Guidelines for the design of remote controlled mining equipment

MDG 5001

Produced by Mine Safety Operations Division

New South Wales Department of Primary Industries

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PRIMARY INDUSTRIES

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MDG 5001

GUIDELINES FOR THE DESIGN OF REMOTE CONTROLLED MINING EQUIPMENT

Foreword

These guidelines for the design of remote controlled mining equipment follow a review into mine safety commissioned by the NSW Minister for Mineral Resources, the Hon Bob Martin MP, in November 1996.

The *Mine Safety Review* examined the safety practices of both industry and the NSW Department of Mineral Resources (DMR) and *MADE* 44 recommendations that addressed areas requiring change.

The Minister supported all 44 recommendations and moved quickly to establish a tripartite process where representatives from government, industry and unions would work together in Task Groups to implement the *Review's* findings.

One recommendation stated that 'there be a tripartite examination of safety issues associated with the introduction of remote controlled equipment underground'. This advice followed concerns that equipment was being introduced into underground work environments before it was well understood. *TASK GROUP 1 WAS FORMED TO ADDRESS THIS PARTICULAR RECOMMENDATION*

Task Group One investigated the issues associated with the introduction and use of remotely controlled underground mining equipment in NSW, in particular, issues that emerged from remotely controlled continuous miners in the coal industry, and load haul *DUMP VEHICLES* in the metalliferous industry.

Information was assembled from NSW, interstate and overseas and an issues paper prepared. Current guidance information (AS/NZS 4240: 1994, "Remote controls for mining equipment" and the Department of Mineral Resources Guidelines for Safe Mining) were assessed to determine if the identified issues are addressed.

Guidelines were drafted and distributed to over 300 stakeholders for comments. Feedback as well as information gained from a fatality involving remote control equipment at United Colliery was incorporated into the final draft.

These guidelines are the work of Task Group One lead by John Waudby (DMR). Other members included Stan Goodman (DMR), Jim Simpson (Powercoal), Brett Fletcher (Pasminco), Ron Stothard, (CFMEU) and Allan McDermott (AWU).

A special technical working group was also established to assist with the guidelines and included Kevin Reed (DMR), Peter Mitchell (Forced Potato and Pempek Systems), Kevin Mc Master (Tamrock), Ray Gooley (Jeffrey Machinery), John Chapman (Joy Manufacturing), Mariusz Dudzik (Nautitech), Eric De Zoeten (Voest Alpine Control Systems), Anthony Ryan (DMR), Patrick Donohue (University of NSW), Jean Cross (University of NSW), John Waudby (DMR) and David Reid (Mining Technologies Australia)
Comments on these guidelines for possible consideration in future editions should be forwarded in writing to:

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Task Group One has also produced 'Guidelines for the Use of Remote Controlled Mining Equipment' - please refer to MDG 5002.

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1 PREFACE

These guidelines have been prepared following the NSW Government's commitment to implement the recommendations of the 'Review of Mine Safety in NSW' Report. The report identified concerns with the use of remote controlled equipment and recommended -

> 'There be a tripartite examination of safety issues associated with the introduction of remote controlled equipment underground'.

2 INTRODUCTION

Because of the inherent hazards associated with mining activities and the complexity of mining equipment and the associated systems, procedures and methods, the potential for a serious accident to occur will always be present. The ultimate responsibility for the safety of any mine, and the manner in which it is operated, rests with the manager of the mine.

The manager of a mine should firstly ensure the mining equipment is fit for purpose and then develop a procedure or protocol which clearly defines the circumstances which will determine when work tasks are to be carried out using remote controlled equipment. This procedure or protocol should be suitably communicated to all relevant personnel at the mine and regular reviews should be carried out to ensure that there is a full understanding of the procedure.

3 RISK MANAGEMENT

It is widely accepted that risk management practices using the various techniques of risk assessment contribute significantly towards the improvement in the safety of complex operations and equipment.

Remote controlled mining machines have been introduced to primarily improve safety. Safety can be enhanced by moving the operator away from hazards such as falls of ground, dust, gases, noise and vibration. However, the use of remote controlled mining equipment can expose workers to different hazards, such as, being crushed by the machine being operated or being crushed by other machines. Also, the risk from the traditional hazards of falls of ground and gas emissions or dust explosions, may be increased in a manner that is not readily recognised.

This recognition of introducing different hazards and increasing the risk from traditional hazards requires a systematic approach to adequately manage the changes. As such, risk management practices, carried out in accordance with MDG1010, 'RISK MANAGEMENT HANDBOOK FOR THE MINING INDUSTRY', should be the basis for the design of remote controlled mining equipment. Guidance on risk assessment for remote controlled equipment is also given in Appendix A, AS/NZS 4240, "REMOTE CONTROLS FOR MINING EQUIPMENT".

4 PURPOSE OF THE GUIDELINE

To provide information to support the technical risk management process, so that appropriate hazard controls can be identified, implemented and managed.

5 SCOPE

This guideline is limited to the equipment environment, equipment design and equipment manufacture.
It applies to systems where the remote controls are located with the operator who remains in visual and audible range of the equipment being controlled. This guideline does not set down control processes for the use of the equipment.
Operational guidance for the control and use of this equipment is given in "GUIDELINES FOR THE USE OF REMOTE CONTROLLED MINING EQUIPMENT".

6 APPLICATION

This Section applies to remote controlled mining equipment and concentrates on continuous miners and load haul dump vehicles. However it is also applicable to equipment such as breaker line supports, flexible conveyor trains, shearers, shovels and shuttle cars.
It does not apply to the following:

(a) Mining equipment operated beyond the natural visual and audible range of an operator, eg. tele operated equipment.
(b) Automatic guided vehicle systems.
(c) Automatic conveyor systems.
(d) Longwall supports
(e) Special purpose equipment.
(f) Cranes.
(g) Shaft and drift winders.
(h) Automatic ore handling facilities.

7 GENERAL

This document gives guidance in the areas of, equipment environment, equipment design and equipment manufacture. However these should not be treated in isolation, they should be elements of a total package that includes procedures for the use equipment. The best efforts in designing the mining environment, designing equipment, designing work processes, training and safety culture will not guarantee a safer workplace unless they are marshaled together to integrate and assimilate the machine into the production scene.

8 WORK ENVIRONMENT

When in remote control, the range of the machine is often extended, because there is no on-board operator, this has implications for general mining hazard controls such as roof support, ventilation and unintentional initiation of explosives due to electromagnetic interference.

The operator, other workers and the machine are often in close proximity, in a restricted space and the operators are no longer protected by the driver's safety cabin or confined to one place. The safety of the operator is subject to the prevailing local conditions and what may have been a safe location when operating manually, may now lead to additional or increased risk to the operator and other workers. The design of the remote control system should consider these factors.

9 TECHNICAL GUIDELINES FOR REMOTE CONTROL EQUIPMENT

These guidelines do not consider the design of controls for the operation of the equipment in manual mode. However where manual controls are provided for mining equipment they shall be provided in a location and with facilities to prevent the operator being injured by any motion of the machine (for example, being crushed between the machine and the rib side).

The sub systems considered in these guidelines are;

- a remote control transmitter unit
- a transmission medium from a remote control unit to the machine microprocessor unit
- a microprocessor mounted on the machine that interfaces with a machine
- a remote control receiver unit

These are generally illustrated in Figure 1.

The basic components from this diagram that need to be considered are;

Hardware	being the physical components that make up the control system.
Software	being the programs that tell the hardware how to operate.
Signal	being the control message that is transmitted from the transmitter to the receiver.

For definitions of terms refer to AS/NZS 4240, “REMOTE CONTROLS FOR MINING EQUIPMENT”.

10 SPECIFIC REQUIREMENTS FOR REMOTE CONTROL SYSTEMS

10.1 Scope

This section sets out requirements for the design and construction, of remote control systems for mining machines. It applies to systems where the remote controls are located with the operator who remains in visual and audible range of

the machine being controlled. This guideline does not set down control processes for the use of the machine.

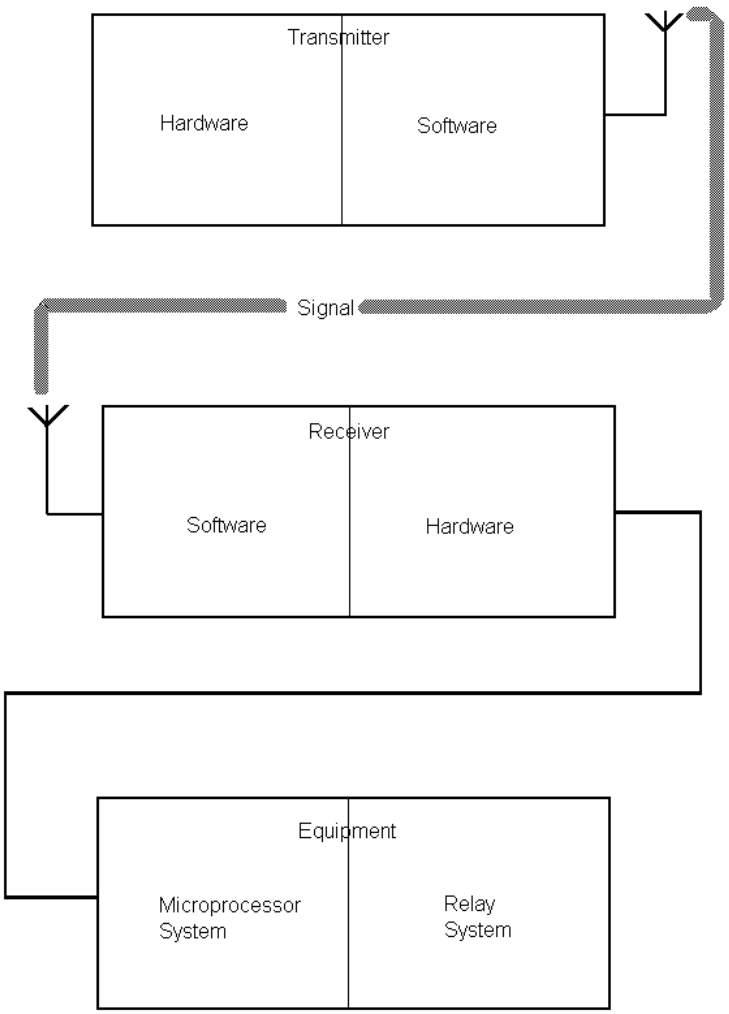
10.2 Remote Control System

10.2.1 General

The physical construction of the remote control systems shall be designed to a minimum of AS/NZS 4240, “REMOTE CONTROLS FOR MINING EQUIPMENT”, and which will facilitate inspection and maintenance. They shall be well constructed, based on sound engineering principles, sound ergonomic principles and suitable for their intended use.

Remote control systems shall only be designed or modified by persons having adequate knowledge of the machine and who are familiar with the operating procedures

Figure 1.



10.2.2 Assessment of the safety risk

An assessment about the safety risk of mining machinery that is remotely controlled shall be made prior to manufacture or modification of the mining machinery. This assessment shall give an indication of the safety importance of the control function concerned and determine the relative attention that shall be paid to the types of barriers and the levels of redundancy and reliability (integrity level) that is required.

Risk assessment barriers as protection against a hazard can be categorised as follows :

Hard barrier : Where the action is taken automatically to remove the hazard without the intervention of people or a physical barrier is placed between people and the hazard.

Mixed barrier : Where action is taken automatically but the hazard is not totally removed and action is required by people to follow a procedure to remove any secondary hazards.

Soft barrier : Where no action is taken and people are required to follow a procedure to remove any hazards.

Where automatic action to implement a hard or mixed barrier is designed into the system, the integrity or reliability of the system to perform the safety function needs to be of a higher level than that required for a non critical function. This requires a more critical examination of the system and components used within the system to ensure the integrity and reliability of the system.
Figure 2 gives a brief overview of different methods that can be applied to a system to ensure degrees of integrity and reliability.
The supplier of the machine should prepare and provide to the purchaser a profile of their machine listing the features that apply to their machine. This should be consistent with the criticality determined by risk assessment.

10.2.3 System requirements

When the machine is under remote control, all motion shall be initiated from the remote controller only, except for emergency stop functions which shall be hard wired at the machine.

Control systems which are duplicated (eg. manual controls and remote control) shall be provided with the following features:

(a) The selection of either mode of control shall be designed with an effective mechanism to prevent the inadvertent operation of any controls associated with the unselected mode. It shall not be possible to place the machine into a remote control mode of operation from the remote control transmitter. This function shall be selected at the machine.

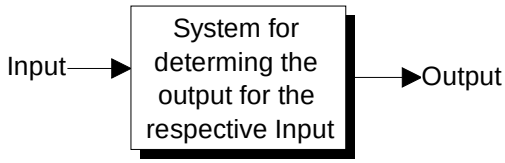
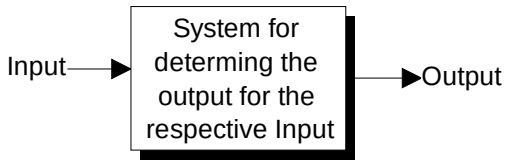
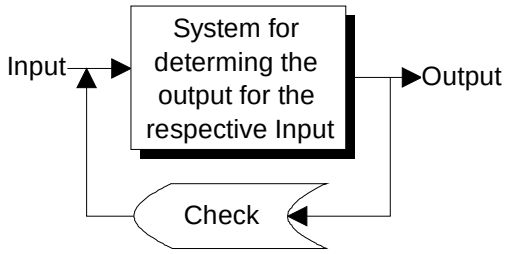
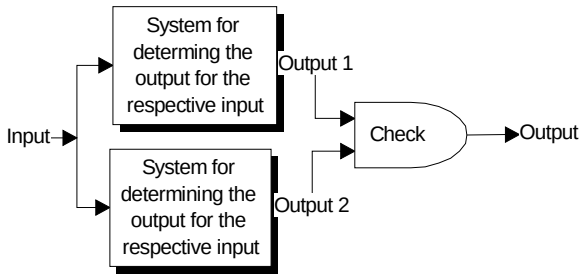
(b) There shall be an effective means of ensuring when the machine is under remote control that it cannot be operated from any other controller or source, unless specifically designed to do so.

(c) A single means of isolating all control modes shall be provided.

(d) Visual indication shall be provided on the machine to indicate the control mode that has been selected.

(e) When switching between different modes of operation the system shall ensure that the machine shuts down or is already shut down and prevents inadvertent start-up or inadvertent motion of the machine.

Figure 2. Integrity/Reliability Methods

BASIC SYSTEM 	Off the shelf components and/or Components operated at maximum rating and/or No scrutiny or control of hardware or software
	Selected components and/or Components operated at below maximum rating and/or Scrutiny and control of hardware and software
	Check that output related to input
	Output 1 & Output 2 checked if not same then no Output

For further information refer to:
AS 4024.1 Safeguarding of Machinery
BS EN 954-1:1997 Safety of Machinery-Safety related parts of Control Systems
Draft IEC 1508 Functional Safety; Safety Related Systems

10.2.4 Prestart warning facilities

A system shall be fitted to the machine to warn of the intention of the critical parts of the machine to start when remote control operation is selected.

10.3 Remote Shutdown Devices and Emergency Stop Device

10.3.1 Remote Shutdown device

Where there is more than one control or work station, a stop device shall be positioned at each station.
The resetting of stop device shall not cause the machine or associated machine to operate. Every remote controller shall incorporate a remote stop device that is both accessible and prominent.

10.3.2 Emergency stop device

Where required by risk assessment or legislation, remotely controlled machine shall incorporate additional emergency stop device(s).

The emergency stop device shall be hard wired and operate independently from any electronic or programmable machine, shall be fail safe and shall not be affected by power failure to the machine or remote control system. The emergency stop device shall be of the lock out type and resetting of the device shall not cause the machine or associated machine to operate.

No Circuit configuration shall allow the emergency stop device to be over ridden or made inoperative.

10.3.3 Proximity protection

The need for proximity protection to prevent the machine operator from being run over or crushed by the machine being controlled shall be determined by risk assessment.

Where proximity protection is required, this may be provided by barriers, guards or signal detectors. Such devices shall suit the individual machine and operating environment.

11 SYSTEM HARDWARE

System hardware shall be suitable for the environment it is to be used in. When used in a hazardous zone as defined by Australian Standards or legislation, the relevant electrical explosion protection technique, as defined in Australian Standards shall be used. The hardware shall have an IP rating in accordance with AS1939, “Degrees of protection provided by electrical enclosures for electrical equipment (IP Code)”.

11.1 Protection From Unintended Operations

A single electric circuit fault on the remote control system shall not cause hazardous motion of the machine or prevent any machine from being stopped. Components of the remote control system shall be designed, constructed, secured, or contained so that breakage or loosening of components does not result in accidental or inadvertent motion of the machine being controlled.
Typical examples of circuit arrangements that are designed to prevent a single fault causing hazardous motion are:

- No switches in earth legs of electrical control circuits.
- No use of 0 volt or earth potential as a signal to initiate any action other than to shut the machine down.
- Functions being controlled by multiple bits and data strings having error checking.
- Proper design of hydraulic circuits, ie. filtering to prevent contamination of valves, or feedback from the process side of a valve to show that the correct action has occurred.
- The remote control system shall not rely solely on the detection of a single analogue value to determine the direction of motion. Proportional controls should also include switches to select direction, and the analogue output should also include a means to ensure disconnection in the event of a fault.

The manufacturer shall conduct a risk assessment to MDG1010, 'RISK MANAGEMENT HANDBOOK FOR THE MINING INDUSTRY' or any other accepted practice, on the remote control system to demonstrate that a single fault can not cause hazardous motion of the machine or prevent stopping of the machine.

11.2 Covers, Guards and Enclosures

Remote control system machine shall be adequately enclosed, guarded or otherwise protected from damage, unauthorised access or inadvertent operation. Removable covers and guards may be provided to facilitate maintenance. Where covers are provided to prevent unauthorised access, the removal of such covers shall be by means of special tools.

The remote control unit shall be guarded to prevent inadvertent operation or damage of the switches.

11.3 Remote Control Connections

Where the incorrect connections 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.

11.4 Standardisation

Where similar remote controllers are used, the remote controllers should be standardised in terms of function, size, shape, colour and direction of operation. Information for designers regarding the characteristics grouping and types of controls are included in Ergonomic standards and guidelines BS PP 7317.

Controls requiring frequent operation shall be easily accessible to the operator.

Typical guiding principles of grouping and arranging controls are shown in Appendix C, AS4240, "Remote controls of mining machine".

The directions of control movements as specified in Table 2.1 of AS4240 shall be adopted for various control functions unless machine operations dictate otherwise.

All control elements (eg. buttons, levers and other devices) of the remote control that cause machine movement shall be designed so that the controlled motions stop when the button or device is released unless considered inappropriate by risk assessment.

Where control functions are incremental or proportional the type and extent of any machine or system response time must be considered in designing control or displays.

The remote controller should be designed so that its orientation to the operator is obvious to the operator.

Controls and displays of the remote controls shall be clearly identifiable and readily distinguishable from each other. They should be identified by either words or symbols to indicate their function or the consequence of their use in accordance with AS 2956.

11.5 Identification and Labeling

The user shall clearly identify which transmitter controls which machine.

The colour identification of push buttons should comply with the following:

(a) “STOP” buttons should be coloured red.
(b) “START” buttons should be coloured green.
(c) All buttons controlling functions other than those given in Items (a), (b) above should be of a colour other than red or green in accordance with the colour meanings given in Table E1 of AS4240.
(d) Where push buttons operate any switch or similar device by means of an auxiliary circuit, the colours should be determined by the effect on the main circuit and not be related to the state of the auxiliary circuit.

Labeling convention should conform to BS 5378 or ISO 7000.

11.6 Visual Display Indicators

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 of AS4240.

An illuminated “power on” indicator shall be provided on the remote controller to reduce the risk of inadvertent operation of either start or stop functions.

Where warning lights are provided on the remote control panel should be within the operator's normal vision.

The most important or frequently used displays should be located in a central panel area.
The risk assessment should consider the ergonomics of all displays and controls.

12 SYSTEM SOFTWARE

The program designed to operate a particular machine shall be identified and the machine supplier shall have a means of controlling the version in use on the machine. Where the user is able to modify the program this will be carried out only through the machine supplier's control system.

Software program functions can be divided into three basic areas as illustrated in Figure 3 and the supplier should identify critical areas of coding of the program using a consistent approach.

Figure 3

Primary : That which provides direct personal protection **PROTECTION** Secondary : That which provides protection of the machine that may result in a condition that may lead to personal danger
Primary : That which provides control that could create a condition that may lead to personal danger **CONTROL** Secondary : That which controls the state of the system
Primary : That which provides an indication of a dangerous condition and requires a person to respond **MONITORING** Secondary : That which shows the state of the system for operational purposes

Control of software shall not allow alteration of that associated with protection systems without a system being in place to verify and validate the integrity of those changes.
The machine supplier shall put barriers in place to prevent inadvertent changes to critical areas of software programming that could effect the safety of people.

Where the machine is operated by two or more remote controllers the machine shall shut down to a safe condition when contradictory commands are initiated.

Remote control commands or instructions that would cause any unwanted movement when the machine is started or restarted shall not be stored in any memory of a remote control system.

13 SIGNAL TRANSMISSION

13.1 Signal Interference

The system shall have means of checking the integrity of the signal that is received against the signal that was transmitted. Where CCITT checking is used a minimum error rate equal to 16 bits is required.

13.2 Electromagnetic and Radio Frequency Interference

The remote control system shall be effectively immune to interference. External signal interference to the remote control system shall not cause hazardous motion of the machine

The design, construction and installation of the remote control systems shall include shielding, filtering, suppression, separation, or grounding to provide immunity from the effects of electromagnetic interference (EMI). (Refer to the relevant parts of IEC 801).

The machine should be tested for electro magnetic compatibility consistent with the machine design.

NOTE:
In Australia frequency and power ratings are specified by the Commonwealth of Australia Radio communications Act 1992,

13.3 Operating Range

The operating range of the remote controller shall be suitable for the environment and operating requirements of the machine The suitability of the range of the controller shall be included in the assessment of safety risk.
Any means of adjustment of this distance shall be tamper proof.

13.4 Transmitter

A means to prevent an incorrect switch command signal which causes dangerous movement from being transmitted shall be provided.

The transmitter shall have a minimum rating of IP65 in accordance with AS1939, “Degrees of protection provided by electrical enclosures for electrical machine (IP Code)”.

13.4.1 Design of transmitter controls

Design of controls on the remote transmitter should conform to the recommendations contained in Appendix D of AS4240.
The transmitter actuating controls shall be designed so as to reduce the likelihood of unintentional operation. For example, a shrouded push button lockable selector switch, or two hand control. Start controls and remote initiation of safety devices (eg. fire suppression) shall be designed so that they cannot be operated unintentionally.

13.4.2 Size of transmitter

The physical loads associated with carrying a remote controller should be minimal. The size and weight of the remote controller should be designed for constant use.

NOTE: Refer to Worksafe Australia Manual Handling Regulations for further guidance.

Remote control transmitters shall be designed to ensure sufficient space and clearance are provided between controls. Refer to Appendix D of AS4240 which indicates the minimum recommended distances between various control types both singularly and, when appropriate, in an array.
NOTE: These minimum separations distances are for bare handed operation. When gloves are worn, separations may need to be increased.

13.4.3 Safeguarding transmitters

Where deemed necessary by a risk assessment, protection shall be provided to prevent operation of the transmitting unit if the angle of inclination of the unit exceeds 45 degrees from the horizontal plane in any direction.

NOTE: This provision guards against the risk of operating the machine when the operator falls over.

14 SYSTEM SAFEGUARDS

Remote control systems shall be rendered inoperative and the machine shall revert to a neutral mode under the following conditions:
(a) failure of transmitter circuitry (eg phase lock loop unlock).
(b) activation of the remote shutdown device located on the transmitter.
Where the remote shutdown is operated the machine shall stop all movement in the shortest possible time.
(c) loss of power supply.
(d) activation of another mode of control on the machine.
(e) simultaneous reception of conflicting signals, (eg. raise and lower).
(f) disparity between output relay status and input signal received.
(g) loss of transmitter signal for a predetermined period of time.
(h) any incorrect output that causes dangerous movement of the machine.
(i) loss of the transmitted signal for a predetermined period of time
(j) receiving corrupted transmission data continuously for a predetermined period of time.
(k) where a jammed transmitter switch is detected for a predetermined period of time
(l) activation of an independent watchdog system to ensure that no output can be energised or is de-energised when a microprocessor hardware or software failure occurs

The predetermined period of time for each function shall be determined by risk assessment.
In the event of any system shutdown the cause shall be displayed.