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FLUORESCENT MAGNETIC TESTING IN UNDARKENED AREAS: KEY SAFETY AND COST ADVANTAGES

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Agenda

1. International Standards
2. The Luminescence of Magnetic Powders
3. The Tests Done
4. Company Case Studies
5. Conclusions

International Standards

ASTM E709; ASME V Art. 7; ISO 9934-1…

"If the indication obtained under the proposed conditions appears the same or better than that obtained under standard conditions, the proposed procedure shall be considered qualified for use"
(Standard conditions: UV light>1.000 µw/cm^2, Visible light<2 fc)

ASME V Art. 7

"A higher UV-A intensity allows the acceptance of a proportionally higher environmental white light intensity, provided that it can be proved that the contrast between the indications and the background is maintained unchanged"

EN ISO 9934-1

8.4.5 *Dual Colors*—Dual-colored particles are available that are readily detectable in visible light and also display fluorescence when viewed under ultra-violet light or a combination visible and ultra-violet light. Use in accordance with the manufacturer's recommendations.

E709

International Standards

Why using Fluorescent magnetic testing in undarkened areas? Key safety and cost advantages

Safety Advantages:

1. Possibility to keep cabin/curtains opened: operators work in a visible light environment
2. No high flammability risk due to white contrast paint when fluorescent MT can be an alternative to visible (black/white) MT

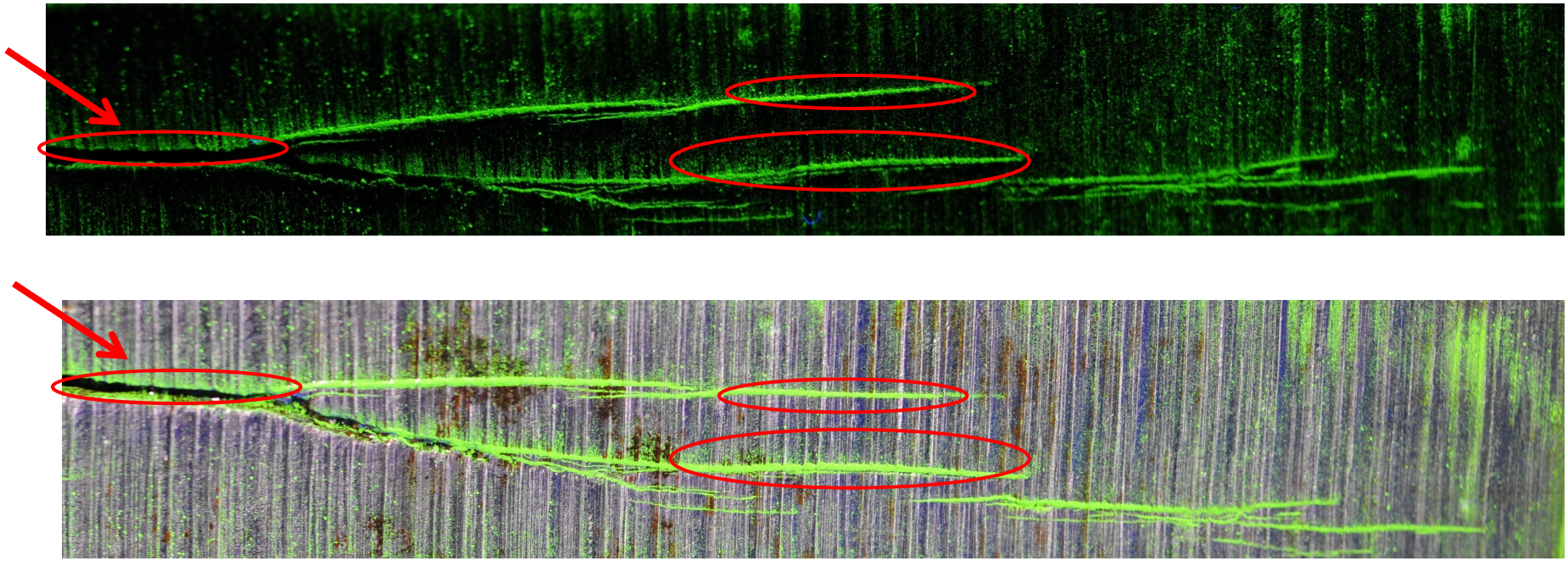
Cost Advantages:

1. No time and costs to darken inspection area (<2 fc)
2. Easier/faster visibility of indications (esp. very large/very superficial)
3. If visible light is >100 fc, VT and MT are done by one operator in quick succession
4. No dark area eye-adaptation time
5. Higher productivity and lower costs compared to visible MT

International Standards

Fluorescent magnetic testing in undarkened areas

Why? Key safety and cost advantages

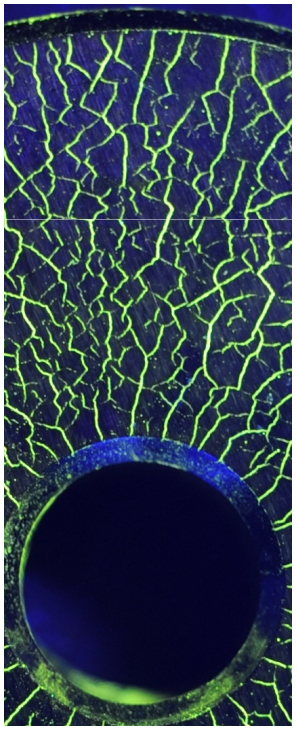


- Dual-colored particles have the same sensitivity of fluorescent particles
- Dual-colored particles may better reveal some critical defects as compared to fluorescent particles in darkened inspection booth

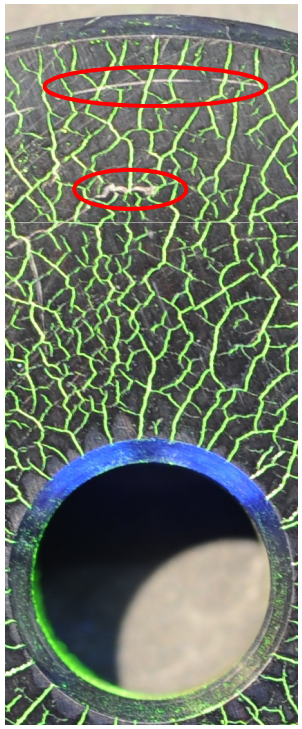
International Standards

Fluorescent magnetic testing in undarkened areas
Why? Key safety and cost advantages

- Reference Block ASTM E 1444 – ISO 9934-2
  - Dual Colored magnetic powder Elite FW1



UV Light: 1.500µW/cm²
Visible Light: < 20 lx



UV Light: 3.000µW/cm²
Visible Light: 1.200 lx

International Standards

Key characteristics of dual-colored magnetic particles:
Specifically designed for dual-color use

TECHNICAL DATA SHEET

1. Product and Supplier identification

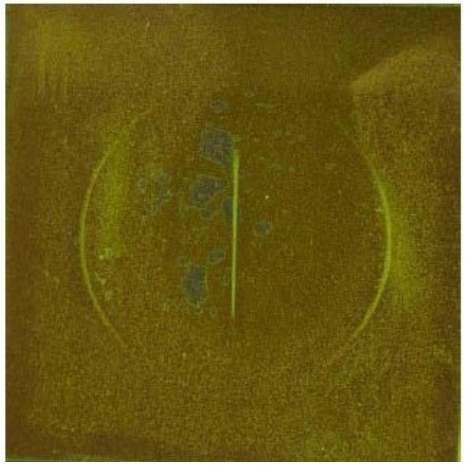
Product name:
ELITE FW1 AC
Fluorescent and Dual-colored Magnetic Liquid Concentrate
High Rust Protection

Supplier:

NDT ITALIANA SRL
Via del Lavoro 28
20863 Concorezzo (MB) Italia
Tel: (39) 039.647590
Fax: (39) 039.647799
www.ndt.it info@ndt.it

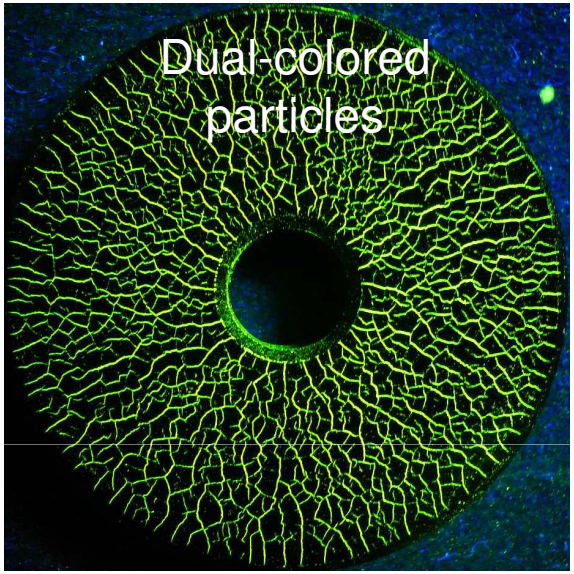
Elite FW1 AC Fluorescent and Dual-colored Magnetic Liquid Concentrate

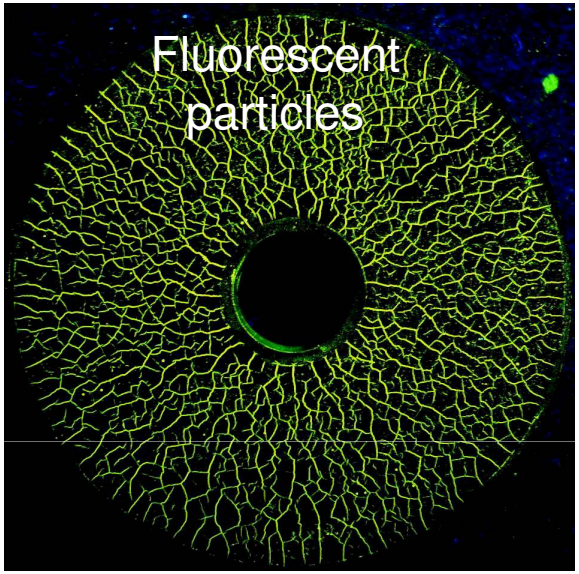
UV Light: 1200 microW/cm^2	UV Light: 2000 microW/cm^2 (or more)	UV Light: 0 microW/cm^2
Visible Light: < 20 lx	Visible Light: 2000 lx (or less)	Visible Light: 500 lx

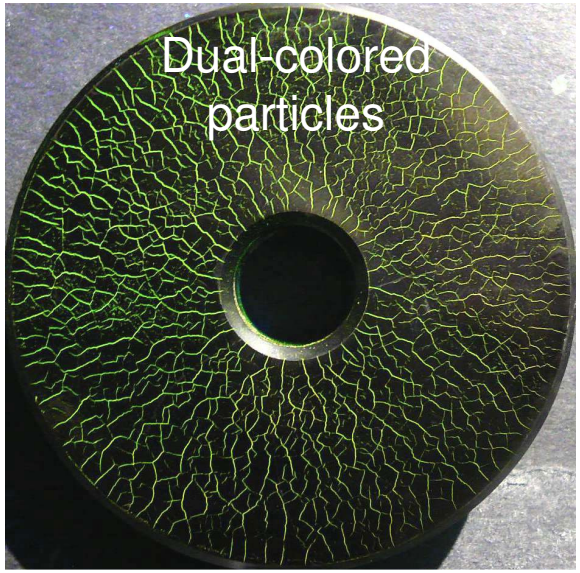

International Standards

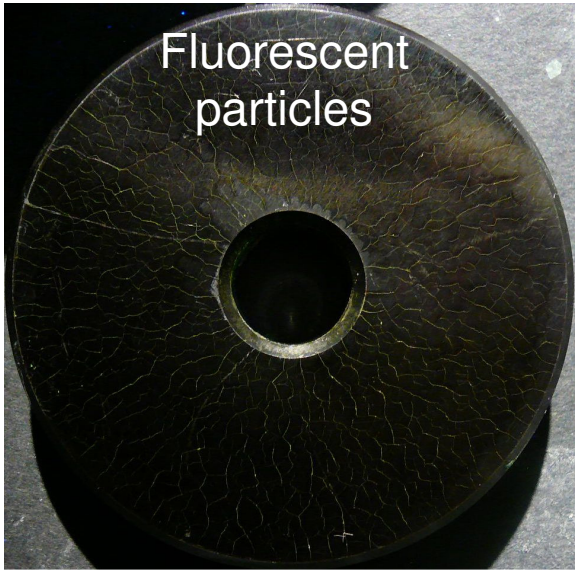
Key characteristics of dual-colored magnetic particles:
Dual-colored Versus Fluorescent powders in undarkened area





Standard conditions
UV light > 1.000 µW/cm²
Visible light < 20 lx



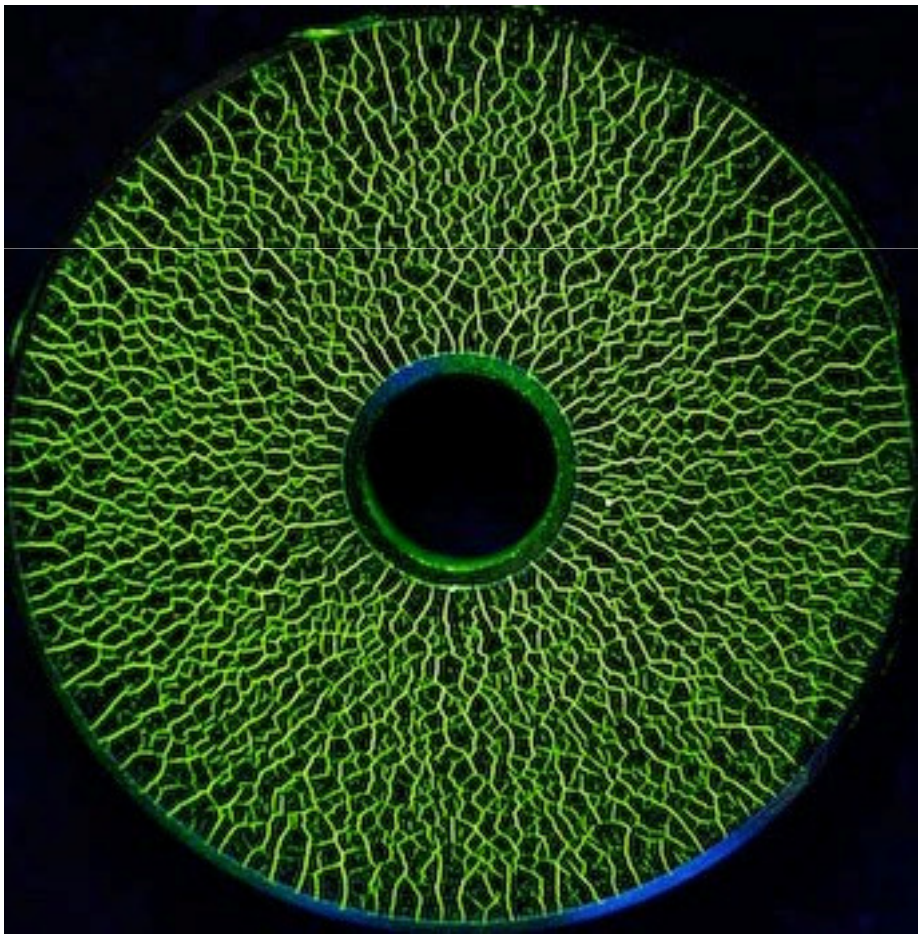


Undarkened area
UV light > 1.000 µW/cm²
Visible light > 20 lx

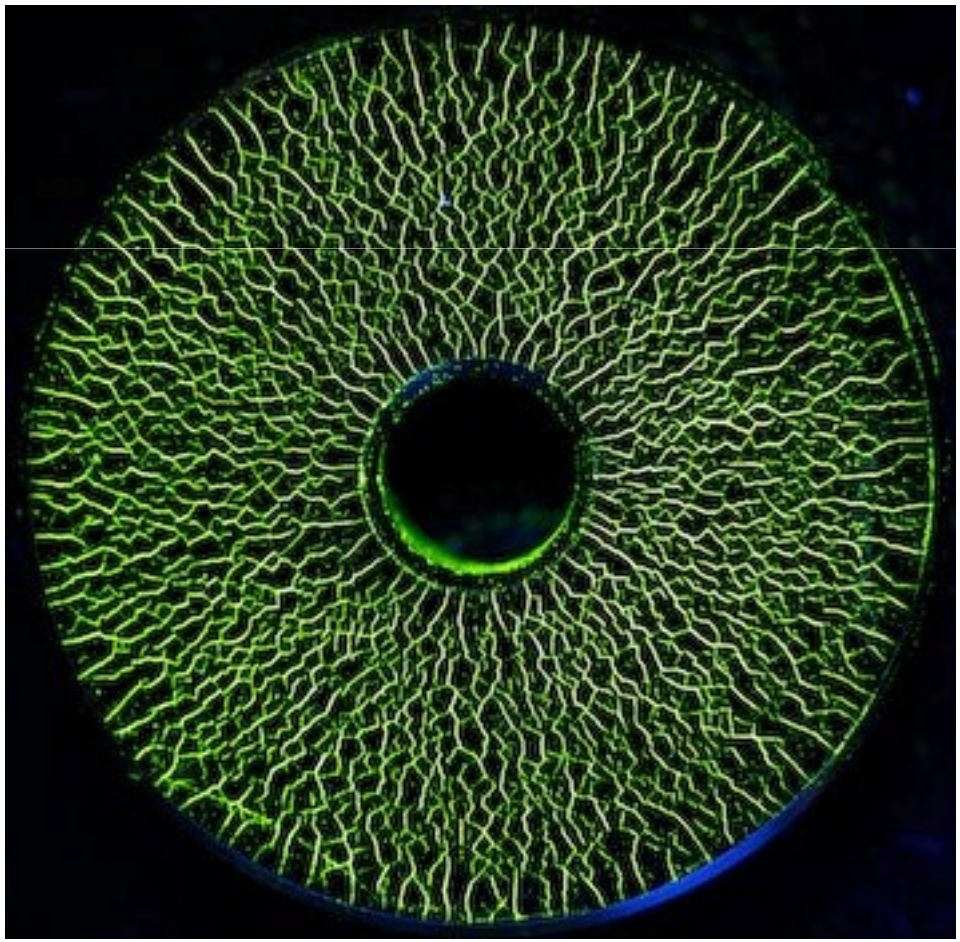
International Standards

Key characteristics of dual-colored magnetic particles:
“Easily suspendable” and good sensibility signal/ background noise

Dual-colored powder



Fluorescent powder with high luminescence but high background



International Standards

Key characteristics of dual-colored magnetic particles: Playing with the key variables

The key variables:

1. Visible light (max intensity)
2. UV light (min intensity)
3. Particle concentration

NB: All parameters are the same in dual-colored and fluorescent magnetic testing (example: magnetization strength, equipment…)

"*The concentration of dual-colored particles in the wet-method bath suspension may be adjusted to best perform in the desired lighting environment*"

ASTM E709

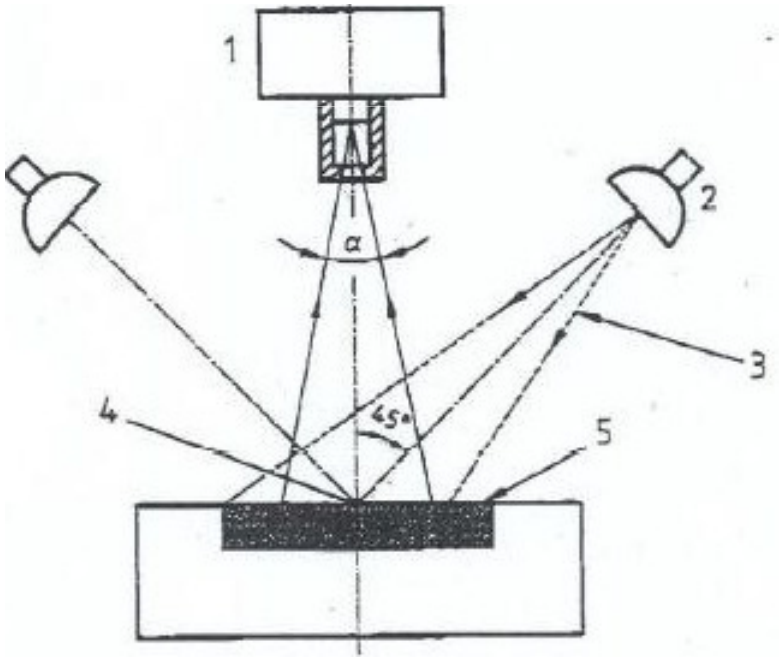
→ Companies can fine-tune these values according to their own production in order to:

- Optimize quick visibility of indications (higher productivity)
- Lower concentration of magnetic powder (lower production variable costs)

The Luminescence of Magnetic Powders

Measuring fluorescence: ISO 9934-2 Vs. ASTM E1135

ISO 9934-2



E1135

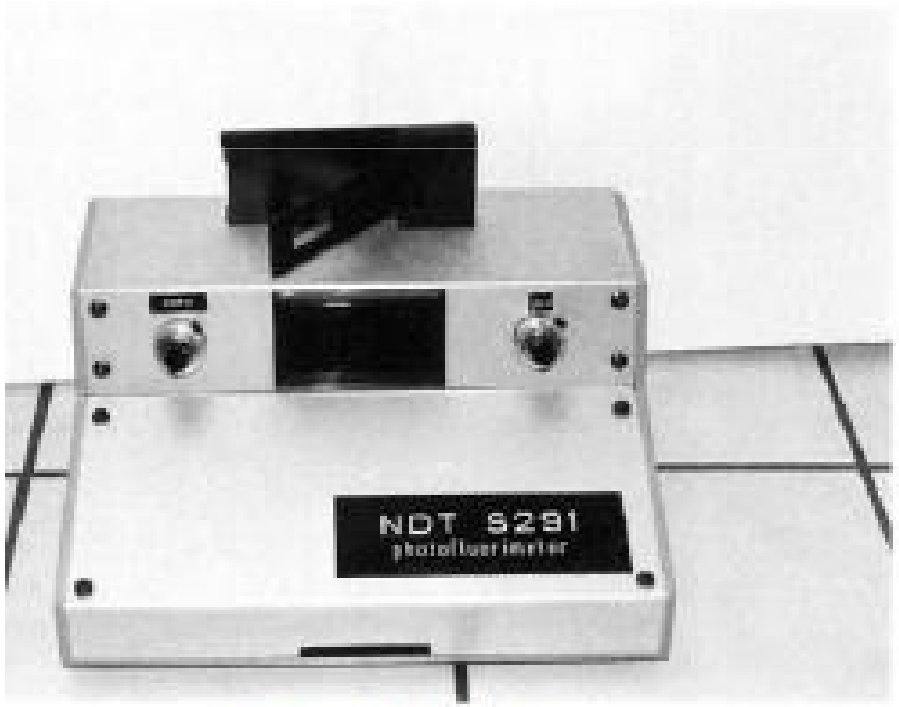


FIG. 5 Sample Holder

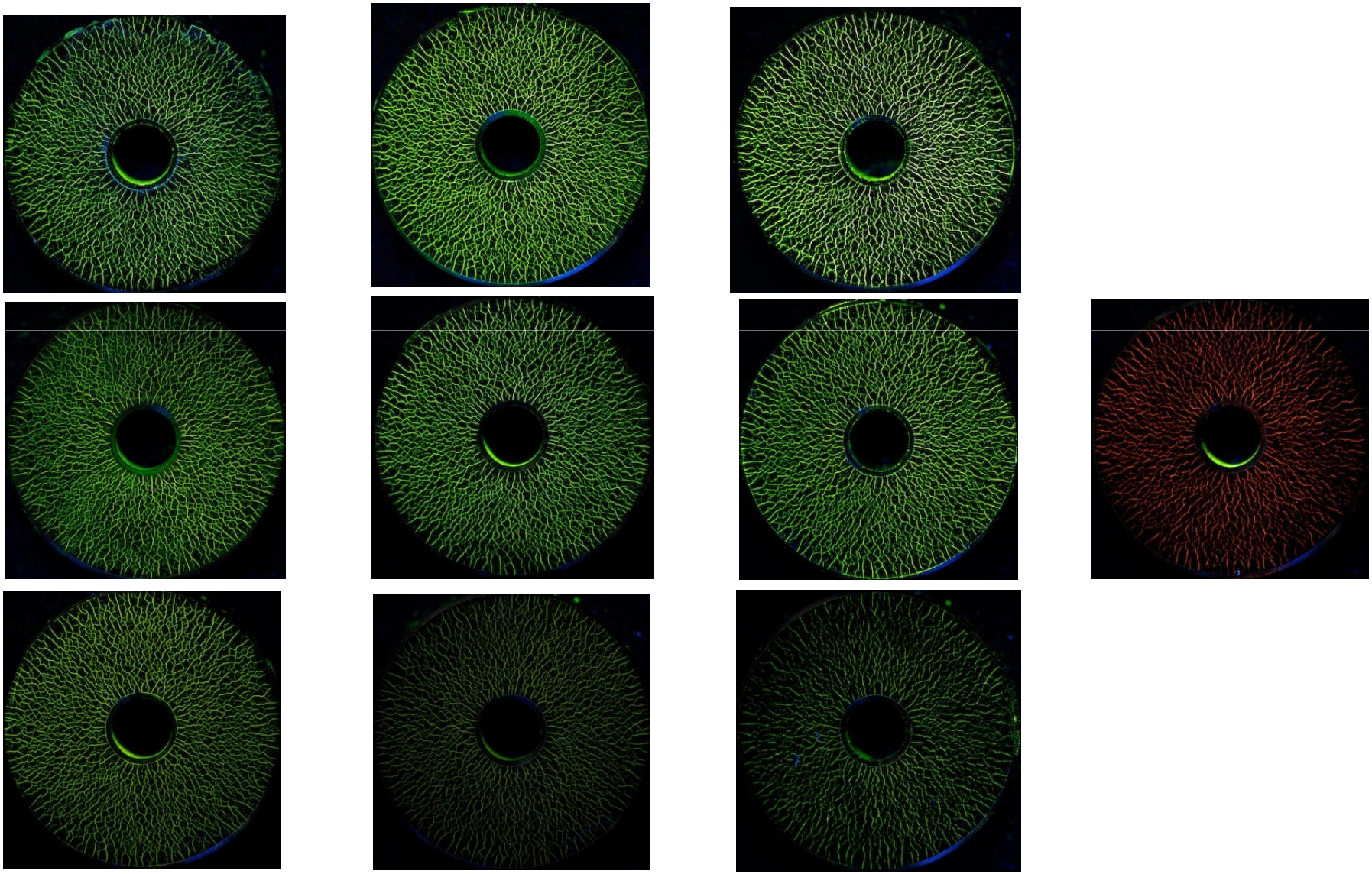
The Luminescence of Magnetic Powders

Results obtained according to ASTM E-1135

Code	% Measured	Difference %
G 8	100 (set @ 100 as reference)	0
G 9	180	+80
G 6	60	-40
M 1	70	-30
M 4	140	+40
L	300	+200
A	40	-60
K	90	-10
C 1	50	-50
FW 1	220	+120

The Tests Done

Pic. A): ref. block type 1 ISO 9934-2 (ASTM E 1444)
UV Light: 15 W/m2; visible light: < 20 Lux



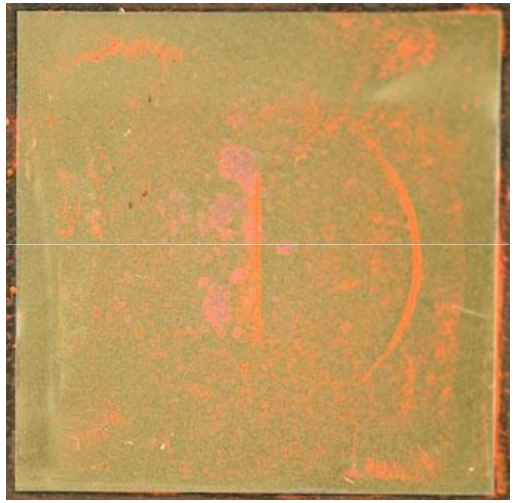
The Tests Done

How does dual-colored particles compare each other and in comparison to visible particles in white light 500 lx

Elite BW2 + WBL5
(visible method)

Elite FW1
(Dual-Colored)

G6
(Dual-Colored “red”)



- Artificial defect shims (ASME V art.7, ASTM E709)
- Dual colored particles can be a substitute for visible (black/white) MT

- Powder recommended concentrations (economic implications)
  - Elite FW1: 1-2 g/l
  - G6: 8 g/l

Company case studies

Energy, Automotive, Oil&Gas/Pipe, Welding Industry

- Forged steel piece
- Elite FW1 dual-colored magnetic particles Versus fluorescent magnetic particles
  - UV light: 2.500 µW/cm^2
  - Visible light: 250 lx

Dual colored magnetic particles

Fluorescent magnetic particles

Company case studies

Energy, Automotive, Oil&Gas/Pipe, Welding Industry

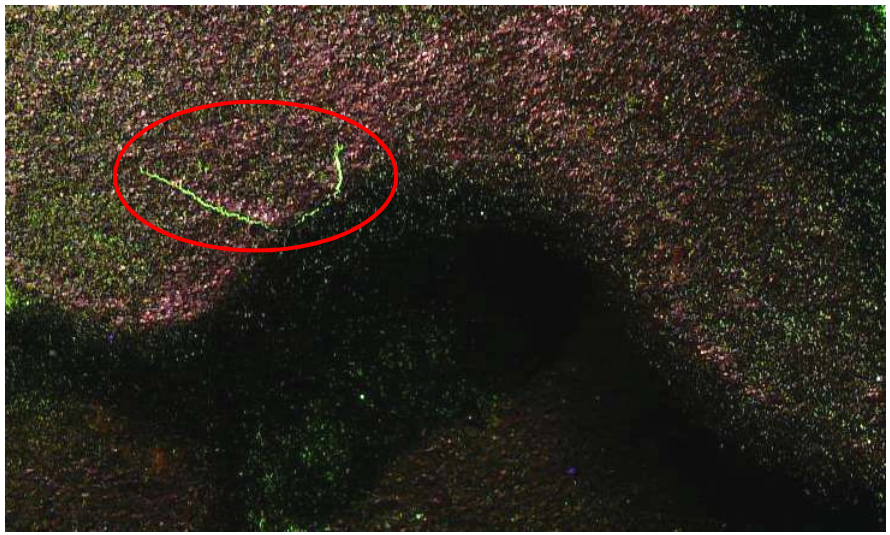
- Welding on a pressure vessel
- Elite FW1 dual-colored magnetic particles Versus fluorescent magnetic particles
  - UV light: 2.000 µW/cm^2
  - Visible light: 90 lx

Company case studies

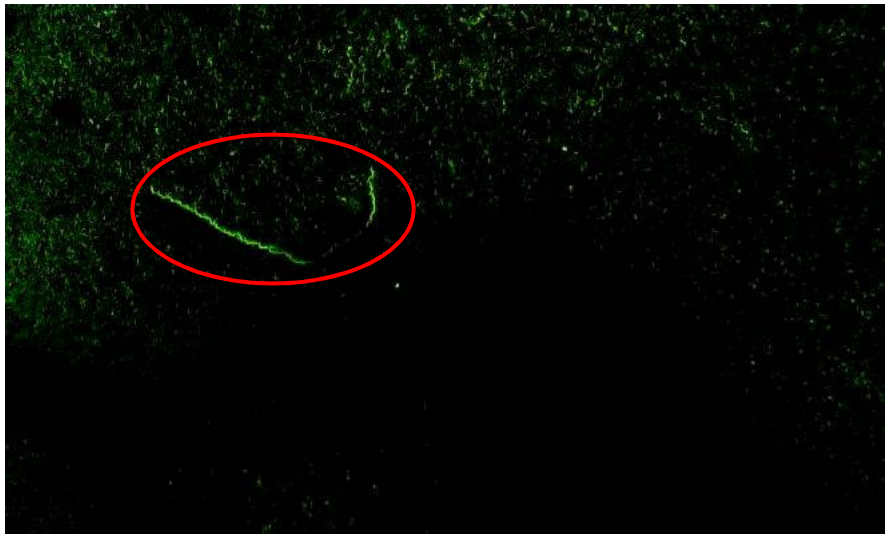
Energy, Automotive, Oil&Gas/Pipe, Welding Industry

- Automotive industry – European car manufacturer

- Elite FW1 dual-colored magnetic particles
  - UV light: 2.000 µW/cm^2
  - Visible light: 300 lx



- Fluorescent particles
  - UV light: 1.200 µW/cm^2
  - Visible light: < 20 lx



Company case studies

Energy, Automotive, Oil&Gas/Pipe, Welding Industry

- Flawtech™ specimen number MT-5220

- Dual colored magnetic particles

- Fluorescent magnetic particles

- Visible magnetic particles

Conclusions

Fluorescent MT in undarkened areas: key advantages

Safety Advantages:

1. Possibility to keep cabin/curtains opened: operators work in a visible light environment
2. No high flammability risk due to white contrast paint when fluorescent MT can be an alternative to visible (black/white) MT

Cost Advantages:

1. No time and costs to darken inspection area (<2 fc)
2. Easier/faster visibility of indications (esp. very large/very superficial)
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5. Higher productivity and lower costs compared to visible MT

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Michele Cevenini

NDT would like to thank all Companies that contributed to this presentation with their pictures and written reports

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"The difference between difficult and impossible is that impossible takes longer. Miracles just require faith"

"FLUORESCENT MAGNETIC TESTING IN UNDARKENED AREAS: KEY SAFETY AND COST ADVANTAGES"

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ABSTRACT

International Standards (ASTM E-709, ASME V Art. 7, ISO 9934-2) allow the use of fluorescent magnetic particles in undarkened conditions. This possibility has proved to have significant economic and safety implications that could be further exploited by Companies. When working in undarkened conditions, the quality of dual-colored magnetic powders used is of primary importance.

Keywords: *fluorescent magnetic powders, dual-colored magnetic particles, UV light, visible light, visual testing, magnetic testing, oil and gas industry*

Fluorescent Magnetic Testing in "undarkened" areas: Key Advantages

International Standards have recently taken into account the need to use fluorescent magnetic particles also outside the "standard" conditions of darkened area (visible light max 20 lx) and UV light 365 nm of minimum 10 W/m^2 (1.000 µW/cm^2). ASME Sect. V Art. 7 describes in Appendix III : "Magnetic Particle Examination using the Yoke technique with Fluorescent Particles in an un-darkened area". ASTM E-709 describes how dual colors magnetic particles (par. 8.4.5) "display fluorescence when viewed under ultra-violet light or a combination of visible and ultra-violet light. Use in accordance with the manufacturer's recommendations". Also the European Standards ISO 9934-1 writes in par. 10.2: "A higher UV-A radiation allows the acceptance of a proportionally higher environmental white light intensity, provided that it can be proved that the contrast between the indications and the background is maintained unchanged".

When doing a magnetic testing in an undarkened area, operators can of course use coloured magnetic particles both dry and wet method: provided that there is enough contrast with the surface under examination, or having to apply white background lacquer (highly flammable) to improve contrast.
Fluorescent magnetic particles have several advantages: higher sensitivity, easy application, no need to apply (and after remove) any white background paint.

The possibility to perform a Fluorescent Magnetic Testing when requested by the final customer also in undarkened areas, does not only mean to solve the big problem of having to darken surface inspection with high costs and time wasting, especially in the case of large pieces or and/or outdoors inspections.

Some Companies have in fact already understood and exploited another key cost advantage of being able to perform fluorescent Magnetic Testing (MT) with a high environment visible light (over 100 foot candles): the possibility to perform a much quicker and less labour intensive Visual Testing (VT), because VT can now be performed by the same operator at the same time or anyway in quick succession with MT.

Other main advantages of being able to perform fluorescent Magnetic Testing (MT) with some environment visible light are:

- Better visibility of indications which are either very large or very superficial: in both cases due to its nature the indication will withhold a lower or no quantity of fluorescent magnetic powder and will be better detected by the operator in presence of some white light;
- Higher level of attention and better working condition of operators: the presence of some ambient visible light and air is likely to better the working conditions of the operators, hence resulting in a higher attention level as compared to a totally darkened and closed environment

Qualification Procedure

ASME Sect. V Art.7 states (Mandatory Appendix III-751) that reference standard artificial flaw shims (described in T-764) shall be used to demonstrate to the Inspector that the alternative procedure allows to obtain indications that are the same or better than those obtained with the "standard" procedure. This procedure would satisfy also the ISO Standards, that ask to prove that the contrast between the indications and the background is maintained by increasing the intensity of UV light when in presence of a higher than standard white light intensity.

In Appendix III (Table III-721) are listed as "essential variables" the qualifying points of the procedure, amongst which we can find "Particle manufacturer name and product designation". This is an important difference to notice with for example the initial Table 721 of ASME Sect.V that lists the essential variables of a standard magnetic test: it is only necessary to specify if particles used are: "fluorescent or visible, colour, particle size, wet or dry", so generically which kind of particles it is being used. When operating in non-standard conditions instead, I have to specify the name of the product and of the manufacturer. This implies that the quality of the fluorescent magnetic particles is considered of primary importance when operating in undarkened areas.

In particular, to pass the qualification tests to be used also in undarkened conditions, the magnetic particles must possess a very high luminescence and low background at the higher levels of UV light needed to compensate proportionally higher levels of visible light and hence maintain "the same or better" contrast.

Another key factor to consider is particles' "weight": in fact, some of the powders we tested from US and Japanese manufactures have shown a fluorescence which is high enough to possibly be qualified to be used in undarkened areas (example the powders we coded "M4" and "L"). On the other hand though, these particles have shown to be much "heavier" with the consequence that their suspension will be more problematic, especially in automatic magnetic benches.

For the qualification tests of fluorescent particles in undarkened areas (UV Light AND Visible Light > 20 lx) shims described in ASME V art. 7 T-764 have been used, and all tests have been photographically documented.

Measuring the Fluorescence of Magnetic Powders

Of great importance is the evaluation of the Luminescence, a parameter directly linked to the visibility of the defect in any lighting condition and hence to the first concern of every operator: to miss a defect because non very well visible. The best visibility is given by the best Luminescence (and other factors such as for example the lowest "background noise").
ISO 9934-2 describes a measurement method of Luminescence in par. 7.5.1 with the objective to quantify the fluorescent coefficient cd/W, through an equipment and a procedure that we have used at the beginning to evaluate the fluorescence of the magnetic particles under test.

Unfortunately this method involves some practical process issues, that in our opinion cause the results to be questionable in terms of reproducibility and comparability.
For example, it is not specified how to prepare the surface of the fluorescent powder under exam. To get an even surface, the same fluorescent powder has been first put under vibration, and secondly pressed down.
The two surfaces looked quite similar to the naked eye: but the pressed one that seemed a little more plain gave us readings even 100% higher than the same sample obtained by vibration; and even the way the surface was pressed caused great luminance differences. Furthermore, in the ISO 9934-2 Standard there is no mention of filters on the luminance sensor to correct the reading for the human eye, as for example is the case in ASTM E1135.

ASTM E1135 covers in fact a similar topic: the comparison of liquid penetrant fluorescence. This standard describes the use of a dedicated instrument, the Photofluorometer NDT S-291 produced by NDT Italiana, that eliminates all of the uncertainties above described, by fixing precise measurement positions, UV irradiation, primary and secondary filters on the measurement sensor, a sample holder containing filter paper wet with

penetrant: all this brings to the best repeatability, with results always varying less than 5% (provided that S-291 is periodically calibrated).

So we have tried to use it to compare fluorescent magnetic particles, by using the same sample holder and a sample of magnetic powder enclosed in non-fluorescent tape which has proved to be simple to prepare, reproducible and conservable. A detailed description of how to prepare samples to compare the fluorescence of magnetic powders can be found on NDT Italiana's S-291 Manual or can be supplied upon request.

The powders and manufacturers of fluorescent magnetic powders in the table below have been considered representative of the global industry; codes have been used to hide the real commercial product names.

Table 1

Code	White Light color	Declared Particle Size
G 8	Dark green	fine
G 9	Medium green	medium
G 6	Red	medium
M 1	Brown	fine
M 4	Medium green	medium
L	Light green	medium
A	Brown	fine
K	Light brown	fine
C 1	Brown	fine
FW 1	Medium green	fine

(FW 1 is part of the Elite line, produced by NDT ITALIANA)

The samples have been read with photofluorometer NDT S-291, setting the first one called "G8" at 100; the measured values have been inserted in Table 2.

Table 2

Code	% Measured	% Difference
G 8	100 (set at 100 as reference)	0
G 9	180	+80
G 6	60	-40
M 1	70	-30
M 4	140	+40
L	300	+200
A	40	-60
K	90	-10
C 1	50	-50
FW 1	220	+120

This width of readings have also been confirmed by our results in cd/W using the ISO 9934-2 method.
ASTM E1135 can help us understanding (point 5.2): "Because the eye responds logarithmically rather than linearly to changes of brightness, differences in brightness must be fairly large to be significant. Differences of 25 % are obvious, 12 % noticeable, and 6 % detectable by the eye. Experts may sometimes detect 3 % differences, but these are not usually significant to the average observer."
If only a 25% difference of brightness is obvious to the human eye, how will powders that give us readings much higher or lower than this percentage perform, in the every day use?

The tests performed on reference blocks

At this point we decided to evaluate all powders on reference blocks with standard defects: first, the reference block type 1 ISO 9934-2, approved also by ASME E 1444.

All photographs of this paper have been taken with a Nikon camera model D700, lens Micro-Nikkor 105/2.8, always specifying the intensity and type of light used. All powders have been diluted in the same liquid carrier at the same percentage.

The first set of photographs of reference block type 1 (identified "A") have been taken with a UV light of 15 W/m^2 and white light under 20 Lx: clear differences of indications can be seen.
All the powders that had measured values between -30% and +80% from the "100 sample" give indications that are only little noticeable; while the 2 powders with the lowest luminance (under -30%) confirm on the real defects very low indications in terms of visibility and contrast, easy to see by naked eye.
For what concerns the 2 powders with the highest luminance values, it is confirmed that between +80% and +200% the visibility of defects is proportionally growing.

The powder coded "L", that has the highest luminance, has also the disadvantage of a very high fluorescent background, which results in an overall lower visibility of defects, due to the lack of contrast and a "dazzle effect" on the operator.

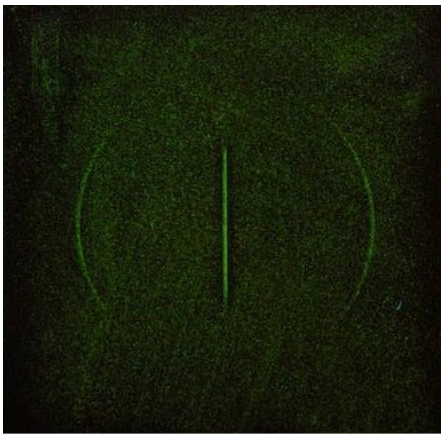
The set of photos identified as "B" have been taken by applying the same magnetic particles to another reference sample described in ASTM E 709, the Magnetic Stripe Card (ISO 7810), with results similar to those of the "A" set of tests. This test has also allowed for a quantitative evaluation of sensitivity of magnetic powders, thanks to a graduated sensitivity line from 1 to 10 on the card.

The powder coded "G6", red under white light, also shows a reddish fluorescence under UV light and is sold by the manufacturer as "dual use", meaning usable also under white light.
Considering that the International Standards do not specify which colour the "dual use" particles have to be, we have thought to compare under white light "G6" powder with fluorescent powder Elite FW1 (green under white light) and with black powder Elite BW2 applied on white background paint Elite WBL5. To do so we have used the requested sample defects "shims" with white light 1.100 lx.

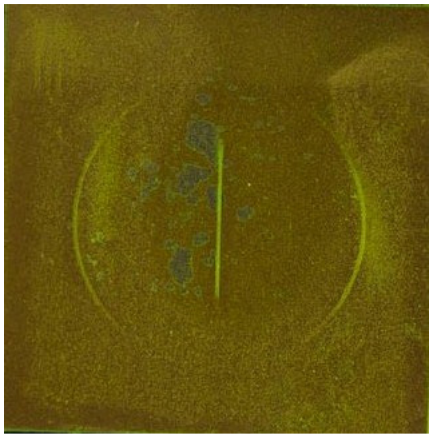
All powders have been diluted according to the manufacturer's instructions: G6 8 g/l, Elite FW1 2 g/l, Elite BW2 10 g/l. These concentrations obviously imply significant economic evaluations.

The results of this test, illustrated in the "C" set of photos, confirm the possibility to use both particles of red colour and of green colour like Elite FW1 under white light, as an alternative to the use of black particles and white background paint, of course always provided there is enough contrast with the colour of the surface under examination. On the everyday use it is easy to find red oxidized steel that gives very little contrast with red magnetic particles; it is difficult to understand why some producers have chosen this colour. Maybe it is just for similitude with the red liquid penetrants, but these require of course the use of a white developer.

Next, we have evaluated fluorescent powders under UV and white light combined, still using the sample defects "shims", with UV light 30 W/m^2 and 1.200 lx visible light, values that could well be found in a situation of high illumination on the field. These qualification test will have to be repeated only if the value of UV intensity (minimum) or white light (maximum) change (ASTM Sect.V Art.7 Appendix III-761 and III-762).
The results of this test, illustrated under the "D" set of photos, confirm that the powders with the highest luminescence in tab.2, like Elite FW1, satisfy the requirements for Qualification to be used in undarkened conditions. The powders with the lowest luminance are nearly invisible, while for what concerns the powders with medium luminance their intensity tends to vary considerably according to the intensity of respectively the UV and white light.



Picture D 1
Fluorescent Magnetic Powder Elite FW1
UV Light: 1.500µW/cm^2
Visible Light: < 20 lx



Picture D 2
Fluorescent Magnetic Powder Elite FW1
UV Light: 3.000µW/cm^2
Visible Light: 1.200 lx

Conclusions

International Standards (ASME V Art.7, ASTM E709, ISO 9934) allow the possibility to use fluorescent magnetic particles in undarkened areas, meaning with visible light greater than 2 foot candles (about 20 lx). The main advantages are:

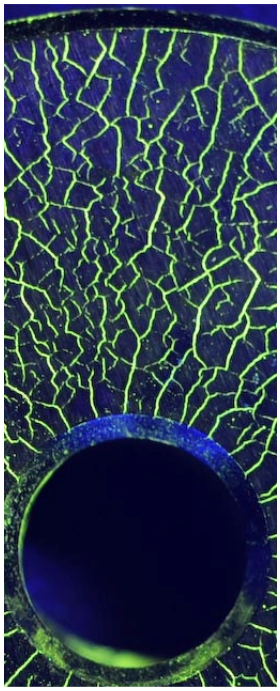
1. **Cost Reduction**:

a) If visible light is kept to a level high enough to perform also visual testing (500 lx according to ISO 3059, 100 foot candles = 1.076 lx to ASTM E709) then both Magnetic Testing and Visual Testing can be conducted by one person and in less time, compared to the two separate NDT tests: Magnetic Tests in darkened area by one operator and a separate Visual Testing;
b) No costs and time needed to darken the inspection area to below 2 foot candles (about 20 lx), especially in the case of large parts and outdoor inspections;
c) No need to buy, apply and remove 2 products (black magnetic particles and white background lacquer) in case fluorescent magnetic testing can be done in place of visible magnetic testing;
d) No dark area eye adaptation time needed when performing fluorescent magnetic testing;
e) Better visibility of indications, in particular those which are very large of very superficial (example rust, scratches)

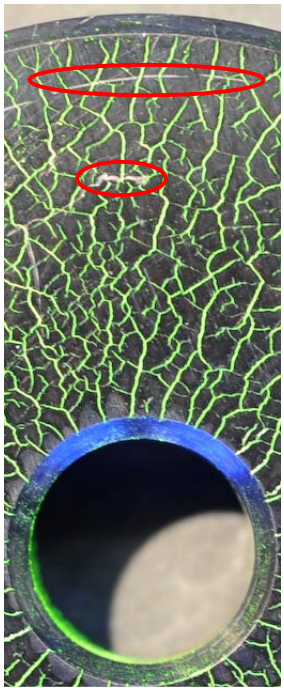
2. **Safety**:

a) No high flammability risk due to the white background lacquer when fluorescent magnetic testing can be an alternative to visible magnetic testing;
b) Possibility to keep existing obscuration means (curtains, cabins) opened for better air circulation and operator's safety. The attention level of operators is likely to be higher compared to a closed and totally darkened area, resulting in higher productivity and easier detection of indications

When doing fluorescent magnetic testing in undarkened areas, of greatest importance is the brand and quality of the dual-colored magnetic powder used: tests have shown that only very few magnetic particles can be actually qualified for use in undarkened areas with a combination of visible and UV light; Elite FW1 dual-colored magnetic powder has been qualified for use in undarkened areas.



Picture of Reference Block
ASTM E 1444 – ISO 9934-2
Fluorescent Magnetic Powder Elite FW1
UV Light: 1.500µW/cm^2
Visible Light: < 20 lx
Fluorescent Magnetic Testing



Picture of Reference Block
ASTM E 1444 – ISO 9934-2
Fluorescent Magnetic Powder Elite FW1
UV Light: 3.000µW/cm^2
Visible Light: 1.200 lx
Visual Testing AND Fluorescent Magnetic Testing (superficial scratches not indicated by fluorescent magnetic testing can be seen)

Company Case Studies

NDT Italiana has worked over the last few years with major international Companies, especially in the Oil and Gas and Automotive industry, on the qualification of fluorescent magnetic powders in undarkened areas in production, meaning with visible light over 20 lx.

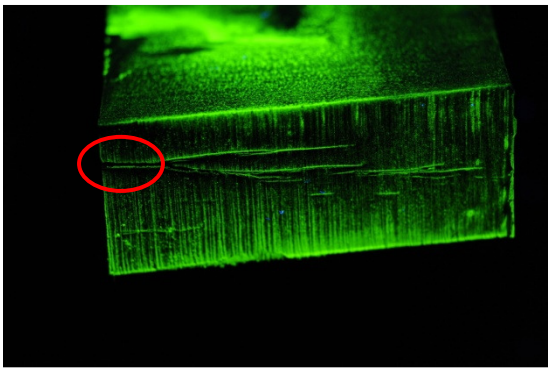
The most interesting possibilities opened are:

1) the feasibility of a fluorescent Magnetic Testing (MT) in presence of visible light of 100 foot candles (1.076 lx) and over, which allows a much quicker and less labour intensive Visual Testing (VT), because VT can now be performed by the same operator at the same time or anyway in quick succession with MT;
2) the elimination of all inspection-area darkening costs.

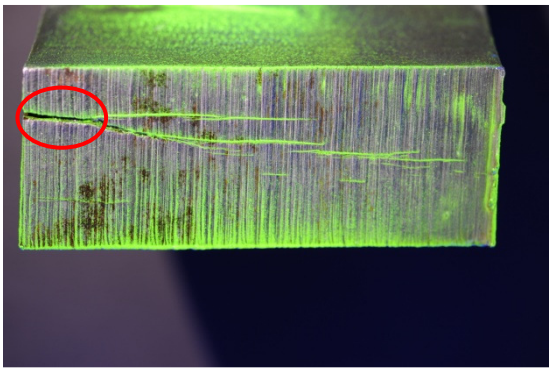
For all photographic evidence both customer production test pieces and Flawtech Specimens have been used.

Picture 1A
Specimen number MT-5220 Flawtech
Fluorescent Magnetic Powder Elite FW1
UV Light: 1.500µW/cm^2
Visible Light: < 20 lx

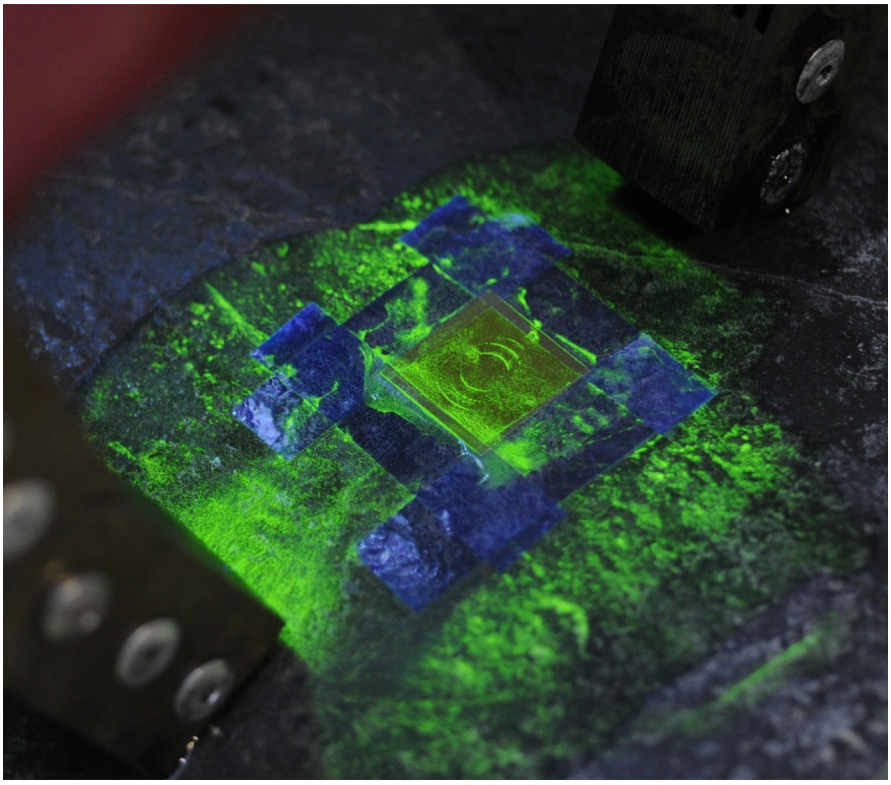
Picture 1B
Specimen number MT-5220 Flawtech
Fluorescent Magnetic Powder Elite FW1
UV Light: 3.000µW/cm^2
Visible Light: 500 lx



Picture 2A
Fluorescent Magnetic Powder Elite FW1
UV Light: 1.500µW/cm^2
Visible Light: < 20 lx



Picture 2B
Fluorescent Magnetic Powder Elite FW1
UV Light: 3.000µW/cm^2
Visible Light: 1.200 lx
Visual Testing AND Fluorescent Magnetic Testing
(large defects identified much better and faster)

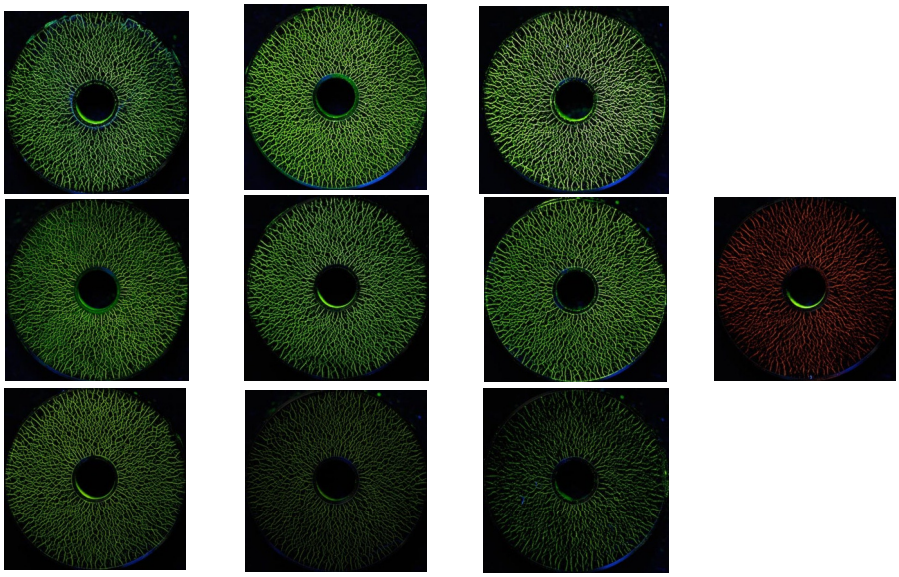


Picture 3
Fluorescent Magnetic Powder Elite FW1
UV Light: 3.000µW/cm^2
Visible Light: 1.200 lx
Visual Testing AND Fluorescent Magnetic Testing of Pipes for Oil and Gas Industry

Appendix

The Tests Done

Pic. A): ref. block type 1 ISO 9934-2 (ASTM E 1444)
UV LIght: 15 W/m2; visible light: < 20 Lux



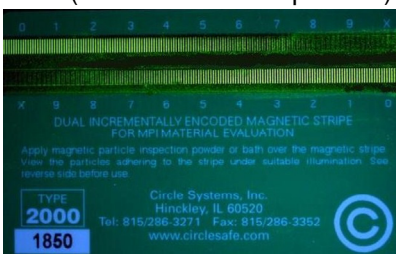
The Tests Done

Picture B): Magnetic Stripe Card (ASTM E 709 – ISO 7810)
UV Light: 15 W/m2; Visible light: < 20 Lux

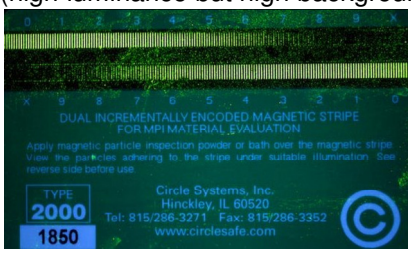
G8 (reference set @ “100”)

C1 (low-luminance powder)

FW1 (HIGH luminance powder)



L (high luminance but high background)

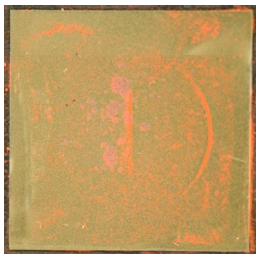


The Tests Done

Picture C): Artificial Defects “Shims” (ASME V Art. 7 T-764. 1.2.2)
FW1, G6, BW2: White Light @ 500 Lux

Elite BW2 + WBL5 (visible method)

G6 (Dual Color “red”)



FW1 (Dual Color “green”)