CASE REPORT

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# Examination of Lightbulb Filaments After a Car Crash: Difficulties in Interpreting the Results

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**ABSTRACT:** A drunk car driver was involved in a fatal crash with a scooter at night. Examination of the lightbulbs from the vehicles revealed some mechanical and analytical incompatibilities. The laboratory's initial observations led to complementary police investigations which finally solved the first incompatibility. The different precautions taken by the technical police investigators on the crime scene finally allowed the forensic scientists to establish the functional state of the lightbulbs during the crash.

**KEYWORDS:** forensic science, criminalistics, automobile accident investigation, bulb filaments, scanning electron microscopy, interpretation

At night in March 1998, on a secondary road in Brittany, France, a Ford car (Fig. 1) crashed into a Peugeot scooter (Fig. 2). The car did not stop and, a few kilometers farther on, slightly bumped another car, causing it to fall into a ravine. The first accident proved fatal for the scooter driver. The driver of the involved car was quickly identified; he was drunk. Technical Police investigations were executed on the Ford car concerned. The Motorcraft H4-type bulb (high beams and low beams) from the front left optical set was removed. Along with it, three R10W-type turn signal bulbs and one P21/5W-type bulb of the rear optical set were removed from the scooter. A H4-type bulb was found on the roadside where the first accident took place. According to the investigators, it belonged to the front optical set of the scooter. All these bulbs were submitted to the forensic laboratory for analysis.

## Examinations

### *The Scooter Bulbs*

Two of the three R10W-type scooter's bulbs were undamaged. On the third, the filament coil was broken and showed a clear brittle fracture under the scanning electron microscope. No deformation of a ductile type was visible on the filaments. Considering the violent shock to the scooter at the time of the crash, such a fact led us to think that the lights were not working at the time (1,2).

The P21/5W-type rear lightbulb of the scooter had lost its protecting glass bulb. The filament coil of the sidelight was not broken but fully stretched and showed some oxidation coloring due to annealing (3,4).

The H4-type bulb found on the roadside (Fig. 3) near the damaged scooter was a much more complex case to analyze. The firm inscription on the bulb base *(NORMA 12V 60/55W H4 • 10 Made in France BO)* proved the bulb was about ten years older than the scooter. Due to the fact that stocks are nowadays systematically kept low at the manufacturer's plant, it seemed reasonable to believe that this bulb was not the original one.

Further verifications were carried out. The bulb possessed a three-part base and two tungsten filaments coils. But the original S3-type bulb had a different base (Fig. 4), a P26s bayonet one, with only one filament coil. So, inconsistencies did appear. The normal working power of the light set of the scooter was 15 W. It would have been overheated in the presence of a H4-type bulb, which has a 55 or 60 W power rating.

As a consequence we were left with two hypotheses: either this bulb had no link with the crash incident concerned in the investigation, or the electric circuit of the scooter was modified to allow use of the existing bulb. An interview of the victim's relatives ultimately confirmed the second hypothesis. Further examination showed the glass bulb to be intact, its filaments coils to have significant ductile deformations, and the low-beam filament coil revealed a ductile-type fracture (Fig. 5).

### *The Ford Car Bulb*

The H4-type bulb removed from the Ford car had lost its protecting glass bulb and was divided into two separate parts: (1) the reflector and half of the low-beam and high-beam filaments coils, and (2) the bulb base and the remaining filaments coils (Fig. 6).

Microscopical examination showed that:

- Both coils had numerous deformations of a ductile type due to stretching (Fig. 6).
- Two types of oxidation could clearly be observed on the filaments coils: a yellow oxide on a black low-beam filament and a black oxidation on the high-beam filament. In the first case the oxidation was due to $WO_3$, in the second to $WO_2$ (5,6). The importance of these oxidations proved that the filaments were

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FIG. 1—*The Ford car involved.*

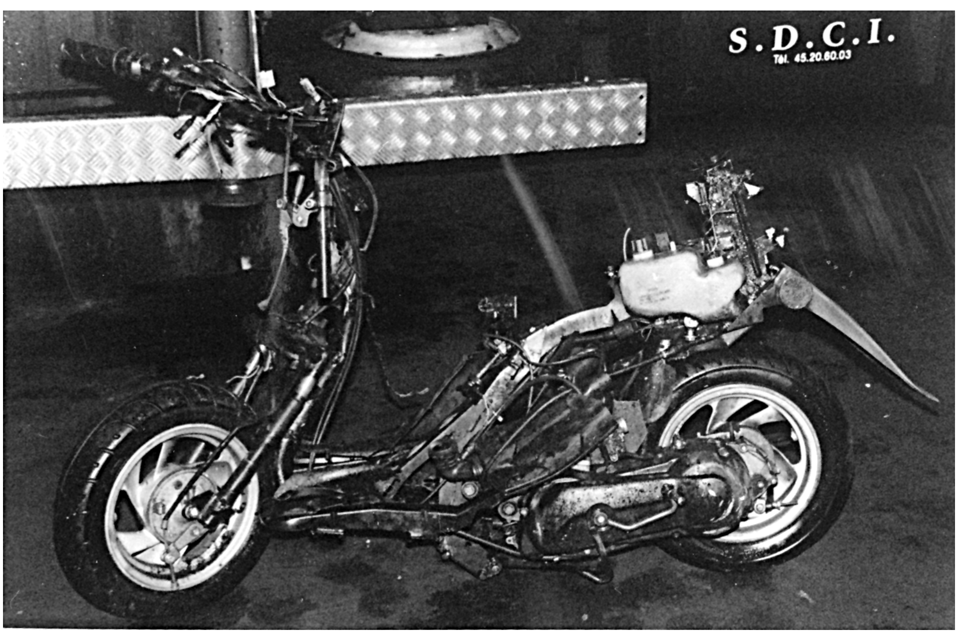



FIG. 2—*The damaged scooter.*

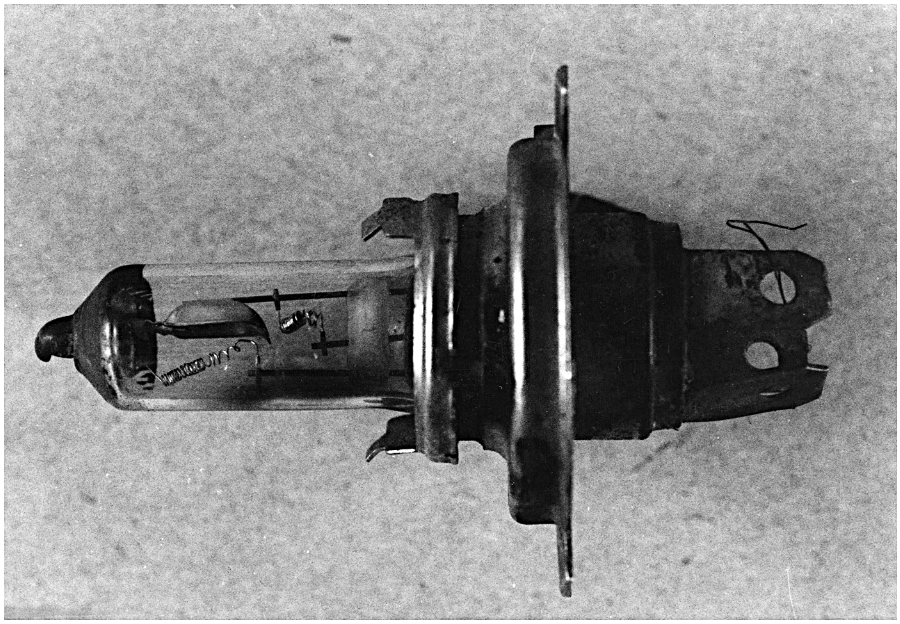


FIG. 3—*H4-type bulb found on the roadside near the scooter.*

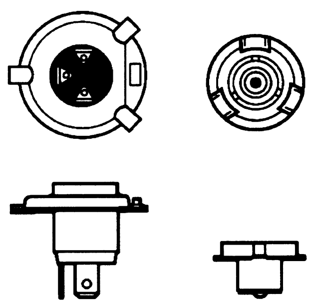


FIG. 4—*Differences between the H4 bulb base type P43t* (left) *and the S3 bulb base type P26s* (right).

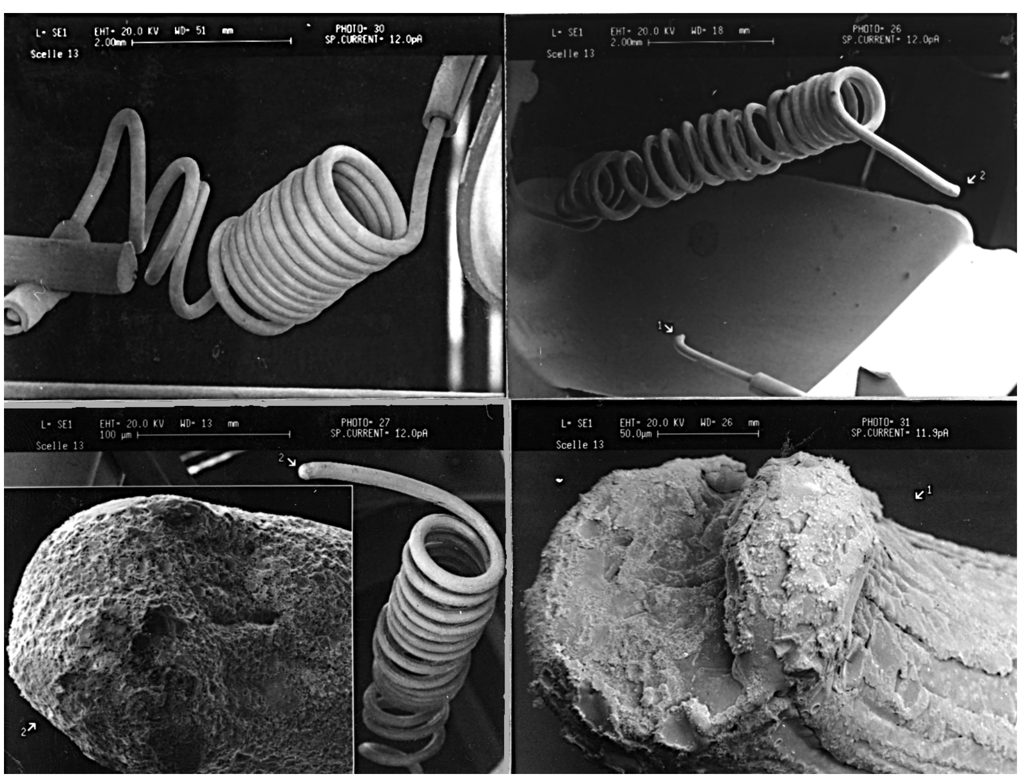



FIG. 5—*Set of photos of the H4-type bulb of the scooter, viewed by SEM.*

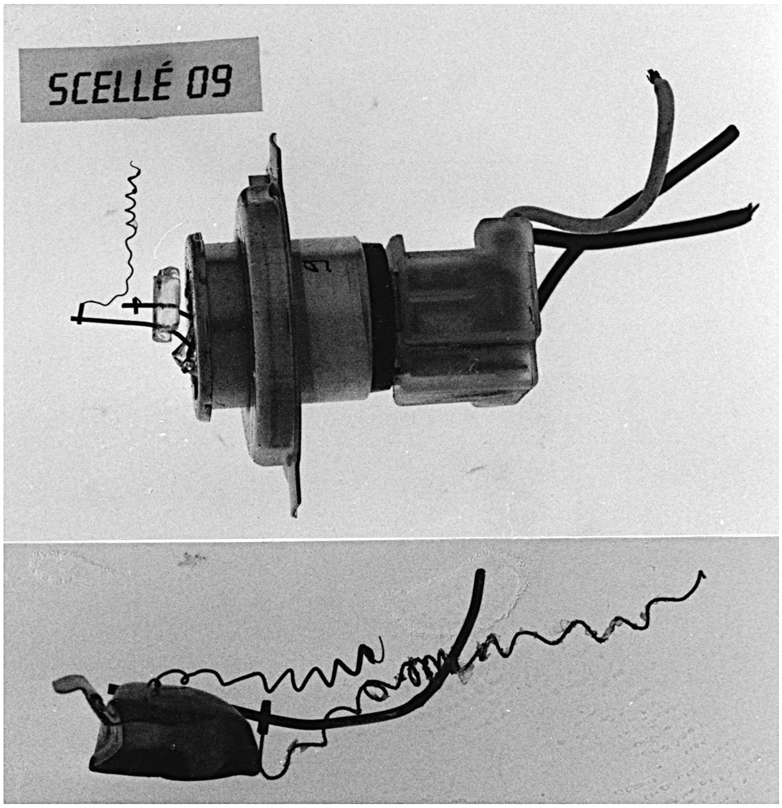



FIG. 6—*The H4-type bulb removed by the investigators from the Ford car. The bulb, shown as it arrived at the laboratory, is divided into two separate parts.*

functioning when an oxygen supply became available, which means after the glass bulb was broken (3,7).

- Numerous vitreous-looking globe-shaped particles with an elementary chemical composition similar to vitrous silica glass (5) were "stuck" on the surface of the high-beam filament coil. This showed that the filament coil was very hot when the glass bulb broke. In contrast, on the low-beam filament coil, only one much larger splinter of a protruding shape could be seen (see Fig. 7), which had locally and superficially melted where it touched the filament. This splinter was also vitrous silica glass. Since there were no other glass particles, it seemed likely that this filament coil was not functioning when the glass bulb broke. Yet it did function after the breaking of the lightbulb. The yellow oxidation on the filament coil surface together with the traces of local fusion on the large glass splinter proved this fact (3,7).
- Examination of the broken points on the low-beam filament coil merely revealed globular fractures of a ductile type with a thinning down at its end, proving that this coil was functioning when it broke—see Fig. 8 (1,5). As for the fractures noted on the high-beam filament coil, they belong to the brittle type and happened when it was cold—see Fig. 8 (1,5). Such observations contradicted those made previously.

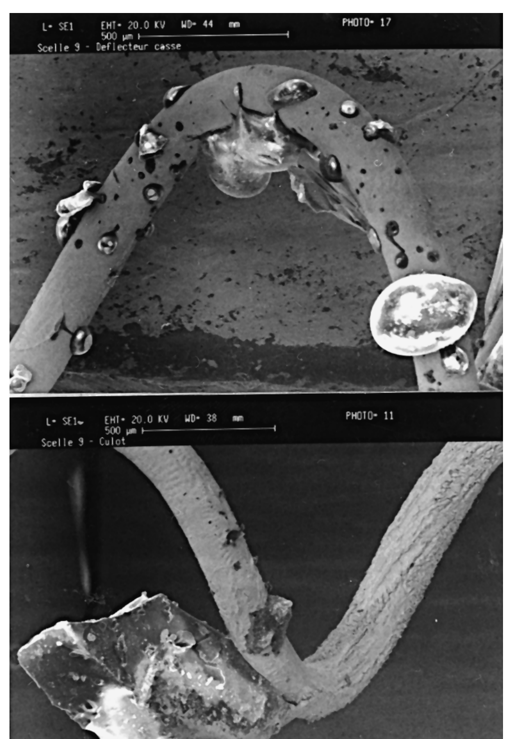


FIG. 7—*The high-beam filament* (above) *shows a multiplicity of small glass hemispheres glued to its surface. The low-beam filament* (below) *shows only one large protruding splinter on its surface.*

## Discussion

### *The Scooter Case*

Examination of the turn signal bulbs was a special case. With an electric circuit perfectly functioning, the duration of the power-off

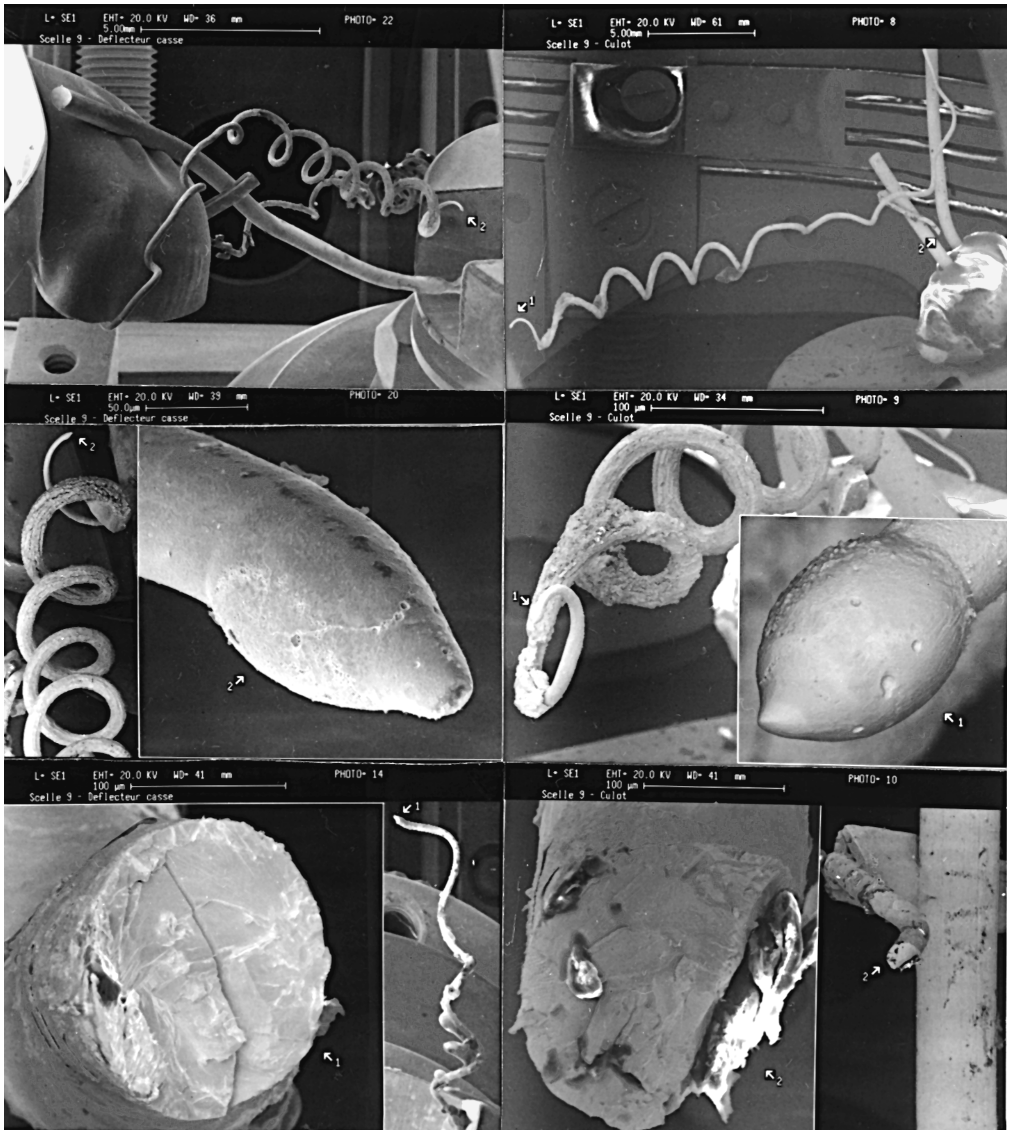



FIG. 8—*Set of photos showing the different fractures observed on the H4-type bulb of the Ford car.* (Left)—*The fractures correspond to both the fragments of the low-beam and high-beam filament coils connected to the reflector.* (Right)—*The fractures correspond to the fragments of the low-beam and high-beam filament coils still connected to the bulb base.*

condition is not generally sufficient for the temperature of a filament coil to fall below the "transition" temperature, which is between the ductile and brittle phases of tungsten (5). So, the data from the examination of the turn signal bulbs of the scooter proved that they could not have been functioning at the time of the crash.

Examination of the rear lightbulb of the scooter showed perfectly that it had been functioning when the glass bulb broke in a severe road accident, after which the lightbulb did not function. Had things been different, the filament would later show a ductile-type crack from its prolonged functioning in the presence of oxygen. It is reasonable to deduce that during the shock, which broke the bulb, the electric circuit was quickly disconnected.

Examination of the front lightbulb of the scooter enabled us to see that its electric circuit was modified. In the present case it is impossible for the expert who does not know the origin of the bulb to make a decision on its functioning capacity at the time of the crash. The expert confessed his difficulties to the investigators, who decided to interview the relatives of the victim. It was established that the bulb came from duplicate equipment and, as a consequence, was very likely new. We can then conclude that both filament coils were functioning at the time of the crash. High beams and low beams were joined. As a consequence, the quality of the lighting called for reservations. The original light set of the scooter was designed for a one-filament light and the electric generator provided about 50 W total power and not the 115 W-power required (55 + 60 W) by this bulb.

### *The Ford Car Case*

The car involved in the crash with the scooter was later implicated in a second road accident. The study of the investigations of this second accident enabled us to assert that it was not very violent, that the vehicles merely bumped each other. There were no visible ensuing modifications of the filament as had been expected.

Examination of the low-beam filament coil led to several conclusions. This coil broke when it was hot as we could see ductile-type fractures. It had functioned in the presence of oxygen, as shown by the yellow-colored oxidation on the surface. The oxidation followed the breaking of glass since no drops of molten glass, such as those present on the high-beam filament coil, could be seen. Very definite deformations of the ductile type, i.e., occurring when hot, could be seen.

On the contrary, examination of the high-beam filament coil led to the conclusion that it was functioning when the glass bulb broke since a multiplicity of molten glass drops could be seen on its surface (3). Very definite deformations of a ductile type could also be seen.

These comments seem incompatible with the results of the study of the breaking point, for the fracture belonged to the brittle type. But thanks to the photos taken at the accident scene, the problem could be solved. The detailed examination of the enlarged photo (Figs. 9 and 10) taken by the investigators before the removal of the

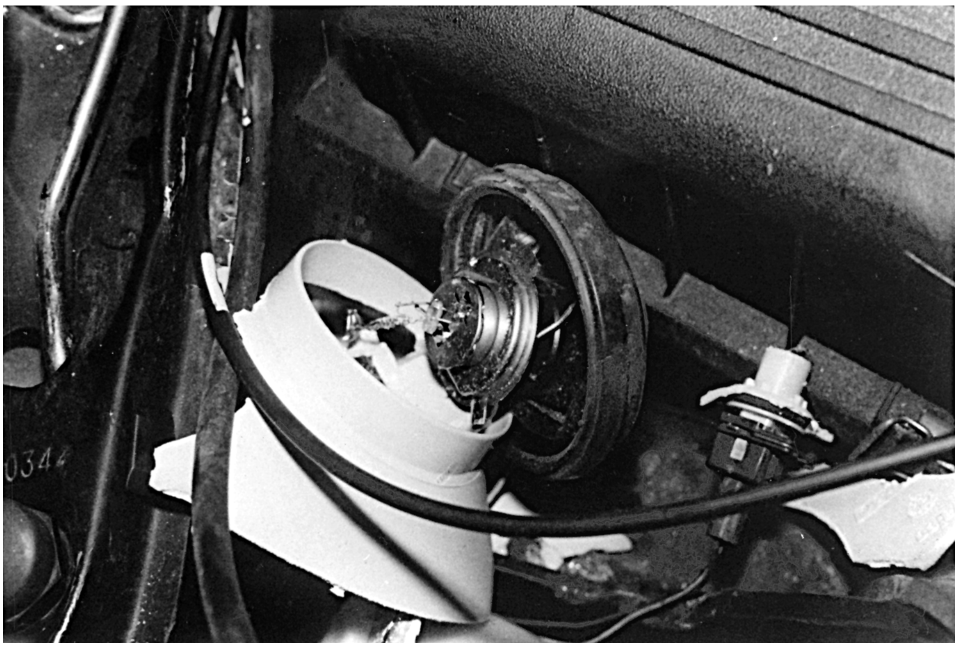


FIG. 9—*The H4-type bulb of the Ford car before its removal from the optical set by the investigators.*

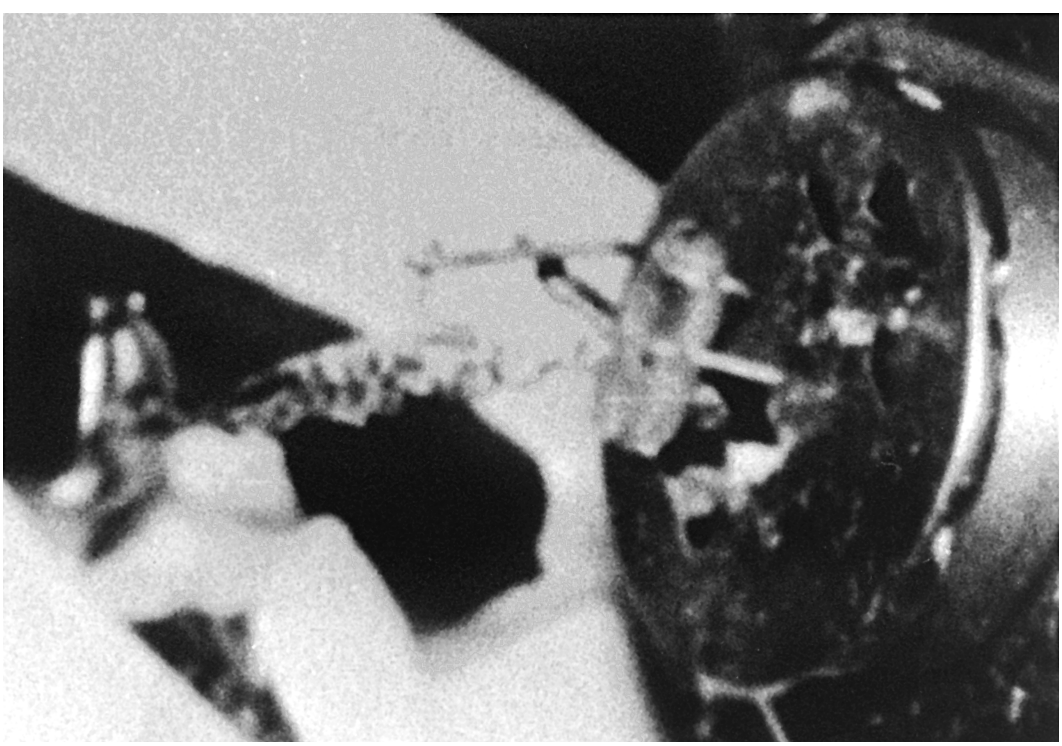


FIG. 10—*Enlargment of Fig. 9. Before removal the filaments are still both connected to the bulb base.*

car bulb showed that the now distinct parts of the lightbulb were connected even after the accident. But the enlarged photo is not sharp enough to reveal the way in which the existing two parts were connected, which we could only deduce. The photo shows that the reflector support, which also was used as ground wire, was broken (because it is twisted, it does not appear in the photo, unlike the reflector). A fracture of a ductile-type can be detected on the low-beam filament coil, which could only happen before the removal of the light. These observations prove that the reflector was connected to the bulb base by the high-beam filament coil at the time of the removal.

Maximum caution was used to carry and store the lamp, but this was obviously not sufficient to guarantee the best preservation of the sample. As a matter of fact, filaments are excessively brittle when they are old and come from a road accident (5). It appears that the stretched filament acted as a lever with the large mass reflector attached. This made removal and transport to the laboratory without alteration of the exhibit very difficult.

The brittle fracture of the high-beam filament was rejected from consideration in this study as it succeeded the crash and probably happened when the lamp was removed or carried to the laboratory.

### Reconstruction Hypothesis

In order to take into account, on the one hand, the observations made under optical and electron microscopes and on the other hand, the laws of physics governing these materials, the hypothesis offered in Fig. 11 is, in our belief, the only possible one.

The car ran with its high beams on before the accident (before time 1). See Fig. 12.

Shortly before or even during the crash with the scooter the selector of the high beams and low beams was operated on the dashboard, either by the driver himself or as a consequence of the shock (Time 1 in Fig. 11). The temperature of the high-beam filament began to cool down and would never warm up again.

The interval between Time 1 and Time 2 corresponds to the period necessary for the control lever changing from high beams to

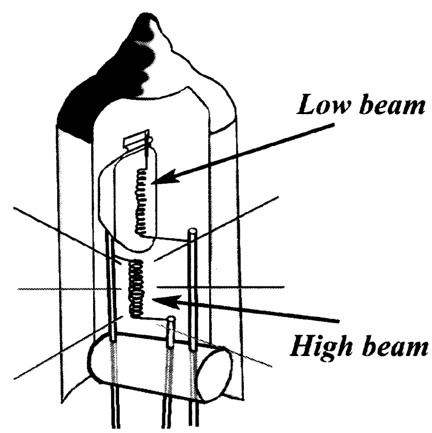
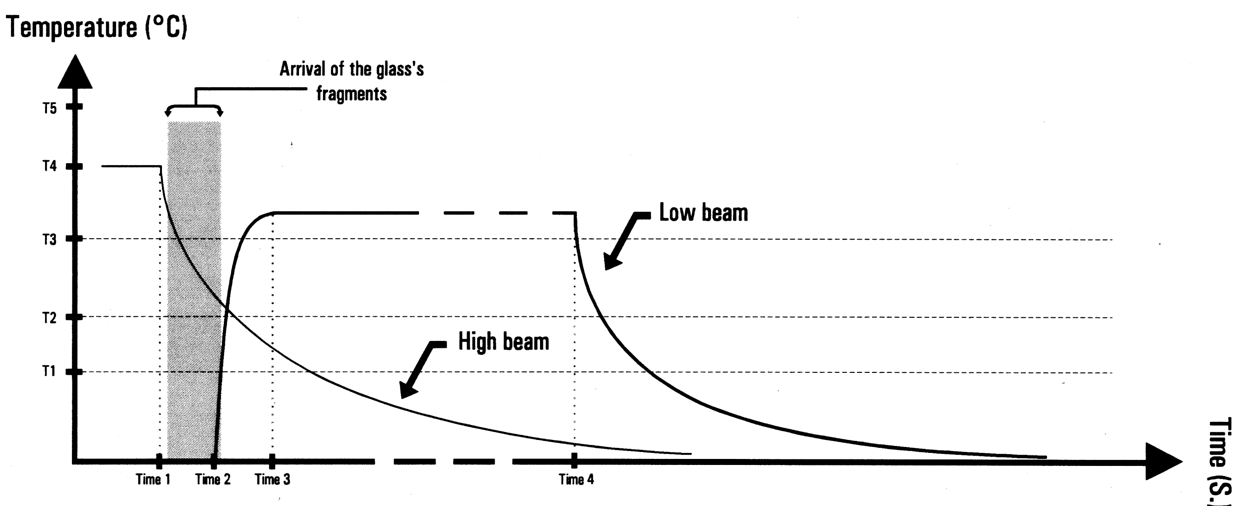



FIG. 12—*The high-beam filament is supplied with voltage (before Time 1).*




T1 : Temperature limit between the ductile and brittle phases of tungsten, about 200/400°C.
T2 : Temperature limit of tungsten oxydation, about 700°C.
T3 : Temperature limit of glass fusion, about 1500°C ; differs according to the quality of vitrous silica glass.
T4 : Normal working temperature of a tungsten filament, about 2900°C.
T5 : Temperature of tungsten fusion, about 3410°C.

Time 1 : The supply of voltage to the high-beam filament is interrupted.
Time 2 : The low-beam filament is supplied with voltage.
Time 3 : The filament rises to a maximum temperature below T4.
Time 4 : The supply of voltage to the low-beam filament is interrupted.

Grey band : period of time when the glass splinters from the glass bulb or from the optical set came into contact with the filament coils.

FIG. 11—*How the H4-type bulb filaments of the Ford car reacted to the crash with the scooter according to time. The curves refer to what really happened, but are only indications.*

low beams (far less than 1 second). During the collision the scooter crashed into the left front optical set of the Ford car, then the glass orb of the H4 bulb broke (gray band in Fig. 11)—see Fig. 13.

The high-beam filament, although cooling down, was still hot (it takes its temperature about 4 s to fall below 500°C (5)) when it was hit by fragments of optical glass or of the bulb that melted on touching it. Its temperature at this moment was above the temperature of the melting point of vitrous silica glass, (T3 in Fig. 11), about 1500°C (5). The high-beam filament oxidized and showed a black color (degree of oxidation $WO_2$); its temperature was above the oxidation point of tungsten, (T2 in the figure), or about 700°C.

The low-beam filament was cold; the small particles of glass that touched it did not remain on it except for a large splinter that remained stuck between two spirals of the coil. No oxidation took place, the temperature of the filament being below T2.

Eventually with Time 2 the working of the selector closed the electric circuit that supplies the low-beam filament. The temperature of this filament quickly rose (until Time 3), whereas that of the high-beam filament continued to cool (Fig. 14). The scooter kept on crashing into the car. One or two of its external parts came into direct contact with the light supports of the car and its filaments. There they caused the ductile-type distortions here noted, the temperature of both filaments rising above the limit between the ductile and brittle phases of tungsten (T1 in Fig. 11), about 200/400°C. As soon as it rose above temperature T2 in the figure, about 700°C,

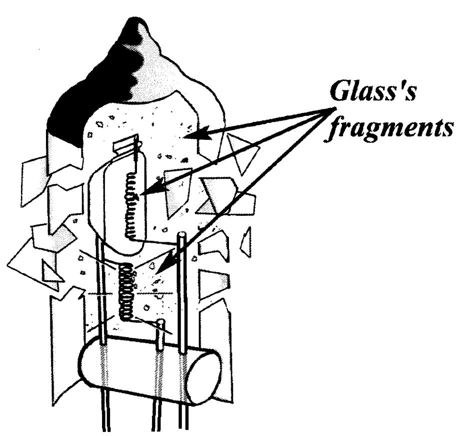



FIG. 13—*Time 1 to 2. The selector is switching from high beam to low beam. The glass orb breaks, small splinters of glass come into contact with the filaments.*

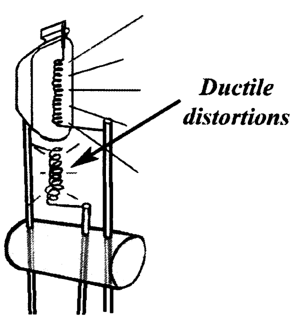



FIG. 14—*Time 2 to 3. The broken glass bulb lets in oxygen. The low-beam filament is supplied with voltage and the high-beam filament keeps on cooling down.*

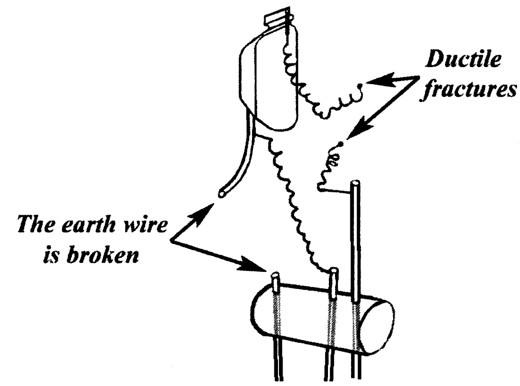



FIG. 15—*Time 3 to 4. The filaments are stretched through the shock(s). The still-working low-beam filament eventually breaks with a ductile fracture. The support wire of the reflector is warped and eventually also breaks. The lightbulb can no longer be supplied with voltage. This figure corresponds to the observations made at the time of bulb removal (Figs. 9 and 10).*

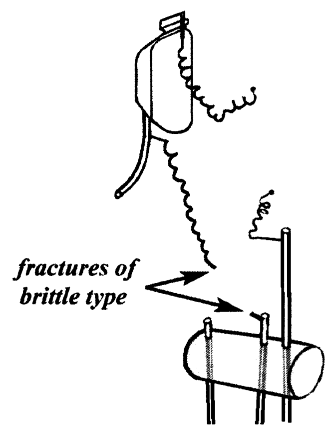



FIG. 16—*The front bulb of the Ford car as seen when the sealed material was opened in the forensic laboratory.*

the low-beam filament began to oxidize. From temperature T3, about 1500°C, the large glass splinter caught between the two spirals began to melt locally where it touched the coil.

From Time 3 to Time 4 (Fig. 15) the low-beam filament coil could not reach its normal working temperature T4, about 2900°C. This probably was due to the violent flow of air after the breaking of the protecting glass orb. (See also Fig. 16.)

The presence of oxygen explained its yellow-colored oxidation, typical of a $WO_3$-type oxidation. On the contrary, the high-beam filament blackened because it begins to oxidize when cooling down.

The low-beam filament finally broke. Either its breaking followed oxidation (a very unlikely hypothesis considering the still regular diameter of its component spirals and the only narrowing area being located at the fracture ends (4)), or it was due to the mechanical action of an external element in direct contact with the filaments, their supports, and the reflector, causing a still visible fracture of a ductile type.

The presence of the large glass splinter glued to the surface of the filament that is not molten favored this second hypothesis. This showed that it all happened in a very short time and that the filament was not broken because of oxidation. Had it been otherwise, the whole process would have been much longer and the glass splinter would have melted totally.

Because of the different interactions between the filaments and the external actions, the high-beam filament was extremely stretched but yet not broken.

At Time 4 the low-beam filament coil, no longer being supplied with current, cooled down along with the high-beam filament coil. The reflector support served as a ground wire for the filaments. As it also broke due to the different shocks of the impact, the high-beam filament now could not function. The lights in the left optical set were out unless the sidelights, not examined here, were still working. The bulb would be exactly like the one in the photo taken by the investigators before its removal (Figs. 9 and 10).

## Conclusions

From the different examinations performed with the light microscope and the scanning electron microscope, only one hypothesis is supported for each lightbulb submitted to the forensic laboratory.

The Norma H4-type bulb found on the road near the scooter belonged to it but was not original equipment. It was also proved that this lightbulb was functioning at the time of the crash but the quality of the lighting calls for reservation.

Examination of the Motorcraft H4-type bulb of the front left optical set of the Ford proved to be more complex. The hypothesis supported is that shortly before or even during the crash the selector of the high beams and low beams was operated from the dashboard. On the other hand, the brittle fracture discovered on the high-beam filament coil originated from an event that took place after the accident, probably during or after the removal of the bulb by investigators.

The study of lightbulb filaments involved in a traffic accident and submitted to the laboratory is sometimes insufficient to reach a scientifically valid conclusion. The forensic scientist should also be informed of the conditions of the crash, particular circumstances around the event, and the origin of the lightbulbs received. He or she may also need to be able to study the police report of the case in order to support conclusions drawn from the laboratory examination.

*Acknowledgments*

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