final report

Project Code: P.PSH. 0231

Prepared by: Clyde Daly
AgResearch

Date published: December 2006

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Welfare implications for electrical stimulation

This is an MLA Donor Company funded project.

Meat & Livestock Australia and the MLA Donor Company acknowledge the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

An Australian and New Zealand regulatory committee has been formed to develop regulatory guidelines for the application of meat electronics in the meat industry, and it is likely that the outcomes of this forum will be adopted by Australian authorities at various levels. Also, there are existing cultural issues including Halal sticking and electro-immobilisation to accommodate Malaysians. The implications of such guidelines could be significant, and it critical that any Occupational Health & Safety (OHS) and cultural issues are investigated with supporting data to validate its compliance to OHS and other regulatory matters.

The recently completed New Zealand Safety Standard for the use of Safe Application of Electricity in the Meat Processing Industry (NZS 6116:2006) has applied the internationally accepted maximum voltages to which operators can be safely exposed. The maximum levels defined in the code are 6 Volts R.M.S for alternating currents or 15 Volts for ripple-free DC currents.

The critical component of the new regulation is that these voltages apply to the exposure of the worker at their point of contact with the carcass, rather than the total voltage in the circuit. It is therefore the responsibility of the plant management to define the exposure to electrical voltages during the course of normal carcass processing procedures, and ensure their electrical systems work within these constraints. At this stage, procedures to help meet these requirements have not been defined.

As a first step towards this, a procedure was developed for measuring exposure of workers to electrical voltages during carcass processing. In conjunction with this, a survey of current practices was undertaken to identify potential hazards.

Therefore, the current support program for meat electronics will investigate current OHS and cultural matters associated with safe application of current generation one meat electronics. The outcomes of this research will be used to support usage of meat electronics in Australia and New Zealand safely and to develop appropriate guidelines for implementation.

An industry bulletin has been compiled. This document (Standard for the Safe Application of Electricity in the Meat Processing Industry NZS 6116:2006) has been written with the intention that it can be disseminated to meat processors. It explains the background and requirements of the new Safety Standard and provides a clear methodology to enable contact voltages to be measured. This will enable meat processors to develop an electrical safety auditing procedure to ensure they comply with this new standard.

Executive Summary

The direct application of electricity to carcasses has become an integral part of meat processing for many years. In addition to being used for pre-slaughter stunning, electrical applications include:

1. carcass immobilisation, to increase operator safety by controlling carcass movement
2. back stiffening, to avoid broken backs during hide pulling
3. carcass stimulation, to accelerate muscle pH decline and accelerate processing.

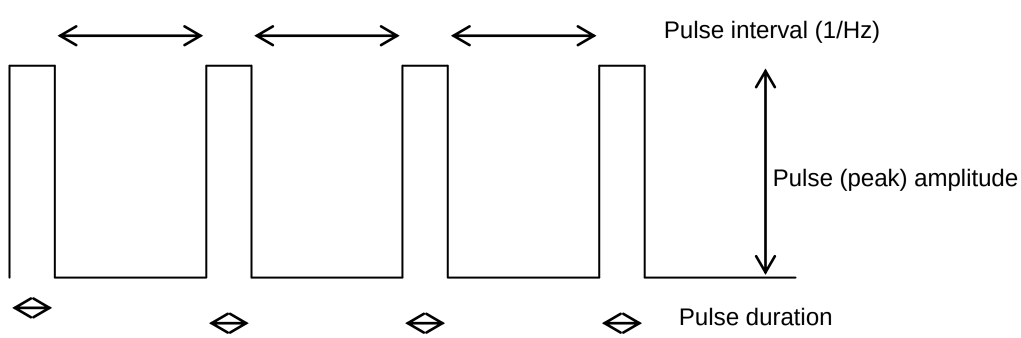
In many cases, the electrical immobilisation and/or stimulation of carcases is integrated into the processing chain and may require that dressing operations are performed while the current passes through the carcass. Even if processing is not taking place during the current application, there is often opportunity for physical contact between workers and the electrified carcass.

The new safety standard addresses the question of acceptable exposure to electrical currents during operations in meat processing facilities. The Standard (NZS6116:2006) introduces three levels of risk associated with electrical equipment:

1. Operator safe (Class A)
2. Touch safe but unsafe to work on (Class B)
3. Unsafe for contact under any circumstances (Class C)

The safety level of an electrical device depends on the risk associated with the specific waveform of the applied electrical voltage. In addition to the magnitude of the voltage, the Safety Standard also recognises that risks are affected by the nature of the of the electrical waveform: in particular, the risk assessment takes into consideration the frequency of the waveform and, where the waveform comprises isolated pulses, the duration of the individual pulses. Since most electrical devices used in meat processing are based on unipolar pulsed waveforms, the key safety considerations are the pulse interval (frequency) and pulse duration (Figure 1).

Figure 1: Electrical waveform components



The voltage used in calculating the safety requirement according to the formulae above is based on the ***voltage exposure at the point of contact with a worker***; it does not relate to the total voltage in the circuit. Therefore a safety evaluation needs appropriate methods to measure and monitor the voltages at likely points of contact, deliberate or accidental, with people. Also, a general appreciation of how the design and maintenance of the electrodes used to delivering the electrical current affects voltage exposures during contact with electrified carcasses will help to manage the risks.

Table of Contents

1 Background

New electrical standards may soon to be implemented in the Australian and New Zealand meat processing industries and this new standard will address the issue of long term exposure of workers to small electric current flows. The standard will state that no worker may work on the carcase when the voltage on the carcase referenced to ground at the point of contact exceeds a nominated voltage. This voltage is still to be determined but will be significantly less than the peak voltages used in current immobilisation and stimulation installations.

An Australian and New Zealand regulatory committee has been formed to develop regulatory guidelines for the application of meat electronics in the meat industry, and it is likely that the outcomes of this forum will be adopted by Australian authorities at various levels. Also, there are existing cultural issues including Halal sticking and electro-immobilisation to accommodate Malaysians. The implications of such guidelines could be significant, and it critical that any OHS and cultural issues are investigated with supporting data to validate its compliance to OHS and other regulatory matters.

With carcase immobilisation in particular it is essential that workers make contact with the carcase while voltage is applied and there is a major risk that some application of electrical inputs to carcases could be banned when the new standard is implemented. Worker contact with a beef carcase during immobilisation and hide puller back stiffening are the only operations which require worker contact and these installations will be investigated in this study.

The document (Safe Application of Electricity in the Meat Processing Industry) was very favorable for the meat industry, and this probably explains the fairly low level of response from the public consultation.

An important concern was whether or not the industry would be allowed to continue to work on, or at the very least make contract with, electrified carcasses. The longstanding international limit for exposure to electrical currents has been 6 volts RMS, or 15 volts DC, well below the levels used in immobilisation or stimulation in the industry.

It has been agreed that this will remain the maximum electrical exposure, but that this will be the voltage at the point of contact between the carcass and the operator. This decision makes it very likely that the current practices will be allowed by the new code, but the onus is now on the industry to demonstrate that the required standard is being met. It is generally understood that this approach hasn't any precedence, so the industry needs to establish some procedures for measuring whether any given commercial procedure complies to the regulation, and some guidelines on what are acceptable practices.

It is probably important that there should be a sound validation for this approach since the alternative could be damaging. Without some guidelines, electrical inspectors are likely either to adopt a safety first approach and undermine a good opportunity, or the credibility of the code could be undermined if procedures are accepted without good evidence of the safety implications.

Therefore, the current support program for meat electronics will investigate current OHS and cultural matters associated with safe application of current generation one meat electronics. The outcomes of this research will be used to support usage of meat electronics in Australia and New Zealand safely and to develop appropriate guidelines for implementation. The voltage gradients will be determined both by theoretical modelling and high impedance measurement techniques.

2 Project Objectives

The objectives are:

- Develop and validate a methodology for measuring the voltages at the point of contact of electrified carcasses. This will involve designing an appropriate methodology and undertake measurements in a number of plants to develop a database
- Develop a mathematical model of the voltage gradients through carcasses during immobilisation and stimulation to allow general principles to be defined.
- Develop and validate a methodology for measuring the voltages at the point of contact of electrified carcasses. This will involve designing an appropriate methodology and undertake measurements in a number of plants to develop a database.
- Produce an industry guideline document.

3 Methodology

3.1 Measuring the voltage exposures:

By convention, the electrical resistance of a person completing the circuit to earth is specified as 500 Ohms. The test circuit therefore consisted of a contact surface connected to a 500 Ohm resistor in series to an earthing point. The voltage was measured across the 500 Ohm resistor using a true RMS (root mean square) multimeter (Fluke Multimeter model 189), set to record both the AC and DC component of the electrical current (Figure 1)

The contact paddle was made from a square of stainless steel of dimensions 100 x 100 mm. As the pressure made at the contact will influence the electrical resistance at the point of contact it was necessary to manufacture the contact paddle in such away that the contact pressure could be standardised. This was achieved by mounting a spring in an insulated housing on the underside of the contact paddle, so that by pushing the assembly firmly against the test carcass, the contact plate would retract to become flush with the edge of the housing and create a constant force of contact between the plate and the carcass. The resultant force of contact was set at 5 KgF.

The contact voltages were measured at 4 beef and 4 sheep plants and at each, measurements were made from 60 carcasses. In each case, the contact voltages were measured at positions on the carcasses where operators are likely to make contact: on the lamb chains, a position on the brisket and the hind leg was selected; on the beef immobilisers, the neck and rib areas were selected and, where the hind quarters of the body were accessible, measurements were made from the rump (Figures 2 & 3).

Furthermore, a measurement was made from the knife blades and rodders during the bleeding and rodding operations. To do this, the contact paddle was replaced with a clip, which was attached to the steel of the knife or the rodder and a measurement was made during the normal operation.

Figure 1. Equipment for measuring contact voltages

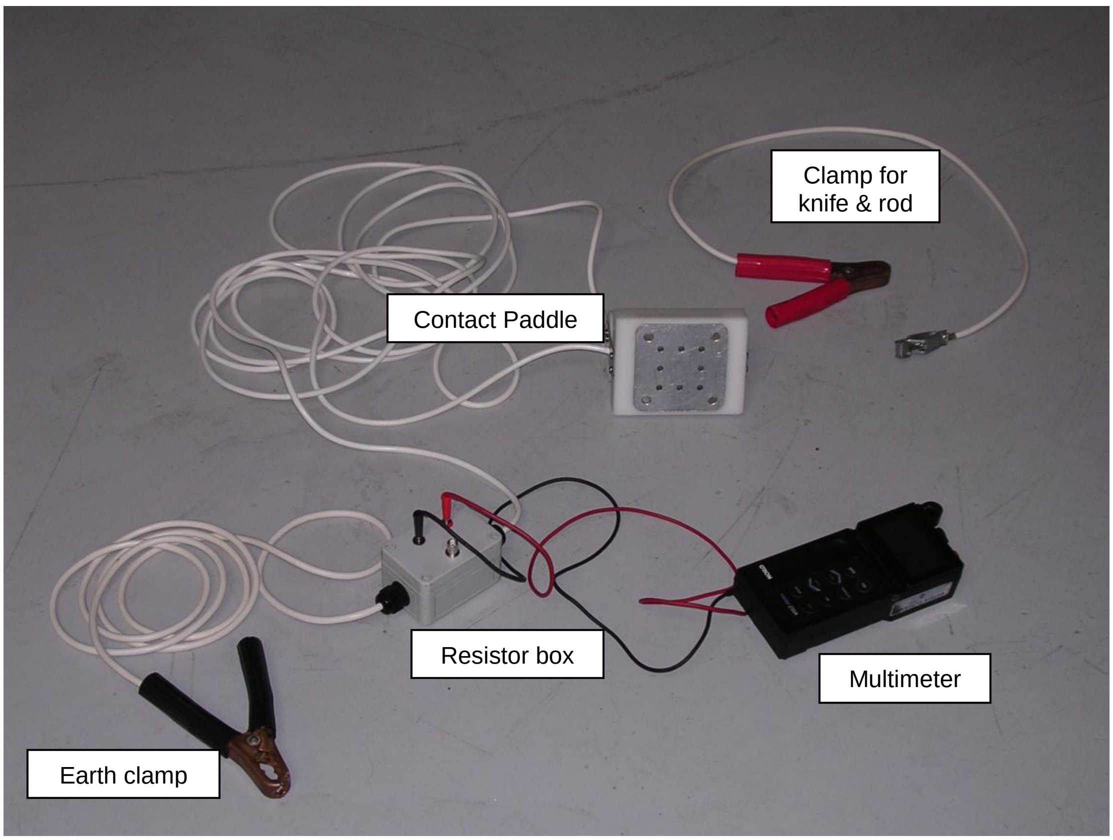


Figure 2. Sites for Voltage Measurement on Beef Immobiliser

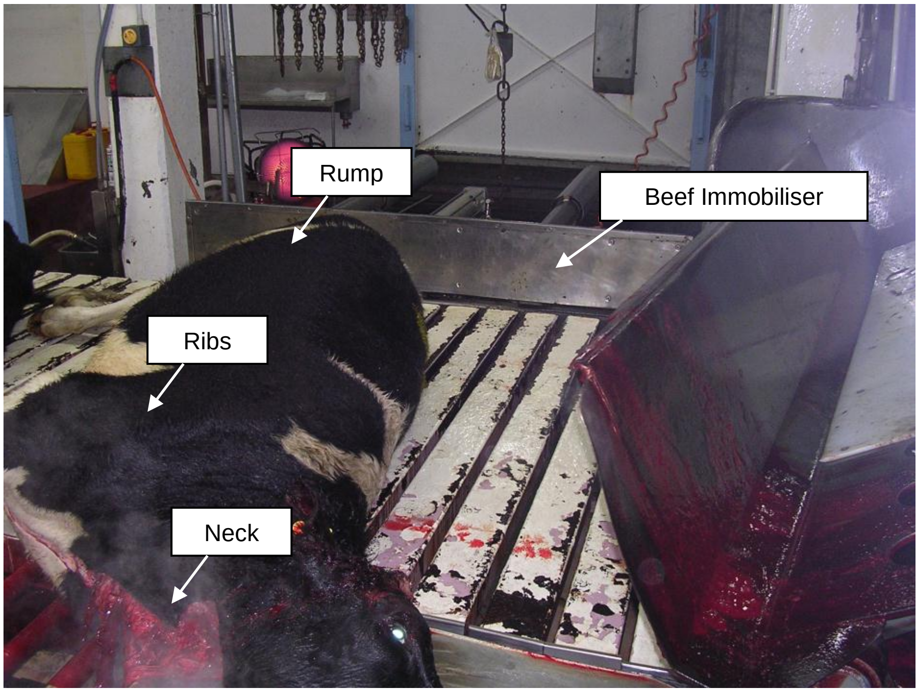
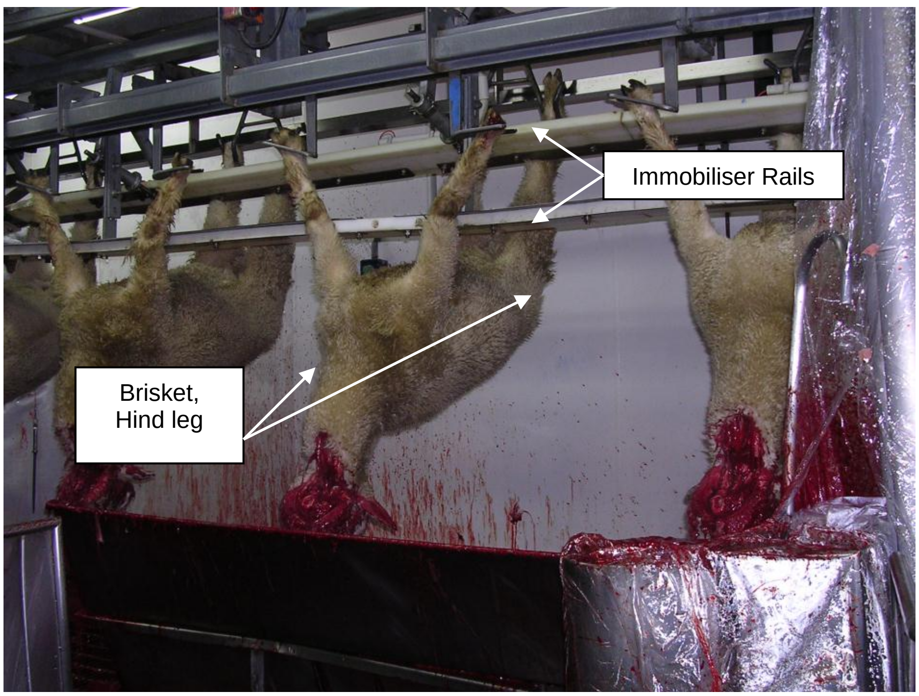


Figure 3. Sites for Voltage Measurement on Sheep Immobiliser



3.2 Calculating the level of risk.

Class A: For continuously pulsed waveforms, the maximum permitted safe exposure voltage on electrified carcasses depends on two components of the waveform:
1. A maximum voltage of 6 Volts r.m.s. for a.c. or pulsed d.c. (or 15V ripple free d.c., which is not likely to apply to processing-related electrical devices)
and
2. I^2 (Amps r.m.s.) x ***pulse duration*** (secs) is less than 48×10^{-3}. The Amperage, in this equation, is calculated as measured exposure voltage / 500 Ohms

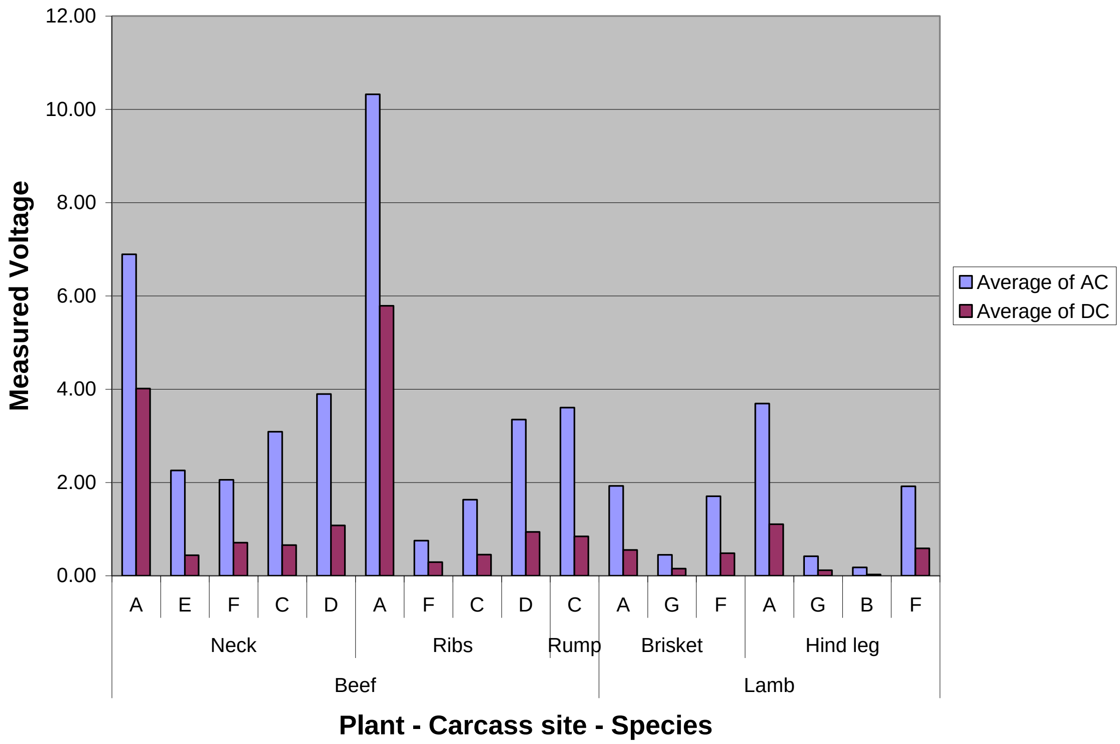
Class B*:* The maximum exposure voltage for a touch safe application, which does not permit working on the electrified carcass, is:
I^2 (Amps r.m.s.) ***x pulse duration*** (secs) is less than 48×10^{-3}.
or
pulse width to pulse interval is less than 1:8 for frequencies less than 1000Hz, or less than 1:3 for frequencies greater than 1000Hz

Class C*:* Unsafe for contact with carcasses
1. I^2 (Amps r.m.s.) ***x pulse duration*** (secs) is greater than 48×10^{-3}.
and/or
pulse width to pulse interval is greater than 1:8 for frequencies less than 1000Hz, or greater than 1:3 for frequencies greater than 1000Hz

4 Results and Discussion

The average measured voltages measured from the surface of the carcasses are shown in Figure 4. In general, the contact voltages were well within the required safety limit and there does not appear to be any reason to substantially re-evaluate the existing procedures to electrically immobilise carcasses.

Figure 4. The average voltages at different carcass sites



The exception to this are the measurements made from the beef carcasses at Plant A. The immobiliser at this plant is a new generation high frequency immobiliser which operates at a higher voltage compared to the conventional immobiliser (140 Volts compared with 90 Volts). Due to the findings of this work, the settings of the immobiliser are being adjusted to comply with the new requirements.

Measurements of the voltages during sticking and rodding were limited because of interference with normal procedures and so could not be carried out at all the plants visited and in fact were only possible on the beef chains at four of the plants.

Table 1. The average voltage recorded from the knife and the rodder during beef work-up operations.

Plant	Mean Voltage from knife at neck cut	No of values exceeding 6Volts	Mean Voltage from rodder	No of values exceeding 6Volts
A	5.4	2	8.2	6
C	2.2	0	3.8	0
D	3.7	0	3.7	0
E	5.7	1	5	0

Across all beef plants and carcass sites, the number of readings greater than 6V AC was 19 (Table 2). On the lamb chains, there were only 2 occasions when the values exceeded the 6VAC limit, both being from plant A and recorded from the neck site.

Table 2. The number of measurements by carcass site exceeding the 6V specification in beef.

Plant	Neck	Ribs	Rump
A	4	6	N/A
C	0	0	2
D	2	4	0
E	1	0	0

The sites of measurement where the recorded voltage exceeded 6V was predominantly the neck and ribs, and these were all recorded from carcasses that were immobilised on a cradle where the immobilising current tends to track across wet routes, typically in the areas of the neck wound and around the shoulders.

5 Impact of this Research

The use of metal tools in contact with electrified carcasses might be expected to increase the exposure voltage but their contribution was relatively small. Furthermore, the testing conditions were worse case scenarios that measured direct contact with the metalwork: in reality, both knives and rodders have insulated handles that will reduce the exposure voltages still further.

The measuring equipment provides a simple and effective procedure for testing the exposure voltages associated with contact with electrified carcasses. These procedures will provide the basis for assessing compliance with the new Electrical Safety Standard.

The outcomes of this research will be used to support usage of meat electronics in Australia and New Zealand safely and to develop appropriate guidelines for implementation.

6 Conclusions

All the plants using the conventional low voltage systems (90 Volt peak amplitude, 10 msec pulses, 70 msec pulse intervals) largely complied with the requirements of the Safety Standard. The incidence of exposure voltages exceeding the 6 V a.c. was 1-2 carcasses per 60 carcasses measured, and the magnitude of the excess was small.

There were substantial differences in the exposure voltages between carcasses, and the different plants produced very different average results. The wetness of the surfaces contributed to part of this variation, but the electrical resistances between the electrodes and the carcass was also an important contribution. Understanding the relationship between the configuration of the electrodes and exposure voltage will need some better understanding but some general principles appear evident at this stage.

1. A simple procedure for measuring voltage exposure during electrical immobilisation of carcasses has been tested
2. Worker contact with electrically immobilised carcasses appears to largely meet the safety requirements
3. Metallic equipment inserted into the carcass while it is being immobilised, primarily knives and rodders, increase voltage exposures, but these still remain largely within the acceptable limits. The presence of insulating handles will ensure that these procedures comply.
4. High electrical resistances at both electrodes produce low exposure voltages but also reduces the effectiveness of the stimulation.
5. An effective contact at the live electrode but poor earth electrode contact increases the exposure voltage
6. A proportion of the electrical current will flow though any metalwork in contact with the carcass. In sheep, the contact is between the hanger and the foot and, in cattle, the contact is with the landing table. The extent of insulation of the metal contacts from earth influences current leakage, which will affect both the exposure voltage and the voltage needed to produce effective immobilisation.

The recently completed New Zealand Safety Standard for the use of Safe Application of Electricity in the Meat Processing Industry (NZS 6116:2006) has applied the internationally accepted maximum voltages to which operators can be safely exposed. The NZ standard developed meets the Australian minimum safety standard, and that all of the industry's new electrical technologies (developed by MLA funded research & development) including electrical stimulation (mid- & low-voltage), immobilisation, electronic bleeding and back stiffening units meet the minimum safety standards requirements recommended by an expert safety standards committee (as per the industry bulletin, see attached). The maximum levels defined in the code are 6 Volts R.M.S for alternating currents or 15 Volts for ripple-free DC currents.

7 Recommendations

The use of metal tools in contact with electrified carcasses might be expected to increase the exposure voltage but their contribution was relatively small. Furthermore, the testing conditions were worse case scenarios that measured direct contact with the metalwork: in reality, both knives and rodders have insulated handles that will reduce the exposure voltages still further.

The measuring equipment provides a simple and effective procedure for testing the exposure voltages associated with contact with electrified carcasses. These procedures will provide the basis for assessing compliance with the new Electrical Safety Standard.

Appendix - Industry Bulletin

Standard for the Safe Application of Electricity in the Meat Processing Industry NZS 6116:2006

The direct application of electricity to carcasses has become an integral part of meat processing for many years. In addition to being used for pre-slaughter stunning, electrical applications include:

- carcass immobilisation, to increase operator safety by controlling carcass movement.
- back stiffening, to avoid broken backs during hide pulling.
- carcass stimulation, to accelerate muscle pH decline and accelerate processing.

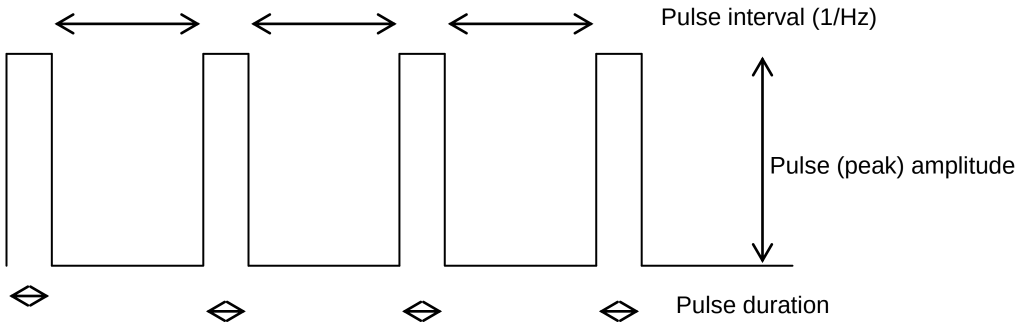
In many cases, the electrical immobilisation and/or stimulation of carcases is integrated into the processing chain and may require that dressing operations are performed while the current passes through the carcass. Even if processing is not taking place during the current application, there is often opportunity for physical contact between workers and the electrified carcass.

The new safety standard addresses the question of acceptable exposure to electrical currents during operations in meat processing facilities. The Standard (NZS6116:2006) introduces three levels of risk associated with electrical equipment:

4. Operator safe (Class A)
5. Touch safe but unsafe to work on (Class B)
6. Unsafe for contact under any circumstances (Class C)

The safety level of an electrical device depends on the risk associated with the specific waveform of the applied electrical voltage. In addition to the magnitude of the voltage, the Safety Standard also recognises that risks are affected by the nature of the of the electrical waveform: in particular, the risk assessment takes into consideration the frequency of the waveform and, where the waveform comprises isolated pulses, the duration of the individual pulses. Since most electrical devices used in meat processing are based on unipolar pulsed waveforms, the key safety considerations are the pulse interval (frequency) and pulse duration (Figure A1).

Figure A1: Electrical waveform components



The voltage used in calculating the safety requirement according to the formulae above is based on the ***voltage exposure at the point of contact with a worker***; it does not relate to the total voltage in the circuit. Therefore a safety evaluation needs appropriate methods to measure and monitor the voltages at likely points of contact, deliberate or accidental, with people. Also, a general appreciation of how the design and maintenance of the electrodes used to delivering the electrical current affects voltage exposures during contact with electrified carcasses will help to manage the risks.

Measuring the voltage exposures:

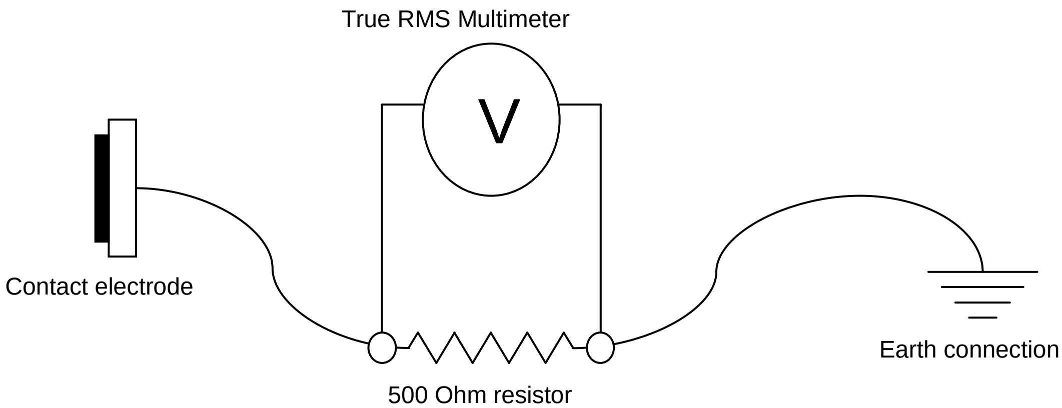
Designing a procedure to measure voltage exposure at the point of contact with an electrified carcass needs to take into account a number of factors:

1. *Electrical resistance of a person:* By convention, a person standing in boots completing an electrical circuit to earth through contact with an electrified carcass is considered to have an electrical resistance of 500 Ohms. A person's body can therefore be simulated by a 500 Ohm resistor
2. *Characteristics of the contact with the electrified carcass.* In addition to the resistance of the human body, there is also the resistance produced at the point of contact. This will depend on a number of factors, but the major ones will be the area of contact – the larger the area of contact, the less the contact resistance – and the pressure applied during contact – increasing pressure reduces contact resistance. The moisture level at the point of contact with a hide-on carcass is also a major variable and should be taken into account as part of identifying the 'worse case' scenario for an installation.

   To standardise the contact resistance, a contact electrode was constructed using a stainless steel plate with a contact surface area of 1000 mm^2 (10x10 cm) to represent a hand contact with a carcass. In addition, the contact pressure was standardised by spring loading the contact surface to produce a maximum pressure of 5 Kgf. A picture of the electrode used to monitor contact resistance is shown in Figure A3.

3. *Measuring system*. The voltage at the contact needs to be measured with a true RMS multimeter (we used a Fluke 189). Many conventional multimeters would not be appropriate because they are designed to measure the RMS of a 50 Hz sinusoidal waveform. More complex waveforms, such as pulsed DC waveforms, result in inaccurate readings.

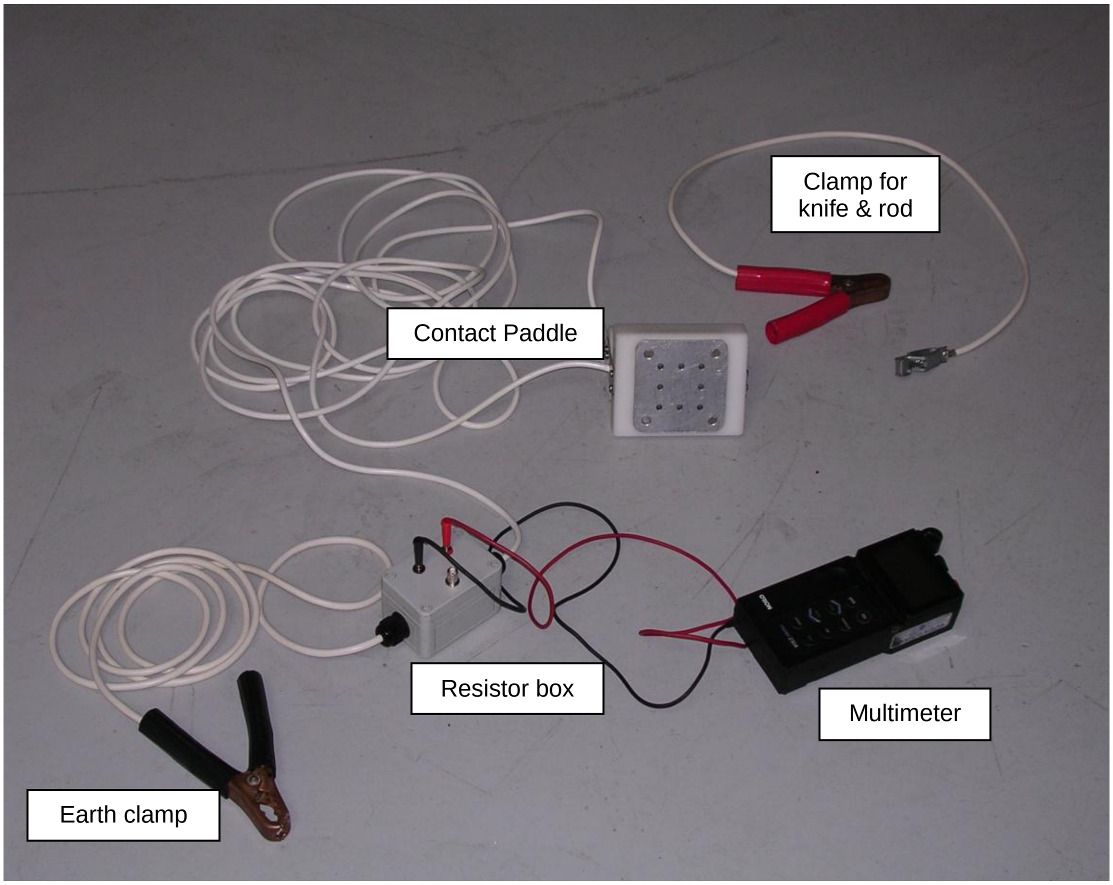
Figure A2: Circuit diagram of exposure voltage measurement.

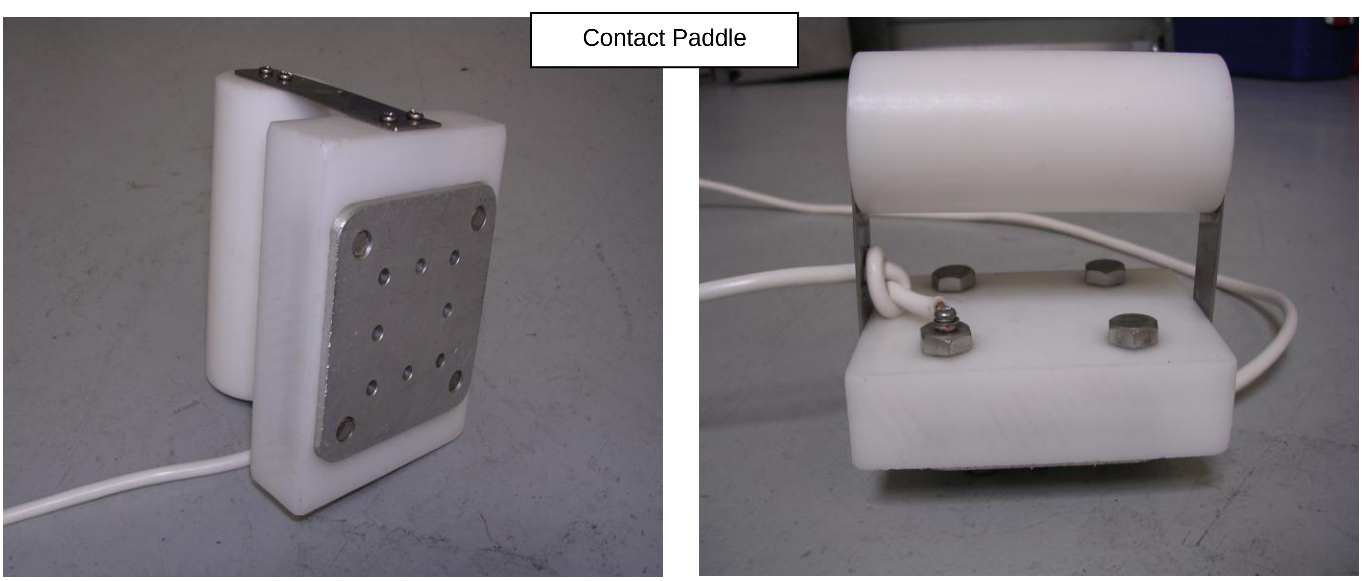


4. Measurement procedure. The complete circuit for the contact voltage measurement system is shown in Figure 2.The circuit is grounded at one end to local metalwork at earth potential. The contact electrode can then be applied to the carcass at positions within arm's reach. A reading of the voltage difference across the 500 Ohm resistance represents the exposure voltage.

   In those operations where dressing operations are carried out on the electrified carcass, metal tools such as knives or rodders can be applied directly to the surface of or inserted into a carcass as part of the normal operation. To test the voltage exposure under these circumstances, the contact electrode can be replaced with a clip which is attached directly to a metal surface of the tool during the operation. The exposure voltage is again measured as the voltage across the 500 Ohm resistor.

Figure A3. Equipment required to measure contact voltages at various points





Calculating the level of risk.

Class A: For continuously pulsed waveforms, the maximum permitted safe exposure voltage on electrified carcasses depends on two components of the waveform:
1. A maximum voltage of 6 Volts r.m.s. for a.c. or pulsed d.c. (or 15V ripple free d.c., which is not likely to apply to processing-related electrical devices)
and
2. I^2 (Amps r.m.s.) x ***pulse duration*** (secs) is less than 48×10^{-3}. The Amperage, in this equation, is calculated as measured exposure voltage / 500 Ohms

Class B: The maximum exposure voltage for a touch safe application, which does not permit working on the electrified carcass, is:
I^2 (Amps r.m.s.) ***x pulse duration*** (secs) is less than 48×10^{-3}.
or
pulse width to pulse interval is less than 1:8 for frequencies less than 1000Hz, or less than 1:3 for frequencies greater than 1000Hz

Class C: Unsafe for contact with carcasses
1. I^2 (Amps r.m.s.) ***x pulse duration*** (secs) is greater than 48×10^{-3}.
and/or
pulse width to pulse interval is greater than 1:8 for frequencies less than 1000Hz, or greater than 1:3 for frequencies greater than 1000Hz

Measured voltage exposures in existing commercial electrical installations.

At the present time, the majority of electrical applications to which workers are likely to be exposed are low voltage electroimobilisation systems. These are used in both beef and sheep dressing operations and typically involve unipolar pulses of 90 Volt amplitude, 10 msec duration and 70 msec pulse interval (15Hz).

Sheep immobilisation systems: All the systems evaluated used 4-point suspension, and the electrodes made contact through passive rubbing electrodes in contact with the fore and hind legs.

The main point of contact is the brisket area during the Y-cut, sticking and rodding operations. However, there is typically access to the back of the carcass and, therefore, contact can potentially be made to the hind legs. The chosen sites for testing were the brisket area and the rump area.

Potential exposure voltages were measured from 60 carcasses in four sheep plants and the results are shown in Table A1 below.

Table A1: Survey results from 4 sheep plants: exposure voltages to carcass contact during low voltage immobilisation.

	Plant 1	Plant 2	Plant 3	Plant 5
Average exposure voltage – brisket	2.20	0.61	1.88	0.29
Average exposure voltage –leg	3.79	0.65	1.96	0.21
Maximum exposure voltage	4.5	2.3	7.1	1.62
No carcasses exceeding maximum exposure voltage	0	0	1	0

Cattle immobilisation systems: Cattle can be immobilised on a landing cradle on which are mounted the immobilisation electrodes; or, where a bleeding conveyor is employed, they are immobilised using a mechanically operated electrode advanced to make contact with the rump. In both cases, the return electrode is either the metal work of the cradle/conveyor, or a separate, electrically isolated return electrode.

The main points of contact are the neck and rib areas during the sticking and rodding operations. In one plant, shackling took place during electrification of the carcass and a measurement was made on the rump

Table A2: Survey results from 4 beef plants: carcass exposure voltages to carcass contact during low voltage immobiliser.

	Plant 1	Plant 2	Plant 3	Plant 4
Average exposure voltage – brisket	2.42	2.11	3.02	3.93
Average exposure voltage –ribs	3.79	1.61	3.44	3.78
Average exposure voltage – rump			3.60	
Maximum exposure voltage	5.12	3.32	6.92	8.31
No carcasses exceeding maximum exposure voltage	0	0	2 (both rump)	1

Table A3: Survey results from 3 beef plants: exposure voltage from metallic contacts on knives and rodders during dressing operation.

	Plant 1	Plant 2	Plant 3
Average exposure voltage – knife blade	2.2	3.7	5.7
Average exposure voltage –rodder	3.79	1.61	3.44
Maximum exposure voltage	5.12	3.32	6.92 (both rump)
No carcasses exceeding maximum exposure voltage	0	0	1

Conclusion:

All the plants using the conventional low voltage systems (90 Volt peak amplitude, 10 msec pulses, 70 msec pulse intervals) largely complied with the requirements of the Safety Standard. The incidence of exposure voltages exceeding the 6 V a.c. was 1-2 carcasses per 60 carcasses measured, and the magnitude of the excess was small.

There were substantial differences in the exposure voltages between carcasses, and the different plants produced very different average results. The wetness of the surfaces contributed to part of this variation, but the electrical resistances between the electrodes and the carcass was also an important contribution. Understanding the relationship between the configuration of the electrodes and exposure voltage will need some better understanding but some general principles appear evident at this stage.

- High electrical resistances at both electrodes produce low exposure voltages but also reduces the effectiveness of the stimulation.
- An effective contact at the live electrode but poor earth electrode contact increases the exposure voltage
- A proportion of the electrical current will flow though any metalwork in contact with the carcass. In sheep, the contact is between the hanger and the foot and, in cattle, the contact is with the landing table. The extent of insulation of the metal contacts from earth influences current leakage, which will affect both the exposure voltage and the voltage needed to produce effective immobilisation.

The use of metal tools in contact with electrified carcasses might be expected to increase the exposure voltage but their contribution was relatively small. Furthermore, the testing conditions were worse case scenarios that measured direct contact with the metalwork: in reality, both knives and rodders have insulated handles that will reduce the exposure voltages still further.

The measuring equipment provides a simple and effective procedure for testing the exposure voltages associated with contact with electrified carcasses. These procedures will provide the basis for assessing compliance with the new Electrical Safety Standard.