A Study on Underground Discharges due to Non-uniform Fields

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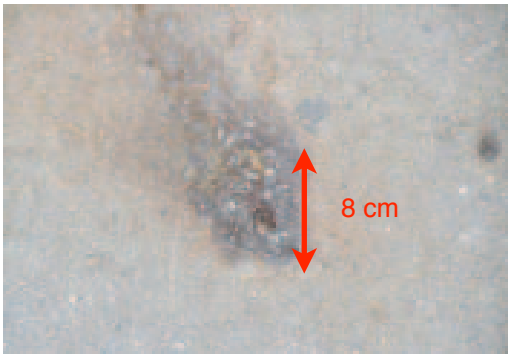
1. Introduction

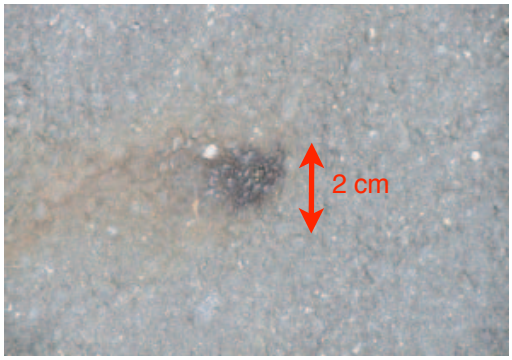
In one thunderstorm day, one factory was encountered lightning stroke and, unfortunately, some information systems were damaged at the same time. Therefore, an inspection was carried out, and one strange phenomenon was reported that there were melt traces on the surface of asphalted road closed to the building. The melt traces on the surface of asphalted road were shown in fig. 1.

(a) Relative location of melt traces(1)

(b) Relative location of melt traces(2)



(c) Close-Up of Trace#1 in (b)

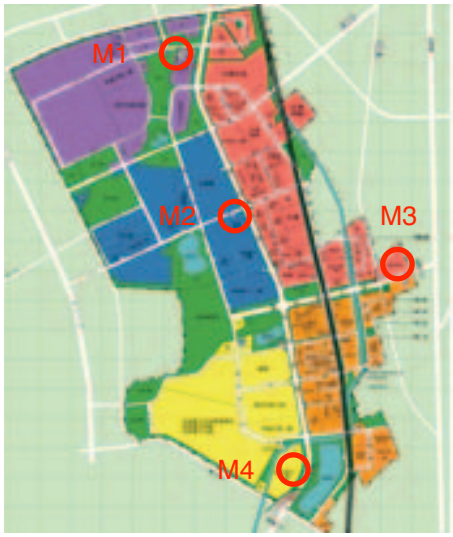


(d) Close-up of Trace#2 in (b)

Fig. 1 Melt traces on the surface of asphalted road

According to the Lightning Location System (LLS) shown in fig. 2, two lightning strokes were reported at that time in this area and the smallest lighting current was 17.6 kA. However, these melt traces didn't show serious destruction due to the high lightning current, but only small areas with 8 cm-diameter and 2 cm-diameter. Hence, the melt traces were not resulted from direct lightning strike, and the lightnings were supposed to strike on the lightning rod. The damaged information systems could be resulted from the ground potential rise (GPR) and the relative circuit might be without proper surge protection.

The unknown mechanism of the melt traces attracts authors, and melt traces are not only found on the surface of the asphalted road but also the surface of concrete road. Figure 2 to figure 5 shows a series photos of melt traces observed in Taiwan and Japan.



(a) Map

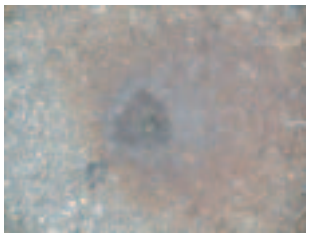
(b) Melt trace at M2 of (a)

(c) Melt trace at M4 of (a)

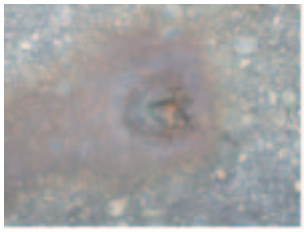
(d) Melt trace at M3 of (a)

Fig. 2 Melt traces on the surface of the asphalted road in Tainan Scient Industrial Park, Taiwan

(a) Switchyard of substation



(b)



(c)

Fig. 3 Melt traces at M1 of Fig. 2(a)

(a)

(b)

Fig. 4 Melt traces at concreted parking lot in Ilan (east Taiwan)

(a) Sakae-machi (b) Miyazaki

Fig. 5 Melt traces on the surface of asphalted road in Japan

Relative literatures about lightning strike on ground usually focus on the calculation of electric field distribution[], the estimation of breakdown channel in the soil[], the impact of lightning strike on buried cables[], and etc.. However, few literatures deal with the phenomenon of melt traces observed in this paper. Although there is no event reported involved with the melt traces, the mechanism of melt traces on the surface of the asphalted road is necessary to be analyzed because it usually occurs at the road close to pedestrians.

As shown in fig. 1 to fig. 5, the melt traces usually occurred at open fields close to buildings, and there are few people walking in a rainy day. Therefore, the detail of melt traces were not observed. Because there were information systems damaged as the melt traces occurred in the event shown in fig. 1, relative inspection[] was carried out and the possible reasons were proposed in this paper. Based on the inspection, the underground side flash, ball lightning, and the underground discharge are the possible causes of the melt traces, and they will be illustrated in this paper.

2. Underground Side Flash (Splash)

There were four information system damaged while the lightning stroke. One telephone exchange system, one network chip on a computer and, one network card on a CCTV system in main building were damaged, and one network card on a computer in the information was also damaged. The damaged telephone system could be resulted in the transfer voltage due to the different ground voltage between local system and remote system via the telephone wire. Others implied that the ground voltage between information and main building were different. In other words, there would be ground potential rise (GPR) in the grounding system.

Figure 6 shows the grounding grids of information and main building, and there are no solid grounding wire connecting these grids. As lightning stroke the lightning rod on the roof of main building, the 18 kA lightning current would result in a GPR in the main building, and the ground potential in information remained low.

The asphalted road, consisting of asphalt and gravel, forms an insulator, and fig. 8 shows there are three layers below the asphalted road: asphalt with gravel, soil, and a mix of sand, stones, and gravel. Because the conductivities of the three layers are different, the interfacial polarization might result in space charge on the surface of asphalted road. As lightning stroke on the lightning rod, the GPR will fully applied on the asphalted road as shown in fig. 7. Because of non-uniformly electric field caused by GPR, the built-up space

charge also non-uniformly distributes along the surface of the asphalted road. Hence, there would be an side flash on the asphalted road while the enhanced electric field caused by built-up space charge excess the breakdown electric field of air. The size of melt trace could vary with the energy stored space charge.

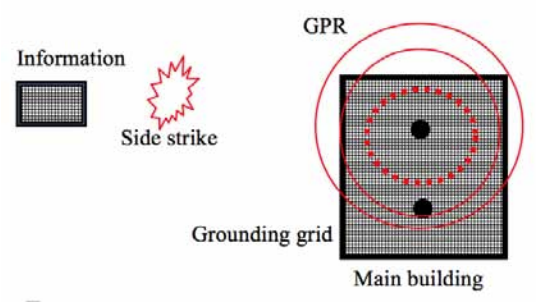


Fig. 6 Grounding grids of buildings

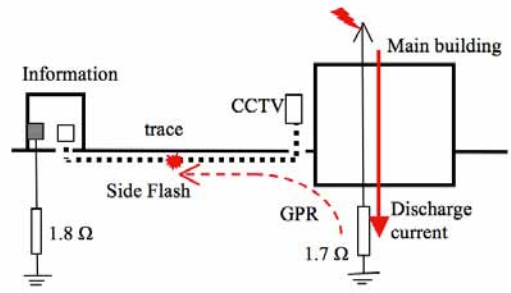


Fig.7 Grounding

Fig. 8 Soil layer of asphalted road

According to the inspection [], one motorcycle rider reported that he suffered a slightly electric shock in the same area; meanwhile, there were lightning and thunder adjacent to the building. This phenomenon also implies that there is high electric field on the surface of asphalted road as high GPR resulted from lightning strike. This could be the one cause of melt trace on the surface of asphalted road.

3. Ball Lightning

Ball lightning is a special phenomenon of lighting, and there are several physical inference about its formation[]. Among them, ball lightning always appears near to the local lightning, where the high electromagnetic disturbance exists.

According to fig. 1 to fig. 4, the melt traces usually occurred at open fields close to buildings. It implies that there might be lightning strike on higher objects, and the local lightning is one condition of ball lightning formation [].

One property of ball lightning is its motion along conductor such as telephone wire, power line, and etc.. However, in Tainan industrial science park, most conductor are underground, and there are almost no conductor outside the building. In the case of no conductor exposed outdoor, the motion of ball lightning might be erratical.

Based on the inspection [], there are 208 V-power line under ground (about 2 m below the surface). Hence, after the ball lightning formation, it might move along the outwall,

which has steel inside, and move above the surface of asphalted road, where has buried cables.

In such assumption, the melt trace could be the mark the ball lightning falling down, or the discharge trace between ball lightning and the asphalted road.

4. Conclusion

Initiated by the inspection of GPR problem, the melt traces on the surface of the asphalted road is analyzed. Up to now, there is no human injury reported due to these locations are few people walking through this area while it is rainy. The study on these melt traces might help to prevent further damage.

There are two possible causes resulting in the melt traces on the surface of the asphalted road. One is the side flash due to the non-uniform electric field, and this is hard to prevent further damage because of invisible electric field. Another one is ball lightning, which is rare observed, and it would be easy to be prevented from injury because the accompanying luminous remind people of its dangerous.

5. Reference