Colour Stability of Navigation Buoys

Customer:

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Target:

Samples of plastic colour materials used in buoys. The materials and colours are listed in Table 1 and shown in Fig. 1.

Table 1. Test specimens.

Sample	Colour	Size [mm]	Q'ty
Meritaito D800	Red	128 × 28 × 33	5
Meritaito	Red	220 × 28 × 6	5
Meritaito	Yellow	220 × 28 × 6	5
Meritaito	Green	220 × 28 × 6	5
RotationsPlast	Red	198 × 48 × 4	3
RotationsPlast	Yellow	198 × 48 × 4	3
RotationsPlast	Green	198 × 48 × 4	3

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Fig. 1. *An example of each test specimen listed in Table 1. From left: Meritaito D800 (Red), Meritaito (Red, Yellow, Green), RotationsPlast (Red, Yellow, Green).*

Testing Time:

The start of the test: 19th November, 2015
The end of the test: 4th January, 2016

Purpose of the Test:

To test the colour stability of the test specimens when exposed to UV light. To compare the colour stability of the different materials with each other.

Test Method:

Exposure
Accelerated exposure to UV light (UVA 340), test method based on ISO4892-1 and -3
T(Amb): ~30°C
Intensity: 110 W/m²
Duration: 1000 h (~6 weeks)

Measurements
Colour CIELAB1976 and Δ*E* (colour change), after 0, ~333, ~667 and 1000 h exposure
Gloss 60° and Residual gloss, after 0, ~333, ~667 and 1000 h exposure

Feasibility of the Test Method:

UV energy dose, which is achieved with the parameters used in this test (110 W/m², 1000 h) is 110 kWh/m². This energy dose corresponds approximately the UV energy dose received in two years in natural conditions in Finland.

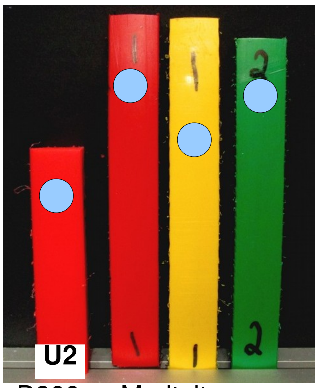
The low temperature was chosen in order to exclude thermal effects.

Both the colour and the gloss was measured as the visual appearance of the product is affected by changes in both colour and gloss.

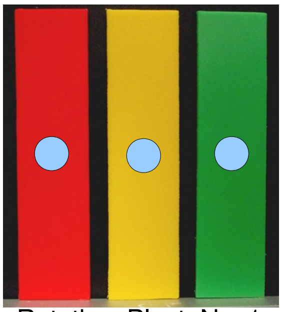
Performed Actions:

For all sample types, Meritaito D800, Meritaito and RotationsPlast, the following actions were carried out:

- Samples 'Meritaito D800' were received as numbered U1 – U5 and samples 'Meritaito' were received as numbered 1 – 5. Samples 'RotationsPlast' were numbered 1 – 3 by marking the number to the backside of the samples.
- Two samples of 'Meritaito D800' (No. U4 and U5) and 'Meritaito' (No. 4 and 5) and one sample of 'RotationsPlast' (No. 3) were left as references that were stored in darkness at room temperature.
- A strip of Al-foil was placed on one sample of each type. A new strip of foil was added next to the previous strip at each measurement session, i.e., after ~1/3 and ~2/3 of the exposure time had passed. In this way, the progress of the possible colour change as a function of time could be followed.
- Colour and gloss measurement was performed on one selected sample of each type and each colour, see Fig. 2. The measurements were performed after 0, 404, 672 and 1000 h exposure.
- Samples were circulated in the test chamber once a week in order to prevent any effects due to the unevenness of the radiation field.



D800 Meritaito



RotationsPlast, No. 1

Fig. 2. *Measurement points and the selected samples for colour and gloss measurement.*

The UV radiation used in this test consists of the same wavelengths as are found in the spectrum of the natural sunlight. The spectrum of the UVA 340 lamps used in the test and that of Sun are shown in Fig. 3. The spectral power density of the UV-lamps (110 W/m²) is compared to that of Sun (60 W/m²) in the wavelength scale covering the UV-range.

The irradiance of the UVA 340 lamps was measured with a precision pyranometer from a 7 × 4 matrix covering the area of exposure uniformly. The irradiance was 110 ± 10 W/m². The total amount of UV-energy onto the samples during the test was thus 110 kWh/m².

The ambient air temperature during ten days of testing is shown in Fig. 4. The temperature was kept as low as possible, and therefore, the test chamber had open sides. The temperature in the test chamber varied according to the laboratory room temperature. The values were typically around 25℃, peak values were 19℃ and 35℃.

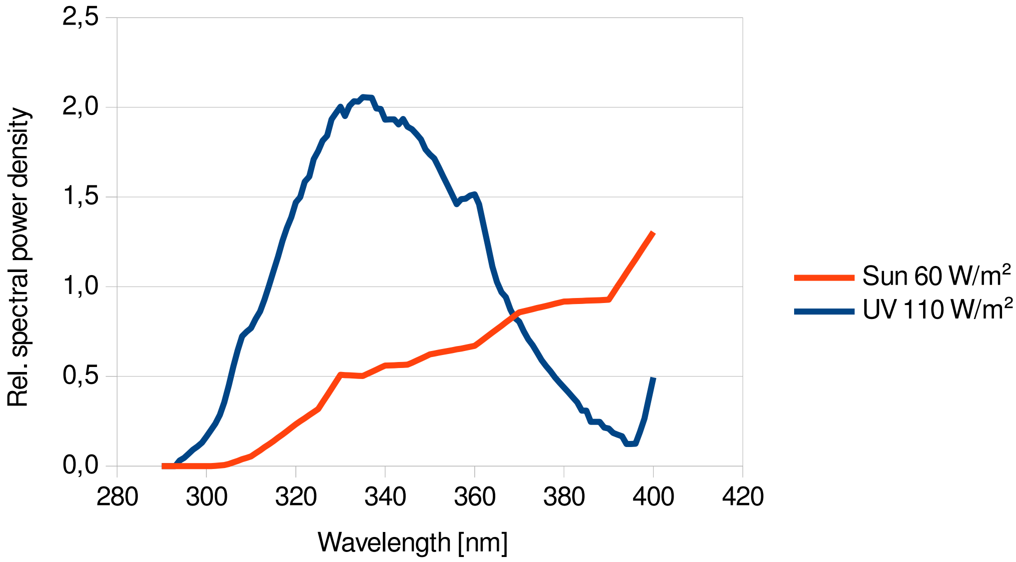


Fig. 3. *Spectrum of the UVA340 lamps used in this test and that of natural sun in the UV range. Relative spectral power density (corresponding to intensity) as a function of wavelength.*

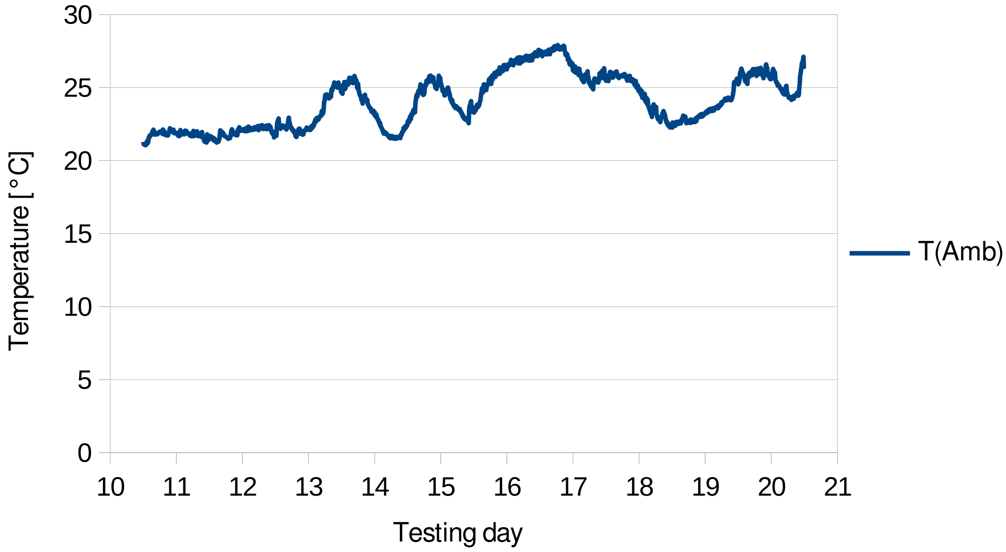


Fig. 4. *Ambient temperature T(Amb) during the testing.*

The UV lamps were located right above the test specimens. Thus the radiation came perpendicularly to the surface of the samples, see Fig. 5.

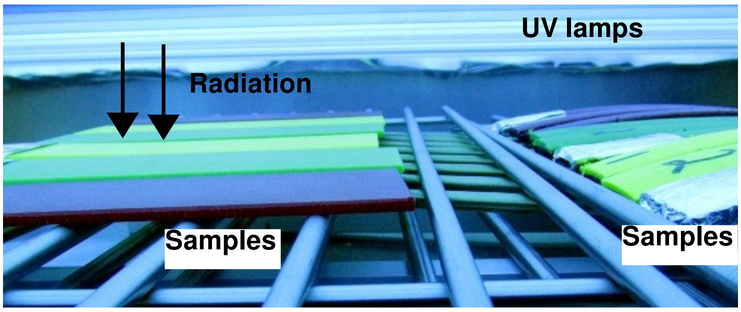


Fig. 5. *Samples in test.*

Blue Wool Reference Samples:
Colour difference of Blue Wool reference materials No. 5, 6 and 7 under test conditions similar to the present test is shown in Fig. 6. The colour change of Blue Wools proves the severity of the exposure and the similarity between different exposures, and also, between the test and natural conditions.

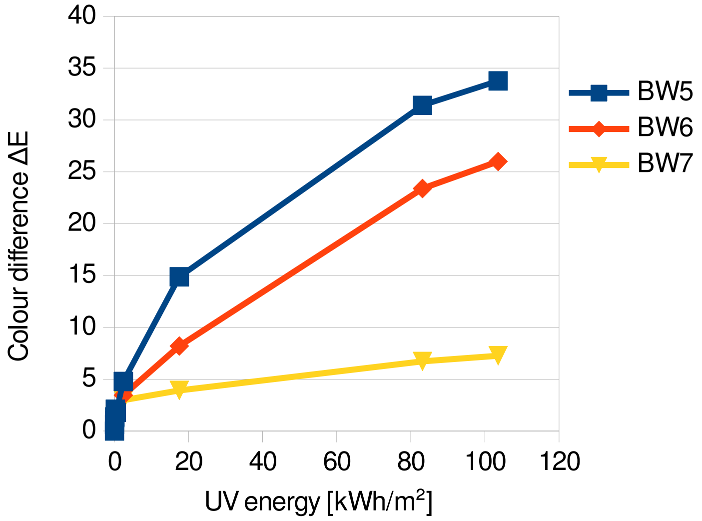


Fig. 6. *Colour difference ΔE of Blue Wool reference materials No. 5, 6 and 7 (BW5, BW6 and BW7, respectively) as a function of UV energy.*

After the exposure, the samples were inspected visually and photographed with unexposed reference samples. No changes in colour caused by the exposure to UV radiation could be seen by eye. The photographs of the samples are shown in Figs. 7 – 9.

Fig. 7. *Meritaito D800 samples after the exposure to UV radiation. From left: No. U5 (reference sample stored in dark at room temperature), No. U1, U2 and U3 (sample with foil strips).*

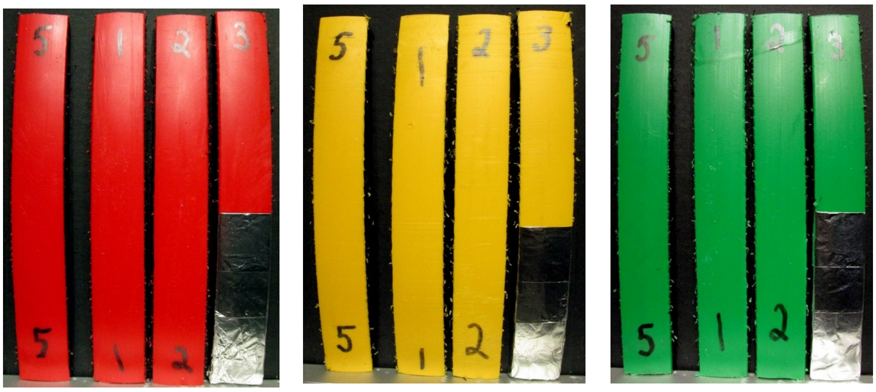


Fig. 8. *Meritaito Red, Yellow and Green samples after the exposure to UV radiation. For each colour, from left: No. 5 (reference sample stored in dark at room temperature), No. 1, 2 and 3 (sample with foil strips).*

Fig. 9. *RotationsPlast Red, Yellow and Green samples after the exposure to UV radiation. For each colour, from left: No. 3 (reference sample stored in dark at room temperature), No. 1 and No. 2 (sample with foil strips).*

Used Equipment:
UV Tester, No. 17
Radiation intensity: Pyranometer No. 11, calibrated 7th October, 2015. Calibration is valid.
Multimeter No. 24, calibrated 19th May, 2015. Calibration is valid.
Temperature: Datalogger No. 64 + K-type thermocouple, calibrated 28th January, 2015.
Calibration is valid.
Colour: No. 70, calibration is made before every measurement session. Calibration is valid.
Gloss: No. 10, calibration is made before every measurement session. Calibration is valid.

Analysis:

Radiation Correspondence:
The mean UV radiation energy in Southern Finland during one year is 54 kWh/m^2 onto a horizontal surface and 47 kW/m^2 onto a south facing vertical surface. Thus at this test the total UV-energy of 110 kWh/m^2 corresponds to 2 years of UV-energy onto a horizontal surface in Southern Finland and 2.3 years of UV-energy onto a south facing vertical surface in Southern Finland.

This estimate is based only on the total energy dose and does not take into account the differences in the spectra of the simulated and natural radiation.

Optical Analysis

The $L^*a^*b^*$ colour coordinate values of the samples were measured. The reflected specular component from the samples is included in the $L^*a^*b^*$ values. Colour difference ΔE represents the Euclidean distance between two colours according to Eq. 1.

$$\Delta E = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \quad (1)$$

L^*-coordinate indicates the lightness of the sample. The bigger the value the lighter the sample.
$+a^*$-coordinate indicates the red direction and $-a^*$ indicates the green direction.
$+b^*$-coordinate indicates the yellow direction and $-b^*$ indicates the blue direction.
The colour coordinates are shown schematically in Fig. 10.

Under ideal viewing conditions a ΔE value of 1 represents a just perceptible colour difference to the human eye. However, the human eye sees differently colour differences in different colours. The differences in darker colours are more perceptible to the eye.

Gloss is a measure of the proportion of light that has a specular reflection from the surface. The gloss measurement was made at 60°. The gloss value indicates the surface gloss: the glossier the surface, the larger the value. Residual gloss represents the ratio between the current and the original value.

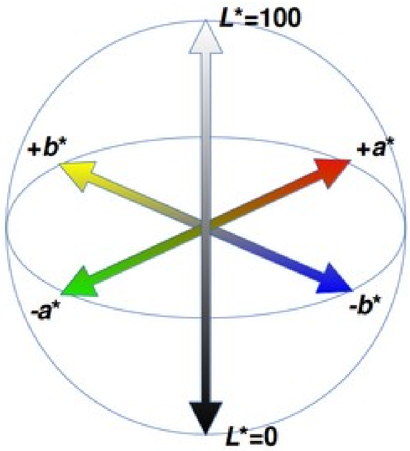


Fig. 10. *CIE L*a*b* colour coordinate system.*

Colour difference Δ*E* (SCI, specular component included), gloss 60° and residual gloss as a function of the UV energy and exposure time are shown in Figs. 11 – 13, respectively. A value of 100 % is given to the original gloss in Fig. 13. The changes in colour and gloss were minor; the colour differences were in the range 0.4 – 1.6 and changes in gloss were within 7 percentage points. However, the changes have not yet stabilized, but are likely to continue.

Comparison between the different materials, Meritaito D800, Meritaito and RotationsPlast, can be found in section Conclusions in Fig. 14.

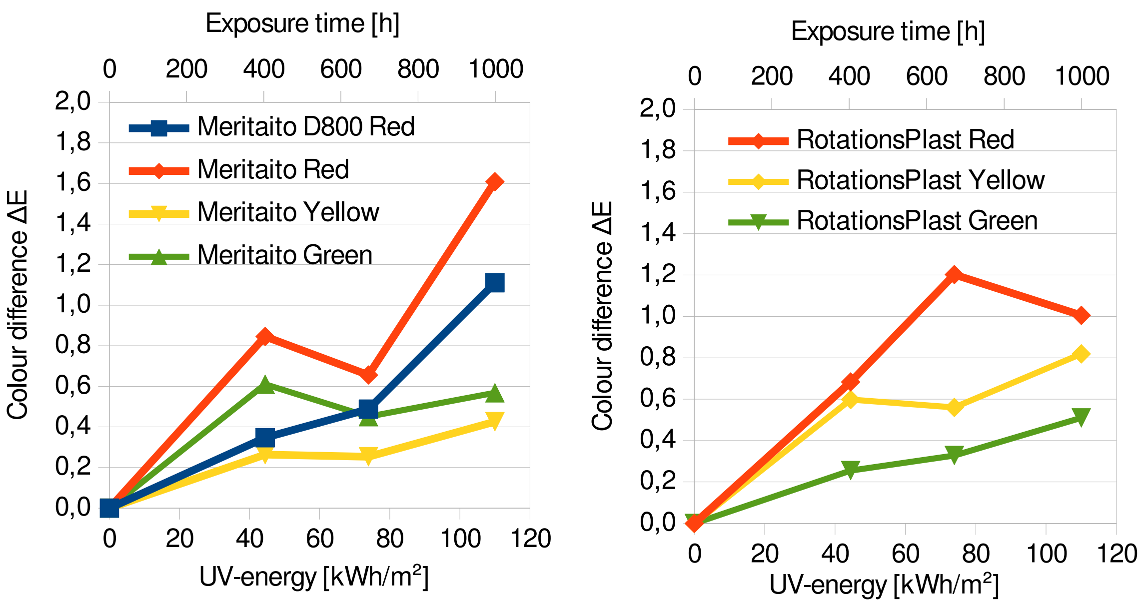


Fig. 11. *Colour difference ΔE as a function of UV energy and exposure time.*

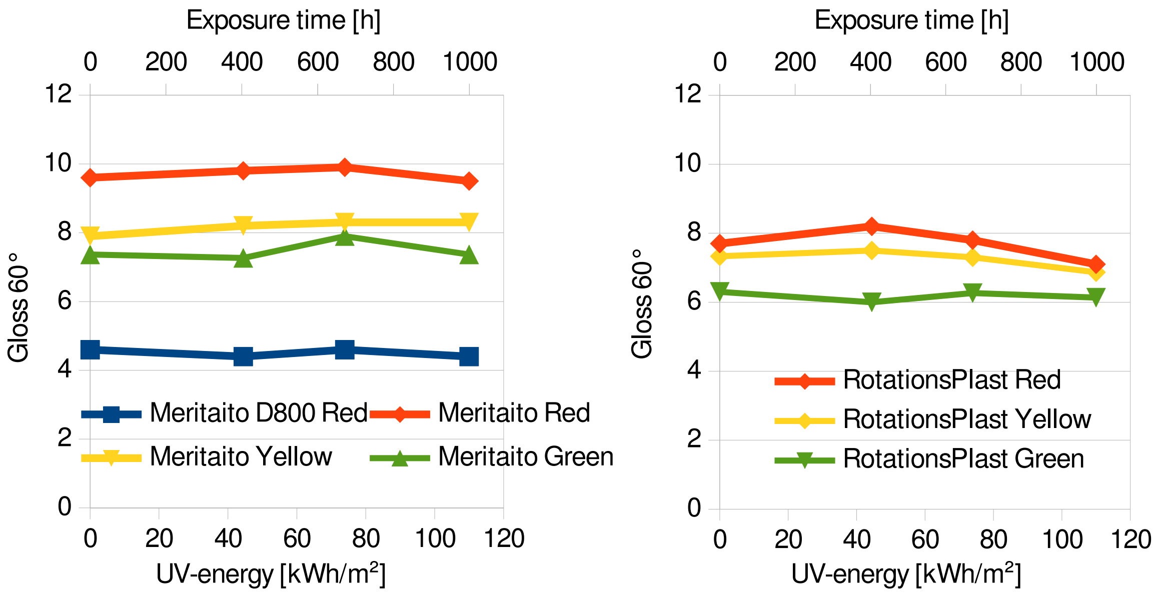


Fig. 12. *Gloss 60 ° as a function of UV energy and exposure time.*

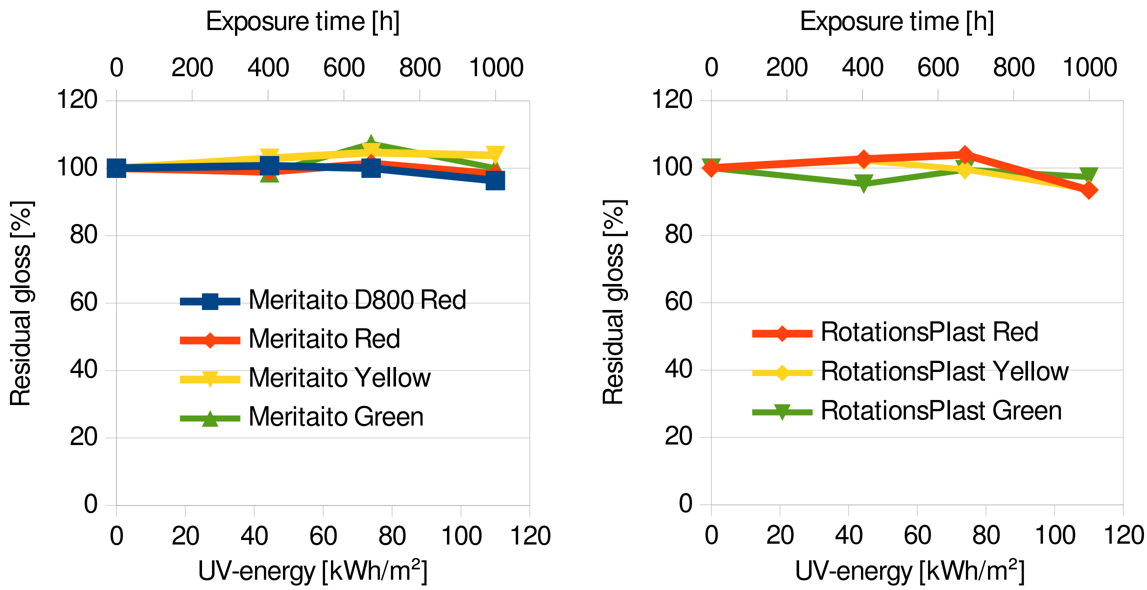


Fig. 13. *Residual gloss as a function of UV energy and exposure time.*

Recommendations:
N/A

Conclusions:

Test specimens, plastic colour materials used in buoys, were exposed to UV radiation for 1000 h. The total UV energy dose was 110 kWh/m².

Colour stability of the materials was investigated. Only minor changes in colour and gloss were observed in measurements. The changes could not be seen by eye. However, the changes have not yet stabilized.

Comparison of the colour stability between the different materials, Meritaito D800, Meritaito and RotationsPlast, is shown in Fig. 14. In Fig. 14, the colour difference Δ*E* (SCI, specular component included) as a function of UV energy is given. The colour difference here means the change of colour of its original value, which was measured before the exposure. Changes in gloss were less significant.

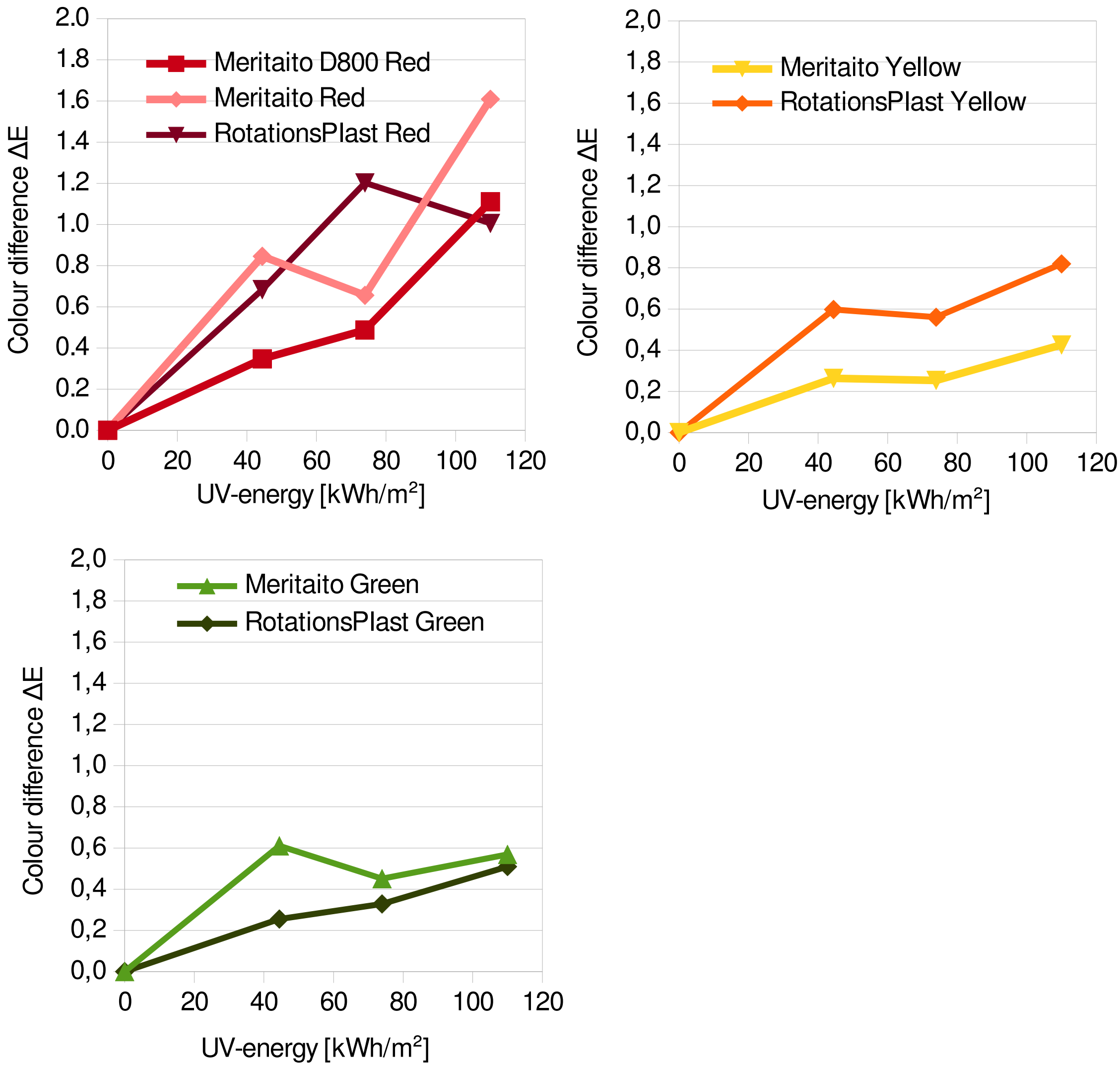


Fig. 14. *Colour changes as a function of UV energy. Comparison between different materials of each colour, i.e., red, yellow and green.*

Remarks:

Actions, operations and reporting are in accordance with IEC/ISO 17025 'General requirements for the competence of testing laboratories'.

Signatures:

Littoinen, 7th January, 2016
Solar Simulator Finland