MP Filtri

ESD in hydraulic filters

The study covered by this article stems from the need to understand and solve the problem of electrostatic discharges within hydraulic filters, resulting from the accumulation of electrical charge caused by the passage of oil inside them

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There are several problems of an electrostatic nature that arise in systems and industrial environments: in machinery and on floors, but also in the air and on persons. In the system under examination these phenomena can damage the filter elements, the oils or other components of the circuits, as well as cause fire hazards if you are in environments where flammable materials are present. This paper presents the results of an experimental study This paper presents the results of an experimental study in order to understand the physical phenomena that intervene in the observed processes and, where possible, to generate a qualitative comparison between empirical and modelling results.

Electrostatic theory

The accumulation of charge on the filters occurs due to triboelectric effects, which take place when two bodies with different electronegativity come into contact (or are in friction). The term “electronegativity” refers to the intensity of the attraction of a nucleus on the surrounding electrons. For composite materials, this will depend on the electronegativity

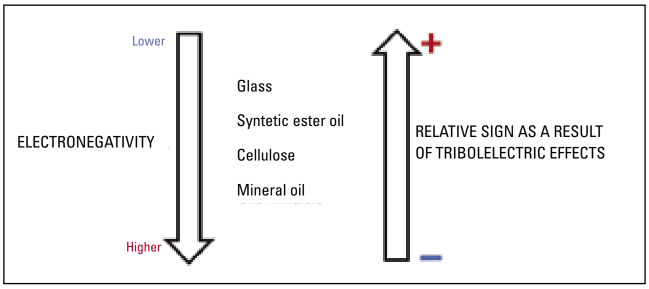


FIG. 1 - Triboelectric scale for material of interest

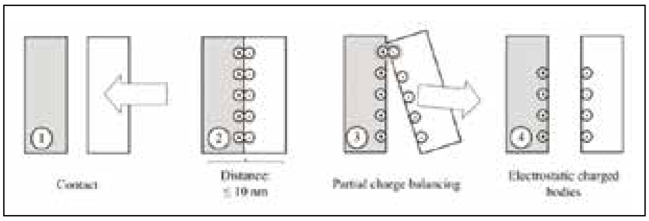


FIG. 2 - Triboelectric effect by contact

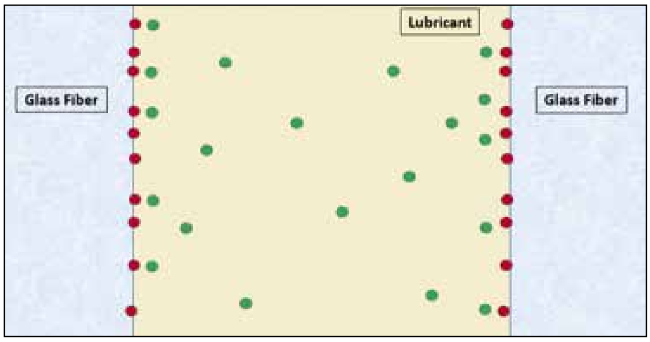


FIG. 3 = Electrostatic double layer (da STLE annual meeting 2016, W. Needleman)

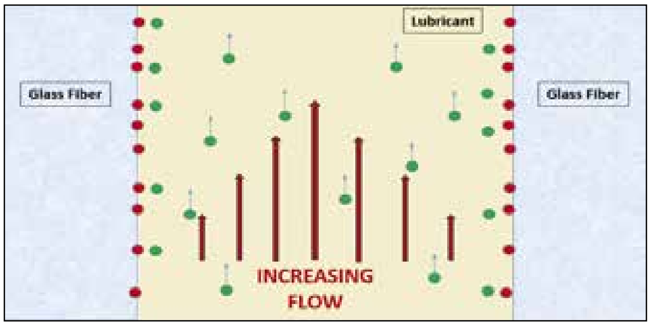


FIG. 4 - Formation of net charge accumulation (from STLE Annual Meeting 2016, W. Needleman)

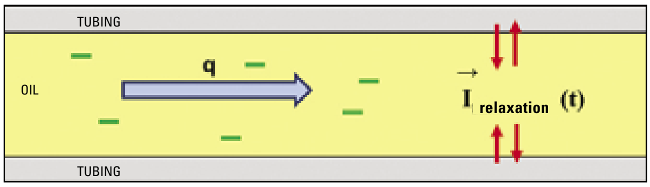


FIG. 5 - Charge relaxation in the pipes

of their constituent elements. The **Fig. 1** shows the triboelectric scale (which provides information on the relative electronegativity) for the materials under examination: cellulose, glass, oils (similar to hydrocarbon derivatives). In the triboelectric effect, the body with greater electronegativity snatches electrons from the other, generating an accumulation of net negative charge on itself, charging the other by the same amount, but with opposite sign. In liquid-solid systems, contact is sufficient to generate this type of effect (**Fig. 2**). At the microscopic level, a *double layer,* is formed, consisting of an accumulation of surface charges (*Helmholtz layer*) on the filter material and a *diffuse layer* in the oil volume, whose charge distribution is exponential (**Fig. 3**). If the fluid is moving at a certain flow rate (**Fig. 4**), the flow carries away the charges in the liquid and causes an accumulation of net charge in the system, which gives rise to high potentials (up to tens of kV). The dissipation of the charge can occur through conduction or electrostatic discharge processes. The former are various, but it is useful to focus on the main dissipation mechanism in fluids: charge relaxation, represented in **Fig. 5**.
This occurs when the pipes or tanks in which the liquid passes or is contained are conductive (and connected to earth); through convective motions, attracted by the zero earth potential, the charged particles tend to approach the walls, where they release the accumulated charge. In solid insulating components such as plastics, however, only conduction currents are generated which, by dissipating the charge, prevent the accumulation of potential from diverging. Rather, the voltage is expected to reach a maximum value when the accumulated charge eaquals that dissipated. The charge accumulated in the system, in addition to being dissipated by conduction, sometimes gives rise to discharge phenomena. An electrostatic discharge is the passage of electrons through an insulating medium, the result of which is to bridge the potential difference between two areas of a body or between two distinct bodies, generating an instantaneous current of very high intensity. This is a process that gives rise to an emission of light due to the ionization of the molecules of the passing medium, which are sometimes damaged. This process takes place in situations where the electric field exceeds the dielectric strength (expressed in kV/mm) of the material (this system can be assimilated to a capacitor whose plate reaches its maximum capacity).

Experimental tests

The experimental apparatus used consists of a test bench containing a hydraulic circuit in which a filter is inserted that can retain the solid contaminant and prevent this from damaging the machinery or the oil itself. The main components of a filter are head, filter element and container. The filter elements used in this study are composed of a filter body, formed by the pleating of one or more layers (called *media*), which surround a perforated metal tube (spiral tube) and are glued together with two components called the base and the bead core. In **Fig. 6** you can see the exploded view of a filter. The three aspects presented previously were investigated during the tests: accumulation of electric charge, conduction phenomena, electrostatic

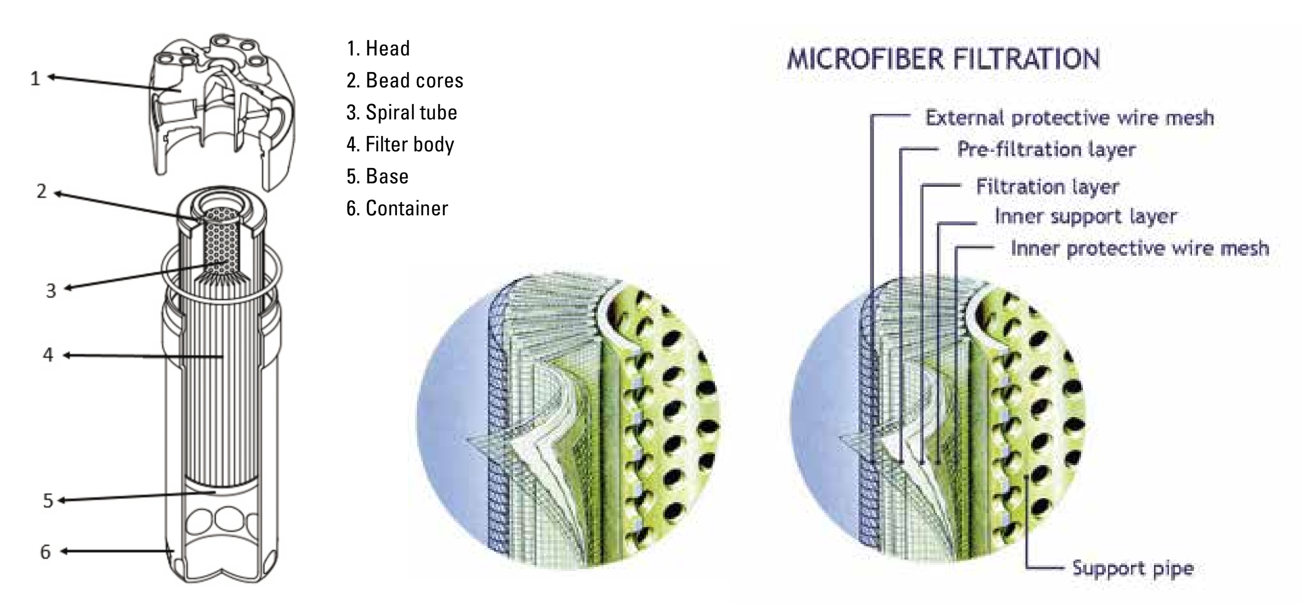


FIG. 6 - Exploded view of a filter

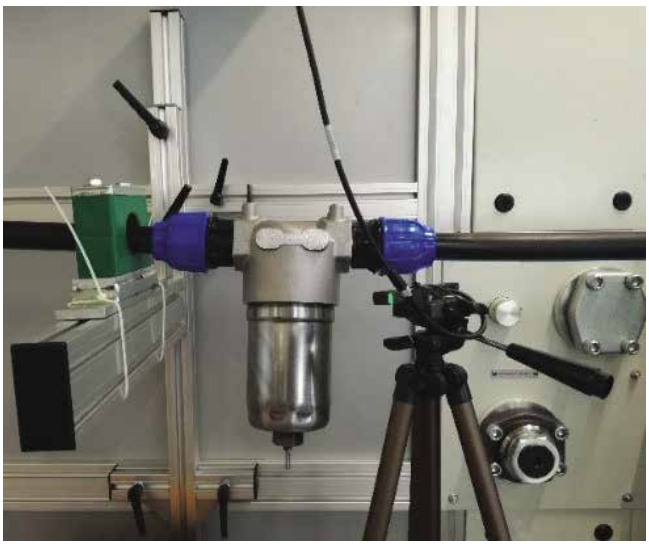
discharges. The first occurs in the dielectrics present in the system: filter materials, oil, insulating pipes. As already mentioned, the origin lies in the triboelectric phenomena, which occur following the passage of the oil through the very fine pores (of the order of ten microns in diameter) of the insulating filter materials, namely cellulose or fibreglass.

Effects of discharges

Discharge phenomena are difficult to investigate when they occur, due to the short duration and variability. It is easier to observe the effects on the bodies crossed: filter and oil. For the second, it appears difficult to identify and analyse the damaged molecules, analyses were carried out on the filter elements, which can be removed from the circuit and analysed in detail after use. In particular, it was considered interesting to analyse the effects of electrostatic discharges on standard elements subjected to a 30-minute test at a range at which discharges are frequent and intense. The discharges occur inside different components of the filter: in the bead core, in the base and through the cellulose of the filter layer.

Significant damage to the filter material has been observed on the cellulose elements, both with the naked eye and using an optical microscope (**Fig. 7**), while the plastic components show no major damage except in the intersection between the spiral tube and the metal head. Therefore, it is assumed that the discharges occur between the filter body and the internal support metal tube, from which the electric charge then passes to the metal head through a further discharge. As for the glass fibre filters, significant damage is observed only at the level of the bead and of the glue that joins it to the rest of the filter. The burns are visible on the surface and also extend inside the material (**Fig. 8**), compromising its mechanical strength. Finding that the fracture line follows the lines of damage caused by discharges (discharges that

Voltmeter that measures the filter potential



A charge collector integrated into the circuit

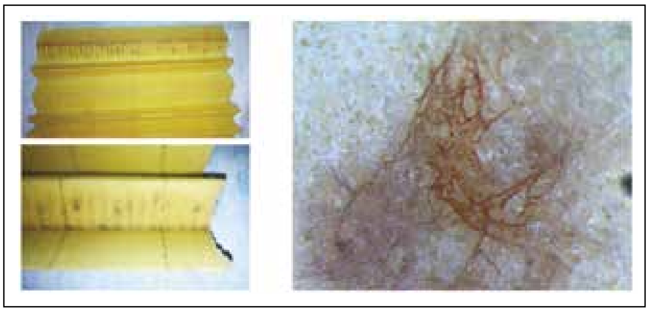


FIG. 7 – Image of a cellulose septum damaged by the discharge and microscopic detail of the affected area

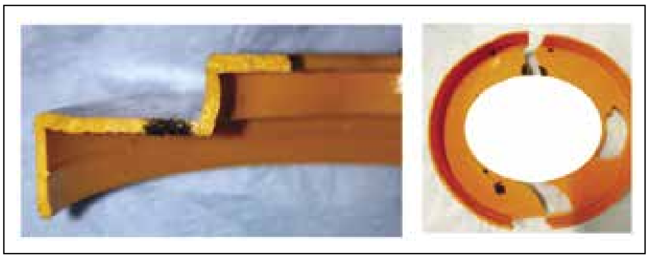


FIG. 8 - Detail of the bead core of a glass filter damaged by drains

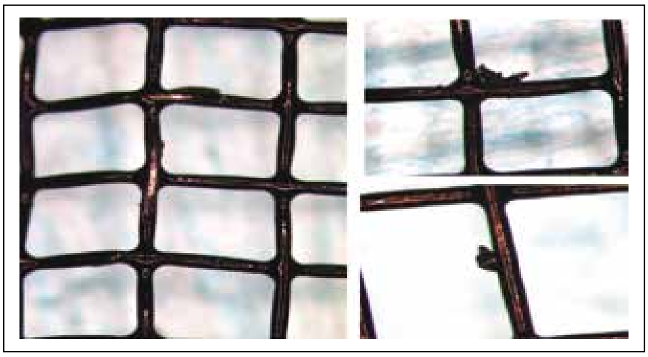


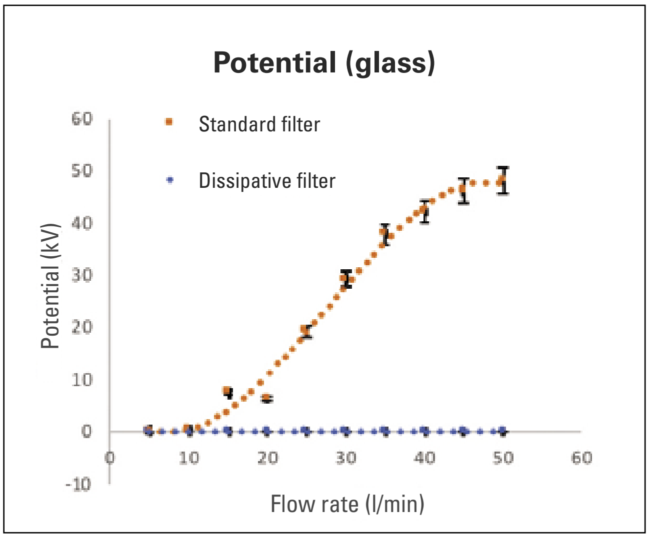
FIG. 9 - Images of the epoxy network at various magnifications

damage the filter material do not occur, also because the glass fibre has a dielectric strength of about 200 kV/mm, much higher than those reached in the system). In addition, minor damage can be seen on the epoxy resin coating of the metal mesh, an element present in the body to hold the different layers together (**Fig. 9**). The hypothesis, in this case, is that the charge accumulated on the filtering material is collected by the epoxy network, in which a conduction current passes through the coating of epoxy resin (insulator) which causes damage to it. From the network, the charges are then dissipated reaching the metal head through electrostatic discharges. In fact, discharge signs can be observed in the glue that follow the profile of the network embedded in it.

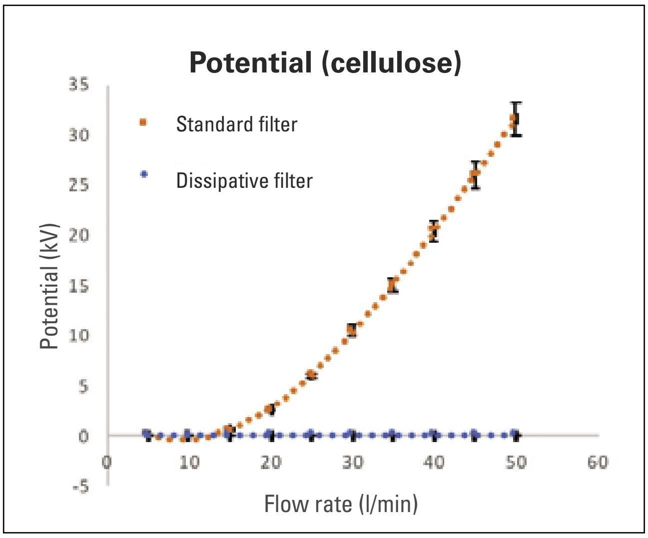
Solutions

A solution has been found to the problem of the accumulation of charges in the filters: a sort of electrical circuit must be created inside the filters themselves, obtained by replacing some insulating components with similar conductive versions, so that the charges on the septum are free to move towards the head and be dissipated to the earth. We will define the filters thus composed as "dissipative", as they do not avoid the occurrence of triboelectric effects but are able to dissipate the charge that accumulates, as can be seen from **Graphs 1 and 2**. The values for the dissipative elements are represented in blue, those not in red. Note how, under standard working conditions, the potential goes from tens of kV to zero, showing the effectiveness of our dissipative filters.

For the glass fibre models the currents (**Graph 3**) have higher values than those in cellulose, but for both the order of magnitude is μA. There is an improvement in using the dissipative elements, despite which, however, no net charge is observed in the oil. The triboelectric effects therefore appear to be minor using dissipative elements, but the oil charge effect due to the passage in the filter materials is not avoided. The trend of the measured current appears to be, similar to the potential, a rapid but not exponential growth. However, there is no damping of current growth at high flow rates, so that the (asymptotic) saturation trend observed for voltage is not repeated. It is believed that this

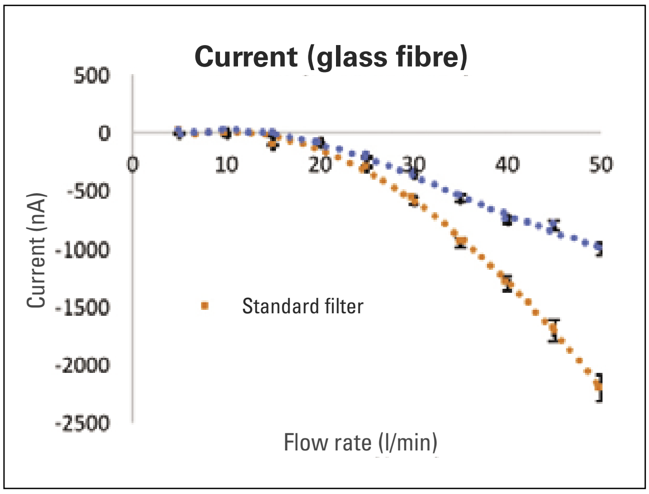


Graph 1

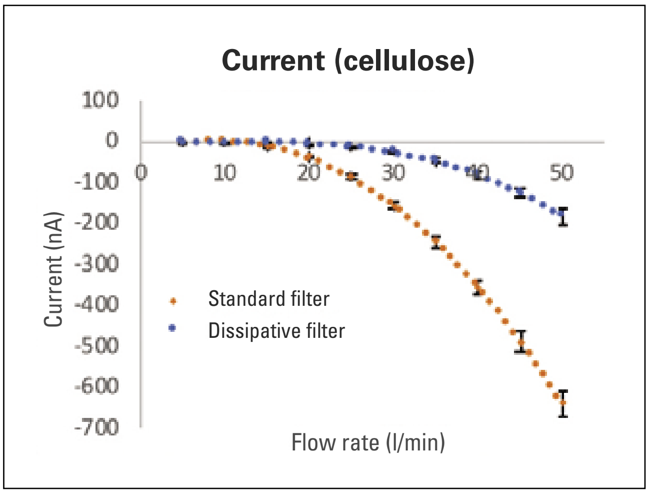


Graph 2

Internal view of the R&D Laboratory of MP Filtri



Graph 3



Graph 4

does not happen since no phenomenon similar to the electrostatic discharge in the filters takes place in the oil, responsible for limiting the growth of the potential. However, there may also be a limit for oil if the maximum ionisation of the molecules is reached. For such analyses it will be necessary in the future to continue the tests on another experimental apparatus.

ITALIAN ABSTRACT

ESD NEI FILTRI OLEODINAMICI

Lo studio oggetto di quest'articolo nasce dall'esigenza di comprendere e risolvere il problema delle scariche elettrostatiche all'interno di filtri oleodinamici, conseguente all'accumulo della carica elettrica causato dal passaggio dell'olio al loro interno. La soluzione? Il problema originario delle scariche elettrostatiche nei filtri viene evitato sostituendo alcune componenti isolanti con equivalenti conduttivi, che creano un circuito elettrico all'interno degli elementi filtranti, così che la carica elettrica generata dagli effetti triboelettrici possa dissiparsi passando per la testata metallica, collegata a terra.

Conclusions

The original problem of electrostatic discharges in the filter is avoided by replacing some insulating components with conductive equivalents. Create an electric circuit inside the filter elements, so that the electric charge generated by the triboelectric effects can dissipate passing through the metal head, connected to earth. The accumulation of charge in the oil cannot be avoided only by making the filters dissipative; these elements ensure the dissipation of the charge that accumulates on the filter, for which different countermeasures will have to be adopted. The built-in charge collector or another dissipater, if inserted in the pipes or in the tank, could be effective but not decisive. ■