

Australian/New Zealand Standard™

Remote control systems for mining equipment

Part 1: Design, construction, testing, installation and commissioning



AS/NZS 4240.1:2009

This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee EL-023, Electrical Equipment in Mines and Quarries. It was approved on behalf of the Council of Standards Australia on 16 March 2009 and on behalf of the Council of Standards New Zealand on 20 March 2009.
This Standard was published on 6 April 2009.

The following are represented on Committee EL-023:

Australian Chamber of Commerce and Industry
Australian Coal Association
Australian Industry Group
Department of Mines and Energy (Qld)
Department of Primary Industries, Mine Safety (NSW)
Electrical Apparatus Service Association
Electrical Regulatory Authorities Council
Mining Electrical and Mining Mechanical Engineering Society
Ministry of Economic Development (New Zealand)
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This Standard was issued in draft form for comment as DR 06670.

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Part 1: Design, construction, testing, installation and commissioning

Originated as AS/NZS 4240:1994.
Revised in part and redesignated as AS/NZS 4240.1:2009.

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Jointly published by Standards Australia, GPO Box 476, Sydney, NSW 2001 and Standards New Zealand, Private Bag 2439, Wellington 6020

PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EL-023, Electrical Equipment in Mines and Quarries as a revision, in part, of AS/NZS 4240:1994, *Remote controls for mining equipment*. It is now Part 1 of a four Part series:

- Part 1: Design, construction, testing, installation and commissioning (this Part)
- Part 2: Operation and maintenance for underground metalliferous mining
- Part 3: Operation and maintenance for underground coal mining
- Part 4: Operation and maintenance for surface mining

The objective of this Standard is to provide requirements for designers, manufacturers, users and regulating authorities concerned with the safe use of remote controlled mining equipment in both the coal and metalliferous mining industries.

Each Section deals with specific aspects of design and safe use of remote control systems for mining equipment.

This Standard is based on the work instigated by a special working group comprising representatives from both the coal and metalliferous mining industries.

This Standard differs from the previous edition in the following significant ways:

- (a) The introduction of the principles of AS 61508, *Functional safety of electrical/electronic programmable electronic safety-related systems*, and safety integrity levels.
- (b) The addition of requirements for the creation of a safety file.
- (c) The expansion of the commissioning and acceptance requirements.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

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Australian/New Zealand Standard
Remote control systems for mining equipment**Part 1: Design, construction, testing, installation and commissioning**

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies requirements for the design, construction, testing, installation, commissioning and modification of remote control systems for mining equipment and machinery. It also recommends safeguarding practices and the provision for training of personnel associated with the operation and maintenance of such equipment and machinery.

It applies to systems where the remote controls are located with the operator who is expected to remain in visual contact (direct or teleremote) with the equipment or machine being controlled. Typical systems of remote control may incorporate, but are not limited to, radio or infra-red transmitters and receivers or direct electrical connection. This Standard recognizes that remote control equipment may be a subset of semi-automated and automated systems.

This Standard focuses on minimizing the risk to mine workers from unexpected movement of remote controlled machines or parts of machines. Risks from hazards such as chemicals, electricity (shocks and burns) and explosions are not intended to be covered by this Standard.

This Standard is focussed on the electrical interface but the design, risk assessment principles and some of the specific requirements are applicable to hydraulic and pneumatic systems.

1.2 APPLICATION

This Standard applies to remote controlled mobile machines and parts of mobile machines.

Examples include, but are not limited to, rubber tyred or tracked machines, breaker line supports, continuous miners, flexible conveyor trains, load-haul dumps, shearers, shovels, tyre handlers and shuttle cars.

It applies to coal and metalliferous mining machines used in both surface and underground mines but does not apply to the following:

- (a) Automatic conveyor and shuttle systems.
- (b) Gantry and monorail cranes.
- (c) Shaft and drift winders.
- (d) Machines that are isolated from personnel.

1.3 RELATIONSHIP TO REGULATIONS

The requirements of this Standard may be read in conjunction with, but do not take precedence over, regulations of a regulatory authority that may apply in a specific area.

1.4 INNOVATION

Special purpose equipment and/or applications, novel materials, designs, methods of assembly, procedures or similar that do not comply with specific requirements of this Standard or are not mentioned in it are not necessarily prohibited. However, the innovation shall result in an equivalent safety outcome to that intended in this Standard. The innovation shall be analysed in accordance with Appendix A or equivalent. Specific approval remains the prerogative of the relevant regulatory authority.

1.5 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

NOTE: Appendix H contains a bibliography of related documents.

AS

- 2187 Explosives—Storage, transport and use
- 2187.2 Part 2: Use of explosives
- 2956 Earth-moving machinery—Instrumentation and operator's controls
- 4024 Safety of machinery
- 4242 Earth-moving machinery and ancillary equipment for use in mines—Electrical wiring systems at extra-low voltage
- 60204 Safety of machinery—Electrical equipment machines
- 60204.1 Part 1: General requirements (IEC 60204-1, Ed. 5 (FDIS) MOD)
- 60204.11 Part 11: Requirements for HV equipment for voltages above 1000 V a.c. or 1500 V d.c and not exceeding 36 kV (IEC 60204-11, Ed. 1.0 (2000) MOD)
- 60529 Degrees of protection provided by enclosures (IP Code)
- 60947 Low-voltage switchgear and controlgear
- 60947.1 Part 1: General rules
- 60947.2 Part 2: Circuit-breakers
- 60947.5.1 Part 5.1: Electromechanical control circuit devices
- 61508 Functional safety of electrical/electronic/programmable electronic safety-related systems
- 61508.1 Part 1: General requirements
- 61508.3 Part 3: Software requirements
- 62061 Safety of machinery—Functional safety of safety-related electrical, electronic and programmable electronic control systems
- HB 59 Ergonomics—The human factor—A practical approach to work systems design
- AS/NZS
- 2381 Electrical equipment for explosive gas atmospheres—Selection, installation and maintenance
- 2381.1 Part 1: General requirements
- 2430 Classification of hazardous areas
- 3000 Electrical installations (known as the Australian/New Zealand Wiring Rules)
- 3931 Risk analysis of technological systems—Application guide
- 4360 Risk management
- 4871 Electrical equipment for coal mines, for use underground
- 4871.1 Part 1: General requirements

ISO	
7000	Graphical symbols for use on equipment—Index and synopsis
14118	Safety of machinery—Prevention of unexpected start-up

1.6 DEFINITIONS

For the purpose of this Standard, the definitions below apply.

1.6.1 Actuating control

A control that initiates motions or power in the mining machine.

1.6.2 Deadman control

A control that is physically maintained by the operator and when released the controlled function stops.

1.6.3 Disparity

The difference between an input and the designed output or result.

1.6.4 Emergency stop device

A manually operated device and associated system, that is located on the machine-under-control, operation of which overrides all other machine controls, removes power from the machine actuator(s), and causes all moving parts to stop.

NOTE: Clause 1.6.22 identifies the term for shut-down devices located on the remote controller.

1.6.5 Fail-safe

Any failure of the machinery, its associated safeguards, control circuits or its power supply that leaves the machinery in a safe condition.

1.6.6 Guard

A physical barrier that prevents or reduces access to a danger point or area.

1.6.7 Hazard

Environmental or physical condition that can cause injury to people, property, or the environment.

1.6.8 Hazardous motion

Machine motion that may cause injury.

1.6.9 Human-machine interface

The physical controls, input devices, information displays, or other media through which a human interacts with a machine in order to operate the machine.

1.6.10 Mishap

An unplanned event or series of events resulting in death, injury, occupational illness, or damage to or loss of equipment or property, or damage to the environment.

1.6.11 Pendant

A specific type of remote controller within the remote control system that sends signals to the machine-mounted components of the remote control system via a direct connection (umbilical cable).

1.6.12 Portable remote controller

A remote controller capable of being readily carried by the operator when in use.

1.6.13 Programmable electronics (PE)

Electrically or electronically programmable or configurable devices (e.g. embedded controller, programmable logic controller, single-loop digital controller, distributed control system controller).

1.6.14 Programmable electronic system (PES)

A system, comprising one or more programmable electronic components or parts, used to control, monitor, or protect machinery or plant and equipment. This includes all elements of the system, such as power supplies, sensors and other input devices, data highways and other communications paths, and actuators and other output devices.

1.6.15 Protection layer

Engineered safety features or protective systems or layers that typically involve design for safety in the equipment, administrative procedures, alarms, devices, and/or planned responses to protect against an imminent hazard. These responses may be either automated or initiated by human actions. Protection should be independent of other protection layers and should be user and preliminary hazard analysis (PHA) team approved.

1.6.16 Receiver

The machine-mounted unit that receives signals into the remote control system from a remotely located transmitter.

1.6.17 Regulatory authority

A statutory body having the authority to issue regulations, orders or other instructions having the force of law in respect of any subject covered by this Standard.

1.6.18 Remote control

The ability to control a mobile machine by an operator from an off-the-machine position using a remote controller.

1.6.19 Remote control equipment

The system that consists of the remote controller, the machine-mounted receiver and the associated interface equipment that conveys the machine function commands into the machine's electronic control system. It does not include the machine's electronic control system and actuating devices.

1.6.20 Remote control system

The whole of the system that controls the machine functions including remote control equipment, relevant electronic controls and interposing equipment, monitoring devices and actuating devices.

1.6.21 Remote controller

The assembly of controls and displays used to operate the machine remotely.

This includes transmitters, transceivers or directly-connected pendants and excludes machine-mounted controls or ancillary equipment controls

1.6.22 Remote shutdown

A device located on the remote controller to initiate shut down of all hazardous motion.

1.6.23 Safe state

A state where all motions have ceased on the machine. The machine then remains in a powered standby mode.

1.6.24 Safeguarding

A guard or device designed for the protection of personnel.

1.6.25 Safety

Freedom from unacceptable risks.

1.6.26 Safety device

A protective device, other than a guard, that reduces the danger, if any, resulting from malfunction or foreseeable/unintended misuse of a machine.

1.6.27 Safety instrumented function

A function that is a single set of actions that protects against a single specific hazard. It is made up of sensors, logic solver, and/or final elements that act together to detect a hazard and bring the process to a safe state.

1.6.28 Safety instrumented system (SIS)

System composed of sensors, logic solvers, and final control elements for the purpose of taking the mining system to a safe state when predetermined conditions are violated. Other terms commonly used include 'emergency shutdown system,' 'safety shutdown system,' and 'safety interlock system.'

1.6.29 Safety integrity

Probability of a safety related system satisfactorily performing the required safety functions under all the stated conditions within a stated time frame.

1.6.30 Safety integrity level (SIL)

Discrete level (one out of a possible four) for specifying the safety integrity requirements of the safety functions to be allocated to the safety related systems, where safety integrity level 4 has the highest level of safety integrity and safety integrity level 1 has the lowest.

1.6.31 Safety life cycle

The necessary activities involved in the implementation of safety-critical systems. The activities begin at the concept stage and cease after the systems' decommissioning.

1.6.32 Shall and should

The word 'shall' indicates a statement is mandatory, and the word 'should' indicates a recommendation.

1.6.33 Software

Computer programs, procedures, and possibly associated documentation and data pertaining to the operation of a programmable system.

1.6.34 Standby mode

A stopping of all movement of the machine during which some or all power is maintained to the machine.

1.6.35 Supervisory software

A computer program, usually part of an operating system, that controls the execution of other software and regulates the flow of work in a programmable system.

1.6.36 Teleremote operation

The operation of remote control equipment utilizing only a control system which consists of both a remote control unit and monitors that provide positional and operational information.

1.6.37 Tolerable risk level

The level of risk that is accepted in a given context, based on the current values of society.

1.6.38 Transceiver

A device that has a combined transmitter and receiver.

1.6.39 Transmitter

A specific type of remote controller within the remote control system that sends signals to a receiver.

1.6.40 Validation

The activity of demonstrating that the safety system under consideration, before or after installation, meets in all respects the safety requirements specification for that safety system.

1.6.41 Verification

The activity of demonstrating for each phase of the relevant safety life cycle by analysis and/or tests that, for the specific inputs, the deliverables meet in all respects the objectives and requirements set for the specific phase.

SECTION 2 DESIGN AND CONSTRUCTION

2.1 GENERAL

Mining machines often work in locations where the clearance to other machines or fixed structures (rib, roof, sidewalls, etc.) is limited. The machines are also large and powerful and, if they move in an unpredictable manner (whole machine or parts of the machine), they present a considerable risk to the safety of mine workers.

Remote control systems design shall be based on sound engineering principles and suitable for their intended life cycle.

Various forms of remote control may be provided including radio or infra-red transmitters and receivers or direct electrical connections.

2.2 MACHINES

At the design stage, the remote control system shall be subjected to a system safety approach as detailed in Appendix A.

The remote control system shall be designed to mitigate hazardous motions identified in the risk assessment to a tolerable risk level.

The risk assessment shall consider, but not be limited to, the following mitigation techniques:

- (a) Automatically defaulting the machine to an acceptable safe state within a specific time period.
- (b) Additional barriers as determined by the risk assessment.
- (c) Comprehensive safeguarding practices.
NOTE: Mining machines are inherently more difficult to guard comprehensively, compared to fixed industrial equipment, and rely on effective safeguarding practices.
- (d) The possible need for a higher level of safeguarding for situations where multiple remote controllers are used on the same machine or multiple machines are in range.
- (e) Isolation of particular sections of the machine to mitigate any hazardous movement while other sections remain energized during specified maintenance procedures.

The remote control system design and its risk assessment shall address the whole operational cycle with respect to identified hazards, e.g. for a continuous miner, cut, flit, breakaway and maintenance.

The remote control system design and its risk assessment shall address the risk to operators and maintenance personnel while gaining visual or activation access to visual displays or control operators. Mitigation of risk options may consider data transfer to a safe location off machine or the fitting of an operating cabin.

2.3 SYSTEM REQUIREMENTS

2.3.1 System safeguarding

Where a risk assessment determines that a failure mode can result in an unacceptable risk, system safeguarding shall put the machine into an acceptable safe state within a time determined by the risk assessment. The process of putting the machine into a safe state shall have priority over all other operational functions. It is recommended that SILs for system safeguarding be determined in accordance with Appendix A. Specific failure modes to be assessed shall include, but not be limited to, the following:

- (a) Deviation (including loss) of power supply, outside the rated limits.
- (b) Reception of more than one signal on the same frequency.
- (c) Simultaneous reception of conflicting signals, e.g. raise and lower.
- (d) Disparity between output status and input signal received. If determined necessary by risk assessment, final element verification shall be included.

NOTE: This means that outputs may need to be monitored at such points as hydraulic cylinders, solenoid valve output ports and motor terminals.

- (e) Receiving incorrect transmitter identification codes.
- (f) Receiving corrupted transmission data for a predetermined period.
- (g) Loss of transmitter signal for a predetermined period.
- (h) A hardware or software fault, e.g. as may be detected by an independent microprocessor watchdog system.
- (i) An unsafe condition at start up.
- (j) A malfunctioning safeguard.

NOTE: The above list is not intended to be comprehensive, and other conditions may require consideration.

In the event of any system shutdown indication of the cause should be displayed.

2.3.2 Inadvertent operation

The remote control system shall be designed and risk assessed to mitigate inadvertent start-up of motors or actuators within the tolerable risk level.

To negate the risk of a transmitter being left on inadvertently, an automatic shut-down system should be considered. The duration of inactivity prior to shut down should be determined by risk assessment.

2.3.3 Ancillary equipment control

When the machine is under remote control, all motion shall be initiated from the remote controller only, unless the design encompasses specific functions under specified circumstances that are safe to operate at the machine, e.g. bolting rigs on a continuous miner.

2.3.4 Multiple remote controllers

There shall be an effective means of ensuring that, when a machine is under remote control, it cannot be operated from any other remote controller or source, unless specifically designed to do so.

For machines specifically designed for operation with two or more remote controllers, e.g. shearer, a means shall be provided to indicate to the operators that multiple control is in operation.

2.3.5 Multiple control modes

Where alternate control modes are provided, e.g. manual controls and radio remote control, a risk assessment shall determine the hazard mitigation controls required to meet the tolerable risk level. Each of the following features shall be considered in the risk assessment along with any additional controls based on circumstances:

- (a) The selection between modes of control shall be designed with an effective interlock to prevent the inadvertent operation of any functions associated with the unselected mode.
- (b) Visual indication shall be provided on the machine to indicate which mode of control has been selected.
- (c) A single means of isolating both modes of control shall be provided.
- (d) Only one point of mode selection shall be available.
- (e) The operation of the mode selection shall not introduce a hazard to the operator or maintainer.
- (f) The mode selection shall be located and arranged such that the person selecting the mode is not exposed to a potentially dangerous situation, e.g. a trapped key system that ensures that the operator is located away from moving parts or swing radius.

2.3.6 Machine start and restart

In a normal mode of operation, e.g. remote control or local, the start or restart of a machine, or part of a machine, shall only be possible when all system safeguards are in place. An exception is for emergency controls and/or recovery where a risk assessment shall determine the normal safeguards that can be overridden for the circumstances (Refer Clause 2.10.8).

A system shall be fitted to the machine to warn of the intention of the machine to start or of the operation of any hazardous functions. The system employed shall be determined in the assessment of safety risk as provided for in Appendix A.

2.3.7 Protection from unintended operations

The remote control system shall be designed to mitigate hazardous conditions arising from unintended operations identified in the risk assessment within a tolerable risk level. It is recommended that SILs, if required, be determined in accordance with Appendix A.

The risk assessment shall include, but not be limited to, the following points of consideration:

- (a) The design of the remote control system shall be such that the likelihood of a single fault resulting in a hazardous condition is mitigated to a tolerable risk level.
NOTE: Examples of potential failure modes are provided in Appendix B.
- (b) A means shall be provided to isolate the remote control equipment from the rest of the machine's control system in order to prevent inadvertent operation by remote control. Operation of this device shall not cause hazardous motion of the machine.
- (c) External interference to the remote control system shall not cause a hazardous condition of the machine.
NOTE: Examples of external interference are electromagnetic interference (EMI) from high power electrical circuits, radio interference, ground fault currents and signal corruption.
- (d) Remote control equipment for machines shall be located, protected or have signs fitted to deter against unauthorised interference by personnel. Authorized access to the interior of remote control equipment shall only be possible by the use of a key or tool.

- (e) Components of the remote control equipment shall be designed, constructed, secured, or contained so that the likelihood of breakage or loosening of components resulting in hazardous motion of the machine is mitigated to a tolerable risk level
- (f) Actuating controls shall be designed so as to reduce the likelihood of unintentional operation. For example, a shrouded push-button lockable selector switch, two-hand control or tactile feedback could be used.

NOTE: Particular attention should be paid to start functions.

- (g) Remote control commands that would cause any hazardous motion when the machine is started or restarted shall not be stored in any memory of a remote control system.
- (h) Start controls and remote initiation of safety devices, e.g. fire suppression, shall be shrouded, gated, positioned or otherwise designed so that the likelihood of them being operated unintentionally is within the tolerable risk level.
- (i) The remote control system should not rely solely on the detection of an analogue value to determine the direction of motion. Any hazards resulting from any unintentional movement shall be mitigated to a tolerable risk level.

NOTE: Proportional joysticks and actuators, for example, may include switches or other means to select direction.

- (j) Where the incorrect connections of a pendant or umbilical cord of a remote control system may cause a hazardous motion of the machine, the connections shall be designed and constructed to prevent incorrect connection. All remote control connections shall be secured to prevent unintentional separation.
- (k) The loss or changes to electrical power parameters outside defined limits shall not cause hazardous motion, nor prevent operation of the remote shutdown or any emergency stop device.
- (l) The restoration of power to remote controllers shall not cause start up.
- (m) All machine remote control systems shall be designed and constructed so that loss of electrical power, hydraulic pressure, or pneumatic pressure shall not result in hazardous motion.
- (n) The loss or changes to battery power parameters outside defined limits shall not cause hazardous motion, nor prevent the operation of the remote shutdown or any emergency stop device.

2.3.8 Design of the remote controllers

2.3.8.1 Standardization

Where different control methods, e.g. manual, pendant and remote are used, the controls should be standardized in terms of function and logic (including direction of operation, where applicable).

Where remote controllers are intended for use at sites with existing machines, the design should take into consideration site standardization of control function and direction of operation, where practical.

2.3.8.2 Controls

Controls shall be designed with the following functionality:

- (a) All control elements, e.g. buttons, levers and other devices, on the remote controller that cause machine motions shall be designed so that the controlled motions stop when the button or device is released, i.e. a 'deadman' control. This requirement does not need to be applied where a risk assessment demonstrates that specific functions under specified circumstances are safe to continuously operate.

- (b) Human machine interfaces (HMIs) including touch screens shall be suitable for exposure to the arduous duty to which they are subjected.
- (c) The remote controller shall have a remote shutdown device that is accessible and prominent.
- (d) A means shall be provided on remote controllers to indicate that the power of the remote controller is on.

NOTE: HB 59 provides guidance on the design and layout of remote controllers.

2.3.8.3 *Safeguarding machine operator using a portable remote controller*

Safeguarding shall be provided to shut the machine down in the event of the machine operator being disabled or falling over while controlling the machine. Where continued operation of sequential equipment, e.g. shearer instigated roof support systems, can cause a hazard, the operation of the safeguarding shall cause sequential operations to stop.

Examples of the means of protection include:

- (a) Protection against inclination of the unit in excess of 45° either in the forward or sideways directions relative to the normal plane.
- (b) Deadman control.

The designer, using risk assessment techniques, may incorporate an alternative safeguarding system.

2.3.9 *Spacing and clearance*

Remote controller panels, including keyboards, touch screens and membranes shall be designed to ensure sufficient space and clearances are provided between controls.

NOTE: Appendix C indicates the minimum recommended distances between various control types both singularly and, when appropriate, in an array.

Those minimum separations are for bare-handed operations. When gloves are worn, separations may need to be increased accordingly.

2.3.10 *Location of controls and displays*

2.3.10.1 *Identification*

Controls and displays on the remote controllers shall be clearly identifiable and readily distinguishable from each other. They should be identified by either words or symbols to indicate their function. AS 2956 and ISO 7000 may provide appropriate symbols or wording.

2.3.10.2 *Visual indication*

Warning lights or visual indication, provided on the remote controller panel, shall be visible to the operator.

Where visual display indicators are installed on the remote controller to indicate critical warning or safety operations, the indication shall comply with the characteristics provided for in Appendix E.

2.3.10.3 *Device location*

Controls requiring frequent operation shall be within easy reach in front of the operator. The most important or frequently used displays should be located within easy view of the operator.

NOTES:

- 1 Refer to Appendix C for design recommendations.
- 2 Typical control characteristics are shown in Appendix D.

2.3.10.4 *Directions of control movements*

The direction of motion of a control, as defined by its movement when viewing the control, should correspond with the movement of the controlled object in the operator's visual field, while viewing the object from a specified operating position.

Table 1 specifies the directions of control movements that shall be adopted for various control functions unless machine operations dictate otherwise.

TABLE 1
DIRECTIONS OF CONTROL MOVEMENTS

Control function	Direction of the control action
On	Right, forward, pull (switch knobs) (Switches down—valves counter clockwise)
Off	Left, rearward, push (switch knobs) (Switches up)
Right	Clockwise, right
Left	Counterclockwise, left
Up or raise	Up rearward
Down or lower	Down, forward
Retract	Backward, pull, counterclockwise, up
Extend	Forward, push, clockwise, up
Increase	Forward, push, clockwise, in
Decrease	Left, down, backward, counterclockwise, out
Open valve	Counterclockwise
Close valve	Clockwise
Forward	Forward
Reverse	Backwards
Emergency stop	Push or cord pull
Remote shutdown	Left, backward, push (switch knobs) (switches up)

2.3.10.5 *Design orientation*

The remote controller shall be designed so that operating the controls with incorrect orientation is mitigated to within a tolerable risk level. This should reduce the likelihood of unintentional misuse of the controls/functions. For example, the design should discourage use of the remote control panel upside down.

NOTE: Where the controller can be used in multiple orientations of machine operator positioning, an incompatibility between the movement of the controlled object and the direction of motion of a control may increase hazards to operators and other persons. Accordingly, risk should be assessed in consultation with the equipment users.

2.3.10.6 *Adjustable controls*

Where incremental or proportional controls are used, the type and extent of any machine or system response lag must be considered in designing the control system.

2.3.10.7 *Identification and labelling*

The colour identification of pushbuttons shall comply with the following:

- (a) 'STOP' buttons shall be coloured red.
- (b) 'EMERGENCY' stop buttons shall be coloured red.

- (c) 'START' buttons shall be coloured green.

All buttons controlling functions other than those given in Items (a), (b) and (c) above should be of a colour other than red or green.

Labelling convention should conform to ISO 7000.

2.3.10.8 Size of portable remote controller

The ergonomics and physical loads associated with carrying a remote controller should be considered in the design of the remote control unit. The size and weight of the remote controller should be designed for constant use, i.e. lightweight, or a method of support provided.

2.4 DROP TEST FOR PORTABLE REMOTE CONTROLLERS

A portable remote controller shall be capable of withstanding a free vertical fall of 1 m onto a rigid steel surface without—

- (a) introducing hazardous motion;
- (b) inadvertently starting; or
- (c) rendering stop controls inoperable.

2.5 IMPACT TEST FOR PORTABLE REMOTE CONTROLLERS

A portable remote controller shall be capable of withstanding an impact test in accordance with Appendix F. At the completion of this test the functionality of the portable remote controller shall be verified to ensure that—

- (a) hazardous motion has not been introduced;
- (b) inadvertent starting does not occur; or
- (c) stop controls are not rendered inoperable.

2.6 RADIO CONTROL

2.6.1 Electromagnetic and radio-frequency interference

The risk assessment shall consider the effects of EMI and radio interference on the remote control equipment in order to mitigate any hazardous motion of the machine within a tolerable risk level. The level of EMI should be related to the life-cycle operating environment of the machine.

The design, construction and installation of the remote control equipment should include shielding, filtering, suppression, and grounding to provide immunity from the effects of EMI.

EMI and radio interference shall not cause premature ignition of explosives. Refer to AS 2187.2.

2.6.2 Spectrum management

The design of the remote controller and externally located remote control equipment should consider the various issues associated with spectrum management.

2.7 OPERATING RANGE

The operating range of the remote controller shall be suitable for the environment and operating requirements of the equipment or machine. The suitability of the range of the controller shall be included in the assessment of safety risk as provided for in Appendix A.

Any means of adjusting the radio RF power output shall be tamperproof.