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COMBUSTIBILITY OF A DUST SAMPLE FROM THE VICTORIA LINE

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1. Introduction

1.1 A dust sample was submitted by Nicola Harrison, LUL Nominee BCV Ltd for analysis to determine its composition and the nature of hazardous components (if any). The results were reported in 4-Rail Services report reference: 4RS-MS-090115-R210828. The dust was understood to have been collected from various sites along the Victoria Line.

1.2 To control the potential levels of airborne dust that occur whilst trains are in operation a programme of cleaning had been undertaken. It was further planned to use a dust extraction unit to reduce the amount of dust present. The possibility that the dust may be combustible and hence, if raised to form a cloud could lead to a dust explosion was of concern. It was therefore requested that an assessment be made of the dust currently present on the Victoria Line.

1.3 A further dust sample collected by LUL Nominee BCV was supplied for examination with respect to combustibility. This dust was supplied in two small vacuum cleaner bags.

2. Background

2.1 Dust explosions have been known to occur in flour mills, coal mines, wood mills, grain silos and alike. The tunnel dust on the Victoria line is known to be able to be ignited. In the past, settled dust on cable runs had been known to smoulder. Figure 1 shows a close up view of cables on the southbound Victoria Line between Oxford Circus and Green Park in a location where smouldering dust had been found in 2003. It was noted that in this example and in other locations the dust that had smouldered was settled on asbestos braid sheathed cables.

2.2 The presence of asbestos braid may contribute to the ease of dust ignition and propagation of the smouldering: asbestos is a thermal insulator and hence does not remove heat from the burning dust (this allows combustion to occur in thinner layers than would otherwise be possible), the surface of the braid is rough which may assist in gathering dust and as the cables are covered in asbestos braid care is taken not to disturb them and hence gathered dust had not been removed either intentionally or unintentionally.

3. Combustibility and Explosion Indices

3.1 The dust collected in the vacuum cleaner bags was slightly lighter, more grey in colour than that previously found. Figure 2 shows a comparison of the dust supplied from the Victoria Line (090115/080709/1) with that collected previously from between Green Park and Oxford Circus in 2003/4 (034381/6). The grey colouration likely reflects a higher proportion of cementitious material within the dust.

3.2 The dust collected in 2003/4 (034381/6) ignited easily and smouldered gently whereas the dust recently collected from the Victoria Line did not ignite (Figures 3 & 4).

3.3 The combustion process is fuelled by skin flakes, fluff, hair, residual oil and also the oxidation of iron containing particles. Figure 5 shows the rusty colour presumably following the conversion of iron and iron oxide (Fe_3O_4) particles to iron oxide (Fe_2O_3).

3.4 To quantify the risks from the dust currently collected from the Victoria Line (sample 090115/080709/1), the sample was submitted for further analysis to BRE. This was to undertake the following:

1) Basic characterisation

   a) Classification to determine if the dust is classed as Group A (explosible) or Group B (non explosible)
   b) Layer ignition test - lowest temperature at which a 5mm layer ignites on a heated surface
   c) Minimum ignition temperature - minimum temperature which a hot surface will cause a dust cloud to ignite and propagate flame
   d) Minimum explosible concentration - determines the lowest concentration of dust that will allow combustion
   e) Minimum ignition energy - test to measure the ease of ignition by electrical or static discharges

2) Explosion indices

   a) If the dust proves explosible then a test to determine the maximum explosion pressure and rate of pressure rise is recommended Explosion indices allow the design of explosion protection systems

The test report from BRE is contained in Appendix 1.

3.5 The test results showed that the dust sample 090115/080709/1 would be classified as a Group B dust that is non explosible. In the layer ignition test no glowing embers were observed, but the sample heated to 460ºC indicating that an exothermic reaction had occurred within the sample.

3.6 The above tests showed the dust to be non explosible however as it is known that some samples of tunnel dust do ignite. An Explosion Indices Test was therefore conducted using pyrotechnic igniters. Following which the dust (090115/080709/1) was confirmed as non explosible.

4. Conclusions

4.1 The dust sample 090115/080709/1 that had been collected from the Victoria Line by the client was found to be non explosible and could not be ignited. An exothermic reaction was seen during the layer ignition test but not such that the sample freely burnt.

4.2 A sample of dust collected in 2003/4 (034381/6) from the Victoria Line between Green Park and Oxford Circus was qualitatively more combustible, smouldering freely when ignited. There was insufficient remaining of this archive sample for extensive testing.

4.3 Qualitative observations show that depending on the makeup of the dust greater or lesser combustibility may be obtained. Settled dust containing higher levels of skin flakes, oils, fluff fibres would be more combustible, whereas dust from construction works containing higher levels of cementitious materials would be less combustible.

5. Recommendations

5.1 The dust collected by the client from the Victoria Line (sample 090115/080709/1) was found to be non explosible indicating the risk of a dust explosion to be low. However, it should be recognised that some samples of dust collected previously were found to be combustible. It would therefore be recommended that the risk of dust explosions/combustibility should still be considered in case the nature of the dust changes or is different in various locations.

5.2 It should also be recognised that if the dust is stored in large amounts then any exothermic reaction with a small energy output may lead to combustion at the much higher temperatures possible within a bulk material.

Figure 1: Cable Fire Location on the Victoria Line Green Park & Victoria

Figure 2: Current sample (Vic) and previous tunnel dust sample

Figure 3: Qualitative ignition test of dust samples

Figure 4: Qualitative ignition test of dust samples

Figure 5: View showing colour change of burnt dust

Appendix 1

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Protecting People, Property and the Planet

Ignitability Assessments on a Sample of Rail Tunnel Dust

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22 July 2009

Test report number 255137

Ignitability Assessments on a Sample of Railway Tunnel Dust

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Ignitability Assessments on a Sample of Railway Tunnel Dust

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Ignitability Assessments on a Sample of Railway Tunnel Dust

1 Introduction

This report describes the results of ignitability assessments undertaken on a sample of railway tunnel dust supplied by 4-Rail Services Ltd.

Material tested :	Railway tunnel dust
Manufacturer/supplier:	4-Rail Services Ltd
Date sample received:	17th July 2009
Date sample tested:	21st – 23rd July 2009

2 Sample preparation

The sample contained material that was too coarse to test. It was passed through a 1mm sieve in order to obtain the finer particles for testing.

The particle size distribution of the prepared sample was determined by using a Malvern Instruments Laser Particle Sizer with a dry powder feed.

The moisture content of the material was assessed by placing a sample of known weight in an oven at 75°C for 24 hours, and calculating the percentage weight loss.

The results of these analyses are shown in Table 1 below.

Table 1 Particle size distribution and moisture content

Sample	<500µm	<315µm	<125µm	<74µm	<32µm	Median µm	% moisture
	% volume						
Rail tunnel dust	97	62	54	39	27	59.1	8.9

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3 Classification test

3.1 Introduction

In cases where the explosibility of a dust has not been determined, or is in doubt, it is necessary to know whether or not the dust will ignite and propagate flame before consideration can be given to specifying explosion protection measures. The classification test offers a qualitative assessment of whether or not a suspended dust is capable of initiating and sustaining an explosion in the presence of a small source of ignition. The classification is made purely on a visual observation of flame propagation, an explosible dust being one which causes flames to move away from the ignition source.

3.2 Test procedure

Initially, a small amount of dust, typically 0.5g, is placed in a dispersion cup around a mushroom-shaped deflector and is then suspended around the ignition source either by an instantaneous or continuous blast of air. Two ignition sources are used, a hot coil of 20 SWG Kanthal `A' wire heated to red heat (approximately 1000°C), and an electric spark of energy 8 - 10 J bridging a 0.6cm gap between a pair of electrodes.

Observations are made as to whether flames, no matter how small, propagate away from the ignition source. This is a qualitative test, and is described in detail in Reference 1.

3.3 Results

Table 2 Test Results

Sample	Ignition Source	Results	Class
Rail tunnel dust	Electric spark	No flame propagation	B
	Hot coil	No flame propagation	

A Group A dust ignites and propagates flame. A Group B dust does not ignite and propagate flame.

The sample was classified as Group B, non - explosible.

The test is valid up to ambient temperatures of 110°C.

4 5mm layer ignition test

4.1 Introduction

This test is designed for the determination of the minimum temperature of a hot surface which will lead to self-ignition of a layer of combustible material having one face in contact with the hot surface and with the other face exposed to the atmosphere. It follows the standard procedure given in BS EN 50281-2:1999[2].

4.2 Test apparatus

A heated surface consisting of a circular metal plate, diameter 200mm, is provided with a 'skirt' which supports it 10mm above the exposed heating element of a commercially available boiling plate. Two thermocouples are inserted into blind holes drilled into the underside of the plate. One thermocouple is connected to a temperature controller in the power supply and the other to a temperature recorder.

The temperature inside the layer of the material placed on the hot surface and the progress of self-heating is recorded with the aid of a fine chromel/alumel thermocouple stretched parallel to the surface of the plate.

4.3 Test procedure

The temperature of the hot-plate was first allowed to stabilise at the desired value. A ring of diameter 100mm and depth 5mm was then placed centrally on the surface and filled with the material to be tested. The temperature recorder was started and the test continued for a minimum of 30 minutes or until the layer has ignited.

Ignition is considered to have occurred if:

a) visible glowing or flaming is observed, or

b) a temperature of 450°C is measured, or

c) a temperature rise of 250°C above the temperature of the heated plate is measured.

If, after a minimum period of 30 minutes, no self-heating is apparent, the test is terminated and repeated at a higher temperature. If ignition or self-heating occurs, the test is repeated at a lower temperature, if necessary, prolonging the test beyond 30 minutes. Testing is continued until a temperature is found which is high enough to cause ignition, but which is no more than 10°C higher than a temperature which fails to cause self-heating.

4.4 Results

Table 3 Results of 5mm layer test on Railway Tunnel Dust

Surface temperature (°C)		Result of test	Time to ignition or to reach highest temperature without ignition (min)
Test 1	390	Ignition	3.2
Test 2	380	No Ignition	4.1
Test 3	380	No ignition	4.2
Test 4	380	No ignition	4.4

Ignition occurs with a 5mm layer of this sample placed on a heated surface at 390°C. No glowing embers were observed, but the sample heated to 460°C.

Density of layer: 695kg/m^3. Ambient temperature: 23°C. See Figures 1 and 2

5 Explosion indices test

5.1 Introduction

The measurement of the explosion severity that may be generated by an explosible powder is essential quantitative information for explosion protection, based on relief venting, suppression and containment. The test is described in BS EN 14034-1[3] and BS EN 14034-2[4]. The severity is characterised by two parameters, the maximum pressure P_{max} and the maximum rate of pressure rise $(dP/dt)_{max}$.

P_{max} is essentially independent of volume, but $(dP/dt)_{max}$ is volume dependent and is therefore related to a volume independent parameter the K_{st} which is defined by an equation known as the Cube root law:

$$K_{st} = V^{1/3}.(dP/dt)_{max}$$

where V is vessel volume in m^3, $(dP/dt)_{max}$ is the maximum rate of pressure rise in bar s^{-1} and K_{st} is a constant in bar m s^{-1}.

The values of K_{st} and P_{max} for a powder are determined under defined conditions in a laboratory test apparatus either 1m^3 or 20-litre volume.

Values of K_{st} are also related to a broader explosion hazard classification which is used to rank groups of powder according to their K_{st} value. This is the St. classification and Table 4 shows the relationship between K_{st} and St. classification.

Table 4 St. Classification

K_{st} Bar m s^{-1}	Explosion Classification
0	St. 0
0 – 200	St. 1
200 – 300	St. 2
300	St. 3

Extensive work has been undertaken to relate the K_{st} value to the sizing of the explosion reliefs and suppression systems [1].

5.2 Test apparatus

The apparatus [1] consists of a spherical chamber with a volume of 20 litres and surrounded by a water jacket. Dust enters the sphere from a 0.6 litre pressurised storage chamber via a pneumatically operated outlet valve. The sample is injected by compressed air and a perforated deflector plate inside the chamber ensures uniform dispersion. The ignition source comprised two pyrotechnic igniters with a total energy of 10 kJ located in the centre of the explosion chamber.

5.3 Test procedure

A known mass of dust was placed into the dust storage chamber. The sphere was then evacuated to 0.4 bar absolute. An automatic test sequence was initiated to pressurise the dust storage chamber to 21 bar absolute and activate the ignition source 60 ms after the dust had been dispersed. This procedure ensured that the explosion took place at atmospheric pressure and at such a degree of turbulence that the explosion data obtained are compatible with that which would be obtained in a 1 m^3 vessel.

Explosion pressures were measured for a range of dust concentrations using piezo-electric pressure transducers. The values of explosion pressure, the rate of pressure rise are measured and the K_{st} value then computed from the pressure/time records. The values of the explosion pressures are corrected to correlate with the 1 m^3 vessel.

* Please note that in the full test procedure the maximum explosion pressure (P_{max}) and the K_{st} of the dust sample tested is defined as the mean values of the maximum values of each test series (total 3 series) over the concentration range close to the observed maxima. This test however was carried out on one series of concentrations only due to the negative results obtained, and confirms the results from the Classification test.

The tests were conducted over the dust concentration range 0.50 – 1.50 kg/m^3

5.4 Results

Table 5 Results of k_{st} test on Railway Tunnel Dust

Concentration (kg/m^3)	Maximum pressure (bar g)	Rate of pressure rise dP/dt (bar/s)	Kst (bar m/s) *
0.50	0.0	0	0
0.75	0.0	0	0
1.00	0.0	0	0
1.25	0.0	0	0
1.50	0.0	0	0

Table 6 Summary of test results

Sample	Dust concentration range used (kg/m^3)	P_{max}* (bar g)	K_{st}* (bar m/s	St. Classification*
Rail tunnel dust	0.50 – 1.50	0.0	0	0

6 General remarks

Please note that the test results are valid for the particle size distribution and moisture content of the sample tested.

If you require further information or advice regarding the use of this data you should contact BRE.

7 References

1. Dust Explosion Prevention and Protection - A practical guide. Edited by John Barton. IChemE. 2002.

2. IEC 1241-2-1 Part 2 Temperature, Section 1, Method B "Methods for Determining the Minimum Ignition of a Dust" 1994.

3. BS EN 14034-1. Determination of the explosion characteristics of dusts – Part 1: maximum rate of pressure

4. BS EN 14034-2. Determination of the explosion characteristics of dusts – Part 2: maximum rate of pressure rise.

Ignitability Assessments on a Sample of Railway Tunnel Dust

Figures

Figure 1

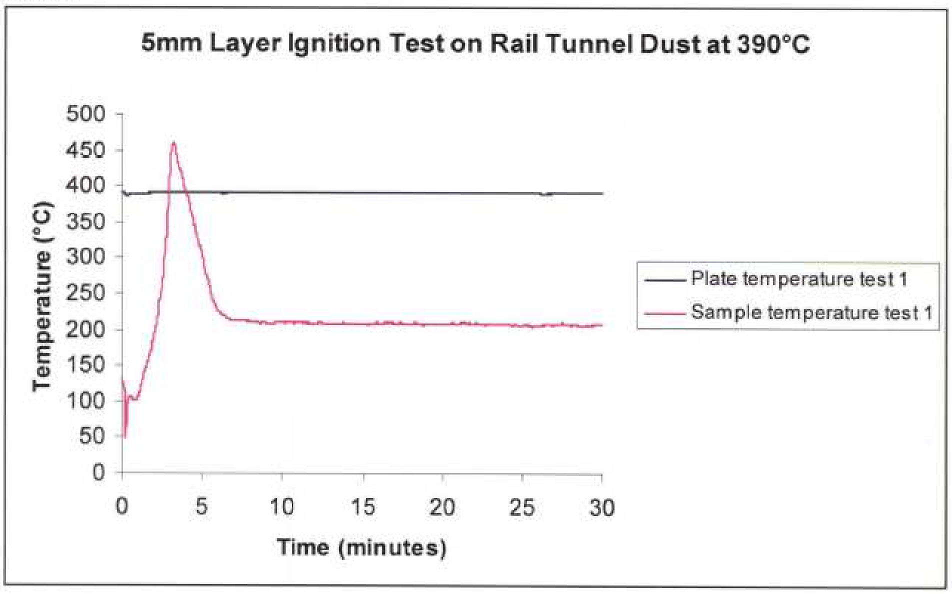
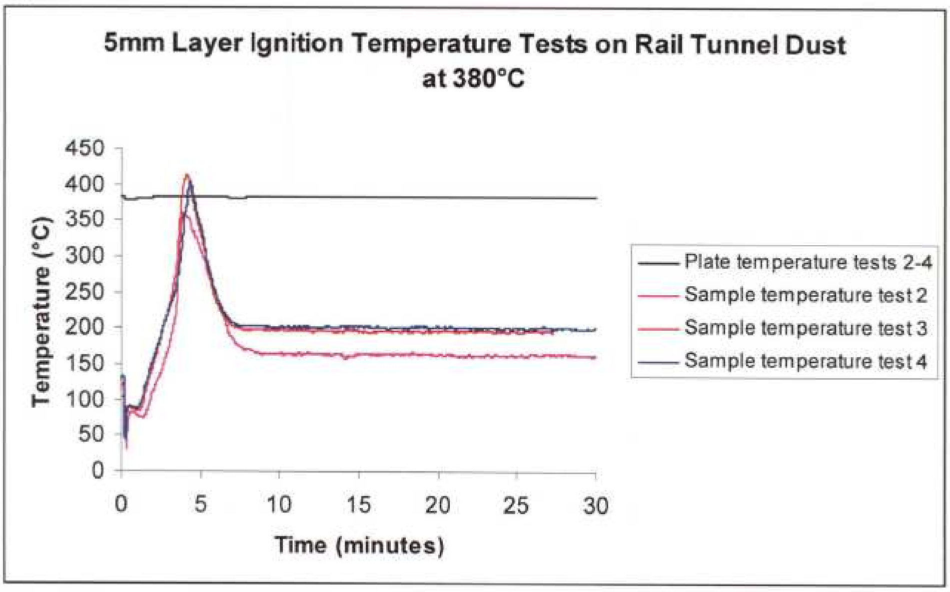


Figure 2



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