

Post-Impact Examination of HID Headlamps

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ABSTRACT

High-intensity discharge (HID) headlamps are increasingly being employed in place of incandescent headlamps for automotive forward light systems. While the post-impact analysis of incandescent bulbs and filaments to determine the power state at impact is a mature field, there is little information currently available in the literature that can be used to determine if an HID headlamp was powered at the time of impact. HID headlamps differ significantly both in architecture and operation compared to incandescent headlamps; the light is produced by passing electrical current through a gas and generating a luminous arc, rather than by resistive heating of an incandescent filament. Though the filament examination techniques often used by accident investigators cannot be directly applied to HID lamps, the unique features of these lamps provide opportunities for new methods.

This paper presents the results of stationary impact tests performed on a representative HID lamp. Several characteristics are described that can be used to determine whether the lamp was powered at the time of impact. Techniques utilized during the examinations included visual, optical microscopic, and scanning-electron microscopic examination of the lamp arc tube and electrodes. These methods all require the arc tube of the lamp to break during the collision.

INTRODUCTION

Incandescent bulbs have been the most common automotive headlamps for the past century. For over 50 years, methods have existed for examining these lamps after a collision to determine whether the filament was powered at the time of impact [1]. The first production automotive high-intensity discharge (HID) headlamp was introduced in 1991 by Bosch

and was incorporated into the BMW 7-Series. HID headlamps are currently used by most major automobile manufacturers in select vehicle lines due to their advantages, which include high performance and efficiency, improved durability, whiter light, and constant output independent of the automotive electrical system voltage [2,3].

As cars equipped with HID headlamps become a larger proportion of the vehicles on the road, accident investigators will continue to need methods for determining whether headlamps were powered on or off during a crash. Though HID headlamps have been in use for nearly two decades, a review of available literature did not yield techniques for inspecting HID headlamps to determine whether they were powered at the time of the collision, only a paper examining the same issue for LED lighting [4]. The current paper addresses this need by introducing several new methods for determining if an HID lamp was powered on or off at the time of impact. Due to the physical characteristics of HID lamps, the methods all require that the HID lamp breaks during the collision.

The remainder of this section of the paper discusses the anatomy of HID lamps and the existing methods for post-impact examination of incandescent headlamps. The next section discusses the testing performed, followed by the results of testing. The conclusion provides characteristics of HID lamps that are indicative of the power state of the lamp at the time of impact.

ANATOMY OF HID LAMPS

The layout of forward lighting systems incorporating HID lamps is similar to traditional lighting systems. The HID light source is mounted in a reflector/lens assembly that controls the beam pattern. The main difference from a conventional lighting system is the addition of electronics to provide the proper current and voltage to the lamp.

The HID lamp itself differs significantly from traditional, filament-based bulbs. HID lamps produce light by passing electrical current through a gas to produce a luminous discharge. While manufacturers have developed numerous variations of HID headlamps (e.g., D1, D2, H1, etc.), the basic layout of the lamps are the same. The lamp consists of the base, the arc tube, and the outer envelope. The base, typically constructed of plastic, houses the electrical connections to the lamp, and adapts to the receptacle inside the vehicle headlight system. The base also retains the arc tube and outer envelope. The arc tube is a small quartz volume that typically contains mercury (Hg), xenon (Xe), and metal halide salts [5]. At each end of the arc tube is a small cylindrical electrode that is typically made of tungsten (W). The arc tube is surrounded by the outer envelope, a quartz cylinder that both protects the arc tube and filters the light output. The tip of the lamp typically points toward the front of the vehicle.

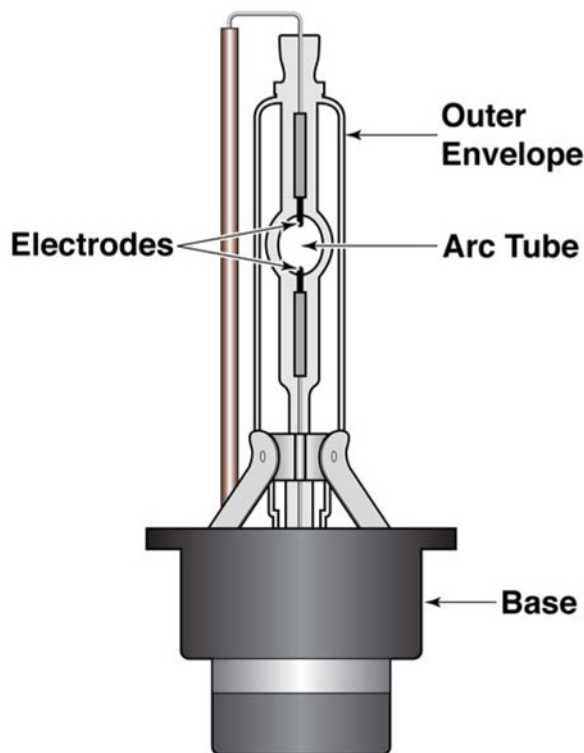


Figure 1. Anatomy of a typical HID lamp

D2 type lamps are among the most common HID lamps on the road today, and can be found on certain vehicles recently produced by most major Japanese and German automakers. They are used throughout this paper as a representative lamp. The arc tube of the D2 type lamp is filled with xenon gas, mercury, and sodium/scandium iodide. The quartz arc tube is approximately 2.7 mm in diameter and has a 4.2 mm gap between the tungsten electrodes. The tungsten electrodes protrude approximately 1.2 mm into the arc tube and are 0.25

mm in diameter. During operation, the electrodes reach temperatures of approximately 2000 K to 2500 K [5].

INCANDESCENT LAMP EXAMINATION

Incandescent lamps consist of tungsten filaments inside a hermetically sealed enclosure. Conventional incandescent sealed beam headlamps contain an inert gas such as nitrogen to prevent oxidation of the tungsten filament, and more modern halogen bulbs also contain a small amount of a halogen, which serves to extend the bulb life [6]. There are a number of well-documented damage patterns associated with the filaments of incandescent lamps, and several are discussed below. For more detail see [references 6,7,8,9](#).

Tungsten does not visibly oxidize in air at room temperature, but will quickly oxidize at higher temperatures [10]. Visible oxidation on headlamp filaments exposed to air is reported to occur at temperatures in the range of 600°C and above. This provides one method of determining if a lamp was powered at the time of impact, as a tungsten filament will appear silver in color and give a bright luster throughout its life unless it is subjected to oxygen when hot. If the bulb is broken, air will rush in and a powered filament (2500+ K) will quickly oxidize and blacken, sometimes leaving white oxide on nearby objects. If the filament was hot but not incandescent when the bulb broke, it may be tinted a dark green, purple, or brown.

If the bulb breaks when the filament is powered, glass particles may fuse to the hot filament. These molten droplets or partially molten chunks provide evidence that the bulb was powered when it broke. The absence of fused glass, however, does not indicate that the lamp was off during the impact.

Even in cases where the bulb does not break, an incandescent bulb may show evidence as to whether or not it was powered at the time of impact. Tungsten becomes more ductile at high temperatures, and may deform due to its own inertia under the accelerations present in some automotive collisions. This is referred to as “hot shock.” If the bulb is unbroken, this may be the only indication that the lamp was powered.

A cold filament will show little to no ductile deformation by its own inertia under accelerations found in an impact. However, a severe impact that imparts high accelerations may break a cold filament. The fracture surface will show signs of a brittle fracture, with jagged edges and abrupt transitions in its cross-section. A brittle fracture indicates that the filament was not powered when the impact occurred.

HID HEADLAMP TESTING

The absence of a filament in HID headlamps means that many of the techniques applied to post-impact inspection of

incandescent lamps cannot be directly applied to HID lamps. Although HID headlamps do not have incandescent tungsten filaments, they do have tungsten electrodes. These electrodes reach temperatures similar to the filaments in incandescent bulbs [5,8]. It is therefore reasonable to consider whether the tungsten electrodes in HID headlamps might permanently deform under acceleration loads when hot, and demonstrate the “hot shock” phenomenon associated with incandescent filaments subjected to impact loads. Unfortunately, the geometry of the tungsten electrodes is not conducive to deformation under their own inertia. The electrodes in D2S lamps have an unsupported length approximately five times the diameter. Calculations show that, even at elevated temperatures, the electrodes will not deform under the acceleration loads present in automotive collisions. Furthermore, the electrodes are oriented longitudinally in the vehicle, parallel with the direction of travel, and therefore are unlikely to experience significant bending loads in a frontal collision.

Since the electrodes will not deform under acceleration loads, we do not expect HID headlamps to show any evidence of the power state during collision events where the headlamp remains undamaged. This paper is therefore focused on examining lamps whose arc tubes are damaged during an impact in order to identify characteristics that indicate their power state at the time of impact.

TEST METHODOLOGY

Philips D2S lamps (model 85122+) were selected for the experiments. These lamps are very similar to the D2R, but do not have any masking on the outer envelope. Each lamp was burned in for at least 24 hours before testing, using a stock ballast.

During testing, the lamp was held in place using the fixture shown in [Figure 2](#). The fixture has two stops located on either side of the HID lamp that can be adjusted to control the penetration of the pendulum into the lamp. Lamps were impacted in both the power on and off states. Those lamps that were tested in the power on state were allowed to warm up for several minutes before impact.

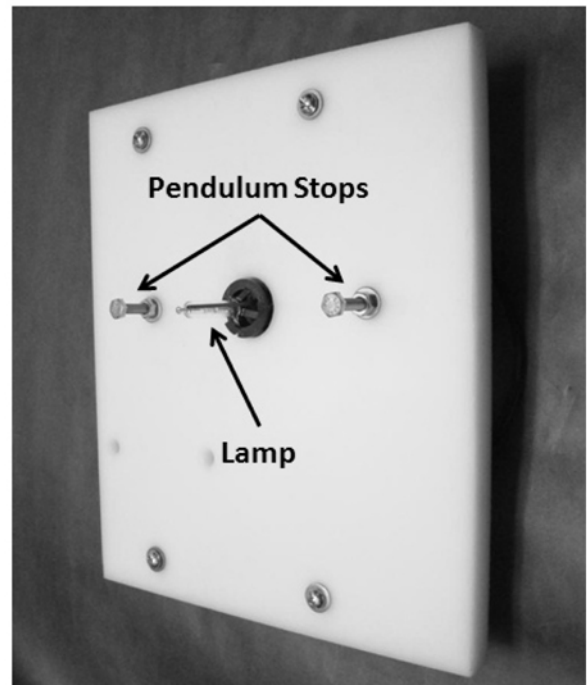


Figure 2. Mounting fixture for headlamp testing

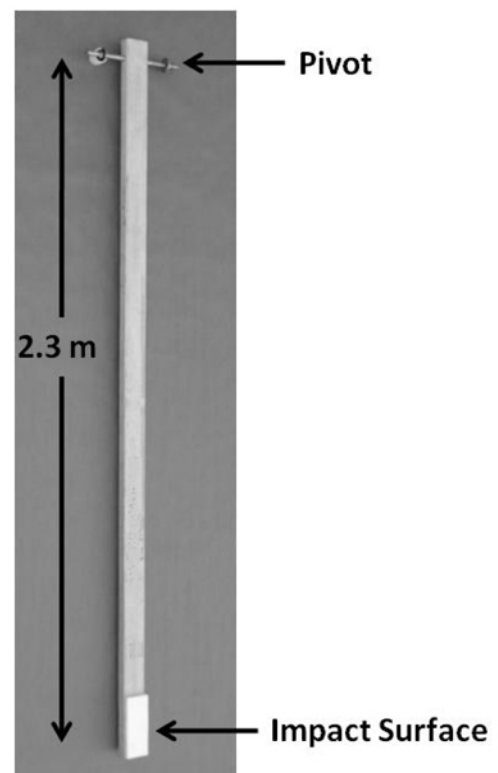


Figure 3. Pendulum assembly

The impact was created using the pendulum shown in [Figure 3](#) striking a stationary lamp. The lamps were oriented such that the arc tube and outer envelope were horizontal, and the