Less Lethal Technologies
Initial Prioritisation and Evaluation

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Publication No 12/01

POLICE SCIENTIFIC DEVELOPMENT BRANCH
HOME OFFICE POLICING AND CRIME REDUCTION GROUP

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FIRST PUBLISHED 2001

PSDB No 12/01

Published by:

Home Office
Police Scientific Development Branch
Sandridge, St. Albans
Hertfordshire AL4 9HQ
United Kingdom

Printed by:

White Crescent Press
Crescent Road
Luton
Bedfordshire

Management Summary

The Home Secretary has tasked the Police Scientific Development Branch (PSDB) of the Home Office with reviewing available technologies that have the potential for use as an option that is less lethal than a firearm. This work is being carried out at the request of the Association of Chief Police Officers (ACPO) and the Northern Ireland Office (NIO).

In February of this year, PSDB carried out a review of commercially available and near-market less lethal technologies, which was made available on the NIO website in April. That report highlighted a wide range of technologies and a large number of products that could potentially be employed in situations where a less lethal option is considered appropriate for use. Many of these devices are used operationally in various countries throughout the world.

Since the report in April, prioritisation of these technologies has taken place based on evaluations of the technologies and comparison with the Operational Requirements. The prioritised areas are impact devices, long-range chemical delivery devices, water cannon, electrical devices that can be used at range, laser/light devices and noise generating devices. Tranquillisers and malodorants have been selected as requiring research over a longer period of time while all other technologies have been placed in the category of not requiring further research at the present time.

The business of policing necessarily involves dealing with people in a wide variety of situations. These situations will range from one on one confrontations with an aggressor, who could be armed with any one of a number of weapons, through to the targeting of individuals within a crowd during serious public disorder. The Operational Requirements (OR) of the police in terms of less lethal tactical options, the units deploying these options and the weaponry itself may differ considerably from one scenario to another.

The purpose of this report is to explain the work that has been carried out in Phase 2 of the project and to demonstrate how devices have been selected for further research from the large number of technologies considered in the April report. Information is provided on testing which has been carried out on the various technologies, information that has been gained, both operational and technical, and the current status of each of the prioritised areas.

A number of devices have been identified within each prioritised category as meeting the basic evaluation criteria. Further testing of these devices will now be carried out to assess how their performance relates to other aspects of the operational requirement. This will be followed by a full medical review of those devices that appear most suitable.

It must be stressed that this work is not focussed on identifying a replacement for conventional firearms since the need to resort to lethal force on occasions will continue. However, a much broader range of options, which can be considered and deployed in response to particular circumstances, is required.

Contents

1 INTRODUCTION

"Less lethal" is a term carefully defined to encompass weapons and equipment which, although less likely than firearms to result in a serious or fatal injury, nevertheless carry some degree of risk. The objective is to provide the police with options to allow a use of force commensurate with the threat being faced. This does not preclude the use of firearms where this is absolutely necessary to protect the public and police officers. In all cases, the following issues have to be weighed in the balance – acceptability (including human rights considerations and risk of injury or death), effectiveness for the purpose, and appropriateness of response.

The business of policing necessarily involves dealing with people in a wide variety of situations. These situations will range from one on one confrontations with an aggressor, who could be armed with any one of a number of weapons, through to the targeting of individuals within a crowd during serious public disorder. The Operational Requirements (OR) of the police in terms of less lethal tactical options, the units deploying these options and the weaponry itself may differ considerably from one scenario to another.

The Home Secretary has tasked the Police Scientific Development Branch of the Home Office with reviewing the currently available technologies and equipment that could potentially be employed in situations where a less lethal option is considered appropriate for use. This work is being carried out as a result of requests from the following groups:

- The Home Office Action Against Crime and Disorder Unit (AACDU);
- The Association of Chief Police Officers (ACPO), specifically the following Sub-Committees
  - Self Defence Arrest and Restraint (SDAR),
  - Police Use of Firearms (PUoF) and
  - Public Order;
- The Northern Ireland Office (NIO), in response to the recommendations made in the report of the Independent Commission on Policing in Northern Ireland (the Patten report)[1].

These groups are all represented on one steering committee, the Alternatives to Baton Round Project Board, formed to address two specific recommendations in the Patten report. Recommendation 69 of the Patten report stated that:

“An immediate and substantial investment should be made in a research programme to find an acceptable, effective and less potentially lethal alternative to the Plastic Baton Round (PBR)”.

Recommendation 70 stated that:

“The Police should be equipped with a broader range of public order equipment than the RUC currently possess, so that a commander has a number of options at his/her disposal which might reduce reliance on, or defer resort to, the PBR”.

Early in the life of the NIO project it was recognised that the work being carried out for the groups mentioned above was essentially the same and that it could be co-ordinated to suit the policing needs of the whole of the United Kingdom, broadening out to encompass individual cases. Consequently, representatives from all interested parties were invited to sit on the project board and a project co-ordinator was appointed (from ACPO).

The review and assessment of less lethal options is being carried out in a number of stages, as defined by the board. Four main phases were identified, each involving separate pieces of work:

Phase 1: This involves defining the operational objectives against which less lethal options must be tested; preparing a literature review of available less lethal options, or those under research and; examining the literature review against the operational objective.

Phase 2: This involves evaluating the literature review and formulating proposals for further research on those options that have the potential for successful transfer to the operational field.

Phase 3: This phase involves conducting further research on the options identified in Phase 2 and will include the evaluation of both performance and safety.

Phase 4: This phase involves the defining of operational objectives for public order equipment.

In February 2001, PSDB prepared a report for the NIO which comprised a survey of technologies and currently available or near market commercial devices, set against the context of the ACPO operational requirements (Phase 1). This report is available from the Northern Ireland Office website (www.nio.gov.uk) under the title 'Patten Recommendations on Baton Rounds' and is contained within the document 'Patten Report Recommendations 69 and 70 Relating to Public Order Equipment', dated April 2001[2].

In July of this year, and on the basis of information supplied by PSDB, ACPO and the NIO prioritised the technologies identified in this report in order that research and testing could be carried out more quickly on those deemed to be most likely to satisfy the operational requirements. The other technologies could be given longer time-scales for completion of the work. This prioritised list split the technologies into three categories:

- <u>Category A</u> included 'devices which may be the subject of immediate more in depth research';
- <u>Category B</u> included 'devices warranting further research over a more extended time frame' and;
- <u>Category C</u> included 'devices which presently do not require further research'.

A summarised version of this list is shown in Appendix A.

This report contains a summary of all of the work that has been carried out by PSDB in relation to less lethal options since the initial review in April[2]. Information is provided on testing which has been carried out on the various technologies, information that has been gained, both operational and technical, and the current status of each of the prioritised areas. The purpose of this report is to explain the work that has been carried out in Phase 2 of the project and to demonstrate how devices have been selected for further research from the large number of technologies considered in the April report.

Before any of the less lethal technologies and devices are used by the police in the UK, it is strongly recommended that they are subject to a full and thorough evaluation, including an assessment of the medical aspects of using such a device. The work that has been carried out to date has resulted in a number of devices being identified as having the greatest potential and meeting the most basic requirements. These devices must now be subjected to more detailed testing to assess how they meet other aspects of the requirement, and various devices will almost certainly be discounted at later stages if they fail to show all of the necessary characteristics.

Those devices that perform well in future tests will be passed to a panel of independent medical experts for an assessment of the effects that they are likely to have on the human body. The results of all of the testing that will have been carried out before this will be provided to the committee in helping them to assess the various options.

The various abbreviations and technical terms used throughout this report are explained in the glossary of terms shown at Appendix B.

2 CATEGORY A TECHNOLOGIES

Those technologies selected for Category A, i.e. those devices meriting immediate further research, are summarised as:

- Impact Devices or Kinetic Energy Rounds
- Long Range Chemical Delivery Devices
- Water Cannon, both vehicle mounted and portable
- Electrical Devices, particularly the taser
- Distraction/Disorientation Devices, particularly laser/light devices and noise generating devices

The methodology used to evaluate the devices within each of the technology areas in Category A is essentially the same. Initially, information is gathered on all devices that are available from a wide range of countries. Manufacturers are asked to supply technical information relating to their product and, if suitable, to submit their products for evaluation.

Submitted products take part in a progressive sifting process. The testing is carried out in stages with the quickest, easiest and cheapest tests being carried out first on all products. This highlights those that clearly do not meet the necessary requirements and excludes them from further testing. Those products that meet the basic criteria are put through to the second stage at which point any deficiencies will again be highlighted. This continues until only those products that have shown the best performance and most closely meet the operational requirements are subjected to the more time consuming and expensive testing, such as the work required for a full medical evaluation.

Information on the operational use of the various devices in different countries is also gathered. This information often comes from police forces but may also be gathered from government agencies, literature and the prison service. This information provides an insight into the extent of use of each device and an indication of its effectiveness.

Those devices that meet all of the scientific and technical evaluation criteria will then be assessed by a medical committee who will comment on their effects on the human body. This committee will consist of a number of independent medical professionals who have expertise in the technology or effects being considered.

3 IMPACT DEVICES

There are a large number of manufacturers producing a wide variety of impact munitions. Many of these rounds may be safe and effective when they strike one part of the body, but may cause serious injury or even death if they strike a different part. Many manufacturers, for instance, recommend that the round is not fired at the head, neck, face or spine. It may be impossible to be sure of avoiding this if the round is inaccurate, therefore accuracy is one of the more important attributes of these types of round if unintended injuries are to be minimised.

The performance of these rounds, including their accuracy, varies dramatically depending on the composition of the round, the weapon from which they are fired, and the quality of the manufacturing process. Manufacturers' data can often not be relied on to provide an accurate assessment of the rounds' capabilities. It is important, therefore, that these rounds are tested thoroughly to ensure that they meet both the manufacturer's claims and the requirements of the user.

Less lethal impact rounds tend to fall into specific classes. These were outlined in the April report[2] and are summarised below:

- **Bean Bag:** A square, rectangular or circular fabric bag containing lead shot. The round is intended to flatten on impact, hitting face on, and spread its energy over a large area. These rounds are intended to be fired directly at an individual;
- **Sock Round:** A modification of the bean bag, designed to have no edges or corners which could lead to penetration, and tending to have a 'tail' to aid stabilisation in flight. These rounds are intended to be fired directly at an individual;
- **Single Flexible Ball Round:** This consists of a single ball (generally rubber or plastic) of various sizes, which may deform on impact to spread the energy over a larger area. These rounds are intended to be fired directly at an individual;
- **Multi-Ball Rounds:** Also known as pellets. A single cartridge can contain from 2 to over 200 pellets, each varying in size from about 0.25 to over 0.75 inch (6–19mm). These rounds can be fired directly or skip-fired off a hard surface in front

of the target. They can be used to target a number of people together and are not as discriminate as many of the other rounds;

- **Fin-Stabilised Rubber Projectile:** A single rubber round with a finned tail to aid stability in flight. These rounds are intended to be fired directly at an individual;
- **Multi-Baton Rounds:** These generally consist of 3 or 5 batons in a single cartridge, generally made from rubber, wood or foam. These rounds can be fired directly or skip-fired in front of the target. As the batons spread during flight, these tend not to be as discriminate as other rounds;
- **Single Baton Rounds:** This class includes sponge and foam grenades and other rubber or plastic batons that are present as a single round per cartridge. This class also includes the current UK baton round, the L21A1, although this has not been included in this study as extensive testing has already been carried out for this round. These rounds are intended to be fired directly at an individual;
- **Encapsulated Rounds:** These include projectiles that contain a liquid, powder or other material within a protective coating or shell; upon impact, the contents should be dispersed. These are dealt with in Section 4, under the heading 'long range chemical delivery devices'.

Most of the rounds detailed above are available in a range of calibres, mainly 12 gauge, 37mm and 40mm. There are also a number of rounds available that are fired from launchers specific to that munition. Figure 1 shows a selection of various impact munitions.

FIGURE 1: ***Various Impact Rounds***

It is clear that there are a vast number of less lethal impact rounds available. Manufacturers also make many versions of each of the different types of munition. The remaining sections of this chapter provide some information regarding the performance of these rounds.

3.1 LASD/Penn State Impact Testing

In February of this year 'The Attribute-Based Evaluation (ABE) of Less-Than-Lethal, Extended-Range, Impact Munitions', prepared by the Los Angeles Sheriff's Department (LASD) in conjunction with the Applied Research Laboratory of Pennsylvania State University, was published[3]. This report detailed a study in which 80 different types of impact munitions were tested for accuracy. The tests, carried out in Los Angeles, provided a preliminary evaluation of off-the-shelf less lethal munitions to allow a side-by-side comparison of different classes of round, different calibres and different manufacturers' products.

It is important to note that only 5 rounds of each type were fired in these tests, and the authors recommended that further tests be conducted using larger sample sizes. The results do, however, give an indication of the capabilities of the various munition types. It is also worth noting that the weapons were fired by hand throughout the study by experienced LASD officers, and the weapon was not clamped. A summary of the most important points from the study is given below.

Table 1 splits the 80 rounds tested into weapon used and class of munition, using the previous definitions (the L21A1 baton round was not included in these tests). This table gives an indication of the range of munitions available and the relative proportions of each class of munition. It can be seen that, of the rounds tested, 5 used launchers other than standard weapons.

Class of Munition	12 gauge	37mm	37/40mm	40mm	Other	Total
Bean bag	10	4	3	4	0	**21**
Sock Round	5	1	0	0	0	**6**
Single Flexible Ball Rounds	0	0	1	0	0	**1**
Multi-Ball Rounds	6	5	9	5	1	**26**
Fin-Stabilised Rubber Projectile	4	2	0	0	0	**6**
Multi-Baton Rounds	1	1	3	4	0	**9**
Single Baton Rounds	0	4	0	2	0	**6**
Encapsulated	1	0	0	0	4	**5**
Total	**27**	**17**	**16**	**15**	**5**	**80**

TABLE 1: ***Distribution of Rounds by Class and Calibre***

All of the rounds were fired at a target from a distance of 21 feet (6.4m). Table 2 shows the spread (in mm) that was achieved for each class of munition within each calibre (spread is taken as the maximum distance between two shots in a grouping).

Class of Munition	12 gauge	37mm	37/40mm	40mm	Other
Bean bag	65 – 75	100-305	150 - 290	100 – 340	-
Sock Round	140 - 790	90	-	-	-
Single Flexible Ball Rounds	-	-	140	-	-
Multi-Ball Rounds	140 – 790	650 - 1150	405 - 1195	585 - 1170	215
Fin-Stabilised Rubber Projectile	75 - 255	65 - 125	-	-	-
Multi-Baton Rounds	75	330	915 - 990	380 - 1120	-
Single Baton Rounds	-	90 - 265	-	90 - 230	-
Encapsulated	100	-	-	-	90 - 240

TABLE 2: ***Spread of Rounds (in mm) at 21ft (6.4m)***

The results at 21ft (6.4m) show that the multi-ball rounds in all standard calibres and the multi-baton rounds in 37mm and 40mm calibres produce the largest spread, with a number of types producing a spread of greater than 1m at this range. This is as expected as these classes of rounds are designed to spread their impact over a larger area. The variation in spread between different devices within a particular class is also highlighted, for instance 5 different types of 12 gauge sock round that were tested produced a spread of 140mm for one type, up to 790mm for a different type of sock round. The most consistent round at this range was the 12 gauge bean bag, with 10 different types producing a spread from only 65mm to 75mm.

A number of rounds were then fired at a target from a distance of 75 feet (22.9m). Table 3 shows the spread (in mm) for each class of munition within each calibre. Only 38 of the 80 munitions were tested at this range. The numbers in brackets (n) indicate the number of each type of munition that was tested within each class.

Class of Munition	12 gauge	37mm	37/40mm	40mm	Other
Bean bag	240-915+ (n=10)	380-915+ (n=4)	530-915+ (n=1)	370-915+ (n=4)	-
Sock Round	165 – 620 (n=5)	650 (n=1)	-	-	-
Single Flexible Ball Rounds	-	-	915+ (n=1)	-	-
Multi-Ball Rounds	NR	NR	NR	NR	NR
Fin-Stabilised Rubber Projectile	190 – 380 (n=4)	495 – 545 (n=2)	-	-	-
Multi-Baton Rounds	NR	NR	NR	NR	-
Single Baton Rounds	-	280 – 405 (n=2)	-	125 – 255 (n=2)	-
Encapsulated	125 (n=1)	-	-	-	915+ (n=1)
KEY: NR indicates that no results were obtained for this class of munition. 915+ means that the spread was greater than 915mm, the maximum size of impact plate.					

TABLE 3: ***Spread of Rounds (in mm) at 75ft (22.9m)***

The results at 75ft (22.9m) highlight the inaccuracy of many of the rounds at this range; a number of rounds did not strike the impact plate, which had a diameter of 915mm. The variation in performance of different rounds within a class is also once again highlighted, for example 10 types of 12 gauge bean bags showed a variation in spread of between 240mm for one type of round up to greater than 915mm for another type.

Two of the observations made by the authors in this report are worth noting:
i) They were 'struck by the general inaccuracy of these munitions';
ii) They had observed several misfires.

A full copy of this report can be downloaded from the website:
http://www.arl.psu.edu/areas/defensetech/defensetech.html

3.2 PSDB Testing and Initial Evaluation Criteria

The purpose of the PSDB testing programme is to identify those rounds that meet the necessary requirements. It has already been demonstrated that there is a wide variation in performance of rounds, both between classes and between individual rounds within a class. It is necessary, therefore, to verify that the rounds can perform to the agreed requirements.

The initial evaluation criteria for this type of munition, which have been agreed with the steering committee, are summarised below:

- The device should be accurate and suitable for use within the range 1-20m, and up to 50m if possible;
- Accuracy is defined as the ability to hit a 400mm wide x 600mm high target: should achieve a 95% probability of hit with a bench-mounted system and an

85% probability of hit when fired by an officer dressed in appropriate patrol/public order dress and equipment, from the standing and kneeling positions;

- The device should have a single point of aim;
- The round should not be of greater energy than that of the L21A1 baton round at 20m;
- Any platforms for delivery are acceptable other than conventional firearms, for example a 9mm handgun or an MP5 (note: a 12 bore shotgun is an acceptable platform);
- The round is intended to deliver a blunt impact and not to penetrate the outer skin;
- The round should consistently strike the target in the manner in which it was intended.

These initial criteria are likely to be refined further as more is learned about the capabilities of the various rounds.

3.2.1 Procedure

PSDB have had positive responses from a number of manufacturers producing a range of impact rounds, interested in submitting products for evaluation. Some of these manufacturers produce a wide range of different classes of impact munition, of varying calibres. PSDB are carrying out a number of basic tests on all submitted less lethal impact munitions. These are designed to measure a number of different characteristics of the rounds and to address some of the initial evaluation criteria:

- **Accuracy** – this is recorded by measuring the spread of the rounds at various distances (spread is taken as the maximum distance between two shots in a grouping). The rounds are fired from a suitable weapon that is securely clamped and mounted. Generally, 10 rounds of each munition are fired at each distance (5, 10, 15 and 20m) for the initial tests.
- **Kinetic Energy** (KE) – the velocity (v) of each round is measured at the muzzle and the target. Using the mass (m) of each round, kinetic energy values can be calculated for each munition at the muzzle and the target ($KE = ½ mv^2$).
- **Orientation of the round on impact** - with the use of a high-speed video camera, it is possible to record the orientation of the round as it strikes the target. This is important as, for example, problems have been noted with bean bags that did not open correctly in flight and struck edge-on, thus leading to a higher energy density (i.e. energy per unit area) than intended and the possibility of penetration.
- **Reliability and Consistency** - throughout these tests, a general assessment can be made of reliability and consistency and any problems noted, for example any misfires or variations in muzzle velocity.

As mentioned previously, the testing of these rounds is carried out in stages. The initial stage involves the testing of products to determine accuracy, range, velocity, kinetic energy, orientation on impact, consistency and reliability. In these initial tests, generally only ten rounds of each type are fired in order to obtain some basic information about their performance. Many more rounds would need to be fired to obtain more statistically significant results and this will be carried out if initial results are promising.

3.2.2 Results

These results are discussed below using the classes defined earlier.

i) Bean Bags

A number of bean bags have been tested so far, of rectangular, square and circular shape. With the square and rectangular rounds, the high speed video camera footage showed that many of the rounds hit the target edge-on while some were still folded in half when they struck the target. This leads to a much higher energy density (energy per unit area) at the target than the intended presentation, i.e. the bag striking face on with the largest surface area hitting the target. This variation in impact energy affects both the operational performance of the round and the degree of risk to which a person is exposed; indeed a number of deaths have been associated with the penetration of bean bags into the body. This effect has been observed elsewhere and is one reason why manufacturers have developed the sock round.

As this effect is well known, and has occurred with a number of different rounds which PSDB have tested, it can reasonably be assumed that the effect is inherent to all bean bags of this type. This does not meet the part of the initial evaluation criteria for impact devices which states that “the round should consistently strike the target in the manner in which it was intended”. For this reason, **square and rectangular bean bags will no longer be included in the PSDB test programme**.

Similar initial tests carried out on circular bean bags show that some varieties are not folded in the cartridge in the same way that the square and rectangular versions are. This means that they may not be subject to the same problems with orientation as previously identified with square and rectangular varieties. Further testing of these types of rounds is required.

ii) Sock Rounds

The sock rounds that have been tested so far have passed the basic requirements for accuracy at 20m. In terms of the orientation of the rounds on impact, the high speed video camera footage showed that, for most of the rounds, the ‘stabilising’ tail was generally not trailing behind the round as expected but was usually standing straight up or hanging below the main body of the sock round. It may be that this behaviour will not cause any undesired effects, and therefore further testing of these rounds will continue.

iii) Multi-Ball Rounds

The rounds of this class that have been tested spread quite considerably when fired and are very inaccurate. This is an inherent property of this class of round as they are designed to spread their impact over a larger area and may even be used to target a number of people at one time. This characteristic does not meet with the part of the initial evaluation criteria for impact devices which states that “the device should be accurate and suitable for use within the range 1-20m, and up to 50m if possible”. For this reason, **multi-ball rounds will no longer be included in the PSDB test programme**.

iv) Multi-Baton Rounds

No multi-baton rounds have so far been submitted to PSDB for testing. These rounds have the same inherent characteristics as the multi-ball rounds, i.e. they are designed to spread after firing and impact over a larger area. It is highly unlikely that this class of round will meet the basic accuracy requirements, however a selection of products will be tested, if submitted, to verify this.

v) Fin-Stabilised Rubber Projectile

A number of products of this class have so far been tested at PSDB. The performance of these rounds varied considerably between individual products, but some have met the basic requirements for accuracy and orientation on impact at 20m. These rounds will go through to the second stage of testing which requires more rounds to be fired to provide statistically significant results. The variation in performance of these rounds demonstrates the importance of submitting each of the products for testing in order that the better performing rounds can be identified and separated from those with poor performance.

vi) Single Flexible Ball Rounds

All of the rounds within this class that have been submitted have failed to meet the necessary basic accuracy requirements at 20m and will not go through any further stages of testing. This could be due to the quality of the submitted products, rather than an inherent problem with all single flexible ball type rounds, therefore initial testing will continue on any other products of this class that are submitted.

vii) Single Baton Rounds

Only one product of this class, apart from the L21A1 which is mentioned in Section 3.3, has so far been found to meet basic requirements for accuracy and orientation on impact at 20m. This round will therefore go through to the second stage of testing, which requires more rounds to be fired to provide statistically significant results. Testing will also continue on any other products of this class that are submitted.

3.2.3 Further Work

It can be seen that a number of products have been identified as meeting the basic requirements for accuracy and orientation of the round on impact. This is based on ten rounds of each type fired from a clamped and bench mounted weapon, i.e. under ideal conditions. These tests are necessary to allow a scientifically accurate comparison between different types of rounds. The tests are also relatively easy and less time consuming than others, and can therefore be applied to the volume of rounds received for initial testing. Further tests are, however, necessary to provide more realistic and statistically significant results. These will be carried out on those products that have passed the initial stages of testing.

The types of further tests to be carried out are summarised below:

- Multiple shots (50) fired from a bench mounted system for each round to ensure reliability;
- Testing of rounds at distances greater than 20m;
- Rounds subjected to extremes of temperature then assessed for performance and accuracy;

- Point of aim/point of impact data obtained for rounds fired at a range of distances from an appropriate weapon;
- User handling trials to assess the performance of the weapon system when hand-fired at stationary and moving targets and under non-ideal conditions;
- Further multiple shots (hundreds) fired from bench mounted and hand held systems to obtain statistical values for accuracy;
- Additional tests as required by the medical committee for assessment.

This series of tests is written in an order which allows the less expensive and time consuming tests to be carried out first, with rounds being progressively dismissed if they fail to meet the requirements at any of the stages. For example, if a round fails to meet the necessary criteria after 50 bench-mounted shots are fired, it will be dismissed from the testing and will not go through the extreme temperature tests.

3.3 L21A1 Baton Round

Although recommendation 69 of the Patten report called for “an acceptable, effective and less potentially lethal alternative to the Plastic Baton Round”, the round that is currently available has been used operationally and a few of its characteristics are worth mentioning here.

3.3.1 Background

The L21A1 round was introduced in June 2001 following an extensive development programme. The round is part of a system that includes the L104 37mm baton gun fitted with a new optical sight. The use of this system will have significant accuracy advantages over the previously used L5A7 with the L104 fitted with iron sights. The statement of the independent medical committee[4], who reviewed this system, concluded that the new system (in comparison to the previous system) will, by virtue of its increased accuracy, reduce the incidence of people other than the targeted individual being struck directly. This will also reduce the incidence of direct head or upper thorax impacts and thereby reduce the incidence of life-threatening injuries, however very serious head injuries will still occur should the round strike the head. These statements assume that both systems are being used according to the guidelines.

3.3.2 Performance of System

The grouping of rounds is exceptionally good, surpassing anything else tested to date. At 20m rounds are grouped well within a 300mm circle and extending out to 50m still fall within the required target area. This is illustrated in Figure 2, which shows a grouping from a typical proof firing of 30 rounds at 50m. The target size is 250mm wide x 750mm high and the rounds have fallen within an area of approximately 150mm wide x 350mm high (well within the desired values as detailed in the initial evaluation criteria, Section 3.2).

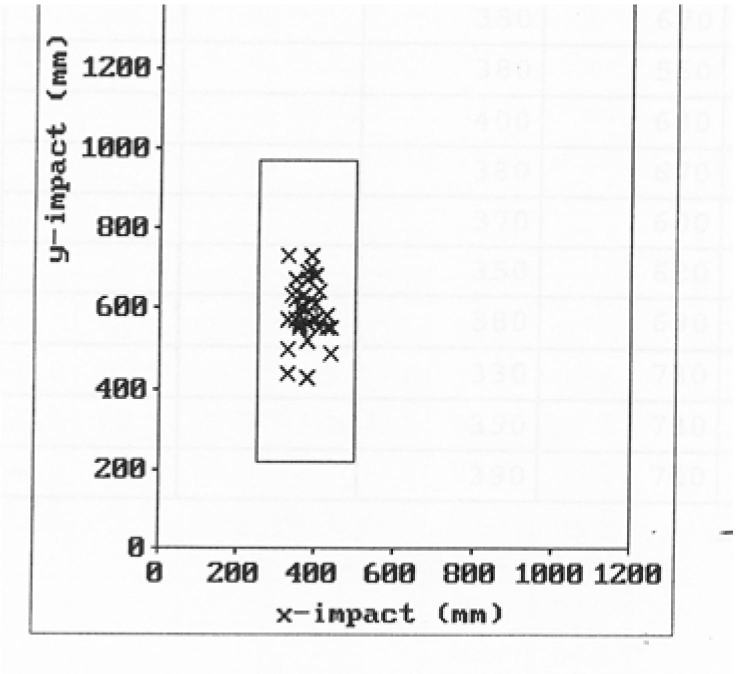

FIGURE 2: ***Grouping of L21A1 at 50m***

3.4 Operational Information

Impact munitions are a widely used category of less lethal device throughout the world and different countries often use different types of round. Impact projectiles were first introduced in the United States for operational purposes in police departments during the 1960's. A wide variety of rounds have been used throughout the various forces with bean bags being the most widely used round and baton rounds also proving very popular. Encapsulated rounds filled with chemical irritant have also been used. Some police forces in Canada have also used each of these rounds.

Some Australian police forces also provide their Tactical Operations Units with twelve gauge bean bag rounds. These have been used operationally but other rounds are now being researched as the results from the bean bags have been 'inconclusive'.

Baton rounds were first introduced into Northern Ireland in 1970 and have been associated with a number of fatalities since that time. More than 125,000 baton rounds have been fired since they were introduced and this has resulted in 17 fatalities and 618 reported injuries; there have been no fatalities since 1989. There have been a number of changes made to the baton round since 1970. The L104 weapon was introduced in 1994 and no fatalities have occurred since this weapon was introduced.

Over seventy L21A1 baton rounds have been fired in Northern Ireland this year. It is worth noting that this round is only available to the UK military and police and is not available to any other agencies, although some have expressed an interest in using it.

3.5 Conclusions

The initial testing phase for kinetic energy rounds, involving testing of all submitted products for accuracy, range, velocity, kinetic energy, orientation on impact, consistency and reliability, is almost complete. Many rounds are highly inaccurate and failed to meet even the basic accuracy requirements; these products have been dismissed from further stages of testing. Additionally, all square and rectangular bean bags and multiple ball rounds have been dismissed from further testing due to inherent problems with the rounds.

A number of products have been identified which meet the basic accuracy and orientation requirements at 20m. These rounds will be subjected to more detailed testing (Phase 3 of the project) to assess various other aspects of their performance. Any rounds failing to meet the necessary criteria in future testing stages will be dismissed from all subsequent testing.

Those products that pass all stages of testing will be passed to the medical committee who will assess the effects they are likely to have on the human body.

4 LONG RANGE CHEMICAL DELIVERY DEVICES

The report in April[2] highlighted a number of chemical irritants that are available for use in various countries throughout the world. The most widely used of these are CS (o-chlorobenzylidene malononitrile), OC (oleoresin capsicum, also known as pepper), PAVA (pelargonic acid vanillylamide), CN (chloroacetophenone) and CR (Dibenz (b.f.)-1:4-oxazepine). CS is currently the most widely used chemical incapacitant within the UK police and the one that will be considered in this section.

CS is a peripheral sensory irritant that works as an incapacitant by producing irritation of pain receptors in the skin and production of a burning sensation over exposed areas. Secondary symptoms include involuntary blinking of the eyes, disorientation, running of the eyes and nose, sneezing and coughing.

The April report also highlighted a number of ways of delivering a quantity of chemical irritant to a subject. These are summarised below:

- Grenades and Projectiles – This method is indiscriminate and is used either for crowd control or to fill a room or vehicle with the irritant. The range of these devices can vary from 10m up to 300m.
- Personal Incapacitant Sprays – Hand held CS sprays have been widely used by police forces in Great Britain since 1996. These sprays are very discriminate and have a maximum range of 3-4m.
- Long-Range Discriminating Devices – These devices should be capable of delivering a quantity of chemical irritant discriminately to one individual at a range greater than that possible with the hand-held sprays.

It is the long-range discriminating devices which have been selected as a priority for further research and for which there is the greatest requirement (the other two types of device are currently available and have been fully evaluated in previous years[5,6]). This type of device tends to combine kinetic impact effects with chemical irritant effects to produce incapacitation of the target. The degree of each effect varies with each system and is dependent on attributes including the velocity, size, shape and design of the round as well as the quantity of irritant contained within it.

This class of round, which has also been described as an encapsulated round, includes projectiles that contain a liquid, powder or other material within a protective coating or shell; upon impact, the contents should be dispersed. These rounds may provide some degree of incapacitation by their direct impact effects, however the material contained within the round, generally a dye, malodorant or chemical irritant, is also designed to have an additional effect. A number of impact devices are currently available, or are being developed, to contain one or more of these materials.

Most of the rounds are available in a range of calibres, such as 12 gauge, 37mm and 40mm. There are also a number of rounds available that are fired from launchers specific to that munition.

As with the impact devices, a number of initial evaluation criteria have been agreed with the steering committee and applied to long range chemical delivery devices. These are shown below (note, these devices can be split into two types: those that are intended to strike the target directly and; those that are intended to strike the ground in front of the target):

i) Subject Specific Rounds:

- The device should be accurate and suitable for use within the range 1-20m if possible, and ideally up to 50m;
- Accuracy is determined by the ability to hit a 400mm wide x 600mm high target: should achieve a 95% probability of hit with a bench-mounted system and an 85% probability of hit when fired by an officer dressed in appropriate patrol/public order dress and equipment, from the standing and kneeling positions;
- The incapacitant ‘cloud’ must rise to meet the face of the target;
- The distribution of the incapacitant ‘cloud’ must be greater than the grouping capacity of the rounds when bench fired at a specific range;
- Secondary missiles should not cause serious injury;
- Minimum potential risk from hazardous debris;
- The round should consistently strike the target in the manner in which it was intended.

ii) Multiple Subject Incapacitant Rounds:

- The round should strike a point on the ground within a $1m^2$ area of the point of aim;
- The incapacitant ‘cloud’ must rise to meet the face of the target;
- The incapacitant ‘cloud’ should be no greater than 3m in diameter;
- Secondary missiles should not cause serious injury;
- Minimum potential risk from hazardous debris.

Once again, these initial criteria are likely to be refined further as more is learned about the various rounds’ capabilities.

Section 3 highlighted 5 rounds of this class that were included in the Attribute Based Evaluation[3] for accuracy. To summarise these tests:

- The 12 gauge encapsulated round gave a spread of 100mm at 21ft (6.4m) and 125mm at 75ft (22.9m);
- The other 4 encapsulated rounds, which used launchers specific to that projectile, gave a spread of between 90mm and 240mm at 21ft (6.4m);
- When one of these projectiles was fired at 75ft (22.9m), it gave a spread of greater than 915mm.

4.1 PSDB Testing and Initial Evaluation Criteria

PSDB are carrying out tests on this class of round to identify those products that meet the necessary requirements. The submitted products are put through a series of initial tests very similar to the kinetic energy rounds. These tests are used to assess various characteristics of the rounds such as accuracy, range, velocity, kinetic energy, orientation on impact, consistency and reliability. Subsequent testing will also follow much the same method as that discussed previously for impact munitions.

Only a limited number of products of this class have so far been submitted to PSDB for testing, despite a large number of manufacturers having been contacted. None of these products have met the basic accuracy requirements at 20m, nor indeed even at 15m. Further rounds, which appear to have greater potential than those tested, are currently in development and some will be available soon for testing. One such round, the Ring Airfoil Projectile, is still in the development stages and will not be available for initial testing for some time. Efforts are also continuing to identify additional manufacturers that may be interested in providing their rounds for assessment.

5 WATER CANNON

Water cannon have been selected for further and immediate investigation and work is proceeding on the investigation of operational issues and technical specifications of water cannon. Water cannon were considered for use in the UK in the early 1980's and the Home Office conducted extensive research into the feasibility of using them at that time. A summary of this work is given below, along with the reasons why water cannon were not adopted at that time. This is followed by a summary of the work that is currently being conducted in relation to water cannon.

5.1 Summary of Home Office Work on Water Cannon, 1981-1987

Following the disturbances during the summer of 1981, the then Home Secretary authorised the use of plastic baton rounds and CS pyrotechnic irritant devices for use as a last resort in situations of extreme public disorder. He also initiated an investigation into the feasibility of water cannon for use in these situations and a large programme of work was set up to explore this issue.

Members of the Home Office Police Technical Services Division (PTSD) visited police forces in Belgium, Holland and West Germany in August 1981 to determine the effectiveness of water cannon for riot control and to examine the type of equipment used by the police service in these countries. They found that six models of water cannon were used operationally in the three countries. In most models examined, the jets of water did not have the force and range required to keep rioters at a distance or to disperse a crowd; they achieved little more than making rioters wet. However it was felt that, even when the jet power was not sufficient to keep back rioters, the water cannon were still of some use in that they attracted missiles and hence took some pressure off the police. The use of a large advancing vehicle would also cause the crowd to retreat and hence ground could be gained.

The prototype MK9 under test in Germany had a higher jet power and was capable of preventing the approach of rioters closer than about 30m. The tank capacity was also larger to allow for the higher pump rate. This model was extremely well protected against attack as it was very high with smooth sides and possessed no hand or foot holds, making it very difficult to climb onto while moving. This model was the only one thought capable of driving rioters back and ‘distancing’ them from the police.

PTSD concluded that water cannon are only effective when used in pairs. It was also noted that no continental studies had been undertaken on the danger of injury to demonstrators from the use of high-pressure water jets.

Water Cannon had been used in Northern Ireland in the early 1970’s, however problems were noticed due to poor manoeuvrability, difficulty in obtaining adequate water supplies, inadequate protection and small capacity. A (medically safe) dye added to the water was also found to look like blood when seen on the television.

In September 1981, based on the findings from the initial visit, the Home Office Scientific Research and Development Branch (SRDB, now PSDB) provided a draft specification for a UK water cannon incorporating all of the best features seen during the visit. UK manufacturers of fire fighting vehicles were invited to meet the UK police specification which sought performance equal to, if not better than, the West German MK9 water cannon.

A committee was set up to develop a prototype water cannon for use in the UK. Two vehicles were built, compatible operationally but containing different features to allow comparisons to be made. They were delivered for evaluation in the summer of 1983 and underwent extensive mechanical and road tests. The opinion of the crews working the machines was taken into consideration during their evaluation. The machines' capabilities were demonstrated to senior police officers.

The committee made recommendations for further work on various parts of the machines and advice on operational issues. One of the recommendations made was that a medical evaluation of the risk of injuries from the use of water cannon should be carried out before the vehicles were operationally deployed. The lack of medical information at that time made it impossible for the committee to provide a firm recommendation about water cannon, although the exercises that had been carried out indicated that police use of this equipment in situations of public disorder was a viable proposition.

In 1984, the Chemical Defence Establishment (CDE) at Porton Down provided a tentative assessment of the hazards of the Home Office water cannon, making predictions that the HO water cannon had the potential for significant risks of both primary injury to the trunk and of secondary skeletal injuries.

To avoid such injuries the then Home Secretary decided that the use of the water cannon in the ‘spray mode’ (i.e. firing over the heads of rioters) should be evaluated instead. This method of spraying would reduce the force per unit area and hence injury potential. The original prototypes were modified to incorporate this; the end of each monitor (or spray nozzle) was fitted with a mechanical device to ‘spread out’ the jet over a larger target area. The possible use of additives, namely dye and/or CS was considered and a system to allow the use of dye or irritant was fitted to each prototype (dye was ruled out for operational reasons at an early stage).

The spray mode was however found to be ineffective and other inherent drawbacks with water cannon were identified, such as the quick exhaustion of the water supply; the need to protect refill sources; their recommended usage in twos and threes; their lack of manoeuvrability; and their vulnerability to attack.

As a result, the Secretary of State produced a statement in 1987 stating that any benefits in the deployment of water cannon would be outweighed by their operational and tactical disadvantages as outlined above and that it was not proposed to add water cannon to the range of police equipment. Any developments, including the use of water cannon overseas, would continue to be monitored so that the position could be reviewed if necessary.

5.2 Current Water Cannon Work

5.2.1 Technical Specifications

A number of international manufacturers have been contacted and asked to provide technical specifications of their vehicles. To date, a limited number of responses have been received. A summary of the technical specifications of currently available vehicle mounted water cannon is provided below.

i) Vehicle Size

Water cannon tend to be large vehicles, with their size largely determined by the capacity of the water tanks on board. Length varies between 6 and 9m, height from 3.6 to 4.2m, and width is generally about 2.5m. Their weight ranges from 18,000kg up to 21,000kg when full. A typical vehicle is shown in Figure 3.

FIGURE 3: ***A typical vehicle mounted water cannon***

The large size of the vehicles can prevent access to some narrow streets. Some forces use hoses attached to the sides of their water cannon to allow water to be used in alleyways and some buildings.

ii) Capacity, Flow Rate and Pressure

The capacity of the tank is the most obvious limiting factor in the use of water cannon. Vehicles tend to hold between 4000 and 9000 litres of water and, at maximum flow rate and with all jets operating, the total water capacity can be used in as little as 4 minutes. Flow rates range from 250 to 1200 litres per minute per monitor and pressure varies between 5 and 25 bar (500-2500kPa).

Firing the cannon in short bursts preserves water and allows assessment of the effectiveness of the water cannon during operation. Some models of water cannon are also available with a "pulsed jet" firing system, which allows conservation of the limited water supply. These vehicles can fire in three different modes:

- Short pulse - a single burst of 5-15 litres of water is fired;
- Automatic pulse - 40 to 70 pulses per minute;
- Continuous Stream - pumping around 900 litres per minute.

Most vehicles have an additional tank to hold either a dye or an irritant additive, which is mixed with the water stream. The capacity of this tank tends to be between 132 and 190 litres, and more than one tank may be present in a vehicle. The concentration of dye or irritant in the water stream can usually be varied by controls within the crew cabin.

iii) Accuracy

Aiming of the monitors requires practice. Visibility from the crew cabin can be limited and the cannon operators are usually seated in the rear of the cabin. They rely on directions from the driver and commander in the front of the cabin to target and direct the water stream. Visibility is further decreased when the monitors are firing.

With practice the crew should be able to effectively target individuals in a crowd, although the width of the water stream prevents the water cannon from being a fully discriminate weapon. Figure 4 shows the cannon being used for practice in a precision shooting exercise.

FIGURE 4: ***Precision Shooting Exercise***

iv) Refilling

If the water tanks are emptied during operational use then refilling will be necessary. Most of the available vehicles are capable of refilling at water hydrants or from open water sources such as rivers and lakes. The refilling operation itself may take 10 minutes to complete, with additional time required for setting up refilling equipment.

Water cannon crews are trained to carry out the refilling procedure. Another option is to have a second team ready at the refilling point who will connect the hoses and carry out the refill and clear away equipment, allowing the water cannon to leave and return to operation more quickly.

v) Range

The force of the water jet decreases with distance from the vehicle. At close ranges and high pressures there may be risk of serious primary or secondary injuries, while at long ranges the water may not be a sufficient deterrent to protesters.

Most manufacturers claim a range of 40-60m for the water jet. As an example, a total range of 60m may be possible when both monitors are fired together, although at this range the pressure of the water may be insufficient to push back or hold a protester; it may, however, act to deter any closer approach. With the same system, a person could be held at a distance of 40m.

vi) Armour and Protection

Armour levels vary from vehicle to vehicle. Protective features may include the following:

- Steel body panels;
- Fixed polycarbonate glazing, fitted as standard to most vehicles;
- Water spray systems on the vehicle body, windscreens, roof and wheel arches to protect against petrol bombs;
- Pressurised cab to prevent penetration of smoke and gas;
- Barbed wire on the top of the vehicle;
- Smooth outer panels and the absence of foot/hand holds to prevent protesters from climbing onto the vehicle;
- Run flat tyres;
- Protective grille screens on windows.

vii) Additional Equipment and Requirements

Vehicles may be equipped with video equipment to improve visibility from the cab and assist in evidence gathering. A public address system may also be used to warn the crowd of the use of the water jets. Radio equipment for communication between crew and officers on foot may also be available in some models.

The specialist nature of these vehicles means that dedicated technical support will be required to provide maintenance and ensure the machines remain in a working condition. A technical officer is often present as a member of the vehicle crew.

5.2.2 Portable Water Cannon Systems

Portable water cannon offer the obvious advantage over vehicle mounted systems in that they are much smaller and therefore more manoeuvrable. These types of device tend to hold the water in a pack which is strapped to the users back, or in a trolley that can be wheeled along by the operator.

One system, primarily designed as a rapidly deployable fire-fighting tool, consists of a 13 litre water reservoir, a compressed air supply and an impulse gun. The 13 litre tank is strapped to the back of the operator who then fires the highly pressurised water at the target area using the impulse gun. The water is discharged as small, high velocity ‘packets’, which use the minimum amount of water therefore helping to conserve the supply.

The overall size of the backpack is 360x260x625mm and it weighs 10.3kg when empty, 23.3kg when full. The impulse gun uses 25 bar compressed air as the power source. It is 800mm in length and weighs 6.8kg. When the valve opens, the compressed air forces the water out of the barrel at high velocity within milliseconds; this is usually accompanied by a loud noise. A choice of three gun barrel sizes is available filled with one, half or quarter litre charges of water. The maximum shot range is said to be 16m, with the width of the spray being 3m at a distance of 5m from the gun.

Trolleys are also available with a capacity of 35 or 50 litres. This unit is assembled on a wheel base with brackets for the impulse gun, the air cylinder and a 15m coaxial hose.

This technology has also been incorporated into a small vehicle. The vehicle is equipped with a 1000 litre water tank and two 12 litre impulse guns. The maximum range of the water shot is said to be 64m and the operating pressure of the system is 25 bar (2500kPa).
Figure 5 represents a portable water cannon system that is similar to the one described.

FIGURE 5: ***Portable Water Cannon***

5.3 Health and Safety Issues

It is accepted that water is capable of inflicting serious injury. These injuries may be classified as primary or secondary injuries. Primary injuries are those resulting from the distortion of the body wall by the impact of the jet. These injuries are likely to occur within the first 0.1-0.2 seconds of impact and may include bruising of internal organs. Secondary injuries occur as a result of the acceleration of the body as a whole resulting in collision with hard surfaces. These injuries are largely skeletal, such as bone fractures. Other injuries could be caused by debris, accelerated by the force of the water, striking the person.

The effects of high-pressure water on the human body have not been extensively studied. The internal kinetics of water jets are complicated, the impact of a jet of water will have a different effect on the human body than a hit from a solid object with similar kinetic energy and must be considered differently. Different models of water cannon have different characteristics, such as coherence of water jet, water pressure, etc. This means that the operational effectiveness and the risk of injury will vary depending on the model used.

A small number of papers[7,8] have been published which describe eye injuries caused by high-pressure water jets and fire hoses. The fire hose operated at a pressure of 10 bar (1000kPa), which is within the range of pressures attributed to water cannon; the distance from hose to target was less than 5m.

5.4 Operational Issues

Information is being gathered from police forces with experience of the use of water cannon in public order situations. Visits have been made to Northern Ireland, Belgium and Germany to obtain information on their experiences with water cannon. Contacts have also been made in other countries and communication will continue to allow more information to be gained.

5.4.1 Northern Ireland

The RUC in Northern Ireland has operated two vehicle mounted water cannon on loan from Belgian forces for the past three years. In their first year the water cannon were not deployed, in the second year they were deployed and used twice and in this third year the cannon have seen extensive use.

The water cannon are currently deployed in pairs with one water cannon used up front while the other is in reserve behind. The vehicles can change position with one covering while the other refills, for example. A crew of five people is used to operate the cannon. The water cannon are effective in dispersing crowds and keeping people at a distance from the police lines, with an effective distance of approximately 20-30m.

The water cannon are thought to fulfil a useful role and are an important resource for public order policing, although the model currently used is felt to be lacking in a number of areas. These include the age of the vehicle (affects vehicle maintenance); the vehicles' large size, which restricts their movement and deployment and prevents access to some narrow streets; limited space and visibility within the cab; lack of sufficient protection from attack and; limited operation before refilling is required.

While some of these factors are inherent to all vehicle mounted water cannon, others may be improved by using newer models of cannon with different features such as a pulsed rather than a continuous stream of water. Other features that may be desirable include the use of camera equipment, both for evidence gathering and in helping to aim the cannon jets.

5.4.2 Belgium

The Belgian water cannon are 14 years old and were manufactured to a specification drafted by the Belgian Gendarmerie. The vehicles cost around £250,000 to £300,000, although this is dependent on the specification and the number of cannon required. The Belgians have used the water cannons successfully in many operations since their introduction, and have not reported any fatalities or injuries connected with their use.

The Belgian Gendarmerie has a total of 24 fully trained crews and 18 water cannon vehicles. At least 10 of these vehicles are kept operational at any one time, allowing necessary repairs and servicing to be carried out and to allow for regular crew training. A crew of 5 people is used to man the water cannon, each of whom undergoes specific training prior to operational deployment. Vehicles operate as a single unit, supported by officers on foot.

At maximum flow rate using both jets, the operational time is limited to 4 minutes, however the operators are trained to use the water sparingly, firing in bursts of 10 to 15 seconds then judging the response before firing again. This preserves the water supply and allows an assessment of the effectiveness of the water cannon; the Belgians have not experienced any problems with the capacity of the water cannon. The length and pressure of the bursts may be gradually increased until the crowd complies with police instructions. The jets are able to fire water up to 60m when used simultaneously and to keep a person at a distance of 40m.

The vehicles have a number of features to protect them from attack. They also have a number of other items of equipment fitted such as: a video monitor and a number of cameras; a public address system; search lights; a double sound horn coupled with blue lights; intercom and radio systems to allow communication of the cabin crew with ground officers, central command and other deployed units. The Belgian water cannon also have the facility to add chemical irritants or dyes to the water supply, although these measures have not been used in practice.

5.4.3 Germany

There are 117 water cannon in service across Germany, operated by the 16 regional police forces. 30 cannon also belong to the federal police. Many of these are older models but a number are of a newer variety, recently introduced. Each vehicle costs approximately £300,000.

The vehicles have a crew of four people. A minimum of two vehicles are deployed to an incident and each will have a unit of nine officers on foot to provide protection. An extinguishing agent (Expyrol) can be injected into the water jet to fight fires and CN is also carried as an irritant additive. The water jets can be sprayed up to 60m. The vehicles have a number of measures to protect them against attack including no foot holds or hand holds, heavy-duty polycarbonate windows and run-flat tyres.

Water cannon were used in a number of German cities to disperse May Day protesters this year, and also during March at Dannenberg against nuclear fuel shipment protests. 30 vehicles were also assembled at the Gorleben rail terminal, the intended destination of the nuclear waste flasks.

A death was reported in Germany relating to water cannon. A person reportedly fell under the wheels of the vehicle; no injuries resulting directly from use of the water jets have been reported.

5.4.4 Other Use of Water Cannon

There are four water cannon in the Netherlands, two in Amsterdam, one in Den Haag and one in Rotterdam. These are all of an older type, although they are now being replaced by newer models.

France has seven water cannon. Three of the new generation cannon are in Paris, four older style models are used in other areas.

The Swiss police have recently purchased the same models of water cannon as used in Germany.

The prison service in England and Wales has one of the portable water cannon systems available, but has never used it. They consider its primary role to be for use in hostage situations, although they do not intend it to be fired directly at a person. Rather, it is intended as a means of distraction by firing against a wall or ceiling and using the effects of the water and the loud noise.

6 ELECTRICAL DEVICES

This section includes any device that uses the effects of electricity to incapacitate the target. There are a variety of different devices available but their principle of operation is the same. They are battery powered and use a low current, high voltage impulse shock to provide incapacitation. The electrical stimulus delivered by the device temporarily interferes with the normal electrical signals generated by the human nervous system. Incapacitation by electrical means appears to offer a virtually instantaneous method of incapacitation with almost instant recovery, although some questions remain on delivery methods and on health effects.

6.1 Tasers

Taser devices operate in the following way: a cartridge is attached to the front end of the weapon, which contains two barbs (the electrodes) each of which is attached to a coiled length of wire. The barbs are fired and attach themselves to the skin or clothing of the targeted individual. When the barbs attach themselves to a person, a current can be sent down the wires and through the person’s body between the two barb points. Figure 6 shows a selection of models of taser that are currently available.

FIGURE 6: ***Selection of Currently Available Models of Taser***

6.1.1 Taser Properties

There are a few different suppliers of tasers and each of their models differs in some way. In many respects, the devices made by each of the manufacturers are very similar as they are essentially designed to do the same thing. The main similarities between current models of tasers are:

- The device consists of a cartridge attached to a hand-held battery operated unit. When fired, it propels a pair of barbed darts attached to two trailing wires at the subject. Once contact is made, it begins discharging a metered and pulsed current through the subject's body resulting in involuntary muscle spasms and severe loss of motor control.
- The current maximum range of any model of taser that we know of is 21ft (6.4m), which is the maximum length of wire in the cartridge. 15ft (4.6m) cartridges are generally also available.
- Most companies now provide new higher powered tasers (up to 26W with a reported pulse energy of 1.4-1.8 Joules) as well as the older 5-7W systems. These higher powered tasers only came into operational use in 1999. This will affect the amount of operational information that can be used to predict the likely risks associated with these devices.

There are also a number of differences between different companies' products that may affect the users' decision as to which one is most suitable. These differences are summarised below:

- Some models are single shot only, i.e. only one cartridge can be inserted at any time, and this must be removed before a new cartridge can be inserted. Other models allow two cartridges to be inserted together, resulting in an immediate second-shot capability if required (note: with all models of taser, multiple discharges of electricity can be applied to the subject using the same initial cartridge, providing both barbs are still suitably attached to the subjects body/clothing);

- Some models of taser resemble a handgun (see Figure 6);
- Models are available using single laser sights that are intended to show where the top barb will land on the target. Others use dual laser sights, which are intended to provide a better judgement of distance and dart angulation by showing where both barbs will land;
- A data port is available on some models, which can be plugged into a computer, with the appropriate software, and downloaded to give information on how often the taser had been used and the time duration of every activation. A remote firing capability may also be possible. Other models do not have this capability;
- Probe-like connections are available on some models, which provide a touch stun capability at distances of up to 3ft (0.91m);
- Some models can also be used in 'stun-gun mode', which does not require the use of a cartridge. This involves using the electrodes on the taser to touch directly against the subjects' body;
- Some models provide a continuous timed burst of electricity when the trigger is pulled, although it may be possible to stop this at any time by flicking the safety switch. Other models require the firer to keep their finger on the trigger for the entire time that the electricity is required to flow;
- Some types of cartridge use a rifle primer as the propellant while others use compressed nitrogen;
- Different cartridges have different angles of separation between the barbs. This means that, at a given distance, some barbs will have separated further than others – this can have implications on the maximum and minimum effective range of the devices;
- After being fired, some cartridges will release a large number of small, confetti-like pieces of paper with the serial number of that particular cartridge printed on them. This helps provide evidence of the use of a particular cartridge at a scene.

In 1999, Sgt. Darren Laur of the Victoria Police Department, Canada, published an 'Independent Evaluation Report of Taser and Air Taser Conducted Energy Weapons'[9]. This report is an unbiased assessment and comparison of a number of models of taser available at that time; it discusses the strengths and weaknesses of each of the models (a full copy of the report can be found at http://www.airtaser.com/laur/report.html). It is worth noting, however, that although only two years old, this report is already out of date as a number of additions have been made to the available products since its publication.

6.1.2 Taser Operational Issues

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

i) Batteries

Different models of taser require different types of batteries, usually either lithium, 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.

The voltage rating and current delivered vary with different types of battery, so the output power produced will also vary. This will affect the amount of electricity that is passed through the target. Higher powered batteries will produce a higher spark rate compared to lower powered batteries.

The performance of the different types of batteries with continuous use also varies. For instance, the performance of alkaline batteries declines steadily throughout the lifetime of the batteries, with the voltage dropping with every use. With rechargeable batteries, however, the voltage and therefore performance remains essentially constant until the batteries are almost exhausted, even after multiple use, at which point there will be a rapid decline in power.

These effects can be observed by firing two of the same models of taser side-by-side, one powered by alkaline batteries and one by rechargeable batteries. With continuous cycles, the spark rate of the rechargeable batteries 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 performance of different types of batteries also varies in cold conditions. Alkaline batteries are affected much more by the cold than rechargeable batteries. This will result in a lower spark rate, and subsequent lower power output, than at room temperature.

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.

Rechargeable batteries offer a number of advantages over other types of battery, however they do 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 – one manufacturer recommends doing this every two weeks.

ii) Effectiveness

John Cover built the first taser prototype in 1970. The name taser was chosen as an acronym for “Thomas A Swift’s Electrical Rifle”, after the Tom Swift fantasy stories. At this time, North American law enforcement agencies did not show much interest in the device and it was sold mainly to the civilian market. In 1976, some American police departments began successfully using the taser, which led to further interest by other police departments, and a growth curve within the American law enforcement community has existed ever since. Today, hundreds of police departments in the United States use taser technology (note: there are approximately 17,000 police forces in North America). There have been at least 10,000 operational deployments of the device. Canadian police forces first began using tasers in December 1998, and an increase in use and sales has also followed there.

Effectiveness ratings for the 5-7W systems have been quoted as between 85% down to as low as 50%. It was found that 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 expected 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, providing of course that the barbs attach.

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. Tests were recently carried out in Canada, using volunteer police officers armed with firearms loaded with blanks, who were subjected to the effects of a higher powered taser. The objective of the exercise was to determine whether the officers were still capable of discharging their firearms. It was found that, often, the officers were able to voluntarily discharge their firearms while the electricity was passing through them.

Operationally, 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. To summarise some of this data, of 356 incidents where cartridges were fired, 38 of these (10.7%) were ineffective in producing the desired effects, i.e. incapacitation. These figures relate to the same model of taser and are combined from a few different sources. Significantly, the portion of these figures which came from Canada show an ineffectiveness rating of 26.0%. This could be due to the cold climate affecting the batteries as well as the thickness of the clothing worn by the subject.

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, there may be some situations where the thickness of the clothing worn exceeds this distance. This is particularly so in 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 lift away from the body;

- **Low battery charge –** 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 battery charge. They have often found that 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 attach to 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 as the cause of failure in some cases;
- **Problem with taser –** other than due to cartridge failure or low battery charge, such as a mechanical or electrical failure in the circuit;
- **Operator error –** for example, failure of the operator to hold down the button to discharge the current.

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. Although ideally the full charge would travel along the wire to the first barb, through the subject’s 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 (if available) 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 (note: this is not possible with all models of taser). 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. Some figures for effectiveness in this mode show that 118 uses out of 552

(21.4%) of one model of taser had been a touch-stun application, with a reported 88.1% success rate.

6.1.3 PSDB Testing

A number of tests have been carried out on various models of taser to measure characteristics such as their accuracy and electrical output. These aspects of performance are important from both an operational perspective and also in terms of the effects they will have on the human body.

i) Accuracy

Tasers can use either a single laser sight that is designed to show where the top barb will land on the target; a dual laser sight that indicates where both barbs should land, or no sights at all. While a large separation of the barbs is desirable 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.

Accuracy tests are therefore carried out to determine the position of the barbs relative to the laser dot(s), where present, and the separation of the two barbs at different distances. Initial 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 and the maximum possible accuracy of the devices.

- Results

The maximum current range of any model of taser that we know of is 21ft (6.4m). This is the maximum length of the wires within the cartridge and cannot be exceeded. 15ft (4.6m) cartridges are also generally available, these tend to have a wider angle of separation between the barbs, meaning that the barbs will be further apart at any given distance than with the 21ft (6.4m) cartridges. The 15ft (4.6m) cartridges may be more suitable for use at close-quarters in order that sufficient separation of the barbs is achieved at relatively close range.

Table 4 shows the typical results that can be expected from 21ft (6.4m) cartridges fired from a single sight taser. 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. These results were obtained from at least ten shots fired at each range from the same model of taser.

	Separation between top barb and laser dot		**Separation between top barb and bottom barb**	
Distance from taser to target	**Range (mm)**	**Mean (mm)**	**Range (mm)**	**Mean (mm)**
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 4: ***Results of Accuracy Tests carried Out at PSDB***

These results are represented in Figures 7 to 10. The 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 (0,0).

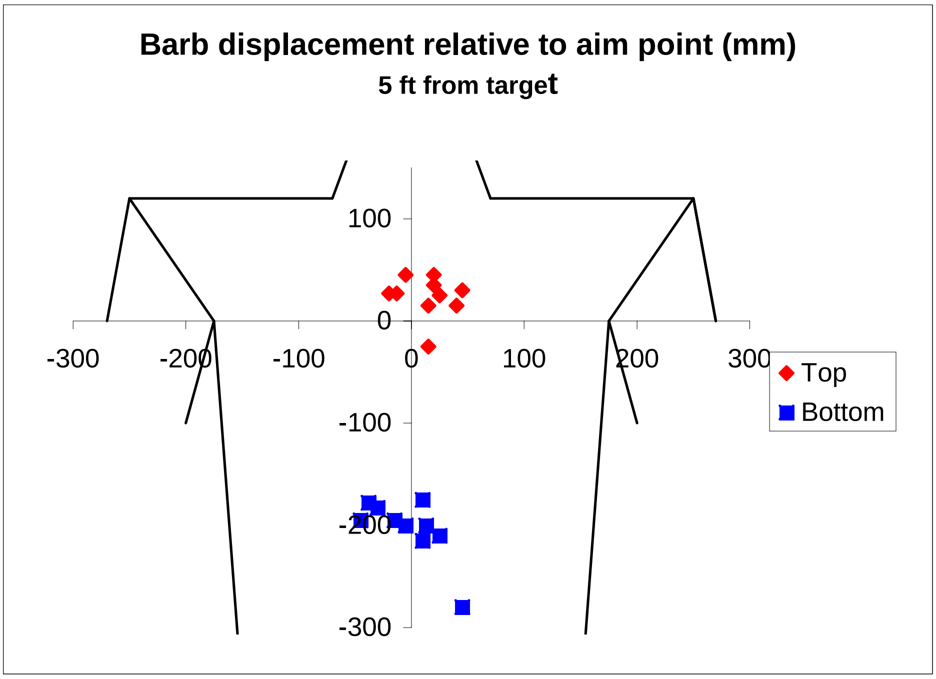

FIGURE 7: ***Position of Taser Barbs at 5ft (1.5m)***

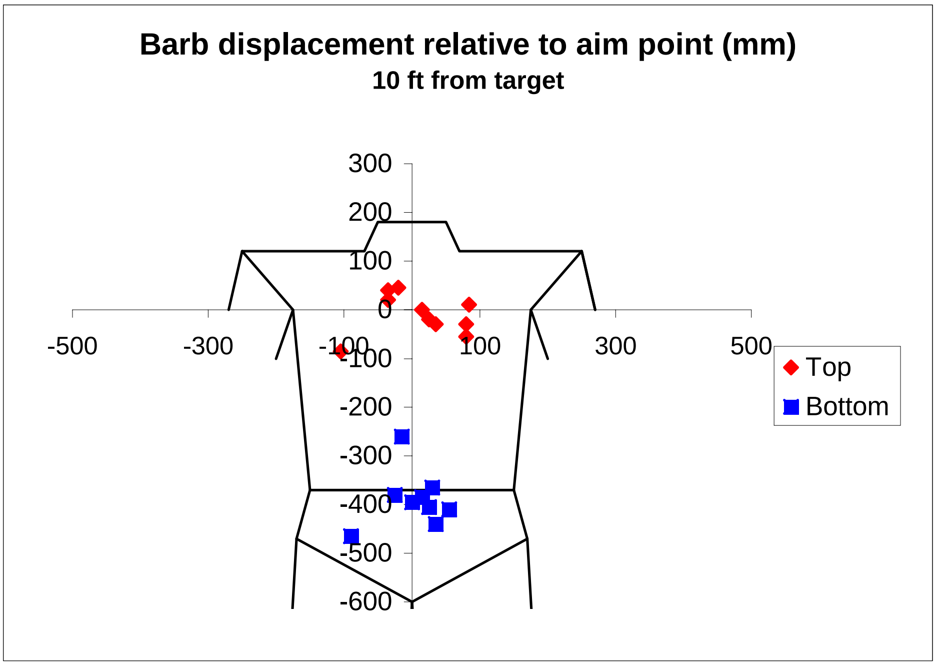

FIGURE 8: ***Position of Taser Barbs at 10ft (3.0m)***

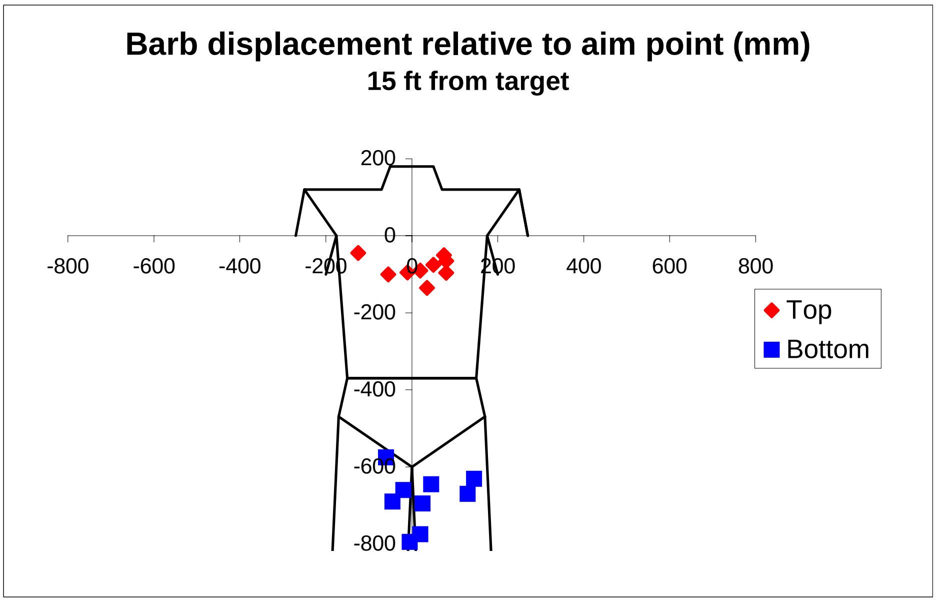

FIGURE 9: ***Position of Taser Barbs at 15ft (4.6m)***

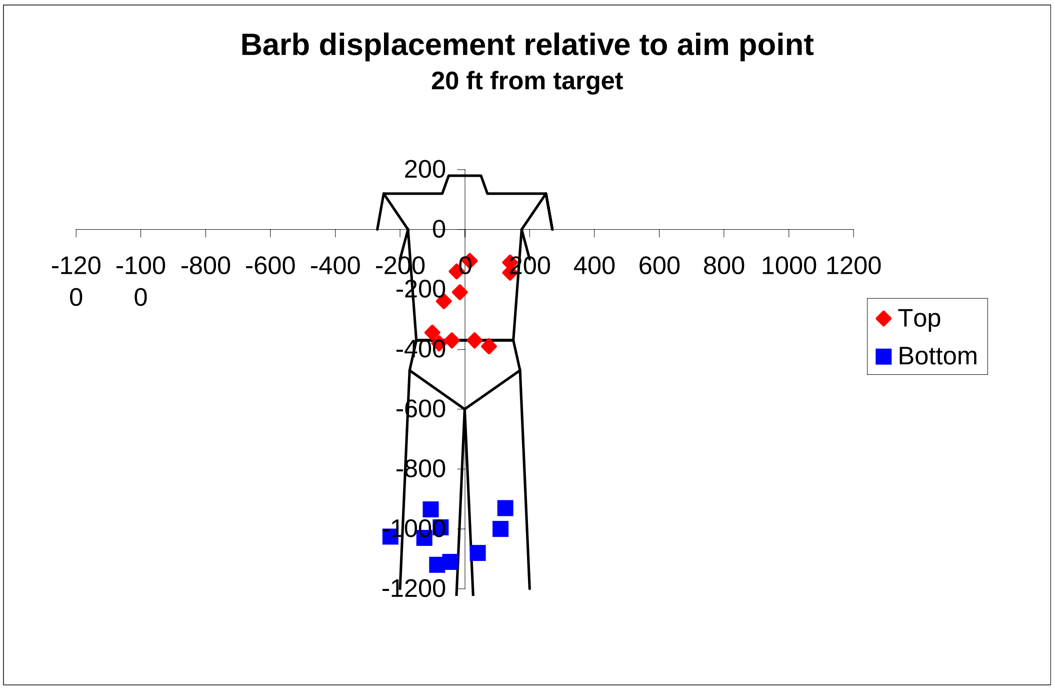

FIGURE 10: ***Position of Taser Barbs at 20ft (6.1m)***

ii) Electrical Output

PSDB have also carried out tests to determine the electrical output of the tasers in terms of waveform, current, voltage, pulse-width, energy and power. Measurements were also made of any changes that 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 in the UK 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 11.

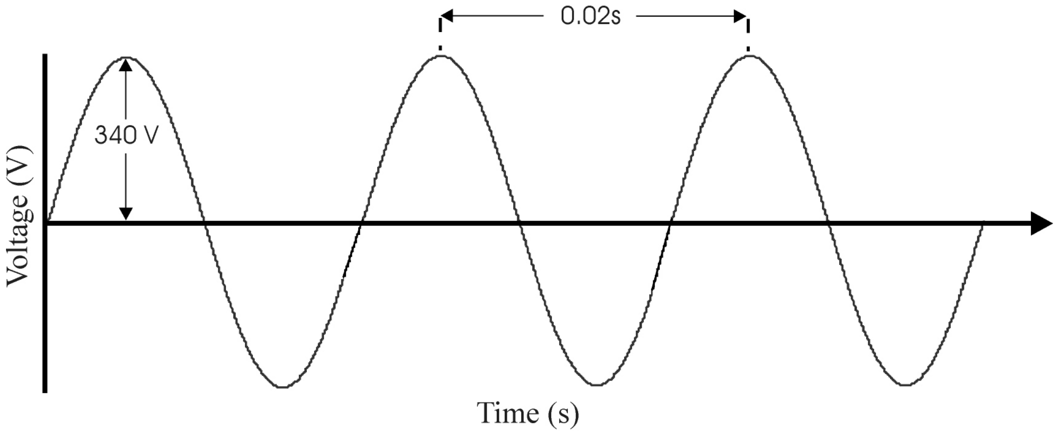

FIGURE 11: ***Waveform for Household Electricity***

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. Current commercial devices tend to have between 10 and 30 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 12 shows the typical waveform that is produced from a taser discharge – only one pulse is represented in this figure.

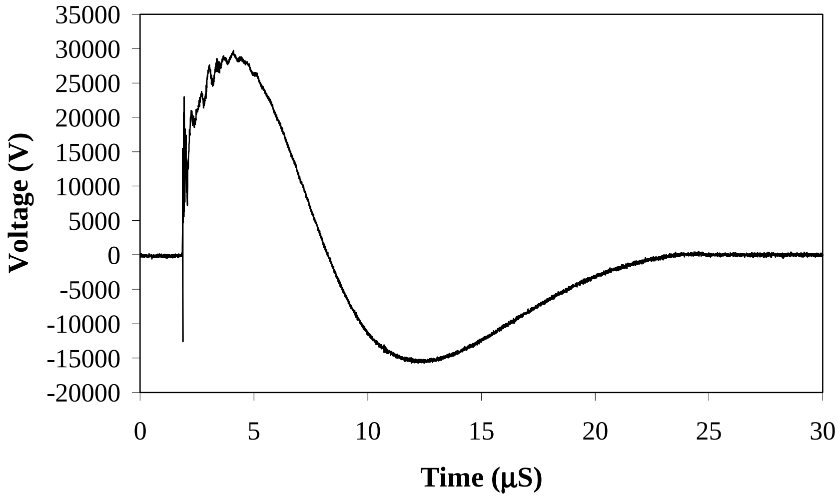

FIGURE 12: ***Typical Waveform for Taser Output***

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 domestic 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.

- <u>Method</u>

The electrical output of the tasers 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 output pulse from the device was discharged across R_t and the output voltage measured using an oscilloscope. The total resistance was intended to simulate that of the human body, but this resistance is highly variable and depends on what part of the body the electricity is flowing through (tissue, bone, organs, etc.) and also on the individual. A range of values was therefore chosen for measurement; these values were based on those previously used in measurements of this type by other agencies[10].

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. These measurements were taken as it is important to establish how the length of the gap will affect the amount of electricity flowing through the subject. The less electricity that flows through the subject, the less likelihood there is of incapacitation occurring.

- <u>Results</u>

In general, the peak output voltage from the tasers increases as the total load resistance within the circuit increases. When an air gap is incorporated into the circuit at a set resistance, the waveform changes slightly so that there is a high-voltage, short-duration spike immediately in front of the first main pulse. There is an increase in the voltage of this spike as the size of the air gap is increased, probably correlating to the voltage necessary to ionise the air and allow the spark to jump the gap. 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 what 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.

At resistances of 500 ohms and greater, the maximum air gap that allows only approximately 50% of the current to flow through the circuit is 20mm (less than an inch).

iii) Clothing Penetration

Tests were carried out to determine whether a selection of clothing materials could prevent the taser barbs from either penetrating through them or attaching on to them. Taser cartridges were fired at a mannequin dressed in a variety of different clothes of various materials. In general, most of the materials tested did not stop the barbs from at least partly penetrating and attaching onto the material. When a number of thick layers were present together, for example the overlapping section of a leather jacket, then the barbs would have difficulty in penetrating all of the layers. The zip area was also a problem as the barbs could not penetrate or attach onto this. Most thin or single layer materials did not present any problem in terms of barb penetration.

iv) Flammability

Tests were carried out 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.

A full canister of one model of CS spray, containing 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.

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 that there is a serious risk of ignition if the taser is fired at a target that has a flammable solvent on their clothing. This risk will extend to all flammable environments, for instance a petrol station.

v) Other Tests

Tests were also carried out to determine how the various models of taser could withstand treatment such as exposure to extremes of temperature ($-10^{O}C$ to $+40^{O}C$) and dropping onto a hard surface. These tests are important as they represent the types of treatment that the device is likely to be subjected to in the real world when used by police officers. The performance of the system after it had been subjected to these conditions was then assessed. Various parts of the system could be affected, such as the batteries, the laser sights, the cartridges and the taser itself and the impact on each of these areas was measured.

Previous tests had highlighted that the electricity can sometimes arc across the wires at various points along the circuit, and tended to happen when the resistance of the target was very high. Tests were therefore carried out to determine at what load resistance the electricity starts to arc across the wires. This assesses the quality of the insulation of the wires and is important from an operational perspective since, the more electricity that is arcing between the wires, the less that is flowing through the target.

6.1.4 Future Tests

The initial tests have looked at aspects such as accuracy, electrical output, penetration characteristics, flammability and performance under extreme conditions. These characteristics affect both the operational and health and safety aspects of tasers. Further tests to be conducted will include handling trials. This will involve the hand-firing of a variety of taser models by police officers at both stationary and moving targets, including in non-ideal conditions such as low or artificial lighting.

On completion of all of the testing, including the electrical output testing, the results will be passed to the medical committee for assessment. They will then suggest any further testing that is necessary before they can provide a full and accurate assessment.

6.2 Other Electrical Devices

Although most recent interest in the UK has been in the taser devices, it is worth detailing the other types of electrical devices that are available (note: performance data has not been verified).

6.2.1 Stun Guns

Many people may be familiar with the concept and appearance of stun guns. They are hand-held units generally ranging in size from 100-220mm in length and weighing between 200 and 300g, including the batteries. The probes or electrodes that deliver the electricity are permanently connected to the unit. These probes are not generally designed to penetrate the skin of the target, but are intended to be held close up to the body to allow the flow of charge.

There are a large number of commercially available hand-held stun guns. Some versions are available which contain extras such as pepper spray or a flashlight as part of the device. Alternatively, a high intensity flash of light or loud noise may be emitted when the device is activated. In some cases, optional screw-on lengthening bars are available to increase the range of the devices; these also increase the distance between the two probes allowing a greater number of muscle groups to be affected. Other than in these cases, close contact is required for operation of these devices, as the probes must be held close to the subject’s skin for effect.

The devices available range in output from 40,000V to 625,000V. Unlike tasers, which have a large separation of the two barbs, stun guns generally have only 2-3 inches (51-76mm) between the probes. This will result in less muscle groups being affected by the electricity, making placement of the probes more important. Also, unlike the tasers, the stun gun does not attach the probes to the subject's body, with the result that close contact must be maintained to prevent the subject voluntarily or involuntarily 'jumping' out of the way of the probes.

Stun guns have been widely used by American law enforcement since the 1970's. Many forces also reportedly use the taser without a cartridge to act as a stun gun.

Stun guns have not been selected as a priority for further research within the current less lethal weaponry programme.

6.2.2 Stun Batons

Stun batons are like standard police batons with an added electrical component. The batons generally have probes attached to the front end; when the probes are touched against a person, the trigger is pulled to deliver a shock. Some versions also have metal bands running part-way along or up the entire length of the baton. In these cases, if a person grabs the baton along its length, they will receive a shock.

Stun batons are available in 'one-length only' and in telescopic/retractable styles with lengths generally ranging from 300mm to 700mm. Some versions are also available that contain pepper spray or a flashlight as part of the device. The output from the batons ranges from 50,000V to 500,000V.

Stun batons have not been selected as a priority for further research within the current less lethal weaponry programme.

6.2.3 Electrified Riot Shields

Riot shields are also available which have a stun capability. These polycarbonate shields with electrical contacts fitted to the edges or surface can be supplied as a unit or alternatively, the electronic package can be modified to mount on other types of non-conductive riot shields.

Electrified riot shields have not been selected as a priority for further research within the current less lethal weaponry programme.

6.2.4 Electrified Nets

One company has produced an electrified net that combines entanglement and electricity to provide temporary incapacitation. When triggered, a large net is deployed which falls over the subject causing some degree of temporary incapacitation via entanglement. A pair of long, continuous electrodes is woven into the net and is attached to a high voltage discharge circuit. These electrodes fall randomly on the subject's body, contacting either the skin or clothing. A high-voltage stunning pulse is then delivered remotely; the net employs a 60,000V electrical pulse at 25-second intervals for up to 30 minutes to keep the subject subdued. The net has a claimed range of up to 30ft (9.1m).

Electrified nets have not been selected as a priority for further research within the current less lethal weaponry programme.

6.2.5 Sticky Shocker

The Sticky Shocker was designed to extend the range for electrically stunning a person. It is a combination of an impact device and an electrical device. The Sticky

Shocker is a wireless, self-contained 37/40mm projectile fired from compressed gas or conventional 37/40mm less lethal weapon launchers. It sticks to the target with a glue-like substance or with short clothing-attachment barbs; a combination barb/adhesive attachment head is also available. The projectile incorporates a battery pack and associated electronics that impart a short burst of high-voltage pulses said to be capable of penetrating several layers of clothing. The pulse characteristics of the device are said to be similar to commercial stun guns, with an output of nearly 50,000V.

At present, accurate range is claimed to be 10m although it may be possible to increase this by reducing the weight and/or increasing the speed of the device. A remote control option for application of a secondary pulse series and longer-range units may be developed at a later stage.

In 1999, the NIJ funded a health assessment of the Sticky Shocker. The conclusion from this was that little information and data currently existed on the health risks of electrical devices. Further work has therefore been commissioned by the NIJ to assess the health effects of the Sticky Shocker and other electrical devices. If the Sticky Shocker is found to be safe, field trials will be conducted thereafter.

6.2.6 Electronic Devices for Security Applications

There are currently a number of unmanned or remotely controlled electronic devices available for security applications; essentially a less lethal alternative to the Anti-Personnel Landmine. These devices use taser technology for perimeter control by causing incapacitation of personnel attempting to enter/exit a protected area. One particular company produces three separate devices of this type. All use cartridges similar to those used on tasers, i.e. two wires with barbs on the end. One device contains multiple, independent taser cartridges (15–30ft, 4.6-9.1m) that, when activated by a sensor, can simultaneously incapacitate a number of subjects. A modified version of this device allows the remote firing of the cartridges from a security station rather than the automatic firing when the device’s sensors are tripped. Each unit will simultaneously launch seven or more independent pairs of darts over an arc of 120 degrees and out to a distance of up to 30ft (9.1m). The lower dart would propel out horizontally, hitting at a height of approximately 1.5–2.5ft (457-762mm) at a distance of 25ft (7.62m). The upper dart would reach a height of 5ft (1.5m) at maximum range. A timing circuit on the unit, which allows periodic, one second breaks, is designed to keep the subject(s) incapacitated until security personnel can attend to them, or until the batteries are depleted.

The third device of this type by the same company is intended to protect key facilities and a number of the devices would be attached to the outside of the building or facility, or could be used to cover internal corridors and access doorways. The device is a permanently installed, armoured, motorised unit incorporating a gun-sighted video camera and the previously mentioned unit, modified to remotely fire one cartridge at a time. The remote operator, located in a security room, can rotate the unit to accurately aim at subjects within 30ft of the device. Once a cartridge is fired, it remains activated until manually deactivated by the operator.

These devices have not been selected as a priority for further research within the current less lethal weaponry programme.

6.2.7 A3P3

The A3P3 (A3: Aerosol Arresting Agent, P3: Pulse Projected Plume) has been reported in Police magazine. The device is intended to incapacitate an attacker without excessive force by discharging a highly controlled and debilitating plume of incapacitant over a range of between one and twenty feet (0.3-6.1m). An 'on board' computer determines distance from the subject and makes a choice on spray pattern, discharge rate and concentration. The device is also fitted with a data recorder (video and sound) for assessment of potential threat and, presumably, later enquiry into user action. Developers also envisage that if the device is fitted with a '*dual stream configuration*' the liquid discharged can be used to conduct and transfer a high voltage/low amperage electric charge to the individual. It is suggested that this will improve the effectiveness of the incapacitant by making the subject inhale in a natural response to the electric shock. This product is still very much in the development stages and a fully built device is not yet ready for evaluation.

6.2.8 Electrified Water Cannon

One company has developed a means of delivering an electric shock via water cannon. A single stream of high pressure, electrified, conductive fluid is emitted from a gun at high velocity making contact with the target. The high-voltage, low current pulse that is delivered is said to be capable of delivering a shock even through thick protective clothing. The water stream can be moved among targets until the selected target is positively engaged before the high voltage is applied; this avoids stunning innocent bystanders (or hostages). Ranges of up to 20ft (6.1m) have been demonstrated with this system (by the manufacturers) but ranges of up to 100ft (30.5m) or more are claimed to be feasible with improved nozzles and fluids.

The technology can also be used in conjunction with a vehicle-mounted water cannon for use in crowd or riot control. Longer ranges and longer run times are likely to be achieved in the vehicle-mounted configuration. The manufacturers have demonstrated this product in both the hand-held and vehicle-mounted configurations at distances of up to 20ft (6.1m) although no testing has as yet been performed on live targets.

6.2.9 Stun Belts

Stun Belts consist of a 'sleeve' or a band containing the stun power pack that is placed on the arm or leg of an individual. A remote control transmitter/receiver is used to activate the device when necessary at distances of up to 200-300ft (61.0-91.4m) away. The hand-held transmitter sends a signal to the battery-operated receiver located in the sleeve that activates the stun pack. Stun Belts are intended for use during the transportation and/or containment of potentially violent individuals. The wearing of the device in itself may also act as a psychological deterrent against violent behaviour.

Amnesty International has raised some particular concerns about stun belts. They believe that the belt should be banned because, even when not activated, it is inherently cruel, inhuman and degrading. The reasons they give for this is that '*the fear of infliction of severe pain, in a setting of total powerlessness, constitutes mental suffering and cruel, inhuman or degrading treatment or punishment*'. They have therefore called for a ban on the manufacture, promotion, transfer and use of the stun belt and not just a suspension of its use as they have for other electrical devices.

Stun belts have not been selected as a priority for further research within the current less lethal weaponry programme.

6.2.10 Telescopic Electronic Restraint Staff

This device is essentially similar to a stun gun; i.e. it has two non-penetrating probes at the end of it that are touched to a subject's body to allow incapacitation. The difference is that this device is 2ft (0.6m) long and can be extended to either 4ft (1.2m) or 8ft (2.4m), using an extendable telescopic pole. This allows a greater standoff distance to be achieved.

This device has not been selected as a priority for further research within the current less lethal weaponry programme.

6.3 Considerations For Acceptability

While it is beyond the scope of this report to provide details on acceptability of various technologies, it is prudent to mention a number of issues that may need to be borne in mind if electrical devices are being seriously considered for use in the UK.

Amnesty International is one organisation that has often expressed concerns about electrical devices (termed 'electro-shock weapons' by them). They do not believe that sufficient health and safety data are currently available with regards to the effects of this type of electricity on the human body. They have asked that '*the stun belt should be immediately banned and the use of other electro-shock weapons such as stun guns, stun shields, and tasers should be suspended pending the outcome of a rigorous, independent and impartial inquiry into the use and effects of the equipment*'.

As regards relevant health and safety information, it is worth noting the conclusion of a health assessment on the Sticky Shocker, funded by the National Institute of Justice (NIJ) in 1999. This review, carried out by a body of independent experts, concluded that **little information and data exist on the health risks of electrical devices** (note, this relates to electrical devices in general although the review was intended to look at the Sticky Shocker only). Further work has therefore been commissioned by the NIJ to assess the health effects of the Sticky Shocker and other electrical devices. This work, some of which uses live pigs to provide data, is due for completion in 2002.

6.4 Conclusions

It has been agreed that only those electrical devices that can be used at range will be considered a priority for further research. Devices such as stun guns, stun batons and electrified shields will therefore not be put forward for further testing at present. Electrified nets and stun belts have also been dismissed as a priority. The taser is probably the best known and widely available (and used) of electrical devices that can be operated at range.

A number of limitations in the operational use of tasers have been identified. These mainly relate to the maximum range of the devices and problems with getting both barbs to attach on to the target. For this reason, particular interest will be shown to any developments that allow a greater range to be achieved and/or use other methods to deliver the electricity to the target.

Tests carried out on tasers so far have included accuracy, electrical output, clothing penetration, flammability and performance under extreme conditions. These tests relate to both operational performance of the tasers and their effects on the human body. Police handling trials will shortly be conducted to assess the relative merits and disadvantages of various models of taser.

All of the information gathered will shortly be passed to an independent medical committee, who are likely to suggest further tests that they consider necessary before providing an assessment of the effects of this type of device on the human body.

7 DISTRACTION / DISORIENTATION DEVICES

A number of diversion and distraction devices that could be classed as less lethal weapons were highlighted in the April report[2]. These devices tended to use the method of overloading the senses by sound, light, smell or a combination of these to produce a distracting or disorienting effect. Laser and light devices and noise generating devices have been selected for further immediate research.

7.1 Laser/Light Devices

Laser and light devices can be used to cause:

- Aversion response (turn away)
- Psychological impact (e.g. fear, confusion)
- Hesitation/distraction
- Disorientation and reduction in functional effectiveness (possibly leading to indirect injuries)

Generally, these devices do not incapacitate a person, although there may be some deterrent effect as the target becomes aware that he/she has been picked out. The effects of bright light/laser devices can range from dazzle or glare (lasting seconds) to image formation (after-image lasting seconds to minutes), flashblindness (lasting seconds to minutes, with after-images lasting from minutes to days) and irreversible damage. Strobe lights may cause temporary incapacitation. A device that dazzles at large distances may cause irreversible damage at close range. These devices are also considerably less effective in daylight or in the presence of strong artificial light (range reduced by at least a factor of 10).

7.1.1 Lasers

It is claimed that the effective range for laser light may exceed 500m (at night) and can provide an effective ‘optical shield’ even in daylight. However, laser light intensity may be severely reduced by smoke and dust.

Blinking and turning away (aversion) is a natural reflex and offers some protection against low-power, long-pulsed lasers but not high-rate, short pulses which cause damage after very brief exposures (nanoseconds) and at very low energies (microjoules).

In general, the eye is most sensitive to 555nm (yellow-green light). Therefore lasers at this wavelength should achieve the same perceived brightness at lower powers than more common red lasers.

At least two devices have been developed for law enforcement applications. One uses red light (650nm) with an optional strobe and has been certified according to international standards as being inoffensive to the eye. The device is similar to a conventional police torch in size and form and is battery powered with a maximum continuous use time of 20 minutes to avoid overheating. The second device uses green light (532nm at 140mW) with a built in strobe effect to add to the distraction effect. The device is about 13 inches (330mm) long, weighs 2.1lbs (953g) and is designed to look and be operated like a conventional police torch. The device needs to be recharged after an hour of operation and costs between £3,000 and £6,000 each depending on quantity ordered.

The power rating of laser distraction devices is relatively high at 100-500mW compared to less than 5mW in a common laser pointer. The energy received by the eye remains low as the beam produced by the device has a diameter of up to 2 feet, spreading the total energy across a wide area.

7.1.2 Lights

Light devices have a shorter range and are less easily focused than lasers. Possible light devices include high intensity lights and flash discharge units as well as more conventional flashlights and strobe lights. New LED technology may also lead to high intensity light devices requiring less battery power. At short range a high intensity flashlight may be as effective as a laser and is potentially less harmful.

There are many light devices available, the two most common types are:

- Flashlights - These typically have light outputs from approximately 20,000-300,000 candela and are 6-9 inches (152–229mm) long, weighing 7-12 ounces (198-340g).
- Portable floodlights - These typically have a light output of 750,000-6,000,000 candela and have dimensions of around 12 inches (305mm) long by 6-15 inches (152–381mm) high and a weight from 3-25 pounds (1.4–11.3kg). Some require external power sources.

7.1.3 Laser Hazards

Laser and bright light eye injuries are extensively documented. Injuries are almost always retinal, ranging from lesions through intraocular haemorrhage to nerve fibre damage and loss of sight. Treatment for injuries is limited. If pupils are dilated (e.g. at night) or the eyes are more heavily pigmented, there is greater absorption of energy and therefore more damage. The effects of coloured laser light on people who are colour-blind must be considered as some reports suggest they may be less sensitive to laser light. The impact of strobe lights in triggering epileptic fits has been widely publicised.

Lasers have been used for many years in various disciplines, including the medical world, and as such there are several British standards that already deal with laser safety issues. In the British Standard EN 60825-1:1994, Clause 13 deals with 'Maximum Permissible Exposure (MPE)'. This is defined as:

"That level of laser radiation to which, under normal circumstances, persons may be exposed without suffering adverse affects. The MPE levels represent the maximum level to which the eye or skin can be exposed without consequential injury immediately or after a long time and are related to the wavelength of the radiation, the pulse duration or exposure time, the tissue at risk and, for visible and near infrared radiation in the range 400nm to 1400nm, the size of the retinal image."

The MPE at the cornea for ocular exposure to laser radiation, and the same to skin, is summarised in the standard.

It is widely known that lasers present a hazard to the eye but the skin is also vulnerable. However, injuries caused to the skin by lasers are less likely to be permanent, especially at comparatively low energies and so hazards to the eye will be concentrated upon here.

The British Standard mentioned above considers several determining factors on which damage to tissue can depend, the first of these being wavelength. The shorter the wavelength of the radiation, the higher the power. The width of the beam, however, may spread the power over a wider region, so the power per unit area is also important. The mechanism of injury is generally accepted to be thermal when the exposure is of around 0.1s to 10s for a continuous wave laser or arc lamp, or of around 1 to 10ms when the exposure is from a long pulsed laser or flashlamp. Injury appears to result from protein denaturation and enzyme deactivation so the variation of temperature with time must be considered. This is where the size of the beam can be important again as heat can be conducted away by surrounding tissue far more efficiently for image sizes of 10μm-50μm than for 1mm. So, although a smaller spot has a higher power density (power per unit area), this has to be balanced against the benefits of a smaller spot size in heat conduction. For example, $10W/cm^2$ for a 1mm image is the threshold for injury whereas $1kW/cm^2$ is required in a 20μm image.

Wavelength is also a factor in the site of the tissue injury. Figure 13 shows the types of injury that can be inflicted at different wavelengths. Some of these injuries may heal (the cornea completely regenerates every 48 hours), some may be operable (cataracts) and some are permanent (severe retinal burns leading to blindness). Visible light and infrared radiation is focussed sharply on to the retina, directly on to the fovea - the area with the greatest concentration of cone photoreceptors (see Figure 14). This can cause a blind spot in the irradiated area. Outside the fovea it would be in peripheral vision and not particularly noticeable but inside a severe visual handicap could occur. At a more detailed level, green lasers are absorbed by the surface layer of the retina causing abnormal blood vessel growth in front of the photoreceptors whereas yellow lasers penetrate to damage the photoreceptors directly.

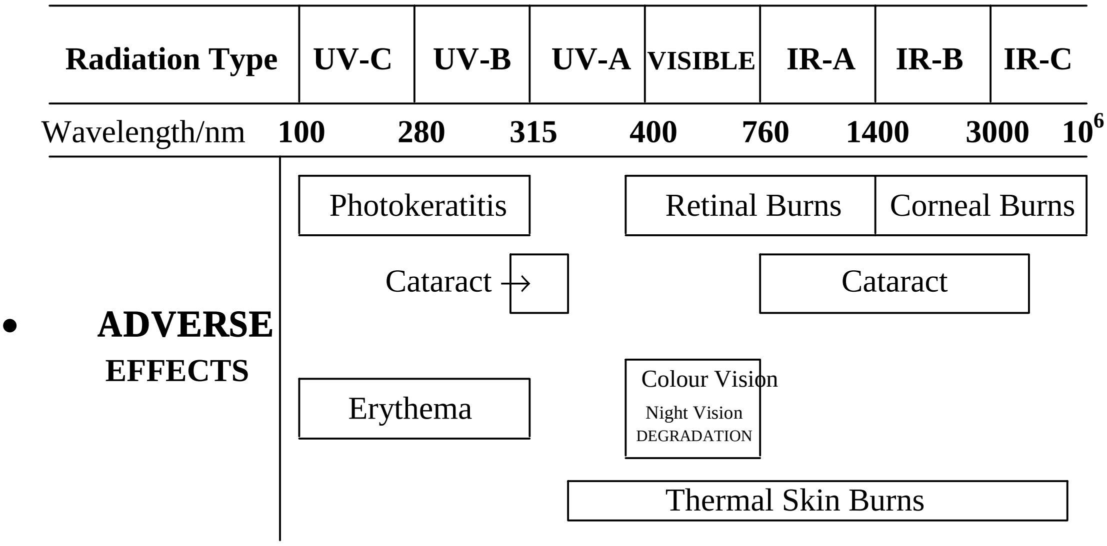

Figure 13: ***Dependency of tissue effects on the wavelength of the incident radiation***

The retina is also sensitive to the near ultraviolet region but the lens is a strong absorber of wavelengths shorter than 400nm down to 315nm while the cornea absorbs heavily at wavelengths below 300nm. It must also be considered that if a laser has any wavelengths that are outside the human visible range there will be no aversion response. Therefore, damage can be caused even when the subject is unaware that they are being exposed.

The British Standard also considers pulse duration and exposure time. The latter is self-explanatory, energy delivered (and thus injury suffered) increasing with time. Pulses are often created by so called “Q-switching”. This is a kind of electronic switch that allows very short, high powered pulses of light to be emitted. It is significant in that the length of the pulse is often much shorter than the time it takes to blink or look away so bodily defence against the light is ineffective.

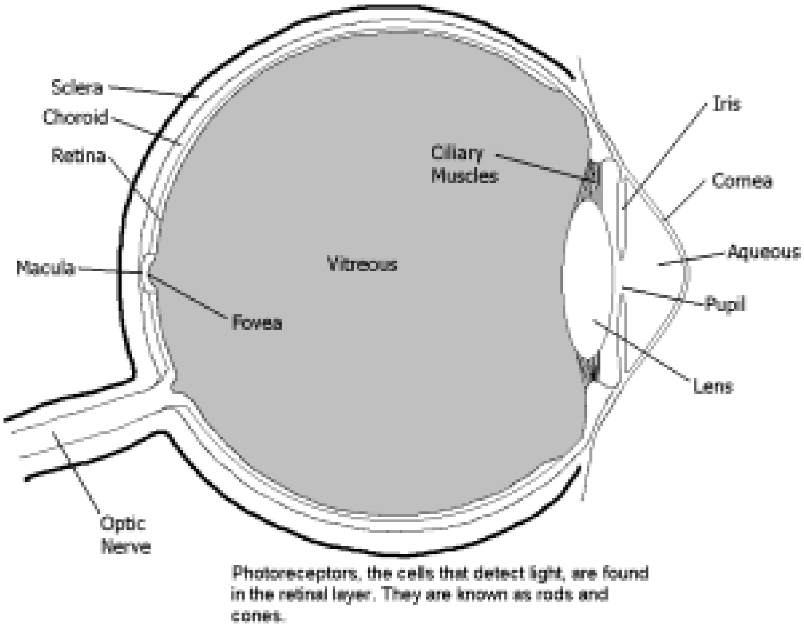

FIGURE 14: ***Composition of the Eye***

7.1.4 PSDB Evaluation

PSDB are gathering information on all of the laser and light systems that are available and have the potential for use in a policing role. The characteristics of these devices will be assessed, such as power output, wavelength, size of the beam, etc. This data will then be compared to existing standards. The performance characteristics of the various devices can then be compared to the operational requirements, and the most suitable system(s) identified.

7.2 Noise Generating Devices

Audible sound may be used in a variety of ways using soothing, unpleasant or very loud sounds (up to 135dB) in an attempt to pacify a crowd or clear an area. Devices may range from whistles and hand-held sirens to large vehicle mounted speakers. Studies have shown anti-social behaviour decreasing in areas where soothing music is played. In one example classical music was successfully used to prevent graffiti in problem areas.

Effects of various noise levels are shown below[11]:

Discomfort	120dB
Threshold of pain	145dB
Eardrum rupture	185dB
Lung damage	200dB
Lethality	220dB

As a comparison, a busy office typically has a sound level of 65dB, heavy traffic 90dB and a jet aircraft taking off 125dB.

The Health and Safety Executive have defined acceptable sound levels at work to be equivalent to no more than 85dB for 8 hours, or a peak level of 140dB regardless of frequency or duration. Hearing protection must be provided for workers exposed to sound at higher levels.

High volume (above 150dB), low frequency (50-100Hz) audible sounds are reported to cause ‘intolerable coughing and choking respiration’ with ‘unpleasant but tolerable respiratory effects’ at lower volumes and frequencies (20-50Hz)[12].

Standard stun grenades use a bright flash of light, a loud bang and intense blast waves to disorient and/or incapacitate the target(s) (see Section 9.1). Some of these devices fragment on impact, which could be hazardous to persons in the immediate area depending on the composition of the grenade. The pyrotechnics used to create the flash can also be hazardous as they may set fire to combustible materials, such as paper or fabrics. In addition to this, blast injuries can be caused by discharge when in contact with or in very close proximity to an individual. The requirement now is for a non-fragmenting and non-pyrotechnic device that creates a loud noise, sufficient to disorient and/or incapacitate a target, with no risk of injury from blast effects.

PSDB are gathering information on all available noise generating devices of this type. Measurements will be made of the peak noise level and sound exposure level of any device that appears suitable. The performance characteristics of the various devices can then be compared to the operational requirements, and the most suitable system(s) identified.

8 CATEGORY B TECHNOLOGIES

Within the second category of prioritisation, as described in the introduction of this report, two types of technologies have been identified as meriting further research, although the current state of knowledge and/or the commercial availability of workable devices has meant that this will necessarily occur over a longer timescale. These technologies are malodorants and tranquillisers, a description of each is provided below.

8.1 Malodorants

A malodorant is an extremely bad-smelling compound, traditional stink bombs being an example of this. Malodorants may be of assistance in dispersing crowds although they are unlikely to prevent a determined assailant at short range. The possibility of developing malodorous devices has not been fully explored. Very little has been published on possible devices.

The US army has proposed that any malodorant used should be perceived highly unpleasant by most people, quickly detected and dispersed, not easily habituated and not incapacitating or a sensory irritant.

Studies found odours named ‘Bathroom malodour’ and ‘Who me?’ most repellent, with transient symptoms of nausea and gagging, but other odours such as cortyl mercapton (Skunk Perfume) have also been promoted. Recently ‘rotting flesh’ was felt too repulsive for use with an exhibit at the Natural History Museum in London.

There are a number of companies specialising in creating chemical smells and flavours for the food and perfume industries that may be capable of developing suitable odours in addition to those already on the market.

Means of independently delivering these smells could include similar methods to those used for delivering CS, dyes, or stun grenades, for example in spray form or within an encapsulated round. Some manufacturers offer malodorants as an additional component within other devices (see Section 4).

The above mentioned studies[13] reported reduction in respiratory volume, an increase in respiratory rate, change in the electric resistance of the skin and other symptoms consistent with tachygastria (nausea). The degree of these responses will be determined by the concentration of the odour.

The possible effects on people suffering from respiratory illnesses should be considered and the toxicity of the chemicals used must be established. There may also be issues about decontamination following deployment, especially in residential or heavily populated areas.

8.2 Tranquillisers

Strictly speaking, tranquillisers will not produce sleepiness or unconsciousness so, in the context of using a drug to incapacitate a person, anaesthetic may be a better term to describe these drugs. However, for the purpose of this update ‘tranquilliser’ will be used as a generic term to describe drugs that can be used to incapacitate or calm a person.

Tranquillisers and delivery methods were investigated in the late 1980’s and early 1990’s in the US. One class of tranquilliser was identified as having a large safety margin between the onset of unconsciousness and death as well as possessing rapid antidotes. However, the substance also caused muscle relaxation and consequently could cause a person’s breathing to stop. The typical delay between delivery and effect was about 30 seconds but could be less if the target was agitated and the drug was circulated round the body more quickly.

The work was stopped because of perceived liability issues surrounding the injection of drugs without consent. There was also concern that the type of offender the system was likely to be used on would possibly be under the effect of some other sort of drug, either legal, illegal or prescription, and unpredictable effects may occur.

The Department of Health have also been consulted and although they say they could not comment without specific details of the type of drug being considered they did say that the idea of using tranquillisers was fraught with the difficulties identified by the Americans.

9 CATEGORY C TECHNOLOGIES

As set out in the categories of prioritisation, described in the introduction of this report, these technologies have been chosen as not requiring further research at the present time, although further consideration may be given to some of the devices at some point in the future.

9.1 Stun Grenades

These are also referred to as concussion grenades, distraction devices or flash-bang devices. These devices aim to disorient and/or incapacitate the target(s), usually by causing flashblindness (lasting seconds) and temporary deafness (lasting minutes) along with the disorienting effects of intense blast waves. The devices are indiscriminate, affecting anybody within range.

Stun grenades are available in a range of forms and sizes depending on the application. Typically, smaller grenades have impact up to 10m from the centre of the detonation, with light intensity of 2 million candela and sound levels of up to 175dB at 2m. More powerful grenades are available with light intensity of up to 8 million candela and sound levels of 185dB at 2.5m (note: sound levels are discussed in Section 7.2). These larger devices are designed for use only outdoors or for large indoor areas (e.g. a warehouse).

The body of the grenade may be metal, cardboard or rubber. Rubber and cardboard-bodied grenades split or fragment relatively harmlessly on impact, although they sometimes contain sub-munitions that can fragment when discharged. The pyrotechnics employed to create the flash may set fire to paper, fabrics and other combustibles.

Grenades may be hand thrown, fired from a launcher (delivery ranges quoted up to 130m) or slid under a door. Multiple munitions, smoke, chemical irritants (e.g. CS), rubber stingballs and/or malodorants may also be incorporated, extending the area and effectiveness of the device.

There may be injuries to sight or hearing, especially for people close to the centre of the detonation. With metal-bodied grenades there is a danger of metal fragments causing shrapnel injuries. Blast injuries may be caused from discharge in contact with or very close to a person. Where grenades also contain other ingredients, such as multiple munitions or CS, additional caution must be used in their deployment. Officers entering an area immediately after detonation require protective equipment dependent on the grenade type used.

Stun grenades have been successfully employed to return order in US prison riots as well as in a number of hostage situations. They have been used against street protestors and rioters, primarily as a means of dissipating crowds. Stun grenades have also been used in the UK in dynamic entry situations and some injuries have been reported by officers, both in use and in training. Manufacturers have been addressing these issues and a limited number of devices reach the ACPO requirements.

9.2 Smoke

The primary use of smoke is to obscure the vision of the target(s). However, this also obscures the vision of police officers and may provide a screen to hide people/actions from the police. Similarly, smoke may be used to screen police movements. The smoke, once deployed, is unpredictable and may be affected by weather conditions.

In general, smoke devices have similar deployment characteristics to chemical gas devices or stun grenades. Ideally the smoke should be non-toxic and have no chemical/biological effect on the target (these will not incapacitate the target). However, some commercially available devices do contain toxic chemicals.

The smoke grenade is an indiscriminate device and cannot be targeted at individuals. There may be issues surrounding decontamination of an area and the fire risk of these pyrotechnic devices. In addition, the possible effects of repeated exposure on the police must be assessed.

Some medical studies have been carried out on types of 'smoke' used in military and fire service training. These show that some long-term toxicity effects are possible dependent on exposure and chemical content of the smoke.

The possibility of ill effects on people with respiratory problems (e.g. asthma), or secondary injuries caused by panic and obscured vision, resulting from use of such devices must be considered.

9.3 Acoustic Devices

Acoustic devices can be sub-divided into three categories:

- Infrasound (less than 20Hz), below the threshold of hearing
- Audible (20Hz-20kHz) (dealt with in Section 7.2)
- Acoustic shock wave devices

Some reports claim physical effects from sound at distances up to 100m. However, as directionality and attenuation (the way in which volume decreases with distance) are frequency dependent, the reported effectiveness and directionality of sound devices are challenged – suggesting a maximum range of a few tens of meters[14]. Other than whistles and compressed air-horns and stun-grenades, current devices are generally large and unwieldy (semi-portable or vehicle mounted).

9.3.1 Infrasound devices

There has been much speculation about the effectiveness of infrasound devices. Frequencies of 19Hz have been reported to cause the subject to observe apparitions in enclosed spaces. Violent nausea has been reported at 12Hz and lower frequencies of 3-7Hz are reported to cause death by resonance with internal organs[15]. The lowest frequencies (less than 3Hz) are claimed to enhance relaxation and drowsiness or sexual excitation. However, when exposed to infrasound not everybody experiences the same effects. It has also been suggested that such frequencies may cause structural damage to buildings. Scientific publications on these devices are not available, leaving no hard evidence for the effects claimed.

Possible dangers posed to the operators of such devices (and their colleagues) must be taken into consideration. Leakage, reflections from buildings and the natural spread of the sound waves will potentially have equal effects on targets, enforcement personnel and bystanders.

It is reported that, even at low amplitudes, some frequencies (3-7Hz) can kill. At other frequencies (7-20Hz) side-effects (to eyes and internal organs) are reported to last several days. However, medical confirmation of the reported effects of infrasound has not been found.

9.3.2 Acoustic shock wave devices

Combustion powered high pressure acoustic shock waves are reported to be more directional than the loudspeaker systems described above. It is claimed that some of these devices are capable of producing Mach disks (pulses or packets of sound energy) of sufficient power to knock the target over. Such devices generally need to be vehicle mounted. At least one smaller, lower-powered, device has been developed (360 degree output, designed primarily for pest control/area exclusion with sound levels in excess of 125dB).

This is not yet a mature technology and there is a lack of scientific evidence on the effectiveness and risks of infrasound and acoustic shock wave devices.

9.4 Electromagnetic Waves

The US Air Force Research Laboratory has developed a device that creates a heating effect in the skin using a beam of high frequency (95GHz), near microwave electromagnetic radiation. The device is intended for use as an area denial or crowd control system. A fixed installation is being tested in the US and a vehicle-mounted version is to be developed.

The radiation generates a burning sensation in the target (reported to be like touching a hot lightbulb) such that the target is motivated to move out of the beam. The radiation penetrates clothing but does not enter more than one sixty-fourth of an inch (0.4mm) into the skin. The device is intended for use in 2-second bursts and has a reported range of 700yds (640m). It is possible that wet, heavy clothes or aluminium shielding may be sufficient countermeasures.

Initial tests in the US on volunteers show no ill effects beyond some skin tenderness after repeated exposure. Testing is continuing in the US throughout 2001. The exposure time for permanent injury and results of studies of long-term effects have not been released. It has not been reported how exposure at different distances from the source affects the target. No studies have been carried out in damp, rainy weather conditions. The radiation does not interfere with electrical devices (such as pacemakers or computers).

9.5 Nets and Wire Entanglement Systems

Nets and bolas systems are designed to disable a target through entanglement. In the case of nets the whole body may become entangled, bolas devices are designed to affect the legs of the target. A number of devices are available commercially.

Some of the nets are supplied as 37mm cartridges to be fired from a standard weapon or a one-shot launcher, while others rely on a specialised reusable launcher device.

The bolas devices are generally fired from standard firearms such as a 12-gauge shotgun, or even a 9mm handgun using a blank cartridge to launch the projectile.

A number of variations on the standard net are available. These include a sticky net coated with glue to further impede motion, an irritant net where the net fibres are coated with an irritant chemical such as OC, and an electrical net where a high voltage electrical discharge (60kV) is passed through the net.

The claimed operational ranges for the nets vary between 2m and 9m. The nets themselves also vary in size, with one model having a 3m diameter, while another uses a 5m x 5m square net. Both nets employ a series of weights attached to the outside edge for stability during flight and expand the net to the correct shape. One model uses fifteen 25mm long flat lead weights, the other uses eight lead ball weights enclosed in a tube of foam padding.

One available bolas device can be used in one of two ways, either as a kinetic energy round at ranges between 2 and 15m or as an entangling device at distances between 3 and 11m. The round contains 1.7m of thin nylon rope. Other bolas systems consist of three rubber balls connected by a few metres of thin rope. The claimed effective range of these devices is 18-36m.

Previous small-scale testing on earlier versions of nets showed that they were ineffective and that the target was able to tear through the net, although it is believed that higher strength nets have been produced since then.

9.6 Glue, Foam and Grease

9.6.1 Anti-Personnel

Sticky foams (also referred to as “Stick'ems”) were investigated by Sandia National Laboratories, USA (SNL). The foam is held under pressure until it is dispensed, when it will expand up to 30 times its original volume on exposure to atmospheric pressure. The foam then sets to form a rigid solid. Various compositions have been developed; common ingredients include rubbers, resins, oils, fire retardants and stabilising chemicals.

Trials were carried out by SNL on the use of sticky foam in prison and law enforcement situations. A shoulder slung dispenser was developed and tested. SNL have discontinued research on sticky foams for prison/law enforcement purposes due to problems with decontamination and clean up, as well as fears of suffocation.

One commercial product consists of a glue contained in an aerosol can. The quoted range for the glue spray is 7-8m with a spray time of 6-7 seconds. The glue is intended for use in marking suspects for later identification as well as slowing the target and inhibiting motion. The spray was developed in association with the Japanese police authorities.

9.6.2 Area Denial

The US Army Edgewood Research and Development Engineering Centre (ERDEC) researched aqueous foams, similar to soap suds, for area denial purposes. The foam can be used as a visual obscurant, fire suppressant, explosive blast suppressant or irritant carrier. Aqueous foam applications were developed by SNL for use in the nuclear industry and later, for use in prison scenarios. The foam itself is not intended to provide an impenetrable barrier and can be easily crossed. The foam could be used to carry an irritant chemical, as part of its chemical make-up, or to hide a more physical barrier.

Southwest Research Institute, USA, investigated the use of rigid foams for area denial (e.g. sealing entrances to buildings). Some commercial rigid foam systems were developed, mainly used in high security vehicles.

Anti-traction materials (“slick'ums”) have been developed by US military researchers. The intention is to deny access to an area by creating a slippery area of ground, which cannot be crossed on foot or, in some cases, in vehicles. Various chemicals have been investigated for this purpose including dry polymer powders activated by addition of water, hydrocarbon based lubricants and Teflon or polyethylene confetti.

US Army investigations into anti-traction systems have focussed primarily on water activated polymers as these have been shown to present few environmental or health hazards and are easily cleared by use of high-pressure water jets. The water/polymer mixture was found to provide satisfactory results on smooth non-porous surfaces such as pavements, runways and well-compacted soils. Heavy rain, high temperatures and high humidity were found to reduce effectiveness. While these materials will effectively immobilise personnel and vehicles they will also adversely affect emergency services until a clean-up operation is carried out.

10 CONCLUSIONS

A large amount of information has been gathered about a wide range of less lethal options. Five main areas have been agreed as meriting immediate further research; these are summarised as:

- Impact Devices or Kinetic Energy Rounds
- Long Range Chemical Delivery Devices
- Water Cannon, both vehicle mounted and portable
- Electrical Devices, particularly the taser
- Distraction/Disorientation Devices, particularly laser/light devices and noise generating devices

Evaluation of each of these areas is at an advanced stage and operational and technical information gathered from various sources has been validated and expanded by an intensive testing programme within PSDB. The initial phase of testing is almost complete for most of these technologies and a number of devices have been identified as meeting the basic criteria for further evaluation. Further testing of these devices will continue to assess their performance against other aspects of the operational requirement.

Those devices that meet all of the scientific and technical evaluation criteria will then be assessed by a medical committee who will comment on their effects on the human body. This committee will consist of a number of independent medical professionals who have expertise in the technology or effects being considered.

11 ACKNOWLEDGEMENTS

A number of PSDB staff have provided invaluable assistance in the writing, preparation and collation of the information contained within this report. They have carried out work on various projects within the less lethal programme, without which this report could not have been written. They have helped research the available technologies, gather information from manufacturers and international contacts, carry out testing of the various devices and liase with the customers.

The following people deserve particular thanks: Dr. Karen Douse, Dr. Michelle Gardner, Graham Smith, Graham Parker, Dr. Tracy Hart, Daniel Longhurst, Dave Wilkinson, Matthew Symmons and Chief Inspector Neil Haynes. Additional thanks also go to Christopher Selway and Eric Brown for their assistance.

PSDB has also drawn heavily on its overseas contacts, including organisations in the United States, Canada and Europe. The particular organisations that have provided assistance are detailed below.

Organisation	Country
Amt fur Wehrtechnik	Austria
Belgian Gendarmerie	Belgium
Canadian Police Research Centre	Canada
Royal Canadian Mounted Police	Canada
Victoria Police Department	Canada
Drug Law Enforcement Unit	Cyprus
National Commissioner of the Danish Police	Denmark
Ministry of the Interior – Police Department	Finland
Police Technical Centre	Finland
Ministry of Interior	France
Bundeskriminalamt (BKA)	Germany
Polizei-Fuhrungsakademie (PFA)	Germany
Garda Siochana	Ireland
Police Operations and Training Dept.	Luxembourg
Politie (Police Institute for Public Order)	Netherlands
Rikspolisstyrelsen (Swedish National Police Board)	Sweden
Kantonpolizei Bern	Switzerland
Association of Chief Police Officers and many individual police forces	UK
Defence Science and Technology Laboratories (dstl)	UK
Department of Health (DoH)	UK
Ministry of Defence	UK
NCIS Liaison Officers	UK
Prison Service	UK
Qinetiq	UK
Royal Ulster Constabulary	UK
Air Force Research Laboratory	US

Organisation	Country
Joint Non Lethal Weapons Directorate	US
Los Angeles Sheriffs Department	US
National Institute of Justice	US
National Institute of Standards and Technology	US
Pennsylvania State University	US
United States Marine Corps at Quantico	US
Wayne State University	US

The assistance of manufacturers and suppliers has also been invaluable, but for commercial confidentiality reasons, a list cannot be included.

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APPENDIX A SUGGESTED PRIORITIES FOR FURTHER RESEARCH

This list provides a summary of the prioritisation of less lethal technologies agreed by ACPO and the NIO in July. This list has formed the framework for the testing programme reported in this document.

Category A

Devices which may be subject of immediate more in depth research:

1) Medium-Range (5-20m) to Long-Range (over 20m) Devices

a) Kinetic Energy Rounds

This generic category includes sponge grenades, bean bags, sock rounds and single and multiple ball rounds. This category also includes the new L21A1 baton round, acknowledged as the most accurate round in its class and currently available for use. (Note, the L21A1 has not been included in this study as extensive testing has already been carried out for this round).

b) Discriminating Chemical Delivery Devices/Rounds

These devices/rounds can be used to deliver a quantity of chemical irritant (e.g. CS) to a target at an extended range, i.e. further than is possible using conventional hand held sprays (10-14ft). These tend to combine kinetic impact effects with chemical irritant effects to produce incapacitation of the target. The degree of each effect varies with each system and is dependent on the velocity, size, shape, material etc. of the round and also the quantity of irritant contained within it.

2) Water Cannon

Conventional vehicle mounted water cannon are in use throughout Europe and in other parts of the world. Work has been carried out by the Home Office between 1981 and 1987 but was discontinued by the then Home Secretary. A review of all currently available vehicle mounted and portable water cannon is underway to identify those systems which most closely meet the operational requirements of the UK police.

3) Electrical Devices (e.g. Tasers)

Electrical devices include any weapons that use the effects of electricity to incapacitate the target. There are a variety of different devices but their principle of operation is the same. They are battery powered and use a low current, high voltage impulse shock for incapacitation. The electrical stimulus delivered by the device interferes with the normal electrical signals generated by the human nervous system. Incapacitation by electrical means appears to offer a virtually instantaneous method of incapacitation with almost instant recovery, although some questions remain on delivery methods and on health effects. Priority has been given to those devices that can be used at a range, for example the taser.

4) **Laser/Light Devices**

The effects of bright light/laser devices can range from dazzle or glare to image formation, flashblindness and irreversible damage. Generally, these devices do not incapacitate a person, although there may be some deterrent effect as the target becomes aware that he/she has been picked out. A device that dazzles at large distances may cause irreversible damage at close range. These devices are considerably less effective in daylight or in the presence of strong artificial light.

5) **Noise Generating Devices**

The potential of loud noise to distract and disorient is well known and can be incorporated into devices that are either hand thrown or fired from weapons. The requirement is for a non-fragmenting and non-pyrotechnic device that will provide a potentially less injurious alternative to the more traditional stun grenade.

<u>Category B</u>

Devices warranting further research over a more extended time frame:

1) **Malodorants**

Malodorants may be of assistance in dispersing crowds although they are unlikely to prevent a determined assailant at short range. There may be issues about decontamination following deployment, especially in residential or heavily populated areas. The possibility of developing malodorous devices appears not to have been fully explored and exploration of this technology will necessarily be longer term. There may also be toxicological considerations for these types of device.

2) **Tranquillisers**

The speed of reaction to any anaesthetic or drug will be an important factor in its use, as will the possibility that different people will react differently to it and the dose required to incapacitate one person may prove harmful to another.

<u>Category C</u>

Devices which presently do not require further research:

1) **Stun Grenades**

These devices could be considered to be too indiscriminate and potentially dangerous.

2) **Smoke**

These devices could be considered to be too indiscriminate and potentially dangerous.

3) **Acoustic Devices**

This is not yet a mature technology and there is a lack of scientific evidence on the effectiveness and risks of infrasound and acoustic shock wave devices.

4) Electromagnetic Waves

This device is still subject to further development. It may also be potentially easily countered by adequate protection by the subjects.

5) Nets and Wire

Potentially injurious due to the indiscriminate nature of the necessary weights attached to the devices.

6) Glue, Foam and Grease

Problems would appear to exist with respect to potential suffocation of subjects, decontamination and exclusion of emergency services as well as disorderly/dangerous individuals.

APPENDIX B GLOSSARY OF TERMS

A ACRONYMS and ABBREVIATIONS

ABE	Attribute Based Evaluation
AC	Alternating Current
ACPO	Association of Chief Police Officers
CDE	Chemical Defence Establishment
CN	Chloroacetophenone
CR	Dibenz (b.f.)-1:4-oxazepine
CS	*O*-Chlorobenzylidene Malononitrile
HO	Home Office
LASD	Los Angeles Sheriff's Department
Laser	Light Amplification by the Stimulated Emission of Radiation
LED	Light Emitting Diode
MPE	Maximum Permissible Exposure
NIJ	National Institute of Justice
NIO	Northern Ireland Office
OC	Oleoresin Capsicum
PAVA	Pelargonic Acid Vanillylamide
PBR	Plastic Baton Round (now generally referred to as baton round)
PSDB	Police Scientific Development Branch
PTSD	Police Technical Services Division
rms	Root mean square
RUC	Royal Ulster Constabulary
SRDB	Scientific Research and Development Branch
Taser	Thomas A Swift's Electrical Rifle (from the Tom Swift fantasy stories)

B TECHNICAL TERMS

Ampere (A)	The basic SI unit of electric current.
Bar	Unit of pressure in the C.G.S. system. 1 bar = $1x10^5$ newtons per square metre.
C.G.S. system	Centimetre-gram-second system. A system of physical units derived from the centimetre, gram mass and the second.
Candela	The SI unit of luminous intensity (the amount of light emitted per second in unit solid angle by a point source, in a given direction).

dB	Decibel, a measure of sound intensity. One decibel = one tenth of a bel.
Electric Current	An electric current is said to flow through a conductor when there is an overall movement of electrons through it. The SI unit of current is the ampere.
Energy	The capacity for doing work. The various forms of energy, interconvertible by suitable means, include potential, kinetic, electrical, heat, chemical, nuclear and radiant energy. Interconversion between these forms of energy can only occur in the presence of matter. Energy can only exist in the absence of matter in the form of radiant energy. The derived SI unit of energy is the joule.
Erythema	A general term signifying several conditions in which areas of the skin become congested with blood, and consequently a red eruption appears. The eruption is accompanied by tingling, and often by itching and pain.
Hertz (Hz)	The derived SI unit of frequency. Defined as the frequency of a periodic phenomenon of which the periodic time is one second; equal to 1 cycle per second.
Joule (J)	The derived SI unit of work or energy. The work done when the point of application of a force of 1 newton is displaced through a distance of 1 metre in the direction of the force. The joule is also the work done per second by a current of 1 ampere flowing through a resistance of 1 ohm.
Kinetic Energy (KE)	The energy which a body possesses by virtue of its motion. The kinetic energy of a mass m, moving with velocity v, is $\frac{1}{2}mv^2$.
Metre (m)	The SI unit of length.
Ohm	The derived SI unit of resistance defined as the resistance between two points of a conductor when a constant difference of potential of 1 volt, applied between these two points, produces in the conductor a current of 1 ampere.
Pascal (Pa)	The derived SI unit of pressure, equal to 1 newton per square metre.
Photokeratitis	Inflammation of the cornea in front of the eye due to light.
Power	The rate of doing work, measured in units of work per unit time. The derived SI unit of power is the watt.
R_t	Total resistance.
Second (s)	The SI unit of time.
SI units	An internationally agreed coherent system of units now in use for all scientific purposes.
Volt (V)	The derived SI unit of electric potential. Defined as the difference of potential between two points on a conducting wire carrying a constant current of one ampere when the power dissipated between these points is one watt. Also the unit of potential difference and

electromotive force.

Voltage	The potential, potential difference or electromotive force of a supply of electricity, measured in volts.
Watt (W)	The derived SI unit of power, equal to one joule per second.
Waveform	The shape of a wave, illustrated graphically by plotting the values of the periodic quantity against time.

C METRIC (SI) MULTIPLIERS

Giga (G)	10^9
Mega (M)	10^6
Kilo (k)	10^3
Deci (d)	10^{-1}
Centi (c)	10^{-2}
Milli (m)	10^{-3}
Micro (µ)	10^{-6}
Nano (n)	10^{-9}
Pico (p)	10^{-12}

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