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Design and Maintenance Considerations For Aircraft Exterior Lighting Plastic Lenses

TABLE OF CONTENTS

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1. SCOPE:

The information in this document is intented to apply to commercial jet transport category airplanes that incorporate plastic (polycarbonate or acrylic) lenses on exterior light assemblies, or are being considered for such an application. Exterior lighting applications include position light assemblies, anticollision light asemblies, and landing light assemblies. However, much of the material provided herein is general in nature and is directly applicable to many aircraft categories including, but not limited to, helicopters, general aviation aircraft, and military aircraft.

1.1 Purpose:

The purpose of this document is to provide guidance pertaining to the use of plastic (polycarbonate or acrylic) lenses on commercial jet transport aircraft to aircraft designers, regulatory certification agents, and maintenance personnel. It is not intended to serve as design instructions for the creation of plastic or acrylic lenses. This document identifies significant performance aspects of plastic exterior light lenses that should be carefully managed for each lens application. Additionally, this document provides basic inspection and maintenance procedures for plastic exterior light lenses.

2. REFERENCES:

There are no referenced publications specified herein.

3. DEFINITIONS:

APPEARANCE: The aspect of visual experience by which things are recognized.

CLARITY: The characteristic of a transparent body whereby distinct high-contrast images or high-contrast objects are observable through the body.

CRAZING: Network of apparent fine cracks on or beneath the surface of materials such as in transparent plastics, glazed ceramics, glass, or clear coatings.

TRANSLUCENT: Transmitting light diffusely, but not permitting a clear view of objects beyond the specimen and not in contact with it.

DISTORTION: Defect in an image forming system whereby the image is not the shape of an ideal image of the object. For example, a straight pole viewed through a window having non-planar surfaces may appear to have bends in it.

MATTE: Lacking luster or gloss. Synonymous with “flat” in paint terminology.

OUTGAS: To remove embedded gas from (a solid), as by heating or reducing the pressure.

4. PLASTIC LENSES

4.1 The Desire for Plastic Lenses:

Traditionally, glass has been the material used for exterior light assembly lenses. While glass offers good optical performance qualities and excellent durability (even when exposed to the airstream), the material has some less desireable traits. Glass is heavy, costly, difficult to work with, requires expensive tooling, and is susceptible to foreign object impact damage. It is capable of withstanding high heat loads, but is naturally flawed such that high heat gradients and/or temperature cycling can lead to the formation of cracks in the glass lenses.

Plastic lenses offer some relief from the drawbacks of glass. Plastic provides a significant reduction in lens weight (low weight is a key performance attribute for all aircraft). Plastic is much simpler to mold and work with, and the tooling required is less expensive. This contributes to a much lower lens cost as well as a shorter lead time for procurement. Plastic also offers good resistance to foreign object impact damage.

The lower cost and weight, combined with the short lead time, makes plastic appear to be the preferred material for exterior light lenses. Section 4.2 discuss some of the serious aspects of plastic materials in this rigorous application.

4.2 Plastic Lens Issues:

The most significant shortcoming of plastic lenses is optical performance. When plastic lenses are exposed to the airstream, particulate (ice and rain) and abrasives in the airstream damage the lenses' exposed surfaces. This is refered to as "lens erosion" damage and it appears as cloudy or opaque areas on the lenses much like sandblasting would produce. The effect of this degradation is reduced light transmission through the lens. The light reduction can be significant. Figures 1 and 2 show actual transmission rates that have resulted from this condition. The amount of light loss resulting from this condition will vary according to the exact material and its exposure to the airstream. With prolonged exposure, the transmission rates will stabilize.

Plastics are sensitive to chemical attack and fluid exposure. Some plastics (such as polycarbonate) are extremely sensitive. In some instances, the plastic wrap that covered polycarbonate lenses for shipment cause lens crazing due to a chemical reaction between the two materials.

Plastics are heat sensitive. If high heat loads are applied to the plastic lenses, they may distort, blister, discolor, and become brittle. Exposure to ultraviolet light will also damage the material over time resulting in discoloration and brittleness.

4.2 (Continued):

Plastics lenses have a coefficient of thermal expansion (CTE) that is different than that of other materials used to construct the light assembly housings or installations. Standard methods of attaching the lenses can allow the different expansion rates to cause mechanical stress in the lenses thereby producing cracks (especially in the areas of fastener mounting holes).

There have been some attempts to prevent or reduce lens erosion by adding a protective hardcoat (spray on and brush on). Industry experience shows that hardcoated lenses do not hold up to the many flight hours at high speeds that a commercial jet transport airplane is exposed to. The plastic material is a soft substrate that flexes when subjected to airloads and vibration causing the coating material to flake and break off. While automobiles have had success with plastic lenses, and some business jets have had limited success with plastic lenses, neither of these applications are exposed to the speeds and/or number of exposure hours (flight hours) that a commercial jet is exposed to.

There have been some attempts to prevent or reduce lens erosion by adding a protective laminate (urethane tape) to the outer lens surface. Tests have shown that the adhesives blister and melt when exposed to high heat loading from the light assemblies combined with heat from solar loading while the airplane is static on the ground. Many of the laminates depart the airplane during flight operations. Therefore, this method is not yet reliable.

The loss of light intensity from discoloration, lens cracks, or transmission loss may result in light levels that are below the required regulatory levels. The change in light distribution because of lens distortion, lens blisters, or lens cracks may result in light distribution that does not comply with the required regulatory patterns.

4.3 Design Guidance:

As can be seen from the information in 4.2, the decision to use plastic lenses instead of glass lenses should be carefully contemplated. Once the decision to use plastic lenses has been made, the following design recommendations are offered:

Understand the transmission loss of the plastic lens material due to flight exposure. Design the exterior lights such that they satisfy all of the intensity and distribution performance requirements with the lens degraded.

Design the exterior light assemblies with low heat generating light sources. Keep all heat producing light sources as far away from the lenses as possible. Keep the lens away from external heat sources such as jet exhaust areas This will help minimize discoloration and lens deformation.

4.3 (Continued):

Choose plastic materials that resist fluid exposure and chemical attack. There is no plastic that resists damage from all fluids, but some plastics are better than others. Fluids such as de-icing fluid, mineral/lube oil, hydraulic fluid, solvents, cleaning fluids, detergents, and jet fuel that are typically found in aircraft operational environments should be of primary consideration.

Avoid the introduction of chemicals onto the surfaces of plastic lenses. The light design should utilize materials that will not outgas and produce chemical deposits on the lens surfaces. If lens deposits from outgassing can not be avoided, then understand the materials incorporated in the light assembly to ensure that the plastic lens material used will be resistant to the chemical deposits that may result from the outgassing process. Keep the lens away from sources of external chemical deposits such as jet exhaust areas.

Design lens attachment methods that avoid CTE related cracking. This usually involves allowing for expansion (float) and using clamping attachments instead of fasteners in fastener holes.

Institute a maintenance inspection program to evaluate the condition of each plastic lens and accomplish the appropriate action to keep the exterior lights performing correctly. A basic maintenance process is provided in Section 5.

5. MAINTENANCE:

5.1 Purpose:

The purpose of an exterior light lens maintenance inspection is to maintain the illumination performance of the lighting equipment being assessed. For lighting systems that have performance levels that are required by a regulatory agency, the inspection may be the means to maintain a certification compliant system.

5.2 Action Required:

Perform a visual inspection of the plastic lens on each exterior light assembly. Evaluate the appearance of each lens with respect to the criteria listed in 5.4. Perform maintenance if required.

NOTE: Ensure that the applicable lighting systems are deactivated per the airplane maintenance manual instructions.

5.3 Inspection Interval:

The inspection interval is discretionary. It is desireable to base the interval on actual in-service performance data, however, such data is not available in many instances. For these situations, it is recommended to apply very conservative (short) intervals and extend the intervals as the cumulative inspection data indicates it is reasonable to do so.

5.4 Inspection:

Visually inspect each lens for the following:

- Dirt and/or deposits.
- Crazing (Lens should not exhibit a network of fine cracks on or beneath the surface).
- Clarity (Lens should be transparent and clear. Lens should not be translucent, cloudy, or opaque in appearance).
- Cracking (Lens should not have cracks)
- Blistering or Bubbling (Lens should not contain air pockets, lumps, or voids)
- Peeling or Flaking (Lens surface or coating should not peel or flake)
- Discoloration (lens should not exhibit signs of yellowing, darkening, etc.)
- Surface deterioration (Lens should be smooth and have a glossy finish. Lens should not exhibit signs of physical deterioration such as abrasions, rough surface texture, matte finish, erosion, physical deformation or irregularities)

5.5 Maintenance Action

Visual inspection of the lens should reveal no optical defects. However, if defects are identified, perform the required maintenance action described below.

a. Remove dirt and/or deposits from the lens. Only use cleaning agents that are compatible with the plastic lens material.

b. Remove and replace the lens if any of the following conditions are present and clearly noticeable in the lens: Crazing, Cloudiness, Cracking, Blisters, Bubbles, Peeling, Flaking, Discoloration, Stains, Physical deformation.

c. Remove and replace the lens if it does not appear optically clear.

d. Allowable Conditions:

   1. Minor scratching of the lens surface

   2. Small bubbles in the lens or coating that do not appear in large quantities or concentrations. The appearance of a few small bubbles can be introduced in the manufacturing process and is considered normal.

   3. Any condition described in 5.5b that has been determined by testing (or other acceptable means) that demonstrates that the lens, with the deleterious conditions present, will still perform in a manner that maintains a regulatory compliant system.