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MIDDLETON SOLAR

DN5-B & DN5-BE

PYRHELIOMETER

ISO 9060 Spectrally Flat Class B

USER'S GUIDE

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1 INTRODUCTION

The DN5-B Pyrheliometer is for measuring solar Direct Normal Irradiance (DNI) when aimed at the sun. The field of view is a solid angle of 5º. It exceeds the International Organization for Standardization (ISO) specifications for a Spectrally Flat Pyrheliometer of Class B[1]. The DN5-B has a passive microvolt output. The DN5-BE version has an in-built signal amplifier to give a millivolt output.

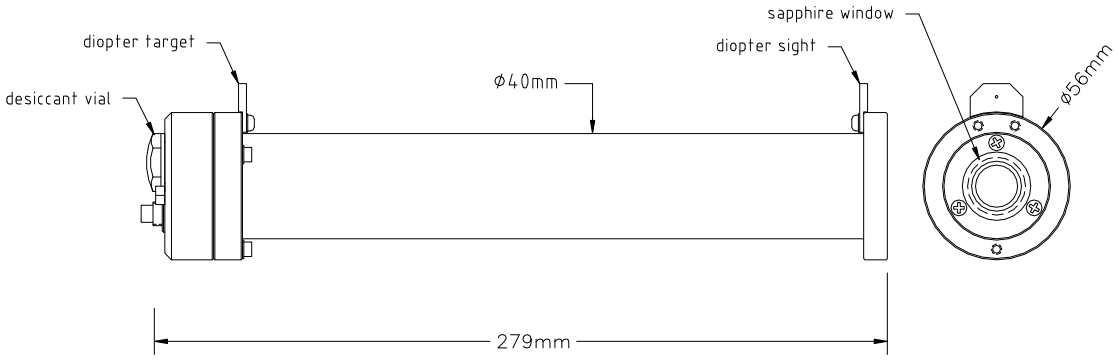
2 CONSTRUCTION

The body is manufactured from marine-grade aluminium and is anodised to provide a durable, corrosion-resistant finish. All fasteners are stainless steel. The window is made from optical sapphire which is superior to optical glass in spectral bandpass and hardness. The window is flush-mounted to prevent build up of rainwater or debris.

The DN5-B series has a twin-thermopile sensor with a sun-facing receiver element and an identical reference element facing into the instrument body. The twin-thermopile configuration helps minimise zero off-set error by cancelling any common-mode response, such as caused by rapid changes in ambient temperature. The sensor unit is embedded in a thermal mass that is isolated from the instrument body. Carbon nanotube (CNT) surface coating is used to provide flat spectral response and temporal stability. The sensor produces an analogue voltage in direct proportion to the magnitude of the incoming solar radiation and the response is corrected for temperature dependence. A separate sensor temperature output is an available option (on the DN5-B version) so that the user can monitor instrument temperature.

The DN5-B series is hermetically sealed, with a silica gel desiccant vial to prevent internal condensation. A diopter is attached to the body so that the instrument can be accurately aimed at the sun.

Figure 1. DN5-B Pyrheliometer



See section 7 for an internal view of the DN5-B.

[1] ISO 9060:2018 Specification and classification of instruments for measuring hemispherical solar and direct solar radiation. ISO 9060:2018 'Class B' roughly corresponds to superseded ISO 9060:1990 'First Class'

3 INSTALLATION

3.1 MOUNTING and ALIGNMENT

For direct solar radiation measurement, select a site where the view the DN5-B has of the sun is not obstructed between earliest sunrise and latest sunset throughout the year. An optional Hood is available (see Appendix B-4).

It is recommended that the DN5-B be mounted to an automatic solar tracking system. Tracking alignment should be better than ± 0.5º. Take care that the DN5-B alignment diopter is not obscured by the chosen tracker mount. A Pyrheliometer Mount and Automatic & Active Trackers (see Appendix B-1 to B-3) are available from Middleton Solar.

Both the front diopter sight and rear diopter target have central "pinholes". When the DN5-B is correctly aimed at the sun, direct light passing through the front pinhole will also pass through the rear pinhole, and can be seen as a bright spot on a card held behind the diopter target.

3.2 ELECTRICAL CONNECTION

The DN5-B lead cores are:

red = signal output positive (typically 7 µV per W/m^2)
blue = signal negative
(option: yellow & green = sensor temperature thermistor)

Use differential input connections to your measurement equipment; do not use single sided inputs as this may cause a zero off-set in the signal. Do not connect power to the signal wires as this will damage the sensor thermopiles.
The measurement equipment should have an input impedance of at least 1MΩ.

The DN5-BE lead cores are:

red = power supply positive (7 to 15VDC, 6mA)
blue = power supply negative
yellow = signal output positive (typically 1 mV per W/m^2)
green = signal negative

Do not operate the instrument outside the specified supply voltage range. Use differential input connections to your measurement equipment. Do not connect the power supply negative (blue wire) to the signal negative (green wire). The measurement equipment should range up to 2V and have an input impedance of at least 1MΩ.

4 MAINTENANCE

Keep the window clean. Use only water and mild detergent to gently wash the surface. If the window is cracked or pitted it should be replaced.

The DN5-B contains a desiccant to ensure that the interior remains dry and free from condensation. The desiccant is orange silica gel (non-toxic). The silica gel changes from orange to clear (or green) if moisture has entered the instrument.

To access the silica gel unscrew the rear dehydrator cap and withdraw the desiccant vial. Take care to correctly position the O-ring seal when refitting the dehydrator cap.

5 CALIBRATION

Each DN5-B Pyrheliometer is individually calibrated during manufacture by outdoor comparison to a reference Pyrheliometer, according to ISO 9059[2]. The reference Pyrheliometer is traceable to the World Radiometric Reference (WRR).

The calibrated sensitivity is inscribed on an identification label on the body of the instrument.

It is recommended that Pyrheliometer calibration be checked every two years to maintain data integrity.

Calibration can be undertaken by the User or by any recognised solar calibration facility. Middleton Solar also offers a calibration service all year round.

[2] ISO 9059:1990/2014 Solar energy – Calibration of field Pyrheliometers by comparison to a reference pyrheliometer

6 TECHNICAL SPECIFICATION

parameter	ISO 9060:2018 Spectrally Flat Class B	DN5-B & DN5-BE
Response time (to 95%)	< 15 sec	5.5 ± 0.5 sec
Zero off-set a) response to 5°C/hour	± 3 $W.m^{-2}$	< ± 1 $W.m^{-2}$
Zero off-set b) total response	± 4 $W.m^{-2}$	< ± 2.5 $W.m^{-2}$
Non-stability (1 year interval)	± 1%	< 0.2%
Non-linearity (100 - 1000 $W.m^{-2}$)	± 0.5%	< ± 0.3%
Spectral error (280 to 4,000nm)	± 1%	< ± 0.5%
Spectral selectivity (350 to 1,500 nm)[3]	< 3%	< 2%
Temperature response (-10 to +40°C)	± 1%	< ± 1%
Tilt response (@ 1000 $W.m^{-2}$)	± 0.5%	± 0.3%
Additional signal processing errors	± 5 $W.m^{-2}$	DN5-B, not applicable DN5-BE < ± 3 $W.m^{-2}$

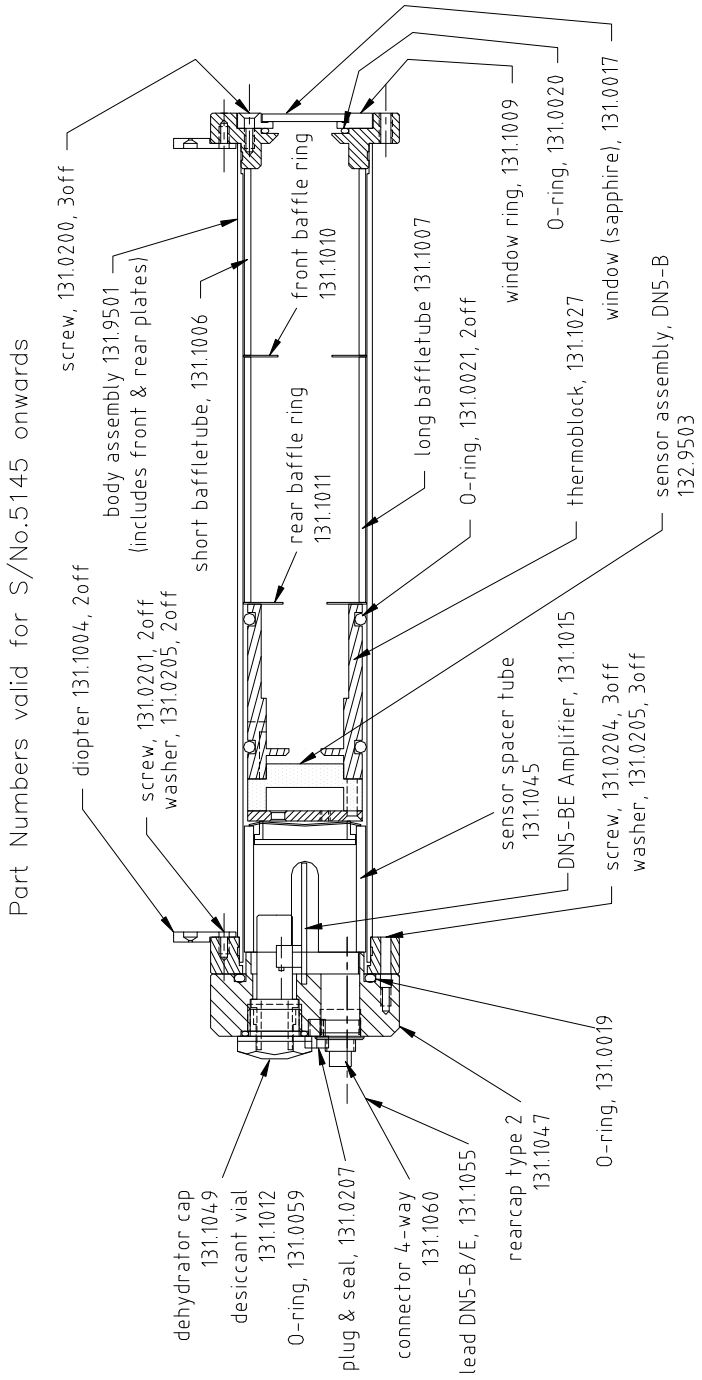
full opening angle	5.0°
slope angle	1.0°
limit angle	4.0°
irradiance	0 – 4,000 $W.m^{-2}$
spectral range (nominal)	200 – 5,000nm
sensitivity (typical)	DN5-B: 7.5 ± 0.5 µV/$W.m^{-2}$ DN5-BE: 1 mV/$W.m^{-2}$
calibration	outdoors to ISO 9059, traceable to WRR
achievable uncertainty (minute totals)	U_{95} = 2.5% (RSS of instrument, calibration, measurement)
operating temperature	-40 to +80°C
operating humidity	0-100% RH
output impedance	20Ω (DN5-B); 65Ω (DN5-BE)
measurement input impedance	>1MΩ
power supply (not DN5-B)	7 to 15VDC, 6mA (DN5-BE)
window material	optical sapphire, 2mm thick
construction	anodised marine-grade aluminium & stainless steel
desiccant	silica gel (orange, non-toxic), externally accessible
IP rating	sealed to IP67
output lead	6m, with connector at instrument end
net weight	0.75kg (excluding lead)
shipping size & weight	310 x 225 x 110mm, 1kg

[3] This requirement designates a Pyrheliometer as 'spectrally flat' in ISO 9060:2018

7 SPARE PARTS

Spare parts may be ordered from Middleton Solar or through an approved distributor. For your convenience the part name and number is shown in Figure 2. Please quote both when ordering. It is also important when ordering parts to include the model type (DN5-B, DN5-BE) and serial number of the instrument, as inscribed on the identification label.

Figure 2. DN5-B/BE Spare Parts



APPENDIX A: SENSOR TEMPERATURE vs THERMISTOR RESISTANCE
For DN5-B instruments fitted with optional sensor temperature output

YSI 44031 Thermistor (accuracy = ±0.2ºC)

Temperature (ºC)	Resistance (Ω)	Temperature (ºC)	Resistance (Ω)
-30	135,200	15	15,130
-29	127,900	16	14,500
-28	121,100	17	13,900
-27	114,600	18	13,330
-26	108,600	19	12,790
-25	102,900	20	12,260
-24	97,490	21	11,770
-23	92,430	22	11,290
-22	87,660	23	10,840
-21	83,160	24	10,410
-20	78,910	25	10,000
-19	74,910	26	9605
-18	71,130	27	9227
-17	67,570	28	8867
-16	64,200	29	8523
-15	61,020	30	8194
-14	58,010	31	7880
-13	55,170	32	7579
-12	52,480	33	7291
-11	49,940	34	7016
-10	47,540	35	6752
-9	45,270	36	6500
-8	43,110	37	6258
-7	41,070	38	6026
-6	39,140	39	5805
-5	37,310	40	5592
-4	35,570	41	5389
-3	33,930	42	5193
-2	32,370	43	5006
-1	30,890	44	4827
0	29,490	45	4655
1	28,150	46	4489
2	26,890	47	4331
3	25,690	48	4179
4	24,550	49	4033
5	23,460	50	3893
6	22,430	51	3758
7	21,450	52	3629
8	20,520	53	3504
9	19,630	54	3385
10	18,790	55	3270
11	17,980	56	3160
12	17,220	57	3054
13	16,490	58	2952
14	15,790	59	2854

APPENDIX B: ACCESSORIES

B-1 PYRHELIOMETER MOUNT (PM02)

The PM02 can accommodate one DN5-B Pyrheliometer. Thumbscrews are provided so that the Pyrheliometer can be precisely aligned. The PM02 has a mount clamp to attach to Trackers with a 1 inch or 25mm axle.

B-2 ACTIVE SOLAR TRACKER (AST-02 & AST-03/3T)

The AST-02 and AST-03/3T are fully automatic trackers with integrated control computer and GPS, and an Eye that locks onto the sun to give real-time active tracking that continuously self-corrects any alignment errors.

B-3 PYRHELIOMETER HOOD (D5H)

The D5H Hood is designed to shelter the pyrheliometer window from rain and dew. The Hood mounts to the front of the DN5-B with two M4 screws. The rotational position of the Hood should be set so that it's drain hole faces the ground.