DfR Solutions
reliability designed, reliability delivered

Technical Case Study:
Projection Lamp Failure Analysis

Summary:
By utilizing life testing and QRD analysis, DfR Solutions was able to recommend several corrective actions that a major avionics manufacturer could use to extend the life of projection lamps and reduce premature failure. Upon implementation of DfR's suggestions, the manufacturer reported that the moving average lamp reliability nearly doubled after one year.

INTRODUCTION

DfR Solutions recently investigated the reduced reliability of projection lamps used onboard many wide-body jet aircraft for showing movies and safety videos.

The customer provided DfR Solutions with both functional and failed projection lamps for failure analysis and life testing. The lamps contained an internal glass bulb, with a tungsten cathode and anode. Each electrode is connected to a thin nickel plate (called a ribbon seal), which seals the bulb.

ANALYSIS AND TESTING

Prior to testing, DfR investigators visually inspected the glass bulbs. A blackening on the inside of the glass wall of failed bulbs was noted, as well as a deformation or rupture of the bulbs. The investigators also noted that the electrodes inside a pristine (never used) glass bulb were not aligned properly. This slight misalignment could lead to premature failure.

The DfR team then developed an automated system to operate electromechanical and solid state relays that would turn the lamps on and off. The lamps were turned on until the lamp temperature was stable then turned off for 7.5 minutes and cooled with a fan. This power-cycling test allowed the investigators to determine the influence of turn-on and turn-off stresses on the life and failure behavior of the lamps.

Upon comparing a pristine bulb to a bulb that had undergone 150 power cycles, the team found noticeable differences between the two bulbs. The cathode electrode in the power-cycled bulb was shorter and the end of the electrode was flat. In addition, the starting coil on the electrode had been consumed, as shown in the picture below.

At a Glance

Situation:
The reliability of lamps being used in an in-flight entertainment system had been significantly reduced.

Key Findings:
DfR investigators discovered that

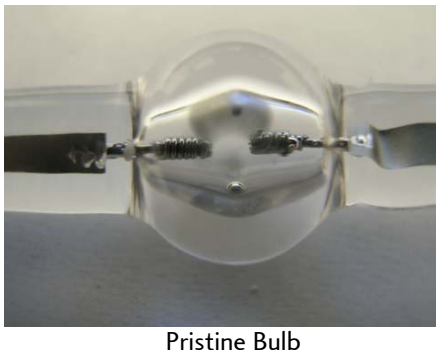
- electrodes in some lamps were not aligned properly,
- electrical-grade silicone was not used to insulate the electrical connections in the lamps, and
- power cycling caused lamp degradation.

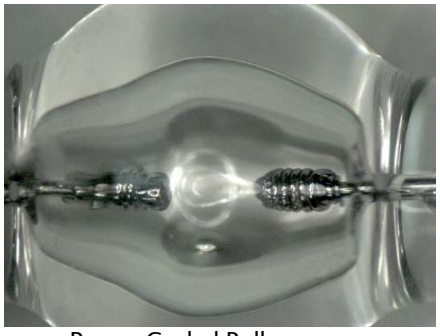
Benefits:
Tangible

- Improved product reliability
- Increased cost savings
- Decrease inventory requirements

Intangible

- Increased efficiency
- Improved safety
- Increased customer satisfaction


Pristine Bulb


Power-Cycled Bulb

Further observation by the DfR team indicated that the electrode tip was vaporized during repeated ignition. As the tip is vaporized, hot air rises vertically from the electrode and cools, depositing the electrode material on the inside of the bulb. The DfR team noted a blackening of the glass where the electrode material was deposited.

More and more material was deposited as the power cycling continued, causing a metallic growth to form at the blackened area. In addition, the temperature of the glass around the deposit increased relative to the surrounding glass, creating a "hot spot." As the temperature reaches the melting point of glass, the bulb will eventually rupture and fail.

The DfR investigators also noted that the pattern of the light distribution became increasingly asymmetrical as the number of power cycles increased. This pattern results from material being removed along one side of the electrode and then deposited.


Symmetrical
Light Pattern

Asymmetrical
Light Pattern

The DfR team then disassembled a failed lamp and discovered that the interconnection of the anode wire was corroded. This corrosion could cause increased run current requirements and possible shut down of the lamp. The team used ion chromatograph to identify the compounds in the silicone used to insulate the connections and discovered that acetate was present. Acetate is a corrosive compound. Silicone-containing acetate is not recommended for use in delicate electrical and electronic applications in which corrosion of copper, brass, or other sensitive metals is undesirable.

RECOMMENDED ACTIONS

On the basis of their analysis, DfR Solutions made the following recommendations:

- **Screen bulbs with regards to electrode alignment**
  Misalignment of the electrodes would lead to excessive vaporization of the electrodes during startup, greatly reducing the life of the bulb. Bulbs should be screened before assembly and those bulbs where misalignment is identified should be rejected.
- **Change silicone material**
  The use of general-purpose silicone for insulating electrical connections is not acceptable. Only silicone that is approved for electrical connections should be used. Lamps assembled with GE RTV-108 should be recalled and the silicone should be replaced. Corrosion of the interconnection could result in multiple ignition sparks that will greatly reduce the life of the lamp. Corrosion can also lead to increased current requirements and cause shutdown or damage to the power supplies.
- **Perform additional characterization**
  The customer should continue testing to determine the effects of orientation, power cycling, and cooling conditions on the life of the lamps. Testing should be expanded to include more samples for statistical significance.

CONCLUSION/CUSTOMER BENEFITS

The reliability of the lamps improved once the recommendations made by DfR Solutions were implemented. According to the customer, the moving average reliability had nearly doubled after one year, with a cost savings of approximately $200,000.