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RADIO SIGNALS FROM LOW ENERGY ELECTROSTATIC SPARKS

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Abstract

Experimental studies are described to show that high frequency radio observations with a tuned loop aerial provide a simple way to monitor the occurrence of low energy electrostatic sparks and to separate sparks from corona discharges. For situations where the maximum potential available is below about 12 kV it is possible to obtain some indication from radio observations on the maximum hazard presented by individual spark discharges. The paper also describes how radio observations have been used in shipboard studies into the electrostatic hazards which may arise during tank washing operations in large crude oil tankers.

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1. Introduction

The observation of radio signals provides a simple and practical way to monitor the occurrence of low energy electrostatic sparks and to distinguish sparks from corona discharges[1]. Corona is not usually relevant to the ignition of inflammable gas mixtures, but sparks may be if they are sufficiently energetic. Radio observations may thus be used to identify the occurrence of events which present an ignition hazard.

We have developed and used a radio monitoring technique for studies into electrostatic hazards associated with tank washing operations on large oil tankers[2,3]. During tank washing operations and during sloshing of water by ship motion in part-ballasted tanks, electrostatically-charged mists are generated in the tank space[2,4], and it is thought that electrostatic hazards arise as conducting bodies, such as slugs of water, approach projections into the tank space where there are concentrations of electric field - or leave such projections and move to the tank wall[3,5]. In both cases a release of electrostatic energy may take place as an isolated charged body reaches a relatively large neutral conductor.

The aim of this paper is to summarise the preliminary work we have done on the radio emission characteristics of electrostatic discharges from isolated bodies and to describe how radio observations have been used in shipboard studies for assessing practical electrostatic hazards.

2. Radio emission characteristics of low energy electrostatic sparks

The discharge of an isolated conducting body to a large neutral conductor forms a radiating dipole with electrostatic, magnetic and electromagnetic components in the radiation field. The electromagnetic radiation component falls off only in proportion to distance, and so provides the best basis for remote sensing. The intensity of this component depends upon the rate of change of current. As spark discharges involve higher currents and greater rates of change of current than corona discharges, it can be expected that observations of electromagnetic radiation will be very sensitive to spark discharges and relatively insensitive to corona.

We have examined the radio emission characteristics of discharges from isolated bodies to conducting surfaces in outdoor studies in an area well away from large buildings and structures which might produce reflection and interference effects. The discharges studied have been between smooth metal spheres of 25, 50 and 125 mm diameter to a plane conducting surface lying flat on the earth surface. The spherical bodies were connected to a high voltage supply through a high impedance lead (around 10^{11} ohms) formed by a small bore plastic tube filled with isopropyl alcohol. The high RC time constant of the distributed impedance ensured that only the electrostatic charge held on the conducting body took part in the discharge and only the body, the discharge channel and the plane conducting surface were involved as aerial radiating elements. The rate of sparking was kept low, below 1 sec^{-1}, to reduce possible interaction effects between successive discharges. For studies on the radio emission characteristics of corona discharges the lead impedance was reduced to 30 MΩ and a sharp 30 mm high projection was mounted on the plane surface with a 30 mm gap from the projection to the 125 mm diameter body.

Observations of the electromagnetic radiation from the above electrostatic discharges were made at a frequency of 38 MHz using a tuned loop aerial of about 100 mm diameter, having a bandwidth of about 2 MHz. This type of aerial was chosen as likely to be insensitive to electrostatic field effects. The aerial was mounted about 2.4 m above ground level at distances of 10 and 20 m from the discharges. The pulsed oscillation of the aerial was sampled at a 50 ohm tapping into a coaxial cable and monitored with a simple straight through receiver having a wide band r.f. amplifier followed by transistor detection. A straight through receiver was used in preference to a superhet to avoid the shot to shot variations in output signal which are associated with frequency changing on short duration signals, and also to take maximum advantage of the bandwidth of the aerial system.

The variations of sampled aerial signals at 38 MHz with breakdown voltage for 25, 50 and 125 mm diameter spheres at 10 and 20 m range are shown in figure 1*. These studies show the following main features:-

1. At low potentials the aerial signal rises with breakdown voltage to a peak value between about 6 kV and 8 kV and then falls at higher breakdown voltages.

2. The variation of aerial signal with breakdown voltage is similar for the various bodies studied.

3. The signal amplitude varies in proportion to distance from 10 to 20 m - confirming that the signals observed relate to electromagnetic radiation effects.

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* The amplitudes of the sampled aerial signals differ somewhat from some previously published values(1) because of changes in the sampling tap arrangements on the tuned loop aerial.

4. Larger spheres give rise to larger aerial signals, but signal amplitude is not directly related to the stored charge on the sphere, the stored energy or the dipole moment.

5. Radio signals are only observed from positive corona discharges, and then only at high potentials and large discharge currents, when strong crackling noises are produced.

6. Even very weak sparks can be observed quite easily. For instance the breakdown of the 25 mm diameter sphere at 2 kV observed at 10 m range involved the discharge of only about 8 nanocoulombs of charge and 7 microjoules of energy.

These studies demonstrate that observations of electromagnetic radiation provide a sensitive way to monitor the occurrence of low energy sparks, and to differentiate sparks from corona. However, it would be useful to have a fuller appreciation of the radio emission characteristics of sparks at various frequencies for various practical situations (for instance discharges to water and to charged insulator surfaces) to see if it is possible to obtain at least some definitive information by remote sensing on the breakdown potential or energy involved in individual spark events.

3. Practical applications

The above radio technique has been used in a number of shipboard studies - in particular in studies for the International Chamber of Shipping[2] to monitor the occurrence of sparks during tank washing and during sloshing of ballast water in part-ballasted cargo tanks. Two radio aerials, spaced well apart, were mounted in the cargo tank studied, with separate aerials mounted outside the tank near each of the inside aerials. Sparks were only considered to occur if signals were observed on both inside aerials at a time when signals were seen by neither outside aerial. By spacing the aerials well apart in the tank the system is insensitive to local events affecting either individual inside aerial, and the anti-coincidence arrangement with the outside aerials ensures that external interference produces no spurious signals. A low power pulse transmitter is lowered to various positions within the cargo tank space to check the sensitivity of the radio detection system to sparks occurring at different places within the tank, and the signal strength of this pulse transmitter is compared with real sparks in outdoor calibration studies to provide a transfer calibration for spark signal observations.

In a large conducting tank environment without too much internal structure the sensitivity of the radio system is fairly constant with position in the tank. In this situation, although it is not possible at present to directly relate the size of radio signals observed to the energy of individual spark events without knowledge of the actual size of the body and breakdown voltage involved, it is possible to estimate the maximum hazard which may have been present if the maximum potentials in the tank are not so high that breakdowns occur beyond the peak of the curves in figure 1. For a particular amplitude of radio signal the larger amount of electrostatic energy is released by the smaller bodies. Figure 2 shows the variations of aerial signal with breakdown potential at 10 m range with dashed lines superimposed giving the potentials at which the spherical bodies released 10, 20 and 100 μJ of energy. Because the capacitance of bodies is increased by approaching the discharge surface the free space potential of the bodies releasing these amounts of energy would have been higher than the dashed curve values - and for the sphere to plane geometry situation the equivalent space potentials are shown by the chained curves to the right of the dashed curves. As it is unlikely that bodies acquire potentials above the maximum space potential, it is possible to estimate, from these chained curves, the maximum hazard indicated by radio signals of a particular amplitude. Because the aerial signals decrease at breakdown voltages above about 6 kV this approach to assessing hazards is only useful for space potentials up to say 10 kV.

Apart from the above approach to a qualitative assessment of electrostatic hazards we have used the coincidence output from our radio monitoring equipment during shipboard studies to trigger flash photography inside a cargo tank to reveal the physical circumstances associated with the occurrence of individual electrostatic sparks[2,3]. This approach gives physical information about the sizes of water slugs, orientations of washing jets etc from which likely hazards can be calculated[3,6]. It also provides a route to find and assess the changes which might be made in the design or operating arrangements to reduce the frequency of occurrence of the more energetic spark discharges.

4. Conclusions

Studies on the radio emission characteristics of electrostatic discharges show that radio detection can form a simple and practical way to monitor the occurrence of low energy electrostatic sparks and to differentiate sparks from corona discharges. Although it would clearly be useful to examine the radiation characteristics of discharges in more detail and under a variety of different physical situations, this radio technique already provides a way to obtain useful information about practical hazards and the physical circumstances associated with their occurrence.

References

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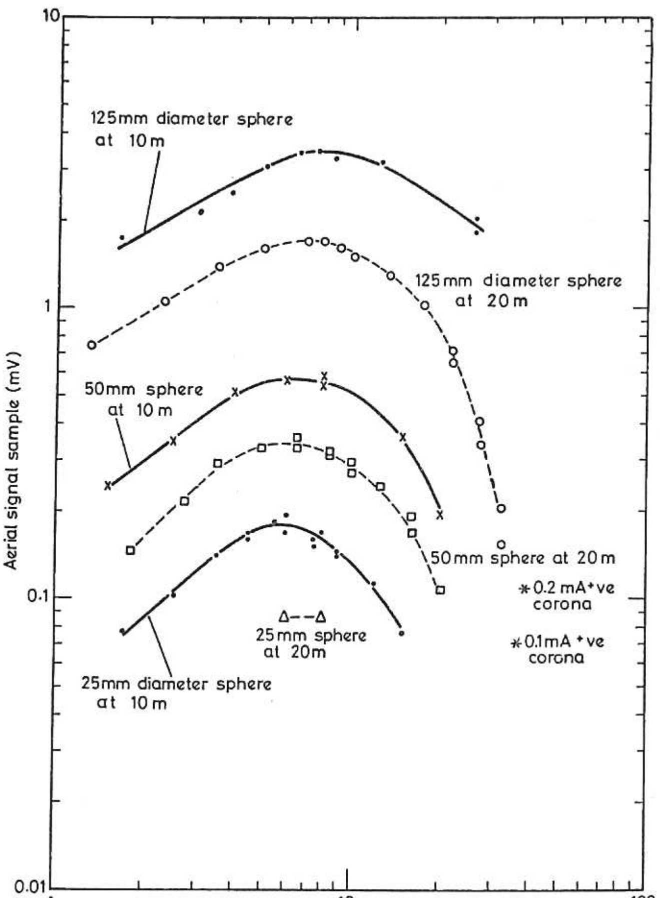

Figure 1

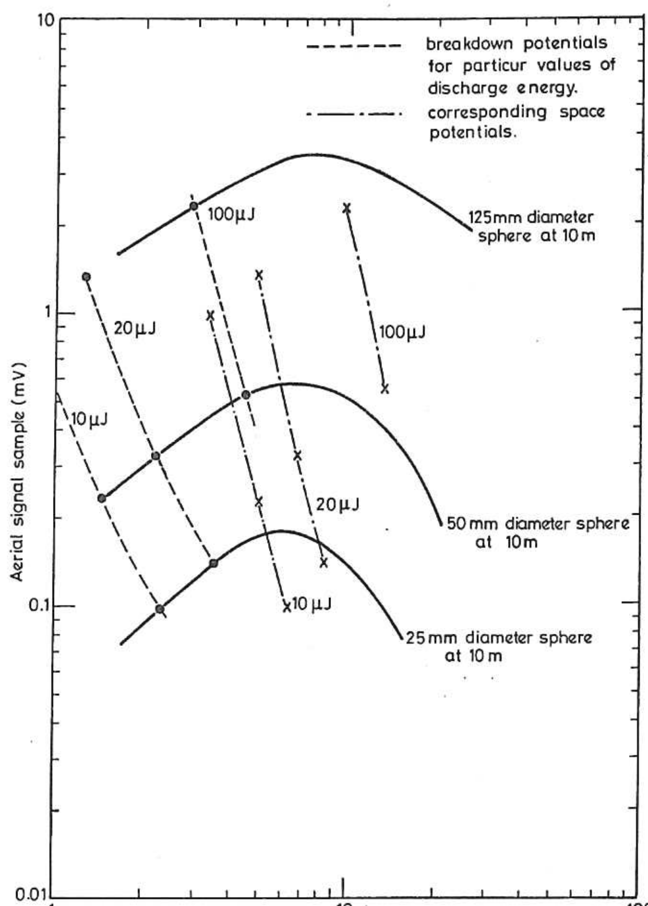

Figure 2