DETECTION OF MICROPARTICLES IN MODEL CHAMPAGNE USING A RUBY LASER

Introduction

The feasibility of detecting microparticles which are sometimes considered to contribute to vacuum breakdown by means of scattered laser radiation from the microparticles has already been discussed in detail (C.G.M. report "Detection of Microparticles using a Laser Beam" September 1966, hereafter referred to as CGM/NPA-Int. 66-24.

At the time the report was written there were no experimental data available on the likely delay times involved in the formation and passage of microparticles across the vacuum gap. However, experiments carried out in the Separator Group of N.P.A. Division during November and December 1966 suggest that the formative time lag of vacuum breakdown in conditions of interest for beam separators may be quite long, i.e. greater than about 10 microseconds: vacuum breakdown occurs at least ten microseconds after the application of the voltage pulse to the electrodes. During this relatively long time, if microparticles are responsible for breakdown, it should be possible to detect their presence from the light they scatter when crossing a beam of laser light directed between the electrodes in the vacuum chamber.

One of the problems involved, since the laser beam power density required to detect small particles is relatively high, is the synchronisation of the laser beam illumination of the vacuum gap with the application of the voltage impulse which causes breakdown in the vacuum gap. One possible solution of this difficulty is to use the laser beam both to illuminate the gap and, simultaneously, to trigger a gas discharge switch to apply the vacuum gap breakdown voltage.

The following is a proposed experimental arrangement which enables this to be done.
Discussion

Previous experiments carried out in N.P.A. Division (NPA/Int. 65-30) have shown that the focussed output of a non-Q-switched ruby laser will initiate a discharge in an undervolted spark gap. Advantage of this fact is taken to synchronize the application of the voltage via a gas discharge switch with the illumination of the vacuum gap with laser radiation using the apparatus shown in Figure 1.

The non-Q-switched output beam from the ruby laser L₁ is divided by the mirror M₁ placed at 45° to the beam. M₁ can be, for example, a 50 o/o transmission dielectric film mirror which thus allows half the laser beam energy to proceed to the lens L₂ which focusses the beam onto the negative electrode of the gas discharge switch causing breakdown of the gas to occur and thus applying the voltage impulse to the electrodes in the vacuum chamber.

The other half of the laser beam passes through the filter F₁ which prevents the passage of any stray light, for example, from the laser pump lamp, other than ruby laser light of wavelength λ. This beam is then deflected through 90° by mirror M₂ which can be a normal 100 o/o reflectivity dielectric film mirror and it then passes between the electrodes in the vacuum chamber. On the exit side it falls on a fast photodiode laser beam power monitor D which is used to measure the fluctuations in the laser beam power density (the parameter P/A in CGN/NPA-Int. 66-24.

In this way the vacuum gap is illuminated for the period during which lasing action continues in the ruby - a period which may be one or two milliseconds and which is very much larger than the expected formative time lag of vacuum breakdown. Any sufficiently large microparticles present between the electrodes during this time will scatter the laser radiation which can be detected by the photomultiplier PM placed a distance L away. The filter L₂, suitable for the ruby laser wavelength λ is used to prevent any light other than that scattered from the microparticles from overloading the photomultiplier and to prevent spurious signals.
It has been shown (CGM/NPA-Int. 66-24, equation 15) that the minimum detectable microparticle cross section $\Sigma$ is related to the laser beam power density $P/A$, the photomultiplier characteristics: signal to noise ratio $\beta$, the dark current $I_D$, the sensitive area $A$, the gain $G$ and the spectral sensitivity $S(\lambda)$ by the equation

$$\Sigma = \frac{\beta I_D 4\pi L^2}{A G^2 S(\lambda)} \left( \frac{P}{A} \right)^{-1}$$

with an uncooled Philips type 5E TVP placed 30 cm away from the vacuum gap electrodes, and, assuming a signal to noise ratio of $\beta = 10$, detection of a microparticle having a radius of $10^{-5}$ cm will require a laser beam power density in the vacuum chamber of $P/A = 20$ Watts cm$^{-2}$. This is easily within the range of the large Bradley Laser which can give about $5 \times 10^4$ Watts cm$^{-2}$ when operating in the non-Q-switched mode and when allowance is made for the transmission coefficient of mirror $M_1$. This expression neglects absorption by the filters $F_1$ and $F_2$ but there is clearly a large margin in hand and particles less than $10^{-5}$ cm in radius should be detectable.

C. Grey Morgan