F.R. Note No. 284

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

THE FIRE HAZARD CREATED BY STATIC ELECTRICITY

by

J. H. McGuire

Summary

The generation of static charge is discussed and reference is made to current theories of static electrification. Industrial problems arising from static are considered and a resumé is made of the methods usually adopted for dealing with these.

January, 1957.

Fire Research Station,
Boreham Wood,
Herts.

THE FIRE HAZARD CREATED BY STATIC ELECTRICITY

by

J. H. McGuire

1. Introduction

Whilst the scope of this note is confined to the fire hazard created by static electricity, the importance it has assumed in industry probably arises principally as a result of the nuisance it causes. In the textile industry for example the charge generated on fibres results in mutual repulsions and attractions and interferes with weaving and spinning operations. Static also affects processes in which small, light objects are being picked up and moved about and it may ruin the processing of a film by giving rise to discharges which fog the film.

An indication of the fire hazard resulting from any particular process or phenomenon can often be obtained from the statistics of the incidence of fires reported to fire brigades in the United Kingdom, and the figures referring to static electricity as a cause of fire are given in Appendix I. The number of fire reports associated with this cause is small but should, in this case, not be taken as a true indication of the importance of the hazard for the following reasons:-

(1) In many industrial processes, involving flammable vapours, fires due to static occur frequently and are dealt with internally without the fire brigade being notified.

(2) The low incidence of reports of fires due to static is probably due in no small measure to the stringent precautions already adopted to eliminate static both because it is known to be a fire hazard and because of the nuisance it creates. The expense thereby incurred in combatting static is an important consideration but is outside the scope of this note.

(3) A discharge of static when it does occur often results in an explosion with the attendant risk of casualties.

This note is largely concerned with the generation of static electricity, the nature of the fire hazard it creates, together with examples, and the methods by which charges are safely dissipated.

2. The generation of static electricity

The generation of static charge is essentially a surface phenomenon associated with the separation of two surfaces. It may be interpreted as a contact potential effect resulting from the transfer of electrons or even ions [1] from one surface to another in contact with it.

The order and sign of the charge generated is dependent on the following factors:-

(1) The areas of surface intimately in contact.

This only affects the magnitude and not the sign of the charge generated. It is of great importance, however, since static is a surface phenomenon and the areas coming into intimate contact in practical conditions are very dependent on the nature of the surfaces and on the pressure between them (2).

(2) The combination of materials involved.

Attempts have been made to list materials in a sequence so that, for any combination, the one appearing earlier in the list will always be charged positively. Different workers have produced contradictory lists and this has raised the question of whether such a sequence exists. Shaw and Jex (3) claim, for example, that it is impossible to derive one simple sequence covering all materials but that, within any one class of materials e.g. glasses, metals, or textiles, such a sequence might be a reality. It may well be that experimental work has not yet produced the correct series because other factors such as friction and surface impurities have influenced measurements. As recently as 1954 Trinchieri (4) has put forward an electrostatic series.

(3) Temperature differences between the surfaces.

It has been demonstrated that static charges can be produced when two samples of the same material are rubbed together so that different areas of the two surfaces are involved. Henry (5) reached the conclusion that the charge separation is a kinetic effect analogous to the thermal diffusion of gas molecules through a porous plug from the hot to the cold side of a container. He attributes the charge separation to the thermal gradient across the interface. The writer sees no reason however why this effect and the effect of using different materials should not be grouped together. Charged particles, either electrons or ions, will pass between one surface and the other and the net transfer will be dependent on the relative densities of charged particles on the two surfaces and on the energy potentials of the particles. The special effects of temperature gradients then stand in relation to the rest of static phenomena as do thermo-electric effects to contact potential.*

(4) The state of strain of the two surfaces.

The theory that the state of strain of the surfaces influences the generation of static electricity has been put forward by Shaw (6). Henry (5) however, says that the effects attributed to strain might well have been due to extraneous temperature gradients. It would be interesting to compare the effects of strain claimed by Shaw with those on the contact potentials of metals.

The part played by friction, which substantially influences the generation of charge, is best interpreted in terms of its two secondary effects. It substantially increases the areas of surface coming into intimate contact and creates temperature differences between elements of the contacting surfaces.

---

* Since this note was prepared Henry (52) has contributed a paper to the Zurich Conference on Static Electricity in Textiles in which he illustrates the theories he has recently developed by describing a model on the above lines.

The above factors also govern the generation of charge at fluid-solid or fluid-fluid interfaces excepting that where electrolytes are involved the principal effect, as might be expected, occurs within the fluid on the separation of the flowing liquid and the fixed laminar layer. Work on the electrification of fluids has been surveyed by Moore and Proudfoot (7).

Several theories have been put forward to explain the mechanism by which static charge is generated and these have recently been reviewed by F. A. Vick (8), P. S. H. Henry (9) (10) (52) and V. E. Gonsalves (11) who between them give a total of some seventy references.

3. The discharge of static electricity

When the potential at the surface of a body reaches a value such that the dielectric field strength of the surrounding medium is attained then a discharge occurs. Usually the surrounding medium is air and the limiting value of the electric field strength which can be attained is of the order of 30,000 volts per cm (12).

The most obvious circumstances in which a substantial discharge will occur is when the body acquiring charge is an insulated conductor. In this case the conductor almost completely discharges and the energy of the discharge is, neglecting any small residual charge, $\frac{1}{2} CV^2$ where C is the capacity of the conductor. In dealing with static electricity a body can usually be considered to be a conductor when its relaxation time constant is sufficiently short for substantially all its electrical energy to be dissipated in a spark discharge. Resistivities of less than 10^5 ohm cm will give relaxation times of less than a microsecond so that many materials (and liquids), conventionally described as non-conducting or even insulating, may be classified as conductors from this point of view.

Where both materials are insulators, substantial discharges can still occur although the most hazardous are generally those in which the discharge takes place between two associated conductors and does not directly involve the materials generating the static. Indirect charging of a conductor can occur in two ways. Firstly a conductor can be charged by induction, that is, it can assume a potential as a result of the proximity of the charged material. This effect is most marked where the conductor entirely surrounds the charged material and thereby behaves as if it had acquired the same charge as the material. Secondly, the high electric field strengths produced around sharp points by relatively low potentials are able to impart sufficient energy to charged particles to allow them to overcome surface attractions and escape. Thus if an insulating belt is being continuously charged by contact with a roller it can pass its charge to a pointed or sharply rounded conductor nearby. This process can continue until the conductor tends to the potential of the belt.

Discharges may occur directly between elements of an insulating material and an earthed conductor and it is possible that the energies involved may be sufficiently large to ignite flammable mixtures.

Where gases, dust dispersions and fluids of high resistivity (e.g. greater than 10^{12} ohm cm) are involved, hazardous discharges are almost invariably associated with an insulated conductor from which the charge has been removed (e.g. the pipe through which the fluid was flowing), with an insulated conductor to which the fluid has passed charge or with an insulated conductor which has become charged by induction. The possibility of a diffuse discharge occurring between an earthed conductor and a mass of high resistivity fluid cannot, however, be ruled out (13).

4. Examples of the fire hazard

The following are examples of how fires or explosions can be initiated by the generation and subsequent discharge of static electricity.

In hospital suites there may be present mixtures of flammable vapour with air or oxygen present which can be ignited by spark energies as small as 200 j or 1 j (14) respectively. Thus the withdrawal of a blanket from a (non-conducting) rubber covered mattress presents a hazard (15) for the resultant charge on the rubber can induce a substantial charge on an insulated bed or operating table. If the latter is of metal it can contribute all its electrostatic energy to a single spark discharge.

Persons (16) (17) walking about in insulating shoes have been found to acquire hazardous charges.

Systems in which a material passes over a roller, at least one of the two being an insulator, are a common hazard in industry. Hazardous discharges generally occur between conductors either directly or indirectly associated with the sources of the charge but the writer has visited the scene of a fire in which it appeared that the discharge from an insulator to an earthed conductor was the only possible cause. The process involved the spreading of a solution of paraffin wax in petrol on to linoleum passing between two earthed steel rollers. A further example of such a fire was in an adhesive tapes factory where fires occurred around a similar type of machine in which all metal parts were earthed. Belt drives are a particular example of such systems in which conditions are most favourable for the generation of very high voltages, possibly up to a million (18). Speeds are often high and if leakage resistance is low the repetitive nature of the operation allows a progressive build-up of charge. Given a suitably disposed nearby conductor a belt drive behaves as a van de Graaf generator and hence despite the fact that the spark ignition energies of most of the chemically stable, ignitable dust clouds found in industry lie in the range 0.01 to 2.5 j (19) (20) (21) (22) compared with a range of the order of 0.0002 to 0.01 j for most gases and vapours, (19) (23) the spark energies which can be derived from a belt drive are so great that dust explosions can be initiated.

The electrostatic hazard associated with the flow of liquids is well known. The Avonmouth explosion and fire (24) is an example of an incident which occurred despite the exercise of considerable care. Fuel was being pumped into an earthed tank through an earthed feed pipe and it is believed that charge from the liquid accumulated on a conducting dipping rod. When a sufficient potential had built up, it discharged to the tank.

In the United States of America, where atmospheric conditions are often more suitable for the build-up of static electricity it has been reported (25) that a fire due to static occurred when a chauffeur poured petrol from a five gallon drum through a chamois leather stretched over a funnel and hence into the tank of a motor car.

Dale (18) refers to several accidents in coal mines in which the use of dust laden compressed air lines ignited fire damp. In each case, however, the discharge took place between an insulated section of the supply line and earth. Earthing of the supply line would have prevented these particular accidents. Transfer of the charge in a gas, or on particles suspended within it, to an insulated conductor or to an insulator which then charges a conductor by induction can, however, give dangerous conditions. Dale (18) describes French and Belgian laboratory experiments which illustrate this. 13 mm sparks have been drawn from a 2 mm diameter galvanised iron wire held in front of the orifice of a compressed air line. In other experiments blocks of coal, limestone and carbon were placed on an insulated sheet of galvanised iron and subjected to a blast of air and sand or air and metal filings from a compressed air line. Sparks capable of igniting fire damp were obtained from the galvanised iron sheet.

The generation of static by wet steam jets has been recorded as long ago as 1840 by Lord Armstrong (26) (27) and the effects to be expected when steam leaves a pipeline or impinges on a surface are similar to those described above.

5. Preventive measures

Modern knowledge on methods of reducing or eliminating the fire risk created by static has been admirably summarised by the National Fire Protection Association (28) and by Bulgin (29) and will only be dealt with briefly here.

It is customary to aim at dissipating charges at such a rate that hazardous levels are never built up. With this end in view all metal parts, in regions where static electricity is generated, are therefore earthed. Although it is difficult to generalise, rates of generation of static are usually much less than a micro-amp (e.g. Fordham Cooper (30) considers 10^{-8} amp a high value) and voltages in excess of 300 (and usually of the order 5 Kv - 50 Kv dependent on the capacity involved) are necessary before hazardous discharges can occur. To eliminate the fire hazard created by static, metal parts or other conductors (see page 3) can therefore be considered earthed even if the earth resistance is as high as 10^8 ohms. Estimations ranging from 10^7 ohms to 10^{11} ohms are given by other workers (30) (31) (32) for the value of the safe maximum earthing resistance under various circumstances.

It has been found quite practical both in hospital operating suites (33) (34) and in industry to earth mobile metal equipments by the use of conductive (or anti-static) tyres and conductive floors. The resistivities of such tyres and floors are generally made high enough to guard against the danger of shock or ignition due to leakage of excessive currents from 250 volt electricity supply mains. Where finished products are being considered a lower limiting resistance value of 100 K (35) between the main body of the product and earth is generally regarded as meeting this requirement. British Standard 2050 : 1953 (35) prescribes maximum values of resistance ranging between 10^6 ohms and 10^7 ohms for various finished products made of rubber, but these values are intended to cater for an increase in resistance with age. In the Foreword to the British Standard it states "Experience has shown that for anti-static purposes, the limits of electrical resistance of a product at any time in its life should lie between 10^5 and 10^{10} ohms and preferably between 10^5 and 10^8 ohms". It is recommended that products with resistance values within the prescribed limits be described as "anti-static" and those with lower values as "conductive".

The use of trailing metal chains as a means of earthing mobile apparatus, vehicles etc., (36) often serves little purpose in reducing static owing to the remarkably high resistance which can result from dirt or corrosion between links or between a link and the floor. Johnson (37) cites cases where several thousand volts were required to break down the insulation resistance. Generation of static on persons walking about can be eliminated by the combined use of conductive (or anti-static) flooring and footwear.

The most desirable method of dissipating static is to make the generating surfaces themselves conductive. As two elemental surfaces are separated and a potential difference appears between them, a current flows along the surfaces to points at which they are still in contact. Conductive (or anti-static) rubber is an example of a material which has been rendered conductive and work is progressing on methods of manufacturing conductive plastics (38).

Where the materials generating static are essentially insulating, static hazard and nuisance is often eliminated by surface treatments, e.g. by coating the surfaces with conducting liquids. Examples of this are to be found in the textile industry (39) (40) and in many locations where static from belt drives (41) (42) (43) must be reduced.

Where it is not possible to render a material or its surface conducting, the charge on a surface can be dissipated by ionising the surrounding air by an external agency such as a high voltage (but low energy) discharge or a radioactive source. The electric static eliminator is sometimes held to be itself a source of hazard either because faulty insulation or design might give rise to an unwanted substantial discharge, or because of the proximity of particularly dangerous gas mixtures which might be ignited even under normal operating conditions. Radio-active static eliminators will of course present a health hazard if personnel place themselves within the region which is being deliberately irradiated to ionise the atmosphere. Both alpha and beta sources are used in British eliminators and the effective ranges in the regions exposed to radiation are of the order of half an inch and twelve inches respectively. To increase the effective range, one manufacturer has incorporated an alpha source in an air blower. In designing a radio-active static eliminator

The preceding paragraphs have all described methods of dissipating static electricity as it is generated. Different combinations of materials produce different quantities of charge on being separated and it is sometimes feasible to choose a combination which will not produce a hazardous charge. Such an approach is unusual, however, since surface impurities and variations in the temperature difference between the two materials involved can completely alter conditions.

6. Discussion

(i) Information regarding the hazard created by static electricity and the available methods of dissipating it has been summarised by various authorities (28) (29) (51). Fires and explosions from this cause still occur however, and it is clear that further publicity is called for.

(ii) The incidence of fires caused by static is greater than is indicated by the statistics of fires reported to the fire brigades in the United Kingdom. The disastrous nature of the explosions which can be initiated emphasizes the importance of adopting stringent preventive measures.

(iii) Despite the importance of the fire hazard, static electricity is probably best known as a result of the nuisance it can create by interfering with industrial processes. In general both the nuisance and the fire hazard can be eliminated and economically the importance of static electricity arises largely from the expense involved in eliminating it.

7. Further work

Further work is required on four aspects of the hazard created by static.

(a) Firstly, where the flow of a non-conducting liquid generates a substantial charge, which may be particularly dangerous if the liquid is flammable, some satisfactory method of reducing the hazard is required. The most practical approach appears to be a search for additives which form stable emulsions and which would reduce resistivities to levels of the order 10^{11} ohm cm or less so that charges would be dissipated in a fraction of a second and would not build up to hazardous levels. With the possible exception of those referred to by Wagg (49) developed for use with trichlorethylene and white spirit, no such additives are known. A programme of work might profitably include an investigation into the mechanism by which additives render non-polar liquids conducting.

(b) Secondly more information, both qualitative and quantitative, is required regarding the generation of static under practical conditions with particular reference to the synthetic high polymers now in general use. The most rewarding approach to this problem, from the long term point of view, would probably be to measure the charges generated under carefully controlled conditions in which, in the first instance, such factors as temperature difference and strain were eliminated. This would probably produce an electrostatic series. If the effect of such factors as temperature, temperature difference and strain were then determined, their effect on the sequence of an electrostatic series would become apparent and the sum total of the results would give quantitative information on the levels of charge to be expected under practical conditions. By determining, separately, the areas of surface coming into intimate contact and the dissipation of the charge as it is generated the quantitative information might be given a more fundamental significance.

If discharges from conductors were being considered, the above information, in conjunction with the information already available on the minimum spark energies required to ignite dusts (20) (21) (22) (50) vapour-air (20) (23) (34) and vapour-oxygen mixtures (14) (34) could be used to assess the hazard of any particular process.

(c) A third aspect on which information is needed is the nature of a diffuse discharge from an area of an insulating surface. In particular an investigation is required into the conditions governing the magnitude of the area involved. With such diffuse discharges the minimum ignition energies referred to earlier might be higher and if it were desired not to give exaggerated predictions of static hazard a determination of minimum ignition energies under diffuse discharge conditions might be called for.

(d) The use of Corona discharges as a means of dissipating static, either directly or by generating ions in the atmosphere, which subsequently migrate to the charged surface and neutralize the charge, may give rise to a fire hazard. Where the discharge is operated from a high voltage power supply, the whole constituting an ion generator, the risk is currently considered to be substantial and the use of this form of static eliminator is restricted to applications in which no fire risk exists.

An investigation into the ignitability of gases by Corona discharges would resolve the scope of the application of this form of static eliminator as well as giving information of more general interest.

Acknowledgment

The work described in this paper forms part of the programme of the Joint Fire Research Organization; the paper is published by permission of the Director of Fire Research.

References

(1) Cooke, B. A. "Charge acquired by powdered salts on moving over metal surfaces". Letter to Nature August 6th, 1955. p. 264.

(2) Bowden, F. P. and Tabor, D. "The friction and lubrication of solids". Oxford, Clarendon Press, 1950.

(3) Shaw, P. E and Jex, C. S. "Tribo-electricity and friction. II. Glass and solid elements". Proc. Roy. Soc. Vol. 118, Series A 1928. pp. 97-108.

(4) Trinchieri, G. translation by Wood, P. J. "Static electricity and anti-static agents". Textile Age. September, 1954. p. 73.

(5) Henry, P. S. H. "The role of asymmetric rubbing in the generation of static electricity". Brit. Jour. App. Physics Supplement No. 2, 1953. pp. S31-35.

(6) Shaw, P. E. Proc. Phys. Soc. (London) 39 p. 449 (1927).

(7) Moore, J. and Proudfoot, W. "Hazardous electrification : a survey". British Industrial Solvents, Report No. HW 35. June, 1955.

(8) Vick, F. A. "Theory of contact electrification". Brit. Jour. App. Phys. Supplement No.2, 1953, pp. S1-S5

(9) Henry, P. S. H. "Survey of generation and dissipation of static electricity". Brit. Jour. App. Phys. Supp. No. 2, 1953. pp. S6-S11.

(10) Henry, P. S. H. "Contact electrification". Science Progress No. 164. Oct. 1953. pp. 627-634.

(11) Gonsalves, V. E. "Some fundamental questions concerning the static electrification of textile yarns. Part 1". Text. Res. J. 1953, 23, 711-718.

(12) Cox, E. G. and Peace, A. G. "The ignition of dust clouds by electrostatic discharge". Soc. of Chem. Industry. Symposium on dust in industry. Sept. 1948, p. 115.

(13) Cooper, W. Fordham. "The practical estimation of electrostatic hazards". Brit. Jour. App. Phys. Supp. No. 2, 1953. p. S75.

(14) Bulgin, D. "Factors in the design of an operating theatre free from electrostatic risks". Brit. Jour. App. Phys. Supp. No.2. p. S87.

(15) Guest, P. G. Sikora, V. W. and Lewis, B. "Static electricity in hospital operating suites". U.S. Dept. of the Interior Bureau of Mines. Bulletin 520, 1953. p.13.

(16) Guest, P. G. et alia, vide supra, p.17.

(17) Guest, P. G. "Static electricity in Nature and in Industry". U.S. Dept. of Commerce, Bureau of Mines Bulletin No. 368, 1933. p. 69.

(18) Dale, R. A. "Electrostatic hazards in coal mining". Min. of Fuel and Power Research Report No. 118. H.M.S.O. SEpt. 1955.

(19) Cooper, W. Fordham. "The practical estimation of electrostatic hazards". Brit. Jour. App. Phys. Supp. No. 2, 1953. p. S76.

(20) Beach, Robin. "Industrial fires and explosions from electrostatic origin". Mech. Engrg. April, 1953. pp. 307-313.

(21) Boyle, A. R. and Llewellyn, F. J. The electrostatic ignitibility of dust clouds and powders". Jour. Soc. Chem. Ind. June, 1950. p. 173.

(22) Hartmann, I. "Recent research on the explosibility of dust dispersions". Indus. & Eng. Chem. Vol. 40. No. 4, 1948. p.752

(23) Boyle, A. R. and Llewellyn, F. J. "The electrostatic ignitibility of various solvent vapour-air mixtures". Jour. Soc. Chem. Indus. 66. March, 1947. p.99.

(24) Watts, H.E. "Report on explosion and fire at Regent Oil Co.Ltd., Premises at Avonmouth, Bristol on 7th September, 1951". Home Office, London, H.M.S.O.

(25) Guest, P. G. "Static electricity in Nature and Industry". U.S. Dept, of Commerce, Bureau of Mines Bulletin 368. 1953,p.70.

(26) Cooper, W. Fordham. "The electrification of fluids in motion". Brit. Jour. App. Phys. Supp. No.2. 1953, p.S14.

(27) Moore, J. and Proudfoot, W. "Hazardous electrification, a survey". Brit. Indus. Solvents Report No. HW35. June, 1955. p.45.

(28) "Static electricity". N.F.P.A. No. 77 National Fire Protection Association. U.S.A. 1950.

(29) Bulgin, D. "Static electricity in relation to fire hazards". The Institution of Fire Engrs. Quarterly. Vol. XIV No. 15 July - September, 1954. pp. 188-198.

(30) Cooper, W. Fordham. "The practical estimation of electrostatic hazards". Brit. Jour. App. Phys. Supp. No.2. 1953, p.S73.

(31) Bulgin, D. "Static electricity on rubber-tyred vehicles". Brit. Jour. App. Phys. Supp. No. 2, 1953. pp.S83-S87.

(32) Bulgin, D. "Factors in the design of an operating theatre free from electrostatic risks". Brit. Jour. App. Phys. Supp. No. 2, 1953. p.S90.

(33) "Electrical safety in hospitals (Static risk)". National Health Service, Ministry of Health RHB (53) 55, 1953, together with Appendix A.

(34) Guest, P. G. . Sikora, V. W and Lewis, B. "Static electricity in hospital operating suites". U.S. Bureau of Mines Bulletin 520, 1953.

(35) B.S. 2050 : 1953. British Standard Specification for Resistance of Conductive and Anti-Static Rubber Products. British Standards Institution.

(36) Guest, P. G. "Static Electricity in Nature and Industry". U.S. Bureau of Mines Bulletin No. 368, 1933. p.81.

(37) Johnson, R.E. "Twenty-one ground chains tested for safety". Elec. World. Vol. 95, 1930.pp929-932.

(38) Dale, R. A. "Electrostatic hazards in coal mining". Ministry of Fuel and Power, Research Report No. 118. H.M.S.O. September, 1955, p. 26.

(39) Trincherieri, G. Translation by Wood, P. J. "Static electricity and anti-static agents". Textile Age. September, 1954. pp. 70-75.

(40) Hayek, M. "Antistatic Agents for Textiles". Amer. Dyest. Rep. Vol. 43, No. 12, 1954. pp. 368-371.

(41) "Static electricity". N.F.P.A. No. 77 National Fire Protection Association. U.S.A. 1950. pp. 37-38.

(42) Dale, R. A. "Electrostatic hazards in coal mining". Ministry of Fuel and Power. Research Report No. 118. H.M.S.O. September, 1955. p. 25.

(43) Memorandum on the electricity regulations". Form 928. H.M.S.O. 1951. p. 68.

(44) Henry, P. S. H. "Electrostatic eliminators in the Textile Industry". Brit. Jour. App. Phys. Supp. No. 2. 1953. p.S78.

(45) Quinton, A. "Safety measures in operating theatres and the use of a radio-active thallium source to dissipate static electricity". Brit. Jour. App. Phys. Supp. No. 2. 1953, p. S92.

(46) Sumner, J. F. Private Communication.

(47) Cooper, W. Fordham. "The practical estimation of electrostatic hazards". Brit. Jour. App. Phys. Supp. No. 2. 1953. p.S75.

(48) Cooper, W. Fordham. vide supra p. S72.

(49) Wagg, R. E. "Deposition of soiling matter from some detergent systems : II non aqueous systems". Jour. Text. Inst. Trans. Vol. 43 No. 7. July, 1952.pp.T331-337.

(50) Hartmann, I and Nagy, J. "Inflammability and explosibility of powders used in the Plastics Industry". U.S. Bureau of Mines RI 3751. May, 1944.

(51) The fire hazard of static electricity <u>Fire Offices' Committee Fire Protection Association Booklet No.20.</u> London, Sept. 1956.

(52) Henry, P. S. H. "Generation of Static on Solid Insulators". Textile Institute Conference, Zurich. 13-17 Setpember, 1956.

APPENDIX I

Incidence of fires, caused by static electricity, reported to fire brigades in the United Kingdom 1949-1953

For the years 1949 to 1953 the total number of fires reported, from all causes, averaged about 85,000 per year of which about 44,000 occurred in buildings. The incidence of fires (estimated by samples varying from one-in-two to one-in-five for different years) in which static electricity was the supposed cause is given in Table I.

TABLE I

	1949	1950	1951	1952	1953
In buildings	24	22	32	8	35
Other than in buildings	-	2	-	4	-