INTERNATIONAL STANDARD

IEC 904-8

First edition
1995-09

Photovoltaic devices –

Part 8:
Guidance for the measurement of spectral response of a photovoltaic (PV) device

Dispositifs photovoltaïques –

Partie 8: Guide pour le mesurage de la réponse spectrale d'un dispositif photovoltaique (PV)

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- la CEI 617 *Symboles graphiques pour schémas*,

et pour les appareils électromédicaux,

- la CEI 878 *Symboles graphiques pour équipements électriques en pratique médicale*.

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Terminology

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The terms and definitions contained in the present publication have either been taken from the IEV or have been specifically approved for the purpose of this publication

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- IEC 27 *Letter symbols to be used in electrical technology*,
- IEC 417 *Graphical symbols for use on equipment Index, survey and compilation of the single sheets*,
- IEC 617: *Graphical symbols for diagrams*,

and for medical electrical equipment,

- IEC 878· *Graphical symbols for electromedical equipment in medical practice*.

The symbols and signs contained in the present publication have either been taken from IEC 27, IEC 417, IEC 617 and/or IEC 878, or have been specifically approved for the purpose of this publication

IEC publications prepared by the same technical committee

The attention of readers is drawn to the end pages of this publication which list the IEC publications issued by the technical committee which has prepared the present publication.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PHOTOVOLTAIC DEVICES –

Part 8: Guidance for the measurement of spectral response of a photovoltaic (PV) device

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields To this end and in addition to other activities, the IEC publishes International Standards Their preparation is entrusted to technical committees, any IEC National Committee interested in the subject dealt with may participate in this preparatory work International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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3) They have the form of recommendations for international use published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense

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International Standard IEC 904-8 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

The text of this standard is based on the following documents:

DIS	Report on voting
82(CO)14	82(CO)21

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

PHOTOVOLTAIC DEVICES –

Part 8: Guidance for the measurement of spectral response of a photovoltaic (PV) device

1 Scope

This part of IEC 904 gives guidance for the measurement of the relative spectral response of both linear and non-linear photovoltaic devices.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 904. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 904 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 904-1: 1987, *Photovoltaic devices – Part 1: Measurement of photovoltaic current-voltage characteristics*

IEC 904-2: 1989, *Photovoltaic devices – Part 2: Requirements for reference solar cells*

IEC 904-3: 1989, *Photovoltaic devices – Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*

3 Relative spectral response measurement

The relative spectral response of a photovoltaic (PV) device is measured by irradiating it by means of a narrow-bandwidth light source at a series of different wavelengths covering its response range, and measuring the short-circuit current density and irradiance at each of these wavelengths

NOTE – In this standard, the words "light" and "sunlight" are used in their broader sense to include the ultra-violet and the infra-red as well as the visible spectrum

The light source should irradiate the device uniformly and the temperature of the device should be controlled. The current densities are then divided by the irradiances or a proportional parameter and plotted as a function of wavelength. Alternatively, the irradiance may be kept constant (for instance, by varying the length of a monochromator exit slit), in which case the relative spectral response is obtained directly from the current density readings.

The irradiance monitor may be a vacuum thermocouple, a pyroelectric radiometer or other suitable detector. Another alternative is a previously calibrated reference photovoltaic device whose relative spectral response covers the required range. In this case, the relative spectral response of the test specimen is computed as follows:

$$k_2 \; s_{2\lambda} = k_1 \cdot s_{1\lambda} \, \frac{J_{mt\lambda}}{J_{mr\lambda}}$$

where

$k_1 \cdot s_{1\lambda}$ is the relative spectral response of the reference photovoltaic device at wavelength λ;

$k_2 \cdot s_{2\lambda}$ is the relative spectral response of the test specimen at the same wavelength;

$J_{mr\lambda}$ is the measured short-circuit current density of the reference photovoltaic device at wavelength λ;

$J_{mt\lambda}$ is the measured short-circuit current density of the test specimen at the same wavelength.

In assembling the test set-up and performing the measuring, special attention should be given to the following:

- Uniformity of irradiance at the test plane (uniform irradiance is very important when test specimen and reference photovoltaic devices are of different dimensions).
- Filter transmission curves should be checked periodically to detect any "harmonic" transmission.
- Load resistor calibration and contact resistance should be checked.
- Linearity of response of the short-circuit current of the device versus the light intensity at all illumination levels and all wavelengths.
- The load resistor should be kept to a minimum practical value in order to remain as close as possible to true short-circuit conditions.

Figures 1 and 2 show two examples of test arrangements, the first embodying a quartz prism monochromator and the second a filter wheel as the monochromatic source.

NOTE – In this standard the word "monochromatic" is used to mean narrow bandwidth

In both cases, the light source is a 1 000 W tungsten halogen lamp operated from a stable supply at a colour temperature of 3 200 K. The test cell and the irradiance monitor are mounted on opposite sides of a rotatable temperature-controlled block, so that either may be presented to the monochromatic beam in precisely the same place Alternatively, they may be mounted on a slide with suitable positioning stops, or illuminated simultaneously by means of a beam splitter

The filter wheel should contain a sufficient number of narrow-band filters to cover the response range of the cell in wavelength steps not exceeding 50 nm. The filters are arranged so that each can be indexed in turn between the light source and the test cell or irradiance monitor. It is important that the filters should have negligible (under 0,2 %) side-bands. The monochromator is normally used with fixed slits and manually set to the same wavelength steps.

With crystalline silicon and other cells where the response has been shown to change linearly with irradiance, the short-circuit current of the cells (voltage drop across a standard 4-terminal fixed resistor) and the open-circuit voltage of the vacuum thermocouple or radiometer may be measured directly with a d.c. digital voltmeter or potentiometer. The requirements for instrumentation accuracy and the measurement of short-circuit currents given in IEC 904-1 and IEC 904-3 apply. If the d.c. method is used, the exit beam, test specimen and irradiance monitor should be completely enclosed in an anti-reflective light-tight box and meticulous precautions should be taken to avoid thermal and random electro-magnetic fields which would cause errors. Alternatively, the exit beam may be chopped at a low frequency and the output voltages amplified and rectified. In this case, it is important to ensure that the amplifiers are linear and drift-free.

With non-linear devices it is necessary to use a chopped monochromatic beam, and to increase the irradiance to the desired operational level (e.g., 1 000 W m^{-2}) using unmodulated bias light from a suitable steady-state simulator as shown in figures 1 and 2. For linear devices the bias light is also necessary unless there is proof that the obtained spectral response will not change significantly when the bias light is not used.

A method for pulsed solar spectral response measurements is shown in figure 3. Apart from the change of light source, the measurement method remains the same, and is based on the comparison of the short-circuit currents generated by the cell to be measured and by the spectrally calibrated reference device. The test set-up comprises:

- a powerful flash lamp which provides high intensity light pulses;
- a filter wheel and light-tight box as previously described;
- a sample holder that ensures reproducible positioning of the test specimen and the reference photovoltaic device;
- reference photovoltaic device(s) spectrally calibrated in accordance with IEC 904-2 (specialized radiometry laboratories are best equipped to perform this calibration);
- a decade load resistor;
- an electronic "peak-detector";
- a digital voltmeter.

NOTE – The pulsed light method cannot be used on test specimens whose response time is too slow. Therefore, it must be verified that the same short-circuit current density is obtained from pulsed and steady-state light sources having the same intensity. This same requirement also applies to the reference device.

In assembling the test set-up and in performing the measurements, special attention should be given to the light pulse intensity monitoring and the subsequent reading correction which may either be manual or, better, automatic.

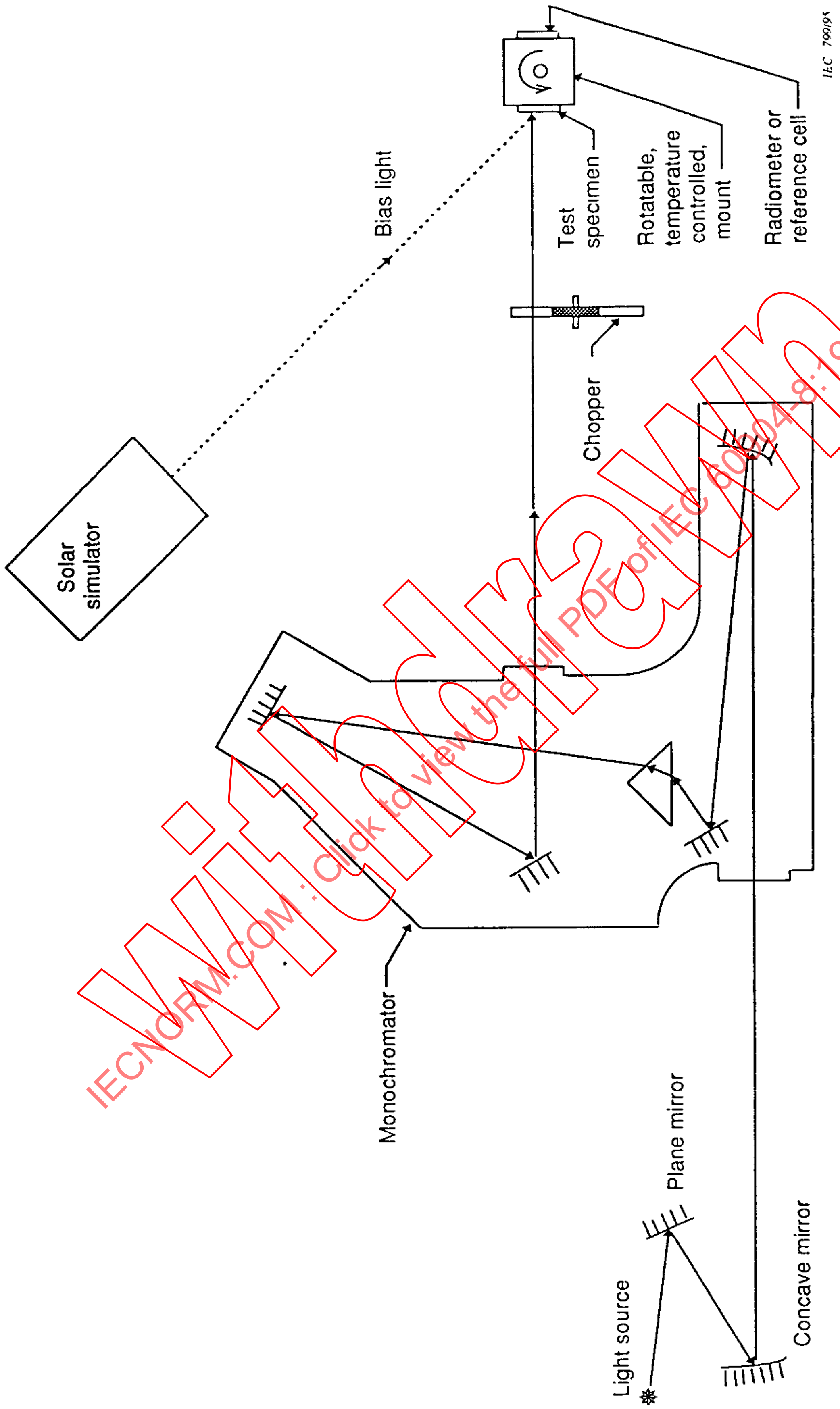

Figure 1 – Spectral response measurement using a monochromator

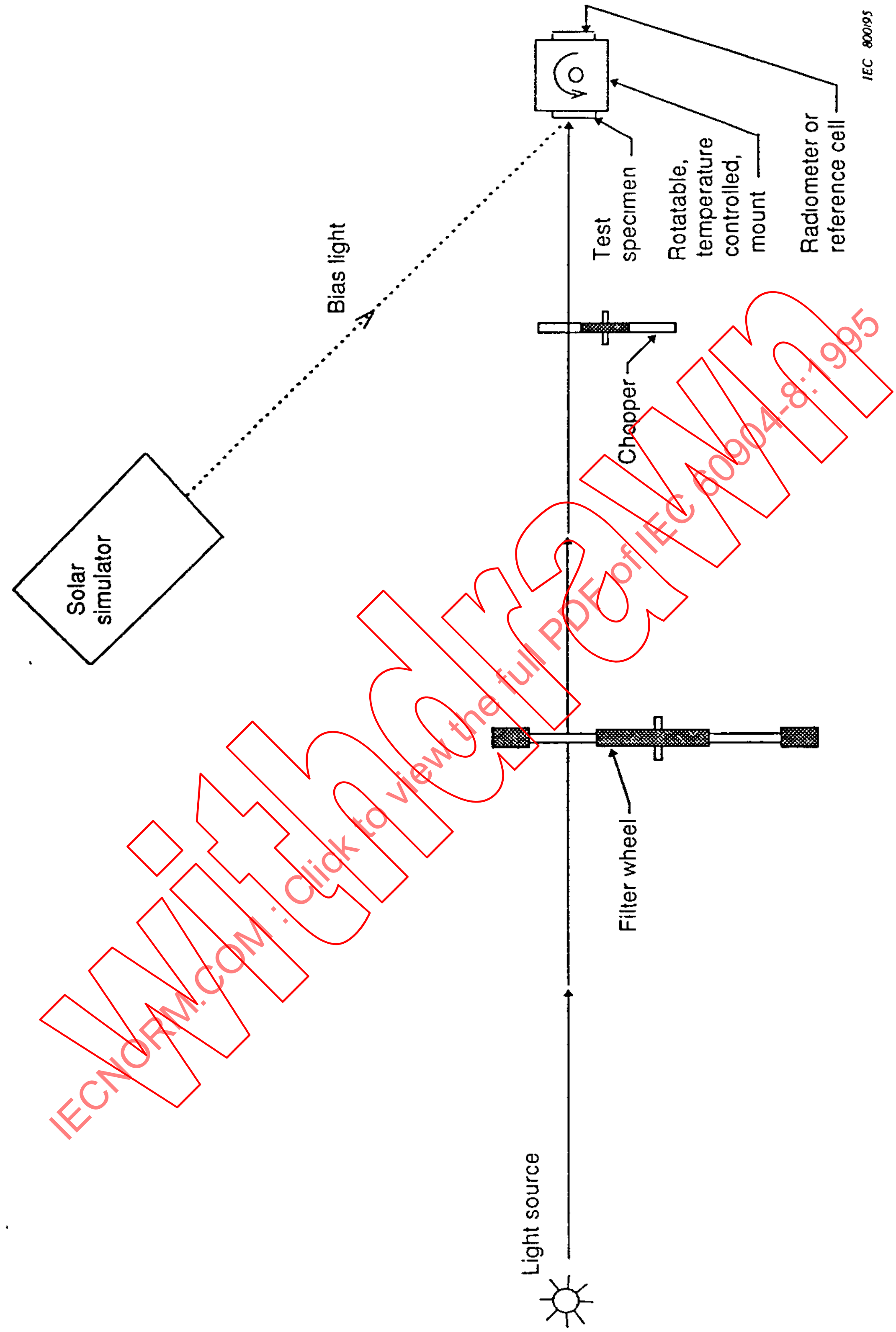

Figure 2 – Spectral response measurement using a filter wheel