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STATIC ELECTRICITY AS A CAUSE OF FIRES IN ROAD SURFACE-DRESSING BINDER SPRAYING VEHICLES

by

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Summary

The possibility that static electricity could be a cause of fire in binder distributors has been considered.

The causes of fires in binder distributors, reported to fire brigades in the United Kingdom during 1956, are discussed and recommendations are made for reducing fire damage.

File No. F 1040/91/1

February 1957.

Fire Research Station,
Boreham Wood,
Herts.

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INTRODUCTION

Various Government Departments, local authorities and other organisations have notified the Joint Fire Research Organisation of fire incidents involving binder spraying vehicles. It has been thought that a discharge of static electricity might be the cause of some of these fires and the object of this note is to discuss this question in the light of the knowledge available at present.

The mechanisms by which a hazardous discharge might occur are listed and are considered both theoretically and in the light of the relevant experimental data. The reported causes of fires in binder spraying vehicles attended by the fire brigades of the United Kingdom in 1956 are examined.

THE GENERATION OF STATIC ELECTRICITY

Hazardous levels of static might be generated by the spraying of the binder or by the movement of the vehicle. These possibilities are considered below.

(a) Binder Spraying.

The separation of surfaces occurring as the binder leaves the jets might generate static electricity giving an accumulation of charge on the vehicle, on the deposited binder or on both. A discharge might then occur between the vehicle and the deposited binder or between either of the above and an earthed conductor or even an insulating surface at a different potential. During a normal spraying operation, the binder does not break into droplets until it has reached a point about an inch or so beyond the spraying orifice. The greater the transit time between the orifice and the point of breakup in comparison with the charge relaxation time of the binder then the greater the proportion of the charge generated that will be dissipated without giving rise to high potentials. The lower limit of transit time can be evaluated from Bernoullis equation

$$\frac{v^2}{2g} = \frac{p}{\rho}$$

The maximum value ever attained by p is 40lb/sq.inch and the minimum specific gravity ρ of a binder is 1.1. From this the maximum value of velocity which could be attained is $v \simeq 74$ ft/sec.

The lower limit of transit time for one inch will be 1.1 m/sec. and if the relaxation time constants of tars and bitumens are less than say 0.3 m sec., then no hazard will exist.

The charge relaxation time constant (τ) of any volume of fluid is $K\rho/4\pi$ (where K = specific inductive capacity and ρ = resistivity in e.s.u.) For both tars and bitumens the value of K will be less than 3 and hence τ will be less than $3\rho/4\pi = 0.24\rho$ where ρ is in e.s.u. or

$$\tau \simeq 2.7 \times 10^{-13}\rho \quad \text{where } \rho \text{ is in ohm cm.}$$

Substituting $\tau = 0.3$ m sec. gives a limiting value of ρ of 10^9 ohm cm. below which no appreciable levels of charge can be expected.

The resistivities of various tars and bitumens have been measured (see Appendix 1) by a method which is accurate to within 0 to-30% and the results are given in Figure 1. At temperatures above 130°C (266°F) for bitumens and 50°C (122°F) for tars, the values of resistivity are below the upper limit referred to. These temperatures are lower than the minimum temperatures at which spraying can be carried out (of the order of 280°F for bitumens and 220°F for tars.) Even if spraying were attempted at temperatures below these minima, it is very unlikely that a substantial charge could be developed. The time interval between the binder leaving the spraying orifice and breaking up into droplets would be substantially greater than 1 m sec. since the high viscosity would give a much lower velocity than the theoretical maximum derived above and the binder would not break up until it was some inches beyond the spraying orifice. Also the spark energies required to ignite the binder would be much greater, if such ignition were at all possible.

The above argument demonstrates that no hazard due to static electricity can exist when binder leaves a spraying orifice in the normal manner. It has, however, been suggested that, as the main tank empties and there is air in the pumping line, the binder will already be broken up as it leaves the jets. To investigate the possibility that substantial levels of static might be generated under these circumstances, a sprayer was operated with an air inlet between the pump and the jets giving conditions at the jets which were comparable with those when the tank emptied. A Baldwin stati-gun was held under the hood under these conditions and indicated that the potential on the spray did not exceed 100 volts which is, of course, negligible. The binder in use was tar.

In the above test the introduction of air into the line reduced the temperature of the tar and hence increased its resistivity and viscosity. The hazard was thus greatly exaggerated. The level of static generated was so low that the higher resistivity of bitumen would not give rise to hazardous levels of static as a tank emptied.

(b) Movement of the vehicle.

The continuous process of bringing into contact and then separating the tyre of a moving vehicle and road surfaces can generate substantial charges and hence charge the vehicle partly by induction but principally [1] by conduction from the outer tyre surfaces to the hubs of the wheels. A discharge might then occur between the vehicle and an earthed conductor or even an area of an insulating surface at a lower potential. The possibility that the generation of static by movement of the vehicles has constituted an appreciable fire hazard in the past is considered unlikely for the following reasons:-

(1) Operators and drivers of road binder spraying machines have not been known to complain of shock on dismounting from vehicles. Levels of static likely to constitute a fire hazard would at some time give rise to detectable shocks.

(2) Whilst spraying, a vehicle travels at a speed of less than 5 m.p.h. and appreciable levels of static would not be generated at this speed [1].

(3) The requisite high levels could only be generated whilst the vehicle was proceeding to a site, but if generated they might not be dissipated by the time spraying commenced. This means that the levels of static during spraying would be greatest at the start of the operation and fires due to this cause would generally be expected to occur immediately spraying commenced.

Whilst this factor is worth bearing in mind when considering future incidents in which the cause is not obvious it must be remembered that this cause is not considered important at petrol filling stations. Here conditions could be considered ideal for a hazardous discharge since an earthed donducting petrol pipe line is brought near to the tank of the vehicle.

SUPPOSED CAUSES OF FIRES ATTENDED BY FIRE BRIGADES

An examination of the reports of all fires attended by Fire Brigades in the United Kingdom during 1956 revealed 12 which occurred in binder spraying appliances. It is believed that there are about 250 major appliances of this type in the United Kingdom and that they are in use almost exclusively during the eight months March to October. Thus, fires that required fire brigade assistance occurred at the rate of 1 for each 21 major appliances; or, taking the time factor into account, the rate of incidence was roughly 7 per 100 major appliances at risk per year. Considering the nature of the process and the material involved, this rate of incidence is not unexpectedly high; it is slightly lower, for example, than that in grass-drying apparatus.

Of the 12 incidents reported, 6 occurred in July, 2 in March and 1 in each of the months April, June, September and October.

The causes of these fires were varied. Four were due to the ignition of accumulations or leakages of the binder; in three of them the source of ignition was the heater and in the other it was burning rags used to heat the jets. In three incidents there was said to be a "blow-back" at the heater; this ignited binder being sprayed in two of them, and "waste tar" on the spray tape" in the third. In one of the fires the cause was given as "hot plate of burner igniting molten tar falling on it" and in another binder appears to have boiled over, though the reason for this is not known. A short in a signal bell circuit is believed to have ignited tar vapour in one incident.

In only two of the 12 fires was a material other than binder recorded as the material ignited first. One of these started in a tarpaulin which was ignited by heat from the flue of a sprayer, and the other started in fuel oil which was ignited by the pilot light of a burner.

In no case was there any suggestion that static electricity was in any way responsible for the fire.

CONCLUSIONS

1) The possibility that static electricity has been the cause of even a small proportion of the fires which have occurred recently in binder sprayers is remote.

2) It is probable that a number of fires will occur whatever preventative measures are adopted. The vehicles should, therefore, carry suitable fire extinguishing equipment.

3) In a number of fires the oil heater has been the igniting source. It would be desirable for the design of the vehicle to permit access to the heater only from a point as far removed from the spraying bar as possible.

REFERENCES

1) Bulgin D. "Static Electricity on Rubber-tyred Vehicles". Brit. Jour. App. Phys. Supp. No. 2. 1953 pp S83 - 87.

Appendix I. The Resistivities of various Tars and Bitumens

Samples of the following binders were examined:

Table 1

Surface-dressing Binder Samples

Description of Binder	R.R.L. Reference	Viscosity (Efflux time from the Standard Tar Viscometer)
Coke-oven tar	5642	26 secs. at 40°C
Vertical Retort tar	5638	28 secs. " "
Mainly horizontal-retort tar	5572	36 secs. " "
Kerosine cut-back bitumen (non-toxic)	5588	40 secs. " "
Normal cut-back bitumen	5633	60 secs. " "

The resistance of a bulk of each of the samples was measured by the arrangement illustrated in Fig. 2, the container in each case being the tin in which the sample was delivered.

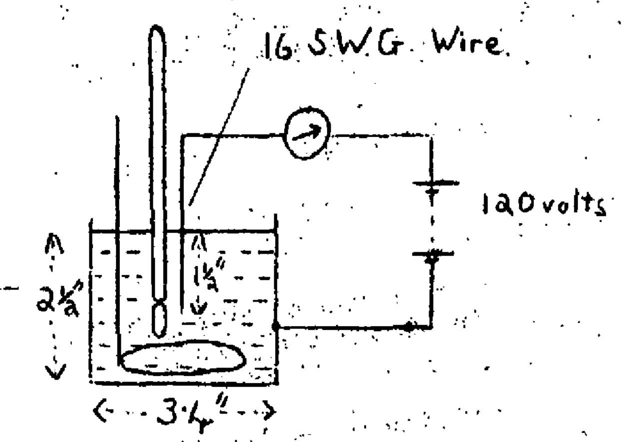

Fig. 2.

The resistance between two concentric conductors of length l in terms of the resistivity ρ of the medium between them is given by:

$$R = \frac{\rho}{2\pi l} \log_e \frac{r_2}{r_1} \qquad (1)$$

so that

$$\rho = 2\pi l R \Big/ \log_e \frac{r_2}{r_1} \qquad (2)$$

In the case illustrated there will be an end effect associated with the medium below the bottom of the 16 s.w.g. probe. The order of the resultant reduction in resistance can be assessed by comparing the resistances of the sections A and B in the arrangement illustrated in Fig. 3. This assembly differs from that used in that the base is hemispherical and that all lines of current flow are taken to be perpendicular to the inner and outer metallic surfaces. The effect of these assumptions will be small.

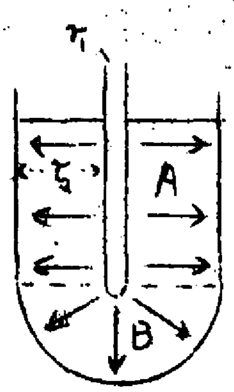

Fig 3

The resistances of the two volumes A and B will be

$$R_A = \frac{\rho}{2\pi l} \log_e \frac{r_2}{r_1} \qquad --- (1)$$

and

$$R_B = \frac{\rho}{4\pi}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \qquad --- (3)$$

Substituting the values of r_2 and r_1 given overleaf

$$R_A = 0{\cdot}166\rho \quad \text{and} \quad R_B = 0{\cdot}96\rho$$

$$\text{Hence} \quad R_B/R_A = 5{\cdot}8$$

To neglect such an end effect would thus give values of ρ which would be of the order of 15% too low. To ensure that the values of ρ are maxima the importance of the end effect will be exaggerated and the value of ρ taken as 50% higher than that given by expression (1).

The expression is therefore taken as

$$\rho = 3\pi l R / \log_e r_2/r_1 \qquad --- (4)$$

The results are given in Fig. 1 and can be considered to have a tolerance of 0 - 30%.

APPENDIX II

Causes of fire in binder sprayers attended by Fire Brigades in the United Kingdom in 1956

Date	Supposed cause of fire
12th March	Heat applied to boiler ignited tar.
20th March	Blow-back from fire box ignited sprayer.
20th April	Heat from flue of sprayer ignited tarpaulin.
6th June	Tar leak ignited by flame of heater.
6th July	Pilot of burner ignited fuel oil.
6th July	Blow-back from fire box ignited waste tar on spray taps.
9th July	Tar in paraffin-heated boiler boiled over and ignited.
10th July	Flame from heater burner ignited accumulation of tar.
13th July	Burning rags used to heat jets ignited tar.
18th July	Short circuit in signal bell ignited tar vapour.
17th September	Heat from hot plate of burner ignited molten tar falling onto it.
17th October	Back-fire of tar heating jet ignited tar being sprayed.

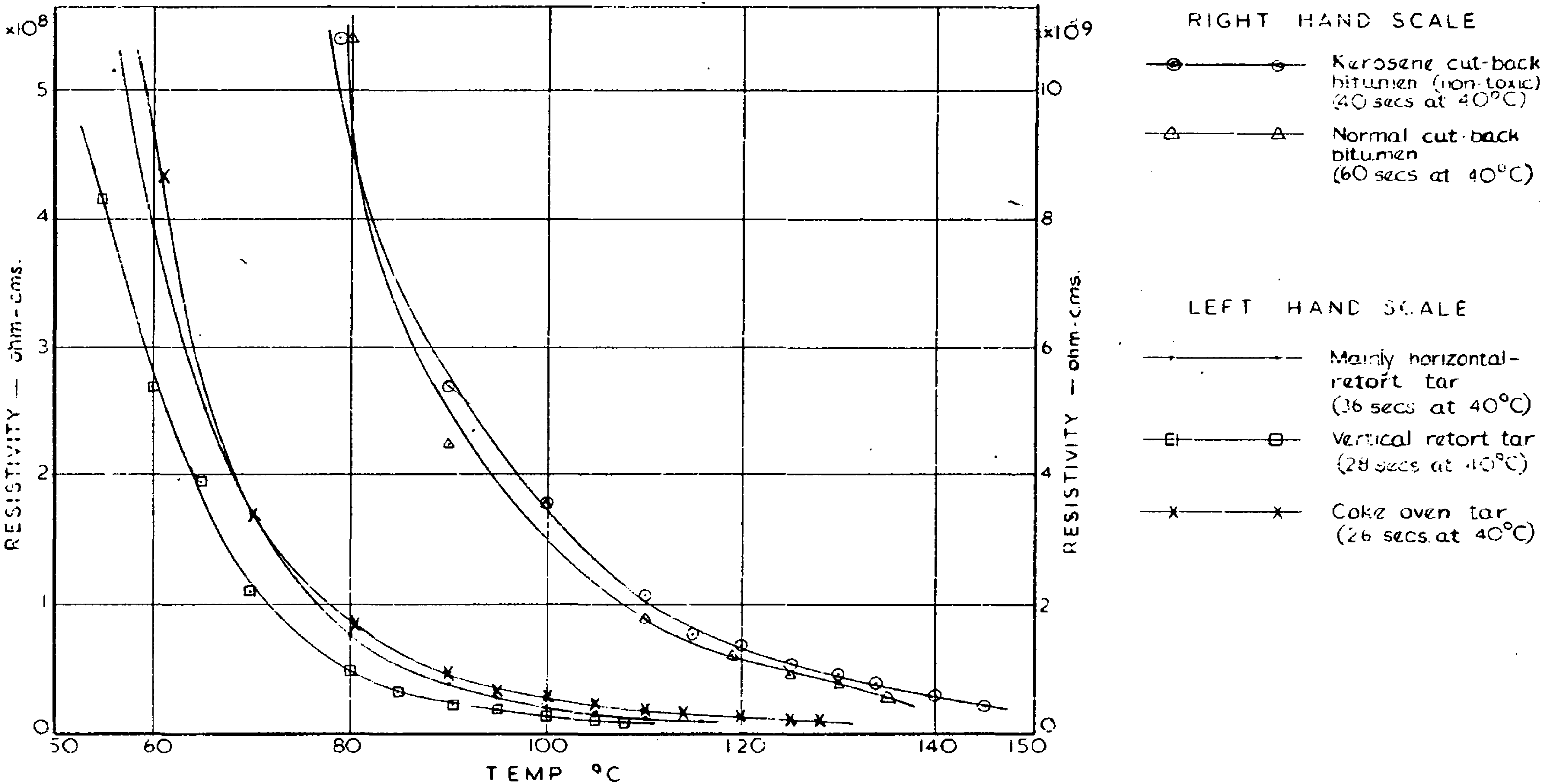

FIG I. RESISTIVITIES OF TARS AND BITUMENS