PSP 32

ADC BioScientific Ltd.

Monitoring Chlorophyll Fluorometer System

Employ in the field or greenhouse to continually monitor large populations of plants

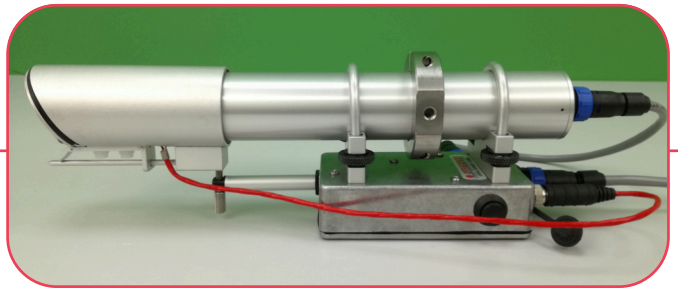
Modulated chlorophyll fluorometer

True dynamic, field measurements

Automated, daylight dark adaption

Continuous, remote

A controller unit with as many as 32 measuring probes,
providing measurement solutions for all types of plant stress.



Monitor plant stress like never before

- Detect the broadest range of stresses across large populations of plants.
- Combine fluorescence probes with chlorophyll content probes and soil moisture sensors to capture every commonly studied plant stress type.
- Deploy in the field, greenhouse or growth chamber.
- Remote programming and data capture via a mobile App.
- Powered by solar panel & 12V battery, or mains.
- Circadian rhythms with continuous, 24 hour measurements.
- Long term, continuous, and reliable data capture and large scale studies.

Tested and approved by key researchers

Professor Tracy Lawson, Lawson Plant Physiology Laboratory, University of Essex, Colchester, UK

"In my laboratory we work on exploring plant responses to dynamic light environments and how this influences photosynthesis and stomatal behaviour over the diurnal period. We are now using this fundamental information and applying it to real world growth environments and particularly indoor growth environments such as vertical farms. To monitor the plants over the course of the entire diel period we have been using the new Opti-Sciences PSP32 Monitoring Chlorophyll Fluorometer to assess changes in PSII efficiency as an indicator of photosynthesis.

We have also worked closely with Opti-Sciences to adapt the instrument to provide real-time digital outputs, which we are now using to provide a real-time plant feedback system where the surrounding environmental conditions are adjusted based on the plant's needs. Opti-Sciences were extremely helpful, providing extra kit to deliver these real-time signal outputs".

Professor Alexander Ruban, The Ruban Laboratory, QMUL, London, UK

One of the most recent developments in my lab was establishment of a new methodology that allows for quantification of plant adaptation to excess light and determination of the maximum light intensity that can be tolerated by them. The major protective mechanism of photosystem II (PSII), NPQ, has finally been quantitatively linked to the light intensity that plants can tolerate without showing signs of photoinhibition. Whilst all previous applications of PAM fluorimetry were focused upon quantitative measurements of photochemistry of photosynthetic electron transport and photophysics of the light harvesting events, assessing amplitudes of qP and NPQ parameters, quantum efficiency of PSII, its functional cross-section etc., the pNPQ method provides parallel measurement of NPQ as well as true photoinhibition of PSII function. Relating these parameters to illumination light intensity enables us to establish and monitor high light tolerance of plants in vivo. Hence, the new monitoring equipment PSP32 is a tool of the future that encompasses the pNPQ technology that could be useful for screening and monitoring of photosynthetic performance and light tolerance.

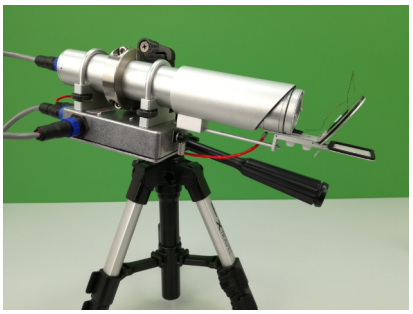
There was an initial sharp learning curve with use of the instrument, especially with regards to programming in new experimental procedures. However, all at Opti-Sciences were incredibly helpful, and the PSP32 proved to be a very versatile instrument.

Standard Probe Versions

Standard PSP32 probes are available with:

- Blue or Red modulated light
- Automated modulated light intensity setup
- Measure Y(II) and ETR during the day
- Measure F_V/F_M at night
- Compute Lake and Puddle Model Quenching parameters from pre-dawn F_V/F_M & daytime Y(II)
- Adjustable saturation flash intensity for F_M' correction of Y(II) and ETR measurements
- Measure PAR and leaf temperature
- Can integrate with soil moisture sensors & weather stations
- Can provide measurement output to drive environmental controls such as light intensity
- Custom protocol capability

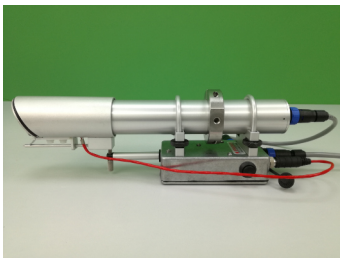
"Daylight-dark-adaption" Probe Versions



Daylight-dark-adaption hoods can be fitted to standard PSP32 probes, giving you all of the standard version features and significantly more…

No need for pre-dawn fieldwork

- Remotely measured pre-dawn F_M can be used as the reference for calculations.
- Measure Quenching Relaxation parameters at different times of the day:
- qE the photo-protective xanthophyll cycle
- qI Photoinhibition
- qM Chloroplast migration
- qT State transitions
- pNPQ & qPd with colour graphing (In collaboration with Ruban, A. & Murchie, E.)
- Measure F_V/F_M at different times of the day
- Measure light saturation characteristics with Rapid Light Curves, ETR_{MAX}, I_M, $I_{K,}$ α
- Custom protocol capability



Options for Plant Variations

Moss and small plant mount for any standard probe:

Monitor plant stress like never before

Long Term Fluorescence Monitoring

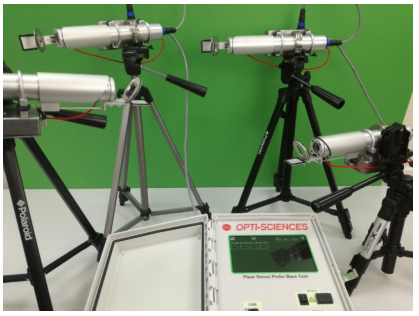
The fluorescence measuring trace can be recorded and viewed over lengthy periods of time.
The quenching reference can be taken from either the highest F_M value during the night or the last F_M value over longer periods of time.

Since it can take between 30 to 60 hours for photoinhibition to completely relax or repair, this choice can facilitate accurate quenching data in line with research guidance.

Research finds that, while a high frequency of saturation flashes on light-adapted plants will not damage plant tissue, frequent saturation flashes on dark-adapted plants, on the same area, can damage plant tissue.
In response, PSP32 provides independent control over the frequency of saturation flashes during the day and during the night. Research recommends once per hour in the dark to avoid tissue damage.

Large Scale Fluorescence Monitoring

To study larger populations of plants, the PSP32 allows as many as 32 measuring heads or probes to be fitted to a single controller unit. This is a cost-effective configuration whilst allowing truly replicated data to be collected.

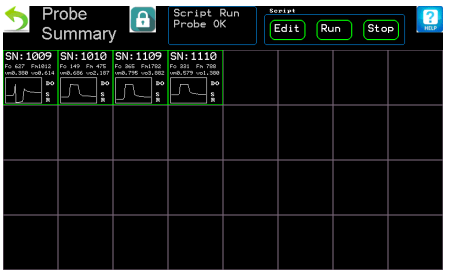


Leaf Temperature Measurement

The PSP32 measures abaxial leaf surface temperature using a contact thermistor. This is a non-destructive measurement method.
The thermistor is extremely durable and provides readings of +/-0.1℃ accuracy.

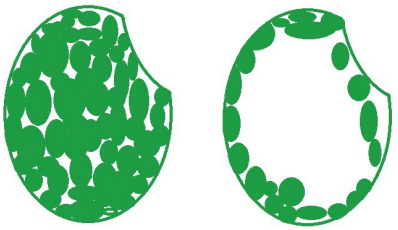
PAR and ETR Measurement

The PSP32 measures light intensity at the leaf surface to determine PAR, ETR and the onset of day and night.



Investigate Chloroplast Migration

- Compare different NPQ protocols and parameters which may differ in their sensitivity to chloroplast migration.
- The Kramer fast quenching protocol NPQ_T (S.Tietz et al., 2017) has been found to be less sensitive than standard NPQ, to the movement of chloroplasts.
- Comparison of these parameters enables the quantification of leaf chloroplast movement.

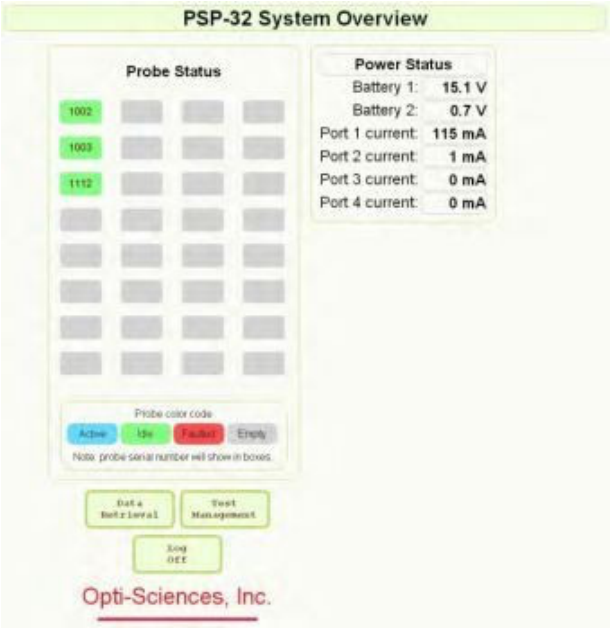


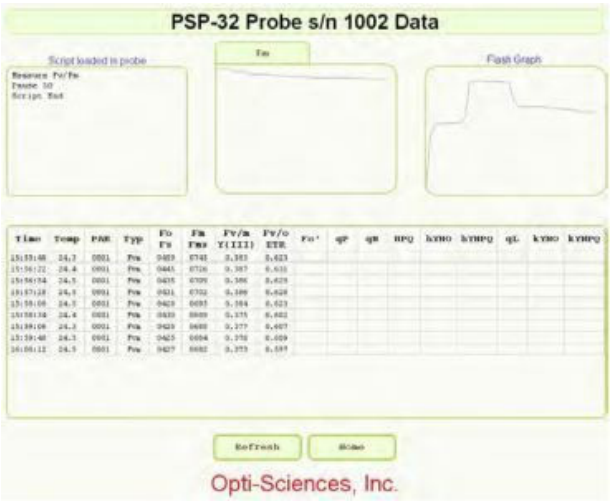
Remote Data Collection and Control

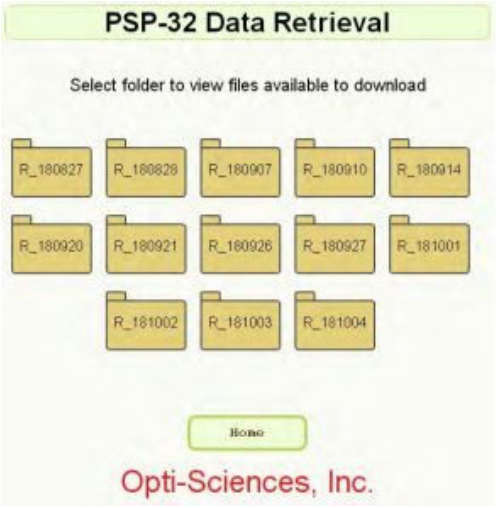
With webpage interface design, control, programming, and data retrieval can be carried out remotely by cell phone, lap top, or desktop computer. This makes the system ideal for growth chamber work, and remote field work. No additional software or updates are necessary.
Warnings of measurement errors can be sent to cell phones or computers to minimise data loss.
The PSP32 system comes standard with: WiFi, Ethernet, and USB capability.
Options include a cell phone modem, radio point to point and a satellite phone modem for more remote situations.

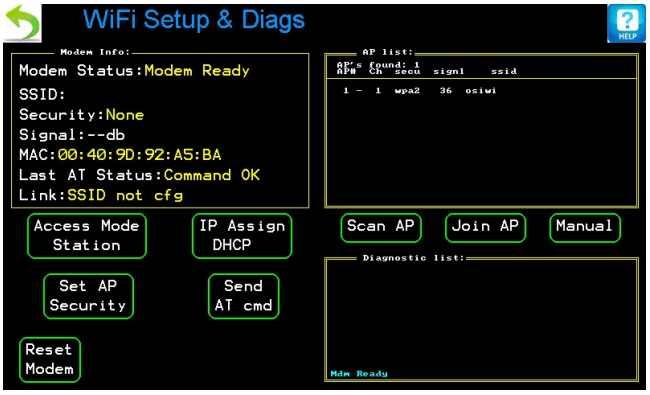
Wi-Fi Webpage Interface

- Remote data collection and multiple probe control from your personal device.
- Wi-Fi webpage interface suitable for smart phone, tablet, laptop or desktop PC.
- PSP32 is IDEAL for greenhouse, growth chamber and remote field work.
- Protects your data by sending warnings or measurement errors to your device.
- PSP32 is supplied with WiFi, Ethernet and USB. Options for smart phone modem, radio point to point and satellite phone modem are available.









The PSP32 calculates, displays and stores a complete set of both established and leading contemporary parameters and protocols for:

Light adapted fluorescence

- Y(II): Quantum Yield of PSII (or $\Delta F/F_M'$ or Y)
- ETR: Electron Transport Rate
- PAR: Photosynthetically Active Radiation
- T: Leaf temperature
- F_{MS} (or F_M'): Maximal fluorescence with actinic illumination using a saturation pulse
- F: Fluorescence under actinic light (prior to saturation pulse)
- Loriaux *et al* (2013) correction of ETR and F_M' correction are options included for Y(II) measurement.

Dark adapted fluorescence

- F_v/F_M: Maximum photochemical efficiency of PSII
- F_v/F_0: A more sensitive detector of stress than F_v/F_M (efficiency is not measured)
- F_0: Minimum fluorescence
- F_M: Maximum fluorescence
- F_v: Variable fluorescence
- F_0': Minimum fluorescence after exposure to far red light. F_0' is calculated with the dark adaption module fitted to a probe, or estimated without.
- Kramer fast quenching parameters:
- NPQ(T)
- qE(T)
- and qI(T)
- can be calculated from given data (with red light probes only).

Rapid Light Curves:

- $rETR_{MAX}$ (Eilers and Peeters) a measure of a leaf's photosynthetic capacity or maximum electron transport rate.
- α is the initial slope of line at low PAR values, created by relating ETR to PAR. It provides a measure of quantum efficiency.
- I_k is the measurement of the actinic light intensity where light saturation dominates, or the minimum saturation level.
- I_m is the (Eilers and Peeters) calculated optimal actinic light intensity related to ETR_{MAX}

Quenching parameters and protocols
Standard with all probes:

- Hendrickson Quenching with NPQ Y/NPQ), Y(NO), Y(II), NPQ, F_V/F_M
- Kramer Quenching qL, Y(NPQ), Y(NO), Y(II), F_V/F_M
- Puddle model parameters NPQ, qN, qP, Y(II), F_V/F_M

Why daytime dark-adapt?

Under dynamic field conditions, plants may lose a significant amount of energy through the mechanisms of non-photochemical quenching (NPQ). NPQ protects plant photosynthetic tissue from damage caused by excessive excitation. To measure certain NPQ parameters involving maximum fluorescence (F_M), accurately, a leaf must be fully dark-adapted so that all available reaction centres are open and no NPQ is occurring. This is commonly achieved by taking pre-dawn measurement or determining a set dark-adaption period.

With the PSP32, this state can now be achieved remotely and even during the daytime. The unique, dark-adaption module with automatic opening/closing mechanism allows the length of dark-adaption to be set, time period is set to suit the sample and the accepted methodology, providing flexibility.

PSP32 System Accessories

A large range of accessories are available with the PSP32:

- Tripods
- Articulated arms for tripod or retort stand mounting
- Solar panels
- Daylight dark adaption module with far red light
- Additional measuring proves (maximum of 32 per system)
- Junction boxes
- Cellular modem
- Radio point to point link
- Satellite communications
- Stainless 1.5inch pipe mount with 1/4inch 20 thread mount hole for articulating arms used to mount measuring heads to pole or pipe mounts
- Integration of external data including but not limited to: weather station data, soil-moisture, irradiance, infrared radiometer output.

Accessories

1) 4 Channel Signal Output Box "PSP32 4IB"

Reports as many as 4 separate voltage values to external instruments and controls. Voltage values originate from either the same probe or separate probes.
Any discrete measurement parameter in voltage such as F_s, F_0, Y(II), PAR, leaf temperature, F_V/F_M etc. Measurement frequency is adjustable to once per second. This allows parameter values to feed into external controls for environmental variables such as irradiance or light spectral quality.

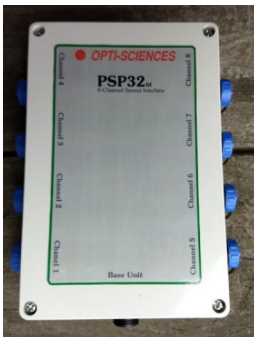
Configuration options:
1. Maximum 4 voltage outputs
2. Maximum 4 current loop outputs
3. Maximum 4 N.O/N.C relay contact sets
4. Custom configuration having a mix of output styles
5. PSP32 system will work with up to 4 of these devices.

The PSP32 offers a text-based scripting capability. Special calculation scripts allow scaling of measurements or calculations to the output signal range. For example: F_V/F_M ranges from 0 to 0.83 and scaling scripts allow the output to range from 0 to 5 volts.
Data variable levels or timed events control the relay output.

2) 8 Analog Input Channel Box "PSP32 PIB"

For connecting Soil Moisture and Soil Temperature Sensors.

Each PIB will allow 8 soil moisture sensors to connect to a PSP32 system.
External data values report to the PSP32 data file along with chlorophyll fluorescence, PAR, and leaf temperature values.
Each channel also supplies power for sensors.
The PSP32 system will connect up to 4 of these devices. While this accessory allow soil temperature and and soil moisture probes to connect to the PSP32, it is also possible to connect leaf wetness sensors, salinity sensors or other analogue sensors to the system. Control of external sensors is by a text script. The script manages external probes like PSP32 probe scripts. Each input can have data range scaling values, unit conversion calculations and sampling interval functions set independently.



Specifications:
Channel Count: 8
Input Range: (Select script per channel) +/-2.5V, +/-5.0V, +/-10V
Input connection: A 4 pin water resistant connector
Excitation Voltage Output: 5.0V DC, maximum load 30mA per sensor.

3) Chlorophyll Content Probe "PSP32 CC"

Automated, non-contact Chlorophyll Content Probe

Ratio fluorescence measurement technique. With a maximum measuring area of 1.2 metres (4 feet) in diameter, this probe can be used with leaves of any size.
Results are independent of lighting conditions.
Ideal for nutrient stress measurement in field-grown plants, greenhouses, and growth chambers.
Allows measurement in mg m^{-2} and will measure reliably from 41 mg m^{-2} up to 675 mg m^{-2}.
It uses the Gittleson ratio fluorescence method that is independent of leaf size.
It can measure at distances up to 1.2 meters with a field of view up to 1.2 meters.
It also uses a modulated light that provides measurements that are independent of actinic light values.
It is ideal for nutrient plant stress applications but it will also work for other types of plant stress.

4) NDVI, NDRE, PPR and CCCI Probe "PSP32 NDVI"

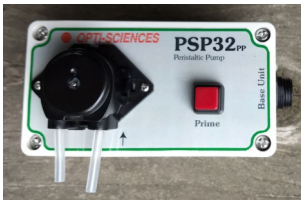
Automated, modulated probe ideal for monitoring drought and nitrogen stress.
Results are independent of external lighting conditions.
Allows sensing of larger areas with a field of view up to 1.2m and distance 1.2m.
This weather proof instrument allows measurement of drought stress in C3, C4 or CAM plants as well as nitrogen stress. Fitting to a standard 1/4 in. /20 tripod mount, the probe works with the PSP32 system or it can work separately with an independent data logger.

5) Weather Station Input Box "PSP32 WS"

Allows collection of weather station data along with PSP32 measurement data in the same measuring file.
It may also be connected to an external CO_2 sensor.
The weather station input box has a standard PSP32 probe connection port on one side and an RS232 data connection and status LED on the other.
The RS232 connector is a water resistant DB9 male connector with standard pin out.
The data LED flashes with the receipt of data to aid in connection troubleshooting.

Specifications:
Data Rate: 300Baud – 115.2KBaud
Parity: Even, Odd, None
Data Bits: 8 Bits
Handshaking: Hardware, None
Supplied with a PSP link cable of 3m in length (custom lengths available)

6) Peristaltic Pump "PSP32 PP"

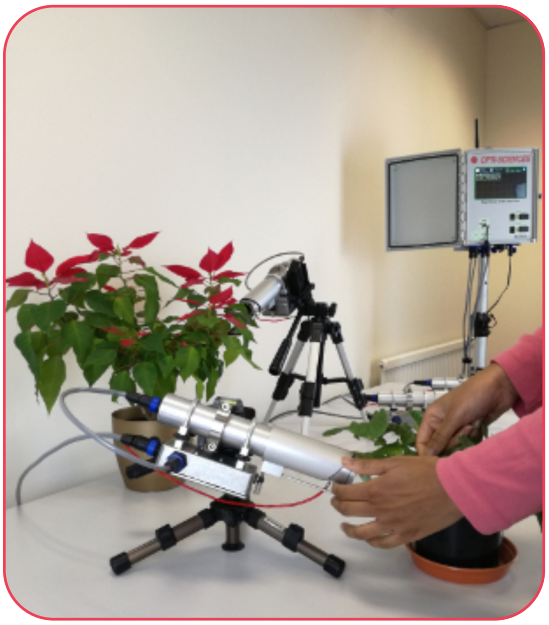


For the addition of water, nutrients, herbicides, pesticides or other liquids, under the control of the PSP32 system.
Configuration of the pump action is by a text script.
The PSP32 manages these scripts like PSP32 probe scripts.
The design allows for configuring such settings as flow rate, duration, or dosing event triggering.

Specifications:
Flow Rate: 0 – 120ml/min
Tubing Connection: 1/8 I.D. Silicone
Supplied with a 3m length of PSP link cable (custom lengths available).

For the investigation of plant, soil and atmospheric interactions, ADC BioScientific Ltd. expertly produce a wide range of portable, user-friendly and cost-effective devices, from photosynthesis to soil respiration systems.

We are committed to enabling carbon cycle research worldwide through quality instrumentation and local, technical support.



ADC BioScientific Ltd. also supply:
Leaf Area Meters, Chlorophyll Content Meters, Advanced Fluorometers, Automated Soil CO_2 Exchange Systems, Portable Soil Respiration Systems and Field Gas Analysers.

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PSP32 Technical Specification

Light Sources:	
Saturation pulse blue LED with:	7,000 µmol m^{-2} sec^{-1} with F_M' correction option 10,000 µmol m^{-2} sec^{-1} with square topped flash
Option for red LED saturation flash:	7,000 µmol m^{-2} sec^{-1} with F_M' correction option 10,000 µmol m^{-2} sec^{-1} with square topped flash
Modulated Light:	Blue 455nm, half band width 18nm *Option* for red LED 640nm half band width 18nm
Actinic light source:	Blue or red option achieve a maximum intensity of 1,800 µmol m^{-2} sec^{-1}
Far-red light source:	An option included with the daylight dark adaption option. it is used to measure F_o', or for pre-illumination of samples in the dark-adapted mode
Detection method:	Pulse amplitude modulated fluorometry
Detector & Filters:	A PIN photodiode with a 700 - 750nm bandpass filter.
Sampling Rate:	Auto-switching from 1 to 10,000 points per second, depending on test & on phase of test.
FM' correction according to Loriaux (2013), for all light-adapted modes:	It may be switched on or off. Used during daylight hours.
Test duration:	Designed to measure samples 24 hours per day, continously, for up to months at a time.
Storage Capacity:	2Gb of non-volatile flash memory, supporting almost unlimited data sets and traces. More than 500,000 data sets supported.
Special Algorithms:	8 point rolling average to determine FM, FM', FO and Fs eliminates saturation pulse NPQ and any electronic noise as an issue.
Remote Communication Data Output:	Comma delineated files may be opened in Excel™. Data may be retrieved by WiFi, cell phone, SD data card, USB stick, ethernet, radio point-to-point or satellite 'phone.
User Interface:	Graphic colour touch screen display. Menu driven. Control unit may be locked and pole-mounted.
Power Supply:	Various external 12 volt batteries upon request. Solar power and mains power can be used.
Operating temperature range:	-10°C to 50°C