05 Lamp Rupture

Xenon lamp bulbs are made from quartz glass. In order to understand the rupture phenomenon of Xenon lamps, first you need to know briefly the destruction mechanism of glass. The theoretical strength of quartz glass, said to be in the order of tens of GPa, comes from the strong chemical bonding force of its constituent Si-O (silicon and oxygen) bonds and the density of the network structure. However, the actual strength is much lower than that at about 50MPa. The difference is reported to be due to a myriad of flaws in the interior and the surface of the glass. When a material having such surface and interior flaws is subjected to external force, the force is focused along the edges of those flaws, increasing the stress at tips (stress concentration). If the elastic strain energy within the glass exceeds the strength of the glass, the flaws (cracks) become larger. In materials such as quartz glass, that are susceptible to the expansion of flaws (cracks), the actual breakage strength becomes lower than the theoretical strength.

☐ Blackening of the Bulb

As time progresses in a lit lamp, the tungsten used for the electrodes evaporates and is deposited on the inside surface of the bulb (blackening). Arc light striking the blackened parts of the bulb causes the temperature of those parts to increase, causing thermal stress that accumulates and increases the load on the bulb (Figure 1).

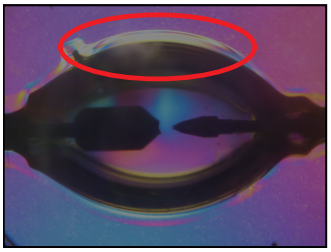

Figure 1. Distortion observed using sensitive color process. The colors appear different due to the changes in refractive index of stressed parts.

☐ Crystallization of the Bulb (Devitrification)

When quartz glass is exposed to high temperatures, a phase transition to structurally stable cristobalite occurs (crystallization). Cristobalite contracts as it cools, causing cracks to occur between parts of the glass. The profusion of cracks makes the bulb appear clouded (devitrification). The cracks also expand into non-crystallized parts of the glass, reducing the strength of the glass. The rate of progression of crystallization depends on impurities and other matter on the bulb surface. The crystallization onset temperature is reduced if substances containing alkali metal ions (e.g. sodium) or alkali earth metal ions (e.g. calcium) adhere to the bulb. Furthermore, water vapor and moisture cause the viscosity of the glass to decrease. As the viscosity falls, impurities can migrate within the glass more easily, promoting crystallization, so this must be avoided as much as possible.

The pressure inside Xenon lamps when lit is on the order of 6 to 7MPa. So, from a purely glass strength standpoint, the glass will not rupture under normal conditions.

If any substances or dirt do adhere to the bulb, wipe the bulb clean using a clean cloth moistened with alcohol. Avoid the use of alkaline surface-acting agents, as insufficient cleaning may cause crystallization.