

Long-term Testing of LED Luminaires

I35W Bridge
Minneapolis, MN



GATEWAY
Demonstrations

October 2014

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OUTLINE OF WEBINAR

- Introduction & Background
- Results:
 - Dirt effects
 - Color shift
 - Gel Bubble
 - Power & light output
 - Illuminance & the MMS
- Summary & Conclusions

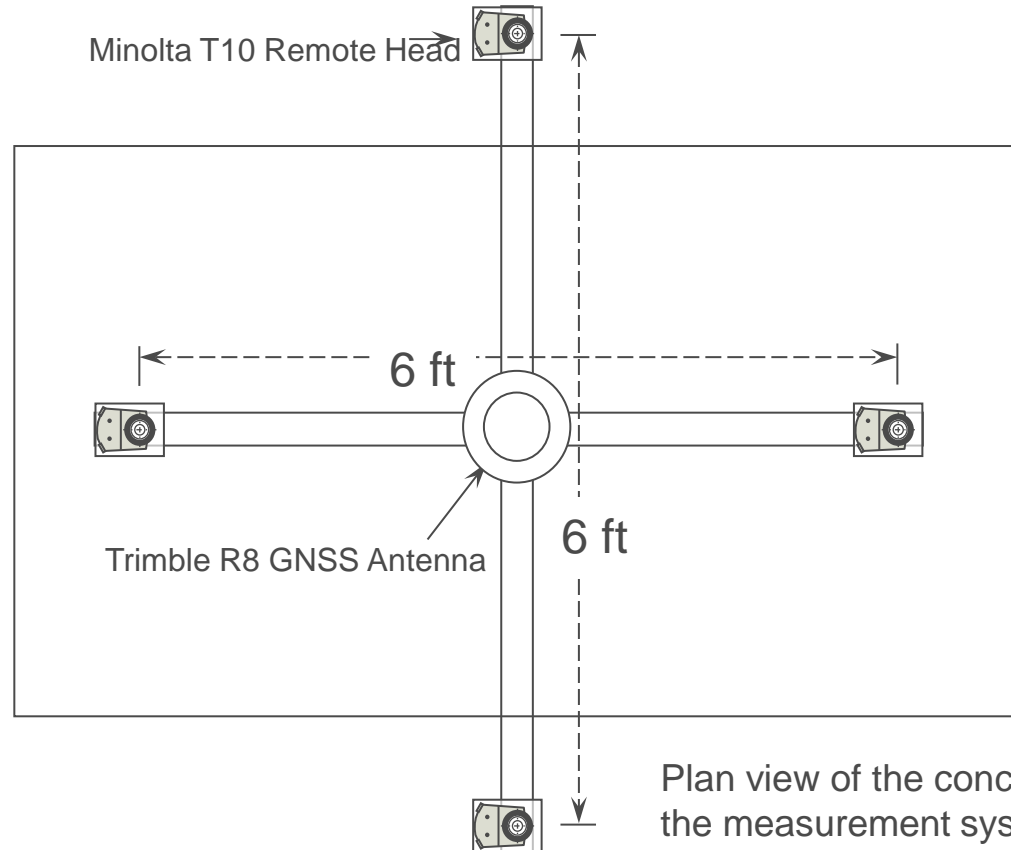
BACKGROUND – I35W Bridge Project

- Bridge located on major interstate – replacement was fast-tracked
- Bridge contractor proposed LEDs, a significant step at the time
- MnDOT requested assistance from GATEWAY
- Original plan included demonstration and report, followed by longer-term evaluation
- This report fulfills the latter commitment, but additional studies may be pursued by MnDOT and others



BACKGROUND: Mobile Monitoring System

Project incorporated a 3-year monitoring effort using a vehicle-mounted system developed by VTTI



Plan view of the concept for mounting the measurement system over the cargo area of a pickup truck.

Limitations of results

- Early-stage products
- New experience for everyone, incl. the testing laboratories
- Lab to lab and test to test precision
- Site specifics
- Limited sample sizes



➤ Trends are more important than specific values!

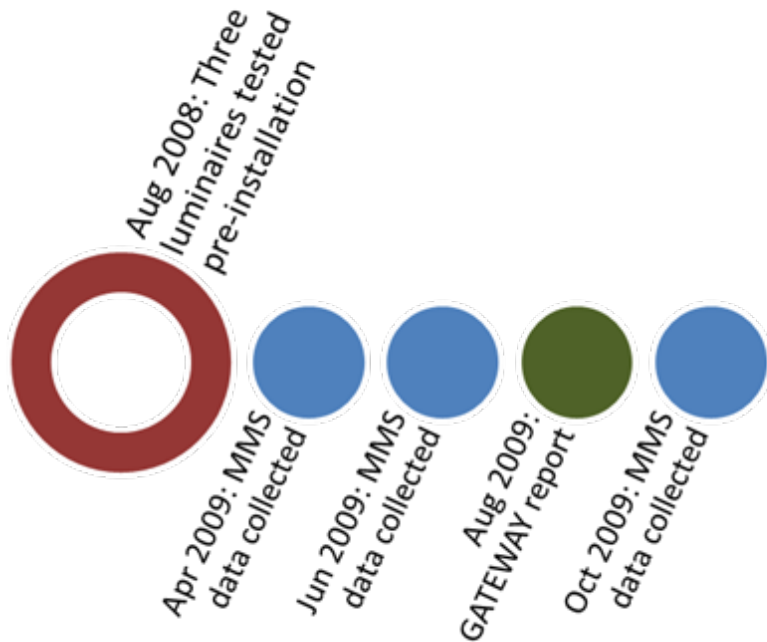
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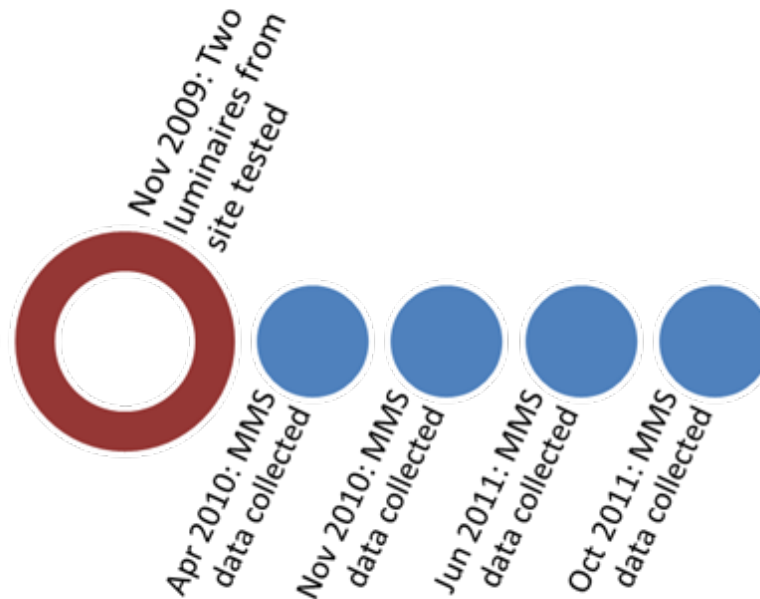
Overview of Testing

Timeline and Nomenclature

Units 200-A, 240-A
Unit 200-B



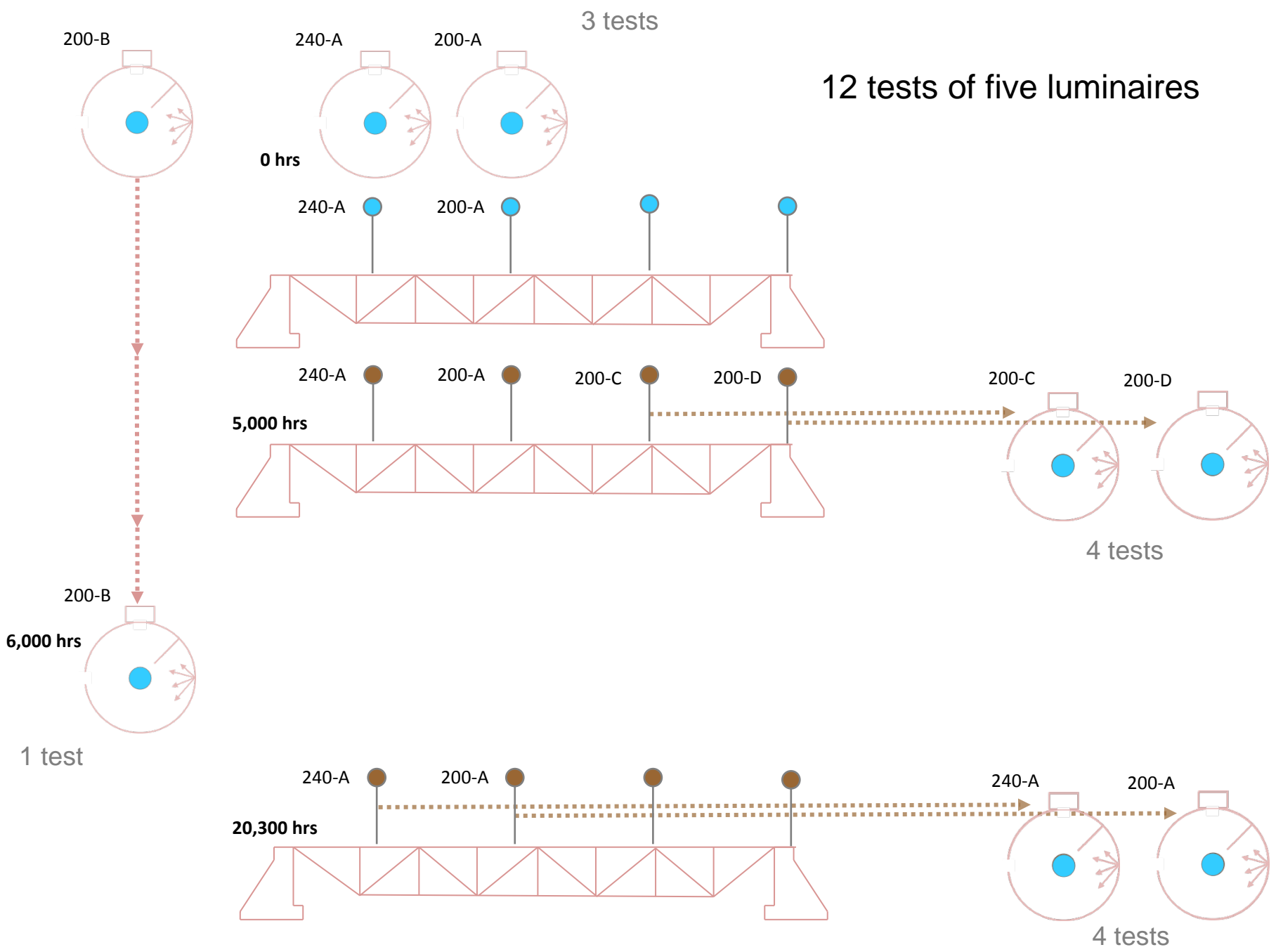
Units 200-C, 200-D



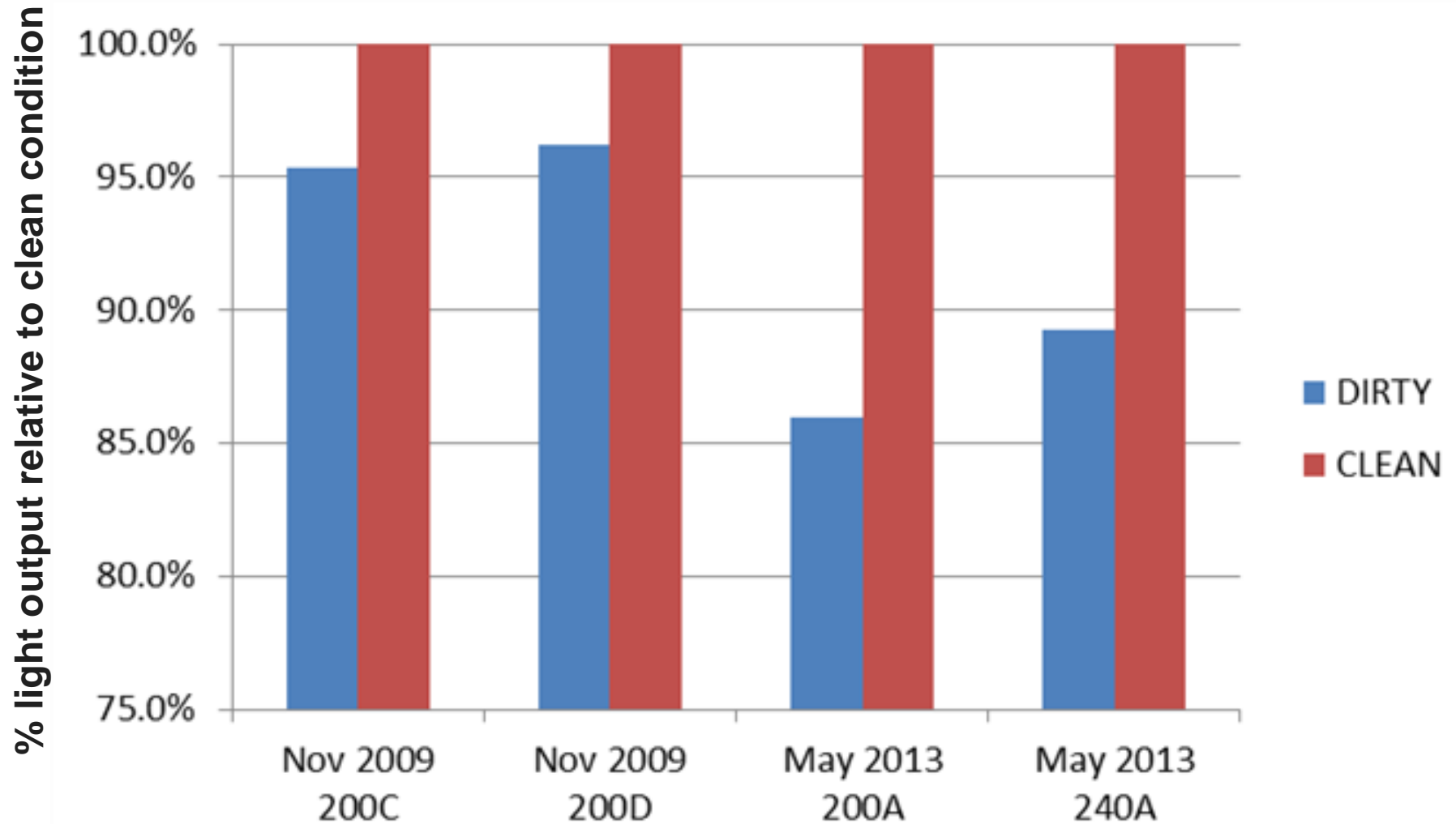
Units 200-A, 240-A



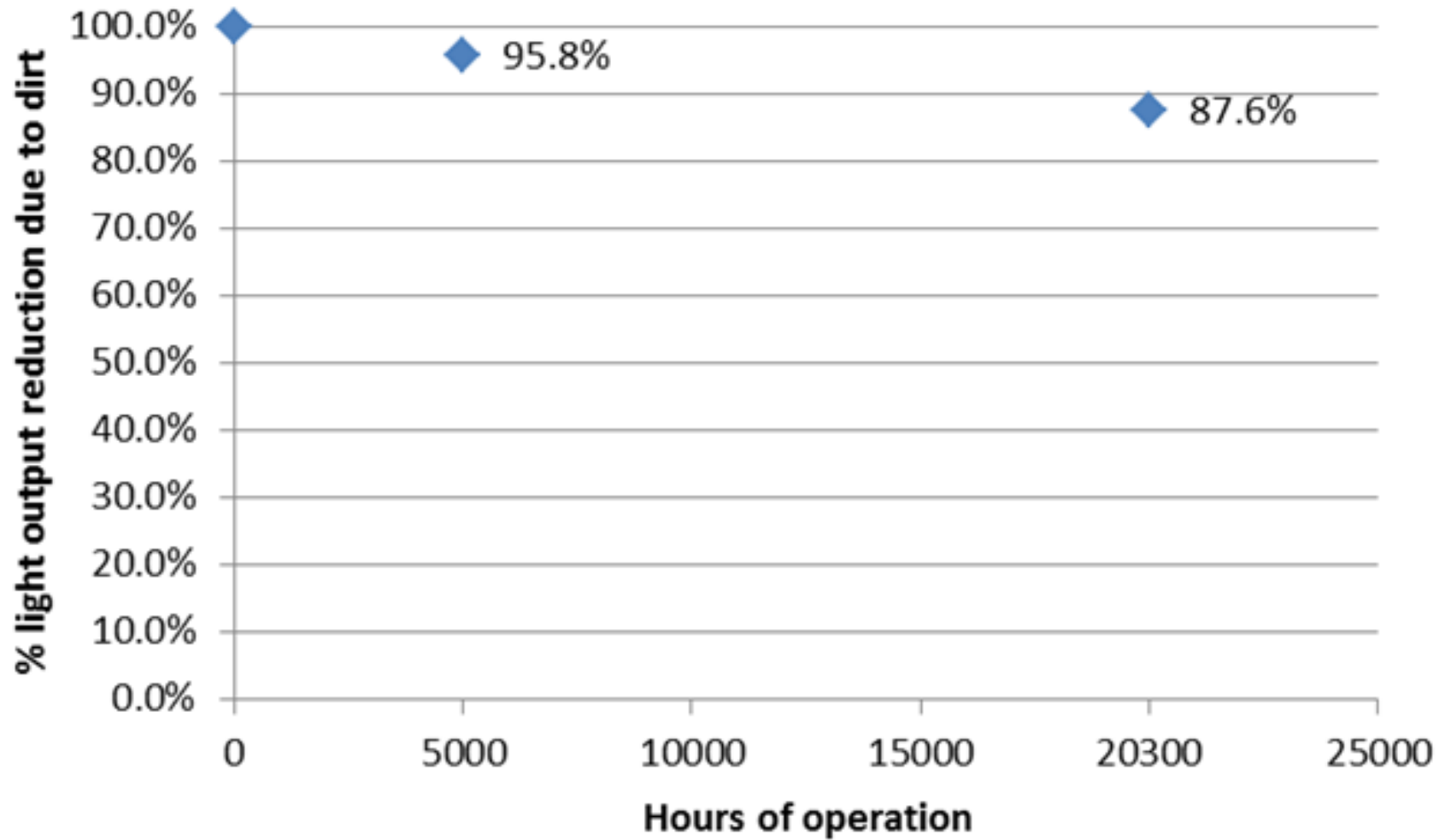
12 tests of five luminaires



Luminaire dirt depreciation

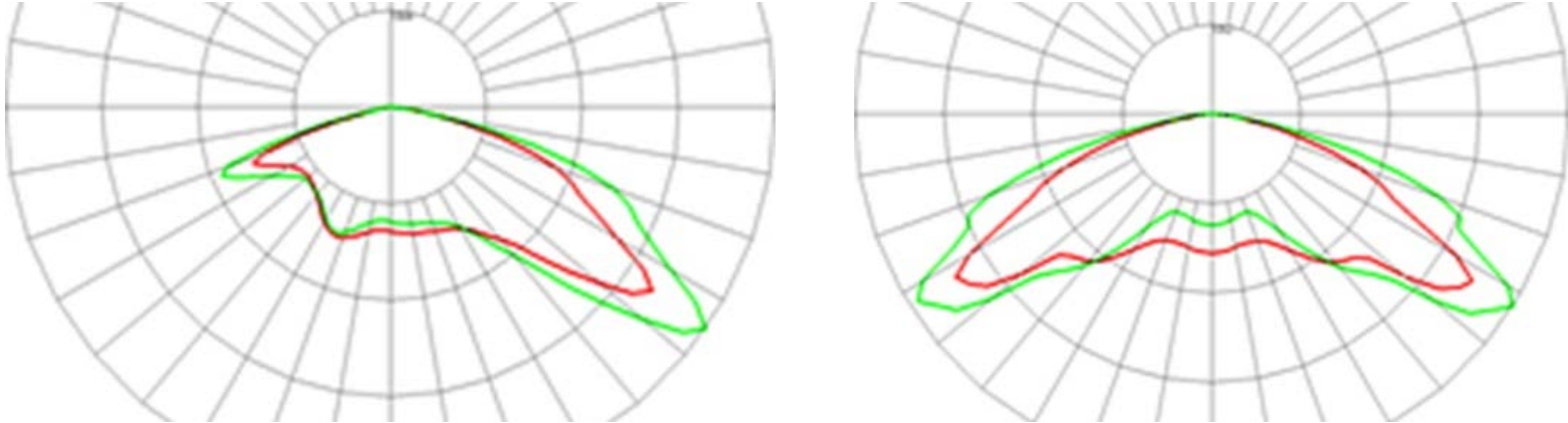


Luminaire dirt depreciation



Luminaire dirt depreciation

Effect on Distribution



- Greater loss at higher angles
- Intensity *increased* at low angles

Effect on Color

- CCT ~50k
- Duv = no change
- $\Delta u'v' = 0.001$

Luminaire dirt depreciation

- Average loss of 4-5% at 5000h
- Average loss of 12-13% at 20,300h
- Loss greater at higher angles
- Intensity increased at low angles
- Minimal effect on color properties

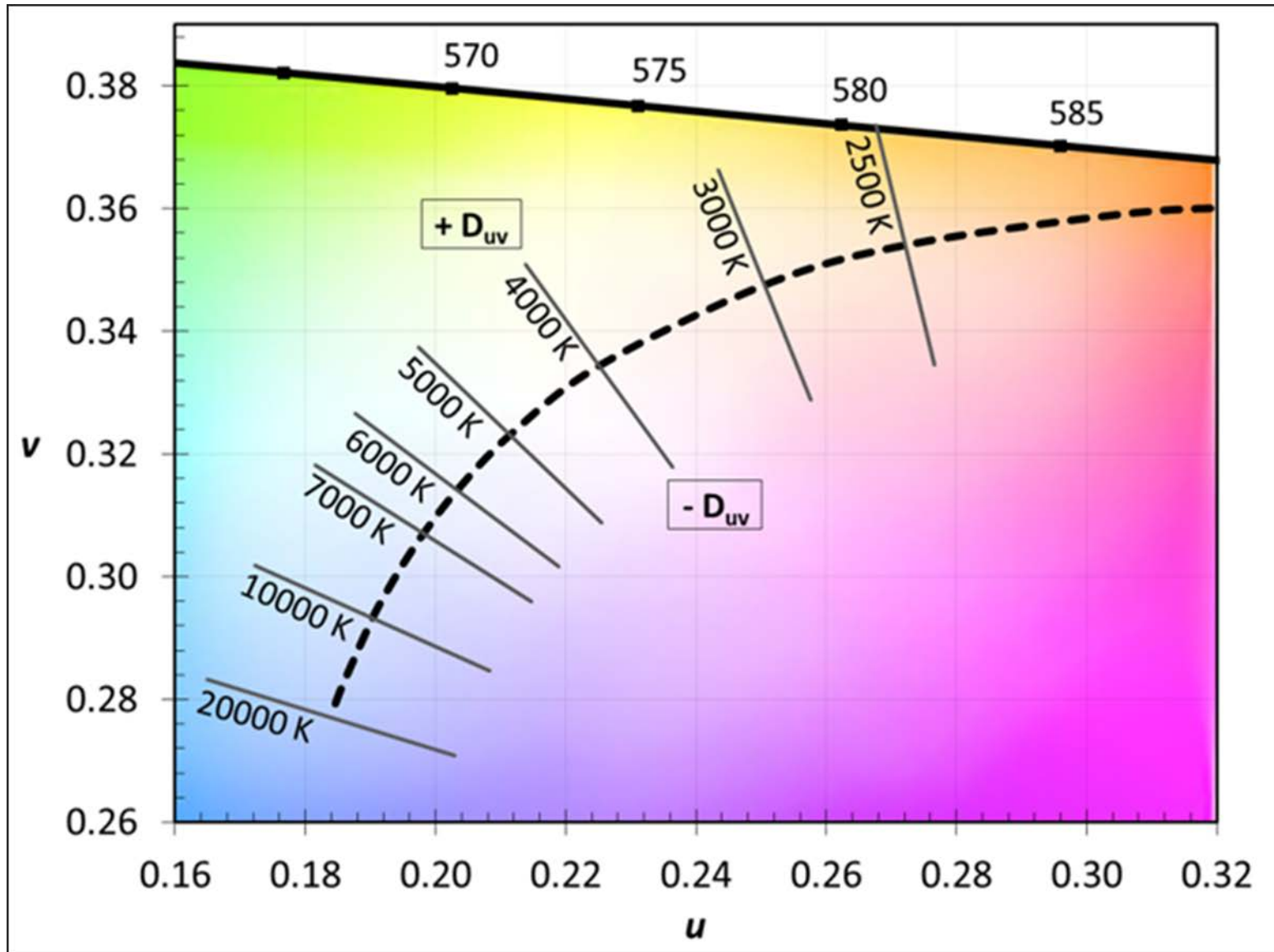


Long-term color data

| Luminaire | 200-B | 200-B | 200-A | 240-A |
|-----------------|--------|--------|--------|--------|
| Hours | 100 | 6,000 | 20,300 | 20,300 |
| CCT (K) | 6061 | 5521 | 5178 | 5182 |
| D _{uv} | 0.008 | 0.013 | 0.018 | 0.017 |
| x | 0.3198 | 0.3321 | 0.3425 | 0.3423 |
| y | 0.3462 | 0.3666 | 0.3867 | 0.3857 |
| CRI | 74 | 72 | 70 | 70 |
| R9 | -25.2 | -35.5 | -47.4 | -46.8 |

- No color data for 200-A and 240-A at 0 hours
- Consistency in data gives confidence to noting trends

Long-term color data



Long-term color data

| Luminaire | 200-B | 200-B | 200-A | 240-A |
|-----------------|--------|--------|--------|--------|
| Hours | 100 | 6,000 | 20,300 | 20,300 |
| CCT (K) | 6061 | 5521 | 5178 | 5182 |
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- Initial ratings: 6000K, 75 CRI
- CCT: shifting lower (warmer)
- Duv: Shifting further above blackbody (greenish)
- Luminaire 200-B had $\Delta u'v' = 0.0117$ at 6000 hours
ENERGY STAR[®] max at 6000 hours = 0.007

Gel Bubble

Test Sample* Showing Formation



Photo on left is initial condition. Right photo shows sample after 54 weeks of thermal cycling.

*BetaLED laboratory sample; not I-35W bridge luminaire.

Power and Output changes after 20,300 hours

Unit 200-A

| | Aug 2008 | Apr 2013 | % Change |
|-------------------|-----------------|-----------------|-----------------|
| Power (W) | 243.9 | 233.3 | -4% |
| Light output (lm) | 16,399 | 13,194 | -20% |
| Efficacy (lm/W) | 67.2 | 56.6 | -16% |

Unit 240-A

| | Aug 2008 | Apr 2013 | % Change |
|-------------------|-----------------|-----------------|-----------------|
| Power (W) | 289.3 | 278.2 | -4% |
| Light output (lm) | 18,882 | 15,653 | -17% |
| Efficacy (lm/W) | 65.3 | 56.3 | -14% |

Power and Output changes for 6000 hr lab test

Unit 200-B

| Luminaire | 200-B | 200-B | % Change |
|-------------------|--------|--------|----------|
| Hours | 100 | 6000 | NA |
| Power (W) | 246.1 | 240.5 | -2% |
| Light output (lm) | 16,482 | 15,659 | -5% |
| Efficacy (lm/W) | 67.0 | 65.1 | -3% |

Unit 200-B: Measurements taken at 500-hour intervals

| Operating Hours | 100 | 500 | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 4500 | 5000 | 5500 | 6000 |
|-------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Illuminance (lux) | 692.4 | 749.2 | 735.8 | 717.9 | 680.1 | 651.8 | 636.8 | 629.7 | 613.7 | 608.5 | 601.8 | 596.0 | 590.7 |
| Color Temperature (CCT) | 5573 | 5506 | 5411 | 5347 | 5320 | 5336 | 5322 | 5321 | 5334 | 5322 | 5327 | 5272 | 5246 |

Power and Output changes for 5000 hr test (Nov 2009)

Units 200-C, 200-D

| Luminaire | 200-C | 200-C | % Change |
|-------------------|--------|--------|----------|
| Condition | As is | Clean | |
| Power (W) | 237.9 | 238.7 | 0% |
| Light output (lm) | 14,520 | 15,227 | 5% |
| Efficacy (lm/W) | 61 | 63.8 | 5% |

| Luminaire | 200-D | 200-D | % Change |
|-------------------|--------|--------|----------|
| Condition | As is | Clean | |
| Power (W) | 238.3 | 238.4 | 0% |
| Light output (lm) | 14,670 | 15,245 | 4% |
| Efficacy (lm/W) | 61.6 | 64 | 4% |

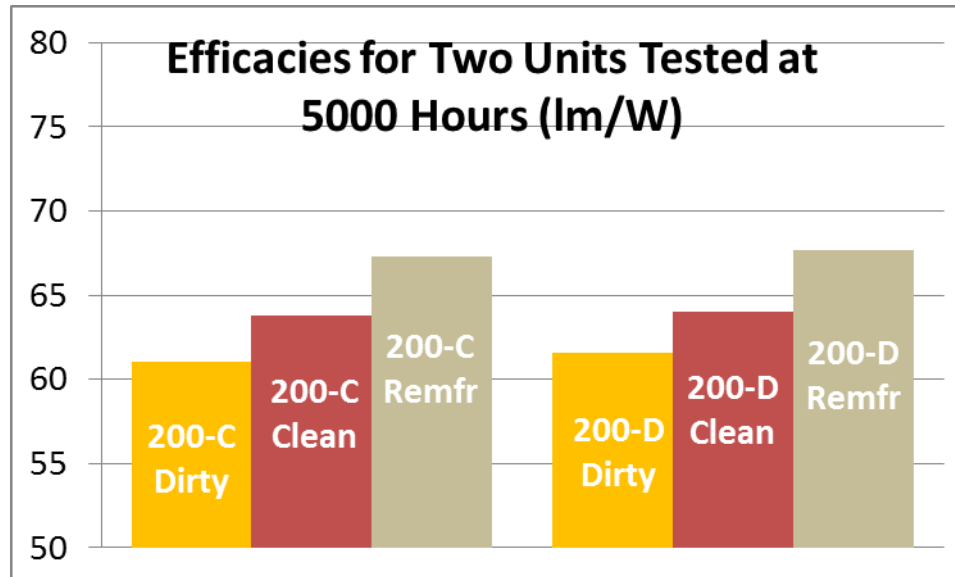
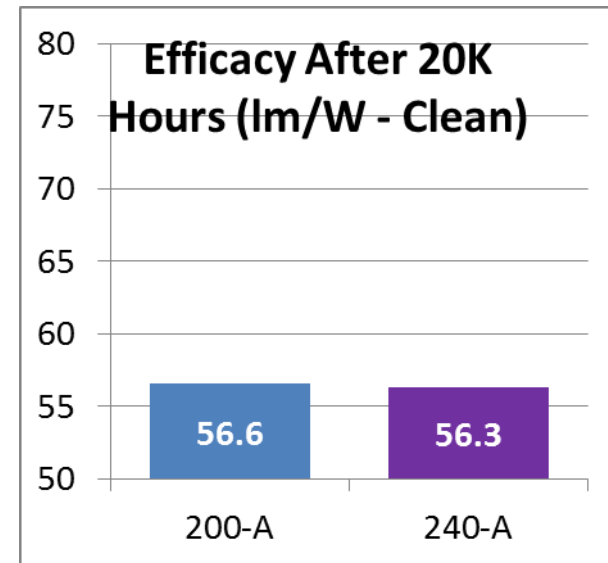
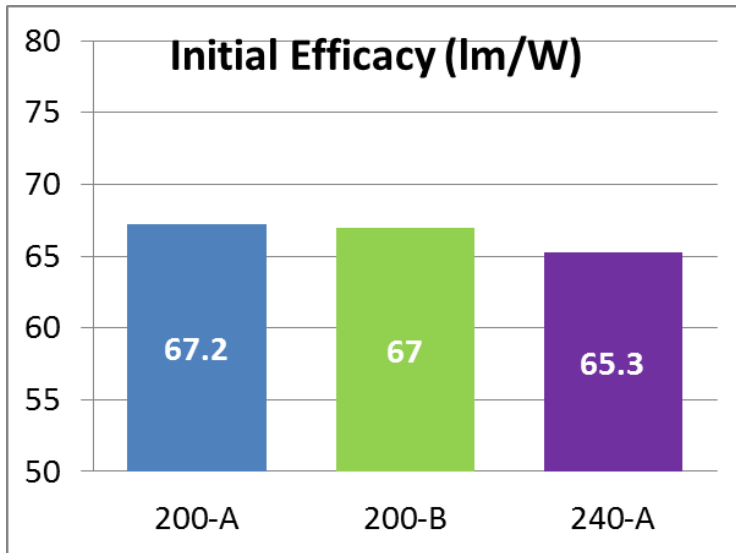
Comparison of clean units following remanufacturing*

| Luminaire | 200-C | 200-C | % Change |
|-------------------|--------|--------|----------|
| Condition | Clean | Remfr | |
| Power (W) | 238.7 | 242.4 | 2% |
| Light output (lm) | 15,227 | 16,305 | 7% |
| Efficacy (lm/W) | 63.8 | 67.3 | 5% |

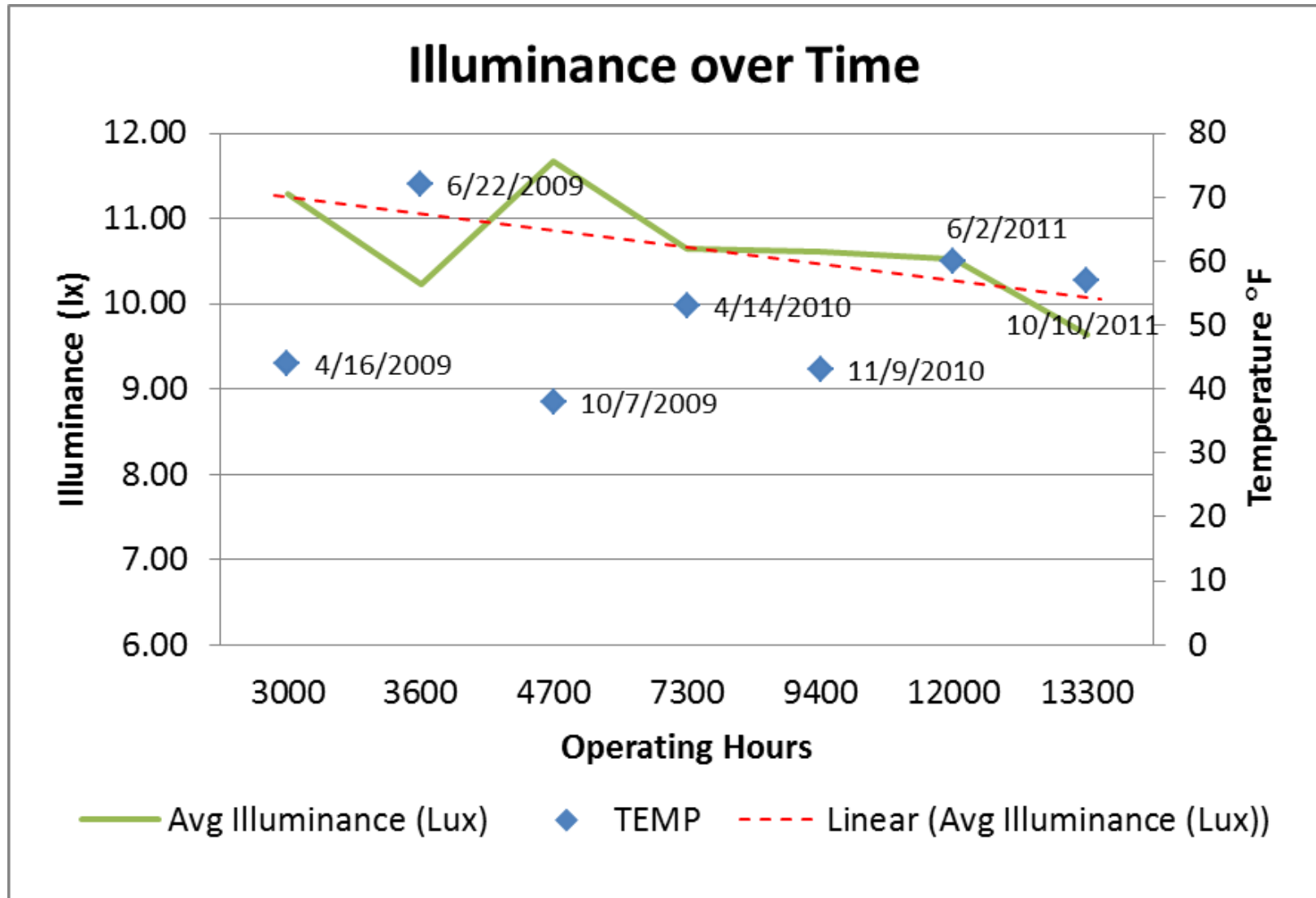
| Luminaire | 200-D | 200-D | % Change |
|-------------------|--------|--------|----------|
| Condition | Clean | Remfr | |
| Power (W) | 238.4 | 243.3 | 2% |
| Light output (lm) | 15,245 | 16,462 | 8% |
| Efficacy (lm/W) | 64 | 67.7 | 6% |

*Optical gel was replaced by manufacturer to measure impact of bubble

Power and Output – Unit Consistency



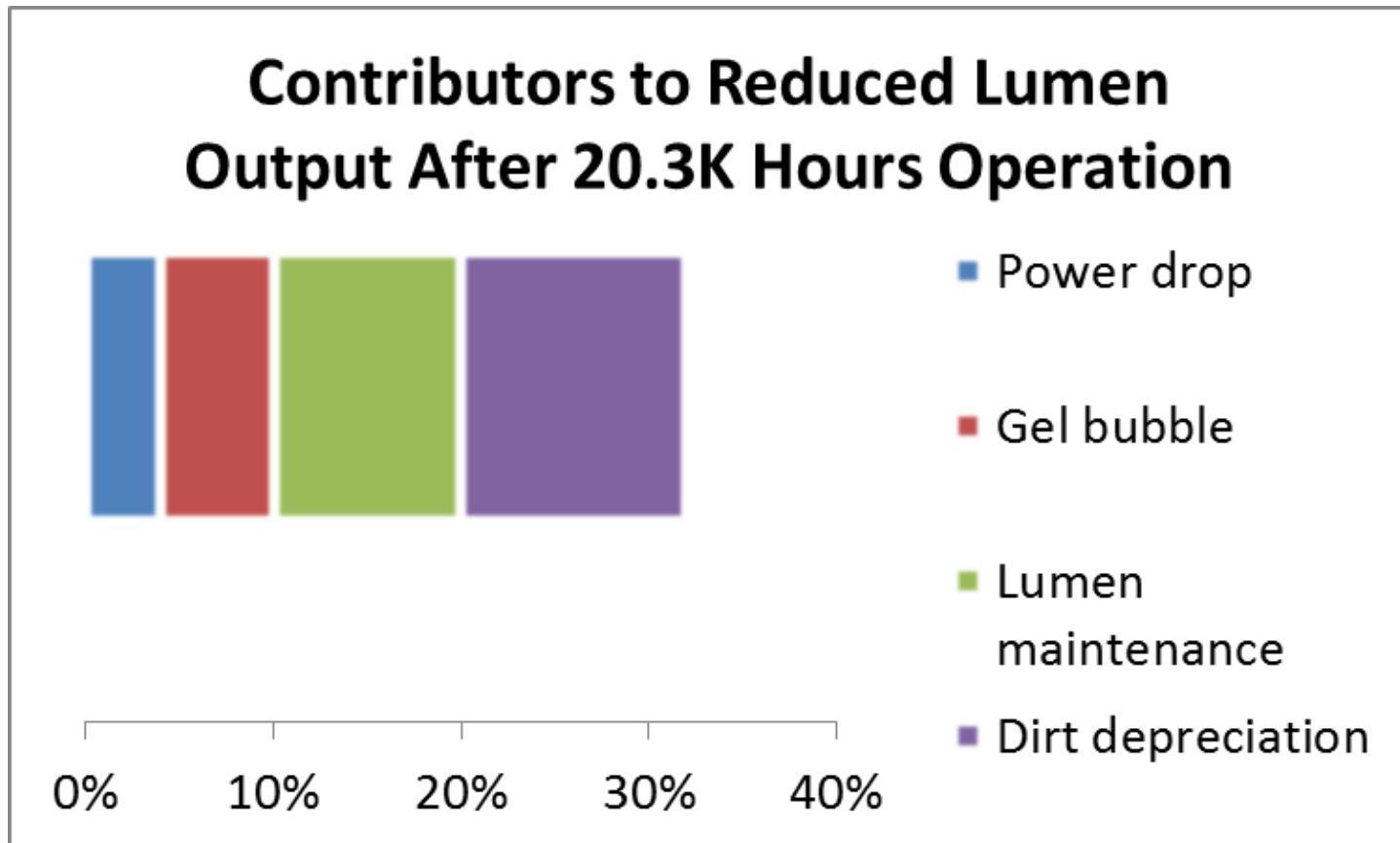
Illuminance & the MMS (Southbound lanes)



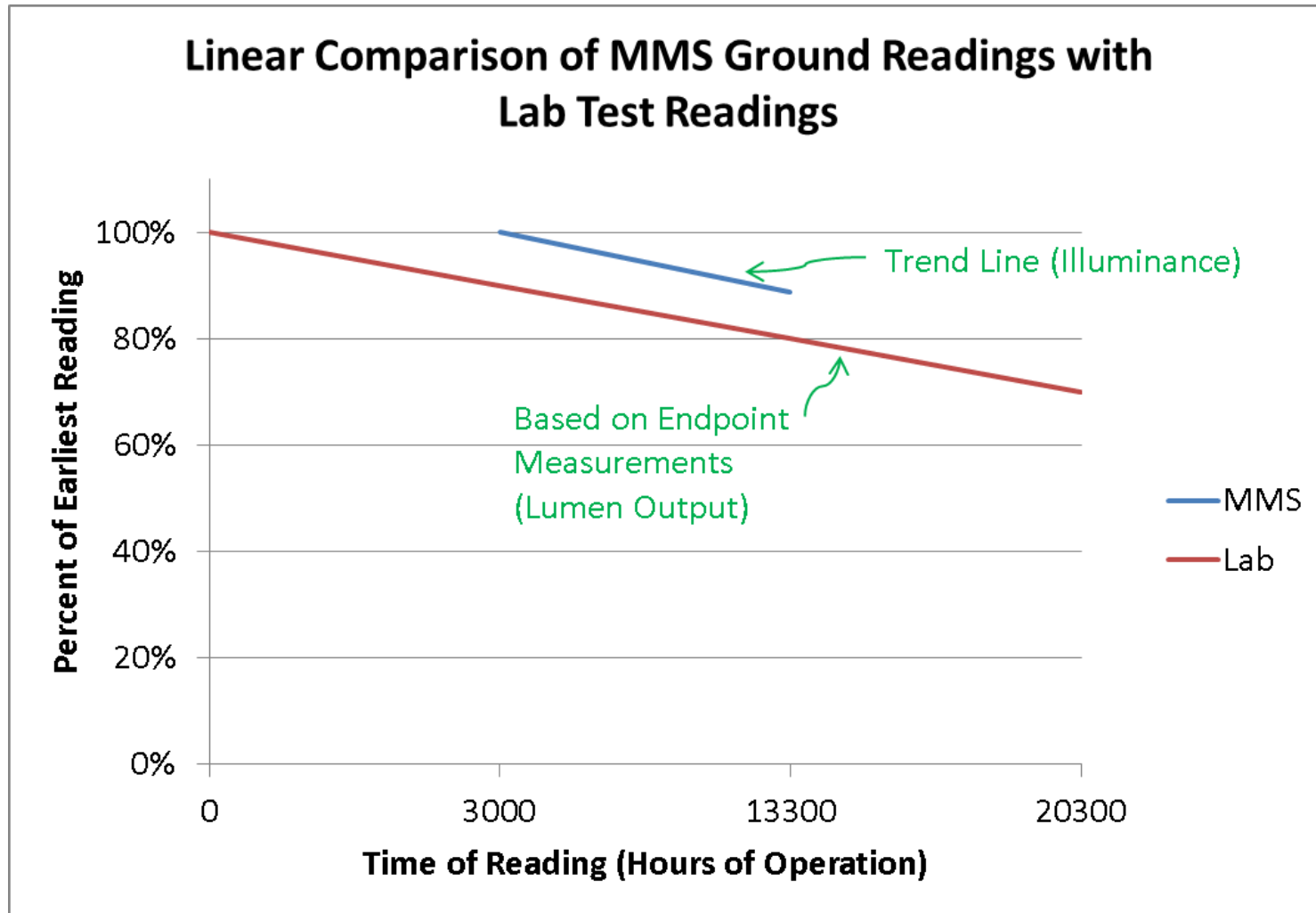
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Summary – Lumen Depreciation Estimated by Lab Tests



Summary – Comparison of Lab and Ground Readings



Conclusions

- The lighting system is showing signs of normal aging and exposure to the elements; lumen maintenance appears to be on track with projections
- New technology brings new issues
 - LLD factors are often site- and product-specific, perhaps even varying by model and vintage
 - Color shift
- Data is limited but suggests LED luminaires should be considered similar to conventional fixtures regarding LDD
 - Sites should plan for cleaning where illuminance is critical
 - Cleaning maintenance is a component of life-cycle costs
- In our opinion, this installation is holding up well and is showing the value of LEDs, even given this particular product's early stage of development and corresponding issues