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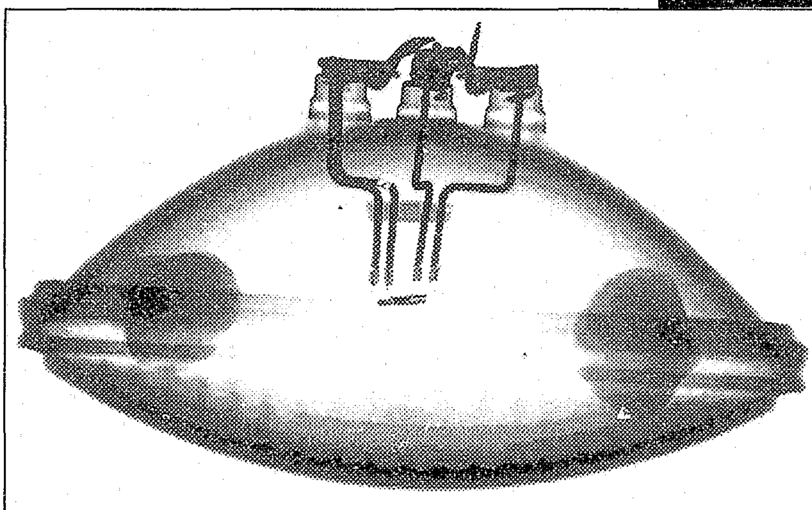

Noninvasive Evaluation of Vehicular Lamp Bulbs

Notes from the Technical Working Group on DNA Analysis Methods

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SPECIAL FEATURES

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Noninvasive Evaluation of Vehicular Lamp Bulbs

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Headlights and other lamp bulbs removed from vehicles involved in accidents and submitted for forensic examination encompass a variety of bulb types and conditions. Frequently, the glass envelopes of the bulbs are intact or unbroken. For some of the bulbs, such as the 1156, 1157, and 9004 varieties, an intact envelope is not an obstacle to successful nondestructive evaluation of filament characteristics. However, the construction of some of the most forensically significant bulbs, notably sealed beam headlights, is not conducive to unobstructed visual and microscopic filament examination.

One technique for examining intact glass envelopes is to look directly into the clear areas of the lens to view portions of the filaments. Ductile filament failures or deformation may be partially observed in this manner. However, brittle failure, one of the best indicators that the filament was not incandescent at the time of the accident, will often not be detected, in part because the entire filament length is rarely observable by this method. It is sufficiently difficult to detect brittle filament failure by direct viewing; indirect viewing and electrical measurements of the filaments do not insure thorough inspection or sound conclusions of filament continuity.

Standard laboratory procedures for the examination of a lamp bulb with an intact glass envelope involve the invasive and somewhat hazardous practice of thermally or mechanically breaching and removing the envelope. In the thermal technique practiced in the FBI Laboratory, the gas pressure differential is eliminated, the glass envelope is file scored, a steep thermal gradient is established to enhance crack initiation and to preclude solder/braze fusion, and an oxyacetylene miniature welding/cutting torch is used to effect circumferential fracture and eventual separation of the reflector. Other techniques observed involve breaking the glass envelope with vise grips, a hammer and prick punch, vise jaws, an electric starter for a charcoal grill, or a propane torch, but most of these procedures do not address preliminary gas pressure equalization to reduce the risk of high velocity glass shard dispersal. The personal safety equipment used with these methods should include a face shield or safety glasses, suitable protective clothing, a fire extinguisher, and adequate ventilation.

A relatively safe and noninvasive technique has been developed by the author for the nondestructive evaluation of lamp bulb filaments in bulbs with intact glass envelopes. X-radiography is effective in conjunction with both static *and dynamic* electrical continuity measurements and is safer than conventional invasive procedures. The only personal safety equipment required is a radiation monitor.

Application of radiological principles to lamp bulb examinations is a natural extension of the metallurgical capabilities of the FBI Laboratory. X-ray examinations are routinely conducted in foreign counterintelligence, espionage, and terrorist matters, in anthropological and other unidentified victim or cause of death examinations, in food product contamination cases and drug cache detection, and in conventional metallurgy applications such as the nondestructive detection of internal defects in metallic and nonmetallic components. This technique is well suited for lamp bulb examinations because it takes advantage of the differences between the relative radiotransparency of the envelope and shielding materials and the radiopacity of the dense filament tungsten.

Level I Certification by the American Society for Nondestructive Testing or knowledge of radiation physics is not required to effectively obtain and interpret the radiographs resulting from application of the technique. Additionally, numerous lamp bulbs can be x-rayed simultaneously to reduce the cost of x-ray film and the time expended by the examiner.

Materials and Methods

Upon receipt, evidential bulbs are properly labeled, photographed, and visually and stereomicroscopically examined for both salient and subtle characteristics. Electrical continuity measurements are performed to assess whether the filaments are electrically continuous or discontinuous. The measurements are conducted both statically and dynamically (measurements conducted with the lamp bulb in motion encompassing violent changes of direction or simulating road shock). During both ductile (hot shock distortion) and brittle failure modes, the fractured filament ends frequently come to rest in contact with another electrical component, often the opposite fracture. Static measurement of electrical continuity will not detect filament failure in these cases. In fact, although dynamic electrical continuity measurements drastically reduce the possibility for error, even dynamic measurements do not guarantee that post-fracture welding has not occurred during the accident. Proper radiographic technique can significantly reduce the possibility for error by discerning regions of post-fracture welding or other electrical continuity resulting from the accident as opposed to metallurgical design. After the photographic, visual, and stereomicroscopic examinations (static and dynamic electrical continuity measurements can be conducted either before or after radiography), the lamp bulbs are ready for examination by x-radiography.

In the FBI Laboratory, an x-ray unit with a maximum electrical potential of 320,000 volts and a maximum tube load of 3.2 kW is used in conjunction with a programmable controller for the majority of metallurgical examinations requiring x-radiography, including the lamp bulb examinations. The tube is mounted on an overhead track in a dedicated, lead-lined vault and is adjustable in any of the x, y, or z axes. This is particularly useful for reducing the radiographic penumbra, a "shadow" caused by geometric considerations which manifests as an exaggeration of object dimensions on the radiograph.

The questioned headlights are placed in the x-ray beam path between the x-ray tube and the radiographic film (type AA film, 35 × 43-cm and 8 × 10-inch formats, is used in the FBI Laboratory) and centered with a laser-centering device. Lead characters are placed along the edge of the film to identify the specimen and the laboratory submission numbers as well as the radiographic exposure parameters (potential, current, distance, and time). After the exposure parameters are selected and programmed into the controller (if they are not preprogrammed), the radiograph is exposed. It is recommended that at least two views, preferably normal to principal specimen axes, be prepared and processed for eventual examination and evaluation on a light box. A 5 X or greater magnifier should be used for evaluating the radiographs because the displacement of some filament fractures is very subtle; after failure, the filament coil often returns to its prefailure position. Numerous bulbs can be x-rayed simultaneously, significantly speeding up the radiography process, particularly if the larger x-ray film (17 × 14-inch) is used.

Exposure Parameters and Geometric Considerations

Since the purpose of this article is to describe a simple and effective technique to supplement visual and microscopic examinations of lamp bulbs, in-depth radiation physics is not discussed. However, the tube potential, current, distance, and time parameters are discussed briefly as well as the effects of a nonparallel or "point" radiation source on the apparent specimen size in the resulting radiograph.

Figure 1 shows schematically the effect of specimen size on a radiograph produced by exposure to a nonparallel or point source of radiation. The regions labeled as penumbra result from being in the shadow of the incoming radiation which is a direct result of specimen geometry. Note in Figure 2 how moving the radiation source away from the film plane toward a more parallel source configuration reduces the size of the penumbra. Theoretically, the penumbra cannot be completely eliminated until the point source is moved to infinity or the radiation source is caused to produce parallel radiation. However, for lamp bulb, as well as most other forensic examinations, a filament-to-film plane distance of 5 to 6 feet results in excellent resolution or image definition.

The other side of the geometry argument is that the larger reproduction of the filament on the radiograph due to the penumbra actually facilitates filament position and condition examinations. Therefore, a balance must be struck between resolution and magnification.

Using the analogy of water flowing through a water pipe, the parameters of tube potential and current can be compared to the velocity and number of water molecules, respectively.

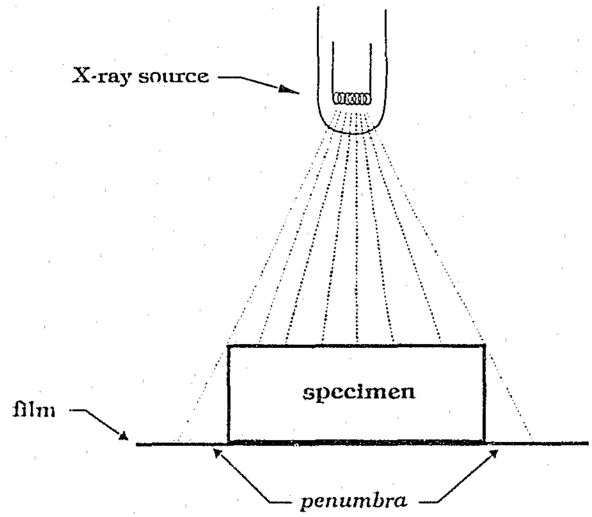


Figure 1. Penumbra formed by a close light source.

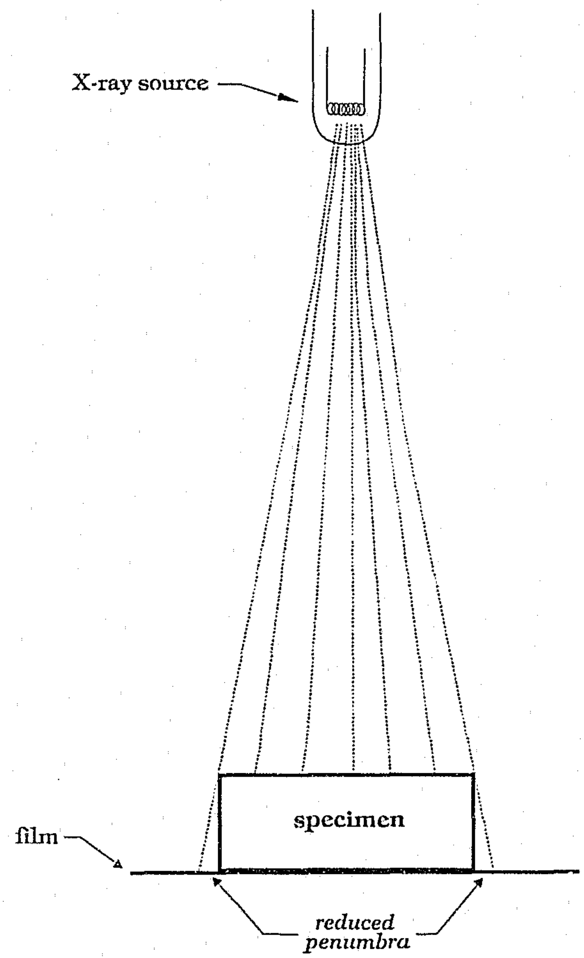


Figure 2. Penumbra reduced by moving light source away from the specimen.

Incorporating the parameter of time, a net flux of radiation or energy per unit time arrives at the film plane. To increase penetration, increase the velocity (penetrating energy). Increasing current increases the number of photons or x-rays arriving at the film plane. The potential, current, distance, and time generally used in the FBI Laboratory if type AA film is used are 150 kV, 5 mA, 5 feet, and 1 minute, respectively. A greater filament-to-film distance can be chosen to further reduce the penumbral effect, but the inverse square law for radiation intensity must be considered and adjustments must be made to one or more of the other parameters to maintain the appropriate radiation flux.

Results and Discussion

Figures 3 and 4 are photographs of case-related radiographs. Although the filaments are somewhat difficult to see because of size reduction and resolution loss during the photographic reproduction for publication, the same observations derived from macroscopic and microscopic examinations can be made from proper radiographic inspection of the filament: ductility or lack thereof, the arc-induced fusion associated with normal burnout, and/or filament displacement. Figure 3 shows brittle failure at impact in a nonincandescent filament. Figure 4 reveals ductile deformation of a filament subjected to impact. Note the filament is still observable in spite of two layers of shielding steel between the x-ray source and the film plane. Figures 5 and 6 are radiograph positives of undisturbed filaments from different types of headlight bulbs also involved in vehicular accidents.

In cases where fracture behavior is a significant consideration or where direct viewing is otherwise prudent (*e.g.*, undisturbed filaments), high magnification stereomicroscopy and/or scanning electron microscopy is still required for the evaluation of fracture morphology and/or for the evaluation of filament age or fabrication characteristics.

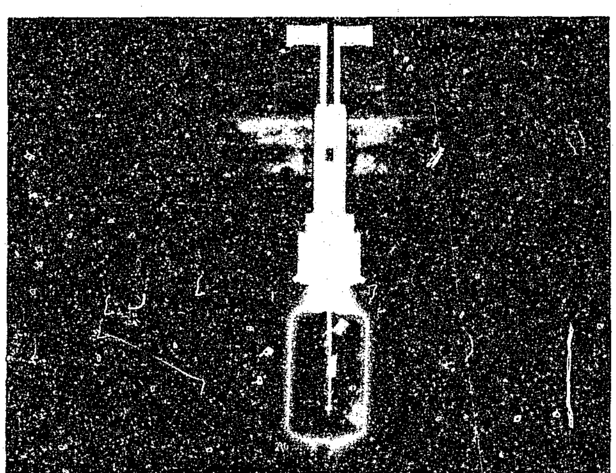


Figure 3. Brittle failure from impact (nonincandescent); 100 kV, 5 mA, 5 feet, 1 minute.

Figure 4. Ductile deformation from impact; 100 kV, 5 mA, 5 feet, 1 minute.

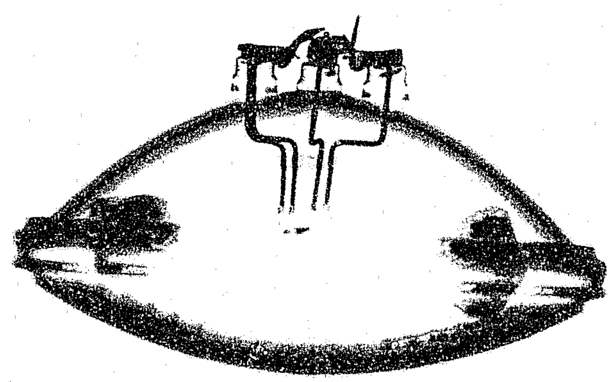


Figure 5. Undisturbed filaments x-rayed at 100 kV, 5 mA, 5 feet, 1 minute.

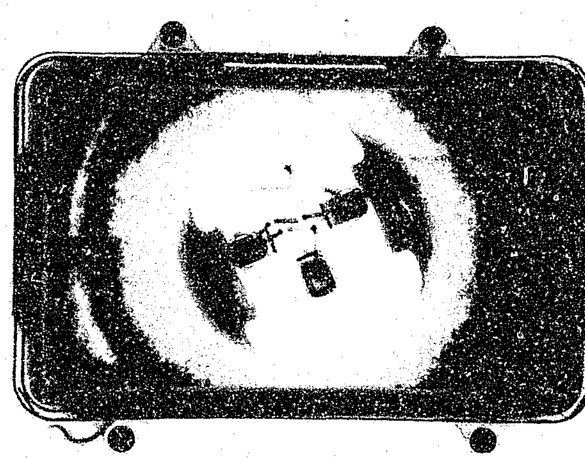
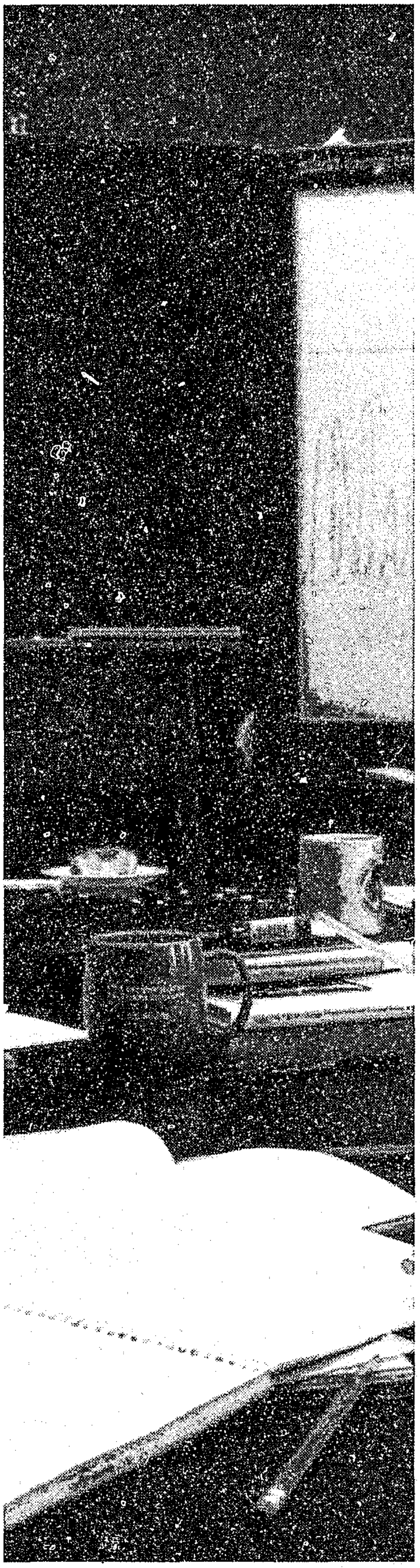


Figure 6. Undisturbed filaments; 150 kV, 5 mA, 5 feet, 1 minute.



Photographer: Kevin Brown
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