NSW GOVERNMENT

NSW Resources Regulator

MINING DESIGN GUIDELINE | MDG 41

FLUID POWER SAFETY SYSTEMS AT MINES

NSW Resources Regulator

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Foreword

Fluid power systems are used as an energy source on mechanical plant in mines. They offer the advantage of high-energy transfer in confined areas. Fluid power systems rely on the transmission and storage of pressurised fluid energy.

Fluid power systems present a range of unique safety hazards. One of the most dangerous of all is being struck by high pressure fluid escaping at high velocity. This results in high-pressure injection injuries. Work places near fluid systems will present risks to the health and safety of workers. The effect on workers range from minor to severe burns, lacerations and amputations, eye injuries and blindness and, in some cases, death.

There is a high risk of fluid power systems causing serious harm if the pressure is not adequately controlled. They are akin to high voltage power systems. The use of high-pressure fluids is considered a major hazard with the potential to result in fatal injuries. It is essential that fluid power systems be adequately controlled where people work near them.

Awareness of the hazards associated with high pressure fluids and effective risk-based control measures has helped to reduce the number of high-pressure fluid injuries.

It is the intent of this document to assist people involved with high pressure fluids to minimise risk throughout plant life cycle activities.

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1. Purpose and scope

1.1. Purpose

The purpose of this guideline is to assist in protecting workers and other people against harm to their health and safety through the elimination or minimisation of lifecycle risks associated with fluid power systems at mines.

1.2. Scope

This guideline provides help to identify, assess and control the risks to health and safety from fluid power systems in mines. This guideline covers the lifecycle activities associated with fluid power systems.

NOTE: This document is not intended to be a compliance document. It is intended to highlight risks and potential risk controls for consideration. Risk assessment methods need to be used to assess the particular risks in the operating environment and applicable risk controls determined.

1.3. Application

This guideline applies to all fluid power systems on plant at mines throughout the life cycle of the plant.

It should be used for all mining plant such as longwalls, mobile plant (open cut and underground mines), development equipment, fixed installations, compressed air systems, etc.

This guideline is not intended to cover mains water supply reticulation.

This guideline should be considered when:

a) undertaking risk assessments
b) designing, manufacturing, altering and/or supplying fluid power systems (new or previously used)
c) installing or commissioning fluid power systems on a mine site
d) operating or using fluid power systems
e) maintaining, repairing or overhauling and other life cycle activities of fluid power systems
f) site contracts are being considered
g) introducing fluid power systems to a mine on the first occasion
h) reviewing the adequacy of risk controls following an incident
i) assessing/auditing existing standards and practices.

1.4. References

1.4.1. Applicable legislation

Principal safety legislation for mines includes:

- Work Health and Safety Act 2011 (WHS Act)
- Work Health and Safety Regulation 2017 (WHS Regulation)
- Work Health and Safety (Mines and Petroleum Sites) Act 2013
- Work Health and Safety (Mines & Petroleum Sites) Regulation 2013

Examples of applicable codes of practice:

- Managing the risks of plant in the workplace

The codes of practice can be found at:

www.workcover.nsw.gov.au/law-and-policy/legislation-and-codes/codes-of-practice

Details of the legislation can be found at: www.legislation.nsw.gov.au

1.4.2. Standards

Appendix B contains a list of Australian and International standards relevant to fluid power systems. Standards are referenced in this guide by abbreviated titles. The full title can be found in appendix B.

Appendix B also includes a list of relevant mining guidelines.

1.4.3. Abbreviations

The following abbreviations are used in this guideline.

AS	Australian Standards
AS/NZS	Australian / New Zealand Standard
BSPP	British Standard Pipe Parallel
BSPT	British Standard Pipe Tapered
DIN	Deutsch International Norm (German standard)
EECP	Electrical Engineering Control Plan
FRAS	fire resistant and antistatic, refer MDG 3608
ISO	International Organisation for Standardisation
ITP	Inspection and Test Plan

JSA	job safety analysis
MBR	minimum bend radius
MDG	mining design guideline
MECP	Code of practice for mechanical engineering control plan
MPa	mega pascal
NFL	non-flexible length
PPE	personal protective equipment
SAE	Society of Automotive Engineers
SDS	safety data sheet (formerly MSDS)
SI	system international
SWP	standard work procedure
WHS	work health and safety

1.5. Definitions

For the purpose of this document the definitions below apply.

1.5.1. Competent person

A person who has acquired through training, qualification and experience the knowledge and skills to carry out the task.

1.5.2. Fire resistant and antistatic (FRAS)

A material that meets the relevant parts of MDG 3608 'Non-metallic materials for use in underground coal mines.

1.5.3. Fit for purpose

Something that is sufficient to do the function it was designed to do, for the intended use, over its lifetime.

1.5.4. Fluid power systems

Fluid power systems include pressurised hydraulic and pneumatic systems for the transmission and control of energy. These include, but are not limited to, fluid power mediums of hydraulic mineral oil, air, emulsion oil, diesel fuel, grease, water etc.

1.5.5. Fluid injection

Streams of pressurised escaping fluid that penetrate the skin and enter the human body. The injection of fluid may cause death, severe tissue damage and loss of limb.

1.5.6. Hazard

A potential source of harm.

1.5.7. High risk area

Any area where an uncontrolled escape of fluid could place a person's health and safety at risk.

Consider:

1. Areas where fluid power components could break, burst or fail and expose people in the vicinity to health and safety risks such as:
   a) areas where fluid power pressure generally exceeds 5MPa (750psi), or
   b) areas where fluid power temperature generally exceeds 60°C, or
   c) areas of high flow/pressure/force e.g., large flow pneumatic air lines
2. The higher the pressure, the higher the potential for harm i.e. a system operating at 32MPa (4800psi) has a higher potential for harm than a system operating at 5MPa (750psi)
3. Note: Refer to ISO 3457 section 9 for further guidance in relation to the vicinity of risk.

1.5.8. Hose assembly

A flexible hose with its hose ends attached. Sometimes referred to as a flexible hose assembly.

1.5.9. Hose end

The hose coupling or hose fitting that is attached to each end of a single piece of hose.

1.5.10. Hose service life

The effective lifespan of the hose, whereby the hose meets the required factor of safety and the required likelihood of failure, (typically a maximum of eight years, see clause 3.7.3).

1.5.11. Impulse life

The set number of impulse cycles that a given fluid power component is able to withstand under controlled test conditions.

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1.5.12. Inspection

A process which verifies that the plant or equipment (which should be cleaned as necessary to permit inspection) is in a condition accepted as working order prior to operation or during maintenance activities.

1.5.13. Lifecycle

Includes design, manufacture, construction or installation, commissioning, operation, maintenance, repair, decommissioning and disposal.

1.5.14. Matched

A matched hose assembly is where the hose and fittings (insert/ferrule) are designed, manufactured and routinely tested to match up to a particular manufacturer's hose type. In this case both (hose and fitting) are assembled and crimped using the methods as specified by the designer, meet the tolerance specified by the designer and have been tested as a hose assembly, at the maximum tolerance, to the specified standards.

1.5.15. Modifications (alterations)

Change in the design of the mobile or transportable plant, where the change may affect health or safety, but does not include routine maintenance, repair or replacement. Note that registered plant may require design re-registration to include the modifications.

1.5.16. Must

Indicates a legal requirement exists.

1.5.17. Plant safety file

A structured compilation of documents providing traceable evidence/information relating to the health and safety features, incorporating each phase of the lifecycle of the fluid power system from design through to demolition. It also contains a record of all 'as-built design features', including information on risks to health and safety that could arise at any phase of its life cycle.

1.5.18. Pressure intensification

The amplification of system fluid pressure in excess of the designed pressure to a level that is hazardous. For example, this can be caused by excess load, blockage of annulus areas in hydraulic or pneumatic cylinders, thermal effects and similar.

1.5.19. Reasonably practicable

The Work Health and Safety Act 2011 defines what is reasonably practical refer subdivision 2 section 18. Reference is also made to the interpretive guideline — model work health and safety act the meaning of 'reasonably practicable'.

1.5.20. Safety critical system

A fluid power system whose failure or malfunction may result in death or serious injury to people.

1.5.21. Should

Indicates a statement is 'recommended'.

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2. Hazards associated with fluid power systems

This section is primarily aimed at the safety of personnel through risk-based methodology.

2.1. Work health and safety legislation

2.1.1. Guidelines and safety legislation

Legislation requires all hazards to be identified, the risks assessed, control measures implemented in accordance with the hierarchy of controls, maintained and reviewed.

The hierarchy of legislation, guidelines and other documents is set out in the diagrams entitled schematic of guidelines and legislation at Appendix A.

The diagram highlights documents that are mandatory, documents that should be followed (or an equivalent level of safety provided) and documents that are informative and should be considered through a risk assessment process.

Further guidance on plant is provided in the Mechanical engineering control plan (MECP) code and the Electrical engineering control plan (EECP) code.

2.1.2. General duties in relation to plant

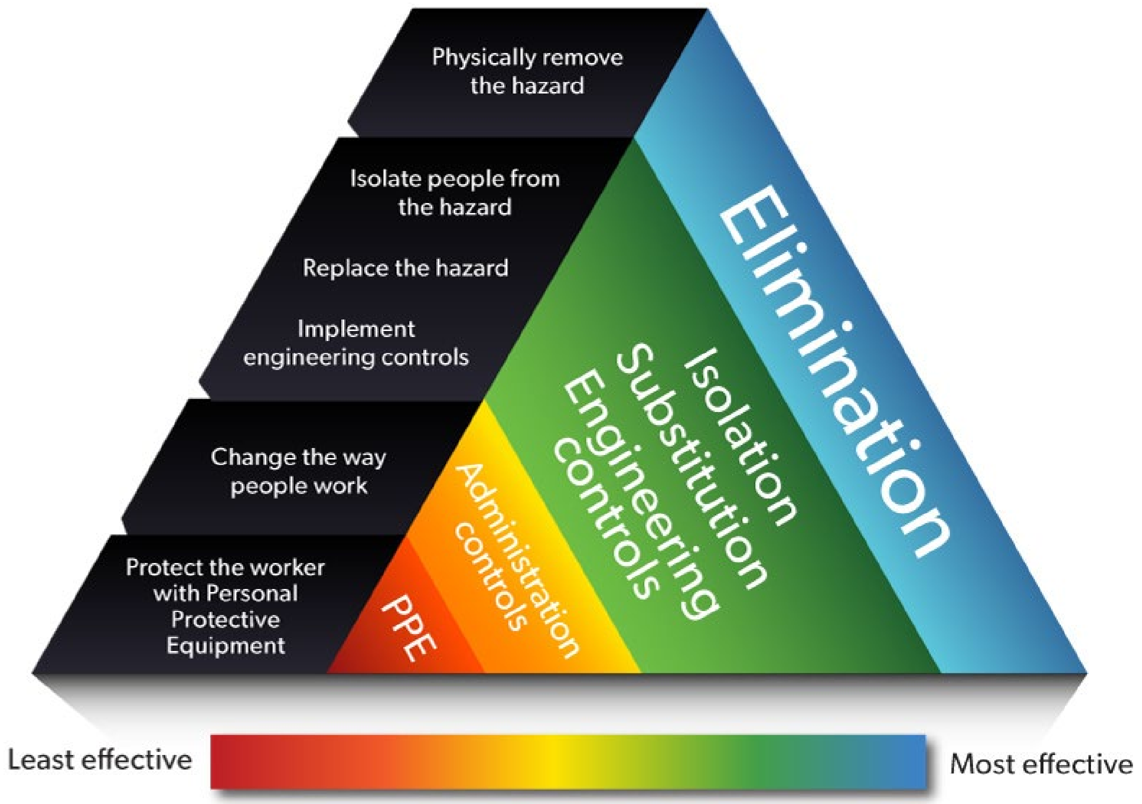
A person conducting a business or undertaking (PCBU) has a primary duty of care under section 19 of the WHS Act to ensure, so far as is reasonably practicable, that workers and other people are not exposed to health and safety risks arising from the business or undertaking. This duty includes ensuring, so far as is reasonably practicable:

- the provision and maintenance of safe plant and structures
- the provision and maintenance of safe systems of work
- the safe use, handling and storage of plant and structures
- the provision of any information, training, instruction and supervision that is necessary to protect all persons from risks to their health and safety arising from work carried out as part of the conduct of the business or undertaking.

In meeting this duty at a mine, a PCBU must manage risks to health and safety associated with mining operations at the mine in accordance with part 3.1 of the WHS Regulation and clause 9 of the WHS (Mines and Petroleum Sites) Regulation 2014:

- ensuring that a risk assessment is conducted by a person who is competent to conduct the particular risk assessment having regard to the nature of the hazard
- identifying all reasonably foreseeable hazards
- eliminate risks to health and safety so far as is reasonably practicable
- if it is not reasonably practicable to eliminate risks to health and safety – minimise risks so far as reasonably practicable in accordance with the hierarchy of risk control measures at figure 1 below.

Figure 1: Hierarchy of controls



Further guidance is provided in the mechanical engineering and electrical engineering codes of practice.

2.1.3. Design, manufacture, import, supply

Designers, manufacturers, importers and suppliers of plant, substances and structures have duties under sections 22-25 of the WHS Act. These duties may be summarised as a duty to ensure, so far as is reasonably practicable, that the plant, substance or structure is without risks to the health and safety of people at a workplace who use it for a purpose for which it was designed or manufactured.

2.1.4. Calculation, analysis, testing or examination

Designers, manufacturers, importers and suppliers must also carry out (or arrange to carry out) any calculations, analysis, testing or examination that may be necessary for the performance of the duty imposed by sections 22-25 of the WHS Act. Alternatively, in the case of importers and suppliers, ensure that such calculations, analysis, testing or examination have been carried out.

2.1.5. Information to be provided

Designers, manufacturers, importers and suppliers must also give adequate information to each person to whom they provide the design, plant or structure (and subsequently upon request) concerning:

- each purpose for which the plant, substance or structure was designed or manufactured
- the results of any calculations, analysis, testing or examination referred to above, including, in relation to a substance, any hazardous properties of the substance identified by testing
- any conditions necessary to ensure that the plant, substance or structure is without risks to health and safety when used for a purpose for which it was designed or manufactured or when carrying out any activity discussed in the previous list.

2.1.6. Maintenance of control measures

Control measures implemented to control risks presented by identified hazards at a mine must be maintained to ensure their effectiveness under clause 37 of the WHS Regulation, including by ensuring that the control measure is and remains:

a) fit for purpose
b) suitable for the nature and duration of the work, and
c) installed, set up and used correctly.

2.2. Hazards associated with fluid power systems

2.2.1. Hazard identification and consequence

For duty holders to meet their obligations and control the risks to health and safety throughout the lifecycle of the fluid power system, it is important to be able to identify hazards and potential consequences in order to assess and treat the risk.

Table 1 provides a list of hazards and potential consequences associated with fluid power systems, which should be considered.

For fatality data related to “Fluid Power System” refer to:

https://www.resourcesregulator.nsw.gov.au/__data/assets/pdf_file/0011/368327/MDG-41-Fluid-powered-systems-fatal-incidents.pdf

Guidance on general mechanical and electrical hazards associated with mining plant, the assessment of risks arising from those hazards and the implementation of fit-for-purpose risk controls is provided in the MECP code and the EECP code. Guidance on risk management is provided in AS/NZS ISO 31000, AS/NZS 4024.1201and SA/SNZ HB 89.

Table 1 – Common hazards and consequences for fluid power systems

Energy / Hazard	Mechanism/scenario (Unwanted event)	Potential consequences
High pressure fluid	• Exposure to uncontrolled release of high pressure fluid due to failure of pressure containing devices or pressure controlling devices • Exposure to uncontrolled release of high temperature fluid • Release of compressible gas	• Direct fluid injection injury • Struck by projectile debris • Struck by whipping hoses • Burns from contact with eyes or skin • Injury to sensitive areas of body, e.g. eye injury • Catastrophic failure of pressurised components • Reduced component life • Loss of production/downtime
Fuel source - hydraulic oil or other	• Exposure to heat or explosion after ignition of uncontrolled release of fuel energy (fire or explosion). For example: A leak under pressure results in fluid contacting an ignition source.	• Burns • Asphyxiation • Equipment and production losses
Toxic chemical or substance	• Uncontrolled release of toxic chemical or substance. For example: fluids such as phosphate esters.	• Skin irritation, dermatitis or burns (short term) • Skin condition or disease (long term) • Lung disease or irritation • Loss of eye sight (short or long term)
Noise (energy)	• Exposure to continuous operation noise source i.e. pumps and motors, electric motors, cavitation, etc • Exposure to discontinuous operation noise ie hammering, operation of functions etc • Noise from rapid expansion of gases	• Loss of hearing (short term) • Loss of hearing (long term)
High temperature	• Development of high temperatures on equipment components from energy being converted into heat within the hydraulic system. Ignition of fluid or vapour	• Skin burns from contact with hot component surfaces or released fluid. • Melted or damaged components and/or hoses (leading to uncontrolled release of high pressure or temperature fluids) • Burns • Asphyxiation

		• Equipment and production losses
Electrical energy sources	• Earth or other faults of the electrical system.	• Electric shock
Static electricity	• Discharge of electrical energy causing ignition of fluid or vapour	• Burns • Asphyxiation • Equipment and production losses
Potential or kinetic energy driven by gravitational or hydraulic forces	• Unplanned movement (by failure to control motion of machine or failure to support suspended load)	• Crush injury (between fixed and moving components) • Crush injury (falling load or roof) • Equipment and production losses

2.2.2. Latent and specific risks

Some risks may also be of a type that is not immediately apparent. Such risks are referred to as 'latent risks'. The list below identifies some latent and other specific risks for fluid power systems that should be considered. Many of the potential consequences listed in table 1 are relevant to latent and specific risks.

a) fluid leakage due to hose/pipe/fitting failure (including pin holes)
b) physical damage from people standing on components
c) physical damage from fallen material
d) pressure intensification and pressure pulsation's
e) over pressurisation/excessive flow or loss of pressure
f) electrical/hydraulic/pneumatic control system failure
g) fluid contamination
h) wear, fatigue, corrosion and age
i) excessive temperature of the systems or environment
j) overload and/or high external loads
k) unplanned movement due to component failure. For example, blockages, pressure drops or leaks which affect the operation of components
l) working pressure and flow, temperature and load changes over time
m) failure of power supply, either hydraulic, pneumatic or electric

n) actuator failure (structural or functional)

o) inappropriate hose/pipe installation

p) potential hazards due to the environment;

   a. explosive dust or gas mixtures

   b. water level or rainfall

   c. release of gas from oxy/acetylene bottles

   d. UV light exposure

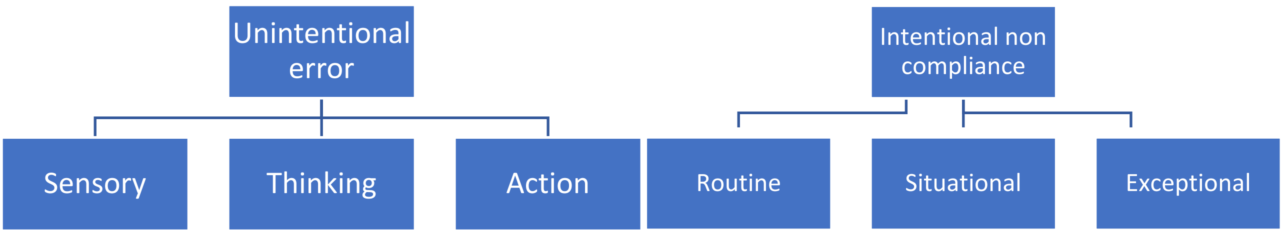
q) system integration and potential incompatibility

r) poor work practices in diagnosing system faults and poor maintenance resulting in ignorance of potential dangers

s) failure to implement change management procedures (i.e. different scale pressure gauges)

2.2.3. Management of human factors

Human factors are often contributing factors in the failure of risk controls. The reduction of human factor potential should therefore be considered for the lifecycle of the fluid power system. Human factors may be described as:



Unintentional error is whereby the person can explain how the failure occurred but not why. The individual is puzzled by their own actions.

Intentional non-compliance is the individual announcing their intention to behave in a certain way. It can also be demonstrated the person knew what should be done. Usually intentional noncompliance is well meaning but misguided.

Further information is available in in the MECP code and Safe Work Australia *Guide for safe design of plant*.

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2.2.4. Incident data

When identifying hazards associated with fluid power systems it is helpful to consider published incident data.

Appendix C provides a summary of escapes of fluid under pressure that were reported to the Resources Regulator over the past few years.

Appendix D provides safety alerts related to incidents.

To facilitate awareness of incidents:

- People in control of fluid power systems should provide the plant designer/manufacturer/supplier with details of relevant incidents and include these in the plant safety file.
- Designers should, provide information on safety-related incidents that they become aware of and their recommendation to rectify such defect. (e.g. safety alerts, technical bulletins and similar).

2.3. Risk management

Risk management techniques should be used to:

a) identify the risk to health and safety of people in the vicinity of fluid power systems. Most injuries occur when people are working close to fluid systems and there is a component failure, e.g. hose, fitting, pressure vessel.

b) identify the risk to health and safety of people operating, maintaining and repairing the fluid power systems

c) identify all high-risk areas

d) identify controls to minimise risks so far as is reasonably practicable

e) assess the required reliability of any implemented control

f) consider recommendations and documentation from stakeholders involved including designers, manufacturers, suppliers, repairers, workers etc

g) develop safe work procedures

h) develop; inspection, testing and maintenance requirements to ensure controls remain effective including the control measure remains fit for purpose

i) develop procedures for the installation, setup and proper use of equipment.

2.4. Plant safety file

Safety information relating to fluid power systems should be readily available to those involved. This gives ready access for life cycle safety considerations.

Safety-related aspects of fluid power systems should be fully documented. These records should be maintained in a plant safety file that covers the lifecycle of the system. The plant safety file should be created by the designer and maintained by the person in control of the fluid power system. The plant safety file should contain the following information:

a) design specifications, performance and operational conditions
b) design documentation
c) as built schematic
d) installation requirements
e) hazard identification and risk assessment documents
f) risk control methods
g) identification of all safety-critical systems and their safety category or integrity level
h) consultation records
i) commissioning and test results
j) maintenance records, safety inspections and test reports
k) change of procedures, monitoring, audit and review reports
l) reports of incidents, accidents and safety statistics
m) fluid system alterations.

The records should be stored and maintained in such a way that they are readily retrievable and protected against damage, deterioration or loss. A plant safety file may not necessarily be one complete document and may refer to where the information can be obtained.

The plant safety file should be kept and maintained for the life of the fluid power systems.

3. Design and manufacture

3.1. General

Fluid power systems should be designed and manufactured using existing engineering standards and principles so it is fit for the intended purpose and is safe to use.

Engineering standards for fluid power systems include ISO 4413, ISO 4414, AS 4041 and ISO 17165 2 (or SAE J1273). These standards should be read in conjunction with this guideline.

Fluid power systems should be designed and manufactured within rated limits of the fluid power system when the fluid power system (including components) is put to the intended use.

All fluid power systems should be designed taking into consideration the relevant principles of AS 4024.1 Safety of machinery series of standards.

Materials used in fluid power systems should be appropriate and compatible for the intended application and the environment likely to be encountered in service.

The design of fluid power system should allow reasonable access to all parts that require adjustment cleaning or service.

3.2. Design hazard identification, assessment and control

3.2.1. Design risk assessment

A design hazard analysis (design risk assessment) should be carried out to identify all reasonably foreseeable hazards associated with fluid power systems and to provide fit-for-purpose means to control risk to health or safety. Consideration should be given to:

a) the purpose of the fluid power system, including intended design life and potential lifecycle risks
b) assessment of those hazards set out 2.2
c) the impact of the mine environment on the fluid power system
d) the provision of safe access to the components of the fluid power system, for the purpose of operation, maintenance, adjustment, repair and cleaning
e) examination of failure modes of the fluid power system and its components
f) information on past incidents including any consultation concerning these incidents
g) the operational monitoring of safety critical componentry to avert the risk of harm to people in the vicinity. This may include the necessity to stop the system.

The outcome of the hazard analysis should identify the required safety critical systems and any performance requirements of those safety critical systems in order to safely operate the fluid power system. The designer should address any foreseeable risk scenario that may cause harm to any person during the fluid power system lifecycle.

Where there are safety risks from unplanned movement of actuators, feedback monitoring on functions should be considered.

Consideration should be given to the control of risks to health and safety that may arise from reasonably foreseeable misuse of the fluid power system.

Guidance may be sought from AS/NZS ISO 31000, SA/SNZ HB 89, AS/NZS 4024:1201 AS/NZS 4024:1303.

Outputs of a risk assessment should include a residual risk register and list of controls for the fluid power system.

All control measures should be assessed for their effectiveness and required reliability.

3.2.2. Design operational risk assessment

A design operational risk assessment should be carried out in relation to the intended use of fluid power system in the mine environment.

3.2.3. Design of safety critical systems

3.2.3.1. Controls for identified risks

Control measures for hazards (safety critical systems) may be identified as either:

a) a safety-related function

b) as safety-related componentry.

The lifecycle effectiveness of the control measures should be assessed to ensure the control measures remain reliable and provide the required level of protection under all stated conditions.

3.2.3.2. Safety-related componentry

All safety-related componentry should be designed, analysed, tested and documented using good engineering practices and according to existing engineering standards.

Safety-related componentry should be systematically analysed to determine all reasonably foreseeable failure modes and to verify that a sufficient level of reliability has been achieved.

Systematic analysis methods such as a failure modes effects analysis, fault tree analysis or other similar analysis methods, should be used to assess safety-related componentry and to determine lifecycle inspection, maintenance, test and discard requirements, as required for lifecycle functionality.

Consideration should be given to fatigue testing or analysis, where applicable.

3.2.3.3. Safety-related functions

All safety-related functions arising from the hazard assessment(s) should be clearly identified.

Safety-related functions should be assessed using functional safety standards, as amended from time to time, as applicable to the design architecture and type of components used, so far as is reasonably practicable. Functional safety standards include:

a. application of performance levels (PL) in accordance with AS/NZ 4024.1503 or ISO 13849.1
b. application of safety integrity levels (SIL) in accordance with AS 61508.1 or AS 62061
c. application of safety categories (CAT) to AS 4024.1501 and AS 4024.1502
d. other relevant functional standards, provided an equivalent level of safety can be demonstrated.

All safety-related functions should be assessed to confirm that the required risk reduction has been achieved. The functional safety assessment should include:

a. validation though evidence documentation
b. a review of possible lifecycle systematic failures and corrective measures taken
c. documentation on any assumptions used, such as those that relate to proof test intervals, periodic inspection and tests, environmental conditions and human behaviour.

3.2.4. Human factors

Designers should be aware of the factors contributing to human factors. Consideration should be given to:

a) the physical and cognitive characteristics of users. For example:
   i. Control stations being compatible with human body measurements (forces required, reach distances).
   ii. The complexity of functions the user is expected to perform.
b) a system that is safe to use. For example:
   i. Minimise unnecessary complexity (i.e. keep it simple).
   ii. Workstations providing a view or feedback for the operator of functions being performed.
   iii. Appropriate instrumentation.
   iv. Quick operational recovery if there is a system failure.
   v. Users are accessible if they need help.
c) reasonably foreseeable misuse, for example:
   i. Quick operational recovery if the user makes a mistake.

ii. Prevention of dangerous misuse of the system (higher order controls, if necessary e.g., interlocks preventing dangerous functions, automatic shutdown in the event of system overpressure).

3.2.5. Operating environment

Fluid systems should be suitably selected and rated to suit the intended operational environmental conditions. The operating environment that the fluid system is designed to operate in should be stated.

Examples of typical operating environmental issues in mines that should be considered include:

a) fluid medium properties e.g., fire resistance, mineral oil, water emulsion
b) ambient temperature range and fluid operating temperature
c) sources of vibration
d) contamination and dusty atmospheres
e) abrasive materials
f) corrosive environments (acidity/alkalinity/salinity)
g) likelihood and severity of fire
h) ventilation
i) ease/standards of maintenance
j) access for maintenance and use
k) explosive and combustible environments (e.g., coal dust, methane atmosphere).

3.3. Design information

3.3.1. General

Incidents have occurred because of documentation being lacking, incorrect or misinterpreted.

To assist in preventing misinterpretation the fluid power systems should be fully documented for the 'As Built' system. Design documentation should contain sufficient detail to enable an evaluation of the fluid system by a competent person other than the designer.

When alterations are being made to the system, documents should be updated as soon as reasonably practicable.

All design documentation should identify system parameters, such as pressure and flow, in the International System of units (SI) units in accordance with AS/ISO 1000.

3.3.2. Synopsis of plant

A synopsis on the fluid power system should be provided and should include:

a) system operating limits and capacities
b) general arrangement drawings showing the physical dimensions
c) hydraulic and pneumatic circuit diagrams. Consider using colour to differentiate circuits
d) schematic and logic drawings of power and control facilities
e) detailed parts lists of all components including reorder codes
f) transport, storage and lifting requirements.

3.3.3. Information on purpose of design

Information on the purpose of the design of fluid power systems should include, without limitation:

a) all purposes of the fluid power system
b) intended operations
c) intended service lifecycle of the system and its components
d) design parameters and assumptions made (refer to ISO 4413, ISO 4414, AS 4041)
e) operating duty / cycle of the system and its components
f) functional specifications and control logic for control of the system
g) operating environment
h) maximum working pressures and temperatures
i) fluid types (specification) and cleanliness levels
j) emergency and safety requirements
k) information on residual risks and controls
l) procedures for servicing and maintenance.

3.3.4. Circuit diagrams

Circuit (schematics) diagrams should be provided and should comply with ISO 1219-2 (see also ISO 4413, ISO 4414 and AS 4041 as appropriate).

All hydraulic and pneumatic symbols should be in accordance with AS 1101.1 or ISO 1219-1.

Circuit diagram should contain the following:

a) All system components, including electro-hydraulic and item identification
b) All pressures settings
c) All flow rates
d) Any other devices

3.3.5. Hose and piping assembly diagrams

Hose and piping assembly diagrams should be provided (see ISO 1219.1 and ISO 1219.2) and should identify:

a) hose type and rating including minimum bend radius and non-flexible length
b) hose/pipe routing
c) hose/pipe size and length
d) accessories, such as sleeves, clamps, colour coding
e) adaptors and couplings
f) components.

3.3.6. Installation testing and commissioning data

Installation, testing and commissioning procedures should be provided and should include:

a) identification of hazards and appropriate controls associated with the installation, testing and dismantling of the fluid system
b) testing, inspection and commissioning to be carried out
c) safe work procedure associated with the installation, testing and dismantling of the fluid system.

3.3.7. Operation and maintenance instructions

Operation and maintenance manuals should be provided. These manuals should contain the following information categorised in appropriate sections:

a) Recommended maintenance requirements to maintain the fluid system in a safe operating condition.
b) Recommended inspection and tests, to check if the equipment is safe to operate.
c) Identification of any hazards involved in maintaining and operating the equipment.
d) Identification of all high-risk areas.
e) Energy isolation, dissipation and control procedures.
f) Safe work procedures to carry out maintenance on the system, including setting of controls.
g) Protective equipment requirements.
h) Trouble shooting guide.
i) Safe handling and disposal of fluids.
j) Recommended spares.

3.4. Fluid power systems design

3.4.1. General

Fluid power systems should be designed, and components selected to provide safe operation over the intended design lifecycle of the systems.

Seals and sealing devices should be compatible with the fluid used, adjacent materials, working conditions and environment. Consideration should be given to incorporating elastomeric sealing for all fluid power connectors.

Fluid systems should be designed to minimise excessive heat generation.

3.4.2. Rated working pressure

To avoid pressurised fluids escaping into the environment, fluid power system components should have appropriate factors of safety on the rated working pressure to bursting pressure.

Hose assemblies should have a factor of safety of at least 4:1.

Adaptor fittings should have a factor of safety of at least 4:1 on rated working pressure to catastrophic failure of the adaptor or fitting

Other fluid power components, such as cylinders, valves, actuators or similar should have a factor of safety of at least 2.5:1.

Where the above safety factors are reduced, appropriate engineering analysis and/or cycle and endurance testing should be carried out and documented. ISO 7751 provides guidance.

When considering a factor of safety for components for fluid power system due consideration should be given to fatigue life of the component.

3.4.3. Excessive pressures

A means or device should be provided to protect the circuit against excessive pressures e.g., relief valve (refer ISO 4413, ISO 4414 and AS 4041 as appropriate).

The device should be:

a) purpose designed to suit maximum flow rate which may include rare events, for example the impact of major roof falls on longwall hydraulics

b) adequately supported and mechanically protected from damage in high wear or impact areas

c) positioned for access for maintenance purposes

d) positioned to reduce the ingress of contaminants from the environment.

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3.4.4. Protection from uncontrolled escape of pressurised fluids

The design should minimise the risk of injury to operators and maintenance personnel from the uncontrolled escape of pressurised fluids. Controls should be provided in accordance with the hierarchy of controls, refer 2.1.2.

Consideration should be given to:

a) routing hoses, pipes and pressurised components away from high risk areas, or otherwise as far away as is possible
b) use of protective fixed guards to prevent escaped fluids entering work areas
c) use of devices to divert or disperse the escaped fluid
d) providing means to detect a potential component failure before it occurs
e) providing means for effective isolation, energy dissipation and verification

It is not considered acceptable to solely rely on PPE in high-risk areas.

3.4.5. Unintended pressure intensification

A means should be provided to prevent unintended pressure intensification on all fluid power systems in particular hydraulic cylinders, such as unloader valves, relief valves and burst discs.

3.4.6. Filtration

Contamination in fluid power systems may cause circuit (component) malfunction such as inadvertent operation. To assist in mitigating this risk, fluid filtration should be provided to protect all fluid circuits. Filtration should be selected in accordance with ISO 4413 or ISO 4414.

The degree of filtration required should be consistent with the filtration requirements for all system components with consideration to the environmental conditions. Typically operating systems greater than 250 bar, (25 MPa) are classified as16/14/8 according to ISO 4406.

Refer to ISO 4406 for filtration ratings and ISO 16889 for evaluation of filter performance.

The effect on the control circuit when the filter is blocked should be considered. Where a hazard exists, a pressure sensor or bypass in the return line should be installed.

Consideration should be given to duplicated filters on all control circuits. All filters should be equipped with a device to indicate when the filter needs servicing.

Blocked or restrictive filters fitted in the return line cause back pressure and may cause inadvertent movement.

3.4.7. Design for maintainability

Hazards associated with maintenance and serviceability should be identified and control measures implemented. For example: sample points within a high pressure fluids should be assessed to identify hazards and control measures implemented which may include sampling on the low pressure side of a high pressure fluid system. Refer to SA06-16 “Fatal high pressure hydraulic injection”.

The system should be designed such that components can be safely adjusted, serviced or replaced without the need to dismantle other components. Particular attention should be given to components and hoses, which need regular maintenance. Consideration should be given to Part 7 of this guideline.

The system design should include provision for ease of access to vent stations, oil draining stations or points and sampling or test points.

3.4.8. Fluids

Fluids should be compatible with the system’s components.

Where there is an unacceptable fire risk, fire-resistant fluids should be used, such as on longwall roof supports and fluid couplings on belt conveyors in underground coal mines.

Compatibility of materials and components should be checked before using fire-resistant fluids.

Safety data sheets (SDSs) should be supplied. Additional information on the toxicity, fire effects, handling requirements and degradability should also be provided where appropriate.

Fluid reservoirs should be designed in accordance with ISO 4413.

3.4.9. Marking and identification

3.4.9.1. General

Sufficient marking and identification of components and operator controls should be provided to assist personnel with the safe use and maintenance of fluid power systems. This assists in preventing human errors in the interpretation of pressures.

Where a hazard could exist from the misinterpretation of a symbol, the meaning of the symbol should be clarified in writing.

All systems components should be labelled to enable clear cross-referencing with the circuit diagram or all systems components should be clearly identifiable to the technical documents.

All pressures should be in standard SI units in accordance with AS/ISO 1000.

Permanent markings, signs and identification plates should be in accordance with AS 1318 and AS 1319.

3.4.9.2. Construction and location

Markings, signs and labels should be:

a) installed or positioned and maintained so that they are clearly visible to maintenance and operational personnel, and
b) of durable construction and be permanently attached.

It is preferable for signs and labels to be constructed of discernible durable material e.g., engraved brass, stainless steel, or similar.

3.5. Components (other than hose assemblies)

3.5.1. General

Components should be selected, applied and installed in accordance with the component manufactures information and ISO 4413 or ISO 4414 or AS 4041 as appropriate. All components of the system should:

a) be designed to withstand surge, dynamic and intensified pressures from the normal operation of the fluid power system
b) be selected to operate reliably over the lifecycle of the system, unless otherwise specified
c) operate within their rated limits, in particular the working pressure and allowable fluid contamination level.

3.5.2. Pressure test points

All fluid systems should have provision for test points to determine pressure in that part of the circuit, including sub-circuits to enable the safe testing and monitoring of the system.

Pressure gauges should also be provided as appropriate.

Test points should be provided to limit the need for dismantling the system for regular monitoring and testing.

3.5.3. Vent ports

The vent port from devices that release pressurised fluid to atmosphere such as relief valves should be diffused (reduce pressure and flow), positioned or protected to prevent injury to people in the vicinity of the fluid being ejected.

3.5.4. Other system components

Energy conversion components such as pumps, motors, cylinders, gas accumulators, reservoirs, etc should be designed in accordance with ISO 4413 & ISO 4414.

All system components should be identifiable and consistent with the fluid system circuit diagram.

In order to minimise risk when obtaining access components should be installed so that they are either accessible from ground level or access platform conforming to appropriate standards.

3.5.5. Valves

All valves should be:

a) designed in accordance with ISO 4413 or ISO 4414 or AS 4041 as appropriate
b) identifiable and consistent with the fluid system circuit diagram
c) securely mounted.

Manual valves should be labelled with the valves function and explanation of operation.

Valves used for isolation should be lockable. Ball or other quick action valves should not be used to vent directly to atmosphere unless the pressure is diffused, refer to Clause 3.4.3.

Ball and gate valves should not be used as metering valves.

3.5.6. Load bearing actuators

Circuits incorporating load-bearing actuators should incorporate the following safety features:

a) Safety devices to protect against the effects of failure of a hose or any other hydraulic component, for example, a device, such as a load lock, that will stop the movement in the event of a hose rupture or pipe fracture.
b) Devices to prevent over pressurisation of the actuator. For example, consideration should be given to thermal expansion of trapped oil, and mismatch of pilot ratios between cylinder and load lock valves (refer clause 7.1.5).

3.5.7. Pumps and pump stations

Fluid power pumps, pump stations and their associated controls should be:

a) adequately supported when installed
b) mechanically protected from predictable damage in high wear or impact areas
c) positioned for access for maintenance purposes with sufficient space around each pump
d) positioned, guarded or cooled to eliminate the likely event of injuring a person where heat is an issue
e) able to be isolated and dissipate stored energy independently of the rest of the system
f) be suitably guarded in accordance with the principles of the AS/NZS 4024.1302
g) design and maintained in consideration to safety alert SA10-01 Longwall hydraulic system over-pressurised.

3.6. Fluid power control circuits

3.6.1. General

Control systems should be designed to prevent unintended movement and incorrect sequencing of actuators over the lifecycle of the plant. Consideration should be given to possible control system failure modes.

Adjustable control valves should be fitted with a tamper-resistant device or require tools where the adjustment of controls may create a hazard.

Clear indication of the fluid system's operational status should be provided, for example pressure indication using a gauge.

Hydraulic/pneumatic control systems should cause the machine to fail to a safe state in the event of any fluid system failure or electrical power loss.

3.6.2. Pilot circuits

To prevent inadvertent operation of components, the pilot circuit return line should be designed to minimise backpressure on control valves. The design risk assessment should analyse all control circuits to determine effects associated with excessive backpressure.

Notes:

- Unplanned movement incidents have occurred from main return line blockages causing excessive back pressure on the pilot circuit.
- One method of achieving this may include a dedicated return line to the tank and be a separate circuit to the main return line.

3.6.3. Return lines

The return line should be protected against over-pressure. Over-pressure in return lines may cause unplanned movements, which in turn can create a hazard to people in the area of influence. A blocked return line can also cause a possible pressure intensification event.

3.6.4. Fire hazard

Where an unplanned loss of fluid could cause a fire hazard, the fluid power systems should be designed to shut down automatically upon release of fluid, where practicable.

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3.6.5. Manual controls

3.6.5.1. General

Hazardous conditions caused by inadvertent operation of the controls should be considered in the design and be minimised.

Where the operation of the control may create a hazard, the system should be safe guarded in accordance with AS 4024.1.

All controls should be accessible for maintenance.

3.6.5.2. Ergonomics

An ergonomic assessment on the layout of all fluid power controls and operator gauges should be carried out. A person competent in ergonomic assessments should carry out an ergonomic assessment. Guidance for ergonomics in the workplace can be found in AS 4024.1 series of standards.

3.6.5.3. Direction of movement

The direction of movement for manually operated levers should be consistent with the direction of operation of the actuator, i.e. lever up raises actuator, refer to Figure 2 below. AS/NZS 4024.1906 provides guidance on general principles.

The direction of manual control lever should not be confusing. Manual controls should be clearly and permanently identified.

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Figure 2: Direction of movement of controls

Function	Direction
On	Down (switches), right, forward, clockwise, pull (pull/push type switch)
Off	Up (switches), left, backward, anticlockwise, push
Right	Clockwise, right
Left	Anti-clockwise, left
Forward	Forward, down
Reverse	Backward, upward
Raise	Up, back, rearward
Lower	Down, forward
Retract	Up, backward, pull, anti-clockwise
Extend	Down, forward, push, clockwise
Increase	Forward, away, right, clockwise, out
Decrease	Backward, towards, left, anti-clockwise, in
Open valve	Anti-clockwise
Close valve	Clockwise
Emergency stop	Push button or pull cord
Remote shutdown	Left, backward, push (switch knobs), up switches

3.6.5.4. Location of controls

The location of manual controls should:

a) be within the reach of the operator's normal working position and such that the control can be operated without inadvertently operating other nearby controls unintentionally

b) not require the operator to reach past rotating or moving devices to operate the control

c) not interfere with the operator's required working movements

d) the location for the operation of controls should be such that the movement of the machine will not impinge on the operator's control space envelope.

3.6.6. Emergency stops

An emergency stop or stopping system complying with AS 4024.1 series of Standards should be provided at each work station. In addition, at least one button should be located remotely to stop the system in the event of an emergency.

Restarting the system after an emergency stop should not cause the automatic operation of the system.

3.6.7. Pressure gauges

All pressure gauges should be in standard SI units in accordance with AS/ISO 1000.

Gauge displays that rely on multiplication or conversion should not be used.

All gauges should indicate the acceptable circuit operating range.

For mechanical or analogue gauges, a snubber should be installed to protect pressure gauges. The upper limit on the gauge should exceed the maximum working pressure by 25%. Green zones should mark correct working pressure range on pressure gauges of hydraulic and/or pneumatic systems. For dial type pressure gauges, the indicating needle should be between 9 o'clock and 2 o'clock on the dial, under normal system pressure.

Labelling or an indication should be provided with the gauge to show the acceptable circuit operating range. Gauges should operate to show the change in state of the circuit. This can be used to show de-energised hydraulic circuits.

Gauges should be adequately supported and mechanically protected from damage in high wear or impact areas.

Gauges should be located where the operators can clearly read the gauge.

Note: Serious injuries and fatalities have occurred because of incorrect identification of pressure.

3.7. Isolation and energy dissipation

3.7.1. General

The unexpected plant movement has caused many injuries and fatalities. Isolation and energy dissipation is a control measure, which is typically used to minimise this risk. Refer to the fatality database Energy Isolation:

www.resourcesregulator.nsw.gov.au/__data/assets/pdf_file/0008/368324/MDG-40-Energy-isolation-fatal-incidents.pdf

In the performance of many lifecycle tasks such as installation, repair, service, component replacement, maintenance and disassembly it is imperative to have isolation and energy dissipation considered in the design of the fluid power system.

Isolation valves should not be installed in the return circuit of a hydraulic system as they provide a means for pressure intensification if left closed.

The designer/manufacturer/supplier should consider effective means of energy isolation, dissipation and verification of fluid power hazards. This should include:

a) identification of all energy sources to prevent a release of energy, (such as stored fluid power, gravity, (suspended loads), springs, electrical) and / or prevent unintended activation or movement of equipment
b) provision of a means to isolate all identified energy sources to prevent a possible state change. This includes purpose designed isolation devices that are lockable. This also includes using purpose designed mechanical stops to isolate against gravity where required.
c) provision of a means to safely dissipate fluid. If used as part of the isolation process a dissipation device should be a purpose-designed dissipation devices and lockable.
d) provision of a system that verifies that pressure has been dissipated. (Test for dead or safe state)
e) clear identification of all isolation and dissipation points
f) provision of safe work methods for the use of the isolation, dissipation and verification devices. Should include removal and restoration of energy.
g) information on required people competence to isolate, diffuse and verify isolation.
h) information available in the MECP code.

Note: There may be more than one source of electrical or hydraulic energy supply as well as gravity, all of which should be isolated.

3.7.2. Considerations in fluid power isolation systems

In the design of fluid power isolation systems, consideration should also be given to:

a) keeping the system simple - be easily identified, be simple to operate and easy to understand its functionality

b) the potential for unplanned movement. Prevent the activation either directly or indirectly of equipment or the release of other energies that could be enacted because of the isolation process.

c) defining function, purpose and state of the isolation point - Identifying a purpose-built isolation point, dissipation point and gauges, isolation signposting, instructions for the isolation point identify a specific safe work method for the isolation process. Gauges indicate when operational, normal working pressures

d) lockable purpose- built isolation and dissipation points - assists in inadvertent operation or build-up of pressure at the isolation point. Not all dissipation points are lockable.

e) Two-point verification of a dissipation event – Such as gauge, or gauges or vent to atmosphere through a diffuser that discharges safely and/or operates a system function.

   Dissipation should not be through unscrewing, removal of staples or loosening hoses and or fittings. Diffusion should be suitably directed and restrained to prevent any unsafe state from being initiated.

f) structure a safe work method - for all isolations for any high-risk activities. Should be based on complexity and include areas of entrapped pressure such as load lock valves used on a cylinder, accumulators, intensification.

g) consult with mine sites - to understand the site isolation policies and procedures.

   Where plant is designed for a specific site, be consistent with the site isolation policies and procedures for any work associated with the system. The restoration of energy to the system should be conducted in a safe manner, safe distance and all functions be tested.

h) a test and inspection plan - provided to verify the safety integrity of the purpose-built isolation, dissipation system and isolation, dissipation and verification devices.

i) Some equipment has a maintenance mode included in the hydraulic system which allows limited operation of the system. If this mode is to be used, the hazards associated with the power on operation of this mode should be fully understood, risk assessed and any necessary control measures to assure acceptable risk need to be applied. Seek manufacturer's instructions and recommendations.

3.7.3. Isolation system features

Consideration should be given to the following features of isolation systems:

a) An interlocked isolation function for the isolation device.

b) An integrated isolation point, which includes simultaneous operation of the isolation and dissipation functions.

c) An integrated isolation point for multiple or complex hydraulic systems, which includes isolation and dissipation functions for all pressure systems.

d) A double block and bleed isolation point, which includes double isolation and dissipation between the isolation devices.

e) Removal of all energy by isolation or disconnection of the complete system or equipment to provide maximum safe state condition, (substitution).

f) A permit system that verifies and controls that the correct process and isolation has occurred.

g) Use of a group complex isolation process for some high-risk complex isolation requirement.

h) Standardise:

- Isolation point, dissipation point and diffuser point colour. (E.g. handle, area colour, typically red.)
- Quality of pressure gauge for the function being used (E.g. Isolation verification device)

i) Provision of safe work procedures relating to isolation points and or procedures to be adopted during isolation, at or adjacent to the working area.

Note: Information on permit systems may be obtained from the appropriate ISO & AS or the HSE website:

www.hse.gov.uk/safemaintenance/permits.htm

3.8. Hose assemblies

3.8.1. General

Failure of hose assemblies have resulted in serious injuries and fatalities in the mine industry, hence appropriate means to mitigate the risk are required.

The selection, assembly and installation of hose assemblies should be in accordance with ISO 17165-1, or SAE J1273 and ISO 17165-2.

Hose assemblies should not be used at pressures exceeding the hose assembly’s maximum working pressure.

3.8.2. Hose selection

3.8.2.1. General

In the selection of hoses the following should be considered:

a) Hydraulic hose should meet or exceed the performance level specified in ISO 8030/8031, ISO 18752 or SAE J517.
b) Hoses should be suitable for the fluid used and the maximum system pressure and temperature.
c) Hoses for conveying air or gas, water or stone dust for use in underground coal mines should be FRAS in accordance with AS 2660. The hose should be effectively earthed. Steel reinforced hydraulic hose is conductive by nature of its construction and may need to be earthed to prevent charge build-up if used in air applications. Documentation/ branding needs to be supplied to substantiate FRAS properties
d) The effect of static electric discharge should be considered for other hoses.
e) Air hoses for mine sites other than underground coal should comply with AS/NZS 2554.
f) Hose assemblies should be adequately sized to minimise pressure loss and avoid damage from heat generation due to excessive internal velocity.
g) Additional testing should be carried out where the hose specification does not cover the application.
h) Hoses should be ozone, weather, abrasion and heat resistant in accordance with ISO 6805.
i) Hydraulic oil hoses on plant in underground coal mines should be fire resistant in accordance with clause 3.8.2.10.

3.8.2.2. Pressure/suction

Hose assemblies should be selected based on the designed maximum system pressure including surge, dynamic and intensified pressures expected in the normal operation of the system.

The maximum working pressure of a hose assembly should be at least equal to, or greater than the maximum system pressure.

Suction hoses should be selected to withstand both the negative and positive pressure imposed by the fluid system.

Where a hose is subject to system spikes and/or irregular pressure variations higher than its maximum working pressure, its life expectancy is rapidly reduced and should be evaluated, refer to SAE J1927.

Note: Surge pressures are rapid and may give a transient rise in pressure. Surge pressure may not be indicated on many common pressure gauges and can best be identified on electronic measuring instruments with high frequency response.

3.8.2.3. Temperature

Hose assemblies should be selected such that both the fluid and ambient temperatures do not exceed the temperature rating of the hose assembly. Hose assemblies near external heat sources (e.g. exhaust manifolds, turbo chargers) should be adequately shielded or covered with heat-resistant sheathing or re-routed to prevent the hose assembly coming into contact with the hot surface. Refer ISO 13732-1 for guidance on guarding, sheathing.

3.8.2.4. Environment

Hose assemblies should be suitably rated or shielded to withstand environmental conditions that can cause degradation. Environmental conditions which should be considered include; ultraviolet light, ozone, water alkalinity/acidity, oils, chemicals, corrosive materials, coal build up, water, vibration, air pollutants, high and low temperature, electricity, abrasion and external loading.

3.8.2.5. Permeation/hose-material – fluid compatibility

Consideration should be given to the compatibility of fluids with the hose and the permeation effects on the hose, refer SAE J1273 or ISO 17165-2.

3.8.2.6. Abrasion resistance

Hoses should meet the abrasion resistance requirements of ISO 6805.

Additional abrasions resistance may be required for specific applications. SAE J2006 provides further guidance.

3.8.2.7. Corrosion resistance

The operating environment should be identified to allow the degree of corrosion resistance to be selected. For a low corrosive environment, all steel hose ends and hose adaptors should achieve a minimum of 72 hours (red rust) when subjected to a salt spray test in accordance with ASTM B117 or ISO 9227. For some more corrosive atmosphere it may be necessary to specify in the range of 200 up to 1000 hours of resistance.

Additional corrosion resistance may be required for specific applications.

3.8.2.8. Hose assembly energy diffusion devices

Where hoses are in a high-risk area and there is no other practical means to provide adequate protection from the uncontrolled escape of pressurised fluids, a hose assembly energy diffusion device may be appropriate if an unacceptable residual risk remains for potential harm to people.

When using diffusion devices, consider the following:

a) the hose assembly energy diffusion device should be able to diffuse the energy in the hydraulic fluid, to a level where the risk of fluid injection is minimised
    i. Diffusion sleeves may not provide adequate protection where a hose burst or a fitting disconnects from the hose, particularly in high fluid flow situations.
    ii. The diffusion device designer/manufacturer/supplier should identify the limits of the device in relation to pressure, flow rating and duration before failure.

iii. Covering layers of spiral guarding may influence the effectiveness of the sleeve.

b) provision should be made for the safe periodic inspection of the hose contained within the diffusion device. Inspection of hose assemblies should be undertaken with the sleeves removed. This particularly applies where there are many hoses in use. It should be combined with fatigue testing to failure of the hoses assembly to allow prediction for the remaining useful life of the other hoses assemblies in the system.

c) diffusion sleeves are required to be a loose fit over the hose to redirect the energy of any ejected fluid.

d) the sleeve should be manufactured from high abrasion, ozone, heat resistant material and should be suitably attached

e) in underground coal mines, this sleeve should be fire resistant

f) typically, stainless steel or other metal mesh has been successfully used to guard high pressure hydraulics from the workplace.

3.8.2.9. Hose assembly restraint devices

'Whip restraints' are hose-tethering devices and are intended to limit hose assembly movement in the event of hose separation or failure and to prevent or limit harm to people.

Where 'whip restraints' are used, the restraint needs to be capable of withstanding the kinetic loading of a hose failure. Whip restraints, where fitted should limit hose assembly end displacement to a practical minimum. Mountings (tether points) for whip restraints should be load rated. Whip restraints, where fitted should not interfere with the function of the sleeving if fitted, and should be routinely inspected.

For air or gas applications, whip restraints should be considered for hose assemblies operating above 700 kPa or greater than NB 35, if there is a risk to people from the failure of the hose.

3.8.2.10. Fire resistance

All hydraulic hose assemblies should be fire resistant unless the hose is in a low risk fire area.

Fire resistance hoses should be tested in accordance with AS 1180-10B or ISO 8030 and the average duration of the flaming and glowing should not exceed 30 seconds.

Note: MDG 3608 provides guidance on FRAS in underground coal mines.

In some applications, a high level of fire resistance may be required, such as brake, turbo lube hose assemblies and fire suppression system hoses. These hoses may need to comply with less common specifications such as (or equivalent level of fire resistance provided) SAE Aerospace Standard SAE AS 1339-2003 (R2007), Hose Assembly, Polytetrafluoroethylene, Metallic Reinforced, 3000 psi, 400°F, Lightweight, Hydraulic and Pneumatic. The operating limit for this hose assembly is -54°C to +232°C.

3.8.2.11. Antistatic hose

Where hydraulic hose assemblies require antistatic properties, they should meet the requirements of clause 14 of ISO 6805 when tested in accordance with ISO 8031 or MDG 3608.

3.8.2.12. PVC piping

Nylon or PVC piping for pneumatic safety control systems should not be used unless the loss of pressure within these systems causes the system to fail to safety. All such piping should be adequately protected and shielded from contact with hot and/or sharp surfaces.

3.8.2.13. Specific applications

To safely handle elevated discharge temperature of air compressors elastomeric (rubber type) hose assemblies should not be used on a delivery line between an air compressor and air receiver. Fit-for-purpose Polytetrafluoroethylene with steel braid is satisfactory. All delivery hose assemblies should be heat resistant, guidance is given in SAE J517.

3.8.3. Factors impacting hose service life

To minimise the potential for a hose failure hose life should be considered in the design, selection and installation of hose assemblies. To maximise the effective service life, see SAE J1273 or ISO 17165-2.

3.8.3.1. Impulse life

Typical factors that may affect impulse life, assuming that the hose assembly has been assembled correctly, include:

a) Minimum bend radius (MBR) – static and dynamic
b) bend angle adjacent to the end fitting. This section of hose is referred to as the non-flexible length (NFL) and is generally recommended to be a minimum of six times the hose outside diameter
c) mechanical flexing
d) pulse frequency
e) pulse pressures (normal and transient spikes)
f) twisting
g) mechanical damage
h) internal and environmental conditions including temperature.

Refer to SAE J1927 for further guidance.

3.8.3.2. Service

In addition to the above, typical factors that reduce the in-service life of a hose assembly include:

a) external cover damage (abrasion, impact, rubbing, gouging, etc)
b) environmental factors (temperature, UV, ozone, chemical, etc)
c) mechanical loads – vibration, tensile, shear
d) installation/routing (orientation, clamping, vibration, mechanical loads, equipment extension, securing methods, etc.)
e) corrosion of end fittings and reinforcement wires
f) working fluid – temperature, velocity and contamination
g) bending in more than one plane.

3.8.3.3. Effective service life

To minimise the potential for hose failure and to maximise the effective service life of hose assembly, design and installation should be carried out in accordance with SAE J1273 or ISO 17165-2. Poor design of installation standards is a predominate factor in effective service life

In addition, consideration should be given to:

a) external cover protection that may be exposed to abrasion or impact damage
b) shielding to protect hose assemblies from heat sources such as engine manifolds, exhausts, turbos etc
c) accidental damage caused by: falling rock, vehicle collision, tensile load, shear load, crushing, fire
d) mechanical loads – vibration, tensile, shear
e) corrosive spillage, molten metal, pressure surge
f) corrosion of end fittings (alkalinity / acidic water) / Coal (sulphur)
g) heat generated internally and externally to the hose assembly
h) refer hose life degradation (ref S-N studies) ACARP C17020
i) working fluid temperature, velocity and contamination.

Refer to section 7.6 Hose assembly management

3.8.3.4. Hose and hose assembly shelf life and storage

Storage and age control can affect hose life. The following should be considered:

a) A system of age control should be implemented to ensure hose assemblies are used prior to shelf life expiration.
b) Hose and hose assemblies should be stored in accordance with ISO 8331.
c) Storage areas should be relatively cool and dark, as well as free of dust, dirt, dampness and mildew.

Note: Hose and hose assemblies can be adversely affected by temperature, humidity, ozone, sunlight, ultraviolet light, oils, solvents, corrosive liquids, and fumes, acids and alkalis, insects, rodents, sharp edges and abrasive surfaces, electric or strong magnetic fields, mould and fungi, and radioactive materials.

d) Storage of tested hose assemblies should be limited to two years from inspection, refer to SAE J1273 Clause 9.1.c.

e) Hose assembly stored for more than two years, should be visually inspected and proof tested or follow manufacturer's recommendations.

f) Hoses should be re-proof tested (see 3.8.7.1) after 5 years from their cure date and discarded after 8 years unless recommended by the hose manufacturer. After successfully retesting, the hose assemblies should be clearly remarked.

3.8.4. Premature failure of hose assemblies

Statistics on the failure of flexible hose assemblies in workplaces indicate that the major mechanism of hose failure is abrasion followed by stresses inducing pin holing near the hose ends.

Control measures for the risks presented by such failures include:

a) route hose assemblies to avoid abrasive situations

b) cover and protect hose assemblies to avoid abrasion (from abrasive material for example accumulation of debris on underground equipment).

c) keep stress on hose assemblies to a minimum by:

- adhering to the manufacturers minimum bend radius (MBR) and
- using a non-flexible length (NFL) adjacent hose ends
- clamp the hose and to use directional hose ends to reduce torsional effects
- understanding the effects of pressure loading on the hose assembly.

3.8.5. Markings of hose assemblies for identification

Markings should be designed to last for the life of the hose assembly and be placed on both ends (where practical) of the hose assembly and be visible without removing protective devices such as sleeving or restraints.

Hose, hose ends and hose assemblies should be labelled as follows:

a) Hose

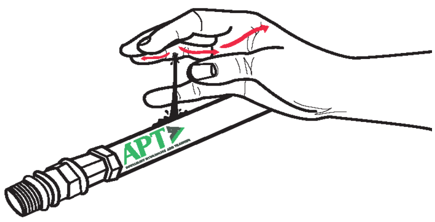
i. Manufacturer's name or mark

ii. Class/type of hose, where applicable

   iii. Month and year of manufacture
   iv. Hose description, e.g., 10 mm, 13 mm etc. where applicable
   v. Batch code
   vi. Maximum working pressure.

b) Hose ends
   i. Manufacturer's name or mark
   ii. Date code or batch code, where practicable
   iii. Part number, where practicable.

c) Hose assemblies
   i. Supply company name (or logo)
   ii. Hose assembly part number or description or unique Id No.
   iii. Test certificate number and/or serial number, refer clause 3.7.11.4
   iv. Date of assembly
   v. Maximum assembly working pressure
   vi. For hose assemblies in high risk areas and accessible to personnel consideration could be given to providing additional information as a warning, for example "Warning – fluid injection injury" or a symbol like one below.



3.8.6. Hose ends

3.8.6.1. General

Hose ends should not be interchanged and should be properly matched to the hose based on proven type test result.

Only select hose ends compatible with the hose for the application. The fitting and hose manufacturer's recommendations should be strictly followed.

For longwall applications, a permanent crimp-style fitting is preferred.

Corrosive resistance should be in accordance with Clause 3.7.2.7.

Threads on all hose ends and adaptors should be mated so they cannot be mismatched, for example do not intermix BSPP with BSPT.

Hose ends should not be reused unless recommended by the manufacturer for that application.

Hose ends, adaptors and flanges should be in accordance with recognised standards.

Pressure rating of the hose assembly may be limited by the hose end selection.

Where hose connections are used in an installation where they could work themselves loose due to movement, vibration, rotation or similar and people in the vicinity could be exposed to risks to health or safety, consideration should be given to installing soft-seal or other high-performance connections.

Refer to section 9.9 Appendix I for hose end adaptor pressure ratings

3.8.6.2. Staple type fittings

People have suffered fatal injuries from the withdrawal of staple type fittings when the fitting inadvertently or unknowingly remained under pressure. For this reason, consideration should be given to alternative to staple type fittings when designing new fluid power systems. Staple fittings should only be used when there is no other reasonably practicable alternative fitting.

Unlike some other fittings, a staple fitting does not leak and gives no indication there is pressurised fluid in the system when the staple is being removed. Once the staple is removed full pressure and flow will expel from the fitting. It is preferable to use a fitting which shows signs of leakage prior to a total disconnect of the fitting.

Staple lock connections are a legacy longwall technology, which need be managed with appropriate control measures to be implemented for continued use. Staples are not recommended above those pressures nominated in DIN 20043, BS 6537 and SAE J1467. All staple life expectancy is limited by cyclic loading (cyclic fatigue). This information should be included in suppliers' data.

There are alternate non-staple/pin connections available cannot be disconnected under pressure that may be suitable.

Issues regarding failure modes of staple connections include:

Staple failure mode	Control measures
• Staple deforms permanently on installation allowing staple to move easily from coupling assembly allowing uncontrolled release of fluid	Staple material too malleable – increase Brinell Hardness.
• Staple legs break off because of metal fatigue allowing what is left of the staple to move easily from the coupling assembly and an uncontrolled release of fluid ensues.	Staple material too brittle – decrease Brinell Hardness.
• Staple "walks" out of coupling. This is caused by the relative rotational movement between the male hose end and the mating female coupling half while the hose is under operational pressure. The frictional forces between the staple and the rotating male component drives the staple out of the joint resulting in the uncontrolled release of fluid. A known example of this migration is in intershield hoses in longwall applications.	Where staple lock fittings are installed a secondary retention, method should be employed.

Note: Further information is available from ACARP document C19011 "Longwall hydraulic staple lock staple fatigue assessment", Safety Alert SA06-18 "Longwall staple failures Non-standard type hose ends and adaptors"

3.8.6.3. Non-standard staple type fittings

Staple type hose ends and adaptors which do not comply with a recognised standard, such as "staple less", 'super staple' or 'pin type' connections should:

a) Be assessed to SAE J1065 and proof tested to ISO 6605 or SAE J343 or AS 1180.5. Testing to ISO 6802 is preferred.

b) Be designed such that the use of other manufacturer's proprietary fitting/components cannot easily be mistaken and used in the wrong system creating a hazard to the end user.

c) Be suitable for the intended application over the fitting lifecycle, such that the fitting does not fail due to fatigue, cyclic loading or contamination from the intended operating environment or removal and assemble for maintenance.

For staple applications, see Safety Alert SA06-18, i.e., staples are one-use only and should be replaced when hoses and components are replaced.

3.8.7. Flexible hose assembly manufacture

3.8.7.1. General

The following are applicable to flexible hose assembly manufacture:

a) Only competent people should perform hose assembly fabrication.

b) Hose assembly fabrication should be in accordance with the hose and hose end manufacturer's assembly instructions.

c) Generally, tolerance on overall hose lengths should be ±1%, unless otherwise specified.

d) Hose assembly should be cleaned and flushed for removal of cuttings/debris.

e) When lubrication is required for assembly, the lubrication should be compatible with the system the hose is being used in or otherwise inert.

f) An inspection and test plan (ITP) should be carried out during all phases on hose assembly.

g) The hose assembly should be rated by the lowest pressure component in the hose assembly.

h) For threaded type hose assemblies, the final hose assembly length should be the overall length as shown in Appendix G specified from the tip of the seat of one hose end to the tip of the seat of the other hose end.

i) For staple type hose assemblies, the final hose assembly length should be the overall length.

j) Hose assemblies should only be fabricated using "matched" hose and hose fittings.

3.8.7.2. Matched hose and hose fittings

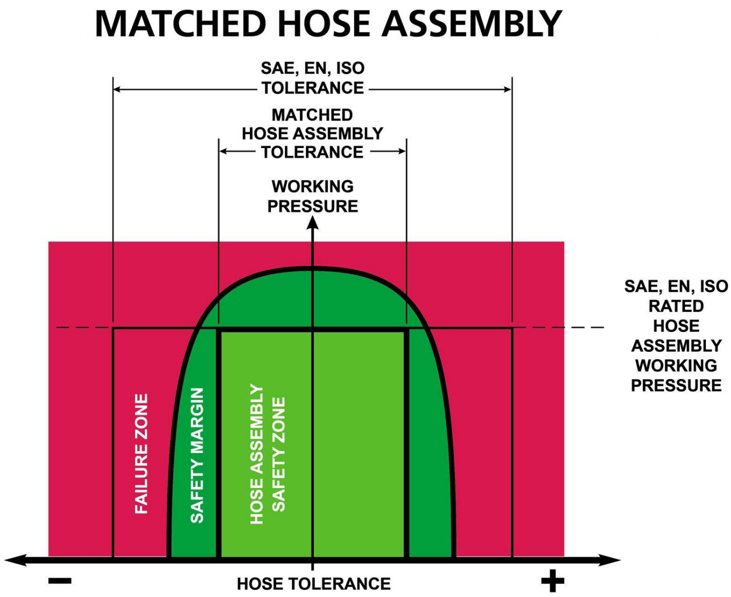
Matched means that the hose dimensions and tolerances are compatible with the dimensions and tolerance of the fittings to ensure that the joint meets the impulse and burst tests for the hose assembly, refer Figure 3.

The use of fittings that are not matched to a hose may result in hose/fitting separation or other premature catastrophic failure. Although a hose assembly fabricated using non-matched fittings may achieve the required burst test pressure, it will most likely fail the required impulse testing. Suppliers of manufactured hydraulic hose assemblies should verify that the hose and fittings used are matched.

Hose assemblies have failed from hose ends being attached to a hose for which it was not designed. The hose end (fitting) should have the correct tolerance to fit the particular hose that it is to be attached to.

The tolerance in the hose standards, i.e. ISO 18752 is performance based, whereas ISO 6805 & SAE J517 are dimensionally based. This means hoses and hose ends may be dimensionally different for the same size hose.

Figure 3 – Illustration of hose assembly safety margin



3.8.7.3. Procedures for hose assembly manufacture

The hose assembly should consist of componentry that, when assembled, results in a matched, qualified product. The hose assembly components should be assembled strictly in accordance with the respective procedures, which should cover:

a) Material supply verification – product compatibility, material quality
b) Hydraulic hose cutting – calculate cut length, cutting of hose, cleanliness
c) Skiving or buffing – skiving, buffing, cleaning
d) Coupling assembly – depth, lubrication, verification
e) Crimping
f) Final assembly inspection, see clause 3.8.11.3
g) Hydrostatic testing (where required), see clause 3. 8.11.1
h) Quality plan.

3.8.8. Quality plan

Hose and hose end manufacture should be carried out under a quality system certified to comply with ISO 9001 and ISO 9002, which includes appropriate batch testing for conformance and records.

Completed hose assemblies may be certified and tested. in accordance with clause 3.8.11.1.

3.8.9. Competence

People fabricating hose assemblies should be competent and trained in the proper use of equipment, materials, assembly procedures and testing. People should be assessed in their competence for hose assembly and the assessment should be recorded. See clause 3.7.16.

3.8.10. Cleaning and packaging

Hose assemblies should be supplied free from water, debris, metal shavings, dirt or any other foreign material. A cleaning projectile should be shot through the hose in both directions before assembly of the hose ends.

End connections should be sealed and capped to maintain cleanliness.

Hose assemblies should be packaged such that external abuse during shipping, handling and storage does not damage the hose or fittings.

3.8.11. Testing and certification of hose assemblies

3.8.11.1. Individual hose assembly proof testing

Hose assembly proof testing minimises assembly related errors which may cause premature failure of the hose assembly in the operating environment.

Hose assembly testing, where required, should be carried out in accordance with ISO 6605 or SAE J343 or AS 1180.5.

All hose assemblies which involve high risk as defined by risk assessment (see Clause 2.3) should be proof tested at two times the maximum working pressure.

The test pressure should be held for a period of 30 to 60 seconds. There should be no indication of leakage or failure.

Proof testing should be conducted using compatible fluid rather than with compressed gases.

Polytetrafluoroethylene type hose should be tested with water only.

3.8.11.2. Type testing of hose assemblies – dynamic cycle testing

The matched hose and hose end should be dynamically type tested at the impulse pressure and to the number of test cycles specified by the hose's manufacturer or by the hose's relevant standard (ISO 1436, ISO 3862, ISO 4079, ISO 6805, ISO 11237, ISO 18752 or SAE J517), whichever is greater, in accordance with ISO 6803, hydraulic pressure impulse test without flexing at the lesser minimum bend radius as specified by the hose's manufacturer or by the hose's relevant standard.

In applications of high dynamic cycling consideration should be given to type testing the hose assembly in accordance with ISO 6802, 'hydraulic impulse test with flexing' to minimum bend radius, for 80,000 cycles at 120% of the working pressure. See Appendix F.

3.8.11.3. Visual Inspection of hose assembly (before despatch)

All hose assemblies should be visually inspected before dispatch and inspections recorded.

The inspection is conducted to make sure that:

a) labelling is true and correct
b) assembly condition is free from kinks, loose covers, bulges or ballooning, soft spots, cuts, broken or protruding wires, any other obvious defects
c) fittings and attachments are: securely crimped or fastened, correct for hose size, series or type, free from cracks, not distorted, free from bulges where they join the hose, free to swivel, free from rust
d) the assembled hose corresponds to the order – verification
e) the assembled hose is free from contaminants, hose ends are capped, plugged and the hose is packed correctly for transport. Caps/plugs should be non-metallic.

Where practical, the person carrying out the visual inspection should be different to the person who assembled the hose.

3.8.11.4. Individual hose assembly test documentation

Each test certificate should bear a unique number for traceability. This document should be held by the manufacturer and be available upon request.

Test certificates should include the following information as required:

a) Test certificate number
b) Testing location and name
c) Test procedure reference number
d) Assembler's name
e) Fabrication number
f) Hose assembly part-number and or serial number(s)
g) Hose assembly details including length, type of hose and size
h) Hose assembly standard
i) End fitting details with types of ferrules and seals used
j) Test date
k) Confirmation that the hose assembly consisted of matched hose and hose ends
l) Hose end information and check for correct matching of hose ends to hose

m) Test pressure

n) Pass/fail

o) Signature of person doing the inspection

3.8.11.5. Batch certificate of conformance

A certificate of conformance should be supplied, on request.

The certificate of conformance should have the following information, if applicable:

a) Customer’s name, address, purchase order, contact details

b) Specification, drawings, part number and standards the assembly conforms to

c) Supplier’s name, address, purchase order, contact details

d) Supplier’s order number

e) Description and quantity of supply

f) Additional information as requested

g) Supplier’s authorisation signature

h) Date of supply.

3.8.12. Tagging

Tagging is one method used to assist with individual hose assembly reliability management. Where using a tagging system, consideration may be given to the following:

a) Each hose assembly should be identified with a unique identification number physically attached to the hose (i.e. a tag).

b) Tagging may be achieved using an electronic system such as RFID (radio frequency identification) or barcode system and the tag information should be consistent with the data in the register.

c) Care should be taken to ensure that the tag or its fixing does not promote a local corrosion site, or create a site for chafing or cutting the hose surface under operating conditions.

d) Any electronic tag reading system should be compatible with the hazardous area classification requirements for the areas inspected.

Tagging arrangements should be linked to the records system. See clause 7.5.

3.8.13. Hose assembly installation

3.8.13.1. General

The hose assembly installation should be consistent with ISO/TS 17165-2 or SAE J1273 and:

a) be secure and be adequately supported

b) be supported in such a way that external loads are not transferred to the hose end or adaptor
c) be supported if the weight of the hose assembly could cause undue strain on the hose end
d) be neat and tidy, with minimal crossover to eliminate rubbing, refer to MDG 15 for guidance on mobile equipment
e) be routed to prevent coming into contact with sharp edges or other surfaces that may wear the hose cover (see Appendix G)
f) be mechanically protected from damage in high wear or impact areas
g) be connected to adaptors which allow for full articulation for the intended movement
h) be the correct length as required for the intended movement, consider Minimum Bend Radius and Non-Flexible Length
i) be fitted with a hose energy diffusion device if required
j) be restrained near people to eliminate whipping of a blown hose assembly
k) not be positioned where stone, coal or mud is likely to build up causing abrasion
l) not be subject to shock, surge pressures which exceed the manufacturer's recommendations
m) have a length necessary to avoid sharp flexing and straining of the hose assembly during operation
n) not be bent at a radius smaller than those recommended by the manufacturer Minimum Bend Radius
o) have minimal torsional deflection during installation and use, e.g., because of a fitting jammed
p) be located and be protected to minimise abrasive rubbing on the hose cover
q) be cleaned during manufacture and prior to installation.

The date installed and/or machine hours should be recorded in accordance with Section 7.

3.8.14. External loads

External mechanical loads should be minimised during the installation of a hose assembly.

Swivel type fittings or adapters should be used to ensure no twist is put into the hose assembly. In some applications live swivels may be necessary, e.g. two rotating components.

Hose assemblies are designed for internal forces only, they should not be used in applications which apply external forces to the hose or hose end.

Mechanical loads include: flexing, twist, kinking, tensile or side loads, bend radius and vibration (amplitude and frequency).

3.8.15. Hose assembly length

Hose length varies due to motion, pressure variations and equipment tolerances. Hoses that are too short stress hose ends and induce premature failure. Hose routes, lengths and supports should be clearly identified at the design stage. The hose assembly route should allow for hose replacement and access

All air, hydraulic, fuel, refrigerant and fire suppression hose assemblies should be routed separately and suitably clamped to prevent vibration and pulsation causing fretting between services leading to hose and cable failures.

3.8.16. Competence of hose assemblers and installers

People installing hose assemblies should be trained and competent in the following:

a) Safe working practices and energy dissipation and isolation
b) Hose and fitting selection, construction and identification
c) Hose specification and standards
d) Hose assembly maximum working pressures
e) Hose assembly lengths
f) Hose cleanliness and system contamination
g) Hose assembly storage
h) Hose outer protection
i) Hose end fittings and coupling identification
j) Fluid compatibility
k) Installation/routing
l) Mechanical loads
m) Physical damage to hose and hose end couplings
n) When to change a hose assembly
o) Anti-seize application methods and its benefits
p) Seals and seal replacement
q) Sealing or seating face damage
r) Importance of environment conditions.

3.9. Pressure equipment

3.9.1. General

All pressure vessels, including accumulators, should be designed, inspected, maintained and operated in accordance with:

a) AS 1200, 'pressure equipment'
b) AS 1210, 'pressure vessels'
c) AS 1271 'safety valves'
d) AS 2971, 'serially produced pressure vessels'
e) AS 3788, 'pressure equipment – in-service inspection'
f) AS 3873, 'pressure equipment – operation and maintenance'
g) AS 3892, 'pressure equipment – installation'
h) AS 4037, 'pressure equipment – examination and testing'
i) AS 4343, 'pressure equipment – hazard levels'
j) AS 4458, 'pressure equipment – manufacture'
k) other equivalent international standards where applicable (these may include ISO, ASME, EN).

The manufacturer should provide a current 'certificate of inspection' with the delivery of equipment, as applicable.

A drain line with a manual valve should be provided to drain the lowest point of all air receivers. This line and valve should be suitably protected against damage during transport.

3.9.2. Registration of pressure equipment

The designs of the following types of pressure equipment must be registered before the plant is manufactured, imported, supplied, commissioned or used.

- Pressure equipment, other than pressure piping, and categorised as hazard level A, B, C or D according to the criteria in Section 2.1 of AS 4343:2005 (Pressure equipment—hazard levels).
- Gas cylinders covered by Section 1.1 of AS 2030.1:2009 (Gas cylinders—general requirements).
- except
    - any pressure equipment (other than a gas cylinder) excluded from the scope of AS/NZS 1200:2015 (Pressure equipment). See section A1 of Appendix A to AS/NZS 1200:2015 (Pressure equipment)

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The following items of pressure equipment must be registered before the item of plant is used.

- Pressure vessels categorised as hazard level A, B or C according to the criteria in Section 2.1 of AS 4343:2005 (Pressure equipment - hazard levels), except:
- (a) gas cylinders, and

  (b) LP gas fuel vessels for automotive use, and

  (c) serially produced vessels.

except

- o any pressure equipment (other than a gas cylinder) excluded from the scope of AS/NZS 1200:2015 (Pressure equipment), or See section A1 of Appendix A to AS/NZS 1200:2015(Pressure equipment).

3.9.3. Hydraulic accumulators

The following information is applicable to hydraulic accumulators. The information has been developed because of investigation of serious accidents and fatalities:

a) Hydraulic accumulators should be securely installed and protected from damage by falling objects.

b) The attachments to the accumulator should be by means of a minimal length adapter and flexible hose for mobile plant.

c) Fittings should be located or otherwise guarded to provide mechanical protection against operational and maintenance damage e.g., Rock damage or stepping onto components during maintenance etc.

d) A means (e.g. bleed valve) should be fitted to allow service personnel to quickly deplete pressure. The fluid should return to tank and the tank depressurised.

e) A means for service personnel to relieve gas pressure safely in a gas-charged accumulator(s) should be provided.

f) A means of diffusing pressure (e.g. relief valve) should be provided between the manual gas charging circuit and gas-charging accumulators.

g) Gas charged accumulators should be in accordance with ISO 4413 and registered if greater than 4 litre capacities.

h) Spring type accumulators should be labelled with a warning informing the content is under spring pressure.

i) Accumulators should be installed providing adequate protection to personnel. Accumulators should be protected against damage and an uncontrolled release of energy.

j) Accumulators should incorporate a means for confirming pressure on oil side (e.g. pressure gauge).

k) Warning sign to identify accumulators in the hydraulic system and to depressurisation before maintenance work should be installed. (Generally, be at the main isolation points and on the hydraulic circuit/drawing).

4. Assembly and installation

4.1. Manufacture and assembly

Manufacturers and assemblers of fluid power systems and components should use the design specifications provided by the designer.

The following should be considered in the manufacture and assembly of fluid power systems and components:

a) Specific conditions relating to the method of manufacture.

b) Instructions for fitting or refitting plant parts and their location on other components of the plant or their housings where errors could be made when installing the plant.

c) Instruction where hot or cold parts or material may create a hazard.

d) Specifications of material.

e) Schematic diagrams.

f) Specifications for proprietary items e.g. electric motors.

g) Component specifications including drawings and tolerances.

h) Assembly drawings.

i) Assembly procedures including specific tools or equipment to be used.

j) Manufacturing processes e.g., requirements for crimping.

k) Details of hazards presented by materials during manufacturing.

l) Safety outcomes for programming.

Any alterations during the manufacturing / assembly phase of a fluid power system is considered a design change in which designers' obligations apply.

4.2. Installation at mines

4.2.1. General

This section applies to the installation of fluid systems, including pumps, hoses, valves, gauges, components, accumulators and actuators when being carried out on mines.

Fluid power systems should be installed or reassembled in accordance with the designer's/manufacturer's installation/assembly documentation, which should identify the exact location and route of all components and hoses.

Before the installation of a fluid power system, a safety management system commensurate with the complexity of the system should identify:

a) the installation program (schedule);
b) all hazards, risks and controls associated with the installation, including but not limited to:
c) exposure to dangerous areas before installing guards, whip restraints
d) plant interacting with people
e) plant interacting with other plant e.g. connected services and installations
f) any special tools, jigs, fixtures or appliances necessary to minimise the risk of injury
g) any environmental factors affecting installation.
h) when a risk assessment is required
i) tasks which require an installation procedure or safe work method statement (SWMS)
j) tasks that can be covered by people's competencies
k) training requirements prior to or during installation
l) change management, auditing and review requirements.

4.2.2. Installation procedure

The installation procedure should include:

a) isolation, depressurisation and re-energising instructions
b) change of shift or hand over procedures
c) testing procedures
d) competencies to complete the task safely
e) tools and equipment required
f) group isolation if applicable.

4.2.2.1. Procedure input

The installation procedure should be prepared from:

a) equipment manufacturers' and designers' recommendations
b) site risk assessments, risk reviews and job safety analyses
c) safety alerts
d) relevant standards and guidelines
e) site knowledge through consultation with workers
f) other site-specific requirements.

4.2.2.2. When a procedure is required

The installation procedure should be prepared or revised when:

a) equipment is new or modified or the system is changed
b) the hazards create a risk to health and safety of workers and equipment
c) the task is complex in its nature
d) a task is done infrequently
e) an accident or incident occurs
f) there is a change in the environment or application
g) recommendations from workers are made
h) a high-risk activity is planned.

When a procedure is not required, other systems to identify hazards, access risks and implement controls should be implemented, for example; 5 × 5, Job Safety Map, JSA, and similar.

4.2.2.3. Procedure standard

The installation procedure should comply with:

a) the mine site standard
b) the fluid power system design specifications
c) the manufacturer's installation standards.

4.2.3. Communications/consultations

Before the installation of a fluid power system, workers should be consulted with regarding:

a) foreseeable hazards, risk assessments, risk controls, JSA, SWP, and similar
b) design documentation relevant to the installation such as hydraulic circuit, function and layout, hose/pipe routes, etc

c) safety instructions such as; no standing zones, PPE, set down areas for the equipment, specific isolation procedures, emergency stops locations
d) emergency response (including fluid injection response)
e) supervision
f) competencies required
g) change management procedures, such updating of drawings, designs, specifications, training, procedures and similar.

A debrief meeting with workers should be conducted to review the process and identify the areas where improvements can be made.

Workers should have the ability to suggest improvements of the system and procedures.

4.2.4. Inspection and test plan (ITP) – verification

An inspection and test plan (ITP) should:

a) be developed to identify all critical inspections, stops and checks during the installation
b) verify the system is installed in accordance with the design documentation and the site standards, for example routing of hoses, component locations, etc
c) be completed prior to the normal operation of the system
d) be carried out by a person independent to the person that installed the system
e) raise a non-conformance report (NCR) where defects or non-conformances are identified.

4.2.5. Installation records

'As Built' installation records should be documented with the relevant drawings and manuals updated.

The mine should maintain as built records. These records should be kept in the plant safety file.

4.3. Longwall installations – underground coal mines

Longwall pre-installations or relocations in underground coal mines should include consideration of:

a) pump installations, routing of the hydraulics hoses to the face and retention of the hoses
b) reducing the installation pump pressure to the lowest practicable pressure, for example 35Mpa to 10Mpa during the installation phase
c) the location and function of remote emergency stops
d) how the hoses are installed and connected
e) remote operation for roof supports during recovery and installation

f) alterations or changes to existing high-pressure supply including venting of any installation/recovery system, the labelling and training

g) the removal of entrapped air prior to powering leg cylinders or other actuators, For example operate a ram a few times before raising the leg cylinder

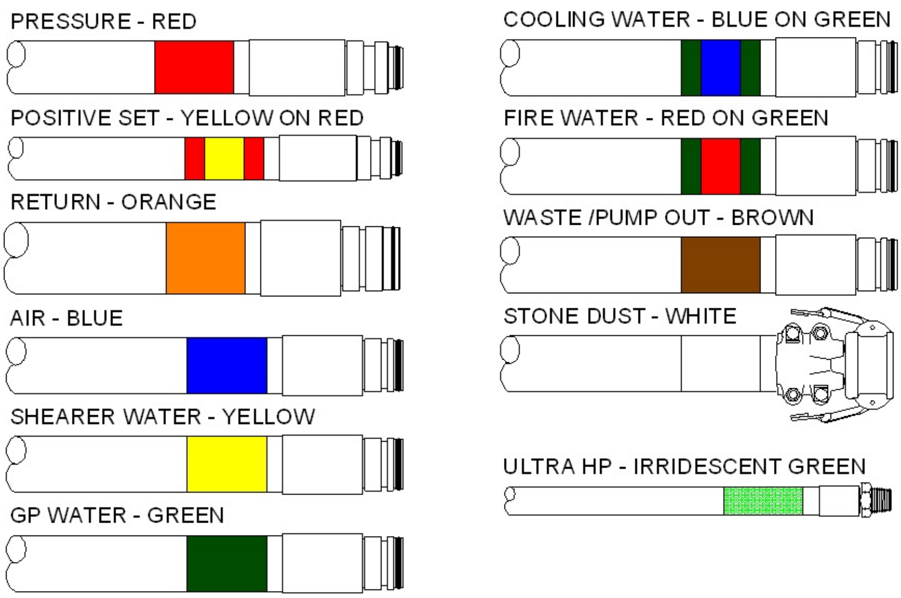
h) how the temporary pump station and hydraulics should be installed

i) failure modes for hydraulic actuators should be such that they will not add risk to the work area. For example: roof support shield legs should fail internally or have adequate fluid discharge capacity external to the cylinder which does not add risk to the workplace. This may also apply to roof support advance cylinders, roof support canopy alignment cylinders and canopy tip cylinders.

Longwall hoses are characterized by a large number of hoses, hoses of different pressure ratings, different functions, risk of cross contamination and the inability to read pressure rating of hoses which are encapsulated by diffusion of sleeves. Hence preference should be given to using a consistent colour code at hose ends.

Longwall hose assemblies and/or pipes should be marked using the following designations to indicate distribution circuits as listed and illustrated in the figure below:

Figure 1 – Colour designations for underground coal hose assemblies



Longwall hose assemblies and/or pipes should have a unique coupling style or size to prevent cross-connection of different circuits.

5. Commissioning

5.1. General

This section applies to the commissioning of the fluid systems at mines, including pumps, hoses, valves, gauges, accumulators, filters and actuators.

Fluid power systems should be commissioned in accordance with the designer's documentation and ISO 4413, ISO 4414 and AS 4041 as applicable.

Refer to MECP code of practice for further information related to commissioning.

5.2. Commissioning plan

A commissioning plan should be developed for the fluid system. The plan should consider:

a) potential hazards and risks associate with commissioning the fluid power system
   i. exposure to dangerous areas before installing guards, whip restraints
   ii. plant interacting with people
   iii. plant interacting with other plant e.g. connected services and installations
   iv. any special tools, jigs, fixtures or appliances necessary to minimise the risk of injury
   v. any environmental factors affecting commissioning

b) commissioning in accordance with the designer's, manufacturers and site-specific requirements

c) initially commission each part of the system at a lower pressure where practicable. This is to minimise dangers associated with leaks and componentry failure at higher pressures

d) examination and tests to prove the correct operation and installation of all safety devices

e) all air is expelled prior to pressure testing. Refer to OEM recommendations

f) pressure testing each component of the system at the designed working pressure where required

g) a testing schedule to check, test and operate all functions in a safe manner with consideration to the electrical commissioning checks

h) documenting results of commissioning checks

i) a system to identify commissioning is complete and the system is ready for normal operation.

5.2.1. Commissioning criteria

Commissioning should test the installation against the design specifications.

Commissioning criteria should be quantifiable and set pass failure limits for each test.

Commissioning criteria compare the system performance when compared against the design criteria or functional specification and should include, but be not limited to:

a) circuit pressure, restrictions and flows
b) completeness of circuits to drawings, identification and labelling of components
c) discharge patterns and performance criteria (number of operations from an accumulator)
d) control device functionality and operability
e) emergency stop functions
f) isolation points
g) timing of component movement (speed of function) and full extent of movement. e.g., time to extend a cylinder
h) hose layouts and routes (Wear points, hose bend radius, movement range)
i) software functionality
j) protection devices settings and alarms as applicable
k) fluid leakage rates
l) temperature, vibration and noise
m) cleanliness of the hydraulic fluid
n) hydraulic fluid specification
o) air entrapment in the system (refer to OEM recommendations).

5.2.2. Commissioning procedures

Commissioning procedures should be included within the commissioning plan.

Consultation should be carried out between all relevant stakeholders such as mechanical, electrical and operational departments to determine the commissioning sequence.

The commissioning procedure (checklist) should identify areas required to be tested. All results should be documented.

These procedures could be for the entire system or could be several procedures for individual components of the system.

5.2.3. Commissioning records

Commissioning records should be maintained and stored for future reference. As-built drawings and specifications should be updated. These records should be kept in the plant safety file.

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5.2.4. Decommissioning of fluid power systems for further use

Consideration for reintegration into the appropriate life cycle stage should be made.

Considerations include but are not limited to the following:

a) Safe disposal and recycling of fluids retained in the fluid power system
b) Withdrawal of fluids from reservoirs and components where practical to reduce the potential for spills from assemblies and components
c) Retained pressure should be released
d) Consideration for the potential for pressure intensification and fitment of appropriate safeguards
e) Safe disassembly procedure of the plant structures including effects on stability and movement of components.

All fluid may not be able to be withdrawn from all components without complete disassembly. Components with retained fluids should be marked with the appropriate SDS information.

6. Operation

6.1. General

This section applies to the operation of fluid power systems.

6.2. Selection of hydraulic systems and componentry

Serious accidents have occurred resulting from the unsafe use of hydraulic systems and componentry. It is important to identify all hazards and implement correct control measures to produce acceptable risk. Refer to section 2.

The characteristics of any hydraulic systems or components should be fully understood for the safety of personnel in the workplace.

From information gathered ascertain criteria of use, specification for the system and componentry. To minimise the risk to people, consider identification of modes of failure, maximisation of reliability and performance of the systems and provision of adequate barriers to hazards.

6.3. Procedures

6.3.1. Operational procedures

Site specific operational procedures should be developed based on the application of the designer's operational procedures and site specific environmental conditions. Procedures should outline:

a) how the fluid power system is operated in a safe manner
b) the identification of residual risks and how to address them, e.g. any PPE that should be worn;
c) the designed operational limits (envelope)
d) the operational functions and expected response to controls
e) normal operations conditions such as pressures, temperatures, flows, actuator positions, etc
f) any environmental conditions which would affect the operation of the fluid power system
g) storage and handling of hydraulic fluid.

6.3.2. Emergency procedures

Emergency preparedness is an essential part of working with fluid systems and should form part of the emergency management plan and First Aid Management Plan (Refer MDG 1016).

Procedures should be developed for operators' responses and initiation of wider responses to emergencies, e.g. in response to a hydraulic oil fire or suspected fluid injection.

Emergency procedures should include actions to be taken in the event of a fluid injection injury, refer fluid injection protocol, refer Appendix 9.5.

NOTE: Do not delay or treat as a simple cut. Specialist treatment is urgently required.

6.4. Defects

Defects identified during operation should be reported and dealt with in accordance with the mine's defect management system. Variances to the normal operating condition should be reported.

A defect management system documents actions to be taken when a defect is identified and how the details of the defect and actions taken are recorded.

6.5. Operator competence

All equipment operators of fluid power machinery should be competent in:

a) the operational and emergency procedures
b) all operational functions
c) preoperational checks
d) understanding the indicating devices, which indicate the equipment operating condition (e.g. flow, pressure, error messages, motor current and voltage)
e) understanding of energy isolation process, in particular for hazardous activity isolation
f) understanding the hazards associated with working near fluid power systems.

6.6. Prestart and operational inspections

Pre-start and operational checks and inspections should be carried out on a regular basis, and should be carried out in accordance with the designers' recommendations. These checks should consider:

a) normal operation of all functions
b) functionality/status of indicating devices and warning alarms such as:
    i. hydraulic pressures
    ii. hydraulic flow
    iii. water pressure and flow
    iv. filter condition (filter monitor)
    v. fluid levels and fluid leaks
c) time to carry out a specific operation
d) fluid leakage, visually and over time
e) guarding is in place and functional
f) suspect hosing that is physically damaged or leaking
g) unusual increases in temperature, noises and smell from the system.

7. Inspection, maintenance and repair

7.1. General

The fluid power system should be regularly inspected, maintained and repaired so that the system remains fit for purpose and in a safe condition to operate over its lifecycle.

Inspections, maintenance and repairs should be carried out in accordance with the designer's documentation and should extend to:

a) verifying the functionality of the circuit
b) systematically inspecting and maintaining all components of the system in accordance with the manufacturer recommendations, refer to Clause 3.9.7
c) periodically checking safety critical systems and warning devices
d) only using competent persons familiar with the particular fluid power system.

Refer to MECP code of practice.

7.1.1. Competence

All people associated with the maintenance of the fluid power system (including contractors) should be competent to safely carry out work on the fluid system.

Some relevant competencies include:

- MEM18052B Maintain fluid power systems for mobile plant
- AURTTA3013 Repair hydraulic systems

Competence of maintenance personnel should include:

a) system functional requirements and operating parameters
b) troubleshooting and individual component testing
c) safe energy isolation and dissipation in accordance with the mines isolation management plan
d) electrical / fluid power interfaces and control circuitry
e) hose management
f) importance of cleanliness
g) energy isolation process in particular hazardous activity isolation.

Specific competence on energy isolation should be carried out on large and complex fluid power systems such as longwall roof supports.

7.1.2. Inspection, maintenance and repair procedures

Safe systems of work should be developed and maintained for routine activities such as fluid sampling, component testing, inspections, etc. A risk assessment should be carried out for all abnormal maintenance activities and a safe work method statement (SWMS) made available and followed where there is significant risk, e.g. replacement of any item that may cause a significant risk if removed or installed incorrectly i.e. (hazardous task).

Refer to MEM18021B Maintain hydraulic Systems & MDG 3007 Hydraulic Safety.

7.1.3. Inspection and maintenance

Periodic inspections and maintenance schedules should be developed and implemented in accordance with:

a) the designer's / manufacturer's recommendations
b) consultation with site personnel
c) lifecycles
d) maintenance strategy.

These schedules should include the inspection of hose assembly condition with consideration to clause 3.7.3 and Appendix E 'Hose failure and discard criteria'.

7.1.4. Safe working with fluid power systems

When working with fluid power systems:

a) never feel for leaks
b) never vent hydraulic fluid to atmosphere unless it is safely controlled, such as into collection drums/trays or through a diffuser
c) never disconnect any line that has not been de-energised and tested for de-energisation
d) always apply energy isolation procedures, refer to clause 3.6.

A typical model for safely performing maintenance is includes (refer figure 5):

ALWAYS

A. Isolate

- The correct valve
- The power supply

B. Lock

- The isolation valve in the closed position

- With personal locks at the isolation point

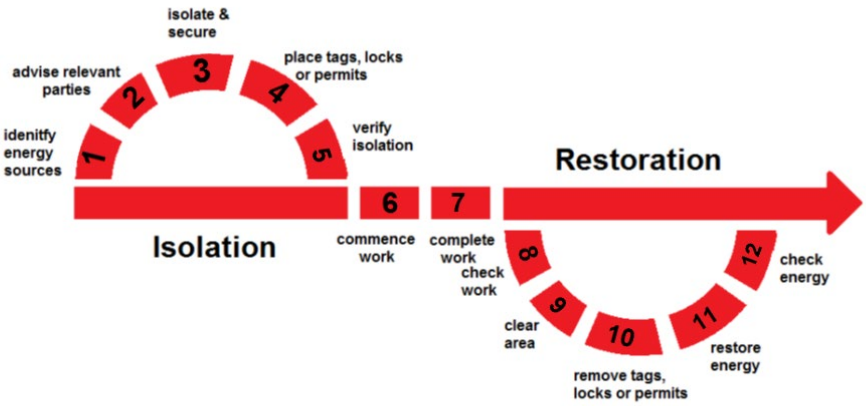
C. Depressurise the energy source

D. Lock the bleed valve in the open position

E. Verify effective isolation (test for dead)

- Prove that the line is depressurised
- Check the gauge is at zero
- Check fluid no longer passes through the bleed valve

Figure 5 – Isolation and restoration for maintenance



7.1.5. Pressure intensification potential in storage or transport

Any component with the potential for intensification, especially in storage or transport should be supplied with a means that will pressure relieve (blowout), (e.g. non-metallic caps, breather) in the event of the component being pressurised. Fatalities have occurred because the component has been supplied with steel caps allowing the component to be intensified.

7.1.6. Filtration

Fluid power system filtration and replacement or testing of filtration components should be considered in the maintenance schedule. Consideration should be given to the site environmental conditions, which may change and may require a more rigorous service schedule to that specified by the designer.

Special attention should be paid to pilot control system to verify the oil is filtered to the correct cleanliness and does not induce excessive back pressures.

At no stage should the fluid power system operate without filtration.

Designers should specify appropriate cleanliness levels with consideration to the failure mode of the components. The mine should maintain that level of cleanliness.

7.1.7. Pipe/tube assemblies

Pipes should be correctly matched and rated.

Galvanised water pipe should not be used in any hydraulic circuits including return lines.

Threads should be capable of withstanding the pressure in the system.

Only matching threads and fittings of the same pattern should be used.

The environmental effects on the pipes and fittings such as corrosion should be considered in the maintenance plan.

7.1.8. Hydraulic component cleaning

Hydraulic component cleaning agents used should not compromise the integrity of the fluid power system and components. Some cleaning agents have been known to degrade seals and hoses.

7.2. Isolation and energy dissipation

The mine will have an energy isolation management plan, refer to MDG 40

This plan will include:

a) an energy isolation process used for the de-energisation of all energies
b) an assessment process for people who need to demonstrate competence
c) identified specific isolation processes for high risk activities
d) emergency management
e) training.

All safe work methods should identify energy isolation, dissipation and verification requirements.

MDG 40 offers guidance on the requirements for energy isolation management.

7.3. Repairs and defects

7.3.1. General

A safe work procedure should be available for the replacement of all major components and where an item may cause a risk to people if replaced incorrectly.

System components should only be replaced with components manufactured to the same standard, for example correct micron rating on the filters, correct pressure rating, correct durometer hardness and size tolerances and material for O-Rings etc. Refer to Appendix B 2 for failure information including O-Ring failures.

When replacing components, they should be kept clean and without damage.

Following repairs, the functionality of the system should be checked.

All repairs to notified defects should be recorded. Safety defects should be reported to the designer/manufacturer.

7.3.2. Recommissioning after repairs

The system should be checked to ensure it is in an operable state, e.g. hoses not connected, ports left open, connections tight.

When re-energising fluid power systems after repairs the area should have restricted access to people until verification of system integrity is confirmed. (See also clause 4.2.2 and section 5.) If practical re-energisation should be carried out at a low pressure to minimise risk and verify system integrity where practicable.

7.3.3. Temporary repairs

All repairs should be carried out by people competent to carry out those repairs.

Where temporary repairs are carried out to allow continued operation then permanent repairs should be recorded and scheduled to be carried out at a later maintenance shift. For example, if a 1 metre hose fails during operation and a 3-metre hose is used as its temporary replacement, then the correct hose should be installed and correctly routed at a later maintenance shift. Another example could be the use of galvanised or brass plugs where corrosion and the pull-out thread factor of safety must be equivalent to purpose designed plugs for the installation.

These repairs should be documented and recorded against the equipment.

7.4. Audits

All site inspection, maintenance and repair activities should be periodically audited against the:

a) mine’s inspection and maintenance system
b) designer’s/manufacturer’s recommendations
c) keeping of records
d) appropriateness and currency of competencies.

Audits should be carried out by a person not normally involved in the maintenance activities.

7.5. Records

Records should be kept on the results of all inspections, maintenance and repair activities.

These records should be reviewed to determine if any modification and improvements could improve safety and the reliability of the equipment.

Fluid power circuits and maintenance documents should be kept up to date and be readily available for use on the equipment.

Any change in design or duty should be recorded and appropriate changes implemented. These records form part of the safety file.

7.6. Hose assembly management

7.6.1. General

The unplanned failure of a hydraulic hose has potential to cause harm. Appropriate management of hydraulic hoses need to be considered.

A hose management program should be developed, implemented and maintained (refer to clause 7.5 and clause 3.7.12). The hose management program should be established and maintained in consultation with all stakeholders, including site management, maintenance and suppliers. The hose management program should be integral with the mines maintenance system and the site-specific maintenance strategies.

A hose management program will reduce equipment downtime, maintain peak operating performance, and reduce the risk for personal injury and/or property damage. The hose management program should include:

a) a database of the range of hose assemblies on the mine site

b) a maintenance schedule such that all hose assemblies are inspected at a frequency as required for their risk to safety and equipment operation

c) discarded hose assemblies or hoses with no known history (e.g. longwall, monorail, AFC/BSL hoses) not being reinstalled unless tested and certified in accordance with clause 3.7.11.1 Individual Hose assembly proof testing. If reinstalled, the hoses being cleaned and labelled in readiness for reuse. This is not intended to include the disconnection and reconnection for operational or maintenance purposes.

d) hose failure mode analysis.

7.6.2. Hose failure modes

When hoses are replaced a record of their failure should be recorded. These failures should be periodically reviewed and used for future improvement. Refer SAE J1927.

Typically hose assemblies are discarded by either of the following two mechanisms:

a) Inspection and assessment to discard	• excessive mechanical damage (such as abrasion, cuts, crushing etc.), • corrosion (of both fittings and hose wire reinforcement) • degradation (age, chemical, cracking, overheating, fatigue etc)
b) Catastrophic in-service failure	• leakage • burst • hose/hose end separation • pinholes

The mine's hose management plan should aim for the in service 'inspection and assessment to discard' the hose prior to a 'catastrophic in-service failure' occurring. Consideration should be given to the failure modes of the fitting, particularly staple or pin type fittings.

7.6.3. Hose inspections

7.6.3.1. General

All hose assemblies and adaptors should be inspected periodically, in accordance with the mine's maintenance plan, by a competent person to ensure the system remains in a safe operating condition. Where hose assemblies show damage, steps should be taken to determine the suitability for continued use.

Hoses should be tested insitu to determine if they are operating properly, without leaks or signs of failure.

The inspection frequency of in service hoses should be based on the severity of the application, past failure history and the risk to people safety if failure occurs.

7.6.3.2. In-service inspections

In-service inspection of hose assemblies should only be carried out by competent personnel, who can make a valid assessment of the condition of the inspected hose assemblies and provide recommendations as to whether the hose assembly:

a) is fit for continued service
b) is fit for limited service
c) should be replaced immediately.

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7.6.3.3. Hose discard criteria

Hose assemblies should be replaced when the hose assembly is damaged and is no longer fit for purpose or does not offer the desired level of safety.

Mines in consultation with suppliers should establish discard criteria. Refer to Appendix F 'Hose failure and discard criteria'.

7.6.3.4. Hose storage

Hose assemblies should be stored in a cool, dark, dry area with non-metallic end caps fitted. When storing care should be taken not to damage or shorten the hose service life, refer to clause 3.7.3.4.

7.6.3.5. Maintenance

Hydraulic hoses and components have a finite life, and at some stage the hose assembly should be replaced irrespective of the visual condition. This period may vary depending upon the risk to people upon failure of the hose, the effective service life (affected by e.g. operating environment, refer to clause 3.7.3) and the site hose management plan.

Where hose assemblies in high risk areas have been in service for a period of greater than five years (but less than eight years) then they should be replaced, unless:

a) a sample of hose assemblies have been inspected and tested in accordance with clause 3.7.11, and

b) an assessment based on service history and condition is made to justify an extended period.

Consideration should be given at what point in time is it better to replace all hoses at once rather than replace an individual hose, based on the age and expected remaining life of the remaining hoses.

The replacement hose assembly should be at least rated to, or greater than the maximum system pressure.

Maintenance issues, which should be considered, include:

- use of correct hose design and material for the replacement hose
- use the correct fitting configuration for the duty and use of matched hose and fittings
- maintain proper cleanliness at all times before installation
- use adequately sized hose for the duty
- ensure correct length of hose to minimise tension forces
- ensure the minimum bend radius of the hose is not exceeded
- ensure that no twisting remains in the installed hoses

- secure the hose assembly as per the design documentation using the correct mounting points
- protect the hose from impact or abrasion damage while in service
- ensure staple type fittings are not being dislodged during in-service use
- use system health monitoring techniques to determine cyclic fatigue life
- management of lifecycle of hose and fittings.

8. Decommissioning, dismantling and disposal

8.1. General

Where the fluid system is to be decommissioned, relocated and recommissioned, a risk assessment on the decommissioning process should be carried out. Standard work procedures should be developed and followed.

Decommissioning procedures should be developed for the reclaim of hazardous substances and for long term storage.

Items to be considered when decommissioning fluid systems include:

a) environment (underground and/or surface)
b) pressure intensification
c) cleanliness of the hydraulic system (if system is to be recommissioned)
d) storage of fluids
e) corrosion protection (if system is to be recommissioned)
f) handling during and after storage (associated equipment)
g) long term care and maintenance
h) disposal procedures
i) potential use of storage fluids

Decommissioning fluid power systems for disposal.

Where a fluid power system is to be decommissioned and disposed, consideration should be given to the following:

1. Consideration should be given to the potential for future usage of the plant.

2. Withdrawal of fluids from reservoirs and components where practical to reduce the potential for spills from assemblies and components.
3. Retained pressure should be released.
4. The potential for pressure intensification and fitment of appropriate safeguards.
5. Safe disassembly procedure of the plant structures including effects on stability and movement of components.
6. Safe disposal and recycling of fluids retained in the fluid power system.
7. All fluid may not be able to be withdrawn from all components without complete disassembly. Components with retained fluids should be marked with the appropriate SDS information.

9. Appendices

9.1. Appendix A – Relevant standards and documents

Abbreviation of standard	Title of standards
AS/ISO 1000	AS ISO 1000-1998: *The international system of units (SI) and its application*
AS 1101.1	AS 1101.1:2007: *Graphic symbols for general engineering - Hydraulic and pneumatic systems*
AS 1180.5	AS 1180.5-1999: *Methods of test for hose made from elastomeric materials - Hydrostatic pressure*
AS 1180-10B	AS 1180-10B-1982: *Methods of test for hose made from elastomeric materials – Determination of combustion propagation characteristics of a horizontally oriented specimen of hose using surface ignition*
AS/NZS 1200	AS/NZS 1200:2015: *Pressure equipment*
AS 1210	AS 1210-2010: *Pressure vessels*
AS 1271	AS 1271-2003: *Safety valves, other valves, liquid level gauges, and other fittings for boilers and unfired pressure vessels*
AS 1318	AS 1318-1985: *Use of colour for the marking of physical hazards and the identification of certain equipment in industry (known as the SAA Industrial Safety Colour Code) (incorporating Amdt 1)*
AS 1319	AS 1319-1994: *Safety signs for the occupational environment*
AS 2030.1	AS 2030.1-2009: *Gas cylinders – General requirements*
AS/NZS 2554	AS/NZS 2554: *Hose and hose assemblies for air*
AS 2660	AS 2660-1991: *Hose and hose assemblies – Air/water – For underground coal mines*
AS 2671	AS 2671-2002: *Hydraulic fluid power - General requirements for systems*
AS 2788	AS 2788-2002: *Pneumatic fluid power - General requirements for systems*
AS 2971	AS 2971-2007: *Serially produced pressure vessels*
AS 3788	AS 3788:2006: *Pressure equipment – In-service inspection*
AS 3873	AS 3873-2001: *Pressure equipment – Operation and maintenance*
AS 3892	AS 3892-2001: *Pressure equipment – Installation*
AS 4024.1	AS 4024.1-2014: *Series: Safety of Machinery*

AS/NZS 4024.1302	AS/NZS 4024.1302:2014: *Safety of machinery - Risk assessment - Reduction of risks to health from hazardous substances emitted by machinery - Principles and specifications for machinery manufacturers*
AS/NZS 4024.1501	AS/NZS 4024.1501-2006 (R2014): *Safety of machinery - Design of safety related parts of control systems - General principles for design*
AS/NZS 4024.1502	AS/NZS 4024.1502-2006 (R2014): *Safety of machinery - Design of safety related parts of control systems – Validation*
AS/NZS 4024.1503	AS/NZS 4024.1503:2014: *Safety of machinery – Safety-related parts of control systems – General principles for design*
AS/NZS 4024.1906	AS/NZS 4024.1906:2014: *Safety of machinery - Displays, controls, actuators and signals - Indication, marking and actuation - Requirements for the location and operation of actuators*
AS 4037	AS 4037-1999: *Pressure equipment – Examination and testing*
AS 4041	AS 4041-2006: *Pressure piping*
AS/NZS 4024:1201	AS/NZS 4024.1201:2014: *Safety of machinery - General principles for design - Risk assessment and risk reduction*
AS/NZS 4024:1303	AS/NZS 4024:1303:2014: *Safety of machinery - Risk assessment - Practical guidance and examples of methods*
AS 4343	AS 4343:2014: *Pressure equipment – Hazard levels*
AS 4458	AS 4458-1997: *Pressure equipment – Manufacture*
AS/NZS ISO 31000	AS/NZS ISO 31000:2009: *Risk Management Set – Principles and guidelines*
AS 61508.1	AS 61508.1-2011: *Functional safety of electrical/electronic/programmable electronic safety-related systems - General requirements*
AS 62061	AS 62061-2006: *Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*
ACARP C17020	*The Australian Coal Industry's Research Project* *Stage Two: Performance Based Specifications For Longwall Hose Assemblies*
SA/SNZ HB 89	*SA/NZS HB 89 Risk management – Guidelines on risk assessment techniques*

	Reference to ISO Standards
ISO 1219-1	ISO 1219-1:2012: *Fluid power systems and components - Graphical symbols and circuit diagrams - Part 1: Graphical symbols for conventional use and data-processing applications*
ISO 1219-2	ISO 1219-2:2012: *Fluid power systems and components - Graphical symbols and circuit diagrams - Part 2: Circuit diagrams*
ISO 1436	ISO 1436:2009: *Rubber hoses and hose assemblies – Wire-braid-reinforced hydraulic types for oil-based or water-based fluids – Specification*
ISO 3457	ISO 3457:2003: *Earth-moving machinery – Guards – Definitions and requirements*
ISO 3862	ISO 3862:2009: *Rubber hoses and hose assemblies – Rubber covered spiral-wire-reinforced hydraulic types for oil-based or water-based fluids – Specification*
ISO 4079	ISO 4079:2015: *Rubber hoses and hose assemblies – Textile-reinforced hydraulic types for oil-based or water-based fluids - Specification*
ISO 4406	ISO 4406:1999: *Hydraulic fluid power - Fluids - Method for coding the level of contamination by solid particles*
ISO 4413	ISO 4413:2010: *Hydraulic fluid power - General rules and safety requirements for systems and their components*
ISO 4414	ISO 4414:2010: *Pneumatic fluid power - General rules and safety requirements for systems and their components*
ISO 4520	ISO 4520:1981: *Chromate conversion coatings on electroplated zinc and cadmium coatings*
ISO 6605	ISO 6605:2002: *Hydraulic fluid power – Hoses and hose assemblies – Test methods*
ISO 6802	ISO 6802:2005: *Rubber and plastics hoses and hose assemblies with wire reinforcements – Hydraulic impulse test with flexing*
ISO 6803	ISO 6803:2005: *Rubber or plastics hoses and hose assemblies – Hydraulic pressure impulse test without flexing*
ISO 6805	ISO 6805:1994: *Rubber hoses and hose assemblies for underground mining - Wire-reinforced hydraulic types for coal mining - Specification*
ISO 7751	ISO 7751:1991/Amd 1:2011: *Rubber and plastics hoses and hose assemblies - Ratios of proof and burst pressure to maximum working pressure - Amendment 1: Replacement of "design working pressure" by "maximum working pressure" throughout text*
ISO 8030	ISO 8030:2014: *Rubber and plastics hoses – Method of test for flammability*

ISO 8031	ISO 8031:2009: *Rubber and plastics hoses and hose assemblies - Determination of electrical resistance and conductivity*
ISO 8331	ISO 8331:2014: *Rubber and plastics hoses and hose assemblies - Guidelines for selection, storage, use and maintenance*
ISO 9001	ISO 9001:2015: *Quality management systems – Requirements*
ISO 11237	ISO 11237:2010: *Rubber hoses and hose assemblies – Compact wire-braid-reinforced hydraulic types for oil-based or water-based fluids - Specification*
ISO 13732-1	ISO 13732-1:2006: *Ergonomics of the thermal environment - Methods for the assessment of human responses to contact with surfaces - Part 1: Hot surfaces*
ISO 13849-1	ISO 13849-1:2015: *Safety of machinery -- Safety-related parts of control systems -- Part 1: General principles for design*
ISO 16889	ISO 16889:2008: *Hydraulic fluid power - Filters - Multi-pass method for evaluating filtration performance of a filter element*
ISO 17165-1	ISO 17165-1:2007: *Hydraulic fluid power - Hose assemblies - Part 1: Dimensions and requirements*
ISO/TS 17165-2	ISO/TS 17165-2:2013: *Hydraulic fluid power - Hose assemblies - Part 2: Practices for hydraulic hose assemblies*
ISO 18752	ISO 18752:2014: *Rubber hoses and hose assemblies - Wire- or textile-reinforced single-pressure types for hydraulic applications - Specification*

	Reference to SAE standards
SAE J343	*Test and Test Procedures for SAE 100R Series Hydraulic Hose and Hose Assemblies*
SAE J517	*Hydraulic Hose*
SAE J1065	*Nominal Reference Working Pressures for Steel Hydraulic Tubing*
SAE J1273	*Recommended Practices for Hydraulic Hose Assemblies*
SAE J1467	*Clip Fastener Fitting*
SAE J1927	*Cumulative Damage Analysis for Hydraulic Hose Assemblies*
SAE J2006	*Marine Exhaust Hose*

	Reference to MDGs
MDGs are found on NSW Resources Regulator website: www.resourcesandenergy.nsw.gov.au/miners-and-explorers/safety-and-health/publications/mdg	
MDG 40	MDG 40:2007 *Guideline for Hazardous Energy Control (Isolation or Treatment)*
MDG 3007	MDG 3007: 2018 *Guideline for Hydraulic Safety*
MDG 3608	MDG 3608:2012 *Guideline for Non-metallic materials for use in underground coal mines*

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9.2. Appendix B Fluid power system incidents

The following figures shows results of data from escapes of pressurised fluid reported under the mining legislation.

1. Figure B1 below shows escapes of fluid reported to the NSW Resources Regulator.

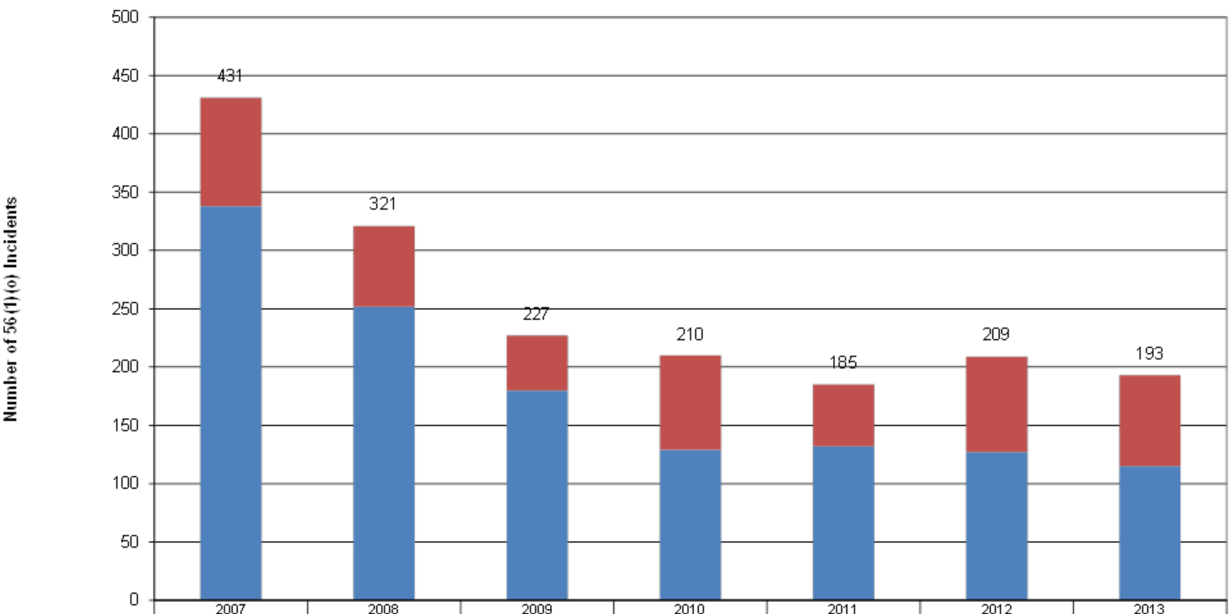
Figure B1 - Escapes of Fluid 2007 – 2013

9.3. Appendix C Fluid power system incidents

The following figures shows results of data from escapes of pressurised fluid reported under the mining legislation.

2. Figure B1 below shows escapes of fluid reported to the NSW Resources Regulator.

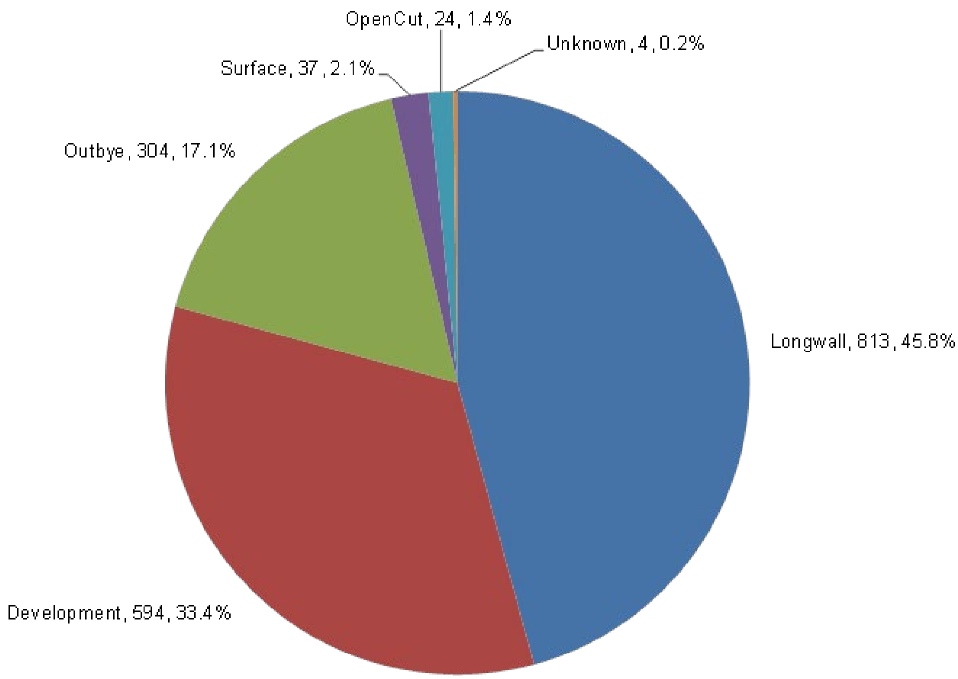
Figure B1 - Escapes of Fluid 2007 – 2013



	2007	2008	2009	2010	2011	2012	2013
North East Area	93	69	47	81	53	82	78
South East Area	338	252	180	129	132	127	115
Total	431	321	227	210	185	209	193

1. Figure B2 below shows the distribution by mining type reported to the NSW Resources Regulator.

Figure B2 Distribution by mining type 2007-2013



1. For the two largest areas, longwall and development, the breakdown of escape of fluid events causes can be seen in the data presented in Table B1 and B2.

Table B1 – Longwall escapes of fluid 2007 – 2013 (Underground Coal Mines NSW)

Longwall Failed Equipment	2007-10	2011	2012	2013	Total	Percentage
Hose Failures	363	37	40	19	459	56.5%
Undeterminable (e.g. Burst hose – worn)	66				66	8.1%
Staple Related	34	12	7	5	58	7.1%
"O" Ring Failure (on valves etc)	49	3	3	1	56	6.9%
Fitting Failures	25	6	10	6	47	5.8%
Isolation Issues	17	4	7	6	34	4.2%
Human Error	11	2		3	16	2.0%
Monorail Area	15			1	16	2.0%
Pump Station	6	3	3	4	16	2.0%
Yield Valves	8		6	1	15	1.8%
Duplicated i.e. multiple people + 3 & multiple injuries = 5 Total = 8	8				8	1.0%
BSL Area	5			2	7	0.9%
Leg Cylinder Failures	6	1			7	0.9%
DA Ram Failures	2				2	0.2%
Stabiliser Cylinder / Compensation Ram Failure	2				2	0.2%
Unknown			2		2	0.2%
Base Lift Ram Failures	1				1	0.1%
Manifold			1		1	0.1%
Valves					0	0.0%
Total	**618**	**68**	**79**	**48**	**813**	**100.0%**

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Table B2 – Development Unit Escapes of fluid 2007 – 2013 (Underground Coal Mines NSW)

Development Units Failed Equipment	2007-10	2011	2012	2013	Total	Percentage
Drill rigs (roof)	86	23	40	50	199	33.5%
Hoses	129	15	10	8	162	27.3%
Insufficient information	110	12			122	20.5%
Fittings	20	6	1	5	32	5.4%
"O" rings	13	4		1	18	3.0%
Rib bolters	11	1	3	1	16	2.7%
Cable bolt tensioner on miner	8	2	1	1	12	2.0%
Head shear jack area	5				5	0.8%
Human error	1			4	5	0.8%
Isolation	2	1	1		4	0.7%
Shuttle car			3		3	0.5%
Valves		2	1		3	0.5%
Cylinder RH			2		2	0.3%
Gauge			1	1	2	0.3%
Shuttle car tyre			1	1	2	0.3%
Staples	2				2	0.3%
Swing cylinder	2				2	0.3%
Boom swing hose			1		1	0.2%
Chain breaker count			1		1	0.2%
Monrail/Miner			1		1	0.2%
Total	**389**	**66**	**67**	**72**	**594**	**100.0%**

9.3.1. Safety Alerts and Safety Bulletins

Published safety alerts and safety bulletins relating to fluid power systems include:

SA15-07 Workers hurt when pressurised fluid escapes

SA14-03 Fluid injection from high pressure water cleaning

SA10-01 Longwall hydraulic system over-pressurised

SA09-04 Hydraulic injection near miss

SA06-16 Fatal high pressure hydraulic injection

SA06-06 Atomised hydraulic oil

SA05-15 Dangerous uncontrolled release of hydraulic energy

SA05-13 Stored Energy

Fluid injection incidents

SA04-14 Loss of eye from injection of grease

SA04-13 Injury from high pressure fluid injection

SA04-04 High pressure air hose burst on exploration drill rig

SA02-14 Injury from high pressure fluid injection

SA02-13 Longwall support cylinder leg failure

SA02-09	Hot water from pump burns quarry worker
SA00-02	Oil injection to left thumb
SA99-02	Serious accident involving a pump
SB13-01	Fluid injections result in surgery
SB12-03	Fluid power isolation failures

For the above safety alerts refer to:

https://www.resourcesregulator.nsw.gov.au/safety-and-health/incidents/safety-alerts

9.4. Appendix D – Ancillary information

9.4.1. Fluid nomograph for mineral oil

The following fluid nomograph for mineral oil assists in selecting flow rate, flow velocity and hose size.

Selecting the right hose size (see nomograph below,). With this nomograph, you can easily select the correct:

1. hose ID size;
2. desired flow rate; or
3. recommended flow velocity.

If any two of these factors are known, the third can be determined. To use this nomograph:

1. Pick the two known values.
2. Lay a straightedge to intersect the two values.
3. Intersection on the third vertical line gives the value of that factor.

Example:

To find the bore size for a pressure line consistent with a flow rate of 100 litres per minute (26 US or 22 Imperial gallons per minute), and a flow velocity of 4.5 metres per second (14.8 feet per second), connect flow rate to flow velocity and read hose bore on centre scale.

Answer: The line crosses hose bore between -12 and -16.

The velocity of the fluid should not exceed the range shown in the right-hand column. When oil velocities are higher than recommended in the chart, the results are turbulent flow with loss of pressure and excessive heating. For long hoses and/or high viscosity oil, or if the flow of hydraulic fluid is continuous, it is recommended to use figures at the lower end of the Maximum Recommended Velocity range. For short hoses and/or low viscosity oil, or if the flow of hydraulic fluid is intermittent or for only short periods of time, figures at the higher end of the Maximum Recommended Velocity range can be used.

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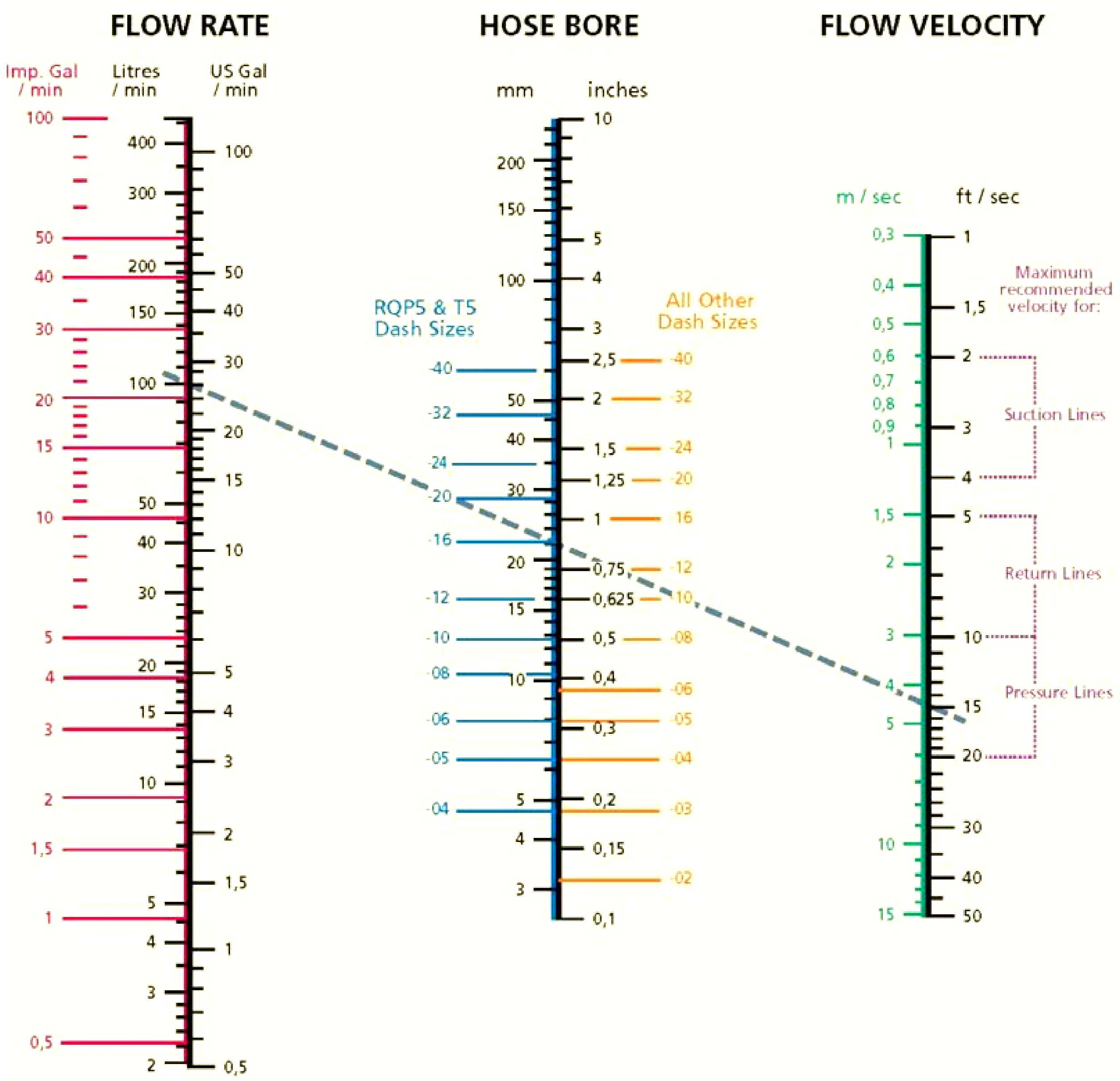

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9.5. Appendix E Hose failure and discard criteria

9.5.1. Hose typical failure modes

Failure mode	Possible causes
Hose rupture	overload – pressure overload – mechanical deterioration of hose material twisting damage too sharp bends (see App H, Fig 11)
Outer sheath wear	too sharp bends (see App H, Fig 11) inadequate abrasion protection incorrect material selection
Fitting failure	overload – pressure overload – mechanical incorrect material selection general wear and age maturity fatigue and cyclic loading
Fitting corrosion	inadequate corrosion protection incorrect material selection
Reinforcement wire corrosion	inadequate abrasion protection incorrect material selection
Hose/fitting separation	compression set of hose material loss of compression pressure on hose overload – pressure overload – mechanical mismatched components poor assembly practices
Outer layers of hose penetrated	abrasion damage to hose by foreign material hoses rubbing together inadequate hose cover material environment (for example ozone, UV)
Delamination of inner hose	excessive vacuum conditions prolonged vacuum conditions material degradation incorrectly selected hose causing too high a velocity
Fatigue failure of reinforcing mesh	cyclic/random bending of hose cyclic/random pressure changes

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Fatigue failure of hose material	cyclic/random bending of hose cyclic/random pressure changes
Hose deterioration	fluid/material compatibility ultraviolet radiation temperature ozone environmental surrounding hose solvents

9.5.2. Hose in-service inspection check lists

If any of the following conditions exist, the hose assemblies should be replaced.

a) visual evidence of leaks along the hose or around the hose ends
b) degraded hose, hard, stiff, charred, blistered, soft, heat cracked
c) exposed, damaged, corroded or broken outer wire braid
d) corrosion, may be identified by small lumps in the hose
e) wear and abrasion
f) bulges, blistered, soft, degraded or loose outer covers
g) outer cover sheath damage, cuts in the hose cover or cracked and heat affected
h) kinked, crushed, flattened or twisted hose
i) wrong bend radius
j) incorrect hose routing
k) incorrect length of hose
l) permanent or physical damage to the hose or hose ends, kinked crushed or flattened hose
m) hoses too close to heat sources
n) hoses tangled with moving parts
o) cracked, damaged, or badly corroded hose ends or adaptors
p) unsecured or loose hoses and fittings
q) fitting thread is damaged
r) inspection of staples (broken, twisting, cracked or "walking out")
s) other sign of deterioration
t) hose exceeding shelf life before installation, refer to clause 3.8.3.4
u) hose exceeding designed service life, refer to clause 3.8.3

v) visual evidence of movement of hose and hose end fitting

9.5.3. Analysing hose installation failures

A physical examination of the failed hose can often offer a clue to the cause of the failure. The following are symptoms to look for along with the conditions that could cause them:

Symptom	Cause
a) The hose is very hard and has cracked.	Heat has a tendency to leach the plasticiser out of the tube. This is a material that gives the hose its flexibility or plasticity. Aerated oil causes oxidation to occur in the tube. This reaction of oxygen on a rubber product will cause it to harden. Any combination of oxygen and heat will greatly accelerate the hardening of the hose tube. Cavitation occurring inside the tube would have the same effect.
b) the hose is cracked both externally and internally but the elastomeric materials are soft and flexible at room temperature.	The probable reason is intense cold ambient conditions while the hose was flexed. Most standard hoses are rated to – 40 degrees C.
c) The hose has burst and examination of the wire reinforcement after stripping back the cover reveals random broken wires the entire length of the hose.	This would indicate a high frequency pressure impulse condition. SAE or ISO impulse test requirements should be followed as recommended by the manufacturer but it is strongly recommended for underground conditions to be in accordance with Clause 3.7.11.
d) The hose has burst, but there is no indication of multiple broken wires the entire length of the hose. The hose may be damaged in more than one place.	This would indicate that the pressure has exceeded the minimum burst strength of the hose. Either a stronger hose is needed or the hydraulic circuit has a malfunction, which is causing unusually high-pressure conditions.
e) Hose has burst. An examination indicates the wire braid is rusted and the outer cover has been cut, abraded or deteriorated badly.	The primary function of the cover is to protect the reinforcement. Elements that may destroy or remove the hose covers are i. Abrasion; ii. Cutting; iii. Battery acid; iv. Steam cleaners; v. Chemical cleaning solutions; vi. Muriatic acid; vii. Salt water; viii. Heat; or ix. Extreme cold
f) Hose has burst on the outside bend and appears to be elliptical in the bent section.	Violation of the minimum bend radius is most likely.

g) Hose appears to be flattened out in one or two areas and appears to be kinked. It has burst in this area and also appears to be twisted.	Torqueing of a hydraulic hose will, tear loose the reinforcement layers and allow the hose to burst through the enlarged gaps between the braided plaits of wire strands. Use swivel fittings or joints to be sure there is no twisting force on a hydraulic hose.
h) Hose tube has broken loose from the reinforcement and piled up at the end of the hose. In some cases it may protrude from the end of the hose fitting.	The probable cause is high vacuum or the wrong hose for vacuum service. No vacuum is recommended for double wire braid, 4 and 6-spiral wire hose unless some sort of internal coil support is used. It could also be that the hose diameter is too small for the return line flow.
i) Hose has burst about 150 mm to 200 mm from the end fitting. The wire braid is rusted. There are no cuts or abrasions of the outer cover.	Improper assembly of the hose and fitting allowing moisture to enter around the edge of the fitting socket.
j) There are blisters in the cover of the hose. If one pricks the blisters, oil will be found in them.	A minute pin hole in the hose tube is allowing the high pressure oil to seep between it and the cover. Eventually it will form a blister wherever the cover adhesion is weakest. A faulty hose can also cause this condition.
k) Fitting blew off the end of the hose.	It may be that the wrong fitting has been put on the hose. Recheck the manufacturers' specifications and part numbers. In the case of a crimped fitting the wrong machine setting may have been used resulting in over- or under-crimping. The die could also be worn beyond the manufacturer's tolerances or the hydraulic pressure was incorrect. The fitting may have been applied improperly to the hose. Check manufacturing instructions. The hose may have been installed without leaving enough slack to compensate for the possible 4% shortening that may occur when the hose is pressurised. This will impose a great force on the fitting. The hose itself may be out of tolerance. The end ferrule may not have been pushed on the hose far enough during assembly or they totally forgot to crimp the end or there was insufficient crimping force.
l) The tube of the hose is badly deteriorated with evidence of extreme swelling. In some cases the hose tube may be partially "washed out".	Indications are that the hose tube is not compatible with the agent being carried.
m) Hose has burst. The hose cover is badly deteriorated and the surface of the rubber is crazed.	This could be simply old age. The crazed appearance is the effect of weathering and ozone over a period of time.

n) The spiral-reinforced hose has burst and literally split open with the wire exploded out and badly entangled. Conical wire deformation.	The hose is too short to accommodate the change in length occurring while it is pressurised.
o) The hose fitting has been pulled out of the hose. The hose has been considerably stretched in length.	Insufficient support of the hose. It is very necessary to support very long lengths of hose, especially if they are vertical. The weight of the hose and the weight of the fluid inside the hose is being imposed on the hose fitting.

9.6. Appendix F Good practice for hose installation

The following represents good practice for hose installations, SAE J1273 provides further guidance.

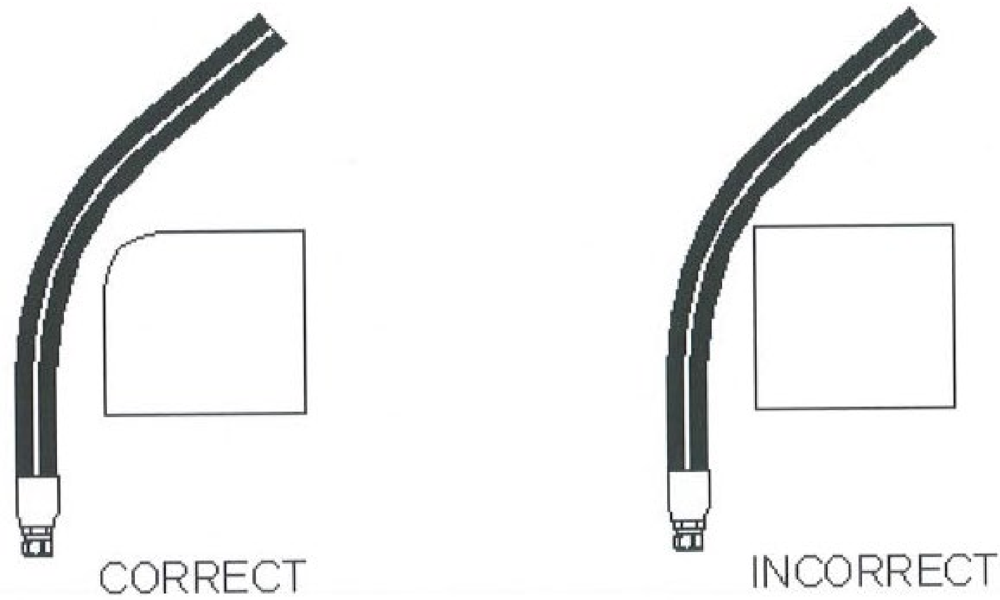
Proper hose installation is essential for satisfactory performance. If the hose length is excessive, the appearance of the installation will be unsatisfactory and unnecessary cost of equipment will be involved. If hose assemblies are too short to permit adequate flexing and changes in length due to expansion or contraction, hose service life will be reduced.

The following diagrams show proper hose installations that provide maximum performance and cost savings. Consider these examples in determining length of a specific assembly.

When hose installation is straight, allow enough slack in the hose line to provide for length changes, which will occur when pressure is applied.

Protect the hose cover from abrasion, erosion, snagging and cutting. Special abrasion-resistant hoses and hose guards are available for additional protection. Route the hose to reduce abrasion from hose rubbing other hoses or objects that may abrade it. (See Figure F1).

Figure F1 Prevention of external damage



The minimum bend radius, R (also referred to as MBR), of a hose is defined in relevant hose standards and manufacturer’s literature. Routing during assembly and use at less than minimum bend radius may reduce hose life. Sharp bending at the hose/fitting juncture can result in leaking, hose rupturing, or the hose assembly blowing apart. See Figure F2A and Figure F2B. A minimum straight length (L) as recommended by the manufacturer (often referred to as the non – flexible length or NFL) should be allowed between the hose fitting and the point at which the bend starts. A recommendation of this length is made in section 3.7.3.1.

Figure F2A Minimum bend radius

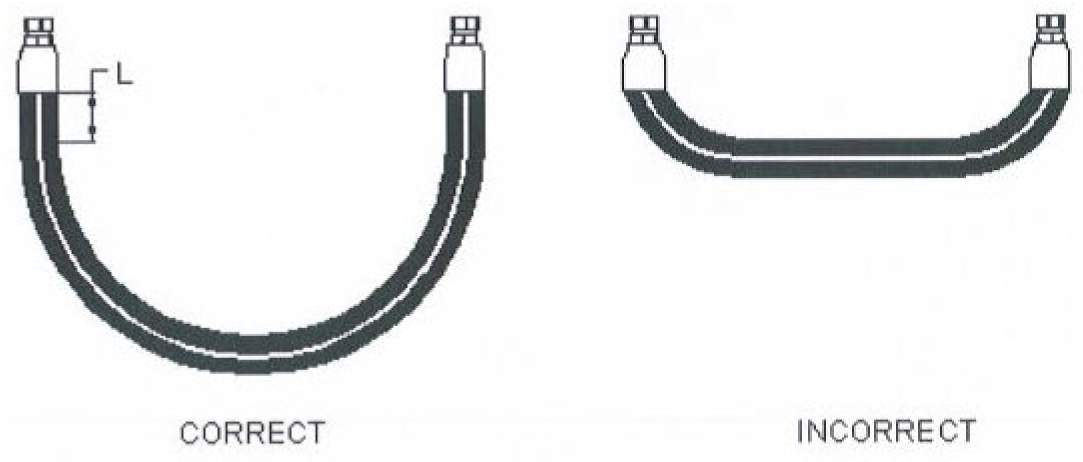


Figure F2B Minimum bend radius

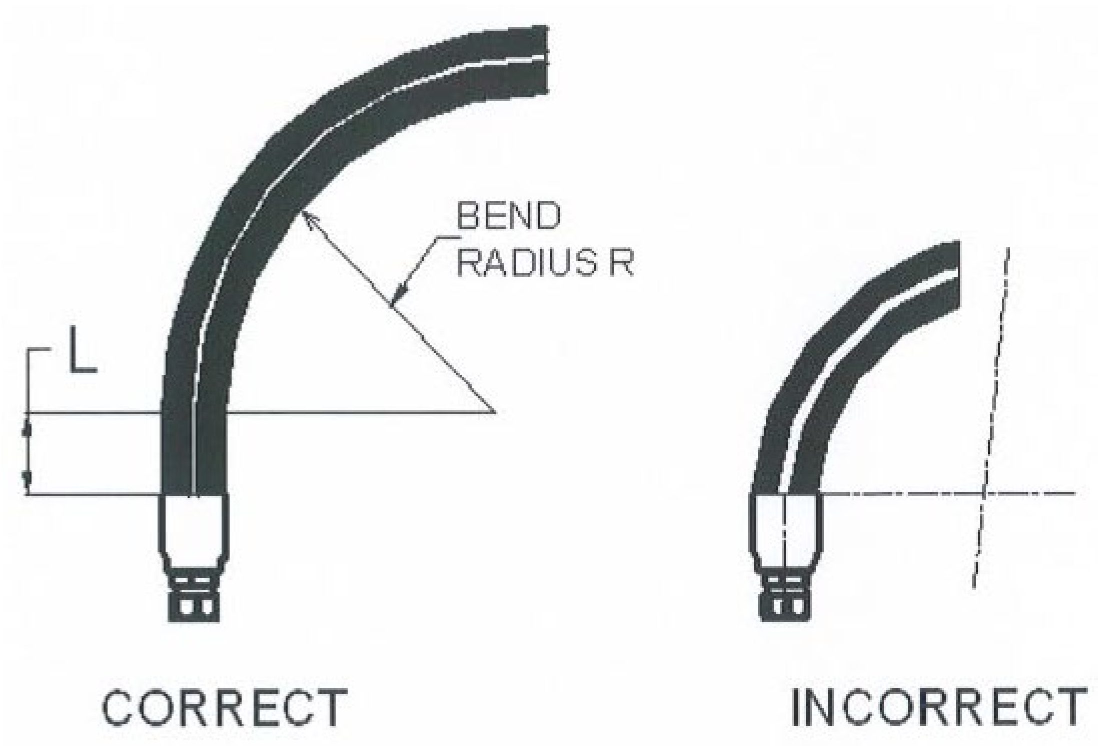
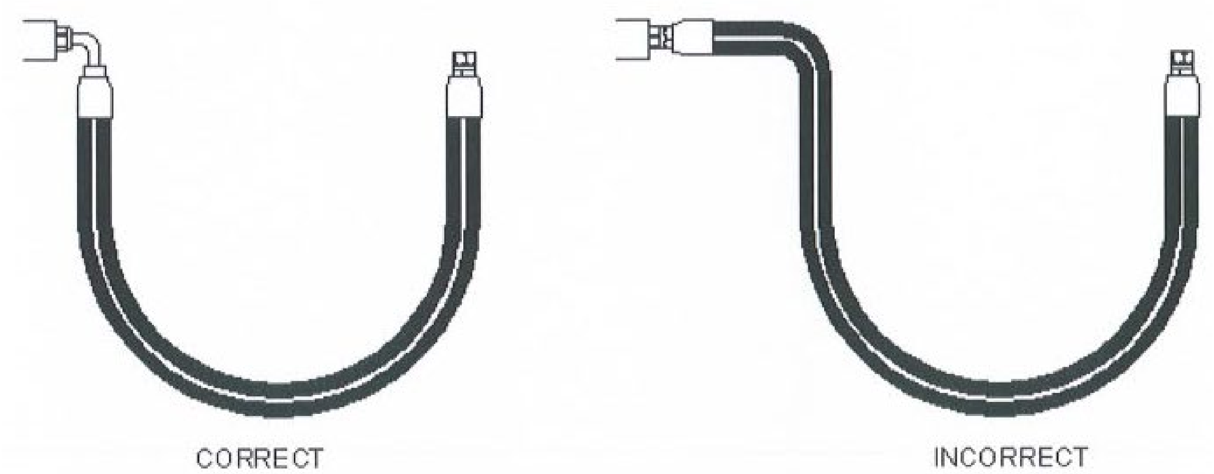


Figure F3 Elbows and adapters



Unnecessarily long hose can increase pressure drop and affect system performance. When pressurised, hose that is too short may pull loose from its fittings, or stress the hose fitting connections, causing premature metallic or seal failures. Figures F4, F5 and F6 provide guidance for selecting hose length.

Provide adequate hose length to distribute movement and prevent bends smaller than the minimum bend radius, R.

Figure F4 Motion absorption

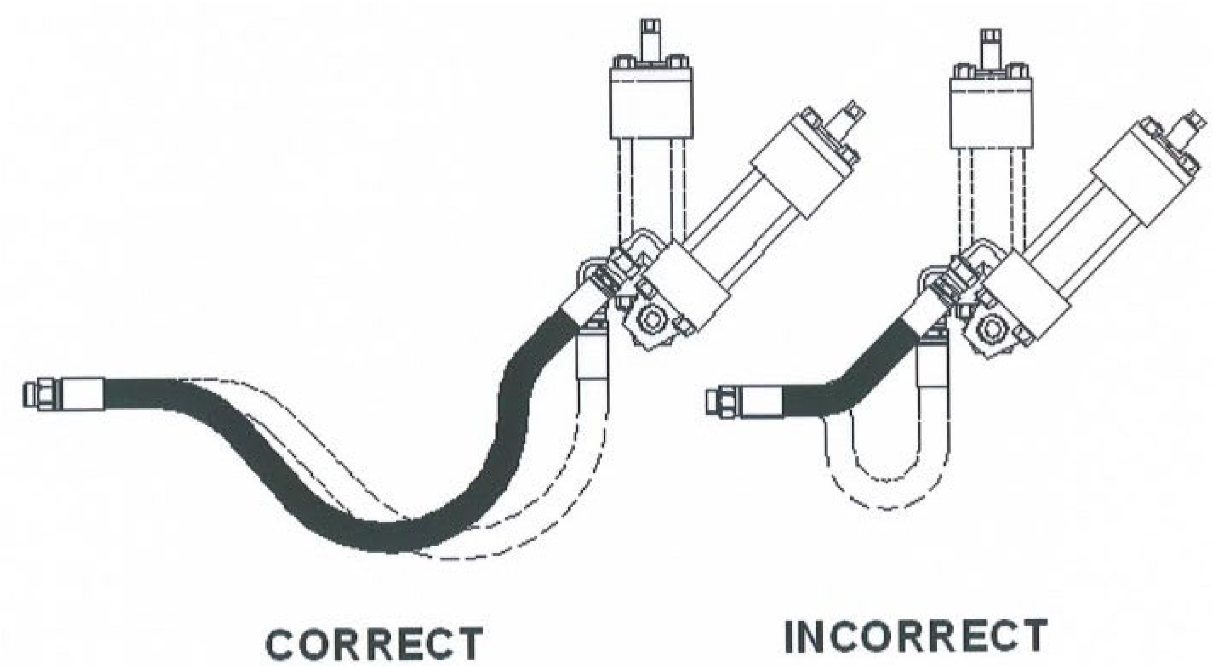
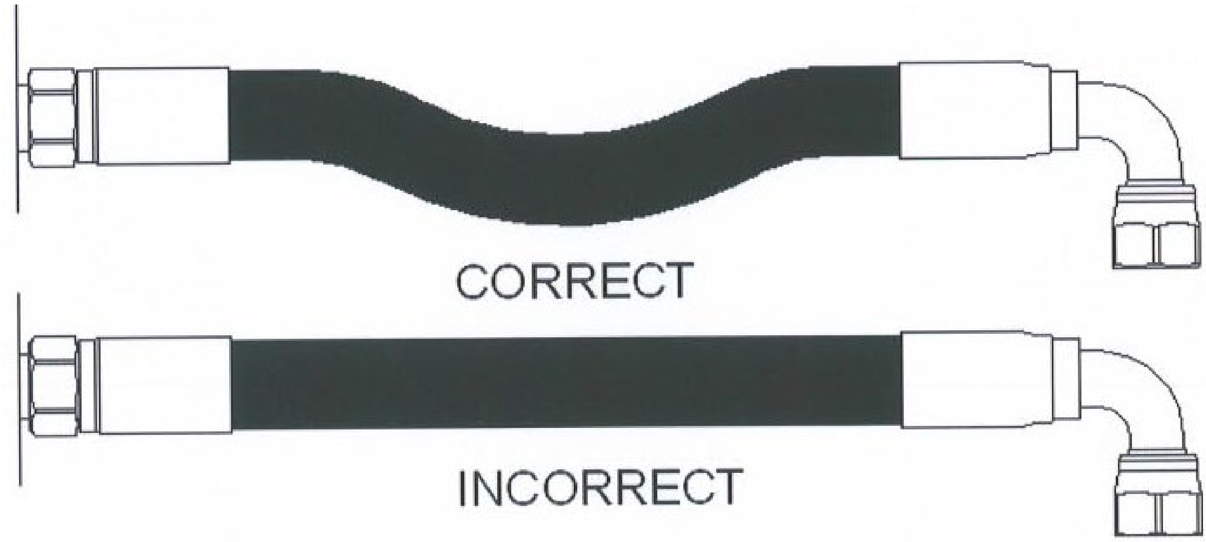
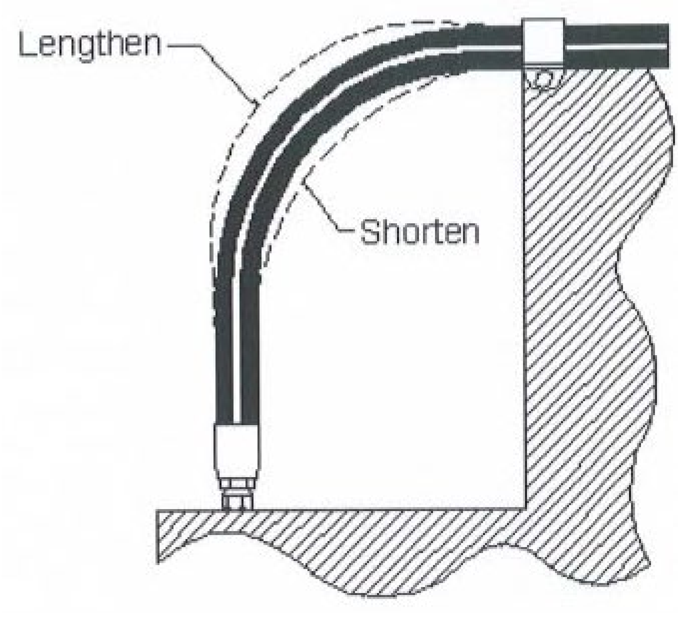


Figure F5 Hose and machine tolerances



Design hoses to accommodate length changes from changing pressures. Do not cross or clamp together high- and low-pressure hoses. The difference in length changes could wear the hose covers.

Figure F6 Hose length change due to pressure



Where hoses are connected between system components that move relative to each other, hoses should be designed taking this into consideration. Avoid multiple planes of motion and twisting motion. Consider the motion of the hose when selecting the hose and predicting service life. In applications that require the hose to move or bend, see Figures F7A, F7B and F8.

Bend in only one plane to avoid twisting. See Figures F7A and F7B.

Figure F7A Bend in only one plane to avoid twisting

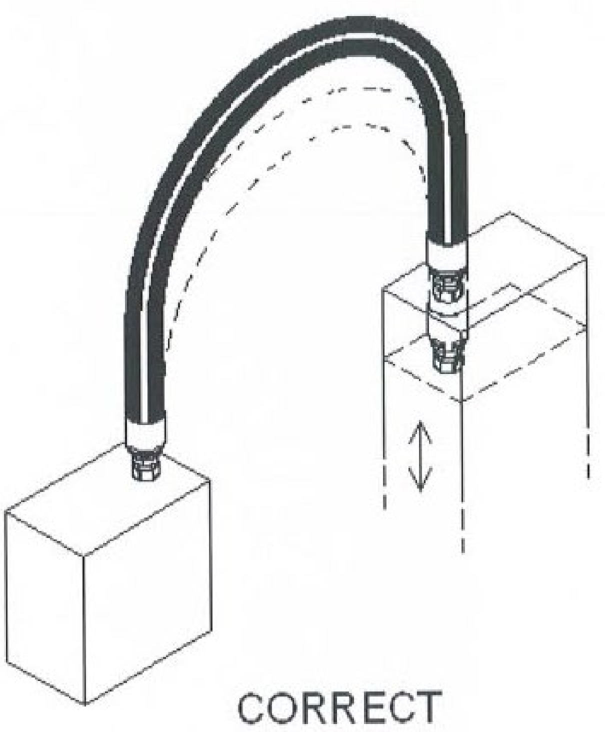
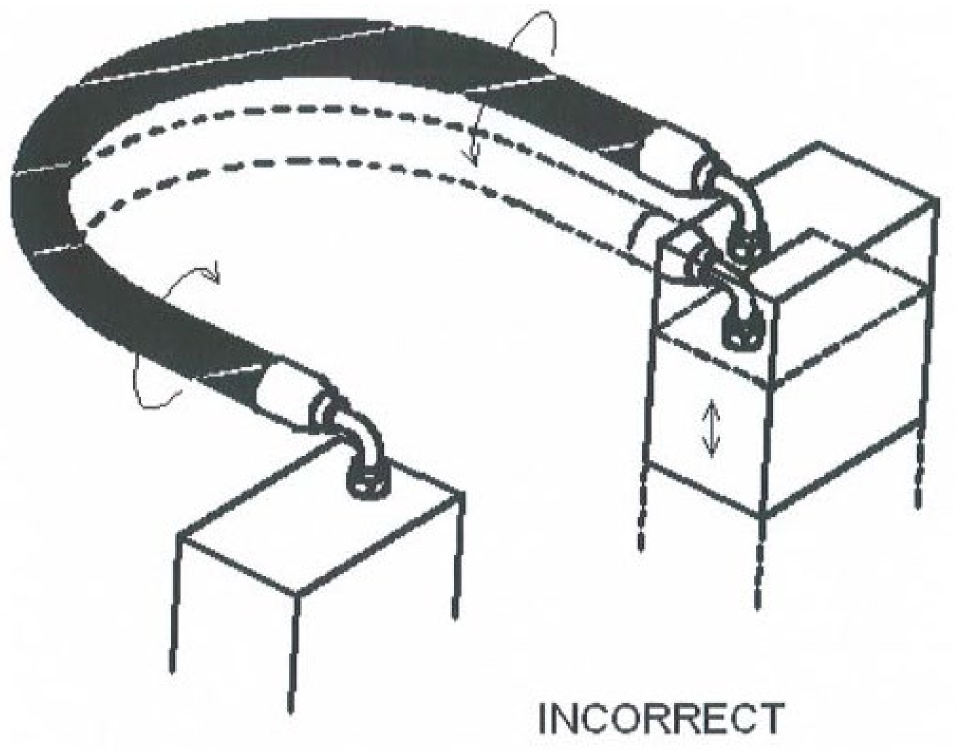
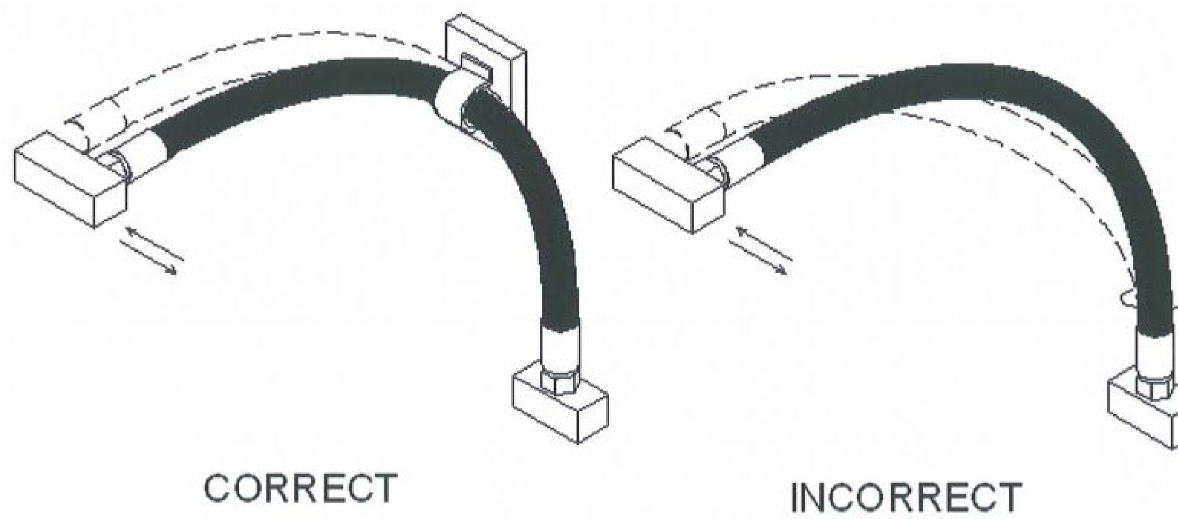


Figure F7B Bend in only one plane to avoid twisting



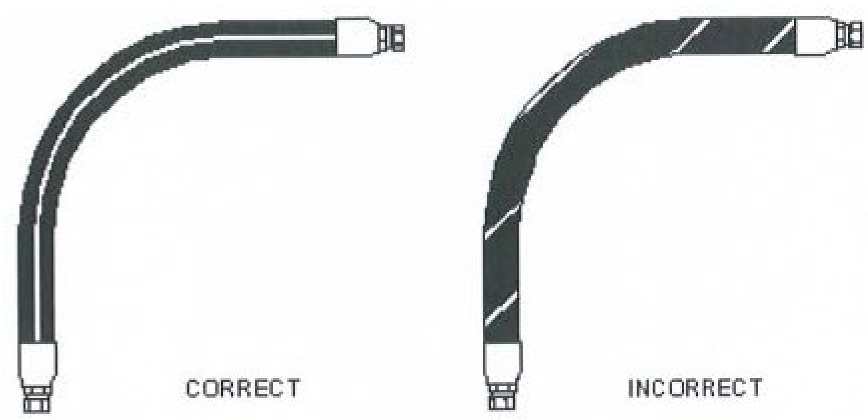
If a hose follows a compound bend, couple it into separate segments or clamp it into segments that each flex in only one plane. See Figure F8.

Figure F8 Prevent hose bending in more than one plane



Pressure applied to a twisted hose may shorten the life of the hose or loosen the connections. To avoid twisting, the hose layline or marking can be used as a reference (see Figure F9) if the layline or marking is parallel to the axis of the hose. Twisting can also be avoided through the use of two wrenches during the installation of swivel connectors.

Figure F9 Twist angle and orientation

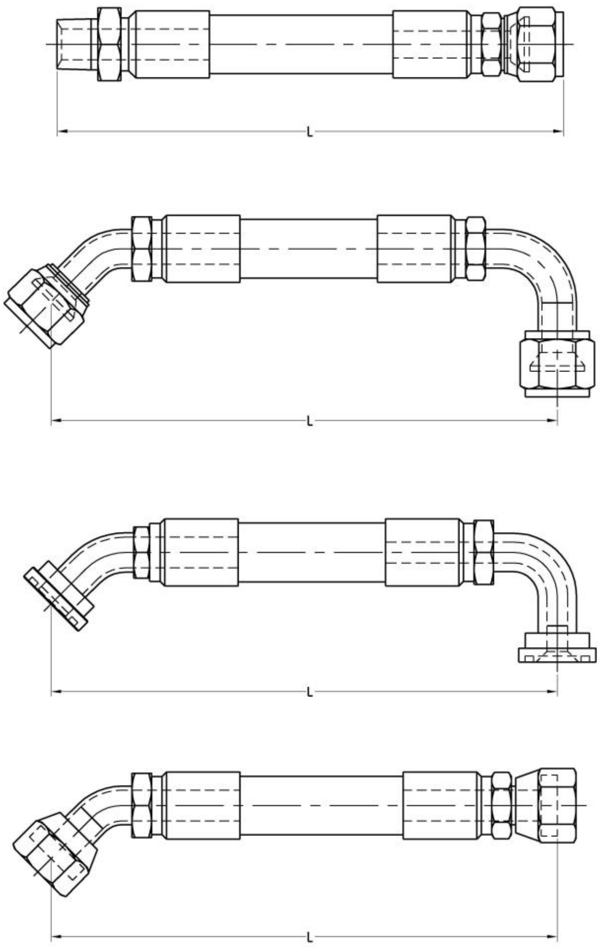


9.7. Appendix G Hose length diagrams

9.7.1. Threaded type hose assemblies

Figure G1 shows locations for measuring typical hose lengths for threaded type hose assemblies.

Figure G1 Threaded type hose assemblies – Locations for measuring hose lengths



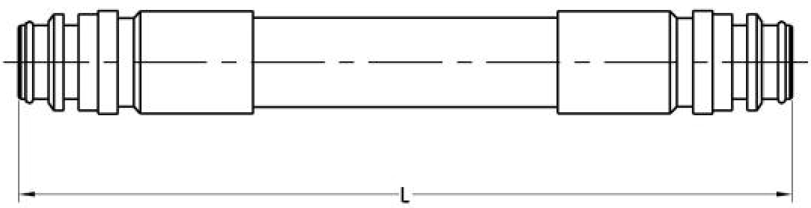
Except for O-ring faced seals

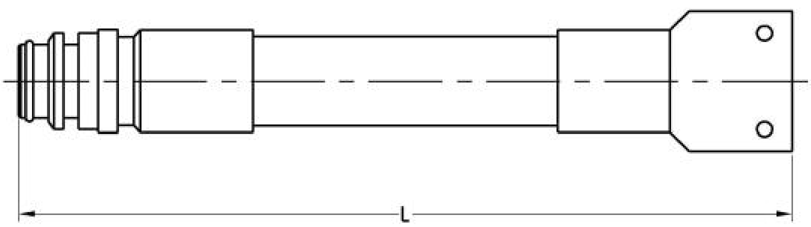
For O-ring faced seals

9.7.2. Staple type hose assemblies

Figure G2 shows locations for measuring hose lengths for staple type hose assemblies.

Figure G2 Staple type hose assemblies – Locations for measuring hose lengths

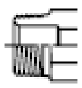
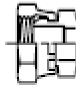
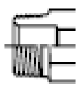
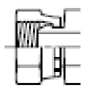
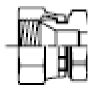
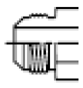
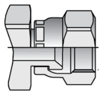
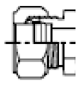
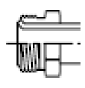
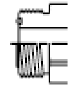
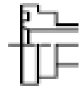
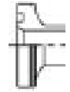




9.8. Appendix H Hose end adaptor pressure ratings

Table I – hose end adaptor maximum allowable working pressure based on 4:1 design factor

Pressure Ratings of Connectors

Description		Male Pipe (NPTF)		Female Pipe (NPTF, NPSM)		Male Pipe (BSPT)		Female Pipe (BSPP)		JIS		37° JIC		37° JIC F/male swivel		SAE Flareless		SAE Inverted Flare		ORFS (Face Seal)		SAE Flange Code 61		SAE Flange Code 62	
Standard		SAE J476a		SAE J476a		BS-21 ISO 7-1		BS5200 ISO 8434-6		B8363		SAE J514 ISO 8434-2		SAE J514		SAE J514 Part 2		SAE J512		SAE J1453 ISO 8434-3		SAE J518-1 ISO 12151-3-S-L		SAE J518-2 ISO 12151-3-S-S	
Fitting Size																									
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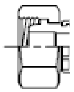
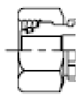
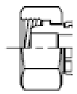
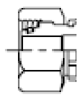
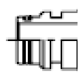
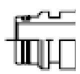
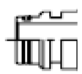
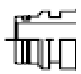
3	-2	84	12 000	52.5	7 500			35	5 000																
6	-4	84	12 000	49	7 000	No known standard defining rating		35	5000	35	5 000	35	5000	31	4500	35	5000	19.2	2 750	41	6000				
8	-5											35	5000	27.5	4000	35	5000	17.5	2 500						
10	-6	70	10 000	42	6 000			35	5000	35	5 000	35	5000	27.5	4000	35	5000	15.7	2 250	41	6000				
12 or 13	-8	70	10 000	35	5 000			31.5	4500	35	5 000	31	4500	27.5	4000	31	4500	14	2 000	41	6000	35	5 000		
16	-10							31.5	4500			24	3500	21	3000	24	3500								
19 or 20	-12	52.5	7 500	28	4 000			25	3600	28	4 000	24	3500	21	3000	24	3500			41	6000	35	5 000	42	6 000
25	-16	45.5	6 500	21	3 000			20.0	2900	21	3 000	21	3000	17	2500	21	3000			35	5000	35	5 000	42	6 000
30 or 32	-20	35	5 000	17.5	2 500			16.0	2300	17.5	2 500	17	2500	14	2000	17	2500			28	4000	28	4 000	42	6 000
38	-24	21	3 000	14	2 000			12.5	1800	10.5	1 500	14	2000	10.5	1500	14	2000			21	3000	21	3 000	42	6 000
50 or 51	-32	17.5	2 500	14	2 000			8.0	1200	10.5	1 500	10.5	1500	8	1125	10.5	1500					21	3 000	42	6 000

Description		DIN Light (L) 24° Cone No O-ring		DIN Light (L) 24° Cone With O-Ring		DIN Heavy (S) 24° Cone No O-ring		DIN Heavy (S) 24° Cone With O-ring		Staple lock		Staple Lock		Staple Lock with 'D' Staple		Super Staple Lock with 'D' Staple	
Standard		ISO 8434-1		ISO 12151-2-SWS ISO 8434-1		ISO 8434-1		ISO 12151-2-SWS ISO 8434-1		DIN 20043		BS 6537		see manufacturer		MDG 41.1	
Fitting Size																	
mm	inch *	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi
6		25.0	3625	31.5	4 500					40	5800	34	4900				
8		25.0	3625	31.5	4 500	63	9 000	63	9 000								
10		25.0	3625	31.5	4 500	63	9 000	63	9 000	33	4785	29	4130	No known standard defining rating			
12	1/2	25.0	3625	31.5	4 500	63	9 000	63	9 000	42	6000	23	3370			42	6090
14						63	9 000	63	9 000								
15		25.0	3625	31.5	4 500												
16						40	5 750	42	6 000			21	3000				
18		16.0	2320	15.7	2 250												
20	3/4					40	5 750	42	6 000	35	5000	21	3000			42	6090
22		16.0	2320	15.7	2 250												
25	1					40	5 750	42	6 000	28	4000	21	3000			42	6090
28		10.0	1450	15.7	2 250												
30						25.0	3625	42	6 000								
32	1 1/4									21	3000	13	1850			42	6090
35		10.0	1450	15.7	2 250												
38						25.0	3625	31.5	4 500								
40	1 1/2									9	1300					42	6090
42		10.0	1450	15.7	2 250												
50	2									8	1160					42	6090

Note:
Manufactures of hose fittings and adaptor may exceed the minimum nominated above. Test data and certification should support any claims.
Fatigue life cycles should be reviewed in line with application requirements

9.9. Appendix I Hose dynamic test rigs

9.9.1. ISO 6802 - Impulse test and flexing to minimum bend radius

Figure I1 – Hydraulic impulse test with flexing – Arrangement of test piece using a revolving manifold

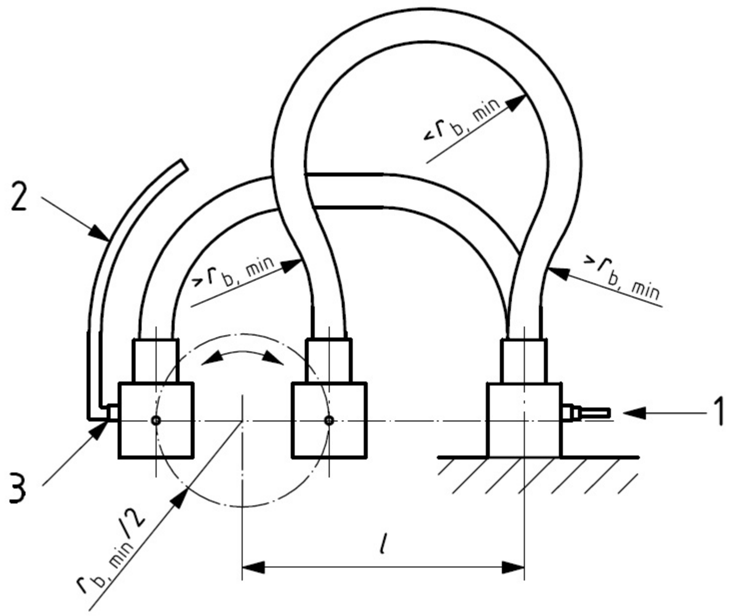
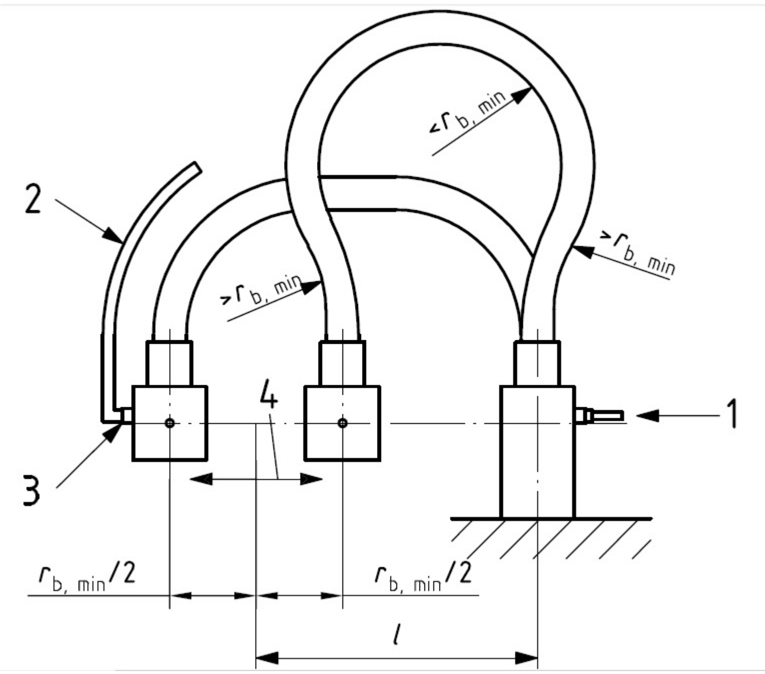


Figure I2 – Hydraulic impulse test with flexing Arrangement of test piece using a horizontally reciprocating manifold



9.10. Appendix J – Human and organisational factors

9.10.1. Human and organisational factors and plant design

Human machine interface is an important performance shaping factor to consider in HOF. Plant, equipment and their subsequent controls are increasing in complexity. Multiple displays, including the linking of computer displays with handheld controls and new technologies have increased the skill requirement of operators (Charles, 2015)

Some examples of unintended outcomes considered through the lens of human and organisational factors, poor design and systems of work are outlined in Table J1.

Table J1
Human and organisational factors and poor design

Unintended outcome	Possible causes due to poor design
Inadvertent activation of plant.	• Lack of interlocks or time lockouts. • Lack of warning sign against activating equipment under specified damaging conditions.
Errors of judgement, particularly during periods of stress or high job demand.	• Several critical displays of information are too similar or too close together. • Job requires user to make hurried judgements at critical times, without programmed back-up measures.
Critical components installed incorrectly.	• Design and instructions are ambiguous on installing components. • Lack of asymmetrical configurations or guides on connectors or equipment.
Inappropriate use or delay in use of operator controls.	• Critical operator controls are too close, similar in design, awkwardly located. • Readout instrument blocked by arm when making adjustment. • Labels on operator controls are confusing. • Information is too small to see from user’s position.
Inadvertent activation of operator controls.	• Operator controls are too easily activated by the operator e.g. by being too close to other controls. • Operator controls can be activated accidentally e.g. by brushing past the control. • Lack of guards over critical operator controls.
Critical instruments and displays not read or information misunderstood because of clutter.	• Critical instruments or displays not in most prominent area. • Design of all displays is similar.

Failure to notice critical signal.	• Lack of acceptable auditory and visual warning to attract user's attention to information.
Plant use results in unexpected direction or response.	• Direction of operator controls conflicts with normal operation or expectancies.
Lack of understanding of procedures.	• Instructions are difficult to understand.
Following prescribed procedures results in error or incident.	• Written prescribed procedures are wrong and have not been checked. • Procedure is identified as the main control to control a hazard
Lack of correct or timely actions.	• Available information incomplete, incorrect or not available in time. • Response time of system or plant too slow for making the correct action. • Lack of automatic corrective devices on system with fast fluctuations.
Exceeding prescribed limitations on load or speed.	• Lack of governors and other parameter limiters. • Lack of warnings on exceeding parameters.

Further guidance on human factors can be found at:

www.hse.gov.uk/humanfactors/topics/types.pdf

www.hse.gov.uk/humanfactors/topics/testing.htm

www.hse.gov.uk/humanfactors/topics/06maintenance.pdf

References:

Besnard, D. Hollnagel, E. 2014, I want to believe: some myths about the management of industrial safety, Cognitive technical Work, Vol 16, pp 13-23.

Charles, R. Sharples, S. Rajan, J. Wilson, J, & Wood, J 2015, *Analyzing and Designing Control facilities,*, In J.R Wilson & S. Sharples, Evaluation of Human Work (pp 384-413). Taylor & Francis Group, Boca Raton

Laumann, K. & Rasmussenn, M. 2016. Suggested improvements to the definition of standardized plant analysis of risk human reliability analysis (SPAR-H) performance shaping factors, their levels and multipliers and the nominal tasks, Reliability Engineering & System Safety, Vol 145, pp 287, 300.

Grey, E & Wilkinson, P. 2004, Applying what we know about Human Error: From Theory into Practice, APPEA Journal, pp 885-890

Dekker, S. (2012). Global Concept: Safety. In HaSPA (Health and Safety Professionals Alliance), *The Core* Body *of Knowledge for Generalist OHS Professionals.* Tullamarine, VIC. Safety Institute of Australia.

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9.11. Appendix K – Example inspection and test plan

SUPPLIER reference; ____________________

Business unit; ____________________

Order number: ______________ Circuit drawing number ____________________

Contractor: ______________________________. Date: .../.../...

1	Components: 1.1 Does assembly comply SITE standards 1.2 Is latest parts list complied with? 1.3 Are pump/motor shafts correctly aligned? 1.4 Is all labelling as specified in SITE Standards	Yes/No Yes/No Yes/No Yes/No	
2	Piping: 2.1 Do termination points comply with that specified? 2.2 Are all mating connection halves fitted on termination points?	Yes/No Yes/No	
3	Miscellaneous: 3.1 Are overall dimensions as per design? 3.2 Is all equipment readily accessible for maintenance?	Yes/No Yes/No	
4	Function report: 4.1 Has specified fluid been used for testing? 4.2 Has assembly been successfully tested to required pressure? 4.3 Design pressure Pump flow rate at design pressure	Yes/No Yes/No	MPa L/Min

	Electric motor maximum rated current draw Electric motor current draw at design pressure and flow 4.4 Do all hydraulic functions comply with specification? 4.5 Do all electrical functions comply with specification?	.... Yes/No Yes/No	Amps Amps

Note: 1. Any non-compliance is to be detailed and attached to this report with reasons for non-compliance specified.

2. Any point not applicable is to be marked N/A

Test complete and functionally correct

Contractor ________________ Date: ..../..../....