CPNI
Centre for the Protection of National Infrastructure

UK Mail Screening Test Piece (MSTP) – A Guide

April 2015

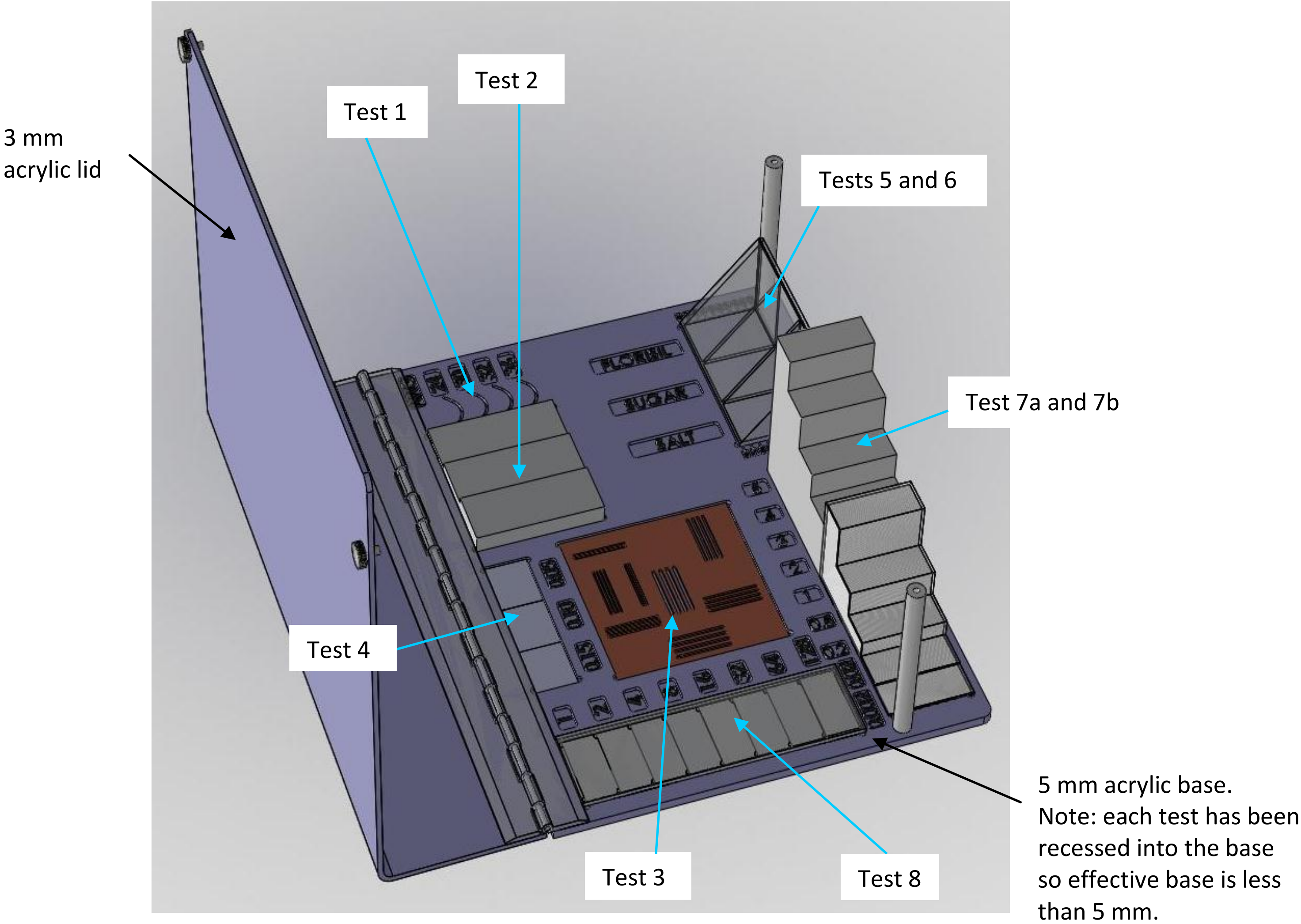
Introduction

For a number of years, a standard test piece (referred to commonly as the STP) has been used to ensure that baggage X-ray machines used operationally in airports meet a minimum performance standard. The test piece contains a series of tests to determine penetration and resolution of the system and whether or not the system is capable of determining the difference between organic and inorganic materials. The test piece is approximately A4-size and is run through the X-ray machine. The image obtained is assessed to determine system performance. Various image processing functions can be used to achieve the best possible image for assessment. The use of X-ray systems in aviation is regulated by the Department for Transport and minimum performance standards are in place.

It is acknowledged that the STP yields useful information about conveyorised X-ray machines for aviation security, but this has limitations when applied to mail screening applications. Therefore, the UK Mail Screening Test Piece has been designed by the Home Office Centre for Applied Science and Technology (CAST), at the request of and in association with CPNI, for such applications. Some tests on the STP have been used on the mail screening test piece and others have been added to enable better assessment of the performance of X-ray machines and fluoroscopes for the screening of mail items. A technical drawing of the mail screening test piece showing the individual tests is shown in Figure 1.

What follows is a description of each test outlining the purpose of the test, its applicability to conveyorised (linescan) and/or cabinet (fluoroscope) X-ray systems, the minimum performance requirements that should be expected and the particular relevance of the test to mail screening.

The tests on the mail screening test piece are designed specifically to cover the full range in capability of both conveyorised and cabinet X-ray machines used for mail screening but also allow for advances that may be made to the technologies in future years.



Test 1 – Single wire resolution
Test 2 – Aluminium penetration
Test 3 – Spatial resolution
Test 4 – Thin material imaging

Test 5 – Materials discrimination
Test 6 – Powder imaging
Tests 7a and 7b – Paper penetration and threat resolution
Test 8 – Foil imaging

Figure 1: UK Mail Screening Test Piece showing individual tests (test piece lid is open for ease of viewing)

Description of tests

Test 1 Single wire resolution

This test is applicable to both conveyorised and cabinet X-ray machines. The purpose of the single wire resolution test is to assess the ability of the system to display a single thin wire (see Figure 2). Within the mail screening context the resolution of wires of varying gauge is relevant to threat devices such as mail bombs that have wire components as part of their construction. The test uses non-insulated tinned copper wire of sizes 24, 30, 32 and 36 American wire gauge (AWG)[1]. The wires are laid out in S-shaped curves to enable resolution to be ascertained in two dimensions.

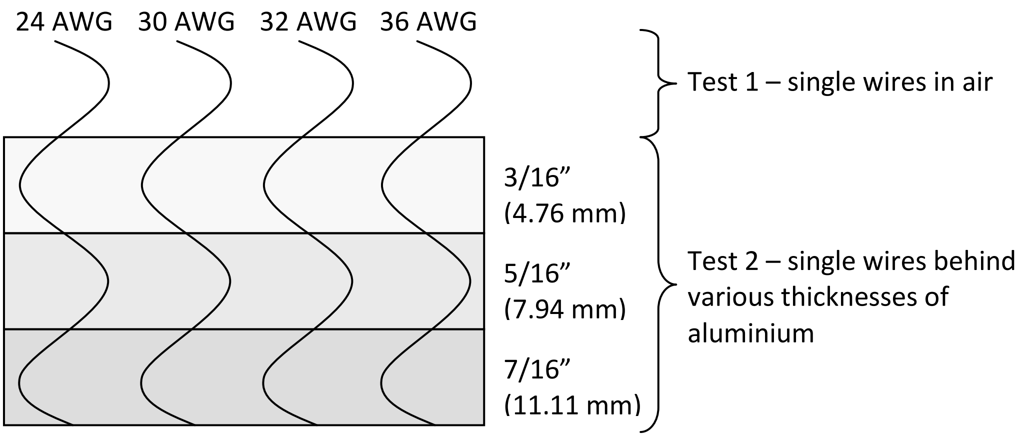


Figure 2: Schematic diagram showing Tests 1 and 2

Test 2 Aluminium penetration

This test is applicable to both conveyorised and cabinet X-ray machines. The purpose of this test is to assess the ability of the system to display a single thin wire which is obscured by varying thicknesses of aluminium (see Figure 2). Within the mail screening context this test complements Test 1, ascertaining the resolution of wires in the presence of various thicknesses of aluminium; aluminium has been used as a proxy for thicker quantities of paper.

The test uses non-insulated tinned copper wire of sizes 24, 30, 32 and 36 American wire gauge (AWG). The wires are laid out in S-shaped curves beneath three steps of aluminium of thickness 3/16 inches (4.76 mm), 5/16 inches (7.94 mm) and 7/16 inches (11.11 mm).

[1] Test 1 and Test 2 are taken from the STP which uses AWG as a unit of measurement. AWG dimensions are defined in ASTM standard B 258-02.

AWG	Diameter (mm)	Cross-sectional area (mm^2)
24	0.511	0.205
30	0.255	0.051
32	0.202	0.032
36	0.127	0.013

Test 3 Spatial resolution

This test is applicable to both conveyorised and cabinet X-ray machines. The purpose of this test is to evaluate the horizontal and vertical spatial resolution of the system (see Figure 3)[2]. Within the mail screening context this test determines how well small or closely packed items can be identified as individual items. The test comprises a copper grid with 0.5 mm, 1.0 mm, 1.5 mm and 2.0 mm gratings.

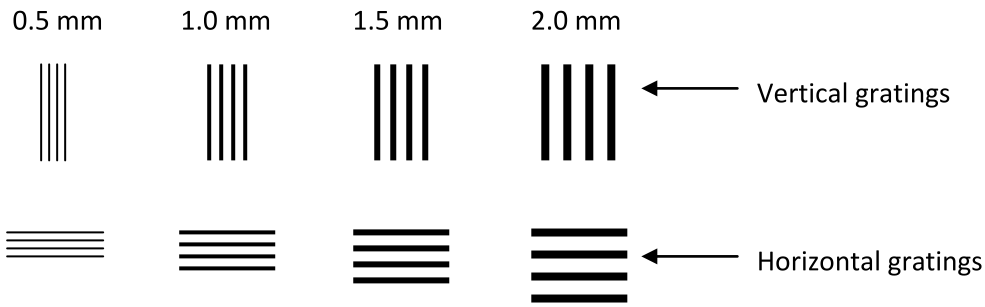


Figure 3: Schematic diagram showing Test 3. *Note that the layout of the gratings presented here differs from the layout on the test piece.*

Test 4 Thin material imaging

This test is applicable to both conveyorised and cabinet X-ray machines. Its purpose is to assess the ability of the system to resolve thin metallic objects, which might, in the mail screening context, be electrical conductors in a circuit. The test comprises three steel shims of thickness 0.15 mm, 0.10 mm and 0.05 mm, respectively (see Figure 4). This test is similar to Test 8, but uses steel shims to represent electrical contacts within circuitry instead of aluminium kitchen foil (which is often used to contain and/or disguise powders such as drugs).

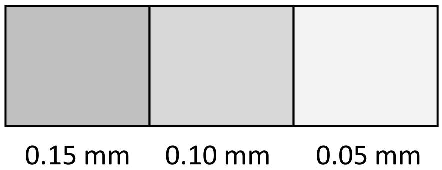
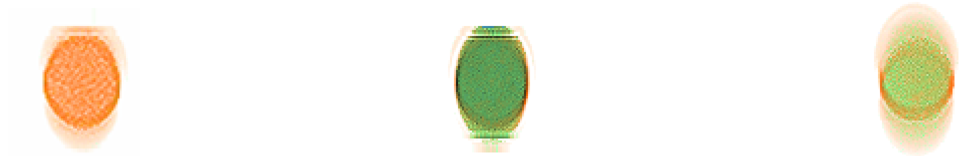


Figure 4: Schematic diagram showing Test 4

[2] For conveyorised X-ray machines, 'vertical' is defined as perpendicular to the direction of travel of the conveyor belt and 'horizontal' is defined as parallel to the direction of travel of the conveyor belt. For cabinet X-ray machines, 'vertical' is defined as the y-axis and 'horizontal' is defined as the x-axis of the cabinet base.

Test 5 Materials discrimination

This test is only applicable to conveyorised X-ray machines[3]. The purpose of the materials discrimination test is to show whether or not a system can distinguish between different classes of materials according to their density. Organic substances (e.g. sugar) typically appear orange, whilst inorganic substances (e.g. salt) are typically denser and likely to appear green or blue; some materials of intermediate density may appear orange-green as shown in Figure 5.



Organic powder

Inorganic powder

Not all powders can be categorised as easily as others

Figure 5: Example X-ray images of plastic pots containing different powders (viewed as if looking down through the container)

The test piece contains three materials (sugar, salt and Florisil[4]) housed in 2 mm thick acrylic 'wedges' (see Figure 6) with markings which have been added at 5 mm intervals which correspond to the thickness of the powder at that point (the markings are relevant to Test 6).

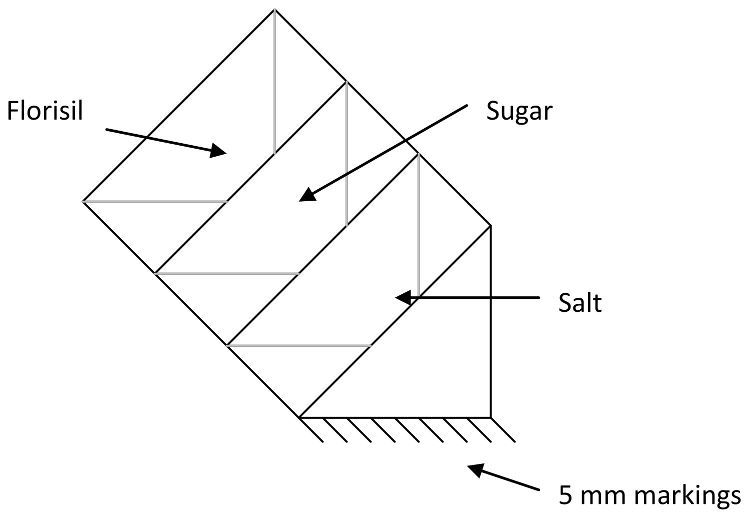


Figure 6: Schematic diagram showing Tests 5 and 6

NOTE: Operators of cabinet X-ray systems need to be particularly careful in the interpretation of any pseudo-colour image processing used as these are typically single energy systems which are not capable of materials discrimination.

[3] Currently, most conveyorised X-ray machines have materials discrimination capability due to the technology used (dual energy X-ray) but most cabinet X-ray systems do not.
[4] Florisil is an odourless white magnesium silicate powder used as an adsorbent in the chemical industry.

Test 6 Powder imaging

This test is applicable to both conveyorised and cabinet X-ray machines. The purpose of this test is to determine the minimum thicknesses of powders that can be resolved.[5] Three powders are contained on the test piece – sugar, salt and Florisil (see Figure 6). The powders are housed in 2 mm thick acrylic 'wedges' with markings which have been added at 5 mm intervals which correspond to the thickness of the powder at that point.

Test 7 Paper penetration and threat resolution

This test is applicable to both conveyorised and cabinet X-ray machines. This test provides an approximate indication of how much paper the system can penetrate whilst still enabling two simulated threat items to be resolved[6]. Within the mail screening context the paper penetration and threat resolution test provides an indication of how well certain threats can be seen in mail comprising differing amounts of paper.

A very thin strip of steel the same thickness as a razor blade and a 3 mm strip of material which represents sheet explosive (the strip used is an inert simulant) are concealed below a 'paper step wedge' (see Figure 7). Test 7a relates to the simulant razor blade and Test 7b relates to the simulant sheet explosive. Real explosives and razor blades have not been used for safety reasons.

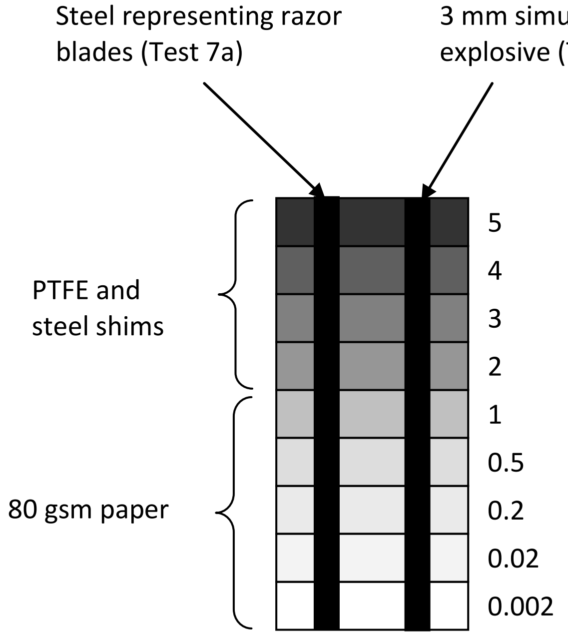


Figure 7: Schematic diagram of Test 7a and 7b – numbers represent the number of reams of paper, not number of sheets. ***NOTE: 1 ream is the same as 500 sheets of paper.***

[5] This highlights the difficulty of spotting the presence of small quantities of powder in X-ray images.
[6] It is important to note that the operator may be looking for other threats in addition to or instead of the ones represented here.

The first steps on the paper step wedge are made up of 1, 10, 100, 250 and 500 sheets of typical 80 gsm paper. Note that the numbers on the test piece are given in reams rather than sheets of paper, where 1 ream is the same as 500 sheets of paper. The remaining steps are made up of PTFE in combination with steel shims to represent 2, 3, 4 and 5 reams of paper respectively. This representation reduces the height of the test piece (5 reams measures approximately 25 cm) and ensures that the image of the wedge is a reasonable representation of the respective quantities of paper.

Test 8 Foil imaging

This test is applicable to both conveyorised and cabinet X-ray machines. The purpose of the foil imaging test is to assess the ability of the system to image layers of foil, which may for example in the postal context be used to contain or conceal narcotics or other hazardous materials, or as electrical conductors in an explosive device. This is a similar test to Test 4, but uses typical aluminium kitchen foil. The test comprises a foil step wedge where each step is twice the previous one (see Figure 8) and the number of layers is given alongside the step wedge.

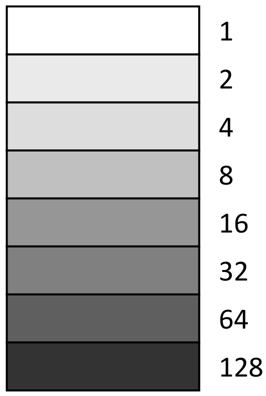


Figure 8: Schematic diagram of Test 8 – numbers show the number of layers of foil

MAIL SCREENING TEST PIECE LOGSHEET

This logsheet is for conveyorised X-ray machines; an alternative version of this logsheet is available for recording the performance of cabinet X-ray (fluoroscope) systems.

Date: ______________ Time: ______________ Operator: ____________________

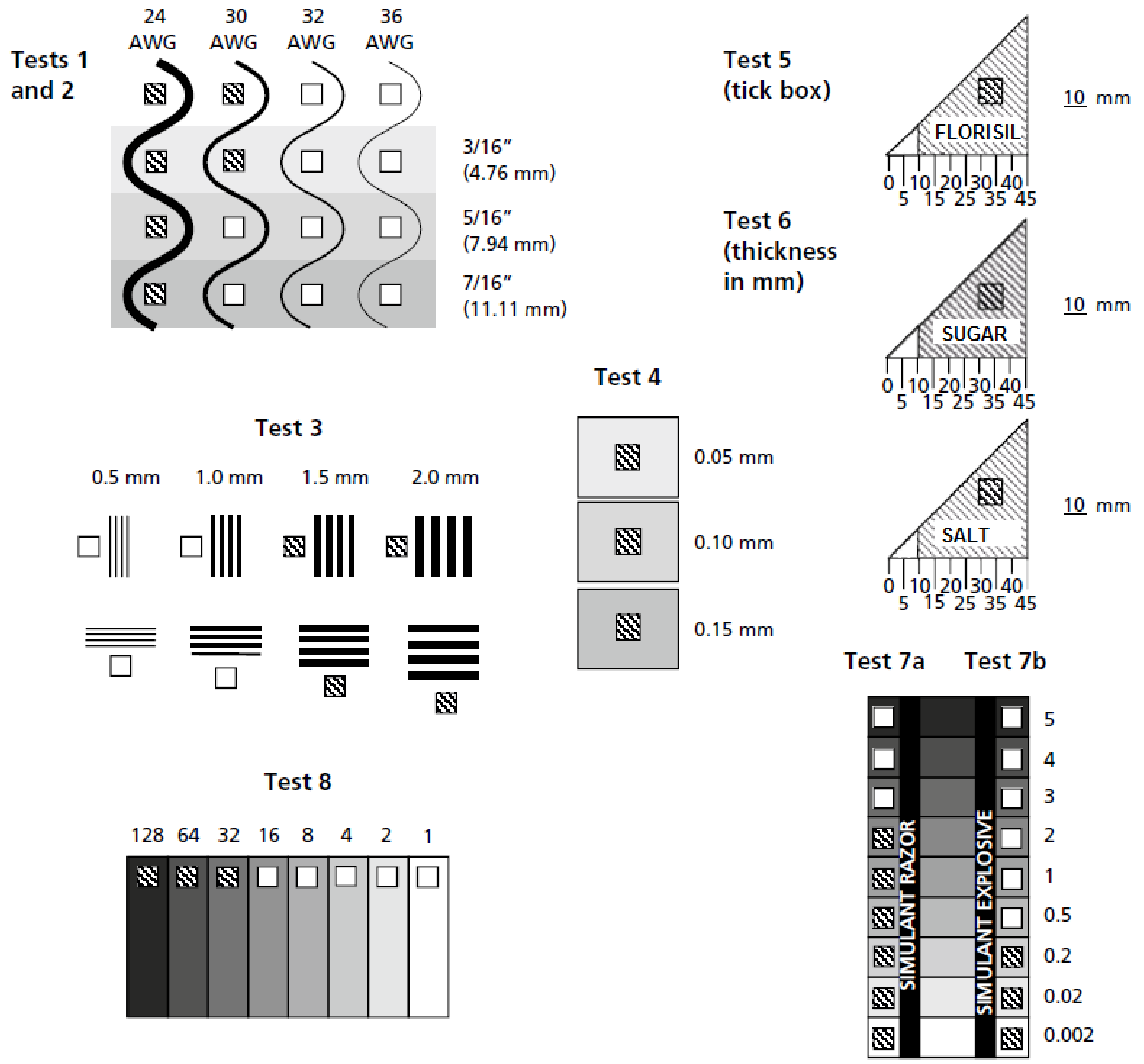
Conveyorised or cabinet X-ray: ____Conveyorised_____ Tunnel size: ____________________

Machine manufacturer and model: ____

Machine identity number: ______________________ Machine location: ______________

Software version: ________________

Optimum position of test piece on belt (left/middle/right): ______________________



MAIL SCREENING TEST PIECE LOGSHEET

This logsheet is for cabinet X-ray (fluoroscope) systems; an alternative version of this logsheet is available for recording the performance of conveyorised X-ray machines.

Date: ________________ Time: ________________ Operator: ____________________________

Conveyorised or cabinet X-ray: ____Cabinet_________ Chamber size: _______________________

Machine manufacturer and model: ____

Machine identity number: ____________________________ Machine location: ____________________

Software version: ___________________

Optimum position of test piece in cabinet (front/back/left/right/middle): _________________________