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HUMAN EFFECTS ADVISORY PANEL

Report of Findings:
Sticky Shocker Assessment

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Table of Contents

List of Figures

Executive Summary

The Human Effects Advisory Panel was asked to address six questions regarding the Sticky Shocker's human effects. The following summarizes the Panel's findings and recommendations.

Task 1

NIJ asked what adverse, irreversible, health effects might occur if this device was used by law enforcement officers. The Panel found that the Sticky Shocker's blunt impact could cause commotio cordis, which will cause death. It also could cause serious injuries similar to those caused by sports projectiles such as a baseball. These include contusions, concussions, fractures, internal injuries, eye injuries and dental injuries. There also may be a low probability of liver fracture.

The Shocker's electrical insult could cause acidosis, which can lead to death. It also has a high probability of skin burns. The Sticky Shocker's electrical insult also may cause other serious injuries. The problem is, little data exists regarding how electrical current passes through the human body. There is also no data on the combined effects of blunt impact and electrical insult.

Task 1 also included assessing the effects on the general population, and sub-groups that might be at greater risk. However, insufficient data exists for such generalization. The existing electrical insult data is based mostly on adult males, many of which were intoxicated. Comparative sports projectile data is focused on children, and predominately male. Determining probabilities for a wider population will require collecting data from sample groups that are representative of population groups.

Task 2

NIJ asked the Panel to consider what additional testing might be required to ensure the Sticky Shocker did not cause any irreversible adverse health effects, or provide information necessary for confident assessment. The Panel believes that before the Sticky Shocker's human effects can be predicted, its performance must be predicted. Current weapons performance data is insufficient. This may be because of proprietary reasons. Yet, this data is needed to measure energy transfer from the projectile to the body; this includes kinetic and electrical energy.

While this data is fundamental to understanding the body's response, even more testing must be done on the Sticky Shocker's human effects. They are largely unknown. Some general data exists regarding blunt impact effects on the human body. However, it is not complete, nor does it accurately relate to the Sticky Shocker. Far more testing must be done on electrical insult effects. This will require a groundbreaking effort.

Task 3

The NIJ asked what modifications might be made to enhance the Sticky Shocker's safety and effective use, or provide information for confident assessment. The panel considered several modifications to enhance safety. Its primary focus was on reducing blunt impact, since it is not the primary means of immobilization.

The Panel proposed that an energy absorbing mechanism be used to lessen the projectile's impact. This might be a spring, recoil mechanism, or crumple zone. Additionally, blunt impact might be reduced by lowering the projectile's weight or the velocity. However, this would depend on tests determining the minimum impact needed for the projectile's effectiveness. The Panel realized the tradeoff between performance and safety.

Task 4

NIJ asked what other information might be needed for safe human testing in a field evaluation. Such testing must comply with Title 45 of the Code of Federal Regulations, Part 46. These regulations are intended to ensure the safety and protect the privacy of human subjects in research. These regulations require a full disclosure to human subjects and their consent to undergo research.

Also, these regulations charge the researching agency with these responsibilities. Agency management must conduct varying degrees of review, depending on the type of research and the risk involved. The Panel believes that any human testing evaluating the human effects of blunt impact and electrical insult would require an agency to conduct full review and oversight.

Task 5

NIJ asked what laboratory-based human testing might be required before using the device as a less-than-lethal weapon. The Panel emphasizes that human testing should be part of an integrated process. Initially, hypotheses should be developed regarding how the causes of human effects. Testing as detailed in Task 2 should then be conducted to validate these hypotheses. Human testing is only one data source and limited. Data must come from several sources that complement each other. One source may continue where others leave off. Some sources might be used to confirm data from another. Moreover, this process must be managed by one agency.

Task 6

NIJ asked if the device would be ready for field evaluation if the Sticky Shocker has similar or safer electrical characteristics as stun guns and Tasers. The Panel saw this as greatly depending on NIJ's expectations. If NIJ seeks no adverse, irreversible health effects or known risks, then this device is not ready for field-testing. Its human effects have not been scientifically determined, and are largely unknown. It has not been scientifically proven that the Sticky Shocker and Taser cause similar effects. Also, the Taser's effects have not been adequately studied. Finally, differences exist between the Taser and Sticky Shocker's performance.

If NIJ accepts an unknown degree of risk of such effects occurring, the device may be ready for field evaluation. The problem in accepting unknown risks, though, is expectations. NIJ must know that a device will meet its expectations – whatever they may be. The dilemma NIJ will face if it conducts a field evaluation is determining what its new expectations for this device will be.

Task 1

What adverse, irreversible, health effects, if any, may occur in the use of this device by law enforcement officers on the general population, and any sub-groups that might be at risk?

Task 1 Description

The Sticky Shocker produces two physical effects: blunt impact and electrical insult. The panel determined that the Sticky Shocker could cause the following irreversible or adverse health effects:

- Blunt impact could cause commotio cordis, which will cause death. The probability of this occurring is unknown.
- Blunt impact can cause injuries similar to those caused by sports projectiles such as a baseball. These include contusions, concussions, fractures, internal injuries, eye injuries and dental injuries.
- Blunt impact could cause liver fracture. There is a low probability of this occurring.
- Electrical insult could cause acidosis, which can lead to death. The probability of this occurring is unknown.
- Electrical insult has a high probability of causing skin burns.

Insufficient data exists to generalize for the population and sub-groups. Of the little data that does exist, most of the electrical insult data is focused on adult males. In many cases they were intoxicated by drugs, alcohol, or both. The comparative sports projectile data is focused on children, and predominately male. Very little is know about the effects of age, gender, and body type. Determining probabilities for a wider population will require collection of data from sample groups that are representative of each population segment. High confidence levels will require large sample groups.

Task 1 Discussion

The section will discuss the data that the Panel used to render its findings. It will specifically address the Panel's:

- Review of all known data on the Sticky Shockers Human Effects
- Review of comparative blunt impact data
- Assessment of blunt impact causing serious injury
- Assessment of blunt impact causing commotio cordis
- Review of electrical insult data
- Assessment of electrical insult causing skin burns
- Assessment of incapacitation

- Assessment of electrical insult causing acidosis
- Comparison of the Sticky Shocker and the Taser
- Generalizing for the Population and Sub-groups that Might be at Risk

REVIEW OF ALL KNOWN DATA ON THE STICKY SHOCKERS HUMAN EFFECTS

The Panel evaluated the Shocker Final Technical Report. It contained two appendices entitled "Evaluation of potential injury trauma by impact of the Sticky Shocker" and "Medical literature search shock and impact safety. This was the entire body of data on the Sticky Shocker's human effects.

The author of the first appendix, Jaime H. Cuadros, concluded that the level of kinetic energy from the Sticky Shocker was "below the level where damage to the body and to the bare skin can be expected". Cuadros used Sticky Shocker characteristics that were provided by JAYCOR and compared them to 1975 and 1976 Edgewood Arsenal studies and a 1984 Aberdeen Proving Ground study. He also compared the energy level of the Sticky Shocker to the energy levels of baseball impacts. He concluded that, "from the impact trauma point of view, the Sticky Shocker would be considered a safe projectile".

Dr. Jeff Millard authored the second appendix, which focused on the "safety of the device, particularly in regard to the electrical output of the Sticky Shocker projectile". From the standpoint of electrical safety, he concluded that the "safety margins appear at least an order of magnitude, which should be adequate to prevent lethal effects such as ventricular fibrillation."

Dr. Millard was concerned about injury from blunt impact. He noted that "the Sticky Shocker is safe provided that (1) it is not fired at close range (less than about 10 to 20 ft, actual distance to be determined) and (2) it is not fired at the face, especially the eyes." Dr. Millard did not measure the characteristics of the Sticky Shocker, but used the data provided by JAYCOR, as did Cuadros. See Figure 1.

JAYCOR conducted its own study of the Sticky Shocker as reported in the Final Technical Report. They compared the blunt force trauma of the Sticky Shocker to other LTL weapons. They reached the conclusion that the Sticky Shocker was as safe as other LTL weapons.

Figure 1. Guidelines for Less Lethal Projectiles

GUIDELINES FOR LESS LETHAL PROJECTILES				
	Large Projectile Mass	Low Projectile Velocity	Large Impact Area	Low Peak Load Density
Guideline Values	**20 to 150 g**	**150 to 300 ft/s**	**1.25 to 3.0 in. dia.**	**20 to 50 ft-lbs/sq.in.**
Sticky Shocker	155 g	70 to 90 ft/s	1.375 to 1.5 in. dia.	28 ft-lbs/sq.in.
.45 caliber bullet	15 g	850 ft/s	0.45 in. dia.	2,100 ft-lbs/sq.in.
Baseball (60 mph)	147 g	88 ft/s	3.0 in. dia.	13 ft-lbs/sq.in.
Shotbag	82 g	185 ft/s	0.71 in. dia.	56 ft-lbs/sq.in.
Non-lethal bullet	56 g	179 ft/s	2.0 in. dia.	21 ft-lbs/sq.in.

JMK-904-34.eps

(Millard, 1996)

It appears that JAYCOR did not conduct electrical safety tests. Rather the electrical characteristics were compared to other electric shock LTL weapons. Based on this comparison, JAYCOR concluded that "pulse currents will not cause ventricular fibrillation" and that "the Sticky Shocker is as electronically safe as current stun gun units." However, in arriving at these conclusions, JAYCOR noted that "there is very little authoritative medical research on the subject of shock effectiveness for pulse wave technology, although substantial research has been done on electric shock from ac sources (e.g., 60Hz) and ms-long pulses (defibrillation, electro-convulsive therapy)."

JAYCOR representative Dr. Peter Coakley provided a review of the Sticky Shocker Final Technical Report. He responded to the many questions of the Panel. The Panel found his answers to be very helpful and the cooperation of JAYCOR was appreciated.

Dr. Peter Coakley believed that the Sticky Shocker would produce similar bioeffects as the widely used Taser. The Panel, therefore, reviewed Taser literature, which is very limited, and attempted to extract conclusions. Finally, the Panel reviewed police log-based information on similar non-lethal technologies, including the stun gun.

Dr. Coakley provided the Panel with two demonstration videos illustrating the apparent effectiveness of the Sticky Shocker and the Taser. Their respective manufacturers produced two videos. The Panel had the opportunity to review videotapes of the Sticky Shocker being tested on three humans and a promotional video on the effects of the Taser. These tapes were played several times and Dr. Coakley provided background and comment.

In the Taser video it appeared that there was some form of incapacitation, although the video was inconclusive. Every subject appeared to lose voluntary leg muscle control upon electrode contact. This reoccurring phenomena observed in the video has never been explained.

The test subjects of the Sticky Shocker displayed responses to the electrical shock, which the Panel was unable to interpret. There was also a wide disparity in each test subject's response to the electrical shock in the same location of the body. One of the subjects was Dr. Coakley who reported that he suffered these temporary effects:

- Exhaustion
- Involuntary control of leg muscles
- Reddening of electrode contacted region
- Slight pain

If these effects are founded, it would permissible to describe the Sticky Shocker as a weapon of incapacitation. However, both videos failed to provide the Panel with a reasonable explanation for the method of incapacitation.

REVIEW OF COMPARATIVE BLUNT IMPACT DATA

The Panel was also provided with relevant studies and data outside of those provided by the National Institute for Justice. Although this was outside its charter, the Panel felt it was necessary to examine this information because of the paucity of Sticky Shocker human effects data.

The Panel reviewed studies on injuries resulting from blunt impact of sports projectiles. Compared to non-lethal weapons projectiles, sports projectiles are fairly large and slow. A regulation-size baseball, for example, weighs between 5 and 5.25 oz. (141.75 and 148.84 g) and has a circumference of 9 to 9.25 in. (22.86 to 23.5 cm). In youth baseball and softball games, where most of the injuries considered here occur, the balls rarely reach velocities above 50 mph (22.5 m/s). For a comparison of a baseball to the Sticky Shocker projectile see Figure 2.

Figure 2. Comparison between the physical characteristics of the Sticky Shocker and a baseball

Projectile	Size (cm)	Weight (g)	Velocity (m/s)	Lethal Distance (m)
Baseball	23.0	142–149	13.5–22.5	5–37
Sticky Shocker	3.8	120–150	25.9–28.9	?

BLUNT IMPACT CAUSING SERIOUS INJURIES.

Sports projectiles, such as baseballs, lacrosse balls, and hockey pucks, are obviously not intended to be weapons, but they can cause serious injuries. The relatively slow velocity of sports projectiles means that the injuries caused by these projectiles usually have a low mortality rate. Most common ball-related injuries are bruises. In a few cases, they have been very serious. In 1995, the United States Consumer Product Safety Commission estimated that emergency rooms treated 162,000 baseball-related injuries. Of these, 55% were due to ball impact. Of these injuries, 33% were severe, including fractures, concussions, internal injuries, and dental injuries.

The Sticky Shocker is not intended to impact either the head or neck regions. Nevertheless, its impacts to these could be very dangerous and cause serious injuries. These injuries might be similar to those caused by sports projectiles and include concussions, fractures to the facial bones, eye damage, and fracture of the larynx.

BLUNT IMPACT CAUSING COMMOTIO CORDIS

Blunt impacts from sports projectiles have also caused death. Between 1973 and 1995, the Commission recorded 68 ball-impact deaths in youth baseball. Of the deaths, 56% were caused by impact to the chest and 31% by impact to the head (United States Consumer Product Safety Commission, 1998). Deaths due to ball-impact usually occur at fairly close ranges, varying between 5 and 37 m. Fatalities have been recorded in both competitive and recreational settings (Maron, et al, 1995).

Ball-related deaths have also been recorded in softball, lacrosse and ice hockey (Maron, et al, 1995) Another study that included all four of these sports found 47 instances of ball-related chest trauma. In all cases, the victims suffered commotio cordis, concussion of the heart (Maron, Poliac & Kyle, 1997).

Commotio cordis is a functional injury, defined by a lack of cellular damage (Tenzer, 1985). It is caused only by blows to the anterior chest, particularly to the sternum (Tenzer, 1985) and the area directly above the left ventricle (Maron, et al, 1995).

The important factor in commotio cordis is not the force, but the timing. It occurs when the heart is struck during repolarization, a time window of about 15 ms. The period of repolarization represents roughly 2 to 3% of the cardiac cycle, depending on the heart rate. The rate of repolarization is constant. Because of the impact, the heart does not repolarize properly and ventricular fibrillation results (Link et al, 1998). This causes different sections of the heart to contract at different times. As a result, the heart cannot pump blood at all.

Even small impacts can cause commotio cordis. Witnesses to cases of commotio cordis agree that the impacts were not unusual in either velocity or force (Maron, et al, 1995). Ventricular fibrillation has also been induced in juvenile pigs by impacts of only 30 mph, or 13.5 m/s. (Link et al, 1998). In comparison, the average velocity of a baseball in youth baseball games is 30–50 mph (13.5–22.5 m/s).

Although most cases of commotio cordis are fatal, case studies show that the initiation of cardiopulmonary resuscitation within one minute greatly increases the chances of survival. In one study, 5 of 55 victims of commotio cordis survived cardiac arrest; 4 of the 5 survivors received CPR within one minute (Maron, Poliac & Kyle, 1997). This statistic is important to note. Defibrillation is the standard therapy for ventricular fibrillation, but the fibrillation induced by commotio cordis seems to be resistant to this therapy.

Children are particularly vulnerable to commotio cordis – 90% of its victims are younger than 16 (Maron, Poliac & Kyle, 1997). This may be because children's rib cages are more elastic than adults, allowing more of the force to be transmitted to the heart (Van Amerongen, Rosen, & Winnik, 1997) It could also be that more children than adults participate in these sports (baseball, softball, lacrosse, and ice hockey). Little data is available on the role of gender in susceptibility. Most victims are male, but this may be only because more males than females participate in these particular sports (Maron, et al, 1995).

Victims of commotio cordis usually collapse within a few seconds of impact. Many collapse immediately. Occasionally, a person will collapse after a chest impact, as if commotio cordis occurred, but then spontaneously regain consciousness. These appear to be cases of "near-miss" commotio cordis (Curfman, 1998). Such cases could occur when the impact occurs outside the vulnerable period of repolarization, but still very close to it.

Experiments with juvenile pigs have shown that impacts just outside this period tend to cause brief bursts of ventricular tachycardia, which is a very fast heart rate. This is less a serious arrhythmia than ventricular fibrillation, but one that can degenerate into ventricular fibrillation. Also, when the impact occurs during the QRS complex (contraction of the ventricles), transient complete heart block occurs in 4 of 10 cases (Link et al, 1998). Both ventricular tachycardia and complete heart block can cause loss of consciousness due to ineffective heart pumping (decreasing the blood pressure of one's body).

Sports projectiles and non-lethal rounds are very different in size, velocities, and energies. However, if sports projectiles, which have relatively small energies, can cause commotio cordis, it is very likely that non-lethal projectiles can also. Because commotio cordis is triggered not by high energies of impact, but rather by the timing of the impact to the cardiac cycle, it may always present a small, unavoidable risk of death no matter how carefully a weapon is designed.

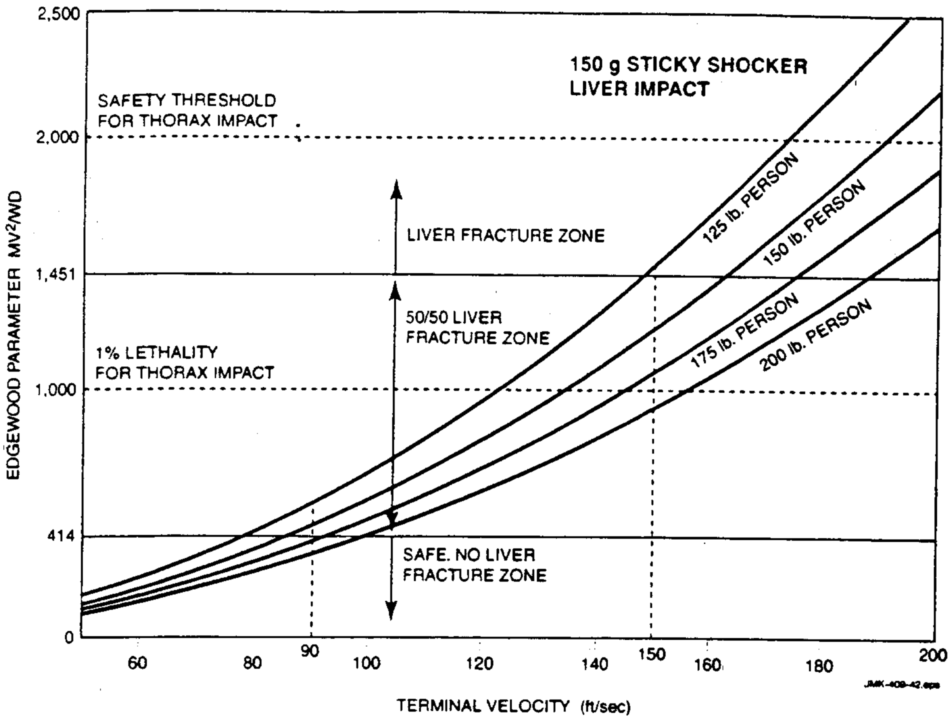
BLUNT IMPACT CAUSING SERIOUS INJURY

The Panel also considered the probability of the Sticky Shocker's blunt impact causing liver fracture. The Panel reviewed tests conducted by the Edgewood Arsenal. Based on these tests, the Panel concluded that there was a low probability of liver fracture as can be seen in Figure 3. However, this opinion has the following caveats:

- The data is old and was not collected for the specific intention of blunt impact from the Sticky Shocker.
- The curves were developed for the 50-percentile male and are not applicable to the entire human population.
- The curves were created from data collected on live animals. There are problems associated with the accurate extrapolation of animal data to human data.

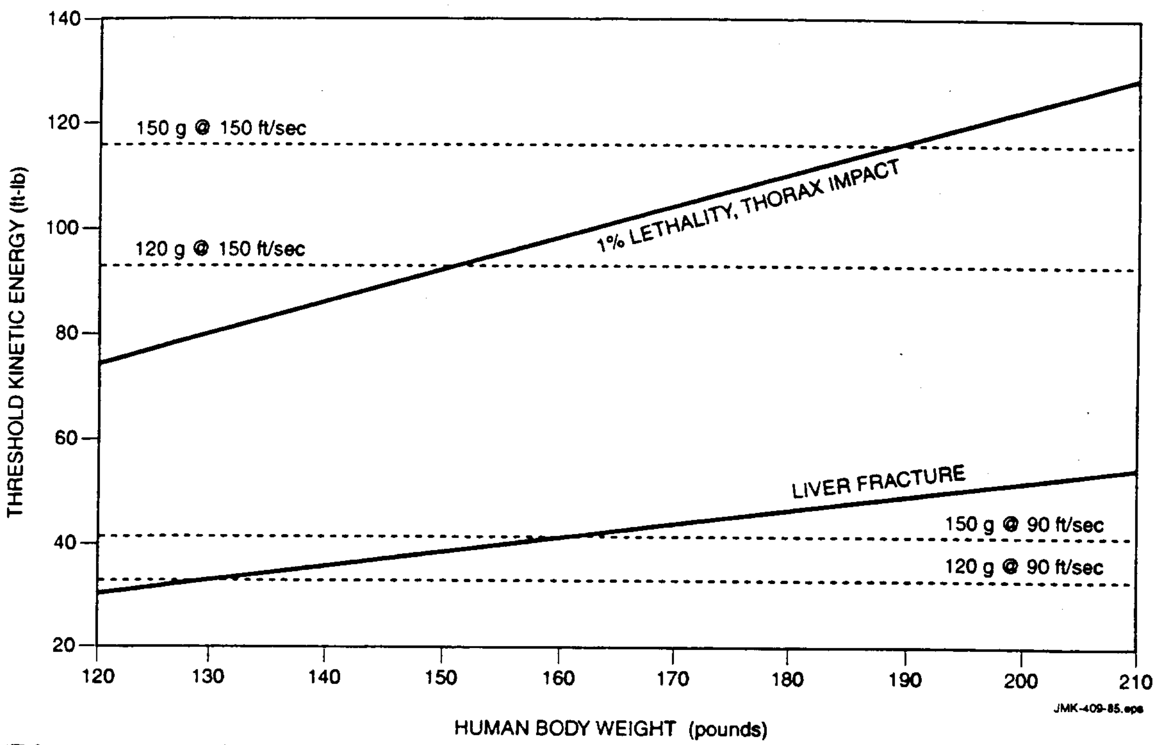
There is a low probability of death caused by the Sticky Shocker's blunt impact to the thorax. The Sticky Shockers terminal velocity is approximately 85 feet per second as reported by JAYCOR. This was compared to the curves created by Edgewood Arsenal, as depicted in Figure 4. However, the same caveats apply as were discussed for liver fracture. The Panel did not take into consideration the blunt impact insult of breast tissue due to the lack of data available.

Figure 3. Impact of 150g Sticky Shocker on the liver.



(Edgewood Arsenal Model, 1975)

Figure 4. 150g and 120g Blunt projectile impacts to the thorax



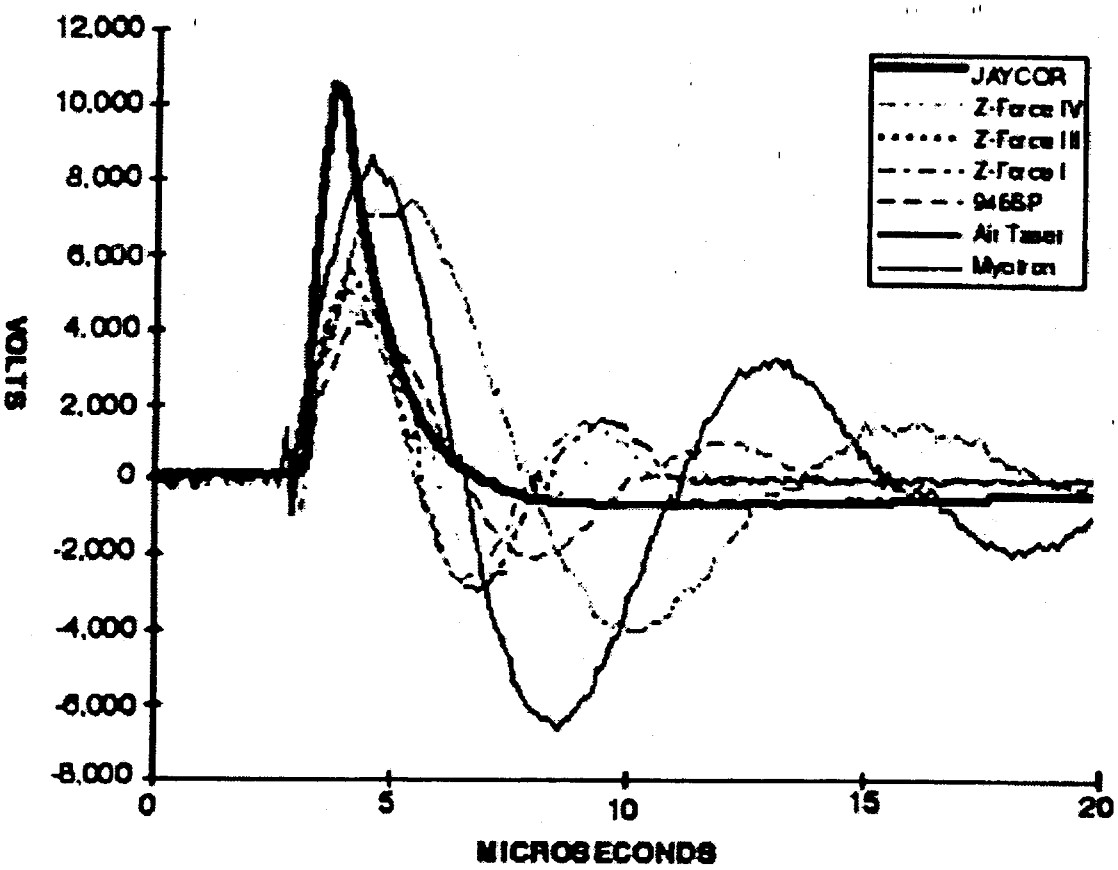
(Edgewood Arsenal Model, 1975)

ASSESSMENT OF ELECTRICAL INSULT DATA

The primary biophysical effects of the Sticky Shocker occur from its electric shock. An understanding of applied electrical current on the human body was seen as necessary to understanding of bioeffects, and ultimately an understanding the electrical safety factors for the Sticky Shocker.

The Panel reviewed the Sticky Shocker's reported electrical characteristics. JAYCOR's design goal was to engineer a device with similar electrical pulse characteristics to current stun gun and Taser technologies. The Sticky Shocker delivers a very brief monophasic current, as seen in Figure 5. Over the Sticky Shocker's electrical duration, this pulse is repeated into a pulse train. The pulse train causes behavior resembling an AC current, or pseudo AC current. The shock train duration of the Sticky Shocker is 8 seconds.

Figure 5. Waveform of the Sticky Shocker electric pulse when in direct skin contact



(JAYCOR'S Sticky Shocker Final Technical Report, 1998)

JAYCOR measured the repetition rate, load, peak voltage, and pulse energy as prerequisites to define other characteristics of the waveform. The repetition rate explains if the pulse train is effective in producing muscle contractions. The load is the predetermined impedance of the human body. The peak voltage represents a potential force. It becomes important when the projectile is not in direct contact with a subject. The higher the voltage, the further the voltage is able to arc to reach through a subject's garments. The pulse energy is the amount of energy from a single pulse. The electrical pulse measurements are shown in Figure 6.

Figure 6. Electric pulse characteristics of the Sticky Shocker as reported in the JAYCOR Technical Report

Rep Rate (Hz)	Effective Pulsewidth (μSeconds)	Peak Power (kWatts)	Average Power (W)	Pulse Energy (Joules)	Peak Current (Amps)	RMS Current (mA)
12 or 15	1.0	108.0	----------	0.103	10.5	54

From the measured values, it is possible to derive the average power, peak power, effective pulse width, peak current, and RMS (root mean square) current. The average power is the measure of the heating that can be produced and that may lead to the thermal injury. The peak power is the maximum possible heat that can be produced from a single pulse. The effective pulse width is time duration of a single pulse that does the work (or releases energy). The peak current is the maximum current that will pass through the human body upon direct contact with the skin. RMS current provides an adequate estimate of a sinusoidal pulse. It is also commonly used by Underwriter's Laboratory (UL) and the International Electrotechnical Commission (IEC) for estimating safety standards.

Figure 7. Calculated values of the Sticky Shocker Electrical Pulse

Rep Rate (Hz)	Effective Pulsewidth (μSeconds)	Peak Power (kWatts)	Average Power (W)	Pulse Energy (Joules)	Peak Current (Amps)	RMS Current (mA)
12	1.0	110.0	1.32	.110	10.5	36.4
15	1.0	110.0	1.65	.110	10.5	40.7
12	3.0	110.0	0.06	.331	10.5	63.0
15	3.0	110.0	0.07	.331	10.5	70.4

The Panel found differences between JAYCOR's reported electrical characteristics and the calculated characteristics. The calculated peak power is a little higher than JAYCOR reports. The calculated energy per pulse is slightly lower than JAYCOR reports. The effective pulsewidth of the signal is lower than Figure 5 displays. JAYCOR reports the projectile's RMS current as 54 Amps, but using Equation 5, and a 12 or 15 Hz repetition rate and the variation of effective pulsewidths, the accurate RMS current ranges from 36.4 to 70.4 mAmps.

The following equations were used to determine the Sticky Shocker's actual pulse characteristics in Figure 7:

$$\text{Pulse Energy} = \left(\frac{V^2}{R}\right)dt \qquad \text{Eq. (1)}$$

$$\text{Peak Current} = \left(\frac{V}{R}\right) \qquad \text{Eq. (2)}$$

$$\text{Peak Power} = \left(\frac{V^2}{R}\right) \qquad \text{Eq. (3)}$$

$$\text{Average Power} = \left(P \times \Delta t \times \text{RepRate}\right)^{\frac{1}{2}} \qquad \text{Eq. (4)}$$

$$\text{RMS Current} = \left(I^2 \times \Delta t \times \text{RepRate}\right)^{\frac{1}{2}} \qquad \text{Eq. (5)}$$

where,
V is the voltage measured in volts,
R is the resistance measured in ohms,
Δt is the pulse width measured in seconds,
P is the energy of one pulse measured in watt - seconds or joules,
i is the average pulse current in Amps.
RepRate is the repitition rate of the charge.

JAYCOR reports an effective pulsewidth of 1 µsecond, but Figure 4 displays the projectile's direct contact effective pulsewidth closer to 3 µseconds. Therefore we have calculated values for both pulsewidths.

All signals are comprised of harmonics from low to high frequencies. A FFT (Fast Fourier Transform) will show the magnitudes of the harmonics. For a single pulse, a crude estimate for the dominant frequency is the reciprocal of the signal pulse length. Over the time duration of eight seconds, the lower frequencies will add and the dominant frequencies will be around the repetition rate, i.e. 12 or 15 Hz. Estimating the pulse length as 1 µseconds, the dominant frequency of a single pulse is 100,000 Hz. If the pulse length is 3 µseconds, the dominant frequency of a single pulse is over 300,000 Hz. The Panel recommends JAYCOR perform a FFT on the signal to see how the dominant frequencies are dispersed.

The Panel sought to assess the bioeffects that result from the Sticky Shocker's actual electrical pulse characteristics. However, the Panel found a lack of relevant data; this finding was based on the Panel's exploratory research and JAYCOR's presentation. The Sticky Shocker Technical Report's provided no quantitative data measurements of the device's electrical current in the human body.

The Panel, therefore, reviewed studies that used swine, canines, and cadavers to simulate the bioelectrical effects of humans. The majority of research involved the typical household outlet frequency of 60 Hz. Most of the data does not account for human variability. In addition, JAYCOR fits the available data in a specific manner, i.e. muscle and cardiac response plots. We did not "judge" their data fits these plots. This lack of relevant data scientifically limits the ability to predict the Sticky Shocker's human effects.

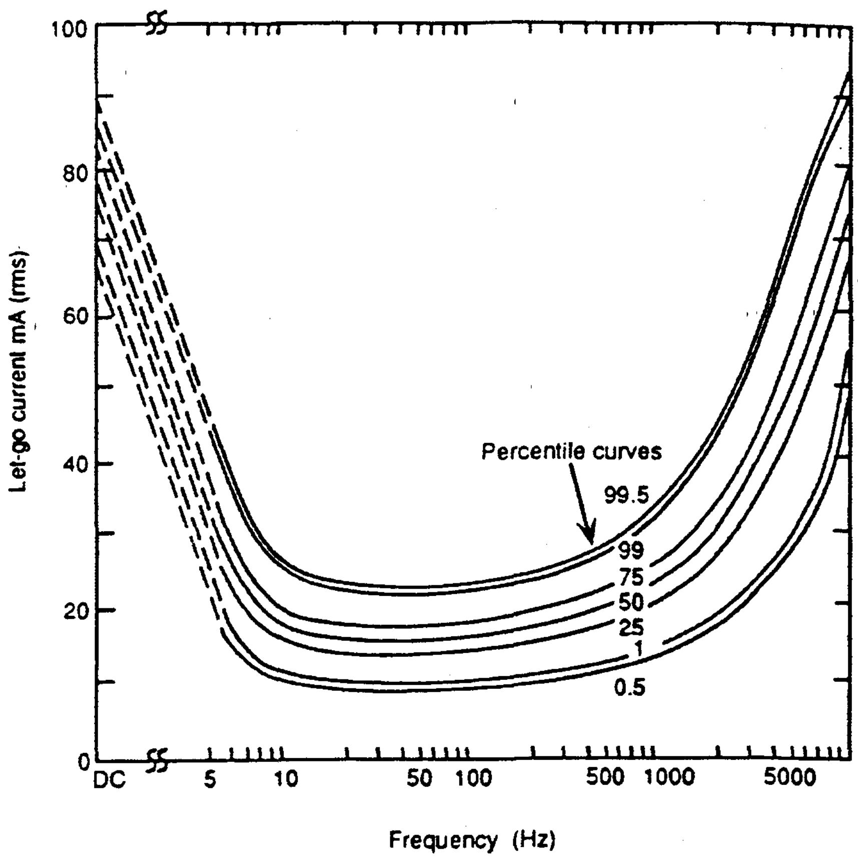
The Panel relied on its own expertise in addressing key parameters of electrical insult on the human body. Various members briefed the rest of the Panel on the effects of applied bioelectricity. The Panel determined that electrical insult would result in bioelectrical changes to the subject, which could lead to incapacitation, further injury, or fatality.

The Panel evaluated the sensation caused by electrical insult. The initiation of electrical stimulation begins with the local sensory neurons. These are the same pathways our body uses to sense its surroundings. The threshold range of an individual's electrical sensation from perception to pain is very small. For sinusoidal currents or pulse trains, the pain threshold was found to be up to 2.5 times greater the perception threshold (Reilly, 1999). The accepted minimum sensation is 0.5 rms mAmps.

As a recipient of the Sticky Shocker's electrical insult, JAYCOR's Dr. Coakley noted that he felt a "stinging" sensation throughout his body when he tested the device on himself. There is no explanation for this global effect, but the Panel does agree that localized pain is definitely associated with this device in the case of poor electrode contact. Dr. Coakley also noted that while the Taser causes no "pain," the Sticky Shocker has less pain with proper application of the device to the skin. Neither Dr. Coakley nor the Panel were able to explain these results.

The Panel also examined muscle response. Motor neurons are primarily responsible for innervating muscle tissue. At the stimulation perception (nerve feel) threshold, a small region of the contacted area is stimulated, causing a twitch. These are known as action potentials (APs). When a succession of APs are produced on the motor neuron, the individual twitch quanta fuse together. Maximum muscle tension is achieved at about 80 Hz (Reilly, 1992).

Figure 8. The let-go current threshold versus frequency for adult males



(Dalziel, 1972 and Reilly,1992)

This phenomena is known as "can't let-go," or tetanus. The subject is unable to release the energized conductor. Tetanus can also be achieved with high current levels. Figure 8 is the accepted "let-go" current standard for DC and AC current in healthy adult males. Grip tetanus is related to excitation of motor neurons in the forearm (Reilly, 1999). This figure illustrates the "let-go" thresholds of small muscle groups (i.e. hands and feet). There is no data available for the "let-go" thresholds of larger muscle groups. There have been studies that showed that prolonged currents to the thoracic region can result in asphyxiation (Dalziel, 1959; Reilly, 1998).

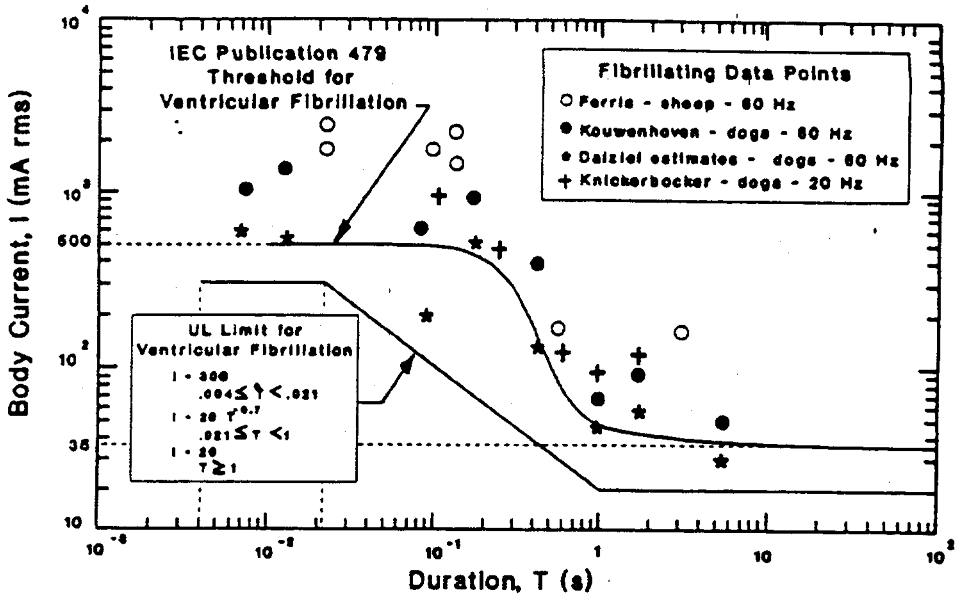
The Sticky Shocker's rms values are all under the "let-go" threshold for a single pulse, estimating that most of the pulse's energy is at, or over 100,000 Hz. Figure 8 does not account for extremely high frequencies, therefore no assumption can be made. If we consider the Sticky Shocker's pulse over it's shock train duration, Figure 8 illustrates that the current is significantly above the "let-go" threshold and that "let-go" will be achieved for all of a given population over the shock train's duration.

JAYCOR did not do not conduct any experiments on muscle response and pulse characteristics, therefore it is unclear whether tetanus would be likely for a sample population. In the Sticky Shocker video provided by JAYCOR, the Panel noticed that the subjects displayed wide varying reactions to current applied in the same regions. In addition the subjects extensor muscles appeared to be reacting instead of the flexor muscles, which is not the expected reaction. The current should activate the flexor muscles, causing the subject to "curl up" and not "straighten out" his/her body. The physiologic flexor extension in upper extremities results in "net" flexor, i.e. "let go".

The Panel also considered cardiac excitation resulting from electrical insult. Cardiac excitation is directly related to extrasystoles that occur during the relaxed state of the heart. Extrasystoles can potentially become lethal if they occur during the relative refractory (partially polarized) period of the heart pulse. High current can as also be lethal, causing uncoordinated contractions of the heart muscle. This condition is known as ventricular fibrillation. The heart will not recover on its own and must be defibrillated within a very short time duration to avoid brain damage and ultimately, death (Reilly, 1998).

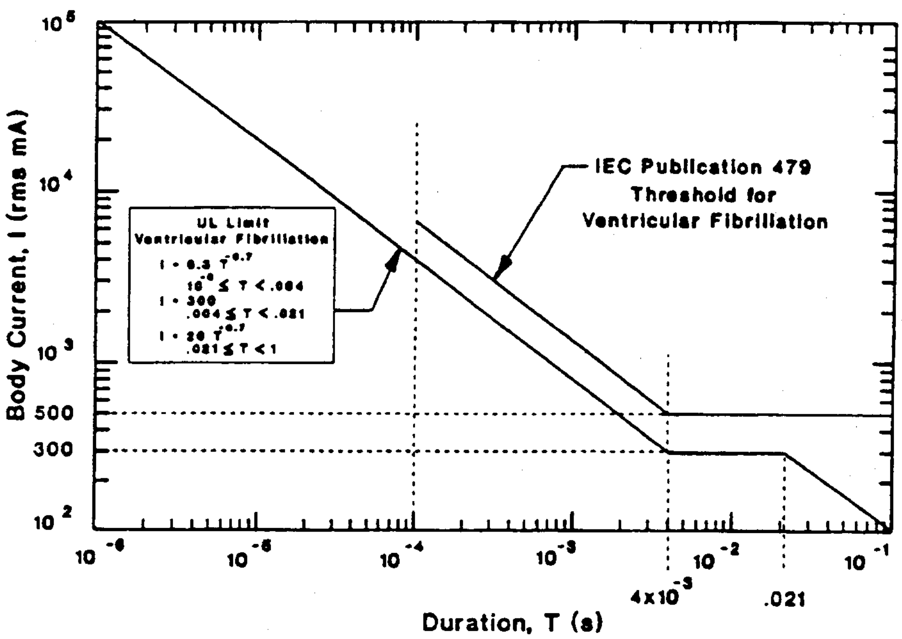
Figure 9 and Figure 10 show the ventricular fibrillation thresholds on current versus time plots. If we consider a single pulse as JAYCOR does in their report, then ventricular fibrillation is not likely. However, over the shock train duration, Figure 9 shows us that ventricular fibrillation is likely above 35 mA. Depending on the effective pulsewidth, ventricular fibrillation is realistic with a subject with heart conditions. Overall, there is currently not enough relevant heart current data available to predict the Sticky Shocker's cardiac effect. Heart current-duration plots are 60 Hz currents that do not fit the Sticky Shocker's electrical characteristics.

Figure 9. Ventricular fibrillation thresholds for current versus time



(Reilly, 1992)

Figure 10. Ventricular fibrillation thresholds for single pulse currents versus duration of the pulse



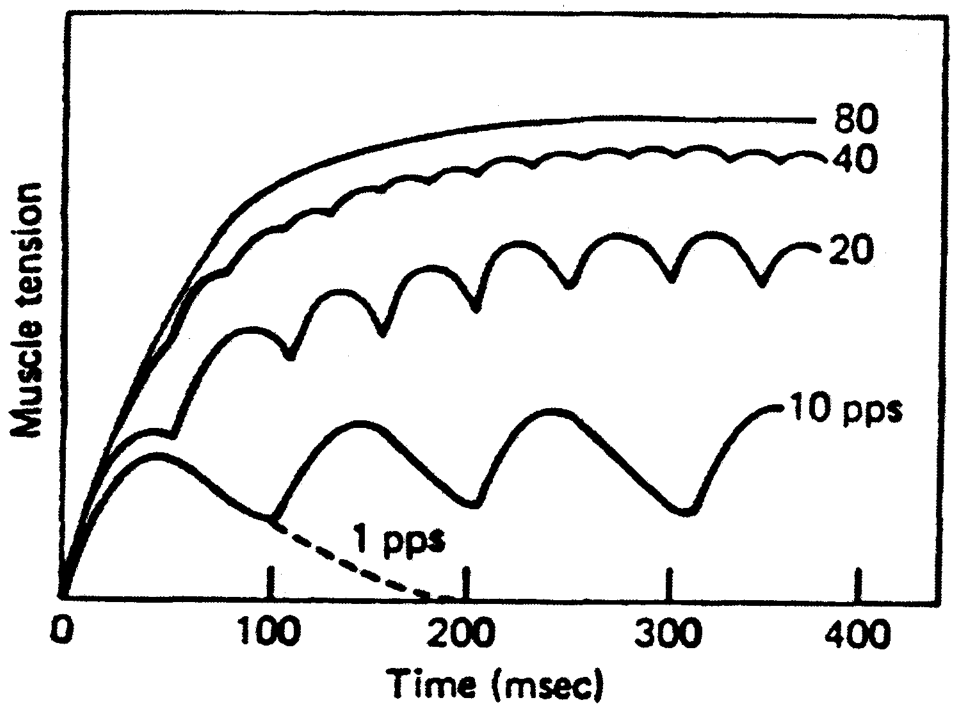
(Reilly, 1992)

The panel also considered the repeated use of pulsed stimuli. It greatly enhances physical reaction (Reilly, 1998). Repeated pulses above the threshold of excitation affect sensory, motor, cardiac, and dermatological responses. The repetition rate and duration of a pulsed stimulus train dictate the magnitude of a subject's physical reaction (Reilly, 1998).

Figure 11 illustrates the effect of pulse repetition on muscle tension for stimulation of a motor neuron (McNeal and Bowman, 1985). If an individual pulse is above the threshold of excitation, muscular reaction in the localized region occurs. As previously discussed, this is a twitch resulting from individual twitch quanta fusing together when individual pulses are repeated as illustrated in the figure. The maximum excitation rate of the motor neurons occurs at about 80 pulses per second.

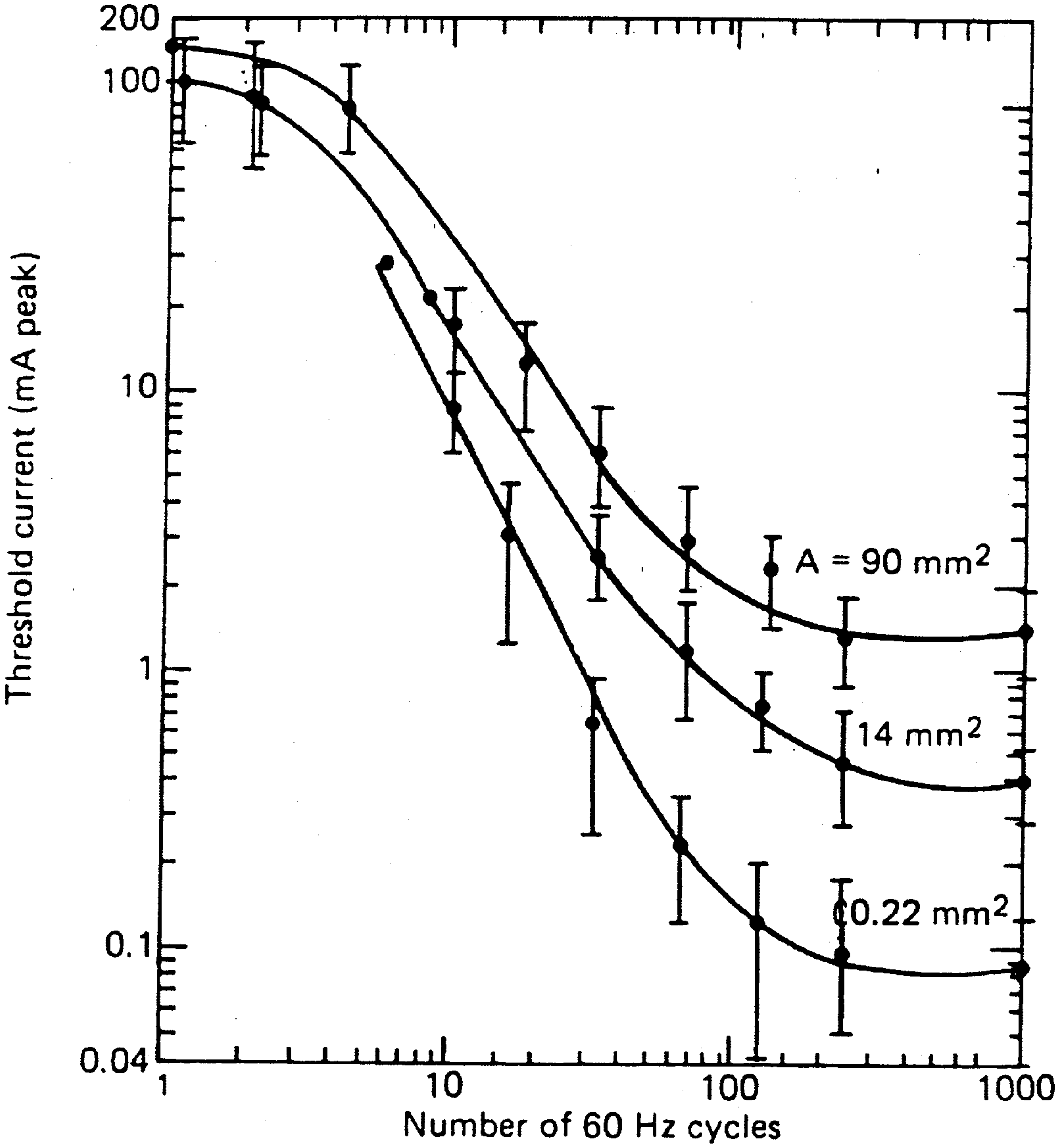
Figure 12 illustrates the effect of pulse repetition on the cardiac system. (Roy et al, 1977). The experiment investigates the ventricular fibrillation threshold in a dog. In this experiment a catheter electrode induced pulsed current into the right ventricle of the dog's heart. The horizontal axis is the number of 60 Hz cycles of the stimulus. The curves vary with respect to the area of the electrode. Reilly (1999) recommends the large-area data to represent the effects of an externally applied electrode. The horizontal axis can be treated as the number of individual pulses in a pulse train.

Figure 11. Effects of stimulus pulse repetition rate on muscle tension



(McNeal and Bowman, 1985; Reilly, 1999.)

Figure 12. Relationship between ventricular fibrillation threshold and number of 60Hz cycles



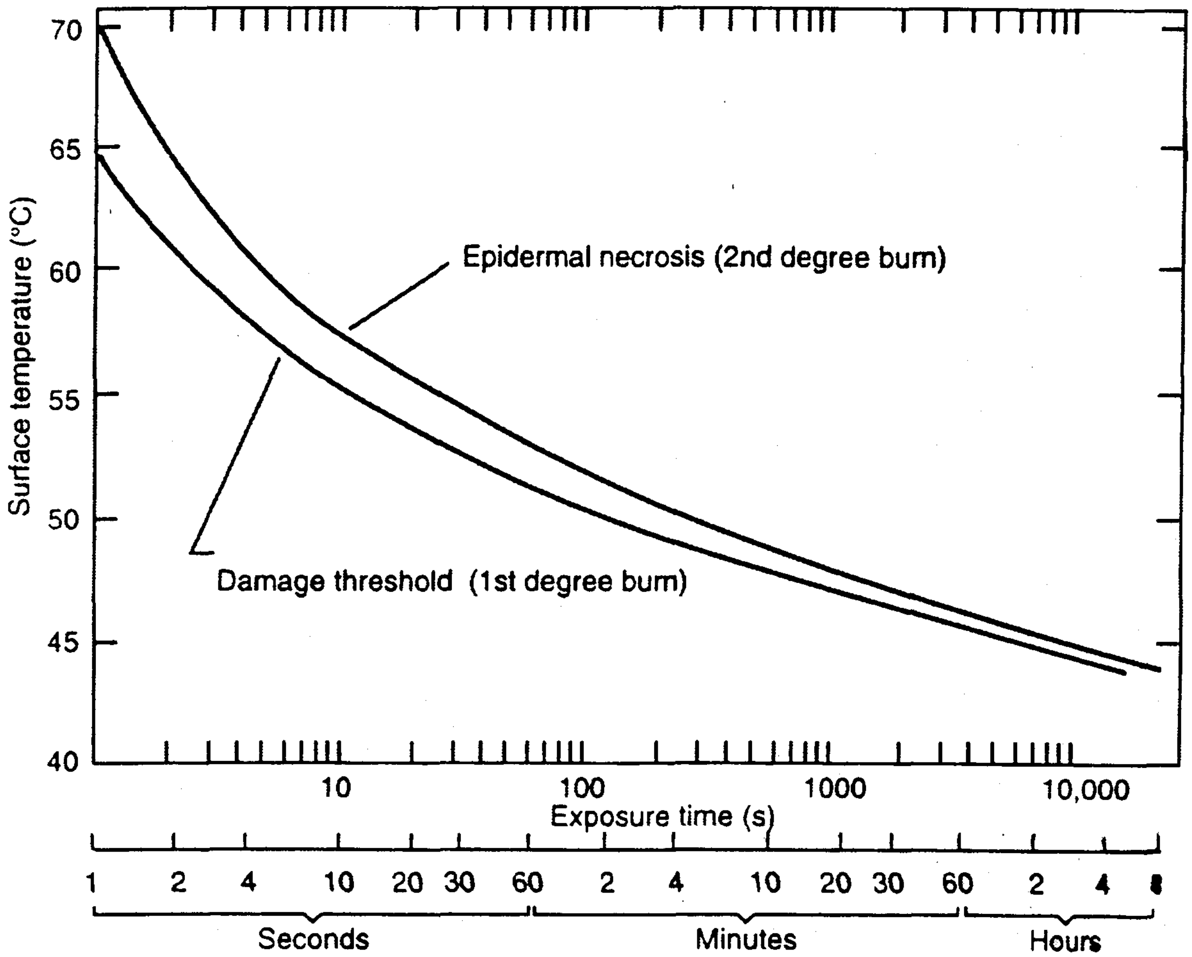
(Roy et al, 1997; Reilly, 1998.)

The ventricular fibrillation threshold significantly drops as the pulsed excitations increase for a 60 Hz current. Notice the minimum plateau at 4 seconds (240 cycles). Reilly (1999) reports the ventricular fibrillation threshold has decreased from an initial factor of 50 to a factor of 2.0 above the excitation threshold of the heart.

ASSESSMENT OF ELECTRICAL INSULT CAUSING SKIN BURN

The panel assessed the dermatological response to electrical insult. JAYCOR's Dr. Coakley reported the Sticky Shocker did leave reddened region under the electrode contacts when he was inflicted with the electric insult from the Sticky Shocker. Electrical burn appears to be the most likely thermal reaction. Burns will most likely appear directly below the contact area of the electrode (Reilly, 1998). Figure 13 illustrates the strength-duration curve for skin tissue damage. This Figure is considered a good model for human skin. A thermal burn is perceived as painful at 45° C. The IEC and UL have recommended a limit of 70 mA rms to protect against thermal burns (Reilly, 1998).

Figure 13. Electrical burn damage thresholds



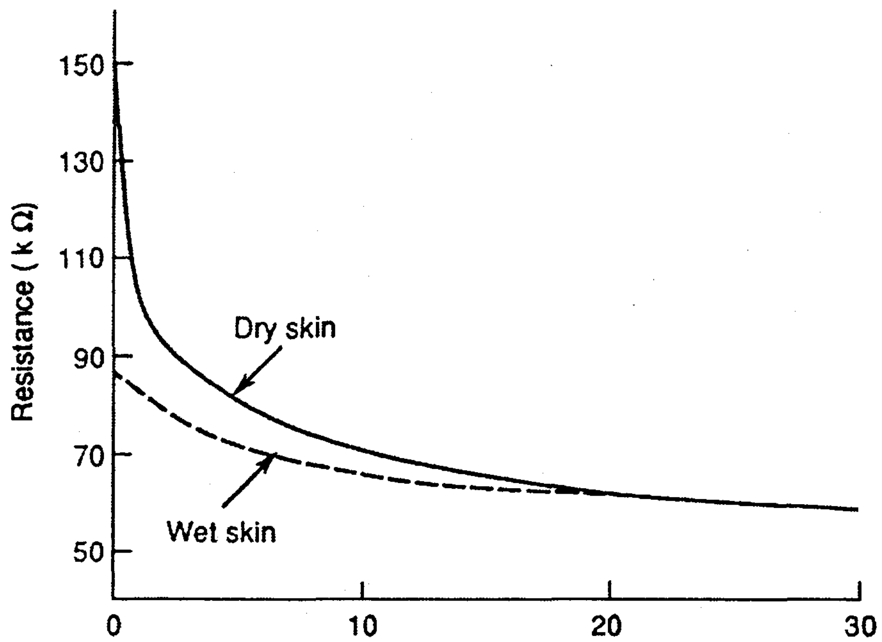
(Moritz and Henriques, 1947; Reilly, 1998)

Each tissue's resistance will determine the currents ultimate path (Chilbert et al., 1985). There is a lower resistance along longitudinal tissue layers than across transversing layers. Impedance will change with elapsed time. Burns also will be directly dependant on the skin's condition, as well as, the environment.

Skin resistance sharply decreases after ~2 minutes of electrical shock current. Dry skin has higher impedance than wet skin due to the efficient electrical conductivity of water and sweat. Figure 14 illustrates this difference. Notice the sharp drop in the skin impedance after ~1 minute of electrical shock. The sharp deterioration in resistance over time bottoms out at ~20 minutes.

As frequency increases, the impedance of the skin decreases. This is due in part to the capacitive behavior of the skin. At 2000 Hz, the resistance of the dry skin is ~750 Ω (Reilly, 1998). At very high sinusoidal currents, the impedance drops dramatically. For high voltages (above 200 volts) and transient current, Taylor (1985) conducted an experiment an experiment of subjects grasping an electrode with their left hand and standing on a copper plate with their bare left foot. The subjects were shocked with 500 volts. Taylor reported that the results of total impedance for dry and treated skin varied slightly, supporting the theory that skin impedance is negligible with high voltage (Reilly, 1992). Internal body impedance is reported to be responsible for most of the total impedance.

Figure 14. Variation of skin resistance with time



In considering dermatological response to electrical insult, the Panel also considered electroporation. In the body, current flow passes across different cellular membranes (Reilly, 1999). A potential difference will be created. The strongest flow will be along the nerve and muscle cells. At high enough levels, the intense electric field will cause pores to develop across the cellular membrane. This event is called electroporation. It is reversible at the low end of the current threshold, but irreversible at higher levels (Reilly, 1999). The result is cellular death. Tissue burns are a good indication of the existence of irreversible electroporation.

The sudden current flow through the cellular membrane causes electroporation. Its severity is dependent on the electrode contact time duration and voltage gradient across the tissue. Reddened regions are signs of possibly reversible tissue damage due to electroporation, thermal damage, or both. Electroporation involves breakdown of cell membranes due to a voltage gradient effect (Lee, 1991). It can happen quickly. Thermal damage is the heating that increases linearly with time (other parameters staying constant). Thermal damage is defined as:

$$ThermalDamage = I^2 R$$

where,

I is the current measured in Amps,

R is the resistance of the skin measured in ohms.

Therefore, both effects can occur together. Electroporation may predominate with short times, while thermal damage builds with time.

ASSESSMENT OF INCAPACITATION

The biggest problem in understanding the Sticky Shocker's biophysiological effects is the lack of relevant data explaining the method of incapacitation. Most information has been acquired either from law-enforcement or clinical observations. The Taser, in use in law-enforcement since the early 1970's, has not been reviewed in a controlled experiment for unbiased analysis. Plenty of anecdotal data exists with little science to back up the findings.

This section briefly summarizes a widely accepted theory on incapacitation of a human subject through the use of electrical shock. Murray and Resnick (1997) report experiments of muscular contraction responses from electrical impulse trains. According to experiments conducted by John Cover, the Taser's inventor, the electrical current causes partial tetanus when the electrodes are 6 or more inches apart (Murray and Resnick, 1997). According to experiments conducted by researchers

James McNulty, Jr., and author John Murray, Taser contacts 10 inches apart will freeze the leg muscle in the flexed position (Murray and Resnick, 1997).

These scientists conclude that distance is the key factor in incapacitation. Both experiments conclude that Kirchoff's law of current following the path of least resistance over time is what is occuring in the body. As one pathway becomes exhausted and tries to recover, the current will move to another route.

The Panel does not agree with the findings that Murray and Resnick (1997) report for incapacitation. The Panel would like to clarify that current following the path of least resistance is a misleading statement. Current actually follows many parallel paths, some of which have more resistance than others. Pathways do not become exhausted or try to recover. They may be thinking in some vague way of nerves or muscles getting fatigued, but those are not current pathways.

Murray and Resnick (1997) report a counterbalancing of the body when the current twitches a lower back muscle. The abdominal muscles are programmed to react although they're not in the path of the current. A spastic seizure follows, explaining why the subject falls to the ground. The subject is able to break his fall with his hands. The subject is not totally immobilized, since only the portion of the muscles in direct electrical contact between the darts are affected. Cover postulates the subjects may become faint or psychologically immobilized, for example, unwilling to move or resist. There is no clinical data available endorsing this theory.

The Panel would like to point out that muscles are not programmed. They may be stimulated through some as-yet-undefined mechanism. But even then, it is not an organized programming. In addition, a seizure is not what occurs: loss of consciousness occurs with seizures. There may be some pattern of muscle contractions, though we could not define any single such pattern watching those videos.

ASSESSMENT OF ELECTRICAL INSULT CAUSING ACIDOSIS

The Panel considered the possibility of electrical insult causing "acidosis." Dr. Fish, a member of the HEAP Panel, provided a brief on acidosis, a problem that is readily known to most emergency room physicians. Acidosis means that the pH of the blood is less than normal. He stated that pH levels of the blood change drastically when current passes through the body. A small drop in pH balance in blood could easily affect the respiratory system of the heart. Acidosis can result in death.

Acidosis can be metabolic, respiratory, or a combination of respiratory and metabolic. Metabolic acidosis can be caused by a number of conditions, including increased production of lactic acid by muscle activity. Respiratory acidosis occurs when there is depression of respiration.

Greater than normal breathing (hyperventilation) can cause lower than normal carbon dioxide levels in the blood. This would increase the pH, leading to an alkalosis that may compensate, at least partially, for a metabolic acidosis. Hyperventilation is nature's way of compensating for metabolic acidosis and is an important clinical sign in diabetic ketoacidosis and some drug overdoses. Acidosis may be exacerbated under conditions of physiological exercise stress.

COMPARISON OF THE STICKY SHOCKER AND TASER

JAYCOR scientist Dr. Coakley claims, "The Sticky Shocker's electrical effects are synonymous with that of John Cover's Taser." While there was no scientific proof of this claim, the Panel compared the two devices.

The Sticky Shocker is a low-impact wireless projectile that delivers a combined blunt and electrical impact. It is designed to have be muzzle-fired from a distance of 0 to 30 feet. The projectile attaches to the subject via an adhesive substance or mechanical means. A battery pack in the projectile delivers short bursts of high voltage pulses allowing the current to arc through clothing and into the subjects' body.

The Taser is one of the first electrical non-lethal weapons to be used by law enforcement. It is designed to be an effective non-lethal weapon at a range from 0 to 15 feet. The projectile attaches to the subject via mechanical means. The mechanical attachment delivers the electrical insult through wires connected to a battery housed in the launch platform. The Taser delivers high voltage pulses to allow the current to arc across any air gap between the subject's clothing and body.

There are three attachment designs that fit on the head of the Sticky Shocker: adhesive, mechanical, or both. The less clothing a subject is wearing, the more likely the adhesive would be employed. The mechanical attachments are fishhook barbs that would be optimal on subjects wearing more than 1 layer of clothing. Upon impact with the subject, the projectile falls into a vertical position, hanging from the attachment.

The Taser uses fishhook barbs similar to the Sticky Shocker's mechanical attachment. In addition, two small hollow cylindrical weights connect to hooks to enhance aerodynamic efficiency. The advantage of the mechanical attachments is its ability to conduct electrical current. No data was attained determining the electrical conduction of the adhesive attachment.

The electrode is the electric current distributor from the device to the subject. It is important to know the electrode pathways in order to understand its human bioeffects. Both devices rely on enough voltage to break the impedance between the air and average (1/8" thick) clothing of a subject. Once the voltage reaches the skin, the current is transmitted through the contacted region of the body. The spacing between the clothing and the body lessens the effectiveness of the current. The shorter spacing may not incapacitate the individual, but cause burning or pain sensations due to arcing. The Sticky Shocker's projectile contains a star-shaped electrode at the head and whiskers in the rear to enhance the voltage contact between the subject. The star-shaped electrode has a 1.41 inch diameter. The full length of the projectile from front to end of whisker electrodes is about 7 inches.

The Sticky Shocker and Taser's electrical pulse characteristics were calculated and are displayed in Figure 15. The values were calculated using the 1000 ohms resistance.

Figure 15. Comparison of the reported electrical pulse characteristics of the Taser and Sticky Shocker

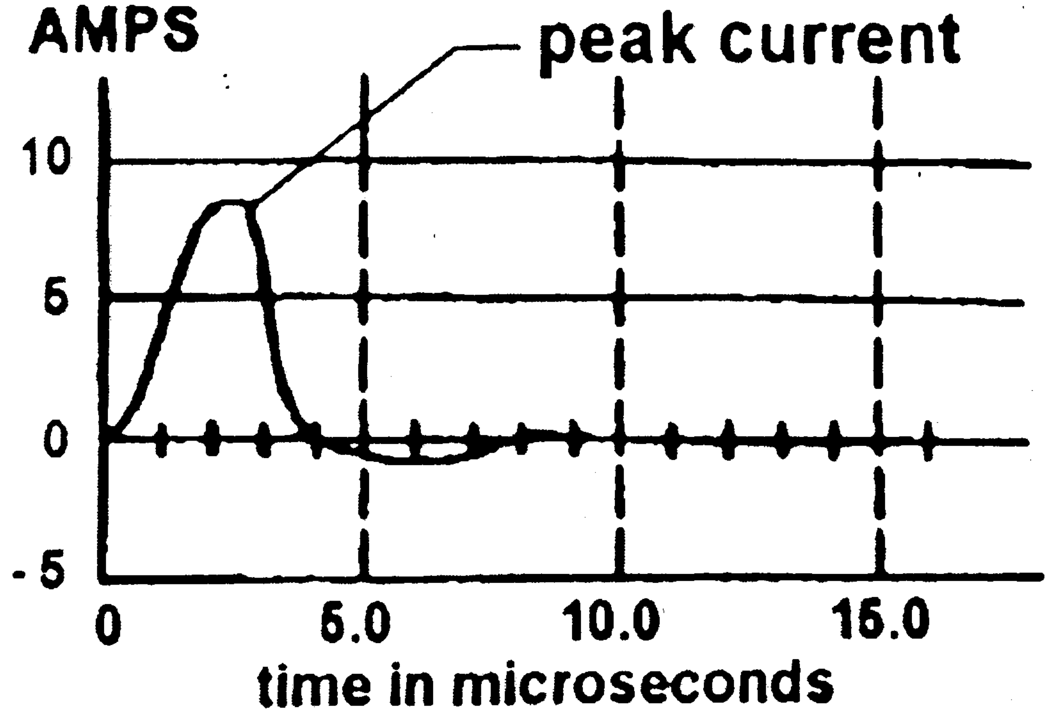
	Rep Rate (Hz)	Effective Pulsewidth (μSeconds)	Load (Ω)	Peak Power (kWatts)	Average Power (W)	Pulse Energy (Joules)	Peak Current (Amps)	RMS Current (mA)
Sticky Shocker	12 or 15	1.0	1000	108.0	----------	0.103	10.5	54
Taser	11.1	5.4	2000	33.6	2.0	.18	5.8	45

JAYCOR reports a peak current measurement of 5.8 Amps, 5.4 μseconds effective pulse width, and pulse energy of 0.18 for the Taser, although Figure 15 does not illustrates these typical characteristics.

Figure 16 illustrates the current pulse-duration curve for the Taser. The Taser delivers a pseudo AC current that is predominantly monophasic.

The load of the Taser current waveform is different than the load used for JAYCOR's reported statistics. An example of a Taser waveform with 1000 ohms was not available.

Figure 16. Electrical pulse current duration curve for the Taser



(Murray and Resnick, 1997).

The shock train duration of the Sticky Shocker is 8 seconds. JAYCOR is exploring the option of allowing the operator to vary the shock duration. The shock train duration of the Taser is controlled by the operator. The electrical insult delivered by the Taser has been reported to incapacitate the individual. However, there have been only minimal clinical observations reported predominantly through Los Angeles Police Reports.

Based on this information the Panel sought to compare the human effects of the Sticky Shocker and the Taser. With respect to sensation, Both devices are significantly above the sensory threshold. The minimum perception current for an AC current is 0.5 mA (Reilly, 1992). Therefore, an initial involuntary muscular reaction, and pain are to be expected from both devices.

The Panel then considered muscle response. The tetanus current threshold for the 99^{th} percentile of healthy adult males is about 25 rms Amps. The Sticky Shocker current is between 36 and 70 rms mAmps at a 12 to 15 Hz repetition rate. It is well known that females are more sensitive to electric current than males (Reilly, 1998). Therefore it is expected that let-go for all normal healthy males and females will occur, and children inflicted with this electrical insult will reach grip tetanus at a lower current threshold. See Figure 8.

At 45 rms mAmps of the Taser waveform, the current will affect the entire population of healthy adult males. Elevated threshold responses in subjects with neuropathological conditions, as well as psychopathological conditions were noted by Dr. Reilly (1998). No quantitative data has been reported.

It is unclear how each device's electrical pulse affects the human body. The Sticky Shocker's applied current needs to be further examined. By comparison, the Taser's electrical pulse has been very effective on affecting a subject's muscle reactions as seen by many law-enforcement observations.

As previously mentioned, there is currently not enough relevant heart current data available to predict the Sticky Shocker's cardiac effect. The Taser lacks relevant heart data as well. But based on a few clinical (Ordog, 1987) and law-enforcement (Kornblum and Reddy, 1991) observations, the Taser has appeared effectively innocuous to its majority of subjects.

Those who did die after Taser use may have done so because of indirect cardiac effects involving acidosis. These deaths usually have been delayed. Respiratory and cardiac arrest in the cases are reported in the medical literature 5 to 45 minutes after the stunning. Thus, the deaths did not involve the immediate induction of ventricular fibrillation or other dysrhythmias by the Taser.

Most deaths following the use of Tasers have involved persons taking PCP or cocaine. PCP and cocaine can lead to fatal arrhythmias or cardiac failure, especially in the presence of acidosis. Dysrhythmias (abnormal heart rhythms) will occur with lower drug levels in the presence of acidosis. Persons who are taking these drugs and are agitated enough to require police action are usually acidotic -- their blood pH is lower than normal. Increased muscular activity and decreased breathing, increases acidosis and increases the likelihood of fatal dysrhythmias and cardiac failure.

Therefore, <u>deaths following Tasers use may be due to acidosis</u>. Acidosis may have caused cardiac dysrhythmias or failure in the presence of illicit drugs that are usually present in persons being Tasered. Deaths following Tasers use may be related to the ability of these devices to cause increased muscle activity and decreased breathing. Persons being Tasered are usually agitated and hyperactive.

Measurements in animals have shown that acidosis is associated with such agitation. Treatment is with IV sodium bicarbonate and supporting respiration (Sedgwick, 1979). Similarly, patients with cocaine toxicity in emergency departments often have severe acidosis. In a study by Stevens et al (1994), 33% of 156 patients with cocaine-associated emergency department visits were acidotic. In 33 patients the acidosis was metabolic, and in 18 it was primarily respiratory (due to hyperventilation).

Additionally, premature ventricular contractions (PVCs), ventricular tachycardia, and other ventricular dysrhythmias have been described in patients with cocaine ingestion. Acidosis, exercise or an increase in sympathetic tone can increase the arrhythmogenic effects of cocaine (Jonsson et al, 1983; Bauman et al, 1994).

The references in Figure 17 list strong muscle contractions followed by weakness as effects of Tasers. These effects have not been quantified, but need to be. The effects are probably dependent on the duration of Tasering and the position and separation of electrodes.

Upon comparison of the Sticky Shocker and the Taser's electrical insults, their biophysiological effects appear very similar. Again, most of the Taser's data has been from observations, and quantitative data needs to be gathered. Even after years of field use, no scientifically based theory is available to explain its means of incapacitation. Why does the person fall to the ground but their arms are able to protect against the fall? This needs to be based on an understanding of the device's function, electrical current distribution (surface versus interior of body) and the physiological effects on intact organisms.

GENERALIZING FOR THE POPULATION AND SUB-GROUPS THAT MIGHT BE AT RISK

Determining probabilities for the Sticky Shocker's human effects on a wide population requires collecting data from sample groups representing each population segment. Data on these sample groups is important for assessing variability in the larger population. Without such data samples, it is impossible to accurately predict the Sticky Shockers bioffects. High confidence levels will require large sample groups.

However, the existing data is limited. With respect to the sticky shocker's blunt impact, comparative sports projectile data is focused mostly on children, and predominately male. Very little is known about the effects of age, gender, and body type. Regarding electrical insult, most of the data that exists is focused on adult males. Of these, many were intoxicated by drugs, alcohol, or both.

Figure 17. Effects of Tasers and related devices as presented by Dr. Raymond Fish

Reference	Effects of Tasers and Related Devices	Nature of Study	Drugs in Deaths	Time from Stun Until Death or Arrest
Ordog, 1987	Mortality: 1.4% for Taser; 50% for bullets. Long term morbidity: 0% for Taser; 50% for bullets. Taser complications: contusions, abrasions, lacerations (38%); mild rhabdomyolysis (1%); testicular torsion (0.5%). Cardiac Rhythms: All normal except for 3 asystole (all with high PCP levels). One with sick sinus syndrome on Digoxin. "Three patients died, probably due to cardiac arrhythmia in a preexisting irriTableheart."	218 patients Tasered by Police, compared to 22 GSW	All 3 had PCP. One also had digoxin and a history of SSS.	#1, 2: Cardiac arrest 5 & 15 minutes after Taser. #3: Respiratory followed by cardiac arrest 25 minutes after Taser.
Welsh, 1997 in Lancet	Immediate effects include severe pain, convulsions, fainting, involuntary defecation, and urination. Long-term: impotence, scarring, PTSD.	Review by Amnesty Inter-national		
Roy & Podgorski, 1989	Stun gun: asystole during discharge through three layers of towels (likely to turn to v fib if lasting over 30 seconds). In pig with pacemaker: immediate v fib.	Experiments on pigs		
Edelson, 1985	"One massive charley horse on a whole side of your body... Other people have compared it to a grand-mal seizure."	Info from Taser's Richard Caven		
Robinson, 1990	0.5 second: repel. 1-2 second: inability to stand. 3 to 5 seconds: immobilized, weak, and incapacitated for up to 15 minutes. "Skeletal muscle is reduced to a functionless mass..." Beyond the period of incapacitation, stiffness may remain.	Med Science Law Review article		
Stun Tech, 1997	Violent muscle contraction with production of lactic acid.	Product Manual		
Kornblum & Reddy, 1991 (Also see review by Allen)	Examination of 16 deaths associated with Taser use in LA County form 1983-1987. Conclusions is that Taser may have contributed to one death (SSS & Digoxin). Allen says Taser contributed to 9 of these deaths. The neuromuscular stimulation is painful and fatiguing. No drugs in persons with (2) later GSW, (1) cardiomyopathy. Margin of safety is reduced in arteriosclerotic cardiovascular disease (quoting CPSC).	Review of deaths following Taser use.	PCP (8) Cocaine in 6 Amphet-amine in 1. Those with no PCP or cocaine had trauma.	11: 15 to 45 minutes. 3: from 1 to 3 hours. 1: arrested during restraining, 1:died at 3 days. 1: at 2 days: hepatorenal failure.
Allen, 1991	"...drug concentrations by themselves rarely determine that death was due to overdosage." Nine of Kornblum & Reddy's cases "were alive and active, collapsed on tasering, and did not survive... the taser contributed to at least these nine deaths..."	Critique of K&B's article by one of the involved pathologists.		

There is a wide variance in individual differences regarding electrical current. Gender and weight are the most distinct factors that have been documented. It has been experimentally proven that an individual's body-size is directly proportional to their current threshold. Beyond body size, mixed hypotheses exist regarding gender, and occupational differences playing a role in one's perception of pain. A large sample population is needed to account for the wide variation of distribution of body size and gender. Such large samples are needed to ensure high confidence levels.

Task 1 Conclusions

The Panel considered the combined data above in rendering its findings. It determined that the weapon is still in the development stage and little data exists concerning Sticky Shocker performance. The manufacturer may not have disclosed more data for proprietary reason. However, such data are integral to assessing the Sticky Shocker's human effects.

In the Final Technical Report provided by JAYCOR, the Panel provided only comparative data for the Sticky Shocker's blunt impact. However, these comparisons were not measured independently. The Panel found no Sticky Shocker electric insult data in the report, nor was there data concerning the specific effects of pulse wave shocks. Beyond a videotape of three human subjects, there are no Sticky Shocker effects data. Furthermore, there were no data on the combined effects of the Sticky Shockers blunt impact and electrical insult.

There is also no data to measure incapacitation. Incapacitation from blunt impact could be caused by physically impairing movement, or by merely causing enough pain to discourage further activity. Incapacitation may also be the result of an overlap between physical injury and psychological discouragement. The precise cause of electrical incapacitation is also unknown. As with blunt impact incapacitation, it could be a combination of pain and psychological discouragement.

The Panel's only recourse was to assess the Sticky Shocker against the results of other studies. Based on this comparison, the Panel determined that adverse, irreversible health effects could occur from the use of the Sticky Shocker. The probability of these effects, however, could not be determined. There is also insufficient data for extrapolation. Given the amount of data available, generalization to the entire range of the human population is highly inaccurate. Sub-groups that may be at higher risk cannot be accurately identified.

Task 2

What additional testing of the device may be required to ensure its safety, i.e. no irreversible adverse health effects, or to provide information necessary for a confident assessment?

Task 2 Description

In an effort to ensure irreversible adverse health effects do not occur, a confident assessment of the Sticky Shocker is required. Two categories of tests are recommended: weapons performance tests and human effects test. These tests are detailed as follows:

- Weapons Performance Tests
    - Assessing the Sticky Shocker Projectile's Performance
    - Assessing the Projectile's Blunt Impact
    - Assessing the Attachments' Performance
    - Assessing the Sticky Shocker's Electrical Current
- Human Effects Tests
    - Assessing the Human Effects of Blunt Impact
    - Assessing Nerve Depolarization
    - Assessing Minimum Current for Immobilization
    - Assessing Electrical Current on the Human Body
    - Assessing Acidosis
    - Assessing the Combined Effects of Blunt Impact and Electrical Insult

Task 2 Discussion

The only data currently available on the Sticky Shocker is that provided by the manufacturer. First and foremost, it is recommended that all points listed in the Final Technical Report be scientifically validated. It is further recommended that a test methodology be established so tests can be done systematically when the Sticky Shocker's components are altered.

More data is needed to determine whether or not the Sticky Shocker will cause adverse, irreversible health effects, or to confidently assess its use. The existing data does not fully cover all aspects of electrical and mechanical performance. There is even less data regarding its human effects. Therefore, the following tests are recommended:

WEAPONS PERFORMANCE TESTING

Before the Sticky Shocker's human effects can be predicted, its performance must be predicted. To do this, velocities, masses, shapes, materials and electrical data must be determined. While this seems apparent, current weapons performance data is insufficient for making such measurements. This may be because the manufacturer did not provide all the information for proprietary reasons. Nevertheless, this information will enable the measurement of energy being transferred from the projectile to the body. This is key to understanding the body's response.

Assessing the Sticky Shocker Projectile's Performance. The velocity and weight of the Sticky Shocker's projectile must be accurately determined. The Panel did not have a clear understanding of the actual weight and terminal velocity of the Sticky Shocker's projectile. JAYCORs Final Technical Report gave several different weights and velocities. Also, the manufacturer tested several prototypes. Some of the existing data pertains to the prototypes rather than the final product. The Sticky Shocker's projectile should be tested under a range of ideal and less than ideal conditions. Ballistic profiles should be developed for cross winds, rain, mist and different temperatures. These profiles should include stability, arc of flight path and duration of flight.

Assessing the Projectile's Blunt Impact. The Sticky Shocker's blunt impact should be predicted. This means assessing the projectile's impact rate, degree of deformation and rate of deformation. This requires information regarding the projectile's composition, as well as, its velocity and ballistics. In addition to this information, modeling will depend on high-speed measurement. Ultimately, this data will enable the measurement of kinetic energy being transferred to the body.

Assessing Attachments' Performance. The Sticky Shocker's attachments should be tested to accurately determine their performance. The Sticky Shocker uses three attachments: adhesive, mechanical and a combination of the two. These attachments should be tested under a range of ideal and less than ideal conditions. Tests should determine the braking effect of hooks and adhesive, in terms of aerodynamics and impact. They should also determine the minimum impact for these attachments to be effective.

Assessing the Sticky Shocker's Electrical Current. The Panel recommends an independent assessment of the Sticky Shocker's electrical current be examined with all three attachments. The electrode is the electric current distributor from the device to the subject. It is important to know the electrode pathways in order to understand its human effects. No data was attained to determine the electrical conduction of the adhesive attachment.

The electrical performance of these attachments should be tested under a variety of conditions. The Sticky Shocker relies on enough voltage to break the impedance between the air and an average 1/8" thick layer clothing on a subject. The projectile should be tested with new and partially depleted, long-term storage batteries. Performance in rain or mist may decrease external voltage with loss of effectiveness. The projectile's performance should be tested using a range of electrode distances separating the positive and negative electrodes.

Additionally, the performance of these attachments should be assessed against varying types of resistance. For instance, a lower resistance may be experienced with clothes heavily covered with sweat or seawater. A higher resistance may result from thick, layered clothes with gaps in between. The spacing between the clothing and the body lessens the effectiveness of the current. Additionally, the shorter spacing may not incapacitate the individual, but rather cause burning or pain sensations due to arcing. Tests should also be conducted against simulated uncovered skin.

HUMAN EFFECTS TESTING

Once the Stick Shocker's performance data has been determined, then efforts to determine how the body will respond can be initiated. This is the bigger challenge, because this is largely uncharted territory.

Assessing Human Effects of Blunt Impact. The Sticky Shocker's blunt impact should be evaluated for its human effects. This also includes determining the impact area, the impact duration and its deformation rate. This along with weapons performance data will enable an understanding of how kinetic energy is transferred to the body. Models must then be created to evaluate how this energy is transposed to individual organs and how they will respond to this energy transfer (See HEAP Report on Blunt Impact Weapons: USMC Contract M67854-98-C-0012).

This testing should also consider any damage that might be done to the skin by attachments. The data available to the Panel did not include any description of skin penetration by the Sticky Shocker. However, all subjects with skin penetrations by Tasers had to be taken to an Emergency Room for removal and assessment.

Assessing Skin Burns Caused by Electrical Current. Tests should determine the extent of skin damage caused by electrical current. The data available to the HEAP indicated that the Sticky Shocker caused minimal skin sensation when applied tightly to the skin, However, when poor contact occurred, it caused skin sensation and arcing (sparking) to the skin. In the latter case, a red mark was reported to appear at the site of the arc. Furthermore, it was reported that the Taser did not cause any sensation at the site of skin penetration. Studies are needed to determine the following:

- Macroscopic description of skin effects
- Microscopic (histological) views of skin and sub-cutaneous damage
- Flux density of the electrical current with various depths of skin penetration
- Superficial skin arcing between electrodes with "wet" skin

Assessing Nerve Depolarization. Testing should be conducted to determine which types of nerves would be depolarized. No data was available to the Panel on this subject. Candidate nerve types include superficial skin nerves (during arcing), but the nerves depolarized with skin penetration remain to be determined. This is one of the crucial, early studies to be performed, as so much other research will depend on exactly what is occurring at this level.

Assessing the Minimum Effective Current for Immobilization. Studies are needed to identify the minimal range of currents that can be sensed by a human and the minimal effective current for immobilization. No data is available to the Panel to indicate whether the currents and voltage used in the Taser and Sticky Shocker are close to, or far above the minimal effective values. The effects of repeating the stimuli at various intervals also need to be elucidated.

Animal experiments are needed to determine how impulse affects sensation limits, let-go-current, etc. The Panel used information on electrical shock effects garnered from a variety of sources, which may or may not be applicable to the Sticky Shocker. The available data is derived from much longer durations and different voltages. For instance, a macro-shock with 50 or 60 Hz AC (pulse duration 17 - 20 milliseconds) may not have the same effect as shocks from the TASER or Sticky Shocker, where the pulse duration is more than one thousand times shorter (pulse duration 1-3 micro-seconds). There is no scientific data available to the HEAP to describe the effects of these impulses, i.e. the limits of sensation, let-go-current, etc..

Assessing Electrical Current on the Human Body. Little is known about current passing through the human body and the Panel recommends the development of an impedance model. The model is necessary because impedance will change with time. This model will also enable an understanding of other body responses. The cardiac and muscle reactions need to be more discretely reviewed. Sufficient data is currently not available to predict the Sticky Shocker's cardiac effect. Heart current-duration plots are 60 Hz currents that do not fit the Sticky Shocker's electrical characteristics. The Taser lacks relevant heart data as well. No data exists regarding what seizures might occur from the Sticky Shocker. The biggest problem in understanding the biophysiological effects of the Sticky Shocker is the lack of relevant data that explains the method of incapacitation.

Assessing Acidosis. Studies are needed to evaluate the effects of electrical stimuli on arterial blood gases – pH, oxygen, carbon dioxide, and bicarbonate, as well as lactate levels; this includes with and without drug effects. Some cases of morbidity occurred several minutes to hours after Taser use. Electrical current per se' did not cause mortality; rather an altered physiology is blamed. Depressed breathing that lead to respiratory acidosis, and increased muscle activity that lead to a metabolic lactic acidosis possibly caused this. Illicit drug use and alcohol would aggravate such depressed breathing, along with tight restraints over the upper body and chest.

Experimentation is recommended involving measurement of serum lactate levels and arterial blood gases (pH, oxygen, carbon dioxide, and bicarbonate) before and again two to four minutes after the Sticky Shocker's current passes through the body.

Assessing the combined effects of blunt impact and electrical insult. Tests are needed determine the combined effects blunt impact and electrical insult. The effect of blunt impact trauma includes depolarization of nerves, which is perceived as pain. Subjects also feel tired, exhausted and unable to move after blunt impact trauma. The Sticky Shocker adds an additional dimension to these sensations by adding an electrical current, which also causes an inability to move as well as tiredness by an unknown mechanism. Studies are required to investigate these combined effects which occur in close proximity of each other.

Task 2 Conclusion

Considerable work is needed to ensure either a confident assessment of the Sticky Shocker, or that irreversible, adverse health effects will not occur. Tests are needed to gather data on weapons performance, most notably the projectile's weight, velocity, and electrical change. This is needed to measure the transfer of energy from the projectile to the body. This includes kinetic, as well as, electrical energy. Far more work is needed to provide data on the human effects of blunt impact and electrical current. Data in this area is greatly deficient and will require a groundbreaking effort.

Task 3

What modifications should be considered to enhance the safe and effective use of the device, or to provide information necessary for a confident assessment?

Task 3 Description

The Panel offers the following options for modifying the Sticky Shocker:

- Incorporate an energy-absorbing mechanism into the projectile to reduce blunt impact
- Reduce the projectile's velocity to minimize blunt impact
- Reduce the projectile's weight to minimize blunt impact
- Design a projectile that will reduce the possibility of it being immediately removed.

Task 3 Discussion

The panel considered several modifications that might enhance the Sticky Shocker's safety. Its primary focus was on reducing blunt impact. This was seen as offering the greatest opportunity for improving safety since it is not the Sticky Shocker's primary intended means of incapacitation. The Panel, therefore, offers the following options for reducing blunt impact:

ENERGY-ABSORBING PROJECTILE

An energy absorbing mechanism might be used to lessen the projectile's impact. The current projectile is cylindrical in shape and approximately 4.0 inches long and 1.5 inches in diameter. It contains a star-shaped electrode at the head and whiskers in the rear to enhance voltage contact with the subject. With whiskers it is seven inches long. It may be possible to incorporate an energy absorbing mechanism within the Sticky Shocker projectile; this might be a spring, recoil mechanism, or crumple zone.

LOWER PROJECTILE VELOCITY

It might be possible to minimize blunt impact by lowering the projectile's velocity. This greatly depends on tests determining the minimum necessary velocity and impact for the projectile to be effective.

LOWER PROJECTILE MASS

Another option would be to reduce the projectile's weight. The projectile is about the same weight as a baseball, 4.5 ounces (~126 grams). Lowering this weight would reduce its blunt impact. Again this depends on the minimum impact needed for the projectile to be effective.

REDUCING THE POSSIBILITY OF IMMEDIATE REMOVAL

The Panel also offers a possible modification that might make the projectile more effective. The videos presented to the Panel showed the Sticky Shocker projectile attached to clothing, which swung away from the person. During these periods, no shocks were delivered. It may be possible to remove this device during such periods. This potential may be reduced with a design that causes the whiskers to swing forward and adhere to clothing.

The delay may be shortened by a design, using for instance inertia; this would enable faster contact after striking the target while still in the horizontal position. Even though the flight time and the "fall time" may each be less than 0.75 seconds, the combined time needs to be investigated to ensure that the target does not have sufficient time to remove the projectile.

Task 3 Conclusion

The Panel appreciates the tradeoff between performance and safety. Those tradeoffs were discussed extensively in the JAYCOR Technical report. While the Panel offers options for reducing blunt impact, it recognizes that final weight and velocity of this projectile should be determined by the needs of the user, and not by this Panel.

Task 4

What other information might be required for safe human testing of this device by a law enforcement agency in a field evaluation?

Task 4 Description

Information regarding safe human testing in research is stipulated in Title 45 of the Code of Federal Regulations, Part 46. Essentially, these regulations state that research on human subjects requires their informed consent. It further details the elements of this informed consent. It prescribes the responsibilities for agencies conducting research on human subjects.

Task 4 Discussion

Any research on human subjects must comply with Title 45 of the Code of Federal Regulations, Part 46. These regulations are intended to ensure the safety and protect the privacy of human subjects in research. These regulations require a full disclosure to human subjects and their consent to undergo research. They also require agency management to conduct varying degrees of review for different types of research and research involving increasing levels of risk. The requirements as detailed as follows:

INFORMED CONSENT

This is essential in research on human subjects. Ethically and legally, consent is not considered to be "informed" unless the researcher discloses all facts, risks, and discomforts that might be expected to influence an individual's decision to willingly participate in a study. This applies to all types of research: surveys, interviews, observations in which subjects are identified, and other experiments. Subjects must be provided with a copy of consent documents, regardless of whether signed or implied consent is used

ELEMENTS OF INFORMED CONSENT

Federal regulations require that consent documents contain a number of basic elements. They are as follows:

- Description of the study's purpose in terms the subject can understand
- Description of procedures (e.g., what is expected of subjects, what data will be collected, and how it will be used)

- Statement regarding audio/visual recording of subject, including who will have access to tapes and when they will be destroyed (if applicable)
- Description of all discomforts and risks (if applicable)
- Statement about potential benefits (specify any compensation)
- Period of time required for subject participation (if applicable)
- A contact person's name, title, address, and telephone number
- Description of how confidentiality of records identifying subjects will be maintained
- Identification of the researcher's affiliation
- Statement informing subjects that they may decline to answer specific questions
- A statement informing subjects that their participation is voluntary
- If applicable, include the following injury clause should be included:
  "I understand that medical care is available in the event of injury resulting from research but that neither financial compensation nor free medical treatment is provided. I also understand that I am not waiving any rights that I may have against the researching agency for injury resulting from negligence."
- The subject's signature

INFORMED CONSENT FOR MINORS

If children are research subjects, informed consent has added requirements. Parents or legal guardians must give written consent for a minor to participate as a human subject. For research involving minimal risk, the signature of one parent may be sufficient. For research involving greater than minimal risk without direct benefit to the subject, the signatures of both parents are required.

If a minor subject can understand the consent procedure, his/her consent must be obtained. Consent from minors must be obtained either in writing or orally. The age and maturity of the minor subject must be considered in determining whether written or oral consent is appropriate. An appointed guardian must provide written consent for subjects who are mentally impaired. Written institutional approval must also be obtained for institutionalized subjects.

Informed consent from human subjects is always required except when conditions of anonymity exist. This may be when no means of identifying subjects exist. Examples of such anonymous conditions are mailed questionnaires, or random dialed telephone interviews. Informed consent also may not be required if the only record linking the subject and the research would be the signed consent document, and the principal risk would be potential harm resulting from a breach of confidentiality.

Deception in research is discouraged. Federal agencies disapprove of any deception in research involving human subjects. However, the Code of Federal Regulations, 45 CFR 46, allows some alteration in the elements of informed consent if: the research involves minimal risk; the rights and welfare of the subjects are not compromised; the research cannot be conducted otherwise; and subjects are provided with all pertinent information after participation.

If full disclosure is impossible, it is recommended that the following statement be included on consent documents:
"Because the validity of the results of the study could be affected if the purpose of the study is fully divulged to me prior to my participation, I understand that the purpose of the study cannot be explained to me at this time. I understand that I will have an opportunity to receive a complete explanation of the study's purpose following my participation in the study."

LEVELS OF REVIEW

Agencies must conduct varying degrees of review regarding research on human subjects, depending on the type and research involved. Agency management is responsible for ensuring that safety and privacy protection procedures comply with federal regulations. Upon approval, agency management must provide varying degrees of oversight.

RESEARCH EXEMPTED FROM REVIEW

Some research on human subjects does not necessarily have to undergo agency review and oversight. When no more than "minimal risk" to personal safety exists, research on human subjects may be permissible if:

- Subjects cannot be identified, either by name or code
- Subjects are above the age of minors
- Responses outside the research do not place subjects at risk of criminal/civil liability
- Responses do not damage subjects' financial standing, employability or reputation

Such research includes data gathered in an established, or accepted, educational setting involving normal educational practices. This might include research on instructional strategies, or curricula. It also may be research involving the use of educational tests that are cognitive, diagnostic, aptitude and achievement in nature. Also permissible is any research that uses any data on human subjects that is publicly available information; this can include data from documents, records, pathological specimens, or diagnostic specimens.

RESEARCH REQUIRING LIMITED REVIEW

Some research should undergo limited agency review and oversight, even though no more than minimal risk exists to subjects. Such research would involve:

- Collecting excreta and external secretions including sweat, uncannulated saliva, placenta removed at delivery, amniotic fluid at the time of rupture of the membrane prior to or during labor, urine, feces, expired gases, etc.
- Recording data from subjects 18 years or older using noninvasive procedures routinely employed in clinical practice. These procedures should not involve the input of matter or significant amounts of energy into the subject or an invasion of privacy. Such procedures involving subjects less than 18 years of age must be reviewed extensively by the researching agency.
- Collecting blood samples by venipuncture, in amounts not exceeding 450 milliliters in an eight-week period and no more often than two times per week, from subjects 18 years of age or older and who are in good health and not pregnant. Such procedures involving subjects under the age of 18 must be extensively by the researching agency.
- Voice recordings made for research purposes such as investigations of speech defects.
- Moderate exercise by healthy volunteers. (Research should follow guidelines set forth by the American College of Sports Medicine, or the American Heart Association)
- Study of existing data, documents, records, pathological specimens, or diagnostic specimens.
- Research on individual or group behavior or characteristics of individuals, such as studies of perception, cognition, game theory, or test development, where the investigator does not manipulate subjects' behavior and it will not involve stress to subjects.
- Research involving drugs or devices for which an investigational new drug exemption or an investigational device exemption is not required.

RESEARCH REQUIRING FULL AGENCY REVIEW

Any research on human subjects not previously covered or involving more than "minimal risk," should under go extensive review and scrutiny by the researching agency. Proposals for collecting blood samples from subjects under the age of 18 also must be fully reviewed.

Task 4 Conclusion

Federal regulations regarding human testing are explicit. Their primary concern in is ensuring that the rights and safety of human subjects are protected. Additionally, they charge the researching agency with this responsibility. Agencies conducting such research should therefore ensure their review and oversight procedures are consistent with these regulations.

Task 5

What laboratory-based human subject testing, if any, may be required before using the device in a real world application as a less-than-lethal weapon?

Task 5 Description

The evaluation of the Sticky Shocker depends on data gathered from a number of sources, in addition to human testing. Moreover, data from these sources must be gathered in coherent manner and integrated into a scientific process. This should enable the validation of previously formulated hypotheses and ultimately the Sticky Shocker's real-world application.

Task 5 Discussion

The Panel emphasizes that human testing should be part of an integrated process. Initially, hypotheses should be developed regarding how Sticky Shocker causes certain human effects. Testing as detailed in Task 2 should then be conducted to validate these hypotheses. Following their validation, the Sticky Shocker's technologies can then be considered for real-world application.

This effort may be analogous to the process for introducing new pharmaceuticals in this country. Initially, new drugs require a series of animal testing. This is followed by a series of well-defined clinical trials. At their conclusion, the data is used to estimate the drugs efficacy and side effects in the targeted population. If the drug meets certain standards, it is released to the public. However even after release, it is not uncommon to continue monitoring the drug.

The introduction of the Sticky Shocker as well as other less than-lethal weapons might follow a similar process. Data must come from several sources before their effects can be known. These sources could complement each other. For example, one source may continue where another leaves off. Additionally, some sources might be used to confirm data from another source. This reliance on multiple sources is particular important for evaluating the Sticky Shocker which involves blunt impact and electrical insult.

The panel recommends data be collected from the following sources:

LIVING CELL TESTING

Research has determined that living cells can be used to model systems in the human body exposed to blunt impact munitions. Theoretically, this testing offers the possibility of replicating many of the body's organs and determining their susceptibility to blunt force.

This system could be instrumented to assess blunt impact and electrical insult on cells. This testing relies on a DNA chip. When a cell is stressed from blunt impact, hundreds of thousands of cells are turned on or off. The DNA chip allows simultaneous observation of the genes. Essentially, it determines the number of cells that are killed from blunt impact and the number that recover. Ultimately, this enables high value predictions regarding a particular organ. Other technological applications will be available in three to five years.

GELATIN CLAY TESTING

These systems attempt to replicate body tissue and are used to measure blunt impact and energy transfer. They passively measure force passing through them.

CADAVER TESTING

These may be used to assess the Sticky Shocker's electrical insult and blunt impact. With regards to electrical insult, cadavers may be used to measure and assess the distribution of high voltage, high frequency currents in the body. However, cadavers present different impedances than do live humans.

Cadaver testing can provide structural information, particularly with respect to the more serious injuries that might be caused by the Sticky Shocker's blunt impact. It can determine how the projectile might cause bone fractures. It can also provide a fairly good approximation of impact measurement and energy transfer on the body. This is needed to determine the amount of energy released, and if it was released slowly or rapidly. It will also show the deformation of the projectile as well as the tissue around it.

BIOMECHANICAL SURROGATE TESTING

Like cadavers, biomechanical surrogates can be used to examine the structural effects of kinetic energy. They are used primarily to determine the answers to very focused problems. Compared to cadavers, biomechanical surrogates are more readily available and reusable. The bio-fidelity of surrogates is improving. However like cadavers, the use of biomechanical surrogates is limited to gathering structural information.

LIVE ANIMAL TESTING

These studies would serve to gather data on the Sticky Shocker's electrical insult and blunt impact. Animal experiments are needed to assess the Sticky Shocker's electrical insult with respect to sensation limits, let-go thresholds, and other bioelectrical effects. There is no known scientific data using Sticky Shocker pulse characteristics. The available data is derived from much longer durations and different voltages. Additionally, animal testing would enable the study of repeated pulses.

Because an animal is a deformable object, it can be used to measure the distribution of energy. This data can be collected by means of implanted sensors, as well as, analysis of the test outcomes. This research can show how energy is transposed to an organ and how that organ dissipates that energy. Specifically, animal testing can be used to measure the physical properties of organs and ultimately assess organ damage.

While this data can not be directly extrapolated to humans, it does provide a basis for making comparisons and interpretations. For example, animal testing could determine the rupture strength of a pig's liver. These results could then be compared with the existing data on the rupture strength of a human liver. A conversion factor could then be determined that would be relatively accurate as opposed to guessing.

Animal testing might also provide insights and data regarding the Sticky Shocker's incapacitating mechanism. It also might enable an assessment of the combined effects of blunt impact and electrical insult.

HUMAN DATA COLLECTION OPPORTUNITIES

Essentially, this is data collected on the actual employment of non-lethal weapons. Some data has already has been gathered in this country on the use of several less-than-lethal weapons. Some data has been collected in the United Kingdom on the use of blunt impact weapons, as well. The California prison system offers another possibility, as well. Because of its relatively large prison population, riots are a frequent occurrence and non-lethal weapons are often employed. This environment would provide more controlled data. A retrospective analysis should be conducted of these uses should be conducted.

A prospective data collection effort should also be initiated. This could include a comprehensive questionnaire used for debriefing of law enforcement officers, as well as, strategic placement of video cameras in areas of likely use. The officers should be made aware of the contents of the questionnaire to enable adequate data collection at the time and place of use. This would include questions about firing distance, duration of incapacitation, etc. Questionnaires should also be provided to those recipients capable of remembering details.

Conclusions based on this type of data must be viewed with some caution. Data collected in the field is totally uncontrolled. The conditions of wounding are basically unknown. As previously mentioned, confrontational situations may result in biased data. However, this collection opportunity represents a major source of human data. It is going to provide the only means of estimating the variability of the population. In this respect, it can be used to develop a working hypothesis that can then be compared to data from another source. If this other source data agrees, then there is improved confidence in the hypothesis.

Additionally, clinical data might be collected on acidosis. This would enable the study of the effects of electrical stimuli on arterial blood gases and lactate levels.

HUMAN TESTING

This obviously would provide the best source of data on the human effects of lethal-lethal weapons. This is not a viable option with respect to blunt impact insults. However, opportunities may exist with regards to evaluating electrical current in the body.

Several standard and FDA-approved medical applications routinely use low voltage, high frequency currents on patients. These are such non-invasive monitors as respiratory impedance monitors to detect breathing rate and impedance cardiac-output monitors. Such proven safe devices could be used to measure and model the distribution of such high frequency currents in the body. The next step would be to determine whether higher voltage, high frequency currents follow this pattern. This would be done through the use of cadaver testing, as previously discussed.

At a more detailed level, studies might be done to investigate the current pattern of the two electrodes and surrounding tissues, as well as the effect of distance between electrodes. Knowing the relationship between low and high frequency currents could simplify this dramatically.

Task 5 Conclusion

Whether data is gathered from human testing or other sources, it must be integrated into a coherent process. Moreover, this process would be best managed by a single agency. Otherwise the outcome cannot be assured. This agency should develop hypotheses. It should also compile data in accordance with research standards and objectives. Once this data has been compiled, hypotheses can be validated by interdisciplinary analysis modeling.

Task 6

Would the device be ready for evaluation if, as NIJ understands from the information provided by JAYCOR, the Sticky Shocker has similar (or safer) electrical characteristics to the stun guns and Tasers, commercial devices which are in current use by police and corrections agencies?

Task 6 Description

The answer to this question greatly depends on NIJ's expectations. If NIJ seeks a device that will not cause adverse, irreversible health effects, or it seeks known risks, then this device is not ready for field evaluation. However, if NIJ can accept an unknown degree of risk of such effects occurring, the device may be ready for field evaluation.

Task 6 Discussion

The Panel considered the question from two standpoints:

- Would the device be ready for field evaluation, if NIJ seeks no irreversible, adverse health effects, or a known risk of such effects?
- Would the device be ready for field evaluation, if NIJ accepts an unknown risk of irreversible, adverse health effects?

IF THE INTENT IS NO ADVERSE, IRREVERSIBLE HEALTH EFFECTS

The Panel believes the Sticky Shocker is not ready for field evaluation, if NIJ seeks no adverse, irreversible health effects, or a known risk of such effects. The reasons for these opinions have been detailed in Task 1 and are summarized as follows:

- Points made in the Sticky Shocker's Final Technical Report require scientific validation. They should not be accepted until this occurs.
- The weapons performance data in the Final Technical Report is not consistent. This makes it difficult to predict not only weapon performance, but also its human effects.
- The report compares the Sticky Shocker projectile's energy level to that of a baseball and states that its blunt impact is safe. However, a more extensive comparison shows that baseballs and other sports projectiles have caused serious injuries and deaths.
- The device's electrical effects on the body are largely unknown. The Final Technical Report admits, "there is little authoritative medical research on the subject of shock effectiveness for pulse wave technology."

- While it is asserted that "the Sticky Shocker is as safe as other less-than-lethal weapons in present use," this claim has not been scientifically validated.
- While it has been asserted that the Sticker Shocker will cause the same human effects as Tasers, this claim has not been scientifically validated.
- The Taser's effects have not been extensively studied.
- Differences exist in the Sticky Shocker and Taser's performance, specifically with respect to the distance of their electrodes; this may cause different human effects.
- Some individuals have died after the Taser's use; Taser usage *may* have contributed to some deaths.
- The Sticky Shocker's effects on the general population and its sub-groups cannot be determined. There is insufficient data for extrapolation.

The Sticky Shocker should be regarded as being in the developmental stage, if the intent is to ensure no irreversible, adverse health effects occur, or if it is to know the risk of these effects occurring. From a scientific standpoint, there is more uncertainty associated with the device than there is certainty. Considerable work remains to be done to ensure the device meets these expectations.

ACCEPTANCE OF AN UNKNOWN RISK OF ADVERSE, IRREVERSIBLE HEALTH EFFECTS

The Sticky Shocker could be regarded as ready for a field evaluation if NIJ, or another testing agency, accepted an unknown risk of adverse, irreversible health effects. As stated above, the probability of these risks cannot be scientifically proven, yet. They can only be assumed. While the probability *seems* low that such effects will occur, it also *seems* likely that adverse, irreversible health effects will occur. The problem in accepting unknown risks, though, is expectations. NIJ must know that a device will meet its expectations – whatever they may be. The dilemma NIJ will face if it conducts a field evaluation is determining what its new expectations for this device will be.

Task 6 Conclusion

Less-than-lethal technologies like the Sticky Shocker seemingly have the potential to reduce casualties in law enforcement. But, relative to more lethal technologies, this is a new field of endeavor, both for science and law enforcement. While many have very specific (and high) expectations for these technologies, their effects cannot meet these expectations with any degree of certainty. A more thorough research effort is needed to determine this certainty.

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Appendix: Correspondence with JAYCOR

The Panel's correspondence with JAYCOR began early on during the evaluation period. JAYCOR representatives were invited to make a presentation to the Panel. The purpose of the assessment and assessment methods were discussed with JAYCOR.

In addition to making a several hour presentation to the Panel, JAYCOR also provided a copy of the Sticky Shocker Final Technical Report. This report was provided to all Panel members, who reviewed the document. Their review generated a set of question, which are listed below. The Panel's questions are italicized. JAYCORS responses follow each question.

(1) Provide typical waveforms (current versus time) for both spark contact and direct contact, with explanation of their sensitivity with respect to the arc gap in the case of spark contact, and subject impedance in the case of direct contact. Provide cases that illustrate the range of variation in shock waveforms with respect discharge or contact variables. Explain test set up and methods.
See Figures 2.8-5 and 2.9-5. Direct contact and arc across a gap appear similar. We will forward lab notes that C. Mallon summarized in a brief.

(2) Give a tabulation of test data for Sticky Shocker, including as parameters the spark gap and contact impedance for both spark and direct contact modes. Explain test methods, and include the following measurements (note that "pulse" refers to a single shock waveform in a train of pulses).
This is not available and it wasn't deemed necessary.

a, Is the pulse monophasic or biphasic?
Monophasic

b. Initial phase charge (i.e., charge under initial phase of an oscillating waveform, or net charge of a monophasic waveform).
Voltage and current are in phase

c. Net charge per pulse.
See Figure 2.9-3 (.5*I*width)

d. Phase duration (duration of + or - phase of waveform).
See Figure 2.9-4 (20 ms)

e. Total waveform duration.

See Figure 2.9-4 (20 ms)

f. Oscillation frequency in the case of biphasic waves.

See Figure 2.9-4 (none)

g. Decay time constant in the case of exponential and damped sine waves.

See Figure 2.9-4 (1.5 us)

h. Peak current.

See Figure 2.9-3 and 2.9-4 (10.5 A)

i. Energy per pulse.

See Figure 2.9-3 (.103 J)

j. Repetition frequency of pulse train.

See text on page 30 (15 Hz)

(3) Explain the variations in the parameters listed in (2) that may be expected with Sticky Shocker, either due to manufacturing variations, or to variations in load conditions.

Better than 10%

(4) Provide data as in (3) for other devices examined, such as those listed on Tables 2.5.1 and 2.5.2, and Tables (1) and (2) of Appendix D. Were the data in those tables measured by JAYCOR? Provide citations if taken from other publications.

Data shown in Figure 2.9-4

(5) Provide data as in (2) for Figures 2.8.5 and 2.9.4. In addition:

a. Explain whether waveforms are via spark or direct contact.

Contact

b. Why is the JAYCOR waveform biphasic in Fig. 2.8-5, and quasi-monophasic?

Two different versions of pulser, early version and later version. in 2.8-6?

c. Explain the conditions (load or circuit) that lead to the two waveform types.

Conditions the same with a 1,000 ohm load.

d. Fig. 2.9-4 appears to have a negative tail. Is this an artifact of the measurement, or is it real?

Real

e. What happens to the tail after 20 ms?

Gets really small

f. How much charge is in the tail compared with the initial phase?

Estimate from Figure 2.9-4

g. What is responsible for the negative tail?

Circuit design

h. In Fig. 2.9-4, why is the JAYCOR waveform monophasic, while all the others are oscillatory biphasic waveforms?

Circuit design

i. What characteristics of the circuits are responsible for these distinctions?

Matched load and rectified output of transformer

j. Provide an estimate of the charge in the initial positive and first negative phases of the JAYCOR waveforms in 2.8-5 and 2.9-4.

(0.5*I*width)

(6) Except for the JAYCOR plot, the various traces in Figs. 2.8.5 and 2.9.4 cannot be matched with the legend. We may need a color coded plot.

We'll provide

(7) Describe the circuit elements that control the parameters of the discharge waveforms (peak; mono- versus bi-phasic; phase duration of frequency of oscillation; decay time constant; net charge; phase charge). To what extent can these parameters be specified if so desired, without adversely affecting other necessary constraints of the device?

We don't wish to prepare a tutorial on custom power supplies. Do you really need this information?

(8) Which electrode is at an initial + and - polarity? Can these polarities be reversed if desired?

Front electrodes positive

(9) Is it possible for the Stick Shocker projectile to adhere to an individual and apply shock if it strikes an unclothed area of the body, including the head?

Sticky Shocker is not intended for head shots. It can stick to bare skin.

(10) Discuss the potential for injuries due to electrode penetration of the skin.

Injury would be similar to taser darts and/or fish hooks. It should be much less than a pen knife.

(11) Does JAYCOR have an opinion regarding the possibility of induced seizures with shocks applied to the head? Explain the basis for that opinion.

We think that a head shock would be similar to a neck shock, which have been applied by stun guns.

(12) Reference is made to a 30-second shock train duration to avoid asphyxiation. Appendix D implies that the 30-second periods will be repeated. What will be the duration of quiescence between the 30-second periods? Can it be controlled by the individual firing the projectile? What is the total duration of the shocks, including active and quiescent periods?

Sticky shocker is presently 8 to 10 seconds. Air Taser is 30 seconds and may be repeated every few seconds.

(13) Please provide copies of References (6) and (7) on page 39. These are not available to the review Panel.

We'll provide our charts from our private communication with Ken Hubbs.

(14) Reference is made to a paper by Robinson (Page 25.1 and elsewhere). Provide a complete citation, and a copy of the paper. Provide a copy of the Air Taser report cited on page D-5.
Please make your own request of Air Taser information. Call Rick Smith, Air Taser, 602-905-2004, or contact them via their web site.

(15) Page D-20 refers to ". . . other reports of Taser-related fatalities . . ." Summarize these reports, and provide complete citations, and copies of the studies.
Best reference is probably that of Kornblum (cited on page D-32)

(16) Provide a complete bibliography of papers and reports examined by JAYCOR or its consultants that treat the safety and effectiveness of similar devices (e.g., Stun Guns and Tasers).
Sorry, but the final report must do. We can't afford to list everything we looked at.

(17) Reference is made to Sticky Shocker discharges given to JAYCOR employees (p. 38). Provide a complete description of these tests and observations, including:

a. *Number of employees tested, and their characteristics (age, weight, height, gender). Number of times tested on each individual. Skin conditions, including whether wet or dry.*
b. *Method of applying shocks, including where the shock electrodes were applied, and whether with spark or direct contact. Duration and repetition rate of shock waveforms. Waveform parameters likely to have been present in the tests.*
c. *Description of reactions, including sensations, motor reactions, and*
d. *whether the individual seemed to be incapacitated during and/or after the shock.*
e. *Presence or absence of burns, skin lesions, red marks, or other physical manifestations of the shock.*
f. *Whether effects lasting more than a few seconds were noted.*

We will discuss our own internal tests in person, orally and do not want to see it in writing.

(18) On page 38, reference is made to a ". . . successful DARPA program." Provide details of objectives and conclusions from that program, and why it has bearing on the Sticky Shocker. Is this statement referring to an electric shocker, or to an impact device?
Answer Forthcoming

(19) Through what thickness of clothing will the Sticky Shocker be effective?
Maybe 1/2 inch

a. How does the length of the arc gap affect safety and effectiveness?

No effect

b. How does spark versus direct contact affect safety and effectiveness?

None

c. Are there particular clothing materials that would reduce or enhance safety or effectiveness?

HV insulated safety clothes

(20) List and summarize information and citations known to JAYCOR or consultants that bears on the possibility of reduced thresholds in sensitive individuals, such as the elderly, children, those with pathological conditions, or those taking drugs (legal or illegal). Explain JAYCOR's opinion regarding the possibility of enhanced dangers in the use of Sticky Shocker on such individuals.

None known to us