Vapourtec UV-150 Photochemical Reactor

User Manual

Original date: 23rd April 2014

This revision: Revision 1.6 (8th October 2020)

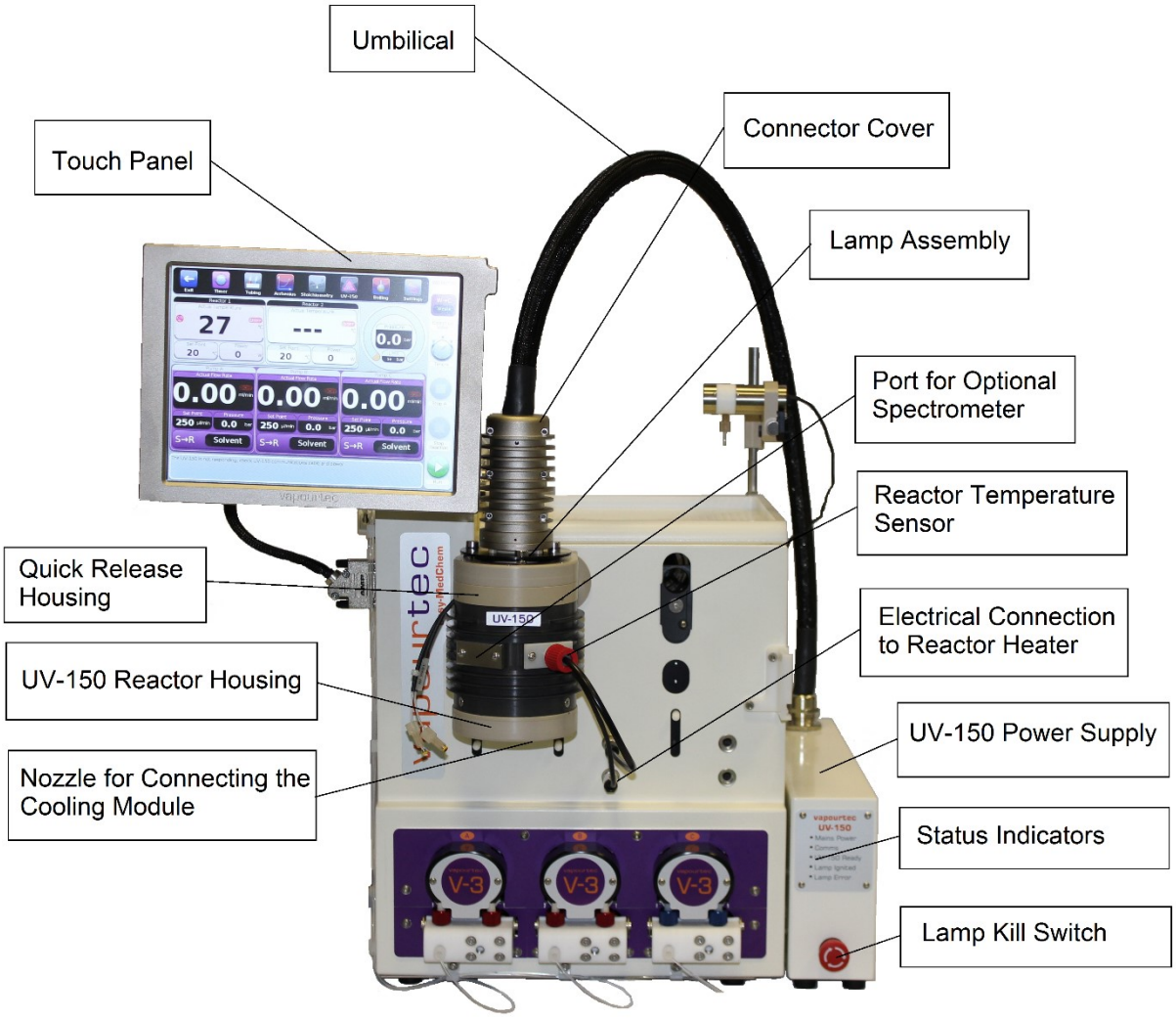
CONTENTS

1 PRODUCT DESCRIPTION

The Vapourtec UV-150 Photochemical reactor is a revolutionary compact reactor with volumes of 2ml to 10ml. Three different light sources are available to offer precise wavelengths between 220 nm and 650 nm. Available light sources: Medium pressure mercury lamp, Low pressure mercury lamp and Monochromatic LEDs.

The reactor has been designed to interface with both Vapourtec R-Series and E-Series flow chemistry systems, it cannot be used as a standalone product. The Reactor uses air to heat and cool and also the Vapourtec Cooled Module accessory to control reactions below ambient temperature. The working temperature range of the UV-150 is -20^{O}C to +80^{O}C depending on control configuration and type of lamp source.

The UV-150 power supply monitors the interlock state of the reactor and also the communication state with either the E-series or R-Series systems and will display the current status via 5 front panel LED's. A CCD Spectrometer may be used to verify the active wavelength at the tube reactor.



UV-150 with Medium Pressure Mercury Lamp on Vapourtec E-Series system

2 SAFETY INFORMATION

The symbols shown below will be used throughout this manual to draw the reader's attention to important information.

Attention. Important notes.

Caution. Hot surfaces.

Not permitted.
Misuse may cause damage.

Isolate equipment from mains

Note.

Tools required

Caution! Check any operators do not have pacemaker fitted or other electronic medical device

3 INSTALLING THE POWER SUPPLY AND REACTOR

Your Vapourtec UV-150 Reactor can be installed by the User.

Before the Reactor can be used, this manual should be read.

3.1 Unpacking

When the UV-150 is removed from its packaging, caution should be exercised as there are fragile components.

The UV-150 is packed into a single box containing both the Power Supply and the Reactor.

The bag, foam and box may be retained in case the Reactor is ever to be shipped between sites in the future.

Contact Vapourtec or your distributor immediately if there is any visible shipping damage.

3.2 Siting

The UV-150 Power supply must be sited within a fume cabinet or other suitably ventilated enclosure and must sit next to an existing Vapourtec Flow Chemistry E-Series or R-Series system. If it is decided to site the Power Supply in an open lab then the user should undertake a thorough risk assessment prior to operation.

Do not store liquids on or above the Power supply. Damage may result from spillage of liquids into the Power Supply. If spillage of liquids does occur, isolate the system from mains electricity supply immediately.

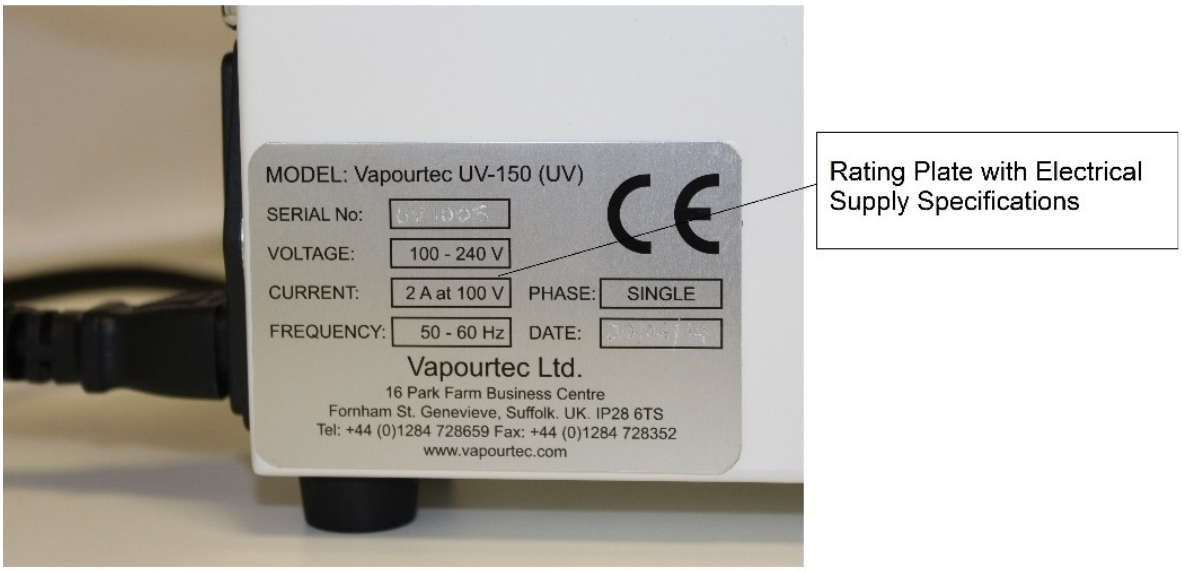
Provide a firm surface for the Power Supply and check that the structure is adequate for supporting its weight. Leave a minimum distance of 100 mm between the rear of the system and any solid objects. The Power Supply requires this clearance to ensure

adequate air flow through the Power Supply electronics system.

Do not block any of the ventilation panels. These are necessary to ensure adequate air flow through the Power Supply. Pay particular attention to the air intake located at the back of the system. These must not be covered.

3.3 Electrical connections

Check the rating plate located to the rear of the system to ensure that the electrical supply you intend to connect to the Power Supply is suitable.

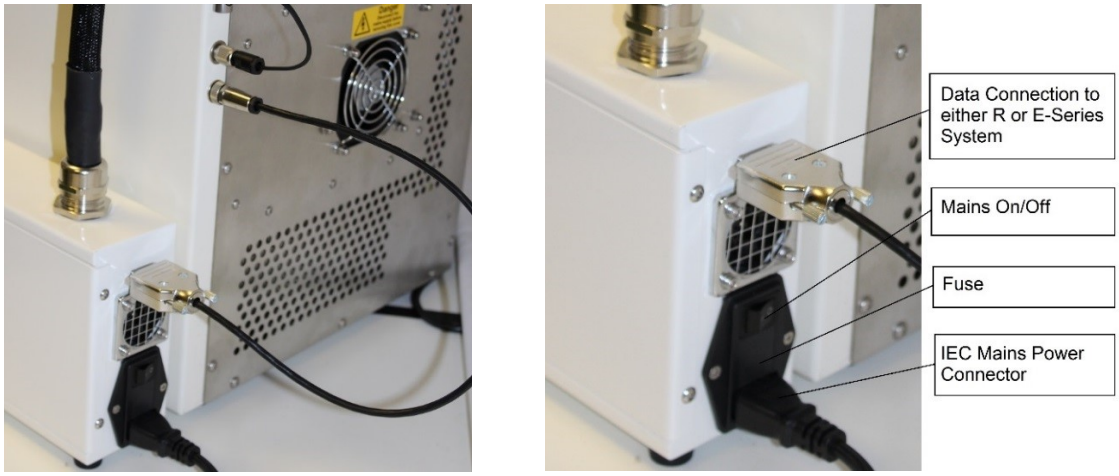


3.3.1 Connection with Vapourtec E-Series

For Vapourtec E-Series, the connection with UV-150 power supply is via the serial-to-7 pins connection cable supplied by Vapourtec.

UV-150 E-Series connection cable

The electrical connections should be made in accordance with the picture below on an E-Series system.

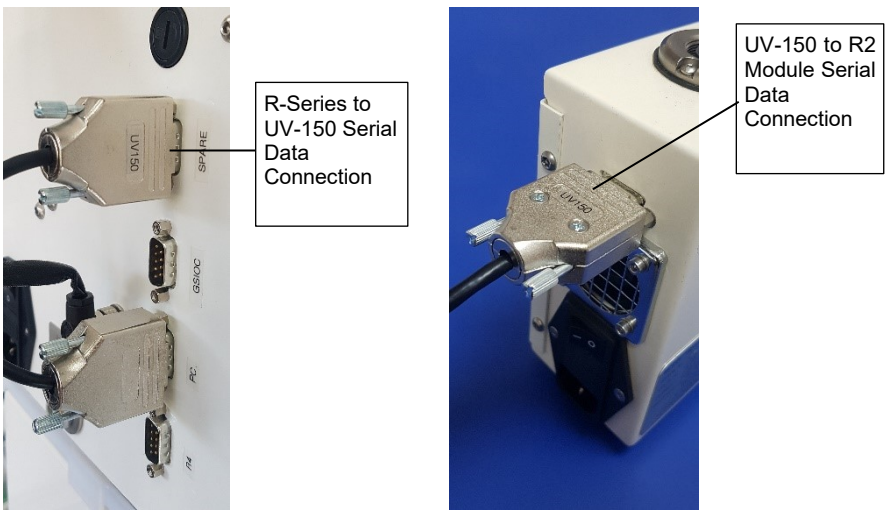


Connecting UV-150 to Vapourtec E-Series

3.3.2 Connection with Vapourtec R-Series

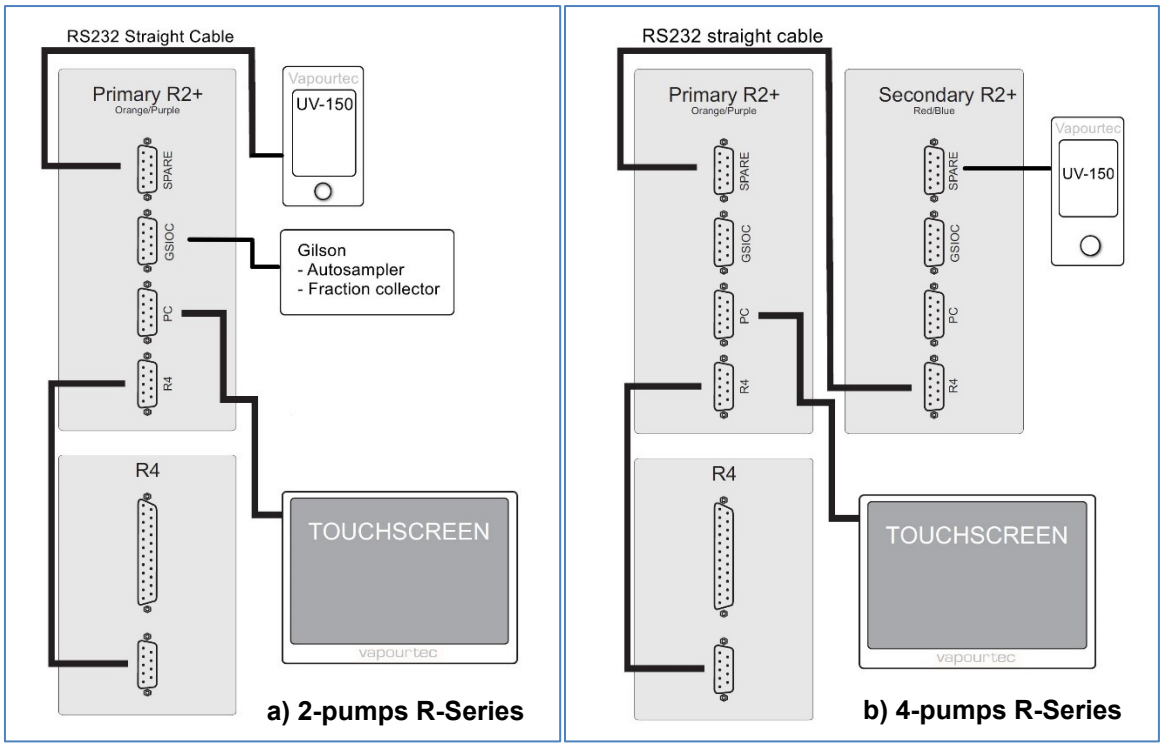
For Vapourtec R-Series, the connection with UV-150 power supply is via the RS232 male to female connection cable. The connection cable is plugged into the 'Spare' port on the R2 pump module. Refer to the below diagram for the cable connection for a 2-Pumps and 4-Pumps system configuration.

UV-150 R-Series connection cable



Connecting UV-150 to Vapourtec R-Series

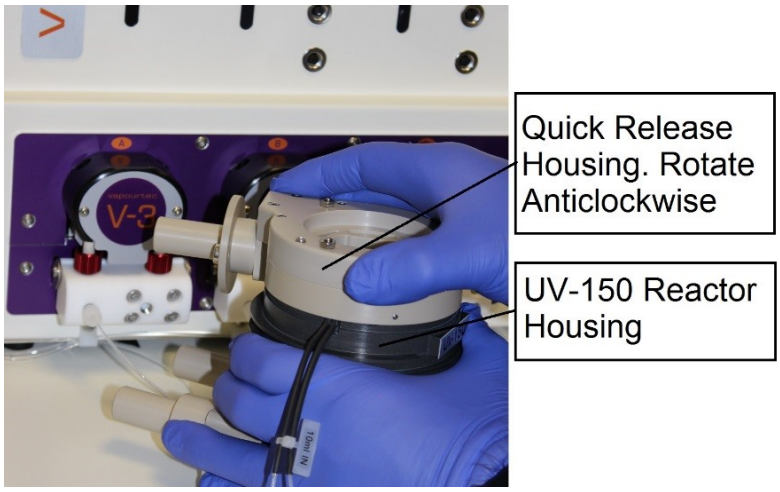
The electrical connections should be made in accordance with the diagram below for 2 pumps & 4 pumps R-Series system.



R-Series cable connection for: a) 2-pumps and b) 4-pumps system

3.4 Opening the UV-150 Reactor Housing

The UV-150 Reactor Housing must be removed from the E-Series or R-Series system as a complete assembly prior to attempting to open. The upper housing of the UV-150 can be removed by rotating in an anticlockwise direction by 20 degrees (see picture below).



3.5 Filter Choice and Fitting (for medium pressure mercury lamp only)

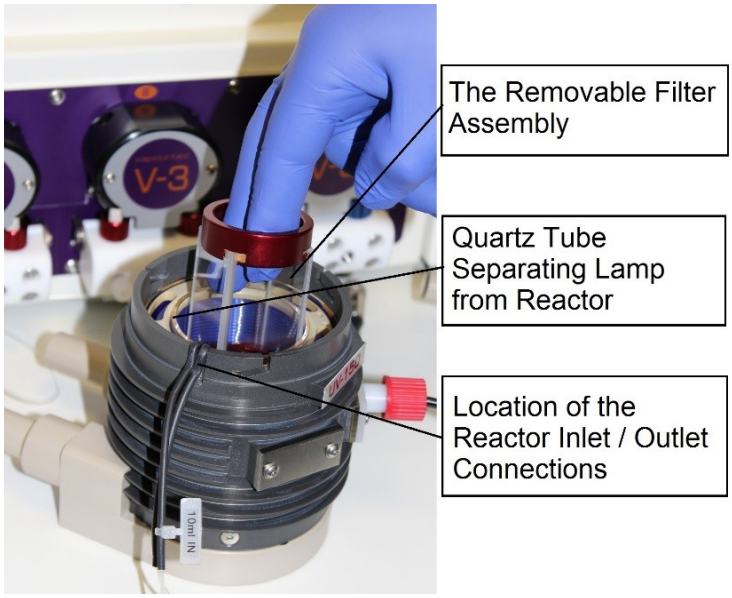
The high intensity medium pressure mercury lamp has a broad radiant output – providing wavelengths from 220 nm to 600 nm. For this reason, Vapourtec offers a range of 9 wavelength filters for use with the medium pressure mercury lamp. Wavelength filters allow selection of only desired wavelengths to promote intended reaction. Furthermore, the filters can eliminate unwanted wavelengths that cause side reactions or decomposition of products. It can also remove heating effect of mercury lamp by 40%.

Only Medium Pressure Mercury Lamp requires wavelength filters. **NO** filters are needed for LED & low-pressure mercury lamp.

The UV-150 Medium Pressure Mercury Lamp is supplied with three filters; Type 1 (Pass 190 – 2000nm), Type 2 (Pass 250 to 390nm) and type 3 (Pass 300 – 2000nm). Other filter types for different cut-off wavelengths can be supplied by Vapourtec, please refer to section 9.2 of this manual for specifications of available filters. It is strongly recommended that a Filter is always used for Medium Pressure Mercury Lamp as the filters will absorb a significant portion of the unwanted Infra-red energy.

Three filters supplied with Medium Pressure Mercury Lamp

The filter is simply located into the inner section of the reactor assembly (see photo below). Ensure that the filter is seated correctly and is central before fitting the reactor's quick release housing and lamp.



The choice of filter and selected lamp power will have an effect on the minimum reactor temperature that can be achieved using the UV-150 **Medium Pressure Mercury Lamp**. The table below gives a summary of the temperatures that can be achieved for an ambient temperature of 22°C.

Lamp power (%)	Lamp Power (watts)	Filter Type	Min temp. achievable (Degree C)	
			Heated Mode	Cooling Mode
50%	75 watts	Type 1 & 3	43°C	5°C
		Type 2	31°C	<< -5°C
75%	112 watts	Type 1 & 3	53°C	10°C
		Type 2	35°C	-5°C
100%	150 watts	Type 1 & 3	64°C	15°C
		Type 2	39°C	5°C

Example (refer to section 6.3 on Setting Cooling and Heating modes):

- Running the medium pressure mercury lamp at 50% power using Type 2 filter at Heated Mode, the heat from the lamp itself will bring the reactor temperature up to 31°C.
- Running the medium pressure mercury lamp at 75% power using Type 1 or 3 filter at Cooling Mode, the lowest temperature achievable is 10 °C due to large amount of heat from the lamp.

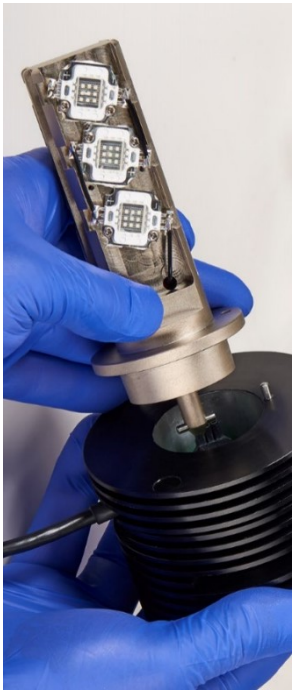
** User selectable power (from 50% to 100%) is only applicable to Medium Pressure Mercury Lamp. Monochromatic LEDs and Low Pressure Mercury Lamp are non-dimmable.

4 UV-150 LIGHT SOURCES

4.1 Overview

Vapourtec offers 3 different light sources to offer precise wavelengths between 220 nm and 650 nm. Available light sources: **1) Medium pressure mercury lamp**, **2) Monochromatic LEDs**, **3) Low pressure mercury lamp**. Each light source will require a specific lamp holder and power supply unit but they can all be fitted in the same reactor housing and interacts with either E-Series or R-series Flow Chemistry system.

a) Medium Pressure Mercury Lamp



b) LED Lamp

c) Low Pressure Mercury Lamp

4.2 Medium Pressure Mercury Lamp

The medium pressure mercury lamp provides constant and precise UV output, with user selectable UV power between 75 W to 150 W. This allows dimmable operation without compromising lamp life or spectral output. Manufactured specifically for Vapourtec, power is supplied by a state-of-the-art electronic ballast for maximising lamp life. Lamp end-life and fault conditions are automatically detected, with automatic system shut down for safety. Due to the nature of medium pressure mercury lamp, wavelength filters are needed to select the desired wavelengths and reduce heat effect from the lamp. Refer to section 3.5 on filter choice and the minimum reactor temperature that can be achieved.

4.3 Monochromatic LEDs

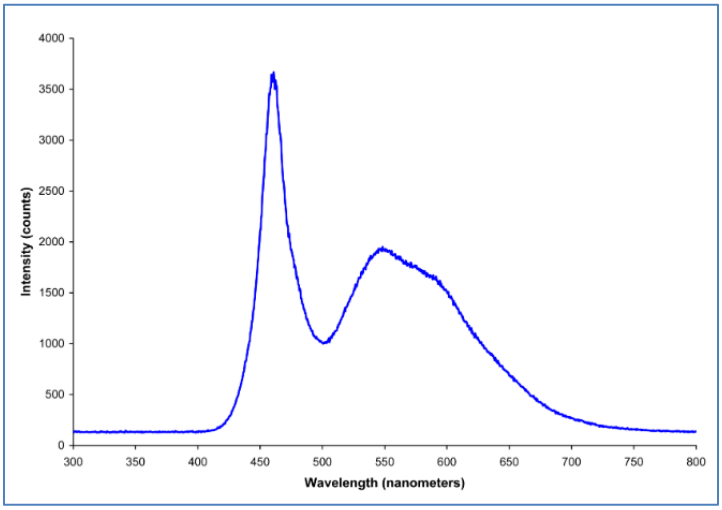
There are a selection of 14 specific non-dimmable LEDs ranging from 365 nm to 525 nm. These provide a precise wavelength and therefore do not need to be used with a filter. In addition to that, a cool white LED is also available to provide a broad spectrum of wavelengths and a peak in the blue region.

Each of the LEDs provided are interchangeable and fit into the same lamp holder and reactor housing. They can be easily changed by hand in less than a minute - providing versatility as the research needs change.

LEDs are extremely efficient with a life expectancy of approximately 10,000 hours. The low heat load from the LEDs allows the lamp to be cooled to temperatures as low as -20°C, in addition to the ability to heat to 80°C.

LED Lamp			
LED Lamp peak maxima(s) wavelength (nm)	LED lamp (60 watts input) - Radiant Output (Watts)	LED - Approx. efficiency (%)	LED output Mole / hour of photons
365 nm	3 W (Gen-1)	5%	0.033
365 nm	16 W (Gen-2)	26%	0.18
380 nm	4.2 W (Gen-1)	7%	0.048
385 nm	18 W (Gen-2)	31%	0.21
395 nm	6 W (Gen-1)	10%	0.071
405 nm	9 W (Gen-1)	15%	0.11
410 nm	12 W (Gen-1)	20%	0.15
420 nm	18 W (Gen-1)	30%	0.23
430 nm	24 W (Gen-1)	40%	0.31
440 nm	24 W (Gen-1)	40%	0.32
450 nm	24 W (Gen-1)	40%	0.32
470 nm	24 W (Gen-1)	40%	0.34
495 nm	8.8 W (Gen-1)	14.7%	0.13
525 nm	3 W (Gen-1)	5%	0.047

14 specific wavelength LEDs



Cool white LED spectra

4.4 Low Pressure Mercury Lamp

In addition to the medium pressure mercury and LEDs light sources, Vapourtec also offer three low pressure mercury lamps. These offer specific wavelength emission and provide wavelengths not available with the medium pressure mercury or LED light sources. The three wavelengths available are:

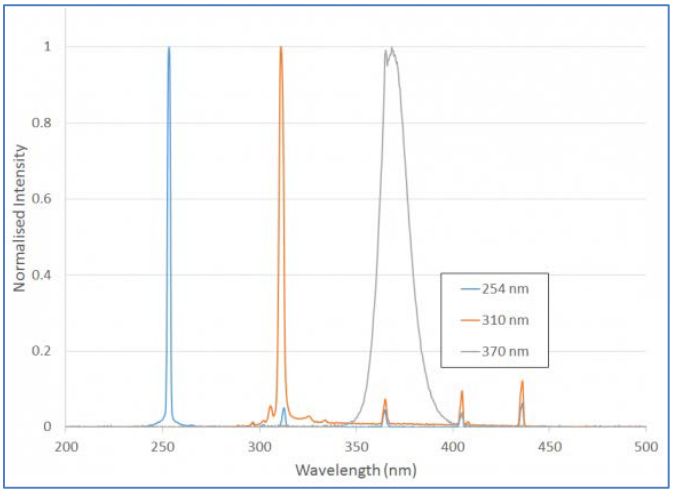
- 254 nm (UVC)

- 310 nm (UVB)

- 370 nm (UVA)

Due to the low heat load of the low-pressure mercury lamps, lamps do not require filtering and allow a

temperature range of -20°C to 80°C to be achieved.



Wavelength spectrum of Vapourtec Low Pressure Mercury Lamp

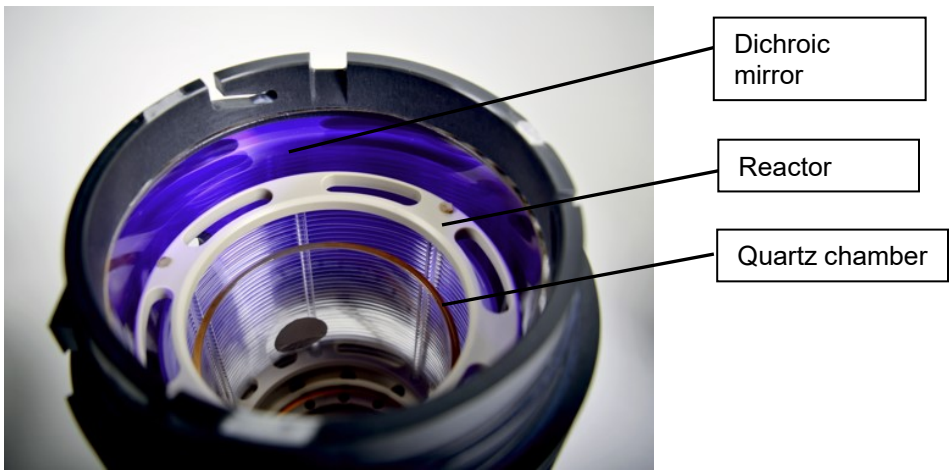
5 REACTORS

5.1 Overview

The reactors are constructed from fluoropolymer tubing exhibiting excellent chemical compatibility combined with good UV transmission in the range 220 nm to 400 nm. The reactor tubing has an internal bore of 1.3 mm and a wall thickness of 0.15 mm. Reactors should be regularly checked by eye to ensure there are no “dark” deposits on the tube walls. If deposits are noted then the reactors can be washed using organic solvents such as DCM and DMF. Note and strictly adhere to the pressure limits detailed in section 5.4.

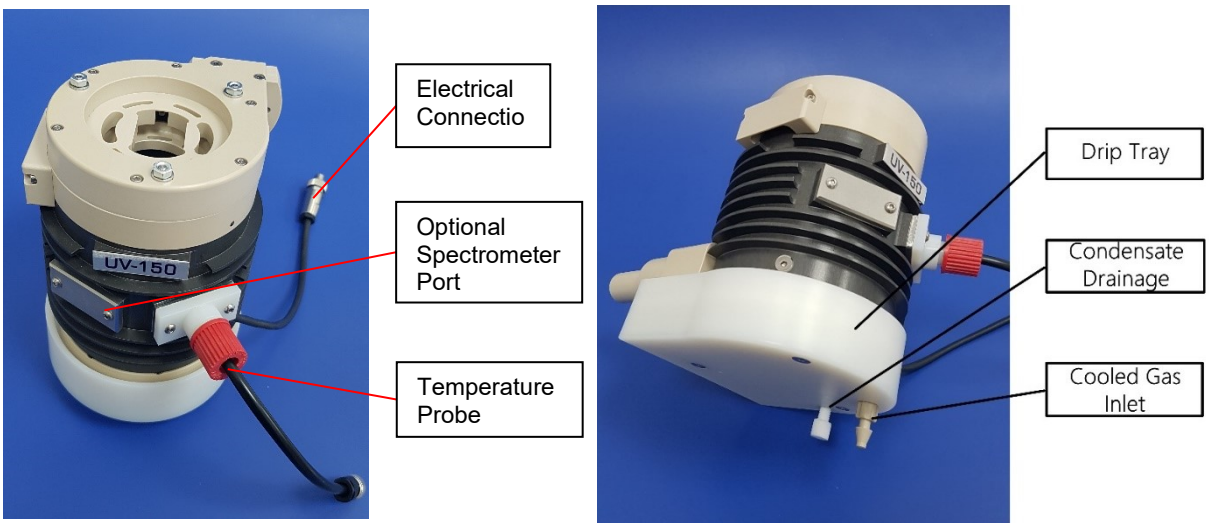
5.2 Reactor Housing

Reactor and lamp are housed in separate, sealed quartz chambers. Air is circulated within each chamber to cool the lamp/reactor and to dissipate heat. Warmed air from each chamber is then separately exhausted from the system. High flow rate of gas allows effective temperature control. Dichroic mirror also removes heat from the system, beside that the mirror ensures more than 90% of UV energy is reflected back into the reactor.

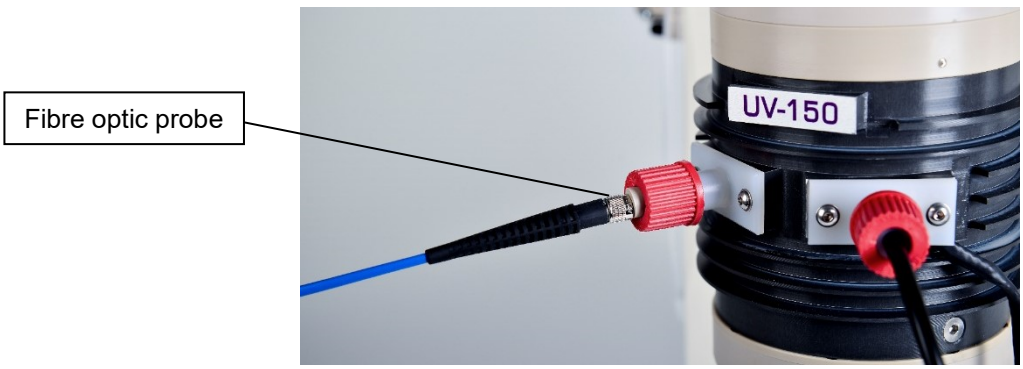


This is a magnetic safety interlock on the top housing to detect and ensure the light source is completely enclosed in the housing. The power is automatically disconnected if lamp becomes exposed.

A drip tray is fitted on the bottom of the reactor housing. When the reaction is running in cooled mode, condensate formed can be vented through the drain port. A long PEEK adaptor is supplied to connect the cooled gas inlet. Refer to section 6.8 for connecting the cooling module to the UV-150.



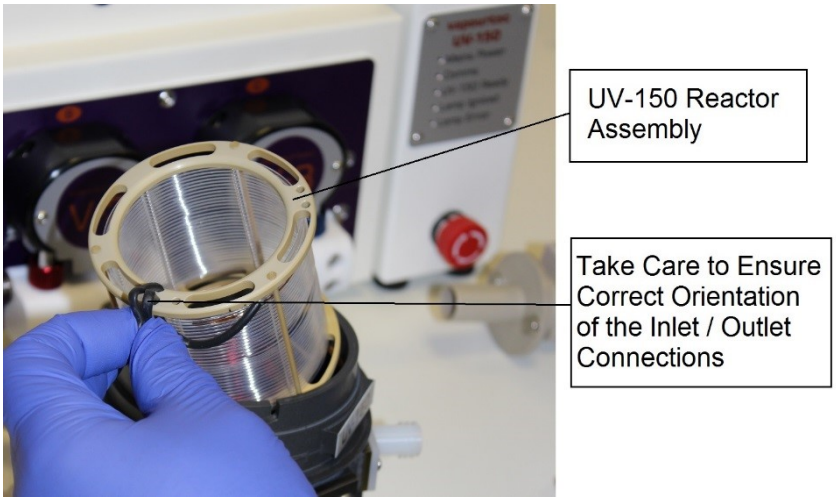
An optional spectrometer allows spectral intensity, wavelengths and reactant absorption to be measured. Real time spectral information can be a huge benefit in photochemical reactions. The UV-150 reactor housing comes with optional port for spectrometer probe insertion. The port position enables the probe to 'look through' the reactor directly towards the lamp. This allows the relative spectral intensity to be measured as the reaction occurs. Contact Vapourtec for details information.



5.3 Assembly of the Tube Cartridge into the Reactor

The UV-150 is supplied with one 10 ml reactor cartridge. Fit the Reactor Cartridge by removing the quick release top housing, as pictured below, and aligning the reactor so the inlet and exit tubes sit in the Reactor body inlet position (indicated below).

Remove the temperature probe prior taking out the reactor cartridge to prevent damage to the reactor coil.



5.4 UV-150 Reactor Types and Pressure Limits

There are three different sizes of reactor replacement cartridges available. The below table lists the available sizes, part numbers and pressure limits. Other sizes may be available on request. Please note that the pressure limits are defined for the maximum operating temperature of 80^{O}C:

Part Number	Description	Internal Volume (ml)	Bore and wall (mm)	Pressure Limit (bar at 80 ^{0}C)
50-1580	UV-150 reactor re-windable cartridge - 10ml	10 ml	1.3 x 0.15	12 bar
50-1581	10ml replacement UV-150 reactor tubing for use with 50-1580	10 ml	1.3 x 0.15	12 bar
50-1288	UV-150 reactor - 5ml	5 ml	1.3 x 0.15	12 bar
50-1289	UV-150 reactor - 2ml	2 ml	1.3 x 0.15	12 bar

5.5 Tubing Connections

Connect the tube labelled “IN” on the UV-150 reactor to the system pump output. Connect the other tube to the back pressure regulator, or second reactor.

6 OPERATION

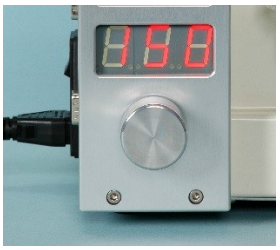
6.1 Safety First

	Do not attempt to handle or operate the UV-150 or its electronic power supply (EPS) before completely reading and understanding this safety notice. Contact Vapourtec if you are uncertain of hazards associated with these devices.
	Safety Inspection – A procedure for periodic inspection of the installation area should be established and carried out. The recommendations from these inspections should be followed by corrective actions so that the following safety criteria are met.
	Ensure the UV-150 is grounded. To avoid electrical shock, it is essential to ensure that the power supply is properly grounded before making any connections or operating. If in doubt, a suitably qualified electrician should be consulted prior to operation.
	The lamp igniter produces starting voltages of up to 5 kV and momentary electromagnetic radiation interference which can be hazardous to personnel and sensitive instrumentation. Exercise appropriate care in the handling of high voltage equipment. In the event of damage to any cables or insulation, immediately isolate the power supply and report the damage to Vapourtec. Always isolate the mains before removing any covers.
	Never apply power too or operate the UV-150 with any panels or covers removed. There are no serviceable parts inside the UV-150 power supply enclosure. If a fault is suspected do not operate the UV-150 and contact Vapourtec Service (section 8.5)
	Ensure the power supply for the UV-150 is switched off before exchanging the lamp. The residual charge left on the power supply can be a danger to life if the units are still connected to mains.
	The UV-150 and its power supply must never be installed or operated in an explosive atmosphere. Never site the electronic power supply near flammable gases or liquids. Never allow flammable liquids to pool within the same enclosure as the power supply. See that there will be no moisture, dust or similar which could lead to short circuits or fire. Do not block the air intake to the rear UV-150's power supply.
	The Emergency Stop button (also known as E-Stop or Lamp Kill Switch) must be accessible to the operator at all times.
	Components within the lamp enclosure of the UV-150 will attain temperatures of 250^{O}C under conditions of full power. Never operate the unit using solvents or reagents having an auto ignition temperature of below 300^{O}C (see Section 8.3 for properties of common solvents).
	Operators with pacemakers or other electronic medical devices should not operate the UV reactor or be in close proximity to the power supply when the system is igniting. If in doubt please contact Vapourtec first.

6.2 The User Interface

The UV-150 has a convenient “app” in the E-Series user interface. For the R-Series systems the UV-150 is controlled EITHER using the manual interface via the control knob on the R4 heater unit or setup and run an automated experiment with Flow Commander™ software.

E-Series “App”



R-Series control knob

6.3 Setting Cooling and Heating modes

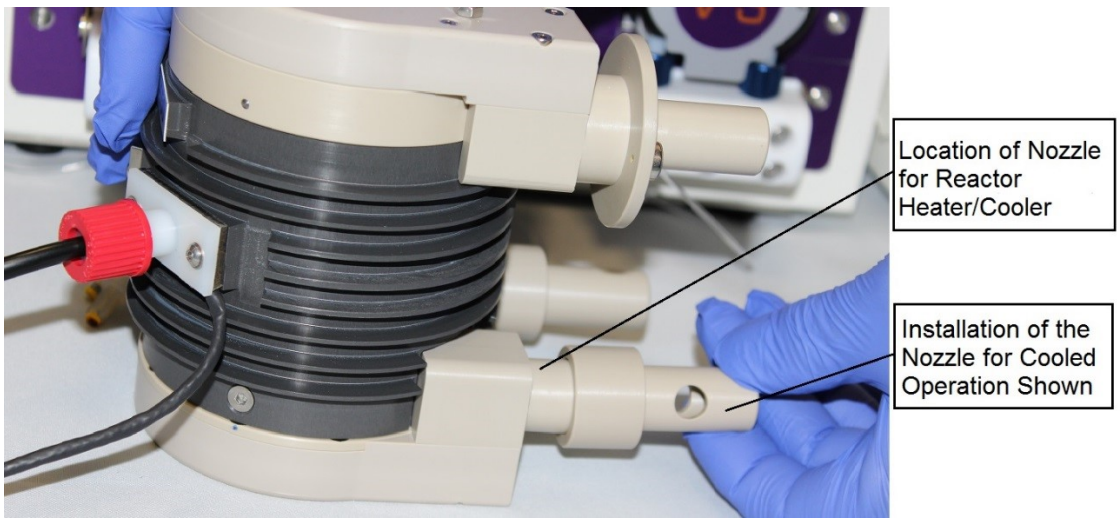
The UV-150 has two modes of operation, cooling and heating. For the previous design (MARK I), changing between these modes requires a physical change of the hot air inlet nozzle (see section 6.3.1). For latest MARK II design, the inlet nozzle can be slid ON/OFF.

Cooling mode should only be used when the Vapourtec cooling module is connected to the system (see section 6.8). Heating mode must be used for all other conditions.

The working temperature range of the UV-150 is -20^{O}C to +80^{O}C depending on control configuration and type of lamp source. Medium pressure mercury lamp generates large amount of heat thus it will be difficult to reduce the temperature below -5^{o}C and a filter is always needed for wavelengths selection and heat control (Refer section 3.5). When set for heating mode but at a temperature below the current reactor temperature, the inlet nozzle will allow ambient air to circulate around the reactor to reduce the temperature. Alternatively, if the temperature is set above the temperature of the reactor then the reactor heater will heat the air so that the reactor temperature is elevated to achieve the set point.

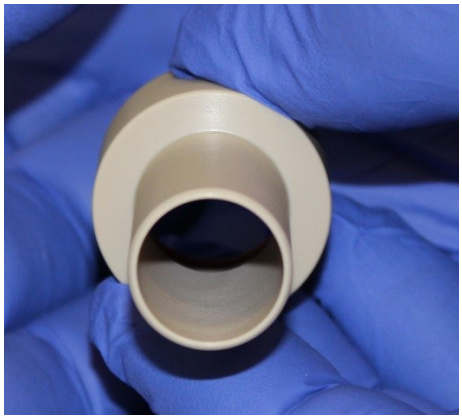
6.3.1 Cooling and Heating for Mark I Reactor Design

Mark I reactor supplied with **2 types** of inlet nozzle. User need to change the nozzle according to the mode of operation: Heated Mode or Cooling Mode.



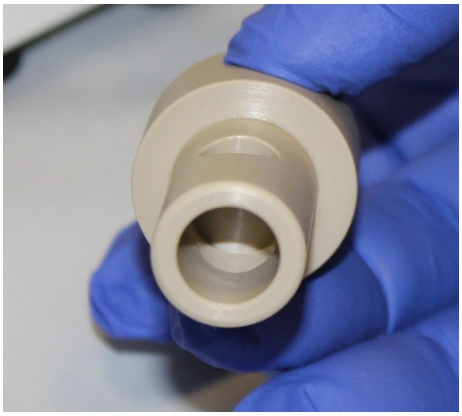
Nozzle for Heated Mode

(note the through hole)



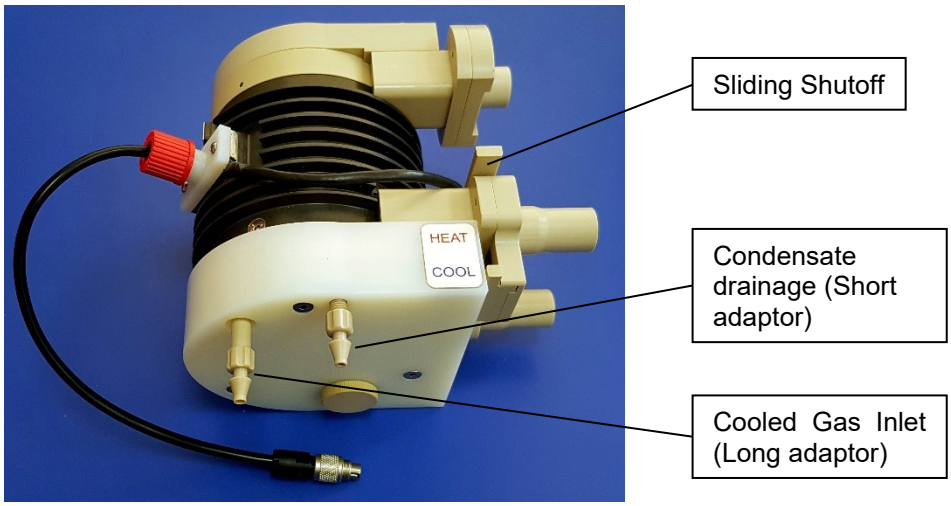
Nozzle for Cooling mode

(note that the nozzle is closed)



6.3.2 Cooling and Heating for Mark II Reactor Design

The latest Mark II reactor comes with a sliding shutoff. The inlet nozzle can be slid ON/OFF with the sliding shutoff without the need of changing the inlet nozzle.



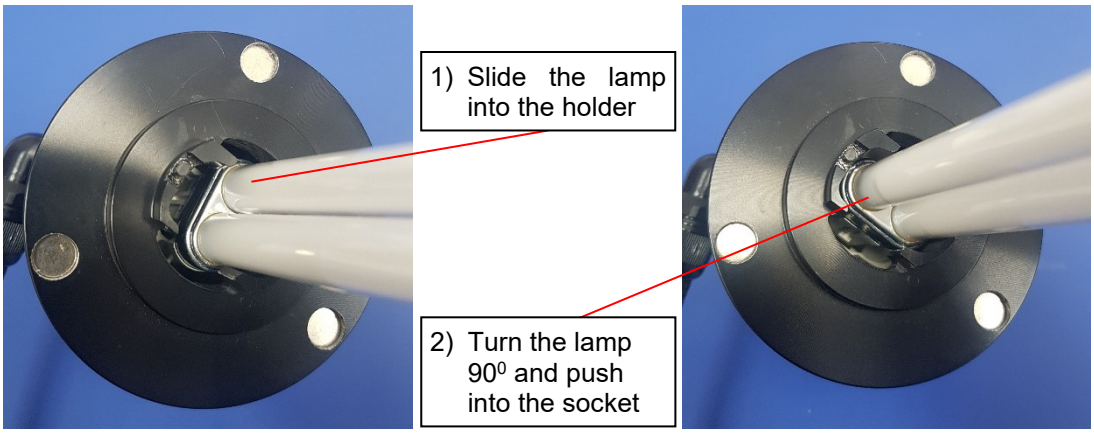
6.4 Changing LEDs and Low Pressure Mercury Lamp

LEDs and low pressure mercury lamp emits specific wavelength of light thus filter is not required. User can choose to have their prefer wavelength for the reaction by changing the lamp. See section 4 for the available wavelengths.

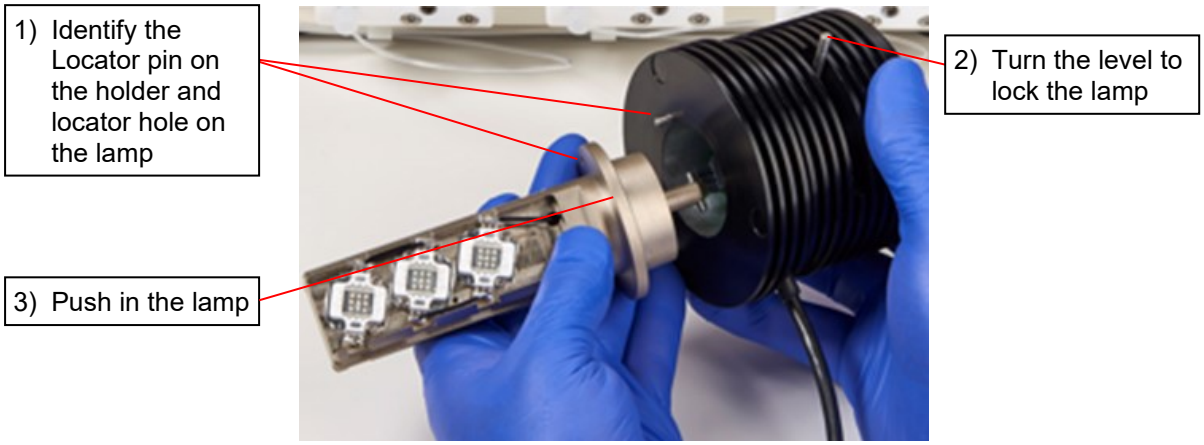
The LEDs and Low pressure mercury lamp are using different lamp holder and power supply unit (PSU). The PSU looks similar but **NOT** interchangeable. Plug into the wrong PSU will cause the lamp fails to strike. Check the rating plate on the left side of the PSU to ensure you have the correct unit with you.

The medium pressure mercury lamp is screwed on the holder. User can replace the bulb when it is end of life. Refer to section 8.1.2 on replacing the lamp.

To change the low pressure mercury lamp:



To change the LEDs lamp:

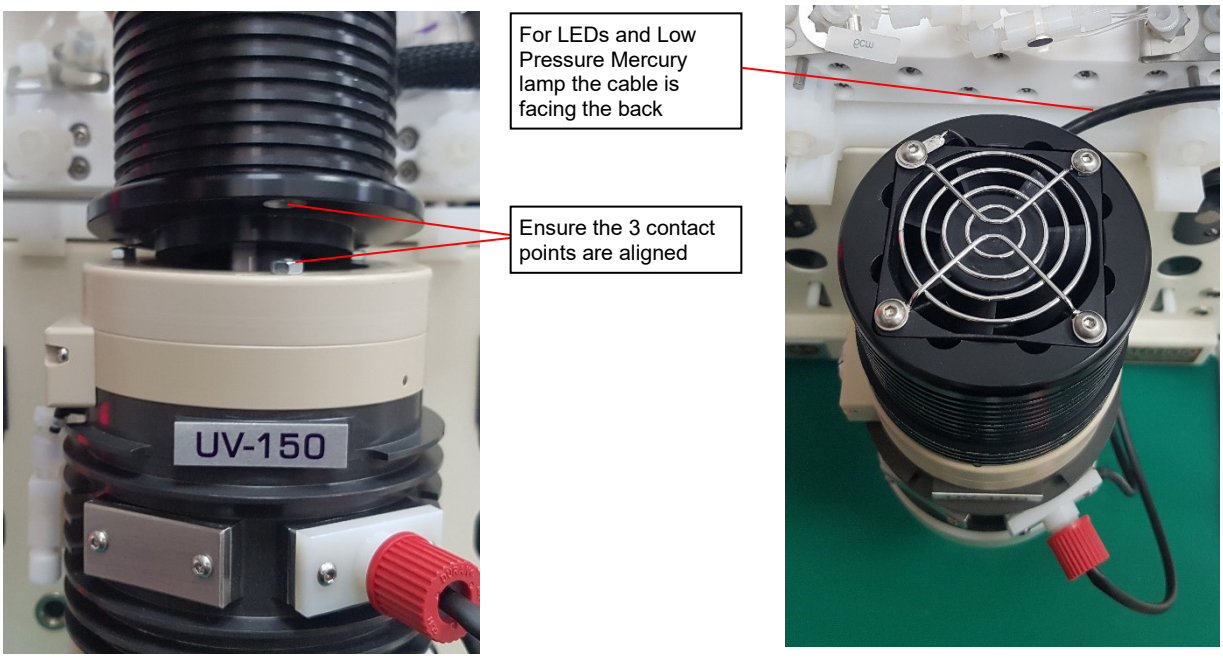


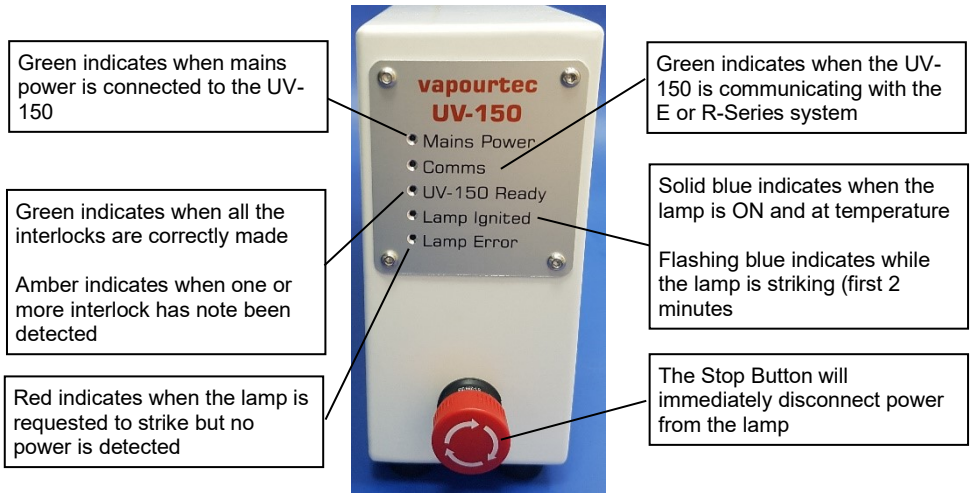
6.5 Interlocks

The UV-150 is designed to operate only with an E-Series or R-Series Flow Chemistry Systems. If no serial connection is made between the UV-150 Power Supply and the E-Series or R-Series system, the “app” will be unavailable and the Reactor isolated from use. Refer to section 3.3 for the electrical connection.

Once the UV-150 has been set to the desired temperature the reactor can be started by pressing the green RUN button on the E-Series User Interface or turned on via the control knob on the R-Series. Refer to the following section on software behaviour.

The lamp should sit inside the reactor housing with all 3 contact points on the housing and lamp holder aligned. The lamp can only go in the housing in one direction. **DO NOT** force in the lamp. For LEDs and Low pressure mercury lamp, the cable is facing the back. See picture below.



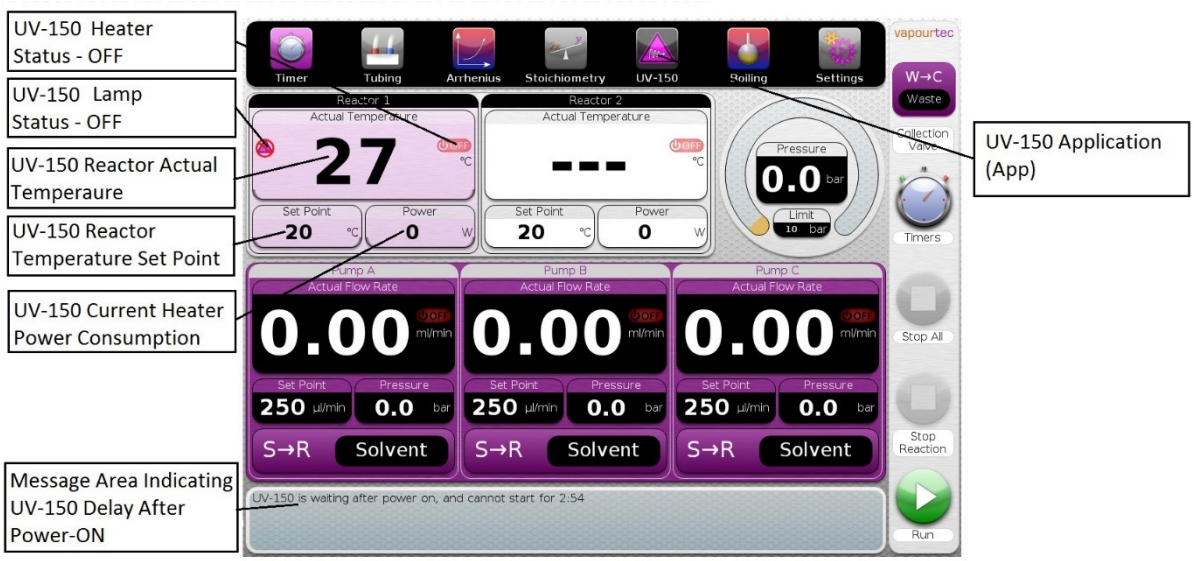


6.6 Software Behaviour - E-Series

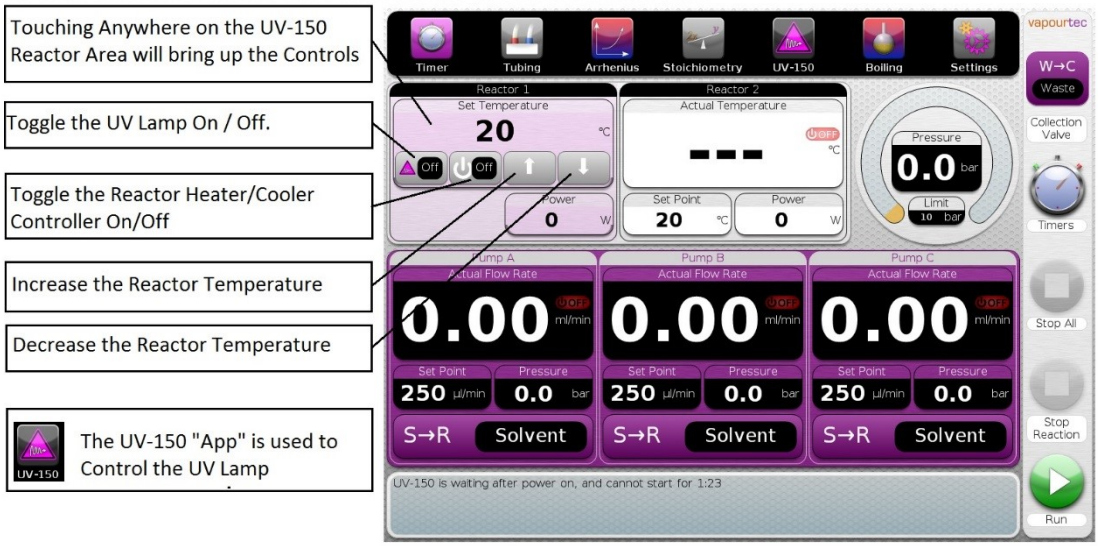
The Operation of the UV-150 reactor is controlled via the E-Series Touch Panel interface. The controls for the UV-150 will only be available if the following conditions are met:

- UV-150 reactor is physically engaged with the E-Series system
- The temperature sensor is connected
- The electrical connector is engaged
- The serial data connection is made between the E-Series and the UV-150 power supply.

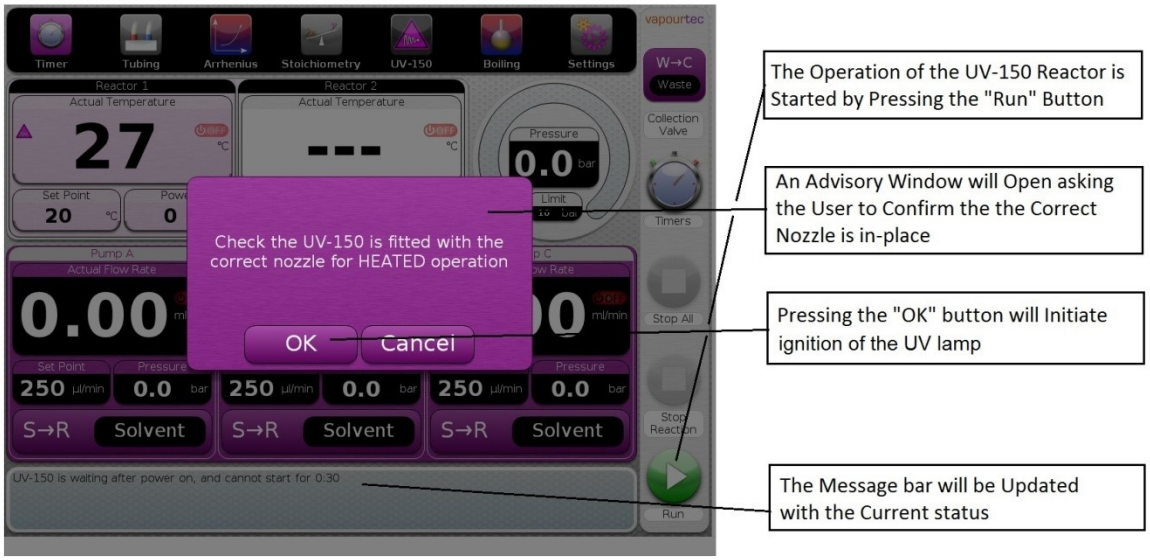
If the above conditions are met then the touch panel interface will appear as shown below with the UV-150 reactor shown with light purple shading.



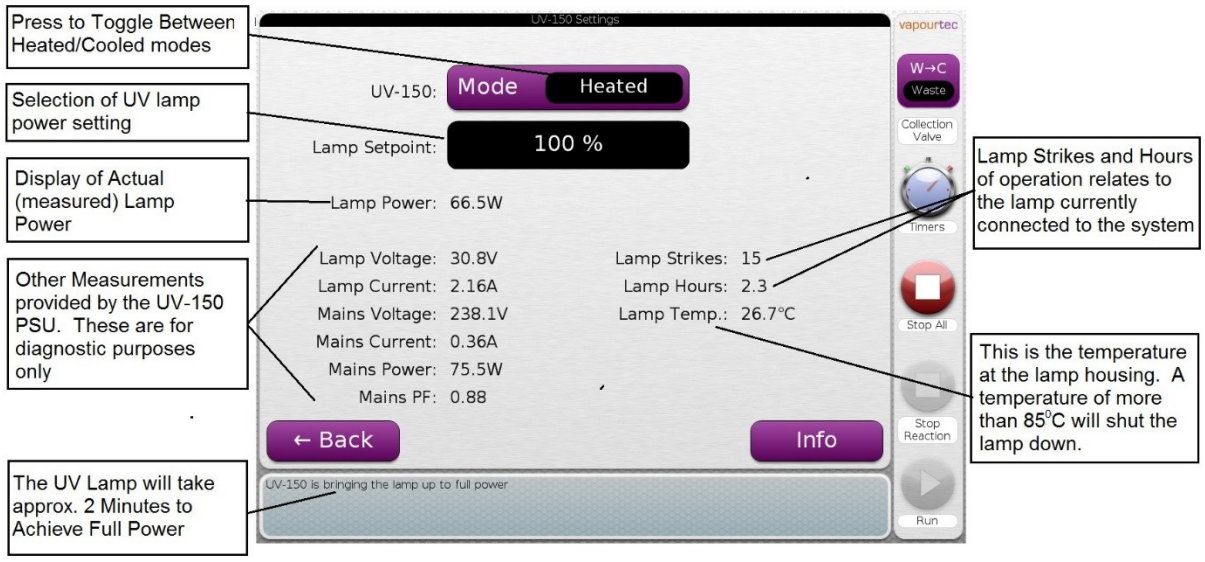
Touching anywhere on the light purple area will allow the temperature settings associated UV-150 to be modified (See below).



Once the UV-150 has been set to the desired temperature the reactor can be started by pressing the green RUN button on the User Interface (see below).



The UV lamp will ignite and run at full power for 2 minutes before reverting to the power setting specified within the UV-150 App. The lamp is run at full power to ensure it is heated rapidly to its operational temperature. The settings for the lamp power can be accessed by touching the 'UV-150 App'. Details are shown below:



The start-up sequence for the UV lamp is as follows:

- User presses the "Run" button
- Lamp strikes with power set to 100%
- Lamp voltage and power increase until full power is achieved. This will take about one minute.
- The lamp will remain at full power for a further one minute
- The lamp power will then revert to the set power point (between 50% and 100%)

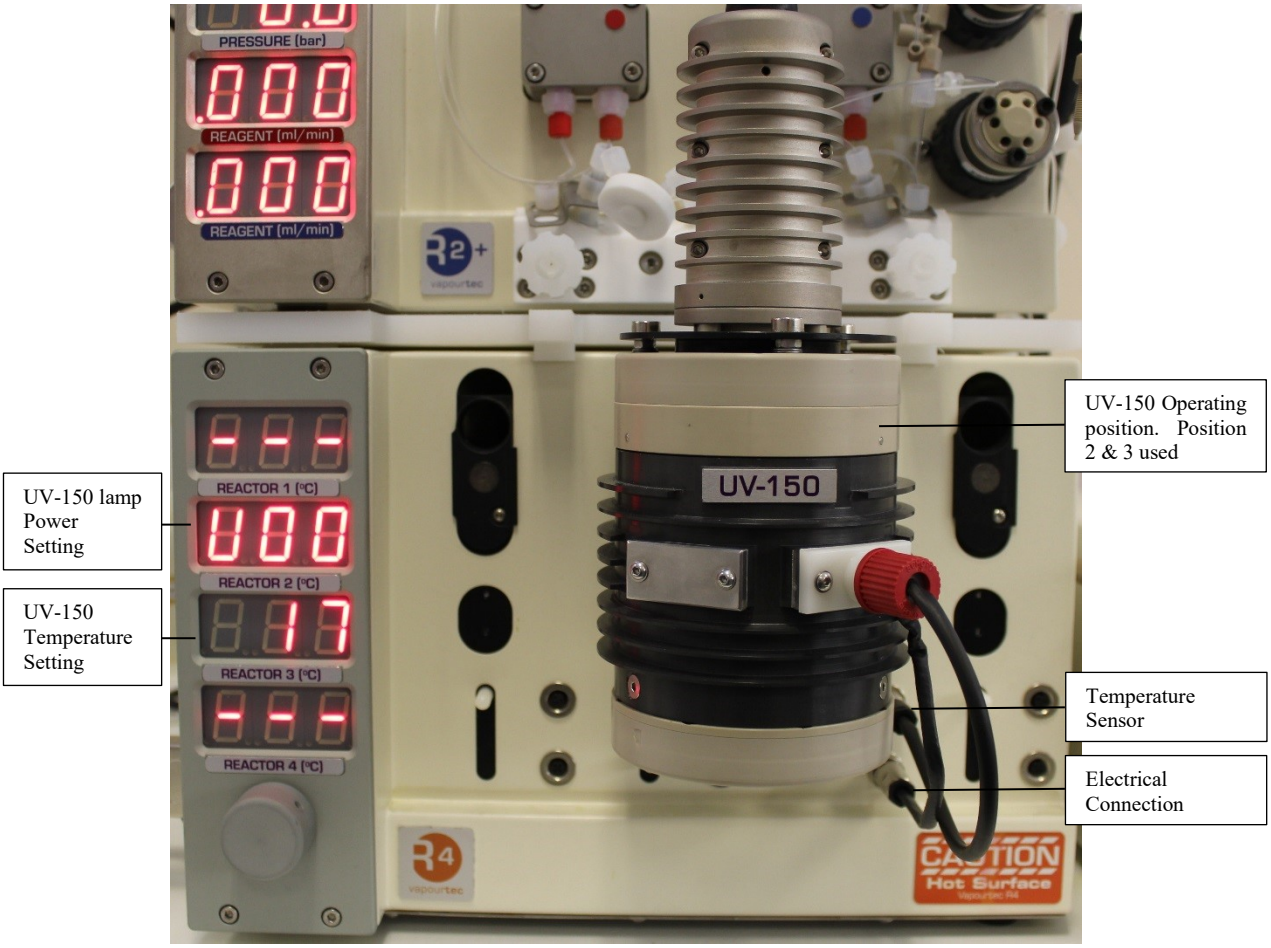
The above sequence will take approximately 2 minutes from the initial strike of the lamp.

6.7 Software Behaviour R-Series

The Operation of the UV-150 reactor is controlled via the R-Series Manual Control Knob or the Flow Commander software. The controls for the UV-150 will only be available if the following conditions are met:

- UV-150 reactor is physically engaged with the R-Series system
- UV-150 is only supported on Position 2 & 3 on the R4 heater unit
- The temperature sensor is connected (to R4 position 3)
- The electrical connector is engaged (to R4 position 3)
- The serial data connection is made between the R-Series and the UV-150 power supply (Refer to section 3.3.2).

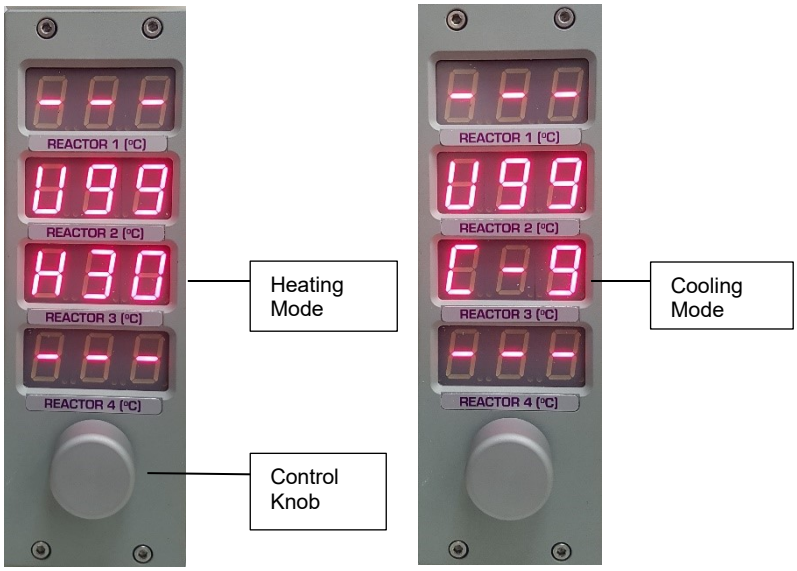
If the above conditions are met then the display panel will appear as shown below.



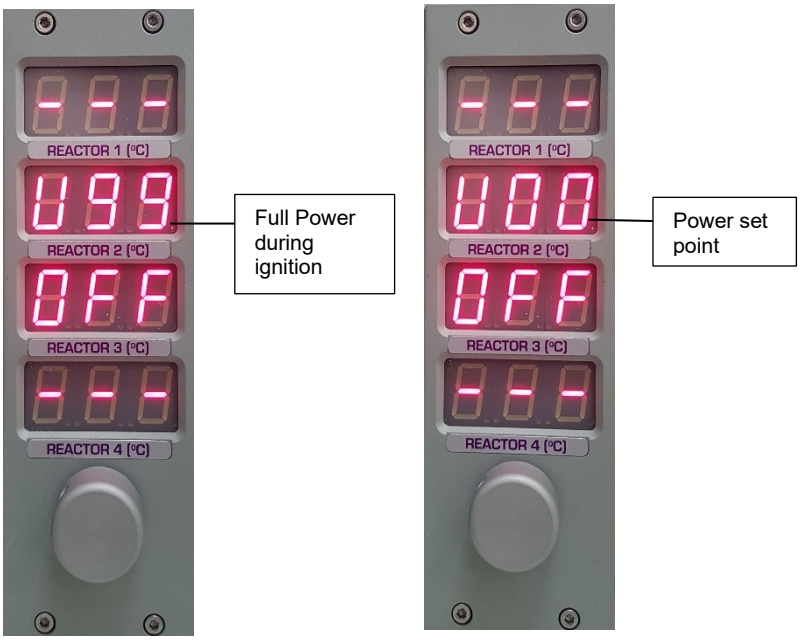
6.7.1 Control via R-Series Manual Control Knob

Press the manual control knob on the R4 heater until the Power setting display is flashing. Turning the control knob will increase or decrease the lamp power % set point.

Press the manual control knob on the R4 heater until the Temperature display is flashing. Turning the control knob will increase or decrease the UV-150 temperature set point. Details are shown below:



The UV lamp will ignite and run at full power for 2 minutes before reverting to the power setting set on the display panel. The lamp is run at full power to ensure it is heated rapidly to its operational temperature. The settings for the lamp power can be accessed by turning the control knob when the power display is flashing. Details are shown below:

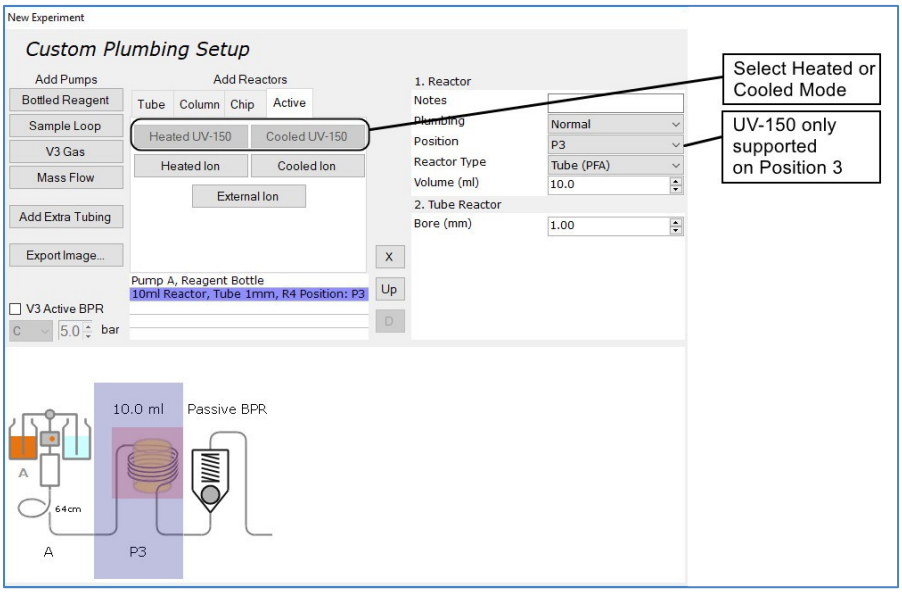


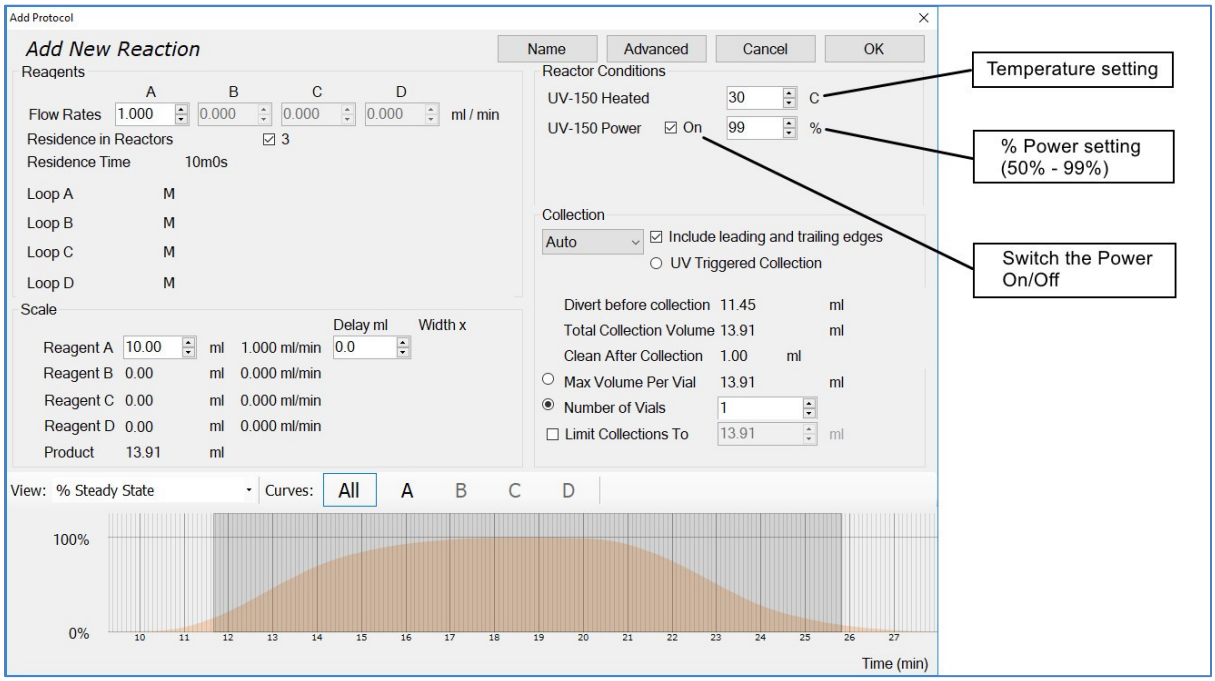
LEDs and low pressure mercury lamps are **non-dimmable**. Any non-zero value set on Power % will turn on the lamp.

Medium Pressure Mercury Lamp has a built-in countdown timer. There will a cooling period of around 3 minutes in between each lamp strike.

6.7.2 Control via Flow Commander™ Software

To ignite the UV-150 lamp with Flow Commander software, an experiment needs to be created. Refer to Flow Commander™ user manual for detail information.





LEDs and low pressure mercury lamps are **non-dimmable**. Any non-zero value input on Power % will turn on the lamp.

6.8 The Cooling Module

The cooling module is an optional extra required for use with a UV-150 reactor or cooled tube or column reactor. The cooling function is provided by bleeding dry nitrogen gas or dry compressed air at low pressure through a bed of dry ice. The resulting mixture of nitrogen (or air) and carbon dioxide is cooled to a temperature close to -78° C and is fed intermittently via a pinch valve into the cooled reactor assembly. Within this assembly the cooled gas mixture is recirculated around the reactor assembly to provide heat transfer between the gas and the reactor.

The cooling module consists of a chilled gas generator and an insulated pipe, which carries the chilled gas to the Reactor (see section 6.8.1).

Connection of the Cooling Module should proceed as follows:

- Fill the cooling module with dry ice. A full tank would require approximately 2kg of dry ice.
- Insert the loop of silicone pinch tubing into the pinch valve. E-Series, upper pinch valve (labelled ‘Reactor 1’). R-Series, middle pinch valve (labelled ‘Reactor 3’).
- Remove the plug from the bottom of the UV-150 reactor housing and insert the 6 mm PEEK barbed connector provided in its place. See section 5.2 for cooled gas inlet and condensate drainage ports.
- Connect the end of the insulated umbilical cord to the 6 mm PEEK barbed connector.
- Attach the nozzle appropriate for cooling mode (for Mark I reactor housing)). This is the nozzle with a blanked off hole but with the cross-drilled hole OR slide the shutoff to ‘Cooled’ position (for Mark II reactor housing). See Section 6.3
- Using the UV-150 App select the “cooled” mode of operation on E-series OR turn the R4 manual control knob to sub-ambient temperature on the display. See section 6.2.

Only dry ice should be used in the cooling module. Using solvents or other liquids will CAUSE damage and may create a potential hazard.

6.8.1 Assembly of Cooling Module

Assembly of the Cooling Dewar parts prior to use:

1 4 x M4 Button head screws

2 1 x Insulated Umbilical Cord

3 1 x Pinch Tube

4 1x Regulator with bracket

5 1 x E-Series Bracket (E-Series Module only)

6 1 x Pressure Relief Valve

Step 1 – Fit the regulator and bracket in the threaded holes using the 4 x M4 screws provided (See Fig A). If being used with an E-Series module, the E-Series bracket also needs to be fitted (See Fig B).

Step 2 – Fit the pinch valve tube by screwing into the threaded hole. Finger tight is sufficient (See Fig C). Attached the opposite end (larger of tube) into the push fitting on the regulator, pushing in until you can't release by pulling (See Fig D).

Step 3 – Fit the Pressure Relief valve into the threaded hole on the side. Finger Tight is sufficient. (See Fig E)

Step 4 – Remove one of the blanking plugs and fit the insulated umbilical cord into the threaded hole positioned opposite of the regulator. Leaving the second hole blanked. (See Fig F)

Fig. A

Fig. B

Fig. C

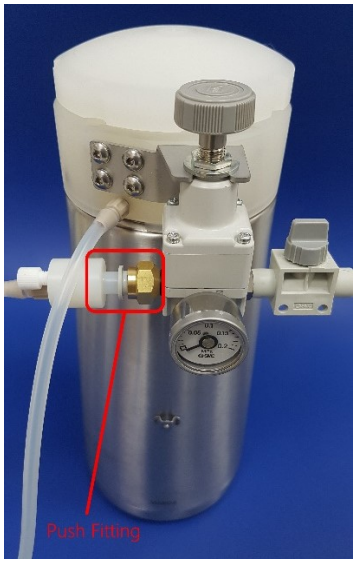


Fig. D

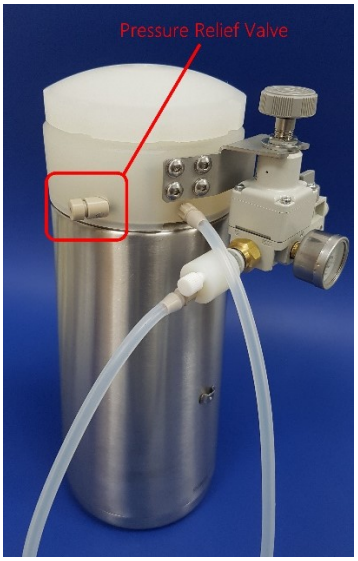
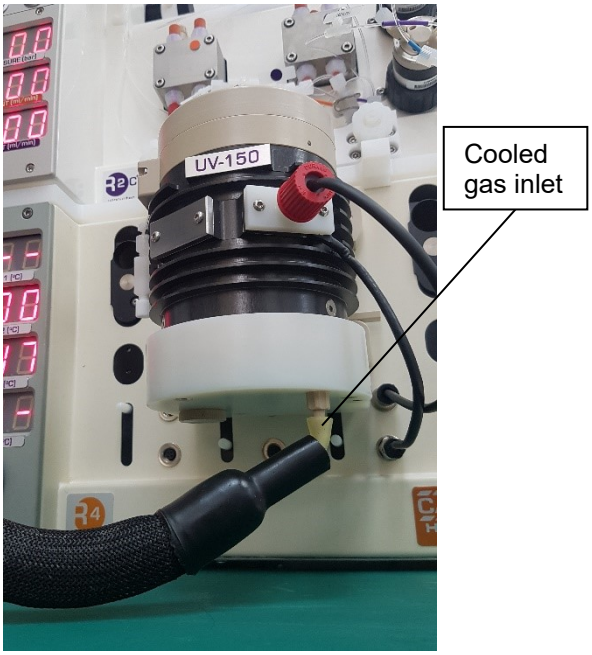


Fig. E

Fig. F

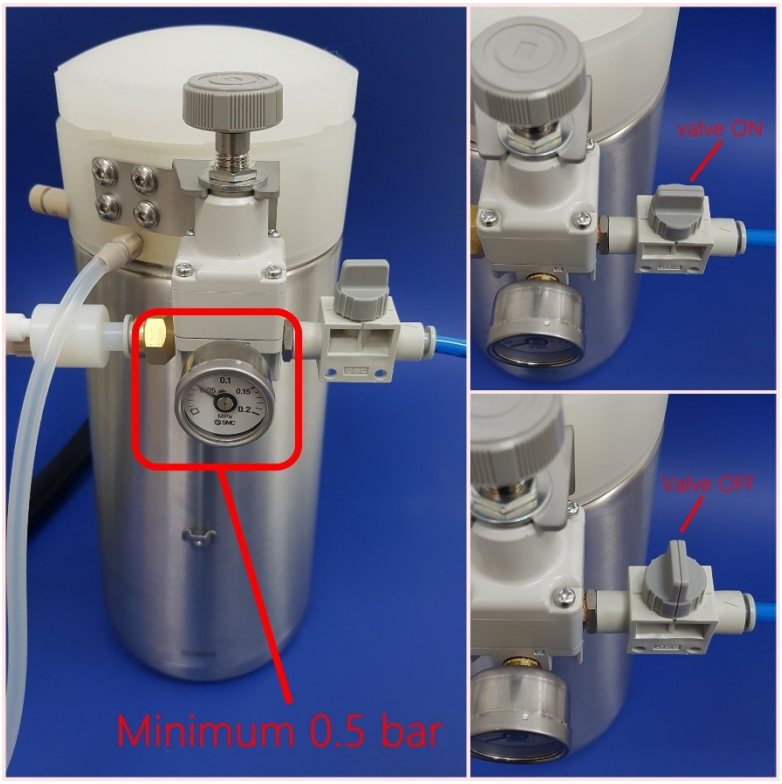
The cooling module is normally sited to the left-hand side of the R2+ pumping module in close proximity to the three pinch valves on the side of the E-Series / R4 module.



Pinch tube on R4

Pinch tube on E-Series

Connect the dry nitrogen supply using 6mm OD / 4mm ID blue pneumatic tubing supplied. Connect the dry nitrogen supply to the inlet connector of the pressure regulator mounted on the cooling module. Ensure the gas valve is turned on. The incoming N_2 gas supply (from gas cylinder or in-house supply) should have a minimum of 2 bar pressure. The regulator on the cooling module is pre-set, with 2 bar incoming pressure, the outlet pressure will be regulated to 0.05 MPa (0.5 bar).



6.9 Spectrometer Assembly and Analysis

For more details for the spectrometer option contact: info@vapourtec.com

6.10 Notes on Running Photochemical Reactions

When running photochemical reactions with the UV-150 in continuous flow the following points should be considered:

1) Select a solvent that will not block the wavelengths of interest (see section 9.3 for properties of common solvents)
2) Materials will only react to wavelengths in which they absorb. Absorption spectra is therefore valuable data to have for the starting materials and products
3) If the wavelengths of activation are known then select an appropriate filter (for medium pressure mercury lamp) or lamp (for LEDs and low pressure mercury)
4) If the wavelengths of interest are not known then use the medium pressure mercury lamp and select the filter No 1
5) One common occurrence in photochemical reactions is that the reaction products can absorb photons preventing a photon reacting with the starting materials. This absorption by the product can prevent a reaction progressing to completion. Reducing the reaction concentration will help in these cases but will not eliminate the problem. Absorbing of photons by the product can also lead to side reactions.
6) Always consider the lamp to be a source of reagents (photons / second). Think in terms of “exposure time” rather than “residue time” For example:
    - Doubling the flow rate of the solution will half the concentration of photons / ml of solution.
    - If the concentration of the starting material is halved then the flow rate of the solution must be doubled to return to the same Photons / Mol ratio of the reaction.

7) When evaluating a new reaction using medium pressure mercury lamp, always start at medium power setting as this will give better control over the reaction temperature and scope for increasing and decreasing the power. Vapourtec's recommendation is to start at 70% power.

8) Always run photochemical reactions at pressure. Many photochemical reactions will generate gaseous products and intermediates. A pressure of a few atmospheres will prevent the generation of gases adversely affecting the exposure time in the reactor. Vapourtec's recommendation is 3 bar as a starting pressure for photochemical reactions.

7 TROUBLESHOOTING

Problem	Possible Cause	Solution
No LED's	Power source failure or Fuse blown	Check system is plugged in and turned on. Replace fuse as described in Section 7.1.1 of this manual.
No ignition and blue LED fast flashing	- Lamp ignition timer running - Wrong power supply unit	- Wait 20 seconds and try again - Power supply unit (PSU) for LEDs and low pressure mercury lamp looks similar, check the rating plate on the left back side of the PSU to identify the right unit
No Green LED adjacent to Comms label	Reactor not plugged in or Comms cable not plugged in or Flow System switched off or software not latest version	Check connections and make sure E-Series or R-Series control software is running. Ensure E-Series is running version 1.0.6.23 or higher.
Red LED adjacent to UV-150 ready label	Emergency stop button pushed	Twist Emergency Stop anticlockwise to release
Amber LED adjacent to UV-150 ready label	Either lamp not placed into top of UV-150 Reactor Housing or Quick Reactor housing not engaged with the main part of the reactor or lamp connector cover is not in place	Check lamp is fully engaged with the reactor housing and the Quick release reactor housing is twisted fully clockwise. Ensure the connector cover is screwed in-place.
Red LED adjacent to Lamp Error label with no indication on the E-Series status area	The lamp has struck but subsequently the lamp's arc has been lost or the UV-150 power supply has failed.	If the lamp has been run regularly on low power try running the lamp at high power for 30 minutes. Replace the lamp. Call Vapourtec service.
Red LED adjacent to Lamp Error label with "UV-150 fan has failed" indicated in the E-Series status area	The UV-150 system fan has reported an error.	Call Vapourtec Service

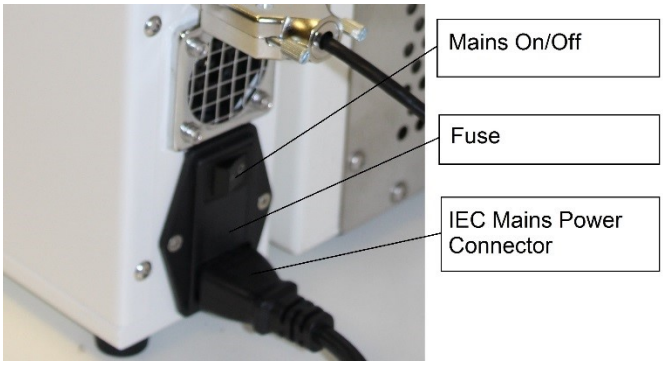
8 SERVICE

8.1 User serviceable parts

8.1.1 Replacing the fuse

Isolate the equipment from mains before removing ANY covers.

Remove the fuse cover on the rear panel (see picture below). For description of fuse function and specification see General Specifications.



8.1.2 Replacing the Lamp

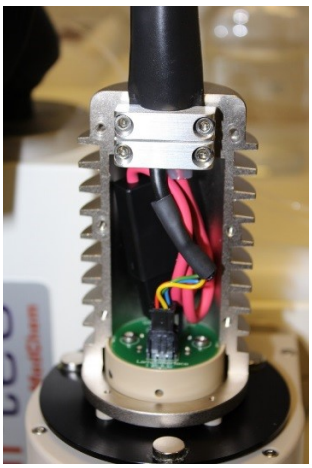
Isolate the equipment from mains before removing ANY covers.

For Medium Pressure Mercury lamp, allow the lamp 10 minutes to cool down from last operation before removing the lamp assembly.

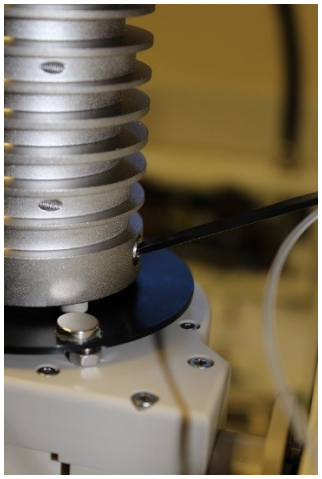
Replacement medium pressure mercury lamp assemblies can be ordered from Vapourtec, the ordering information is listed in section 8.2 below. Once the UV-150 Power Supply has been isolated from the mains, the procedure for replacement of the lamp is as follows:

1) Leaving the lamp / umbilical assembly connected to the reactor assembly use a 2.5 mm Allen key to remove the 6 screws locating the finned cover to the connector assembly. Remove the cover and set aside.

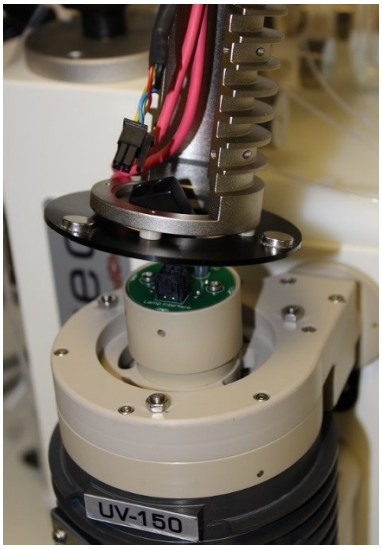
2) Disconnect both of the electrical connectors from the lamp's electronics board.



3) Using a 3 mm Allen key, loosen and remove the single screw holding the finned metal connector to the lamp body. Carefully slide the finned metal connector off the top of the lamp holder. Set the finned metal connector with umbilical attached aside.



4) Carefully remove the lamp holder from the top of the reactor assembly. Insert the new replacement lamp into the reactor assembly. Note that the lamp will only locate fully one way round. Avoid touching the quartz lamp enclosure.



5) Refit the finned metal connector and umbilical and tighten the retaining screw. Re-connect the two electrical connectors and replace the finned metal cover taking care not to trap any wires. Tighten the 6 screws.

8.1.3 Exchanging the Filters for Medium Pressure Mercury Lamp

Isolate the equipment from mains before removing ANY covers.

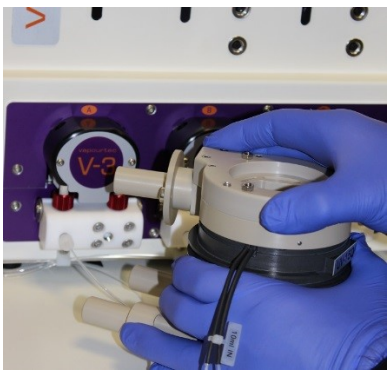
Allow the filter 10 minutes to cool down from last operation before removing the lamp assembly. Replacement filter assemblies can be ordered from Vapourtec, the ordering information is listed in section 8.2 below.

Once the lamp PSU has been isolated from the mains, the procedure for exchanging of the filters is as follows:

1) Remove the lamp / umbilical assembly from the top of the reactor assembly, avoid touching the lamp and place the lamp assembly in a safe location.

2) Disconnect the temperature sensor and earth connector from the front of the reactor heater and remove the UV-150 reactor assembly from its location in the front of the reactor heater / cooler.

3) Remove the upper quick release cover by rotating 20 degrees anti-clockwise. The filter can now be removed from the inner section of the housing. Replace the filter with an alternative unit to address the desired wavelengths.



4) Reassembly of the reactor is the reverse of the stages (1) to (3).

8.2 Spare parts & Accessories listing

Vapourtec Part No.	Description of Spare Parts and Accessories
50-1296	Wavelength Filter Type 1
50-1297	Wavelength Filter Type 2
50-1298	Wavelength Filter Type 3
50-1299	Wavelength Filter Type 4
50-1284	Wavelength Filter Type 5
50-1285	Wavelength Filter Type 6
50-1455	Wavelength Filter Type 7
50-1456	Wavelength Filter Type 8
50-1457	Wavelength Filter Type 9
50-1291	Replacement Lamp, 150 watt, medium pressure mercury
50-1287	UV-150 reactor – 10 ml
50-1288	UV-150 reactor – 5 ml
50-1289	UV-150 reactor – 2 ml
50-1140	Cooling module including umbilical – R-Series
50-1314	Cooling module including umbilical – E-Series
50-1289	2ml replacement UV-150 reactor coil
50-1288	5ml replacement UV-150 reactor coil
50-1580	10 ml replacement tubular reactor for UV-150
50-1581	10 ml replacement UV-150 reactor tubing for use with 50-1580
50-1453	UV-150 photochemical LED power supply - no light source provided
50-1451	LED Lamp 510 to 540 nm, peak 525 nm
50-1450	LED Lamp 480 to 510 nm, peak 495 nm, 13 W (Gen-1)
50-1449	LED Lamp 450 to 480 nm, peak 470 nm, 24 W (Gen-1)
50-1448	LED Lamp 420 to 450 nm, peak 450 nm, 24 W (Gen-1)
50-1447	LED Lamp 420 to 450 nm, peak 440 nm, 24 W (Gen-1)

50-1446	LED Lamp 420 to 450 nm, peak 430 nm, 24 W (Gen-1)
50-1445	LED Lamp 420 to 450 nm, peak 420 nm, 18 W (Gen-1)
50-1444	LED Lamp 390 to 420 nm, peak 410 nm, 12 W (Gen-1)
50-1443	LED Lamp 390 to 420 nm, peak 405 nm, 9 W (Gen-1)
50-1442	LED Lamp 390 to 420 nm, peak 395 nm, 6 W (Gen-1)
50-1441	LED Lamp 360 to 390 nm, peak 380 nm, 4.2 W (Gen-1)
50-1440	LED Lamp 360 to 390 nm, peak 365 nm, 3 W (Gen-1)
50-1439	LED Lamp 360 to 390 nm, peak 365 nm, 16 W (Gen-2)
50-1458	Cool white LED light
50-1342	254 nm low pressure mercury lamp, ultraviolet C (9W)
50-1341	310 nm low pressure mercury lamp, ultraviolet B (9W)
50-1339	370 nm low pressure mercury lamp, ultraviolet A (9W)
50-1283	Spectrometer 165-800nm, resolution 0.5nm and fibre optic probe

8.3 Vapourtec warranty

The Vapourtec Ltd standard UK warranty follows. The warranty covers parts and labour for a period of 12 months, commencing the date of invoice, for any repairs deemed resultant of a defect in materials and/or workmanship by Vapourtec Ltd. This warranty excludes wear and tear of parts considered to be 'consumable', a list of these parts is given below. Replacement of consumable parts or repairs to equipment that is not covered by this warranty will be chargeable.

Any factory approved changes or extensions to this warranty should be received in writing from Vapourtec Ltd and filed with this warranty statement. If your equipment is eligible for coverage, please review this warranty thoroughly and contact Vapourtec Service Department with any questions you may have. If your equipment is not covered by our standard warranty, or you are seeking optional or additional coverage, see sections below for service plans offered.

Consumable parts and other items not covered by the standard warranty:

- Glass Filters
- Temperature sensors
- Tubing
- Lamps over 100 hours of duty

Items COVERED by the limited warranty

- Parts and labour for a period of one (1) year from date of delivery. Any part excluding those in the list above found to defective will be either repaired or replaced at the discretion of Vapourtec Ltd, free of charge by Vapourtec Ltd.
- Medium pressure mercury lamps are warranted for the first 100 hours of operation only.
- On site labour if repairs require that Vapourtec Ltd personnel travel to the equipment.

Items NOT COVERED by the limited warranty

- Travel time, travel expenses and mileage expended by Vapourtec Ltd personnel if repairs require

on-site labour.

- Transportation of equipment for repair.
- Vapourtec Ltd cannot be held responsible for incidental or consequential damages

The above statement is a final and complete statement of the agreement between the Customer and Vapourtec Ltd. Vapourtec Ltd makes no other warranties expressed or implied, of merchantability, fitness or otherwise, with respect to the goods supplied under this agreement, which extend beyond the description of this limited warranty.

Vapourtec Ltd will have the right to inspect the equipment and determine the repairs or replacements necessary. The customer will be notified within a reasonable time of any damages incurred that are not covered by this warranty prior to initiation of such repairs.

Any customer modification of this equipment or any repairs undertaken without prior written consent of Vapourtec Ltd will render the limited warranty void.

9 REFERENCE DATA

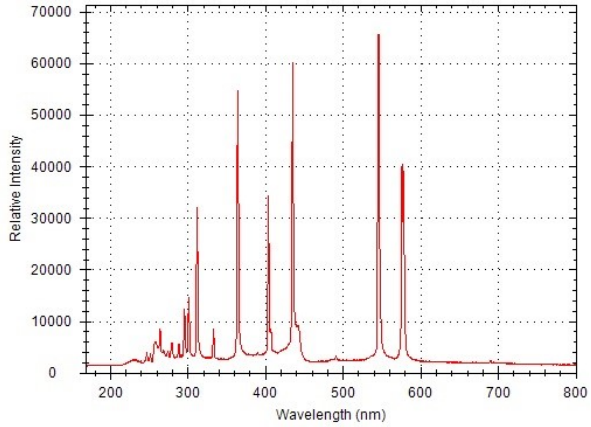
9.1 General Specifications

Tube type reactor maximum working volume	10ml
Lamp power	**For Medium Pressure Mercury Lamp:** Maximum: 150 watts Minimum: 75 watts **For LEDs:** Refer to section 4.3
Environmental	Operational ambient temperature range: 15 to 25 C Operational humidity: 20 to 70% RH
Size & Weight	Width Reactor: 120 mm Width PSU: 70 mm Height Reactor: 260mm Height PSU: 160mm Depth Reactor: 190mm Depth PSU: 360mm Weight: 7 kg (Power supply and Reactor Assembly)
Services	Power: 100 - 230V (+/- 10%), 50 - 60 Hz, 2A at 100V (see rating plate)
Fuses	IEC socket (230 V external): 2 A, 5x20 mm, type T IEC socket (110 V external): 2 A, 5x20 mm, type T
Conformity	Conforms to all applicable EEC standards, CE marked.

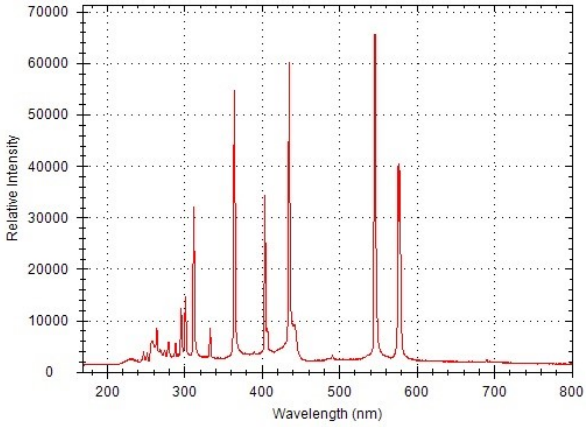
9.2 Filter Specifications for Medium Pressure Mercury Lamp

The table below shows the Vapourtec Filter types available for medium pressure mercury lamp as accessories and the respective spectral data.

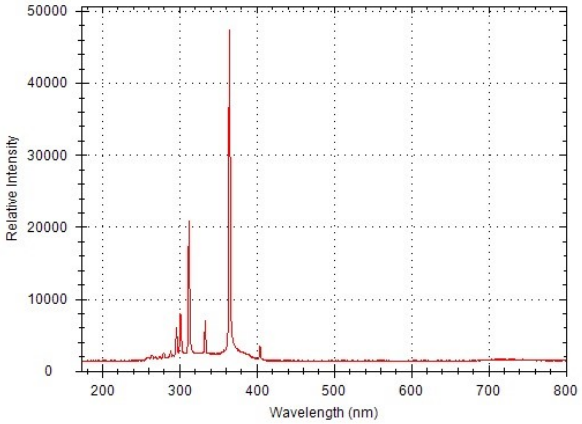
Lamp Spectra only



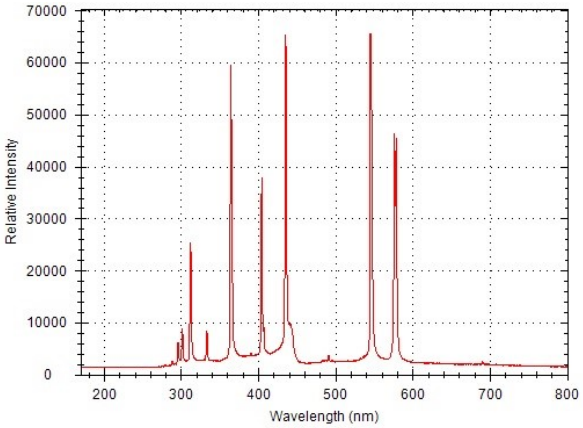
Transmission Spectra Type 1 Filter - Silver



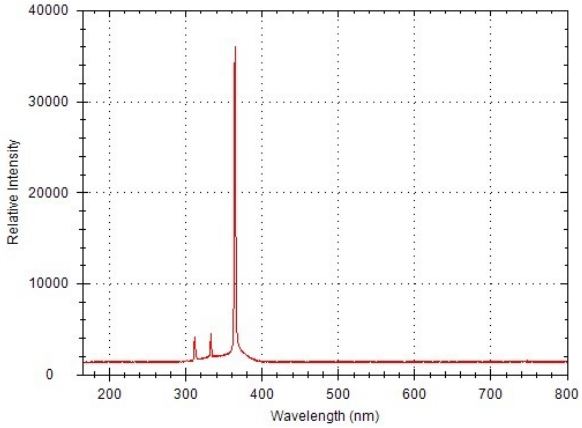
Transmission Spectra Type 2 Filter - Gold



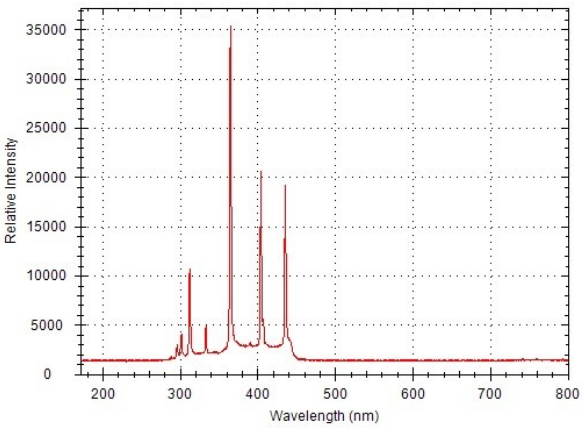
Transmission Spectra Type 3 Filter - Red



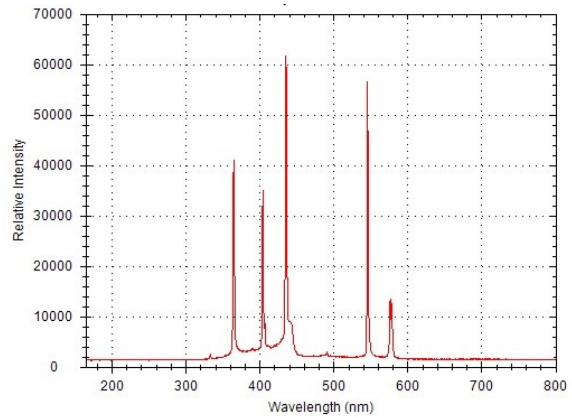
Transmission Spectra Type 4 Filter - Blue



Transmission Spectra Type 5 Filter - Silver



Transmission Spectra Type 6 Filter - Silver



9.3 Properties of common solvents

The table below shows the solvents commonly used for photochemical applications together with the lower UV cut-off wavelength and auto-ignition temperature. The solvents highlighted in RED are NOT recommended for use in the UV-150 **Medium Pressure Mercury Lamp** due to their low auto-ignition temperature and large amount of heat generated by the lamp. This solvent data is provided for information only. A through and independent risk assessment must always be completed before running the UV-150 reactor.

For solvent with low auto-ignition temperature, user might want to consider using LEDs or Low Pressure Mercury Lamp for their reaction.

Solvents	UV Cutoff (L_o/nm)	Autoignition temperature
1,2,4-trichlorobenzene	350	571°C
1,2-dichlorobenzene	350	571°C
1,2-dichloroethane	250	413°C
1,2-dimethoxyethane	300	201°C
2,2,4-trimethylpentane	230	418°C
2-ethoxyethanol	280	235°C
2-methoxyethanol	270	235°C
2-propanol	240	399°C
4-methylpentanone	375	No data
5-methylhexanone	350	400°C
acetone	340	465°C
acetonitrile	200	524°C
benzene	295	498°C
butan-2-one	345	404°C
chlorobenzene	310	593°C
chloroform	260	Not flammable
cyclohexane	235	245°C
cyclopentane	220	361°C
decalin	250	238°C

Solvents	UV Cutoff (L_o/nm)	Autoignition temperature
dichloromethane	245	556°C
diethyl ether	255	160°C
dimethysulphoxide	330	300°C
ethanol	240	365°C
ethyl acetate	280	427°C
heptane	230	203°C
hexane	225	225°C
isobutanol	250	430°C
methanol	240	464°C
n-butanol	245	343°C
n-butanol acetate	275	420°C
NN-dimethylformamide	300	445°C
n-propanol	250	371°C
o-xylene	325	432°C
p-dioxane	290	179°C
pentane	230	260°C
Pyridine	345	481°C
s-butanol	285	405°C
tetrachloroethylene	320	677°C
tetrahydrofuran	280	321°C
toluene	315	480°C
trichloroethylene	>400	414°C
water	190	Not flammable

9.4 Vapourtec contact details

Address: Vapourtec Ltd
Park Farm Business Centre
Fornham St Genevieve
Bury St Edmunds
Suffolk
IP28 6TS
U.K.

Tel: +44 (0) 1284 728659
Fax: +44 (0) 1284 728352
e-mail service@vapourtec.com
Web: www.vapourtec.com

9.5 Sample copy of EC declaration of conformity

EC DECLARATION OF CONFORMITY

CE

Product	Vapourtec UV-150 Photochemical Reactor
Serial no.	

Manufacturer	Vapourtec Ltd
Address	Park Farm Business Centre Fornham St Genevieve Bury St. Edmunds Suffolk, IP28 6TS

We hereby declare that the product above complies with the essential health and safety requirements of the following directives:

MACHINERY	**Directive 2006/42/CE** Implemented in the UK by Supply of Machinery (Safety) Regulations 2008 (SI 2008 no. 1597).
Low Voltage Directive (LVD)	**Directive 2014/35/EU** Implemented in the UK by The Electrical Equipment (Safety) Regulations 2016 (SI 2016 no. 1101).
Electromagnetic Compatibility (EMC)	**Directive 2014/30/EU** Implemented in the UK by The Electromagnetic Compatibility Regulations 2016 (SI 2016 no. 1091).
CE marking	**Directive 93/68/EEC** Implemented in the UK by The EMC (Amendment) Regulations (1994 no. 3080).

The product has been designed and manufactured in accordance with European standards:

EN 12100-1: 2004	Safety of Machinery: Basic concepts, general principles for design. Part 1: Basic terminology, methodology
EN 12100-2: 2004	Safety of Machinery: Basic concepts, general principles for design. Part 2: Technical principles
EN 13849-1: 2016	Safety of Machinery: Safety related parts of control system. Part 1: General principles of design
EN 60204-1: 2006	Safety of Machinery: Electrical equipment of machines. Part 1 General requirements
EN 61010-1: 2013	Safety requirements for electrical equipment for measurement, control and laboratory use Part 1: General requirements

A Technical Construction File is retained at the manufacturer's address.

Signed	
Name	
Position	
Date	