ELECTRICAL SUPPLY AND ELECTRICAL SAFETY STANDARDS

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Richard Clarke: Gentlemen, this afternoon I would like to talk about the electricity supply and safety standards. There are two components, the electricity supply and how do you get it, and secondly how you make it safe. I'll talk about the electrical supply first and will be assisted by my collegues for the second part of the talk.

Firstly, the electrical supply is the most important thing that sets a tramway museum apart from just about all other vehicle preservation organisations. The rails the trams run on and the electrical supply are the things that bring us together as a group. It would be very difficult for us, as individuals, to construct all the elements of an electric tramway. It is groups such as ourselves that are brought together to amalgamate the rails and the power supply. It is quite a different activity to that of restoring a vinatage car or such like things. We got together as a group because we needed each other to help lay the rails and erect the overhead wire.

The museums in Australia and New Zealand have all addressed the matter of rail and overhead and all were able to get the track down well in advance of the overhead wire. We are now all operating electric tramways, that is, those that are meant to operate as such, and I acknowledge the members from the Parramatta Park steam tramway.

The provision of a power supply was originally a daunting task. Those that saw the original tramway in operation remember massive, ornate brick buildings with very heavy and very costly components inside, and in the early days of the tramway preservation movement, most members thought that this was the only way to go, and at the time it was. Many museums almost broke their financial backs by going out and purchasing ex-tramway power supply equipment. The position now has changed in that now power supply equipment can be obtained quite cheaply and with quite different characteristics than the equipment used by the old tramway systems which closed down over 25 years ago. The philosophy in applying the new equipment can also be quite different too.

Each museum has overcome the problems of applying a power supply and each museum has come up with an almost unique solution which suited their particular application. Problems such as the local mains supply situation, second-hand equipment obtainable locally and the willingness of members to put it together have all been overcome. So what we now have is a interesting mixture of power supply arrangements at our museums around Australia and New Zealand. I personally am always fascinated when I visit other museums to see how the same problems have been overcome in different ways.

As I mentioned earlier, tram museum power supplies can be different to those of the previous tramway system operator. We, as museums, are running much smaller systems and with not the same need for absolute reliability that would be required for a heavy city street. Never the less, we expect our systems to operate every day, and be sufficiently reliable to be able to please our visitors.

Those who operate major tramway systems talk proudly about their 10,000 amp capacity supplies. I remember a supply at Darlinghurst that had a 10,000 amp ammeter. Supplies of that size are in no way needed for tram museum use. As a guide, the average tramcar circuit breaker is set for between 400 and 500 amps, and that was the capacity of the supply that people tried to aim for. That size of supply equates in Sydney to a four-motor P class tramcar really packed, 80 people seated, 120 standing, a crush load of about 200 people, leaving Circular Quay and rounding the sharp 1 in 50 bend and going up the 1 in 15 grade.

Now most of us would like to operate that way, but most of our operations do not require a power supply so big. From our early experience at the old National Park site, 100 amps is enough to run a tramcar. If you are lucky enough to have a power supply bigger than that, it certainly gives you more flexibility, but may also give you more problems. However, when starting off with new equipment or reconditioned second-hand equipment, a 100 amp power supply should be sufficient.

Now for a simple rule of thumb, those who have access to a 415 volt mains supply, one amp of direct current requires just a whisker under one amp of each of the three phases of alternating current. So it is a very simple calculation, you do not have to convert from ac to dc, they are both the same. That allows you to advise the local authority the type of supply you require.

As I mentioned previously, everyone has probably overcome the initial hurdles so there is probably not much need to dwell on that any further. However, the world is progressing and the public in general and legislators are requiring greater safety standards than was required many years ago and we need to address this matter. The safety of electrical supplies ensures that we are providing electrical plant and methods of operation which are satisfactory and comply with the requirements that the authorities and legislators now think we should be providing.

I would like to go into the protection of the power supply and bring up some points and also note the differences in philosophy concerning different sized power supplies. First of all, let us talk about the characteristics of a tramway power supply. They are quite different from those of an ordinary alternating current distribution system such as you might find in a house, factory or a commercial facility.

Like the people who speak about cubic inches in motor cars, there is nothing like a lot of amps to make a tram go. Trams love amps and amps equals drawbar pull, tractive effort, acceleration and generally the force to drive the tram along. Without amps a tram may not be able to operate.

Voltage is rather different. Those who have been brought up with alternating current networks, and that would be the average electric supply authority employee or an electrician in a factory, all of these people have been brought up knowing that stability of voltage is very important. That belief goes back to basically two things, alternating current used for domestic lighting and television sets. Both of these items are particularly susceptible to voltage fluctuations, and can provide poor performance if the voltage changes. With trams, voltage does not matter at all. As long as there is enough power to keep the circuit breaker closed, the tram will go, almost regardless of the voltage. So dc systems for tramways, and particularly for tramway museums where money is short, can cope with quite a high voltage drop. One could cope with a drop of 20 to 25% and still operate quite satisfactorily. In an ac distribution system, the rules speak about a 5% drop maximum. However most people aim for a drop of not more that 3%. So that is the scene on how the power supplies are different, and why if you get an electrician who is an expert on factory installations, he or she might well get it wrong and end up costing you quite a deal of money.

With that as an introduction, let's speak about protection. Protection serves two purposes, to prevent the current overheating and the fire hazard that could result, and to protect against electric shock. I'll deal initially about protection to prevent damage.

It is a fairly simple process and philosophy to design the system so that at no time the current gets to a level dangerous enough as to cause overheating and failure of the cables. However, there are different approaches to the to the solution, dependant on the size of your system.

For a semi-conductor rectifier, and I believe most of us have semi- conductor or mercury arc rectifiers, for anything other than a rotating machine rectifier, the current on the dc side immediately reflects back onto the ac side. So if cables are sized correctly, protection on the ac side can more than give adequate protection, and there is no need for any other protection on the system. If, however, there are large rotary converters with a lot of mass or a remote generator set with brushes, dc protection is necessary to cut off the current before damage is done to the brush gear or before additional energy is taken out from the spinning mass of the converter or generator set.

Now, why do I say that ac protection is important and cheap? Well, it's upstream, so it protects everything. It's also very cheap to obtain and it's modern. dc protection is not readily available and is twenty to thirty times the cost of ac protection. So for a small operation, if the size of the wire is correct, ac equipment will give total protection of the system.

Now I'll tell you the checks you have to do for this. A fault can occur right alongside the substation, and that's obviously the worst case. You have to check that the protection is adequate to cover a fault at this location. Again, I'll reinforce that tramway systems have a lot of voltage drop, so at the far end of the system, the amount of current which flows through a fault can be much lower. One has to make sure that if a fault occurs at the far end of the system, the protection equipment at the substation must be able to detect this fault and turn the current off in time. If one designs and checks a system appropriately, one can use ac protection equipment to protect the feeder.

Protection of the rectifiers is another subject. Silicon rectifiers have become so cheap these days that they are cheaper than the fuses people used to buy to protect them. Right now it is cheaper to buy a second set of rectifiers, put them in the substation, and not particularly have a fuse on each diode. Again, diodes can be obtained over-size quite cheaply so that protection for the feeder and the transformer will also protect the diodes.

So much for the electrical protection of the system, and perhaps I might point out that if you are using a very large power supply, some of these points may need modification. With a large power supply, one may need extra protection, especially if there is rotating machinery there. In general, however, the previously mentioned is all the protection you will need.

Now let us discuss safety of the overhead wire. By its nature, a tramway system cannot be protected from someone touching the overhead wire. It's just not designed that way and there is no feasible way of turning it off. So overhead wire has to be designed and installed so that it cannot be touched. There are fairly well set out guidelines, setting out minimum heights of trolley wire to ensure that the public don't touch. There are a few other tricks, for example in Sydney, we use wooden poles outside the depot area. A number of other museums use metal poles and metal brackets. One should be very careful with metal poles and brackets, and ensure that these are kept quite a distance away from the overhead trolley wire so that inadvertent contact by maintenance staff is reduced. If you cannot keep the wires and the structures apart, it means that maintenance of the overhead wires using live wire techniques will not be possible. But if the trolley wire and the metal can be kept apart, then live overhead line maintenance techniques are possible.

I'll let Peter and Craig talk about harmonics and safety rules in particular, but I'll make some introductory remarks about safety.

These days safety is achieved by safety systems, a system which is able to cover contingencies, cover the vagaries of people. We know that everyone does not behave perfectly every time, and every safety system put in place must be robust enough and have enough depth that it is able to allow for the unexpected behaviour of people. Now, many years ago there were proscriptive rules by government and major authorities which set out, step by step, what you had to do. If you did that you would be safe, and if you did not, it was your fault if you got hurt. The position is changing. The old style of rules are being superceded by new rules which allow for the fact that people will have lapses of memory, and will not perceive dangers that they should be aware of. So as well as having a set of rules, the designer of a system has to think about what contingencies might occur, and has to incorporate into the design, right from the beginning, a safety factor for the person who may act irresponsibly. That is perhaps the greatest challenge. To recognise how tramway systems were designed in the past, see their foibles, and then design new systems to operate them safely, and operate them in such a way that they can tolerate a few indiscretions from both the public and museum members.

I now ask Peter to talk about harmonics and then ask Craig Tooke to talk about the rules and why the rules were introduced in Victoria.

Peter Hallen: One of the main differences between a tram museum and a tramway system is that under the old system, the tramway authorities were their own supply authority. They got their power from their own systems and as a result were self-regulating. We, as tramway museums, must get our power from a local electrical authority with the result that we have to abide by their rules such as you would expect for an installation in a factory or a private house. Any application of electricity, be it ac or dc, has to abide by the rules of that authority. You cannot expect to build a standard tramway substation, stick it in your museum, and expect it to abide by the authority's rules. There are certain regulations that you must follow.

Firstly, the wiring rules must be followed. Every electrician in Australia has a copy of the standards handbook and must follow it for the design of any form of electrical installation, including tramway museums. These rules cover transformers that contain oil, drainage rules, etc. We must abide by all the requirements set out in these rules. So when you design your substation and design the equipment you must use, you must follow the rules. It would be nice to copy a 1930s tramway substation but it may not comply with the current requirements from the supply authority, hence you may be picked up on that.

Another situation that a number of museums do not understand is that, with the move to solid state rectifiers, there is a thing called harmonics. By operating an ac to dc conversion system, you can actually cause a disturbance in the ac line which can cause problems such as flickering of domestic lighting and the subsequent effect on the eyesight in the households within your local area. There is a standard in New South Wales which is in effect a limitation on the harmonics in the system. So when you decide to install or upgrade to a rectifier unit, you must have close contact with your supply authority to enable them to approve and sort out what you need in the way of equipment, otherwise you could be in for having to rectify the problem or up for a greater expense to avoid having the problem. You must be aware of these problems and many electricians are not. This again means that it is essential to contact your authority and negotiate with them and become aware of the problems before spending your money. This is especially important if you decide to upgrade your system. Your small system may be quite satisfactory. However, should you decide to upgrade or change something, you could be altering the effect you have on the system.

Each supply authority may also have their own specific service rules which may effect you. Each may present different applications to the same situation, and it would be difficult to say which museums have specific rules against another. Here in Sydney, at Loftus we are on the edge of a large suburban area with a large distribution system, while a situation such as at Bylands, which is away from the city and hence a large supply, because of the different situations, the authorities will impose different rules. So every museum has its own particular problems with supply and the methods of application by the authorities.

Another of the rules covered by the standard is the one called the overhead line workers regulations. In New South Wales there are specific regulations for working on overhead wires and lines, covering mainly overhead street wires and this is why you have licensed linesmen in this State. Despite the fact that the rules exempt traction supplies, and we as a museum can seek exemption under the rules, the exemption is mainly put there for the benefit of the railways who have their own rules and practices. It is a good set of regulations to base your own working practices on because again, if we are basing our methods on old tramway practices, we must try to translate that into modern methods. These regulations provide a basis for the safety rules and how we look at these problems.

I'll now hand over to Craig Tooke from Haddon who has a short paper to deliver on electrical safety.

Craig Tooke: I would like at this stage to introduce a paper entitled "We can bury out heads in the sand only for so long."

Perhaps it is due to ignorance, perhaps it is due to lack of knowledge, or is it because we believe that an electrical accident could never happen.

Why is it that tramway museums have never taken matters of electrical safety seriously and only given them token priority. With the impending completion of the electrification project at the Haddon site of the Melbourne Tramcar Preservation Association, thought was given to the matter of electrical operation safety and it was decided a set of electrical operational safety rules were needed.

On what basis were the rules formulated? Having reached a decision that that there was a need for the electrical operations rules, on what basis should such rules be drafted? Our Association was in the fortunate position in having two members who carried on their occupations in the power distribution field: Noel Gipps, who was employed as the Operator-in-Charge of the State Electricity Commission of Victoria's terminal station at Richmond, and myself, who is a Power Control Officer with the Melbourne Metropolitan Transport Authority, employed at Carlton. Mr. Gipps has recently retired from the service of the S.E.C.

These two members' combined talents were put together and the drafting commenced. Valuable assistance was supplied by Mr Tony Cunningham, Electrical Operations Superintendent, M.T.A. Tram and Bus Division, and Mr A. Tooke, Substation Maintenance and Construction Engineer, Metrolink. The result of these combined efforts resulted in the production of the Electrical Operations Rules booklet.

What is the need for electrical operations rules and will they ever be used? When we drafted these rules we firstly thought, can they be practical and can they be applied to museum tramway operations?

A rather interesting incident came to light recently. As mentioned earlier in this paper, I am employed with the M.T.A. and was on duty when the incident occurred. In April this year, a rather serious electrical accident took place in Gilbert Road, West Preston involving the tramway electric traction power supply. Extensive damage was caused by the Preston City Council electrical supply wires coming into contact with the tramway overhead trolley wire. The result was massive damage and a large insurance pay-out. Thankfully nobody was injured.

Now how does this incident effect weekend tramway museum operations and why the need for electrical safety rules. In response to the incident mentioned earlier, a letter from the Coroner's Court to the M.T.A. stated in part "I would also be pleased if you could detail to me what safety features are incorporated in the electrical system when domestic power and tramway power lines are crossed during operation." Could you imagine the situation where your museum had a electrical accident take place, due to the negligence of an unsuspecting member who, for example, decided he knew what he was doing working near the trolley wire and was badly burned or killed as a result of coming into contact with the trolley wire. After all, he was only going to paint the pole or work on the roof of a tram and should have known that the trolley wire was alive with 600 volts. Did he realise the danger? It is too late to ask these questions after the incident has taken place.

Along comes a letter from the Coroner's Court, similar to the one received by the M.T.A., and the question is asked: "What safety rules were in place when working near live equipment?" What will your reply be? "Our museum does not have any." Where will all other museums stand as a result?

Of course, you say, electrical accidents will not happen at tramway museums. Without going into details or placing individual blame, a number of accidents have taken place and thankfully none have had fatal results. As a matter of fact, when the rules of the Melbourne Tramcar Preservation Association were being formulated, a serious electrical accident occurred in Victoria where a person received serious burns to the hands.

What can C.O.T.M.A. do to help this situation? What is urgently needed is a set of electrical operations rules to be in place, agreed to and abided by all museums within Australasia. C.O.T.M.A. is the ideal body to produce these rules. While every state in Australia and New Zealand has regulations in force for the installation of electrical equipment, I know of no regulations regarding the operation of tramway traction systems.

While an attempt has been made to interest other Victorian museums in the development of a common set of electrical operations rules, sadly the response from some museums has been "we cannot see the use of such rules" or "we do not think this applies in our situation" or worse still, no reply at all. I do not intend for one minute to imply that the electrical rules of the M.T.P.A. are the be all and end all, and are applicable in total to every museum. However, I believe they are a the basis of a common set of rules for all museums to abide by. I would strongly suggest that a committee be formed to look into the issue of drafting a set of common electrical operations rules and their implementation throughout the tramway museum movement. Consideration must also be given to how such rules could be enforced by C.O.T.M.A. and the penalties for breaching any such rules. It would be a complete waste of time should such rules be formulated and not policed. I am sure that those museums who abided by such rules would not want to be penalised as the result of irresponsible actions of other museums.

Should we decide that such rules are unnecessary, which I believe they are not, I am sure that should an accident take place, the electrical authorities and the coroner would not hesitate to impose strict and possibly unworkable regulations. The choice is up to us. Either we make the rules and cover ourselves or let others make the rules for us. I know which option I would choose.

As I said at the commencement of this paper, perhaps it is due to ignorance, perhaps it is due to a lack of knowledge or is it because we believe an electrical accident will never happen. Like playing Russian roulette or burying our heads in the sand, sooner or later our luck is going to run out. Thanks for your attention.

Richard Clarke: If the other members of the panel could come forward, perhaps David Rawlings could moderate the discussion and any questions....

David Rawlings (Chairman): Before we have any questions, John Radcliffe would like to make a few comments on C.O.T.M.A's work on this subject.

John Radcliffe: I might point out that what Craig has described has, in fact, had the backing of C.O.T.M.A. in so far as some months ago our attention was drawn to the need of this and there were discussions between Tony Smith, who was then assistant executive officer, Bill Kingsley, myself and correspondence with Lindsay Richardson and Dave Hinman, who are the two C.O.T.M.A. committee members. We advised them that Tony would arrange for the convening of a working group in the State of Victoria, involving the museums in that state to address the need for operational rules. It was our belief at the time that if we did not establish a code of practice, which might well not have a basis in law but which was accepted by C.O.T.M.A. museums, there was the risk that we might have something more distasteful imposed upon us later. I think what has come out of what Craig has said, is there appears to have not been as much participation by the Victorian museums in that process as he might have wished for. But it is with the background of that action taken by the elected C.O.T.M.A. group that we are now in the position that Craig described.

Ron Grant (WTM): I think that I have a part answer to my concern, thanks to John, but I have felt very concerned about this, but if we had rules as outlined in this paper it would be very helpful, if only for us to take back to our own organisations to nub over. I can fully subscribe to C.O.T.M.A. going into this but, seriously, at the same time we should seriously look at our own operations right from now.

Craig Tooke: I have a couple of spare copies with me, but did not have time to run off copies for everyone. If any museum would like one and I am unable to supply a copy today, I will see that they are sent a copy of what we have done.

Ron Grant: Would you reserve one for Christchurch, please.

John Radcliffe: If I could take the process a bit further, I believe that we should move towards the process where the individual C.O.T.M.A. museums do look at the draft set of rules which has been prepared, with perhaps less input from some of the Victorian museums than we might have preferred, with the intention that we might, at the formal meeting on Monday, agree that individual component museums would examine that set of draft rules with the intention of their ultimate adoption as a code of practice. At the rate in which we conduct our business around here that process might take two years, but it is not impossible if we got our backsides organised. In fact it could be done out of session.

Tony Griffin (SPER): Mr. Chairman, I speak as a delegate who has had professional responsibility for the protection and operation of a large high voltage power system and a large 1500 volt electric railway system. I would like to speak on a few points raised by Peter Hallen. Firstly the wiring rules AS3000 are revised every five years while the design of railway and tramway substations are in a process of evolution. Things started back in the year dot, things have developed and are still developing. What is now current in the 1986 edition is likely to be changed in the 1991 edition. Nothing is static, everything is still changing, so you build to the current requirements and when you rebuild you do something different.

Regarding harmonics, there is a problem with reflection back into the AC distribution system. However, I suspect that when the museum starts to operate for distances over a mile, there is going to be a problem with telephone interference. This can be solved by the installation of a wave filter on the DC side, housed in a grey box about so big.

In terms of voltage drop, Mr Clarke said 25%, I go one step further and say 50%.

Richard Clarke: That would mean about 300 volts for our museums. I understand the railways' voltage drops to 1000.

Tony Griffin: We go down to 750 volts, thank you.

I must take a point with Mr Clarke when he said that safety is achieved by the safety system which is designed to cover contingencies of the habits of people. Earlier he said that the fault to your substation must be adequately covered. He did not state how. Is it in design contingencies? He also said that a remote fault current is much lower, which is true, and he went on to say that the protection must see the fault and turn it off in time, but how long?

One of the problems in designing any form of a dc traction system is that there are two constraints. If you beef your fault level up at the substation, you have rupture capacity problems. The same thing happens in ac railways, only worse. You need, at the substation source, a high-speed dc breaker which will clear the fault; which has adequate rupture capacity. The thing that is most frequently not recognised is the distant fault condition.

Protection for a traction system is usually designed so that protection is set-up to see the minimum fault condition. There is usually no over current protection in the form of thermal protection. Usually you rely on the thermal mass of the conductors to get you over the short-term peaks. You do not put protection on as you would for an ac system.

Having spent a few years with these responsibilities, and having spent a couple of months travelling around the world talking to manufacturers of railway electrical equipment, and to the people operating various traction systems, some rules have come out it. With protection, no tramway, electric railway or light railway anywhere in the world will contemplate blind spots in their protection systems. In other words, they will not permit a situation where a fault would never be protected.

Next, all faults must be cleared in less than one second. With close-up faults, it is possible to achieve a clearing time of 15 milliseconds, 15 thousandths of a second, which is something you never hear of in an ac system. The rupturing capacity of the switch gear always must not exceed the fault level at the point of installation of the system, except that, with the rolling stock switch gear technology of the 'twenties through to the 'seventies and 'eighties, the line breakers on the vehicles are relatively slow. We are talking about 150 milliseconds to clear a short circuit on the vehicle itself. They typically have a rupturing capacity of about 5000 amps for railway type applications. Taking my experiences on the Illawarra line as an example, the minimum fault current which would not be seen by a substation breaker is in the order of about 15,000 amps. We have now changed the switch gear on the trains to withstand that sort of fault level. In the old system, the substation circuit breaker cleared that fault before the line switches had a chance to open, so therefore they opened on no current, hence no problem.

All of our tramcar equipment is slow gear. To protect it, it has a rupturing capacity of 1500 amps and we need a circuit breaker with a rupturing capacity of at least the fault level of the system, preferably a bit more, in the substation, on the output side of the rectifier, before it goes out to the overhead wiring. Second-hand switch gear to do this job is usually available at around $100 each and is the sort of gear that will clear 50,000 amps in 15 milliseconds.

Another point to be raised is the fact that one of the reasons for clearing the fault in the minimum possible time is to minimise the damage at the point of the fault. The damage can be a fire on the vehicle, it can be fires on the track or in the grass around the track. It can be caused by the flashing you get from the pantograph and overhead wiring when the fault occurred on the vehicle. It starts a fire. Where does it go? To adjacent properties. It has always been the strategy of dc traction systems to clear the fault before it has reached the maximum perspective current to minimise that damage, and high speed breakers, available second-hand, can do the job.

The last point. For 107 square millimetre hard-drawn copper contact wire, the energy input, which is recognised as the maximum that would be tolerated before the wire would burn through with a fault current, is 1000 amps squared seconds, which in terms of, say, 1000 amps would give you one second to clear it. Thank you.

Richard Clarke: Tony and I have had long discussions on this matter. I think I can say we have enjoyed these discussions. I will start by acknowledging that Tony is a highly qualified electrical engineer and he thinks these matters through very carefully. The Sydney Tramway Museum takes his views and looks at them quite seriously and, if anything, Tony makes sure that the Sydney Tramway Museum is honest.

Now, in answering your comments, I must state that there is always a cost and a benefit for safety, and yes, all things are possible. It is just a question as to whether things are practicable, desirable or appropriate at the particular time or circumstance.

We would love to put in high-speed dc circuit breakers everywhere, with a rate of rise protection, maybe with a micro-computer which has worked out the characteristics of the line. Remember, donations to the tramway museum are tax deductable!

Now to go back and put a few things in perspective, Tony would like a 15 millisecond interrupting time on dc. So would I. Presently close-up faults, according to the chart supplied by the manufacturer, are cleared in times approaching 30 to 35 milliseconds, and for distant faults, the experience and the calculations show, provided that it is a solid fault, the distant fault has been tested and cleared very fast.

Howard Clark (SPER): The question of self-regulation interests me, and as a chartered accountant, we are always advocating self-regulation as well. I think in any professional body, such as a tramway museum, self-regulation is preferable rather than having a regulating body impose rules upon us. The question I pose is this: If we produce the rules, who will examine them in regard to quality control? My main worry is legal concerns. Suppose we produce a set of rules to govern ourselves, and these are challenged at some time. How do we cover ourselves if someone says, for example, we have left something out. Would there be a claim for negligence because of the omission?

Richard Clarke: Perhaps I could answer part of that. Government is changing and I work for a major government organisation involved in safety matters. We are getting out of writing safety rules as fast as we can, and getting industry to write their own. A set of rules should be prepared using the best advise you can get, not only seeking advise from the suppliers of the services, but also seeking advice from the users as well. Any set of rules put forward in this manner should achieve a consensus.

Craig Tooke: My views are similar to Richard's. I feel that any rules formulated should be submitted to the local supply authority for an opinion, and any challenge thrown up should be investigated.

Another point is that most of our museums, with one or two exceptions, use medium voltage supplies. That is, supplies under 650 volts. With high voltage operations, the supply authorities insist that the substation be manned by authorised operators, trained in switching. The safety rules that apply to high voltage operations should also apply to medium voltage installations as well.

Another interesting sideline is that in the past two years on the Melbourne tramway system, there have been three people killed as a result of 600 volt shocks, and five others injured as a result of coming into contact with 600 volts.