SOUTHERN FEDERATION
of
MODEL ENGINEERING SOCIETIES
Formed from the Federation established in 1970 by Model Engineers for Model Engineers
A Company Limited by Guarantee in England & Wales: No. 9002737
www.sfmes.co.uk

The safe construction and use of electrically-powered miniature locomotives and other vehicles.

August, 2015

1. General and introductory comments.

Steam locomotives and other vehicles are subject to a comprehensive safety regime, some of which might be mandated by legislation. That includes safety pressure testing of the boiler and associated fittings and some other aspects, such as the ability to feed the boiler with adequate supplies of water.

Locomotives and other vehicles powered other than by steam have no requirements for formal checks and so it is sensible to provide some guidelines for their design, construction and use in order to try to ensure safe operation. This is especially important if the locomotive is to be used for public passenger hauling.

2. Scope.

This Guidance Note is intended to cover the special hazards relating to the operation of electrically-powered miniature locomotives or other vehicles. It is additional to the common requirements for sound mechanical design and construction (that the vehicle is capable of carrying the required loads), track-gauging requirements (that it can safely run on the track/road), that it has the necessary compatible couplings (that it can be safely connected to the attached load) and that it has adequate braking for itself and any attached load (that it and any attached load can be stopped in an acceptable distance).

This Note is intended for application to model and miniature vehicles of the scales usually encountered in passenger-carrying 'model' vehicles. Models of scales up to about Gauge 1 or the equivalent are usually too small and/or low powered to represent a significant hazard. Large models, including full-size vehicles, are substantially more hazardous and require professional construction and use considerations.

Henceforth throughout this Note, the term "locomotive" shall be taken to include other types of vehicles without being its being expressly stated.

3. Special Hazards.

The special hazards associated with electrically-powered locomotives are …

a) The potential for rapid release of the stored energy.
b) The potential for uncontrolled running.
c) The potential for fire/smoke/burning from overloaded or defective wiring.

3.1 Rapid release of energy.

In a coal-fired steam locomotive, the energy stored in the fuel is essentially almost inaccessible. It requires quite elaborate arrangements to release it at a rate high enough to be useful. There is no significant chance of a hazard arising from the fuel itself (other than dust/ingestion).

An electrically-powered locomotive is fundamentally different. With a battery system, the total energy stored could be released in a very short time, with a substantial risk of explosion/smoke/fire or burning. (The potential discharge rate for an ordinary car battery is around 100 kW.) With a generator rather than a battery, the potential for significant energy dissipation under fault conditions is probably less but still significant.

The wiring and overload protection arrangements should be adequate for the conditions. Generally, the traction circuits and ancillary circuits (e.g. controllers, sound effects, lights, etc.) will need to be separately protected.

3.2 Uncontrolled running.

Uncontrolled running can result from at least three different causes. One is the electrical failure of the controller. The second is the accidental or unintentional setting of the controller to a non-zero speed. The third is the controller becoming disconnected, e.g. because it is hand-held and the driver gets separated from the vehicle or the controller is mounted on the vehicle but the driving car gets separated from the locomotive.

Most modern commercial control systems rely on the integrity of the semiconductor output devices (MOSFETs, etc.) to provide a ‘zero-speed’ setting. That fails if the controller becomes defective. It is possible, and has happened, that a failure of one or more of the semiconductor output devices applies full battery voltage to the motor(s). Relying on the electronic integrity of the controller is very risky and should be avoided.

Some control systems will permit the power to be applied to the traction motors when first connected or switched on with the controller at a non-zero speed setting. More modern commercial systems require that the controller be set back to zero before any power can be applied to the motors. The control system should be interlocked in some way, electronic or mechanical, to prevent this form of uncontrolled running.

It is also advisable to use a control input device that automatically ‘returns to zero’ when not being set to some other speed/power. That might help to overcome the initial start up issue, but not if the control input becomes sticky or has been put down with the control being held off the ‘zero’ by some nearby object.

Once running, the control system could become disconnected from the control input. Most modern commercial control systems include some form of ‘lanyard’ (as in power boats) to cut the power to the traction motors if the controller should become disconnected. Note that this will not overcome the problem of control system failure.

All of the ‘disconnection’ issues could be overcome by the inclusion of either a high-current relay (readily available for up to at least 200A DC) or some form of high-current mechanical isolator. These should be attached by a lanyard to the driver. In the case of the relay, the low-power actuating coil could be routed through a simple, low-power pull-out connector (e.g. ‘jack plug’) attached to the driver by a lanyard. It is rather more difficult to envisage a high-power mechanical isolator arrangement that would carry the required current and at the same time be reasonably easy to remove by means of a lanyard.

3.3 Overloaded or defective wiring and circuit protection.

Protection by means of fuses or circuit breakers should be adequate for the purpose. The main traction circuit will involve normal running currents of up to 50A even in a small model and may involve currents up to 500A in a large model.

The traction system in electrically-powered locomotives is almost always DC (direct current). It is substantially more difficult to safely break a DC circuit (even a low voltage one) than an AC circuit of the same current. Ordinary AC circuit breakers will not do it reliably.

Specially-rated fuses are available for DC circuits. For low power applications (e.g. up to 50A at 12V) automobile fuses may be adequate. They are designed for the interruption of significant currents in low-voltage systems.

If the electrical supply system is ‘split’ in some way, e.g. by tapped or paralleled batteries, it is important that the protection system itself does not create a hazard as a result of partial protection. For example, a motor control system might go into an anomalous mode if half of its supply voltage were removed by a protection system.

The wiring of an electrically-powered locomotive needs to be adequate for the purpose. The conductors and connectors must be rated to carry at least the normal load currents. The whole installation is also subject to substantial vibration and therefore needs to be well secured. Terminations and connections should be resistant to loosening by vibration and/or age. A compression screw connection on to a soldered-up stranded wire will deform with age and will eventually result in a poor connection.

4. Acknowledgement.

This document has incorporated ideas and concepts, and some text, from the guidance notes prepared for the FLMR (Frimley?) Society drafted by Mr. Paul Naylor, with their permission. That prior work is gratefully acknowledged.

R. Walker
Safety Officer, Southern Federation of Model Engineering Societies.

30th July, 2015.