

The enclosed information has been extracted from the report “Update on Electrical Devices as Less Lethal Options. Report for ACPO and NIO, June 2001” by the Home Office Police Scientific Development Branch. All information has been included that relates to Taser International and their products without mentioning any other manufacturers products.

**These results have been provided for your information only and should not be used for advertising purposes or to exploit any favourable comments as an endorsement of this product.**

## 1. TASER INTERNATIONAL

Taser International, formerly known as Air Taser, was formed in 1993. Although initially geared towards the civilian market, the company are now heavily promoting their products within the North American law enforcement community.

Taser International produces two series of tasers: the 34000-Series and the M-Series.

- **Air Taser 34000-Series** (see Figure 1): These models are not shaped like firearms. They are 7W systems (pulse energy = 0.44J) and weigh 8-9 ounces (227-255g). These models are single shot and have a detachable single laser sight. They have an automatic 30-second timing cycle that is activated once the darts have been deployed, although this can be turned off at any time by the person controlling the unit.
- **Advanced Taser M-Series** (see Figure 2): This series comprises the M18 model and the M26 model. Both models are shaped like conventional handguns, have single laser sights built in and weigh 18 ounces (510g). The M18 model has a power output of 18W and a pulse energy of 1.76J. The M26 model has a power output of 26W although pulse energy is also reported to be 1.76J. Both models are single shot and have an automatic 5-second timing cycle that is activated once the darts have been deployed, although this can be turned off at any time by the person controlling the unit. This model can be used as a ‘touch stun’ device when the cartridge is removed. More than 750 North American and Canadian police forces are now believed to be using the M26.

All Taser International cartridges use compressed nitrogen as the propellant.



FIGURE 1: *The Air Taser 34000-Series*



FIGURE 2: *The Advanced Taser M-Series*

## 2. TASER OPERATIONAL ISSUES

A number of important generic points have been learned about tasers that can affect their use operationally.

### 2.1 Batteries

Different models of taser require different types of batteries, usually either alkaline or rechargeable are recommended. Different types of batteries have varying levels of performance in terms of their power, both in use and when stored, and when used in different climates. This point is best illustrated by taking the Taser International M26 Advanced Taser as an example.

Taser International recommends the use of either Energizer NiMH rechargeable batteries or Duracell Ultra alkaline batteries. The M26 takes 8 AA batteries. Each NiMH rechargeable has a voltage of 1.2V, resulting in an overall voltage of 9.6V. Each Duracell Ultra battery has a voltage of 1.5V, resulting in an overall voltage of 12V. Despite the NiMH rechargeable batteries having a lower voltage than the Duracell Ultras, they can deliver higher currents, resulting in an increased output power.

The performance of the different types of batteries with continuous usage varies. This is shown in Figure 3, which plots the change in voltage for each of the types of batteries against the number of uses. The performance of the Duracell Ultra batteries declines steadily throughout the lifetime of the batteries, with the voltage dropping with every usage. With the NiMH rechargeable batteries, the voltage and therefore performance remains constant for a long period with a rapid decline after a large number of uses.

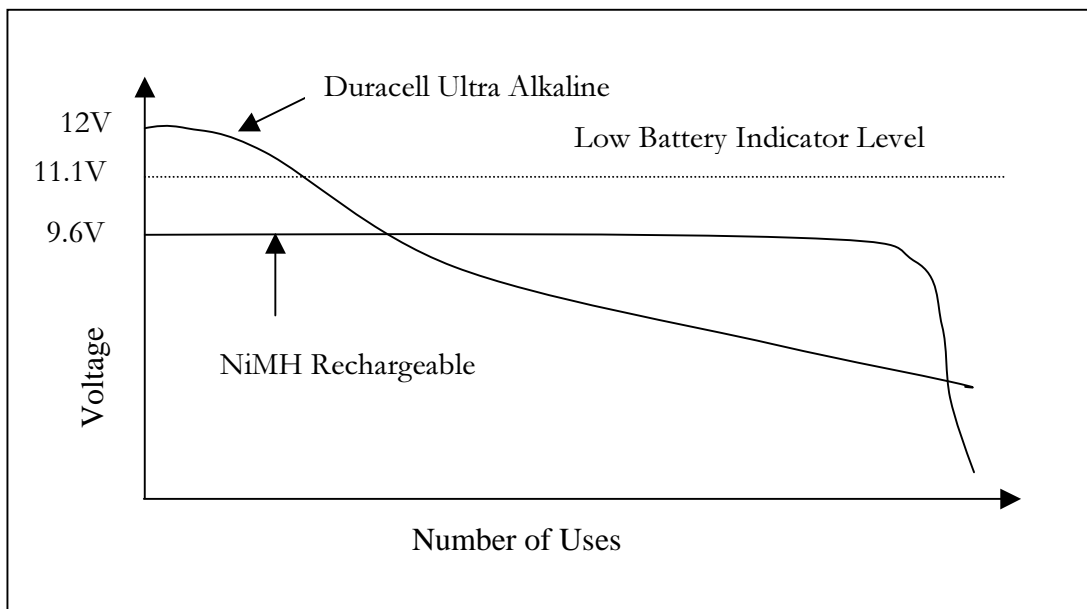


FIGURE 3: **Change in Voltage of NiMH and Alkaline Batteries with Number of Uses**

These effects can be observed by firing, side-by-side, two tasers – one powered by Duracell Ultra alkaline batteries and one by NiMH rechargeable batteries. The initial

spark rate will be higher when using the rechargeable batteries, due to their higher power. Also, with continuous 5-second cycles, the fast spark rate of the NiMH's will be maintained whereas with the alkaline batteries the spark rate will decrease rapidly with continuous cycles. Note: when the taser is not fired in continuous cycles, this decline in performance will not be as rapid as the batteries will have had time to recover in between uses.

The M26 has a low battery indicator at its rear that indicates when the overall battery voltage has dropped below 11.1V which was designed for use with Duracell Ultra batteries to allow the user to know when their performance had dropped below a certain level. When the taser is used with NiMH batteries, however, this indicator shows a low battery indication even when the batteries are fully charged. This is also shown in Figure 3.

The performance of the different types of batteries also varies in cold conditions. The Royal Canadian Mounted Police (RCMP) carried out tests on both types of batteries at temperatures varying from  $-20^{\circ}\text{C}$  to  $+40^{\circ}\text{C}$ . They found that the spark rate using the Duracell Ultra batteries was significantly slower at  $-10^{\circ}\text{C}$  and  $-20^{\circ}\text{C}$ . The spark rate for the NiMH Energizer batteries was much more consistent, although there was some reduction at  $-20^{\circ}\text{C}$ . For more information on performance of tasers at extreme temperatures, see section 3.7.

When the spark rate is lower than normal, due to either partly exhausted or cold batteries, the number of pulses per second reaching the target will be lower. This will result in muscular contraction/relaxation cycles at the target instead of the overall complete muscle stiffening required for total muscular control. This effectively means that tasers operating at lower spark rates are not as likely to lead to incapacitation.

From the evidence provided so far, it would appear that rechargeable batteries are the best option. It should be noted, however, that rechargeable batteries self-drain at approximately 1% per day. Therefore, if the taser is not used for a period of time and the batteries are not recharged, there will be a large reduction in the power. If rechargeable batteries are used, it is extremely important to remember to recharge them at regular intervals – Taser International recommend doing this every two weeks.

Taser International is currently working on a rechargeable taser. This would allow the M26 to be plugged into a recharger via the dataport every two weeks or so. Extra connections have already been incorporated into the existing dataport so that existing tasers can use the recharging capabilities when they are introduced (expected to be before the end of 2001).

## **2.2 Effectiveness**

Effectiveness ratings for the 5-7W systems have been quoted as between 85% down to as low as 50%. It was found that, with the lower-powered systems, focused individuals were able to fight through the effects of the electricity and could continue with an attack. 26W tasers were introduced as an alternative to 5-7W systems as they were believed to be more effective. The lower-powered systems are believed to interfere with the communication signals within the nervous system of the target, while the new higher-powered tasers are believed to completely override the central

nervous system and directly control the skeletal muscles, causing an uncontrollable contraction of the muscle tissue. This is said to be close to 100% effective regardless of the pain tolerance or mental focus of the individual.

Since the introduction of the higher powered tasers, a large number of volunteers have been subjected to their effects, mainly American and Canadian police officers, including those who had previously been able to fight through the effects of the lower-powered versions. The feedback from these volunteers indicates that the higher-powered tasers are indeed more effective with few people capable of fighting through the effects. Operationally, however, there have been a number of cases where individuals have not been fully incapacitated by the device. Their muscles have contracted while the taser is active, but they have not fallen to the ground and, as soon as the power is turned off, they have been able to remove the barbs from themselves and continue with their attack.

Since the introduction of the higher-powered tasers, there have been a number of operational uses allowing some initial effectiveness data to be obtained. The figures shown in Table 1 relate to the use of the M26 Advanced Taser.

Source of Data	# Cartridges Fired	# Times Ineffective	% Ineffectiveness
Taser International	257	19	7.3%
American Police Force	16	3	18.8
American Police Force	33	3	9.1%
Canadian Police Force	50	13	26.0%

TABLE 1: *Ineffectiveness Data For M26 Advanced Taser*

There are a number of possible reasons for the failure of taser devices. These are summarised below:

- **Clothing** – although the electricity can arc across a gap up to a certain distance (see section 5.5 for more information about this), there may be some situations where the thickness of the clothing worn exceeds this distance. This is particularly so in very cold climates where heavy jackets are worn. Also, if clothes are loose and hanging and the barb(s) penetrate the clothing only and not the body, then the current flow could be broken when the clothes flow away from the body;
- **Low batteries** – the issue of batteries has been discussed already and reasons have been given as to why they are likely to fail. This has been recognised as a serious issue by the users and trainers in America and Canada and a number of failures, which had initially been thought to be due to clothing, are now suspected to have been caused by low batteries. They have found that often, when an officer first receives their taser, they will demonstrate its sparking to colleagues - usually a number of times. They may also do a ‘spark-test’ before taking their taser on duty with them to ensure it is working correctly. These actions combined can seriously affect the performance of the taser when the time comes to use it operationally;
- **One or both darts miss the target** – this could be due to a number of reasons including: operator error, errors in the sighting system, errors in the cartridge, a moving target and the target being out of range. Generally speaking, unless both barbs hit the target, the circuit will not be completed and the electricity will not flow through the target;

- **Subject fought through the effects of the electricity** – this has been discussed already and it is recognised that this may still be a possibility even with the new higher-powered tasers. Reasons for this happening could include the barbs not being sufficiently separated or affecting a group of muscles that are not sufficiently sensitive;
- **Cartridge failure** – identified already as the cause of failure in some cases;
- **Problem with taser** – other than due to cartridge failure or low batteries;

The path that the electric current will take after the barbs have been fired at a target is often difficult to predict. Essentially, electricity will flow along the path of least resistance, or will follow a number of different paths. Although ideally the full charge would travel along the wire to the first barb, through the subjects' body, then out through the second barb, this is not always the case. Contributing factors to the unpredictability include: the presence of metal or other good conductors; the presence of water; highly resistant material at the target; and arcing across the wires.

All of the figures for effectiveness quoted previously have only included those cases where a cartridge was actually fired from the taser, however the taser is often also used to gain compliance in other ways and often the use of the laser sight(s) alone will be enough to gain compliance. In other instances, firing the taser without a cartridge inserted is enough to gain compliance; this allows the subject to see the effects of the electricity sparking and hear the loud crackling caused by the electrical discharge across the electrodes. Additionally, some tasers can be used in stun gun mode to provide a touch stun capability, this method of application is often used in some American and Canadian forces. Figures from Taser International showed that 69 uses out of 439 (15.7%) of their M26 Advanced Taser had been a touch-stun application, with a reported 85.5% success rate. Further figures from Canada have shown that 49 uses out of 113 (43.4%) of the M26 have been touch-stun applications with a reported 89.0% effectiveness.

### 3. PSDB TESTING

This section describes a number of tests carried out at PSDB on the M26 Advanced Taser. All of the tests were carried out using three identical models of taser with 21ft (6.4m) cartridges.

#### 3.1 Accuracy

The M26 employs a single laser sight that is designed to show where the top barb will land on the target. While a large separation of the barbs is desirable in order to provide maximum incapacitation, it is also important that both barbs will penetrate the target or at least attach onto their clothing, otherwise the circuit cannot be completed and the electricity will not flow through the target. A number of basic accuracy tests were therefore carried out to determine the position of the top barb relative to the laser dot and the separation of the two barbs at different distances.

##### 3.1.1 Method

An M26 taser was clamped firmly into a tripod and the device checked to ensure it was level. A flat cardboard target covered in foil was secured at a set distance from the taser. With the laser sight turned on, the red dot position was marked on the target with a spot. A cartridge was inserted into the front of the taser and fired at the target.

The position of the laser spot was taken as the zero point and the position of the top barb was measured relative to this. The position of the bottom barb was measured relative to the top barb.

21ft (6.4m) cartridges were used for each of these tests and tests were repeated at 5, 10, 15 and 20ft (1.5, 3.0, 4.6 and 6.1m). At least 10 cartridges were fired at each of these ranges. These tests were carried out indoors at room temperature, with no wind effect and with the taser clamped firmly using a tripod, therefore representing an ideal situation.

**3.1.2 Results**

Table 2 shows the results for the testing carried out at PSDB. Values given are the separation between the top barb and the point of aim (the laser-sighting dot), and the separation between the top and bottom barbs. The ranges show the maximum and minimum values for these while the mean gives the average values at each distance.

<b>Distance from taser to target</b>	<b>Separation between top barb and laser dot</b>		<b>Separation between top barb and bottom barb</b>	
	<b>Range (mm)</b>	<b>Mean (mm)</b>	<b>Range (mm)</b>	<b>Mean (mm)</b>
5ft (1.5m)	20 - 55	39	205 - 260	225
10ft (3.0m)	15 - 135	63	305 - 440	378
15ft (4.6m)	90 - 140	109	534 - 685	601
20ft (6.1m)	105 - 410	287	563 - 905	786

TABLE 2: **Results of Accuracy Tests carried Out at PSDB**

At 5ft (1.5m), 9 shots out of 10 resulted in the top barb hitting above the aim point. At 10ft (3.0m), 4 shots out of 10 resulted in the top barb hitting above the aim point. At 15 and 20ft (4.6m and 6.1m), all shots resulted in the top barb hitting below the aim point.

These results are represented in Figures 4 to 7. These figures show the position of each of the barbs at each distance as they would fit on a man-sized target with the outline showing torso, leg and arm areas. The point of aim is taken as the centre of the chest area just above the nipple line.

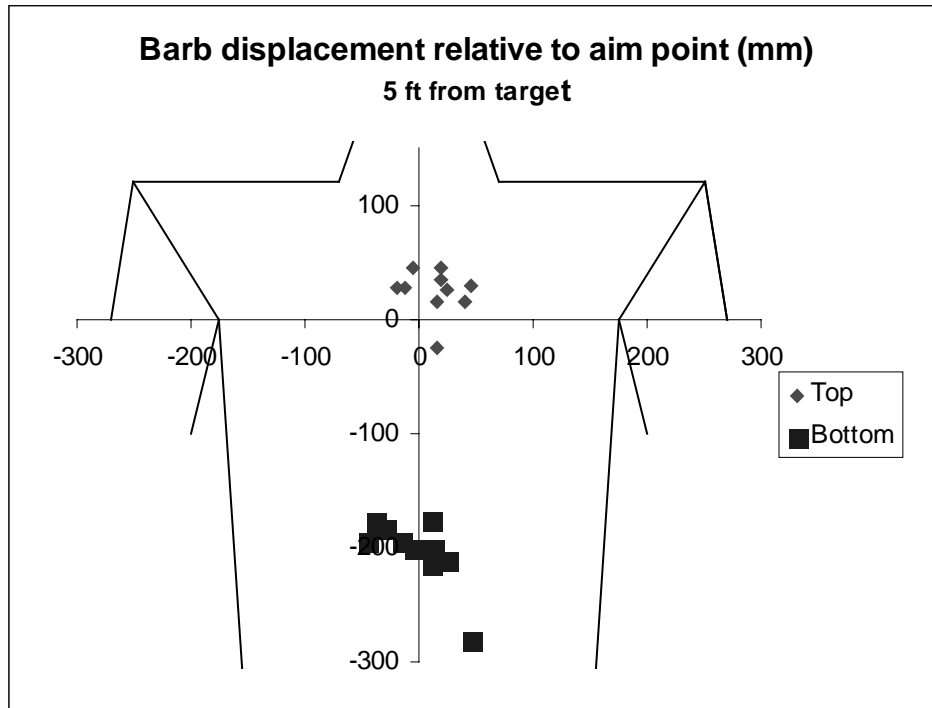


FIGURE 4: *Position of Taser Barbs at 5ft (1.5m)*

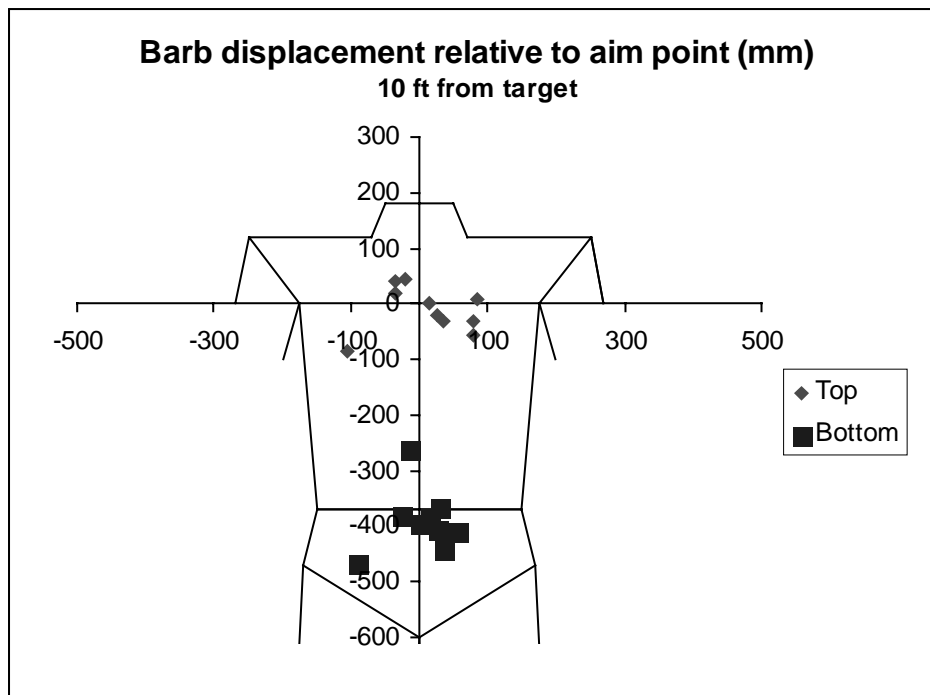


FIGURE 5: *Position of Taser Barbs at 10ft (3.0m)*

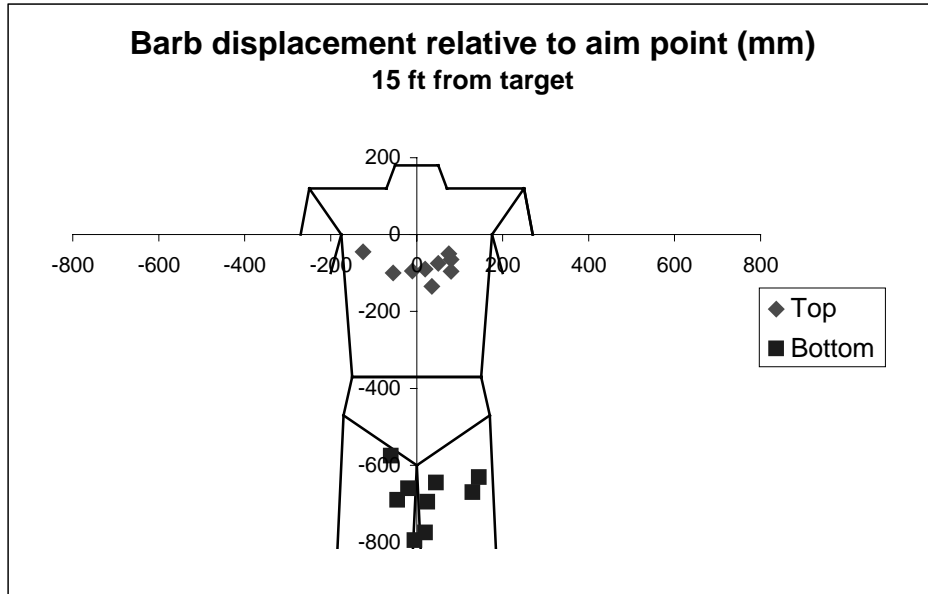


FIGURE 6: *Position of Taser Barbs at 15ft (4.6m)*

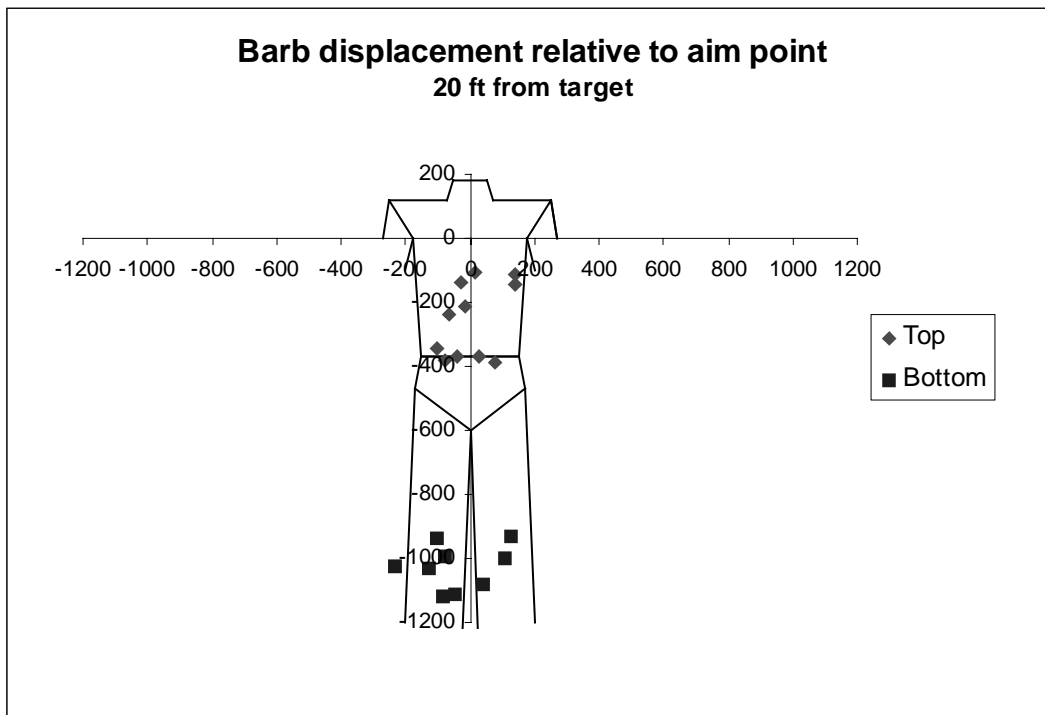


FIGURE 7: *Position of Taser Barbs at 20ft (6.1m)*



### 3.2 Velocity

The velocity of the taser barbs during flight was measured while the accuracy tests were being carried out. These results are shown in Table 3.

Distance from taser	Velocity of barbs
1m	$36 \pm 4$ m/s
2m	$33 \pm 2$ m/s
2.5m	$30 \pm 1$ m/s
4m	$22 \pm 1$ m/s

TABLE 3: **Change in Velocity of Taser Barbs with Distance**

### 3.3 Electrical Output

A series of tests were carried out at PSDB to determine the electrical output of the M26 in terms of waveform, current, voltage, pulse-width, energy and power. Measurements were also made of any changes which occurred to these when an air gap was incorporated into the circuit (as would be the case if a barb did not penetrate the skin of the target but instead attached onto their clothing). These tests were necessary not only to give us a fuller understanding of the taser output, but also to provide information to an independent medical committee to help them assess the effects of the taser on the human body. The results provided in this report are not exhaustive and further analysis of some of the electrical effects is necessary. A more detailed report of this testing will be prepared for the medical committee to provide them with the information they require.

The electrical signal produced by a taser is very different from the signal produced from household electricity. Household electrical appliances have a continuous alternating current (AC) with a peak voltage of 340V, a root mean square (rms) voltage of 240V and a frequency of 50Hz (i.e. 50 oscillations per second). This type of waveform is represented in Figure 8.

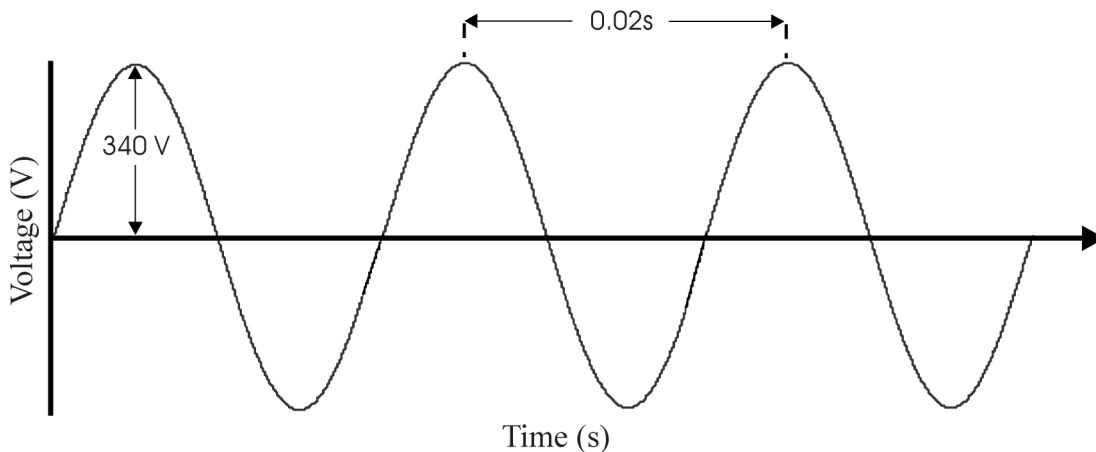


FIGURE 8: **Waveform for Household Electricity**

The waveform produced by the taser is very different to this. The taser operates by charging up and then instantaneously discharging a capacitor. The result is a series of pulses of very high voltage and very short duration. The pulses last only a few

microseconds, while the pulse separations are relatively long in comparison, lasting tens of milliseconds. In current commercial devices, there are between 10 and 20 pulses per second. The high potential difference (or voltage) is necessary to allow the electricity to jump across an air gap, such as would be the case if the barbs attached onto a subject's clothing, rather than penetrating their skin. The power (wattage) relates to the rate at which the energy is transferred. Figure 9 shows the typical waveform that is produced from a taser discharge – only one pulse is represented in this figure.

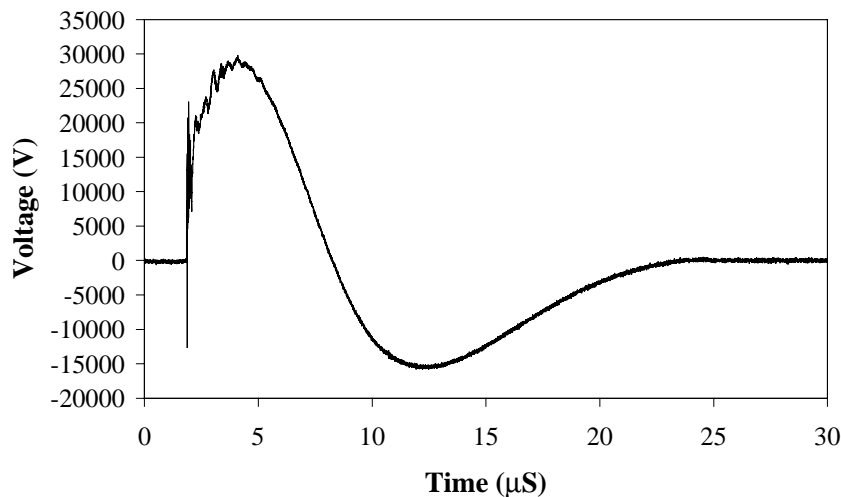


FIGURE 9: *Waveform for Taser Output*

Another important distinction between the mains electricity and the output from the taser is the availability of energy. Each pulse from the taser represents a discrete package of energy of a more or less constant value, therefore the number of sparks or packages per second will be the maximum power delivered. Power from the mains is not limited in this way, the current that can be drawn (which is proportional to the energy) is not limited to discrete packages and will increase until the load (or resistance) is met or the fuse or safety device operates.

### 3.3.1 Method

The electrical output of the M26 was measured in the following way: a potential divider of total resistance  $R_t$  was placed across the ends of the barbs, which had been ejected from the taser cartridges, in order to complete the circuit. The total resistance was intended to simulate that of the human body, but since this resistance is highly variable, a range of values was chosen for measurement. The output pulse from the device was discharged across  $R_t$  and the output voltage measured using an oscilloscope.

Measurements were made of the change of current and voltage with total resistance. These tests were then repeated with an air gap of a certain distance incorporated into the circuit. The effects of an air gap on the waveform must be considered if the taser barbs do not penetrate the skin of a subject, but instead attach onto their clothing. In this case the electricity can still arc across the gap and be passed through the subject's body (depending on the distance of the air gap). In these tests, a gap was created between one of the barbs and a potential divider of total resistance  $R_t$ ; the gap was

then increased in 5mm increments. These measurements were repeated using different values of  $R_t$ .

Measurements were also taken of the maximum air gap that could be introduced into the circuit before the electricity started to arc across the electrodes on the head of the taser, rather than through the circuit. The limit of the gap was taken as the distance at which approximately half of the discharges sparked between the two electrodes on the taser rather than passing through the circuit. These measurements were repeated using different values of  $R_t$ .

### 3.3.2 Results

Figures 10 and 11 show the changes in voltage and current respectively with the change in total load resistance,  $R_t$ .

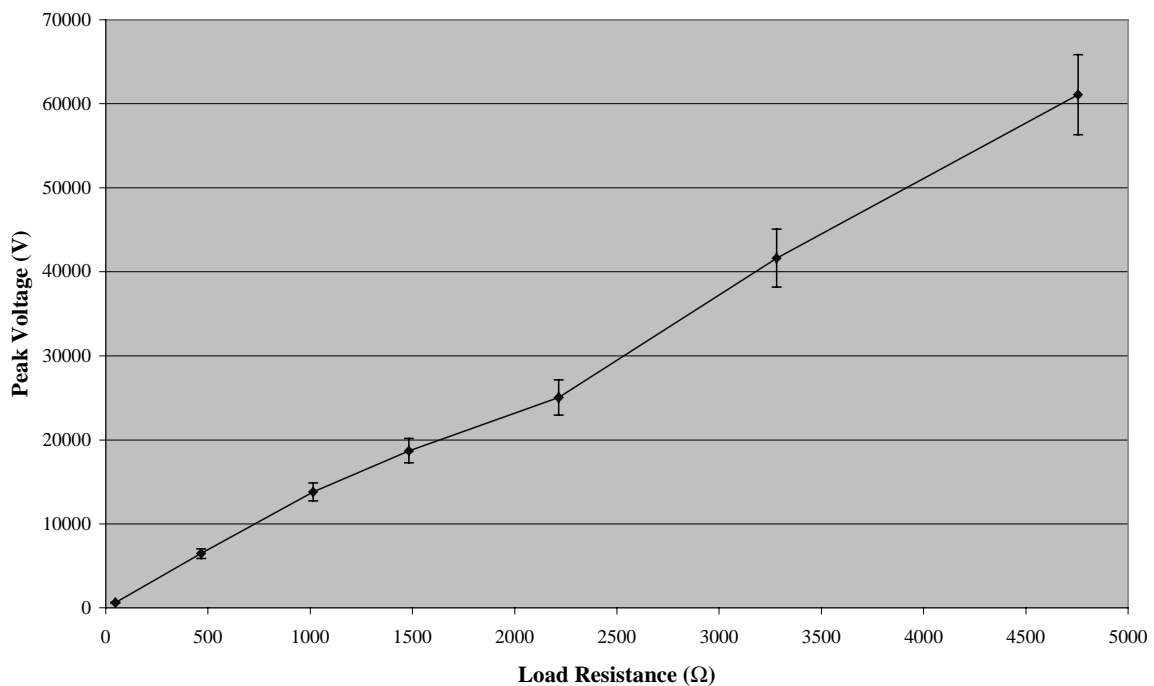


FIGURE 10: *Variation of Peak Voltage from M26 Taser with Changing Load Resistance*

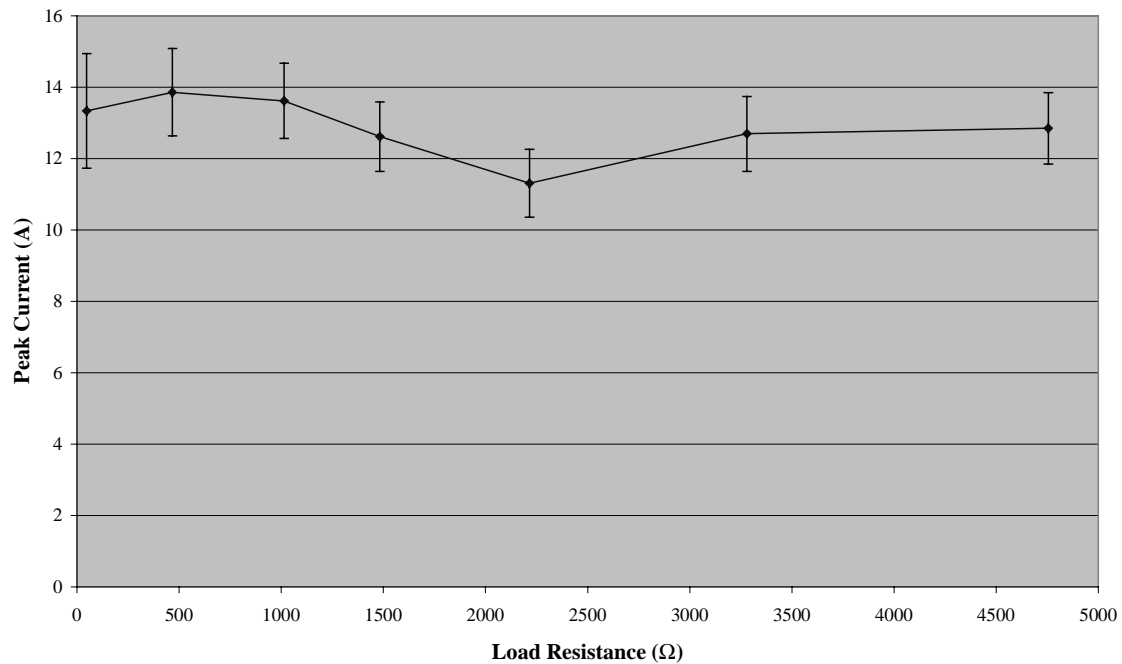


FIGURE 11: ***Variation of Peak Current from M26 Taser with Changing Load Resistance***

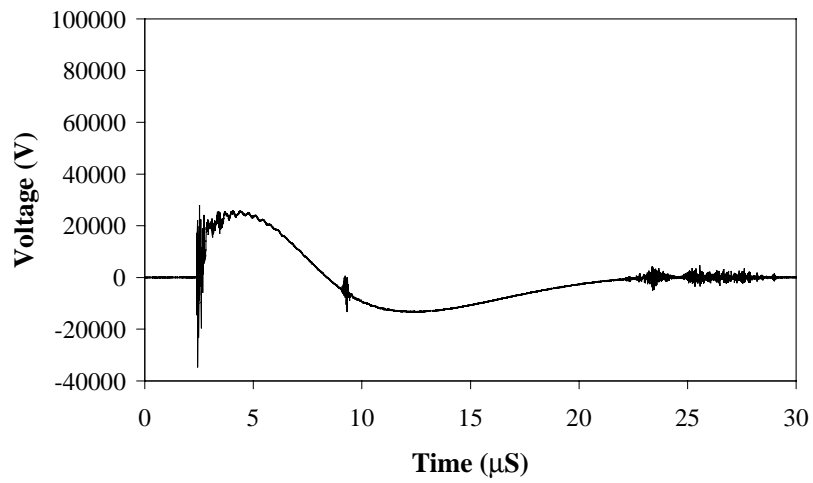
From these graphs, it can be seen that the peak output voltage increases as the resistance within the circuit increases, with the often-quoted value of 50,000V occurring at a total resistance of approximately 4,000 ohms. The peak current, on the other hand, remains essentially constant at 11.5-14 amps, despite changes in the total resistance.

Figure 12A-C shows the change in waveform that results when an air gap is incorporated into the circuit at a set resistance. The resistance chosen was 2,200 ohms and the graphs represent changes in peak voltage with time.

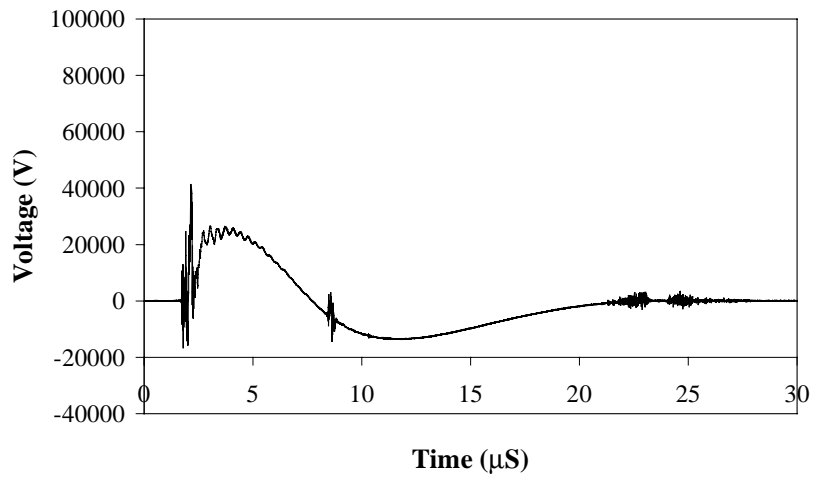
Graph A shows the output when there is no air gap incorporated into the circuit. Graph B shows the output when an air gap of 5mm is incorporated into the circuit and graph C shows the output for an air gap of 10mm.

By comparing graphs A-C, it can be seen that there is an increase in the voltage of the spike observed at the front of the first pulse as the size of the air gap is increased. The presence of a spike in graph A can be observed, even with no deliberate air gap incorporated into the circuit. The reason for this may be that the current jumps across from the taser electrodes on the taser body to the wires within the cartridge.

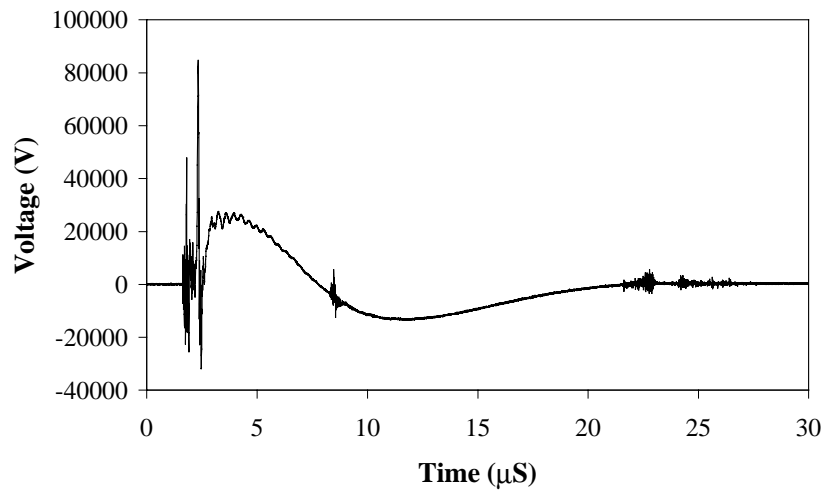
This large spike in front of the pulse has a much higher peak voltage than the main pulse, although it only lasts for a very short period of time. It is as yet unknown how much difference, if any, this will have on the effects of the electricity on the human body. This information, along with all the other electrical output data, will be passed to the medical committee when they make their assessment.



a) Taser Output with 2,200 ohm Load (Air Gap = 0mm)



b) Taser Output with 2,200 ohm Load (Air Gap ≈ 5mm)



c) Taser Output with 2,200 ohm Load (Air Gap ≈ 10mm)

FIGURE 12: **Change of Voltage with Time for Varying Air Gap Distance**

It should be noted that the values plotted in figures 10 and 11 are for the peak voltage and current of the main pulse, and not the spike in front of this pulse.

Figure 13 shows the size of the air gap that allows approximately 50% of discharges to arc across the taser electrodes rather than through the circuit with varying resistance.

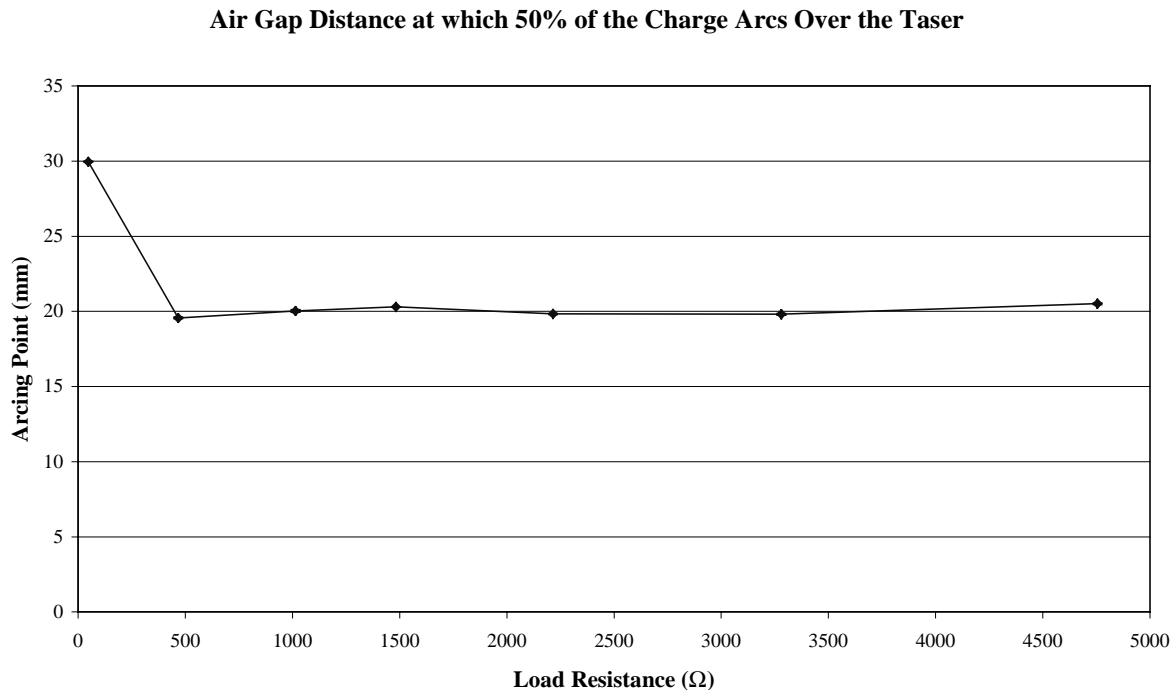


Figure 13: ***Change in Arcing Gap Distance with Load Resistance***

It is clear from this graph that at resistances of 500 ohms and greater, the maximum air gap that allows approximately 50% of the current to flow through the circuit is 20mm (less than an inch). It is useful to compare these results to those found by Sgt Laur - he found that a spark gap of 2.25inch (57mm) was possible for the same cartridges. His tests were carried out by placing two barbs together so that they were pointing at each other. The darts were then separated at 0.25 inch (6.3mm) increments, the taser activated and the arc between the barbs observed. The main difference between his test and the PSDB test is that no resistance was present within the circuit used by him. We can see from Figure 13 that a very low resistance within the circuit will allow a much greater spark gap to exist. The PSDB test is more realistic as the resistance of the human body will always be an important factor in taser usage.

### 3.4 Drop Tests

These tests were carried out to determine what kind of treatment the M26 could withstand while still remaining in a working condition. The drop test involves dropping the item under examination from a height of 2m onto a steel plate and observing any damage that occurs.

### 3.4.1 Method

A taser, with a 21ft (6.4m) cartridge inserted into the firing bay, was dropped from a height of 2m onto a steel plate. The test was repeated eight times using the same taser held at different angles and with a different cartridge inserted each time. Any damage to the taser or cartridges was noted. Following the drop, and for those cartridges still intact, each cartridge was fired from an intact taser and the position of the barbs noted along with any unusual results.

This test was then repeated for the cartridges alone by dropping them from a height of 2m onto a steel plate. A new cartridge was used for each drop and four cartridges were dropped in total. Any damage to the cartridges was noted. Following the drop, and for those cartridges still intact, each cartridge was fired from an intact taser and the position of the barbs noted along with any unusual results.

### 3.4.2 Results

When the taser with a cartridge attached was dropped, the cartridges sometimes fell out of the firing bay (3 times out of 8). On one of these occasions the striped 'doors' on the front of the cartridge became detached, although the rest of the cartridge remained intact. This test was repeated eight times using the same taser but with a different cartridge each time. When these cartridges were fired afterwards, the position of the barbs fell within the range expected at that distance and no other problems were noted.

As regards the effects on the taser itself when dropped in this way, a number of problems occurred:

- In the first two drops, the battery catch at the bottom of the taser loosened and had slid forward a little, although the batteries remained firmly in place;
- After the third drop, the taser split down the middle at its rear and after this the battery catch could no longer be properly attached;
- After the fifth drop the safety catch fell off from the right hand side of the taser;
- After the sixth drop, the battery indicator button fell off.

Although little damage occurred to the cartridges when attached to the taser and then dropped, this was not the case when the cartridges were dropped on their own. Four separate cartridges were dropped from a different angle each time:

- The first cartridge suffered no damage when dropped although the position of the top barb when fired was slightly outside the range that would be expected at that distance. There were no other problems;
- When the second cartridge was dropped the striped 'doors' came off, both wires came out and unravelled (one wire was found to be torn in two) and one of the barbs was ejected;
- When the third cartridge was dropped the striped 'doors' came off, one wire came out and unravelled and one of the barbs was ejected;
- When the fourth cartridge was dropped the striped 'doors' came off, both wires came out and unravelled but the barbs were not ejected;

Three out of four cartridges were unusable after they had been dropped.

### 3.5 Clothing Penetration

The intention of these tests was to determine whether a selection of clothing materials could prevent the taser barbs from either penetrating through them or attaching on to them. 21ft (6.4m) taser cartridges were fired at a mannequin dressed in a variety of different clothes at a distance of 5ft (1.5m).

Seven different types of material were used for these tests: a heavy waterproof anorak, cotton overalls, a polyester reflective vest, a leather jacket and three types of body armour: dual purpose, covert (ballistic only) and ballistic. Two cartridges were used on each of these materials. The results for these tests are shown in Table 4.

With the exception of the zip, none of the materials tested here stopped the barbs from at least partly penetrating and attaching onto the material.

### 3.6 Flammability

The aim of these tests was to determine the risk of ignition if a taser is fired at a person with flammable liquid on their clothing. The liquid used in these tests was methyl isobutyl ketone (MIBK), the solvent present in the CS sprays used by the UK police.

#### 3.6.1 Method

A full canister of Alsetex/Primetake MIBK only (30ml) was sprayed at a mannequin wearing a standard jogging sweatshirt (material is 65% polyester, 35% cotton). The mannequin was first covered in foil to allow conduction of the electricity through the barbs. The entire canister was sprayed at the front of the sweatshirt. A taser cartridge was then fired at the mannequin from a distance of 5ft (1.5m). This was repeated a total of seven times with a new, but otherwise identical, sweatshirt used each time.

#### 3.6.2 Results

In five of the occasions, there was no ignition at the mannequin, although sparking was observed at the barbs attached to the mannequin, indicating that electricity was flowing through the circuit. On the other two occasions, however, ignition occurred at the mannequin after the barbs penetrated the sweatshirt. On one occasion the sweatshirt ignited as soon as the barbs attached to it, and on the other occasion a second or two passed before the flames began. In both cases, the flames produced were severe and engulfed the entire top half of the mannequin, including the head.

It is clear from these tests therefore that there is a serious risk of ignition if the taser is fired at a target that has a flammable solvent on their clothing.

### 3.7 Extreme Temperature

The aim of these tests was to determine whether the M26 would still be in a working condition after being subjected to extremes of heat and cold.

#### 3.7.1 Method

Two tasers with cartridges inserted were placed in an oven at +50°C for a minimum of 12 hours. One of the tasers contained Energizer NiMH rechargeable batteries and the other contained Duracell Ultra alkaline batteries (both sets fully charged). A number of spare cartridges were also placed in the oven. After this period, the tasers were removed, one at a time, and the cartridge fired at a target to determine if the



Clothing Material	First Cartridge		Second Cartridge	
	Top Barb	Bottom Barb	Top Barb	Bottom Barb
<b>Heavy waterproof anorak</b>	Hit the zip of the jacket and did not penetrate or attach onto it. The barb actually rested on top of the zip puller, although if this had not been present the barb would have fallen away.	Penetrated the first outer layer of the jacket but failed to completely penetrate the inner layer, although barb was firmly attached to the jacket.	Penetrated the first outer layer of the jacket but failed to completely penetrate the inner layer, although barb was firmly attached to the jacket.	Penetrated the first outer layer of the jacket but failed to completely penetrate the inner layer, although barb was firmly attached to the jacket.
<b>Cotton overalls</b>	Fully penetrated all layers of the overalls, including the double velcro layer where the overalls fastened.	Fully penetrated all layers of the overalls, including the double velcro layer where the overalls fastened.	Fully penetrated the single layer of cotton overall.	Penetrated the outer layer of cotton and one layer of velcro, then lodged in the second layer of velcro.
<b>Polyester reflective vest</b>	Fully penetrated the single layer of material.	Fully penetrated the single layer of material and the reflective band.	Fully penetrated the single layer of material.	Fully penetrated the single layer of material.
<b>Leather jacket</b>	Fully penetrated two layers of leather (jacket folded) but not through third layer – barb securely attached.	Fully penetrated two layers of leather (jacket folded) but not through third layer – barb securely attached.	Penetrated one layer of leather, attached onto second layer (struck at fastening area of jacket with double layer).	Fully penetrated one layer of leather.
<b>All body armours</b>	Barb penetrated armour up to the point where the diameter of the barb increased. Securely attached to armour.	Barb penetrated armour up to the point where the diameter of the barb increased. Securely attached to armour.	Barb penetrated armour up to the point where the diameter of the barb increased. Securely attached to armour.	Barb penetrated armour up to the point where the diameter of the barb increased. Securely attached to armour.

TABLE 4: ***Behaviour of Taser Barbs when Fired at Different Materials***

system worked correctly. These tests were repeated at  $-20^{\circ}\text{C}$  after the tasers had been kept in a freezer.

### 3.7.2 Results

#### i) At $+50^{\circ}\text{C}$

At this temperature, the laser sights and battery indicators did not work on either taser. The tasers themselves were also incapable of being fired. These problems were not caused by the batteries as these worked as normal when placed in a room temperature taser. Furthermore, using room temperature batteries in the hot taser resulted in the same problems as before.

The problems were also not related to the cartridges since six cartridges, each also held at  $+50^{\circ}\text{C}$ , were fired from a room-temperature taser; all cartridges fired as normal with no problems, and the barbs fell within the range to be expected at that distance.

As the tasers were allowed to cool back to room temperature their performance gradually improved. During the first hour or so there seemed to be a problem with the connections within the device: the tasers could be fired on some occasions but not consistently. After an hour or so, both tasers were capable of firing every time, although the laser dot did not return to full brightness. After 24 hours the lasers had returned to normal.

#### ii) At $-20^{\circ}\text{C}$

At this temperature, the laser dots and battery indicators were functioning, but the tasers were incapable of firing. For the taser containing the NiMH batteries, two distinct laser dots were observed at the target, while for the taser containing the Duracell Ultra batteries, the laser spot was large, dim and unfocussed.

As the tasers were allowed to return to room temperature their performance gradually improved. After half an hour the taser would fire on some occasions but not consistently. After an hour or so, both tasers were capable of firing every time, although the laser dot did not return to full brightness. After 24 hours the lasers had returned to normal.