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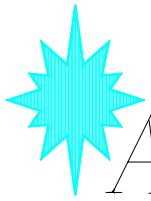
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SCIENTECH®



Astral SERIES
CALORIMETERS

# Setup and Operating Procedures

PN9458L

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Thank you for choosing a Scientech Astral calorimeter. Scientech, an ISO 9001 registered company, and our employees are pleased to provide you with a product designed for years of reliable service. Please read this manual completely before using your indicator. This information will enable you to fully utilize the equipment and should be located nearby for reference. The calorimeter is intended to be used only in the manner outlined in this manual. Misuse of the equipment may cause product failure.

The words "calorimeter" and "detector" are synonymous as used in this manual.

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## CALORIMETER OPERATING PARAMETERS:

| Calorimeter 1: | | Calorimeter 2: | |
|---|---|---|---|
| Model No: | _____ | Model No: | _____ |
| Serial No: | _____ | Serial No: | _____ |
| Calibration Wavelength | _____nm | Calibration Wavelength: | _____nm |
| Output Sensitivity (S): | _____V/W | Output Sensitivity (S): | _____V/W |
| Time Constant (1/e): | _____sec. | Time Constant (1/e): | _____sec. |
| Calibration Temp: | _____°C | Calibration Temp: | _____°C |
| Sub. Heater Resistance ($R_c$): | _____ohms | Sub. Heater Resistance ($R_c$): | _____ohms |
| Sub. Heater Voltage ($V_h$): | _____volts | Sub. Heater Voltage ($V_h$): | _____volts |
| Sub. Heater Wattage ($W_h$) | _____watts | Sub. Heater Wattage ($W_h$): | _____watts |



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# ASTRAL™ CALORIMETER SPECIFICATIONS:

| Model | **AC2500** | **AC25HD** | **ACX25HD** | **AC2501** | **ACX2501** | **AC25UV** | **AC2504** |
|---|---|---|---|---|---|---|---|
| Type of Absorber | Surface | Surface | Surface | Volume | Volume | Volume | Volume |
| Aperture Diameter | 25.4 mm | 25.4 mm | 8 mm | 25.4 mm | 8 mm | 25.4 mm | 25.4 mm |
| Spectral Response | .25-35 µm | .193-12 µm | .4-2 µm | .266-1.2 µm | .4-1.2 µm | .193-.36 µm | .85-4.2 µm |
| Average Power Maximum | 10 W | | | | | | |
| Average Power Minimum | 1 mW when installed in an Isoperibol Enclosure | | | | | | |
| Noise Level | 10 µW or µJ | | | | | | |
| Maximum Power Density | 200 W/cm² | 1.5 kW/cm² | 12 kW/cm² | Note 1 | Note 2 | Note 3 | Note 4 |
| Maximum Peak Power Density | 1 MW/cm² | 100 MW/cm² | 800 MW/cm² | Note 5 | 8.5 GW/cm² | Note 6 | Note 7 |
| Maximum Single Pulse Energy | 10 J | | | | | | |
| Maximum Energy Density | Note 8 | Note 9 | Note 10 | Note 11 | Note 12 | Note 13 | Note 14 |
| Precision | < 1 % | | | | | | |
| Accuracy | ± 3 % | | | | | | |
| Response Time | 3 sec when connected to a Scientech Indicator in Watts Mode | | | | | | |
| Dimensions DxL - inches | 3.75 x 2.2 | 3.75 x 2.2 | 3.75 x 3.82 | 3.75 x 2.2 | 3.75 x 3.82 | 3.75 x 2.2 | 3.75 x 2.2 |
| cm | 9.53 x 5.6 | 9.53 x 5.6 | 9.53 x 9.7 | 9.53 x 5.6 | 9.53 x 9.7 | 9.53 x 5.6 | 9.53 x 5.6 |
| Weight - pounds/kg | 1.5/0.68 | 1.5/0.68 | 1.7/0.77 | 1.5/0.68 | 1.7/0.77 | 1.5/0.68 | 1.5/0.68 |
| Indicator Compatibility | H410, H410D, S310, S310D, D200PC, D200C | | | | | | |

| Model | **AC5000** | **AC50HD** | **ACX50HD** | **AC5001** | **ACX5001** | **AC50UV** | **AC5004** |
|---|---|---|---|---|---|---|---|
| Type Absorber | Surface | Surface | Surface | Volume | Volume | Volume | Volume |
| Aperture Diameter | 50.8 mm | 50.8 mm | 16 mm | 50.8 mm | 16 mm | 50.8 mm | 50.8 mm |
| Spectral Response | .25-35 µm | .193-12 µm | .4-2 µm | .266-1.2 µm | .4-1.2 µm | .193-.36 µm | .85-4.2 µm |
| Average Power Maximum | 30 W | | | | | | |
| Average Power Minimum | 40 mW | | | | | | |
| Noise Level | 400 µW or µJ | | | | | | |
| Maximum Power Density | 200 W/cm² | 1.5 kW/cm² | 12 kW/cm² | Note 1 | Note 2 | Note 3 | Note 4 |
| Maximum Peak Power Density | 1 MW/cm² | 100 MW/cm² | 800 MW/cm² | Note 5 | 8.5 GW/cm² | Note 6 | Note 7 |
| Maximum Single Pulse Energy | 30 J | | | | | | |
| Maximum Energy Density | Note 8 | Note 9 | Note 10 | Note 11 | Note 12 | Note 13 | Note 14 |
| Precision | < 1 % | | | | | | |
| Accuracy | ± 3 % | | | | | | |
| Response Time | 3 sec when connected to a Scientech Indicator in Watts Mode | | | | | | |
| Dimensions DxL - inches | 4.75 x 2.3 | 4.75 x 2.3 | 4.75 x 3.92 | 4.75 x 2.3 | 4.75 x 3.92 | 4.75 x 2.3 | 4.75 x 2.3 |
| cm | 12.07 x 5.8 | 12.07 x 5.8 | 12.07 x 9.96 | 12.07 x 5.8 | 12.07 x 9.96 | 12.07 x 5.8 | 12.07 x 5.8 |
| Weight pounds/kgs | 2.9/1.3 | 2.9/1.3 | 3.1/1.4 | 2.9/1.3 | 3.1/1.4 | 2.9/1.3 | 2.9/1.3 |
| Indicator Compatibility | H410, H410D, S310, S310D, D200PC, D200C | | | | | | |

Note 1: AC2501, AC5001 — 30W/cm$^2$ @ 1064nm, 23W/cm$^2$ @ 532nm, 8.5W/cm$^2$ @ 355nm, 175mW/cm$^2$ @ 266nm

Note 2: ACX2501, ACX5001 — Note 1 specs x 8 for 400nm to 1.2µm

Note 3: AC25UV, AC50UV — 50W/cm$^2$ @ 355nm

Note 4: AC2504, AC5004 — 35W/cm$^2$ @1064nm

Note 5: AC2501, AC5001 — 100GW/cm$^2$ @ 1064nm, 78GW/cm$^2$ @532nm, 29GW/cm$^2$ @ 355nm, 580MW/cm$^2$ @266nm

Note 6: AC25UV, AC50UV — Repetitive pulses: 101MW/cm$^2$ @ 355nm
Single pulses: 3.5GW/cm2 @ 355nm

Note 7: AC2504, AC5004 — 125GW/cm$^2$ @ 1064nm

Note 8: AC2500, AC5000 — Max J/cm$^2$ = 1,000 x (pulse width)$^{1/2}$ to a maximum of 200J/cm$^2$.

Note 9: AC25HD, AC50HD — Max J/cm$^2$ = 4,500 x (pulse width)$^{1/2}$ to a maximum of 14J/cm$^2$.

Note 10: ACX25HD, ACX50HD — Max J/cm$^2$ = 36,000 x (pulse width)$^{1/2}$ to a maximum of 42.5J/cm$^2$.

Note 11: AC2501, AC5001 — Repetitive pulses: 4.1J/cm$^2$@1064nm, 3.2J/cm$^2$@532nm, 1.2J/cm$^2$@355nm, 24mJ/cm$^2$@266nm
Single pulses: 8J/cm$^2$@1064nm, 6.2J/cm$^2$@532nm, 2.3J/cm$^2$@355nm, 46mJ/cm$^2$@266nm

Note 12: ACX2501, ACX5001 — Note 11 specs x 8 for 400nm to 1.2µm

Note 13: AC25UV, AC50UV — Repetitive pulses: 1.1J/cm$^2$ @ 355nm
Single pulses: 40J/cm2 @ 355nm

Note 14: AC2504, AC5004 — Repetitive pulses: 4.8J/cm$^2$ @ 1064nm
Single pulses: 10J/cm2 @ 1064nm



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## ABSORPTION OF HD ABSORBING MATERIAL:

**Warning: You must exercise caution when using HD detectors. They exhibit spectral reflection of between 7% and 18%, of the input power, back out of the aperture. Please refer to Figure 1 to determine the reflectance for the wavelength you are measuring. These detectors should be treated as a partial mirror or any other type of reflective optic and the appropriate caution level observed, especially at the $CO_2$ wavelength.**

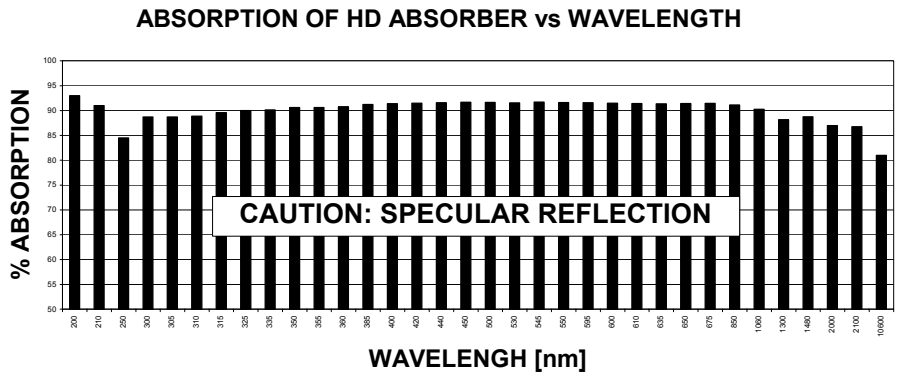



Figure 1

**Note: HD calorimeters might show "beam" marks on the absorbing surface. These marks are characteristic of the material and do not affect the performance of the calorimeter. Do not rub off or remove the marks. Polishing or cleaning the absorbing surface might change the performance of the calorimeter.**

Please see the table at the end of this manual for specific absorption vs. wavelength information.

## CE MARK CERTIFICATION:

All of the calorimeters listed in this manual have been certified for the European CE mark.

## ENVIRONMENTAL REQUIREMENTS:

This product is intended for indoor use at altitudes up to 2000 meters, Pollution Degree 2 in accordance with IEC 664 and transient overvoltages according to Installation Categories (Overvoltage Categories) II. Note that each of the above detectors will not pass the IEC 801 Publication, Part 3, Radiated Electromagnetic Field Requirements. The system, meter and detector, is designed to measure radiation within the test's radiation band. The detectors were held outside the radiated electromagnetic field during this test. It is up to the user to be aware of RF fields present during measurements and their effects if any on those measurements.

## UNPACKING AND SET UP:

The calorimeter and accessories are shipped in custom packing materials. All packing materials should be saved for future damage free shipments.

A ½" diameter mounting post is included. Screw the post into one of the mounting holes in the body of the calorimeter. Mount the post to your optical bench or working surface. An optional mounting base, Scientech Model 301-019, is available for this purpose.

A 3 meter mini DIN interconnect cable is also included. If you are using a Scientech indicator, connect the calorimeter to the indicator with the interconnect cable. Follow the detailed set up instructions that are in the indicator's instruction manual. If you are not using a Scientech indicator operating requirements are contained in this manual.



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**Note: Astral calorimeters are sensitive to all types of thermal input. Due to the handling of the calorimeter during setup and possible environmental temperature differences, thermal gradients may exist in the calorimeter. Allow the calorimeter to sit undisturbed for several minutes to, reach thermal equilibrium, before using.**

**Note: When using a 25mm Astral calorimeter for measuring average power levels below 30mW and single pulse energy levels below 30mJ, a Scientech Model 36-0203A, Isoperibol Enclosure, is highly recommended. The isoperibol enclosure should not be used at average power levels above 30mW, and single pulse energy levels above 100mJ because heat build up will occur.**

## CORRECTING ASTRAL™ SERIES HD CALORIMETERS OPERATING PARAMETERS FOR USE AT DIFFERENT WAVELENGTHS:

Scientech Astral calorimeters in general have a flat response to all wavelengths within their specified spectral response. HD and HDX calorimeters are an exception to that rule and are calibrated at a specific wavelength by adjusting the calorimeter's gain circuitry for that wavelength. The calibration wavelength is recorded in the Operating Parameters section at the front of the manual and on the detector's serial tag. When a HD or HDX calorimeter is used at a wavelength other than the calibration wavelength, the calorimeter's output sensitivity can be adjusted to compensate for the absorption rate at the new wavelength as follows:

1. Find the absorption rate from the chart at the end of this manual for the calibration wavelength of your calorimeter.
2. Find the absorption rate for the wavelength where you will be working.
3. Determine the new output sensitivity using the following formula:

$$\frac{\text{absorption rate of the new wavelength}}{\text{absorption rate of calibration wavelength}} \times \text{output sensitivity} = \text{output sensitivity for new wavelength}$$

from serial tag

## CALORIMETER OPERATION WITHOUT AN INDICATOR:

### Cable Requirements:

Astral calorimeters are powered up by the indicators. To use an Astral calorimeter without a Scientech indicator, but with a volt meter or chart recorder, you must apply +/-8VDC to the mini DIN connector as shown in Figure 2. The voltage output of the calorimeter, from pin 8, should be connected to the positive side of the DVM or chart recorder. All 3 of the grounds should be tied together at the negative side. Pins 2 and 3 are not used.

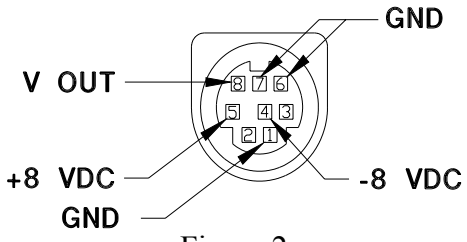



Figure 2



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## Operation of Astral™ Calorimeters with a Digital Volt Meter:

The calorimeters may be used with any digital volt meter (DVM) capable of reading 5 volts full scale.

Connect the output of the calorimeter to the DVM.

Select the DC volts mode.

Direct the laser beam on to the absorbing surface of the calorimeter.

When the display of the DVM has stabilized (about 2 minutes), calculate the laser power using the formula:
W = V/S
where:
W = Laser power in watts
V = Voltage reading of the DVM in volts
S = Sensitivity of the calorimeter from page 2.

## Operation of Astral™ Calorimeters with an Analog Chart Recorder:

### Calorimeter Response:

The response of a calorimeter to a single pulse input as displayed by a chart recorder appears below.

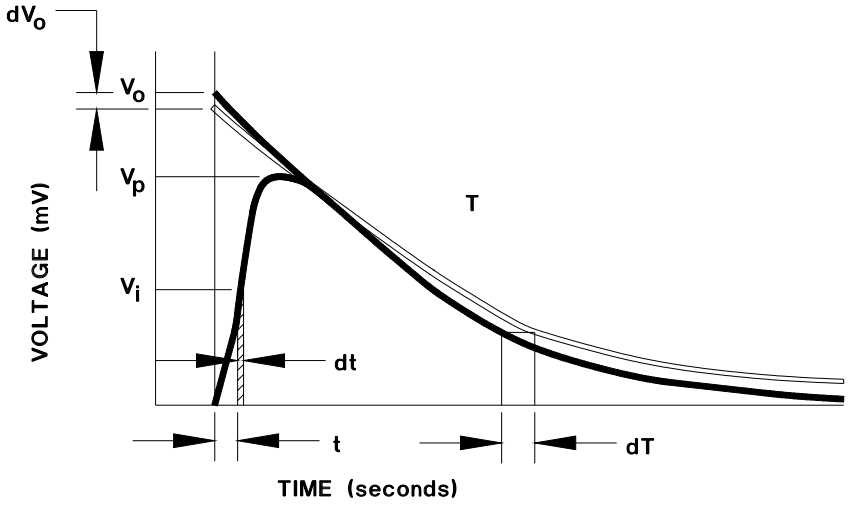


Figure 3

The output voltage from a chart recorder can be converted to wattage at any time by:

$W = V/S$, $W_i = V_i/S$

V = Chart recorder voltage level in mV
S = Calorimeter sensitivity in mV/W

The total energy (E) in the pulse can be found by integrating the instantaneous wattage over time:

$$E = \int_0^\infty W(t)\, dt$$

The following methods may be used to compute the total integrated energy:



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**Numerical Integration:**

Finding the area under the curve in figure 7 is the equivalent procedure for determining pulse energy. Choose an appropriate time interval, dt, and perform the summation:

$$E = \sum_{I=1}^{N} W_i x dt = (dt/S) \sum_{i=1}^{N} V_i$$

The error caused by this procedure is:

$$dE = (dt/S) \sum_{i=1}^{N} dV_i$$

The error, in theory, is only dependent upon the value of $\sum dV_i$, that is the cumulative random error of $V_i$. This number should approach zero if data is carefully taken. The accuracy is also increased if the time interval, dt, is minimized. Numerical integration can yield accurate results, but is a tedious task.

**Initial Voltage Interpolation:**

A method used to eliminate the tedious numerical integration task is to project the thermal decay envelope on to the voltage axis, determine the 1/e decay time constant T, and estimate the total energy value (E):

$$E = (V_o/S) \times T$$

The change from thermal absorption to thermal transport phenomena near the peak causes difficulty in accurately projecting the envelope on to the voltage axis introducing an error, $dV_o$. Further, the determination of the time constant T, introduces another error, dT. The total error is the sum of the two errors.

$$dE = (V_o/S)dT + (T/S)dV_o$$

The difficulty in eliminating the potential error makes this method typically less accurate than numerical integration, but much faster in application.

**Peak Voltage Estimate:**

The peak voltage method requires using an independent determination of total energy and referencing it back to the peak voltage value, $V_p$.

For a given pulse, use the numerical integration method to obtain E. Note the peak voltage, $V_p$. Compute the value, F

$$F = E/V_p$$

For the next pulse compute the total energy: $E = F \times V_p$

The error in using this method yields: $dE = FdV_p + V_p dF$

The accuracy of this measurement depends upon the error in the original calibration, dF, and the error in the peak voltage $dV_p$. A careful numerical integration yields a value for dF near zero. The value of $dV_p$ can be minimized by maintaining the geometry of the system (i.e. beam intensity, beam profile, wavelength and environment) during operation to be the same as during calibration. Under controlled circumstances, the peak method accuracy usually falls between the numerical integration and initial voltage interpolation methods.



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# CALIBRATION OF ASTRAL™ CALORIMETERS USING ELECTRIC SUBSTITUTION HEATING:

For Astral calorimeters the electric substitution heating option must be ordered and installed at the factory when the calorimeter is purchased. It can not be retrofitted to a calorimeter at a later time. To calibrate using electric substitution heating proceed as follows.

A. Remove the screws holding the calorimeter's ID tag and remove the plate to expose the circuit board.

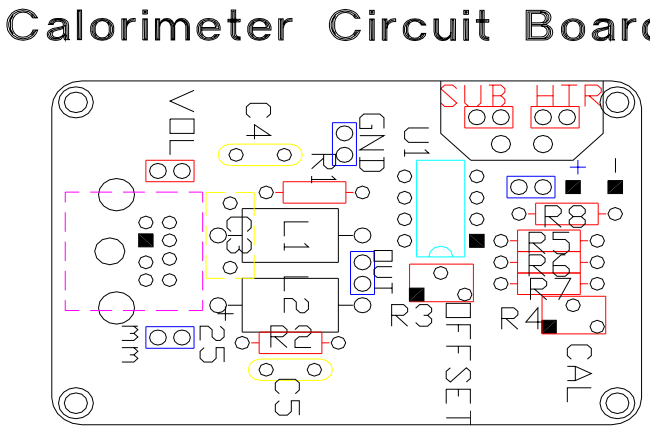



Figure 4

B. Connect a DVM to the test points labeled SUB and HTR on the calorimeter circuit board.

C. Measure the resistance of the substitution heater making sure to subtract the resistance of the patch cables from the total resistance measurement. Compare this resistance to $R_c$ in the calibration data in the front of the manual. The two should agree within 2%. If not contact Scientech.

D. Remove the DVM. Connect a power supply to the SUB and HTR test points and connect the DVM to monitor the power supply.

E. Connect a second DVM to the output and ground of the Astral calorimeter.

F. Apply $V_h$ volts, stated in the calibration data you received with the calorimeter, to the substitution heater.

G. Verify that the output voltage is one of the following values depending on the type of calorimeter being tested:

0.750 volts for 25 mm calorimeters
0.333 volts for 50 mm calorimeters

H. If needed, adjust the calibration trim pot, R4 on the calorimeter circuit board, until the voltage measured in step G is from the calibration data, is displayed by the indicator.



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# HD ABSORPTION VS. WAVELENGTH:

| Wavelength µm | Absorption % |
|---|---|
| 0.200 | 93.00 |
| 0.210 | 91.00 |
| 0.220 | 88.00 |
| 0.230 | 85.00 |
| 0.240 | 82.00 |
| 0.250 | 84.48 |
| 0.255 | 85.03 |
| 0.260 | 84.90 |
| 0.265 | 85.08 |
| 0.270 | 85.26 |
| 0.275 | 85.84 |
| 0.280 | 86.56 |
| 0.285 | 86.86 |
| 0.290 | 87.06 |
| 0.295 | 88.28 |
| 0.300 | 88.68 |
| 0.305 | 88.68 |
| 0.310 | 88.84 |
| 0.315 | 89.57 |
| 0.320 | 89.42 |
| 0.325 | 90.01 |
| 0.330 | 89.91 |
| 0.335 | 90.14 |
| 0.340 | 90.31 |
| 0.345 | 90.52 |
| 0.350 | 90.59 |
| 0.355 | 90.60 |
| 0.360 | 90.76 |
| 0.365 | 90.75 |
| 0.370 | 91.03 |
| 0.375 | 91.10 |
| 0.380 | 91.06 |
| 0.385 | 91.20 |
| 0.390 | 91.20 |
| 0.395 | 91.29 |
| 0.400 | 91.39 |
| 0.405 | 91.41 |
| 0.410 | 91.44 |
| 0.415 | 91.54 |
| 0.420 | 91.49 |
| 0.425 | 91.64 |
| 0.430 | 91.54 |
| 0.435 | 91.66 |
| 0.440 | 91.58 |
| 0.445 | 91.67 |
| 0.450 | 91.66 |
| 0.455 | 91.68 |
| 0.460 | 91.69 |
| 0.465 | 91.64 |
| 0.470 | 91.67 |
| 0.475 | 91.61 |

| Wavelength µm | Absorption % |
|---|---|
| 0.480 | 91.54 |
| 0.485 | 91.63 |
| 0.490 | 91.74 |
| 0.495 | 91.67 |
| 0.500 | 91.63 |
| 0.505 | 91.57 |
| 0.510 | 91.52 |
| 0.515 | 91.57 |
| 0.520 | 91.63 |
| 0.525 | 91.54 |
| 0.530 | 91.55 |
| 0.535 | 91.63 |
| 0.540 | 91.74 |
| 0.545 | 91.71 |
| 0.550 | 91.60 |
| 0.555 | 91.53 |
| 0.560 | 91.56 |
| 0.565 | 91.58 |
| 0.570 | 91.57 |
| 0.575 | 91.46 |
| 0.580 | 91.52 |
| 0.585 | 91.49 |
| 0.590 | 91.51 |
| 0.595 | 91.59 |
| 0.600 | 91.46 |
| 0.605 | 91.41 |
| 0.610 | 91.40 |
| 0.615 | 91.31 |
| 0.620 | 91.20 |
| 0.625 | 91.31 |
| 0.630 | 91.29 |
| 0.635 | 91.33 |
| 0.640 | 91.41 |
| 0.645 | 91.46 |
| 0.650 | 91.40 |
| 0.655 | 91.47 |
| 0.660 | 91.28 |
| 0.665 | 91.38 |
| 0.670 | 91.36 |
| 0.675 | 91.43 |
| 0.680 | 91.28 |
| 0.685 | 91.32 |
| 0.690 | 91.30 |
| 0.695 | 90.99 |
| 0.700 | 91.37 |
| 0.705 | 91.16 |
| 0.710 | 91.08 |
| 0.715 | 91.02 |
| 0.720 | 90.88 |
| 0.725 | 90.96 |
| 0.730 | 91.16 |

| Wavelength µm | Absorption % |
|---|---|
| 0.735 | 90.77 |
| 0.740 | 91.22 |
| 0.745 | 90.79 |
| 0.750 | 90.80 |
| 0.755 | 90.99 |
| 0.760 | 90.90 |
| 0.765 | 90.67 |
| 0.770 | 90.83 |
| 0.775 | 90.99 |
| 0.780 | 90.82 |
| 0.785 | 91.05 |
| 0.790 | 90.92 |
| 0.795 | 91.19 |
| 0.800 | 91.12 |
| 0.805 | 90.92 |
| 0.810 | 90.73 |
| 0.815 | 90.24 |
| 0.820 | 91.32 |
| 0.825 | 90.40 |
| 0.830 | 91.00 |
| 0.835 | 90.93 |
| 0.840 | 90.82 |
| 0.845 | 91.15 |
| 0.850 | 91.10 |
| 0.855 | 89.92 |
| 0.860 | 90.44 |
| 0.865 | 91.04 |
| 0.870 | 91.04 |
| 0.875 | 91.21 |
| 0.880 | 91.03 |
| 0.885 | 91.10 |
| 0.890 | 90.47 |
| 0.895 | 91.19 |
| 0.900 | 90.70 |
| 0.905 | 90.96 |
| 0.910 | 90.87 |
| 0.915 | 90.97 |
| 0.920 | 90.91 |
| 0.925 | 90.89 |
| 0.930 | 90.82 |
| 0.935 | 90.95 |
| 0.940 | 90.80 |
| 0.945 | 90.83 |
| 0.950 | 90.66 |
| 0.955 | 90.64 |
| 0.960 | 90.67 |
| 0.965 | 90.60 |
| 0.970 | 90.57 |
| 0.975 | 90.60 |
| 0.980 | 90.57 |
| 0.985 | 90.59 |



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| Wavelength µm | Absorption % |
|---|---|
| 0.990 | 90.51 |
| 0.995 | 90.52 |
| 1.000 | 90.49 |
| 1.005 | 90.48 |
| 1.010 | 90.49 |
| 1.015 | 90.50 |
| 1.020 | 90.45 |
| 1.025 | 90.44 |
| 1.030 | 90.44 |
| 1.035 | 90.39 |
| 1.040 | 90.37 |
| 1.045 | 90.30 |
| 1.050 | 90.29 |
| 1.055 | 90.25 |
| 1.060 | 90.25 |
| 1.065 | 90.27 |
| 1.070 | 90.31 |
| 1.075 | 90.31 |
| 1.080 | 90.28 |
| 1.085 | 90.30 |
| 1.090 | 90.28 |
| 1.095 | 90.20 |
| 1.100 | 90.12 |
| 1.105 | 90.10 |
| 1.110 | 90.08 |
| 1.115 | 89.75 |
| 1.120 | 89.62 |
| 1.125 | 89.54 |
| 1.130 | 89.51 |
| 1.135 | 89.43 |
| 1.140 | 89.39 |
| 1.145 | 89.29 |
| 1.150 | 89.21 |
| 1.155 | 89.13 |
| 1.160 | 89.11 |
| 1.165 | 89.05 |
| 1.170 | 88.99 |
| 1.175 | 88.98 |
| 1.180 | 88.91 |
| 1.185 | 88.91 |
| 1.190 | 88.90 |
| 1.195 | 88.79 |
| 1.200 | 88.62 |
| 1.205 | 88.54 |
| 1.210 | 88.42 |
| 1.215 | 88.36 |
| 1.220 | 88.35 |
| 1.225 | 88.29 |
| 1.230 | 88.29 |
| 1.235 | 88.22 |
| 1.240 | 88.23 |
| 1.245 | 88.19 |
| 1.250 | 88.23 |

| Wavelength µm | Absorption % |
|---|---|
| 1.255 | 88.20 |
| 1.260 | 88.20 |
| 1.265 | 88.21 |
| 1.270 | 88.26 |
| 1.275 | 88.15 |
| 1.280 | 88.12 |
| 1.285 | 88.16 |
| 1.290 | 88.19 |
| 1.295 | 88.13 |
| 1.300 | 88.15 |
| 1.305 | 88.11 |
| 1.310 | 88.14 |
| 1.315 | 88.20 |
| 1.320 | 88.32 |
| 1.325 | 88.32 |
| 1.330 | 88.35 |
| 1.335 | 88.30 |
| 1.340 | 88.34 |
| 1.345 | 88.46 |
| 1.350 | 88.71 |
| 1.355 | 89.17 |
| 1.360 | 89.19 |
| 1.365 | 89.22 |
| 1.370 | 89.22 |
| 1.375 | 89.12 |
| 1.380 | 89.08 |
| 1.385 | 89.11 |
| 1.390 | 89.11 |
| 1.395 | 89.02 |
| 1.400 | 88.97 |
| 1.405 | 88.99 |
| 1.410 | 89.04 |
| 1.415 | 88.96 |
| 1.420 | 88.91 |
| 1.425 | 88.92 |
| 1.430 | 88.95 |
| 1.435 | 88.91 |
| 1.440 | 88.84 |
| 1.445 | 88.82 |
| 1.450 | 88.74 |
| 1.455 | 88.74 |
| 1.460 | 88.79 |
| 1.465 | 88.74 |
| 1.470 | 88.71 |
| 1.475 | 88.72 |
| 1.480 | 88.72 |
| 1.485 | 88.67 |
| 1.490 | 88.61 |
| 1.495 | 88.61 |
| 1.500 | 88.61 |
| 1.505 | 88.66 |
| 1.510 | 88.61 |
| 1.515 | 88.59 |

| Wavelength µm | Absorption % |
|---|---|
| 1.520 | 88.50 |
| 1.525 | 88.52 |
| 1.530 | 88.51 |
| 1.535 | 88.49 |
| 1.540 | 88.48 |
| 1.545 | 88.44 |
| 1.550 | 88.44 |
| 1.555 | 88.40 |
| 1.560 | 88.40 |
| 1.565 | 88.44 |
| 1.570 | 88.44 |
| 1.575 | 88.40 |
| 1.580 | 88.38 |
| 1.585 | 88.43 |
| 1.590 | 88.40 |
| 1.595 | 88.35 |
| 1.600 | 88.33 |
| 1.605 | 88.35 |
| 1.610 | 88.38 |
| 1.615 | 88.28 |
| 1.620 | 88.24 |
| 1.625 | 88.23 |
| 1.630 | 88.23 |
| 1.635 | 88.25 |
| 1.640 | 88.22 |
| 1.645 | 88.24 |
| 1.650 | 88.19 |
| 1.655 | 88.20 |
| 1.660 | 88.24 |
| 1.665 | 88.16 |
| 1.670 | 88.20 |
| 1.675 | 88.12 |
| 1.680 | 88.05 |
| 1.685 | 88.06 |
| 1.690 | 88.11 |
| 1.695 | 88.07 |
| 1.700 | 88.06 |
| 1.705 | 88.00 |
| 1.710 | 87.99 |
| 1.715 | 87.91 |
| 1.720 | 87.99 |
| 1.725 | 87.94 |
| 1.730 | 87.89 |
| 1.735 | 87.80 |
| 1.740 | 87.83 |
| 1.745 | 87.88 |
| 1.750 | 87.85 |
| 1.755 | 87.82 |
| 1.760 | 87.79 |
| 1.765 | 87.73 |
| 1.770 | 87.75 |
| 1.775 | 87.72 |
| 1.780 | 87.77 |



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| Wavelength µm | Absorption % |
|---|---|
| 1.785 | 87.73 |
| 1.790 | 87.64 |
| 1.795 | 87.62 |
| 1.800 | 87.66 |
| 1.805 | 87.64 |
| 1.810 | 87.59 |
| 1.815 | 87.58 |
| 1.820 | 87.56 |
| 1.825 | 87.58 |
| 1.830 | 87.67 |
| 1.835 | 87.49 |
| 1.840 | 87.58 |
| 1.845 | 87.52 |
| 1.850 | 87.62 |
| 1.855 | 87.50 |
| 1.860 | 87.56 |
| 1.865 | 87.48 |
| 1.870 | 87.52 |
| 1.875 | 87.42 |
| 1.880 | 87.44 |
| 1.885 | 87.38 |
| 1.890 | 87.38 |
| 1.895 | 87.32 |
| 1.900 | 87.29 |
| 1.905 | 87.18 |
| 1.910 | 87.11 |
| 1.915 | 87.41 |
| 1.920 | 87.06 |
| 1.925 | 87.10 |
| 1.930 | 87.08 |
| 1.935 | 87.06 |
| 1.940 | 87.13 |
| 1.945 | 87.02 |
| 1.950 | 86.97 |
| 1.955 | 87.06 |
| 1.960 | 87.07 |
| 1.965 | 87.20 |
| 1.970 | 87.04 |
| 1.975 | 87.12 |
| 1.980 | 87.10 |
| 1.985 | 86.91 |
| 1.990 | 86.98 |
| 1.995 | 86.92 |
| 2.000 | 86.96 |
| 2.005 | 86.81 |
| 2.010 | 86.85 |
| 2.015 | 86.75 |
| 2.020 | 86.90 |
| 2.025 | 86.89 |
| 2.030 | 86.82 |
| 2.035 | 86.79 |
| 2.040 | 86.77 |
| 2.045 | 86.78 |

| Wavelength µm | Absorption % |
|---|---|
| 2.050 | 86.86 |
| 2.055 | 86.83 |
| 2.060 | 86.72 |
| 2.065 | 86.71 |
| 2.070 | 86.71 |
| 2.075 | 86.60 |
| 2.080 | 86.63 |
| 2.085 | 86.62 |
| 2.090 | 86.69 |
| 2.095 | 86.66 |
| 2.100 | 86.74 |
| 2.105 | 86.58 |
| 2.110 | 86.48 |
| 2.115 | 86.59 |
| 2.120 | 86.59 |
| 2.125 | 86.62 |
| 2.130 | 86.60 |
| 2.135 | 86.57 |
| 2.140 | 86.59 |
| 2.145 | 86.46 |
| 2.150 | 86.62 |
| 2.155 | 86.58 |
| 2.160 | 86.56 |
| 2.165 | 86.66 |
| 2.170 | 86.67 |
| 2.175 | 86.65 |
| 2.180 | 86.65 |
| 2.185 | 86.69 |
| 2.190 | 86.71 |
| 2.195 | 86.63 |
| 2.200 | 86.65 |
| 2.205 | 86.44 |
| 2.210 | 86.42 |
| 2.215 | 86.30 |
| 2.220 | 86.30 |
| 2.225 | 86.17 |
| 2.230 | 86.33 |
| 2.235 | 86.38 |
| 2.240 | 86.38 |
| 2.245 | 86.15 |
| 2.250 | 86.39 |
| 2.255 | 86.25 |
| 2.260 | 86.17 |
| 2.265 | 86.13 |
| 2.270 | 86.39 |
| 2.275 | 86.22 |
| 2.280 | 86.28 |
| 2.285 | 86.20 |
| 2.290 | 86.32 |
| 2.295 | 85.99 |
| 2.300 | 86.31 |
| 2.305 | 86.17 |
| 2.310 | 86.09 |

| Wavelength µm | Absorption % |
|---|---|
| 2.315 | 86.25 |
| 2.320 | 86.07 |
| 2.325 | 86.04 |
| 2.330 | 86.01 |
| 2.335 | 85.97 |
| 2.340 | 85.96 |
| 2.345 | 86.54 |
| 2.350 | 85.94 |
| 2.355 | 86.02 |
| 2.360 | 86.01 |
| 2.365 | 85.68 |
| 2.370 | 85.87 |
| 2.375 | 86.30 |
| 2.380 | 85.77 |
| 2.385 | 85.68 |
| 2.390 | 85.97 |
| 2.395 | 85.99 |
| 2.400 | 85.26 |
| 2.405 | 85.40 |
| 2.410 | 85.84 |
| 2.415 | 85.64 |
| 2.420 | 86.09 |
| 2.425 | 85.77 |
| 2.430 | 86.26 |
| 2.435 | 85.72 |
| 2.440 | 85.41 |
| 2.445 | 86.02 |
| 2.450 | 85.92 |
| 2.455 | 85.46 |
| 2.460 | 85.77 |
| 2.465 | 85.96 |
| 2.470 | 85.87 |
| 2.475 | 85.29 |
| 2.480 | 86.08 |
| 2.485 | 85.59 |
| 2.490 | 86.26 |
| 2.495 | 85.54 |
| 2.500 | 85.12 |
| 10.600 | 82.10 |



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