Newest Requirements for LED UV Lamps used in Fluoresecent Magnetic Particle and Penetrant Testing

German Manufacturer of

Technology Leading UV LED Sources,

Especially Designed For Easier, Better, Faster,

More Reliable and Less Tiring Fluorescent Mag

and Pen Inspection Without Compromises

Because Failure Is Not An Option

Marc Breit

Managing Director and Head of development and sales

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 close with Aircraft- and Engine-manufacturers

Huge 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

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!

Process security

Mercury vapor lamps only know 2 status:

ON = works properly

OFF = always in case of any failure

Intensity rises when warming up

Wavelength physically determined by Hg in the bulb

Intensity determined by voltage (when warmed-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

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),
searching of indications within a spot is **not** detecting!

INSPECTION (central vision)

INTERPRETATION (supported by white light)

Technical Basis of Fluorescent MPI and FPI

The human vision and its physiology is the

MOST UNCHANGEABLE

part of the whole system

The only thing we can and have to do is to support the human vision as good as possible to
Allow the usage of the full capability of detection

The Human Vision

Peripheral (outer) Vision (unsharp and fast):

Allows **FAST & RELIABLE DETECTION** OF INDICATIONS

GIVES ORIENTATION ON THE SURFACE

CONDUCTS THE CENTRAL VISION

TO THE RELEVANT INDICATIONS

is 35 faster than the central vision

➜ **Requires sufficient large irradiation area for free eye movement (area ≥ 100 µW/cm²)**

➜ **Requires very high uniformity for sufficient and fatigue-proof inspection**

The Human Vision

Peripheral (outer) Vision (unsharp and fast):

Allows **FAST & RELIABLE DETECTION** OF INDICATIONS

GIVES ORIENTATION ON THE SURFACE

CONDUCTS THE CENTRAL VISION

TO THE RELEVANT INDICATIONS

is 35 faster than the central vision

➜ **Requires sufficient large irradiation area for free eye movement (area ≥ 100 µW/cm²)**

➜ **Requires very high uniformity for sufficient and tire-prof inspection**

The Human Vision

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

RESPONSIBLE FOR
INTERPRETATION OF INDICATIONS

INAPPROPRIATE TO DETECT INDICATIONS
(can only search indications)

ALLOWS ONLY TUNNELVIEW
(needs high intensity**,** only area ≥ 1.200 µW/cm² usable)

Central importance of the UV-Source and its Reliability

Generation of fluorescent indications and detection possibility by the human vision is totally depending on the quality of the radiation

- 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 can not be easily detected, due to a failure of the source or
  insufficient irradiation area (beam pattern)
  the inspector **TRUSTS that there IS NO indication**

Central importance of the UV-Source and its Reliability

If the sources doesn't work

ALWAYS RELIABLE AND PROPERLY

the whole process crashes

Design, Performance and Qualification Requirements: Standards

Aerospace Standards:

AITM 6-1001 Issue 11

Rolls Royce RRES 90061

Pratt & Whitney FPM Master

Boeing

ASTM E-3022 is **not** an Aerospace Standard and
does **not** securely ensure expected brightness of penetrant
always during usage the UV LED Source as qualified per AMS-2644

Design, Performance and Qualification Requirements: Classification

Type A: Mains Powered UV LED Sources

Type B: UV LED Sources Powered by Rechargeable Batteries

(Lamps that can be Mains and Battery powered need Qualification of Type B)

Type C: Small Torch and Flashlight Type with limited Performance

Only allowed for Partial Inspection of difficult to reach areas

(and when verifiable better than Type A or B lamps)

Type D: Sources for special application like light guides

Design, Performance and Qualification Requirements: Wavelength Distribution

Peak Wavelength: 365 ± 5nm

FWHM: ± 10 nm

10% of Maximum: ± 15 nm

ALWAYS DURING OPERATION

Concerns of non-conform wavelength:
Penetrants do not reach the qualified brightness when stimulated by other wavelength distribution

Design, Performance and Qualification Requirements: Beam Size

BEAM AREAS:

- Size of the main irradiation area (≥ 1.200 µW/cm²)
- Size of the usable area (≥ 100 µW/cm²; main and peripheral area)

3 RELEVANT DISTANCES:

- Minimum working distance (distance where the beam is uniform while moving over a whit sheet of paper)
- Typical working distance (15 inches / 38 cm)
- Maximum Working Distance (maximum distance where at least 1.200 µW/cm² area are available)

Design, Performance and Qualification Requirements: Beam Size: CENTRAL BEAM (≥ 1.200 µW/cm²)

Lamp Type	Beam Dimension	Beam Area	Max. Intensity	Min. Working Distance
Used 100W Mercury Vapour Lamp	ø 3,5 in. (ø 9 cm)	10 sqin (65 cm²)	≥ 2.000 µW/cm² (20 W/m²)	0 in. (0 cm)
New 100W Mercury Vapour Lamp	ø 4,5 in. (ø 12 cm)	17 sqin (110 cm²)	≥ 5.500 µW/cm² (55 W/m²)	0 in. (0 cm)
Lamp A (Adequate)	ø 7.5 in. (Ø 19 cm)	45 sqin (290 cm²)	≥ 3.000 µW/cm² (30 W/m²)	3,0 in, (8 cm)
Lamp B (Industry Standard)	ø 8.5 in. (Ø 22 cm)	55 sqin (350 cm²)	≥ 4.600 µW/cm² (30 W/m²)	4,0 in, (10 cm)
Lamp C (Industry Standard)	ø 6.0 in. (ø 17 cm)	30 sqin (200 cm²)	≥ 4.500 µW/cm² (24 W/m²)	6,0 in, (15 cm)

Design, Performance and Qualification Requirements: Beam Size: USABLE BEAM (≥ 100 µW/cm²)

Lamp Type	Beam Dimension	Beam Area	Max. Intensity	Min. Working Distance
Used 100W Mercury Vapour Lamp	ø 15 in. (Ø 38 cm)	1.100 cm² (175 sqin)	≥ 2.000 µW/cm² (20 W/m²)	0 cm (0 in.)
New 100W Mercury Vapour Lamp	ø 19 in. (ø 48 cm)	280 sqin (1,800 cm²)	≥ 5.500 µW/cm² (55 W/m²)	0 cm (0 in.)
Lamp A (Adequate)	ø 23,5 in. ø 60 cm	440 sqin 2.800 cm²	≥ 3.000 µW/cm² (30 W/m²)	3,0 in, (8 cm)
Lamp B (Industry Standard)	ø 11.0 in. (Ø 28 cm)	95 sqin (615 cm²)	≥ 4.600 µW/cm² (30 W/m²)	4,0 in, (10 cm)
Lamp C (Industry Standard)	ø 8.0 in. (ø 20 cm)	50 sqin (320 cm²)	≥ 4.500 µW/cm² (24 W/m²)	6,0 in, (15 cm)

Design, Performance and Qualification Requirements: Beam Size

Concerns of less gradual and smaller beams than Mercury Vapour Lamps:

Process performance and

POD will drastically decrease

Orientation on the inspection surface can be lost

costs of inspection will increase

Intuitive ”natural” inspection can be disordered, where the eyes freely move and easy detect indications, when the lamp can intuitively follow the view of the inspector

Design, Performance and Qualification Requirements: Uniformity

For clear observation, fast and secure detection and non tiring inspection the beam shall be uniform in that way, that there are

- **NO VISUAL INHOMOGENITIES, like:**

  Hotspots, Blind Spots, Cloudiness, Tiny variation, Structured Textures (scratchy micro variation), Splashy Fragments

- **Within the full used beam (area ≥ 100 µW/cm²)**
- **While moving the UV LED Source**
- **Over a white squared paper sheet**

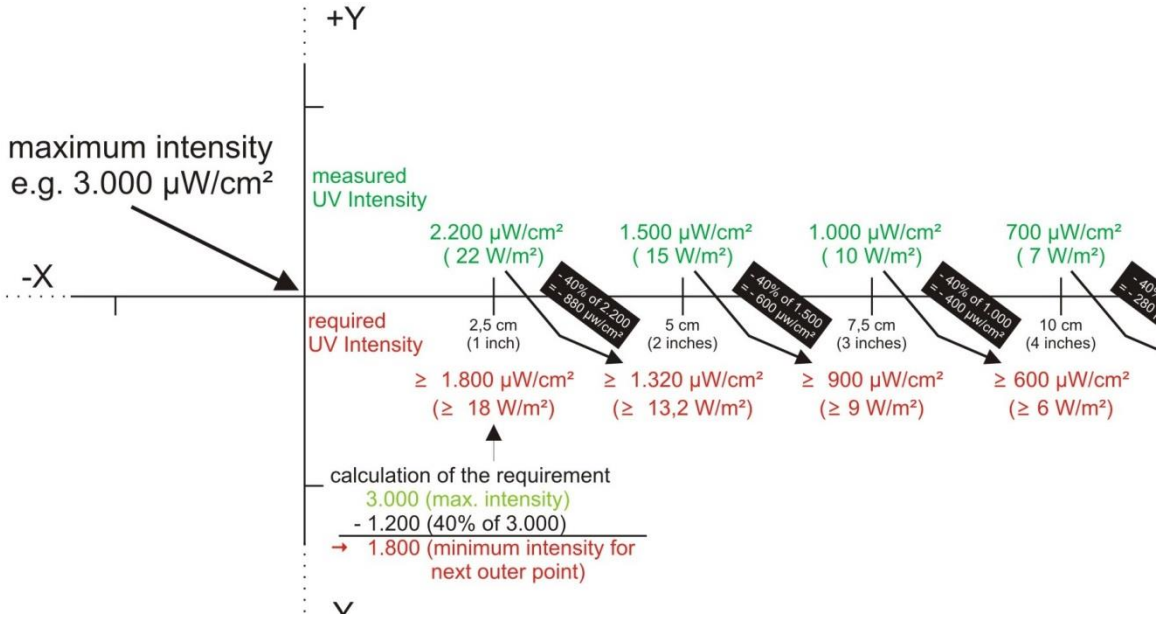
Design, Performance and Qualification Requirements: Uniformity

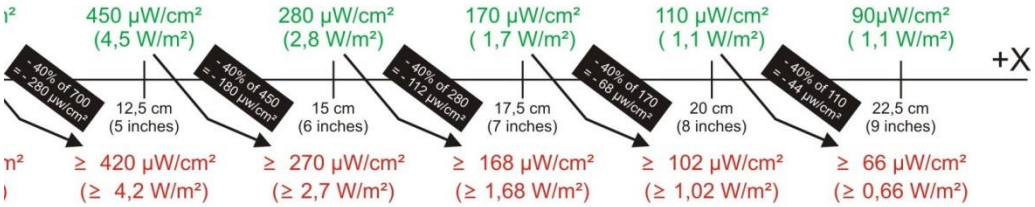
Concerns of non-uniformity:

Causes flickering while moving lamp or part and generate unclear view

what makes inspection much more stressful and extremely tiring for the inspector

Design, Performance and Qualification Requirements: Soft Gradual Drop





Design, Performance and Qualification Requirements: Soft Gradual Drop

Concerns of hard-drop at the edges:

Lost of orientation on the inspection surface

Complete Inspection not intuitively ensured

Tunnelview prohibits detection of indication (indications can be only searched)

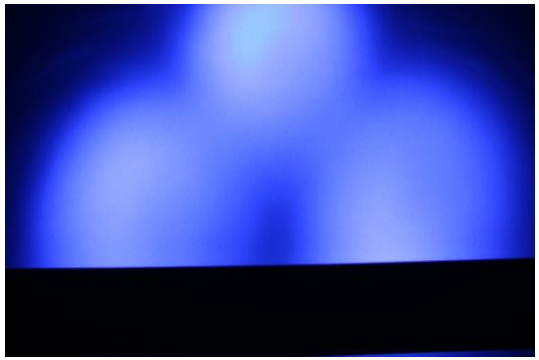
No natural observation possible
(eyes have to follow the lamp)

Design, Performance and Qualification Requirements: Uniformity

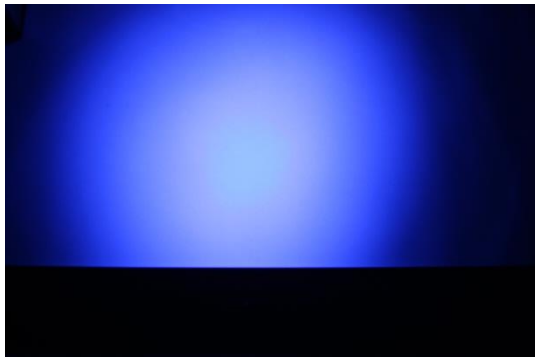
100W Mercury vapour lamp

35W Xenon lamp

Non-uniform
UV-LED lamp



UV LED lamp with blind spot



Common UV LED lamp

Optimized UV LED lamp

Design, Performance and Qualification Requirements: Indicators

Green/Yellow indicators

are not allowed during UV operation

Concerns:

Handicaps and irritates the detection of indications by the inspector who is focussed in detection green-yellow indications

Design, Performance and Qualification Requirements: Cooling Issues / Overheat Monitoring

Monitoring of Active Cooling and Overheat Issue (Lamp and Ambient) are Necessary

Concerns of Overheat Conditions:

Unacceptable Intensity Drop

Unacceptable Wavelength Shift

Drastic Reduction of the Life-Time

Design, Performance and Qualification Requirements: Limitation of intensity drop to 20%

In Contrast to Hg lamps Intensity of UV LED Lamps decrease when warming up

Concerns of Unexpected Intensity Drop:

Indications will not appear and can not be detected.

Design, Performance and Qualification Requirements: Battery Operated UV LED Sources

Battery operated lamps shall automatically switch off when constant output is not ensured

Concerns of Battery Operated UV LED Sources:

Slow Unnoticed Intensity Drop can occur if not electronically monitored and switched off

Lost of Process Stability

Indications can be missed.

Design, Performance and Qualification Requirements: Electronic LED Monitoring with Automatic Switch Off

LED Elements can fail during operation

Concerns of LED failure:

Unnoticed Intensity Drop

Change of the beam pattern

Non-uniformity of the beam occur

Design, Performance and Qualification Requirements: Limitation of Ripple and Pulse Firing

Concerns of Ripple and Pulse Firing:

Invisible Flickering of Indications

Much More Tiring Inspection

Higher Fade of Penetrant

Extensive Qualification and Detailed Certification

Type Test of a Specific Lamp Model

Unit Test of Each Individual Lamp

Detailed Certification Stating the Results of the Qualification Process

Why?

To ensure the expected performance

within the needed temperature range

Enable the user and auditor to have evidence of the

correct and needed performance

User Checks
Intensity Measurement (Daily)

Consider Possible Intensity Drop When

Measuring UV Intensity

prior to stabilization

At least 1.500 µW/cm² shall be measured

to ensure at least 1.200 µW/cm²

when drop is limited to 20%

User Checks
Uniformity Check (Daily)

Moving the Lamp over a White Paper While Observing the Beam Pattern to Check the Uniformity and Beam Style

(Clear Main Centre Area (≥ 1,200 µW/cm² and soft dropping surrounding area ≥ 100 µW/cm²)

User Checks
All Over Performance and Health Check (Monthly)

Checking Constancy of Stabilization Time and Stability of UV Intensity

To check periodically the

all over performance and

stability of the UV LED system

Repair Requirements

Repair needs to be made or at least approved by the lamp manufacturer

Concerns:

Every single component of a UV LED source can cause significant change in performance of an UV LED source

Change of components that can cause major impact requires new qualification to ensure the needed system stability and performance

Optimized UV protection glasses

Optimized for Usage in Darkness

Large size (no limitation of the area of vision)

High Optical Quality

UV400 Cut-off Filter

No Reflections (even Micro Reflections)

High Wearing Comfort

User Adjustable

CE conform (EN 166F & EN 170) / ANSI conformity

Conclusion

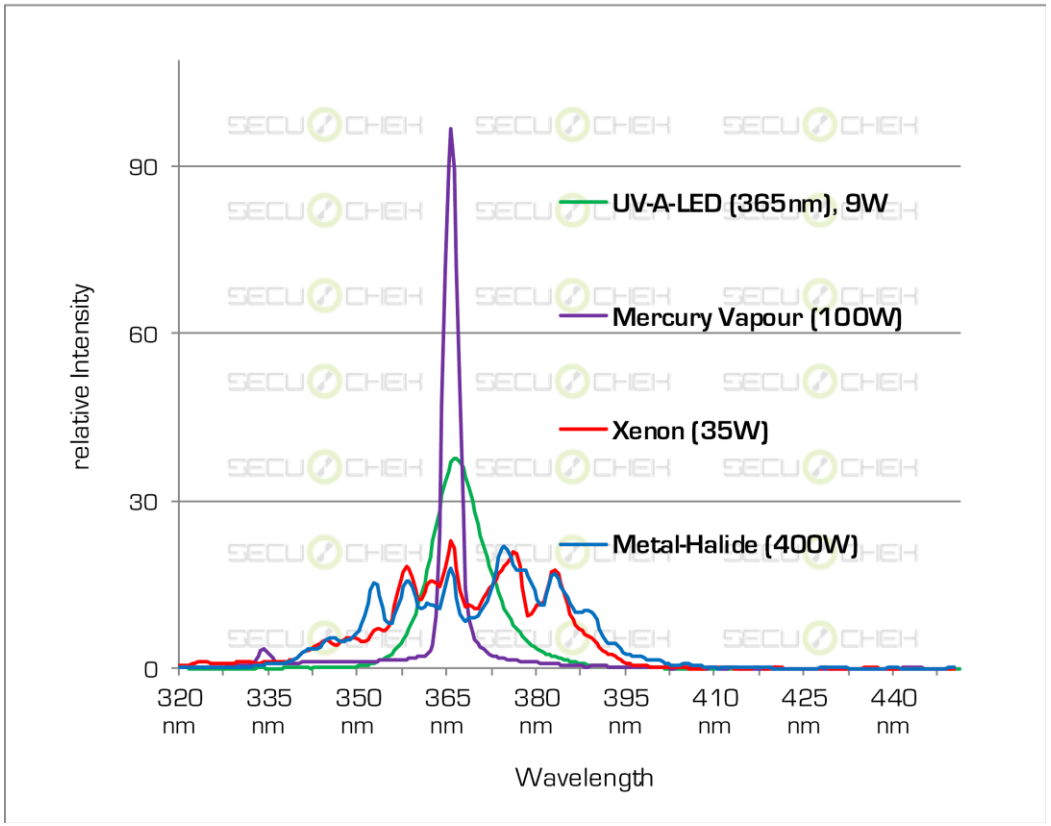
Optimized UV LED lamps (better than Mercury Vapor) can enormously enhanced inspection performance and reduce sustainable the costs for the inspection, while non-optimal UV LED Lamps can dramatically increase the costs for the inspection and drastically reduce the process performance and POD

The price of the source can not significantly affect the price of the inspection, while the UV Source and its performance can drastically influence the costs of the inspection

Questions?

Same Intensity, Different Wavelength Distribution

Comparison of the distribution of the spectral emission of 2.000 µW/cm² from different UV Sources used in NDT



Influence of lamp characteristic on inspection performance and POD

Beam Pattern

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

Influence of lamp characteristic on inspection performance and POD

Beam Uniformity

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