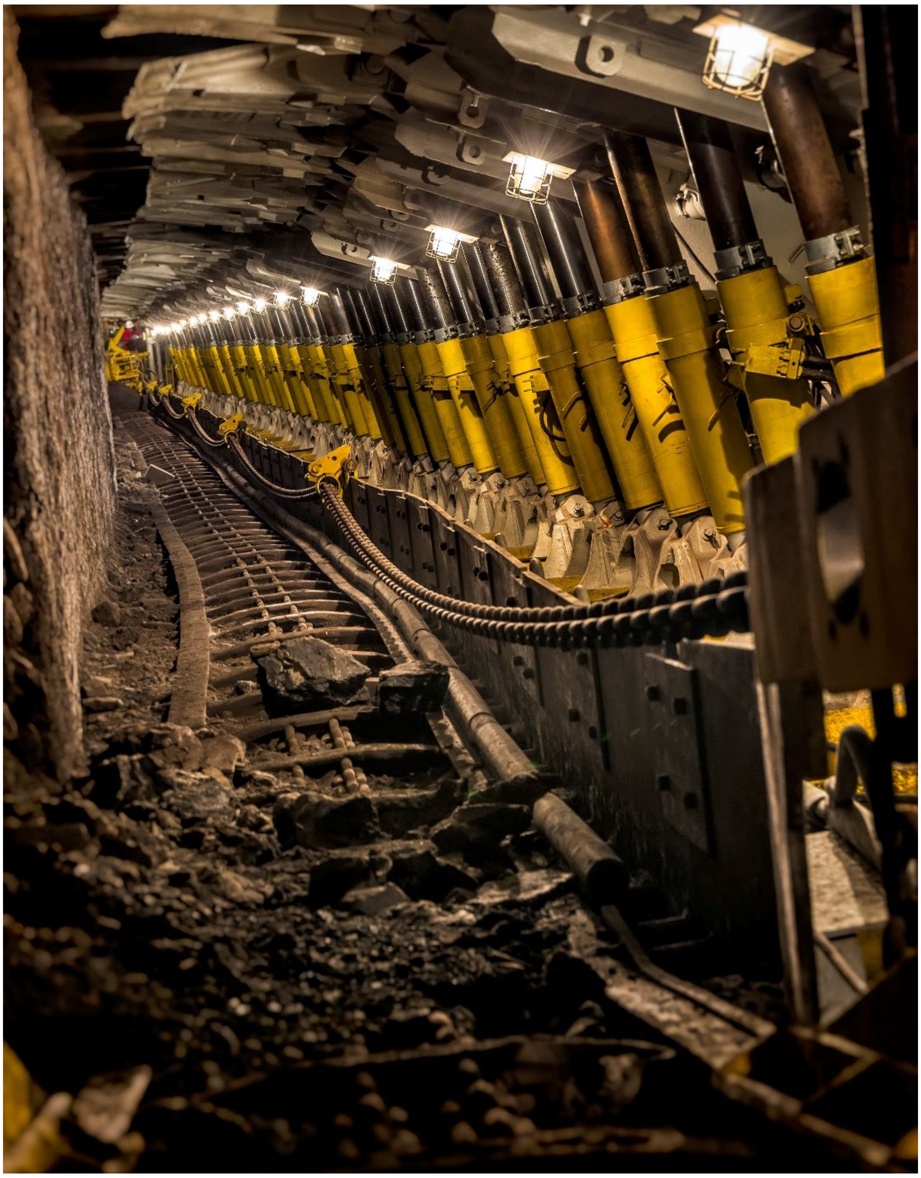
NSW Resources
Resources Regulator

Technical reference guide 41

Fluid power safety systems at mines

March 2025



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Amendment schedule		
Date	Version	Amendment
April 2024	Consultation draft	Amalgamation of MDG 41; MDG3007; MDG41-TR 420 super staple lock fittings
March 2025	2.0	Addressed stakeholder feedback and included relevant content from MDG10

Foreword

Fluid power systems use pressurised fluid to transmit and store energy. Mining operations use fluid power systems as an energy source on mechanical plant as they offer the advantage of high-energy transfer in confined areas.

Fluid power systems present a range of unique safety hazards, the most dangerous being high pressure fluid escaping at high velocity and hitting workers. This is considered a major safety hazard that can result in high pressure injection injuries. These injuries range from minor to severe burns, lacerations, amputations, eye injuries and blindness. In some cases, these injuries have been fatal. It is essential that mine operators adequately control fluid power systems where people work near them.

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

This technical reference guide (TRG 41) will help designers, mine operators and workers involved with high-pressure fluids to minimise risk throughout plant life cycle activities.

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1. Purpose and scope

1.1. Purpose

This technical reference guide (TRG) provides guidance on managing the lifecycle work health and safety risks associated with fluid power systems at mines. This document replaces MDG41 Fluid power safety systems at mines, MDG3007 Hydraulic safety, MDG41-TR1 420 Super staple lock fittings and adaptors for hydraulic power-transmission circuits, and MDG 10 Design guidelines for hydraulic load locking valves for use in coal mines.

This TRG should be used for all mining plant such as mobile plant (surface mines, quarries, and underground mines), longwalls, development equipment, fixed installations and compressed air systems. This TRG is not intended to cover mains water supply reticulation.

This TRG should be used when:

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

1.2. References abbreviations and definitions

1.2.1. 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 (WHS (MPS) Act)
- Work Health and Safety (Mines & Petroleum Sites) Regulation 2022 (WHS (MPS) Regulation).

This legislation can be viewed at www.legislation.nsw.gov.au

1.2.2. Standards and codes of practice

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 along with a list of relevant technical reference guides and codes of practice.

Examples of applicable codes of practice include:

- SafeWork NSW code of practice - Managing the risks of plant in the workplace
- NSW code of practice: Safety management systems in mines
- Mechanical engineering control plan (MECP) code
- Electrical engineering control plan (EECP) code.

1.2.3. Abbreviations

Table 1 details the abbreviations that are used in this TRG.

Table 1: Abbreviations used in this TRG

Abbreviation	Title
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 TRG 3608 – Non-metallic materials for use in underground coal mines and reclaim tunnels in coal mines)
ISO	International Organisation for Standardisation
ITP	inspection and test plan
JSA	job safety analysis
MBR	minimum bend radius
MDG	mining design guideline
MECP	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

Abbreviation	Title
TRG	technical reference guide
WHS	work health and safety

1.2.4. Definitions

Table 2 provides the definitions used in this TRG..

Table 2: Definitions used in this TRG

Term	Definition
Competent person	A person who has acquired through training, qualification and experience the knowledge and skills to carry out the task.
Designer	A person that has the duty of a designer under the *Work Health and Safety Act 2011*
Fire resistant and antistatic (FRAS)	A material that meets the requirements of the relevant parts of TRG 3608 – Non-metallic materials for use in underground coal mines and reclaim tunnels in coal mines.
Fit for purpose	Something that is sufficient to do the function it was designed to do, for the intended use, over its lifetime.
Fluid power systems	Pressurised hydraulic systems for transmitting and controlling energy. These include, but are not limited to, fluid power mediums of hydraulic mineral oil, air, emulsion oil, diesel fuel, grease, water etc.
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.
Hazard	A potential source of harm.
High risk area	Any area where an uncontrolled escape of fluid could place a worker's health and safety at risk. Consider: • areas where fluid power components could break, burst, or fail and expose people in the vicinity to health and safety risks such as: — where fluid power pressure exceeds 5MPa (750psi), or — where fluid power temperature exceeds 60°C, or — high flow/pressure/force are present e.g., large flow compressed air lines • 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). Note: Refer to ISO 3457 section 9 for further guidance in relation to the vicinity of risk.
Hose assembly	A flexible hose with hose ends attached. Sometimes referred to as a flexible hose assembly.

Term	Definition
Hose end	The hose coupling or hose fitting that is attached to each end of a single piece of hose.
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 8 years.
Impulse life	The set number of impulse cycles that a given fluid power component can withstand under controlled test conditions.
Inspection	A process that verifies the plant or equipment (which should be cleaned as necessary to permit inspection) is in a condition accepted as working order before operation or during maintenance activities.
Lifecycle	Includes design, manufacture, construction or installation, commissioning, operation, maintenance, repair, decommissioning, and disposal.
Matched hose assembly	The hoses and fittings (insert/ferrule) are designed, manufactured, tested, and verified compatible with 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.
Modifications (alterations)	Change in the design of the 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.
Must	Indicates a legal requirement exists.
Plant safety file	A structured compilation of documents providing traceable evidence and information relating to the health and safety aspects incorporating each phase of the lifecycle of the fluid power system from design through to demolition. It contains a record of all 'as-built design features,' including information on risks to health and safety that could arise at any phase of the life cycle.
Pressure intensification	The amplification of system fluid pressure more than 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.
Reasonably practicable	The *Work Health and Safety Act 2011* defines what is reasonably practical - refer subdivision 2 of section 18. Reference is also made to the guideline — model work health and safety act meaning of 'reasonably practicable'.
Rated working pressure	The maximum pressure the component is designed to operate at, as specified by the original equipment manufacturer. Note: Controls to protect components from exceeding the rated working pressure are typically set by the hydraulic control system. Where yield valves or rupture discs are incorporated into a component, the rated working pressure is not determined by the protection pressure setting.
Safety critical system	A system whose failure or malfunction may result in death or serious injury to people.

Term	Definition
Should	Indicates a statement is 'recommended.'

2. Work health and safety legislation

2.1. Guidelines and safety legislation

Mine operators are classified as persons conducting a business or undertaking (PCBUs) under the WHS (MPS) Act. This means mine operators are legally required to identify all hazards, assess risks, and implement control measures using the hierarchy of controls. These controls are to be maintained and reviewed. An overview of applicable legislation, guidelines and other documents is set out in Appendix A.

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

2.2. Consultation

A mine operator has a legal duty to consult with workers on matters that relate to work health and safety that directly effect, or are likely to, directly affect the workers.[1]

Consultation may be undertaken in accordance with the arrangements agreed at the mine such as consulting with Health and Safety Representatives (HSRs), Safety & Health Representative (SHR) and/or any health and safety committee.

The mine operator must, as far as is reasonably practicable, consult, cooperate, and coordinate with other people who it also has a duty to consult, such as other PCBUs and workers (e.g., contractors).[2]

The following documents offer further information on consultation, cooperation, and coordination:

- NSW SafeWork code of practice: Work health and safety consultation, cooperation and coordination
- Resources Regulator Guide: Preparing a principal hazard management plan
- Resources Regulator Guide: Contractors and other businesses at mines and petroleum sites
- Resources Regulator fact sheet: Consulting workers.

2.3. General duties in relation to plant

A mine operator has a primary duty of care under section 19 of the WHS Act to ensure, as 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, as 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

[1] *Work Health and Safety Act* 2011 s47

[2] Ibid ss46 and 47

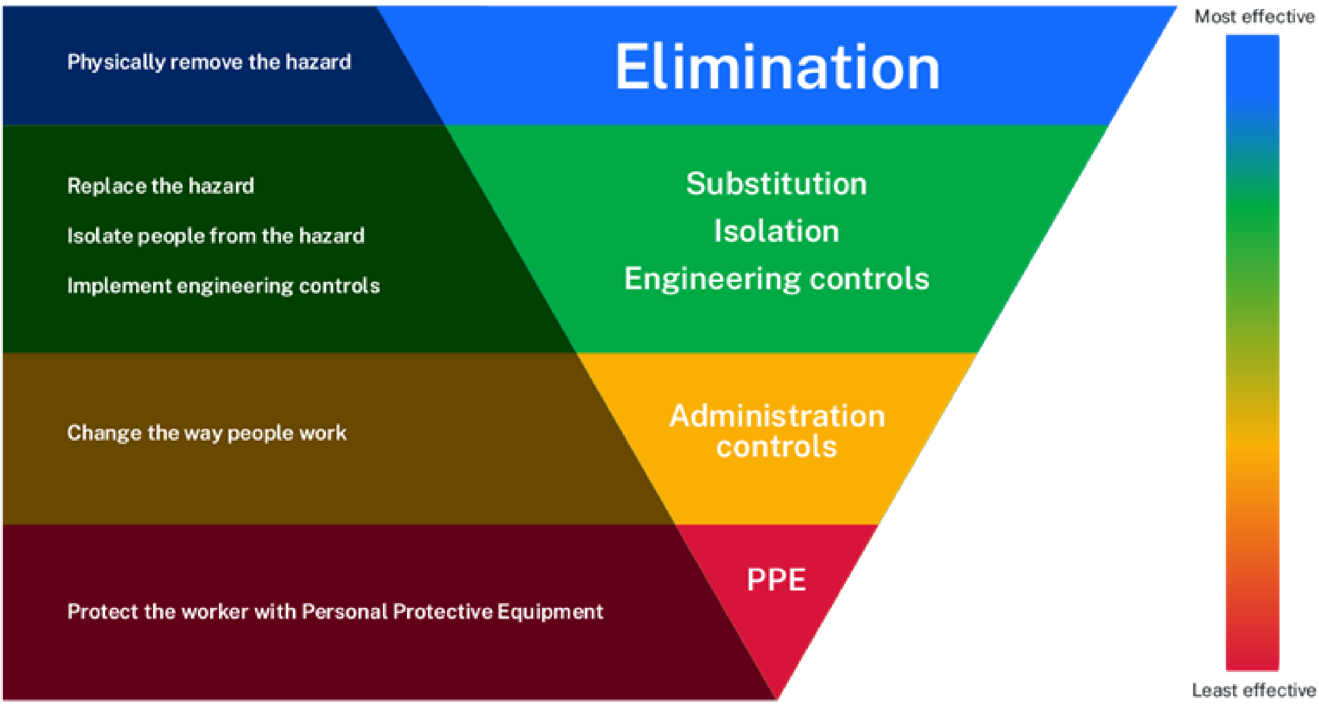
- the provision of any information, training, instruction, and supervision that is necessary to protect all workers from risks to their health and safety arising from work carried out as part of the conduct of the business or undertaking.

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 section 14 of the WHS (Mines and Petroleum Sites) Regulation 2022. This includes:

a. 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
b. identifying all reasonably foreseeable hazards
c. eliminating risks to health and safety as far as is reasonably practicable.

If it is not reasonably practicable to eliminate risks to health and safety, minimise risks as far as reasonably practicable following the hierarchy of risk control measures detailed in Figure 1 below.

Figure 1 - Hierarchy of controls



2.3.1. Design, manufacture, import, supply

Designers, manufacturers, importers and suppliers of plant, substances and structures have duties under sections 22-25 of the WHS Act. In summary, these duties include, as 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.

2.3.2. Calculation, analysis, testing or examination

Designers, manufacturers, importers, and suppliers should carry out (or arrange to carry out) any necessary calculations, analysis, testing or examination.[3] Importers and suppliers should ensure that such calculations, analysis, testing or examination have been carried out.

2.3.3. Information to be provided

Designers, manufacturers, importers, and suppliers must also provide information on the design of, plant;

- for the purpose for which the plant was designed or manufactured
- the results of any calculations, analysis, testing, or examination referred to above
- any conditions necessary to ensure that the plant is without risks to health and safety when used for a purpose for which it was designed or manufactured or when carrying out activities such as inspection, operation, planning, maintenance or repair.

2.3.4. Maintenance of control measures

Under the WHS Regulation, mine operators are required to maintain the control measures for the risks identified hazards can present. This ensures their continued effectiveness, including that they remain:

a) fit for purpose

b) suitable for the nature and duration of the work, and

c) installed, set up and used correctly.

2.4. Hazards associated with fluid power systems

2.4.1. Hazard identification and consequence

It is important for duty holders to be able to identify hazards and their potential consequences when assessing risks associated with using a fluid power system. This helps duty holders meet their obligations and control the risks to health and safety throughout the fluid power system's lifecycle.

Table 3 provides a list of some of the hazards and potential consequences associated with fluid power systems that duty holders should consider.

The MECP and EECP codes of practice provide 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. Guidance on risk management is provided in AS ISO 31000, AS/NZS 4024.1201 and SA/SNZ HB 89.

[3] WHS Act 2011 s22-25

Table 2 - 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. • hit by projectile debris. • hit 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 chemicals or substances. 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 eyesight (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 (i.e. hammering, operation of functions etc). • Noise from rapid expansion of gases.	• loss of hearing (short term)

Energy/hazard	Mechanism/scenario (unwanted event)	Potential consequences
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
Thermal shock	• Inadvertent movement of equipment (e.g. thermal shock causing a jammed spool).	• crushing or impact type injury

2.4.2. Latent and specific risks

Some risks may not be immediately apparent. These are known as latent risks. Many of the potential consequences listed in Table 3 are relevant to latent and specific risks. The list below identifies some latent and other specific risks for fluid power systems that mine operators should consider:

a) fluid leakage due to hose/pipe/fitting failure, including pin holes
b) physical damage from people standing on components
c) physical damage from falling material
d) pressure intensification and pressure pulsations
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) hose damage due to abrasion from material build up around hoses
j) excessive temperature of the systems or environment
k) overload and/or high external loads
l) unplanned movement due to component failure. (e.g., blockages, pressure drops or leaks which affect the operation of components)
m) working pressure and flow, temperature, and load changes over time
n) failure of power supply, either hydraulic, pneumatic, or electric
o) actuator failure, structural or functional
p) inappropriate hose/pipe installation

q) potential hazards due to the environment:
   i. explosive dust or gas mixtures
   ii. water level or rainfall
   iii. release of gas from oxy/acetylene bottles
   iv. UV light exposure.
r) system integration and potential incompatibility
s) poor work practices when diagnosing system faults and poor maintenance resulting in ignorance of potential dangers
t) failure to implement change management procedures
u) human factors and human error.

2.4.3. Incident data

Published incident data can be helpful when identifying hazards associated with fluid power systems.

Appendix C 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 about safety-related incidents they become aware of and their recommendations to rectify defects. (e.g., safety alerts, technical bulletins and similar).

2.5. Risk management

Risk management is the identification, assessment, and control of risks. When managing the risks associated with fluid power systems, mine operators should consider the NSW code of practice: How to manage work health and safety risks.

Once hazards have been identified, duty holders must assess their associated risks and implement controls. This can be an iterative process. The risk assessment may identify hazards that pose an unacceptable risk and duty holders may need to develop additional controls.

The following documents may be useful:

- Managing risks in mining and petroleum operations
- National Minerals Industry Safety and Health Risk Assessment Guideline
- AS/NZS 4024.1303 Safety of machinery risk assessment - Practical guidance and examples of methods
- AS ISO 31000 Risk Management - Guidelines.

2.6. 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 designer should create the safety file and the person in control of the fluid power system should maintain it.

The plant safety file should contain the following information:

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

Records should be readily accessible 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.

3. Design and manufacture

Designers and manufacturers of plant, substances and structures have duties under sections 22-23 of the WHS Act. Fluid power systems should also be designed and manufactured using existing engineering standards and principles, so they are fit for the intended purpose and safe to use.

Engineering standards for fluid power systems include AS 2671, AS 2788, AS 4041 and ISO/TS 17165-2 (or SAE J1273). These standards should be read in conjunction with this TRG.

Fluid power systems should be designed and manufactured to operate within nominated rated limits (including components) when the system is used as intended.

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

Design and manufactures must meet the standards in the SafeWork code of practice – Managing the risks of plant in the workplace.

3.1. Design hazard, identification, assessment, and control

3.1.1. Design risk assessment

Designers should carry out a design hazard analysis (design risk assessment) to identify all reasonably foreseeable hazards associated with fluid power systems and to provide fit-for-purpose means to control risks to health or safety. Designers should consider:

a) the purpose of the fluid power system, including intended design life and potential lifecycle risks

b) assessment of the hazards set out in Table 3

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 the 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 minimise the risk of harm to people in the vicinity. This may include the necessity to stop the system.

Risk analysis methods that duty holders should document and maintain include:

a) the methods used at the site to identify the level of risk, threats, controls, and consequences

b) testing methods used to assist in evaluating the risks

c) justification for using such methods and why they were considered valid and reliable

d) a record of the most recent risk assessments.

Hazard analysis should identify the required safety critical systems and the requirements those systems play in operating the fluid power system. The designer should address:

a) any foreseeable risk scenario that may cause harm to any worker during the fluid power system lifecycle.

b) risks from unplanned movement of actuators, feedback monitoring on functions, for example spool position monitoring

c) the control of risks to health and safety that may arise from reasonably foreseeable misuse of the fluid power system.

AS ISO 31000, SA/SNZ HB 89, AS/NZS 4024:1201 AS/NZS 4024:1303 may provide guidance.

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

Designers should assess all control measures for their effectiveness and required reliability.

3.1.2. Design operational risk assessment

The designer in conjunction with the end user should carry out a design operational risk assessment in relation to the intended use of the fluid power system in the mine environment.

3.1.3. Design of safety critical systems

3.1.3.1. Controls for identified risks

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

- a safety-related function
- safety-related componentry.

Duty holders should assess the lifecycle effectiveness of the control measures to ensure they remain reliable and provide the required level of protection under all stated conditions.

3.1.3.2. Safety-related componentry

Designers should ensure that all safety-related componentry is designed, analysed, tested, and documented using sound engineering practices and according to existing engineering standards.

Duty holders should ensure that plant designers and testers systematically analyse fluid power system componentry. This should determine all reasonably foreseeable failure modes and verify that a sufficient level of reliability has been achieved. Systematic analysis methods such as a failure modes and effects analysis, fault tree analysis or other similar analysis methods, should be used. The analysis is to assess safety-related componentry and determine lifecycle inspection, maintenance, test, and discard requirements, as required for lifecycle functionality. Findings from this analysis should be used to inform end-users via manuals and guidance on lifecycle.

Where applicable, designers and suppliers should test and analyse components for fatigue.

3.1.3.3. Safety-related functions

Designers should ensure that all safety-related functions arising from the hazard assessment(s) are clearly identified.

Safety-related functions should be assessed using functional safety standards applicable to the design architecture and type of components used. Functional safety standards include:

a) application of performance levels (PL) in alignment with AS/NZ 4024.1503 or ISO 13849-1

b) application of safety integrity levels (SIL) in alignment with AS 61508.1 or AS/NZS 62061

c) application of safety categories (CAT) to AS/NZS 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 the required risk reduction has been achieved. The functional safety assessment should include:

a) validation through evidence documentation

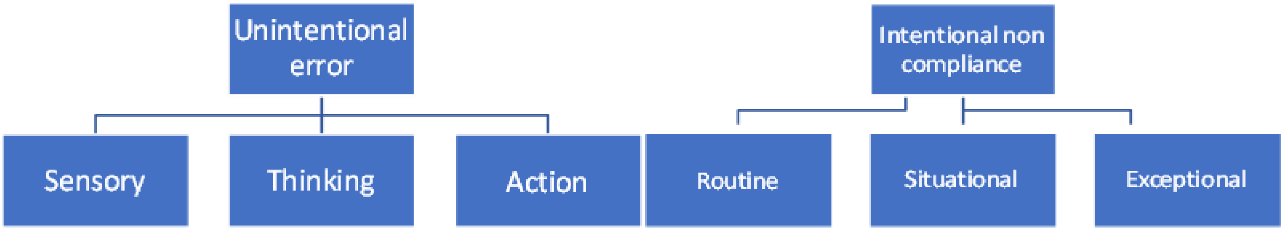
b) a review of lifecycle systematic failures and corrective measures taken

c) documentation on any assumptions used, such as those that relate to proof test intervals, periodic inspection and tests, environmental conditions, and human behaviour.

3.1.4. Human factors

Human factors often contribute to risk control failure. Mine operators should therefore consider how to reduce human error over the lifecycle of the fluid power system. Human factors are described below as either unintentional or intentional errors as shown in Figure 2 below.

Figure 2: Human error factors



An error is unintentional when the person can explain how the failure occurred, but not why it occurred.

A person is intentionally non-compliant when their actions signal an intention to behave in a certain way. It can also be demonstrated the person knew what they should have done. Usually, intentional noncompliance is well meaning, but misguided. For further information, see Appendix J and the MECP code and Safe Work Australia Guide for safe design of plant.

Designers should be aware of the role human factors play when using fluid power systems. Designers should consider:

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) provision of a system that is safe to use. For example, the system:
i. minimises unnecessary complexity (i.e. keep it simple)
   ii. includes workstations that provide the operator a view of functions being performed and relevant feedback
   iii. includes appropriate instrumentation
   iv. has quick operational recovery capability if there is a system failure.
c) reasonably foreseeable misuse, for example:
   i. incorporate quick operational recovery capability if the user makes a mistake
   ii. prevent dangerous misuse of the system using higher order controls, if necessary, (e.g., interlocks preventing dangerous functions, automatic shutdown in the event of system overpressure).

3.1.5. Operating environment

Fluid power systems should be selected and rated to suit the intended operational environment.

Examples of typical issues in the operating environment of a mine include:

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

3.2. Design information

To assist in preventing misinterpretation and incorrect use of design information, designers should fully document the fluid power system 'as built'. Design documentation should contain sufficient detail to enable a competent person, other than the designer, to evaluate the fluid system.

After making any system changes, designers should update all design documents 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) or bar (pressure).

3.2.1. Synopsis of plant

Designers should provide a synopsis of the fluid power system, which includes:

a) system operating limits and capacities
b) general arrangement drawings showing the physical dimensions
c) hydraulic and pneumatic circuit diagrams (may be colour-coded)
d) schematic and logic drawings of power and control facilities
e) detailed parts lists of all components including reorder codes, if known
f) transport, storage and lifting requirements.

3.2.2. Information on purpose of design

Information on the purpose of the design of fluid power systems should include (but is not limited to):

a) purposes for 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 AS 2671, AS 2788, AS 4041)

e) operating duty/cycle of the system and its components

f) functional specifications and logic for control of the system

g) operating environment

h) maximum working pressures and temperatures

i) fluid types (specification) and required cleanliness levels

j) emergency and safety requirements

k) information on residual risks and controls

l) procedures for servicing and maintenance.

3.2.3. Schematic diagrams

Designers should provide schematic diagrams that align with ISO 1219-2 (see also AS 2671 as appropriate).

All hydraulic and pneumatic symbols should align with ISO 1219-1. Circuit diagrams should contain the following:

a) all system components, including electro-hydraulic and item identification

b) all pressures settings

c) flow rates where relevant

d) any other devices

e) hose diameter where this is critical to correct operation of the circuit.

f) identify port connections on all pumps, manifolds and components

g) where practicable the schematic should mimic the layout of the design.

3.2.4. Hose and piping assembly diagrams and documentation

Designers and/or manufacturers should provide hose and piping assembly diagrams and documentation (see ISO 1219.1 and ISO 1219.2) that 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.

g) All connection points are to show port identification matching the marking on the components (pumps, motors, manifolds, etc).

3.2.5. Installation testing and commissioning information

Designers should provide installation, testing and commissioning procedures that should include the:

a) identification of hazards and appropriate controls associated with the installation, testing, and dismantling of the fluid power system

b) testing, inspection, and commissioning to be carried out

c) safe work procedure associated with the installation, testing, and dismantling of the fluid power system.

3.2.6. Operation and maintenance instructions

Designers should include the following information in the operation and maintenance manuals:

a) Recommended maintenance requirements to maintain the fluid power system in a safe operating condition.

b) Recommended inspection and tests, including proof tests to maintain integrity of safety critical functions, 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 guides.

i) Safe handling and fluid disposal procedures.

j) Recommended spares.

3.3. Fluid power systems design

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

Seals and sealing devices should be compatible with the fluid used, adjacent materials, working pressure, working conditions and environment. Designers should consider incorporating elastomeric (O-ring type face seal fittings) sealing for all fluid power connectors.

Fluid power systems should be designed to minimise excessive heat generation.

3.3.1. Rated working pressure

To avoid pressurised fluids escaping into the environment, fluid power system components should have appropriate factors of safety for the rated working pressure to bursting pressure. All 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 should be designed to withstand surge, dynamic and intensified pressures experienced during the normal operation of the fluid power system. Fluid power components, such as cylinders, actuators or similar should have a factor of safety of at least 2.5:1 on rated working pressure.

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

Designers should consider the fatigue life of fluid power system components when considering their appropriate safety factor.

3.3.2. Excessive pressures

The design of the fluid power system should protect the circuit against excessive pressures (e.g., relief valve - refer AS 2671, AS 2788 and AS 4041 as appropriate).

The protective means or device should be:

a) purpose designed to suit maximum flow rate that 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.

3.3.3. Protection from uncontrolled escape of pressurised fluids

The design should minimise the risk of injury to workers from the uncontrolled escape of pressurised fluids. Control measures should be provided in accordance with the hierarchy of controls, refer to Figure 1.

The following should be considered:

a) Routing hoses, pipes, and pressurised components away from high-risk areas, or otherwise as far away as possible.

b) Use of protective fixed guards to prevent escaped fluids entering work areas.

c) Use of devices to divert or disperse 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 acceptable to rely solely on personal protection equipment (PPE) in high-risk areas.

3.3.4. Unintended pressure intensification

Designs should prevent unintended pressure intensification in all fluid power systems, particularly hydraulic cylinders. Designers should consider use of unloader valves, relief valves and burst discs where appropriate.

3.3.5. Filtration

Contamination in fluid power systems may cause circuit (component) malfunction such as inadvertent operation. Fluid filtration can assist in mitigating this risk and designs should provide filtration to protect all fluid circuits. Filtration should be selected to align with AS 2671 and AS 2788.

The degree of filtration required should be consistent with the filtration requirements for all system components and consider environmental conditions. Typically, systems operating at greater than 250 bar, (25 MPa) require a cleanliness rating equivalent to or exceeding 16/14/8 (ISO 4406).

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

Designs should consider the effect on the control circuit when the filter is blocked. Blocked or restrictive filters fitted in the return line result in pressure and this may cause inadvertent movement. Where a hazard is identified, a pressure sensor or bypass in the return line should be considered.

Designs should consider duplicate filters on all control circuits. All filters should be equipped with a device to indicate when the filter needs servicing.

3.3.6. Design for maintainability

Designers should identify maintenance and serviceability hazards, mine operators should implement appropriate control measures. For example, sample points for high pressure fluids should be assessed to identify hazards and control measures implemented. Controls 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 so components can be safely adjusted, serviced, or replaced without the need to dismantle other components. Particular attention should be given to components and hoses that need regular maintenance.

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

3.3.7. Fluids

Fluids should be compatible with the system's components.

Designs should use component-compatible fire-resistant fluids where there is an unacceptable fire risk, such as on longwall roof supports and fluid couplings on belt conveyors in underground coal mines.

Designers should supply safety data sheets (SDSs) and additional information on fluid toxicity, fire effects, handling requirements and degradability, where appropriate.

Oil soluble fluorescent dye additives can be added to oils and emulsions and used to assist with tracing and detection of high-pressure fluid injection injuries (Appendix N).

Fluid reservoirs should be designed to align with AS 2671.

3.3.8. Marking and identification

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.

The design should clarify the meaning of symbols with written descriptions where misinterpretation could create a hazard.

Systems component labels should enable clear cross referencing with the circuit diagram, or all systems components should be clearly identifiable in line with the technical documents.

All pressures should be in bar or standard SI units as described in AS/ISO 1000.

Permanent markings, signs and identification plates should align with AS 1318 and AS 1319.

Porting on manifolds, pumps, motors, valves and components should be marked to identify the connection point for all hose connections and sampling points.

3.3.8.1. Construction and location

Markings, signs, and labels should be:

a) installed or positioned and maintained so that they are clearly visible to maintenance and production workers, and

b) of durable construction and permanently attached.

Signs and labels should be durable and readable (e.g., made from engraved brass, stainless steel, or similar).

3.4. Components (other than hose assemblies)

The fluid power system designer should select, apply, and instal components to align with the component manufacturer's information and AS 2671, AS 2788 or AS 4041, as appropriate. All components of the system should:

a) be designed to withstand surge, dynamic and intensified pressures experienced during 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.

3.4.1. Pressure test points

All fluid power systems should have provision for test points to determine pressure in that specific part of the circuit, including sub-circuits. This will enable the safe testing and monitoring of the system. They should also include pressure gauges, as appropriate.

All fluid power systems should include test points to limit the need for dismantling the system for regular monitoring and testing.

3.4.2. Vent ports

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

3.4.3. Other system components

Energy conversion components such as pumps, motors, cylinders, gas accumulators and, reservoirs, should be designed to align with AS 2671, AS 2788.

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

Designs should allow worker access from ground level or an access platform conforming to appropriate standards.

3.4.4. Valves

All valves should be:

a) designed based on AS 2671, AS 2788 or AS 4041, DIN EN 1804-3 as appropriate

b) identifiable and consistent with the fluid system circuit diagram

c) securely mounted.

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

Valves used for isolation should be lockable. Ball or other quick action valves should not vent directly to atmosphere.

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

3.4.5. Load bearing actuators

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

a) Devices to protect against the effects of failure of a hose or any other hydraulic component. An example safety device is a load lock, which will stop the movement in the event of a hose rupture or pipe fracture.

b) Devices to prevent over pressurisation of the actuator. Issues to consider include thermal expansion of trapped oil, and mismatch of pilot ratios between cylinder and load lock valves, refer to section 7.1.5.

3.4.6. Pumps and pump stations

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

a) adequately supported when installed

b) mechanically protected from foreseeable damage in high wear or impact areas

c) positioned to allow access for maintenance purposes with sufficient space around each pump

d) positioned, guarded, and/or cooled to minimise the risk of burning a worker

e) able to be isolated and stored energy dissipated independently of the rest of the system

f) be suitably guarded based on the principles of the AS/NZS 4024.1302.

3.5. Fluid power control circuits

Designers should include controls that prevent unintended movement and incorrect sequencing of actuators over the lifecycle of the plant. Designs should consider control system failure modes.

Where designs have adjustable control valves that may create a hazard if incorrectly adjusted, they should be fitted with a tamper-resistant device or require special tools.

Designers should include mechanisms to show information about the system's operational status, for example pressure gauges.

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

3.5.1. 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:

1. unplanned movement incidents have occurred from main return line blockages causing excessive back pressure on the pilot circuit
2. one method of minimising the risk of excessive return pressure affecting the pilot circuit is the inclusion of a dedicated pilot return line to the tank being a separate circuit to the main return line.

3.5.2. Return lines

Designers should protect the return line against over-pressure, this may cause unplanned movements. This in turn can create a hazard to workers. A blocked return line can also cause a possible pressure intensification event. Designers may consider a bypass check valve for filters in return lines to avoid high pressures when the filters are clogged.

3.5.3. Fire hazard

The fluid power system should be designed to shut down automatically upon unplanned release of fluid that may be a fire hazard (e.g., A total loss of pressure in a fan drive circuit).

3.5.4. Manual controls

Designers should consider and minimise inadvertent operation of any manual controls that create a hazard (AS4024.1).

The designer should ensure the choice of manual controls is appropriate for the operation being initiated (e.g. a push button used for on/off controls, levers for proportional controls, etc.). All manual controls required by automatic, semi-automatic or gripper jaw functions should automatically return to the neutral position when released by the operator.

The neutral position on manual controls should be easy to find.

The neutral position on a manual control valve should not hold stored pressure on the actuator side of the valve to prevent unintended movement. Pressure should divert back to the tank unless required by the plant function (e.g. gripper jaws).

If any function has more than one manual control station, the designer should provide effective protection or interlocking to control the dual operation risk.

All manual controls should be accessible for maintenance.

3.5.4.1. Ergonomics

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

3.5.4.2. 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 Table 4 below). AS/NZS 4024.1906 provides guidance on general principles.

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

Table 3 - Direction of movement 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

3.5.4.3. Location of controls

The location of manual controls should:

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

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) be located so that the movement of the machine will not impinge on the operator's control space envelope.

3.5.5. Emergency stops

Fluid power systems should include an emergency stop or stopping system complying with the AS 4024.1 series of Standards at each workstation. 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 to recommence.

3.5.6. Hydraulic stops

Fluid power systems that include a hydraulic stop to immobilise hydraulic functions should be a push button to prevent operation. A risk assessment should determine the location of hydraulic stops and where reasonably practicable provide control to the workers interacting with the machine. Hydraulic stops should indicate the mode of operation to the operator and workers interacting with the machine.

When fitted, this device should stop and interrupt hydraulic energy to the controls and should stop all functions.

Hydraulic stops should be designed with the appropriate performance level of reliability.

3.5.7. Pressure gauges

All pressure gauges should be in bar or standard SI units. Gauge displays that rely on multiplication or conversion should not be used.

All gauges should indicate the acceptable circuit operating range.

A snubber should be considered for mechanical or analogue gauges 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.

Gauges should include labelling or an indication of 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 if needed for normal machine operation.

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

3.5.8. Hydraulic load locking valves[4]

All hydraulic cylinders used to elevate cutting heads and conveyor boom loading machines and continuous mining machines should be equipped with hydraulic load locking valves meeting this criteria.

The hydraulic cylinder assemblies which elevate conveyor booms and cutting head shall be equipped with load locking valves to prevent unintentional fall of the boom or cutting head in the event of hydraulic circuit failure. If the boom or cutting head is elevated by more than one cylinder, each cylinder shall be equipped with a load locking valve capable of holding the boom or cutting head in position.

Cylinder load locking valve should:

a) be attached directly to the cylinder port that is subject to the hydraulic pressure induced by the weight of the boom or cutting head.

b) have a rated working pressure greater than the system operating pressure.

If the load locking valve has over-pressure relief capability, the pressure needs to support the static weight of the boom.

If the load locking valve is pilot operated, the hydraulic system shall ensure that the residual pilot pressure will not hold the load locking valve open when the control valve located on the operator's control unit is in the neutral position.

3.5.8.1. Load locking valves applications

Load locking valves should be used in similar applications where a cylinder is holding an elevated load a. Some examples may include but not limited to:

- lift or tilt/crowd cylinders supporting work platforms on mobile plant
- luffing cylinders on stockpile yard equipment such as stackers and reclaimers
- material bin discharge gate cylinders where personnel may access under the discharge point.

3.6. Isolation and energy dissipation

Unexpected plant movement has caused many injuries and fatalities. Designers should include isolation and energy dissipation in hydraulic circuits as a control measure to minimise this risk.

In the performance of many lifecycle tasks such as installation, repair, service, component replacement, maintenance, and disassembly it is critical to consider isolation and energy dissipation 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 use effective means of fluid power energy isolation, dissipation, and verification to achieve zero energy post isolation.

The designer should include:

[4] Extract from MDG 10 - extract of the Mine Safety and Health Administration of the U.S. Department of Labour issued on 17th October, 1980

a) identification of all energy sources that could release energy, (such as stored fluid power, gravity, suspended loads, springs, electrical) and/or cause unintended activation or movement of equipment

b) a means to isolate all identified energy sources to prevent a state change. This includes purpose-designed isolation devices that are lockable and use purpose-designed mechanical stops to isolate against movement due to gravity where required

c) a means to safely dissipate fluid. If used as part of the isolation process a dissipation device should be purpose-designed and lockable

d) a system that verifies that pressure has been dissipated and test for zero energy or safe state

e) clearly identifying all isolation and dissipation points

f) safe work procedures for the use of isolation, dissipation, and verification devices. These procedures should include removal and restoration of energy

g) information on required worker competencies to isolate, diffuse and verify isolation

h) information available in the Mechanical engineering control plan code of practice.

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

3.6.1. Fluid power isolation systems

Fluid power isolation system design should consider:

a) simplicity – easily identified, simple to operate and its functionality easily understood

b) the potential for unplanned movement. This can be mitigated through isolation processes that either directly or indirectly prevent the activation of equipment or the release of other energies

c) defining the function, purpose, and state of the isolation point – by identifying a purpose-built isolation point, dissipation point and pressure state, isolation signposting, instructions for the isolation point, and a specific safe work method for the isolation process

d) lockable purpose-built isolation and dissipation points (this assists in minimising the risk of inadvertent operation or build-up of pressure at the isolation point)

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

f) a means of dissipation that does not require unscrewing components, removal of staples or loosening hoses and or fittings. Diffusion should be suitably directed and restrained to prevent unsafe pressure dissipation

g) safe work methods for all isolations for any high-risk activities. These should be based on complexity and include areas of possible entrapped pressure such as load lock valves used on a cylinder, accumulators and, intensification

h) consulting with mine sites to understand the site isolation policies and procedures

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

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

k) whether a maintenance mode is to be used. Some equipment has a maintenance mode included in the hydraulic system which allows limited operation of the system. The system operator should fully understand the hazards associated with the power-on operation of this mode, the risks assessed, and any necessary control measures applied.

3.6.2. Isolation system features

Designers should consider the following isolation system features:

a) an interlocked function for the isolation device

b) an integrated isolation point that allows 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) removing all energy by isolation or disconnection of the complete system or equipment to provide maximum safe state condition

f) a permit system that verifies and controls that the correct isolation process and that isolation has occurred (e.g. HSE permits).

g) using a group isolation process for some high-risk complex isolation requirements

h) standardising:

  i. the isolation point, dissipation point, and diffuser point colour (e.g., handle, area colour, typically red)

  ii. the quality of the pressure gauge for the function being used (e.g., isolation verification device)

i) providing safe work procedures for isolation points and/or procedures to be adopted during isolation, at or adjacent to the working area.

Additional information is available in the SafeWork NSW Plant, Equipment and machinery Energy Isolation Guidelines.

3.7. Hose assemblies

Failures of hose assemblies have resulted in serious injuries and fatalities in the mining industry. Appropriate means to mitigate this risk are required.

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

Hose assemblies should not be used at pressures exceeding their nominated maximum working pressure.

3.7.1. Hose selection

When selecting hoses consider:

a) the hydraulic hose should meet or exceed the performance level specified in ISO 18752, or SAE J517

b) the hose suitability 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 line with AS 2660 and:

   i. 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.

   ii. documentation/ branding needs to be supplied to substantiate FRAS properties (TRG 3608 Technical reference guide Non-metallic materials for use in underground coal mines and reclaim tunnels in coal mines)

d) the effect of static electric discharge should be considered for other hoses

e) the compliance of air hoses for mine sites other than underground coal 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. (See Appendix D for a Fluid nomograph for mineral oil)

g) additional testing should be carried out where the hose specification does not cover the specific application

h) hoses should be ozone, weather, abrasion, and heat resistant

i) that hydraulic oil hoses on plant in underground coal mines should be fire resistant.(refer section 3.7.1.9).

3.7.1.1. 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.

Selected suction hoses should be able to withstand both the negative and positive pressure imposed by the fluid power system.

Where a hose is subject to system spikes and/or irregular pressure variations higher than the 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.

3.7.1.2. Temperature

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

3.7.1.3. Environment

Hose assemblies should be suitably rated and/or shielded to withstand environmental degradation. Environmental conditions that can degrade a hose assembly 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.

3.7.1.4. Permeation/hose-material – fluid compatibility

The compatibility of fluids with the hose and the permeation effects on the hose should be considered (SAE J1273 or ISO 17165-2).

3.7.1.5. Abrasion resistance

Hoses should meet the abrasion resistance requirements EN853/EN854/EN856/EN857/ ISO6945.or max 10g after 2000 cycles with 50N.

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

3.7.1.6. Corrosion resistance

The degree of required corrosion resistance depends on the operating environment. For a low corrosion environment, all steel hose ends, and hose adaptors should achieve a minimum of 72 hours (red rust) when subjected to a salt spray test following ASTM B117 or ISO 9227. For some more corrosive atmospheres 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.

3.7.1.7. Hose assembly energy diffusion devices

When hose assemblies are in a high risk area there may not be a practical means to provide adequate protection from the uncontrolled escape of pressurised fluids. In these instances, a hose assembly energy diffusion device may be appropriate if an unacceptable residual risk for potential harm to workers remains.

When using diffusion devices, consider:

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. When using diffusion devices consider:

   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

iv. the diffusion device being fire resistant

b) periodic inspection of the hose contained within the diffusion device. The inspection:

i. hose assemblies should be undertaken with the sleeves removed where practical. This particularly applies where there are many hoses in use

ii. should be combined with fatigue testing to failure of a sample of hose assemblies to allow prediction for the remaining useful life of the other hose 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) stainless steel, steel plate, or other metal mesh can be used to guard workers from high pressure hydraulics.

3.7.1.8. Hose assembly restraint devices

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

Where whip restraints are used, the restraint should:

a) be capable of withstanding the kinetic loading of a hose failure

b) limit hose assembly end displacement to a practical minimum.

c) have mountings (tether points) that are load rated.

d) not interfere with the function of the sleeving if fitted

e) 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 workers from the failure of the hose.

3.7.1.9. Fire resistance

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

Fire resistant hoses should be tested following AS 1180-10B, or ISO 8030 and the average duration of the flaming and glowing should not exceed 30 seconds.

Note: For further guidance on FRAS in underground coal mines, please consult TRG 3608 – Non-metallic materials for use in underground coal mines and reclaim tunnels in coal mines.

Some applications may require a high level of fire resistance. For example, brake or turbocharger lubrication hose assemblies, and fire suppression system hoses. These hoses may need to comply with less common specifications (or equivalent level of fire resistance provided) such as SAE AS 1339J, 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.

3.7.1.10. Antistatic hose

Where hydraulic hose assemblies require antistatic properties, they should meet the requirements of clause 6.2 of ISO 6805 when tested using ISO 8031 or TRG 3608 – Non-metallic materials for use in underground coal mines and reclaim tunnels in coal mines.

3.7.1.11. 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.

3.7.1.12. Specific applications

To safely handle the elevated discharge temperature of air compressors elastomeric (rubber type) hose assemblies should not be used on the 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 (see SAE J517).

3.7.2. Factors impacting hose service life

System design and the selection and installation of hose assemblies should consider hose life as part of minimising the potential for a hose failure. Further information on maximising the effective service life of hydraulic hoses refer to SAE J1273 or ISO 17165-2.

3.7.2.1. Impulse life

Typical factors that may affect impulse life, assuming 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 recommended to be a minimum of 6 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.

3.7.2.2. Service life

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

a) external cover damage through abrasion, impact, rubbing, gouging
b) environmental factors such as temperature, UV, ozone, chemical
c) mechanical loads such as vibration, tensile, shear
d) installation/routing factors such as orientation, clamping, vibration, mechanical loads, equipment extension, securing methods

e) corrosion of end fittings and reinforcement wires

f) working fluid temperature, velocity, and contamination

g) Insufficient bleeding of air completely out of the system before full pressurization

h) bending in more than one plane.

3.7.2.3. Effective service life

Fluid power system design and installation should follow SAE J1273 or ISO/TS 17165-2 to minimise the potential for hose failure and maximise the effective service life of the hose assembly. Poor design and installation standards is a predominate factor in determining effective service life.

To maximise effective hose service life a fluid power system design should consider:

a) external cover protection for hoses that may be exposed to abrasion or impact damage

b) shielding to protect hose assemblies from heat sources such as engine manifolds, exhausts, and turbochargers

c) protection from accidental damage caused by falling rock, vehicle collision, tensile load, shear load, crushing, fire

d) mechanical loads (e.g., vibration, tensile, shear)

e) protection from corrosive spillage, molten metal, and pressure surges

f) the susceptibility of end fittings to corrosion through water alkalinity / acidity / Coal (sulphur)

g) the impact of internally and externally generated heat on the hose assembly

h) hose life degradation (ref S-N studies) ACARP C17020

i) working fluid temperature, velocity, and contamination level.

j) 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:

   i. a sample of hose assemblies has been inspected and tested; and

   ii. an assessment based on service history and condition justifies an extended period.

3.7.2.4. Hose and hose assembly shelf life and storage

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

a) Implementing an age control system to ensure hose assemblies are used before shelf-life expiry.

b) Storing hose and hose assemblies according to iso 8331.

c) Keeping storage areas cool, dark, and free of dust, dirt, dampness, and mildew.

Note: There are many factors that can adversely affect hose and hose assembly integrity. These may include temperature, humidity, ozone, sunlight, ultraviolet light, oils, solvents, corrosive liquids, fumes, acids and alkalis, insects, rodents, sharp edges, abrasive surfaces, electric or strong magnetic fields, mould and fungi, and radioactive materials.

d) limiting the storage life of tested hose assemblies to 2 years from inspection (refer to SAE J1273 clause 9.1.c)

e) Hose assembly stored for more than 2 years, should be visually inspected and proof tested or follow manufacturer's recommendations.

f) Hoses should be proof tested and then re-proof-tested 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.

3.7.3. Premature failure of hose assemblies

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

Control measures for the risks presented by such failures include:

a) routing hose assemblies to avoid abrasive situations

b) covering and protecting hose assemblies to avoid abrasion such as accumulation of abrasive debris on underground equipment

c) minimising stress on hose assemblies by:

  i. adhering to the manufacturers minimum bend radius (MBR)

  ii. following the non-flexible length (NFL) requirements adjacent to the hose ends

  iii. clamping the hose and use of directional hose ends to reduce torsional effects

  iv. understanding the effects of pressure loading on the hose assembly.

3.7.4. Identification markings on hose assemblies

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, description or unique identification number.

  iii. test certificate number and/or serial number, refer to section 3.7.10.4

  iv. date of assembly

v. maximum assembly working pressure

vi. for hose assemblies in high-risk areas and accessible to workers consider providing additional information as a warning, for example “Warning – fluid injection injury” or a symbol like one below in Figure 3.

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

Figure 3 - Example of warning symbols and signs

3.7.5. Hose ends

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.

Corrosion resistance measures should follow section 3.7.1.6 of this TRG.

Threads on all hose ends and adaptors should be mated so they cannot be mismatched. For example do not intermix BSPP ((G) parallel thread[5]) with BSPT((R) tapered thread).

Hose ends should not be reused unless recommended by the manufacturer for that application. Hose end, adaptor and flange designs should use recognised standards.

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

Hose connections used in an installation where they could work loose due to movement, vibration, rotation or similar and workers in the vicinity could be exposed to risks to health or safety, consider installing soft-seal or other high-performance connections.

Refer to Appendix H for hose end adaptor pressure ratings.

3.7.5.1. Staple type fittings

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

[5] ISO 228 -1 Pipe threads where pressure-tight joints are not made on the threads — Part 1: Dimensions, tolerances and designation and IOS 228-2 – Pipe threads where pressure-tight joints are not made on the threads Part 2: Verification by means of limit gauges

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

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

Typical staple connection failure modes and control measures are listed in Table 5.

Table 4 – Staple connection failure modes and control measures

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 allowing an uncontrolled release of fluid occurs.	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 occurs 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.

Staples are designed for single use application only, and should be replaced when hoses and components are replaced. Refer to Safety alert SA06-18 Longwall staple failures.

3.7.5.2. 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 due to the intended operating environment or removal and assembly.

3.7.5.3. Super staple type fittings

Appendix L has been included in this document to add clarity to some design aspects of 420 bar Super Staple Lock Fittings and Adapters.

3.7.6. Flexible hose assembly manufacture

The following principles apply to flexible hose assembly manufacture:

a) only competent people should perform hose assembly fabrication

b) hose assembly fabrication should use the hose and hose end manufacturer's assembly instructions

c) tolerance of overall hose lengths should be ±1%, unless otherwise specified

d) the complete hose assembly should be cleaned and flushed to remove cuttings/debris

e) any lubrication used during assembly should be compatible with the system the hose is being used in, or otherwise inert

f) an inspection and test plan (ITP) should be in place during all phases on hose assembly

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

3.7.6.1. Matched hose and hose fittings

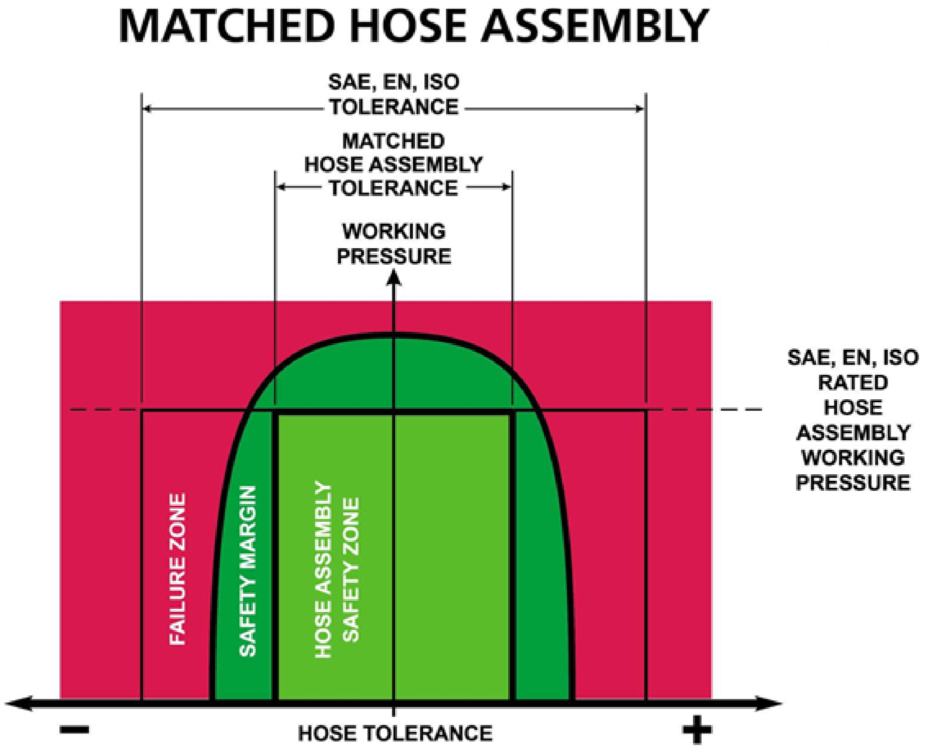
Matched means the hose dimensions and tolerances are compatible with the dimensions and tolerance of the fittings. This ensures the joint meets the impulse and burst requirements for the hose assembly. This is illustrated in Figure 4 below.

Using non-matched fittings on 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 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 standard 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 4 - Illustration of hose assembly safety margin



3.7.6.2. Procedures for hose assembly manufacture

The hose assembly should comprise componentry that results in a matched, reliable product once assembled. The hose assembly components should be assembled following 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 section 3.7.10.3

g) hydrostatic testing (where required), see section 3.7.10.1

h) quality plan.

3.7.7. Quality plan

Hoses and hose ends should be manufactured under a quality system certified to comply with ISO 9001, and include appropriate batch testing for conformance and records.

Completed hose assemblies should be certified and tested in accordance with section 3.7.10.1.

3.7.8. Competence

Workers fabricating hose assemblies should be trained and competent in the proper use of equipment, materials, assembly procedures and testing. Workers should be assessed in their competence in hose assembly and the results recorded.

3.7.9. Cleaning and packaging

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

Hose end connections should be sealed and capped to maintain cleanliness.

Hose assemblies should be packaged to protect the hose or fittings from damage during shipping, handling and storage.

3.7.10. Testing and certification of hose assemblies

3.7.10.1. Type testing of hose assemblies – dynamic cycle testing

The matched hose and hose ends should be dynamically type tested at the impulse pressure and to the number of test cycles specified by the hose 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. Testing should be carried out using 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, a competent person should consider type testing the hose assembly using ISO 6802, 'hydraulic impulse test with flexing' to minimum bend radius, for 80,000 cycles at 120% of the working pressure. See Appendix F.

3.7.10.2. Individual hose assembly proof testing

Proof testing a hose assembly identifies any assembly related errors which may cause it to fail prematurely in the operating environment.

All hose assemblies associated with high risk as defined by risk assessment should be proof tested at two times the maximum working pressure.

Where required, hose assemblies should be tested following ISO 6605 or SAE J343 or AS 1180.5.

The test pressure should be held for a period of 30 to 60 seconds and show no signs of leakage or failure.

Proof testing should be conducted using compatible fluid rather than compressed gases. Polytetrafluoroethylene type hose should be tested with water only.

3.7.10.3. Visual Inspection of hose assembly (before despatch)

Hose manufacturers should visually inspect all hose assemblies before dispatch and record these inspections. This will verify:

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, and free from rust

d) the assembled hose corresponds to the customer order

e) the assembled hose is free from contaminants, the hose ends are capped and plugged, and the hose is packed correctly for transport. Caps/plugs should be non-metallic.

Where practical, the person visually inspecting the hose should be different to the person who assembled the hose.

3.7.10.4. Individual hose assembly test documentation

Hose manufacturers should create and file uniquely identifiable hose assembly test certificates for all assemblies. These need to be available upon request.

Test certificates should include the following information:

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 consists of matched hose and hose ends

l) hose end information and check for correct matching of hose ends to hose

m) test pressure

n) outcomes of test pass/fail

o) signature of person doing the inspection.

3.7.10.5. Batch certificate of conformance

The manufacturer should issue a certificate of conformance. This document is to be made available on request.

The certificate of conformance should include the following information:

a) customer's name, address, purchase order, contact details

b) specification, drawings, part number and standards for the assembly

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.

3.7.11. Tagging

Tagging is one method to assist in managing individual hose assembly reliability. Where using a tagging system, consider 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 hose assemblies may be achieved using an electronic system such as RFID (radio frequency identification) or a barcode system. The tag information should be consistent with the data in the register

c) verify that the tag or its fixing does not promote a local corrosion site, or result in chafing or cutting of 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 section 7.5.

3.7.12. Hose assembly installation

Hose assemblies should be installed in accordance with ISO/TS 17165-2 or SAE J1273 and:

a) be secure and be adequately supported

b) be supported so 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 [6]for guidance on mobile equipment

e) be routed to prevent encountering 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 for the intended movement, considering Minimum Bend Radius and Non-Flexible Length

i) be fitted with a hose energy diffusion device, if required

j) be restrained near workers to eliminate whipping of a blown hose assembly

k) not be positioned where stone, coal or mud is likely to build up and cause abrasion

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[6] www.resources.nsw.gov.au/sites/default/files/documents/mdg-15-guideline-for-mobile-and-transportable-plant-for-use-at-mines-other-than-underground-coal-mines-2020-version.pdf

l) not be subject to shock, or surge pressures which exceed the manufacturer's recommendations

m) have a length necessary to avoid the hose assembly sharply flexing and straining 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 jammed fitting)

p) be located to protect against and minimise abrasive rubbing on the hose cover

q) be cleaned during manufacture and before installation

r) the date installed and/or machine hours should be recorded.

3.7.13. External loads

Hose assemblies should be installed in a way that minimises external mechanical loads such as flexing, twisting, kinking, tensile or side loads, bend radius and vibration (amplitude and frequency).

Swivel type fittings or adapters should be used to minimise the twist put into hose assemblies. In some applications live swivels may be necessary (e.g. 2 rotating components).

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

3.7.14. Hose assembly length

Hose lengths vary due to motion, pressure variations and equipment tolerances. Hoses that are too short stress hose ends and induce premature failure. Designs should clearly identify hose routes, lengths and supports. 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.

3.7.15. Competence of hose assemblers and installers

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

a) safe working practices, 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 measures

i) hose end fittings and coupling identification

j) fluid compatibility

k) hose assembly installation/routing

l) hose assembly mechanical loads

m) physical damage to hose and hose end couplings

n) when to change a hose assembly

o) hose assembly and fitment product application methods and benefits (e.g., anti-seize)

p) seals and seal replacement

q) sealing or seating face damage

r) importance of environment conditions.

3.8. Pressure equipment

All pressure vessels, including accumulators, should be designed, inspected, maintained, and operated in alignment 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/NZS 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 at the lowest point of all air receivers. This line and valve should be suitably protected against damage during transport.

3.8.1. Registration of pressure equipment

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

a) 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 4343:2014 (Pressure equipment — hazard levels)

b) gas cylinders covered by Section 1.1 of AS 2030.1:2009 (Gas cylinders — general requirements)

c) except:

i. 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).

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

a) pressure vessels categorised as hazard level A, B or C according to the criteria in Section 2.1 of AS 4343:2014 (Pressure equipment – hazard levels)

b) except:

i. gas cylinders, and

ii. LP gas fuel vessels for automotive use, and

iii. serially produced vessels

iv. 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).

3.8.2. Hydraulic accumulators

The following information has been developed in response to investigations into 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 use minimal length adapters and for mobile plant, flexible hose

c) fittings should be located or otherwise guarded to protect against mechanical damage that may occur during operation or maintenance (e.g. falling object damage or stepping onto components during maintenance)

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) gas charged accumulators should include a means for service personnel to relieve gas pressure safely

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 follow AS 2671 and be registered if their capacity exceeds 4 litres

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

i) accumulators should be installed in a way that adequately protects workers. Accumulators should be protected against damage and uncontrolled release of energy

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

k) warning signs to identify accumulators in the hydraulic system and depressurisation before maintenance work should be installed. These should 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 designer's specifications and should consider the following:

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) material specifications

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 are considered a design change in which designers' obligations apply.

4.2. Installation at mines

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

Fluid power systems should be installed or reassembled using the designer's/manufacturer's installation/assembly documentation. This 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:

   i. exposure to dangerous areas before installing guards and whip restraints

   ii. interaction with workers

   iii. interaction with other plant (e.g., connected services and installations)

iv. any special tools, jigs, fixtures, or appliances necessary to minimise injury risk
v. any environmental factors affecting installation
vi. when a risk assessment is required
vii. tasks which require an installation procedure or safe work method statement (SWMS)
viii. the scope of required worker competencies relating to tasks
ix. training requirements before or during installation
x. change management, auditing, and review requirements.

4.2.1. 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) required competencies for safe task completion
e) required tools and equipment
f) group isolation if applicable.

4.2.1.1. Procedure input

The installation procedure should be prepared using:

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 obtained through consultation with workers
f) other site-specific requirements.

4.2.1.2. 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) any identified hazards create a risk to health and safety of workers and equipment
c) the task is complex
d) a task is done infrequently
e) an accident or incident occurs
f) there is a change in the environment or application
g) workers make relevant recommendations
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 used (e.g. 5 × 5, Job Safety Map, JSA, and similar).

4.2.1.3. Procedure standard

The installation procedure should comply with:

a) the mine site standards

b) the fluid power system design specifications

c) the manufacturer's installation standards.

4.2.2. Communications/consultations

Before the installation of a fluid power system, workers should be consulted 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 (e.g., no standing zones, PPE, set down areas for the equipment, specific isolation procedures, emergency stop locations)

d) emergency response, including fluid injection response

e) supervision

f) required competencies

g) change management procedures (e.g., updating of drawings, designs, specifications, training, procedures and similar)

h) debrief meetings to review processes and identify areas for improvement.

Workers should have the ability to suggest improvements to the system and procedures. See section 2.2 regarding consultation.

4.2.3. 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 using the design documentation and complies with site standards (e.g., 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 of the installer of the system

e) raise a non-conformance report (NCR) where defects or non-conformances are identified.

4.2.4. Installation records

'As built' installation records should be maintained, and the relevant drawings and manuals updated. These records should be kept in the mining operations plant safety file.

4.3. Longwall installations – underground coal mines

Longwall pre-installations or relocations in underground coal mines should consider:

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 of roof supports during recovery and installation

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

g) the removal of entrapped air before powering leg cylinders or other actuators (e.g. operating a ram a few times before raising the leg cylinder)

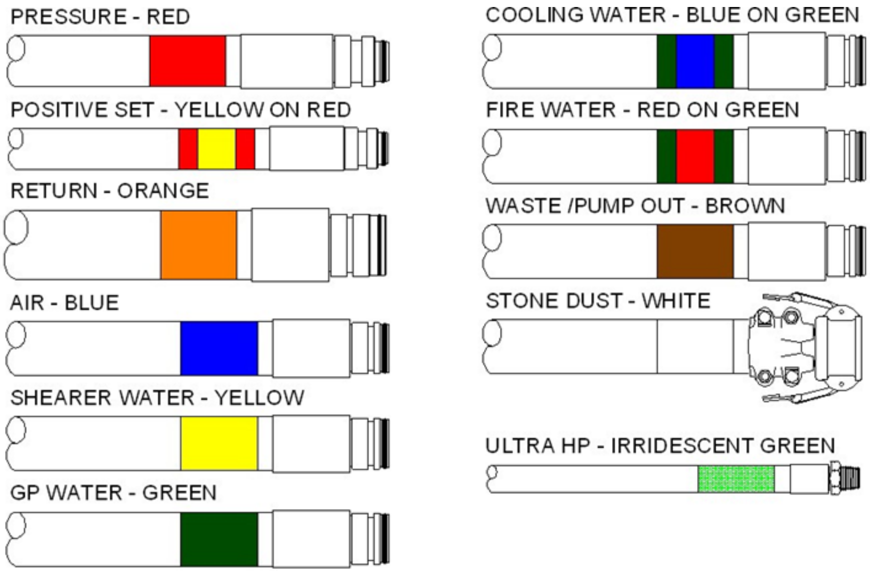
h) how the temporary pump station and hydraulics should be installed

i) failure modes for hydraulic actuators should be such that they will not add risk to the work area (e.g., 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).

Longwalls have many hoses of different pressure ratings and functions. This carries a risk of error (e.g. low pressure hose is fitted where a high pressure hose is required). There may be an inability to read hose pressure ratings that are covered by diffusion sleeves. Preference should be given to using a consistent colour code on hose ends.

Longwall hose assemblies and/or pipes should be marked using the following designations to indicate distribution circuits as listed and illustrated in Figure 5 below.

Figure 5 - 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

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

Fluid power systems should be commissioned using the designer's documentation and AS 2671, AS 2788 and AS 4041 as applicable.

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

5.1. Commissioning plan

The mine operator should develop a commissioning plan that considers:

a) potential hazards and risks associate with commissioning the fluid power system:
   i. exposure to dangerous areas before installing guards and 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) the commissioning procedure follows specific requirements of the designer, manufacturer, and any site-specific requirements

c) initially commissioning 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 testing to prove the correct operation and installation of all safety devices

e) verifying all air is expelled prior to pressure testing (refer to OEM recommendations)

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

g) establishing a testing schedule to check, test and operate all functions in a safe manner and considers any required electrical commissioning checks

h) documenting the results of commissioning checks

i) a system to indicate when commissioning is complete, and the system is ready for normal operation.

5.1.1. Commissioning criteria

Commissioning should test the installation against the design specifications. Commissioning criteria should be quantifiable and have set pass/fail limits for each test.

Commissioning criteria compares the system performance 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 (e.g., number of operations from an accumulator)

d) control device functionality and operability

e) emergency stop, machine stop, and hydraulic 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 (e.g., wear points, hose bend radius, movement range)

i) software functionality

j) protection devices settings and alarms as applicable

k) fluid leakage and bypass 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).

5.1.2. Commissioning procedures

Mine operators should include commissioning procedures within the commissioning plan.

Mine operators should consult all relevant stakeholders to determine the commissioning sequence. These include designers, mechanical, electrical, and operational departments.

The commissioning procedure or checklist should identify areas 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.

5.1.3. 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.

5.1.4. Decommissioning of fluid power systems for further use

Mine operators should plan for decommissioning and consider 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) the release of retained pressure

d) potential for pressure intensification and fitment of appropriate safeguards

e) safe disassembly procedure for 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. Fluid power system operation

6.1. Selection of hydraulic systems and componentry

It is important to identify all hazards and implement control measures for fluid power systems used at the mining operation. (Refer to section 2). The characteristics of any hydraulic systems or components should be fully understood to ensure worker safety.

Information provided with the design regarding criteria of use, and the specification for the system and componentry should be implemented at the mine site. To minimise the risk to workers, mine operators should consider identification of modes of failure, maximisation of reliability and performance of the systems and provision of adequate barriers to hazards.

6.2. Procedures

6.2.1. Operational procedures

Mine operators should develop site specific operational procedures 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 limit envelope

d) the operational functions and expected response to controls

e) normal operational conditions such as pressures, temperatures, flows, actuator positions, etc.

f) any environmental conditions which would affect the operation of the fluid power system

g) site procedure for storage and handling of hydraulic fluid.

6.2.2. Emergency procedures

Emergency preparedness is an essential part of working with fluid systems and should form part of the emergency management plan.

Mine operators should develop emergency response procedures, including 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 to the fluid injection protocol in Appendix N).

Note: Do not delay or treat fluid injection injuries as a simple cut. They will usually require urgent specialist treatment.

6.3. Defects

Defects identified during operation should be reported and dealt with using 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.

6.4. Operator competence

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 the energy isolation process, for hazardous activity isolation
f) understanding the hazards associated with working near fluid power systems.

6.5. Prestart and operational inspections

Pre-start and operational checks and inspections should be carried out on a regular basis using 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

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

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

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

Refer to the MECP code of practice for further guidance.

7.1. General

7.1.1. Competence

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

Some relevant competencies include:

- MEM27017 - Maintain, fault find and rectify hydraulic systems for mobile plant
- MEM40119-03 – Certificate IV in Engineering (Fluid Power)
- AURTTA113 - Diagnose and 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 using the mine's 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 required on large and complex fluid power systems such as longwall roof supports.

7.1.2. Inspection, maintenance, and repair procedures

Mine operators should implement safe work systems for routine activities such as fluid sampling, component testing, inspections, etc. A risk assessment for all abnormal maintenance activities and a safe work method statement (SWMS) should be 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 MEM18021 Maintain hydraulic Systems, and Appendix M Hydraulic Safety Information for Workers for further guidance.

7.1.3. Inspection and maintenance

Mine operators should periodically inspect and develop, implement and update maintenance schedules following:

a) the designer's/manufacturer's recommendations

b) consultation with site workers

c) lifecycles

d) the mine operator's maintenance strategy.

These schedules should include the inspection of hose assembly condition with consideration to section 3.7.2, 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.

A typical model for safely performing maintenance includes (refer to Figure 6 below):

ALWAYS

a) isolate

i. the correct valve

ii. the power supply

a. lock

iii. the isolation valve in the closed position

iv. with personal locks at the isolation point

b) depressurise the energy source

c) lock the bleed valve in the open position

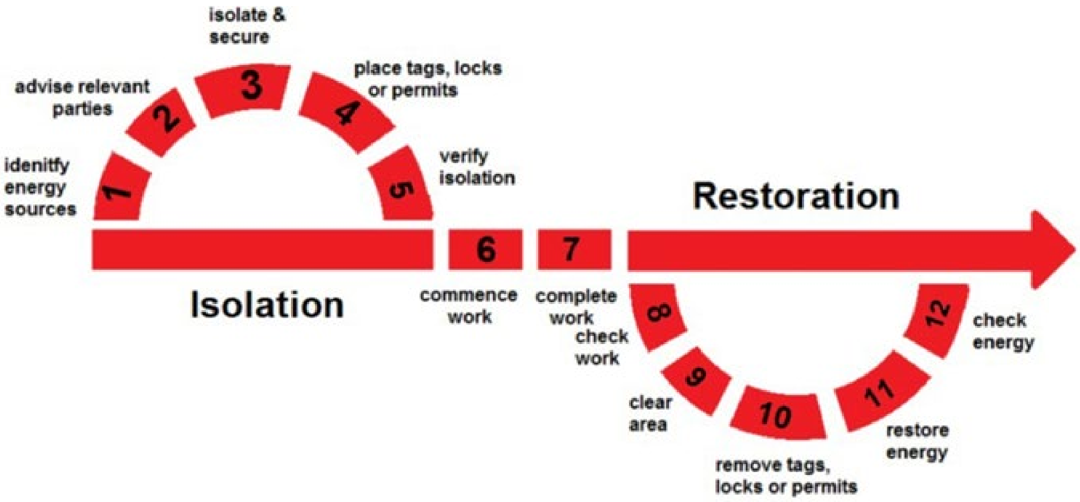
d) verify effective isolation (test for dead)

v. prove that the line is depressurised

vi. check the gauge is at zero

vii. check fluid no longer passes through the bleed valve.

Figure 6 - Isolation and restoration for maintenance



For safety information for workers see Appendix M

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), in the event of a component being pressurised. Safeguards include plastic caps, or breathers. Fatalities have occurred because the component has been supplied with steel caps allowing pressure to intensify in the component.

7.1.6. Filtration

Fluid power system filtration and filter element replacement and testing of filtration components should be considered in the maintenance schedule. Mine operators should consider 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 the pilot control system to verify the oil is filtered to the correct cleanliness and does not induce excessive back pressures.

At no stage should a 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. Pipe threads should be capable of withstanding the pressure in the system.

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

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

Mine operators should have an energy isolation management plan in place. This plan will include:

a) an energy isolation process used for the de-energisation of all energies

b) an assessment process for workers who need to demonstrate isolation 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.

7.3. Repairs and defects

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 (e.g. correct micron rating on the filters, correct pressure rating, correct durometer hardness and size tolerances and material for O-Rings, etc.)

When replacing components, they should be kept clean and not damaged. Following repairs, the functionality of the system should be verified.

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

7.3.1. Recommissioning after repairs

Following repairs, a recommissioned system should be inspected and verified as being in an operable state (e.g., hoses not connected, ports left open, connections tight).

Worker access to areas where fluid power systems are being re-energised after repairs should be restricted until system integrity is confirmed. If practical, re-energisation should be carried out at a low pressure to minimise risk and verify system integrity.

7.3.2. Temporary repairs

All fluid power system repairs should be carried out by competent people.

Where temporary repairs are carried out to allow continued operation, the need for permanent repairs should be recorded and scheduled for a later maintenance shift. For example, if a 1 metre hose fails during operation and a 3 metre hose is used for its temporary replacement, the correct hose should be installed and correctly routed at a later maintenance shift.

Temporary repairs should be documented and recorded in the site maintenance management system against the relevant 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) relevant records
d) required competencies and their currency.

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

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 and implemented. The hose management program should be established and maintained in consultation with all stakeholders, including site management, maintenance teams, and suppliers. The hose management program should be integral with the mines maintenance system and site-specific maintenance strategies.

A hose management program will reduce equipment downtime, maintain peak operating performance, and reduce the risk of worker 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) the requirement that discarded hose assemblies or hoses with no known history (e.g., longwall, monorail, AFC/BSL hoses) not be reinstalled unless tested and certified. If reinstalled, these hoses should be 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.

7.6.1. Hose failure modes

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

Table 6 below shows hose assemblies are typically discarded by either of the following 2 mechanisms:

Table 6: Mechanisms for discarding hose assemblies

Mechanism	Failure modes
a. **Inspection and assessment to discard**	1. excessive mechanical damage (such as abrasion, cuts, crushing etc.), 2. corrosion (of both fittings and hose wire reinforcement) 3. Degradation (age, chemical, cracking, overheating, fatigue etc)
b. **Catastrophic in-service failure**	4. leakage 5. burst 6. hose/hose end separation 7. pinholes

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

7.6.2. Hose inspections

A competent person should periodically inspect all hose assemblies and adaptors in accordance with the mine's maintenance plan. This will keep the system in a safe operating condition. Where hose assemblies show evidence of damage or leakage from hose end fittings, steps should be taken to determine the suitability for continued use.

Hoses should be tested/inspected in-situ 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 worker safety if failure occurs.

7.6.2.1. 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.

7.6.2.2. Hose discard criteria

Hose assemblies should be replaced when they are damaged and no longer fit for purpose or do not offer the desired level of safety.

Mine operators should establish discard criteria in consultation with suppliers. Refer to Appendix E Hose failure and discard criteria for further guidance.

7.6.2.3. 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.

7.6.2.4. 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 workers when the hose fails, the effective service life (refer to section 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 5 years, but less than 8 years,) they should be replaced, unless:

a) a sample of hose assemblies has been inspected and tested; and

b) an assessment based on service history and condition justifies an extended service period.

Mine operators should consider at what point in time is it better to replace all hoses at once rather than replace individual hose, based on the age, and the expected residual service life of the remaining hoses.

Replacement hose assembly should follow the manufacturers specifications, or in the absence of these at least rated to or greater than the maximum system pressure.

Maintenance issues to consider include:

a) using correct hose design and material for the replacement hose

b) using correct fitting configuration for the duty and use of matched hose and fittings

c) maintaining proper cleanliness before and during installation

d) using adequately sized hose for the duty

e) using the correct length of hose to minimise tension forces

f) verifying the minimum bend radius of the hose is not exceeded

g) ensuring that no twisting remains in the installed hoses

h) securing of hose assemblies as per the design documentation using the correct mounting points

i) protecting hoses from impact or abrasion damage while in service

j) verifying staple type fittings are not being dislodged during in-service use

k) using system health monitoring techniques to determine cyclic fatigue life

l) managing the lifecycle of hose and fittings.

8. Decommissioning, dismantling and disposal

Where a fluid power 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 power systems include:

a) environment (underground and/or surface)

b) pressure intensification

c) cleanliness of the hydraulic system, if the system is to be recommissioned

d) fluid storage

e) corrosion protection (if the system is to be recommissioned)

f) handling during and after storage, including associated equipment

g) long term care and maintenance

h) disposal procedures

i) potential use of storage fluids.

j) decommissioning fluid power systems for disposal.

Where a fluid power system is to be decommissioned and disposed the following should be considered:

a) the potential future usage of the plant

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) the potential for pressure intensification and fitment of appropriate safeguards

e) safe disassembly procedures for the plant structures including effects on stability and movement of components

f) safe disposal and recycling of fluids retained in the fluid power system

g) 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. References

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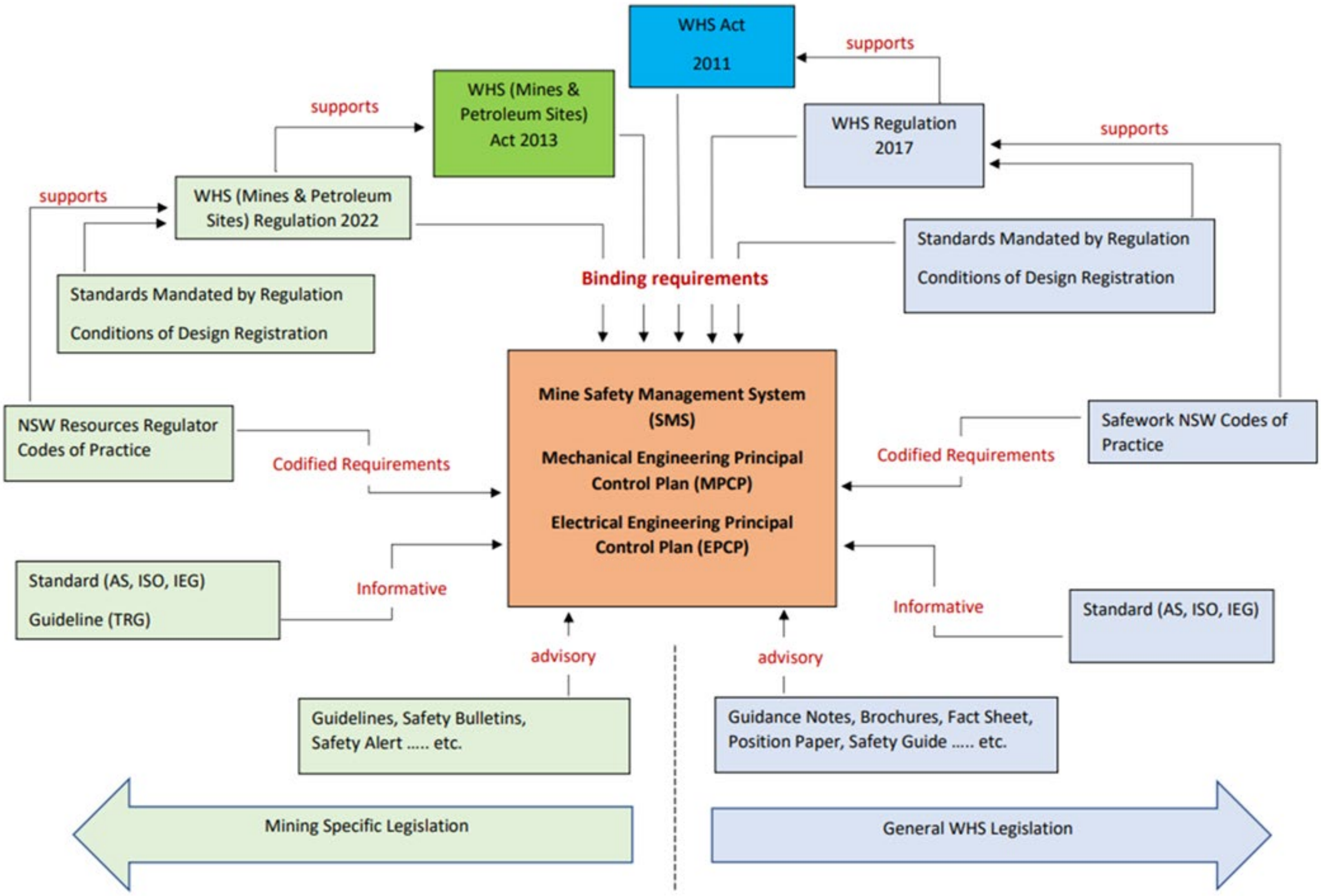
Appendix A – Schematic of guidelines and legislation

Appendix A Figure 1: Schematic of guidelines and legislation



Appendix B – Relevant standards and documents

Appendix B Table 1: Australian and/or New Zealand Standards

Abbreviation of standard	Title of standards – AS or AS/NZS
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 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 2554-1998: Hose and hose assemblies for air
AS 2671	AS 2671:2021: 1Hydraulic fluid power - General rules and safety requirements for systems and their components (ISO 4413:2010, MOD)
AS 2788	AS 2788:2021: Pneumatic fluid power - General rules and safety requirements for systems and their components (ISO 4414:2010, MOD)
AS 2971	AS 2971-2007: Serially produced pressure vessels
AS/NZS 3788	AS/NZS 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/NZS 4024.1:2019 Series: Safety of Machinery
AS/NZS 4024.1302	AS/NZS 4024.1302:2019: Safety of machinery, Part 1302: 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: Safety of machinery, Part 1501: Design of safety related parts of control systems - General principles for design
AS 4024.1502	AS 4024.1502-2006: Safety of machinery, Part 1502: Design of safety related parts of control systems – Validation

Abbreviation of standard	Title of standards – AS or AS/NZS
AS/NZS 4024.1503	AS/NZS 4024.1503:2014: Safety of machinery, Part 1503: Safety-related parts of control systems – General principles for design
AS/NZS 4024.1906	AS/NZS 4024.1906:2014: Safety of machinery, Part 1906: 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, Part 1201: General principles for design - Risk assessment and risk reduction
AS/NZS 4024:1303	AS/NZS 4024.1303:2014: Safety of machinery, Part 1303: 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 ISO 31000	AS ISO 31000:2018: Risk management - Guidelines
AS 61508.1	AS 61508.1-2011: Functional safety of electrical/electronic/programmable electronic safety-related systems, Part 1: General requirements
AS/NZS 62061	AS/NZS 62061:2019: Safety of machinery - Functional safety of safety-related electrical, electronic, and programmable electronic control systems (IEC 62061:2005+AMD1:2012+AMD2:2015 CSV (ED.1.2)/COR1:2015 MOD)

Appendix B Table 2: DIN Standards

Reference to DIN standards	
DIN 20043	DIN 20043:2003-09: *Staple-Lock Couplings for Hydraulic Power-Transmission Circuits*
DIN EN 853	DIN EN 853 Rubber hoses and hose assemblies - Wire braid reinforced hydraulic type - Specification
DIN EN 854	DIN EN 854 Rubber hoses and hose assemblies - Textile reinforced hydraulic type - Specification
DIN EN 856	DIN EN 856 Rubber hoses and hose assemblies - Rubber-covered spiral wire reinforced hydraulic type - Specification

Reference to DIN standards	
DIN EN 857	DIN EN 857 Rubber hoses and hose assemblies - Wire braid reinforced compact type for hydraulic applications - Specification

Appendix B Table 3: IOS Standards

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 1436:2020: Rubber hoses and hose assemblies – Wire-braid-reinforced hydraulic types for oil-based or water-based fluids – Specification
ISO 228 -1	ISO 228 -1 Pipe threads where pressure-tight joints are not made on the threads — Part 1: Dimensions, tolerances and designation
IS0 228-2	IS0 228-2 – Pipe threads where pressure-tight joints are not made on the threads Part 2: Verification by means of limit gauges
ISO 286-1	ISO 286:2010: Geometric product specifications – ISO code system for tolerance on linear sizes – Basis of tolerances, deviations and fits
ISO 3457	ISO 3457:2003: Earth-moving machinery – Guards – Definitions and requirements
ISO 3862	ISO 3862:2017: Rubber hoses and hose assemblies – Rubber covered spiral-wire-reinforced hydraulic types for oil-based or water-based fluids – Specification
ISO 4079	ISO 4079:2020: Rubber hoses and hose assemblies – Textile-reinforced hydraulic types for oil- based or water-based fluids - Specification
ISO 4406	ISO 4406:2021: Hydraulic fluid power - Fluids - Method for coding the level of contamination by solid particles
ISO 4520	ISO 4520:1981: Chromate conversion coatings on electroplated zinc and cadmium coatings
ISO 6605	ISO 6605:2017: Hydraulic fluid power –Test methods for hoses and hose assemblies
ISO 6802	ISO 6802:2018: Rubber or plastics hoses and hose assemblies – Hydraulic impulse test with flexing
ISO 6803	ISO 6803:2017: Rubber or plastics hoses and hose assemblies – Hydraulic-pressure impulse test without flexing
ISO 6805	ISO 6805:2020: Rubber hoses and hose assemblies for underground mining - Wire-reinforced hydraulic types for coal mining - Specification

Reference to ISO Standards	
ISO 6954	ISO 6954 Rubber hoses — Determination of abrasion resistance of the outer cove
ISO 7751	ISO 7751:2016: Rubber and plastics hoses and hose assemblies - Ratios of proof and burst pressure to maximum working pressure
ISO 8030	ISO 8030:2014: Rubber and plastics hoses – Method of test for flammability
ISO 8031	ISO 8031:2020: Rubber and plastics hoses and hose assemblies - Determination of electrical resistance and conductivity
ISO 8331	ISO 8331:2016: 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 11237:2017: 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 16889:2022: 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 17165-2:2018: Hydraulic fluid power - Hose assemblies - Part 2: Practices for hydraulic hose assemblies
ISO 18752	ISO 18752:2022: Rubber hoses and hose assemblies - Wire- or textile-reinforced single- pressure types for hydraulic applications - Specification

Appendix B Table 4: SAE Standards

Reference to SA/SNZ standards	
SA/SNZ HB 89	SA/SNZ HB 89:2013: Risk management – Guidelines on risk assessment techniques
SAE AS 1339J	SAE Aerospace Standard (AS 1339J), Hose Assembly, Polytetrafluoroethylene, Metallic Reinforced, 3000 psi, 400° F, Lightweight, Hydraulic and Pneumatic.
SAE J343	Test and Test Procedures for SAE 100R Series Hydraulic Hose and Hose Assemblies J343_201712
SAE J517	Hydraulic Hose J517_202007

Reference to SA/SNZ standards	
SAE J1065	Nominal Reference Working Pressures for Steel Hydraulic Tubing J1065_202207
SAE J1273	Recommended Practices for Hydraulic Hose Assemblies J1273_202110
SAE J1467	Clip Fastener Fitting J1467_201808
SAE J1927	Cumulative Damage Analysis for Hydraulic Hose Assemblies J1927_201406
SAE J2006	Marine Exhaust Hose J2006_201302

Appendix B Table 5: Australian coal research projects

References to Australian coal research projects	
ACARP C17020	The Australian Coal Industry's Research Project Stage Two: Performance Based Specifications for Longwall Hose Assemblies

Appendix B Table 6: Codes of practice and Technical Reference Guides

Reference to MDGs, Technical Reference Guides (TRGs) and Codes of Practice	
MDG 15	Mobile and transportable plant for use on mines and petroleum sites
TRG 3608	Non-metallic materials for use in underground coal mines and reclaim tunnels in coal mines
RR code of practice	Managing the risks of plant in the workplace
RR code of practice	Safety management systems in mines
RR code of practice	Mechanical engineering control plan
RR code of practice	Electrical engineering control plan
SafeWork code of practice	Work health and safety consultation, cooperation and coordination
RR Guide	Preparing a principal hazard management plan
RR Guide	Contractors and other businesses at mines and petroleum sites
RR Factsheet	Consulting workers

Appendix C – Safety publications

Safety alerts and safety bulletins

Published safety alerts (SA) and safety bulletins (SB) relating to fluid power systems include:

SB24-06	Incidents involving pressurised systems increase
SB19-04	Workers injured by high pressure fluid
SA16-07	Operator suffers broken arm while operating high pressure hose
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	Contractor fatally injured by high pressure hydraulic equipment
SA06-06	Diesel engine system running on atomised hydraulic oil
SA05-15	Dangerous uncontrolled release of hydraulic energy
SA05-13	Stored Energy

Fluid injection incidents

SA18-03	Two workers suffer serious high pressure fluid injuries in separate cleaning incidents
SA06-18	Longwall staple failures
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
SA98-08	Operator of Integrated tool carrier injected with hydraulic oil
SB13-01	Fluid injections result in surgery
SB12-03	Fluid power isolation failures

Other incidents

SB24-09	Safety critical system failures – steering
SB24-02	LHD crowd cylinder failures
SB23-04	Hose ball valves injure mine workers
SB22-06	Pipe clamp failures
SA15-08	Worker seriously injured when pipe assembly failed pressure test

The above safety alerts and bulletins are accessible by searching www.resourcesregulator.nsw.gov.au/safety/safety-resources/safety-alerts-and-bulletins

Appendix D – 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:

a) hose ID size

b) desired flow rate, or

c) recommended flow velocity.

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

a) pick the two known values

b) lay a straightedge to intersect the two values

c) intersection on the third vertical line gives the value of that factor.

Example:

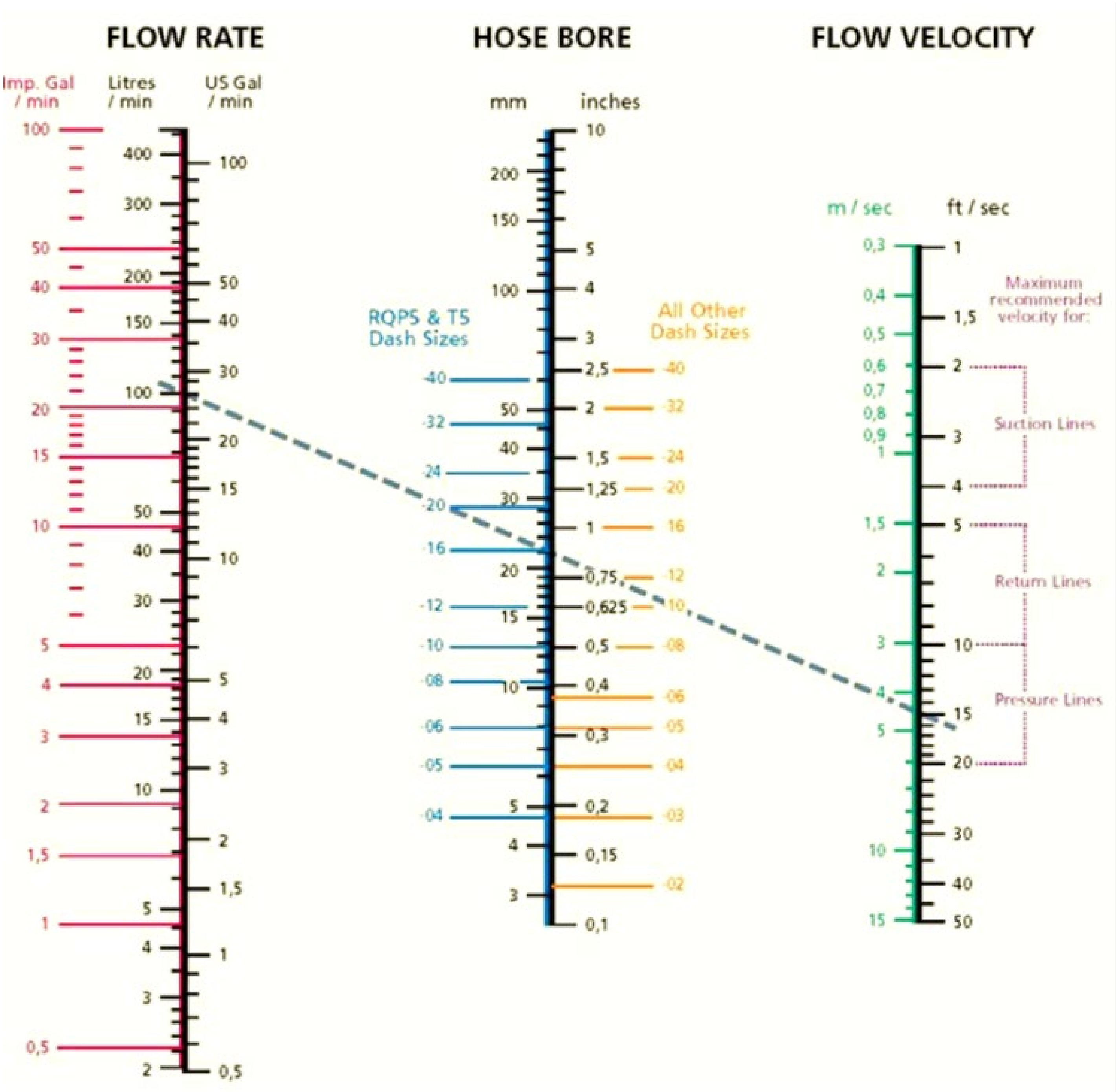
To find the bore size for a pressure line consistent with a flow rate of 100 litres per minute (26 US or 22 Imperial gallons per minute), and a flow velocity of 4.5 metres per second (14.8 feet per second), connect flow rate to flow velocity and read hose bore on centre scale.

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.

See a fluid nomograph in Appendix D Figure 1 below

Appendix D – Figure 1: Fluid nomograph



Appendix E – Hose failure and discard criteria

Appendix E Table 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 Appendix I, Fig 1)
Outer sheath wear	• too sharp bends (see Appendix I, Fig 1) • inadequate abrasion protection • incorrect material selection
Fitting failure	• overload – pressure • overload – mechanical • incorrect material selection • general wear and age - maturity • fatigue and cyclic loading • leakage
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 (ozone, UV)
Delamination of inner hose	• excessive vacuum conditions • prolonged vacuum conditions • material degradation • incorrectly selected hose causing too high a fluid velocity

Failure mode	Possible causes
Fatigue failure of reinforcing mesh	• cyclic/random bending of hose • cyclic/random pressure changes
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

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 (e.g., broken, twisting, cracked or “walking out”)

s. other sign of deterioration

t. hose exceeding shelf life before installation

u. hose exceeding design service life

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

Analysing hose installation failures

A physical examination of the failed hose can often offer a clue to the cause of the failure. Table 13 shows symptoms to look for along with the conditions that could cause them.

Appendix E Table 2:Symptoms of hose installation failure

Symptom	Cause
The hose is very hard and has cracked.	Heat tends 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 accelerate the hardening of the hose tube. Cavitation occurring inside the tube would have the same effect.
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.
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 using section 3.8.11.
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 indicates 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.
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: • abrasion • cutting • battery acid • steam cleaners • chemical cleaning solutions • muriatic acid • salt water • heat; or • extreme cold.

Symptom	Cause
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.
Hose is flattened out in one or two areas and appears to be kinked. It burst in this area and appears twisted.	Torquing 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.
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.
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.
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.
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.
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.

Symptom	Cause
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 time.
The spiral-reinforced hose has burst and 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.
The hose fitting has been pulled out of the hose. The hose has been 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.

Appendix F – Good practice for hose installation

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

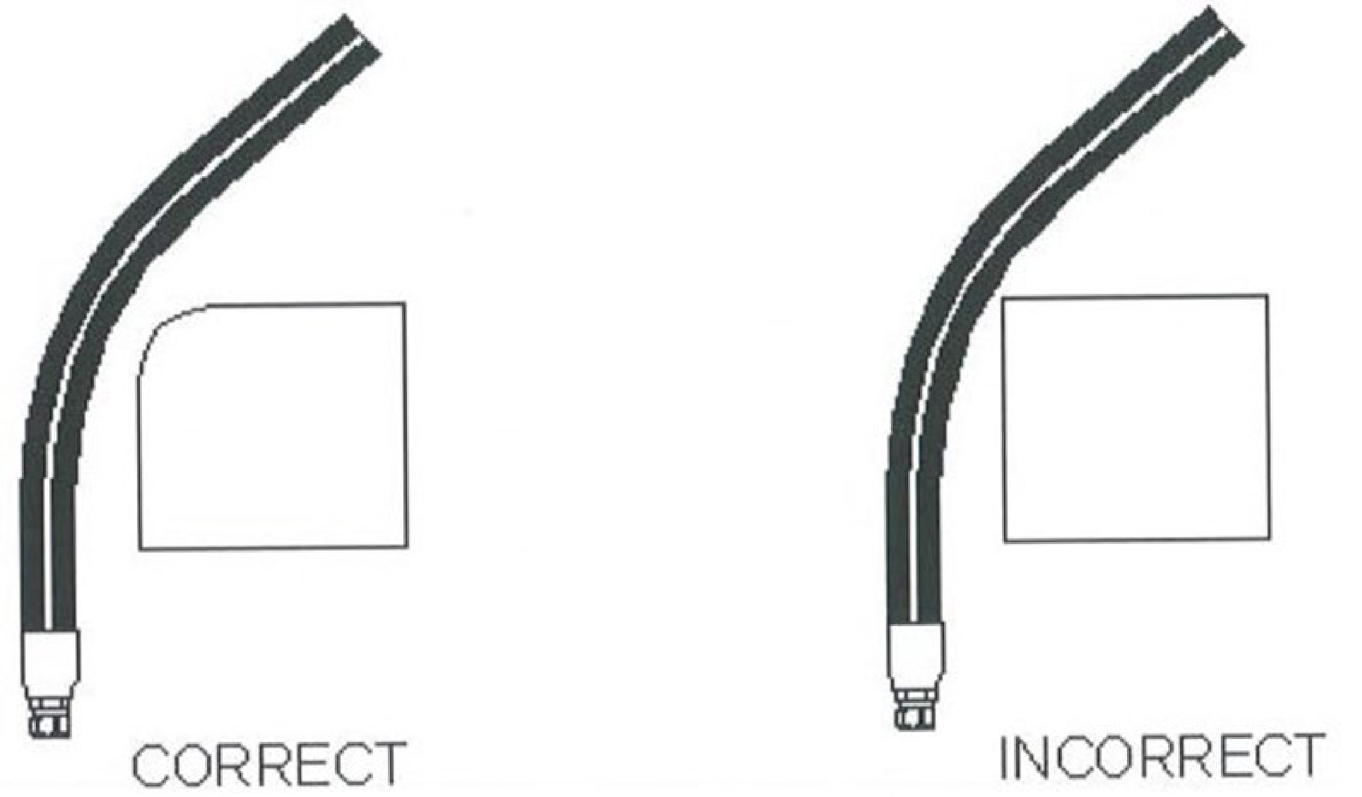
Proper hose installation is essential for satisfactory performance. If the hose length is excessive, the appearance of the installation will be unsatisfactory and there will be unnecessary cost involved. If hose assemblies are too short to permit adequate flexing and changes in length due to expansion 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 the length changes, which will occur when pressure is applied.

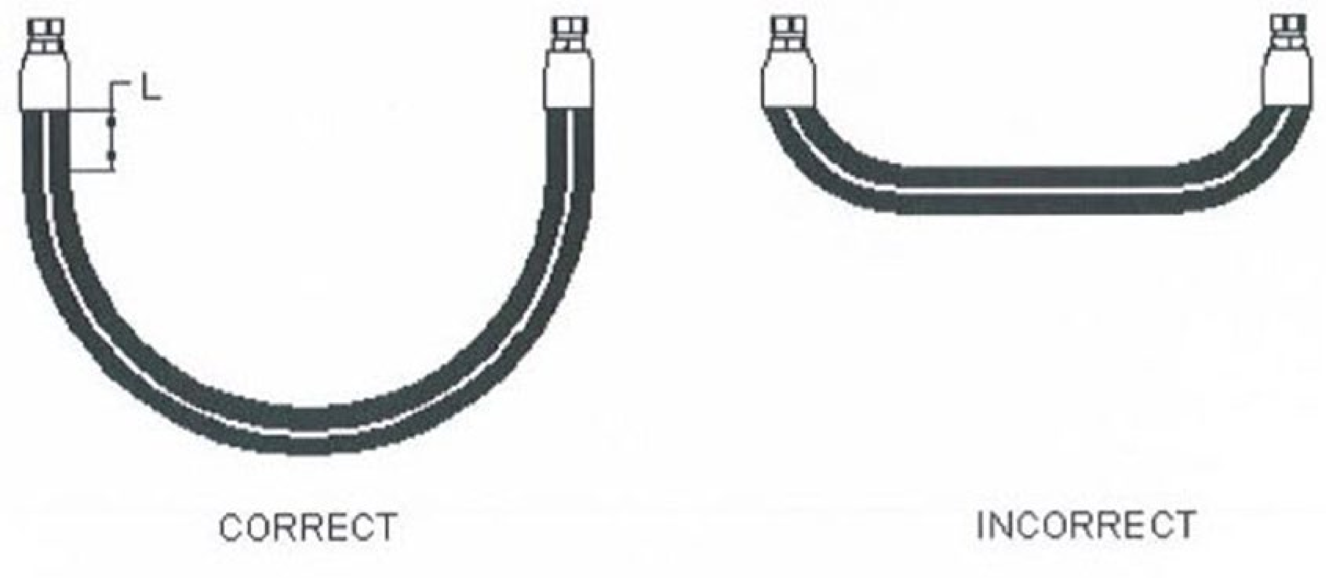
Protect the hose cover from abrasion, erosion, snagging and cutting. Special abrasion-resistant hoses and hose guards are available for additional protection. Route the hose to reduce abrasion from hose rubbing other hoses or objects that may abrade it. (See Appendix F - Figure 1).

Appendix F - Figure 1 - Prevention of external damage

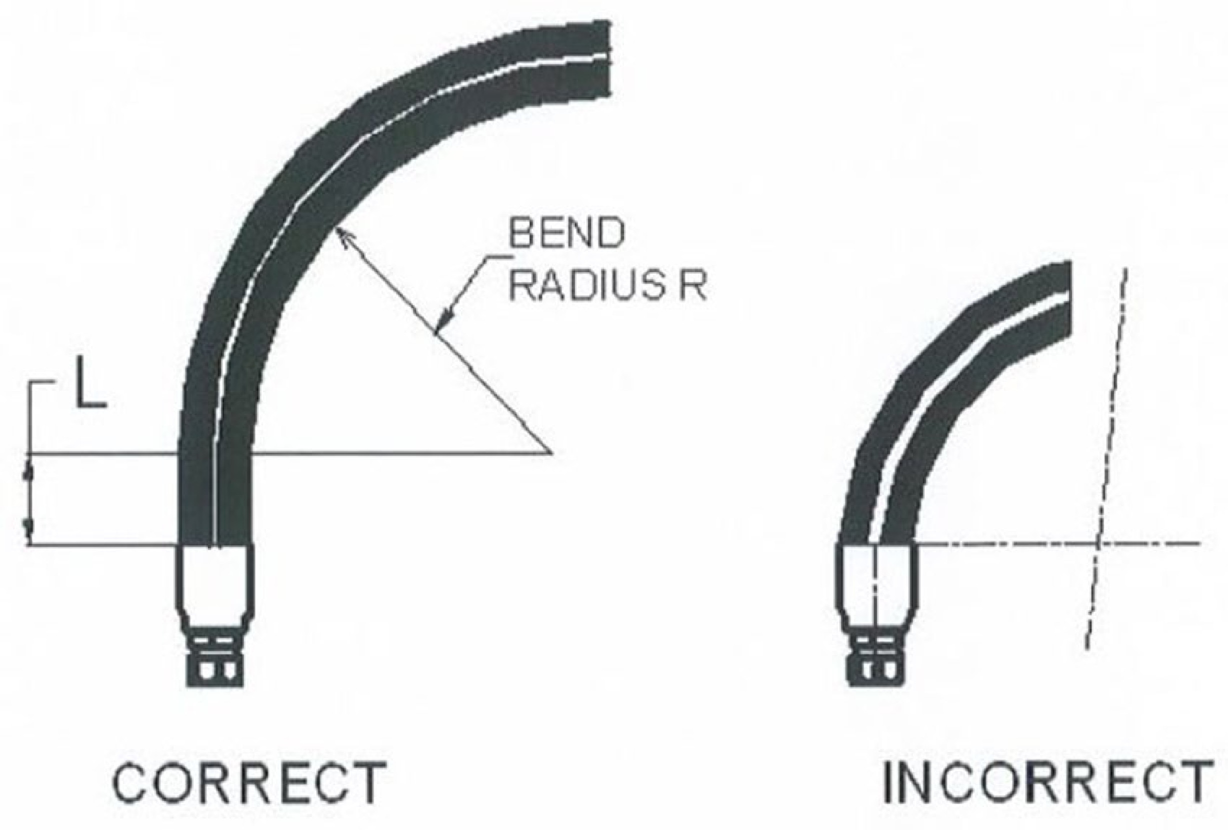


The minimum bend radius, R (also referred to as MBR), of a hose is defined in relevant hose standards and manufacturer's literature. Routing during assembly and use at less than minimum bend radius may reduce hose life. Sharp bending at the hose/fitting juncture can result in leaking, hose rupturing, or the hose assembly blowing apart. See Appendix F - Figure 2A and Figure 2B. 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.

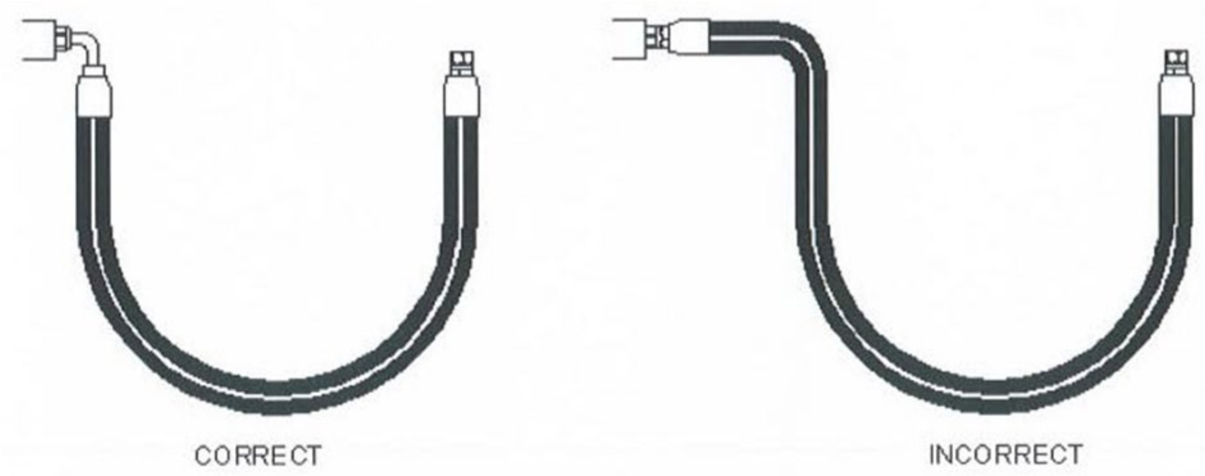
Appendix F - Figure 2A - Minimum bend radius



Appendix F - Figure 2B - Minimum bend radius



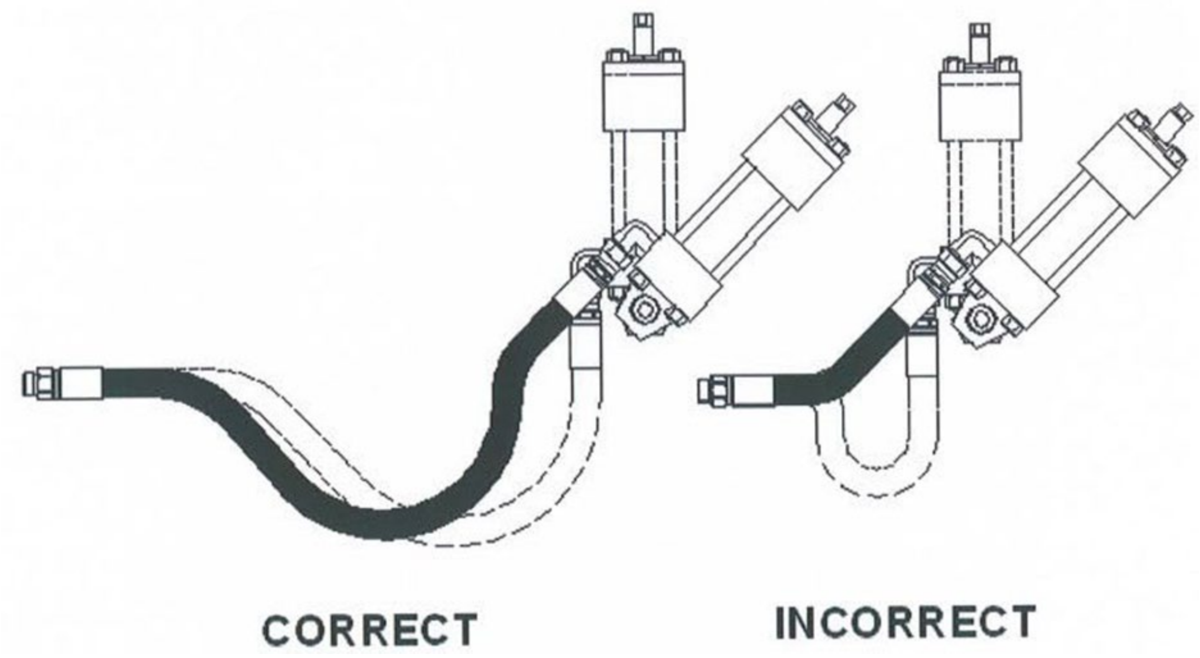
Appendix F - Figure 3 Elbows and adapters



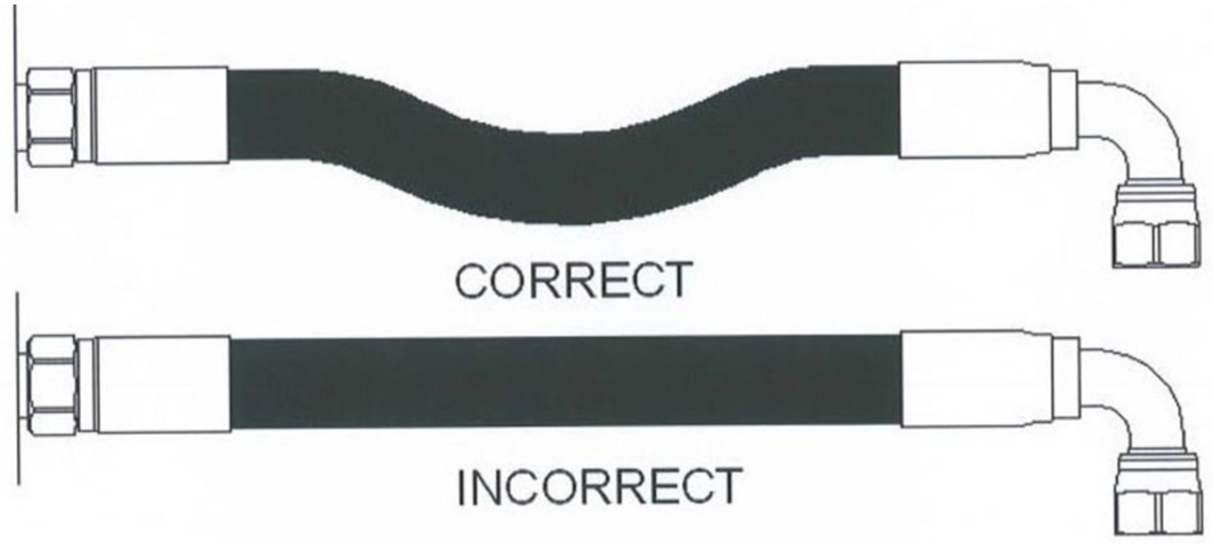
Unnecessarily long hoses can increase pressure drop and affect system performance. When pressurised, hoses that are too short may pull loose from their fittings, or stress the hose fitting connections, causing premature metallic or seal failures. Appendix F - Figures 4, 5 and 6 provide guidance for selecting hose length.

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

Appendix F - Figure 4 - Motion absorption

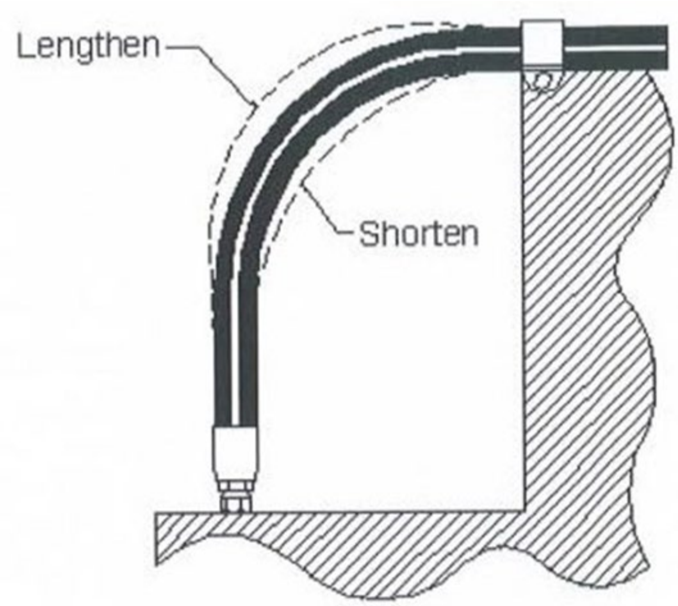


Appendix F - Figure 5 - Hose and machine tolerances



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.

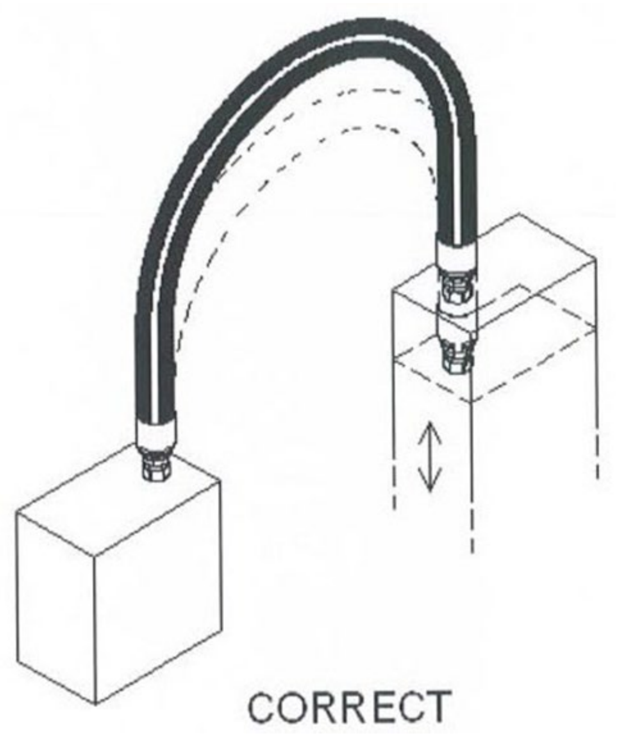
Appendix F - Figure 6 - Hose length change due to pressure



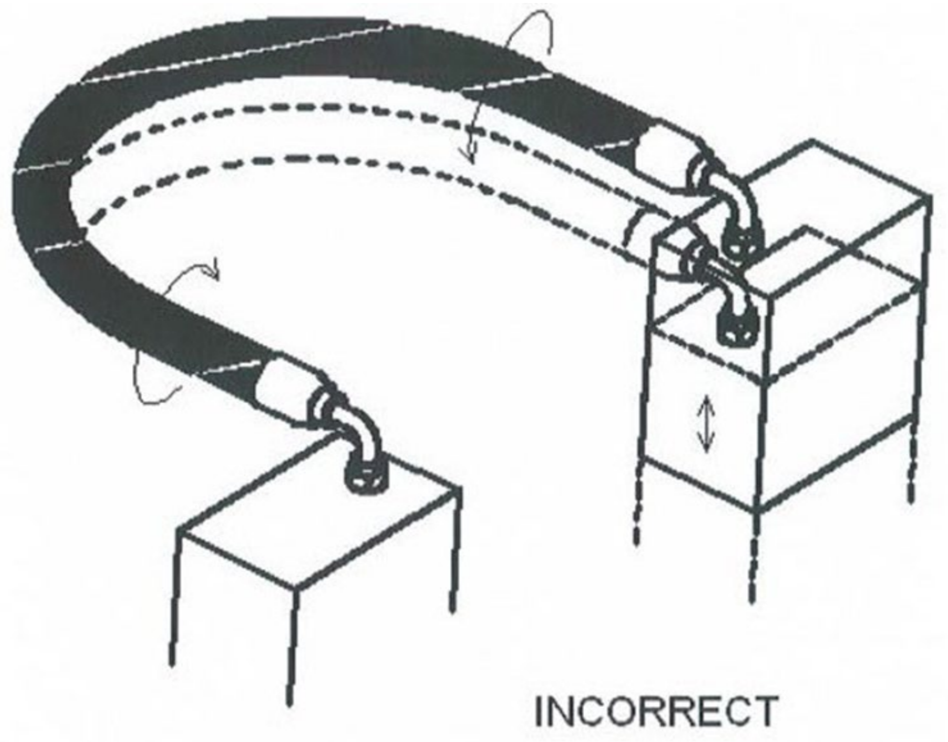
Where hoses are connected between system components that move relative to each other, hoses should be designed taking this into consideration. Avoid multiple planes of motion and twisting motion. Consider the motion of the hose when selecting the hose and predicting service life. In applications that require the hose to move or bend, see Appendix F - Figures 7A, 7B and 8.

Bend in only one plane to avoid twisting. See Appendix F - Figures 7A and 7B.

Appendix F - Figure 7A – Bend in only one plane to avoid twisting

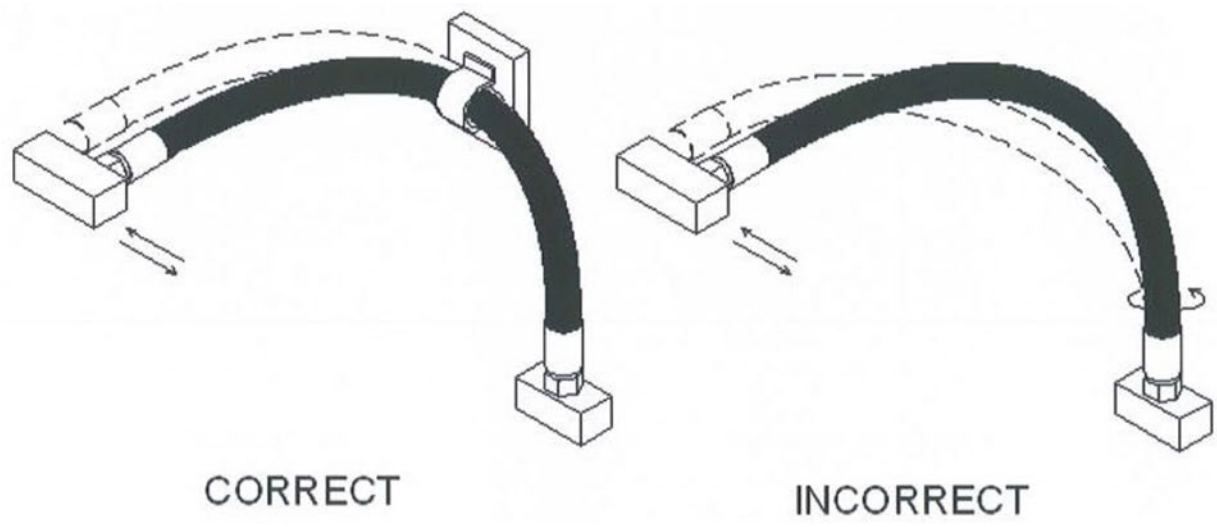


Appendix F - Figure 7B - Bend in only one plane to avoid twisting



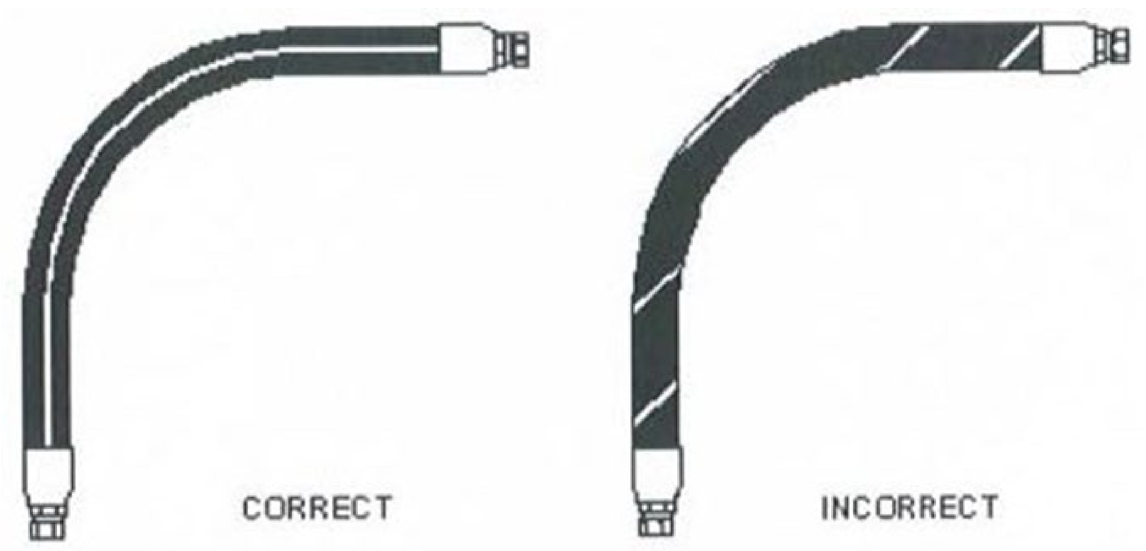
If a hose follows a compound bend, couple it into separate segments or clamp it into segments that each flex in only one plane. See Appendix F - Figure 8.

Appendix F - Figure 8 - Prevent hose bending in more than one place



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 Appendix F - Figure 9) if the layline or marking is parallel to the axis of the hose. Twisting can also be avoided by using two wrenches during the installation of swivel connectors.

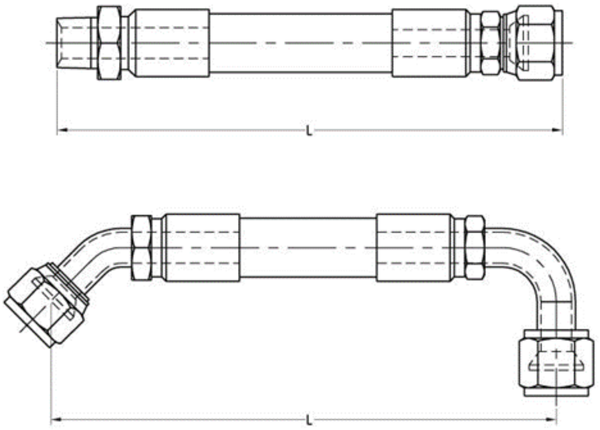
Appendix F - Figure 9 - Twist angle and orientation



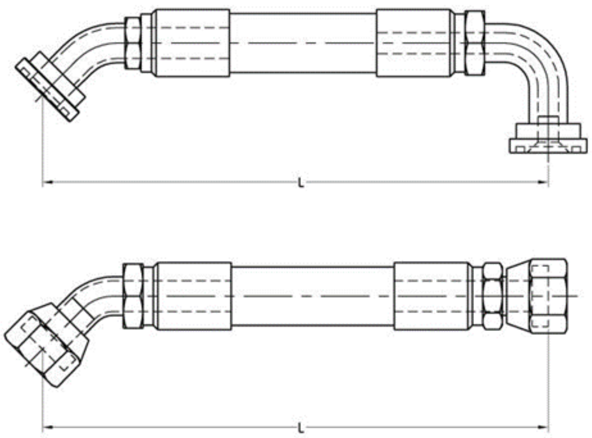
Appendix G – Hose length diagrams

Threaded type hose assemblies

Appendix G - Figure 1 - Threaded type hose assemblies - Locations for measuring hose lengths



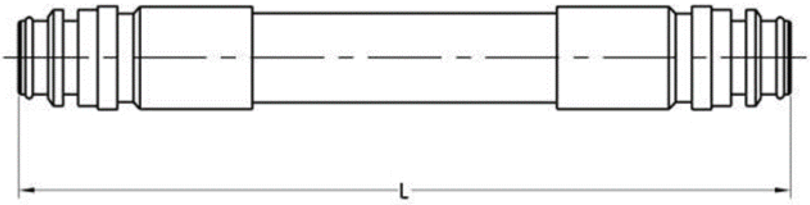
Except for O-ring faced seals

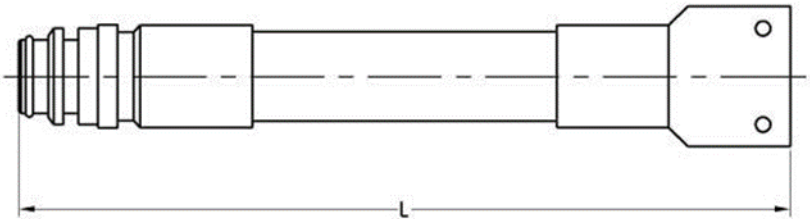


For O-ring faced seals

Staple type hose assemblies

Appendix G - Figure 2 - Staple type hose assemblies - Locations for measuring hose lengths





Appendix H – Hose end adaptor ratings

Appendix H - Table 1 - Hose end adaptor maximum allowable working pressure based on 4:1 design factor[7]

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																									
mm	inch	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi
3	-2	84	12 000	52.5	7 500	No known standard defining rating		35	5 000																
6	-4	84	12 000	49	7 000			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

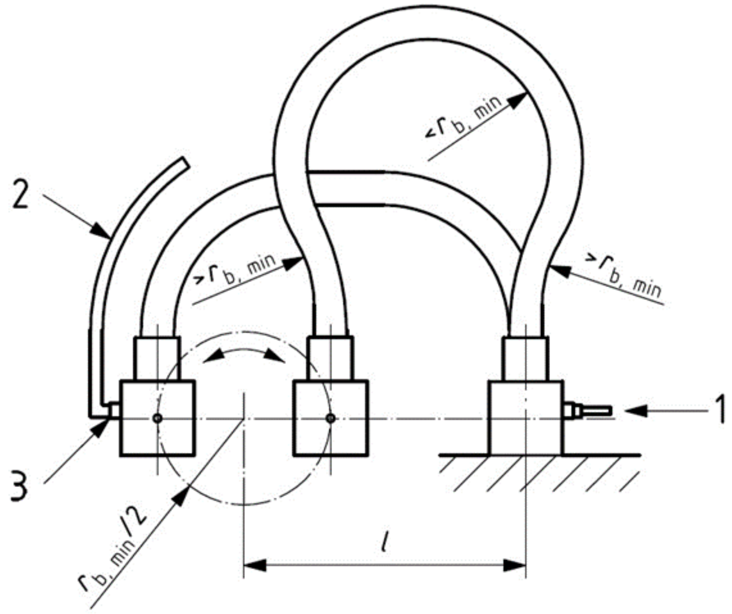
Note:
Manufactures of hose fittings and adaptor may exceed the minimum nominated above. Test data and certification should support any claims.
Fatigue life cycles should be reviewed in line with application requirements

[7] This table was extracted from MDG 41 (published Dec 2010) unedited, for the purposes of providing an example only.

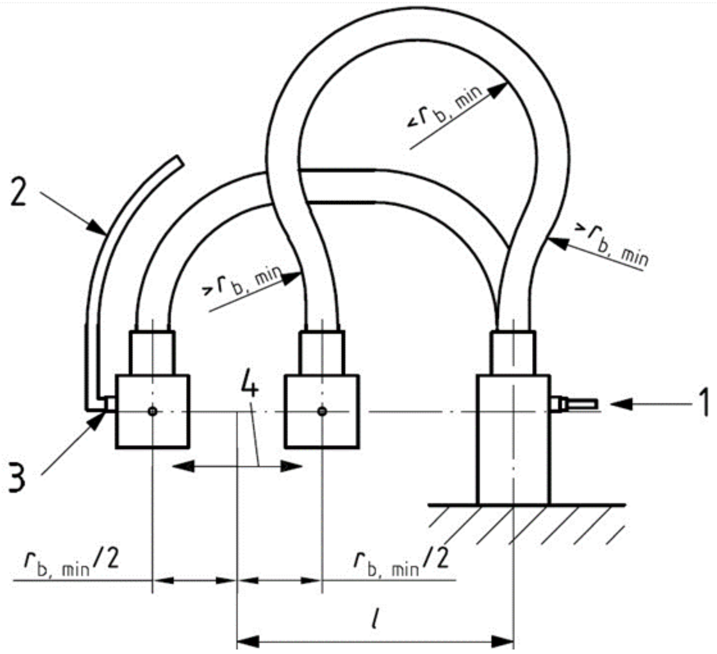
Appendix I – Hose dynamic test rigs

ISO 6802 - Impulse test and flexing to minimum bend radius

Appendix I -Figure 1 – Hydraulic impulse testing with flexing – Arrangement of test piece using a revolving manifold



Appendix I- Figure 2 - Hydraulic impulse testing with flexing - Arrangement of test piece using a horizontally reciprocating manifold



Appendix J – Human and organisational factors

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[8]

Some examples of unintended outcomes considered through the lens of human and organisational factors, poor design and systems of work are outlined in Appendix J -Table 1.

Appendix J - Table 1 – 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 the 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 the 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.

[8] Charles et al, 2015

Unintended outcome	Possible causes due to poor design
Critical instruments and displays do 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 expectations.
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.resources.nsw.gov.au/resources-regulator/safety/health-and-safety-management/human-and-organisational-factors-mine

www.resources.nsw.gov.au/sites/default/files/documents/factsheet-human-and-organisational-factors-in-mining.pdf

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

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	Yes/No	
	1.2 Is latest parts list complied with?	Yes/No	
	1.3 Are pump/motor shafts correctly aligned?	Yes/No	
	1.4 Is all labelling as specified in SITE Standards?	Yes/No	
2	Piping: 2.1 Do termination points comply with that specified?	Yes/No	
	2.2 Are all mating connection halves fitted on termination points?	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?	Yes/No	
	4.2 Has assembly been successfully tested to required pressure?	Yes/No	
	4.3 Design pressure		MPa
	Pump flow rate at design pressure		L/Min
	Electric motor maximum rated current draw		Amps
	Electric motor current draw at design pressure and flow		Amps
	4.4 Do all hydraulic functions comply with specification?	Yes/No	
	4.5 Do all electrical functions comply with specification?	Yes/No	

Note: 1. Any non-compliance is to be detailed and attached to this report with reasons for non- compliance specified. Any point not applicable is to be marked N/A.

Test complete and functionally correct

Contractor: ________________________________ Date: ……/……/………

Appendix L – 420 bar super staple-lock fittings and adaptors for hydraulic power-transmission circuits

(MDG41TR)

This appendix is intended to add clarity to some design aspects of 420 bar super staple-lock fittings and adapters.

Super staple-lock fittings and adaptors are used to connect hydraulic fluid-based power transmission systems. Such equipment is primarily used in high pressure applications within the mining industry.

This equipment is intended to be used based on the principles referred to within the body of this document. The content of this document is assisted with information from DIN 20043 "Staple-lock couplings for hydraulic transmission circuits", SAE J 1467 "Clip fastener fittings", NCB 638 and BS 6537 "Specification for staple type connectors for hydraulic fluid power application".

General

This Appendix applies to 420 bar super staple-lock fittings and adaptors, which are used to connect hydraulic fluid-based systems. The proposed standard seeks to clarify minimum material and dimensional requirements for a 420-bar connection, whilst maintaining a 4:1 factor of safety (FOS).

This document defines: -

1. minimum working pressure of the assembled fitting (including its staple)
2. relevant testing and conformance standards
3. arrangement of components & their individual dimensions
4. material specifications for the components
5. corrosion resistance of metal components
6. identification
7. minimum burst pressure
8. impulse requirements of the assembled fitting

Section 1. Minimum working pressure

Appendix L - Table 1 - Minimum working pressure of the assembled super staple-lock fitting. This table is based on 4:1 FOS per ISO 7751 "Rubber and plastic hoses and hose assemblies. Ratios of proof and burst pressure to design working pressure."

Nominal size DN	Maximum working pressure bar
25	420
32	420
40	420
50	420

Section 2. Relevant standards

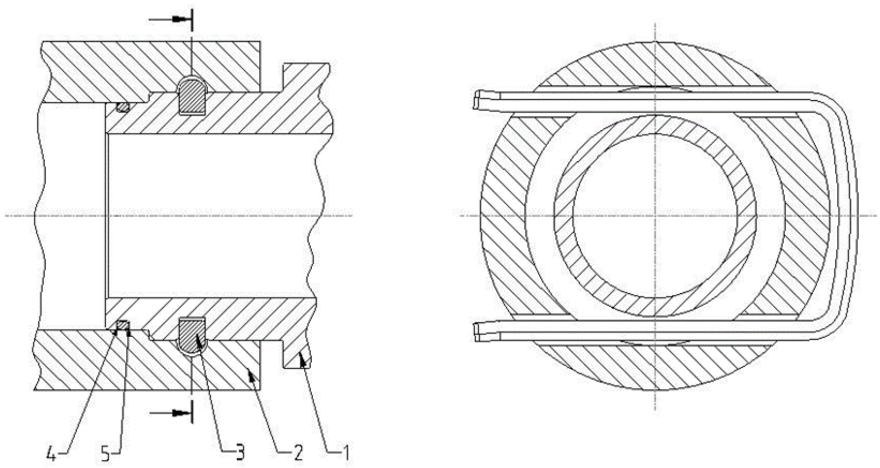
ISO 23529:2016	Rubber — General procedures for preparing and conditioning test pieces for physical test methods
ISO 1043-1:2011	Plastics – Symbols and abbreviated terms – Part 1 – Basic polymers and their special characteristics. Refer to this standard for Back-up Rings.
ISO 1629:2013	Rubber and lattices – Nomenclature. Refer for O-Rings (also ref ISO 3601-3 Fluid power systems - O-Rings - Part 3: Quality acceptance criteria (ISO 3601-3:2005)”).
ISO 1402:2021	Rubber and plastic hoses and hose assemblies – Hydrostatic testing. Refer to for hydrostatic testing.
ISO 6803:2017	Rubber or plastic hoses and hose assemblies – Hydraulic-pressure impulse test without flexing. Refer for hydraulic pressure impulse test without flexing.
ISO 7751:2016	Rubber and plastic hoses and hose assemblies - Ratios of proof and burst pressure to maximum working pressure. Refer to for ratios of proof pressure to design working pressure.
ASTM B117-19	Standard Practice for Operating Salt Spray (Fog) Apparatus. Refer to for methods of salt spray (fog) testing.

Section 3. General arrangement and component tolerances

Super staple-lock assembly

Tolerances are based on ISO 286.1: Geometric product specifications (GPS) – ISO code system for tolerance on linear sizes – Basis of tolerances, deviations and fits

Appendix L – Figure 1 - Description of super staple-lock assembly

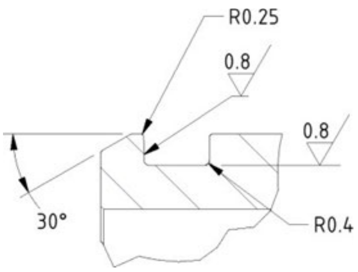


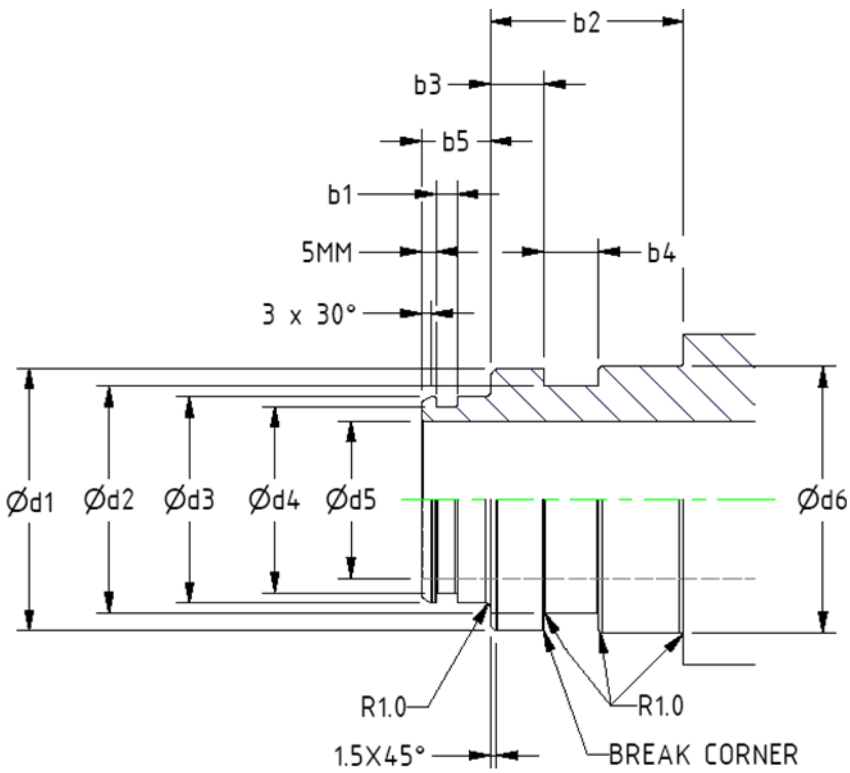
Legend

1. Male Super staple-lock nipple
2. Female Super staple lock coupler
3. Staple
4. O-Ring
5. O-Ring Back-up Washer

Male super staple lock coupler

Appendix L - Figures 2 (a) and (b) - Dimensional details of male super staple lock coupler



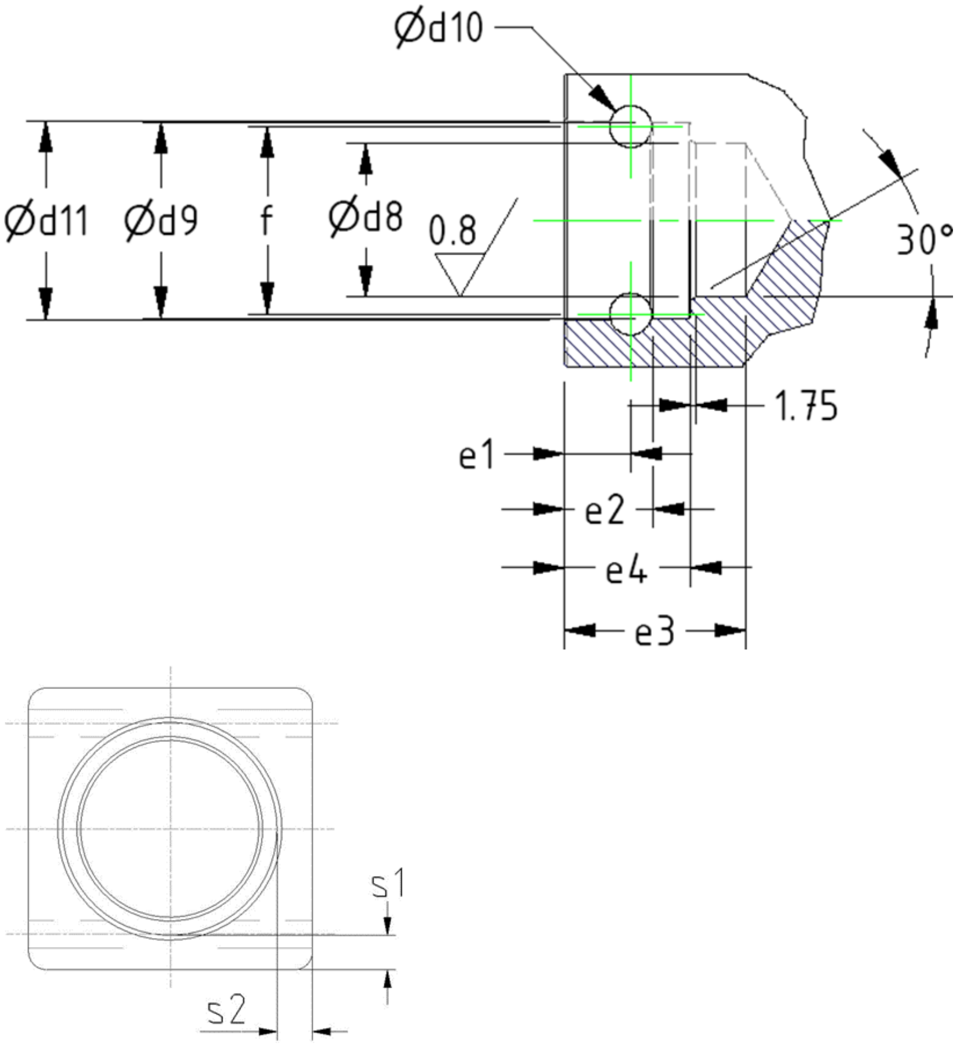


Appendix L - Table 2 - Male super staple lock nipple (all dimensions in millimetres)

Nominal size DN	b1 ± 0.1	b2	b3 ± 0.1	b4 ± 0.1	b5 ± 0.2	d1	d2	d3	d4	d5 ± 0.2	d6
12	3.6	21	4.9	9.1	11.0	23.80c9	**17.40 js11**	**16.00 c10**	**12.00 h10**	8.9	**24.30 c9**
20		27	7.1			**28.00 b9**	**22.40 js10**	**22.00 d10**	**18.00 h10**	15.3	**29.30 c9**
25		40	10.1	13.1	15.0	38.60c9	**29.90 js10**	**31.00 d9**	**27.00 g9**	22.2	**39.60 b9**
32		43				**45.60 b9**	**36.90 js10**	**38.00 d9**	**34.00 f9**	27.2	**46.60 b9**
40	5.1	47	12.9		16.5	**54.60 b9**	**45.90 js10**	**44.00 d9**	**39.00 f9**	32.2	**55.60 b9**
50		47	12.9		16.5	**63.60 b8**	**54.90 js10**	**50.00 d8**	**45.00 f9**	38.0	**64.60 b8**

Female super staple lock coupler

Appendix L – Figures 3 (a) and (b) - Dimensional details of female super staple lock coupler

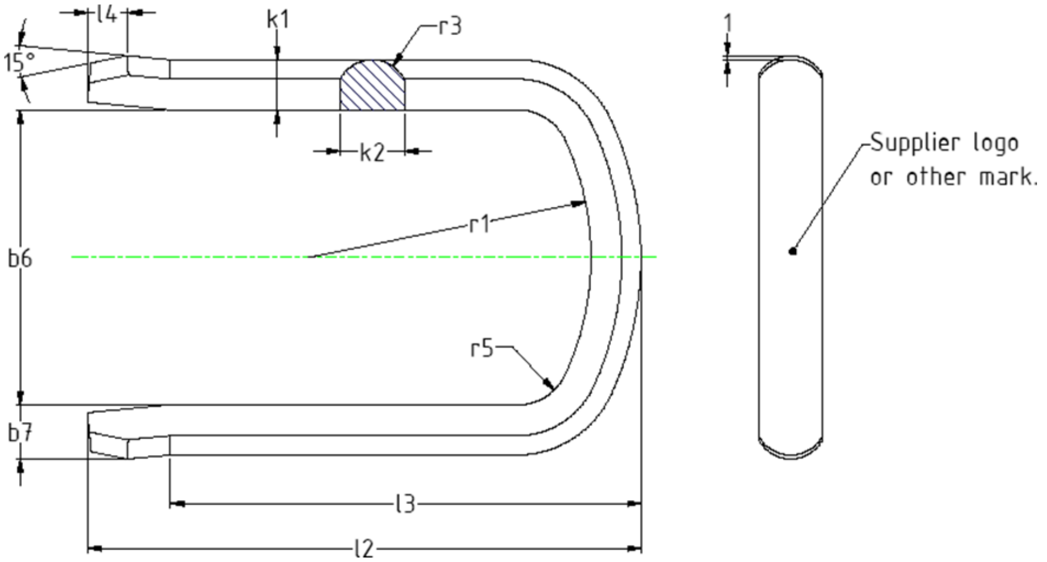


Appendix L - Table 3 - Female super staple lock coupler (all dimensions in millimetres)

Nominal size DN	d8 .02	d9	d10	d11	e1 ± 0.2	e2 ± 0.2	e3 min	e4 ± 0.1	f	s1 min	s2 min
12	**16.00 G9**	**23.80 H10**	**9.00 JS13**	**24.30 F10**	9.7	14.7	28	19.2	22	66.5	6.5
20	**22.00 F8**	**28.80 H10**		**29.30 F10**	12.7	17.7	39	24.4	27	7.5	7.5
25	**31.00 F8**	**38.60 H9**	**13.60 JS13**	**39.60 H9**	18.6	26.3	53	35.5	36	10.0	10.0
32	**38.00 F8**	**45.60 H9**		**46.60 H9**	19.6			36.5	43	11.5	11.5
40	**44.00 F8**	**54.60 G9**		**55.60 G9**	21.6	28.3	57	41.0	52	13.5	13.5
50	**50.00 F8**	**63.60 F9**		**64.60 F9**			59	41.0	61	13.5	13.5

Details of super staple

Appendix L - Figure 4 – Dimensional details of super staple

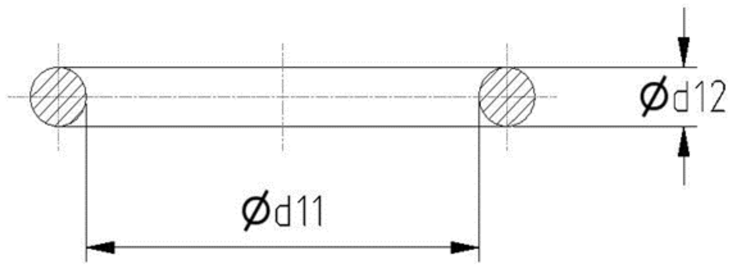


Appendix L - Table 4 - Super staple (all dimensions in millimetres)

Nominal size DN	b6 ± 0.5	b7 ± 0.25	k1 ± 0.1	k2 ± 0.15	l2	l3	l4 ± 0.5	r1 min	r3 ± 0.25	r5 min
12	17.5	7.0	6.4	7.9	53	45	5.5	8.75	4.475	-
20	22.5				60	52		11.25		-
25	30				75	60		35.0		
32	37	10.25	9.3	11.95	85	70	7.0	40.0	6.73	10
40	46				92	77		47.0		
50	55				103	88	7.5	52.5		

Details of O-ring

Appendix L - Figure 5 – Dimensional details of O-ring



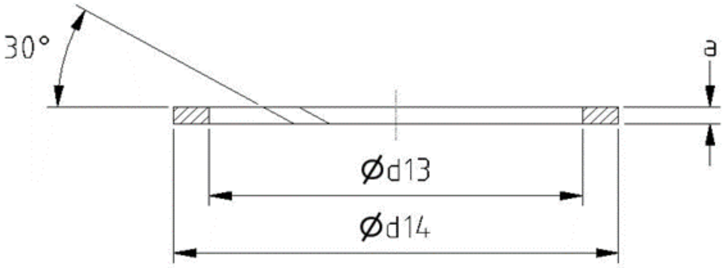
Appendix L - Table 5 - O-ring (all dimensions in millimetres)

Nominal size DN	d11		d12 ± 0.08
12	11.0	± 0.15	2.5
20	18.0		
25	25.0	± 0.25	

32	33.0	± 0.30	
40	38.0		3.0
50	44.0		

Details of O-ring back-up washer

Appendix L - Figure 6 – Dimensional details of O-ring back-up washer



Appendix L - Table 6 - O-ring back-up washer (all dimensions in millimetres)

Nominal size DN	d13 ± 0.10	d14		a ± 0.1
12	12.00	16.00	± 0.02	0.8
20	17.95	21.95	± 0.05	
25	27.05	31.05		
32	34.00	38.00		
40	39.15	43.95		1.5
50	45.15	49.95		

Section 4. Materials

The male staple-lock nipple shall be manufactured from 1.0718 steel per EN10277-3 (Bright steel products. Technical delivery conditions. Free cutting steels, minimum tensile 345 Mpa, minimum UTS 200 Mpa.

The female staple-lock adaptor shall be manufactured from 1.0718 steel per EN10277-3 minimum tensile 345 Mpa, minimum UTS 200 Mpa.

Note: All male and female 420 bar rated nipples and couplers shall be constructed from one piece forgings, cold headed or machined from bar stock. Fittings fabricated from multiple components are not permissible without written approval by customer's engineers.

The staples shall be manufactured from stainless steel.

Stainless steel staples shall be manufactured from 420S45 stainless steel The hardness of the staples shall be Rc28 +/- 3

The O-ring shall be manufactured per ISO 1629 "Rubber and lattices – Nomenclature" and made from Nitrile (NBR) rubber having a Shore A hardness of 88 +/-3 unless otherwise specified

The O-ring Back-up washer shall be manufactured per ISO 1043-1 and made from a Polyamide, such as Teflon (PTFE), Acetal homopolymer

Section 5. Corrosion resistance (of metal components)

When the assembled male nipple, female coupler & staple are salt spray tested using ASTM B117 "Salt spray testing". A minimum of 400 hrs (before red rust) shall be required.

Section 6. Identification

The male staple-lock nipples and female staple-lock couplers should be marked with the manufacturer's identity (logo) and traceability details. All staples should have the manufacturer's identity (logo) permanently marked on them.

Section 7. Burst

Minimum burst qualification of the assembled male nipple (c/w O-ring, backup washer), female coupler and staple shall be per table 7, when tested per ISO 1402 "Rubber and plastic hoses and hose assemblies – Hydrostatic testing".

Appendix L - Table 7 - Minimum burst pressure of assembly

Nominal size DN	Minimum Burst Pressure bar
25	1680
32	1680
40	1680
50	1680

Section 8. Impulse

Minimum qualification requirement is 500,000 impulse cycles at 1.33 times max rated pressure (i.e. 560 bar) per ISO 6803 "Rubber and plastic hoses and hose assemblies – Hydraulic– pressure impulse test without flexing" is required per assembly size.

Appendix M – Hydraulic safety information handout for workers

(extracted from MDG 3007)

Handout
Safety information for workers
hydraulic safety

Safety procedures for the maintenance and operation of heavy equipment begin with the understanding that anyone who works with hydraulic machinery must be aware of the potential hazards involved. It is important to follow manufacturer/supplier's recommended information on assembly, operation, and maintenance. The following is general safety information that is often common to these life cycle activities.

The simplicity of control of many hydraulic systems can cause operators to forget the hazards and potential dangers that result from the enormous power and mechanical forces associated with the equipment.

One error or a simple oversight, could result in serious injury and death.

Section 1 - Hydraulic systems

A confined fluid is one of the most versatile means of controlling motion and transmitting power.

Fluid power or specifically – hydraulic systems operate on the following basic principles:

- a hydraulic pump is used to create a flow of an incompressible fluid
- a pressure can then be generated on a surface by restricting the flow of a fluid

If actuators (e.g., hydraulic cylinders) are placed in the flow of fluid, a pressure will be exerted on the piston of the cylinder, resulting in a mechanical movement of the piston

As a result, this mechanical movement causes the arm of the digger to extend or retract. A flow of fluid in the opposite direction will cause mechanical movement in the opposite direction.

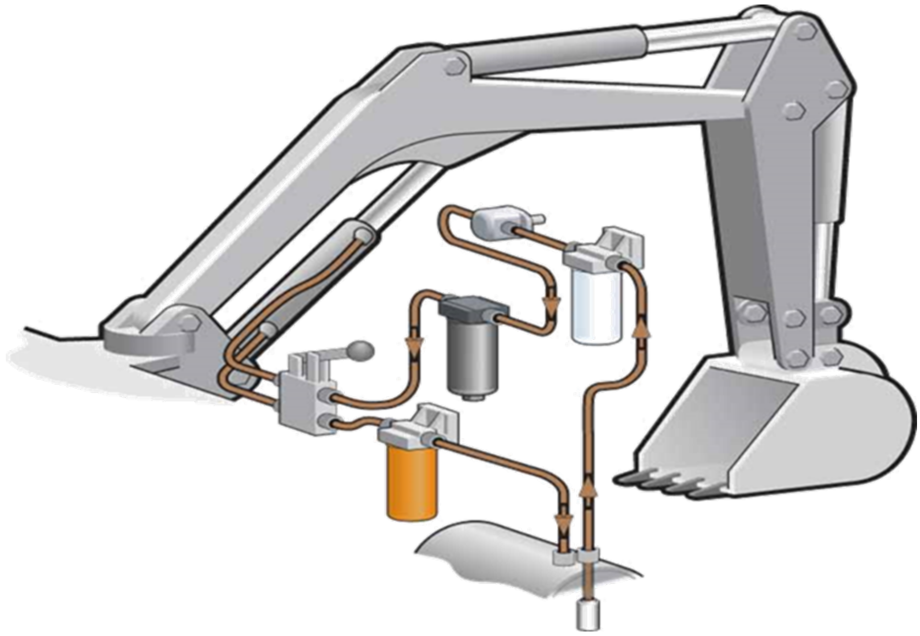
Note: Flow makes it go.

Pressure acting on the surface of the piston produces force.

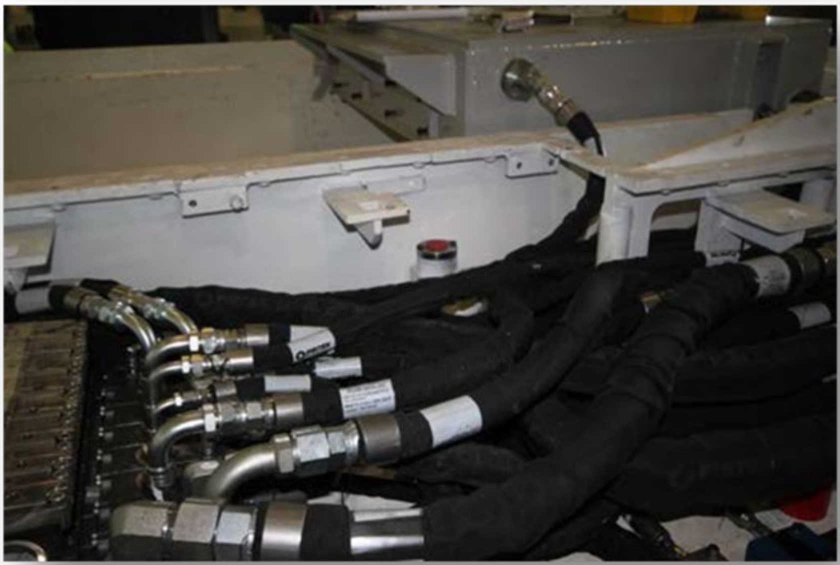
Force from the hydraulic cylinder produces work done by causing the arm of the digger to move.

Hydraulic systems are used in many applications such as trucks, cranes, dumpers, bulldozers, and excavators.

Appendix M - Figure 1 - Hydraulic hose diagram for boom lift cylinder - arrows show direction of flow



Appendix M - Figure 2 - Hydraulic valve bank with multiple hoses and diffusion sleeves



Before working on any hydraulic circuit always assess the task you are going to do for potential hazards and dangers

This is especially important if attempting a task for the first time or you are unfamiliar with the circuit or system/machine.	
	You need to have a thorough knowledge of the subject. Conduct a thorough assessment of any requirements that may assist in minimising all risks involved with hydraulics. Always use but understand the limitations of **personal protective equipment.**
Ensure you have a diagram of the circuit, and you can read and understand the circuit. Identify all isolation points in the system and any stored energy such as accumulators or load locks on actuators that need to be dissipated. Effects of gravity on hydraulic componentry causing pressure in the hydraulic system need to be dissipated or components mechanically locked.	
	Make sure the circuit is hosed correctly and all the protection equipment is in place and correctly set. Protection may include covers, guarding and hose sheathing/sleeves.

NEVER use part of the hydraulic circuit for any task for which it was not intended.

NEVER feel for leaks.

NEVER vent hydraulic fluid to atmosphere unless it is safely controlled, such as into collection drums/trays or through a diffuser.

NEVER disconnect any line that has not been de-energised and tested for de-energisation

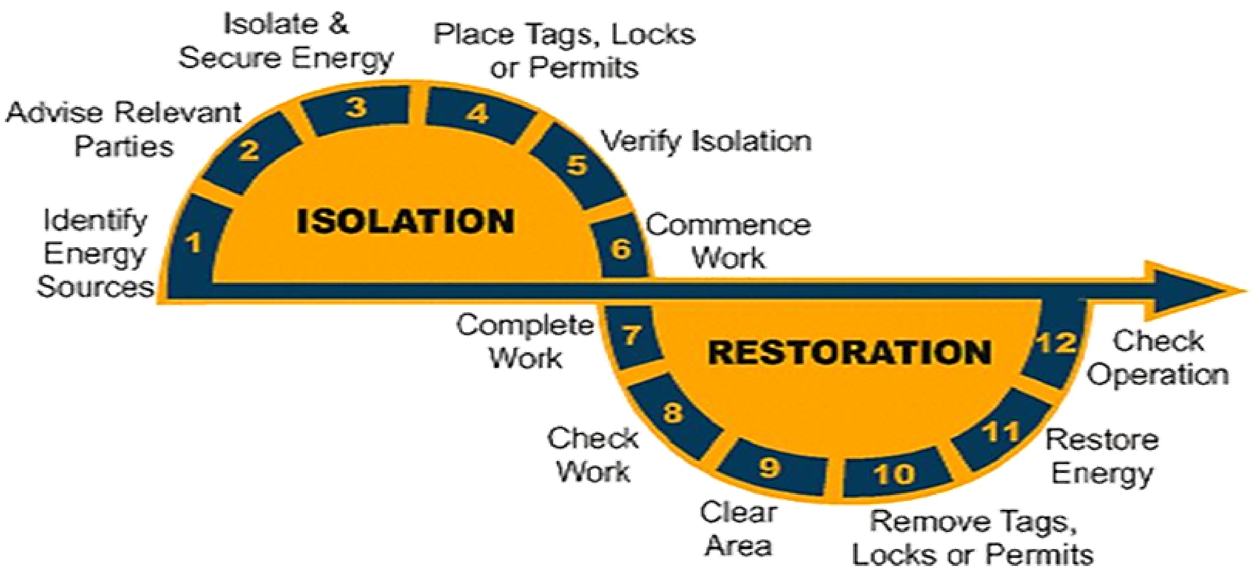
ALL hoses need be connected before a system is engaged.

Note: Isolation is a process which includes:

1. **identification** of all energy sources
2. **provision** for means to isolate the circuit or part of the circuit using **isolation devices** which are preferably lockable.
3. means to **prevent** movement of components due to gravity, where required
4. means to **dissipate residual pressure**
5. means to **verify** pressure is dissipated and circuit is safe to work on
6. **safe work procedures**
7. **competent people.**

For detailed advice on **ISOLATION** see the Technical Reference Guide: Fluid power safety systems at mines.

Appendix M - Figure 3 – Isolation and Restoration steps



Fluid power systems are often powered by energy sources such as electricity or diesel engines.

These power sources need to be considered during isolation. Isolate and secure all energy sources.

ALWAYS

A. isolate (the circuit fully before working on it):

- 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.

Section 2 - Personal protective equipment

Check you have all the correct personal protective equipment (PPE), required to do the task safely. This may include the following:

Remember: Personnel protective equipment may not protect against fluid injection – for example high pressure will penetrate most gloves.

Section 3 - Operating fluid

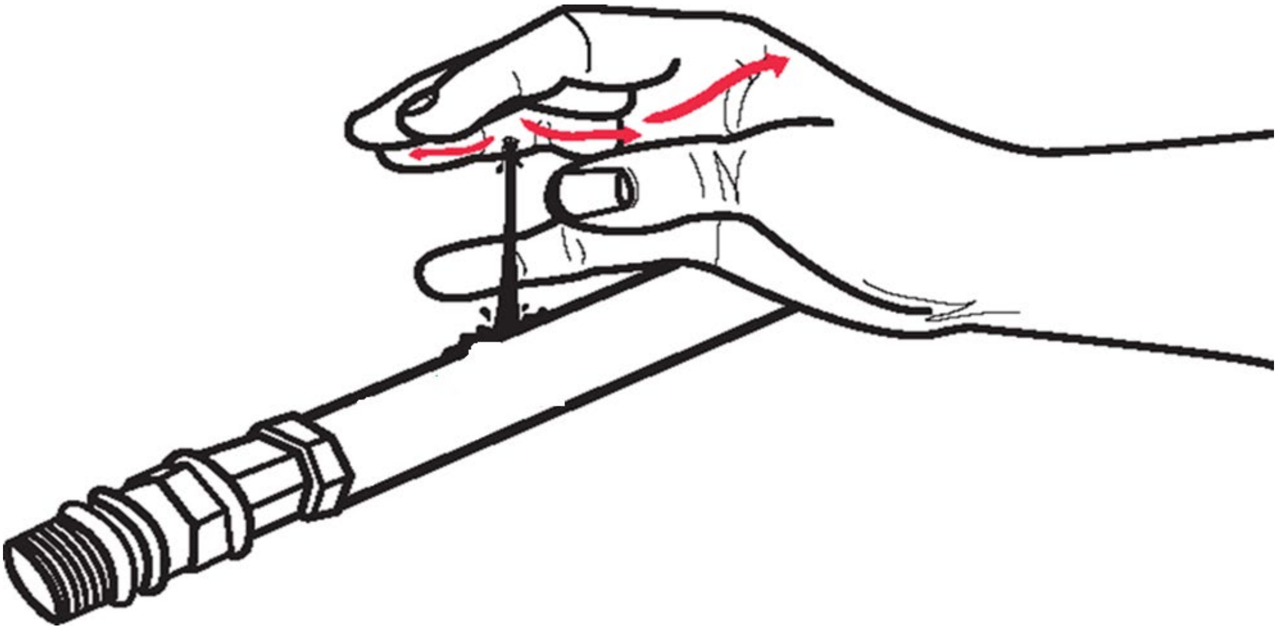
Section 3.1 Personal safety

Hydraulic fluids such as oils, phosphate esters and other fluids may harm your health. You should refer to the manufacturer's safety data sheet:

- reduce skin contamination to a minimum
- use suitable equipment and work methods
- do not allow oil to soak into floors or benches - clean up spills immediately
- barrier cream may be used for sensitive skins
- do not wear oil-soaked clothing or shoes for prolonged periods
- avoid breathing oil mist or vapours
- oils in a hydraulic system are often under high pressure (and may also be hot) so beware of leaking hoses and, pipes. -These should be reported/ repaired as soon as possible.

A pinhole in a hydraulic line operating at 13.7 MPa (2000 psi) will create an oil exit velocity of approximately 1500 kilometres per hour (946 miles per hour) - which could easily penetrate the skin and enter the blood stream. Note that lower pressures can result in serious injury for example to the eyes and other sensitive areas of the body.

Appendix M - Figure 4 - fluid injection injury from pin hole in hydraulic hose



Oil temperature is normally in the vicinity of 60C depending on the system design.

Some mobile applications often operate at temperatures much hotter than this, sometimes approaching the boiling point of water.

Oil burns are painful, serious, and long lasting.

Appendix M - Figure 5 - Person in hospital following fluid injection injury.

Hydraulic fluids trapped in the tissue cannot be easily removed and instances of gangrene have often occurred. It is important **not** to put your finger or any part of your body over a jet of fluid that may be observed coming from a faulty hose, fitting, or other leak.

Appendix M - Figure 6 - Fluid injection injury to hand following surgery

Fluid escaping from a small hole can be almost invisible.

Searching for fluid leaks by "FEEL" is a dangerous practice and will eventually result in injury to fingers or even your hand. Use a piece of cardboard, wood, paper, or a mirror, instead of your hands, to search for suspected leaks.

Appendix M - Figure 7 - Looking for hydraulic leaks with a mirror

Section 4 - Hoses and fittings

All hydraulic components including hoses should always be compatible with the fluid in the system. Some fire-resistant fluids (e.g., phosphate ester) require specific hoses and seals.

All hydraulic components including hoses should always be manufactured using recognised standards. Hydraulic hoses should have a minimum factor of safety of 4:1 based on hose burst pressure to maximum working pressure at maximum operating temperature.

Appendix M - Figure 8 - Galvanised water pipe elbow - not suitable for hydraulic systems

Always use appropriate hydraulic fittings.

NEVER use galvanised fittings in hydraulic circuits.

Always check that the hose type and ends are rated adequately for the operating pressures in the system. (Some hose ends like BSP/JIC have reduced pressure rating as the sizes get larger larger.)

Take care when using staple type fittings in circuits. They are convenient and allow rapid connection and assembly, but it is harder to determine if the system still retains pressure. Verification of fluid pressure should occur for example through reading a pressure gauge.

Appendix M - Figure 9 - Broken BSPP thread on hydraulic hose end

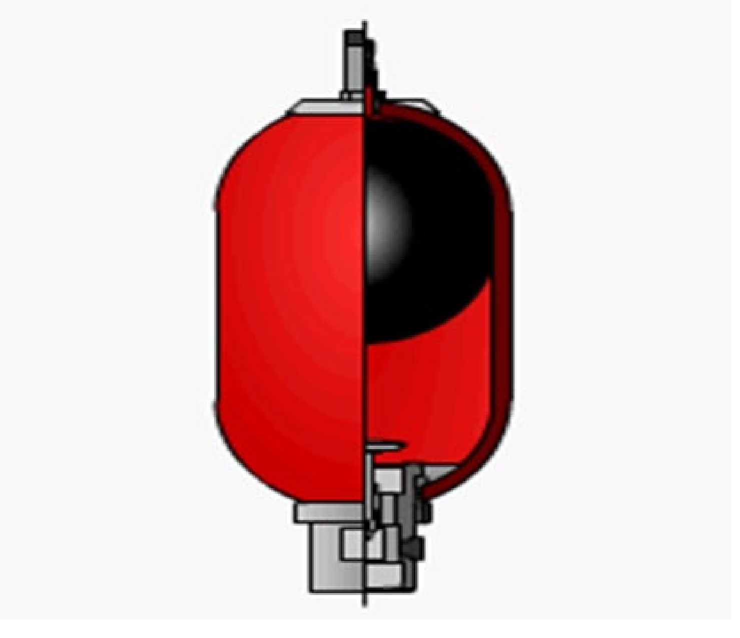
Never re-use a staple. Use a new staple and when installing a staple use a secondary retention method. Components released under pressure may be propelled at high velocity.

Accumulators

An accumulator looks a little like a **BOMB** and can go off like one if not treated properly.

Many hydraulic systems are fitted with an accumulator which is a specially designed pressure vessel and is one of the most potentially dangerous components in the system.

Appendix M - Figure 10 - pressure accumulator



Appendix M - Figure 11 - photo of failed accumulator

The accumulator can be used to take the place of the hydraulic pump for short periods to maintain system pressure in the event of a power failure or it can be used to absorb shock or pressure surges due to sudden stopping or reversing of oil flow.

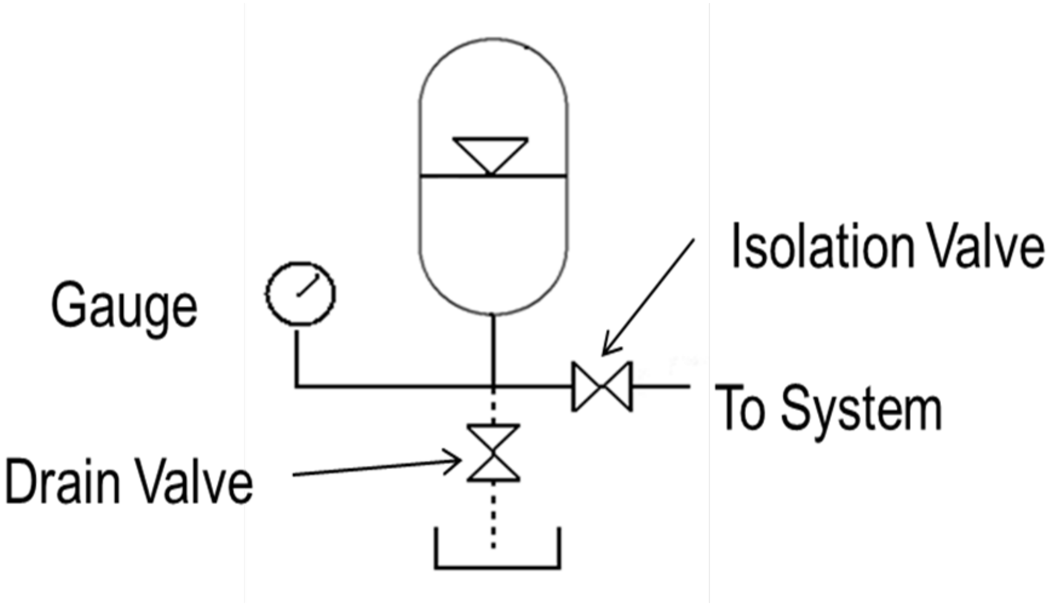
AN ACCUMULATOR CAN OPERATE A HYDRAULIC SYSTEM NORMALLY EVEN WHEN THE SYSTEM IS SHUT DOWN AND ISOLATED.

Isolate the accumulator from the circuit or completely discharge it **before** attempting to disconnect any hydraulic component.

A specific procedure is required.

If at all unsure, do not proceed with the work.

Appendix M – Figure 12 – Pressure accumulator isolation diagram



NEVER try to disassemble an accumulator without **FIRST** releasing the pre-charge gas.

If the accumulator is removed from the circuit **without depressurising**, fluid can be discharged at an uncontrolled rate, and this may cause the accumulator to behave like a **projectile** launching its heavy steel case into the nearest person or object with disastrous results.

An important function of the accumulator is that it requires a pressurised inert gas (nitrogen) to function properly.

Nitrogen gas when discharged in a confined **space** can cause an oxygen deficient atmosphere.

Atmospheres containing less than 18% oxygen are extremely dangerous and atmospheres at less than 10% will certainly cause brain damage and often death.

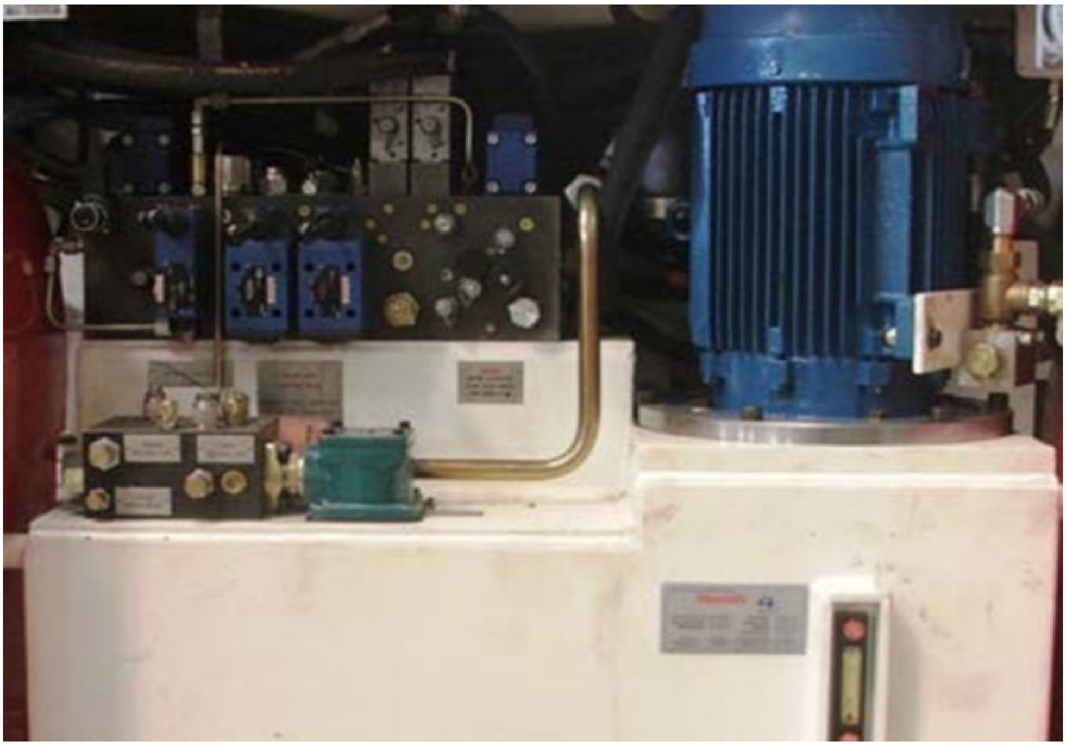
While Nitrogen is non-toxic, in high concentrations it is an effective asphyxiant and may result in death.

Appendix M – Figures 13 (a) and (b) - warning signs

Section 5 - Hydraulic apparatus

Use extreme care when removing the breather, filler connection, or hose to a reservoir. Many units are pressurised to prevent the entry of contaminants and may discharge hot fluid unless pressure is relieved properly.

Appendix M - Figure 14 - Hydraulic power pack



Section 5.1 Faulty control valves

Appendix M - Figure 15 - Hydraulic control valve bank

Section 5.2 Load lock valves

Even though load-lock valves are fitted for example to boom lift cylinders on continuous miners and shuttle cars **ALWAYS** use the mechanical stops provided when working under raised booms or other componentry that is subject to gravitational forces.

Appendix M - Figure 16 - Mechanical stop for hydraulic cylinder

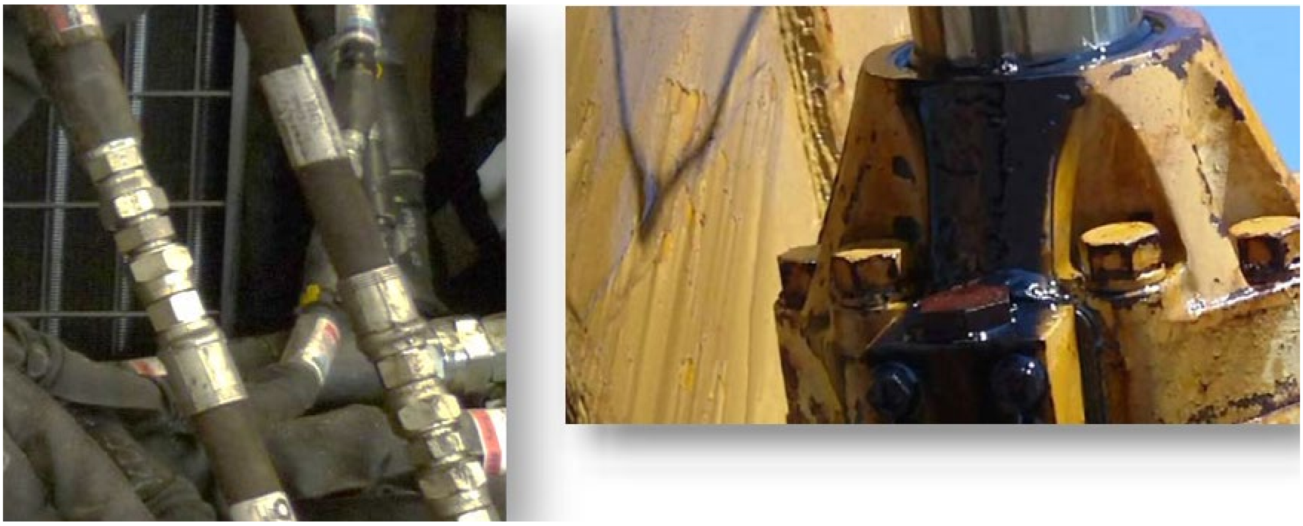
Note: Load-locks and other hydraulic componentry for example cylinders can fail. Hence the need for a mechanical stop as shown in the picture above.

Section 6 - Hydraulic cylinders and actuators

On assembly and prior to testing, make sure all connections and hoses are properly fitted.

Blockages in return flow lines can cause over-pressurisation and intensification well beyond designated system pressure. This may result in dangerous fluid discharge.

Appendix M – Figures 17 (a) and (b) - Left - multiple hydraulic hoses; Right: leaking rod seal on hydraulic cylinder.



Section 7 - Inspections of hydraulic systems

Be conscious of the following when inspecting a hydraulic system:

Hydraulic lines:

- kinked or chafed hoses
- hoses in contact with electrical cables
- dented pipelines
- hoses too close to heat sources
- hoses tangling with moving parts
- leaks, weeps, and spills which could indicate:
  - loose or cracked fittings or pipes
  - blown O-rings or seals
  - excessive pressure in circuit causing components or hose lines to become stressed
  - incorrect fittings or hoses being used.

Appendix M - Figure 18 - Failed crimping of hose end fitting

Appendix M - Figure 19 - Old failed hoses

Condition of oil for smell, colour, and solid content:

- dark colour together with almond smell usually indicates overheating
- milky appearance could indicate water inclusion.

Unusual vibrations or noises:

- this could be due to a mechanical fault
- fault within the hydraulic system
- cavitation conditions.

Appendix M - Figure 20 - Damage from cavitation

Jerky or unresponsive operations:

- normally due to air entrapped within the hydraulic system
- could be faulty accumulator.

Excessive shock in the system:

- Could indicate incorrect relief valve setting
- Mechanical faults
- Operational faults.

Section 8- Hydraulic tools

Hydraulic power is one of the safest methods of applying force to your work when fit for purpose equipment is used correctly.

Hydraulic tools come in many varieties; and pressures up to 700 Bar (10,000 psi) are common.

Section 8.1 Safety tips

When operating hydraulic power tools always wear appropriate personal protective equipment.

- DO NOT exceed rated pressure or force capacity of the equipment.
- hydraulic pressures should NOT be applied through kinked hoses.
- DO provide a solid, firm foundation before attempting to lift a load.
- DO NOT rely on pump valving for load holding, securely pack.
- NEVER stand over jack handle as it may move violently and unexpectedly!!!
- NEVER walk under a load supported ONLY by hydraulic cylinders.
- Off-centre loads should NOT be lifted as they put unnecessary strain on the cylinder rod.

- The rated cylinder stroke should NOT be exceeded as it puts unnecessary strain on the cylinder plunger, other cylinder componentry and may prevent operation.

Section 9 - General safety rules

Section 9.1 Machine shut down procedure

Typical example: a hydraulic loader. After operating a machine there is a certain safety shutdown procedure that **should** be observed:

1. park the machine on level ground and apply the park brake.

   DO **NOT** UNDER ANY CIRCUMSTANCES LEAVE A MACHINE WITH THE IMPLEMENTS RAISED AND/OR UNSUPPORTED.

THEN

2. lower all implements so that there is no hydraulic actuator force required for support.

THEN

3. turn off the engine and isolate the machine as required.

THEN

4. operate all the directional control valves through all possible positions to relieve any trapped pressure in the system.

THEN

5. if maintenance or repair work is required on the machine, securely block all actuators and implements to prevent movement. If an accumulator is fitted, use the correct isolation procedure and verification of depressurisation.

Section 9.2 Machine start-up procedure

Before start-up, a thorough inspection **should** be performed.

Check for:

- leaks, weeps, and spills
- frayed hose lines and connectors
- correct fluid levels.
- correct operation of all hydraulic controls
- no stuck controls or valves

THEN

Start the machine and let it run until the system has warmed up.

On initial start-up of a hydraulic system, the actuators may move without notice due to air entrapped in the circuit and actuators. In most cases the system will self- purge after a couple of minutes.

THEN

Operate all actuators a few times to allow the air to purge from the system and the actuators to fill with fluid.

Recheck the fluid level with the pump running.

Identify and report any hydraulic defects immediately and isolate and tag out any defective equipment.

Remember to be safe

- Do not take short cuts.
- Always apply proper safety procedures.
- These good safety habits are essential for **your safety** and the **safety of your co-workers**.

For more information on work health and safety see www.resources.nsw.gov.au/resources-regulator/safety

Appendix N – Fluid injection protocol

The intention of this document is to make all workers aware that effects can occur, in some cases several hours or days after a fluid injection under the skin.

Treatment and assessment of fluid injection injuries should not be delayed.

WARNING: Failure to act appropriately may result in death of patient, or the need to amputate the affected limb.

Table of contents for Appendix N – Fluid injection protocol

1.0 Purpose

This procedure defines the protocol to follow for a person who receives fluid injected through the skin. This protocol establishes a minimum level of treatment for any person who has received fluid injected through the skin. This procedure is to go with the Patient and to the Doctor / Hospital.

2.0 Scope

This procedure applies to any person reporting to a medical centre after receiving fluid injected under the skin, regardless of how minor the contact may appear upon reporting.

This procedure applies to all employees, contractors, and visitors on the site.

3.0 References

Safety Alerts. SA 00-02, SA 98-08, and SA 02-14.

4.0 Responsibilities

Site manager: Authorise persons to carry out this procedure.

Department managers: Ensure that all employees (including contractors and visitors) working under their control are aware of the need to follow this procedure.

Managers of contractors: Ensure that all employees (including sub-contractors and visitors) workings under their control are aware of the need to follow this procedure.

Contractor companies: Ensure that all employees (including sub-contractors and visitors) workings under their control are aware of the need to follow this procedure.

All personnel: Comply with this procedure.

5.0 Procedure

Any person (whether employee, contractor, or visitor) receiving fluid injected under the skin, no matter how small, during their work is required to follow the procedure listed below.

Step 1: Make the area safe to prevent other employees from also receiving a fluid injected injury.

Call for an ambulance to transport the injured worker to hospital.

First Aid treatment given at the mine would consist of gentle cleaning of the injured part, immobilise, and elevate the affected limb to a comfortable position.

Rest the injured worker to avoid anxiety.

The injured worker should NOT be given food or fluids as they must remain fasted in anticipation of anaesthesia and surgery being required.

Commence observations, if possible, as follows:

- **Baseline Observations**: Measuring of pulse, blood pressure and temperature. Feel near the cut or puncture wound: is there severe pain, throbbing, or numbness?
- **Look for entry wound / site**: check whether any fluid has punctured the skin and/or likely to have injected the fluid under the skin of a person.

Step 2: Transport the injured worker to the surface first aid room. If observations not yet commenced, then commence Baseline observations and look for entry wound/site.

Attach the following documents to the patient and a copy to the ambulance (see following pages).

- Dear Doctor Letter (Attachment 1)
- Additional Information (Attachments 2, 3 and 4)
- Injuries involving High Pressure Injection (Attachment 5)
- Material Safety Data Sheet of the fluid involved e.g., hydraulic oil safety data sheet (To be attached from the Mine's records).

Step 3: The injured worker must not be left alone or allowed to drive themselves to the medical facility. Repeat baseline observation every 20-30 minutes especially if suspicious of systemic infection (into blood stream).

Step 4: Upon arriving at the hospital, the injured worker should report that **"I am an employee of (..company..) at (...location ...) where I received a fluid injection injury about XX minutes ago. I am here for a medical assessment."**

Step 5: When the doctor arrives, the injured worker should hand over the INFORMATION KIT for HIGH PRESSURE INJECTION INJURIES and "Dear Doctor" form for the doctor's information and assessment. A medical check of the injury will be performed. If considered necessary, the doctor may require the person to be admitted for observation or surgery if required. The medical facility should then advise the injured worker's family of the situation.

Step 6: If following the medical examination and investigations the injured worker is not admitted they will be driven back to work.

Step 7: Upon arrival back at work, the injured worker should report to the Medical Centre and advise the Supervisor of the results of the investigation.

Attachment 1: LETTER TO THE DOCTOR

INSERT SITE LETTERHEAD

Date:

Dear Doctor,

The patient presenting with this letter has sustained a suspected high-pressure fluid injection injury:
of (insert substance name) ……………………………………………………………………………………;
at (maximum working pressure) ………………………………………………….Bar / KPa / PSI (circle);
at (distance in mm) …………………………………….distance from impact to point of energy release;

The patient should have the relevant Safety Data Sheet for the injected substance to give to you. We **have / have not** introduced a fluorescent dye to our fluids to assist in tracing and a Blue Light kit should be with the patient.

The patient received a fluid (oil) injection injury at ………………. am/pm on ………/………/……….

The mine's First Aid Management System requires our employees to have a medical assessment to check for any medical complications regarding this incident.

Their baseline observations at ____________________ am/pm were:

Pulse:

Blood pressure:

Temperature:

The patient is complaining of:

1. Sydney Hand Unit Phone No: 02 9382 7201. (24-hour advice).

   Note: If the employee is required to be admitted to the hospital for observation overnight, please contact the company and advise of the situation.
2. Royal North Shore Hospital Phone No. 02 9926 7111.
3. Mine Phone No:………………….

Attachment 2: ADDITIONAL INFORMATION

Background information

The high-pressure injection of a fluid such as hydraulic oil, grease and paint constitutes a medical and surgical emergency, requiring access to appropriate specialist surgical expertise as soon as possible.

The injury sustained in a high-pressure injection incident is usually worse than it will first appear. The injury is rare, and it may be that some medical practitioners or hospital services will not be alert to the severity of an injury of this type.

Dr Ian Isaacs, Director of the Sydney Hospital Hand Unit, has provided advice on the response to 'High Pressure Injuries of the Hand,' and this is included as Attachment 3.

The injured person will require specialist surgery or hand surgery services. Such services will usually be available through the Accident and Emergency Department at a major public health system teaching hospital or, as appropriate, through a specialist Hand Clinic. Urgent transport to the appropriate service is required. The locations of such services in NSW are indicated at Attachment 4.

Where Emergency Transport is required for a person working in a remote area, a local medical officer or service can usually arrange this more effectively than a work site representative or the injured individual. However, if establishing contact with a local medical officer or service entails any delay, contact can be made directly with the specialist services.

Issues for mine site consideration and management

Prevention

Personnel should be made aware of the potential dangers of fluids at high pressure.

Mitigation

Oil soluble fluorescent dye additives can be added to oils and emulsions and used to assist with tracing and detection of high-pressure fluid injection injuries. The dye may help pinpoint the location of hydraulic fluid under the skin, assisting in decreasing the amount of cases requiring surgery and also limiting the amount of soft tissue dissection required during surgery. When viewed under high intensity blue light, the fluorescent glow can be seen under the skin, enabling quick detection of an oil injection injury on site. The fluorescent response will remain visible in the tissue for at least 24 hours after the injection, with no ill effects to the human body.

Reporting a high-pressure fluid injection injury

Mine site personnel should report any incident where they may have received a high-pressure fluid injection.

Response to an 'Injection of High-Pressure fluid' incident

First aid response

As suggested in the attached advice of the Director of the Sydney Hospital Hand Unit.

In addition, there should be clear identification of the injected material, and its chemical constituents, if possible, for the information of specialist medical services.

Access to specialist medical services

A person who has sustained a high-pressure fluid injection injury requires emergency assessment and/or treatment at specialist medical units (see Attachment 4).

Transport to the emergency medical service

The use of emergency medical transport to the specialist service is warranted with a high-pressure hydraulic oil or other fluid injection injury. For people in areas remote from the specialist services, local medical officers or medical services may facilitate and speed up access to emergency medical transport.

Where mine sites have their own medical advisers this document and SA98-08 could be discussed with them as part of establishing the work sites' response to the high-pressure injection of hydraulic oil or other fluids.

Attachment 3: ADDITIONAL INFORMATION SYDNEY HOSPITAL & SYDNEY EYE HOSPITAL[9]

Macquarie Street, Sydney, 2000
G.P.O. Box 1614, Sydney, NSW 2001

Our reference: IJl:ejh/Il030299
Your reference: 3rd February 1999

Telephone: (02) 9382 7111
Direct: (02) 9382____
Facsimile: (02) 9382 7320

Enquiries to:

The Mine Managers - New South Wales Department of Mineral Resources

re: High Pressure Injection Injuries of the Hand

The advice of Sydney Hospital Hand Unit has been sought in updating the protocols for the management of high-pressure injection injuries occurring in the hand.

The information that has been distributed is by no means an over-statement of the problems that can arise as a result of such injuries. It needs to be emphasised that high pressure injection injuries to the hands are one of the very few injuries that require prompt and highly specialised treatment to minimise tissue damage and maximise restoration of function. 'Ihe only effective treatment for high pressure injection injuries is surgical. This invariably will require extensive decompression of the area that has been affected by the injection injuries and this can involve a very extensive area beyond the apparent initial point of entry. The faster the injured worker is able to be transported to a centre that is able to perform this surgical treatment, the better the outcome will be.

The most important consideration at the worksite is the employer and employees to all be aware of these injuries and their potential problems. Prevention remains the best treatment and the safety procedures that you use within the mines, avoiding exposure to hydraulic lines and teaching employees the proper techniques in handling high pressure hoses and components, are paramount.

A high index of suspicion of this injury must be entertained when a worker reports an accident whilst handling such equipment. Make note that the point of entry may look exceedingly small and may not bleed. It will usually be on the working surface of the hand, that is, on the pulps of the fingers or towards the palm. The worker may not complain initially of pain but may have a feeling of numbness and tenseness within the affected part. Within a short period following this injury, however, the part usually becomes quite irritated with the worker complaining of throbbing pain which can seem out of proportion to what is visible to the naked eye. Once the diagnosis has been entertained, there is little to be done apart from expediting that worker's transfer to a surgical facility where he can get treatment with the minimum of delay.

The First Aid procedures would consist of gentle cleaning of the part, resting the patient to avoid anxiety, and elevating the affected limb in a comfortable position so that activity of the extremity is minimal. A resting splint applied gently to the wrist would be an advantage. The patient should not be given fluids or food as they must remain fasted in anticipation of anaesthesia and surgery being required.

The urgency of transfer is of the same degree as would be required for an amputation injury where replantation is being considered. In this regard there are some situations where, due to the isolation of the mine, the Occupational Health & Safety Officer at the site may wish to liaise directly with the Specialist Unit for advice re the transfer. The staff at Sydney Hospital Hand Unit would be available 24 hours a day for advice and assistance in expediting treatment of any of your workers suspected of having these injuries.

Ian J. Isaacs FRACS Director
SYDNEY HOSPITAL HAND UNIT
FACILITIES OF THE SOUTHEASTERN SYDNEY AREA HEALTH SERVICE *DTP/283*

[9] This letter has been extracted, unedited, from Fluid Injection Protocol published by Mineral Resources NSW on 21/11/2002.

Attachment 4: List of Specialist Hospitals

SPECIALIST HAND UNITS AND MAJOR ACCIDENT AND EMERGENCY UNITS IN NSW

For a hand injury there are "Hand Clinics" at Sydney Hospital (02 9382 7201) and Royal North Shore Hospital (02 9926 7111). These services can be contacted by phone and advice sought when a high-pressure fluid injection injury has occurred to a hand.

The Accident and Emergency Services at the major public hospitals are likely to be equipped to deal with high pressure fluid injection injuries.

In NSW, these hospitals are:

- Royal North Shore Hospital
- The Prince of Wales group of hospitals
- Royal Prince Alfred Hospital
- Westmead Hospital
- Liverpool Hospital
- Nepean Hospital
- Concord Hospital
- John Hunter Hospital.

Attachment 5 Injuries

INJURIES INVOLVING HIGH PRESSURE INJECTION

High pressure injection injuries resulting from inadvertent contact with grease gun tips or leaking hydraulic pipes are a rare occurrence (150 reported cases in the 50 years to 1984 in the UK).

When they do occur the speed of treatment is probably the most important factor in limiting the ultimate severity of the injury.

Injury typically involves pressures well in excess of 1500 psi (10.342 bar) punching a hole in the skin and soft tissue. Pressures below I 000 psi (6.895 bar) are unlikely to be energetic enough to cause an injection unless skin has previously been broken or is healing from a recent injury. After the initial injection, the fluid travels in a narrow stream until a structure of sufficient density (i.e., muscle or bone) is encountered. The fluid then rapidly disperses in all directions. Dependent upon the entry pressure, injected fluid can travel a great distance from the initial site of entry.

Damage at this stage is normally related to physical phenomena such as compression, rupture, and impact together with the chemical nature of the injected material.

With lesser injections only a small puncture hole may be apparent often with no bleeding and little or no pain. If the material is a low hydrocarbon such as white spirit or kerosene, then local anaesthesia can result as fat and myelin nerve sheaths dissolve. With such injections injecting local anaesthetics will potentiate the effects and so must not be administered. With higher distillates such as those typically used as hydraulic mineral oils, the higher viscosity usually results in less lateral penetration but can be more difficult to remove.

After a short period of time, the body's natural defence mechanism is activated and local swelling, pain and heat is noticed. If the material consists of tissue irritants, as would be the case with soluble hydraulic fluids and to lesser extent with their emulsions, this reaction would be faster than if it were just mineral oil.

Urgent surgical treatment is required to reduce the long-term implications of this type of injury. First aid treatment is very limited, being mainly restricted to comforting the casualty until qualified medical assistance can be obtained. The general treatment **would include** decompressive surgery and deep cleansing of the wound and affected tissues, removing as much of the foreign material as possible. Relief of pressure on tissues caused by swelling of damaged tissue is continued after the operation by the application of steroids. The wound is closed after cleaning out all necrotic tissue and debris, with loose sutures to help reduce internal pressure.

Obviously, the treatment of this type of injury is highly individualised, depending to a great extent upon the nature of the fluid (its viscosity, chemical nature, etc.) and the impact pressure. One would expect a greater risk of amputation with low viscosity substances, but treatment can be over very extended periods (may be years) with greases. Information concerning systemic toxicity of any injected substance is very sparse and not generally of immediate concern in these instances. However, it is worth noting that certain fluids, namely soluble hydraulics, often contain biocides, alkaline anti corrosion inhibitors and other components, which can have a toxic effect.

Consideration of the quantity which is likely to be injected, however, and relating this to the proportion of toxic substance it can be seen that very little enters the body so, whilst the possibility of toxic effects cannot be discounted, the treatment of the more acute damage caused by the actual injection should be paramount.

It cannot be emphasised too much that the eventual severity of the disability is strongly dependent upon the immediacy of treatment. With rapid, effective, and educated treatment there is a reduced risk of amputation or loss of function of the limb. Therefore, personnel must be trained to inform supervisors of any injection injury as soon as it happens and to seek urgent immediate medical attention.