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ISO/TC94/SC6/WG2 in WG4

Artificial welding and ambient light sources - calibration

for the proposed “Eye Protection” ISO standard

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Contents

Introduction

Testing the light sensitivity of automatic darkening filters (ADF) requires an artificial welding-arc as well as ambient light sources that can be easily reproduced in various ADF testing laboratories anywhere in the world:

I. Artificial welding light source:
   a. Frequency modulated low power DC driven Xe-arc light (75W) → equivalent to low power DC TIG welding (30A)

II. Ambient light sources:
   a. DC driven halogen light, simulating outside ambient lighting conditions (2000 lx),
   b. Combination of fluorescent light and DC driven halogen light simulating inside ambient lighting conditions (200 lx, which include specific “light noise”, characteristic for fluorescent lighting)

A new test method for testing the sensitivity of welding detection of automatic welding filters will be proposed for a new ISO standard for occupational eye and face protectors. The following is the description of the primary calibration procedure to define parameters for the proposed test method and how to bring the light sources in a test laboratory to meet the requirements of the proposed test method:

A - List of required equipment

1. Light sources:
   - 1.1. Power stabilized low-power DC driven Xe-arc test light source (75W; e.g. Osram XBO 75W-2 OFR) with computer controlled power modulation in order to provide light frequency spectrum equal to the “average DC TIG welding spectrum” (described in detail in Supplements 1 and 2)
   - 1.2. Standard DC driven incandescent (halogen) light source providing ~ 1000 lx at the distance ~ 50cm from the source (e.g. Schott – KL 2500 LCD)
   - 1.3. Reference automatic low power DC TIG welding device operating at 30A (described in detail in Supplement 3)
   - 1.4. Ambient light illumination system:
     - 1.4.1. Incandescent light source 3 x 35 W halogen light source (e.g. Osram HRGS//UBIB-35-12-GU5,3-51/10)
     - 1.4.2. Fluorescent light source 2x 6W fluorescent light source (e.g. Osram L 6 W/640) with passive inductive ballast (e.g. DFN 530-4/6/8).

These light sources are built into a complete optical assembly constructed on an optical bench. The block diagram of the apparatus is shown in the Fig. 1. Together with the driving electronics and the test device PC computer with dedicated control and measuring

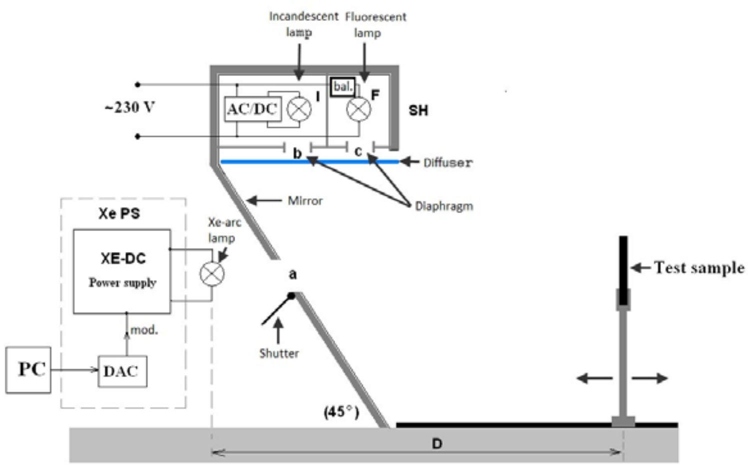

Fig 1: Block diagram for the optical system for ADF light sensitivity test in ADF test laboratory

software, this system allows for complete ADF optical light sensitivity testing, as required by the proposed test method (see Supplement 1 for more detail):

2. Measuring equipment:

2.1. Silicon photodiode with spectrally flat optical filter (e.g. Gamma Scientific model: 24600 silicon photodiode with flat response filter model: 24960) providing wide spectral response (475 – 975 nm) with current to voltage converter and linear amplifier (DC – 10 kHz).
2.2. Set of spectrally flat (475 – 975 nm) optical density filters (e.g. OD 1, 2, 3, 4; e.g. Melles-Griot, Edmund Scientific, Corion,…), and measured/calibrated by using a spectrophotometer (e.g. Varian, Perkin Elmer)
2.3. Calibrated photometer (e.g. Gamma Scientific “flexOptometer” with model 24600 silicon photodiode and photopic filter 24973-x),
2.4. Digital VOM (e.g. Keithley DMM 196) allowing for RMS measurements of low frequency AC signals and Oscilloscope (e.g. Agilent 54622A) for higher photodiode signal frequency monitoring
2.5. Personal computer with analog and digital experiment interface (e.g. National Instruments NI-USB 6211) and a dedicated software - Based on the data CD provided by ISO (average TIG welding (1.3) frequency spectrum). It allows for:
    2.5.1. Digital filtering of the input signal from the measuring photodiode (2.1) – low-pass filter with the 3dB cutoff frequency set to 1 Hz,
    2.5.2. Digital filtering of the input signal from the measuring photodiode (2.1) – band-pass filter with the 3dB cutoff frequencies set to 400 Hz and 6000 Hz,
    2.5.3. Digital filtering of the input signal from the measuring photodiode (2.1) – band-pass filter with the 3dB cutoff frequencies set to 50 Hz and 6000 Hz,
    2.5.4. Digital readout of the DC signal value of the photodiode (2.1) after low-pass filtering (A2.5.1) allowing for verifying the linearity of the light measuring system comprising photodiode (2.1) measured by the PC via A/D conversion interface (e.g. National Instruments NI-USB 6211) and dedicated software.
    2.5.5. Digital readout of the RMS signal value of the photodiode (2.1) after band-pass filtering (A2.5.3) measured by the PC via A/D conversion interface (e.g. National Instruments NI-USB 6211) and dedicated software.
    2.5.6. Amplitude & frequency spectrum modulation of the light output from the DC driven Xe-arc light source (1.1): The Xe-arc frequency spectrum is adjusted according to the proposed test method “average DC light frequency spectrum (see – supplement 3)”. Adequate modulation electric signal is generated by the PC (2.5) using a D/A conversion interface (e.g. National Instruments NI-USB 6211) and fed into the power modulation input of the electronic driver for the Xe-arc light source (see supplement 2).
    2.5.7. Peak detection of the digitally filtered signal from the measuring photodiode (2.1). Digital filtering comprises a band-pass filter with the 3dB cutoff frequencies set to 400 Hz and 6000 Hz (2.5.2)
    2.5.8. Fast Fourier transform of the signal from the measuring photodiode (2.1) after passing the digital band-pass filter with the 3dB cutoff frequencies set to 50 Hz and 6000 Hz (2.5.3)

B - Primary calibration of the low power Xe-arc light source:

The primary calibration is performed by a group of experts authorized by the ISO/TC94/SC6/WG2 and WG4 in order to standardize the Xe-arc light source parameters for the proposed test method.

1. Verification of the linearity of the light measuring system comprising photodiode (A2.1), digital low pass filtering (A2.5.1) and PC evaluation/ readout (A2.5.4)
   1.1. Turn on the standard DC driven incandescent source (A1.2) and let it stabilize for 10 minutes.
   1.2. Measure the illuminance (~ 1000 lx) at ~ 50 cm from the light source directly and through the set of spectrally flat (neutral) light density filters (A2.2) with the calibrated photometer (A2.3) and with the measuring photodiode (A2.1) with its PC readout (A2.5.4). The two sets of measurements must exhibit a linear relationship $\leq$ 0.1%.

2. Measuring the light output parameters for the reference low power TIG welding arc (A1.3) (see Supplement 3, 4 for details). There are three parameters that specify the light, originating from the welding arc. They have to be determined over the wide light spectrum using the photodiode detector (A2.1):
   - DC light intensity (V)
   - AC light intensity vs. DC light intensity ratio: AC/DC (%)
   - TIG (A1.3) light frequency spectrum

   2.1. Adjust the welding current of the reference TIG welding device (A1.3) to 30 A $\pm$ 0.5 A and Ar-gas flow to 6 l/h $\pm$ 0.1l/h (details of the welding parameters – see Supplement 4)
   2.2. Measure the “DC light intensity” at the standard distance 50cm $\pm$ 0.5cm by a photodiode detector (A2.1) via the digital low-pass filter (A2.5.1; Fig. 2). The dedicated welding light signal analyzing software displays the value of the **“DC light intensity$_{TIG}$”** (in Volts) on a PC screen (A2.5.4; Fig. 2)
   2.3. Measure the relative value of “AC light intensity” at the same distance 50cm $\pm$ 0.5cm from the welding arc by a photodiode (A2.1) via the digital band-pass filter (50 Hz – 6 kHz). The dedicated welding light signal analyzing software performs an AC-RMS conversion (A2.5.3; Fig. 2) - measured in V
   2.4. Calculate the ratio of the “AC light intensity” (B2.3) / “DC light intensity” (B2.2), which is characteristic

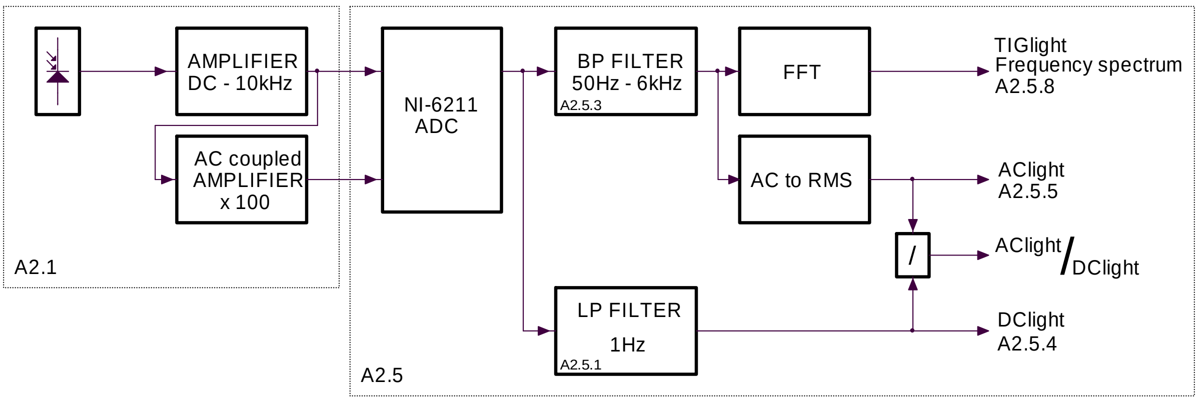

Fig. 2: The measurement system for Xe light calibration

for the type of welding. The average value of AC/DC for TIG welding (A1.3) is specified (supplement 3) as the **“AC/DC$_{TIG}$ ratio”** of the TIG welding (measured in %).

   2.5. Measure the time dependence of “AC light intensity” at the same distance 50cm $\pm$ 0.5cm from the welding arc by a photodiode (A2.1) via the digital band-pass filter (50 Hz – 6 kHz). The dedicated welding light signal analyzing software performs Fast Fourier transform (A2.5.8) – **frequency spectrum of the TIG welding** light signal (A1.3 - see supplement 3).

2.6. TIG welding light parameters have been determined for 5 different state-of-the-art low power TIG welding devices (A1.3). The standardized TIG welding signal for the proposed test method is determined as being described by the average values:

- "DC light intensity$_{TIG}$"
- "AC/DC ratio$_{TIG}$"
- "TIG frequency spectrum$_{ISO}$"

3. Transferring the TIG welding light parameters to the Xe-arc light source:

In order to transfer the standardized TIG welding (A1.3) parameters (B2.6) to the "ADF testing laboratories", the latter are transferred to the standardized artificial TIG welding light source (Xe-arc – A1.1):

3.1. The standardized Xe-arc lamp (A1.1) is run at nominal power (75W) for ≥ 15 minutes in order to stabilize.

3.2. The PC controlled light frequency modulation (A.2.5.6; Fig. 2) is turned off. Digital readout of the DC signal value of the photodiode (2.1) after low-pass filtering (A2.5.4) is used to determine the distance D_0 (see Fig 1 in Supplement 1) from the Xe-arc, where the latter is providing the same average "DC light intensity$_{Xe}$", as determined in B2.6 for the standardized TIG welding (DC light intensity$_{TIG}$).

4. Determination of **"transfer parameters"** for the Xe-arc artificial welding light source used in test laboratories:

4.1. The light sensor of the calibrated photometer (A2.3) is placed at the same **distance** D_0 (see Fig 1 in Supplement 1) as determined in B3.2 and the DC **illuminance$_{Xe}$** provided by the Xe-arc is measured (in lx).

4.2. The light of the Xe-arc at the distance D_0 (B3.2) is therefore characterized by the following parameters:

- "**DC illuminance$_{Xe}$**", as determined in B4.1; tentative value → 132 lx ± 10 lx
- "**AC/DC$_{TIG}$ ratio**", as determined in B2.6; tentative value → (0.39 ± 0.02)%
- "**TIG Frequency spectrum$_{ISO}$**", as determined in B2.4 see supplement 3

It is equivalent to the light generated by the standardized TIG welding arc (A1.3) at 30A and at the standardized distance 50 cm ± 0.5 cm from the arc.

C - Adjustment of the test Xe-arc light source in the ADF test laboratory

The adjustment of the Xe-arc light source parameters is performed by an ADF test laboratory in order to comply with the ADF sensitivity test as specified in the proposed sensitivity test method.

C1 - Adjustment procedure for the DC driven test Xe-arc light source (A1.1):

1. Verification of the linearity of the light measuring system comprising photodiode (A2.1) and PC evaluation (A2.5.1 and A2.5.3.):
   1.1. Turn on the standard DC driven incandescent source (A1.2) and let it stabilize for 10 minutes.
   1.2. Measure the illluminance (~ 1000 lx) at ~ 50 cm from the light source directly and through the set of spectrally flat (neutral) light density filters (A2.2) with the calibrated photometer (A2.3) and with the measuring photodiode (A2.1) and its PC readout (B2.3) and (B2.4). The two sets of measurements (B2.3 and B2.4) must exhibit a linear relationship ≤ 0.1% with the measurements performed by the calibrated photometer (A2.3).
2. The standardized Xe-arc lamp (A1.1) is run at nominal power (75W) for ≥ 10 minutes in order to stabilize. The PC controlled light frequency modulation (A.2.5.6) is turned off. The calibrated photometer (A2.3) is used to determine the distance D (see Fig 1 in Supplement 1) from the Xe-arc, where the latter is providing the same DC illuminance$_{Xe}$ (B4.1), as specified by the proposed sensitivity test method for TIG welding at 30 A (A1.3, B4.2) → tentative value 132 lx ± 10 lx
3. The photodiode detector (A2.1; C1-1) is placed at the position D (C1-2).
4. The light intensity is measured again using the signal from a photodiode (A2.1):
   4.1. The signal from a photodiode (A2.1) is digitally filtered by a low pass filter (A2.5.1; Fig. 2) and displayed on the PC monitor (B2.2). This value represents the relative value of a "DC light intensity" measured in V.
   4.2. The signal of the photodiode (A2.1) is filtered by a band-pass filter (50 Hz – 6 kHz). The band-pass filtering (A.2.5.3; Fig. 8) is implemented in the software of the test device PC computer that also performs the AC-RMS conversion (A2.5.5). The latter is taken as a measure for the "AC light intensity" – measured in V.
5. The PC controlled frequency spectrum modulation (A2.5.6) adjusted to provide the standardized average TIG welding light spectrum "TIG Frequency spectrum$_{ISO}$" is turned on. The "software gain" of the PC controlled frequency modulation is adjusted (see supplements 1 and 2) so that the AC light (C4.2) of the Xe-arc light source (A1.1) is increased until the same DC/AC ratio is obtained, as determined during the primary calibration ("AC/DC$_{TIG}$ ratio; page 6) and specified by the proposed sensitivity test method → tentative value (0.39 ± 0.02) %

⇓

C2 - Adjustment of the DC driven test Xe-arc light source is completed → the light from the test Xe-arc light source (A1.1) is **equivalent to the DC TIG welding** (A1.3) at the test position D (C1-2) from the test Xe-arc.

D - Ambient light source adjustment

Ambient light affects the sensitivity of the ADFs. Because of a very specific light sensing system design with ADFs, one has to distinguish between two different ambient lighting conditions:

1. Indoor lighting conditions
2. Outdoor lighting conditions

Ad 1 Outdoor light source

The outdoor light source is to simulate the behavior of a steady sunlight. This is made by using a number of halogen incandescent lamps (A1.4.1) that are driven by a well regulated DC current at their nominal power rating. The adjustment of the optical output from the lamp assembly is made by an adjustable diaphragm to give a specific illuminance at the place of the test object Such a test condition can be realized with the optical assembly, the block diagram of which is shown in the Fig. 1 and described in more detail in supplement 1.

Adjustment procedure:

1. Close the light shutter (a) in front of the Xe arc light source
2. Turn on the halogen the lamps (A1.4.1) for ≥ 5 minutes.
3. Measure the illuminance, at the position of the test object (D – Fig.1), by the use of calibrated photometer (A2.2).
4. Adjust the diaphragm in front of the lamps until the reading of 2 000 ± 200 lx on the photometer (A2.3) is achieved

   ⇒ outdoor lighting conditions at the test sample position D (Fig. 1) are established.

Ad 2 Indoor light source

The proposed indoor light source consists of a combination of two different lamps (– see supplement 5):

- AC-driven fluorescent lamp with passive inductive ballast (A1.4.2) is chosen to generate a representative level of optical ripple signal (as well as some static illuminance component) and
- DC-driven incandescent lamp (A1.4.1) is used to add extra static illuminance on top of this in order to reach a specific effective illuminance level (200 lx ± 10 lx).

The two light sources are built-in the optical assembly, the block diagram of which is shown in the Fig. 1. With both lamps equipped with optical diaphragms (b, c in the Fig. 1), the amount of light from each lamp can be adjusted to the desired level.

Adjustment procedure:

The static light component, the illuminance, is to be measured by a calibrated photometer (A2.3). The “ripple” signal is to be measured by a photodiode with spectrally flat response (A2.1). Due to a vast number of different fluorescent light sources and their driving electronics a specific ripple detection method has been designed (see supplement 5):

1. Close the light shutter (a) in front of the Xe arc light source (Fig. 1)
2. Turn on the incandescent (A1.4.1) and fluorescent (A1.4.2) light for ≥ 15 min (warm up)
3. Measure the illuminance at the test sample position D (Fig. 1) with the calibrated photometer (A2.3)
4. Approximately adjust the diaphragms ((b) and (c) - Fig. 1) until the photometer shows 200 ± 10 lx

5. Measure the light at the test sample position D with the spectrally flat photodiode (A2.1) using the digital low-pass filtering and PC computer processing (A2.5.4 ; Fig. 8).
6. Measure the light AC ripple amplitude at the test sample position D by peak detection of the signal of spectrally flat photodiode (A2.1) after the digital band-pass filtering (400 Hz – 6 kHz). The digital band-pass filtering and the peak detection are implemented in the software of the test device PC computer (A.2.5.7; Fig. 8) - see supplement 5.
7. Adjust (iteration) the diaphragms (b) and (c) until the ratio of the AC ripple amplitude (A.2.5.7) and effective DC voltage signal of the photodiode (A2.5.4) measured by the PC is (0.12 ± 0.02) %, while the photometer (A.2.3) measures 200 ± 10 lx.

   ⇒ indoor lighting conditions at the test sample position D (Fig. 1) are established.

E. Test Procedure

After the calibration procedures of the Xe-arc light source (chapter C) as well as the ambient light sources (Chapter D) are done, the sensitivity test for ADFs can be performed. It consists of various individual measuring steps. By means of a visual inspection or a suitable method for measuring luminous transmittance it shall be determined, whether the ADF test sample is in its light or in its dark state:

1. The shade 9 setting is selected for “variable shade” ADFs (- fixed shade ADFs can be tested without this adjustment).
2. The minimum “delay” setting is selected for the “variable delay” ADFs (- fixed delay ADFs can be tested without this adjustment).
3. The Xe-arc light source is turned on ≥ 15 minutes before the testing of ADFs starts.
4. The indoor light source is turned on to illuminate the ADF test sample placed in the position D (≥ 15 minutes before the testing of ADFs starts).
5. The light shutter (a) of the Xe-arc light source is closed (Fig 1)
6. The test sample is placed in the position D (Fig. 1).
7. In the case of welding filters with adjustable sensitivity, the latter shall be adjusted to the maximum sensitivity value that still keeps the tested ADF in the open (transparent) state (- fixed sensitivity ADFs can be tested without this adjustment).
8. The shutter (a in the Fig. 1) of the trigger (Xe-arc) light source (A1.1) is opened, so that parallel to the indoor ambient light the light from the Xe-Arc lamp is illuminating the test sample. Now the ADF has to switch to its dark state and has to keep this dark state as long as the trigger light source is turned on (≥ 15 s).
9. The shutter of the trigger light source is closed again so that the ADF test sample is again illuminated only by the “indoor ambient light” source (see section D). In that condition the ADF has to switch back to its light state.
10. This test procedure is then repeated (after ≥ 5 min warm-up time) with the outdoor light source (see section D) as ambient illumination.

The ADF has to fulfill all required light and dark state conditions in the various steps of the measurements to pass the complete sensitivity test.

Supplements:

Supplement 1: Aparatus for ADF light sensitivity test in the ADF test's laboratory

Supplement 2: Power stabilized low-power DC Xe-arc test light source - detailed description

Supplement 3: Average TIG spectrum

Supplement 4: Reference automatic low power TIG welding device - detailed description

Supplement 5: Peak detection of the AC ripple in ambient illumination

Apparatus for ADF light sensitivity test

Experimental Setup

This supplement describes the experimental setup of the apparatus to simulate a typical TIG welding process (A1.3) in order to test qualitatively the possible sensitivity of ADFs for that specific welding process.

The schematic setup of the sensitivity device is shown in Fig. 1 (-identical as on page 3).

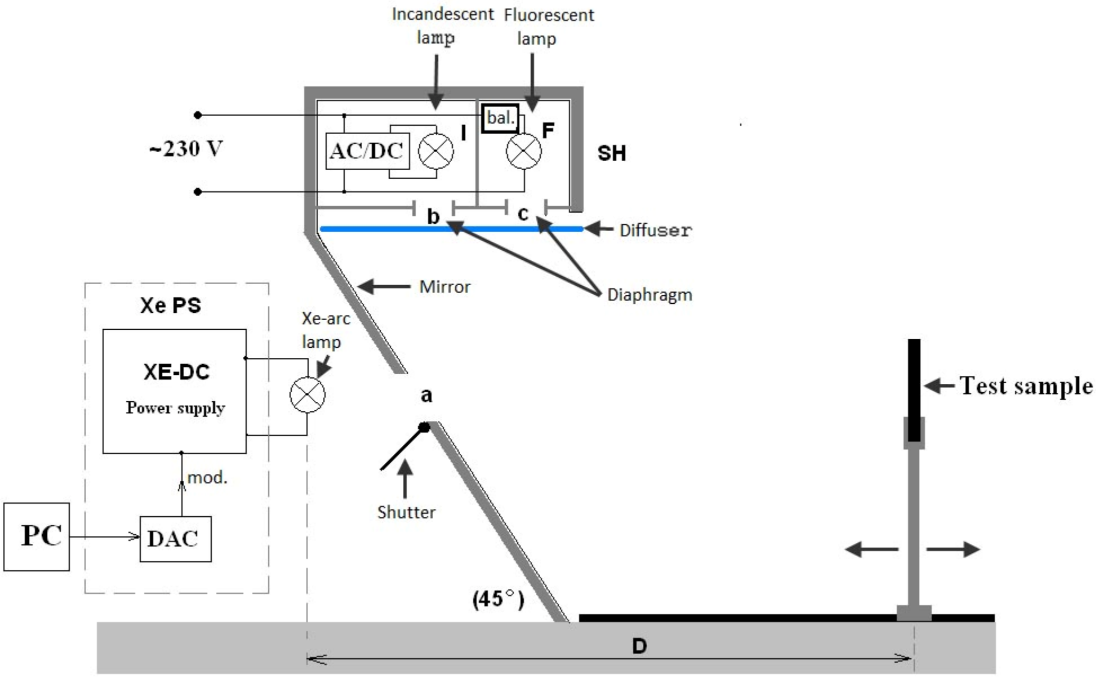

Fig. 1 – Arrangement of apparatus for testing the sensitivity of welding detection

This apparatus basically consists of three light sources: an outdoor light source, an indoor light source and a trigger light source.

The indoor light source is intended to simulate the influence indoor ambient light (like e.g. typical fluorescent light tubes) on the sensors and electronics of the ADF.

The indoor light source itself consists of a combination of two individual light sources: a DC-driven Halogen incandescent light source (I in Figure 1; 3x35W; e.g. Osram HRGS/UBIB-35-12-GU5, 3-51/10) and an AC-driven fluorescent light source (F in Figure 1; 2x6W; e.g. Osram L6W/640) with a standard inductive load (e.g. DFN 530-4/6/8). During the indoor light measurement only 1 of the 3 Halogen lights is used. This combination of Halogen and fluorescent light sources is needed to reach a specific light illuminance level combined with a specific ripple signal level to simulate the worst case of the vast number of different indoor light situations. The optical diaphragms (b and c in Figure 1) can be used to adjust the amount of light from each lamp type. Behind the diaphragms (b) and (c) a diffuser (sanded glass) is built in the optical path to remove spatial maxima of the light intensity.

The outdoor light source is intended to simulate the behavior of outdoor ambient light like steady sunlight. During the daylight illumination the other two Halogen lights are used to illuminate the test sample. Again the optical output of the Halogen lamp assembly can be varied in intensity with an adjustable diaphragm (b).

The light from both light sources, indoor and outdoor ambient light, is reflected by a 45° tilted mirror towards the ADF test sample mounted at the right side of the test device in Figure 1.

The trigger light source is intended to simulate the TIG welding arc. It consists of a high-pressure DC-driven Xenon arc lamp (Xe in Figure 1) with controlled power modulation to provide a broad frequency spectrum to simulate the original frequency spectral performances of a TIG welding arc (A1.3). A detailed description of that PC-controlled Xe-arc bulb power modulation that affects/determines its light frequency spectrum can be found in the supplement 2. The light from the Xenon arc lamp is directed through light shutter (a in Figure 1) of the tilted mirror towards the mounted ADF test sample. During measurement the light from the trigger light source can be blocked with a mechanical shutter.

Power stabilized low-power DC Xe-arc test light source - detailed description

The principle purpose of the Xe-arc lamp artificial welding light source is providing clean, repeatable light source that simulates the light produced at TIG welding that is easily reproducible in ADF test laboratories and allows for the testing the light sensitivity of automatic light filters for personal protection in welding applications.

The required stability and the frequency spectrum of the light from the Xe-arc lamp can be achieved by power control circuit, as presented in block diagram at Fig. 3. The classical analog feedback is used to stabilize the power dissipation of the Xe-arc lamp.

Two amplifiers A_{volt} and A_{curr} detect the voltage over the Xe-arc lamp and the current through it, and provide two voltage signals U_{volt} and U_{curr}. These signals are multiplied to form a voltage signal U_{pow} representing the power dissipation of the Xe-arc. A reference voltage signal U_{pref} is subtracted from it, and the difference voltage signal U_{diff} is amplified in error amplifier A_{err} and fed to the power driver A_{pow}, which controls the current through and simultaneously the voltage over the Xe-arc. By making the reference signal U_{Pref} constant, a constant power is dissipated on a Xe-arc lamp and a constant light is produced. By changing the reference signal U_{Pref} the light of the Xe-arc lamp can be modulated to form a desired frequency spectrum. The reference signal U_{Pref} is constructed from a DC component U_{DCref} that defines the average light output of the Xe-arc lamp and is selected to drive the lamp at its nominal power (75W for the selected bulb), and an AC component U_{ACref}, which is added to modulate the light adequately. The shape and amplitude of this component is selected to mimic the light from the welding.

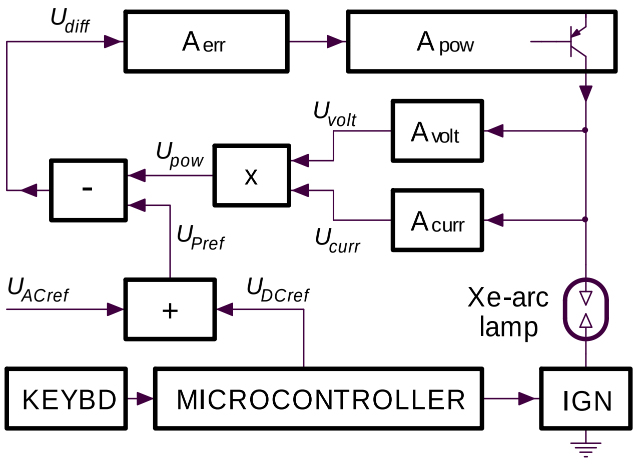

Fig. 3: The block diagram of the driving electronics

The Xe-arc lamp requires a high voltage spark to ignite, such is provided by a commercially available starter circuit IGN (IREM model AS-1530). Additionally, the ignition procedure requires a higher-than-nominal voltage over the Xe-arc lamp, and a microcontroller based circuit is added to initiate the ignition and simultaneously elevate the reference signal U_{DCref} for the duration of the ignition. The ignition can be requested manually through a keyboard KEYBD.

In order to mimic the spectrum of the welding arc an adequately shaped modulation signal U_{ACref} is generated by a PC compatible computer and a commercially available interface (like National Instruments NI USB 6211). The software running at the PC computer reads samples from a CD provided by ISO group, and plays it through the

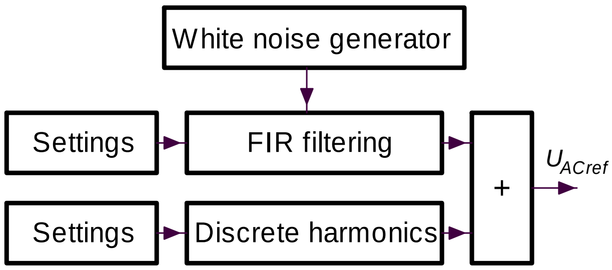

Fig. 4: The generation of U_{ACref}

interface to modulate the electronics from Fig. 3, U_{ACref}. The amplitude of the modulating signal can be adjusted ("software gain") as required at C1-5.

The software has a second function, which is available to the "group of experts authorized by the ISO/TC94/SC6/WG2 and WG4 in order to standardize the Xe-arc light source parameters for the proposed test method" only. Using this function a CD with samples to be played in standardization laboratories can be prepared. The function includes the generation of white noise with Gaussian amplitude distribution, which is digitally filtered (FIR filtering) to achieve the required modulation signal U_{ACref}. The filtering settings are available to the notified user. Additionally, several discrete harmonic signals can be added to the shaped noise signal in order to closely match the required "average spectrum" of the light from the welding, as specified in Supplement 3. The block diagram of the second function of the software is given at Fig. 4. All settings are saved to a file together with the noise samples.

The file is plain ASCII file comprising of floating point numbers, each number in new line. The file is typically more than 5MB long. The numbers have the following meaning (grayed lines are for second function of the software only):

line	meaning
1 to 2048	2048 coefficients for FIR filtering, used for generation of new noise samples.
2049	Empty line
2050 to 2069	Settings for FIR filtering, values between 0 and 1023
2070	Empty line
2071 to 264214	Noise samples, values between -10.0 and -10.0
264215	Empty line
264216 to 264227	Enable harmonic signal generation
264228	Empty line
264229 to 264240	Amplitude of the harmonic component, values between 0 and 1023
264241	Empty line
264242 to 264253	Frequency of the harmonic component, values between 5 and
264254	Empty line
264255	Overall amplitude, "software gain", value between 500 and 1500
264256	Empty line

Standardized »Average frequency spectrum« for the TIG welding

The frequency spectrum of the light generated in the TIG welding process was evaluated using an automatic TIG welding system (A1.3) with rotating stainless steel drum as described in supplement 4. The system allows for using different commercial TIG welding devices.

Five different state-of-the-art commercial low power TIG welding devices (A1.3) were used a s a reference:

a. Miller Dynasty 200
b. Lincoln electric - Invertec V 160
c. Rehm RWK 1000
d. Fronius Magic wave 3000
e. Kemppi MinarcTig 180MLP.

The light was measured at the distance of 50 cm from the welding arc. The frequency spectra for each of these devices were obtained in the following way:

1. The time dependence of the TIG welding light signal was measured by a photodiode (A1.2) and sampled for 1 s at the rate 32 kHz by the universal data acquisition device (National Instruments NI-6211) connected to the on-line PC (A2.5).
2. A digital band-pass filtering (50 Hz - 6 kHz) of the welding light signal was performed by a PC (A2.5.3).
3. The welding light frequency spectrum of a band-pass filtered signal (A2.5.3) was calculated using a Fast Fourier Transform (A2.5.8)
4. Ten consecutive Fast Fourier Transforms (frequency spectra) of the welding light signal (B3.3.1, B 3.3.2) were averaged to give the frequency spectrum for each of the reference commercial TIG welding devices.
   4.1. The standard TIG frequency spectrum is determined as the average of the frequency spectra of five representative TIG welding devices (a-e) - **"TIG frequency spectrum$_{ISO}$"**. It should be identical to the frequency spectrum of the test lab artificial TIG welding light source (Xe-arc bulb – A1.1).
   4.2. However, the transfer function from the required average spectrum to the actual power control spectrum of the standard Xe-arc lamp depends on a specific electronic realization of the electric power control of the test lab's artificial TIG welding light source (A1.1). So only the "TIG Frequency spectrum$_{ISO}$" expected from the DC driven Xe-arc bulb (A1.1) can be transferred by the proposed ISO Standard to the ADF test laboratories.
   4.3. The standard **"TIG light frequency spectrum$_{ISO}$"** is available from ISO on a CD together with the user instructions.

The standard DC TIG frequency spectrum **"TIG frequency spectrum$_{ISO}$"**, which is identical to the expected frequency spectrum of the test lab's artificial TIG welding light source (Xe-arc bulb – A1.1) is shown in the Fig 5:

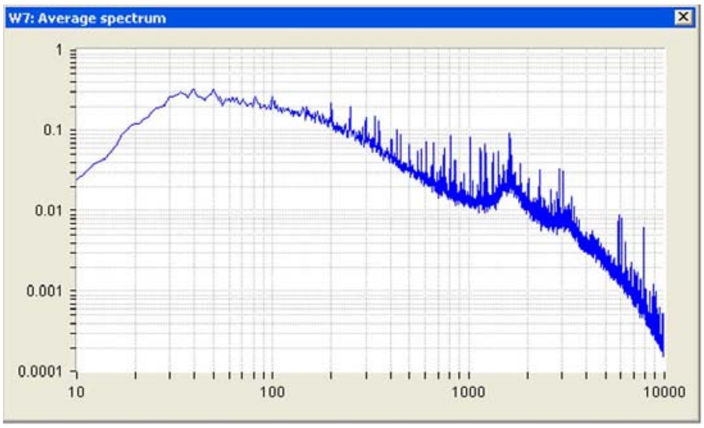

Fig. 5 – **TIG light frequencspectrum$_{ISO}$:**
Horizontal axis represents the frequency in Hz;
Vertical axis represents the spectrum in logarithmic scale and arbitrary units

Automatic TIG welding device (A1.3)

This supplement describes the procedure that was used to obtain and measure the characteristics of radiation emitted during a typical TIG welding process in order to be able to reproduce this signal in the laboratory with simpler means than an actual welding process to test ADFs.

In order to measure the typical TIG welding radiation, a setup has been built that assures a very stable and reproducible welding process. This setup consists of the following components:

- an automatically rotating stainless steel drum cylinder
- a welding torch
- a fixture of the welding torch with a micrometer to control the distance between the electrode's tip and the drum
- a rotameter to control and ensure a constant Argon gas flow
- any commercially available inverter can be attached to the welding torch to provide the welding current as specified for the recommended scale number of N = 9 (from EN 169: 2002, p 9 table, c.f. Fig. 6). For determination of the average spectrum from a typical TIG welding process as described in supplement 3 the following 5 welding machines have been used:
  1) Miller Dynasty 200
  2) Lincoln Electric - Invertec V 160
  3) Rehm RWK 1000
  4) Fronius Magic wave 3000
  5) Kemppi MinarcTig 180MLP

EN 169:2002 (E)

Table A.3 – Recommended use of the different scale numbers for arc welding

	Current A																				
Process	**1,5**	**6**	**10**	**15**	**30**	**40**	**60**	**70**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**300**	**350**	**400**	**450**	**500**	**600**
Covered electrodes						8		9		10		11		12			13			14	
MAG							8	9		10		11				12			13		14
TIG				8		9			10		11			12		13					
MIG with heavy metals									9		10		11			12		13	14		
MIG with light alloys											10		11		12		13		14		
Air-arc gouging											10	11		12		13		14		15	
Plasma jet cutting									9	10	11		12			13					
Micro- plasma arc welding	4		5		6	7		8	9		10		11		12						

Fig. 6: recommended scale number table from EN 169:2002. The welding current leading to a recommendation of a scale no. of 9, is at least 30 A.

A photograph of the welding device is shown in Fig. 7.

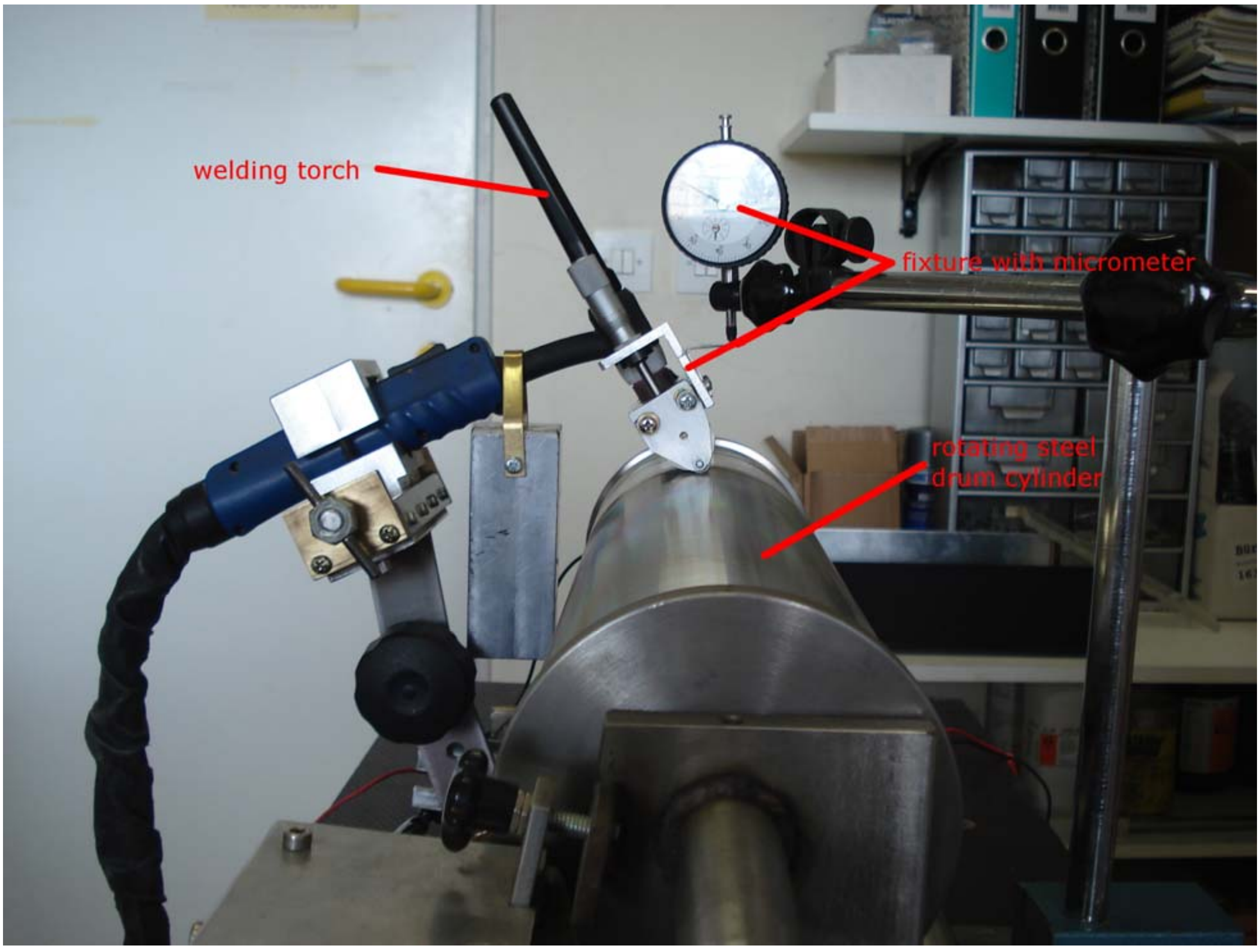

Fig. 7: Device to measure the radiation emitted from a TIG welding process, containing an automatically rotating steel drum, a welding torch and fixture, together with a micrometer, a gas flow rotameter (not shown) and an inverter (not shown)

The following settings and specifications have been used to achieve a TIG welding process with reproducible characteristics:

1. The stainless steel drum having a diameter of 200 mm ± 0.1mm and a wall thickness of 3-5 mm rotates automatically with a speed of 2 cm s^{-1}. For each measurement a fresh trace on the steel drum is chosen.
2. The welding torch consists of a tungsten electrode (WT20; Standard EN 26848; Tungsten + 1.8 to 2.2% of Th) with a diameter of 2.4 mm ± 0.05 mm and a tip angle of 30° ± 1°. The ceramic gas tube of the welding torch has a diameter of 11 mm ± 0.5 mm and the length of the tungsten electrode outside of the ceramic tube is 4.0 mm ± 0.2 mm
3. In order to keep the distance of the electrode's tip to the surface of the steel drum constantly at 0.5 mm ± 0.05 mm, it is important to compensate for potential asymmetries of the steel drum. This was done by

using a fixture mounted on the welding torch comprising a wheel that rolls over the drum surface and keeps the distance of the torch from the drum surface unchanged even if the drum is deformed. The torch is pressed to the drum surface by a lead weight in order adjust the adequate pressure of the micrometer fixture to the surface (c.f. Fig. 7). For a reproducible welding process, accurate adherence of these specifications is essential.

4. The Argon gas flow was adjusted to a flow rate of 6 ± 0.2 l min^{-1} using a commercially available DK47 rotameter by Krohne Messtechnik GmbH & Co. KG, which allows an accuracy of the flow measurement of 2% over the full scale of 8 l min^{-1}.
5. In order to have a properly prepared surface, the stainless steel drum is machined on the lathe. For each measurement, a fresh tungsten tip is used and three full 360° rotations are performed with a current of 30 A (c.f. Fig. 6) on the same track. The next seven 360° rotations are then used for the actual measurements of the emitted radiation of the standardized welding process. The reproducibility of this method is better than 5%, if care is taken to adhere to the above mentioned specification

Peak detection of the AC ripple in ambient illumination

The indoor light source has to simulate an average illumination in the industrial halls, where most of the welding is performed. Due to low power consumption and reasonably longer life time various fluorescent light sources are used for illumination of such places. As there are a vast number of different types of indoor light assemblies, this test light source is to make a reasonable approximation of the constant indoor light and specific AC "ripple" that is likely to be found in an indoor ambient light.

The light detection electronics of the ADFs has to selectively detect the light generated by the welding- arc plasma and the light from the plasma in fluorescent lights. Besides the optical filtering the major selective detection mechanism is based on the electronic "frequency filtering". In the frequency range from ≥ 300 Hz to ~ 6 kHz the light of the welding arc is significantly stronger than the AC ripple light stemming from the fluorescent ambient light sources → selective light detection of ADFs.

Therefore the adjustment procedure has to pay attention not only to the static illuminance level but especially also to the peak ripple signal level in a specific range of frequencies relevant for the ADFs' light sensitivity. Only the peak AC ripple signal from the photodiode (A2.1) after passing the band- pass filter with cut-off frequencies 400 Hz and 6 kHz (A2.5.2) is actually the one that affects the performance of the light sensitivity in the ambient lighting conditions.

The "ripple" signal is detected by a photodiode with spectrally flat filter (A2.1) and measured by the PC computer performing an on-line experiment control via a general AD/DA interface (e.g. National Instruments NI-USB 6211; A2.5) – see Fig. 8. The signal at the output of the linear amplifier is filtered by a band-pass filter implemented in software (A2.5.2) with the 3dB cutoff frequencies set to 400 Hz and 6 kHz. The maximum (repetitive) peak signal value (A2.5.7) at the output of the filter is taken as a measure of the AC ripple signal level of interest. The average DC signal value of the ambient light (A2.5.4) is obtained by low pass (≤ 1 Hz) digital filtering of the same light signal (A2.1). In such a way the ambient light is characterized by the ratio:

AC ripple (A2.5.7) / DC light (A2.5.4),

measured and calculated by PC computer performing an on-line experiment control. Since only the light in the relevant frequency range (ADF sensitivity) is taken into account, such a characterization of ambient light can be traceable everywhere in the world.

The ambient light in ADF testing laboratories can be adjusted by a calibrated photometer (A2.3) measuring the overall effective illuminance (200 lx) at the test sample position D, while the relative light intensities of the fluorescent (A1.4.2) and incandescent (A1.4.1) lights are adjusted by the diaphragms b, c (Fig. 1) so that the above specified ratio: AC ripple (A2.5.7) / DC light (A2.5.4) is obtained (see section D for details)

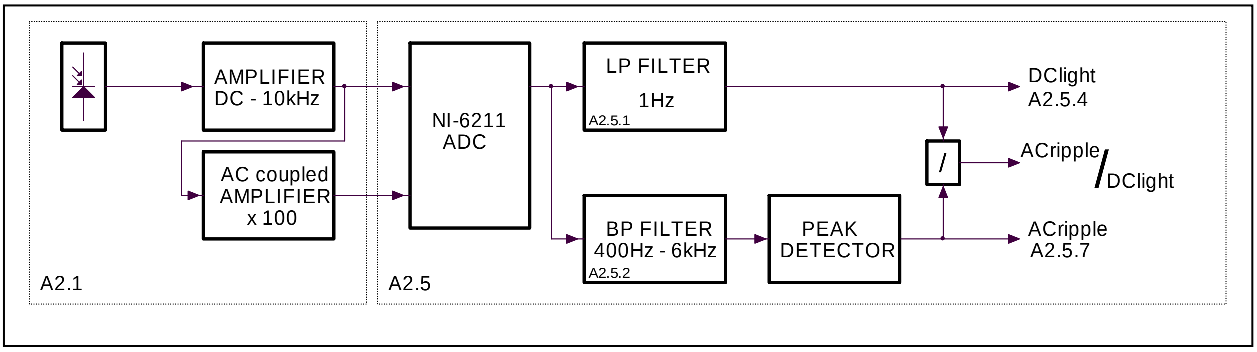

Fig. 8 – Block diagram for ambient light measurements

NOTE:
The outputs DClight, ACripple and ACripple/DClight are numbers on the screen of a PC computer:
ACripple/DClight output is used during the procedure of adjusting the diaphragms (b), (c) in front of fluorescent and incadescent lights in order to set the correct ratio of both.

Band-pass filter specification:

The band pass filter, used for the indoor light source adjustment, should have the following characteristics:

- pass band gain: 0 dB
- low cutoff frequency (-3dB): 400 Hz
- high cutoff frequency (-3dB): 6 000 Hz
- slope rate: 18 dB/octave
- filter type: Bessel (in order to give low peak overshoots)