TOWARDS A TEST STANDARD FOR CONDUCTED ENERGY WEAPONS

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ABSTRACT:

Conducted Energy Weapons (CEWs) are increasingly used by police in many countries as a less-lethal use of force option. The most widely-used CEWs work by firing two small darts (electrodes) attached to wires into the subject to transmit a pulsatile electrical signal sufficiently rapid and with enough energy to cause muscular incapacitation. Public concern over the safety of CEWs and the recommendations of a public commision of inquiry in Canada have driven the need for a test protocol to ensure that weapons continue to function properly, meet safety standards, and can be repaired or withdrawn if they do not. We propose a framework standard for testing of CEWs in which the main section addresses the general testing of CEWs, with annexes for the specific details for the two most common weapons in service. The standard is designed for routine (periodic) and post-incident inspection, and requires three 5-second firings of the weapon into a test load and data acquisition system. The test protocol includes an absolute permitted maximum charge, capture of every pulse in a 5 second window and sufficiently high sampling rates to ensure less than 1% error in signal capture and analysis. The initial framework for the standard was elaborated at workshops held at Carleton University (May 2009 and May 2010) and subsequently developed by an ad hoc group of subject matter experts, representing academic researchers, government scientists and companies involved in CEW testing in consultation with police, and Canadian policy organizations. None of the group of experts which authored the protocol has any financial or personal interest with TI or any other CEW manufacturer.

INTRODUCTION:

Conducted Energy Weapons (CEWs) are increasingly used by police in many countries as a less-lethal use of force option. While this presentation refers to the Canadian experience, the use of CEW's is widespread and increasing in other nations including the United States, Australia, United Kingdom and some European nations. CEW's have been used in Canada for over 10 years. Yet benchmark, routine, and forensic testing and performance verification of the weapons are relatively new practices in Canada. Public concern over the safety of CEWs and the recommendations of a public commision of inquiry[1] conducted by Mr. Justice Braidwood in Canada have driven the need for a test protocol to ensure that weapons continue to function properly, meet safety standards, and can be repaired or withdrawn if they do not. Additionally police services, like most publicly funded agencies, are determined to achieve value-for-money in capital purchases. The absence of a performance testing regime for CEW's has undermined equipment budget planning and diminished lifecycle management of an important less lethal weapon in the tools available to police.

In the past, researchers have been unable to validate the performance of the most common CEW, the Taser X-26, during its implementation and life in the field.[2] A significant amount of testing for biomedical research has not used the actual weapon on animal or laboratory models. Some testing has been done on healthy humans to determine the biomedical effects of CEW emissions but there was no indication of the condition and performance of the weapon itself in the testing.

The testing procedure suggested by the manufacturer does indeed measure the performance of the X-26 Taser in accordance with the performance standard. However, this procedure raises some unanswered questions about method and equipment and has necessitated consideration of a more generalized higher level procedure with regard to accuracy rates, precision and completeness.

Thus, several factors have led to the creation of a more general test procedure for all Conducted Energy Weapons:

- public awareness of CEW performance and biomedical effects (transparency)
- police sensitivity about acquisition and maintenance of CEW's (accountability)
- identification of failure modes (accountability)
- direction of oversight bodies for regular testing of CEW's (accountability)
- generation of complete data sets from emissions of CEW's for biomedical research (thoroughness)

A GROUP OF EXPERTS AND THE CANADIAN TEST PROCEDURE

In late 2008 and early 2009 testing of CEW's in Canada was being done in two provinces, jurisdictions with individual oversight of police agencies and operations. Alberta and British Colombia directed police agencies under their authority to ensure that all CEW's in operation were tested in accordance with the performance specifications issued by the manufacturer. These test results were made public by the Solictors-General of the two provinces and a new regime was established[3]. These results were shared widely at the first CEW Workshop held at Carleton University in Ottawa, Canada in May 2009[4]. Every weapon used in the two provinces was tested extensively for performance and a more complete understanding of the electrical characteristics of CEW's [5] in service began to develop outside the testing environment. Officials from both provinces played a very large role in helping scientists and engineers understand what was important from a public perception point of view and conversely, what was important to establish from a scientific point of view. In addition, the Royal Canadian Mounted Police, Canada's national police force, undertook a comprehensive testing program of all CEW's in their inventory. It must be noted that these are the first broadly based testing experiences which involved several thousand weapons in a relatively short period of time.

In May 2010, a second CEW workshop was held at Carleton University and it was apparent that the depth of experience and interest in scientific understanding of CEW performance were increasing very rapidly. Different constituencies were sharing information about their experiences. Police oversight agencies, police services, testing services, scientists and engineers sought and found agreement on what was important and relevant to test. In addition, methods and reporting formats for test results were agreed upon to ensure integrity of results, no matter who did the testing and what equipment was used. A collateral goal was to generate more complete data from testing large numbers of weapons to study failure modes, indicators of failure and make provision for data mining.
In August 2010 the group of experts who had committed to creating the first Canadian Test Procedure for Conducted Energy Weapons, published the procedure.[6] These experts included those with extensive CEW testing experience, design engineers making a product to allow user-testing, and scientists and engineers from Carleton University. None of the group of experts which authored the protocol has any financial or personal interest with TI or any other CEW manufacturer.

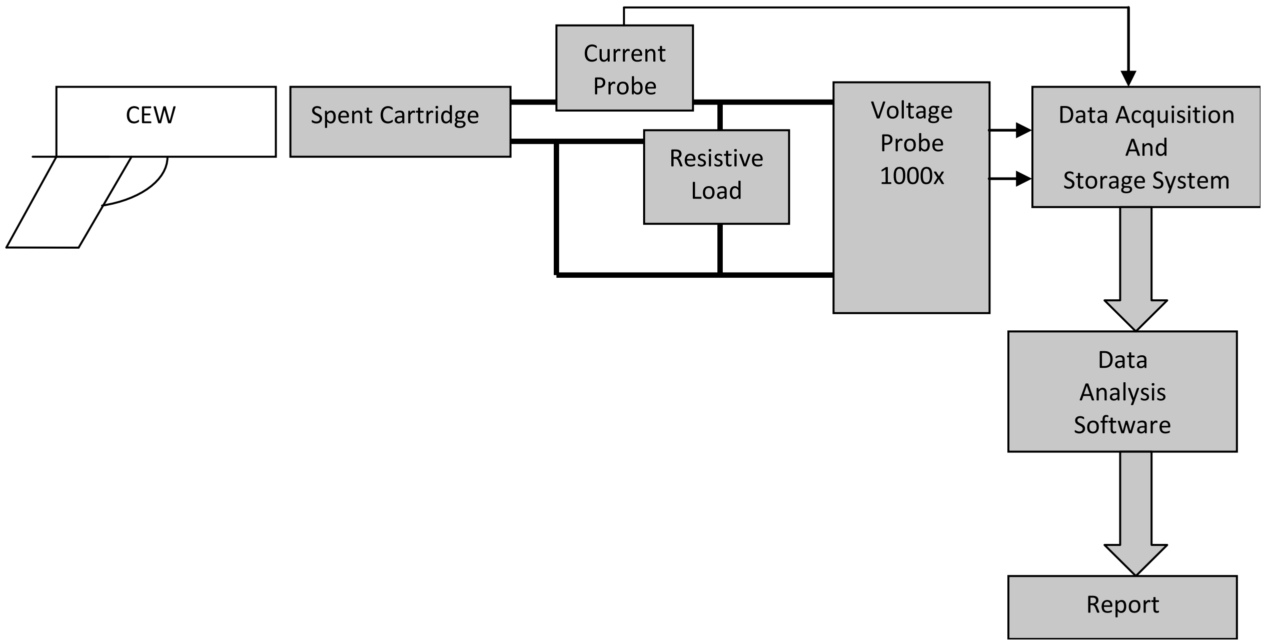
THE CANADIAN TEST PROCEDURE

A standard proceedure for testing, analysis and reporting on the electrical output of a CEW was developed by the group of experts noted above. The purpose of the Procedure was two-fold:

- to establish a methodology by which testing facilities and personnel across Canada will be able to test CEWs and determine whether they are operating within manufacturers' specifications; and
- to define data collection requirements so that data collected during the testing of any CEW in Canada may be used in forensic analysis of that weapon and may also be added to a central data base for future research and data mining programs.

The CEW is connected to the test system, consisting of the weapon connection, a resistive load, a voltage or current probe, and data acquisition equipment. The weapon is fired into the load while data are acquired at a resolution (minimum 8 bit quantization) and sampling rate (Minimum 10 MS/s) designed to keep acquisition errors below 1%. Data are then analysed to calculate parameters related to CEW performance and safety. The procedure is structured as a main section on the general testing of CEWs, with annexes for the specific details for the two most common weapons in service: the M26 and X26 from TI.

The Canadian Test procedure for CEW Weapons is designed for routine (periodic) and post-incident inspection, and requires three 5-second firings of the weapon into the test load. If daily, pre-service inspection is desired, a shorter test is recommended.



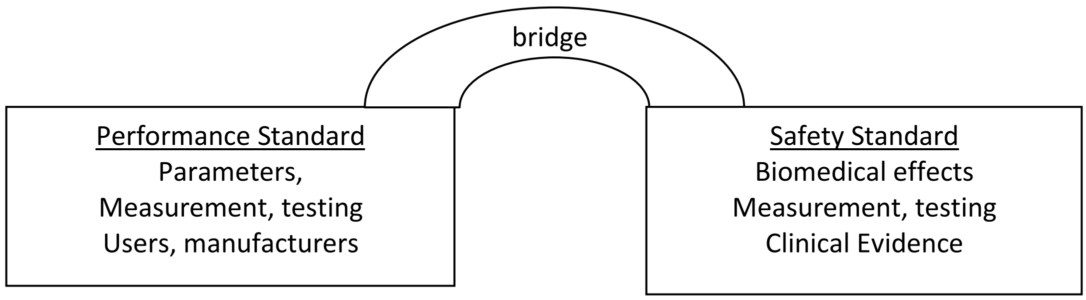
The specified electrical measurements are designed to accomplish the following:
1) measurement of the parameters which, as best can be determined, will enable safety testing against limits based on future research;
2) performance testing against manufacturer specifications; and
3) data gathering to allow statistical analysis of weapon behaviour, such as determination of early indicators of failure.

Thus this Test Procedure includes performance specifications, but goes beyond the one proposed by the TI[7]. It extends the recommended tests in that all pulses are measured and recorded and the maxima and minima calculated, while the manufacturer's specifications are concerned with the average across pulses (and specifically the last eight pulses).

This Test Procedure recommends the calculation of a new pulse parameter which may be related to electrical safety standards for ventricular fibrillation. For this parameter, the most relevant specification is that of IEC 60479[8] which considers the effects of unidirectional single impulse currents of short durations (0.1 ms and above). Section 11 of the specification defines curves based on the probability of fibrillation risk for current flowing through the body from the left hand to both feet. Calculations are based on the C1 curve which is defined as "no risk of fibrillation". For currents above 500 µA, this curve may be fitted to a limit of $Q = 1{:}35(\Delta t)^{0.28}$ where Q is the charge threshold in µC, and Δt is the pulse duration in ms. Thus, the threshold is mostly a function of the charge alone, with a small increase with pulse duration. If we consider the main current contribution from the CEW pulse to be approximately 0.1 ms, this is equivalent to a 710 µC charge limit. For comparison, if a pulse length of Δt = 0.11 or 0.12 ms were used, the limit would be 728 or 746 µC, respectively.

To account for differences in body size and placement of stimulation electrodes, the group of experts recommended the imposition of an additional safety factor of four. Then the maximum allowable value for any individual stimulating pulse would be the value listed in the corresponding appendix of the Canadian Test Procedure for the standard specific models of CEW. Since CEW waveforms are not unidirectional, the tables of section 11 of the IEC standard[8] do not apply exactly. Thus, there was a need to derive a parameter from the CEW discharge which may be compared to the standard. Parameters Total Charge (TC), or Monophasic Charge (MC) were considered, where TC is the integral of the absolute value of current in a CEW pulse, and MC is the maximum of the integral of current in one direction in a pulse. TC is a more conservative measure; however, MC may be justified based on physiological models such as indicated by Reilly et al.[9] Based on an understanding of the current literature, MC is the appropriate measure, Consequently it was recommended as the appropriate safety limit for the threshold from IEC 60479 for the waverforms of the TASER M26 and X26. The test load recommended by TI (non inductive loads of 600Ω for the X26 and 500Ω for the M26) was considered to be an adequate model of the impedance load of the body. These CEWs behave largely as a current source and have relatively little variation in TC with load. Savard [10] found a variation of approximately 25% from the average across loads below 1000. Such variation may be accounted for by the safety factor.

The Canadian Test Procedure goes beyond a performance standard and sets an upset safety limit of 180 µC per pulse. It provides a bridge between a performance standard and a safety standard based on the best information available with current knowledge. Common to the domain of the Performance Standard and the domain of the Safety Standard is the measurement and testing regime proposed by the Canadian Test Procedure.



In addition to the upset limit of 180 µC per pulse charge limit, some other key components of the Canadian Test Procedure include specification of the capabilities of test equipment, a physical inspection of the CEW, test firing three times and the acquisition and analysist of performance data over the entire pulse train of approximately 80-100 pulses or 5 seconds.

RESULTS:

The Canadian Test Procedure has been accepted by the organizations who are doing testing of CEW`s in Canada. The oversight agencies which regulate police activities have endorsed the Test Procedure by requiring testing work to be done in conformity with the Canadian Test Procedure. In addition, regular[11] testing of CEW`s is required.

Police agencies have responded positively to the need to test CEW`s as part of the regular maintenance of the weapon analagous to the care given to ballistic weapons. Older generations of CEW`s have been retired from service because they did not meet the upset charge limit of 180 µC per pulse and all other weapons in service are certified as meeting the expected performance standard.

Scientists and researchers are now better positioned to do data mining on several thousand files from current and future CEW tests. It is hoped that work on aggregated sets of test data will begin in the summer of 2011. The purpose of this work will be to quantify standard deviations of performance parameters, prevailing out-of-tolerance conditions, and identify possible sources of out-of-tolerance events.

Some police services have now begun bench-marking newly acquired weapons with a performance check, before the CEW`s are entered into service.

CONCLUSION AND DISCUSSION:

A stable, consistent test procedure is critical to better understand and manage the electrical performance of CEW's. The understanding of the electrical performance of CEW`s is now more pervasive despite continuing anxiety surrounding use of the weapon. Scientists and engineers have a much better understanding of the performance characteristics of CEW`s across large populations of the weapon. This validates much research, at least on healthy humans, of the biomedical effect of CEW emissions.

Endnotes

[1] http://www.braidwoodinquiry.ca/reports.php
[2] Adler A Dawson DP Evans R Garland L Miller M Sinclair I, 2010 Test Procedure for Conducted Energy Weapons: Version 1.1, Online: curve.carleton.ca/papers/2010/CEW-Test-Procedure-2010-ver1.1.pdf
[3] https://www.solgps.alberta.ca/SiteCollectionDocuments/Alberta%20CED%20Test%20Summary.pdf
[4] The Workshop was sponsored, in part, by the Canadian Police Research Center
[5] The most common weapon in service was the Taser X-26
[6] Ibid. AdlerA et al
[7] Taser International, 2009 Feb 6 TASER X26E Series Electronic Control Device Specification Version 2.0 Online: ecdlaw.info
[8] IEC/CEI/TS 60479-2:2007, Effects of current on human beings and livestock { Part 2: Special Effects", Figure 20, Threshold of ventricular fibrillation".
[9] Reilly JP, Diamant AM, Comeaux J, 2009 Dosimetry considerations for electrical stun devices. Phys Med Biol 54 1319-1335
[10] P Savard, R Walter, A Dennis, Analysis of the Quality and Safety of the Taser X26 devices tested for Radio-Canada / Canadian Broadcasting Corporation by National Technical Systems, Test Report 41196-08.SRC", Dec 2, 2008, Online: www.cbc.ca/news/pdf/taser-analysis-v1.5.pdf
[11] Annual, although some jurisdictions prefer semi-annual