New Standard Requirements and Possibilities using UV-LED lamps for fluorescent Magnetic-Particle- (MPI) and Penetrant Inspection (FPI) in Aerospace
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more than 15 years NDT-experience in Magnetic- and Penetrant-Testing
Active Member and participant of all relevant groups and standardization committees worldwide regarding UV-LED- Technology:
ASTM
DIN EN ISO committees for MT and PT
NADCAP
SAE
Working Aircraft- and Engine-manufacturers
Manufacturer of:

High quality, standard and customized UV-A-LED-sources developed by and for the inspection practice

Ultrasonic-Couplants

Fluorescent Magnetic-Particle consumables

Optimized Electrostatic Spraying Equipment

FPI-Lines (manual, semi-automatic, full-automatic)

Sister company of RIL-CHEMIE
Introduction

- Discharge bulb based UV-A Sources (Mercury Vapor, Xenon, Metal-Halide) shall get unavailable in the near future and they are more and more substituted by LED-based sources in practice.

- The technology change interferes the inspection practice enormous.

- The user needs a tool that supports the detection of indications of the human vision, not just an UV Source that just stimulates fluorescence.

- Standardization does acutally not reflect this requirement, even if we are hardly working on that.
Technical Basis of Fluorescent MPI and FPI

- Process just helps **DETECTING INDICATIONS** (seeing it easier)

- Process has to be:
  - reliable
  - secure
  - fast
  - efficient and economic

**IT’S ALL ABOUT CONTRAST**
between indication and background
Technical Basis of Fluorescent MPI and FPI

What is commonly summarized as **INSPECTION** of indications are physiologically and technically **3 different steps**:

**DETECTION** (peripheral vision)

**INSPECTION** (central vision)

**INTERPRETATION** (supported by white light)
Technical Basis of Fluorescent MPI and FPI

The human vision and its physiology is the UNCHANGEABLE PART of the whole system THAT NEEDS TO BE SUPPORTED.
The Human Vision

Peripheral (outer) Vision (unsharp and fast):

FAST & RELIABLE DETECTION OF INDICATIONS
GIVES ORIENTATION ON THE SURFACE
CONDUCTS THE CENTRAL VISION
TO THE RELEVANT INDICATIONS

→ REQUIRES LARGE BEAM or
SOFT DROP at the edges
The Human Vision

Foveal (central) Vision (very sharp, coloured and slow):

RESPONSIBLE FOR INTERPRETATION OF INDICATIONS

INAPPROPRIATE TO DETECT INDICATIONS

REQUIRES UNIFORM BEAM

ALLOWS ONLY TUNNELVIEW
The Human Vision

Allows intuitive, fast and reliable inspection

WHEN using its FULL

CAPABILITY OF DETECTION

(like when using Mercury vapor lamps)

Stimulation Of Fluorescence

IS BY FAR NOT ENOUGH
Central importance of the UV-Source and its Reliability

A failure (e.g. lost of intensity) of the source can not be seen and realized by inspector due to the invisibility of the radiation.

If a physical existing indication does NOT APPEAR OR IS NOT SEEN, due to a failure of the source or insufficient radiation area, the inspector TRUSTS that there IS NO indication.
Central importance of the UV-Source and its Reliability

If UV LED sources doesn’t work

ALWAYS RELIABLE AND PROPERLY

(as Mercury Vapour lamps do)

THE WHOLE PROCESS CRASHES
Technology Shift

from a simple electric device to a complex sophisticated electronic system

with opposite behavior after switch-on used in a harsh industrial environment
Technology Shift:

When using discharge bulb-based UV sources the user had to find a way to inspect with the determined tool.

UV LED technology offers optimized lamps for different applications.
Technology Shift:

**Optimized UV-LED Source can:**
- Enhance the process performance (faster and easier inspection)
  - Enhance the quality of the inspection process
    - Eliminate reflections
    - Safe Energy and a lot of money
  - Enhance the health and safety of the user

**Non-Optimized UV-LED Source can:**
- Make inspection more tiring, harder or impossible
  - Dramatically increase the process costs
  - Crash the process and do NOT stop the user
Process security

Mercury vapor lamps only know 2 status:

ON = works properly

OFF = always in case of any failure

Intensity rises when warming up
Process security

UV LED Lamps:

Intensity drops when warming-up

Errors typically occur inconspicuous and sneaking, what makes it impossible to be realized by the inspector immediately when they occur or get critical.

Undetected failures of the UV sources are inacceptable.

To ensure same or better process security adequate electronic monitoring or additional checks are mandatory.
Process security

Additional checks (if not electronically monitored)

- Check of proper function of all UV-LED-elements on multi array UV-LED-sources
- Check of correct function of the cooling system
- Monitoring of the allowed ambient temperature
- Check of the output constancy on battery powered lamps
- Determination, Documentation and Monitoring of this additional checks
Features for Enhanced Inspection Quality and Performance

Process Security

Auto Switch OFF at Low Battery or System Failure

Monitoring of UV LEDs

System health monitoring

Signalization of operating status and system status

Tested and Qualified for Ambient Temperatures of 50°C (122°F) or more
Features for Enhanced Inspection Quality and Performance

Conformance

Adaption Time Signalization

Detailed Certificate with
- Separated Sections for Each Individual Standard
- Data Linked to Relevant Sections for Easy Demonstration of Evidence

Readiness for Upcoming standards

Sealable Customizing by Responsible
Features for Enhanced Inspection Quality and Performance

Enhanced Interpretation

White Light Toggling (UV or VIS)

Additional White Light (UV and VIS together)

In-Use Adjustable White Light output
Features for Enhanced Inspection Quality and Performance

Enhanced Interpretation

Slow **step less** dimming instead of switching

Uninterrupted observation while changing

**NO loss of orientation** or sharpness

**NO flash blinding** of the eyes
Features for Enhanced Inspection Quality and Performance

Enhanced Features

Eco Mode to safe energy and lift-time

Optical, acoustical and tactile signals

Individual customizing by the user
Lamp selection and usage

Choose the right lamp for a specific application

Check orientation and detectability of indications

Focus on optimal support of the inspection process not price

Compare lamps in practice (not datasheets)

Check uniformity while moving over white sheet of paper
The unwritten standard:
100W Mercury-vapour bulb based UV-Sources

All lamps are technically equal and based on same bulb, filter and ballast

Same physical determined and fixed spectral output

Same high reliability

Same irradiated area

Same beam pattern (central spot with soft radiation drop)

NO or only only coarse laminar inhomogeneties
The unwritten standard:
100W Mercury-vapour bulb based UV-Sources

To ensure at least the same QUALITY, RELIABILITY, PERFORMANCE and COSTS of the inspection

UV LED sources must be EQUAL OR BETTER than mercury vapor lamps in ALL MATTERS without compromises!
ASTM Standards

ASTM E 3022 contains only manufacturing requirements for non-aerospace UV LED sources

Is included in aerospace standard ASTM E1444 and E1417

Peak 365 ± 5nm needs only to be reached at low ambient temperatures (Reduction of sensitivity level can occur, due to the emission spectrum of conform UV-LED-lamps)

No additional electronic or manual user checks and further controls required

Certification Report does not require to state results of unit qualification

Existing standards as well as the terminology shall be adapted within the next years.
AMS / SAE Standards

AMS 2647 will be changed in the future
EN / ISO Standards

EN ISO 3059 is in revision

Shall get an appendix for acceptance and qualification criteria for UV-LED

A Technical Report will explain the basics of fluorescent and colour contrast technique

Shall be available late in 2017 or 2018
Rolls-Royce Engineering Specification RRES 90061

First Prime Standard available in Aerospace Industry that terminated the ban of UV-LED-sources by Rolls Royce

Includes manufacturing requirements and additional user checks

Requires 365 ± 5 nm always during usage at ambient temperatures within 40 – 122°F (5 to 50 °C)

Requires even irradiation

Requires surrounding area with gradual reduction

Actually the highest reliability requirements

Over temperature switch-off required

Security switch-off for battery powered lamps when output could decrease mandatory
NADCAP

NADCAP NDT task group is working on standard questions

The last draft contains only 4 questions according the following themes:

Evidence that lamp manufacturer validates peak wavelength 365 ± 5nm

Procedure to ensure correct output of battery powered UV LED lamps in place (does procedure exist and does it ensure correct output)

Torches shall be only used to local inspection
**Airbus**

Issue 9 of AITM 6-1001 allows the usage of UV-LED-source with a peak of 365nm without variation, what is technically a ban of the usage of common UV-LED-lamps available.

New revised shall be published soon and contain specific requirement for UV LED sources.

* Without claim to be the last updated and complete information.
GE Aviation*

Usage of UV-LED sources are not allowed and not forbidden

Acceptance criteria shall be published in the future

* Without claim to be the last updated and complete information
Pratt & Whitney*

lowest aerospace requirements

365 ± 5 nm within 60 – 104°F (10 to 40 °C) when tested, no usage restriction

Visible light output less than 2 fc (20 Lux) at minimum working distance

Limitation of maximum UV-A intensity to 10,000 μW/cm² at 15 inches (38.1 cm)

Some intensity measurements required when using battery powered sources

* Without claim to be the last updated and complete information
Conclusion (technically)

- LED-based UV-Sources are not simple electric lamps, they are electronic device that require adequate qualification and maintenances.

- NDT has the highest requirement for UV LED Sources due to its insecure security.

- Adequate qualification and additional electronic or manual process controls are required for secure and reliable usage of UV LED sources.

- Well qualified and designed high-quality UV-A-LED-sources can easily and completely substitute conventional bulb-based-UV-lamps without any technical and practical disadvantage in NDT.

- Fluorescent inspection processes can be improved using optimal UV LED sources.

- Fluorescent inspection processes can be destroyed by using inadequate and unreliable UV LED sources.
**Conclusion (practically)**

- Users have to select the right sources for their specific applications.
- The price of the lamp does not interfere the costs for the process.
- The quality of the lamp drastically influences the costs of the process.
- Costs of the process can be reduced while the performance of the process will be increased when using optimized UV LED sources.
- Beam size needs to be large enough or have sufficient large soft drop surrounding area to ensure orientation on the inspection surface and to allow detection by the peripheral vision.
- Uniformity needs to be checked by the user while moving the lamp over a sheet of white paper.
- Standardization is far behind the reality and it is not easy to standardize the unwritten Standard ‘100 W Mercury vapor lamp’.
- Much inadequate UV LED lamps actually available and used.
To see what you heard please come to my booth

Thank you very much for your attention!

Any questions?
## Influence of lamp characteristic on inspection performance and POD

### Beam Pattern

<table>
<thead>
<tr>
<th></th>
<th>Main area (&gt;1.200 µW/cm²)</th>
<th>Junction between main center and peripheral area</th>
<th>Peripheral area</th>
<th>Support of the central vision</th>
<th>Support of the peripheral vision</th>
<th>Intuitive interaction between eyes and lamp</th>
<th>Orientation on the part</th>
<th>Way of detection (scanning)</th>
<th>Influence on inspection performance (compared to Mercury Vapour)</th>
<th>Influence on POD compared to Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury Vapour (unwritten Standard)</td>
<td>Central hotspot</td>
<td>Steep drop (industry standard)</td>
<td>Optimal and gradual (less than 40% per inch in 15 in. distance)</td>
<td>Semi-optimal support</td>
<td>Supported (industry standard)</td>
<td>Lamp gets intuitively adjusted to the focus of the human eyes</td>
<td>Good orientation</td>
<td>Scanning necessary (industry standard)</td>
<td>Standard inspection performance</td>
<td>Standard POD</td>
</tr>
<tr>
<td>Xenon Spot</td>
<td>Tiny central hotspot</td>
<td>Abrupt drop</td>
<td>Less gradual than standard and more even with hard drop at the outer edges</td>
<td>Limited Support</td>
<td>Supported, but less than the standard does</td>
<td>Lamp gets intuitively adjusted to the focus of the human eyes within limits</td>
<td>Limited orientation</td>
<td>Slow detailed scanning necessary, slow and tiring inspection</td>
<td>Lower 2 to 3 times longer</td>
<td>Standard POD</td>
</tr>
<tr>
<td>Xenon Flood</td>
<td>Central spot</td>
<td>Steep drop (comparable to Standard)</td>
<td>Comparable to standard, sometimes with hard drop at the outer edges</td>
<td>Semi-optimal support</td>
<td>Supported, similar to the standard</td>
<td>Lamp gets intuitively adjusted to the focus of the human eyes</td>
<td>Good orientation</td>
<td>Scanning necessary, near industry standard</td>
<td>Standard inspection performance</td>
<td>Standard POD</td>
</tr>
<tr>
<td>LED with hard drop</td>
<td>Depending on the lamp type</td>
<td>NO Junction</td>
<td>NO peripheral area</td>
<td>Acceptable</td>
<td>NO support, totally handicapped</td>
<td>Focus has to 'stay' within in the beam, tiring and limited detection</td>
<td>NO orientation on small beams, limited on big beams</td>
<td>Slow detailed scanning necessary, slow and tiring inspection</td>
<td>Much lower performance, up to 10 times slower</td>
<td>Drastical reduction of POD (missing indications), due to the loss of the primary detection capability of the human vision</td>
</tr>
<tr>
<td>LED with soft drop</td>
<td>Depending on the lamp type</td>
<td>Smooth and gradual</td>
<td>Depending on lamp type and definition (can be better than standard)</td>
<td>Enhanced support</td>
<td>Optimal support to use the full capability of detection for easy and fast detection</td>
<td>Lamp gets intuitively adjusted to the focus of the human eyes and allows natural movement of the eyes without any interferences</td>
<td>Optimal orientation</td>
<td>Intuitive by using optimal usage of the full capability of detection</td>
<td>Higher inspection performance and security while less tiring inspection work</td>
<td>Better POD while inspection is more easy and faster than using the standard</td>
</tr>
</tbody>
</table>
# Influence of lamp characteristic on inspection performance and POD

## Beam Uniformity

<table>
<thead>
<tr>
<th></th>
<th>Description of the non-uniformity</th>
<th>Possibility of separation by the human vision of the variation on the part caused by the non-uniformity of the beam</th>
<th>Strain for the human vision</th>
<th>Influence on inspection performance only about uniformity (independent from soft drop area)</th>
<th>Influence on POD compared to standard only about uniformity (independent from soft drop area)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mercury Vapour</strong></td>
<td>Some large coarsely splitted areas</td>
<td>Good possibility of separation by the human vision</td>
<td>Acceptable strain</td>
<td>Standard inspection Performance</td>
<td>Standard POD</td>
</tr>
<tr>
<td>(unwritten Standard)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Xenon Spot</strong></td>
<td>Single main steps at junction between central hotspot and peripheral areas</td>
<td>Good possibility of separation by the human vision</td>
<td>Acceptable strain</td>
<td>Standard inspection Performance</td>
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</tr>
<tr>
<td><strong>LED with some hotspot</strong></td>
<td>Gradual hot spots</td>
<td>Good possibility of separation by the human vision</td>
<td>Acceptable strain</td>
<td>Standard inspection Performance</td>
<td>Similar to standard POD</td>
</tr>
<tr>
<td><strong>LED with marblings</strong></td>
<td>Undefined, unstructured variations of different sizes and shapes</td>
<td>Impossible to separate by human vision, very high up to unacceptable negative influence</td>
<td>Extremely high strain</td>
<td>High reduction of inspection performance, very tiring</td>
<td>High reduction of POD</td>
</tr>
<tr>
<td><strong>LED with very tiny variations</strong></td>
<td>Tiny scratches, difficult to be perceived, when not moving the lamp</td>
<td>Impossible to separate by the human vision, detrimental influence, 'moving effect'</td>
<td>Totally unacceptable strain</td>
<td>Detrimental reduction of inspection performance, extremely tiring inspection</td>
<td>Drastical reduction of POD</td>
</tr>
<tr>
<td><strong>LED completely uniform</strong></td>
<td>No visual non-uniformity</td>
<td>Not relevant, due to all perceived variations are caused by the inspection surface, optimal inspection conditions, no interference of the perception by the beam</td>
<td>Minimum strain</td>
<td>Enhanced inspection performance, less tiring inspection</td>
<td>Enhanced POD, although faster and less tiring inspection</td>
</tr>
</tbody>
</table>
Uniformity of the irradiation area

100W Mercury vapour lamp

35W Xenon lamp

Non-uniform UV-LED lamp

UV LED lamp with blind spot

Common UV LED lamp

Optimized UV LED lamp