Home Office

Police Scientific Development Branch

Crime Investigation and Officer Safety Sector

Fingerprint Development and Imaging Newsletter: Special Edition

August 2004 Publication No. 54/04

In this issue –

The Powders Process, Study 1:

Evaluation of Fingerprint Brushes for Use with Aluminium Powder

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ABSTRACT

This is the first in a series of newsletters giving guidance to scene examiners on the powders process. In particular, this newsletter will demonstrate that there is a difference in the performance of various fingerprint brushes when used with aluminium powder on surfaces commonly encountered at scenes of crime. The data is based on extensive laboratory trials carried out at PSDB.

Airborne concentrations of aluminium powder and glass fibres shed from brushes were measured during the normal working day of scene examiners. All concentrations were measured below the current exposure limits.

INTRODUCTION

Fingerprint powders have been used successfully for over 100 years for the detection of latent marks at scenes of crime. The success that powdering has enjoyed is due to the fact that it is a low-cost, efficient process, which is believed to present no excessive health and safety issues. In 2001/2002 there were 61,098 fingerprint identifications across England and Wales - approximately half of these marks were developed with powder, yet there is limited guidance given to scene examiners on best practice procedures.

There are many factors that influence the quantity and quality of marks developed with powder. Some factors cannot be controlled, such as the nature and condition of the surface to be examined and the nature of the mark left on the surface, although the likelihood of development may decrease with the age of the mark.

Equipment selection is a large factor. There is a bewildering choice of powders, brushes, lifting media, sources of illumination etc. available to scene examiners. Their choice may be based on previous experiences of products, the nature of the surface, word of mouth, information in the literature, or simply made for them by force procurement procedures. Determining effectiveness at scenes is virtually impossible for examiners. Hundreds of scenes would need to be studied in order to see differences in effectiveness between products. This is especially true when the differences are small. Additionally, the examiner does not know whether marks are present at a scene until they have powdered. Most brush/powder combinations will develop the heaviest of marks, but some may be ineffective in developing the weaker marks.

The care, expertise and training of the scene examiner are other factors that can influence the number of marks found. This can include time spent on an area, amount of powder loaded onto the brush, technique etc. Additional guidance and improved training should reduce the user dependence currently shown.

It is clear that small improvements to this already effective process should result in a greater number of identifications. Therefore, PSDB will issue a series of newsletters that give guidance on the most effective powdering techniques for use at scenes of crime. Each newsletter will focus on a particular aspect of the process and will be based upon extensive trials. This initial newsletter (Study 1) will concentrate on use of aluminium powder. Subsequent ones will concentrate on alternative powders (magnetic, granular etc), lifting media and imaging. Additionally, PSDB strives to provide the user with up-to-date health and safety information regarding any recommended process. Therefore, each newsletter will advise on health and safety of recommended processes.

OBJECTIVES: Study 1 – Brushes Used With Aluminium Powder

Within the UK, aluminium powder has become one of the most popular powders used by scene examiners. However, surveys, focus groups and conversations with users have led us to believe that there is wide variation in the way it is used. For example, some use aluminium powder in preference to alternative powders on all surfaces, whilst others will use alternative powders for all surfaces and never use aluminium powder. As far as we know, the majority of practitioners use aluminium powder on smooth clean surfaces and would consider one of the many alternative powders if presented with surfaces with texture or slight contamination.

Study 1 of this series will concentrate on the effectiveness of a range of fingerprint brushes when used with aluminium powder. To date there has been no extensive evaluation that compares the performance of different fingerprint brushes. Therefore the first objective is:

- *To ascertain if there is a significant difference in the performance of fingerprint brushes used with aluminium powder on a range of surfaces commonly found at scenes of crime*

Some forces, primarily due to health and safety concerns, do not purchase glass fibre brushes. The fibres can break off during use and become airborne. These may be inhaled if a suitable facemask is not worn. Also, although we suspect that there are limited health and safety issues associated with the use of aluminium powder at scenes, this has not been effectively tested. Therefore the second objective is:

- *To monitor exposure to glass fibres shed from fingerprint brushes and aluminium powder at scenes of crime.*

TRIAL METHODOLOGY

This section describes the methodology used during the laboratory trials of various brushes with aluminium powder.

Aluminium Powder

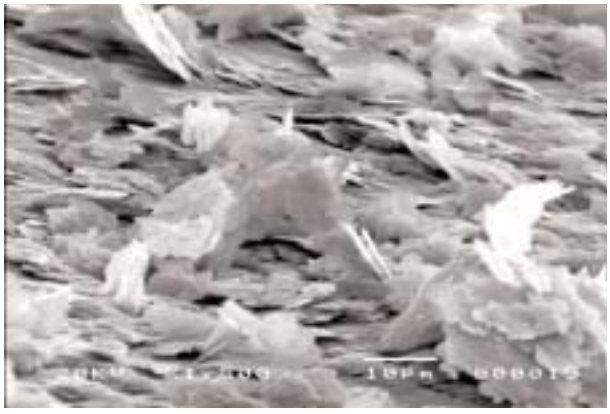

Figure 1: Scanning Electron Microscope (SEM) image of aluminium flake fingerprint powder

The Scanning Electron Microscope (SEM) image in Figure 1 shows that aluminium fingerprint powder has a flake structure. It is generally understood that under many circumstances the flake powders are more sensitive than other types of powder. The flat plate-like structure of the material gives it particularly good adhesion properties and its hardness and high reflectivity make it suitable for lifting and subsequent photography. Unless significant data suggest otherwise, it should normally be regarded as the first choice of powder unless obvious factors such as surface condition preclude this[1].

For this trial, five aluminium flake powders from a range of scene-of-crime suppliers were

studied initially and it was found that there was little difference in the morphology of the particles. All had a sub-micron thickness, with the flake diameter ranging from just under 1µm up to approximately 12µm. Super8000 aluminium flake powder from Wolstenholme was subsequently selected for the trial as, at the time of selection, this was the main supplier of aluminium flake powder to scene-of-crime suppliers within the UK.

Brushes

A recent survey of main UK and US scene-of-crime equipment suppliers revealed that there is a large number of brushes available for use with fingerprint powders. It was not feasible, nor considered necessary, to test comprehensively all of the brushes, as many of them could be classified into a number of generic types.

Prior to the main trial, considerable time was spent using the brushes to ascertain the best method of applying aluminium powder to latent marks on glass surfaces for each of them. The brushes were used in the optimum way throughout this study.

During the course of our work the range of brushes on the market has changed. Where possible, new brushes have been included in the trial and discontinued brushes have been eliminated unless they appeared particularly promising.

Fingerprint brushes vary in several ways. The fibre mounting is one such variable. Figure 2 shows a common mount for many of the man-made fibres. This is generally known as a 'zephyr' style mount. The fibres in these brushes are generally straight cut, quite long and attached to a thin handle. Figure 3 shows the 'mop' or 'artist' style mount where the head of the fibre bundle is rounded. These fibres tend to be shorter that those in a 'zephyr' style mount.

Fingerprint brushes can be made from a range of fibre types. The different fibres will vary in thickness, flexibility and shape as well their ability to adhere powder to the fibre surface and release powder to the mark – all of these factors may contribute towards the effectiveness of the brush.

Figure 2: 'Zephyr Style' fibre mounting

Figure 3: 'Artist Style' fibre mounting

Polyester Brushes

There are several polyester fibre brushes currently available from scene-of-crime suppliers. As far as we know, the Tetra Washable brush is the only one where the tips of the fibres are tapered to a fine point (Figure 4). All of the others have a uniform thickness down the length of the fibre and the tips appear to have been cut (Figure 5). These are sometimes referred to as Skye I, II or III or Whisper brushes and all have a 'zephyr' style fibre mount.

The Tetra Washable and Skye II brushes were used throughout this trial. The Skye I brush was dropped from the trial mid-way due to manufacturers confirming that fewer that 10 were sold each year and its performance appeared no better that the Skye II brush. The Skye III brush came onto the market mid-way through the trial but offered no advantage over the Skye II brush in a small trial.

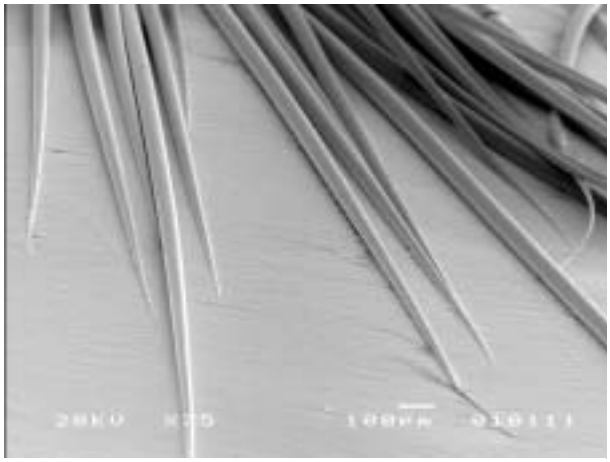

Figure 4: SEM image of the tip of a tapered polyester brush. Average tip diameter = 4-14mm; Average body diameter = 50-60µm

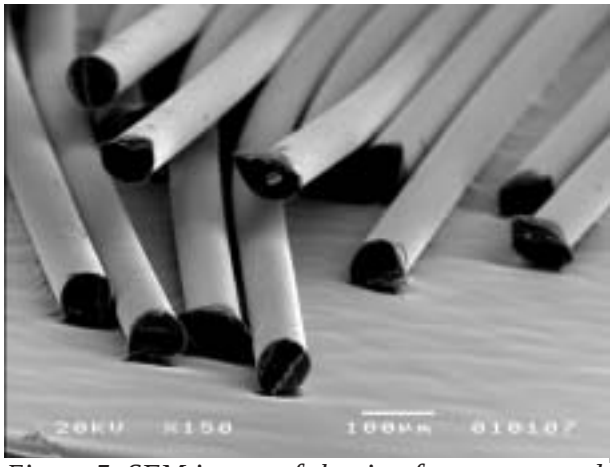

Figure 5: SEM image of the tip of a non-tapered polyester fibre brush. Average fibre diameter = 50-75µm

Glass Fibre Brushes

These brushes, commonly referred to as 'zephyr' brushes, consist of uniform fibreglass strands that are a lot thinner than the fibres in most fingerprint brushes made with other materials (Figure 6). The fibres can be either lightly starched or unstarched. Generally, scene-of-crime suppliers sell the slightly starched version to render the fibres less prone to tangling in use. We are aware of only one force using the unstarched brush.

Although they have the disadvantage of becoming tangled when used inappropriately (in damp or contaminated areas or if used too vigorously), these brushes have been considered extremely effective when used with aluminium powder. Therefore, both the starched and unstarched types were included in the trial.

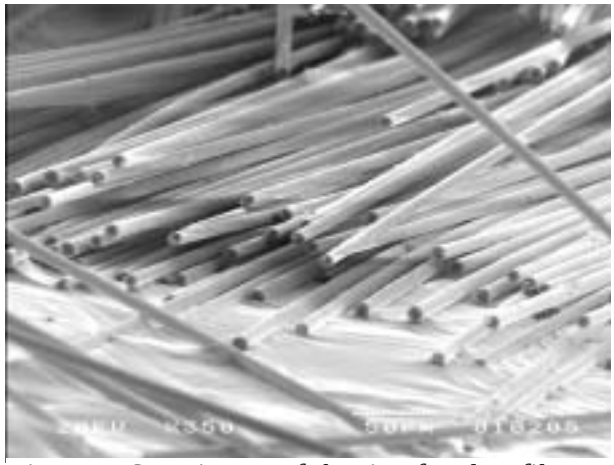

Figure 6: SEM image of the tip of a glass fibre brush. Average fibre diameter = 7-10µm

Natural Hair Brushes

There are numerous natural hair fingerprint brushes available, both zephyr and artist style, with squirrel being the most common. They are available in a range of sizes. Being natural hair, the surface is covered with scales. The cross-section tends to indicate a hollow structure with a thin exterior and may appear dumbbell shaped (see Figure 7).

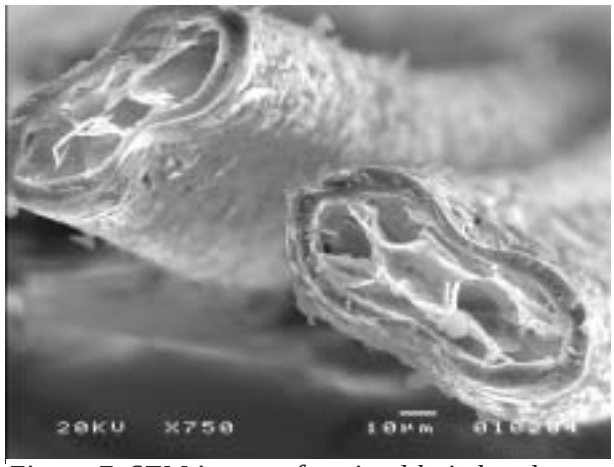

Figure 7: SEM image of squirrel hair brush (cross-section). Average tip diameter = 7-27µm. Average body diameter = 38-95µm

Traditionally, the artist style brushes are used with granular powders by most scene examiners. However, some use them with aluminium powder. For this reason, an artist style squirrel brush was included in the trial along with a zephyr style squirrel brush.

Feather Brushes

Feather brushes are gaining popularity partly because of their ability to cover large areas relatively quickly. However, little is known about their effectiveness. As can be seen from the SEM image in Figure 8, some of the tips of the feathers have been trimmed to leave a coarse end to the feather. Additionally, jagged barbs are noticeable at regular intervals towards the tips of the feathers (see Figure 9)

Figure 8: SEM image of a typical feather showing the trimmed end

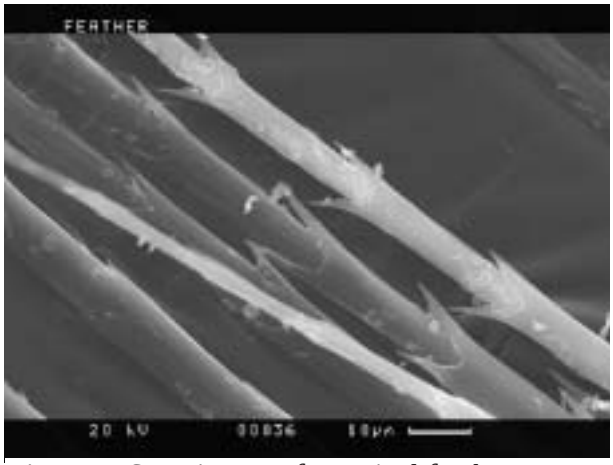

Figure 9: SEM image of a typical feather showing the jagged barbs towards the tip of the feather

A marabou feather brush became available as a fingerprint brush mid-way through the trial. It was considered important to include it in the trial due to its popularity with some police forces.

Carbon Brushes

Only one main UK scene-of-crime equipment supplier sells the carbon fibre fingerprint brush. The fibres are crinkled as shown in Figure 10. A carbon fibre brush was purchased for the trial but was deemed inappropriate due to the large amount of fibre shedding. Even prior to loading the brush with powder, large clumps of fibres were easily detached from the brush. We are not aware of any scene examiners using this brush.

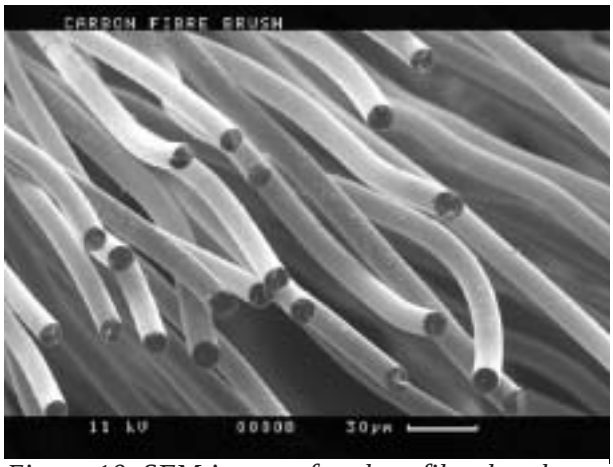

Figure 10: SEM image of carbon fibre brush

Nylon Brushes

The nylon brush is not available from any of the main UK scene-of-crime suppliers, however it can be purchased in the US. From the SEM image (Figure 11) the fibre body and tip looks similar to the chopped polyester fibres.

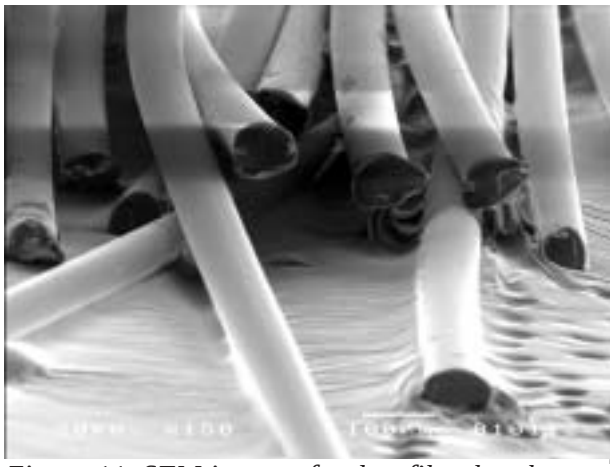

Figure 11: SEM image of nylon fibre brush

It was included in the trial as little is known about its performance.

Laboratory Control Methods

All of the powdering was carried out in a Bassaire SPL 4 RFM powdering cabinet with a flow rate across the sash in excess of 0.3 ms^{-1} (as recommended in the MoFDT[1]).

Test Surfaces

The surfaces used in this trial were chosen from the results of a survey completed by scene examiners at the start of the project. It was found that the most commonly powdered surfaces at crime scenes were glass, u-PVC, gloss painted wood and painted metal and so these were included in the study.

Sheets of glass and u-PVC were bought from a local DIY store. White/cream gloss-painted doors were obtained from a house clearance of unknown history. Painted metal was obtained from car bonnets and a fridge acquired from a breakers yard and house clearance respectively, again all of unknown history. Most surfaces were cut to A4 size and cleaned with household cleaning product and thoroughly rinsed.

Fingerprint Donors

All of the fingerprints used in this trial were obtained from a pool of 30 donors. As with all fingerprint laboratory trials at PSDB the donors were categorised as a good to poor donor. This system ensured that each experiment consisted of a range of latent fingerprints in which the results from the powders process was known to vary considerably.

Fingerprint Donation

For all laboratory trials a PSDB standard protocol was followed for the collection of fingerprints from donors. Donors were requested that they did not wash their hands for at least 30 minutes prior to leaving fingerprints on the sample surfaces. This allowed adequate fingerprint residue to collect naturally on the fingers. Donors were not encouraged to rub their fingers across the face, hair etc just prior to donating, as this increases dramatically the amount of latent material (predominantly sebaceous) on the finger. This was considered unrealistic and could skew the results of the trial considerably. Just prior to fingerprint donation, donors were asked to rub their hands together in order to get an even coating of sweat across the fingers.

For each sample surface panel, one donor was asked to deposit 8 series of fingerprints, using a single finger for each series, starting at the top of the panel, moving towards the bottom. This is shown schematically in Figure 12, which demonstrates the diminishing quantity of material left in the mark.

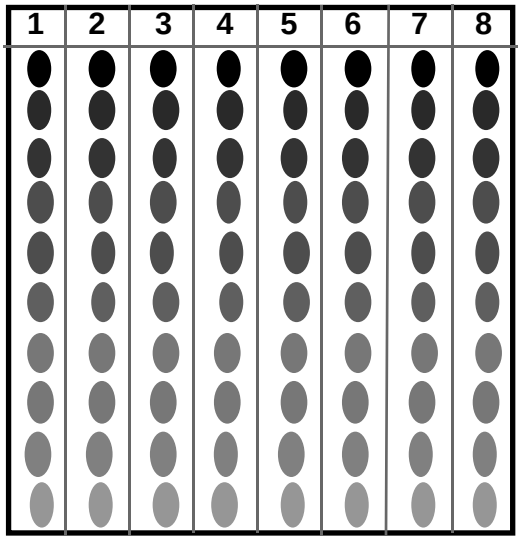

Figure 12: Schematic diagram showing a typical surface panel. The ovals represent fingerprints with varying amounts of deposit.

The panels of latent fingerprints were left in the laboratory in vertical racks out of direct sunlight and aged for either 1 day or 1 week prior to development.

Development

After ageing, each column within a panel was powdered with aluminium flake powder applied with one of eight brushes. The brushes were loaded with aluminium powder according to the MoFDT[1]. Sufficient powder could be obtained by running the brushes round the inside of the walls of the container rather than dipping the brush into the bulk of the powder. The brushes did not need to be reloaded with powder very often although some brushes held powder better than others. In order to expose one column at a time a suitable mask was used to prevent cross-contamination between columns.

Lifting Media

There is an extensive array of fingerprint lifting media available, ranging from tapes to gel-lifters to various casting materials. For this trial, 3M 483 lifting tape was used throughout. This tape is commonly used by many scene examiners and is slightly stretchy allowing it to be used successfully on surfaces that may have texture or are not flat. Disadvantages of this tape are that it is less transparent than some alternative lifters. Additionally, the tape can produce distortion if the operator pulls excessively on it during application rather than rolling it on. However these concerns are relatively minor and the product is considered to be an excellent lifting tape.

Once the material had been lifted, the tape was stuck onto acetate sheets.

Imaging

All lifts were imaged on a Camtac machine and processed through an Ilford black and white processing machine to produce a high quality image of black fingerprint ridges on a white background.

Grading the Fingerprints

A system was devised to score each mark treated with aluminium powder on the quality of ridge detail, contrast and level of brush damage. For this report only ridge detail quality is discussed, as both the contrast and brush damage affect the ridge detail. The grading system is described in Table 1.

Grade	Comments
0	no development
1	no continuous ridges. All discontinuous or dotty
2	1/3 of mark continuous ridges. (Rest no development, dotty, smudge or infill)
3	2/3 or mark continuous ridges. (Rest no development, dotty, smudge or infill)
4	full development. Whole mark continuous ridges

Table 1: Grading system used for determining the quality of ridge detail for developed marks

Trial Size

As already mentioned, there are many factors that affect the performance of the powdering process. One way to reduce the chances of spurious results (especially for variables out of our control such as age of latent marks, donor-donor variation, donor-time variation) is to carry out large studies so that anomalous results do not influence the overall conclusions. As there are so many variables it is clear that a trial can very quickly become extremely large – in this work 12640 fingerprints were studied (see Table 2). Statistical analysis of this data was considered but deemed extremely difficult due to the many variables and subjective nature of the grading.

Surface	Glass	u-PVC	Gloss Painted Wood	Painted Metal	Total
Number of Donors	10	15	28	30	
Number of Prints per Depletion Series	6	10	10	10	
Number of Ages	2	2	2	2	
Number of Brushes	8	8	8	8	
Number of Fingerprints Developed	960	2400	4480	4800	**12640**

Table 2: Total number of fingerprints developed in this trial

RESULTS

Table 3 shows the order of performance of the brushes for each surface studied in this trial. These results were calculated by simply summing the individual mark scores within a depletion series and for different donor on a surface. The results are calculated for both 1 and 7 day old marks. This table does not indicate the extent of the difference between the brushes, but merely ranks them from 1 (the most effective brush) to 8 (the least effective brush) based on the grading system used. It can be seen that glass fibre brushes appear in the top three, in terms of performance, for most surfaces. Similarly, the artist style squirrel brush is one of the least effective brushes on all surfaces. Other brushes, such as the non-tapered (2) polyester, were erratic in their performance and proved to be the most effective brush on one surface and the least effective on another.

Figure 13 represents the data in a slightly different way. Firstly, it attempts to gather all of the information together and present the effectiveness of the brushes across all surfaces. Secondly, unlike the data in Table 3, it gives average scores for each brush and as a result differences in performance can be determined. In order to establish the overall effectiveness of the different brushes it is necessary to take a weighted average to account for differences in numbers of fingerprints developed on each surface (Table 2).

Surface	Glass		u-PVC		Gloss Painted Wood (uncleaned)		Gloss Painted Wood (cleaned)		Painted Metal	
Brush/Age	**1 day**	**7 days**	**1 day**	**7 days**	**1 day**	**7 days**	**1 day**	**7 days**	**1 day**	**7 days**
Glass Fibre (unstarched)	1	2/3	1	3	1	2	1/2	1	3	4/5
Glass Fibre (starched)	2/3	2/3	2	1	2	1	3	3	1	1
Squirrel (Zephyr Style)	2/3	1	4	2	5	5	4	4/5	2	3
Polyester (tapered)	4/5	4/5	3	4	3/4	6	6	4/5	7	6
Nylon	7	7	6	5	6	8	7	8	5	4/5
Feather	N/A	N/A	N/A	N/A	3/4	3	5	6	4	2
Polyester (non-tapered 1)	4/5	4/5	7	6	N/A	N/A	N/A	N/A	N/A	N/A
Polyester (non-tapered 2)	8	8	8	7	7/8	4	1/2	2	6	7
Polyester (non-tapered 3)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Squirrel (artist style)	6	6	5	8	7/8	7	8	7	8	8

Table 3: Order of performance of fingerprint brushes and aluminium powder on a variety of surfaces with planted prints aged for 1 day and 7 days

Figure 13 shows the weighted average score for all brushes used in the final trial. The minimum possible score would be 0 (no development at all), whilst the maximum score would be a 4 (all prints developed perfectly). The first point to note is that there is a significant difference in the performance of the brushes when used with aluminium powder. In fact, the weighted average scores range from 1.47 to 2.22 for 1-day old marks and 1.18 to 1.93 for 7-day old marks. The glass fibre brush (both starched and unstarched) weighted average score for ridge detail is higher than the score for all other brushes, whilst the score for the artist style squirrel brush is lower than all others.

The second point to note is that in all cases aluminium powder performed better on 1-day old prints than 7-day old. As with most fingerprint development processes, the chances of developing marks at scenes decreases considerably with time.

The data from Figure 13 can be rearranged to give an order of effectiveness across all surface (see Table 4). Although there are some difference between 24 hour and 7 day old marks, the overall conclusions are similar.

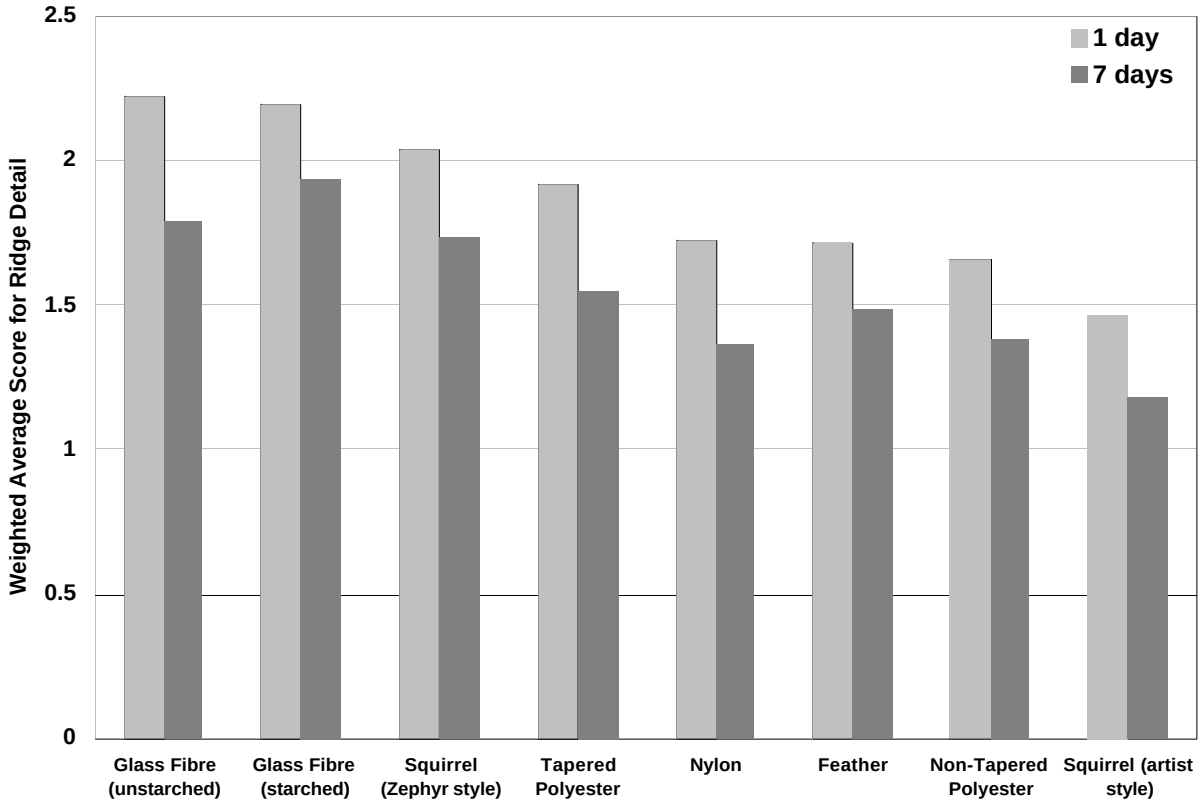

Figure 13: Weighted Average Scores for Ridge Detail at 24 hours and 7 days for all Surfaces

Rank	24 Hours	7 Days
1	Glass Fibre (unstarched)	Glass Fibre (starched)
2	Glass Fibre (starched)	Glass Fibre (unstarched)
3	Squirrel (Zephyr Style)	Squirrel (Zephyr Style)
4	Polyester (tapered)	Polyester (tapered)
5	Nylon	Feather
6	Feather	Polyester (untapered)
7	Polyester (untapered)	Nylon
8	Squirrel (Artist Style)	Squirrel (Artist Style)

Table 4: The overall order of performance of fingerprint brushes and aluminium powder

DISCUSSION

This study has looked at the effectiveness of a variety of fingerprint brushes when used with aluminium powder on a range of surfaces commonly treated by scene examiners. From the data we are able to conclude that the glass fibre brush performs exceptionally well, relative to other brushes, on all surfaces tested. The MoFDT[1] already recommends that aluminium milled flake powder is best applied with a very lightly loaded glass fibre brush, although at the time of its publication little comparative data was available. This data adds strength to the current recommendation.

This study was performed in a laboratory where the conditions were ideal for powdering with a glass fibre brush. However, from initial studies on brush usage, if used too vigorously, or on slightly damp, greasy or sticky surfaces then the fibres can tangle. On such contaminated surfaces, the squirrel (zephyr style) or the tapered polyester (Tetra washable) brushes could be used as alternatives to the glass fibre brushes. Both of these brushes can be cleaned and dry out much more easily than the glass fibre brushes and are less prone to tangling. The starched glass fibre brush is less prone to tangling than the unstarched one. Additionally, spinning the brush during application of the aluminium powder offered no advantage in terms of development of marks. It did, however, cause the brush to tangle much more readily than if swept from side-to-side.

Stating categorically which is the most effective brush for a particular type of surface is extremely difficult and only indications of the best brush to use can be suggested from this data. Thus, although this was an extremely large trial, there is still insufficient data to say that starched glass fibre brushes will always be the most effective on painted metal surfaces for example. This is because the uncontrolled (and often unknown) variations in surface property such as age, type of paint, cleanliness etc will affect the performance of the powder and brush. In this trial the data obtained for the painted metal surface came only from two car bonnets and a fridge of unknown history. Thus, the final recommendations may not necessarily be the best choice for all surfaces, but it may provide the scene examiner with the knowledge that enables them to maximise the possibilities of developing marks on surfaces.

HEALTH AND SAFETY

The second objective was to monitor exposure of scene examiners to both aluminium powder and glass fibres shed from fingerprint brushes at scenes of crime. For both cases, scene examiners were monitored using equipment provided by the Health and Safety Laboratory (HSL). The Health and Safety Executive (HSE) performed final analysis of the filters.

Monitoring took place during the normal working day of scene examiners from four police forces. All scenes attended during the day were monitored from the time of opening the scene examiner's case to the time of leaving the scene.

Exposure Limits

The Health and Safety Commission's Advisory Committee on Toxic Substances (ACTS) has assigned aluminium powder and glass fibres the following exposure limits:

Aluminium	Occupational Exposure Standard (OES) / mg m^{-3} (8 hr TWA*)
Total Inhalable Dust	10
Total Respirable Dust	4
Glass Fibre	**Maximum Exposure Limit (MEL) / fibres ml^{-1} (8 hr TWA*)**
	2
* Time Weighted Average	

Table 5: Exposure limits for aluminium powder and glass fibre

No short-term exposure (15-minute TWA) limit is listed for aluminium. In such cases, the HSE recommend that a figure of 3 times the long term limit (8-hour TWA) be used as a guideline for controlling short term peaks in exposure.

Glass fibres are classed as Machine Made Mineral Fibres (MMMF): fibres that are counted have a length of > 5mm, average diameter < 3mm and a ratio of length to diameter > 3:1.

Exposure to Aluminium Powder

Eight scene examiners were monitored for 1 day each. Exposure to aluminium powder during the trial ranged from 29-104 minutes during the 8-hour working day. In all cases, exposure was below the allowed limits with values ranging from 0.021 mg m^3 to 0.289 mg m^3 (8 hr TWA). These values are at least an order of magnitude below the exposure limits. These results confirm already reported studies on exposure of scene examiners to aluminium powder.

Exposure to Glass Fibres

Two scene examiners were monitored for 1 day each. One examiner was exposed to glass fibres for 89 minutes whilst the other was exposed for 159 minutes during the 8-hour working day. In both cases, exposure to glass fibres was negligible. This is because fibres shed from glass fibre fingerprint brushes are too large (and therefore are not counted) to cause any measurable health effects to the respiratory system.

Currently no exposure limit exists in the UK that relates to irritation of eyes and skin by glass fibres. Skin sensitisation is not a recognised hazard from glass fibres suggesting that it is purely mechanical friction from fibres that may cause irritation. However, individuals vary greatly in their tolerance to the skin irritability of glass fibres and so some workers may find it much more unpleasant than others. Appropriate protective equipment should be provided if the user complains about eye/skin irritation.

CONCLUSIONS

There was a considerable difference in the performance of aluminium powder when applied with a variety of fingerprint brushes to the surfaces used in this study. Overall, glass fibre brushes proved to be the most effective, closely followed by the zephyr style squirrel brush and the tapered polyester brush. The artist style squirrel brush proved to be the least effective.

Exposure monitoring of both aluminium powder and glass fibres suggest that scene examiners are not exposed to quantities above the OES or MEL respectively whilst carrying out normal duties.

RECOMMENDATIONS

Based on this trial the following recommendations are made:

- Aluminium powder should, where possible, be applied with a glass fibre brush.
- Zephyr style squirrel brushes or tapered polyester brushes should be used on surfaces where it is inappropriate to use glass fibre brushes.
- The health and safety advice given in the MoFDT[1] is still appropriate for aluminium powder.

ACKNOWLEDGEMENTS

There are many contributors associated with the gathering and interpretation of data contained in this newsletter. Although it is not possible to name all involved, special thanks go to Stephen Lau for the SEM images, Sheila Hardwick, Simon Walker, Carmine Ruggiero and Andrea Wiggett for the data collection and interpretation, Andrew Gibson for the health and safety monitoring and Terry Kent for overall management of the programme.

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1 T.Kent, Home Office, Manual of Fingerprint Development Techniques, 2nd Ed. 1998

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