>Process engineers, resin experts</td>
</tr>
</tbody>
</table>

Examples of this review cover different installation techniques with an \(f_2\) factor higher than 1.0. Test results after installation can be undertaken to prove the integrity of the method of construction. These results can be used to gather evidence for a change in the installation factor.

Another example is for higher temperature conditions than stated in this code. This will impact the factor \(f_1\). Extra testing can be conducted to determine if a higher mean wall temperature can be used and its effect on the strength of the material. This may be needed when pumping brine solutions as tests to date indicate that temperature of the fluid exceeds 85 deg C in some cases.

A further example is for the risk factor \(f_3\). The most significant risk to the CSG gathering systems is mechanical damage by first or third parties.

This code acknowledges that advancements in PE resin composition and properties may provide opportunities to further mitigate the risk of rupture in cases of overpressure events.

The Operator may design and evaluate a defined overpressure excursion other than the nominal 110% of MAOP already stated in this Code of Practice, provided it is evaluated as per the requirements above and Section 4.17.

To provide mechanical protection of the pipeline extra wall thickness in many cases may not be the best solution and extra depth, marker board and/or concrete slabbing may be a suitable method of providing this physical protection. In addition other procedural methods such as extra signage and/or extra warning tape may also be considered to reduce the risk of damage.
4.6 ROUTE

The route of a pipeline shall be selected having regard to public safety, pipeline integrity, environmental impact, and the consequences of escape of fluid due to leakage or rupture.

Route selection shall take into account the location of start and end points, well locations and access requirements, hydraulic requirements based on topography, existing services and infrastructure, and current and future land use. Route selection shall form part of the system design process.

The route of a pipeline shall be selected such that the pipeline can be installed, tested, and operated safely and practically. This includes considerations such as limiting of significant elevation changes, proximity to existing roads and infrastructure and avoiding areas of high land use.

Route selection shall also include the grouping of pipelines into common trenches as appropriate, along with consideration of separation distances where new pipelines are required to cross existing assets.

The presence of existing pipelines shall be identified and documented, along with any requirements to amend existing access arrangements in areas where the new pipeline is likely to closely parallel or cross a licensed pipeline.

4.7 LOCATION CLASSIFICATION

4.7.1 General

The pipeline route shall be allocated location classes that reflect threats to pipeline integrity and risks to people, property and the environment. The primary location class shall reflect the population density. For a new pipeline, the location class analysis shall be based on the land use permitted in gazetted land planning instruments. Although CSG and PFW pipelines are generally located in remote areas, and within mining and/or petroleum leases under the occupation and control of the various lease owners, consideration needs to be given to the surface use of the land (farming, grazing etc.).

Location class analysis of an existing pipeline shall take full account of current land use and authorised developments along the pipeline route, and consideration needs to be given to land use which is planned, but not yet implemented.

4.7.2 Location classification

The pipeline route shall be classified into Location Classes as defined below (adapted from AS 2885.1).

a) Rural (R1): Land that is unused, undeveloped or is used for rural activities such as grazing, agriculture and horticulture. Rural applies where the population is distributed in isolated dwellings. Rural includes areas of land with public infrastructure serving the rural use; roads, railways, canals, utility easements.

b) Rural Residential (R2): Land that is occupied by single residence blocks typically in the range 1 ha to 5 ha or is defined in a local
land planning instrument as rural residential or its equivalent. Land used for other purposes but with similar population density shall be assigned Rural Residential location class. Rural Residential includes areas of land with public infrastructure serving the Rural Residential use; such as roads, railways, canals and utility easements.

c) Residential (T1): Land that is developed for community living. Residential applies where multiple dwellings exist in proximity to each other and dwellings are served by common public utilities. Residential includes areas of land with public infrastructure serving the residential use; roads, railways, recreational areas, camping grounds/caravan parks, suburban parks, small strip shopping centres. Residential land use may include isolated higher density areas provided they are not more than 10% of the land use. Land used for other purposes but with similar population density shall be assigned Residential location class.

4.8 **ISOLATION REQUIREMENTS**

The system shall have sufficient valves and isolation facilities as required to enable regular operation and maintenance activities, and limit exposure in the event of a controlled or uncontrolled release. The position, type and spacing of valves and isolation facilities shall be approved.

The location of valves shall be determined for each pipeline. An assessment shall be carried out and the following factors shall be considered –

a) The fluid;
b) Security of supply required;
c) Response time to events;
d) Access to isolation points;
e) Ability to detect events which might require isolation;
f) Consequences of fluid release;
g) Volume between isolation points;
h) Pressure;
i) Operating and maintenance procedures.

Valve selection shall provide the appropriate level of isolation and leak tightness based on the fluid in the pipeline and the location. Location may include end-of-line or intermediate stations, and shall also take into account above or below ground installation.

If a PE pipeline is designed to be “piggable”, valve selection must be limited to full bore through-type (ball, through-conduit gate, etc).

Valves shall be installed so that, in the event of a leak, the valves can be expeditiously operated. Consideration shall be given to providing for remote operation of individual valves to limit the effect of any leak that may affect public safety and the environment.
4.9 DEPTH OF COVER

PE pipelines shall be buried at a minimum depth of cover as shown in table 4.9 below except where specific circumstances exist which would justify a lesser depth. For example, depth of cover may be reduced in areas of rock, or where the conditions may make the installation risk greater than the expected risk reduction. Depth of cover may also be reduced where one pipeline crosses an existing pipeline operated by the same Operator, and the Operator has full control over pipelines in that area.

The basis for the specific circumstances where depth of cover is reduced shall be assessed and documented in the Safety Management Study and shall be approved. Additional controls shall be implemented.

Small diameter pipelines (DN160 and less) may be buried at reduced depths of cover (not less than 600mm) subject to a risk assessment confirming no decrease to safety and pipeline integrity.

Table 4.9

<table>
<thead>
<tr>
<th>Location Classification</th>
<th>Gas and all water types Minimum Depth of Cover (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>750</td>
</tr>
<tr>
<td>Rural-Residential</td>
<td>900</td>
</tr>
</tbody>
</table>

The depth of cover shall be increased as required to provide additional protection based on the pipeline Safety Management Study completed in accordance with Section 2. (Further guidance is provided in Appendix H). A pipeline closer than 250D (where D is the nominal diameter of the pipeline) to any of the locations listed below will need to be considered in the Safety Management Study and additional protection will need to be provided as determined by the Safety Management Study –

- Road and rail crossings;
- Buildings, plant and locations where people gather.

Subject to the Safety Management Study and the required design life, PFW pipelines may be installed above ground within the plant or pond areas. Consideration shall be given to potential temperature increases during periods where the pipeline may be static (no flow) or out of service.

4.10 RESISTANCE TO MECHANICAL DAMAGE

The pipeline shall be analysed to determine its risk to mechanical damage based on location, land use and depth of cover. Where required, the depth of cover shall be increased or suitable protection placed above the pipeline. Land use shall include the frequency and type of deep blade ploughing regularly undertaken on rural properties.

External interference protection shall consider physical measures to prevent personnel access to the pipeline in the vicinity of the CSG well-heads.
As PE pipelines have very little resistance to external interference, additional “early warning” physical measures such as tracer wire and marker tape should be used to assist in non-intrusive pipeline detection and early warning confirmation during exploratory dig-ups.

4.11 SEPARATION

Separation of pipelines shall be adequate to address design aspects related to –

- constructability;
- future tie-in requirements;
- maintenance;
- emergency response, especially related to the use of “squeeze-off” equipment.

4.11.1 Adjacent parallel pipelines

Where pipelines are grouped in a common trench and are servicing various utility providers/owners the minimum separation distances shall be used as shown in Table 4.11.1. Where pipelines within a common trench are operated by an individual Operator, the Operator may choose to deviate from the following separation requirements based on Risk Assessments.

Table 4.11.1 Minimum Separation Distances

<table>
<thead>
<tr>
<th>External diameter (mm)</th>
<th>Minimum Spacing (mm)</th>
<th>Preferred Spacing (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤315</td>
<td>200</td>
<td>300</td>
</tr>
<tr>
<td>&gt;315, ≤450</td>
<td>300</td>
<td>400</td>
</tr>
<tr>
<td>&gt;450</td>
<td>300</td>
<td>500</td>
</tr>
</tbody>
</table>

Where pipelines of different diameters are used, spacing shall be determined based on the average diameter of the two.

The separation distances may need to be increased should they prove to be insufficient for installation and maintenance purposes.

4.11.2 Vertical separation of crossing PE pipelines

Pipelines crossing within a gathering system network should be avoided where possible but, where necessary, adequate spacing should be allowed for construction, maintenance and emergency response purposes.

The minimum vertical separation between pipelines shall be 300 mm. This separation shall be filled with compacted embedment material.

Where 300 mm separation is not possible, or is impractical, the separation may be reduced to a minimum of 200 mm based on a Risk Assessment and
with the agreement of the Operator(s) concerned. Compressible packing (e.g., expanded polystyrene) shall be used between the pipes to reduce the risk of point loading.

4.11.3 Foreign crossings

PE pipelines may cross a variety of other services including fibre-optic, telephone and electrical cables, high pressure gas steel pipelines and other gas and water PE gathering lines. Adequate separation shall be maintained, with a minimum of 300 mm, and other precautions similar to Section 4.11.2 (above) may be used.

Where necessary, specific attention should be directed to the provision of additional buried marker tapes and/or marker posts at these locations.

4.12 SPECIAL CONSTRUCTION

Special construction methods apply to sections of the pipeline that are not generally formed from full pipes joined together and laid in a trench at normal cover.

Because these sections are location and pipeline specific, each application requires special consideration to identify and analyse factors that exist at the location and to develop special designs that are adequate to protect the pipeline from the threats that do, or may, exist at that location.

4.12.1 Above-ground or reduced cover systems – (gas excluded)

PE water pipelines and assemblies may be installed above-ground or at reduced cover within a facility or other location where public access is excluded by security fencing or equivalent measures. Designs shall consider issues such as increased temperature and UV degradation and include appropriate protective measures.

Above-ground systems shall be installed to provide protection and support for the PE material. Installations shall also include measures for temperature control to ensure the material does not exceed its maximum rated temperature due to environmental effects. This includes special start-up sequences to cool the PE material when surface temperatures result in the pipeline strength being too low to provide suitable pressure containment.

Where PE is installed with reduced cover, the basis for the reduced cover shall be assessed and documented in the Safety Management Study.

4.12.2 Installation of pipes on a curve

PE piping can be safely installed by pulling it round curves to accommodate direction changes using methods described in the PIPA guideline POP 202. Jointing by butt fusion or electrofusion should always be done on straight pipes.
4.13 **DESIGN FOR EXTERNAL LOADS AND SEISMIC SURVEY ACTIVITY**

External loads may be imparted onto the pipeline by various forms of dead and live loads. However, for axle loads ≤120 kN no action is needed provided the depth of cover is >0.75 m and the SDR is ≤21.

For axle loads >120kN and/or SDR>21, an engineering assessment shall be required. The assessment shall be approved.

External pressure loads may also be imparted onto PE pipelines as a result of seismic surveys or other underground blasting being conducted in the local area. Blast loads are seen as a potential threat to a pipeline, and shall be appraised during the risk assessment.

NOTE: PE pipes have performed better than other materials installed in earthquake zones.

Reference documents such as “PRC – Pipeline Response to Blasting – PR-15-712” and “US RI 9523 – Surface Blasting near Pressurised Pipelines”, although not strictly applicable to PE pipelines, may be used as a guide for consideration of seismic loads.

4.14 **PIPELINE ROUTE MARKING**

Pipeline route design and planning shall include the installation of markers to identify the location of PE pipelines.

Both gas and water pipeline marker signs shall comply with Section 5.13.

4.15 **RISER AND VALVE ASSEMBLIES**

Above-ground valve assemblies shall comply with the requirements of ASME B31.3 or AS4041 for gas and PFW.

Underground valve assemblies shall be buried in accordance with the manufacturer’s instructions. Provision shall be made for operational and maintenance access to buried valve assemblies.

Location of risers, low point drains and high point vents shall be included on the alignment sheets. The design process shall include provision for capturing and draining liquid from low point drains.

Consideration shall be given to the locking and/or removal of valve operators to prevent unauthorised operation.

Above-ground valve assemblies and risers (including High Point Vents or Low Point Drains) shall comply with the requirements of ASME B31.3 or AS4041 for Gas. PFW, Saline water and Permeate water installations shall comply with the requirements of the Water Services Association of Australia WSA 03.

Atmospheric vents on PFW lines are to be used in rural locations only, and preferably a minimum of 100m away from the property line of rural- residential and residential areas.
4.16 **STRUCTURAL DESIGN**

Structural design of pipelines shall take into account all expected stresses and loads which may impact on the pipeline during its lifetime. Transitions from surface to sub-surface should particularly be addressed. Further information can be found in PIPA guideline TP010/1 “Flexible pipe design”.

4.17 **OVER PRESSURE PROTECTION**

PE pipelines shall be equipped with facilities to prevent pressures rising above 110% MAOP. The number, type, and location of over-pressure devices shall be documented and approved. Over-pressure design shall ensure the pipeline does not exceed MAOP under normal operating pressure scenarios.

The MAOP of a pipeline can be exceeded by up to 10% for transient situations subject to the pipeline having been tested to 125% of MAOP. However, pressure controllers must not be set to operate continuously at pressures above MAOP.

Operators may nominate an overpressure excursion limit beyond the 110%, for a defined period, given they comply with the requirements of the “Fit for Purpose” assessment detailed in Section 4.5. In such cases the system shall be qualified by pressure testing to 125% of nominated excursion limit. See Section 8 for details of pressure testing.

Pressure control and over pressure protection shall include events during normal and abnormal operating conditions.

Where any pressure control or overpressure protection will discharge fluids from the pipeline, the discharge shall be safe, have minimal environmental impact and not impair the performance of the pressure control or over pressure protection system. Risks associated with liquid discharge shall be managed to ALARP.

4.18 **OVER-TEMPERATURE PROTECTION**

Over-temperature protection is not generally required for CSG PE gathering lines.

For PFW pipelines, over-temperature monitoring and/or protection shall be incorporated in locations and services where excess temperature is likely to reduce the PE strength to a point where pressure integrity may not be guaranteed (e.g. above-ground pipelines in hot conditions).

The design and selection of over-temperature protection systems shall be documented and approved. Consideration may be given to a system which initially cools the PE material prior to introduction of pressurised fluids.
4.19 TEMPERATURE CONSIDERATION FOR PE PIPELINES

4.19.1 Temperature re-rating

The pressure rating of PE pressure pipe shall be based on the temperature of the pipe wall, which may be determined from –

a) an assumption of a constant pipe wall temperature typical for continuous service at a set temperature;

b) the determination of a mean service temperature where temperature variations are likely to occur in a predictable pattern; or

c) the maximum service temperature less 10°C for installations where large unpredictable temperature variations occur up to a maximum of 60°C.

For installations where predictable temperature variations occur, the average material temperature shall be determined from Item (a) or Item (b) above as follows –

- Across the wall of the pipe, the material temperature taken as being the mean of the outer and inner pipe wall temperatures. These can be approximated by measuring the internal (fluid) and external (ground/ambient as appropriate) temperatures;

- For pressure and temperature conditions where flow is stopped for prolonged periods so that fluid temperature and outside temperature may equalise, a time weighted mean temperature may be determined.

4.19.2 Provision for expansion and contraction

For fully welded buried PE pipe there is generally no need to allow for thermal expansion and contraction.

For PE100, the value of the thermal expansion coefficient used in calculations shall be 20 x 10^{-5}/ °C.

4.20 STATIC ELECTRICITY

For CSG PE gathering lines where the gas generally has a high moisture content, static electricity is not generated.

Other areas of the pipeline identified as having potential for static build-up shall be treated as hazardous areas in accordance with AS/NZS 60079.

AS4645.3 Section 5.3 may be used as a guideline for design against the effects of static electricity.

4.21 EFFECTS OF PRESSURE SURGE – WATER ONLY

Systems for water shall be capable of withstanding surge or transient loads experienced in the events of pump start-up, shut-down, and unexpected trips or valve closures.
Refer to PIPA Guideline POP 010A for information about the fatigue resistance of PE pipes, which can result from multiple surge events.

Where required, the system design should be supported by transient analyses to identify areas of high surge potential, and determine appropriate restraining mechanisms. Such analyses may be undertaken in conjunction with those for determining over-pressure protection requirements.

Pumps, valves (including opening and closing rates), pipe diameter and flow velocity shall be selected to minimise the possibility of surge events.

Consideration shall also be given to the fitting of such devices as pressure accumulators (pneumatic or hydro-pneumatic) to mitigate water hammer from transient loads and/or air/vacuum valves to mitigate vacuum re-closure water hammer.

4.22 EFFECTS OF VACUUM – WATER ONLY

Where potential vacuum effects cannot be avoided, PFW pipelines shall be designed to resist buckling under full vacuum.

PFW pipelines contain a mixture of water and gas. Design of external protection devices should ensure that air is not introduced into the pipeline in quantities which may give rise to an explosive atmosphere.
5 CONSTRUCTION

5.1 BASIS OF SECTION

The Operator shall be responsible for ensuring that the pipeline construction and the completed installation are in compliance with the engineering design and the following –

a) Construction shall be carried out to ensure the safety of the public, construction and operating personnel, equipment, adjacent property and the pipeline;

b) During construction care shall be taken to minimise damage to the environment;

c) On completion of construction any necessary restoration along the route shall be carried out to minimise long-term degradation of the environment;

d) Construction personnel shall be competent and where required, qualified for their task.

5.2 DEVELOPMENT OF SPECIFICATIONS AND PROCEDURES

The following criteria shall form the basis for developing specifications and procedures for installing a pipeline in a trench, and covering it –

a) Where the trench bottom is free of rocks, stones or other material with an angular profile that may cause damage to the pipe and the trench profile enables continuous contact with the pipe, the pipe may be laid directly on the bed of the trench;

b) Where the trench is required to be bottom padded prior to lowering the pipeline into the trench then the material used shall be selected or screened excavated material or imported fines;

c) Unless other provisions are made, the installed pipe shall be supported (restrained) in its intended position by the trench and the compacted backfill;

d) Backfilling shall give adequate compaction around the pipeline and shall minimise subsequent soil movement;

e) Compaction shall be done to ensure that no induced stress is placed upon the pipe;

f) Where backfill material contains rocks or stones that could damage the pipeline, care shall be taken to prevent such damage;

g) Where a trench is flooded with water to consolidate the backfill, steps shall be taken to ensure that the pipeline does not float from its firm bearing on the bottom of the trench;
h) The backfilling shall be placed in a manner that shall not result in future subsidence;

i) Precautions shall be taken to avoid the trench becoming a drainage path;

j) The backfilling materials surrounding the pipe shall protect the pipe both during installation and through subsequent operation;

k) The permeability of the backfilled and compacted trench shall be similar to that of the unexcavated material to minimise drainage along the trench invert, and potential ‘tunnel’ erosion;

l) The standard of compaction shall be sufficient to deliver the required engineering properties of the backfill.

5.2.1 Soil inversion

Soil inversion during backfill shall be prevented and, where specified, backfilling shall control excavated material and return it to the trench in the sequence that it was removed.

NOTE: Where long sections of a pipeline that has been jointed alongside a trench are lowered into the trench, care shall be taken not to jerk the pipeline or impose any stresses that could kink or cause a permanent bend in the pipeline. Slack loops or snaking can sometimes be used to reduce induced stresses.

5.3 SURVEY

5.3.1 General

A survey should be made to locate the pipeline relative to permanent marks and benchmarks complying with Mapping Grid of Australia (MGA94) or other approved datum. The construction survey shall adopt the same marks and benchmarks as used in the engineering design unless otherwise approved.

The survey shall develop sufficient information on the constructed pipeline to satisfy the materials traceability requirements of this Code. Where the pipeline centre-line is straight, the survey shall establish the location of at least every fifth weld, the weld sequence, and the pipe number sequence.

More frequent survey locations should occur at road crossings, rail crossings, river crossings, creek crossings and other featured crossings, change of direction, fence-lines and boundaries.

Where a sequence of reference points for location of the network using Global Positioning Systems (GPS) co-ordinates exists, it may be used for reference only.

The existence of services, structures, and other obstructions in or on the route shall be checked, identified, and recorded before construction begins, and the location of these shall be recorded in the as-constructed survey record.

5.3.2 Survey Accuracy

The survey shall establish the coordinates that locate the pipeline as suited to the location and the engineering design. The uncertainty of the X-Y coordinates shall not exceed ±100 mm.
The uncertainty of the as-built cover shall not exceed ±50 mm. Where approved in R1 Location Classes remote from third-party activity this tolerance may be relaxed, but where relaxed, the X-Y uncertainty shall not exceed ±500mm. Where the survey is required to establish the elevation of the pipe, the accuracy of the elevation measurement shall be documented.

NOTES:

1. It is preferred that the recording of the pipeline shall be in X-Y-Z co-ordinates to the highest tolerance achievable by Real Time Kinematic (RTK) GPS Survey equipment utilising dual frequency receivers
2. Where survey is by GPS methods, the accuracy of the elevation measurement is poor unless high quality differential GPS instrumentation is used.

5.3.3 Installation by Trenchless Construction

Where a section of the pipeline is installed by trenchless construction methods, an as-built survey shall be undertaken to establish the position of the installation in X-Y-Z coordinates.

As a minimum—

a) the deviation from the design X-Y coordinates shall not exceed 0.4 degrees measured from the coordinates of the pipe string at the start and the end of the drill;

b) the survey shall be coordinated with the survey coordinate system used for the pipeline; and

c) the accuracy limits of the as-built survey shall be defined on the as-built alignment sheets (and/or GIS).

5.3.4 Records

A record of surveys shall be made so that, after the pipeline has been constructed, an accurate record of the constructed pipeline can be made to show the precise location of the pipeline and its related facilities and should include, as a minimum, weld numbers and pipe numbers for identification.

The Operator shall provide the unique weld numbering format to be used on their projects.

NOTES:

1. Data should be in digital format, suitable for incorporating in a geographic information system (GIS).
2. Electronic and paper records of the as constructed design may also be required.

5.4 TRANSPORT, HANDLING & STORAGE

5.4.1 General

PE pipes are relatively light and flexible, but are susceptible to damage from sharp objects and stones, or if dragged or subjected to rough handling during loading, transporting and unloading operations.

Pipes may be nested for transport or storage provided that permanent distortion does not occur.
Additional information on storage, transport and handling of PE pipes may be found in POP 005. In particular, attention is drawn to the dangers associated with energy stored in coiled pipes.

### 5.4.2 Handling

Pipes and other components shall be handled, transported, and stored in a manner that will provide protection from physical damage and other types of deterioration.

In particular—

a) pipes shall be stacked to prevent excessive localised stresses and to minimise damage;

b) supporting blocks and bearers shall not damage pipes;

c) pipes that may be subjected to damage from traffic shall be located either at a safe distance from the traffic or be guarded by protective barriers;

d) temporary stockpiles shall be designed, operated and managed to protect the pipe from damage during storage and handling;

e) temporary stockpiles should not be located in areas where environmental damage may occur;

f) stringing, joining and lowering-in operations, shall be designed and managed to protect the pipe from damage;

g) during lifting, the pipes shall be adequately protected to prevent damage such as scoring and crushing; and

h) sharp sections bearing against the pipes shall be avoided as these can cause indentations in, or scoring of, the pipe wall.

### 5.4.3 Storage

In the storage and issuing of pipes, the principle of ‘first in, first out’ needs to be considered.

Pipes stacked for transport or storage shall be adequately supported to avoid distortion. This shall include adequate support and protection utilising bolsters, timbers or other means to alleviate the potential for damage during transport and storage.

Safety and handling shall be considered with respect to stacking height, taking into account surface and climatic conditions. Bundled packs of pipe should be stacked in a suitable manner to allow the use of mechanical loading and unloading equipment without the risk of accidental damage to the pipes.

Pipes shall be stored in a manner to prevent damage from elevated temperatures, contact with chemicals, and prolonged exposure to direct sunlight and distortion. Stored pipes shall be covered to prevent exposure to direct sunlight over long periods, as degradation of the material may occur. Pipes other than plain black should not be stored for more than 24 months unless protected from direct sunlight.
NOTE: Striped pipes are nevertheless considered suitable for above-ground usage carrying water within a facility as described in Section 4.9.

Pipes stacked in small quantities at work sites and along the route of the work may be placed directly on flat, smooth ground provided it is free from hard, sharp objects which could cause damage to the pipe.

5.4.4 Coils
PE pipe may be stored and transported in coils. In uncoiling, care shall be taken that sharp objects do not score the pipe. When stored for use on a work vehicle, pipes should be uncoiled on a dispensing reel.

Coiled pipe shall be stored on a flat surface and only to such a height that the bottom layer does not become distorted. Care shall be taken when uncoiling the pipe and the movement of the ends of the pipe should be controlled to prevent whiplash.

Additional information on storage, transport and handling of PE pipes may be found in POP 005. In particular, attention is drawn to the dangers associated with energy stored in coiled pipes.

5.4.5 Drums
Stored energy is found in drums as with coils, except that the pipe is under more control when it is restrained on a drum.

Drums are very heavy and must always be handled with the appropriate equipment.

Drums must be stored on flat, stable ground to make sure they will not topple over, and should be controlled by the use of chocks to ensure they do not roll out of position.

When lifting drums from the vehicle, they should be lifted by use of a strap placed under the plate carrying the pipe, and not through the outer rim of the drum, as this will bend the rim inwards and damage both the drum and the pipe.

If lifted by a fork, the tines should be fitted inside the drum under the cross members, making sure the length of the tine is sufficient to fit through the drum to support both sides.

Under no circumstances should a drum be allowed to drop from the back of a vehicle on to the ground, or even on to a stack of tyres or other buffer system.

When lifting steel drums, care must be taken to make sure they do not come in contact with overhead wires.

5.5 STRESSES INDUCED DURING LAYING
Laying stresses induced in the pipeline during construction shall be minimised. The trench bottom shall be constructed to provide a uniform padding for the pipeline and shall be free from stones or hard, sharp material which could damage the pipeline.
Where long sections of pipeline that have been jointed alongside a trench are lowered into the trench, care shall be taken not to jerk the pipeline or impose any stresses that could kink or cause a permanent bend in the pipeline. Slack loops or snaking can sometimes be used to reduce induced stresses.

5.6 **CLEARING AND GRADING**

Clearing and grading shall be carried out in accordance with the EMP and other required approvals.

The route shall be cleared to the width necessary for the safe and orderly construction of the pipeline. The cleared width shall not exceed the permissible width of the Right of Way.

Where a route is graded, permanent damage to the land shall be minimised and soil erosion prevented.

In developed farmland, liaison with property owners is to be maintained to minimise disruption to farming activities.

**NOTE:** Where possible the Right of Way should be located alongside existing or new roads to minimise overall disruption to the location amenity.

5.7 **STRINGING OF PE PIPES**

PE pipe shall only be strung on to areas of the Right of Way where clearing and grading is complete.

When pipe is strung from end to end, adequate provision shall be given to allow for access by property owners, fauna and construction traffic. This could be by leaving a gap or providing alternative access that does not hinder users.

5.8 **WELDING OF PE PIPES**

Pipeline Operators shall establish a unique weld numbering system so as to identify each production weld and tie-in for traceability records.

Each pipe shall be internally and externally inspected to ensure compliance with wall thickness and end preparation requirements.

Additionally each pipe shall be internally inspected for any obstructions that might prevent the operation of the pipeline. These, together with any grit or dirt that might interfere with the joining process, shall be removed prior to welding.

The welding process for PE pipe shall be nominated and approved by the Operator prior to welding procedures being developed and prior to commencement of any PE welding.
5.9 TRENCH CONSTRUCTION

5.9.1 Safety
Excavation shall be performed in a safe manner. Damage to buried services, structures and other buried pipelines shall be avoided.

Blasting shall be carried out in a safe manner and in accordance with AS 2187.2 and statutory requirements.

5.9.2 Separation of topsoil
Where required, topsoil from trenches shall be stored separately from other excavated and backfill materials.

NOTE: Consideration needs to be given to preventing the transfer of noxious weeds.

5.9.3 Dimensions of trenches
The width of trenches shall be sufficient to allow pipelines to be installed in position without being damaged and to permit full consolidation of padding and backfill material.

Statutory separation requirements shall be considered when establishing the trench dimensions.

5.9.4 Bottoms of trenches
Where a pipe is installed in a trench, the bottom of the trench shall be free from cave-ins, roots, stones, rocks and other debris that could cause damage to the installed pipe.

5.9.5 Scour
Where scour could occur in a trench, barriers shall be installed to prevent scour. Barriers shall be built of masonry, non-degradable foam, sandbags or other approved material.

5.10 INSTALLATION METHODS

5.10.1 General
The installation methods, materials, compaction and restoration shall support and protect the pipeline for its design life.

A pipeline shall have a firm continuous bearing on the bottom of the trench or padding and rest in the trench without the use of an external force to hold it in place, until the backfilling is completed.

5.10.2 Installation requirements
A typical pipe installation requires the following –

a) The trench profile to be designed to achieve the design cover and to minimise bending, maintain minimum separations from parallel
pipelines and trench wall while recognising landform and other constraints, including environmental objectives;

b) Pipe bedding if required;

NOTE: This Code does not specifically require pipe bedding for PE pipe systems.

c) Installing the pipe;

d) Covering with shading material to secure the pipe in position and protect the pipe from damage;

e) Application of backfill;

f) Backfill compaction.

5.10.3 Trenchless Construction

Trenchless construction is a type of subsurface construction technique that employs materials, methods and equipment to install a pipe or casing between two defined points where it has been determined that the usual open cut trenching or ploughing will cause an unacceptable impact on a project, community or environmental level. The range of trenchless techniques discussed can be categorised into the following subsets:

- Horizontal Directional Drilling;
- Micro Tunnelling (Closed Face);
- Auger or Thrust Boring (Open Faced).

In all cases, the profile and layout design shall be performed by qualified engineers with relevant design experience.

The choice of method requires consideration of the crossing configurations, soil characteristics and any possible loads that may be applied to the pipe as a result of sub-terrain conditions or surface activities. Utility authorities may dictate which methods are permitted for the crossing. All trenchless construction methods ultimately excavate a horizontal hole between two defined points into which a product pipe is inserted. A casing pipe may be inserted first where necessary. The pipe is pushed or pulled into position depending on the trenchless method being adopted.

Each trenchless construction technique has its own suite of considerations; however the following are applicable to all techniques –

- Operational Considerations. Trenchless construction is a minimal surface impact technique. Consider access if the pipeline or service needs to be removed or attended to.
- Competency of personnel.
- Signage and third party awareness.
- Pipeline pressure ratings or de-ratings according to the construction method used.
- Solids build up in low points.
• Pressure pre-testing. Fabricated pipe strings to be used in a trenchless construction installation shall undergo a pressure pre-test in accordance with Section 8 of this Code of Practice.

• Pressure testing. A post installation pressure test shall be conducted as per Section 8.

• Geotechnical survey requirements. This may include investigating environmentally sensitive areas.

• Casing pipe requirements. Jacking loads during installation can mean that PE pipes are unable to be used as single pass systems.

• Site investigations (topographical surveys, hydrographic surveys, etc.)

• Sub-surface investigations (test holes/bores, soils analysis, etc.)

• Safety (machine safety practices, entry into excavations, exposure to chemicals used in drilling, high pressure fluids, etc.)

Further advice and discussion on the different techniques is available from the Australasian Society for Trenchless Technology at www.astt.com.au.

5.10.3.1 Horizontal Directional Drilling

Horizontal Directional Drilling (HDD) is a form of trenchless technology. HDD is used for the installation of pipes and utility lines and is characterised by its use of a surface-mounted drill rig that launches and places a drill string at a shallow angle to the surface and has tracking and steering capabilities.

The utilisation of HDD is intended to minimise surface damage, restoration requirements, and disruption of vehicular or maritime traffic with little or no interruption of other existing lines or services.

When proposing to use HDD the following should be considered –

• Subsurface conditions. (Considerations should be adequately determined and the drill path should be aligned horizontally through a geological stratum that is stable, homogeneous, and devoid of gravelly soils, loose deposits and discontinuities.)

• Steering and drill rod constraints (typically for design, the radius of curvature should not be less than 1200 times the drill rod diameter).

• Drill path profile and trajectory including specification of drill entry point, drill exit point and radius of curvature.

• Entry and exit tangent section lengths (including entry tangent casing to prevent inadvertent near surface returns).

• Analysis of stresses for selected drill path.
PE pipe shall be selected to withstand loads and stresses as follows –

- Operational and installation loads including internal (operational) pressure loads, external (operational) hydraulic and earth loads, and net external pressure.
- Pipe resistance to earth loads including pipe deflection (ovality) and unconstrained collapse.
- Axial bending stress, axial tensile stress and torsional stress
- Pulling force including pipe stiffness, coefficient of friction, effective weight and buoyancy forces, hydrokinetic pressure, and special considerations for bundled pipes (where applicable).
- Combined loads during installation including reduced PE collapse strength and thermal effects.
- Combined loads during operation including thermal stresses.
- Removal of the external butt weld bead should be considered where the carrier pipe is to be installed in a casing.
- A visual inspection of the first 2 metres of carrier pipe pulled through the exit point (drill entry point) should not show signs of yielding or other damage. Gouges or scratches shall not exceed 10% of the minimum wall thickness.
- Grouting may be specified to fill the annulus between the drill hole and the carrier pipe (or between the casing pipe and the carrier pipe).
  NOTE: Grouting pressures need to be carefully monitored to ensure that pipe buckling is avoided. Consideration should be given to filling the pipe with water during the grouting process.
- Gauging to demonstrate that the ovality limits as per the design criteria are met may be specified.

NOTE: ASTT “Guidelines for Horizontal Directional Drilling, Pipe Bursting, Microtunnelling and Pipe Jacking”, ASTM F1962 and Chapter 12 of the PPI PE Guidelines Handbook provide guidance on methods used in the design and selection considerations of PE pipe for HDD. It is recognised that there are circumstances where a suitable PE pipe is not available (due to limits in SDR) to satisfy stress criteria for the installation. In this case, it is recommended that the full crossing be cased using a casing of suitable material (typically carbon steel).

5.10.3.2 Microtunnelling (Closed Face)

Microtunnelling, sometimes called “closed face” boring, is a form of trenchless construction that employs a remotely operated Microtunnelling Boring Machine.

Microtunnelling is typically used in situations where a pipeline needs to traverse under rail, road or other sensitive features and the geology is un-cohesive, granular and water charged.

The limitations and disadvantages of microtunnelling are listed below –

- Microtunnelling must be installed on a relatively flat and constant grade. This results in the process requiring pits or shafts at either end.
- Microtunnelling is unable to negotiate tight vertical or horizontal curves.
• Microtunnelling requires elaborate machinery to conduct and support the process which has an impact on time and cost.

When proposing to use Microtunnelling the following should be considered –

• Geology and hydrogeology;
• Pipeline / tunnelling alignment;
• Design and construction method of pit / shaft and thrust wall construction;
• Design and construction method of launch and reception seals;
• Design and construction method of carrier pipe spacers and annulus grouting;
• Approvals from the client and all relevant third parties (e.g. road, rail and environmental authorities) for the use of this method;
• Settlement monitoring of sensitive structures and a comprehensive contingency plan for settlement problems.

5.10.3.3 Auger Boring or Thrust Boring (Open Face)

Auger Boring is one of the oldest trenchless methods for installation of pipe sections under obstacles. The bore is formed from a launch pit by means of an open faced rotating cutting head that is pushed through to a receiving pit. Typically the rotating head is hydraulically pushed through and the soil removed back to the launch pit by helical auger sections as the casing is jacked into place. This method only offers limited steering capabilities and limited length and is normally used when precise accuracy or length is not crucial.

When proposing to use Auger Boring the following should be considered –

• Auger Boring tends to be suitable for straight, uncontrolled drives in softer ground, although some systems offer limited steering capability and rock conditions can be possible with specialised equipment.
• Ground conditions may mean limitations in terms of depth and capability particularly in high water table areas.
• Auger Boring does not normally install carrier pipes directly but installs casing pipes.
• Launch pit dimensions for auger boring machines may mean access requirement limitations and the use of large bell holes and shoring equipment
• Disadvantages include limited bore lengths and an inability to avoid obstacles in the bore path.
5.11 THERMAL EXPANSION AND FLEXIBILITY

5.11.1 Installation of pipelines in extremely hot or cold weather

The high thermal linear expansion factors of plastics need to be taken into consideration when laying PE Pipelines on extremely hot or cold days.

To limit the effects of expansion and contraction, pipelines shall be protected from direct sunlight wherever possible, and final connections of the pipeline to existing systems shall be performed only after the pipeline temperature has stabilised.

NOTE: The coefficient of thermal linear expansion for PE pipe is \( 20 \times 10^{-5} \, \text{C}^{-1} \), nearly 10 times that of steel \( (30 \times 10^{-6} \, \text{C}^{-1}) \).

5.11.2 Covering ends

Ends of pipeline shall not be left open in the trench between working periods, but shall be closed with caps or expandable plugs to prevent the entry of animals, water or foreign matter, until work is resumed.

Where two or more lengths of pipeline are to be jointed together above ground, the ends shall be covered at all times that the job is left unattended. At the conclusion of each day's laying, open ends of pipelines shall be sealed and sections being welded shall be covered.

5.11.3 Cleaning internally

The entry of dirt, water or other substances into pipes during construction should be avoided. The internal wiping of the pipe prior to welding should be sufficient to achieve the desired cleanliness.

If the level of cleanliness has not been achieved and where pipelines are piggable, the pipeline shall be cleaned internally prior to tie-in and commissioning.

5.12 POSITIONING

5.12.1 Alignment

Pipelines should be laid as true to line. Any significant deviation shall be recorded.

5.12.2 Structures

Pipelines shall not be installed under structures and foundations where—

a) the integrity of the pipeline will be affected;

b) the integrity of the structure or foundation will be affected; or

c) a gas leak may accumulate in a confined space.
5.12.3 **Installation of Above-Ground Pipes**

Any installation of above-ground pipework for PE must be to the requirements set by the Operator. Above-ground carbon steel pipework shall comply with the relevant standard.

**NOTE:** Above-ground PE installations are not permitted for gas pipework.

### 5.13 **MARKERS, MARKER TAPE, TRACER WIRES**

#### 5.13.1 *Tracer Wire*

When installing a pipeline in an open trench, a detectable wire and marker tape, or a detectable marker tape or a marker board shall be installed above the pipeline, to enable the location of the pipeline to be traced with a pipe locator, and so reduce the likelihood of damage during future excavations in the vicinity of the main or service.

Tracer wire should be durable and connected using an approved technique acceptable to the Operator.

When the pipeline is installed using boring techniques only tracer wire needs to be installed.

Tracer wires shall not be electrically connected to a source of electrical current for which they are not designed. This includes steel pipelines and any earthing or grounding systems and risers.

#### 5.13.2 *Pipeline marker signs*

This Code mandates the placement of markers for each buried pipeline at a wide range of specific locations. Pipeline marker signs shall comply with the requirements for safety signs in accordance with AS 1319, “Safety Signs for the Occupational Environment”.

The purpose of pipeline markers is to alert people, who are planning to work near a pipeline but have not contacted the pipeline Operator, to the presence of the pipeline, and the possible consequences of damaging it.

Effective pipeline marking applies these rules regardless of land use in the area, including in remote areas. Commonly used marker styles, listed in descending order of effectiveness, are the following –

- **a)** Large cylindrical signs mounted at eye level;
- **b)** Large double-sided flat signs mounted at eye level;
- **c)** Large single-sided signs mounted at eye level;
- **d)** Small flat signs at low level, or short tubular signs.

**Notes:**

1. In land subject to cultivation where the required sign placement (as per Section 5.13.3) is unacceptable to the landowner or cannot be maintained, an acceptable alternative is to place an appropriate sign at fence lines and at every gate giving access to the cultivated area. Elsewhere on the property, signs need to be placed on the ROW as close as practical to the edges of cultivated areas.
2. In common infrastructure corridors the sign spacing shall be as required by the location class, except that where a pipeline is parallel to an overhead power line a sign shall be placed adjacent to each power pole or pylon.

5.13.3 Sign location

Signs shall be placed at the following locations and be inter-visible –

a) Both sides of public roads;
b) Both sides of railways;
c) At each property boundary (and at internal fence lines as appropriate);
d) Both sides of rivers;
e) Both sides of vehicle tracks;
f) Each change of direction;
g) Utility crossings (buried or above-ground);
h) At the landfall of submerged crossings or submarine pipelines, which shall be legible from a distance of at least 100m on the water side of the landfall;
i) At all pipeline facilities;
j) At all other places where signs marking the location of the pipeline are considered to contribute to pipeline safety by properly identifying its location;
k) Signs must not exceed the maximum separation listed below for classification areas:
   - R1 – 500m;
   - R2 – 250m;
   - T1 – 100m.

5.13.4 Marker Sign contents

Marker signs shall—

a) indicate the approximate position of the pipeline, its description, the name of the Operator, and a telephone number for contact for assistance and in emergencies;
b) indicate that excavating near the pipeline is hazardous; and
c) include a direction to contact the pipeline Operator before beginning excavation near the pipeline.

5.13.5 Buried Pipelines Installed in Parallel

Buried pipelines running in parallel are at particular risk of being impacted when an excavation or drilling machine operator is unaware of the presence of more than one pipeline in the immediate vicinity. Therefore, where pipelines share a common trench, or where two or more pipelines run in parallel, one of the following options shall be applied:
a) Individual Pipeline Marking.

Where pipelines are marked individually, the requirements stated above shall apply as a minimum requirement for each pipeline. At each location, where the presence of one pipeline is indicated by a marker sign, an additional sign shall also be placed to represent the presence of each additional pipeline in the vicinity. Posts shall be separated from each other to clearly indicate the presence of all pipelines.

b) Grouped Pipeline Marking

Alternatively, pipelines may be marked by a single sign at each location. In such cases, the sign shall clearly indicate the presence of multiple buried pipelines or services in the vicinity. The marker sign format, visibility and display of company information shall be in accordance with the above requirements.

A single sign shall not be utilised to indicate the presence of two or more pipelines unless the sign clearly indicates that multiple pipelines or services exists in the vicinity.

5.13.6 Marker Tape

Marker tape shall be installed at all locations designated by the design or alignment sheets. Where two pipelines are laid in a common trench, such as gas and associated water, a marker tape that indicates the presence of both pipelines is to be installed separately.

5.14 REINSTATEMENT

After backfilling has been completed, construction tools, equipment, and debris shall be removed.

Areas that have been disturbed by the installation shall be reinstated.

Appropriate measures shall be taken to prevent erosion (e.g. the construction of contour banks or diversion banks and minimise long-term degradation of the environment).

Fences that have been removed to provide temporary access to the route shall be re-erected.

Reserves shall be reinstated in accordance with the requirements of the appropriate authority.

In developed farmland, it shall be ensured that topsoil is being replaced without contamination, and drains and general contours are reformed.

NOTE: Reinstatement should be completed as soon as practicable.

5.15 RECORDS

At completion of construction, survey data and as-built drawings complying with AS 1100.401 that identify and locate the pipeline, stations, crossings, valves and pipe fittings, shall be prepared.
All spatial data shall be referenced against (MGA94 or GDA55 to AHD) or another approved datum.

Where necessary, permanent reference marks and benchmarks shall be provided. The scale and detail shall be appropriate to the location class and complexity of that location. In addition to survey data and drawings the following design and construction records shall be prepared –

a) **Design and approval records**: The design and approval records are the following –

- Design Basis;
- Design drawings revised to as-built status;
- Relevant project specifications and data sheets
- Design calculations;
- Location class;
- Records of land ownership;
- Operating procedures that form part of the design;
- Safety and environment related records;
- Approvals and relevant correspondence with regulatory authorities;
- Materials and components used in the pipeline.

NOTE: The name of the manufacturer and process of manufacture should be included.

b) **Manufacturing and construction records**: The manufacturing and constructions records required are the following –

- Manufacturing data records including the traceability of all materials and components, and all associated test results and inspection reports;
- Welding records;
- Hydraulic and/or pneumatic test records (including pressurisation and strength test records);
- All other tests and inspections that are required to verify the integrity of the pipeline in accordance with this Code of Practice;
- Any construction information that may be relevant to maintenance of the pipeline.

c) **Commissioning records**: Commissioning records are to include all records from the commissioning activity relevant to the ongoing operation and maintenance of the pipeline.
6 JOINTING

6.1 BASIS OF SECTION

This Section includes general information on the recommended procedures for the most common methods of joining PE pipe and fittings.

The user of this jointing information must consult and follow appropriate safety instructions for jointing equipment, which are available from manufacturers. Further information is contained in PIPA Guidelines POP 001 and POP 003.

6.2 GENERAL PROVISIONS

PE pipe or fittings can only be joined to each other by heat fusion (welding) or with mechanical fittings.

NOTE: PE pipe and fittings for CSG and PFW applications cannot be joined by adhesives, cements or elastomeric joints.

PE pipe and fittings may be joined to other materials by means of mechanical fittings, flanges, or other qualified types of manufactured transition fittings. There are many types and styles of fittings available from which the user may choose, but whatever fitting is used it must comply with the requirements of Section 3 of this Code.

Each jointing method offers its particular advantages and limitations for each situation the user may encounter. Contact with the relevant manufacturers is advisable for guidance in proper applications and styles available for joining.

6.3 HEAT FUSION

6.3.1 Introduction

There are three types of heat fusion joints currently used in the industry - butt fusion welding, electrofusion welding and saddle fusion welding. The principle of heat fusion is to heat two surfaces to a designated temperature, and then hold them together by application of a sufficient force. This force can be applied either by a direct force holding the ends of the pipe together as in butt fusion welding and saddle fusion welding or by indirect forces caused by the melting of two surfaces in a confined space as in electrofusion welding. In all three cases this causes the melted materials to flow and mix, thereby resulting in welding or fusion. As soon as the joint cools to near ambient temperature, it is ready for handling.

The following sections provide general procedural guidelines for each of each of these heat fusion methods.

6.3.2 Butt Fusion Welding

The most widely used method for joining individual lengths of larger diameter PE pipe is by heat fusion of the pipe butt ends as illustrated in Figure 6.3.2a.
**Figure 6.3.2a – Standard Butt Fusion Joint**

This technique, which precludes the need for specially modified pipe ends or couplings, produces a permanent, economical and flow-efficient connection.

Butt fusion welding can only be carried out with pipe or fittings of the same SDR unless a suitable transition piece approved by the manufacturer is used or a qualified procedure is used to ensure that the joining procedure achieves an equivalent joint integrity.

A field constructed transition piece constructed in a workshop can only be used for joining one SDR to the next SDR, that is not more than one SDR step up or down per transition (See Figure 6.3.2b). Other transition pieces or transition pipe/fitting ends are to be to an approved design and manufactured and certified in a controlled environment. All components need to have adequate nominal pressure rating for the operating conditions.

**Figure 6.3.2b Transition piece design for one SDR step**

Field-site butt fusions may be made by trained operators using specially developed butt fusion machines (see Figure 6.3.2c) that secure and precisely align the pipe ends for the fusion process.
6.3.3 Types of Butt Fusion Welding

6.3.3.1 Background information

A successful butt weld requires the correct combination and sequence of the welding parameters of time, temperature and pressure.

Various proven butt fusion methods with minor differences have been in use in different countries for many years. ISO 21307 contains three distinct fusion methods described below for pipe and fittings with a wall thickness up to and including 70mm.

It is essential that the parameters specified for a given method are followed. Do not mix and match parameters for each method.

NOTE: Wall thickness is expected to very rarely exceed 70mm in CSG development. However, where wall thickness exceeds 70mm, welding parameters should be agreed between the Operator and the installer. Under these circumstances the pipe and fitting supplier should also be consulted.

The three methods employed are as follows –

a) Single pressure-high fusion jointing pressure.

This method has been used extensively in North America and has been almost universally adopted within the CSG industry in Queensland.

The weld interface pressure is approximately three times the low pressure method detailed below and, as a consequence, more of the molten material is extruded from the weld zone, thereby enabling a reduced cooling time. Extra attention is required to ensure that suitable welding machines are used to ensure that the high pressure parameters are achieved in a safe manner, with confirmation to be sought from the machinery manufacturer. In addition, the welding operator shall be competent and sufficiently trained, experienced and proficient with the parameters.
NOTE: Several equipment manufacturers have adapted this technology to be used in tracked equipment which provides mechanically-assisted lifting equipment to assist in the alignment of the PE pipe, and a controlled environment for the welding process (Section 6.3.3.2 refers). In addition, controlled conditioned air cooling is available to reduce the total welding duration for a butt fusion weld. ASTM F2620-11 Section 8.3.7 Note 8 states –

“Pouring water or applying wet cloths to the joint to reduce cooling time is not acceptable. Applying chilled air is acceptable only as part of a controlled cooling cycle procedure where testing demonstrates that acceptable joints are produced using the controlled cooling cycle procedure.”

No change to the welding parameters set by the manufacturer of the butt fusion welding machine is involved.

b) Single pressure-low fusion jointing pressure
This method has been used in most European countries and has been widely used by utilities in Australia. The single pressure-low parameters specified are very similar to those previously specified by PIPA.

c) Dual pressure-low fusion jointing pressure
This method is used by the water industry in the U.K., and in Europe. These parameters are not commonly used in Australia.

Welding parameters are detailed in PIPA guideline POP 003. This document is regularly reviewed and provides guidelines for butt fusion welding parameters as detailed above.

Data loggers are now extensively employed to verify conformance to the nominated welding parameters.

6.3.3.2 Environmental Conditions for Carrying out Butt Fusion Welding

The fusion or welding process is sensitive to weather and climatic conditions and, as such, the butt welding process needs to be carried out in clean, dry and draft free conditions. To manage these aspects the following is advised –

a) Where necessary, use a weather shelter or cover to keep moisture and dust away from the prepared pipe ends;

b) When temperatures fall near or below zero, special precautions may need to be taken – consult pipe manufacturer’s recommendations;

c) Cover the remote open ends of the pipes being welded to avoid draughts. Air can be drawn through open ends and pass over the surfaces being welded, cooling them prematurely, which can result in a cold weld.
6.3.3.3 Planning for successful butt fusion welding

To ensure the integrity of the butt welds the following procedures should be adopted –

a) Select a qualified welding contractor. A qualified butt welding contractor shall have –
   - demonstrated experience in butt welding of PE pipe;
   - suitably sized equipment which has been maintained in good condition with calibration status documentation available for temperature and pressure measurement;
   - qualified operators who have an up to date log detailing project and welding experience;

b) Assess the proposed welding procedures –
   - Pre-qualified welding procedures for pipe class and diameters being proposed for the project and the welding machines which will be used and destructive weld testing data can be considered;
   - Carry out trial welds on the actual pipe to be used for the contract and have these destructively tested to meet the specified performance requirements (testing and minimum performance requirements are detailed in Section 7 – Inspection and Testing);
   - Determine and document the agreed welding parameters, procedures, and welding equipment (this may also include the use of welding tents, pipe end covers etc.);
   - The agreed welding parameters, procedures and welding equipment then become the contract requirements and should not be varied without additional evaluation and testing.

c) Determine quality control and assurance requirements including but not limited to –
   - Maintaining a detailed welding log for each joint;
   - Destructive testing of a percentage of joints;
   - Assessment of weld bead.

d) Continuously review process and results.

Comprehensive details for weld inspection and testing can be found in Section 7 and Appendix B.

Butt Fusion Welding is a skilled operation and to achieve a successful joint a number of very specific procedures need to be carried out. All operators shall be trained by appropriate registered training organisations (RTOs).
6.3.4 Electrofusion Welding

6.3.4.1 Introduction

Electrofusion fittings are used widely in the construction of PE pipe systems. The fittings rely on the use of electrical resistance elements which are incorporated in the fitting which, when connected to an appropriate power supply, melt and fuse the materials of the pipe and fitting together.

![Typical Electrofusion Coupling](image)

**Figure 6.3.4.1 Typical Electrofusion Coupling**

Electrofusion is a skilled operation and to achieve a successful joint a number of very specific procedures need to be carried out. All operators shall be trained by appropriate RTOs.

To consistently make satisfactory electrofusion joints it is important to follow the jointing procedure with particular emphasis on pipe surface preparation, cleanliness, restraint of the joint during the fusion and cooling cycles, and temperature control.

**NOTE:** There is a convention that cooling time of an electrofusion fitting should be at least 4 times the duration of the weld formation. Where a greater time is specified in the Manufacturer’s instructions, it shall be followed.

6.3.4.2 Jointing Types

Electrofusion welding is available for two specific types of joints. These are –

a) Electrofusion Socket Joints – which are used for jointing pipe and fittings in line. They come in many configurations and range from straight couplings to more complex bends, tees and other fitting arrangements;

b) Electrofusion Saddle Joints – which are specifically designed to connect to the external surfaces of the pipe where off-takes and/or new connections are required.
Pipes and electrofusion fittings used for pressure applications must comply with AS/NZS 4130 and AS/NZS 4129 respectively.

Electrofusion fittings are available in the size range DN20 to DN800 with larger sizes under development. The larger the fitting the more difficult are aspects such as alignment and roundness and the physical effort required to assemble the joint and the pipe before fusion takes place.

Pipes and fittings of different SDR can be joined together by the electrofusion process, e.g. a DN250 SDR11 pipe can be successfully electrofused to a DN250 SDR17 pipe using a DN250 SDR17 coupling.

All components shall have adequate nominal pressure rating for the operating conditions and the PE materials shall comply with AS/NZS 4131.

Electrofusion fittings for pressure applications are usually recommended for use with PE pipes SDR17 or lower (i.e. increased wall thickness). Some manufacturers supply electrofusion fittings for thinner pipes, down to SDR33 whereas others limit the use of some saddle type fittings to SDR11 or thicker.

These limitations are usually detailed on the fitting body or on the packaging. If in doubt, check with the supplier or manufacturer as unsatisfactory joints are likely to occur if the fitting/pipe combination is incorrect.

Further information can be found in the PIPA guideline POP 001 - Electrofusion Jointing of PE Pipe and Fittings for Pressure Applications. This comprehensive document provides detailed information and requirements to make successful electrofusion joints.

6.3.4.3 Welder Training

Fusion jointing is a skilled operation. Prerequisite training shall be by appropriate RTOs and shall consist of PMBWELD 301 and 302 and an advanced training course approved by the CSG Operators.

6.4 MECHANICAL JOINTS

Where fusion joints are not appropriate, mechanical fittings can be used, particularly for the small sizes of PE pipe. There are three basic fittings which can be used.

6.4.1 Mechanical compression joints (water service only)

These fittings are typically of plastics construction and are manufactured to AS/NZS 4129. These fittings are usually limited to DN 110 and PN 10 or PN 16.
6.4.2 Mechanical Couplings

These fittings are of metallic construction and are available larger sizes up to DN 375 and PN 16. They are designed to meet the performance requirements of WIS 4-24-01 Type 2 and ISO 14236. Some fittings require the use of internal support bushes which need to be placed inside the pipes being joined. Depending on the materials used for the manufacture some additional corrosion protection may be required in buried situations.

6.4.3 Flanges

When jointing is required to other materials a flanged joint is generally the most practical.

NOTE: PIPA guideline POP 007 – “Metal Backing Flanges for use with PE Pipe Flange Adaptors” provides dimensions of metal backing flanges suitable for the use with PE flange adaptors in the sizes DN20 through to DN1000 and flanges in accordance with AS 2129, ANSI/ASTM B16.5, AS/NZS 4331.1 (ISO 7005-1) and AS 4087.

The materials used in sealing gaskets must be suitable for the intended purpose.

Jointing to other pipe materials may also be achieved by the use of mechanical flange adaptors which are similar to mechanical couplers except one end is replaced by a flange.
6.4.3.1 **Flange Management**

Consideration must be given to the following when fitting a bolted mechanical joint:

- a) Cleanliness
- b) Alignment
- c) Gasket type
- d) Temperature
- e) Torque settings
- f) Tightening sequence
- g) Torque checks after relaxation

Prior to completing a mechanical joint the flange faces must be free from dirt and debris. Ensure the flange faces are free from scratches, gouges and defects. Check to ensure the flange face is ‘flat faced’ and not bowed.

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**Figure 6.4.3 Typical Flanged Connections**

**Figure 6.4.3.1a Flange Face Check**
Gasket materials must be chemically and thermally compatible with the internal medium of the gathering system and external environment. They should be recommended by the gasket manufacturer for use with PE pipe flanges. Types of gasket used in conjunction with PE are listed as follows:

![Gasket Types](image)

**Figure 6.4.3.1b Types of Gaskets**

Flanges must be properly supported or free from stress when bolting a mechanical joint. Flange temperature must be kept below 40°C (minimal latent heat) prior to tightening. Flange bolts should be tightened to the appropriate torque value by turning the nut with a calibrated torque spanner. Each nut should be tightened to the sequential number patterns as in the example 6.4.3.1c.

In the first instance, establish an initial sealing surface pressure by tightening the flange as per the example sequence below and applying a torque setting of 7-15 Nm. Bolts should be tightened to a value recommended by the gasket manufacturer.

![Tightening Sequence](image)

**Figure 6.4.3.1c Typical Tightening Sequence**

Flanges should be re-checked for torque tightness after the joint has had adequate time to relax. Typically this is recommended at intervals of 4 hours and 12 hours respectively after the initial torque.

NOTE: Depending on the face pressure requirements of the particular gasket in use, consideration should be given to allow up to 50% of additional torque to allow for creep. All tightening is to be performed at temperatures as low as practical.
7 INSPECTION AND TESTING

7.1 BASIS OF SECTION

Inspection and testing forms an integral part of the pipeline system. It ensures all parts of the pipeline including the material manufacture, design, and installation have been carried out in accordance with this code of practice. The Operator shall ensure that the appropriate inspections and testing are carried out during the total life cycle of the works.

7.2 INSPECTIONS AND TEST PLANS

Inspection and Test Plans shall be designed, approved and implemented for the required parts of the works including materials handling, installation and commissioning. Inspection and Test Plans (ITP) shall as a minimum include –

a) Description and item number of the activity;
b) Description of each test, examination or inspection to be performed;
c) Responsible persons;
d) Reference documents, controlling specifications and procedures;
e) Acceptance criteria;
f) Verifying documents or check sheets;
   NOTE: The ITP itself may also be used as a check sheet.
   g) Provision for Hold, Witness, Verify and Review points.

ITPs shall be applied to specified sections of the works so as to allow sign off in discreet stages, not just at final completion. ITPs shall be approved and cover all stages of the works.

7.3 MATERIALS INSPECTION

Pipe and fittings shall be packaged, handled and transported in accordance with the PIPA guideline POP 005 and upon receipt of pipe and fittings and before installation inspection of materials shall be carried out to ensure –

a) correct type, size, rating and SDR of pipe and fittings;
b) no damage is evident that reduces the wall thickness more than 10%;
c) correct identity and traceability markings are present;
d) no debris is in the pipe.
7.4 INSTALLATION

Inspection and testing upon installation shall verify that –

a) correct lifting and laying equipment has been used;

b) trench bottom is free of debris, rocks or clumps that could cause damage to pipe;

c) trench depth and cover is correct to specification;

d) adequate bedding has been used where required;

e) pipe and fittings are within specified tolerances for diameter and out of roundness;

f) correct amount of embedment is around pipe;

g) pipe is not laid up against sharp objects on wall of the trench;

h) correct backfill has been used;

i) marker tape and/or trace wire has been installed;

j) compaction of backfill is in accordance with the specification; and

k) as-built records have been completed before final backfill.

7.5 WELDING/JOINING

Joining pipes and fittings by electrofusion or butt welding shall be to an approved joining procedure that has been qualified by destructive testing in accordance with ISO 13954 “Plastics pipes and fittings - Peel decohesion test for polyethylene (PE) electrofusion assemblies of nominal outside diameter greater than or equal to 90 mm” and ISO 13953 “Polyethylene (PE) pipes and fittings - Determination of the tensile strength and failure mode of test pieces from a butt-fused joint” respectively.

For electrofusion welding, an acceptable alternative method of destructive testing may be undertaken in accordance with ISO 21751 “Plastics pipe and Fittings- Decohesion test of electrofusion assemblies- Strip-bend test”.

Due to the simplicity of the ISO 21751 testing methodology, it is also practical for indicative checks on site (e.g. when trying new fittings, procedures, equipment or for training of the welders).

For the welding procedure qualification or production tests, the ISO 21751 testing needs to be done in a testing laboratory by competent personnel.

Refer to Appendix B for more information.

The acceptance criteria for ISO13954 and ISO21751 peel decohesion tests require the test samples to rupture in a ductile mode with the percentage of brittle failure de-cohesion being less than or equal to 33.3% for each test specimen (not the overall test specimens combined). The percentage of brittle failure is determined as a ratio of the largest length of brittle failure to total length of fusion zone at the same location - refer to ISO 13954 for more information.
The acceptance criteria for ISO 13953 tensile strength test require that the test samples present a ductile failure mode, be free from defects and contamination in the weld plane, and shall have a minimum tensile strength of 90% of the parent pipe.

NOTE: Qualified procedures may be grouped by diameter to reduce the amount of qualification testing. The recommended groupings are shown in Table 7.5.

**Table 7.5 Welder and Welding Procedure Qualification Groupings**

<table>
<thead>
<tr>
<th>Procedure Test Diameter</th>
<th>Qualification Type</th>
<th>Type of joining process</th>
<th>Qualifies for sizes within range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any ≤ DN110</td>
<td>Butt Weld</td>
<td>Any ≤ DN110</td>
<td></td>
</tr>
<tr>
<td>Any ≥ DN 125 to DN280</td>
<td>Butt Weld</td>
<td>Any ≤ DN280</td>
<td></td>
</tr>
<tr>
<td>Any ≥ DN 315 to DN 800</td>
<td>Butt Weld</td>
<td>Any ≥ DN 315 to DN 800</td>
<td></td>
</tr>
<tr>
<td>Any ≥ DN 800</td>
<td>Butt Weld</td>
<td>Any ≥ DN 800</td>
<td></td>
</tr>
<tr>
<td>Any ≤ DN 110</td>
<td>Electrofusion Weld Other Than a EF Saddle Weld</td>
<td>Any ≤ DN 110</td>
<td></td>
</tr>
<tr>
<td>Any ≥ DN 125 to DN280</td>
<td>Electrofusion Weld Other Than a EF Saddle Weld</td>
<td>Any ≤ DN280</td>
<td></td>
</tr>
<tr>
<td>Any ≥ DN 315 to DN 800</td>
<td>Electrofusion Weld Other Than a EF Saddle Weld</td>
<td>Any ≥ DN 315 to DN 800</td>
<td></td>
</tr>
<tr>
<td>Any ≥ DN 800</td>
<td>Electrofusion Weld Other Than a EF Saddle Weld</td>
<td>Any DN ≥ 800</td>
<td></td>
</tr>
<tr>
<td>Any ≤ DN 160 (carrier pipe)</td>
<td>Electrofusion Saddle Weld</td>
<td>Any ≤ DN 160(carrier pipe)</td>
<td></td>
</tr>
<tr>
<td>Any &gt; DN 160 to DN 315 (carrier pipe)</td>
<td>Electrofusion Saddle Weld</td>
<td>Any &gt; DN 160 to DN 315 (carrier pipe)</td>
<td></td>
</tr>
</tbody>
</table>

The essential variables for the weld qualification shall include:

- Procedure (process type – high pressure, low pressure, dual pressure);
- Individual welder (Training and competency);
- Diameter group size as per Table 7.5.
- Pipe thickness > 70mm
Qualification for individual welding machines shall be undertaken where design differences between machines may lead to unacceptable operator error.

Equipment used for welding such as butt fusion and electrofusion machines must be qualified for the diameter group size as per Table 7.5. The welder must be qualified for operating the welding machine which has been qualified for the weld procedure.

All welders undertaking work on the pipeline shall be assessed by performing test welds on the same size groupings in Table 7.5. Destructive testing shall then be carried out in accordance with ISO 13954 or ISO 21751 for electrofusion welding, and ISO 13953 for butt fusion welding. This assessment is in addition to the competency certificate issued by an appropriate RTO.

Supplementary specialised training by the proprietor or other qualified person is a requirement for all personnel involved in welding using proprietary equipment/methods as described in Section 6.3.3.1.

Site welding assessments may be considered approved as long as the welder has been welding the same type/group of pipe and fittings in the last 12 months.

Site welding assessments may be transferred between projects provided that –

- the welder has been welding the same type/group of pipe and fittings in the last 12 months;
- there is a record of a destructive test undertaken in the last 12 months; and
- they are approved by the Operator.

Minimum inspection that shall be carried out during electrofusion and butt welding include –

a) materials checked for damage and type;

b) clamping and alignment complies with qualified procedure;

c) cleaning and oxidised material removal of components comply with qualified procedure;

d) heating and pressures are within the qualified procedure;

e) bead shape and height of butt welds is as per Section 6 of this Code; and

f) as-built and material traceability records are completed.

7.5.1 Final Construction and Repair Tie-ins (Golden welds)

Final butt or electrofusion tie-ins (golden welds) connecting pipe sections that have already been pressure tested shall be installed in accordance with the welding jointing requirements of Section 7.5 and shall be evaluated for integrity. The methodology of evaluation shall be approved. Appendix G provides guidance on testing of golden welds.
7.6 **PERSONNEL**

Quality Assurance and Inspection shall be carried out by competent personnel who have had appropriate training and experience, are able to produce a current competency certificate and have been approved by the Operator. Training shall have been undertaken by an appropriate RTO.

7.7 **PRESSURE TESTING**

Except for components that are exempt from field pressure testing, all pipelines and components shall pass an approved pressure test in accordance with Section 8 of this Code.

7.7.1 **Exemptions from a field pressure test**

The following items may be exempted from field pressure testing –

- a) Pipes and other pressure containing components that have been pre-tested to a pressure that is not less than that specified for the pressure test;
- b) Tie-in welds made between pressure test sections after they have been pressure tested;
- c) Small bore controls, instruments and sampling piping.

7.8 **VISUAL AND NON DESTRUCTIVE TESTS**

All components of the pipeline shall be visually inspected before installation to ensure compliance with Section 3 of this Code.

Each butt weld or electrofusion weld shall be visually inspected in accordance with Appendix B before testing or commissioning.

7.9 **PRODUCTION TESTING**

After the initial qualification of both EF and Butt welding procedures there shall be a requirement for ongoing testing by the removal of a butt and an EF joint out of the pipeline and destructively testing them to ISO13954 or ISO 21751 for EF welding, and to ISO13953 for butt welding. The frequency of testing shall be approved by the Operator with a recommended minimum requirement of one butt and one electrofusion weld taken within the first 10 welds of the individual welder for each type (i.e. EF or butt welding). Test samples shall be taken from a range of different diameters where practically possible. If the weld complies then a sample rate of 1 in 200 for the same welder shall apply. If the production weld fails then two more welds from the same welder shall be removed for testing, if either fails to comply then an investigation is to be carried out to determine the cause and recommend action.

**NOTES:**

1. To effectively carry out this testing it will be necessary to have a high level of weld traceability back to the welder and weld location.
2. Data loggers can provide valuable information in assessing welds.
8 PRESSURE TESTING

8.1 BASIS OF SECTION

All new pipelines and any part of an existing pipeline that is repaired, diverted or altered in any way shall be subject to a pressure test to validate mechanical strength and detect leakage of the pipeline prior to commissioning. A formal test procedure shall be developed and qualified prior to being used. This procedure shall clearly contain the –

- acceptance criteria;
- design and operation of test equipment;
- risk mitigation measures to ALARP.

NOTE: It is recognised that there must be untested joints (such as closure joints) which cannot be subject to pressure testing, but these shall be kept to an absolute minimum.

Experience has demonstrated that the risks associated with pressure testing are amongst the highest in the field development and construction activities associated with gathering network development.

Pressure testing organisations certified under NATA or an equivalent organisation should be considered preferentially.

The test procedure and the instruments used shall demonstrate clearly that there is no leakage that will constitute a hazard following commissioning of the tested system. The test procedure shall be established to ensure that, when the testing is carried out, the highest standards of safety are maintained throughout the test period. Adequate facilities shall be provided by the Operator to enable these standards to be met.

For a CSG PE gathering network system, pneumatic strength testing shall not be used for both gas and water pipelines in exclusion zones around key facilities (e.g. compressor stations, RO plants), residences and as listed in Section 8.4.1.1.

Due to the visco-elastic nature of PE, it is not practical to conduct such tests in a manner that will ensure no pressure change. Variations of atmospheric pressure, temperature of the test fluid in the pipeline and material creep will have a significant effect on the test pressure. Therefore it is necessary to permit some drop in measured pressure over the test period.

Consideration for volume increases due to creep occurring during the testing period will have to be made for PE pipelines. When a PE pipe is subjected to a test pressure there will be pressure decay, even in a leak free system, due to creep of the PE material.

As a result of this material behaviour, pipe testing procedures used for other materials such as steel may not be suitable for PE pipe.

The pipeline or a system of pipelines may be tested whole or in sections depending on the test pressure requirements, the length and diameter of the line, exclusion zone limitations and the spacing between sectioning valves or blanking ends.
The designer/Operator should, in the process of designing the system, give due consideration to how the pipeline system will be tested, including –

a) the number of test sections in relation to the exclusion zones;

b) the potential for reduction in size of the exclusion zones as cited in Section 8.2.8 of this code;

c) minimising the number of closure joints (tie-in joints).

The pipeline (or section) shall be properly supported and, if it includes non-load bearing joints, be anchored to prevent the movement of pipes or fittings during the test.

8.2 SAFETY

8.2.1 General Precautions

The hazards involved in pressure testing shall be considered, and the following procedures shall be observed –

a) Owing to the presence of one or more undetected defects in equipment or pipeline, or for other unforeseen reasons, a rupture may occur at some stage during the application of pressure. The test procedure shall ensure that, as far as is practicable, if the test equipment or pipeline fails during the testing, there will be no possibility of injury to any person.

b) Test equipment, including flexible hoses shall be marked with their MAOP which shall not be less than twice the set pressure of the Pressure Safety Valve (PSV), if installed on the pressurising equipment, or twice the maximum pressure the system can generate. Flexible hoses shall be fit for purpose and include whip socks if required for risk mitigation.

c) A service test of temporary test equipment shall be performed prior to commencement of pressurisation.

d) Flexible hoses and their connections shall be visually examined prior to use to ensure that they are fit for their intended purpose and are in test. They shall be secured and anchored by a secondary restraining device (e.g. whip check chain, hose sock or similar) to prevent movement in the event of failure.

e) Test instrumentation shall have a valid certificate of calibration from a recognised and certified testing agency.

f) Verification of testing instrumentation i.e. gauges, recorders etc. shall be performed in accordance with a documented procedure against a prime reference instrument that is traceable to a primary standard.

g) All flanges which are blanked for the purpose of the test shall have their full component of bolting and be of the same pressure rating.
h) Work to be undertaken at any pressure must be conducted under an approved procedure or be subject to a risk assessment.

i) Testing shall not be carried out against closed valves. Installed valves shall be open and plugged or capped.

j) The test section should be physically isolated from any commissioned system.

k) Normally the test section is to be buried. However if pipework is exposed it should be secured adequately and protected against temperature variation.

l) Adequate barriers and signage shall be positioned at the limit of the primary exclusion zone, as determined in Section 8.2.3. It is recommended that barrier tape, coloured blue and white with the wording “Pressure Testing”, is placed at regular intervals.

m) The testing supervisor shall to ensure that all necessary precautions are taken –
   - before pressurisation;
   - during pressurisation;
   - during de-pressurisation and before dismantling of equipment; and
   - after de-pressurisation and during dismantling of equipment.

n) The impact of noise generated during pressurisation and de-pressurisation shall be considered and minimised by the controlled introduction and release of the test medium. Noise exposure limits for personnel in the area must be assessed and not exceeded.

o) Prior to commencing a pressure test a detailed Emergency Response Plan shall be available.

p) After the completion of a low pressure test (<200kPa as per Section 8.5.6 b), personnel shall not enter the primary exclusion zone throughout the duration of the strength test unless the test section has passed the strength test and the pressure has been reduced to MAOP or lower.

q) If the test section is being strength tested and there are indications that it is failing, authorised personnel may only enter the primary exclusion zone to check for causes as to why it has failed after the test section has been depressurised to below 200 kPa.

r) Throughout the duration of the strength test only personnel involved in the testing operation may enter the secondary exclusion zone.

s) When using nitrogen for the use of testing components, tracer gas and pre-commissioning purposes, consideration shall be given to the dangers associated with asphyxiation, high pressure and
nitrogen handling, particularly for work in confined spaces. Vent stacks and pipes should be positioned at least 2 metres above ground in order to achieve a safe atmosphere. A separate risk assessment shall be performed.

t) Temporary valves used for testing purposes, such as isolation or control valves, should be positioned upright as shown below.

![Temporary Valve Positioning for Pressure Test]

**Figure 8.2.1 Temporary Valve Positioning for Pressure Test**

### 8.2.2 Site test exclusion zones

The primary safety control for pressure testing is QA/QC compliance, primarily in material selection and welding. The secondary safety control measure is the introduction and use of calculated exclusion zones.

The test section shall have a defined exclusion zone. This shall be defined as the primary exclusion zone. On the completion of the low pressure test (<200 kPa), no persons shall enter the primary exclusion zone while the test section is being pressurised and while the test section is being strength tested. After successful completion of the strength test and after the pressure has been reduced to MAOP or lower, authorised personnel may be allowed inside the primary exclusion zone.

The test equipment shall be located outside the primary exclusion zone and be surrounded by a secondary exclusion zone. Only authorised personnel can enter the secondary exclusion zone.

Land owners, contractors and other relevant persons must be notified where they may be directly affected.
Figure 8.2.2 Defined Exclusion Zone

While the test pressure is being introduced, and for the period of the actual strength test, strict precautions shall be made to ensure that unauthorised persons are prevented from entering the exclusion zone (primary and secondary) test areas. Barriers, signs or other markers shall be clearly displayed to indicate the restricted area. Consideration should be given to patrolling road crossings and other higher risk locations while the test section is under test to ensure that no persons enter the test area.

The number of personnel involved in conducting the test shall be kept to a minimum.

The test equipment needs to be located with respect to escape routes in the advent of an emergency and ease of installing the test equipment. In addition, the location of the test equipment shall consider the effect of missiles that may come from a failed test section. A general rule is not have the control point in line with the test end as per illustration Figure 8.2.2 'Defined Exclusion Zone', and to be away from pipeline features such as tees, elbows and tapping saddles.

The primary exclusion zone shall be designed to surround the entire test section. Consideration shall be made for other work in the vicinity of the primary exclusion zone. A formal risk assessment could be made for routine work such as driving along access tracks near the pipeline being tested as long as the track is not near pipeline features such as elbows, tees or tapping saddles.

The primary exclusion zone is designed to achieve a specified distance from the test section to the area that any unauthorised person can be present during the test.

The primary exclusion zone area needs to be determined to take into account the amount of stored energy released upon test section failure.
The distance to the primary exclusion zone boundary shall take into account the following –

- The diameter of the pipeline being tested.
- The length of the pipeline being tested.
- The test pressure.
- Potential projection of solid objects from a failed test section.

The distance that objects will travel in the event of a pipeline rupture is related to test section pressure.

### 8.2.3 Pneumatic testing Primary Exclusion Zone (R1)

The primary exclusion zone boundary shall be calculated by using the approach defined in ASME PCC-2. This approach calculates the amount of stored energy and then calculates a distance based on the blast wave impact to personnel and structures. The minimum Primary Exclusion Zone is:

- 30 m if the calculated energy is less than 135.5 MJ;
- 60 m if the calculated energy is between 135.5 and 271 MJ;
- for energy levels greater than 271 MJ, the distance \( R_{\text{scaled}}(\text{TNT})^{1/3} \) in metres, calculated in accordance with Appendix D4, based on an \( R_{\text{scaled}} \) number of 20, where TNT is the energy measured in kilograms of TNT (Trinitrotoluene).

These distances are subject to increase in specific direction of failure to allow for potential projected missiles.

Appendix D2 details the method of calculating the stored energy and the safe distance in the pipeline to be used in strength tests.

Section 8.2.8 details methods of reducing this Primary Exclusion Zone.

### 8.2.4 Pneumatic testing Secondary Exclusion Zone (R2)

The Secondary Exclusion Zone boundary shall be established around the Control Point. The minimum recommended approach is to use the distance based on an \( R_{\text{scaled}} \) number of 20. In this calculation the stored energy is the energy in the test equipment – hoses and headers. An alternative is to use an exclusion distance of 10 m.

**NOTE:** A 100 m long, 50 mm diameter hose will have an exclusion zone of less than 5 m.

During testing operations no unauthorised person will be permitted to enter this zone.

Appendix D2 details the distance calculation to be used in strength tests.

### 8.2.5 Hydraulic Testing Primary Exclusion Zone for Above-ground Sections and Open Bell-holes (R1)

This distance shall be calculated with a minimum distance of 5 metres from any part of the test section. The calculation shall determine the amount of stored energy in the test section. The Operator and testing personnel will be
required to ascertain the air content of the test section and determine if this is acceptable.

Appendix D3 describes the process of calculating the amount of stored hydraulic energy in the test section.

Appendix D2 describes the process for determining the amount of energy stored in the air content in the test section.

The minimum safe distance to be applied to the hydraulic test primary exclusion zone (R1) shall be the greater of:

a) 5 m;

b) \( R = R_{\text{scaled}}(\text{TNT})^{1/3} \).

where \( R = \) actual exclusion zone distance from test section/equipment.

\( R_{\text{scaled}} = 20 \) (Scaled consequence factor).

\( \text{TNT} = \) Energy measured in equivalent kilograms of TNT (Trinitrotoluene).

NOTES:

1 TNT in the above equation is the sum of stored hydraulic energy (calculated in accordance with Appendix D3) and stored pneumatic energy from residual air remaining in the test section (calculated in accordance with Appendix D2). The volume (V) used in the calculation given in Appendix D2 will have to be adjusted to match the estimated volume of residual air in the test section (e.g. 0.2% of the total test section volume).

2 This reduction in the exclusion zone for hydraulic testing is based on the extremely small calculated energy content. The risk of a pneumatic blast wave, present during hydraulic tests, is only applicable to the minimal residual air component during hydraulic tests which enables reduction in the safe distance used.

8.2.6 Hydraulic Testing Primary Exclusion Zone for buried section of pipelines (R1)

The test section shall have an exclusion zone around all above ground or open sections. The buried section does not need an exclusion zone, however consideration shall be given to sensitive areas such as road crossings, right of ways, access tracks and populated areas. These areas should have signage stating ‘Entering Pressure Testing Area. Remain in vehicle at all times’ erected within the area of the system under pressure. In special circumstances consideration should be given to patrolling the area. At exits, the area should have signage stating, ‘Exiting Pressure Testing Area’.

NOTE: This reduction in the exclusion zone for hydraulic testing is based on the calculated energy content.

8.2.7 Hydraulic testing Secondary Exclusion Zone (R2)

The secondary exclusion zone boundary shall be erected around the control point. The minimum secondary exclusion zone shall be 5 m.
8.2.8 Methods of reducing the amounts of pneumatic stored energy in the pipeline test section

The owner or testing contractor may consider methods of reducing the exclusion zone of the test section.

The advantage of the following methods is that the distance to the exclusion zone boundary can be reduced as there are effectively two smaller sections of the pipeline being tested together.

8.2.8.1 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.

![Diagram of Loop over Hose](image)

**Figure 8.2.8.1 Interconnecting pipes with use of loop over hose.**

8.2.8.2 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 8.2.8.2 Interconnecting pipes with use of orifice plate.

8.2.8.3 Blast Mats

Blast mats are normally used with trench blasting to consume stored energy and stop fragmentation or missile propagation during blasting. They are available in different forms ranging from interlocking wire mesh, recycled rubber, aramid fibre and heavy duty woven matting.

Mats can be used where exclusions zones cannot be met due to site restrictions. They shall only be used in conjunction with the manufacturer’s recommendations and used only on short sections of pipe work or over vulnerable areas such as EF couplings or mechanical joints.

A risk assessment and calculation sheet shall support the requirement of blast mats taking into account manufacturer’s recommendations in relation to the stored energy of the pipe, type of backfill and surrounding areas.

Figure 8.2.8.3 Blast matting over vulnerable joints
8.2.8.4 Partially Filled Systems

An example of a partially filled system is shown below. The amount of water needs to be measured to accurately to determine the residual air content of the system.

A calculation shall be conducted to calculate the amount of air required to raise the pressure from static head pressure to the Calculated Test Pressure (CTP).

Once the air content and the calculated volume required to complete the test is obtained, these can be used to calculate to the amount of stored energy.

![Diagram of partially filled system](image)

Figure 8.2.8.4 Partially filled system

The above method will need to have the amount of stored energy and safe distances determined using the calculations in Appendices D2 and D3.

The above method will have a smaller distance to the exclusion zone than a 100% air-filled system is using a pneumatic strength test, however consideration shall be given as to the locations along the test section where there may be sections of air filled sections. In these cases the exclusion zone shall apply along the entire route of the test section.

It is recommended that this method be used only by an experienced test team as there are different considerations compared to a 100% pneumatic or hydraulic strength test.

8.2.9 Pre-testing

Sections of pipeline in key areas may need to be pretested or tested separate to the main pipeline section. Examples are road, creek crossings, and sections near plants and houses where the impact of a failure of a pressure test is critical. In other cases the section of pipeline may be tested before being inserted into a HDD or after it is installed to ensure that it is suitable.

These sections can later be tied into a longer section of test section. In these cases the exclusion zone around the pretested section can be reduced as it has previously passed a strength test.

8.2.10 Alternative Safe Distance Calculation Methodologies.

ASME PCC-2 remains the minimum requirement under this Code unless the Operator independently qualifies an alternate calculation methodology which is as safe as the mandated requirement prior to use and has been verified by a qualified third party.
In addition, an Operator contemplating the use of alternatives to ASME PCC-2, would need to complete the following points as a minimum consideration:

a) Full review of all design & constructability issues related to the network system due to be pressure tested;

b) Pressure test method to be nominated;

c) Full hazard assessment to be conducted for each location;

d) Formal risk assessment to be conducted based on the above;

e) Calculation of stored energy based on the qualified length of pipeline test section.

8.3 TEST PLAN

A test plan needs to be developed for all pressure tests. This plan can be a general document to cover most cases. However in all cases the risks and hazards of the particular test need to be understood and managed.

The testing plan shall be able to –

- ensure the implementation of all risk controls;
- ensure that a JSA is completed and all items identified are adhered to;
- ensure that all relevant equipment has a current calibration certificate from a recognised and certified testing agency;
- ensure that all measuring equipment is located at a suitable distance from the test section to comply with exclusion zone requirements;
- ensure that the EMP is followed for the disposal of the test fluids and other wastes;

The person or persons responsible for preparation of the test plan shall have appropriate qualifications and experience.

8.3.1 Approvals

The test equipment shall be approved by the Operator. This approval shall include a suitable risk assessment method.

The water used in testing needs to be approved as being suitable to be used for the test and for subsequent disposal.

The Operator should also assess the potential environmental impact of loss of containment in the event of pipe rupture during testing.
8.3.2 Test Sections

When developing the test plan, the person or persons responsible for defining the test sections should take into consideration the following –

- Exclusion zone distances to boundaries;
- Water sources and discharge points;
- Configuration of the test system; and
- Elevation of the high and low points of the system

Where it is not feasible to pneumatically test due to constraints associated with larger exclusion zones, the pipe may be strength tested in smaller sections hydraulically and, then installed within the larger test section. The larger test section may then be pneumatically tested as the sub-sections in vulnerable areas would have already undergone strength testing. This process will eliminate untested joints within the test system.

8.3.3 Testing Different SDRs

Normally a heavy SDR rated pipe will be used for special crossings such as road crossings, rail and river crossings. The pipe strings are pre-tested prior to insertion and are normally incorporated into a final test.

It is common when designing the system to allow a heavier SDR at low points or special crossings as illustrated in Figure 8.3.3

![Figure 8.3.3 Testing different SDR rated pipes](image)

The test pressure will always correspond to the lightest SDR rated pipe and where heavier SDR rated pipe is used, the maximum pressure applied during hydraulic testing shall be determined by the elevation difference as recorded by the “As Built” survey data.
8.4 TEST METHODS

The pressure testing of the PE gathering system shall be broken into separate test types - a Strength Test and a Leak Test. These can be conducted either by hydraulic or pneumatic methods.

Pressure testing PE pipes may require special processes since they may continue to expand significantly throughout the test period. When a PE pipe is sealed under a test pressure there may be decay, even in a leak free system, due to the creep response and stress relaxation of the PE material. Due to this material behaviour, standard pipe testing procedures used for other pipe materials may not be suitable for PE pipe.

The following factors can affect a PE pipe pressure test –
   a) Length of section and pipe diameter;
   b) Test pressure, rate of pressurisation and duration of the test;
   c) Presence of air (hydraulic test);
   d) Level of support from pipe embedment;
   e) Accuracy of test equipment;
   f) Ambient temperature changes during testing;
   g) The presence of leaks.

Long test sections may incorporate a large number of joints that need to be checked for leakage. The longer the test section the harder it may be to locate a leak – this will depend on the chosen leak test method.

The pipeline or system may be tested as a whole or in sections, depending on test pressure requirements, the length and diameter of the line, the availability of water (if undertaking a hydraulic test), and the spacing between sectioning valves or blanking ends. The pipeline (or section) shall be properly supported and, if it includes unrestrained joints, be anchored to prevent the movement of pipes or fittings during the test.

When undertaking hydraulic testing the test section shall be filled with water, taking care to purge all free air from the section. Where a motorised positive displacement pump is used for the test, consideration should be given to the installation of an effective form of pulsation damping. The pressure shall be monitored at some convenient point and the test pressure adjusted to take account of the elevation difference between the pipeline’s lowest point and the test rig. The adjustment shall be made by subtracting 10 kPa for every metre that the rig is elevated above the lowest part of the line.

The source of any leak shall then be ascertained and any defects repaired. The pipeline shall then be retested.

---

4 Sometimes also called a “Proof Test”
8.4.1 **Strength Test**

The intent of the strength test is to prove the integrity of the pipeline and identify any large leaks or defects in the system being tested.

**Table 8.4.1a Strength Test Criteria – Gas Pipeline Hydraulic Test**

<table>
<thead>
<tr>
<th>Hydraulic Strength Test Gas Pipeline</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting pressure 1.25 MAOP at the highest point, the lowest point shall not exceed PN*1.25.</td>
<td>1. Structural integrity maintained for 6 hours while pressure held between 1.25 MAOP and MAOP at the highest point.</td>
</tr>
<tr>
<td>Test pressure to remain between 1.25 MAOP &amp; MAOP during test at the highest point.</td>
<td>2. No evidence of sudden pressure drop.</td>
</tr>
<tr>
<td>6 hours minimum hold duration.</td>
<td>P&gt;= MAOP at highest point.</td>
</tr>
<tr>
<td>P&gt;= MAOP at highest point.</td>
<td></td>
</tr>
</tbody>
</table>

**Table 8.4.1b Strength Test Criteria – Water Pipeline Hydraulic Test**

<table>
<thead>
<tr>
<th>Hydraulic Strength Test Water Pipeline</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting pressure 1.25 MAOP at the lowest point, the highest point shall not be less than MAOP.</td>
<td>1. Structural integrity maintained for 6 hours while pressure held between 1.25 MAOP and MAOP at the lowest point.</td>
</tr>
<tr>
<td>Test pressure to remain between 1.25 MAOP &amp; MAOP during test at the lowest point.</td>
<td>2. No evidence of sudden pressure drop.</td>
</tr>
<tr>
<td>6 hours minimum hold duration.</td>
<td>P&gt;= MAOP at lowest point.</td>
</tr>
<tr>
<td>P&gt;= MAOP at lowest point.</td>
<td></td>
</tr>
</tbody>
</table>

**Table 8.4.1c Strength Test Criteria – Pipeline Pneumatic Test**

<table>
<thead>
<tr>
<th>Pneumatic Strength Test</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting pressure 1.25 MAOP.</td>
<td>1. Structural integrity maintained for 6 hours while pressure held between 1.25MAOP &amp; MAOP.</td>
</tr>
<tr>
<td>Test pressure to remain between 1.25 MAOP &amp; MAOP during test.</td>
<td>2. No evidence of sudden pressure drop.</td>
</tr>
<tr>
<td>6 hours minimum hold duration.</td>
<td></td>
</tr>
</tbody>
</table>

Note: In pipeline sections where an overpressure excursion greater than 110% is designed, the test pressure shall be 125% of the excursion in accordance with Section 8.4.1.2.
8.4.1.1 **Strength Test Method Considerations**

There are two methods of pressure testing, namely hydraulic (using water as the test medium) or pneumatic (using air as the test medium).

When strength tests are required to be performed in high risk locations, hydraulic strength tests should be the preferred method of testing as opposed to pneumatic strength testing due to the incompressible nature of liquids and hence greatly reduced stored energy. High risk locations include the following –

- places where other people may be working;
- process facilities;
- significant road crossings;
- rail crossings;
- populated areas;
- 3rd party infrastructure;
- where simultaneous or conflicting operations are ongoing within the exclusion zone area.

Pneumatic strength testing in high risk locations is not a preferred method but may be selected where –

- the pipeline has tees or changes in diameter that make pigging or water filling impractical;
- there are significant changes in elevation;
- the location is remote;
- suitable test water is not available.

The Operator shall conduct a specific and thorough risk assessment and take the necessary actions to ensure an ALARP condition.

Consideration shall be given in the design phase of the project to allowances for pressure testing and its constraints. Design options to be considered include –

- the provision of steel lines from the plant for a suitable distance to the joint with the PE lines. This will reduce the risk of failure of the lines in the vicinity of the plant;
- allowing for the fabrication and installation of all PE lines in the vicinity of the plant to be constructed before the plant is commissioned – therefore all tie-ins to the field pipeline are outside the battery limits of the plant and thus reducing the impact of pressure testing with persons in the vicinity.

Consideration needs to be given to testing in larger sections which will result in less untested (golden) welds, tie-in welds and the associated risk of these untested welds.
Disposal of the test water upon completion of the pressure test needs to be considered as part of the overall pressure test process.

8.4.1.2 Test Pressure

The test pressure shall be 1.25 times the proposed MAOP of the pipeline for a pneumatic strength test.

For a hydraulic strength test of a water system the starting test pressure is 1.25 times the proposed MAOP of the pipeline measured at the lowest point (elevation) of the pipeline and the pressure at the highest point shall not be less than the MAOP.

For a hydraulic strength test of a gas system the starting pressure is 1.25 times the proposed MAOP of the pipeline measured at the highest point (elevation) of the pipeline and the pressure at the lowest point shall not exceed the pipeline PN*1.25.

In pipeline sections where an overpressure excursion greater than 110% is designed, the test pressure shall be 125% of the excursion. Change to the exclusion zone may be required.

Care shall be taken to ensure that the introduction of the test medium does not cause the maximum test pressure to be exceeded.

Care shall be taken to ensure that changes in elevation do not lead to excessive test pressures.

EXAMPLE:

Pipe MAOP is 250 kPa. Test pressure is 250 x 1.25 = 313 kPa.

Maximum difference allowable between the highest and lowest point in the test section is 62.5 kPa. This relates to 6.25 m in elevation between the lowest and highest point in the pipeline being tested. Multiple tests will be required for elevations > 6.25 m.

NOTE: It is recognised that the above criteria are not consistent with traditional steel pipeline testing. Further note that decimals of kPa are not to be used in performance of test. They are only included here for demonstration purposes.

Figure 8.4.1.2 Elevation Diagram

This will result in several tests being required when pipelines are located in hilly terrain (unless pipe of increased MAOP is utilised in places at a lower elevation).
Above ground test sections can be affected by high ambient and test fluid temperatures. Consideration shall be given to shading the test section or completing the test outside hot periods of the day. The test pressure may need to be adjusted depending upon the measured temperature.

8.4.1.3 Compensation for Test Temperature
Where the testing pipe temperature is greater than the temperature for which the system has been designed, commensurate reduction in test pressure will be required in accordance with the design factors for temperature detailed in Table 4.4.1.2. For example, for a system designed with an MAOP of 1000 kPag at 20 °C, the test pressure at 40 °C should be 1000*1.25/1.2 kPag.

Note: There is no advantage in compensating for the case where the test temperature is lower than the design temperature.

8.4.1.4 Test Period
The test period shall be a minimum of 6 hours.

8.4.1.5 Type of Pipeline
All types of pipeline categories can be tested using the Strength Test methods detailed in this code.

8.4.1.6 Strength Test Constraints
There are no constraints as to the length of pipe and the diameter that can be tested in each test as long as the exclusion zone can be achieved and the parameters are followed within this code.

8.4.1.7 Stabilising Period
The stabilising period is not critical for a strength test as the intent is to determine if there are significant defects in the system. However the temperature and material creep stabilising will have a detrimental effect on the pressure and therefore considerations should be given to temperature stabilisation of the test medium for all strength testing.

8.4.1.8 Acceptance Criteria
The pipeline will have passed strength test if at the end of the test period the pressure in the pipeline is above MAOP and that there is no evidence of a sudden pressure drop.

8.4.2 Leak Test
The intent of the leak test is to determine if there are any small leaks in the system. The leak test shall be undertaken after a successful completion of a strength test.

Exclusion zones are not normally required for leak tests as the pipeline system has been proven to have adequate structural integrity with no significant leaks. However, it is recommended that exclusion zones should still be maintained around above-ground pipe sections and testing equipment to keep unauthorised people out of the area during leak testing activities.
Table 8.4.2 Leak Test Criteria

<table>
<thead>
<tr>
<th>Leak Test - Options</th>
<th>Hydraulic Test</th>
<th>Pneumatic Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acceptance</td>
<td>Acceptance</td>
</tr>
<tr>
<td></td>
<td>Criteria</td>
<td>Criteria</td>
</tr>
<tr>
<td>1. Constant Pressure Test</td>
<td>Based on AS 2566.2 Appendix M5.</td>
<td>1. Tracer Gas Fails if gas detector detects leak.</td>
</tr>
<tr>
<td>2. Pressure Decay Test</td>
<td>Based on AS 2566.2 Appendix M6.</td>
<td>2. Allowable Pressure Loss 1 litres/hr/actual m³</td>
</tr>
<tr>
<td>3. Pressure Rebound Test</td>
<td>Based on AS 2566.2 Appendix M7.</td>
<td>3. Other proven / approved method. To be determined based on risk evaluation. Method to be approved.</td>
</tr>
<tr>
<td>4. Visual test</td>
<td>Based on AS 2566.2 Appendix M8.</td>
<td></td>
</tr>
<tr>
<td>5. Other proven / approved method.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Consideration shall be given to tightening the minimum acceptance criteria for the type of fluid, e.g. more critical for brine pipelines. In addition consideration shall be given to the minimum acceptance criteria for built up locations (T1 or T2).

8.4.2.1 Constraints per type of test

The type of test to be used will be identified in the Inspection and Test Plan (ITP). When planning a test plan consideration should be given to the criteria set out in Section 8.3. System volumes are divided into 3 categories –

- Low Volume;
- Medium Volume;
- High Volume.

Each category is defined as follows –

Low Volume Systems consist of components, road crossings, horizontal directional drill strings and short sections of buried pipe. They also include all pipe work that can be visually inspected.

Medium Volume Systems consist of long above ground pipe strings, buried pipe work with volumes approximately up to 50 cubic metres for pneumatic tests and up to 250 cubic metres for hydraulic tests.

High Volume Systems consist of system volumes above 50 cubic metres for pneumatic testing and over 250 cubic metres for hydraulic tests.

Leak test methods suitable for these systems are –

a) Low Volume:
- Hydraulic Visual Test;
- Hydraulic Rebound Test.
- Pneumatic test methods – all (including tracer gas leak testing).
b) Medium Volume:
   - Hydraulic Rebound Test;
   - Hydraulic Pressure Decay Test;
   - Pneumatic test methods – all (including tracer gas leak testing).

c) High Volume:
   - Hydraulic Pressure Decay Test;
   - Constant Pressure Test;
   - Pneumatic test methods – all (including tracer gas leak testing).

8.4.2.2 Acceptance criteria

The acceptance criteria are defined in Section 8.6 due to the different types of permitted leak tests.

8.4.3 Component Testing

During construction it may be required to carry out pre-testing or component testing. These may be valves, under pressure T-sections, riser manifolds etc.

Component testing can be carried out using water, air or nitrogen as a test medium. The pressure is raised to test pressure in increments of 25% of the test pressure, stopping at each increment to allow for settlement. On reaching test pressure the system should be held for a 30 minute stabilisation period whilst maintaining the test pressure. On completion of a 60 minute strength test the pressure should be reduced to MAOP before approaching the component to inspect for leaks. Once the component has been fully inspected the pressure will be reduced to zero or head pressure.

Exclusion zones as defined in Section 8.2.2 shall apply for the above test case.

When undertaking some key activities such as hot tapping a pipeline (post system commissioning) the hot tap fitting shall be tested prior to the cutting of the coupon. Testing of a hot tap assembly shall be performed using a combined strength and leak test using hydraulic methods only. The test section should encompass the tapping saddle, isolation valve and tapping equipment. The test duration shall be a minimum of 6 hours at 1.25 x MAOP. During the test period a minimum exclusion zone of 5 metres shall apply.
8.5 **STRENGTH TEST**

A strength test requires a written test procedure which shall address –

a) Installation of test equipment;

b) Pressure test requirements;

c) Pressurisation of the network pipeline;

d) Maximum allowable test section inlet temperature;

e) Pressure test;

f) Test pass/fail assessment;

g) De-pressurisations of pipeline;

h) Test records.

8.5.1 **Tools and Equipment**

The following tools and equipment are required –

a) Test pressure gauges and temperature measuring devices calibrated by a recognised and certified testing agency;

   NOTE: Test pressure gauges shall be sensitive enough to accurately measure pressure change required by the acceptance criteria. Digital gauges with ±1 kPa sensitivity should be used. The measuring devices shall be calibrated at a minimum of 12 monthly intervals

b) Pressure rated hoses equipped with hose restraint;

c) Pressure test warning signs, barricading;

d) Approved test headers;

e) Air compressor with oil filter/separator and cooler or suitable supply of water, meters and pump;

f) Silencer or muffler for discharging air during de-pressurisation of pneumatic tests.

g) Flexible hoses shall include whip sock protection.

The test procedure shall be fully documented and approved by the Operator. This approval may include a formal hazard assessment or other suitable risk assessment method.

The temperature of air or water being injected into the pipeline may be significantly higher than ambient conditions. Consideration needs to be given to the installation of an after-cooler on the compressor to prevent overheating when using a pneumatic strength test and air temperature measurement during pressurisation.
8.5.2 Installation of Test Equipment

Suitable test equipment shall be connected to the pipeline. Requirements include –

a) The location of the test equipment shall consider suitable escape routes in the event of an emergency;

b) Test equipment shall be located in accordance with the exclusion zone detailed in this code;

c) The pipeline shall be restrained against movement. Ideally the ends of the pipeline being tested should be backfilled;

d) Exposed pipe should be shielded from direct sunlight during testing operations. This can be achieved by using a suitable shading material (not black);
e) The test equipment shall be checked by the Operator and a service test carried out on the temporary test equipment prior to the introduction of pressure;

f) Suitable warning notices shall be prominently displayed at the boundaries of the exclusion zone;

g) Consideration should be made to the test equipment having a suitable method of over pressure protection device set to 10% above the maximum calculated test pressure.

**Figure 8.5.2a** Hydraulic Test Setup

**Figure 8.5.2b** Pneumatic Test Setup
8.5.3 Pressure Test Requirements

8.5.3.1 Test Pressure
The test pressure shall be as defined in Section 8.4.1.2

8.5.3.2 Test Temperature
The test temperature shall not exceed the design temperature.

8.5.3.3 Temperature stabilising period
As test fluid is being introduced into the pipeline being tested it may be a different temperature to the ground temperature. A suitable time needs to be allowed for the test fluid in the pipeline to stabilise. The Operator shall ensure that temperature stabilisation has been achieved.

As PE is an insulating material, significant time is required to ensure that the fluid inside the pipeline is similar to ground temperature.

This is critical for the leak test if being conducted as part of the strength test. If a tracer gas leak test is being conducted temperature stabilising is not critical.

Appropriate temperature measurements may need to be carried out.

8.5.4 Strength Test Period
A 6 hour strength test period is required.

8.5.5 Filling – Hydraulic test only
The objective is to fill the pipeline with water to ensure that residual air content in the section is minimised. This may be controlled by using a pig propelled with water to expel the air or by the release of air through air valves at high points in the pipeline. Consideration should be given to elevations and where required a back pressure used to control the pig speed.

Where pigging is not a viable option due to short sections of pipe, dual diameter pipe lines or large volume systems, filling will be conducted so that all air is expelled from all possible high point vents.

8.5.6 Pressurisation of Piping
During pressurisation and hold period the following shall be observed –

a) The test fluid shall be introduced into the test section in a controlled manner;

b) At a low pressure (<200 kPa), after allowing a short stabilisation period at this pressure, check all above-ground components for signs of leakage.

c) While the pipeline section is pressurised, no unauthorised person shall be inside the primary exclusion zone. After the initial low pressure test no persons are to enter the primary exclusion zone until the pipeline has passed the test and the pressure is reduced to MAOP or lower.

d) Line valves shall not be operated;
e) Backfilling or excavation shall not be carried out within the exclusion zone area or anywhere else along the section of pipeline under test.

8.5.7 Strength Test Procedure

The following shall be carried out whilst the pipeline is being subjected to the pressure test –

a) Following the period of temperature stabilisation, the initial pressure reading shall be taken;

b) A further pressure reading shall be taken at the end of the strength test period and the apparent volume loss shall be determined. Intermediate pressure readings shall also be taken during the test period or alternatively, a continuous chart or electronic recording of the test pressures can be taken;

c) The supervisor responsible for the pressure test shall be present at the beginning and at the end of the pressure test to witness whether or not the test section has successfully passed the test and this shall be recorded on the test certificate.

8.5.8 Test Pass/Fail Assessment – Strength Test

The pipeline will have passed strength test if at the end of the test period the pressure in the pipeline is above MAOP and that there is no evidence of a sudden pressure drop. After the successful completion of the strength test the pipeline will then be subject to a leak test process.

8.5.9 De-Pressurisation

8.5.9.1 Pneumatic test

After the test, the pipeline shall be de-pressurised in accordance with approved test procedures under the supervision of a competent person.

a) The air will be released from the test system. This process will be controlled from the control point;

b) Due to the hazards in venting air, PPE will be required;

c) Measures shall be taken to minimise noise generated during depressurising and its impact on the public and other personnel;

d) The testing operator shall confirm that the pressure has been reduced over the entire pipeline under test before further work can proceed within the designated test area.

8.5.9.2 Hydraulic Test

After testing the pipeline shall be de-pressurised and then de-watered (if required) in accordance with approved test procedures under the supervision of a competent person.

a) The water will be released from the test head located at the control point;
b) Pressure water will be discharged in a controlled manner and rate as dictated by the test procedure.
c) Considerations should be given to the discharge point.
d) Dewatering for gas pipe shall be carried out by driving pigs towards the discharge end of the pipeline using compressed air. This may not be required if it is intended for water service;
e) The competent person shall confirm that the pressure has been reduced over the entire pipeline under test before further work can proceed within the designated test area.

8.5.9.3 Acceptance Criteria

The pipeline will have passed strength test if at the end of the test period the pressure in the pipeline is above MAOP and that there is no evidence of a sudden pressure drop.

8.6 LEAK TEST

The following principles apply to the design, conduct and acceptance of a leak test –

A pipeline shall not contain a detectable leak;

Due to the compressibility of air (pneumatic test only) and pressure fluctuations due to the effects of creep, temperature and barometric pressure, it is possible to have a leak on a system which will not be apparent on the test equipment. Therefore when considering the test duration the following should be taken into account –

- Volume of the system;
- Ambient and ground temperatures;
- Barometric pressures;
- Creep (relates to pipe SDR and material).

Pressure drop due to creep depends upon the pipe material, ambient temperature, SDR, any previous stress history and the degree of restraint offered by the backfill. It does not vary with pipe volume.

If the temperature of the gas in the pipeline being tested changes there will be a gain or loss in the recorded pressure in the pipeline. This effect can be calculated and if necessary the difference in pressure due to temperature can be added to the total pressure loss effect.

8.6.1 Hydraulic Visual Test

A visual test can be applied for specific above ground sections of a pipeline. These generally are component tests, special crossings that are tested before being installed if the consequence of failure is significant.

In this visual test the pipeline has previously passed the 6 hour strength test. The pressure is then reduced to the design pressure and then inspected for
leaks. The test section shall be visually inspected for leakage at all joints, fittings, valves and all connections.

Consideration shall be given to not completing visual tests on pipelines in rainy conditions.

8.6.1.1 Procedure
This test can be applied to any length of section as long as the section can be fully inspected visually at all joints, components and across the entirety of the section.

- Pressurise the pipe to the test pressure and then isolate;
- On completion of the strength test reduce pressure to MAOP;
- Visually inspect the test section for leakage at all joints, fittings, valves and connections;
- Pressure gauges shall be installed and checked to ensure that the pressure has not fallen indicating an undetected leak;
- Where no leak has been detected a vent valve can be opened and the test section drained to a suitable location.

8.6.1.2 Acceptance Criteria
The test section shall be visually inspected for leakage at all joints, fittings, valves and all connections. If no leaks are present then the section will be deemed acceptable.

8.6.2 Pressure Rebound Test
The pressure rebound test is predominantly for low volume systems. Consideration should be given to the volume of the pipeline, pump capacity and more importantly the ability to discharge a volume of water quickly in order to achieve the rebound result. This last is critical to achieve a satisfactory test. Consideration should also be given to the volume of the pipe and the sudden discharge of water to ensure a ‘hammer effect’ does not occur. The rebound procedure is a rapid means of testing low volume systems and should normally be completed in a relatively short time.

Details of this test method are described in Appendix D4

8.6.3 Hydraulic Pressure Decay Test
This test is suitable for Medium or Low Volume Systems and is recommended for volumes up to 50 m³. The pressure decay test is based on a 3 point analysis test procedure. The test duration is based on the pressurisation time it takes to raise the pressure from head pressure to CTP (Load Time).

A pressurisation pump that has a high volume output capacity will be needed to ensure the test is completed in reasonable time. The test time is calculated on 15 x load time and should be completed within 1-12 hours. The procedure is based on a pressure decay curve and consideration should be given to air inclusion and the type of backfill within the system as this could affect the end result.
Details of this test method are described in Appendix D5.

### 8.6.4 Hydraulic Constant Pressure Test

This test method can be used for all systems and is based on the Constant Pressure (water loss) method for visco-elastic pressure pipelines.

For plastics pipes that are subjected to internal pressure, there will be a progressive drop in that pressure due to creep. Accordingly, it may be difficult to assess whether a pipeline is leaking or simply subject to creep. In order to overcome this difficulty, this method is based on the principle that if the pressure is held constant, there will be a linear relationship between hoop strain and logarithmic time.

Variables such as pipe stiffness and soil compaction are irrelevant, as the test result is based on actual performance during the test. Temperature may be considered constant, as with other test methods, unless special conditions exist.

The Constant Pressure Test is suitable for large volume systems where several kilometres of pipe can be tested at once. On completion of the line fill the system should be pressurised to CTP, the test section isolated and allowed to stabilise for a 12 hour period. It is recommended that this is carried out overnight to allow pressure stabilisation due to creep and temperature variations. On completion of the 12 hour stabilisation period, a 5 hour constant pressure test shall be conducted where water is added to maintain CTP and the volumes added are recorded. Assuming there are no pipeline component failures, no visible leakage and $V_2 \leq 0.55V_1 + V_{all}$, the test shall be deemed acceptable and the constant pressure test completed.

Details of this test method are described in Appendix D6.

### 8.6.5 Tracer Gas Test

Tracer gas surveys are normally conducted as a leak test on completion of the strength test using an approved gas which has traceable capabilities. At present the three main tracer gases available are –

- Helium (usually 1% in Nitrogen);
- Nitrogen 95%/ Hydrogen 5% Mix;
- Methane (CSG).

The acceptability of this method shall be tested by suitable trials. The trial shall take into account the time taken for the tracer gas to travel from a leak in the pipeline to the surface and that the pressure in the pipeline of the tracer gas mix and the detection equipment is appropriate to locate the leak. Environmental conditions such as wind and rain and well as the speed of travel over the pipeline under test need to be considered.

For existing systems where the ground has fully compacted over long periods of time, consideration should be given to the time for tracer gas to permeate though the ground. In some circumstances, further planning may be required where sniff tubes are inserted at either side of road/ river crossings and paved
areas, and inserted at strategically placed points along the system, especially in the vicinity of vulnerable areas such as welded and mechanical joints.

When planning a tracer gas survey consideration should be given to the type of tracer gas used. For example the use of methane as a tracer gas may incur problems when a leak has been detected and the system may require decommissioning with an inert gas to carry out the repair.

The tracer gas shall be introduced into the system at the manufacturer’s recommended concentrations. The entire system will require a full purge to ensure the gas is uniformly distributed and the system pressure as a minimum 100 kPa. Consideration should be given to the soak time as the higher the pressure the quicker the tracer gas will permeate through the ground. After a suitable time has elapsed to allow the tracer gas to permeate through the ground, a tracer gas survey shall be conducted by passing a ppm gas detector over the surface of the ground above the pipeline to detect any leakage. Careful planning is required to survey the entire system and to ensure that the speed of the detector allows the capture of all leaks. A typical manufacturer’s recommendation is that this speed be no more than 2.5 km/hr. It is good practice to have marker pegs along the route of the system to guide operators as to direction.

The gas detector used shall be suitable for this application and calibrated for the desired tracer gas application. Attention should be given to untested joints, tarmac roads and pathways where a snoop tube is normally inserted above the joint and at either side of the road crossings.

The system will pass the leak test if no detectable leaks are located with the gas detector.

When using nitrogen in leak testing, the danger of asphyxiation needs to be taken into account, especially when working in confined spaces. Vent stacks and pipes should be positioned at least 2 metres above ground in order to achieve a safe atmosphere. Personal gas monitors shall be carried by operators during this testing.

8.6.6 Pneumatic Pressure Decay test

In order to achieve an acceptable pneumatic pressure decay test the volume should be kept as low as possible as leaks will be more apparent. Generally all tests on pipelines with large volumes should be held to a minimum leak test period of 24 hours. This will result in a full temperature cycle of the test section to be completed.

The longer the test period, the more certain the detection of leaks, so for very large volume systems the duration of the test may need to be extended.

8.6.6.1 Leakage Effects

Any leak on a pipeline will result in a loss of pressure. However the effect of small leaks can be masked by creep and temperature effects.

Therefore the duration of the test needs to be of sufficient time to determine if any leaks are present.
8.6.6.2  **Acceptance Criteria**

The total pressure loss or gain over the test period is related to the temperature change, creep and leakage of the test fluid. When leak testing over long durations, pressure will normally follow the trend of the barometric and internal pipe temperature as the elasticity of the pipeline will be significantly less at lower pressures.

The minimum acceptable maximum allowable volume loss is 1 litre/hr/actual m$^3$ volume of test fluid.

NOTE: The word “fluid” in this context means air or other gaseous medium.

Appendix D1 details the calculation process for this test method.

8.6.7  **Other proven/approved methods**

Other methods of leak detection including acoustic testing are available or are being developed. In order to use any of these methods, acceptable criteria need to be approved by the client and the contractor and the method verified by technical assessment and field testing experience.

8.7  **TEST RECORDS**

Test report sample sheets can be found in Appendix D7. A test report shall include as a minimum the following details –

- a) Test limits and identification of the section of pipeline being tested including location, length, diameter, SDR and material;
- b) Date and times the test was performed;
- c) Specified MAOP;
- d) Test pressure at the start and at the end of the strength test;
- e) Pressure recorder chart or data logger readings;
- f) Details of hold periods and stabilisation times;
- g) Temperature of the pipeline where relevant;
- h) Statement that the section of pipeline under test has passed or failed the strength and leak test requirements showing relevant calculations;
- i) Name and signature of the person validating the test.

8.8  **PRESSURE TEST FAILURE**

If a pipeline fails the pressure test it shall be repaired and subjected to a further full pressure test prior to being commissioned.
8.9 QUALIFICATION AND ASSESSMENT OF A PRESSURE TEST PROCEDURE

The pressure testing procedure for testing PE pipelines shall be approved by the Operator. The test procedure shall be based on this Code and address all operational and safety issues.

Quality and OH&S specialists of or contracted by the Operator shall have input into the development of the pressure test procedure. This is to ensure that all hazards associated with pressure testing have been mitigated to as low as reasonably practicable (ALARP) through the implementation of identification, evaluation and control methods.

The Operator shall provide sufficient resources to ensure that relevant information, instruction, training and supervision are available to conduct all work activities safely. The test procedure shall be assessed and monitored to ensure that it complies with the requirements of this Code. It shall be reviewed on a regular basis.

8.10 QUALIFICATION OF THE PRESSURE TEST PERSONNEL

The pressure test operator and all relevant personnel included in the work permit shall pass an approved pressure test course before being permitted to conduct a test. This course shall cover all relevant elements of this Code of Practice.

The person conducting the pressure tests may also be assessed by the Operator prior to conducting any tests. This assessment may include a practical assessment of the person’s skills and may need to be repeated from time to time.
9 RECORDS MANAGEMENT

9.1 BASIS OF SECTION

Primarily, the purpose of records is to preserve—

a) historical information required for the safe operation and maintenance of the network over the network’s life;

b) objective evidence of NMS effectiveness and compliance; and

c) records of decision-making and approvals.

The Operator shall establish procedures for the identification, collection, storage and disposal of records pertinent to the NMS and to the achievement of the above objectives. Procedures shall cover electronic as well as paper-based records. As a minimum the following shall be addressed—

- The records to be retained;
- The retention period of each record type;
- The records storage and preservation methods;
- Record update and maintenance procedures.

The Operator shall obtain and maintain records that are necessary to —

- safely operate and maintain the network;
- demonstrate compliance with this Code of Practice and relevant legislation;
- identify decisions made and actions taken by the Operator; and
- confirm the fitness for purpose of the network at any stage of the network operating life.

9.2 DESIGN, CONSTRUCTION AND COMMISSIONING RECORDS

During the design stage, receipt of materials for the network, and network construction, the Operator shall obtain, prepare and keep current, records of the following —

a) Safety management studies or risk assessments conducted;

b) Hazard and operability study records;

c) Design basis;

d) Project specifications and data sheets;

e) The traceability of all materials and components including all test results and inspection reports;
f) All tests and inspections that are required to verify the integrity of the network in accordance with this Code of Practice;

g) The required MAOP;

h) All drawings, as built and alignment (developed in accordance with AS 1100.401) relating to the network and facilities;

i) The condition of the internal and external surfaces;

j) Operation procedures that form part of the design;

k) A list of the authorities that have granted operating permits, and land-holders through whose land the network passes, including contact history and title information;

l) A list of other easements (especially easements in gross for other networks, power lines and communications cables) through which the network passes, their contact details and other relevant information;

m) Records of network sections or components identified as potentially high risk in an emergency;

n) Commissioning records;

o) Quality assurance records and traceability;

p) Safety and environment records;

q) Approvals and correspondence with regulatory authorities.

9.3 OPERATION AND MAINTENANCE RECORDS

The Operator shall prepare a Records Management Plan. The Plan shall detail the records to be obtained, the records to be retained, storage methods and procedures to maintain currency of the records, until the abandonment of or removal of the network. The Plan shall be approved.

Records that shall be included in the Plan are the following –

a) Records required due to Operating Condition changes;

b) Historical NMS plans and procedures;

c) Any approved change to operating conditions, engineering investigations and any work carried out in connection with any changes to operating conditions;

d) Any modifications to the maps, charts, plans, drawings and procedures, which are required to allow the procedures to be properly administered (e.g. exposure to the public, changes in design and operating conditions);

e) Details of any deformation, damage or other anomalies;

f) Details of any leaks, ruptures or other loss of containment events;

g) Routine inspections, and inspections and testing carried out when cutting into a network or making hot taps;
h) Repairs and maintenance work to networks;

i) Details of inspections of internal or external network condition;

j) Correspondence with statutory and regulatory authorities;

k) Safety management study or risk assessment reviews;

l) Incidents and subsequent preventative actions;

m) Operation and maintenance personnel competency details and training records;

n) MAOP review documents;

o) Location class review documents;

p) Reports on landholder and third-party liaison and the information given;

q) Records of emergency response exercises, the actions arising, and the completion of those actions.

r) Records of any pressure excursions as a result of fit for purpose decision under Section 4.5.3 including the location, time, date and duration of the excursion and any effect on pipeline life.

The Operator shall also prepare and retain for a minimum of 5 years records of the following –

- Necessary operational data;
- Network surveillance patrol reports.

NOTE: Legislation may require more extended record retention times.

**9.4 ABANDONMENT RECORDS**

The Operator shall document the archiving or disposal of records associated with an abandoned network.

A record should be kept of all abandoned networks that remain in-situ, to prevent possible mistakes in identifying an abandoned network as an operational network.

**9.5 RECORDS MANAGEMENT AND DOCUMENT CONTROL**

The Operator should ensure that appropriate records are identified, retained, managed and recorded in the Records Management Plan. In addition to the requirements of Section 9.3, the Records Management Plan should address as a minimum:-

- the records to be retained;
- retention period;
- storage and preservation methods;
d) record update and maintenance procedures; and
e) audit schedule.

Primarily the purpose of records is to preserve—

- historical information required for the safe operation and maintenance of the pipeline over the pipeline’s life;
- objective evidence of compliance with and the effectiveness of the pipeline's safety management system; and
- record decision making and approvals.
10 COMMISSIONING

10.1 BASIS OF SECTION
Commissioning shall always be the responsibility of the Operator, and should normally follow immediately after acceptance pressure testing (see Section 8) and other pre-commissioning activities. The integrity of the pipeline shall be established through an inspection testing program undertaken concurrently with construction. The Operator shall ensure that inspection and testing are undertaken as necessary during manufacture, transport, handling, welding, pipeline construction and commissioning, to ensure that the completed pipeline complies with the engineering design, this Code of Practice and relevant Standards and has the intended quality and integrity.

10.2 COMMISSIONING PLAN
The Operator shall prepare a Commissioning Plan which will detail the persons to be involved in the commissioning and their responsibilities.

10.3 COMMISSIONING PERSONNEL
The Operator shall appoint a suitably qualified Commissioning Manager who will direct the commissioning processes.

The Commissioning Manager shall ensure that all personnel responsible for commissioning are suitably experienced and take relevant precautions required when working on the live gas pipeline facilities.

The Commissioning Manager is also responsible for co-ordinating activities between all associated groups involved with the commissioning process including communication and interaction with other contractors and operating plant, and has sighted that all pre-commissioning documentation is completed prior to commissioning. Field staff provided by the operating authority will be directed by the Operator.

10.3.1 Installers
Installers shall be generally required to test and inspect all products, materials, equipment, installation and workmanship included in the works covered by the project specification to prove compliance with the specification requirements and to provide all equipment, materials, water and power supplies required to carry this out.

Testing includes pre-commissioning, field testing and performance testing of each item of the whole installation.

10.3.2 Commissioning sign-off
When satisfied that all activities and final checks are complete, the Commissioning Manager shall sign off the necessary paperwork at the end of commissioning and hand over the commissioned system to the Operator for operation.
10.4 PLANS & PROCEDURES

The Commissioning Manager shall prepare a Plan and Procedures document covering all inspections and tests required by this Code of Practice and the engineering design. A Risk Workshop shall be considered a key element in this planning process, although this may be combined with the associated Pre-Commissioning Risk Assessment/Workshop. Inspections and tests shall be made in accordance with the documentation. Corrective actions shall be taken where an inspection or test reveals that specified requirements are not satisfied, with specific persons made accountable to ensure these actions are undertaken in a timely manner.

Commissioning procedures first require all pre-commissioning documents to have been completed and signed off prior to commissioning commencing.

Pre-commissioning, commissioning and start-up are the responsibility of the commissioning team under the direction of the Commissioning Manager.

Assistance from the Operator during the commissioning process is essential for a smooth handover to operations.

Commissioning is broadly defined as the range of activities that is required between mechanical completion of the plant and handover of the plant for operation. Commissioning involves introduction of process fluids and electrical power into plant, and the functional and performance testing of all equipment and systems prior to handover.

Commissioning will involve a phased approach, which will consist of –

a) Pre-Commissioning;

b) Component Commissioning;

c) System Commissioning.

Pre-commissioning and Component Commissioning activities normally involve the preparation of the plant for System Commissioning and Operation. In some instances however, as the plant services are required for Component Commissioning, Component Commissioning and System Commissioning may occur at the same time.

Pre-commissioning and Component Commissioning tasks may be performed by either the mechanical or electrical contractor, suppliers of packaged equipment or the commissioning team, and may be performed prior to the plant being handed over from the construction contractors. The extent to which the construction contractors perform the commissioning tasks is detailed in their respective construction contract and scope of work.

Post-handover of the plant to the commissioning team, the mechanical and electrical installation contractors may be included in the overall commissioning team.

All commissioning will reference commissioning issued documents that have been stamped “Issued for Commissioning”.

At any time during the work, if the work parties identify any unforeseen risks, work shall cease and the Commissioning Manager shall be notified and shall take the appropriate actions.

The Commissioning Manager shall advise the work teams of permission to proceed.

10.5 **SAFETY & ENVIRONMENTAL PRECAUTIONS**

10.5.1 **Safety**

The purging and commissioning of the pipeline must be performed in a safe and efficient manner with every precaution taken to ensure the continued safety of all personnel, property and equipment.

All operations conducted during the course of commissioning shall be in accordance with the safety requirements specified by the following documents:

- Relevant Government Regulations. (e.g. The Queensland *Petroleum and Gas (Production and Safety) Act 2004*);
- The Construction Network Management System for the relevant field where the commissioning is to take place;
- The Operations Network Management System for the relevant field where the commissioning is to take place.

All work shall be carried out under the Operator’s NMS system. The Operator shall have the responsibility to ensure that these procedures are developed with safety as the prime concern. It is essential that all personnel involved in construction, shutdown, commissioning and in eventual operation of the system being commissioned know and understand –

- a) plant safety rules;
- b) personal protection requirements;
- c) fire control and emergency procedures;
- d) fire prevention and control equipment;
- e) Permit to Work System;
- f) Emergency Management Response Procedure;
- g) Network Management System.

A “Safety Tool-Box Meeting” including all parties involved shall be held at the beginning of each day during the commissioning and at other times as needed.

Each commissioning team member shall have the responsibility to thoroughly read and understand the fundamental processes of the commissioning of the pipeline and to highlight any activity that is unclear or considered unsafe. Commissioning activities shall be suspended immediately on any safety issues/concerns being raised by any person during the process.

A permit system shall be implemented during the commissioning process. This system consists of the following procedures:
• Permit to Work System;
• JSA;
• Lock-out/Tag-out System.

Any planned deviation shall be clearly identified and communicated to site personnel.

From the start of commissioning, all work must be done to the Work Permit and Danger Tag Procedure. Electrical system lockout or tagging shall also be in force. With several trades testing equipment for faults, this method is the only way of ensuring a safe transition from plant construction to plant operation.

All operating safety and personnel safety equipment must also be in place and functional at this stage. Where relevant “No Smoking” and wearing of protective safety equipment regulations must be brought into force at this stage and the Work Permit system must include permits for “Hot work”.

Each member of the commissioning team shall clearly understand that the existing installation or other infrastructure associated with the new pipeline is critical to the safe and secure operation of the pipeline system. All personnel involved in the commissioning operations shall be adequately trained and experienced with the relevant tasks.

A commissioning workshop shall be held prior to the commissioning work commencing at which all the associated risks shall be identified and to make clear these aspects.

The Commissioning Manager or delegate shall also conduct Safety/Toolbox meetings at the site with all parties involved with the commissioning process present. Toolbox Meetings or Job Safety Analysis meetings must be conducted prior to any critical or new operation.

Written commissioning procedures shall be developed to ensure that all commissioning team members are fully aware of the hazards associated with pipeline commissioning and what measures are necessary to make the activities safe to perform.

To ensure all sites involved in the commissioning process remain safe and secure during natural gas purging and pressurising procedures, all other work activities associated with the pipeline being commissioned shall normally be suspended until final commissioning of the section has been completed. Any exceptions shall only occur under strict Permit conditions.

The Commissioning Manager shall notify all appropriate parties of the start and completion of commissioning activities.

10.5.2 Emergency Response

Detailed emergency response procedures shall be documented in the site specific Emergency Response Plan. It shall be made clear that the protection of personnel is paramount and that no attempt shall be made to protect or salvage equipment at the risk of personnel.
10.5.3 Environment

All commissioning operations conducted shall be in accordance with the relevant Environmental Management Plan.

All persons involved with the commissioning operation shall be formally inducted before entering the work site.

Any site specific concerns regarding environmentally sensitive areas should be adequately communicated making clear all required actions at each Toolbox Meeting.

10.6 READINESS FOR OPERATION

10.6.1 Contaminants

No pipeline shall be placed in service before it has been cleaned of contaminants, before it has satisfied test requirements and, in the case of water pipelines, before the quality of water supplied from the pipeline has met the Operator’s standards.

Possible contaminants include –

a) materials that enter the pipes and fittings during storage and transport;

b) construction debris;

c) materials introduced during construction, e.g. lubricants used with elastomeric seal joints;

d) bacterial contaminants, which often colonise other contaminants.

10.6.2 Actions

All actions arising from the Commissioning and/or Pre-commissioning Risk Workshop(s) shall be implemented in a timely manner and the implementation documented. Where ongoing action is required, a reporting mechanism to demonstrate action shall be established, implemented and audited.

Safety management documentation shall be transferred from the design and construct phase of the project to the operating phase of the project in a form that enables operations to be undertaken in a safe manner from the time that operation commences.

For new pipelines, all actions that are considered necessary for the safe pressurisation of the pipeline shall be completed prior to the commencement of commissioning.

10.6.3 Ready for Start-up Review

The network or additional flowlines within the network shall not be considered ready to commence or recommence operation until, as a minimum, the following checklist has been completed:

a) The network safety management study has been reviewed, including operations personnel, and determined as ready for operation;
b) The flowline complies with the requirements of all relevant parts of this Code of Practice;
c) The proof and leak test requirements have been achieved and documented;
d) The MAOP has been established;
e) If tie-in welds to existing facilities have not been subjected to c) above, then such welds have been subjected to the requirements of Section 7.5.1, 7.7.1, 7.8 and 7.9, and comply with this Code of Practice;
f) All components have been tested for satisfactory operation;
g) Sufficient operating, maintenance, and emergency personnel have been trained and qualified as competent;

NOTE: Refer to Appendix G for further details regarding testing of tie-in welds.

10.7 **PURGING AND FILLING THE PIPELINE**

10.7.1 **General**

To bring a pipeline into service, the Operator shall ensure that –

a) a procedure is in place and detection equipment used to ensure that the pipeline is fully purged and filled in a safe manner;
b) work is undertaken on the pipeline only when all relevant aspects of this Code have been complied with;
c) an approved procedure is developed specific to the pipeline and the nature of the fluid being purged, filled or commissioned; and;
d) the approved procedure is implemented during purging and filling or commissioning.

The procedure shall address the following requirements –

- The appropriate number, experience, training and induction of personnel involved in the procedure;
- The level and control of the filling rate;
- Controlling and monitoring the discharge of displaced fluids and venting of gases;
- Limiting the mixing of fluids at their interface;
- Controlling and minimising the formation of explosive gaseous mixtures at the gas/air interface;
- Removing unacceptable residues from the pipeline;
- A job safety analysis;
- Appropriate signage;
- Minimisation of hydrocarbon discharge;
• Preventing the discharged fluid from causing unacceptable environmental effects such as damage to crops, excessive erosion, soil contamination or contamination of watercourses or bodies of water.

NOTE: See AGA Operating Section Report *Purging Principles and Practice*, Catalogue No. XK0775, as amended.

10.7.2 Filling a Gas Pipeline

Prior to filling a gas pipeline, a plan shall be prepared, which shall contain all relevant supporting calculations.

Ensure all necessary pre-commissioning punch-list items from all Field Installation Checklists (FIC’s) are complete before proceeding with commissioning.

When a pipeline is being purged of air by the use of gas, prior to filling, consideration shall be given to the safety and operational consequences of the formation of an explosive mixture at the gas/air interface.

During purging, gas should be released into one end of the pipeline in a controlled and continuous flow at an appropriate rate for the pipeline being purged. A slug of inert gas of sufficient length to separate the air from the gas to control the formation of an explosive mixture may be released into the pipeline before the gas. The length of the slug necessary to ensure safety shall be determined and the calculations documented.

A direct purge with gas may be used provided the approved procedures meet the conditions and requirements of AGA Operating Section Report *Purging Principles and Practice*, Catalogue No. XK0775 as amended.

The typical procedure for the introduction of gas into a new gas pipeline is as follows –

a) Ensure that all pre-commissioning punch-list and FIC items are completed before proceeding;

b) Ensure all personnel on the job have reliable and clear communication at critical locations on the pipeline during commissioning;

c) Ensure all sources of ignition are well away from all surface facilities during the entire commissioning process;

d) Ensure all non-essential persons are kept at a distance from all facilities during the commissioning process;

e) Ensure all associated connected facilities and/or pipelines are safely isolated and tagged out;

f) Perform patrol of pipeline to ensure that all low point drains are closed;

g) Slowly open valve at gas inlet point to introduce gas into the pipeline at a controlled rate. Ensure that flow is constant and of sufficient velocity to minimise the air/gas interface;
h) Using a suitable and calibrated gas detector monitor purged gas at venting location until at least the minimum specified percentage concentration of methane is detected;

i) The venting valve should then be closed and the pressure monitored until it reaches the required range;

j) When pressure is acceptably equalised with any other connected live gas gathering lines, the connecting valve to such systems can then be opened to bring the new pipe into service with the broader network. It is important that connecting valves be tagged open to mark it as officially open;

k) Final checks of the new system should be completed such as –
   - checking all connections for leaks;
   - confirm punch list is accepted by operations;
   - all relevant field installation check sheets have been signed by all parties;
   - double check that all required valve isolations are correct.

Where the above conditions cannot be met or controlled for the duration of the purge, then the Commissioning Manager shall ensure that an approved procedure, using an alternative technique, purges the pipeline in a safe manner.

10.7.3 Filling a Produced Water Pipeline

Within CSG fields, there are numerous types of water lines, which shall require specific procedures depending on the type of water being transported. Typical contents within the water include a combination of the following –

- Entrained gas (bubbles) such as methane, hydrogen sulphide or carbon dioxide;
- Varying concentrations of dissolved salts;
- Solids such as coal fines, sand and grit,
- Bacteria and/or other organic matter;
- Pure water devoid of any minerals such as reverse osmosis water (un-buffered).

The composition of the water to be carried in the pipeline shall be established. The desired flow rate to be introduced shall be reviewed to determine the necessary precautions to be taken in the filling procedure to adequately manage potential spillage, storage and safe handling. After pressure testing has been completed as prescribed in Section 8, new and repaired produced formation water supply pipelines may be commissioned using the following procedure –

   a) If necessary to remove construction debris from within the pipeline. The pipeline can be cleaned by pushing a PE pipe compatible foam pig through the pipeline or by just using flushing water depending on the cleaning requirements or specification.
b) Pigging should only be used if the design of the pipeline is such that the seal of the pig will not be compromised and the pig will not be impeded or become stuck. Temporary launching and receiving facilities will need to be installed to enable pigging;

c) Ensure all connected facilities and/or pipelines are isolated and tagged out;

d) Complete all equipment and system checklists and obtain necessary sign off to commence commissioning;

e) In the event entrained combustible gas may be present ensure there are no sources of ignition near the surface facilities during the entire commissioning process;

f) Slowly fill the pipeline within acceptable velocity ranges as to not subject the pipeline and associated fittings to undue stress or damage;

g) Ensure air valves are opened to enable air and/or gas to be vented;

h) Ensure air and/or gas from the system is bled to a safe and approved location. Refer to Job Safety Analysis to manage potential risks involved with the potentially flammable/explosive air gas mixture;

i) Certify acceptance and obtain all necessary sign off.

It is the Operator’s responsibility to initiate suitable integrity management activities to maintain the safe operation of the newly commissioned pipeline.

10.8 FUNCTION TESTING OF ASSOCIATED PIPELINE EQUIPMENT

10.8.1 Protective Devices

All associated upstream and downstream protective devices shall have their compliance plate/tag verified by a competent and qualified inspector. The inspector shall also safely test (if current test records are not already available) the device by simulating a trip or activation event as per its design to an approved procedure. All equipment used for testing protective devices shall have a valid calibration tag certified by a recognised and certified testing agency as per the relevant Australian Codes and Standards. Upon successfully passing activation or trip testing, the device shall be reset, checked that it is in good condition and fully functional for introduction of gas.

10.8.2 Mechanical Equipment

All valves, flanges and associated up and downstream equipment shall be verified by a competent and qualified inspector who will ensure that they are properly aligned, lubricated, installed, tensioned up with torque wrench (correct tension), in good condition and fully functional for introduction of gas or water.
10.8.3 Electrical and Instrumentation Equipment
All electrical and instrument devices shall be checked and verified by a
competent and qualified inspector that they are fully functional for the
introduction of gas or water into the facilities being commissioned.

10.8.4 Changed Operating Conditions
Prior to commencing operation at a new MAOP, a commissioning and testing
plan shall be developed to manage the safe implementation of the changed
operating conditions. The plan shall address at least –

   a) the setting and testing of each instrument and control;

   b) the number and magnitude of pressure increments used in the
      transition from the original operating condition to the new
      condition;

   c) the requirements for leakage testing during the transition.
11 OPERATIONS

11.1 BASIS OF SECTION

This section provides important principles, practices and guidelines for use by competent persons and organisations involved in the operation and maintenance of CSG gas and water PE pipelines. The pipeline facilities are an integral component of the field operations, and are normally covered by the overall Network Management System and related Plans, rather than having a specific individual plan.

The fundamental principles on which this Section is based are the following –

a) Important matters related to safety, engineering design, materials, testing, inspection and operation are reviewed and approved by the Operator.

b) The pipeline facilities are to be incorporated into a documented Network Management System covering the overall CSG field to provide for continued integrity, monitoring and safe operation of the CSG field gathering system in its entirety.

c) Where the Code of Practice does not provide detailed requirements appropriate to a specific item, the principles and guidelines set out in the Code of Practice are the basis on which an engineering assessment is made by competent persons. Specific requirements of the Code of Practice do not replace the need for appropriate experience and engineering judgement.

NOTE: Whilst CSG gathering systems primarily involve PE pipelines, also included are manifolds, valves and (for gas lines) low point drains and (for water lines) high point venting facilities.

11.1.1 Categories.

PE pipelines within the CSG province comprise two categories, namely –

a) Gas pipelines. These are located between the wellhead and the initial nodal or field compression locations and are always buried;

b) Water pipelines have many sub-categories, as follows –

   • PFW (Produced Formation Water): These pipelines carry water produced from each wellhead to interim holding ponds, and then to water treatment plants bring the water to a state suitable for beneficial use;

   • Permeate produced from Reverse Osmosis plants: These pipelines carry purified water from treatment plants to nominated beneficial use;
• Saline water (or CSG water concentrate): These pipelines carry highly saline water to disposal location(s).

11.2 SAFETY AND OPERATION

There are fundamental requirements that shall be met before a new gathering system pipeline can be considered ready for operation, and to ensure an existing pipeline system remains fit for operation.

The primary goal is to manage the safety and integrity of the gathering system to provide a safe and reliable operation for the life of the asset, and also to ensure that the operation and maintenance of the gathering system pipelines do not impact on the health and safety of personnel, the public or have an unacceptable impact on the environment.

To achieve these objectives the Operator shall ensure –

• that the Network Management System (Section 2) is implemented to properly include the gathering system facilities and incorporates risk assessment and an Integrity Management process;

• a CSG Field Environmental Management Plan, when developed and implemented, includes provision for the gathering system, in particular the storage and processing of PFW;

• a compliant gathering system exists and is fit for operation;

• an effective handover process as specified in Section 10 is in place;

• an operating philosophy that will ensure the ongoing fitness for purpose of the gathering system has been prepared;

• an effective CSG Field Emergency Response Plan for the gathering pipeline network is documented and implemented;

• relevant records to enable investigations and analysis to be carried out are retained and updated as required by the Network Management System.

11.2.1 CSG Field Environmental Management Plan

The Operator shall have an approved Environmental Management Plan in place prior to commissioning the total gathering pipeline network and during the life of the asset to ensure that operation and maintenance requirements are effectively applied.

The Australian Pipeline Industry Association, Code of Environmental Practice – Onshore Pipelines considers the environmental aspects in detail.

Relevant government authorities regularly publish revised guidelines related to the treatment of PFW and its by-products, so ongoing attention is suggested to ensure full compliance with statutory requirements.
11.2.2 Approvals
Throughout this Code of Practice, items that are considered fundamental to ensuring the safe operation, maintenance and integrity of the pipeline are identified as requiring approval.

Approval shall be given by the Operator only after the conscious act of reviewing the item, recording the review has taken place and assuming responsibility for the implications of acceptance of the item.

Approval includes obtaining the approval of any relevant regulatory authority where this is legally required.

11.2.3 CSG Field Emergency Response Plan
A CSG Field Emergency Response Plan shall be developed to ensure that response to any identified emergency situations is coordinated and appropriate. Emergency plans and procedures shall be documented and should address the following –

a) The number of experienced operative and supervisory staff shall be adequate at all times to respond to any reported emergency event;

b) All personnel shall be made aware of emergency procedures;

c) Personnel required to implement emergency procedures shall be fully trained in their application including any action required under such procedures;

d) Incident management procedures, covering the necessary planning and preparation to implement responses to the emergency event may include the following –

- Prompt and expedient remedial action for the safety of the public and operating personnel, minimising damage to property and protecting the environment;
- Liaising with the appropriate authorities, including the regulatory authority, and other relevant bodies;
- Limiting the quantity of and controlling any discharged PFW fluid;
- Critically reviewing and revising the plans and procedures at approved intervals;
- Carrying out periodic simulated exercises at approved intervals, to determine the procedural correctness and the understanding by personnel of the emergency procedures.

In addition, the Emergency plans and procedures should address the following –

e) Spill control in the case of PFW;
f) Prohibition of road traffic, low-flying aircraft and the isolation of electrical power in any areas that may be hazardous to safety, to reduce any risk of ignition and resultant dangers;

g) Expeditious transport of repair equipment, materials and personnel to the site.

Emergency plans shall be reviewed periodically at periods not in excess of 2 years and, if necessary, shall be revised and approved.

11.2.3.1 Emergency planning and preparation

The Operator shall plan and prepare for emergency events resulting not only from the gathering system pipelines operation and maintenance but also from external events, which may affect the safe and reliable operation of the pipeline.

In the event of an emergency, the Operator shall ensure that response to any emergency is performed in a planned and safe manner.

11.2.3.2 Emergency response and recovery

The Operator shall ensure that the activities associated with operation and maintenance of the pipeline do not cause harm to personnel, contractors, and the public. During such activities the Operator shall minimise the impact to the environment.

The Operator shall develop and implement emergency response and recovery plans and procedures to address all emergency events including—

a) water pipeline leaks and spills;

b) full bore pipeline rupture;

c) gas pipeline leaks;

d) fires, especially bushfires;

e) natural events;

f) environmental remediation;

g) damage, or suspected damage, by third parties.

11.2.4 Procedures

The Operator shall:

a) have written procedures which shall be approved and reviewed at nominated intervals for the operation and maintenance of the gathering system;

b) Document and record the interval between reviews of the Network Management System, the environmental plan, the emergency plan and the operating and maintenance procedures; and

c) Operate and maintain the gathering system in accordance with these procedures.
11.2.5 Gathering System Description

A Gathering System Plan shall be developed which includes a description of the gathering system, the various pipelines’ system design and operation including suitable maps (alignment sheets and/or Geographical Information System GIS) showing the route of the pipeline, and valve isolations.

The Plan shall also detail the operating philosophy including design parameters of the pipeline, specifying operational limits, including the MAOP, temperature limits and design life.

11.3 RESPONSIBILITIES OF OPERATING PERSONNEL

11.3.1 Operation and Maintenance

The Operator shall have procedures for the normal operation and maintenance of the gathering system and pipelines and any associated systems, including those necessary for maintaining pipeline integrity in accordance with this Code of Practice.

The procedures shall include detailed instructions for persons responsible for the operation and maintenance of the pipeline during normal operation and maintenance. The plan shall also contain a summary of the operational and maintenance processes and procedures.

11.3.2 Environmental Management

Environmental matters are key items in pre-operational planning particularly in respect of the PFW pipelines; however normal good practice adequately controls their impacts. Regular liaison with landowners and other stakeholders regarding environmental matters may also reduce many of the third party interference threats.

The Australian Pipeline Industry Association, Code of Environmental Practice – Onshore Pipelines considers the environmental aspects in detail.

11.3.2.1 Pipeline corridor management

Maintenance programs can be very visible to the community and regular routine operations should seek to manage the maintenance works with a minimal disturbance. Every care should be taken to avoid at all times the spread of disease and weed infestations between properties by vehicle and shoe transfer of soils and seeds.

Easement maintenance generally involves –

a) monitoring easement conditions particularly after heavy rain;

b) maintaining access tracks; and

c) monitoring third party activities.
11.3.2.2 Heritage sites

A register of all such sites should be held, and utilised during pre-planning and design of the gas field facilities. Heritage sites are protected by law and must be identified during pre-planning and protected during construction. Operators should also be aware of the locations in the vicinity of the pipeline and shall ensure that they are protected with appropriate permissions obtained prior to working in those locations.

11.3.2.3 Water management

Management of surface water flows and streams are major issues which can lead to washaways, integrity risks and major expense. Routine surveillance is necessary, particularly after heavy downpours to monitor the condition of the pipeline easement and the access tracks.

11.3.2.4 Pipeline spill prevention and response

Pipelines containing PFW or Saline Water require specific pipeline spill prevention and response planning to contain any spills and minimise the environmental impact. The impact of these spills can be significant and specific training and review of all regulatory requirements is necessary.

11.3.2.5 Environmental management

The Operator shall establish procedures to identify environmental aspects and ensure impacts on the environment are maintained at an acceptable level. Measures to mitigate environmental impacts shall be documented in the plan.

The APIA Code of Practice on Environmental Management should be referred to by the Operator for guidelines on environmental management of pipelines.

11.3.3 Occupational health and safety

The Operator shall ensure that all its actions and activities do not unduly expose its personnel or the public to unacceptable risks. Measures to mitigate these risks shall be documented in procedures and referenced in the plan.

Areas to be considered for inclusion in the plan include the following –

- Safety of the public on or near the pipeline network;
- Safety of personnel working on the pipeline network;
- Safety of contractors including third parties working on or near the pipeline network.

11.4 COMMUNICATION

The Operator shall identify people and organisations outside the Operator’s organisation with a legitimate interest in the safe operation and maintenance of the pipeline.
These may include landowners, local and emergency authorities as well as technical regulators or other government agencies.

The Operator shall establish procedures for regular consultation with, communication and reporting to these identified stakeholders. These procedures shall include statutory reporting requirements.

11.4.1 Community and Stakeholder Awareness

The Operator shall take all reasonable steps to inform people and organisations that may in any way rely upon the safety of the pipeline as follows –

a) Informing the appropriate authorities and other relevant bodies of the hazardous properties of the fluid and the effects of any accidentally discharged fluid on the safety of the public or the environment so that, in the event of an emergency, prompt joint cooperative action can be taken;

b) Informing landowners and other occupiers of land through which the pipeline passes of the methods of recognising risks to the pipeline and an emergency situation. They should be supplied with 24 hour contact telephone numbers of the appropriate responsible persons or organisations to be notified in the case of an emergency;

c) Warnings should be issued concerning the dangers of interference with the pipeline and its appurtenances;

d) Operator staff visits, at approved intervals, to provide landowners and other occupiers of land through which the pipeline passes with information to ensure that their activities do not endanger the pipeline and its appurtenances.

To ensure the integrity of the pipeline network and the safety of the public and the environment, it is critical that identified groups such as property and service designers, owners and operators, construction organisations, excavators, drillers and borers and the general public take into account the presence of the pipeline in their intended activities. Appropriate regular communication with these and with the relevant authorities is required to raise and reinforce awareness of the presence of a pipeline and the constraints with respect to the use of the land on and near the pipeline.

Where the gathering pipeline network occupies public land, consideration should be given to including these sections of the network on the “Dial Before You Dig” database.

11.5 PIPELINE NETWORK INTEGRITY MANAGEMENT PLANS

Structural pipeline integrity is achieved when the pipeline is leak tight, operating within the design parameters and able to safely withstand all identifiable forces to which it may be subjected during operation, including the MAOP.
The Operator shall establish systems and processes that ensure pipeline structural integrity for the design life of the pipeline. The Operator should be able to demonstrate that appropriate systems are established, implemented and maintained.

The objective of maintaining structural integrity of the pipeline is to ensure that the operation and maintenance of the pipeline will not cause injury to the public, pipeline personnel, unacceptable damage to the environment or disruption of production.

11.5.1 Pipeline Network Integrity Management

The Operator shall prepare and implement a pipeline network Integrity Management Plan (IMP) for the pipeline. The monitoring, inspection and mitigation of the identified threats shall be based upon risk based inspection, where the frequency of monitoring, inspection, and mitigation of each threat is based upon the risk level posed by that threat. The adequacy of the IMP shall be reviewed at intervals not greater than 5 years, or immediately upon a pipeline failure event.

Pipeline integrity management procedures shall be maintained for each monitoring, inspection or mitigation action that ensure the PE pipeline infrastructure remains fit for purpose at all times by implementing a systematic approach to operation, maintenance, testing and inspection activities and the application of sound engineering principles with due regard to safety and the environment.

Activities may include –

- Right of way inspection;
- Gas detection surveys for gas lines;
- Critical Function Testing (CFT) of over pressure protection devices;
- Checks to ensure the average temperature is not exceeding the maximum average temperature applicable for the selected design life.

Procedures shall be developed to ensure structural integrity of the pipeline infrastructure is retained during operation and maintenance activities. The procedures shall be approved.

The Operator shall address structural integrity issues of at least the following –

- Pipeline Joints; and
- PE Material over-temperature effects.

The Operator shall continually assess and maintain the pipeline integrity by reviewing pipeline operating conditions both time-dependent and time-independent factors through integrated operation controls and maintenance activities.

The data and information identified and collected for the assessments and reviews should form the basis for ongoing assessment of the risk and
integrity of the pipeline. The findings of such a program will determine actions necessary to ensure the continuous safe and reliable operation of the pipeline.

11.5.2 Pipeline Operation & Controls

Pipeline operation shall be continually monitored by reviewing both pipeline operating data and external factors to ensure that the integrity is maintained. The review shall assess the effectiveness of the implemented control and monitoring processes during the design life of the pipeline. The major areas in operation controls include operating parameters, MAOP and Maximum Operating Pressure (MOP) adjustment.

In order to maintain structural integrity, the Operator shall ensure that a pipeline network meets the following applicable requirements –

   a) Operate a pipeline only when it conveys the fluid or fluids under the conditions (including subsequent changes) for which it was designed, constructed, tested, and approved;

   b) Ensure that during normal operation, the operating pressure at any point in the pipeline does not exceed the MAOP;

   c) Ensure that the average temperatures are such that the design life is not reduced and the thermal stress limits used in the pipeline design are not exceeded.

11.5.2.1 Flow stopping devices

There may be a requirement during the life of a CSG PE pipeline network, that intervention to stop the flow of gas or water is required e.g. in an emergency situation. Procedures to achieve these have been developed in the gas and water distribution industries and are generally adaptable and often involve full or partial de-pressurisation, supplemented by either flow stopping bags or squeeze-off devices. However, the majority of flow stopping bag uses are limited to ≤DN315 pipe.

For further details see Appendix E.

11.6 THREAT MITIGATION

The Operator shall establish and implement pipeline protection systems to ensure that all external interference threats to the pipeline identified in the Network Management System are managed. The effectiveness of the control measures implemented to manage all identified threats and the corresponding risks shall be continually reviewed and monitored.

11.6.1 External interference detection, prevention and control

The Network Management System requires that the Operator identifies and assesses the threats associated with the pipeline and instigates appropriate measures to manage those threats.

To adequately manage risk, the Operator shall develop, implement and monitor the threat mitigation measures and risk management procedures that have been identified in the Network Management System.
The minimum to be considered should include the following –

- Physical measures — depth of cover or barriers;
- Procedural protection measures — one-call systems, landowner liaison, pipeline marking, patrolling, permit to work, and approved procedures;
- Operator reviews/audits;
- Other activities — pipe wall and joint assessment.

**11.6.2 Pipeline Marking**

Signs shall be maintained along the route so that the pipeline can be properly located and identified, as appropriate to each particular situation and as identified in the Network Management System.

Maintenance of pipeline marking shall ensure the following –

- legible signs are maintained at spacings as per the design documentation and in any case at inter-visible distances.
- signs or other markers are placed at each change of direction, at each side of permanent watercourses, at each side of road and rail crossings and at crossings of each property boundary;
- signs exist at all above-ground facilities;
- any other signs needed to identify the location of the pipeline network are placed and maintained; and
- compliance with the requirements set out in Section 5.13

**11.6.3 External Interference Management**

The pipeline integrity can be affected by unauthorised external interference or during an encroachment incident. These incidents can directly impact on the pipeline integrity with the result of loss of containment.

The Operator shall undertake approved risk mitigation measures and management strategy for any identified and/or planned external interference threats.

The minimum clearance from a pipeline to any buried structure shall be 0.3 m.

The minimum clearance for parallel installation shall be such that future maintenance can be conducted, but shall not be less than those detailed in Section 4 table 4.11.1.

The Operator shall consider pipeline protection when determining appropriate separation distances of pipeline to other buried structures.

The pipeline and associated crossings shall be designed to ensure that seismic activities do not affect the pipeline.

NOTE: PE has been shown to have performed well during seismic events.
11.6.4 Protection Methods and Load Limits
Pipeline ground cover is the primary protection against external loadings on the pipeline. The pipe cover shall be maintained at all locations where vehicles are traversing the pipeline. Loads imposed by these vehicles on the pipeline shall be assessed to ensure that they do not exceed the design conditions of the pipeline at the specific location.

NOTE: Also refer Section 4.13

11.7 INSPECTIONS AND PATROLS
Pipeline network surveillance shall be carried out by the Operator to ensure a pipeline network is free from identifiable leaks and to identify any new or changed threats to the pipeline, particularly any un-notified external interference near the pipeline. The type of surveillance and the frequency required for safe pipeline operation varies and should be determined by risk assessment.

11.7.1 Patrol of route
The route shall be patrolled and inspected in an approved manner at approved intervals, and whenever it is considered that damage or risks to the integrity of the pipeline may have occurred or may be expected to occur.

Corrective action shall be initiated immediately a condition requiring such action is detected.

Particular attention shall be given to excavation, flowline network construction, directional drilling, and boring activities, including the use of an auger, and drains or ditches that are maintained and cleaned by an independent party.

Surveillance criteria shall include the following –

a) Variations to surface conditions such as erosion or earth movement;
b) Indications of leaks such as dead vegetation (indicating a gas leak) or evidence of liquid or healthy vegetation by comparison to the general vegetation;
c) Construction activity or evidence of impending construction activity on or near the route;
d) Deteriorating condition, visibility, adequacy and correctness of route markers and signs;
e) Any other factors affecting the safety and operation of the pipeline.

All surveillance patrol records shall be retained for the minimum period specified in the record management plan and be available to determine effectiveness for future Safety Management Studies.
11.8 OPERATING CHANGES

11.8.1 Design conditions changes
Design condition changes shall be subject to Change Management Procedures and may require the modification and re-approval of operating, maintenance and emergency procedures and to the MAOP and design life.

The following list is given as a guide to items of change that should initiate an assessment –

a) Process fluid;
b) Pressure and temperature;
c) Land use location class;
d) Pipeline damage;
e) Pipeline modification;
f) Pressure control and protection systems including logic changes;
g) Design life extension.

The assessment shall include, as appropriate, a review of the following –

- The location class;
- The boundaries of the location class and the location of physical barriers or other features that could restrict the movement of these boundaries;
- Management of risk to the public, property, environment or to the pipeline;
- The change in the design factors resulting in the change to location class;
- The physical characteristics of the pipeline, including the diameter, SDR, MRS, strength test pressure and leak test pressure;
- The physical condition of the pipeline as determined from records of the operation and maintenance and from reports of examinations, inspections and monitoring, including those pertinent to corrosion mitigation;
- The design pressure;
- The action that is required for the approval of a revised MAOP.

11.8.2 Review of Maximum Allowable Operating Pressure (MAOP)
The MAOP of each pipeline shall be reviewed whenever there are changes (including pipe damage or failures; or location class change) that could adversely affect the safety of the public, the operating personnel or
the integrity of the pipeline. Investigations, tests and calculations shall be made during the review to establish the current condition of the pipeline and to determine an MAOP in accordance with this Code of Practice.

11.8.3 Design Changes
The design parameters of a pipeline may need to be changed if any of the following conditions prevail.

11.8.3.1 Pipeline modifications
Where a pipeline is modified and the modifications may result in a change to the MAOP, the addition of a branch line or the inclusion of a pressure-containing component) the MAOP of the modified pipeline shall be determined in accordance with this Code of Practice, and approved.

11.8.3.2 Review of Operating Temperature
At approved intervals not exceeding 5 years the operating temperature shall be assessed to confirm compliance with the design average temperature, the design MAOP and design life. Appropriate corrective action including a reduction in MAOP or design life shall be carried out in accordance with the requirements of this Code of Practice.

11.8.3.3 Review of Network Management System
As part of any design review for change of use or extension of design life and at a period not exceeding 5 years (or as approved), an identification shall be made of the threats that could result in hazardous events affecting the pipeline. Threat mitigation procedures, failure analysis and risk evaluation shall be reviewed at those times.

11.9 PIPELINE ASSESSMENT AND REPAIR

11.9.1 Integrity Assessment
The Operator shall ensure that processes and procedures are implemented to monitor and assess integrity and ensure that there is –

a) sufficient pipe or fitting integrity (absence of cracking or damage) to contain gas or water; and

b) sufficient structural integrity at joints to prevent leakage at the MAOP.

11.9.2 Periodic Inspection
Periodic inspections shall be carried out to identify actual or potential problems that could affect the integrity of the pipeline. The Operator shall plan and perform any maintenance required to rectify and manage any such problems.

Inspections shall be carried out by approved and appropriately trained and experienced personnel.

The inspection and assessment of a pipeline shall include the following –
a) A full visual survey of all above-ground sections of the pipeline, including supports and associated equipment, to locate and assess any defects;

b) Inspections of any sections on the pipeline identified in the Network Management System as being operated at higher temperatures, being of higher propensity for development of cracking due to material selection or in areas prone to ground instability.

11.9.3 Frequency of inspection assessment

The frequency of inspection and assessment should be documented and approved and based on the Network Management System, past reliability of the pipeline, historical records, current knowledge of its condition, the rate of deterioration and statutory requirements.

11.9.4 Damage Assessment and Repair

11.9.4.1 Initial Assessment and Remedial Action

PE has inherent corrosion resistance to the CSG environment and, as such, normal inspection methods associated with metallic pipe are not necessary. Once constructed, the only area of significant concern is third party damage to the pipe.

Where the integrity of a pipeline, or a section of a pipeline, is assessed as being inadequate or at imminent risk, the Operator shall immediately take steps to prevent failure of the pipeline until the integrity of the pipeline is restored.

Interim measures shall be taken to mitigate the risk of a leak or failure. This may include a pipeline pressure reduction, or shutdown.

A permanent repair shall be planned and implemented, and shall reinstate the integrity of the pipeline for the service conditions.

11.9.4.2 Pipe body surface cracks

Crack-like anomalies found on pipe body surface are to be considered defects. Crack-like defects shall be removed by pipe replacement.

11.9.4.3 Anomalies on field welds

Anomalies found on field welds shall be removed unless the anomaly existed at the pressure test and can be shown to be dormant.

11.9.5 Repairs General

11.9.5.1 General

The objective of repair is to ensure that the repaired pipe is fit for service over the remaining pipeline life and having sufficient structural integrity to withstand all the identifiable forces to which it may be subjected during operations including the MAOP and cyclic pressure fluctuations with an acceptable safety margin.

Defects in pipelines may be repaired by a number of methods.
11.9.5.2 Repair Methods

Primary repair methods shall be as follows.

a) Replacement

Where a section of pipe is identified with significant damage the replacement of the defective section of pipe may be desirable. The pipe used for replacement is shall be PE 100 of the same SDR and diameter as the defective section. The repaired pipeline shall be pressure tested in accordance with this Code of Practice.

b) Reinforcement

Where a section of pipe is identified as not having propagating defects in the pipe wall (gouge) and the defect is not in the vicinity of the pipe joints or other fittings, repair may be achieved by reinforcement using a compression sleeve. These sleeves are typically Fibreglass Reinforced Compression Sleeves (FRCS) and are designed so when applied the repaired section of the carrier pipe is placed into compressive hoop stress at the operating pressure.

Alternatively reinforcement may be achieved with electrofusion repair saddles.

This repair method is unsuitable for longitudinal or circumferential crack-like defects.

11.9.6 Refurbishment

Where the remaining life of a pipeline system component has been evaluated as less than its design life (for example due to over-temperature operation) or is assessed not adequate for continuous safe operation, a component refurbishment program shall be planned and implemented to reinstate the structural integrity. The materials for the refurbishment shall be confirmed and approved.

The refurbishment shall be carried out in accordance with approved procedures, performed by trained and experienced persons, and assessed to meet all OH&S and Network Management System requirements.

Materials used for replacing existing pipe and associated fittings shall comply with the latest material specifications subject to further requirements of this Code of Practice.

All materials for the refurbishment shall be provided with material certificates and test records for material traceability that meet maintenance requirements. All work records shall be maintained for system periodic review and analysis.

11.9.7 Pre-repair preparation

Where a pipeline, which has been purged, filled with air and is connected to a source of hydrocarbon fluid that cannot be completely isolated,
jointing or repair operations shall not be permitted unless the flow of hydrocarbon fluid toward the work site is prevented and the pipeline contents at the work site are tested continuously to ensure that an unsafe concentration of hydrocarbon fluid does not occur. This may require —

- the generation of airflow away from the work within the pipeline, by the operation of air movers at suitable locations; or
- the installation of plugs or spheres with bleed vents on each side of the work site, taking care that this does not prevent adequate airflow that may be required in Item (a) above.

Purging of gas flowlines shall be carried out in accordance with this Code of Practice.

11.10 REMAINING LIFE REVIEW

The integrity and remaining life of an existing pipeline shall be assessed at regular intervals or immediately following a pipeline failure. The first assessment shall be completed no later than ten years after commissioning with the interval of subsequent assessments to be determined by the preceding assessment. The data required for the assessment shall include —

a) pipeline integrity degradation data from direct assessments;
b) remedial action(s) taken for the defects e.g. refurbishment profiles or MAOP reductions;
c) operating records such as operating pressure and temperature;
d) threat assessment;
e) change in environmental factors;
f) changes in class location.

The engineering investigation shall include verification of the following issues—

- Proof of structural integrity in accordance with this Code of Practice to confirm the pipeline can continue to contain the fluids at the design conditions;
- That the operating temperature is within the design limits and that no reduction in the design life is required.
- The completion of a safety management study and the identification of any changes required to the mitigation methods;
- Review of the adequacy of the safety and operating plan, operating and maintenance, emergency response, and safety and environmental procedures.

Upon completion of the review, all issues identified in the engineering investigation shall be addressed, and the pipeline records amended in accordance with the requirements of this Section.
The pipeline shall be operated only under the conditions and the limits so established and approved.

11.11 **SUSPENSION AND ABANDONMENT**

11.11.1 **Operation of a suspended pipeline**

The operation of a pipeline or network shall be considered as suspended where the pipeline or network is maintained in a non-flowing condition for an extended period beyond the established maintenance routine.

Where a pipeline or network is suspended for an indefinite period for a later alternative use, the following conditions apply –

   a) The contents of pipelines other than saline water may be stored within the pipeline for the duration of the suspension.

   b) The normal pipeline integrity maintenance functions and reporting shall continue in accordance with the operating procedures, and this Code of Practice.

   c) The level of pressurisation shall be monitored.

   d) The suspension of above-ground PFW or saline water pipelines shall be subject to a risk assessment.

   e) The suspension of a pipeline or network shall be approved through an approved Management of Change process.

The suspension of a pipeline or network should be reviewed after a five year period to determine if the pipeline or network should be abandoned, except where the pipeline is in a multiple pipeline trench, in which case the suspension of the pipeline shall be reviewed five years after all pipelines in the trench are suspended.

11.11.2 **Abandoning a pipeline**

11.11.2.1 **General**

When a pipeline or network is to be abandoned, an abandonment plan, including an environmental rehabilitation plan, shall be compiled and approved. The sequence of decision making that is required to develop and implement the plan should be in accordance with Figure 11.11.2.

When a pipeline is abandoned, it shall be disconnected from all sources of hydrocarbons or water that may be present in other pipelines and other appurtenances, and shall be purged of all hydrocarbons and vapour with a non-flammable fluid. Disposal of the purging fluid shall meet all relevant environmental and safety requirements.
11.11.2.2 Abandonment in place

When abandonment in place is approved, the pipeline or network section shall be abandoned in such a way to ensure that ground subsidence and the risk of contamination of the soil or ground water is minimised.

NOTE: Consideration should be given to filling the abandoned pipeline with an inert substance.

11.11.2.3 Abandonment of above-ground pipelines

Above-ground pipelines or networks shall be abandoned by removal of the pipelines or networks.

11.11.2.4 Additional requirements for abandonment

When a pipeline or network is abandoned, the following additional requirements shall be completed –

a) The cutting of all buried pipelines at a minimum of 750 mm below natural surface or at the pipeline depth, whichever is the lesser;

b) The removal of all equipment;

c) The removal of all signage associated with the pipeline on completion of the post abandonment maintenance period;

d) Obtaining landowner releases for the completed abandonment.

11.11.2.5 Abandonment records

On the completion of the abandonment of the pipeline section in place, "as executed" drawings, complying with AS 1100.401, identifying and locating sections of the abandoned pipeline or network, shall be prepared as part of the relinquishment procedure.

These records shall be made publicly available to prevent possible mistakes in identifying an abandoned pipeline or network as an operational pipeline or network.

Records of approved changes of operating conditions, all engineering investigations and work carried out in connection with any change in the operating conditions shall be maintained until the pipeline or network is abandoned or removed.
Figure 11.11.2 Flow Chart – Network Abandonment
• **APPENDIX A – System Design Considerations (Informative)**

Coal seam gas gathering systems generally involve one system for collecting gas and a separate system for gathering formation water. Coal seam gas producers have varying methods for separating these two systems at the well head. Beyond the wellhead, there are a number of aspects that need to be considered in the design of the gathering system.

The design of gas and water gathering systems need to be considered separately because of differing aspects of their design. However, often the two systems are run in parallel, and normally in the same trench until diverging to the separate gas and water processing facilities.

If the water is not removed from a gas gathering system, it has the potential to form slugs which may inhibit the flow of gas and, in addition, may require additional equipment (inlet separators/slug catchers’) to ensure that the compression facilities work optimally and are not damaged. Accordingly it is important that any significant quantities of water are removed from low points. This water collects in the gathering system from wellhead carry over as well as water condensation as the gas stream cools.

**NOTE:** Compression performance is optimised by processing laminar rather than turbulent gas flows, which are aggravated by two-phase significant water presence.

Water associated with CSG can have significant quantities of entrained gas which can be evolved during transportation through a pipeline. This gas will gather at high points and, if not removed can prevent energy recovery in the gathering system on the down-hill slopes. A water gathering system therefore needs to have any significant amounts of evolved gas removed from the high points.

Consideration should be given to the hydraulic pressure exerted on sections of water pipe at low points, in particular where downstream sections of network can be isolated. In addition to the hydraulic pressure the design should make allowances for residual reservoir/separator blanket pressure acting on the water network system. Isolation of network systems should allow for the impacts of water hammer where there is an interface between the network and surface equipment. Appropriate anchoring will need to be considered.

The designer should consider the effects of vacuum. In areas subject to vacuum the pipe should be appropriately specified.

The level of protection required in various situations needs to be considered by the designer. The following are a list of items that may need to be considered in the design of a gathering system –

- Well locations;
- Flow rates;
- Changes in elevation;
- Topography;
• Roadways;
• Railways;
• Power lines both overhead and underground;
• Fence lines;
• Buildings;
• Mining both present and future;
• Water courses;
• Public utilities such as water transmission pipelines and telegraphic cables or fibre optic cables;
• The use of agricultural land. e.g. Ploughed and levelled field or cattle property;
• The boundaries of Petroleum authorities;
• Potential future land use.

For both systems, the holistic design for each CSG field should incorporate the following –

• Isolation Philosophy;
• Segregation plans (3D where appropriate) for constructability;
• Nomination of exclusion zones for pressure testing.
APPENDIX B – Assessment of PE Welds (Normative)

B1 Introduction

This appendix discusses the existing techniques for both non-destructive (NDT) and destructive testing options for electrofusion (EF) and butt welding options. A section has also been included related to the emerging alternative NDT technologies.

The two common methods of welding Polyethylene (PE) pipe are butt fusion and electrofusion (EF). Butt fusion welding has been used successfully in Australia since the 1960’s and EF since the early 1980’s. These methods are used widely around the world with something in excess of 100,000,000 butt welds and around 20,000,000 EF joints completed annually. PE is the material of choice for gas distribution pipe systems around the world and is also widely used in the water industry, irrigation, mining and industrial applications. Based on this past success PE is now being used in highly critical pipe networks for applications such as nuclear power generation.

The weld procedures and practices used for jointing PE pipe are well understood and well documented. In Australia the major references are the PIPA POP 001 and POP 003 guidelines detailing the procedures for EF and butt fusion respectively (both available from PIPA: www.pipa.com.au). These in turn reference the International Standards ISO 21307 covering butt welding parameters. Other significant documents covering PE pipe welding include the German DVS Technical Codes on Plastics Joining Technologies and the UK Water Industry Standards.

The acceptance criteria suggested in this appendix are based on information contained in existing documentation. In particular the German DVS Technical Codes on Plastics Joining Technologies, AS/NZS2033, AS/NZS4129, UK Water Industry Standards, American Society for Testing and Materials F1055 and F2620 and other established industry practices such as those outlined in POP 001 and the Iplex Poliplex Manual.

B1.1 Background to weld assessment

The examination and testing of PE pipe welds has generally been based on visual and destructive testing options. These have proved very successful techniques for assessing welds along with a dedication to ensuring the correct surface preparation and weld procedures are employed. Visual examination of welds is a particularly useful NDT technique as it yields a great deal of information about the weld preparation, potential contamination, alignment and weld pressures. The value of visual examination of PE welds is often underestimated because many people have been conditioned to relying on radiography or ultrasonics in traditional metal welding.
Butt welding PE pipe differs significantly from metal welding and these differences make visual examination far more effective in PE than in metals. Butt welding PE pipe requires a machine that clamps, aligns and planes the surfaces to be welded so that they are both clean and square, applies heat using a calibrated plate, applies pressure to affect the weld and often also times and records the whole process.

In the case of PE pipe welding there are no welding consumables (i.e. the actual pipe material forms the weld) and the entire surface to be welded is heated uniformly.

After heating, the pipe ends are forced together under pressure and some of the material that was on the original face of the pipe end is rolled out to form the bead.

This contrasts enormously with metal welding where usually the weld is achieved by introducing a consumable welding material that differs from the pipe material. Typically this consumable is introduced to the joint in a small localised molten pool often thousands of degrees Celsius hotter than the remaining weld surfaces and progressively moves around the circumference during the welding process. Hence the appearance, size and shape of the PE weld bead provide a great deal of information about the entire process – visual examination of metal pipe welds cannot provide this information and there is no equivalent in metal pipe welding.

**B1.2 Welder qualifications and training**

The success of any welding process is dependent on the skills of the welder and their dedication to correct surface preparation and weld procedures. Welders shall be qualified and certified. Before undertaking any inspection the experience and skills of the welder shall be verified and the weld procedures adopted. It is also recommended that quality assurance records be examined. In addition, a periodic re-qualification of the welder is recommended; this is due to changes in welding standards and the evolution of the welding equipment. The typical period for re-qualification is 2 years.

A common method used to qualify a welder is the completion of a generic welding course available from several Registered Training Organisations (RTOs) throughout Australia. In addition to generic material, a PE welding course designed to qualify an individual for in-field welding should introduce training modules that address pipe sizes or grouping of pipe sizes and the equipment that is used to complete those PE welds (e.g. tracked fusion machines, large diameter fusion machines etc.)

In addition, emerging technologies will continue to present the industry with innovations that may have a dramatic impact on welding processes which further highlights the need to broaden the scope of the welding training available.

The qualification process should include a rigorous written test that confirms a attainment of the required competencies including the theory aspects of the training and the reasons why the thermoplastic fusion welding process is structured the way it is currently. Lastly, the qualification process should
include a practical examination that the candidate must pass. It is essential that the practical exam be assessed in a fair and consistent manner. To do so the assessment process should incorporate the use of a detailed checklist to ensure a consistent assessment and enable a comprehensive review at the completion of the practical exam.

**B1.3 Long term and short term testing**

Short term testing of PE welds is primarily aimed at field based or rapid turnaround test options typically used as QA/QC measures.

The purpose of long and short term testing is often misunderstood and hence the following outlines some of the long term type testing employed for welded PE pipe joints.

Plastics pipe systems undergo a range of long term type tests to prove their long term performance. These tests are laboratory based and often involve the exposure of the pipe to elevated temperatures during the test program for periods in excess of one year. These are not production tests but rather type tests to qualify materials and design to ensure service lives of 100 years or more will be achieved.

Welds for PE pipe have a range of long term tests that similarly prove the long term performance of jointing techniques. The long term tests for butt welds include the tensile specimen creep rupture test (EN 12814-3), the whole pipe tensile creep rupture test and the hydraulic pressure test (ISO 1167).

The long term creep rupture tests involve preparing a tensile test specimen or using a full pipe section and in both cases an initial axial stress of 5.4-5.5MPa is generated in the pipe wall or at the weld interface. These tests are conducted in a hot water bath at 80°C until failure – which typically occurs after several thousand hours.

The hydraulic pressure test is also conducted in a hot water bath at 80°C until failure – and again failure occurs usually after several thousand hours of testing.

Similarly for EF welds the long term test is the Slow Peel Test undertaken at elevated temperature between 50°C and 95°C and typically for testing times of around 500 hours. This test is currently being incorporated into the ISO suite of standards.

These long term tests are not production tests but rather used to establish the long term performance of welds and qualify weld parameters and procedures. These long term tests are not suitable for field assessment and are not addressed by this appendix.
B2 Non Destructive Testing (NDT)

B2.1 Visual examination of butt welds

NDT examination shall begin with a detailed examination of the weld and weld bead. As described above the nature of PE butt welding means that the bead itself provides a great deal of information about the weld. The weld bead should be uniform and symmetrical around the full circumference as shown in Figure B2.1 below and should not contain any sharp notches. Table B2.1a below defines the quantifiable criteria to be used for butt weld visual examination. Table B2.1b provides a list of bead shapes that are undesirable and Table B2.1c addresses weld defects. Measurement and comparison of bead sizes has deliberately been avoided as these will vary with differing weld parameters, PE materials and indeed simply due to gravity from the top to the bottom of the pipe.

Figure B2.1a Butt Weld Bead
Table B2.1a – Quantifiable Criteria for Butt Weld visual examination

<table>
<thead>
<tr>
<th>Weld Feature</th>
<th>Comments</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cracking</td>
<td>Cracking of any kind anywhere in any direction or orientation</td>
<td>Not acceptable.</td>
</tr>
<tr>
<td>2. Notches at interface</td>
<td>Sharp notch between weld beads that extends below the original pipe surface.</td>
<td>Not acceptable.</td>
</tr>
<tr>
<td>3. Scoring or notching other than at the interface</td>
<td>Notches or scoring in any direction</td>
<td>Acceptable where the depth of the notch or score does not exceed 10% of pipe wall thickness.</td>
</tr>
<tr>
<td>4. Displacement</td>
<td>Where pipes ends are displaced relative to one another.</td>
<td>Acceptable where extent of displacement does not exceed 10% of pipe wall thickness.</td>
</tr>
<tr>
<td>5. Angular misalignment</td>
<td>Where pipe ends are not aligned squarely.</td>
<td>Acceptable where the extent of misalignment measured at a point 300mm from the weld bead does not exceed 5mm.</td>
</tr>
<tr>
<td>6. Variation in pipe wall thickness</td>
<td>Where pipe wall thickness ‘A’ varies compared to adjacent pipe wall thickness ‘a’. In extreme cases the weld bead will be noticeably uneven.</td>
<td>Acceptable where the difference in pipe wall thickness between ‘a’ and ‘A’ does not exceed 10% of the thicker pipe ‘A’.</td>
</tr>
<tr>
<td>7. Blistering, bubbles or lumps on the weld bead</td>
<td>Where the surface of the weld bead contain blisters, bubbles or lumps indicating the weld surface may have been wet, too hot or possibly contaminated</td>
<td>Not acceptable</td>
</tr>
</tbody>
</table>
Table B2.1b – Undesirable bead profiles and associated investigative actions.

<table>
<thead>
<tr>
<th>Weld Feature</th>
<th>Comments</th>
<th>Suggested Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weld bead too narrow</td>
<td>The size and shape of weld beads varies due to the weld procedure. Any comparison must be done in relation to a known good weld using the nominated weld procedure and parameters. Possible causes for variations with known good welds could include incorrect pressures and/or temperatures</td>
<td>Comparisons need to be made to known acceptable welds. Investigate temperature and pressure aspects of welding machine and process.</td>
</tr>
<tr>
<td>or undersize</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weld bead appears flat</td>
<td>See comments for 1 above. Possible cause could be insufficient weld pressure</td>
<td>Investigate weld pressures and capability of welding machine.</td>
</tr>
<tr>
<td>Extremely uneven bead</td>
<td>Possible cause could include excessive temperature to one pipe end.</td>
<td>Investigate preheat times and process.</td>
</tr>
<tr>
<td>size</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table B2.1c – Internal Weld defects and acceptance criteria

<table>
<thead>
<tr>
<th>Weld Feature</th>
<th>Comments</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lack of fusion</td>
<td>Incomplete or no fusion of the pipe faces.</td>
<td>Not acceptable.</td>
</tr>
<tr>
<td>2. Voids and foreign matter</td>
<td>Isolated pores, shrinkage cavities or inclusions within the weld zone.</td>
<td>Permitted where the voids or inclusions are isolated (i.e. not in rows or grouped together) and where the size of individual pores or inclusions do not exceed 10% of the wall thickness</td>
</tr>
</tbody>
</table>
### Fusion Observation Checklist

<table>
<thead>
<tr>
<th>Description</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date Of Observation:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location of Observation:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Name of Technician Observed First Name:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Last Name:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date on VCC:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment Asset Number:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fusion Machine Model:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machine Serial Number:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation Being Performed:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS Butt Fusion ( ), PP Butt Fusion ( ), Sidewall Fusion ( ), Tie Ins ( )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condition of Equipment:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notes:</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pipe Preparation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleaned Appropriately:</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Supported with Pipe Stands:</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Correctly Clamped in the Fusion Machine</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Correct Inserts Installed:</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Faced to the Steps</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Pipe Marked Correctly Legibly</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Joint Number</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Debris Removal:</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Swarf removed from fusion zone</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Swarf removed from ground</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Pipe Adjustment/Alignment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alignment Check Completed:</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Adjustment required?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Facing Required?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Slippage Checked</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Facing Requiring?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Visible Gaps?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Was Drag Pressure Correctly Measured?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>What was the Observed Drag Pressure?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Heater Condition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heater Cleared Prior to Using</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Heater Calibration Valid</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Temperature Checked Prior to Using</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Thermometer Calibrated?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Temperature Observed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calibration Date?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Data Logger Usage</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Logger Calibration Valid</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Information Logged Correctly</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>DL Started before carriage engagement</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Weld Process</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indication of Melt observed</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Shift Sequence Executed Correctly</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Soak Time Requirements Met</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Soak Time Observed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heater Removed Within Specified Time</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Pipe Ends Checked Before Closing Carriage</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Cooling Time Requirements Met</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Cooling Time Observed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Logger Stopped Correctly</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>What was the pressure used during Facing Operations?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Were the Pipe Lifts used during the Drag Measurement Operation</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Were Pipe Stands used throughout the Weld Process</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>If so, how many were used?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How far from the Fusion Machine were they placed?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure B2.1b Example of a Butt Fusion Observation Checklist**
B2.1.1 Butt weld bead testing

Testing of the weld bead after removal from the pipe surface has been used as a simple field test to indicate weld acceptance. The test involves removing the weld bead (using a suitable bead removal tool) after the weld has fully cooled to ambient temperature. The removed bead should contain both sides of the flash joined along the centre line of the weld. The bead is then twisted or alternatively bent in the reverse curvature to the pipe surface (i.e. bend back test every few centimetres around the removed bead to examine it for the presence of slit defects). Refer Figure B2.1.1. The bead should remain intact.

If the bead separates, the parameters and welding process should be investigated.

![Bend back test](image)

Figure B2.1.1 Bend back test

B2.2 Visual examination of electrofusion (EF) joints

Table B2.2 below provides details for visual examination of electrofusion joints.

Table B2.2 – Weld features and acceptance criteria for EF joints

<table>
<thead>
<tr>
<th>Weld Feature</th>
<th>Comments</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Indicator pins</td>
<td>Many EF fittings have indicator pins. These should rise. They indicate sufficient pressure has been achieved during the weld process. Failure of pins to rise does not necessarily indicate a failed weld.</td>
<td>Pins failing to rise should be a trigger to investigate the joint further. Acceptance criteria and suggested actions are provided in POP 001.</td>
</tr>
<tr>
<td>2. Melt run out</td>
<td>Molten PE exudes from the fitting. There are multiple reasons why this could occur.</td>
<td>Not acceptable.</td>
</tr>
<tr>
<td>3. Misalignment</td>
<td>Pipe has been welded at an</td>
<td>Acceptable if the angle ‘y’</td>
</tr>
</tbody>
</table>
angle on one or both sides of a fitting. Misalignment can create gaps and damage the wire filament that may result in an internal defect. does not exceed 1.2 degrees or alternatively measure displacement at a point 300mm from the end of the coupler - the displacement ‘x’ does not exceed 6mm.

<table>
<thead>
<tr>
<th>4. Ovality and joint gap</th>
<th>This deformation may cause an excessive gap between the pipe and the EF fitting. This gap can be tolerated up to a certain limit.</th>
<th>Pipe ovality at fusion zone area prior to welding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Pipe DN &lt; 315</strong>&lt;br&gt;d1 – d2 &lt; 1.5% DN or 3 mm (whichever is the smallest value.)</td>
<td><strong>Pipe DN ≥ 315</strong>&lt;br&gt;d1 – d2 &lt; 1% DN or 5 mm (whichever is the smallest value.)</td>
</tr>
<tr>
<td></td>
<td>Guidance on minimum average pipe diameter after peeling, re-rounding and alternative methods of achieving compliance are provided in POP001</td>
<td></td>
</tr>
</tbody>
</table>

| 5. Extent of surface peeling | Surface peeling of the pipe should extend beyond the end of the EF fitting with the pipe fully inserted. | This feature alone should not be a justification for rejection, but should trigger an investigation of the weld under consideration. Acceptance would rely on all other aspects of the weld being acceptable. |

<table>
<thead>
<tr>
<th>Weld Feature</th>
<th>Comments</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Extent of surface peeling</td>
<td>Surface peeling of the pipe should extend beyond the end of the EF fitting with the pipe fully inserted.</td>
<td>This feature alone should not be a justification for rejection, but should trigger an investigation of the weld under consideration. Acceptance would rely on all other aspects of the weld being acceptable.</td>
</tr>
</tbody>
</table>

### B3 Destructive Testing

#### B3.1 Tensile testing of butt welds

There are a variety of standard test methods used for tensile testing PE butt welds - the WRC\(^6\), those nominated in ISO21307, BS EN 21814, ASTM D 638 and F2634 for example. These tests are carried out on weld specimens cut from the weld and tested in a laboratory or in the field. Generally these tests require the test specimen to fail in a ductile manner and hence the failure mode must be interpreted from the specimen. The photographs below are taken from the WRC WIS 4-32-08 \(^6\) and provide examples of acceptable and unacceptable test results.
In addition there have been several field based tensile testing procedures adopted around the world. These tests are also destructive, requiring coupons to be cut from the weld being examined. As an example the UK adopted a simple field test performed on site using a small tensile testing machine mounted in a van where the result was acceptable if the failure was ductile – similar to the laboratory based tests. Agru have used a simple field tensile test in Australia for many years and ISCO industries have recently offered another field tensile test option that requires little interpretation using a standard test coupon that simultaneously compares the tensile strength of the weld to the parent material.

The acceptance criterion is simply that the parent material fails first (9) – there is no interpretation of failure mode required.

B3.2 Bend testing of butt welds

There are also several standard bend tests used in Europe, Australia and the US - some with relatively well defined acceptance criteria whilst others have a more qualitative assessment. One such test is described in ASTM F2620 where a longitudinal strip of pipe, including the weld, is cut, held in clamping device and bent back on itself. This is a simple test that can be used in the field where the acceptance criteria was simply that the specimen did not crack.
or fracture at the weld. This test however has some physical limitations when the wall thickness exceeds 20-25mm and the stored energy in the bent specimen presents potential OH&S risks for those performing the test.

**B3.3 Destructive testing – electrofusion welds**

This test involves cutting a longitudinal piece of welded fitting and pipe and then mechanically peeling them apart. The acceptance criteria are defined in AS/NZS4129 with subsequent references to ISO13954 and ISO13955. The photographs below are from the WIS 4-32-08 specification showing ductile and mixed mode results.

![Image of test specimen](image)

**Figure B3.3a Acceptable ductile behaviour**

![Image of test specimen](image)

**Figure B3.3b Unacceptable mixed mode behaviour.**

ISO 21751 describes a simple decohesion test for EF joints called the “Strip Bend Test”. A longitudinal specimen is cut through the joint and undergoes a side bend test as shown in Figures B3.3c and B3.3d.

![Image of test specimen](image)

**Figure B3.3c ISO 21751 strip bend specimen prior to bending.**
Figure B3.3d  ISO 21751 strip bend test showing acceptable EF weld after bend testing.
APPENDIX C – PE Materials Selection and Quality (Informative)

An overview of the manufacturing process of PE pipes and fittings from polymerisation to extrusion or moulding is provided. A description is given of the major aspects of the processes and the controls that have been adopted to meet the requirements of all stakeholders. Characteristics of polyethylene, such as the time dependence of some of the properties are discussed.

C1 PE Polymer Manufacture

In contrast to some types of plastics, PE for pipes and fittings is sold by the polymer company as a fully pre-compounded material containing all of the additives, such as antioxidants and pigments, needed to process and protect the polymer. This practice is particularly true in Australia, Europe, New Zealand and Scandinavia. Some countries, including China and the USA allow additives to be incorporated at the extruder during the pipe extrusion process, but this is explicitly disallowed in Australia in the pipe Standard, AS/NZS4130. Restricting pipe companies to the use only fully pre-compounded materials provides a much greater level of control of the process, better reproducibility and higher confidence in the final product. It also allows the establishment of independent compound verification processes such as that adopted by PIPA as published in guideline POP 004.

PE pipe compounds are made in two stages. In the first stage the monomers are reacted to form the polymer. Today this is a very sophisticated process with polymer architecture designed to optimise characteristics such as processing, long-term strength, resistance to slow crack growth and resistance to rapid crack propagation. The polymer comprises long chain hydrocarbon molecules with strategically placed hydrocarbon side chains. The number, length and placement of the side chains play a major role in determining the performance of PE. Recent developments in catalysts and processes have allowed quite specific molecular architecture to be developed, thereby enhancing the performance of PE. Furthermore, PE100 has what is called a bimodal molecular weight distribution. The bimodal distribution, in contrast to the older style monomodal distribution, has allowed optimum physical characteristics to be developed in the polymer whilst maintaining processability.

Whilst PE materials are commonly referred to as high density (HDPE), medium density (MDPE), low density (LDPE) or linear low density (LLDPE) these descriptors are not appropriate for the PE pipe compounds used for the CSG industry. There is no universally accepted delineation between MDPE and HDPE and density alone does not adequately describe the material. The term PE100 should always be applied to the PE pipes used for CSG as it ensures all of the appropriate performance requirements have to be met rather than simply a density range.

After polymerisation and drying, the PE passes through a compounding extruder where the carbon black and other additives are incorporated. The
compounding extruders are specially designed to achieve the high level of dispersion and distribution of the additives critical to long-term performance. Pipe extruders are designed to achieve uniform heat distribution in the PE compound and provide high output. They are generally not designed to develop the high shear rates necessary to disperse additives. This is the primary reason for specifying the use of pre-compounded PE rather than allowing the incorporation of additives such as carbon black into the PE at the pipe extruder.

To ensure the intended compound characteristics have been achieved, compound manufacturers generally test a number of characteristics including density, oxygen induction time (OIT), melt flow rates and dispersion. Density, in this context, is used to show the process is in control. These tests ensure the intended polymer architecture and additive concentration has been achieved, but these aspects are all pre-determined by the close monitoring of the processing conditions.

As the compound exits the compounding extruder it passes through a die and is diced into small, regular granules or beads. The finished compound is packed in 25kg bags, 1 tonne bulk bags or container lots for shipment.

**C2 PE Compound Qualification**

AS/NZS4131 specifically describes the requirements for PE compounds for pipes and fittings. It details the composition and performance needed to ensure the long-term capability of the compound. In turn, AS/NZS4130 and AS/NZS4129 for pipes and fittings state that only compounds fully complying with the compound Standard are to be used to make complying pipes and fittings. In other words, it is not possible to make a pipe complying with AS/NZS4130 unless the material used also complies with AS/NZS4131. Any pipe marked AS/NZS4130 must therefore have been produced using fully pre-compounded material having established performance criteria.

As there are a significant number of compound manufacturers around the world and because determining compliance with the compound Standard is a lengthy process, PIPA has established a compound qualification process that can be utilised by suppliers, pipe manufacturers and specifiers. This process has been established for several years and the accepted compounds are listed in PIPA guideline POP 004. The process for obtaining a listing in POP 004 is as follows. The applicant submits to PIPA a comprehensive summary of all the test results needed to demonstrate compliance with AS/NZS4131, together with independent test reports. A group of PIPA experts, not associated with any compound producer or supplier, examine the submission and determine whether the material complies and therefore warrants listing. This process ensures that there is documentary evidence to show the material complies with all of the requirements of the Standard and this is supported by test reports from appropriately qualified, independent laboratories. Many of the Standard compound tests are extremely expensive and time consuming. For example it will take upwards of 2 years to develop a complete set of stress – regression test results.

These long-term tests are performed initially as a type test for qualification purposes and then repeated according to the requirements of AS/NZS4131.
For example, type tests are carried out when there are significant changes in raw materials and/or processes. There are also well established QA tests carried out on the PE production. An understanding of the relationships between performance in the type tests and in the QA tests means more easily or more quickly measured characteristics are tested and monitored, whilst still providing a high level of assurance of the quality of the compound.

C3 PE Compound Properties

The characteristics of PE paramount to its satisfactory performance in pipe and fittings applications include –

- resistance to slow crack growth,
- resistance to rapid crack propagation (RCP),
- strength and
- thermal stability.

Resistance to slow crack growth is one of the characteristics that has been greatly enhanced by the ability to manipulate the molecular architecture during polymerisation. It is an extremely important property as it defines the ability of the material to resist the propagation of a crack through the wall of the pipe and which would ultimately lead to failure. Improvements have been so great that it has been necessary to develop new test methods to assess this characteristic as the tests employed with the older generation PE materials cannot be completed in an acceptable timeframe. That is, modern materials last too long in the traditional tests.

RCP is a characteristic that is not limited to PE, but is particularly important for pipelines carrying compressible fluids. AS/NZS4131 defines the RCP performance requirements for PE100. Under the temperature and pressure conditions to be experienced in CSG applications in Australia, RCP will not occur in PE100 pipes.

The strength of the PE compound determines the allowable hoop stress, generated by internal pressure that the pipe can be subjected to during service. However, PE along with other plastics materials is visco-elastic and its strength is a time-dependent property. Sometimes this characteristic is mistaken for degradation of the material with ageing. However, if the strength of a sample of PE is re-measured using the same test conditions, some time after an initial measurement, the results will be the same. This will be the case unless there has been some chemical degradation due to, for example, UV attack causing a change in the molecular structure. The original short term strength will be retained even on pipe samples exhumed after many years of service. The time dependency of the strength means particular arrangements need to be made to determine the stress a plastics pipe can withstand for the duration of its intended service life. In the case of PE100, a large number of pipe samples are subjected to a range of pressures at 3 temperatures, usually 20°C, 60°C and 80°C.

The time to failure and the nature of the failure of each sample is noted and analysed in accordance with ISO 9080. Testing at elevated temperatures
accelerates the tests and ISO 9080 provides explicit rules governing the
extrapolation of the results to longer periods. The lower 97.5% prediction limit
($\sigma_{LPL}$) at 20°C is calculated at 50 years. This number is then used to
determine the Minimum Required Strength (MRS) in accordance with ISO
12162. PE100 materials must have a $\sigma_{LPL}$ at 20°C of not less than 10 MPa,
giving an MRS of 10. The use of $\sigma_{LPL}$ at 50 years when determining the MRS
is a matter of convention and should not be interpreted as limit on service life.
Given the period and temperatures for which PE pipes are usually pressure
tested, it is generally accepted that they can be expected to have a service life
in excess of 100 years at 20°C.

Non compounded PE exposed to high temperatures and UV radiation will
degrad. For this reason antioxidants and UV stabilisers or UV absorbers are
incorporated into the compound. The presence of antioxidant is assessed by
the OIT test which is performed both on the compound and the pipe. Residual
antioxidant is needed in the pipe to protect it during welding and service. In
Australia protection against UV radiation is addressed by specifying the
amount and type of UV stabiliser or absorber in the compound.

Other characteristics of PE pipes of interest to the end user are –
- reversion
- residual stress
- creep and stress relaxation
- coefficient of thermal expansion

Reversion is the contraction in length that occurs as a result of the longitudinal
stress imposed on a pipe during extrusion. It occurs on standing and is
accelerated at higher temperatures. With modern extrusion equipment
reversion in PE pipes is invariably well below the maximum of 3% permitted
when tested at 110°C. Reversion is of no real consequence in the context of
CSG pipes.

Residual stress is generated during the cooling process after the pipe exits
the extrusion die. Residual stress is responsible for the toe-in of the cut end
of the pipe. The magnitude of the toe-in is dependent upon the amount of
residual stress and the time dependent modulus of the PE. On a freshly cut
pipe end there will be an immediate toe-in and this will increase slowly with
time. The rate of increase in toe-in will progressively slow. On the other
hand, as a result of stress relaxation, the residual stress diminishes with time.
Toe-in will occur at any freshly cut pipe end, but will be less on old pipes.

Creep is a characteristic that is not limited to plastics as it also occurs in
metals. The difference is that in plastics its magnitude is significant at normal
operating temperatures. Creep is essentially the strain that takes place as a
result of the gradual release of localised stresses by short-range molecular
rearrangement. Because the strain, at a constant stress, increases with time
the modulus of PE is also time dependent, but the rate of change in both
strain and modulus diminishes with time.

A related characteristic is stress relaxation in which a specimen subjected to a
constant strain exhibits a diminishing stress with time. This characteristic
means that stresses created for example, by bending or deflecting a pipe, progressively diminish with time.

The time dependency of some of the properties of plastics is not an impediment to their use in a range of engineering applications as the characteristic is understood and taken into account in product design.

Plastics generally have much higher coefficients of thermal expansion than metals and PE is no exception. This may need to be taken into account during installation and design. For example, a hot pipe placed in an open trench during the day might contract significantly during a cold night if not backfilled. Once the trench has been backfilled, soil – pipe friction prevents contraction.

**C4 Extrusion**

The major pipe manufacturers these days receive PE compound in bulk rather than 25 kg bags. Bulk compound, is transferred to a silo from which it is passed through a drier immediately prior to extrusion. The drier removes any excess moisture absorbed by the compound and eliminates the possibility of porosity in the finished product. The function of the extruder is to melt the compound evenly and form it into the pipe shape. The temperature of the extruder components and the polymer melt are monitored continuously to ensure the material is sufficiently hot to be formed into a pipe, but not over heated so it degrades.

Of all the characteristics of a PE pipe, the ones that the pipe manufacturer controls are the dimensions. He can also influence the residual antioxidant level (as measured by OIT). The strength (i.e. resistance to internal pressure), modulus, slow crack growth and rapid crack growth resistance are determined by the molecular architecture and composition of the compound over which the compound producer has control, but not the pipe manufacturer. Nevertheless, some material properties such as resistance to internal pressure, reversion, pigment dispersion along with a general inspection for freedom from defects may also tested by the pipe or fitting manufacturer as part of their ongoing QA.

Appendix A of AS/NZS 4130 summarises a set of testing requirements for PE pipe along with minimum testing frequencies. Manufacturers often exceed these testing frequencies or employ additional or alternative tests to monitor quality. In some cases, attributes such as dimensions are continuously measured.

For QA purposes the most important things for the pipe manufacturer to monitor are the processing conditions, dimensions and OIT.

The extrusion process is a continuous one, but usually limited to finite production runs. The length of a run will be determined by demand for the product and availability of the extruder given a single extruder will normally be used for a range of pipe diameters and pressure classes.
C5 Moulded Fittings
The same comments as made in relation to extrusion apply to moulding except for the difference in the processing operation.

C6 Product Certification
The plastics pipes and fittings industry in Australia has had a long experience with third party product certification and it is now the norm for all major products, including PE. Product certification has long been a requirement for plastics pipes supplied to the water and plumbing industries for pressure applications. The certification process has the following elements:

a) A formal, auditable quality system and quality plans must exist

b) Compliance with all aspects of the product standard must be demonstrated including selection of compounds complying with AS/NZS 4131 and satisfactory completion of all type tests.

c) Process control methods are in place to ensure the process consistently complies with nominated criteria.

d) There are commensurate QA methods to verify the intended outcomes have been achieved.

e) Compliance audits are regularly performed to ensure the standards are being maintained.

C7 Quality and traceability
The traceability of PE pipes is provided by the message printed on the pipe at regular intervals. The message identifies –

a) the manufacturer.

b) the manufacturing site if the manufacturer has more than one production facility.

c) The production line (i.e. the actual extruder)

d) The date and time the pipe was made

e) The grade of material (for example PE100)

f) Dimensional and pressure class information as appropriate

g) The number of the product Standard to which it is made

h) Product certification details such as licence number.

This information allows people downstream of extrusion to fully identify the pipe and people upstream to link any pipe to the recorded processing conditions, test results and compound as needed. Similar requirements are recorded on PE fittings.
The essence of the PE pipe and fittings quality system comprises –

a) strong, up-to-date raw material and product Standards aligned with best international practice,

b) a process for independently assessing compounds to ensure compliance with the compound Standard and listing these compounds in a publicly accessible document (POP 004),

c) Making it mandatory for fully pre-compounded materials to be used in the production of pipe and fittings,

d) Having independent third party product certification to ensure products comply with the Standards and that appropriate quality systems and procedures are in place and maintained,

e) Comprehensive print messages on products to ensure full traceability.

These methods for the monitoring and control of PE pipe production are considered best practice.
APPENDIX D – Pressure Testing (Normative)

CONTENTS

D1 Calculation for Pneumatic Pressure Decay Method
D2 Stored Energy and Safe Distance Calculation – Pneumatic Tests
D3 Stored Energy and Safe Distance Calculation – Hydraulic Tests
D4 Pressure Rebound Test (Hydraulic)
D5 Pressure Decay Test (Hydraulic)
D6 Constant Pressure Test (Hydraulic)
D7 Typical Test Forms
**D1 Calculation for Pneumatic Pressure Decay Method**

A method of calculation for the allowable pressure loss in the Pneumatic pressure decay test is:

\[ D = \text{the outside diameter of the pipe in a uniform test section, in mm} \]
\[ L = \text{the length of a uniform test section, in metres} \]
\[ t = \text{the wall thickness of the pipe in a uniform test section, in mm} \]
\[ P_a = \text{absolute atmospheric pressure, in kilopascals, 101.3 kPa} \]
\[ P_1 = \text{test pressure, in kilopascals (normally } 1.25 \times \text{MAOP)} \]
\[ \text{Loss} = \text{Acceptable loss rate per hour per cubic metres} = l/\text{hr/act m}^3 \text{ (See Section 8.6.5.2)} \]
\[ T = \text{test period, in hours, normally 24 hours} \]
\[ V = \text{total volume under test pressure, in cubic metres} = (L \times \pi \times (D - 2 \times t)^2) / (4 \times 1000000) \text{ cubic metres} \]
\[ V_1 = \text{Starting volume – actual cubic metres} = V \times (P_1 + P_a) / P_a \]
\[ V_{\text{loss}} = \text{Acceptable loss – litres/hr} = V_1 \times \text{Loss} \]
\[ V_{\text{loss test}} = \text{Acceptable loss in test – m}^3/\text{test} = T \times (V_{\text{loss}} / 1000) \]
\[ P_{\text{loss test}} = \text{Acceptable pressure loss in the test – kPa} = (P_1 + P_a) - [(P_1 + P_a) \times (V_1 - V_{\text{loss test}}) / V_1] \]
\[ P_2 = \text{Acceptable pressure at end of test period – kPa} = P_1 - P_{\text{loss test}} \]
**D2 Stored Energy and Safe Distance Calculation – Pneumatic Tests**

The following method is from AME PCC-2. The stored energy of the equipment or piping system should be calculated and converted to equivalent kilograms of TNT (Trinitrotoluene) using the following equations.

A method of calculation of stored pneumatic energy is:

\[ D = \text{the outside diameter of the pipe in a uniform test section, in mm} \]
\[ L = \text{the length of a uniform test section, in metres} \]
\[ t = \text{the wall thickness of the pipe in a uniform test section, in mm} \]
\[ k = \text{ratio of specific heat for the test fluid, 1.4 for air.} \]
\[ P_a = \text{absolute atmospheric pressure, in kPa, 101.3 kPa} \]
\[ P_{at} = \text{absolute test pressure, in kPa} \]

\[ \text{TNT} = \text{equivalent kilograms of TNT (Trinitrotoluene)} \]

\[ V = \text{total volume under test pressure, in litres} \]
\[ = \frac{L \times \pi \times (D - 2 \times t)^2}{4 \times 1000} \text{ litres} \]

To calculate the stored energy

\[ SE = \frac{1}{(k-1)} \times P_{at} \times V \times [1 - \left(\frac{P_a}{P_{at}}\right)^{(k-1)/k}] \text{ Joules} \]

When using air or nitrogen as the test medium (k = 1.4), this equation becomes

\[ SE = 2.5 \times P_{at} \times V \times [1 - \left(\frac{P_a}{P_{at}}\right)^{0.286}] \text{ Joules} \]

\[ \text{TNT} = \frac{SE}{4266920} \text{ kg} \]

**Safe Distance Calculation – Pneumatic Tests**

This safe distance calculation is based on the stored energy calculation detailed above and the safe distance calculation adapted from ASME PCC-2.

This calculation details the minimum distance required for a pneumatic test. An \( R_{\text{scaled}} \) number of 20 is recommended for the distance from the pipeline to the limited boundary access (primary exclusion zone).
A method of calculation of safe distance is:

\[ R = \text{safe distance, in meters} \]

\[ R_{\text{scaled}} = \text{safe distance scaled consequence factor from ASME PCC-2 Article 5.1, Mandatory Appendix III, Table III-1. Refer Table D3, Appendix D3.} \]

\[ R_{\text{scaled}} = 20 \ (\text{minimum}) \]

For pneumatic testing, the minimum distance between all personnel and the equipment being tested shall be:

(a) \[ R = 30 \ \text{m} \ \text{for} \ SE \leq 135 \ 500 \ 000 \ \text{J} \]
(b) \[ R = 60 \ \text{m} \ \text{for} \ 135 \ 500 \ 000 \ \text{J} < SE \leq 271 \ 000 \ 000 \ \text{J} \]
(c) \[ R = R_{\text{scaled}} \times (\text{TNT})^{1/3} = 20 \times (\text{TNT})^{1/3} \ \text{m} \ \text{for} \ SE > 271 \ 000 \ 000 \ \text{J} \]
D3 Stored Energy and Safe Distance Calculation – Hydraulic Tests

NOTES:
1. This method is based on the calculation in AS 2885.5 - 2012 and adapted for PE. For further information refer to this standard.
2. This equation assumes a maximum residual air content of 0.2%. The test shall be conducted by a competent operator by means of a controlled fill to ensure the maximum residual air content does not exceed the value assumed in the stored energy calculation. Verification of actual volume may be performed during the filling operation.

A method of calculation of stored energy is:

\[ D = \text{the outside diameter of the pipe in a uniform test section, in mm} \]
\[ L = \text{the length of a uniform test section, in metres} \]
\[ P = \text{the test pressure, in kilopascals} \]
\[ SE = \text{total stored energy, in Joules} \]
\[ t = \text{the wall thickness of the pipe in a uniform test section, in mm} \]
\[ T = \text{average temperature of test section, in } ^\circ\text{C} \]
\[ Vo = \text{the total initial volume of water in the test section, in litres} \]
\[ = \left\{ L \times \pi \times (D - 2 \times t)^2 \right\} / \left( 4 \times 1000 \right) \text{ litres} \]
\[ A = \text{Compressibility of testing medium, in kPa}^{-1} \]
\[ = (3.897 \times 10^{-3} \times T^2 - 0.3133 \times T + 50.65) \times (1 - p/411844) \times 10^{-8} \]
\[ \text{TNT} = \text{equivalent mass of TNT (Trinitrotoluene), in kilograms} \]
\[ \% \text{air} = 0.2\% \text{ (assuming a maximum residual air content of 0.2%).} \]
\[ V_{\text{air}} = Vo \times \% \text{air} = Vo \times 0.002 \text{ volume of air in litres} \]
\[ V_{\text{H2O}} = Vo \times (1 - \% \text{air}) = Vo \times (1 - 0.002) \text{ volume of water in litres} \]
\[ \nu = 0.4 \text{ Poisson's ratio} \]
\[ E = \text{Young's Modulus} \]
\[ = 800,000 \text{ kPa} \]

NOTE: 800,000 kPa is used for the purpose of this calculation; typically 600,000 to 1,400,000 kPa for PE.
To calculate stored energy in a water-filled pipeline (assuming a negligible temperature change).

\[ \Delta V = V_{H2O} \times \left\{ (1 - \nu^2)/E \times D/t + A \right\} \times p \]

where the stored energy \( SE_{H2O} \) is the volume under the PV curve:

\[ SE_{H2O} = \text{stored energy of water, in Joules} \]
\[ = 0.5 \times p \times \Delta V \quad \text{Joules} \]

The method contained within AS/NZS 3788 and ASME PCC-2 to calculate stored energy in residual air may be applied:

\[ SE_{air} = 2.5 \times (p + 101.3) \times V_{air} \times \left\{ 1 - \left[ \frac{101.3}{p + 101.3} \right]^{0.286} \right\} \quad \text{Joules} \]

Total stored energy:

\[ SE = SE_{air} + SE_{H2O} \quad \text{Joules} \]

Equivalent kilograms of TNT (Trinitrotoluene)

\[ \text{TNT} = \frac{SE}{4266920} \text{ kg} \]

**Safe Distance Calculation – Hydraulic Tests**

This safe distance calculation is based on the stored energy calculation detailed above, known hydraulic energy release mechanism during pressure testing rupture events, and the safe distance calculation adapted from ASME PCC-2.

This calculation details the minimum distance required for a hydraulic test. A minimum \( R_{scaled} \) number of 20 is recommended for the distance from the pipeline to the limited boundary access (primary exclusion zone).

A method of calculation of safe distance is:

\[ R = \text{safe distance, in metres} \]
\[ R_{scaled} = \text{safe distance scaled consequence factor from ASME PCC-2, Article 5.1, Mandatory Appendix III, Table III-1 below.} \]
\[ R_{scaled} = 20 \quad \text{(minimum)} \]

\[ \text{TNT} = \text{equivalent mass of Trinitrotoluene as calculated above, in kg} \]

**Table D3 – \( R_{scaled} \) Consequence Factor – Extract from ASME PCC-2**

<table>
<thead>
<tr>
<th>( R_{scaled} ) m/kg \text{ }^{1/3}</th>
<th>Biological Effect</th>
<th>Structural Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>. . .</td>
<td>Glass windows</td>
</tr>
<tr>
<td>12</td>
<td>Eardrum rupture</td>
<td>Concrete block panels</td>
</tr>
<tr>
<td>6</td>
<td>Lung damage</td>
<td>Brick walls</td>
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<tr>
<td>2</td>
<td>Fatal</td>
<td>. . .</td>
</tr>
</tbody>
</table>
For hydraulic testing, the minimum distance between all personnel and the equipment being tested shall be the greater of:

(a) $R = 5\text{m}$
(b) $R = R_{\text{scaled}} \times (\text{TNT})^{1/3} = 20 \times (\text{TNT})^{1/3} \text{m}$

NOTE: The risk of blast wave, present during pneumatic tests, is only applicable to the minimal residual air component during hydraulic tests which enables reduction in the safe distance used.
D4 Pressure Rebound Test (Hydraulic) – based on AS 2566.2

D4.1 Application
This Test has been validated for PE pressure pipelines. It may be used for other materials, given the appropriate data. Consideration should be given to systems where there are number of steel components such as risers and manifolds within the system and to the disposal of volumes of water during the test.

This Test is applicable to PE, PP and ABS pressure pipelines up to and including DN 315.

NOTE: This Test is based on BS EN 805:2000, Appendix A.

D4.2 Pressure measurement rig
The test rig shall be a calibrated pressure transducer, data logger and check pressure gauge that has a dial of at least 100 mm diameter and a pressure range that places the CTP within the range 35% to 70% of the gauge’s full scale. The transducer and the check gauge shall read within 5% of each other. If they do not agree within this tolerance, the equipment shall be re-calibrated or replaced.

D4.3 Procedure
The test procedure has the following three phases:

A preliminary phase in which is—

a) the pipeline is depressurized and allowed to relax after the strength test Section 8.4.1

b) the pipeline is pressurized quickly to the test pressure and maintained at this pressure for a period of time without further water being added;

c) the pressure is allowed to decay by visco-elastic creep; and

d) Provided the pressure drop does not exceed a specified maximum, the pressure test can proceed to the second phase.

A secondary phase in which the volume of air remaining in the pipeline is assessed against an allowable maximum.

The main test phase in which the pipeline is maintained at the test pressure for a period of time and decay due to visco-elastic creep commenced. The creep is interrupted by a rapid reduction of the pressure in the pipeline to a specified level. This rapid reduction in pressure results in contraction of the pipeline with an increase (rebound) in pressure.

If, during the rebound period, the pressure vs. time record shows a fall in pressure, the pipeline fails the test.
D4.4 Preliminary phase

The procedure shall be as follows:

a) Reduce pressure to just above atmospheric at the highest point of the test length, and let stand for 60 min. Ensure no air enters the line

b) Raise the pressure smoothly to CTP\(^5\) in less than 10 min. Hold the pressure at CTP for 30 min by pumping continuously, or at short intervals as needed. Do not exceed CTP.

c) Inspect for leaks during the 30 min period, and then shut off pressure.

d) Allow the pressure to decay for 60 min.

e) Measure the pressure remaining at 60 min (P60).

f) If P60 ≤ 0.7% of CTP the test has failed. The cause shall be located and rectified. Steps (a) to (e) shall be repeated. If P60 > 70% of CTP, proceed to the air volume assessment.

D4.5 Air volume assessment

The procedure shall be as follows:

a) Quickly (<5 min) reduce pressure by \(P\) (10%–15% of CTP).

b) Measure water volume bled out (\(V\)).

c) Calculate \(V_{\text{max allowable}}\) as follows: \(V_{\text{max allowable}} = 1.2VP(1/EW + D/ER)\)

Where:

- 1.2 = air allowance
- \(V\) = pipe volume, in litres
- \(P\) = measured pressure drop, in kilopascals
- \(D\) = pipe internal diameter, in metres
- \(ER\) = pipe material modulus, in kilopascals (see Table D1)
- \(EW\) = bulk modulus of water, in kilopascals (see Table D2).

If \(V > V_{\text{max allowable}}\), the test has failed. The cause shall be located and rectified. The preliminary phase shall be repeated. If \(V > V_{\text{max allowable}}\), proceed to the main test phase.

NOTE: \(V\) and \(P\) should be measured as accurately as possible, especially where the test length volume is small.

\(^5\) The acronym CTP “Calculated Test Pressure” is used instead of STP “Stipulated Test Pressure” as this can be confused with “Standard Temperature and Pressure” which is universally recognised as 101.325 kPa (Abs) and 15 deg C.
Table D4.5a - PIPE E MATERIAL MODULUS FOR PE100

<table>
<thead>
<tr>
<th>Temp °C</th>
<th>PE 100- E Modulus (kPa x 10³)</th>
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</thead>
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<tr>
<td></td>
<td>1h</td>
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<tr>
<td>5</td>
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<td>25</td>
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<td>30</td>
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</table>

NOTE: Table assumes MDPE for PE100

Table D4.5b - BULK MODULUS $E_w$ – WATER

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>Bulk Modulus (kPa x 10³)</th>
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</thead>
<tbody>
<tr>
<td>5</td>
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<td>25</td>
<td>2210</td>
</tr>
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<td>30</td>
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</tr>
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</table>

D4.6 Main test phase

Observe and record the pressure rise for 30 min. In the event of failure, locate and repair leaks. If failure is marginal or doubtful, or if it is necessary to determine leakage rate, use a reference test.

NOTE: Figure D4.6 gives an example of a full pressure test with the main test phase extended to 90 min.
Figure D4.6 Typical Successful Modified Rebound Test for a Pipeline
D5 Pressure Decay Test (Hydraulic) - based on AS 2566.2

D5.1 Application

This Test has been validated for PE pressure pipelines. It may be used for other materials, given the appropriate data. Considerations should be given to systems where there are number of steel components such as risers and manifolds within the system.

NOTE: This Method is based on Section 5 of A guide to testing of water supply pipelines and sewer rising mains, 1st Edition, June 1999, published by Water Research Committee (WRc Plc), UK.

D5.2 Pressurising the pipeline

The procedure shall be as follows:

Apply the specified test pressure by pumping continuously at a constant rate.

The rate at which the pressure is increased to the calculated test pressure (CTP), and therefore the pump size, is important. The longer it takes to raise the pressure, the more time the pipeline has to expand (creep). Total test duration is related to the initial load time, leading to a long test duration, which may make other factors, e.g. temperature fluctuations, important. If the rate of pressurization is too high, it becomes difficult to control the pressure and the pipeline could be overloaded.

Air removal from the system could become a problem.

Volume added can be estimated from the number of full strokes of the piston or by direct measurement using a measurement recording device such as a flow meter.

Monitor and record the pressure rise and the time taken (loading time (tL)) to reach the CTP. The load time should not be less than 5 minutes. For smaller systems where this is not feasible, a different test method should be considered or a smaller pump.

Plot pressure against water volume, in litres, or against time (which is directly related to volume at a constant rate of pumping with a positive displacement pump).

NOTES:

1. The relative proportion of air in the system can be gauged by the time taken to pressurize the main for a given pumping rate. Figure D5.2 identifies the changes in curve shape with the increasing presence of air in the test section. Where there is no air in the system, the response is linear (A-B). With increasing amounts of air, the response becomes more curvilinear (A-C, A-D, etc.)

2. Where the analysis indicates significant volumes of air, the test shall be terminated and the air shall be removed before the pressure test shall be recommenced.
D5.3 Early prediction of problems

The predicted pressure shall be calculated using the following equation:

\[ P = P_L (2.5(\frac{t}{t_L}) + 1)^{-n} \]

Where:

- \( P \) = predicted pressure at time \( t \)
- \( P_L \) = test pressure at start of test
- \( t_L \) = loading (pressurizing) time
- \( n \) = slope of the pressure decay curve, as a guide take \( n \) as:

  0.10 for pipes without constraint (e.g. slip lined or no backfill)
  0.05 for pipes with compacted backfill

NOTES:

1. As the test can take some time to complete, it may be helpful to have an early indication of problems such as leakage or air entrapment.

2. Since the logarithmic plot of pressure and time for an ideal PE pipeline system is linear, comparing the actual pressure with the predicted pressure highlights problems.
D5.4 Three-point analysis procedure

The specified test pressure shall be applied and the high point air release valves and the pump feed valve shall be isolated by closing them. The pressure shall then be allowed to decay.

NOTE: The longer the time, between reaching the test pressure and the final reading, the more reliable the test results become. Taking more than three readings improves the reliability of the test results.

With reference to Figure D5.4, The three-point analysis test procedure shall be as follows:

a) At the moment of valve closure, time $t = 0$ and $t_L = $ loading time.
b) Take the first reading of pressure $P_1$ at $t_1$, where $t_1 = 0 + t_L$
c) Take a second reading of pressure $P_2$ at $t_2$ (approximately $7t_L$).
d) Take a third reading of pressure $P_3$ at a $t_3$ (not less than $15t_L$).

![Figure D5.4 Typical Pressure/ Volume Plot](image_url)

To allow for the creep behaviour of PE pipeline whilst being pressurized, the corrected values of $t_1$, $t_2$ and $t_3$ shall be calculated by using:

$t_{1c} = t_1 + 0.4t_L$
$t_{2c} = t_2 + 0.4t_L$
$t_{3c} = t_3 + 0.4t_L$
The slope of the pressure decay curve between \( t_1 \) and \( t_2 \) (slope \( n_1 \)) shall be calculated by using:

\[
  n_1 = \frac{\log P_1 - \log P_2}{\log t_2c - \log t_1c}
\]

and between \( t_2 \) and \( t_3 \) (slope \( n_2 \)) by using:

\[
  n_2 = \frac{\log P_2 - \log P_3}{\log t_3c - \log t_2c}
\]

**D5.5 Acceptance Criteria**

The test length shall be acceptable (no leakage) if \( n_1 \) and \( n_2 \) lie within the range 0.04 to 0.1 as follows:

(i) 0.08 – 0.10 for unsupported pipes (e.g., slip lined or no backfill).
(ii) 0.05 – 0.08 for pipes in intermediate ground conditions.
(iii) 0.04 – 0.05 for pipes in compacted backfill (loading time \( t_L \)).

If the plotted line is not straight, it shall be interpreted as follows:

(A) *Was shallow, now within the above range.* There may have been a small amount of air in the pipeline holding the pressure up, but it has now escaped or has little effect. The test length is acceptable.

(B) *Was steep, now within the above range.* Just after the test section is isolated and before \( t_1 \), there is often a small steep drop. Where the drop is very large, there may have been a pressure sensitive leak. The test length is acceptable.

(C) *Was within the above range, now shallow.* The pipe may have expanded and reached an obstruction e.g. an outer pipe where it was slip-lined or surrounding backfill. The test length is acceptable.

(D) *Was within the above range, now steep.* The test length is not acceptable. There is a leak. Carry out checks as for \( n > 0.10 \)

If the plotted line was not in the above range, the test length shall not be acceptable

**D5.6 Troubleshooting and retesting**

Where a test length is not acceptable, the fault shall be corrected and the pipeline retested.

The minimum time between repeat tests shall be 5 times the total test time.
NOTE: The following interpretations provide guidance:

- $n < 0.04$: there is probably air in the system.
- $n > 0.10$: the system is probably leaking.
- $n >> 0.15$: there is almost certainly a leak.
D6  Constant Pressure Pressure Decay Test (Hydraulic) - based on AS 2566.2

D6.1  Application

The test method in this section is based on the Constant Pressure (water loss) method for visco-elastic pressure pipelines detailed in AS 2566.2.

For plastics pipes that are subjected to internal pressure, there will be a progressive drop in that pressure due to creep. Accordingly, it may be difficult to assess whether a pipeline is leaking or simply subject to creep. In order to overcome this difficulty, this method is based on the principle that if the pressure is held constant, there will be a linear relationship between hoop strain and logarithmic time.

Variables such as pipe stiffness and soil compaction are irrelevant, as the test result is based on actual performance during the test. Temperature may be considered constant, as with other test methods, unless special conditions exist.

D6.2  Pressurisation and procedure

The pipeline shall be tested as follows –

The recommended rate of filling shall be based on a flow velocity of 0.05 m/s, i.e. calculated from the following equation:

\[ Q_f \leq 12.5 \pi D^2 \]

Where \( Q_f \) = filling rate in litres per second

\( D \) = pipe diameter in metres

During the filling process, purge all air from the test section.

Raise pressure to the calculated test pressure (CTP), close of test section and allow to stabilise for at least 12 hours. During this period pressure will fall as a result of pipe expansion and creep.

Using water of the same temperature as that in the pipeline (±3°C) restore and maintain the CTP;

Measure and record water volume added at 2 hr, 3 hr, 4 hr, and 5 hr from start;

Conclude the Constant Pressure Test five hours after completion of the 12 hour stabilisation period. For optimum test results, the following tolerances are recommended –

- Water volume: ±10D litres, where D = pipe nominal diameter in metres;
- Time: ±1 min;
- Pressure: ±1 kPa.
Calculate the water volume added between the second and third hour, $\Delta V(3h-2h)$ and the volume added between the fourth and fifth hour, $\Delta V(5h-4h)$.

Calculate $V_{\text{all}} = 0.14 \cdot L \cdot D \cdot H$ (ref. AS/NZS 2566.2, Section 6.3.4)

Where $V_{\text{all}} =$ Volume makeup allowance, in litres/hour

$L =$ Test length, in kilometres

$D =$ Pipe nominal diameter, in metres

$H =$ Average test head over pipeline length, in metres

**D6.3 Acceptance Criterion**

The test will be acceptable in accordance with AS/NZS 2566.2. Clause 6.3.4 as follows:

a) Test section has been pressurised to CTP and allowed to stabilise for a minimum of 12 hours.

b) Test section has been subjected to a 5 hour Constant Pressure Test.

c) There are no pipeline component failures.

d) There is no visible leakage.

e) $\Delta V(5h-4h) \leq 0.55 \Delta V(3h-2h) + V_{\text{all}}$. 
## TEST NOTIFICATION FORM

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<tr>
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<th>PROJECT NUMBER:</th>
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</thead>
<tbody>
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<tr>
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<td>TEST PACK NUMBER:</td>
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<td>FROM: TO:</td>
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<td>DATE SUBMITTED:</td>
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**TO THE ATTENTION OF:**

**DATE OF PROPOSED TEST:**

**START TIME:**

**SITE CONTACT:**

**CONTACT TELEPHONE NO:**

**EMERGENCY CONTACT:**

**EMERGENCY TELEPHONE NO:**

**TEST TYPE:**

*Hydraulic/Pneumatic**

**TEST MEDIUM:**

**MAXIMUM TEST PRESSURE:**

**KPA**

**EXCLUSION ZONE *(Meters/Map No.):**

**ADDITIONAL COMMENTS:**

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| **CLIENT CONTRACT NUMBER:** |  |
| **TEST PACK NUMBER:** |  |
| **TEST PACK DESCRIPTION:** |  |
| **DRAWING NUMBER:** |  |
| **FACILITY:** |  |
| **TEST DATA** |  |
| **TEST MEDIUM:** |  |
| **PRESSURE START:** |  |
| **KPA** |  |
| **TEST PRESSURE:** |  |
| **KPA** |  |
| **PRESSURE FINISH:** |  |
| **KPA** |  |
| **TEST DURATION:** |  |
| **PRESSURE LOSS:** |  |
| **KPA** |  |
| **TEST DATE:** |  |
| **PIPE VOLUME:** | m³ | **TIME START:** |  |
| **AIR CONTENT:** | % | **TIME FINISH:** |  |
| **PERMISSIBLE LOSS:** | LITRES | **TEMPERATURE START:** |  |
| **ACTUAL LOSS:** | LITRES | **TEMPERATURE FINISH:** |  |
| **CALIBRATION DATA:** |  |
| **SERIAL NUMBER:** |  |
| **DATE OF CALIBRATION:** |  |
| **MODEL:** |  |
| **TEST GAUGE:** |  |
| **TEST RECORDER:** |  |
| **DATA LOGGER:** |  |
| **TEMPERATURE RECORDER:** |  |

| **CONTRACTOR** | **CLIENT** |
| Witnessed by: | Witnessed by: |
| Name: | Name: |
| Position: | Position: |
| Signature: | Signature: |
| Date: | Date: |
• APPENDIX E – Maintenance, Modifications and Emergency Response (Informative)

E1 PURPOSE
This appendix describes methods used to temporarily control or stop flow in polyethylene piping systems in the event of routine maintenance or emergency response operations. Flow stopping systems must not be used as a permanent shut-off device. These flow stopping or flow control techniques are generally used for isolation tie-ins or emergency repairs. The limitations of each process will be detailed in each applicable section.

E2 SCOPE
The main methods of flow stopping are –
• Squeeze-Offs;
• Plugging;
• Semi Supported Flow Stop Bags.

E3 SQUEEZE-OFF

E3.1 Introduction
Squeeze-off is a technique used to temporarily control or stop the flow of gas or liquid in a polyethylene pipe by compressing the pipe between parallel bars with a mechanical or hydraulic squeeze-off device until the inside surfaces make contact.

ASTM standards listed provide guidance on the qualification of tools and equipment along with operator and procedure qualification.

• ASTM F1041, Standard guide for squeeze-off of Polyolefin Gas Pressure Pipe and Tubing
• ASTM F1734-03, Standard Practice for Qualification of a Combination of Squeeze Tool, Pipe, and Squeeze-Off Procedures to Avoid Long-Term Damage in Polyethylene (PE) Gas Pipe.

E3.2 General
When conducting a flow stopping technique or conducting a branch drill connection, consideration must be given to the distance between existing welds, repair welds, branch saddles and the placement of squeeze of tools in relation to a welded joint or saddle.
E3.3 Procedure

Squeeze-off equipment and procedures should be approved.

When selecting equipment and determining the operating procedure, the following should be considered -

a) The pipeline material and dimensions.

b) The operating gas pressure within the pipeline

c) The requirements for a temporary bypass

d) The temperature of the main or service material.

e) Pipe area to be squeezed must be substantially free from marks or scratches especially longitudinally along the pipe and in the squeezed ears region.

f) The suitability of various diameters of squeezing bars or rollers for various pipeline diameters and wall thicknesses, refer to ASTM F1563-01.

g) The maximum compression squeeze rate of 50mm/min is recommended in ASTM 1041. This rate is considered slow enough to allow stress relaxation in the pipe.

h) Prior to squeeze off, provision should be made to prevent static electricity (i.e. damp non synthetic cloth or earth rods)

i) A slow release rate is critical to avoid damage to the pipe and should be a maximum of 12mm/min as recommended in ASTM F1041-02.

j) The provision of stops, integral to the device’s operation, which limit the gap between the roller bars in accordance with pipe manufacturer’s specifications.

k) The device should be placed at 90° to the pipeline centreline and at the recommended minimum distance for the material and associated diameter (refer Sections E5 and E6 below for specific separation distances).

l) The provision of mechanical safety devices on hydraulic squeeze-offs to prevent hydraulic ‘leak back’.

m) The squeeze-off device, hot air, hot water, or any other means, should not be used to accelerate the re-rounding of the pipeline.

n) Before the pipeline is returned to operation, the squeeze-off should be clearly identified (e.g. with permanent ink or paint around the full circumference of the pipe and at least 2x diameters longitudinally or other means such as inscribed tape) to ensure the area at minimum distance of pipeline diameters from the squeeze-off is not squeezed off again, thus minimizing the future risk of wall cracking.

o) Following squeeze-off of PE, inspections for damage must be made, then application of a specially made re-rounding tool if required. After re-rounding, repair clamps or reinforcement fittings at the squeeze-off point may be installed.
**E4 TOOLS AND EQUIPMENT**

Tools and equipment are to include –

- Personal Protective Equipment (PPE) which is to include gas and oxygen monitoring devices and Breathing Apparatus where work is to be carried out below ground level and/or pipe is to be cut or opened.
- Approved squeeze-off tool fitted with limiting stops.
- Cutting equipment.
- Paper towels and water for cleaning pipe.
- Alignment and re-rounding clamps.
- Tape with “Squeeze-off applied” label.
- Clean damp non-synthetic cloth.
- Vent pipes with flame traps and earthing strap (where applicable).

**E5 REQUIREMENTS FOR PIPES UP TO DN315 DN180**

**E5.1 Preparation**

- Select an appropriate site. Where practical, use separate bell-holes to install the squeeze-off tools. Using separate bell-holes to the work area minimises the deflection of pipe after the squeeze has been released. Ensure that the pipe is clean and free from sharp objects that may have a damaging effect on the pipe being squeezed.
- Ensure the excavation is sufficiently large enough to accommodate the width of the squeeze-off tool with the length of the exposed pipe being 5 times the nominal pipe diameter with the squeeze tool located in the centre.
• Ensure that the limiting stops where fitted to the tools match the size of pipe that is being squeezed.

• Thoroughly wash and clean the exposed pipe where squeeze-offs and joints are to be made.

• The tool should be placed at 90 degrees to the pipe length and a recommended 5 pipe diameters minimum distance from any fitting or weld.

• No artificial heating of the pipe should take place either prior to or immediately after a squeeze-off has been applied.

E5.2 Procedure

• Ensure that the squeeze-off tool is fitted in a central position over the pipe to be squeezed.

• Make sure that the hydraulic jack is locked off. Where fitted, ensure that all safety locking pins are operating and the roller bars are locked into place.

  Fit the handle to the hydraulic jack and begin to pump until both rollers are in contact with the pipe. Visually inspect to ensure that the squeeze-off tool is still centrally located on the pipe.

  NOTE: If the tool is not central to the pipe length, a satisfactory squeeze-off is unlikely. Release the pressure from the hydraulics and realign.

• Continue to pump the hydraulic jack until it is evident that a squeeze-off has been established.

• Remove handle from the hydraulic jack. Wind down mechanical safety stops.

  NOTE: In the event that a satisfactory squeeze-off cannot be established using one set of squeeze-off tools, when directed by a qualified and experienced engineer a secondary squeeze and bleed joint may be applied upstream of the primary squeeze-off, to minimise any gas pressure passing into the work area.

• The secondary tools should be fitted at a suitable location where a branch can be fused to the pipe. If a purge stack is used, it shall should be fitted with a flame trap and commissioned to vent off gas between the primary and secondary squeeze-off tools. Other methods, e.g. nitrogen purging can be employed.

• On completion of the squeeze off operation and when the squeeze-off equipment has been removed, the pipe should shall be inspected for damage and gradually (especially in the early stages of re rounding) manually re-rounded using a purpose made re rounding clamp. The clamp should be fitted for a minimum of 10 minutes at each location after which a permanent repair clamp may be applied if needed.

NOTE: Where secondary squeeze-off tools have been fitted, close off and seal the vent tees between the primary and secondary tools. Then release secondary squeeze-off tools slowly.
E6 REQUIREMENTS FOR PIPES GREATER THAN DN315

E6.1 Preliminary Investigation
Before pipe of greater than DN315 is squeezed off and reopened, it is required that investigations and tests be made to determine that the particular type, grade, size, and wall thickness of pipe or tubing of the same manufacture can be squeezed-off and reopened without causing failure under the conditions that will prevail at the time of the squeezing-off and reopening. These tests may be undertaken at any time before the squeeze-off is needed and records of these tests must be retained. See ASTM F1734-03, Standard Practice for Qualification of a Combination of Squeeze Tool, Pipe, and Squeeze-Off Procedures to Avoid Long-Term Damage in Polyethylene (PE) Gas Pipe for details.

NOTE: Squeeze tool equipment of larger sizes is under development internationally to adapt to industry usage of larger PE pipe sizes. Potential users of such equipment should ensure compliance with ASTM F 1734-03 requirements.

E6.2 Preparation
Refer E5.1 above

E6.3 Procedure
Refer E5.2 above

E7 PLUGGING
Plugging is a specialist technique used to stop or control flow by mechanically installing plugs in the pipeline. Utilising a hot-tapping machine, a hole is cut in the pipeline through the tapping fitting and a valve. A plugging machine is then bolted on to install the plug assembly. Utilising vents between plugs is recommended to prevent build-up of pressure and to act as a double block and bleed.

These systems are generally used on up to 315mm diameter PE Pipelines.

E8 SEMI-SUPPORTED FLOW STOP BAGS

E8.1 Introduction
Flow stopping using inflatable semi supported bags is another method that can be used on large diameter PE gathering mains.

This technique uses an existing or a welded branch saddle to the pipeline fitting with an isolation valve. An inflatable bag is inserted into the pipeline. When the bag is in the required position it is inflated using nitrogen to stop the flow (refer to the manufacturer’s recommendations). Bags are deflated and withdrawn once flow is reinstated. Utilising vents between bags is recommended to prevent a build-up of pressure and to act as a double block and bleed.
E8.2 Procedure

Isolation equipment and procedures should be approved. When selecting equipment and determining the operating procedure, the following should be considered:

a) The pipeline material and dimensions.
b) The operating gas pressure within the pipeline.
c) The requirement for a temporary bypass.
d) The temperature of the main or service material.
e) The device should be placed at either 90° or 180° to the pipeline centreline and a recommended minimum of five pipe diameters away from a weld, fitting or other squeeze off machine.
f) The provision of mechanical safety devices on bagging-offs to prevent ‘leak back’.

Figure E8.2 Typical Bagging Insertion

E8.3 Tools and Equipment

Tools and equipment are to include –

- Personal Protective Equipment (PPE) which is to include gas and oxygen monitoring devices and Breathing Apparatus where work is to be carried out below ground level and/or pipe is to be cut or opened.
- Approved bagging insertion and extraction tool fitted with a pressure relief protection system.
- Medium to fill bag (e.g. nitrogen or liquid - refer to manufacturers guidelines).
- Alignment and re-rounding clamps
- Clean damp non-synthetic cloth
- Vent pipes with flame traps and earthing strap (where applicable)

**E9  BYPASS (FLOW STOPPING)**

**E9.1 Introduction**

Where a flow stopping technique is utilised for maintenance or emergency response, a bypass facility may be required to maintain flow or to minimise pressure on the flow stop technique. With reference to Figure E9.1, this can be achieved by utilising either temporary hoses or welded PE piping. It is recommended that temporary certified hosing should only be used up to a maximum size of 50mm. All bypasses that exceed the allowable 50mm should be constructed utilising flanged or welded steel or PE piping and should undergo a strength and leak test prior to commissioning. Considerations must be given to the following:

- Bypass protection due to:
  a) Third Party Damage
  b) Mechanical Damage
  c) Fire protection
- Flow Rate
- Length
- Slugging (dual phase flow)

![Figure E9.1 Temporary Bypass](image-url)
E10 HOT TAPPING

E10.1 Introduction
Hot Tapping, also known as branch drilling, is a method that can be used for providing a branch connection to a live or non-operational pipeline. It is a method that is also used in conjunction with flow stopping techniques such as stoppling and bagging-off.

Hot Tapping can be a “high-risk” operation that should only be conducted by qualified competently trained personnel. When conducting a hot tap, precautions must be given to the following:

- Pipe & fittings preparation
- Continuous checking of gas concentration
- Assembly of the pressure drill and correct drill heads (including coupon catcher)
- Correct measurements
- Drilling operation
- Removal of drilling machine.
- Successful removal of the coupon.

E10.2 Procedure
Branch drilling equipment and procedures should be approved.

When selecting equipment and determining the operating procedure, the following should be considered-

a) The pipeline material and dimensions.
b) Use of earthing rods or use of damp non-synthetic cloths to counter static electricity.
c) With reference to Figure E10.2, the length of the drill and travel calculations.
d) Number of turns to fully open and close the main branch isolation valve.
e) Drill alignment.
f) Without operation, check drill passes through valve and touches pipe.
g) Pressure Leak test on pressure drill prior to pipe penetration.
h) Purging of drilling machine once pilot drill has penetrated pipe.
i) Ensuring the pipeline is fully cut and the coupon retained in the drill head.
j) The retraction of the drilling machine past the isolation valve
k) Ensuring the isolation valve is fully closed, the drilling machine is de-pressurised and removed from the branch saddle.

Distance of Travel 1 = Pilot drill on pipe.
Distance of Travel 2 = Cutting head on pipe.
Distance of Travel 3 = Cutting head through pipe.

Figure E10.2 Pressure Drill

E10.3 Tools and Equipment
Tools and equipment are to include –

- Personal Protective Equipment (PPE) which is to include gas and oxygen monitoring devices and Breathing Apparatus where work is to be carried out below ground level and/or pipe is to be cut or opened.
- Pressure leak test equipment.
- Approved branch drilling machine.
- Nitrogen to purge drill.
- Alignment and re-rounding clamps.
- Clean damp non-synthetic cloth.
- Earthing strap (where applicable).
E11  TRAINING & COMPETENCY

The use of flow stopping equipment is a specialised activity requiring specific competencies. All staff involved should be required to demonstrate such competencies relevant to the specific equipment used.
APPENDIX F – Sidewall Fusion Welding (Informative)

F1 Introduction

Sidewall fusion welding has been used extensively and successfully in international operations for many years. It is used to connect a main line to a lateral line through the use of a moulded polyethylene fitting.

Sidewall fusion utilises principles and processes similar to those used in butt fusion and electrofusion welding. After the specified pipe preparation process has been completed, a specially designed heater is placed between the pipe and the fitting and both surfaces are heated to a designed temperature at the same time. The heater is then removed and the surfaces are held together by an application of sufficient force. This force is applied and maintained directly through the use of hydraulic or manual assistance, holding the fitting and the pipe in contact with one another until they have cooled sufficiently.

Sidewall fusion is a skilled operation and to achieve a successful joint a number of very specific procedures need to be carried out. All operators should be trained by appropriately qualified training organisations, reinforced with random operational evaluation and testing.

To consistently make satisfactory saddle fusion joints it is important to follow the jointing procedure with particular emphasis on pipe surface preparation, cleanliness, restraint of the fitting and the pipe during the fusion and cooling cycles, and temperature control. Smaller diameter main lines may require the use of a “pipe bolster” to inhibit the deflection of the main line during the sidewall fusion process. There are no technical reasons to limit the distance between saddle fusions, only physical limitations based on the space available to complete the sidewall fusion and the design of the equipment being used to complete the operation.

F2 Equipment

There are several equipment configurations that can be used to complete sidewall fusion, they include, but are not limited to:

a) A sidewall fusion machine comprised of a Hydraulic Power Unit (HPU) equipped with a pump, a hydraulic accumulator, utilising a hydraulically assisted process of creating and maintaining force, a mechanical means of holding the pipe and the fitting and an appropriately sized heater and adapters. This approach allows for a lightweight option as the greatest contributor to weight is the hydraulic fluid. Hence, the use of an accumulator can reduce weight significantly. However, if the unit is designed for both sidewall and butt fusion, a system designed with an accumulator may have less available system pressure.
b) A sidewall fusion machine comprised of an HPU equipped with a pump, a hydraulic reservoir, utilising a hydraulically assisted process of creating and maintaining force, a mechanical means of holding the pipe and the fitting and a heater equipped with the appropriately sized heater and adapters. This approach provides the most operational flexibility, but at the cost of weight.

c) A manually operated sidewall fusion machine. Manually operated sidewall fusion machines uses a mechanical method of maintaining force, as opposed to using a hydraulic force to maintain pressure on the pipe and the fitting, and uses a heater equipped with the appropriately sized heater and adapters. This option requires constant operator monitoring and adjustment. While it is the least expensive configuration, it is limited to small outlet sizes.

**F3 Types of Sidewall Fittings**

There are two basic sidewall fitting types that could be used in the CSG environment, both of which can be fused using the same fusion equipment. Those fitting types are:

a) Service Saddle Fitting

This fitting, upon satisfactory fusion installation and testing, will require a hot tap operation to be completed to connect it to the main line. This fitting is available in a round or a rectangular base with varying base sizes and outlet sizes depending on the size of the main line and the lateral line.

To mitigate contamination in the fusion process, each fitting is sealed in a plastic bag, marked and bar coded with the correct fusion pressures. The fittings must be left sealed in the bag until such a time the fitting is fused onto the main line.

Fittings must comply with the information outlined in Section 3.3.2. The fittings may be comprised of a round or a rectangular base.

![Figure F3a Typical High Volume Service Saddle](image)
b) Self-Tapping Service Saddle

This fitting, upon satisfactory fusion installation and testing, utilises an integrated cutting tool to complete the hot tap, and remove and retain the coupon cut from the main line. This fitting is available in a round or a rectangular base with varying base sizes and outlet sizes depending on the size of the main line and the lateral line.

To enhance the fusion process, each fitting is sealed in a plastic bag, marked and bar coded with the correct fusion pressures. The fittings must be left sealed in the bag until such a time the fitting is fused onto the main line.

Fittings must comply with the information outlined in Section 3.3.2. The fittings can be configured to be comprised of a round or a rectangular base and sized appropriately for the outlet and the main line to which they will be connected.

![Figure F3b Typical Self Tapping Service Saddle](image)

F4 Environmental conditions for carrying out sidewall fusion welding

The fusion or welding process is sensitive to weather and climatic conditions and, as such, the butt welding process needs to be carried out in clean, dry and draft free conditions. To manage these aspects the following is advised –

a) Where necessary, use a weather shelter or cover to keep moisture and dust away from the prepared pipe ends;

b) When temperatures fall near or below zero degrees Celsius, special precautions may need to be taken; in such cases, consult the pipe manufacturer’s recommendations;
F5 Planning for successful sidewall fusion welding

To ensure the integrity of the sidewall welds the following procedures should be adopted –

a) Select a qualified welding contractor. A qualified sidewall welding contractor should have –
   - demonstrated experience in sidewall welding of PE pipe;
   - suitably sized equipment which has been maintained in good condition with calibration status documentation available for temperature and pressure measurement;
   - qualified operators who have an up to date log detailing project and welding experience;

b) Assess the proposed welding procedures –
   - Pre-qualified welding procedures for pipe class and diameters being proposed for the project and the welding machines which will be used; destructive weld testing data can be also be considered;
   - Carry out trial welds on the actual pipe to be used for the contract and have these destructively tested to meet the specified performance requirements (testing and minimum performance requirements are detailed in Section 7 – Inspection and Testing);
   - Determine and document the agreed welding parameters, procedures, and welding equipment (this may also include the use of welding tents, pipe end covers etc);
   - The agreed welding parameters, procedures and welding equipment then become the contract requirements and should not be varied without additional evaluation and testing.

c) Determine quality control and assurance requirements including but not limited to –
   - Maintaining a detailed welding log for each joint;
   - Destructive testing of a percentage of joints;
   - Assessment of weld beads via visual examination.

Continuous review process and results.

Pipes and saddle fittings used for pressure applications must comply with AS/NZS 4130 and AS/NZS 4129 respectively.

All components should have adequate nominal pressure rating for the operating conditions and the PE materials should comply with AS/NZS 4131.

Saddle fittings for pressure applications are usually recommended for use with PE pipes SDR17 or lower (i.e. increased wall thickness).
**F6  Acceptance testing for sidewall fusion**

Non-destructive evaluation methods include:

a) Visual Testing

Each weld bead should be examined for pitting and other anomalies. The bead development should produce 3 distinct beads. The fusion bead should be uniformly sized all around the fitting base. The first bead is formed with the base of the fitting melts. The second or outermost bead is produced by the edge of the heating contacting the surface of the main. The third or center bead is the main pipe melt bead. The first and third beads should be about the same size (3.2 mm – 6.4 mm) all around the fitting base. The second bead is usually smaller, but should also be uniformly sized around the fitting base. An additional examination should be completed to ensure that the top/outer most bead does not extend above/beyond the shoulder (the top) of the saddle fitting.

![Proper Sidewall Fusion with three beads](image1)
![Improper Sidewall Fusion - bead height extends above the top of the fitting base/shoulder](image2)

**Figure F6  Sidewall Fusion Visual Examination**

b) Ultrasonic Evaluation

Work continues on Non-Destructive Ultrasonic Evaluation. A recent study commissioned by the United States Nuclear Regulatory Commission conducted by the Pacific Northwest National Laboratory concluded, “The ultrasonic TOFD (Time of Flight Diffraction) and PA (Phased Array) methods, and the electromagnetic wave technologies, show promise in the inspection of PE fusion welds. Higher frequencies are likely needed in order to reliably detect the tight LOF (Lack of Fusion) conditions.”

While non-destructive testing may be undertaken by the Operator, further work is required before being considered a viable non-destructive examination method for PE piping systems.
**F7 Destructive Testing for Sidewall Fusions**

For destructive testing, the ASTM Practice F905 defines the standard practice for qualification of polyethylene saddle-fused joints. This document outlines tests that can be used to qualify polyethylene saddles fused joints; those tests are:

a) Sustained Pressure Test  
b) Impact Resistance Test  

Both of these methods are explained below.

**F7.1 Sustained Pressure Test**

The minimum length of unreinforced pipe on both sides of any saddle fitting should be equal to three times the diameter of the pipe, but in no case less than 305 mm. Test multiple saddle fittings, if desired, on the same pipe specimen as long as they are separated by at least three pipe diameters. Make all saddle-fused joints with the pipe at the maximum allowable operating pressure of the gas distribution system. If tubing intended to be fused to the outlet of the saddle fitting has a higher SDR that the pipe, cap the saddle fitting outlet and do not use the tubing.

Test specimens for 1000 hours at 23°C using equipment, procedures and failure definitions, as specified in the test method documented in ASTM D1598 “Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure”.

**F7.2 Impact Resistance Test**

Conduct each qualification test with the polyethylene saddle fitting fused to a polyethylene pipe that has a maximum pressure rating equal to or greater than that for which the gas gathering systems is designed.

Centre and fuse the saddle fitting on a piece of unreinforced pipe that has a minimum length on both sides of any saddle fitting equal to three times the diameter of the pipe, but in no case less than 305 mm.

Firmly secure the pipe so that movement does not occur during impact. Suggested methods of securing the pipe are shown in Figure F7.2. Other methods for securing the pipe may also be used.

Drop a weight in a vertical free-fall from a height of at least 250 mm. Position the weight so that it strikes the stack of the saddle fitting 50 mm from the pipe. For larger diameter saddle fittings, that is, 76 mm outlet or greater, socket or butt fuse a nipple (whose length is five times the outside diameter) to the outlet and position the weight so that it strikes the center of the nipple. Adjust the drop height or weight, or both, until failure occurs in the specimen by either tearing out the pipe wall or tearing the fitting, or bending the nipple at least 45° from the horizontal axis. Conduct impact evaluations on larger diameter saddle fittings in two ways: (1) with the pipe parallel (axial) to the vertical path of the falling weight; and (2) with the pipe perpendicular (radial) to the path of the falling weight. The fused joint made between the pipe and the saddle fitting should not fail when impacted with a force sufficient to break
the body or other portion of the specimens. Tests of 2.2kN or higher with no failures should be considered a “pass”.

NOTE: Specimens that appear to fail at the joint may actually be tearing out the pipe wall. If the failure mode is questionable, the fitting supplier should be consulted.

Figure F7.2 Impact Resistant Test Setup
- **APPENDIX G – Testing of Final Construction and Repair Tie-ins (Informative)**

Final butt or electrofusion tie-ins or “golden welds” connecting pipe sections that have already been pressure tested, shall be installed in accordance with the welding jointing requirements of Section 7.5. To ensure correcting welding parameters, where practicable, pipe should be constructed such that an overlap occurs at the tie-in point so that excessive pipe can be cut in order to provide a production weld on completion of the tie in (see Figure G1).

![Figure G1 Pipe Overlap](image)

With reference to Figure G1, the production weld should be completed on site in the same field conditions, using the same procedure, equipment and welder that will be used for the final tie-in weld. The production weld should be completed prior to the final tie-in in order that this joint can undergo a destructive test.

![Figure G2 Production Weld/Joint](image)

Where it is not practicable to overlap pipes, where an insertion of pipe (or pup piece) is required, two production welds should be conducted prior to the final tie in as shown in Figure G2.
NOTE: Where Pipe A and Pipe B are from the same continuous linepipe material, only one production tie-in weld is required.

On completion of the tie-in, the production welds should undergo a destructive test. Destructive testing shall be in accordance with Section 7.9. Test samples may include NDT identified defects to ensure the quality control of the weld. If the production weld(s) is a failure, final tie in welds should be cut out and repeated. The system should not be commissioned until a satisfactory destructive test is confirmed.

NOTE: The final tie in weld should be completed as soon as possible on completion of the production welds. Tie-ins can be butt welded or electrofusion welds.
APPENDIX H – Safety Management Process
(Informative)

H1 General
The network safety management process required by this Code of Practice is of fundamental importance to the network design, its operation and maintenance. It is the means by which network safety is demonstrated. It also forms the basis for all operations and maintenance of the network.

The safety management process is integrated and continuous. It requires consideration of design aspects and operating procedures in a combined, holistic way so that the network can be operated safely. Analysis is updated and refined using information as it becomes available throughout the life cycle of the network.

The essential outcomes of a management process are:

a) Assurance that the threats to the network and associated risks are identified and understood by those that are responsible for addressing the threats and risks; and

b) Appropriate plans are made to manage these risks.

The network safety management process requires the application of multiple independent controls to protect the network from each identified threat. Physical (route selection, barrier or exclusion), Procedural and Design methods should be applied to all threats with the objective of preventing failure of the network, minimising the consequence to the public (including the Operators personnel and Contractors) and the environment.

Those threats that result in a failure of the network should be subject to a risk assessment in accordance with the requirement of AS 31000, and the risk mitigated to ALARP. The Operator may determine the appropriate risk matrix to be used, with preference for the 5 x 5 matrix detailed in Section H6.

H2 Whole of Life Network Safety Management

Network safety management to this Code of Practice is an integral component of the planning design construction operation and abandonment of the pipeline.

H2.1 Whole of Life Phases

Safety management studies should be undertaken at intervals during the network design and operational phases to facilitate periodic reassessment of the threats and the implementation of controls as knowledge of the threats is gained over time:

As a minimum the safety management study should be undertaken during the following phases.
a) Design – A detailed safety management study that complies with this Code of Practice should be undertaken in parallel with the design and should consider at least the following:

- Class location or land use;
- Non-location-specific threats;
- Location-specific threats;
- Basic network design parameters;
- The radiation intensity contour radius of 4.7 kW/m² and 12.6 kW/m² in the case of a full diameter failure (Gas);
- Drainage contours based upon topography, soil type and the presence of significant watercourses (PFW or saline water).

b) Pre-commissioning - A review of the detailed safety management study that complies with this Code of Practice should be undertaken prior to commissioning the network and should consider at least the following:

- Any design or route change;
- Land use change, specifically changes within the radiation contour;
- Any change to location or non-location threats;
- Construction defects or deviations from specification;
- Testing defects and pressure test failures;

c) Operation - A review of the detailed safety management study that complies with this Code of Practice should be undertaken at least every 5 years and should consider at least the following:

- Any loss or degradation of integrity;
- Land use change, specifically changes within the radiation contour;
- Any change to location-specific or non-location-specific threats;
- Construction defects or deviations from specification;
- Testing defects and pressure test failures;
- The previous safety management studies.

The review should also be completed:

- At any review for changed operating conditions;
- Before recommencement of operation following a flowline failure where such failure has resulted from a mechanism not previously included in preceding studies;
- At any time when new or changed threats including land use occur;
• At any time where there is a change of knowledge affecting the safety of the flowline or network;
• At any review for extension of design life;

d) Suspension or Abandonment - A review of the detailed safety management study that complies with this Code of Practice should be undertaken when the network or a part of the network is suspended or abandoned and should consider at least the following:

• The possibility of the suspended or abandoned network causing environmental harm (e.g. water conduiting);
• The threat of mistaken asset e.g. network extension being tied into a suspended or abandoned line or network and hydrocarbons being introduced;

H3 Pre-requisites for Safety Management Studies

H3.1 Extent of Safety Management Studies
The detailed management study should cover all threats and land use within the area bounded by the radiation intensity contour radius of 4.7 kW/m² on each side of the centre line of the network pipeline. Where multiple lines of different diameters or service are laid in a common trench, the area under study should be the outermost 4.7 kW/m² radiation intensity contour radius on each side of the common trench.

H3.2 Safety Management Study Information
A robust safety management system requires detailed preparatory information and analysis to provide the correct consistency of approach across the network and to provide all of the tools necessary to correctly identify all threats and to facilitate assessment and control.
The safety management study should be undertaken by personnel with the expertise in each component of design, construction, commissioning and operation of the network, including or with the support of personnel familiar with the land use and environments along the entire route of the network. The safety management study should be chaired by an independent person deemed competent in the conduct of such a study.
The following information should be generated and used for the detailed safety management study:

a) Design basis including network properties, engineering design for non-standard construction, design calculations, and typical design drawings;

b) The threat analysis of common threats;

c) The network alignment and class location identification;

d) The assessment of current land use, and if known, future land use plans;
e) Documented external threats from third parties (landowners, public authorities and contractors) and from existing networks or other infrastructure in the vicinity of the network;

f) List of the construction and landowner constraints;

g) List of environmental constraints;

h) HAZOP and other design reviews relevant to the network including pressure control system design;

i) Scenarios under which full diameter leaks may occur;

j) Consequence modelling which will:
   - Assess the impacts of a fluid release on people, property and the environment;
   - Provide the radiation intensity contour radius of 4.7 kW/m$^2$ and 12.6 kW/m$^2$ in the case of a full diameter failure (gas networks);
   - Provide release rates and drainage contours based upon topography, soil type and the presence of significant watercourses (PFW or saline water).

In the case of the operational review of the safety management plan, the following information should be included:

k) The network management system;

l) The integrity management plan;

m) Land use changes;

n) Any design changes relating to sections added to the network;

o) Inspection and integrity management history;

p) Maintenance history;

q) Loss of control events – failure of pressure control or loss of integrity;

r) Previous safety management studies;

s) Close out reports relating to previous risk mitigation actions.

H4 Threat Identification

H4.1 General

Threat identification consists of the identification of all threats to the network including the following threat categories:

a) Threats that are unique to a particular location, such as the threat of external interference from third parties (public road crossing), or due to topographical features (land instability) of the location;
b) Non-location-specific threats – Threats that could occur at any point along the network and may include external interference (from general construction or agricultural activities), material or construction defects;

c) Location-specific threats - Threats specific to above ground manifolds, low point drains or high point vents or other facilities, or threats which become apparent from a detailed length by length review of the route of the network.

In all cases the details for the threat analysis needs to be sufficient such that the appropriate design, controls or risk mitigation actions can be implemented.

H4.2 Description of Threats

Typical threats include, but are not limited to:

H4.2.1 External Interference

   a) Excavation, such as occurs during construction or maintenance of buried services, roads, and mining;

   b) Power augers, screw piles, drilling operations (vertical, horizontal and directional), and installation of power poles;

   c) Ripping or blade ploughing for agricultural use;

   d) Augers for fence installation or maintenance;

   e) Land use development, such as grading of land;

   f) Land use development, such as dam construction;

   g) Excessive external loads from backfill or traffic;

   h) Blasting for utility installation;

   i) Trenching for new pipelines and services.

H4.2.2 Corrosion

   a) External corrosion of the metallic riser due to environmental factors, such as the type of soil and moisture content;

   b) Internal corrosion of the metallic riser from free water and carbon dioxide, present in the gas.

H4.2.3 Natural Events

   a) Earthquake;

   b) Ground movement, due to land instability;

   c) Bushfires;

   d) Lightning;

   e) Water course damage resulting in tunnel or table drain erosion and excess span;

   f) Inundation, leading to flotation.
H4.2.4 **Operations and Maintenance**  
   a) Exceeding network MAOP;  
   b) Insufficient or incorrect maintenance;  
   c) Fatigue from cyclic service;  
   d) Failure due to surge pressure;  
   e) Excess external loadings.

H4.2.5 **Design Defects**  
   a) Failure to define the correct range of operating conditions, leading to incorrect settings on control or protective devices, or unacceptable pressures, temperatures and loads.

H4.2.6 **Material Defects**  
   a) Manufacturing defect;  
   b) Lack of adequate inspection and test procedures to confirm the acceptability of material and equipment.

H4.2.7 **Construction Defects**  
   a) Inadequate testing of defects.

H4.2.8 **Intentional Damage**  
   a) Terrorism;  
   b) Malicious damage from vandalism.

H4.2.9 **Other Threats**  
   a) Seismic survey, resulting in blast or equivalent external pressure loads;  
   b) Electrical Induction- personnel safety (water lines);  
   c) Flange/Monolithic Joint Failure;  
   d) Failure of Threat Controls;  
   e) Failure of all controls worst location;

**H5 Threat Mitigation General**

Threat mitigation may be achieved by:  
   a) Change in route;  
   b) External interference protection; or  
   c) The use of procedural controls.

**H5.1 Change in Route**

Change in route for parts of the network can reduce the risk from and to external parties. Examples of this may include maintaining pipes and ancillary structures (manifolds, low point drains and vents) away from roads, away from
areas of congregation (plants, camps, administration and maintenance bases) and the selective crossings of waterways.

**H5.2 External Interference Protection**

Options for external interference protection which provide an effective physical control by separation may include:

a) Depth of burial – provided the depth exceeds the maximum normal working depth of the equipment under consideration plus a margin, and is significantly greater than the minimum depth of cover specified in this Code of Practice.

b) Exclusion – fences or barricades; or
c) Barrier – The installation of barrier slabs.

**H5.3 Procedural Controls**

Procedural controls may include:

a) Landowner or Third Party Liaison;
b) Community Awareness;
c) On Call Services;
d) Pipeline Marking using signage;
e) Buried marker tape or tracer wires;
f) Agreements with other Entities using shared lands or infrastructure corridors;
g) Planning notification zones;
h) Patrolling of the network; or
i) Remote Monitoring.

**H6 Qualitative Risk Assessment**

**H6.1 General**

This section provides the requirements for qualitative risk assessment in accordance with AS 31000.

Where a failure event of the network may have several outcomes, the consequence and frequency of each outcome should be considered. Full evaluation of every outcome may not be necessary, but sufficient outcomes should be evaluated to identify the outcome with the highest risk ranking.
H6.2 Consequence Analysis

The severity of the consequences of each failure should be assessed. Consequences to be assessed should include the potential for:

a) Human injury or fatality;

b) Economic impact due to loss of Production;

c) Environmental damage.

A severity class should be assigned to each failure event based upon the consequences at the location of the failure. The following table provides a recommended severity class selection. This table may be modified to suit the requirements of the Operator and network.

Table H6.2 Severity Class

<table>
<thead>
<tr>
<th>Severity Class</th>
<th>Catastrophic</th>
<th>Major</th>
<th>Severe</th>
<th>Minor</th>
<th>Trivial</th>
</tr>
</thead>
<tbody>
<tr>
<td>People</td>
<td>Multiple fatalities result</td>
<td>At least one fatality, with several life threatening injuries</td>
<td>Injury or illness requiring hospital treatment</td>
<td>Injuries requiring first aid treatment</td>
<td>Minimal impact upon health and safety</td>
</tr>
<tr>
<td>Production</td>
<td>Long term interruption of Production</td>
<td>Prolonged interruption or long term restriction of Production</td>
<td>Short term interruption or prolonged restriction of Production</td>
<td>Short term interruption of Production, but shortfall meet from other sources</td>
<td>No Impact, no restriction of Production</td>
</tr>
<tr>
<td>Environment</td>
<td>Effects widespread, permanent ecosystem change &gt;500 kl PFW &gt;100 kl Saline</td>
<td>Long term severe effects, rectification difficult &gt;50 kl PFW &gt;10 kl Saline</td>
<td>Localised effect and short term &gt;5 kl PFW &gt;1 kl Saline</td>
<td>Very localised effect, minimal rectification &gt;500 l PFW &gt;50 l Saline</td>
<td>Minor on site effects, Negligible residual effect &lt;500 l PFW &lt;50 l Saline</td>
</tr>
<tr>
<td>Equivalent Range of Cost</td>
<td>&gt; $300M</td>
<td>$30M to $300M</td>
<td>$3M to $30M</td>
<td>$30k to $3M</td>
<td>&lt; $30k</td>
</tr>
</tbody>
</table>

H6.3 Frequency Analysis

A frequency of occurrence of each failure event should be assigned for each location where risk estimation is required. The following table provides a recommended frequency selection.

The contribution of operations and maintenance practices and procedures to the occurrence or prevention of the failure events should be considered in assigning the frequency of the occurrence.

The frequency for a threat that exists for a limited period should be assessed against the exposure period rather than the life of the network.
Table H6.3 Frequency Class

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Frequency Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequent</td>
<td>Expected to occur once per year or more</td>
</tr>
<tr>
<td>Occasional</td>
<td>May occur occasionally in the life of the Network</td>
</tr>
<tr>
<td>Unlikely</td>
<td>Unlikely to occur with the life of the Network, but possible</td>
</tr>
<tr>
<td>Remote</td>
<td>Not anticipated for this Network at this location</td>
</tr>
<tr>
<td>Hypothetical</td>
<td>Theoretically possible, but has not occurred on a similar Network</td>
</tr>
</tbody>
</table>

**H6.4 Risk Ranking**

The results of the consequence and frequency analysis should determine the risk associated with the failure event.

Risks determined to be low or negligible or demonstrated to be ALARP are acceptable risks.

**Table H6.4 Risk Matrix**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Catastrophic</th>
<th>Major</th>
<th>Severe</th>
<th>Minor</th>
<th>Trivial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequent</td>
<td>Extreme</td>
<td>Extreme</td>
<td>High</td>
<td>Intermediate</td>
<td>Low</td>
</tr>
<tr>
<td>Occasional</td>
<td>Extreme</td>
<td>High</td>
<td>Intermediate</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Unlikely</td>
<td>High</td>
<td>High</td>
<td>Intermediate</td>
<td>Low</td>
<td>Negligible</td>
</tr>
<tr>
<td>Remote</td>
<td>High</td>
<td>Intermediate</td>
<td>Low</td>
<td>Negligible</td>
<td>Negligible</td>
</tr>
<tr>
<td>Hypothetical</td>
<td>Intermediate</td>
<td>Low</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

**H6.5 Risk Mitigation**

Action to reduce risk should be taken in accordance with the following table based upon the risk rank determined. The action(s) taken and its effect on safety management should be documented and approved.

**Table H6.5 Required Actions**

<table>
<thead>
<tr>
<th>Risk Rank</th>
<th>Required Action</th>
<th>Timing of action for an operational Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme</td>
<td>Modify the threat, the frequency or the consequence so that the risk rank is reduced to 'Intermediate' or lower</td>
<td>Immediate</td>
</tr>
<tr>
<td>High</td>
<td>Modify the threat, the frequency or the consequence so that the risk rank is reduced to 'Intermediate' or lower</td>
<td>Within a month</td>
</tr>
<tr>
<td>Intermediate</td>
<td>Repeat the threat identification and risk evaluation to verify and where possible quantify the risk estimation. Where the risk rank is confirmed as 'Intermediate' modify the threat, the frequency or the consequence so that the risk rank is reduced to 'Low' or 'Negligible'.</td>
<td>Within 6 months</td>
</tr>
<tr>
<td>Low</td>
<td>Determine the management plan for the threat to prevent occurrence and monitor changes that could affect the risk rank.</td>
<td></td>
</tr>
<tr>
<td>Negligible</td>
<td>Review at the next review interval.</td>
<td></td>
</tr>
</tbody>
</table>
Where the risk rank cannot be reduced to ‘Low’ or ‘Negligible’, action should be taken to:

a) remove the threat, reduce the frequency or consequence of the threat to the extent practicable; or

b) demonstrate ALARP.

**H6.6 ALARP**

A risk cannot be demonstrated as ALARP until consideration has been given to:

a) means of further reducing the risk; and

b) the reasons why these further means have not been adopted.

ALARP is achieved when the cost of further risk reduction measures is grossly disproportionate to the benefit gained from the reduced risk that would result. Determining if the risk from a specific threat has been reduced to ALARP involves a comparison between the assessment of the risk to be avoided and the cost involved in avoiding the risk. The cost ranges provided in Section H6.2 may be used as the basis of determining the cost of the risk. The measure of whether ALARP has been achieved is if the cost of reducing the risk is grossly disproportionate to the benefit gained.

The concept of ALARP contains an implicit assumption that there are alternative designs or measures that can reduce the risk but some of the alternatives may not be practicable. There is always one alternative - abandon the Project or shutdown the Network or that part of the Network to which the threat is applied.

**H7 Gas Radiation Contour**

**H7.1 General**

The Code of Practice requires consideration of the consequence distance in terms of the radiation intensities of 4.7 kW/m² and 12.6 kW/m². This section provides guidance on the method of calculation of the radiation contour of gas networks.

NOTE: A thermal radiation level of 4.7 kW/m² will cause injury, at least second degree burns, after 30 seconds exposure. A thermal radiation level of 12.6 kW/m² represents the threshold of fatality, for normally clothed people, resulting in third degree burns after 30 seconds exposure.

The radiation contour may be calculated based upon the estimated release rate (MJ/s) and the calculations provided in API 521 “Pressure-relieving and Depressuring Systems”.

As the hole size increases relative to the pipe diameter the release rate and radiation distance will be controlled by the capacity of the Network to deliver gas to the release point.

PE is not normally subject to rupture although full diameter leaks may occur as a result of a pipe joint failure.
The following radiation contour curves are informative based upon full diameter leaks and the leak expected to result from a 120 mm hole due to penetration by a 35 ton excavator (the maximum size machine normally used in CSG operations) at various pressures up to the limit of this Code of Practice.

The calculation of the radiation contour should be completed at the Maximum Allowable Operating Pressure (MAOP) of the Network.

![Estimated 4.7 kW/m2 Radiation Contour PE - Full Diameter Failure](image1)

**Figure H7.1a Radiation Contour Radius – Full Diameter**

![Estimated 4.7 kW/m2 Radiation Contour PE - Excavator Penetration](image2)

**Figure H7.1b Radiation Contour Radius – Penetration**
**H8 Water Network Leaks**

**H8.1 General**

For water network lines the impact upon the environment requires specific consideration of the following:

a) The water characteristic – PFW, saline water or treated water;
   NOTE: Entrained gas should be considered.

b) The topography of the land;

c) The proximity of surfaces of water – watercourses, rivers, dams or billabongs;

d) The soil type in the vicinity of the network segment in question;

e) The failure event hole size;

f) The elevation profile of the network.

The water release rate from the line may exceed the normal design flowrate or pump rate depending upon the change in elevation of the section.

The calculation of the water release rate should be completed at the Maximum Allowable Operating Pressure (MAOP) of the Network.

**H8.2 Penetration Hole Size**

An approximate hole size of 120 mm is suggested for a 35 ton excavator.
(This is the equivalent hole size for penetration of all general purpose teeth on the standard bucket for this machine).
### APPENDIX I – Definitions and Standards

#### Definitions

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above-ground</td>
<td>Installed on or above ground level</td>
</tr>
<tr>
<td>Adequately trained</td>
<td>The provision of sufficient skills or knowledge to perform tasks safely and without harm to the environment or to plant.</td>
</tr>
<tr>
<td>ALARP</td>
<td>As Low As Reasonably Practicable</td>
</tr>
<tr>
<td>Approved</td>
<td>Approved by the Operator and/or by statutory officer as applicable</td>
</tr>
<tr>
<td>CFT</td>
<td>Critical Function Testing</td>
</tr>
<tr>
<td>Control Point</td>
<td>The location where the test personnel conduct pressure tests</td>
</tr>
<tr>
<td>CSG</td>
<td>Coal Seam Gas (generally including water vapour)</td>
</tr>
<tr>
<td>CTP</td>
<td>Calculated Test Pressure</td>
</tr>
<tr>
<td>Design Pressure</td>
<td>The maximum pressure for which a network or pipeline system has been designed to ensure for pressure containment (excluding transient conditions).</td>
</tr>
<tr>
<td>Electrofusion</td>
<td>Fusion of PE induced by the application of electric current.</td>
</tr>
<tr>
<td>EMP</td>
<td>Environmental Management Plan</td>
</tr>
<tr>
<td>Exclusion Zones</td>
<td>Defined areas established to protect public and personnel from an unforeseen discharge event during testing pressure testing. There are two exclusion zones: primary and secondary.</td>
</tr>
<tr>
<td>FIC</td>
<td>Field Installation Checklist</td>
</tr>
<tr>
<td>Fluid</td>
<td>Generally means gaseous or liquid substances. See s8.6.5.2 for particular definition.</td>
</tr>
<tr>
<td>Gauge Pressure</td>
<td>Pressure measured above atmospheric pressure</td>
</tr>
<tr>
<td>Golden weld</td>
<td>A final joining weld which cannot be fully tested (also known as “Closure Weld”)</td>
</tr>
<tr>
<td>GRE</td>
<td>Glass Reinforced Epoxy</td>
</tr>
<tr>
<td>HAZOP</td>
<td>Hazard and Operability Study</td>
</tr>
<tr>
<td>Hydraulic Testing</td>
<td>Testing using a liquid medium, almost always water.</td>
</tr>
<tr>
<td>HDPE</td>
<td>High Density Polyethylene. Refer Appendix C regarding the use of this term.</td>
</tr>
<tr>
<td>HPU</td>
<td>Hydraulic Power Unit</td>
</tr>
<tr>
<td>IBC</td>
<td>Inside Bolt Centre</td>
</tr>
<tr>
<td>IMP</td>
<td>Integrity Management Plan</td>
</tr>
<tr>
<td>ITP</td>
<td>Inspection and Test Plan</td>
</tr>
<tr>
<td>PE</td>
<td>Polyethylene</td>
</tr>
<tr>
<td>PN</td>
<td>Pressure Nominal - Nominal working pressure at 20 degrees C designated in bar. Refer AS/NZS 4130.</td>
</tr>
<tr>
<td>JSA</td>
<td>Job Safety Analysis</td>
</tr>
<tr>
<td>LoF</td>
<td>Lack of Fusion</td>
</tr>
<tr>
<td>Leak Test</td>
<td>The leak test determines if there are any small leaks in the test system. The leak test shall be undertaken after a successful test outcome.</td>
</tr>
</tbody>
</table>

---

6 This term replaces the earlier term “Hydrostatic Testing” which, in some quarters, is now used to define both liquid and gaseous testing processes.
| **Limited Access Boundary** | An area which extends beyond the exclusion zone, and includes the control point and pressurising equipment. |
| **LDPE** | Low Density Polyethylene. Refer Appendix C regarding the use of this term. |
| **LLDPE** | Linear Low Density Polyethylene. Refer Appendix C regarding the use of this term. |
| **MAOP** | Maximum Allowable Operating Pressure – The maximum pressure at which a pipeline system may be operated in accordance with the design criteria and provisions set out in this code, Section 4.3.5. MAOP should not be confused with the PN rating of the pipeline. |
| **MDPE** | Medium Density Polyethylene. Refer Appendix C regarding the use of this term. |
| **MOP** | Maximum Operating Pressure – An interim adjustment representing the highest pressure a piping system may be subjected to during an interim operating period. |
| **MRS** | Minimum Required Strength for the material in MPa at 20°C. |
| **NDT** | Non-Destructive Testing |
| **NMS** | Network Management System |
| **OH&S** | Occupational Health and Safety |
| **OHS&E** | Occupational Health, Safety and the Environment |
| **Operator** | The person in overall charge of the project |
| **P&ID** | Process and Instrumentation Diagram |
| **PFD** | Process Flow Diagram |
| **PFW** | Produced Formation Water |
| **Pneumatic Testing** | Testing using a gaseous medium, almost always air. |
| **Preliminary Test** | A test that is undertaken on a section of pipeline that will be subsequently exposed to a further strength test pressure when included in the main pipeline test section. |
| **Pre-Test** | A pressure test of a pipeline section or component that is undertaken separately from the pipeline and is not re-tested after installation. (eg. Pipeline with a closure weld.) |
| **Pressure test** | A pressure test consists of a strength test followed by a leak test |
| **Production Test** | Destructive testing of a production weld. |
| **Production Weld** | Weld undertaken external to the pipeline installation, using the same material as the associated pipeline tie-in materials, for destructive testing purposes. |
| **Strength Test** | The strength (or proof) test is a means by which the integrity of a test section is assessed, this is carried out by filling with a fluid, sealing and subjecting to a calculated test pressure. The strength test is used to validate integrity and to detect any construction or mechanical defects and also defective materials. |
| **PSV** | Pressure Safety Valve |
| **QA** | Quality Assurance |
| **QC** | Quality Control |
| **RO** | Reverse Osmosis |
| **RTO** | Registered Training Organisation |
| **Safety Management Study** | A process that identifies threats to the pipeline system and applies controls to them, and (if necessary) undertakes assessment and treatment of any risks to ensure that residual risk is reduced to an acceptable level. |
| **SDR** | Standard Dimension Ratio |
| **TDS** | Total Dissolved Salts |
| **Test Section** | The pipeline or portion of pipeline being subjected to a pressure test. |
| **Test System** | The pipeline system being subject to a pressure test. |
| **Threat** | Any activity or condition that can adversely affect the pipeline if not adequately controlled. |
### Referenced Standards and Documents

<table>
<thead>
<tr>
<th>Standard / Document</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGA-XK0775</td>
<td>Purging Principles and Practice</td>
</tr>
<tr>
<td>ANSI/ASTM B16.5</td>
<td>Pipe flanges and flanged fittings</td>
</tr>
<tr>
<td>API 521</td>
<td>Pressure-relieving and Depressuring Systems</td>
</tr>
<tr>
<td>AS 1319</td>
<td>Safety signs for the occupational environment</td>
</tr>
<tr>
<td>AS/NZS 1020</td>
<td>The control of undesirable static electricity</td>
</tr>
<tr>
<td>AS 1100.401</td>
<td>Technical drawing - Engineering survey and engineering survey design drawing</td>
</tr>
<tr>
<td>AS1463</td>
<td>Polyethylene pipe extrusion compounds</td>
</tr>
<tr>
<td>AS/NZS 2033</td>
<td>Installation of polyethylene pipe systems</td>
</tr>
<tr>
<td>AS 2129</td>
<td>Flanges for pipes, valves and fittings</td>
</tr>
<tr>
<td>AS2187.2</td>
<td>Explosives – storage and use – use of explosives</td>
</tr>
<tr>
<td>AS 2566.2</td>
<td>Buried flexible pipelines - Installation</td>
</tr>
<tr>
<td>AS 2885.1</td>
<td>Pipelines - Gas and liquid petroleum - Design and construction</td>
</tr>
<tr>
<td>AS 4041</td>
<td>Pressure piping</td>
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<tr>
<td>AS 4087</td>
<td>Metallic flanges for waterworks purposes</td>
</tr>
<tr>
<td>AS/NZS 4129</td>
<td>Fittings for polyethylene (PE) pipes for pressure applications</td>
</tr>
<tr>
<td>AS/NZS 4130</td>
<td>Polyethylene (PE) pipes for pressure applications</td>
</tr>
<tr>
<td>AS/NZS 4131</td>
<td>Polyethylene (PE) compounds for pressure pipes and fittings</td>
</tr>
<tr>
<td>AS/NZS 4158</td>
<td>Thermal-bonded polymeric coatings on valves and fittings for water industry purposes</td>
</tr>
<tr>
<td>AS/NZS 4331.1</td>
<td>Metallic flanges - Steel flanges</td>
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<tr>
<td>AS 4343</td>
<td>Pressure equipment – hazard levels</td>
</tr>
<tr>
<td>AS/NZS 4645.1</td>
<td>Gas distribution networks - Network management</td>
</tr>
<tr>
<td>AS/NZS 4645.3</td>
<td>Gas distribution networks - Plastics pipe systems</td>
</tr>
<tr>
<td>AS/NZS/ISO 31000</td>
<td>Risk management - Principles and guidelines</td>
</tr>
<tr>
<td>AS/NZS 60079</td>
<td>Electrical apparatus for explosive gas atmospheres</td>
</tr>
<tr>
<td>ASME B31.3</td>
<td>Process piping</td>
</tr>
<tr>
<td>ASTM D1598</td>
<td>Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure</td>
</tr>
<tr>
<td>ASTM F905</td>
<td>Standard Practice for Qualification of Polyethylene Saddle-Fused Joints</td>
</tr>
<tr>
<td>ASTM F1055</td>
<td>Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing.</td>
</tr>
<tr>
<td>ASTM F1598</td>
<td>Standard Test Method for Determining the Effects of Chemical/Solvent Exposure to a Membrane Switch/Graphic Overlay (Spot Test Method)</td>
</tr>
<tr>
<td>ASTM F1734</td>
<td>Standard Practice for Qualification of a Combination of Squeeze Tool, Pipe, and Squeeze-Off Procedures to Avoid Long-Term Damage in Polyethylene (PE) Gas Pipe</td>
</tr>
<tr>
<td>ASTM F1962</td>
<td>Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings</td>
</tr>
<tr>
<td>ASTM F2620</td>
<td>Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings</td>
</tr>
<tr>
<td>ASTT CPJP8029-GUI-C-001</td>
<td>Guidelines for Horizontal Directional Drilling, Pipe Bursting, Microtunnelling and Pipe Jacking</td>
</tr>
<tr>
<td>BS EN 805</td>
<td>Water supply. Requirements for systems and components outside buildings</td>
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<tr>
<td>BS EN 13185:2001</td>
<td>Non-destructive testing- Leak testing- Tracer gas method</td>
</tr>
<tr>
<td>Evisive Paper</td>
<td>HDPE Butt Fusion Weld Inspection and Imaging Using Evisive ScanTM Technology</td>
</tr>
<tr>
<td>Evisive Paper</td>
<td>HDPE Pipe Electro-Fusion Coupling Inspection and Imaging Using Evisive ScanTM Technology</td>
</tr>
<tr>
<td>ICONE17-75742</td>
<td>Microwave based NDE inspection of HDPE pipe welds.</td>
</tr>
<tr>
<td>ISO/AS/NZS 9001</td>
<td>Quality management systems - Requirements</td>
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<tr>
<td>ISO/IEC 31010</td>
<td>Risk management - Risk assessment techniques</td>
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<tr>
<td>ISO 7005.1</td>
<td>See AS/NZS 4331.1</td>
</tr>
<tr>
<td>ISO 11413</td>
<td>Plastics pipes and fittings - Preparation of test piece assemblies between a polyethylene (PE) pipe and an electrofusion fitting</td>
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<td>ISO 11414</td>
<td>Plastics pipes and fittings. Preparation of polyethylene (PE) pipe/pipe or pipe/fitting test piece assemblies by butt fusion</td>
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<td>ISO 13953</td>
<td>Polyethylene (PE) pipes and fittings - Determination of the tensile strength and failure mode of test pieces from a butt-fused joint</td>
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<td>PIPA TN016</td>
<td>Non Destructive Examination of PE welds – Emerging Techniques</td>
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<td>POP 001</td>
<td>Electrofusion Jointing of PE Pipe and Fittings for Pressure Applications</td>
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<td>PVC and PE pressure pipe installation on curved alignments</td>
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<td>PPI Handbook</td>
<td>Handbook of Polyethylene Pipe</td>
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<td>WIS 4-24-01</td>
<td>Specification for mechanical fittings and joints for polyethylene pipes for nominal sizes 90 to1000</td>
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<tr>
<td>WIS 4-32-08</td>
<td>Specification for the fusion jointing of polyethylene pressure pipeline systems using PE80 and PE100 materials.</td>
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<tr>
<td>WSA 109</td>
<td>Industry standard for flange gaskets and O-rings – Water Services Association of Australia</td>
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AMENDMENTS FROM VERSION 2.0

The list below shows where many of the significant amendments from Version 2.0 and Version 3.0 were made. However, users should not assume that these details are complete and should refer to this version in all cases.

Version 3.0 Amendments

s1.2 provides scope clarification for gas and water pipelines covered by this Code.

s2.2.2.3 provides competency references to assist in assessing, training and developing the competency of personnel.

s2.7.5 Safety Management Validation requires a detailed safety management study to be validated by a properly constituted workshop.

s4.3.5 now delineates between MAOP and Design Pressure for pipelines.

s4.9 Depth of Cover adds provisions for reduced depth of cover as well as requirements for considering additional depth of cover in accordance with the safety management study.

s4.11.1 Adjacent Parallel Pipelines adds deviation provisions for pipelines within a common trench which are operated by an individual Operator. Minimum spacing requirement reduced, for pipelines from 400mm to 300mm for pipelines over 450mm external diameter.

s4.11.3 Foreign crossings minimum separation requirement reduced from 400mm to 300mm.

s6.4.3.1 New section covering flange management and gasket requirements.

s7.5 contains additional details on welding acceptance and qualification.

s7.9 provides additional details on testing of production welds.

s8.2.10 allows for an Operator to independently qualify a safe distance calculation method, for pressure testing, as an alternative to ASME PCC-2 which is the minimum requirement under this Code.

s8.4 provides further clarification around pressure testing requirements including improved guidance for compensation for test temperature

s10.6.3 New Section provides a checklist detailing the minimum requirements to be in place before a network may be considered ready to commence or recommence operation.
s11.11 provides more details around the processes for suspension and abandonment of a pipeline or network.

Appendix B s1.2 provides further guidelines for welder qualification and testing

Appendix E expands and modifies the requirements for maintenance, modifications and emergency response techniques. New requirements are detailed for: semi-supported flow-stop bagging procedure; temporary bypass arrangement, and hot-tapping.

New Appendix F provides sidewall fusion welding information.

New Appendix G provides examples of final construction and repair tie-ins; included is tie-in welds, production welds and associated testing.

New Appendix H provides extensive information on the obligations, and process required, to undertake and validate Safety Management Studies (SMS) and the requirement to demonstrate ALARP where risks are considered intolerable and have to be addressed by the implementation of additional risk reduction measures.

Appendix I – new items in lists.

**Version 3.0 Supplementary Amendments**

s1.1 Scope clarification has been made regarding environmental management requirements detailed within the Code. Similar adjustments, in accordance with the clarification, have been made throughout the code where applicable.

s4.17 Improvements made to provide clarity around overpressure protection requirements.

s5.13.2 Qualifications made to signage requirements where PE pipelines are located in cultivated fields.