# Lumen Maintenance
# IESNA LM-80-2008

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Chairman, Testing Procedures SSL Committee

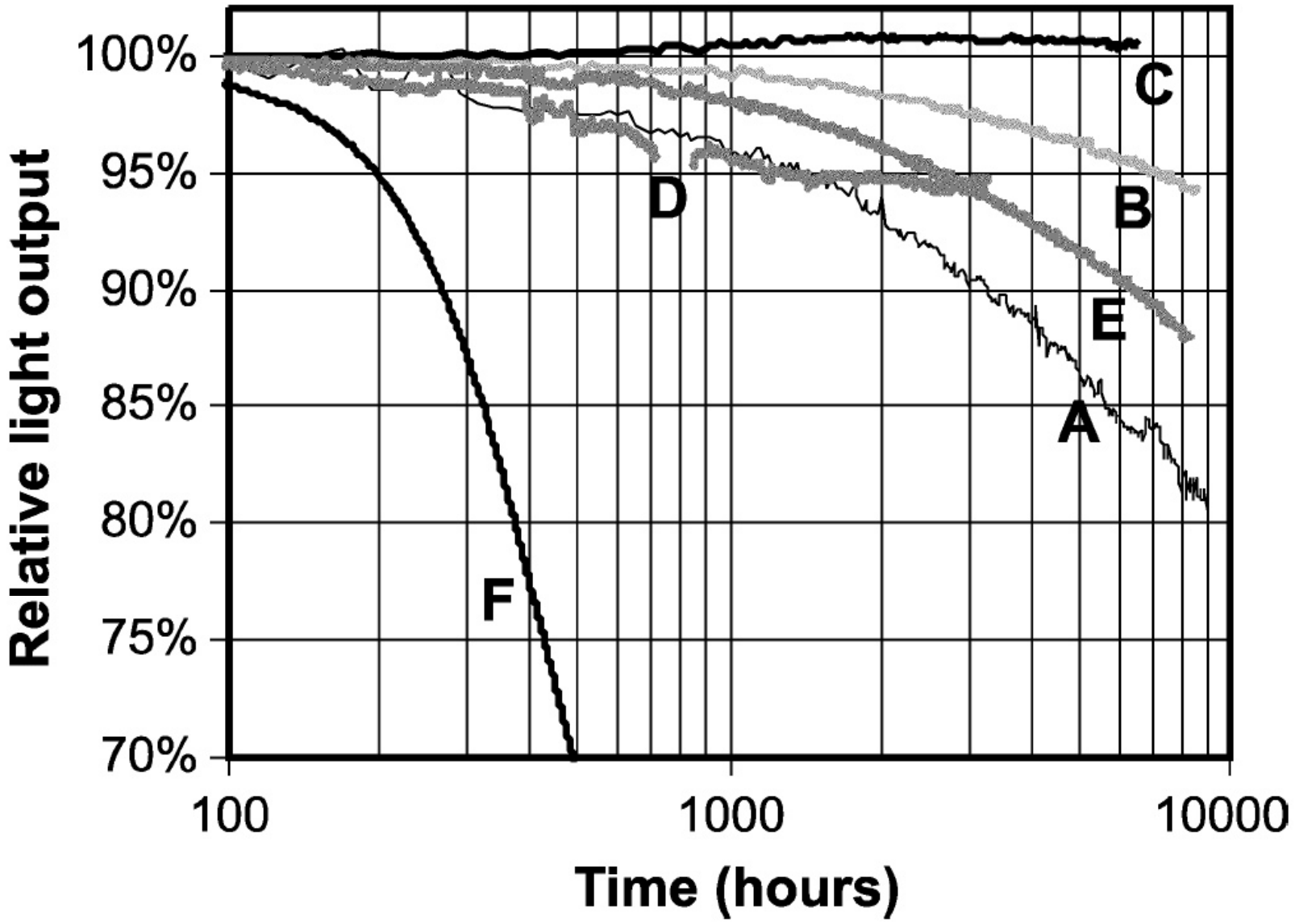
Oct. 30, 2008

# WHY LM-80?

- We need to better determine true lifetimes of LED products
- Standards are needed to provide a consistent and common language for manufacturers and customers
- There is no commonly accepted criteria for lifetime

# The Beginnings

- ASSIST at the Lighting Research Center
  - ASSIST program
  - Narendran et al began looking at lifetime issues in 2000-2001
  - Current packages, 5mm, had very poor long term performance
  - ASSIST program began developing guidelines and methods for determining lumen maintenance.
  - *ASSIST Recommends: LED Life Testing, Vol 1-6, Lighting Research Center, RPI, Troy NY 2005.*


Relative light output
100%
95%
90%
85%
80%
75%
70%
100
1000
10000
Time (hours)
C
D
B
E
A
F

# Needed for Energy Star

- Chromaticity
- Luminous Flux
- Definitions
- Lumen Maintenance

# LM-80 Contents

- Scope
- References
- Definitions
- Ambient and Physical Conditions
- Electrical and Thermal Conditions
- Test and Measurement Procedures
- Lumen Maintenance Testing Method for LED Light Sources
- Test Report

# Scope

- This document provides the methods of the measurement of lumen maintenance of source including sources including LED packages, arrays and modules only
- This approved method does *not* provide guidance or make *any* recommendations regarding predictive estimations or extrapolation for lumen maintenance beyond the limits of the lumen maintenance determined from actual measurement

# Definitions

- Measurement Units
- LED Light Source
- Lumen Maintenance
  - Luminous flux remaining output (typically expressed as a percentage of the max output) at any selected elapsed operating time.
  - LED Light Source Failure
  - Rated Lumen Maintenance Life ($L_{70}$ = time to 70% LM)
  - Case Temperature

# Ambient and Physical Conditions

- 4.1 General
  - Relatively clean environment
- 4.2 LED Unit Marking
  - Marking individual units
- 4.3 Sample Selection
  - Representative sampling to be reported

# Ambient and Physical Conditions

- 4.4 Environmental Conditions
  - Vibration - lamps should not be subjected to excessive vibration and shock
  - Temperature and Humidity
    - Three case temperatures 55, 85C and one picked by the manufacturer. Additional temperatures can be tested.
  - Airflow - minimized
  - Operating Orientation and Spacing
    - As specified by the manufacturer

# Electrical and Thermal Conditions

- 5.1 Input Voltage and Current - ripple held to 2%
- 5.2 Line Voltage Waveshape - Within 3%
- 5.3 Input Current Regulation - regulated within 3%
- 5.4 Auxiliary Equipment including Drivers
  - Per manufacturers guidance
- 5.5 Case Temperature

# Test & Measurement Procedures

- 6.1 Instrumentation
  - Elapsed time measured only when sources are energized
- 6.2 Photometry Measurement
  - In conformance with appropriate laboratory method under test. E.g. LM-79 or other. Recommended that measurements use a spectroradiometer to collect color data as well.
- 6.3 Photometry Measurement Temperature
  - 25C +/- 1C. Source shall cool to room temperature prior to measurement

# Lumen Maintenance Test Method

- 7.1 Testing Duration and Interval
  - At least 6000 hours with data collection at a minumum of every 1000 hours. 10000 hours preferred for improved predictive modeling.
- 7.2 Operating Cycle
  - Shall be driven at constant current
- 7.3 Recording Failures
  - Check for source failure through visual observation or automatic monitoring
- 7.4 Chromaticity
  - Measured and reported

# Test Report

1. Number of LED Light Sources tested
2. Description of LED light sources
3. Description of auxiliary equipment
4. Operating cycle
5. Ambient conditions including airflow, temperature & humidity
6. Test point temperature
7. Drive current
8. Initial luminous flux and forward voltage at current
9. Lumen maintenance data for each LED light source (median, std deviation, min, max LM values for all the LED light sources
10. Observations of LED light source failures including failure conditions and time of failure
11. LED light source monitoring interval
12. Photometric measurement uncertainty
13. Chromaticity shift reported over the measurement time

# TM-21

- Extrapolation and Prediction additions
- In process and in committee

# LM-80 Next Steps

Use LM-80 to gather significant amount of data to provide input into the prediction process and, eventually, fold prediction and extrapolation into LM-80

Further information requested from users and laboratories as LM-80 is used.

THANK YOU!

# ENERGY STAR® Webinar: Requirements for Lumen Maintenance

Jeff McCullough, LC
Pacific Northwest National Laboratory

Oct. 30, 2008

# Agenda

1. In-situ Testing Requirement and ANSI/UL 1598/153
2. The Temperature Measurement Point (TMP)
3. Application of LM-80 test data
4. Example
5. Submission Requirements

# In Situ Testing Requirement

- LM-80-2008 is a component (package, module or array) level test
- Lumen depreciation (Life) determined by in-situ temperature measurements of:
  - Package, Module or Array
  - Power Supply/Driver
- Testing may be conducted at the same time as UL 1598/153
- Tests conducted by Nationally Recognized Testing Laboratories (NRTLs), recognized as qualified by OSHA

# Approved Testing Laboratories

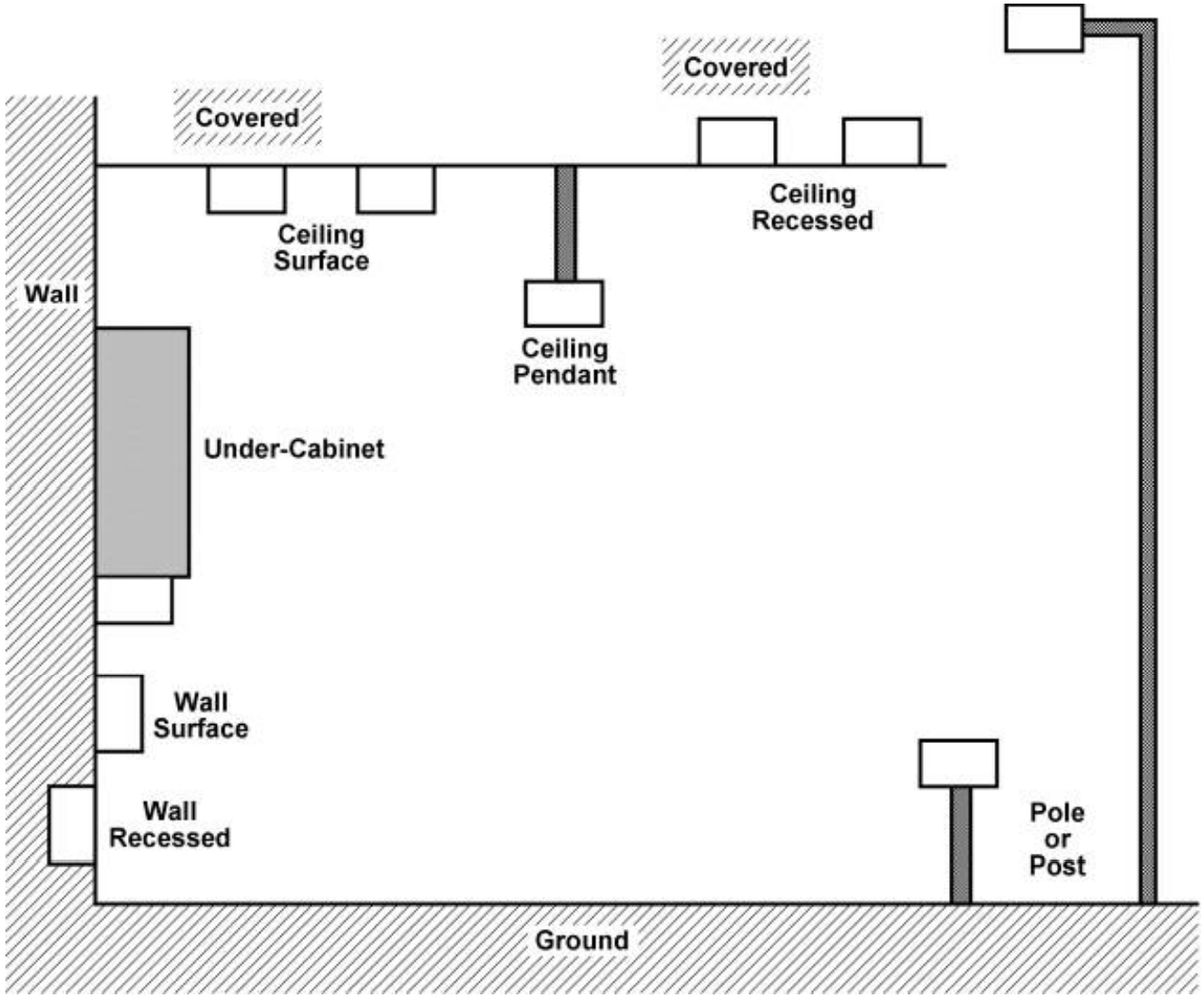
DOE will accept UL 1598 or UL 153 testing and certification from UL, UL signatories or the following NRTLs:

- Canadian Standards Association (CSA);
- Intertek Testing Services NA, Inc. (ITSNA);
- MET Laboratories, Inc. (MET);
- NSF International (NSF);
- SGS U.S. Testing Company, Inc. (SGSUS);
- TUV America, Inc. (TUVAM);
- TUV Product Services GmbH (TUVPSG);
- TUV Rheinland of North America, Inc. (TUV);
- Underwriters Laboratories Inc.(UL); and
- Wyle Laboratories, Inc. (WL).

# Temperature Measurement Point (TMP)

- Manufacturer designated TMP correlating to LM-80 test report or power supply warranty
  - Module/Array
    - Solder Joint Temperature $T_s$
    - Case Temperature $T_c$
    - Board Temperature $T_b$
  - Power Supply
    - Case Temperature $T_c$
    - Could also be $T_b$ for integral Power Supplies

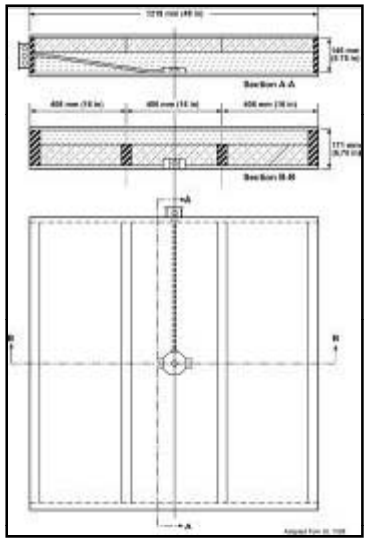

# UL 1598 Environments

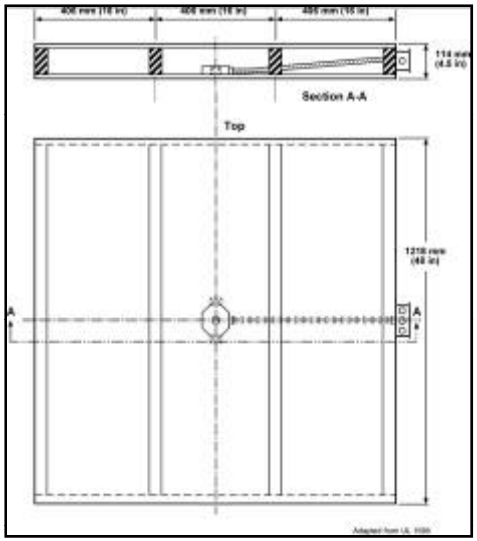


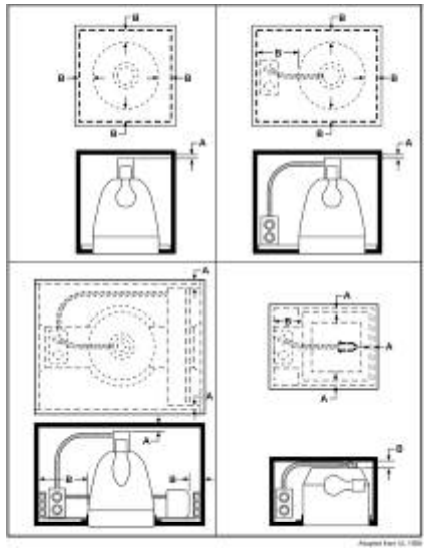
# UL 1598 Environments

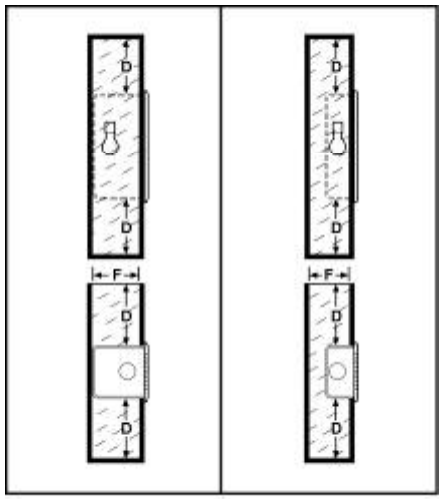
| Luminaire Types | Mounting Orientation | |
|---|---|---|
| | Horizontal | Vertical |
| **Surface** | | |
| Surface | Section 19.10 | Section 19.11 |
| Surface-mounted under-cabinet | Section 19.12 | |
| Suspended | No apparatus required except if in situ mounting is ≤ 4" from the surface in which case mount to Section 19.10 defined apparatus | |
| Freestanding | No apparatus required | |
| **Recessed** | | |
| Non-IC | Section 19.13 | Section 19.13 except without insulation |
| IC | Section 19.15 | Section 19.15 |

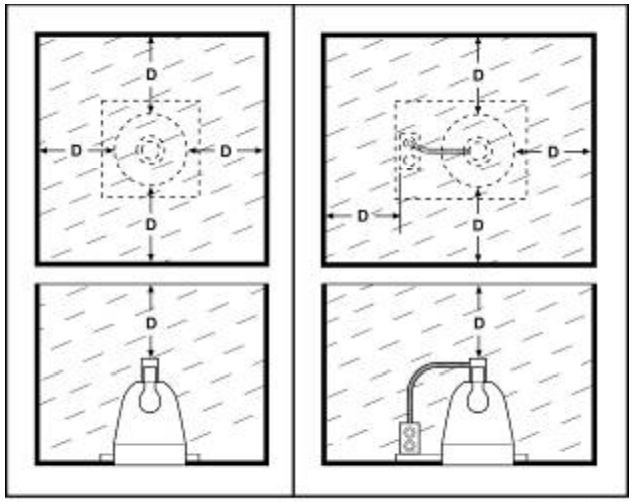
# UL 1598 Test Apparatuses







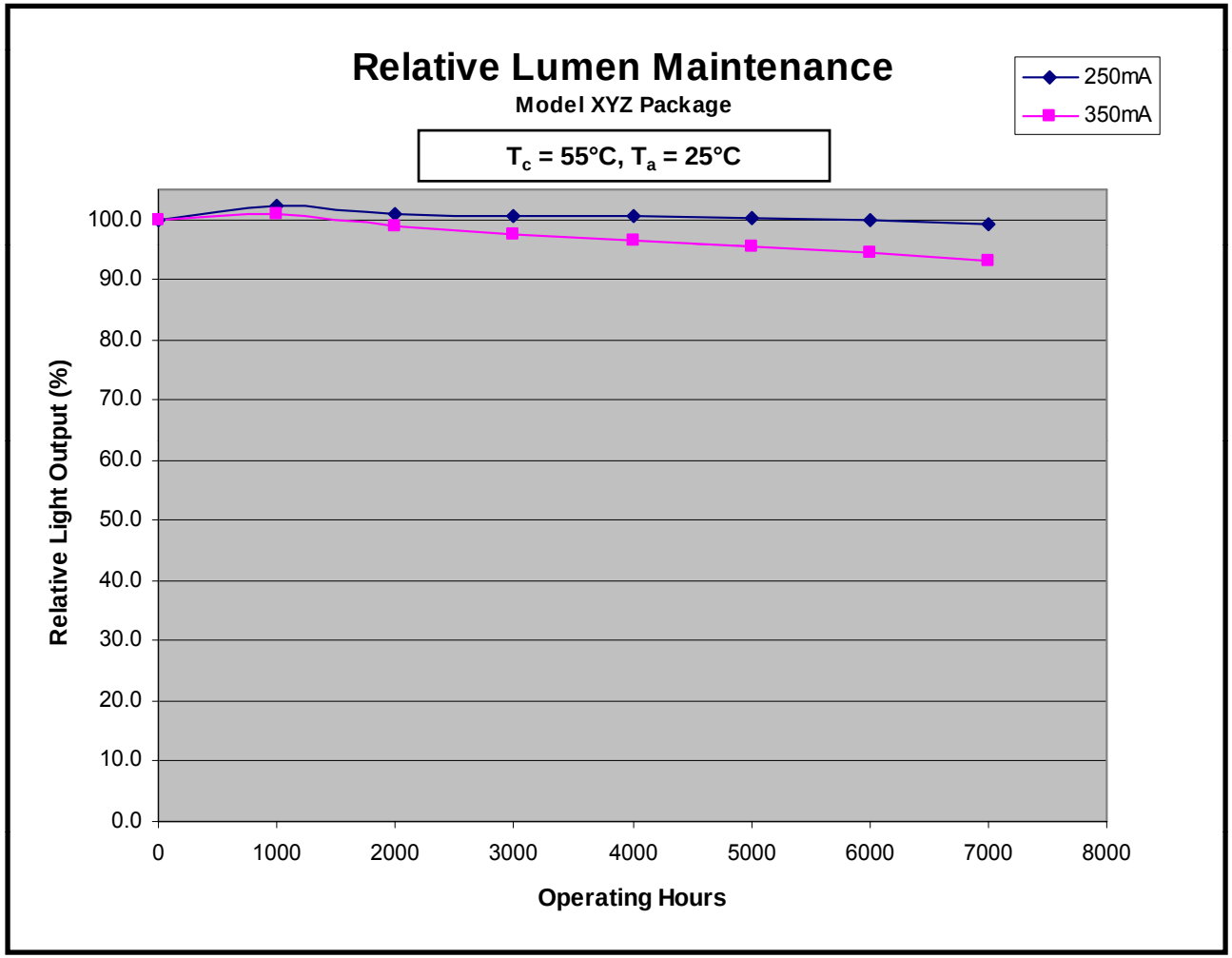
# Actual LM-80 Test Data

$I_f$ = 250mA

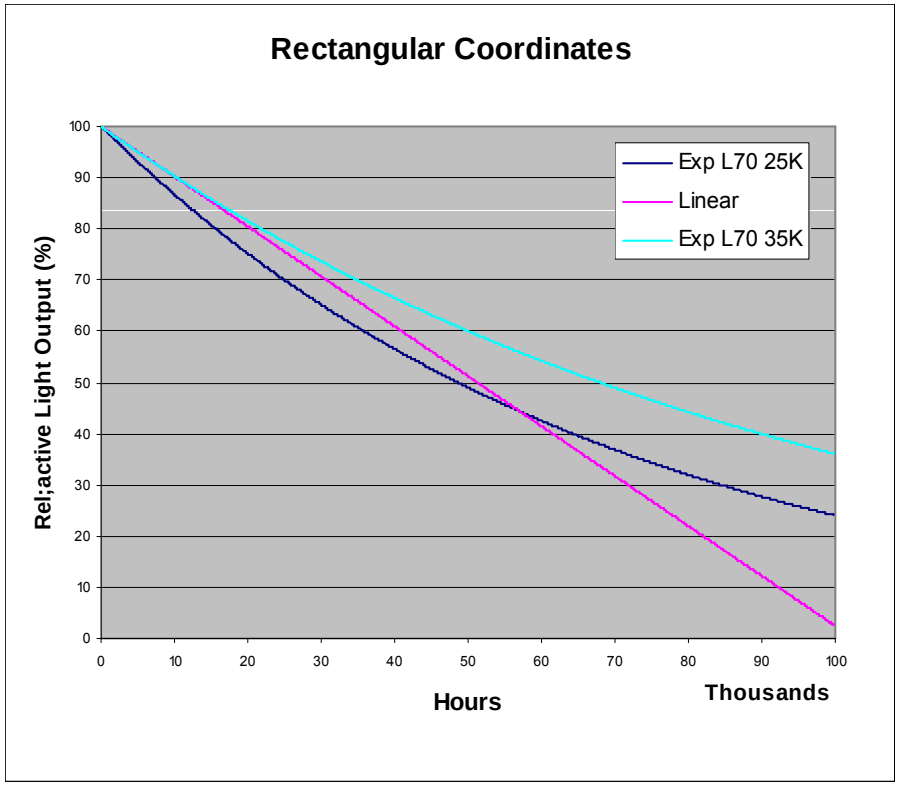
| Operating Hours (hr) | Relative Light Output (%) |
|---|---|
| 0 | 100.0 |
| 1000 | 102.4 |
| 2000 | 101.1 |
| 3000 | 100.6 |
| 4000 | 100.5 |
| 5000 | 100.3 |
| 6000 | 99.8 |
| 7000 | 99.3 |
| … | … |

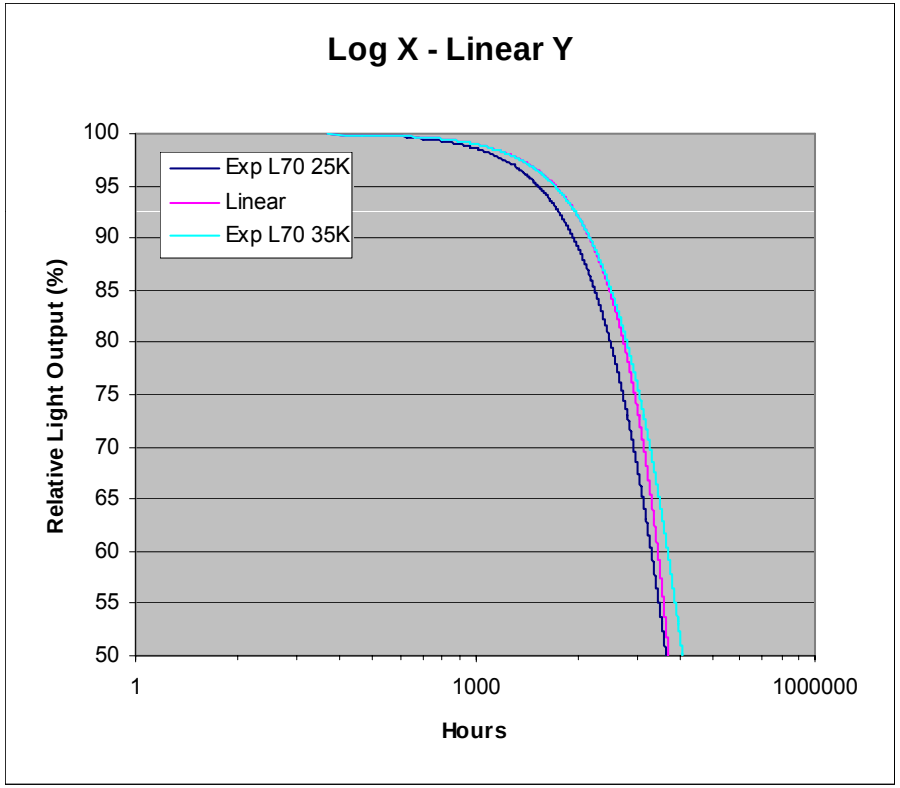
$I_f$ = 350mA

| Operating Hours (hr) | Relative Light Output (%) |
|---|---|
| 0 | 100.0 |
| 1000 | 101.0 |
| 2000 | 98.8 |
| 3000 | 97.5 |
| 4000 | 96.5 |
| 5000 | 95.5 |
| 6000 | 94.2 |
| 7000 | 93.2 |
| … | … |



# Linear vs. Exponential Data



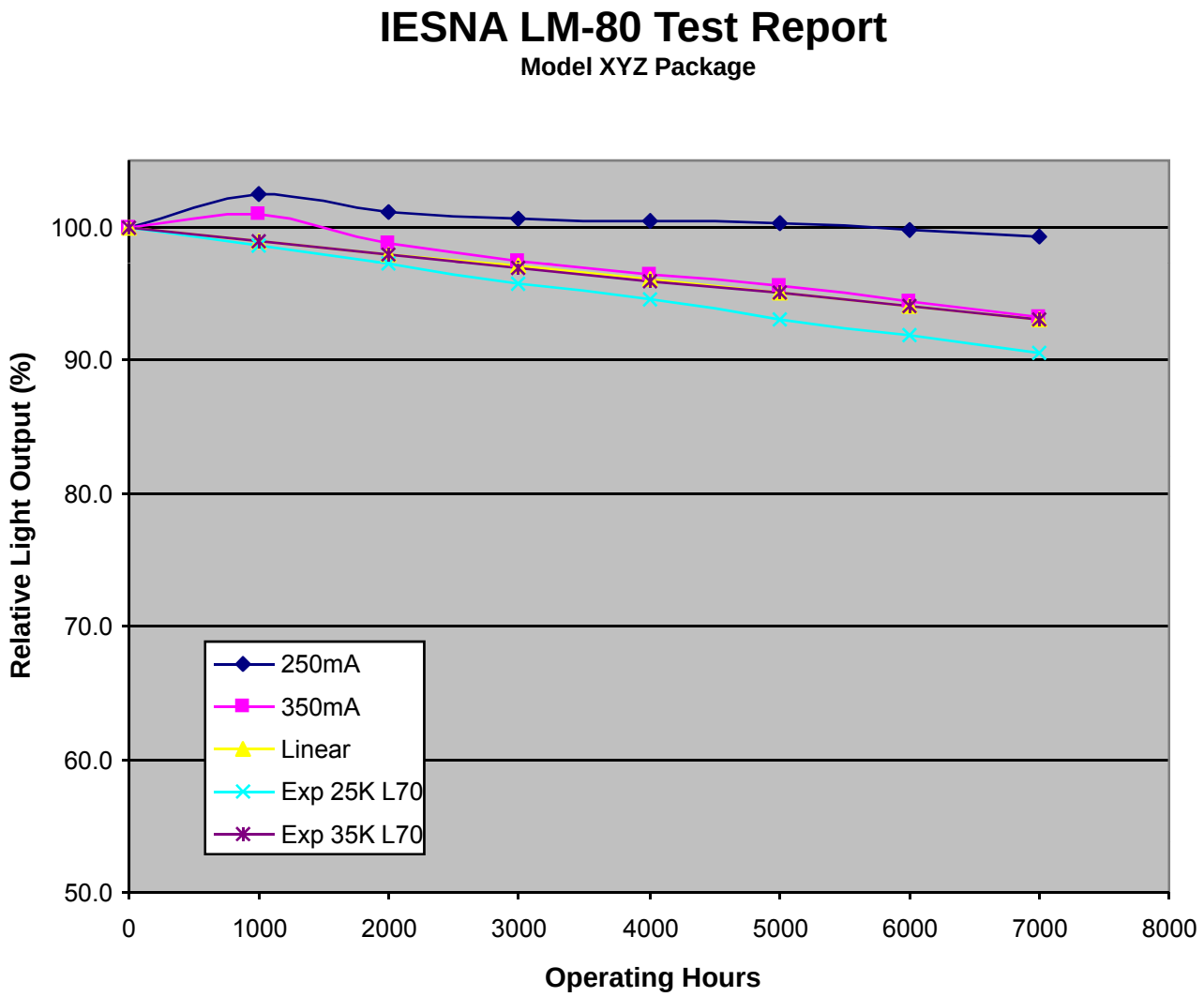



# Lumen Depreciation "Passing" Criteria

The luminaire **PASSES** the Lumen Depreciation requirements if:

- The LM-80 test report for the package, array or module demonstrates lumen maintenance of:
  - ≥ 91.8% (indoor residential)
  - ≥ 94.1% (outdoor residential and all commercial)
- Measured during the in-situ temperature measurement test (UL1598/153), at the hottest $TMP_{LED}$, evaluated at ≥ 6,000 hours.
- The drive current measured in the fixture is less than or equal to the drive current specified in the LM-80 test report.

# Application of LM-80 Data



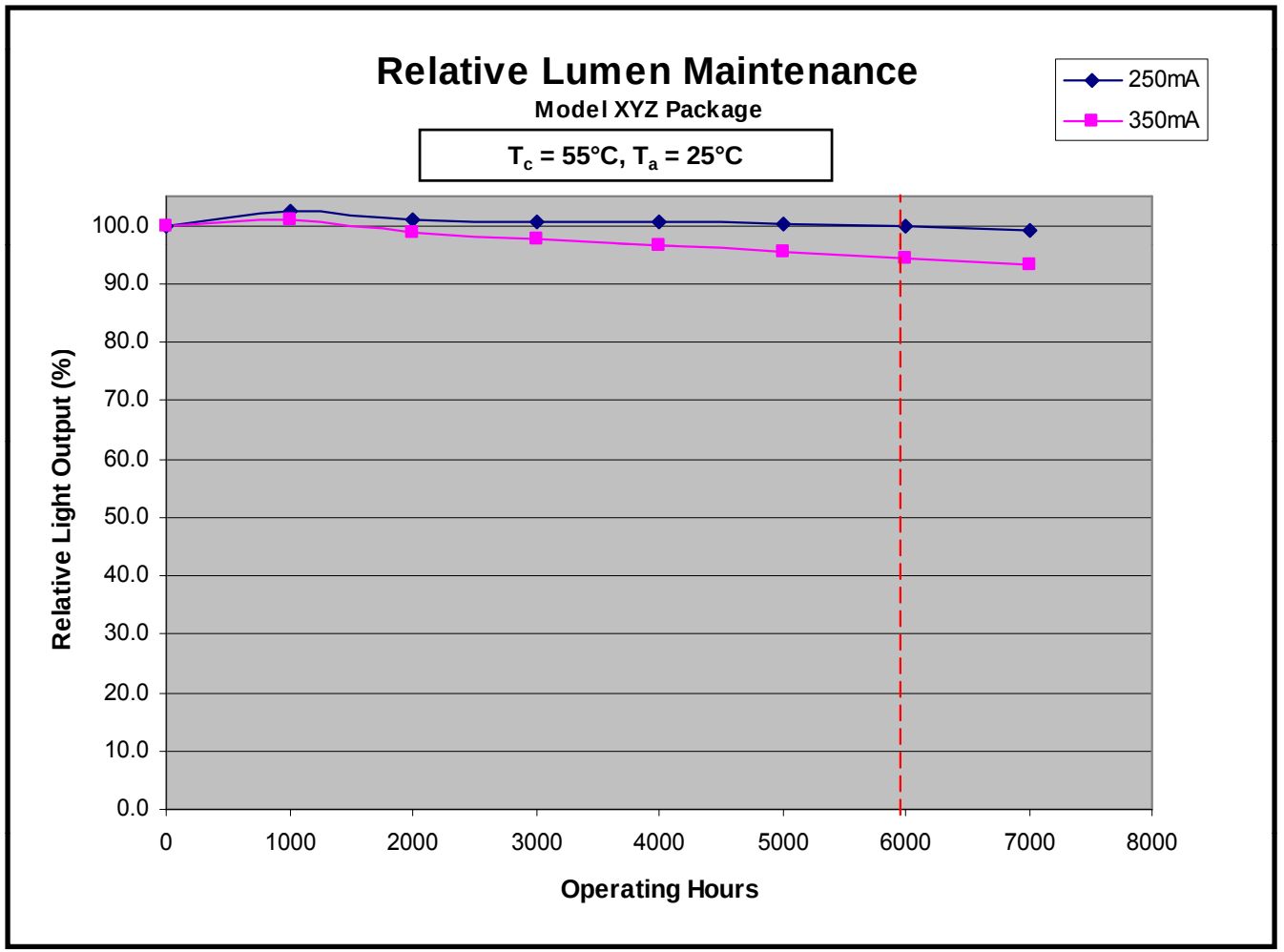
# Application of LM-80 to ENERGY STAR

$I_f$ = 250mA

| Operating Hours (hr) | Relative Light Output (%) |
|---|---|
| 0 | 100.0 |
| 1000 | 102.4 |
| 2000 | 101.1 |
| 3000 | 100.6 |
| 4000 | 100.5 |
| 5000 | 100.3 |
| 6000 | |
| 7000 | 99.3 |
| … | … |

$I_f$ = 350mA

| Operating Hours (hr) | Relative Light Output (%) |
|---|---|
| 0 | 100.0 |
| 1000 | 101.0 |
| 2000 | 98.8 |
| 3000 | 97.5 |
| 4000 | 96.5 |
| 5000 | 95.5 |
| 6000 | |
| 7000 | 93.2 |
| … | … |



# Application of LM-80 to ENERGY STAR

SCENARIO 1

The in situ measured $TMP_{LED}$ is greater than the highest case temperature collected according to LM-80 procedures. In this case the product cannot be qualified as there is no test data to substantiate manufacturer claims.

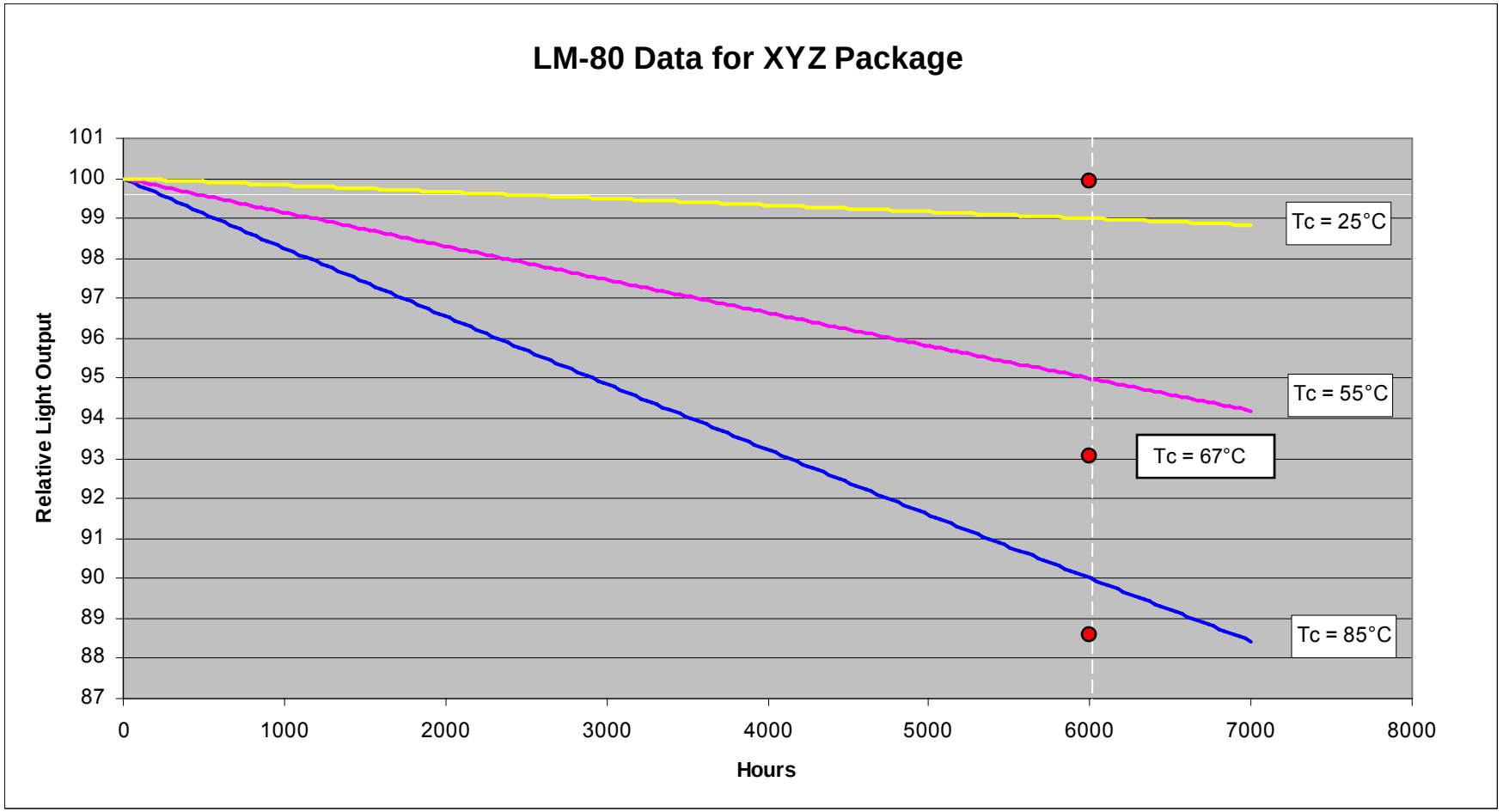
SCENARIO 2

The in situ measured $TMP_{LED}$ is less than the lowest case temperature measured collected according to LM-80 procedures. In this case the product must use the data from the lowest case temperature measured according to LM-80 procedures.

SCENARIO 3

The in situ measured $TMP_{LED}$ is bounded above and below by case temperature data collected according to LM-80 procedures. In this case linear interpolation shall be used to determine the lumen depreciation (maintenance) for the proposed product.

# Example


LM-80 Data for XYZ Package
Relative Light Output
101
100
99
98
97
96
95
94
93
92
91
90
89
88
87
0
1000
2000
3000
4000
5000
6000
7000
8000
Hours
Tc = 25°C
Tc = 55°C
Tc = 67°C
Tc = 85°C

# Example Interpolation

LM-80 test data for XYZ Package

| | Case Temperature ($T_c$) | | |
|---|---|---|---|
| Time (hours) | 25°C | 55°C | 85°C |
| 0 | 100% | 100% | 100% |
| ... | ... | ... | ... |
| 6,000 | 99% | 95% | 90% |

In situ measured TMP ($TMP_{LED}$) = 67°C

$$L_{TMP} = 95 + \left(\frac{90-95}{85-55}\right)(67-55)$$

$$\therefore L_{TMP} = 93.0\%$$

# Submission Requirements

Applicant submits the following information to ENERGY STAR:

- LM-80 test report (data table and chart) showing relative light output over time at various case temperatures ($t_c$) and at a drive current greater than or equal to the measured current of the LED package, array or module used in the luminaire.
- In situ temperature measurement test report with the measured temperature of the hottest LED ($TMP_{LED}$).
- Diagram/picture of the $TMP_{LED}$ location with an arrow indicating the thermocouple attachment point.

# Questions?

Contact Information:

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