AUSTRALIAN ASSOCIATION OF LIVE STEAMERS

Electric Systems for Miniature Locomotives - DESIGN REPORT

ALSSC Authoring Subcommittee

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Australian Association of Live Steamers

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This Design Report provides the design detail and background information for each requirements clause of the Code of Practice for Electric Systems for Miniature Locomotives version 16 November 2017.

Documentation in support of the reasoning and decisions made are:

- **Risk Assessment for AALS Code of Practice for Electric Systems for Miniature Locomotives 29 May 2017.**
- **Comments received on the draft Code of Practice, ending 27 October 2017.**
- **Email discussions amongst members of the sub committee.**
- **AS3000 Wiring Rules 2007.**
- **AS/CA S009:2013 Installation requirements for customer cabling.**
- **AS61508: 2011 Functional safety of electronic safety-related systems.**
- **AS3695.2 2013: Requirements and test methods for electrically powered wheelchairs.**
- **AS2790 Electricity Generating Sets-Transportable.**
- **Various State Legislation on Electrical Safety and Licencing Requirements.**
- **ALSSC letter forming the subcommittee and providing scope dated 3 May 2017.**
- **National Guidelines for the Installation of Electric Drives in Motor Vehicles V2 2011 https://infrastructure.gov.au/roads/vehicle_regulation/bulletin/pdf/NCOP14_Guidelines_Electric_Drive_01Jan2011.pdf**

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AALS - Electric Systems for Miniature Locomotives- Design Report

This document provides the background reasoning for the requirements in the Code of Practice for Electric Systems for Miniature Locomotives. To read this document , the clause is in the left column, the code requirement in the middle and the reasoning and source in the right hand column. This document will form the basis for the independent design verification, in documenting the source of the requirement.

Clause	Item	Reason
1. General	Standard introductory text consistent with other AALS codes of practice.	
2. Context	Standard introductory text consistent with other AALS codes of practice.	
3. Definitions	Definitions are referenced to AALS Code of Practice for Operation of Miniature Railways, Road Vehicles and Plant. Only terms unique to this document are defined here if required.	All definitions preferred to be in one place for consistency however specific functions required by this document are defined in this document.
4. Scope		
4.1	This Code of Practice applies for the building of miniature locomotives which utilise electric systems for operating by an AALS affiliated society in the presence of the public. Locomotive systems may include the power supply, control system, traction system and accessories, any or all of which may be electric, or electric in conjunction with internal combustion, mechanical, hydraulic or other types of systems.	Clarification of scope that defines the document requirements apply only for operation in public, and that any application within a locomotive powered by means other than electric is covered by the code.
4.2	The intention of this Code of Practice is to provide information about the design, construction and operation of the electrical systems of a miniature locomotive to ensure safety for the user or maintainer, and the general public.	Reinforces the requirements aim is safety.
4.3	This Code of Practice will also provide AALS affiliated club executives information regarding these systems should their members wish to pursue this method of locomotive type and establish safe practice to allow visiting members from other AALS affiliated clubs to operate their equipment.	Documents the safety requirements so that it is clear for administrations.

4.4	This code will consider equipment operation at extra low voltage (ELV) which is not exceeding 50v AC or 120v ripple-free DC, and low voltage (LV) which is above ELV and not exceeding 1000v AC or 1500v DC**.** In the case of low voltage (LV) equipment this code shall only consider equipment operating up to common industrial voltages (i.e. 415v AC, or 480v DC) Note: Some jurisdictions consider voltages in excess of 25v AC and 60v DC to be hazardous, even though still ELV. **IMPORTANT** **It is essential for the correct application of this Code that the above explanation and scope of Extra Low Voltage (ELV) and Low Voltage (LV) is clearly understood. Most battery electric drives built by model engineers are Extra Low Voltage (ELV). The typical electrical supply to houses, etc is Low Voltage (LV).**	Clarifies the voltage ranges that this Code covers. These definitions are set in legislation and other standards such as AS3000 and S009 and are not created in this document. Additionally this document considers only typical applications of voltages and thus caps at 415vAC and 480v DC restrain systems to areas where typical industrial standards and experience can apply. However designers / builders need to check in their own jurisdiction the legislated limits applicable to them. The highlighted box is added to highlight the importance of understanding the voltage definitions in the application of the code. It is to combat a popular assumption that 'low' is safe and 'high' is unsafe.
4.5	This code does not consider battery packs greater than 48v DC.	A constraint to typical applications where industrial experience and standards are available.
4.6	This Code of Practice applies to a miniature locomotive that operates within 2½ inch gauge to 7¼ inch gauge railways, and is used for public passenger hauling, or is used on the same tracks at the same time as public passenger hauling.	Clarifies it is for specific sizes of locomotives and only for public operation.
4.7	Due to the rapid change in battery technology, this code is not able to specify practical details for all the various types of batteries that may be utilised now or in the future. Consequently it is a requirement on the designer and builder to adopt the general safety provisions provided for in this code, and to comply with the manufacturers recommendations for installation and operation of such equipment within the safety context.	Battery technology is rapidly changing. This clause recognises the potential for new energy storage systems. If they are to be utilised it is essential that the safety considerations applicable to that technology as stated by the manufacturer be adopted.
4.8	Systems may be electro-mechanical or electronic in nature.	This clause recognises that systems are likely to be of one of two forms,

	A simple electro-mechanical system (ie one that uses relays which have a predictable failure mode) may be used to provide fail safe functionality in an otherwise electronic system.	and electromechanical or fully electronic, and that the electronic system cannot be guaranteed to fail predictably.
4.9	This code uses the concept of failsafe. Failsafe is a specific design philosophy that when applied to a system results in any failure of or within that system having a safe outcome. Specifically certain equipment may be considered to have reliable and predictable failure modes such that they may be designed into a system that produces safe outcomes. Generally such systems require an application of energy to progress to a less safe state (e.g. a higher speed) while a failure will result in the removal of energy, and the equipment thus stopping. In recent radio control systems, the term 'failsafe' has also been used to describe a programmable facility that can respond to a loss of communication between the controller and remote unit. Such facilities are usually set, as a minimum, to remove traction power. However the unit is not necessarily considered failsafe in the traditional sense. Proof of safety is achieved by a detailed analysis of the outcomes of all the various failures of each and every component in the system. Failure Mode and Effects and Criticality Analysis (FMECA) is a technique used in producing a proof of safety. Such analysis becomes increasingly complex as systems become larger and have increased numbers of components. It is recognised that formal and comprehensive proof of safety of systems on miniature locomotives are unlikely to be able to be produced by designers and builders of miniature locomotives used in a hobby environment. Consequently this code will largely consider any control systems that uses electronic components to have an unpredictable failure mode and that such a system would need to be supported by a simple series system which provides the	There are variations in the understanding of 'failsafe'. This clause describes the concept and methods of providing a proof of safety in order to inform designers of an area they may not be familiar with. It is recognised that a proper proof of safety for an electronic system is beyond the scope of most hobbyists.

	level of safety required or an additional independent system that guarantees the reliability of a stop command. Where an all electronic arrangement with safety implications is used in industry then that system would need to comply with AS/IEC 61508 Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems. It is not anticipated that hobbyists will be familiar with these standards nor would suppliers to this hobby so this code attempts to provide guidance to achieve a degree of equivalence. There are other risks that may need consideration and a risk assessment of the overall system shall be conducted by the designer to ensure any hazard is designed out. This code will list some of these potential hazards.	
4.10	The principal safety issue this code addresses is the ability to bring a locomotive to a stand in a reliable way. Thus the safety requirement is to be able to cut traction power and wherever possible, apply brakes reliably upon demand of the operator. (This document refers to this as an Emergency Override. It could take a number of forms). The Emergency Override shall be easily accessible to the driver. Other hazards include the risk of explosion, burns, fire and electric shock or electrocution.	Clear statement of the main safety criteria, and acknowledgement that there are others.
4.11	Commercial builders of genuine model equipment will have their own standards and compliance regime to which their products are built in order to conform to legislated Work, Health and Safety Requirements and electrical regulations and are thus exempt from the design and construction requirements of this Code. However it is recommended that migration to this Code occur wherever its requirements are greater than those currently being used by manufacturers.	This code is not intended to be applied to systems that are already being manufactured to be in compliance with legislated requirements but rather to consolidate and document requirements that are essential for safe operation.

5. Batteries		
5.1	Batteries shall be securely mounted to the vehicle	If batteries can move within the vehicle there is a risk of acid spill, wear of insulation or possible short circuit of terminals.
5.2	Adequate ventilation shall be provided for batteries that gas or have the potential to emit gas so that such gas may freely escape. The design of battery compartments shall ensure that any escaping gas is not channelled to an area that may contain a means of ignition.	Safety requirements for managing gas emission from batteries.
5.3	Wet batteries shall have a means to prevent the escape of electrolyte in the event of an accident.	Battery enclosures are to be suitable to contain any acid spill due to an accident.
5.4	All batteries shall have an isolation device close to the battery. This isolation can be by switch or by removal of a battery lead, in smaller models. The isolation device shall be easily accessible.	Batteries are a source of high current, arcing and ignition and whenever work is being performed or in an emergency, a disconnection point is a important safety requirement to provide isolation.
5.5	Batteries shall be mounted clear of any heat sources.	Overheating batteries can be a hazard due to gassing, or damage to the casing.
5.6	A fuse or circuit breaker shall be provided close to the battery, but external to the battery compartment if a separate compartment is provided, to limit current under fault conditions.	It should be feasible to determine the maximum current draw by the system and thus protect any excess current supply through a fuse or circuit breaker. This is an automatic way of limiting the power of the battery to create a fire or burn out wiring.
5.7	Battery terminals shall be shrouded.	This simple expedient prevents accidental contact from tools or other conducting material causing arcing etc.
5.8	When some battery types are on charge and floating explosive and corrosive gasses are discharged. This is a serious and dangerous explosive hazard. Measures must be taken to charge in very well ventilated areas as an electrical contact opening at the time of battery float can be an ignition source. It is recommended that battery changing take place in a secure well ventilated area away from ignition sources.	Requirement to control the potential for fire or explosion during battery charging.
5.9	When an onboard charger is provided, switching shall be provided to isolate the ELV system when charging, and	Battery charging usually occurs at higher voltage levels than the voltage for which the ELV system operates. There is also a potential for mains

	conversely to isolate the charger when the locomotive is in use.	battery charger faults to be passed through to the charging system. Ensuring the charger disconnects the ELV system and vice versa removes the risk of such faults being conducted through the system.
6. Electrical Systems		
Common Requirements		
6.1	All wiring shall be insulated and held clear of hot or moving parts.	Wiring next to moving or hot parts can have the insulation damaged.
6.2	Care shall be taken that wiring insulation shall be rated for the application and the size of conductor is consistent with the current it is expected to carry as well as any fault current levels.	This provides an awareness that the wire size and insulation type needs to be considered for the application to avoid failure and damage.
6.3	Circuit breakers used on DC systems shall be of a type suited for DC.	DC circuit breakers need to dissipate higher energy levels than AC, so AC breakers should not be used in DC systems. Use of an incorrect breaker may render it ineffective.
6.4	Connectors for wiring between vehicles shall be shrouded to avoids accidental short circuits.	Connectors are often where insulation is at its weakest, but it is also a more likely place for a short circuit.
6.5	Any inclusion of a low voltage on board battery charger shall have the locomotive frame connected to the mains earth and the ELV system shall be isolated from the batteries when charging. It should preferably not be able to operate the locomotive when attached. On board chargers shall not be used while people are on or in the equipment. The presence of an on board charger does not place the locomotive into the Low Voltage category, as the low voltage equipment cannot be used while it is operating.	Low voltage equipment encased in metal need to have an earth connected through to the main earthing system. If it is operated within a locomotive, the metal work of the locomotive is also subject to being an earth situation and thus needs to be earthed (e.g. AS3000)
Requirements for Systems Operating at Voltages within the LV Range		
6.6	All low voltage systems shall be designed and constructed to be double insulated from the locomotive frame. An earth leakage device shall be provided to detect faults to frame. The locomotive shall not be operated while ever a fault to frame	It is not practical on a moving vehicle to have an earthing regime. This means that alternative means needs to be undertaken to protect against short circuits to the frame which may become dangerous. The alternative means specified in AS3000 and S009 include double insulation and the

	exists. A test button shall be provided to test the effectiveness of the earth leakage device. (This is an IT standard type electrical configuration).	provision of a device that detects any short circuit to frame from an active or neutral LV conductor. The use of an ELD is necessary because a single fault will generally be undetectable resulting in a second fault being lethal Thus the first fault needs to be detected.
6.7	All low voltage systems shall ensure there are no accessible terminals, or touch points within the locomotive. Enclosed terminals shall be used. Any bare terminals shall be shrouded, such that removal of the shroud is only possible by the use of a tool.	These are typical precautions against shock for dangerous voltages and are required in AS3000. The use of a tool guarantees that exposure of the terminal is a deliberate act and is thus not accidental.
6.8	ELV and LV systems within the one locomotive shall be separated as far as possible. Double insulation shall be provided on the ELV wiring (either by wiring sheath or insulated ducting) where it runs close (<50mm) to LV wiring.	Separation of ELV and LV wiring is a method to avoid faults between the two systems, and thus dangerous voltages appearing on the ELV system. Where the separation is not possible double insulation is to be provided. This could be by running ELV wiring in a non conductive conduit or duct where it is close to LV wiring. Such requirements are typical in S009. The ELD requirement in 6.6 is not necessarily effective where the fault is between wiring and not to frame, hence the additional double insulation for risk mitigation..
6.9	ELV systems powered from a LV source shall be provided with an isolated power supply to ensure faults within the LV system cannot propagate into the ELV system.	Isolation between the ELV and LV systems is essential to assure safety and prevent mitigation of faults for the LV system to the ELV. Isolated power supplies are those with no physical connection between the two (usually a transformer) but a high level of insulation is provided.
6.10	Consideration shall be given to having all LV traction wiring coloured orange.	Not a mandatory requirement but helpful to identify the LV wiring as needing special consideration.
6.11	No LV wiring shall be accessible in the drivers area.	Safety guaranteed by not actually having a risk of exposure.
6.12	On board LV generators shall not be used to power external equipment unless the generator is compliant with AS2790 - Electricity Generating Sets. Any single or three phase outlets on the generator shall not be able to connect to external devices.	The use of commercial generating sets is predicted but they need to be used with care. As the vehicle can move the use of flexible leads present a danger for which suitable protection as for a typical fixed wiring installation may not be present.
6.13	Some jurisdictions may require LV electrical work to be	Not all States or Territories have the same electrical work requirements.

	performed by an appropriately competent or licensed person. The Builder shall ascertain the specific requirements for their State or Territory.	While this code is National, designers and builders need to ensure LV work conforms to the requirements in their State or Territory.
7. Control Systems		
7.1	Locomotives of 5 inch gauge or larger with the capacity to haul more than one carriage (as indicated in the matrix) shall have a key switch, control box disconnect facility or other arrangement which can be used to immobilise the locomotive against unauthorised use when unattended. It shall not be possible to drive the locomotive with the key, control box or other arrangement removed.	A simple facility to disconnect and immobilise the locomotive is a requirement when it is left unattended to avoid unauthorised operation. this facility can take many forms, however the common requirements is that it is removed from the locomotive to disable it.
7.2	Irrespective of the method of control, an accessible, simple, robust and reliable method shall be provided to be able to bring the locomotive to a stand.	Systems can become complex. This requirement is to ensure that the fundamental safety need to stop the locomotive is done in a fashion that is simple, reliable and able to be easily observed as being so and being effective.
7.3	The system shall be designed to failsafe principles. Any broken wire, defective terminal, defective relay, broken switch or the like shall tend to bring the locomotive to a stand.	Failsafe principles should ensure the system to bring the locomotive to a stand is robust and reliable. Such a system needs no further proof of safety and thus is the preferred approach for the hobbyist.
7.4	Where an electronic control system is provided, compliance with 7.3 can be achieved by providing an independent, reliable and robust method (such as a 'Emergency Override' switch) to bring the locomotive to a stand in the event of a malfunction.	It is realised that most locomotives will have some form of electronic control system as they are simple, inexpensive and power efficient. However such systems are not failsafe and accordingly the addition of a parallel system to provide the robust and reliable method of stopping the locomotive is the simplest means to achieve a compliant system.
7.5	The operator may be remote from the locomotive by use of a control box attached to the locomotive by a lead, or by radio control. The method of control does not alter the need to comply with 7.4.	Acknowledges that there are many methods of control but the principal safety requirement to stop the locomotive is still to be complied with. This may limit the permissible operational methods during public operation.
7.6	Where a remote control system (either by tether or radio) is used, the independent system required in 7.4 may also be an electronic system provided it is totally independent from the main system and the likelihood of any common failure modes is remote. Such dual systems shall be proved operational at all times the locomotive is in use. (i.e. both systems are required to be operational to operate the locomotive). This ensures that in the event of failure of either	Despite the possibility of using a parallel failsafe system of electro-mechanical elements, there remains the potential for a fully electronic control systems that operates in such a way as to provide a high integrity to its safety functionality. This clause acknowledges that this is a possibility with the general requirements for proving such a system is safe. Such a process is expected to make this course of proof an undesirable method for a hobbyist.

	system, the alternate system is available to bring the locomotive to a stand. An analysis shall be made of such an arrangement to demonstrate it provides the safety benefits of a fail safe system through a duplicated system of high reliability.	
7.7	Interlocking of controls may be required (see Matrix) where the locomotive is capable of hauling more than one carriage. Such interlocking should consider the selection of direction only when the locomotive is at a stand, or a very slow speed, and when the throttle is off, or is attached externally to a battery charger.	The scope document requires that the hazards be similar to those when operating a steam locomotive. This limits the degree of hazard reduction at the smaller locomotives, however where the energy levels are higher some simple additional facilities could be provided. In the case of interlocking controls this ensures (as an example) that forward cannot be selected unless the throttle is off. On a small locomotive there is unlikely to be any ill effect if this occurs as wheel slip etc will alert the driver to take suitable action. However on a larger locomotive it could result in an unexpected surge forward while passengers are still boarding. As this hazard does not exist in a steam locomotive, additional protection is considered desirable to prevent it.
7.8	Only one locomotive shall be controllable from the controller at a time, unless the units are coupled and connected as multiple units. Similarly any locomotive shall only be controllable from a single controller at any one time.	There should only be one driver of a train. Precautions may need to be taken to avoid systems capable of operating multiple locos (such as radio systems) from doing so. Interference between systems is also to be removed.
7.9	Where the driver is seated on a vehicle separate to the locomotive, provision of an automatic shut down in the event of the drivers vehicle becoming unattached is highly desirable in locomotives which can haul more than one carriage ('Breakaway Control'). The shut down shall disconnect traction power.	See 7.7 for similar reason. It is noted that breakaway is already controlled through the AALS coupling standards, and thus this feature is an additional control that is implemented because it is relatively easy to do.
7.10	Disconnection or loss of a controller or the control function (either tethered or radio) shall result in a shut down of traction power, and if possible, the application of brakes. In the case of radio control, a loss of the radio link shall shut down traction and, if possible apply the brakes, when applied to a locomotive that can haul more than one carriage.	Disconnection of the controller is a new hazard not present on steam engines. It is perhaps similar to the driver falling off, and the risk is proportional to the size of the locomotive. See 7.7 for similar reason.
7.11	Consideration of the inclusion of dead man control or a driver detector should be given for all locomotives that can haul more than one carriage.	See 7.7 for similar reason.
7.12	An indicator light shall be provided on the control panel to	Shutting down and disabling the loco is a safety requirement. Some clear means needs to be provided if the action of disabling has been effective.

	show when the power is active.	An indicator light is the simplest and most obvious means of doing this, and is observable by others who may not fully understand all the controls.
7.13	When utilising a remote control (wireless) system, builders are encouraged to consider a quality system with robust components and proven reliability. Means of ensuring the transmitter cannot be dropped while the train is operating should be implemented (e.g. use of a lanyard).	Recommendation to assist in managing hazards so that the emergency override is less likely to be needed to be used. Also addresses the new hazard of the driver losing an unattached controller.
7.14	The required application of various hazard reduction controls is shown on the requirements matrix.	See the Requirements Matrix at the end of this document.
8. Proof of Safety Testing and Certification		
8.1	**All Electronic Systems:** All 5 inch gauge or larger locomotives that can haul more than one carriage, and is equipped with an all electronic control system in accordance with Section 7.6 shall have their safety methodology analysed and the results documented as a proof of safety. The analysis may be conducted by the designer, builder or owner. The Proof of Safety shall incorporate a Failure Modes and Effects Analysis, a test plan that demonstrates the effectiveness of the safety systems, and the system shall be tested in the presence of an independent witness who will countersign the proof of safety document.	Clarification of proof of safety documentation required for an all electronic system. See also 7.6 above. This permits club executives to be able to assess suitability for operation in public.
8.2	**Low Voltage Systems:** Any locomotive built with a LV power system shall be certified by a competent electrical engineer or a qualified supervisor electrical to be in compliance with this code of practice. This certificate will be valid for 5 years from the date of inspection and will be void if substantial changes are made to the LV equipment or installation. (See sample template in Appendix 1).	Independent certification that a LV system meets the code requirements to permit club executives to assess suitability for operation in public.
9. Operation		
9.1	The charging of batteries that gas shall be carried out clear of steam locomotives, steaming bays and other areas where an ignition hazard may be present.	Reminder that batteries may gas and that this is a potential hazard if ignition sources are present.
9.2	Consideration shall be given by Societies in regard to a fire	Fire extinguishes may be a simple control following an onboard loco fire.

	extinguisher being carried on trains.	
9.3	The potential of a remote control system could provide a means for a driver to be seated at a different location rather than traditionally at the front of the train. Societies shall consider the hazards and advantages that this may present and ensure suitable operating procedures are in place for any variation to normal operation.	Realisation that other operating methods may result from the use of technology. Not all these hazards may be easily predictable so when a scheme presents, a risk assessment needs to be conducted and operating procedures adjusted where necessary.
9.4	The battery shall be isolated whenever work is being done on the system, except for testing purposes only.	Batteries are a source of high energy and the risk of shorts, arcing and fire are significant and need to be controlled by suitable isolation processes when working on the locomotive.
10. Non Exhaustive List of Hazards		
10.1	Electrical systems	These are an aide de memoire and are used in the risk assessment. Depending on the application, there may be additional hazards. The hazards are deliberately broad and there may be a large number of individual faults that all produce the same outcome. Accordingly controlling the hazardous outcome will also address the many faults that produce it.
10.2	Control System	As 10.1 above.

Reasons for the Requirements Matrix for Hazard Reduction on Miniature Locomotives with Electric Systems

	Small Non passenger hauling loco or vehicle	**Small passenger hauling loco.**	**Major 5 inch or smaller 7.25 inch gauge passenger hauler .**	**Large 7.25" gauge passenger hauler.**
Requirement				
Emergency Override	Not Required	M	M	M
Power On Light	Not Required	M	M	M
Battery Isolation Device	M	M	M	M
Battery Fuse or CB	M	M	M	M
Key Switch	Not Required	R	M	M
Interlocking of controls	Not Required	R	HR	M
Breakaway control	Not Required	R	HR	HR
FailSafe used with Remote Control	R	R	HR	M
Dead Man control	Not Required	Not Required	R	HR

R-Recommended HR-Highly Recommended M-Mandatory N.B. Having a higher level of requirements implementation is always satisfactory.

Emergency Override (Refer to Clause 7.1) - It is always a requirement to be able to reliably stop the vehicle where the consequences are significant. For very small electric locomotives not involved in passenger hauling, it is likely the brakes would be on the driving vehicle and thus this requirement, while most likely still provided, is not as important. Refer to the risk assessment for the energy levels.

Power On Light (Refer to Clause 7.12) - This is a very simple requirement and is thus required for all but the smallest locomotives, similar to the Emergency Override.

Battery Isolation Device (Refer to Clause 5.4) - This requirement is a simple and low cost safety requirements and is thus required always.

Battery Fuse or CB (Refer to Clause 5.6) - Protection devices are also provided in electrical circuits where significant or dangerous conditions could result in high current flows in fault conditions. In such cases the tripping value is related to the expected load current draw. There could be arguments that very high current drives from batteries are impractical to have such devices as in rush currents may cause nuisance tripping. If this is the case then those systems should be designed and built to withstand the highest expected current that the battery can deliver . However the separation of high current drives into separate smaller drives could permit the lower current circuits to be effectively fault limited. Accordingly where this requirement is not adopted the designer / builder needs to ensure that their arrangements are safe.

Key Switch (Refer to Clause 7.1) - There are various ways to achieve an isolation of the system and while a traditional key would appear the obvious way, there are other methods and thus this clause does not restrict the method to be used. The protection provided is related to the potential loss of control energy in the locomotive and is the reason why it is applied only to the larger locomotives. This is in line with the ALSSC scope letter where the level of risk should not be more than an equivalent steam locomotive. This criteria is seen to limit application at lower risk levels.

Interlocking of Controls (Refer to Clause 7.7) - As the consequence increase with mass and power, this requirement is applied as mass and power increases.

Breakaway Control (Refer to Clause 7.9) - This risk is addressed by the AALS coupling standards and thus the requirements for this are additional and recommended because the technology makes it feasible.

Failsafe with Remote Control (Refer to Clause 7.10) - This is a feature of quality radio remote control systems and should be implemented where possible. It is applied as risk levels increase because the hazard of loss of control is already controlled by the inclusion of the Emergency Override function (Clause 7.1). It is thus an additional parallel control.

Dead Man Control (Refer to Clause 7.11) - This is a usual control in full size locomotives, however it is difficult to apply on a miniature locomotive. Accordingly it is included as a desirable function should a design / builder consider it feasible in the particular application.

END