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Stephen D. Tuttle
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TASER International, Inc.
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Re: ADVANCED TASER® M26 Less Lethal System

Dear Mr. Tuttle,

I have reviewed the technical literature on the new ADVANCED TASER® M26 Less Lethal System (see *Document List* below) and have reached the following conclusions.

(1) Consistency: The documents are, for the most part, technically consistent with each other.

(2) Current Pulses: When activated ("fired") the ADVANCED TASER® M26 produces a sequence of approximately half-sinewave current pulses $I(t)$ [Amperes], each having a peak amplitude of I_{peak} of about 18 Amperes, and a duration of of about 11 microseconds, see Fig. 1.

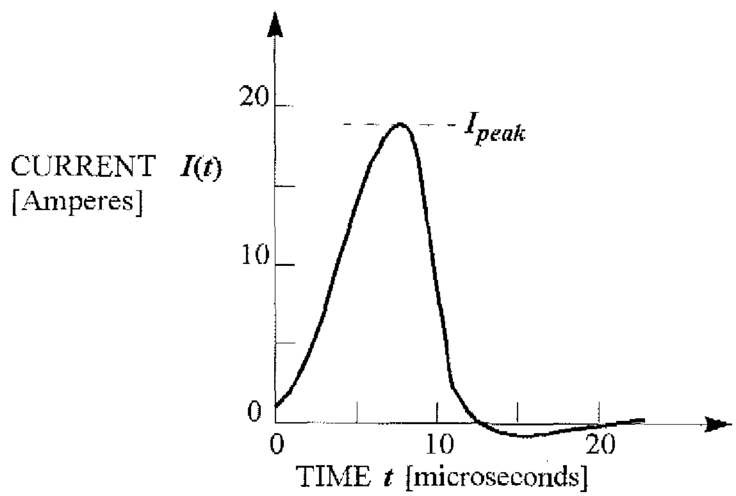

Fig. 1 - Output current $I(t)$ of ADVANCED TASER M26.

Each such current pulse flows from the TASER, along one of the deployed wires, through one of the barbs into the skin of the victim, then back out through the other barb, along the other wire, and finally back into the TASER. Note that there has to be a complete circuit for the current $I(t)$ to flow. Even if the barbs do not actually penetrate the skin, the current path can still be completed if the the peak output voltage V_{peak} appearing between the barbs is high enough to cause a spark to jump the gap(s). This voltage can be estimated from Ohm's Law in the form

$$V_{peak} = I_{peak} \times R \qquad \text{[Volts]}, \tag{1}$$

where R [Ohms] is the equivalent resistance of the subjects's tissue between the two barbs. Assuming that $R = 1{,}000$ Ohms[1], then the peak voltage will be 18 Volts×1,000 Ohms = **18,000 Volts,** enough to jump a gap of about 1/4 inch in normal air, and more when the humidity is high. On the other hand, the actual peak output voltage could be about 50,000 Volts before significant current starts to flow, quickly decreasing thereafter. This means that an *initial* spark could jump a gap of as much as 2/3 inch in normal air.

(3) <u>Peak Power Output:</u> The injection of each current pulse $I(t)$ [Amperes] into the subject is accompanied by a time-varying power pulse $P(t)$ [Watts], given by the equation

$$P(t) = I(t)^2 \times R \qquad \text{[Watts]}, \tag{2}$$

as shown in Fig. 2.

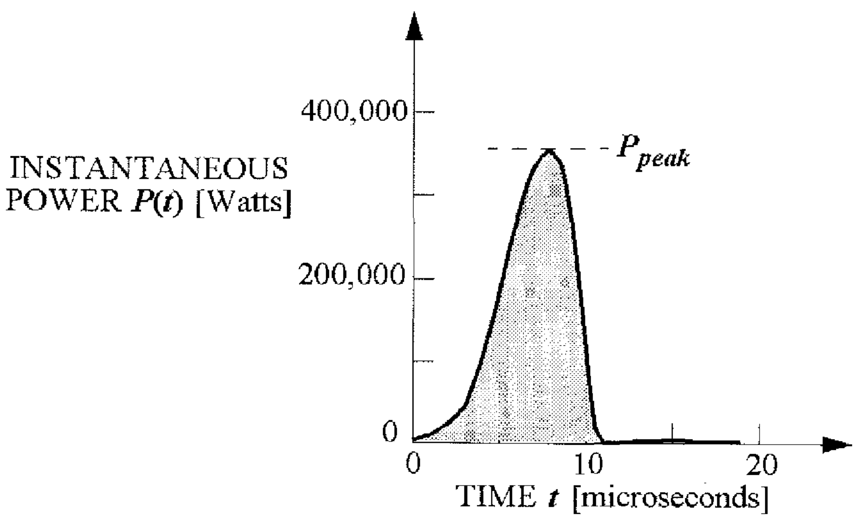

Fig. 2 - Instantaneous output power $P(t)$ of ADVANCED TASER M26.

1 Note that the numerical results obtained will be different if other values are assumed for $\boldsymbol{R}$.

The peak power of each pulse is

$$P_{peak} = I_{peak} \times V_{peak} = (I_{peak})^2 \times R \quad \text{[Watts]}, \tag{3}$$

or in this case, P_{peak} =(18 Amperes)^2×(1,000 Ohms) = **324,000 Watts.** This may look like a lot of power, but it is only there for a very small fraction of the total firing time. The *average* power $P_{average}$ [Watts] is very much less, and is calculated below in item (5).

(4) Energy Per Pulse: The energy-per-pulse W [Joules] is given by the shaded area[2] under the curve in Fig. 2. For the ADVANCED TASER® M26, still assuming R = 1,000 Ohms, this area is found to be

$$W = \mathbf{1.76\ Joules\text{-}per\text{-}pulse.} \tag{4}$$

This is four times the 0.44 Joules-per-pulse produced by the original AIR TASER ® 34000.

(5) Average Power Output: While the ADVANCED TASER® M26 is actually being fired, the pulses are delivered at a rate of

$$N = \mathbf{15\ pulses\text{-}per\text{-}second.} \tag{5}$$

Therefore the *average power* injected into the subject is only

$$P_{average} = (W \text{ Joules-per-pulse}) \times (N \text{ pulses-per-second}) \qquad \text{[Joules-per-second] = [Watts]},$$

that is,

$$P_{average} = 1.76 \times 15 = \mathbf{26.4\ Watts.} \tag{6}$$

2

Mathematically, this area is given by the *integral* under the curve:

$$W = \int_0^T P(t)\, dt \qquad [Watts] .$$

A simple way to find W is to divide the area into small squares of known area, and then multiply by the number of squares.

This is less than one ten-thousandth of the peak power P_{peak}, and is equivalent to about the power used by an ordinary 25-Watt 110-volt lamp bulb. It is for this reason that the ADVANCED TASER® M26 is properly described as a "26-Watt system".

(6) <u>"Body Current":</u> Several documents [1,3,8] show graphs of "Body Current" I_{rms} [Amperes] versus Pulse Width [microseconds]. I_{rms} is the the *effective* current that causes the average power described in item (5). Because the pulse width (T = 11 microseconds) is only about 1/6000th of the time between pulse peaks this current is very much less than the peak current discussed in item (2). The "body current" I_{rms} can be calculated from the average power $P_{average}$ by means of the equation

$$I_{rms} = \sqrt{\frac{P_{average}}{R}} \qquad \text{[Amperes rms]} . \tag{7}$$

Using the appropriate numbers, one finds for the ADVANCED TASER® M26 that

$$I_{rms} = \sqrt{\frac{26.4 \text{ Watts}}{1000 \text{ Ohms}}} = 162.5 \quad \text{milli-Amperes rms.}$$

This is similar to the value of 200 milli-Amperes shown on the "Electrical Output Safety Measurement" charts, and agrees exactly with the result given by the formula[3] quoted there:

$$I_{rms} = \sqrt{(W\,\text{[Joules]})\times(\textbf{Repetition Rate}\ \text{[Pulses/second]})/R\,\text{[Ohms]}} \qquad \text{[Amperes rms]}.$$

(7) <u>The ADVANCED TASER® M18</u> is similar to the M26 unit in all respects except for its pulse rate, which is N = 10 pulses per second. The result is that although the energy W = 1.76 Joules-per-pulse is the same as for the M26, the average power is reduced to

$$P_{average} = 1.76 \times 10 = \mathbf{17.6\ Watts,} \tag{8}$$

or two-thirds of the average power produced by the ADVANCED TASER® M26. The M18 unit is

3 In those documents the energy **W** [Joules] is written in the form E(J) and the [pulses/second] are written in the form (Hz).

thus properly described as an "18-Watt system".

(8) **<u>Engineering:</u>** I have examined key components of the ADVANCED TASER® M26 and am satisfied that it is manufactured according to good engineering principles. It should therefore be reliable in use, provided that it is properly maintained. It might be susceptible to corrosion if depleted batteries are left in place, so a rigid schedule of battery replacement should be enforced.

(9) **<u>In Summary</u>**, I can recommend the adoption of the ADVANCED TASER® M26 as a properly engineered and useful alternative to more lethal ways of controlling violent subjects.

Yours sincerely,

Robert G. Harrison
Adjunct Research Professor

<u>Document List</u>

[1] *"ADVANCED TASER M26 Medical Safety Information"*, 22 pages, © 2000 Taser International, Inc.
[2] *"ADVANCED TASER ELECTRICAL THEORY OF OPERATION"*, December 20, 1999.
[3] *"100% TAKEDOWN POWER"*, brochure, © 1999 Taser International, Inc.
[4] "*Certification Lesson Plan, AIR TASER® Model 34000 and ADVANCED TASER® M26*", (includes the CD-ROM "*TASER® Files Version 4.0*"), Taser International, Inc.
[5] "*Pulse Waveform Document*", `\attach\Pulse Waveform.doc`, 26 January 2000.
[6] "*ADVANCED TASER M-SERIES EMD WEAPONS SPECIFICATIONS*", in the CD-ROM "*TASER® Files Version 4.0*".
[7] "The Voltage Myth", in CD-ROM "*TASER® Files Version 4.0*".
[8] "*ADVANCED TASER M-SERIES* On-Line Owner's Manual", in the CD-ROM "*TASER® Files Version 4.0*".

Note: The opinions expressed in this letter are entirely those of the author, and do not necessarily reflect those of Carleton University.

Notes about the Electrical Units quoted.

Current I describes the rate of flow of electrical charge along a conducting wire. Its units are **Amperes**, and it is analogous to the rate of flow of water in a hosepipe (units gallons/second).

Time-varying current I(t) refers to a *varying* rate of flow of electrical charge along a conducting wire. Its units are **Amperes**, and it is analogous to the varying rate of flow of water in a hosepipe when the water pressure fluctuates.

Peak Current I_{peak} (units **Amperes**) is the maximum value reached by a time-varying current.

The ***Voltage V*** appearing across a resistor R (units **Ohms**) is caused by the current I flowing through it, according to Ohm's Law $V = I \times R$. Its units are **Volts**, and it is analogous to the pressure difference appearing between the ends of a constricted hosepipe when water flows through it (units pounds per square inch).

Peak voltage V_{peak} (units **Volts**) is the maximum value reached by a time-varying voltage.

Energy W per pulse is a measure of the amount of "work" that each electrical pulse can do. Its units are **Joules**, and it is analogous to the "amount of work" that could be done by each glob of water ejected from a pulsating lawn-watering hose.

The ***Power P*** dissipated in a resistor is a measure of the *rate of transfer of energy* into it. The power heats the resistor up, and its units are **Joules/second** or equivalently,**Watts**.