Tornado™ Series
Long Pathlength Gas Cells

User Manual

2I-24205-7

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USER MANUAL- CONTENTS

1. Introduction

Thank you for purchasing a Specac Product.

The Tornado™ Series gas cells are a range of long pathlength gas cells available as T5 (P/N GS24205), T10 (P/N GS24210) and T20 (P/N GS24220) versions for the measurement of gases/vapours at unit ppm levels of their concentration by IR transmission spectroscopy.

The cells can be configured with various different fixed pathlengths to best suit a specific experimental requirement. Change of a fixed pathlength setting is achieved by simple replacement of the mirror carriage assembly within the Tornado™ gas cell. A different pathlength may be required if the concentration of a gas species to be analysed requires a different setting for an appropriate absorption feature of an IR spectrum to be measurable.

The pathlength ranges for each Tornado™ gas cell variant are:-

Tornado™ T5 cell is from 1.0m to 8.0m in 1.0m steps.
Tornado™ T10 cell is from 2.1m to 10.6m in 1.06m steps.
Tornado™ T20 cell is from 2.0m to 20.0m in 2.0m steps.

As standard all of the Tornado™ gas cells (T5, T10 and T20) can be particularly configured for their build from a choice of the following options:-

- A borosilicate glass (**G**) body capable for use up to 14.7psi pressure or nickel coated aluminium metal (**M**) body capable for use up to 125psi pressure.

- KBr (**K**), CaF2 (**C**) or ZnSe (**Z**) windows to be used in the glass bodied cells and CaF2 (**C**) or ZnSe (**Z**) windows in the metal bodied cells.

- Fitting of a low (**L**) pressure gauge kit to glass bodied cells only and low (**L**) or high (**H**) pressure gauge kit to metal bodied cells.

Common to **all** the Tornado™ Gas Cells are the following features:-

- Fixed (**F**) pathlengths only.
- Viton (**V**) O-rings and seals throughout.
- Anodised aluminum/stainless steel internal hardware.
- Protected coated gold mirrors.
- Purgeable interface optics.
- Benchmark™ baseplate compatibility.
- ¼" O.D. stainless steel gas inlet and outlet tubing
- Compatibility with the laser alignment accessory P/N GS24500.

The actual part number of the Tornado™ gas cell received refers to the configuration of the gas cell from the optional components fitted, related to the coded lettering suffix to the cells individual number.

Hence, a cell with P/N GS24205GCFV identifies a Tornado™ T5 size cell with glass body, CaF2 windows, fixed pathlength, Viton O-ring seals and no pressure gauge fitted as supplied.

Another example would be P/N GS24210MZFVH which identifies a Tornado™ T10 size cell with metal body, ZnSe windows, fixed pathlength, Viton O-ring seals and fitted with a high pressure gauge kit as supplied.

Please also note that the part number configuration of the Tornado™ gas cell supplied **does not** refer to the particular FTIR spectrometer system the gas cell can be installed within. Installation of the gas cell into a spectrometer is via the use of a specific Benchmark™ baseplate that is installed into the spectrometer first of all. (See page 12.) The Benchmark™ baseplate for a particular spectrometer should be requested at the time of ordering of a specific configuration of Tornado™ gas cell and will be supplied with the gas cell.

2. Safety Considerations

With use of any spectroscopic accessory that involves the study of a wide range of chemical samples, the associated risk in handling may mostly be attributed to the specific sample type to be handled itself. As far as it possible you should follow a procedure for safe handling and containment of the type of sample to be used.

With respect to safety of use specifically for the Tornado™ fixed long pathlength gas cells, apart from taking necessary precautions when handling pressurized gases etc, different window materials can be used for containment of a specific gaseous/vapour type within either a glass or nickel coated aluminium body for the gas cell itself. As standard, KBr, CaF_2 and ZnSe windows are the three window materials of choice that can be used.

Caution: *Out of these three different window types, ZnSe is the most potentially hazardous material with respect to toxicity risk in use and handling.*

KBr and CaF_2 window materials can be considered relatively safe to use, although these materials may be harmful to the body if ingested in significant quantity. The general rule when working with **any** window/crystal material (and sample) **is to always wear gloves and safety gear** (e.g. safety spectacles) when handling to obviate the risk of contact with the skin.

Provided with each choice of window material that can be fitted for use in the Tornado™ gas cell is a window material safety data sheet for the specific material itself that can be consulted for safe handling. A copy of each of these datasheets can also be found in this User Instruction Manual in the **Notes On Cleaning** Section found on pages 40 to 44.

3. Specifications

The Tornado™ gas cells are supplied as T5, T10 and T20 versions for their overall size in terms of volume of cell and the pathlengths achievable in the size of cell. The smallest volume is for the T5 cell and the largest volume is for the T20 cell. The shortest pathlength that can be set is 1.0 meter with the T5 Cell and the longest pathlength that can be set is 20.0 meters with the T20 gas cell.

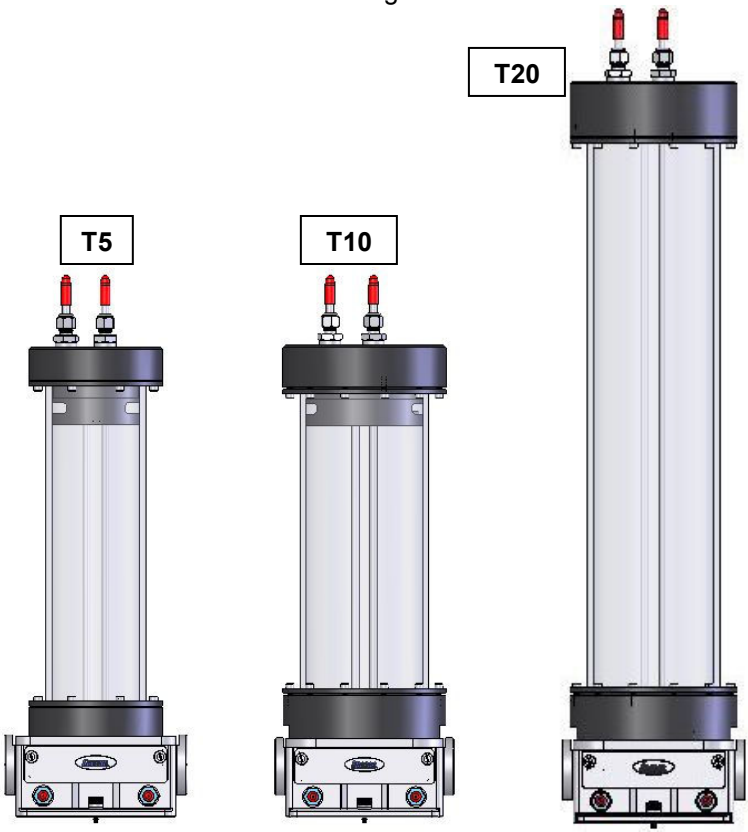

Fig 1. Front View of Tornado™ Gas Cells, T5, T10 and T20 Versions Comparison for Their Relative Sizes/Dimensions

Dimensions of the Tornado™ Gas Cells

	Overall Height	Height from optical unit top surface	Top of cell diameter	Cell body diameter	Width at optical unit
T5 Cell	*455mm*	*385mm*	*114mm*	*86.5mm*	*153mm*
T10 Cell	*470mm*	*400mm*	*142.5mm*	*113.2mm*	*153mm*
T20 Cell	*680mm*	*610mm*	*142.5mm*	*113.2mm*	*153mm*

Volume to Pathlength Options in the Tornado™ Gas Cells

	Base Pathlength	Volume	Pathlength Range
T5 Cell	*25.0 cm*	*1.33 liters*	*1 to 8m (in 1.0m steps)*
T10 Cell	*26.4 cm*	*2.60 liters*	*2.1 to 10.6m (in 1.056m steps)*
T20 Cell	*50.0 cm*	*4.30 liters*	*2.0 to 20.0m (in 2.0m steps)*

"Base Pathlength" is defined as the distance between the two objective mirrors at the top and the "T "shaped field mirror at the base of the Tornado™ gas cell on the mirror carriage frame. The pathlength for the Tornado™ gas cell is provided as "fixed" for the mirrors on the frame, e.g. at a fixed 5 meters pathlength for the T5 cell. (For this size of Tornado™ gas cell options for a fixed pathlength to be set on the mirror carriage frame are from 1m, 2m, 3m, 4m, 5m, 6m, 7m and 8m.)

Vacuum Testing

All Tornado™ gas cells have been rated to a vacuum of $3x10^{-3}$ Torr ($4x10^{-3}$ mbar). The leak rates of the cells are typically:

T5 gas cell $2.25x10^{-5}$ Torr Liters/Sec ($3x10^{-5}$ mbar liters/sec)
T10 gas cell $3x10^{-5}$ Torr Liters/Sec ($4x10^{-5}$ mbar liters/sec)
T20 gas cell $3x10^{-5}$ Torr Liters/Sec ($4x10^{-5}$ mbar liters/sec)

1 Torr = 1.333 mbar

4. Checklist

On receipt of your Tornado™ Gas Cell please check that the following have been supplied:

- Tornado™ Gas Cell configured with specified body (glass or metal) option, windows option, fixed pathlength and Viton O-ring seals.
- Fitting of a low or high pressure gauge kit P/N G24160 (if ordered).
- Set of Allen Keys:-
  Allen Key 2.0 mm A/F for transfer mirror spring (tilt) adjustment.
  Allen Key 3.0 mm A/F for cell/optical unit attachment, transfer mirror radial adjustment.
- Benchmark™ baseplate specifically for your spectrometer.
- Desiccant end caps P/N GS24150 (if ordered) for transfer optical unit.
- Purge bellows P/N GS10707 (if ordered) for transfer optical unit.
- An Essential Spares Kit of parts (P/N GS24206 for Tornado™ T5 Cells and P/N GS24207 for Tornado™ T10 and T20 Cells).
- Benchmark™ baseplate installation guide instruction manual.

Carefully remove the gas cell and all of the parts from their packaging.

The Tornado™ gas cell supplied will be vacuum wrapped in an aluminium/silver foil bag to prevent any moisture or dust etc, affecting the optics (windows and mirrors) during transportation. Remove the foil bag by carefully cutting at the base of the gas cell and sliding up and away over the Tornado™ gas cell itself. By cutting the bag carefully, if desired it may be possible to use the foil bag for recovering the gas cell when stored away in its carry case when not in use.

5. Optical Layout

The optical layout of the Tornado™ gas cells is shown in Fig 2. The infrared beam is reflected within the cell by the 'White' three mirror cell system (as devised by J.U. White in 1942). This system gives multiple passing in increments of 4 passes. The three mirror surfaces are all spherical, each with the same radius of curvature. The radius is determined from the base pathlength of the cell. Fig 2. shows the basic set of a minimum of 4 passes within a Tornado™ gas cell which completes a beam passage through the gas cell. A combination of the base pathlength multiplied by the number of passes through the gas cell determines the pathlength.

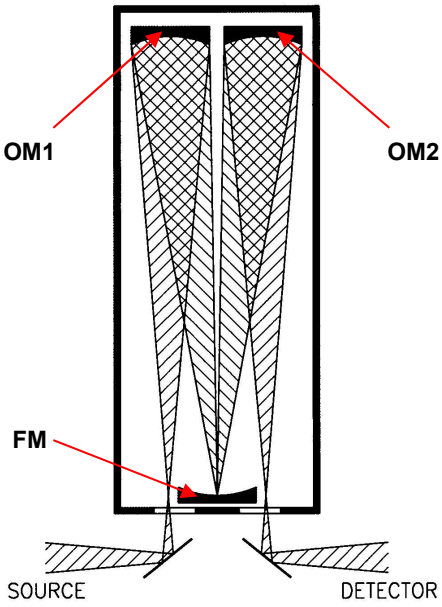

Fig 2: Optical Layout of Tornado™ Cells

The radiation from the source is deflected via the transfer optics input mirror through the cell aperture window into the gas cell. From there, the diverging beam passes to the first objective mirror (**OM1**) which then focuses an image onto the "T" shaped field mirror (**FM**). The beam is returned, diverging to the second objective mirror (**OM2**) which in turn directs it out of the cell to the transfer optics output mirror and on to the detector, or back to the field mirror (**FM**) for additional multipassing. (See Section 6) In order to see the beam passes in a Tornado™ gas cell it can be mounted on a visible light source such as the laser alignment accessory (P/N GS24500).

6. Multipassing

When there are more than 4 passes of the beam in the gas cell, the images will line up on the field mirror in 2 rows, as shown in Figs 3 and 4. The actual pathlength of the gas cell will be the number of passes of the beam multiplied by the base pathlength. (e.g. 12 passes of the T5 gas cell is equivalent to 12 x 25cm = 3 meters.)

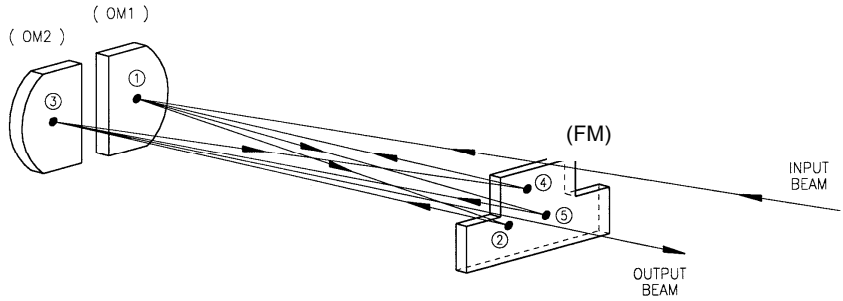

Fig 3: The sequence of the beam passes for the spots is: Input (1), (2), (3), (4), (1), (5), (3) output. There have been 8 passes in this system. This sequence is the same for both left to right (LR) and right to left (RL) beam systems.

To achieve multipassing the beam is directed off the second objective mirror (**OM2**) onto the field mirror (**FM**), on a similar level as the incoming beam. The closer the fourth image is placed to the incoming beam, the more passes there will be in the optical system.

The Tornado™ gas cells have been specified for their pathlength ranges and light beam passes as follows:-

T5 Cell – pathlength range of 1.0 to 8.0 meters - 4 to 32 passes.
T10 Cell – pathlength range of 2.1 to 10.6 meters - 8 to 40 passes.
T20 Cell – pathlength range of 2.0 to 20.0 meters - 4 to 40 passes.

Fig 4. represents the pattern of light spot images on the “T” shaped field mirror (**FM**) as seen from above. In Fig 4. there are 7 spots on the **FM**. The combination of spots in this pattern corresponds to 16 passes in the gas cell.

The number of passes of the light beam though the Tornado™ gas cell can be calculated either by:

1. Counting the number of spots on the **FM**, multiplying by 2 and adding 2, for example, for seven spots (7 x 2) + 2 = 16.

2. Counting the number of spots on the widest part of the ‘T’ shaped **FM** and multiplying by 4, for example, 4 x 4 = 16.

As the number of passes (and spots) increase, the spots in the rows get closer together.

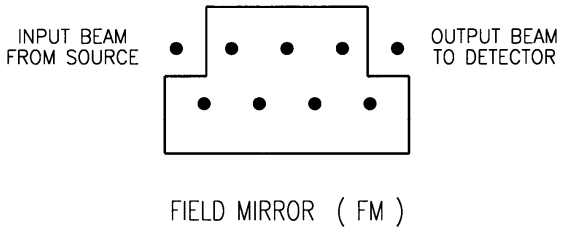

Fig 4: Light Spot Images on Field Mirror (FM)

7. Installation

The Tornado™ gas cell is supplied with its own transfer optical unit assembly (**1**). This mounts directly to any Benchmark™ baseplate by location of the optical unit onto the pillars and /or location studs of the baseplate and securing into position by tightening of the central thumbscrew (**2**). (See Fig 5.) This way of installation means that the Tornado™ gas cell can be used in any FTIR spectrometer fitted with an appropriate Benchmark™ baseplate.

For installation of the Benchmark™ baseplate supplied for your spectrometer please refer to the separate Benchmark™ baseplate installation guide instruction manual supplied with the gas cell. Once the Benchmark™ baseplate is installed, the Tornado™ gas cell can be mounted to the baseplate.

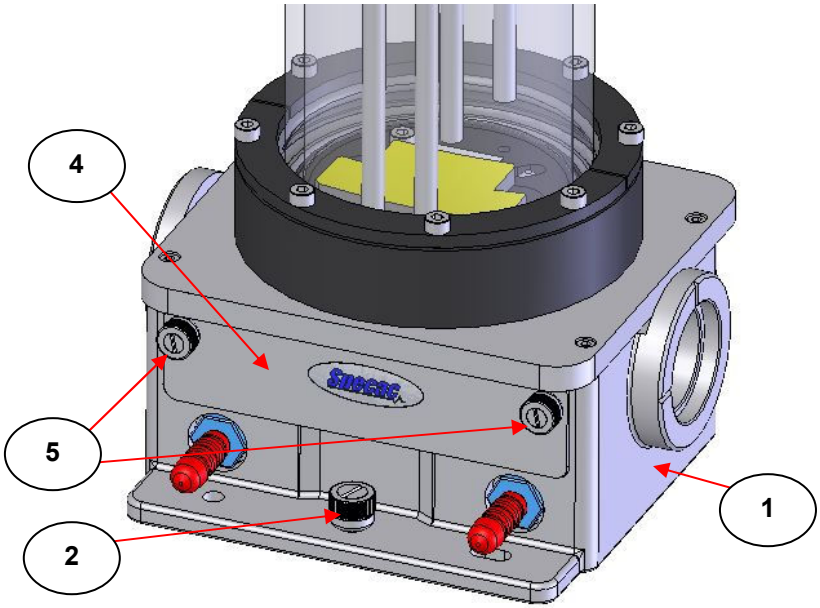

Fig 5. Optical Unit of the Tornado™ Gas Cells (Optical unit used with T5 Type of Cell)

Note: *Due to the larger size of the Tornado™ T10 and T20 cells, some spectrometers with small sample compartments may not be able to accommodate these particular Tornado™ Cell variants. (See Compatibility Guide Section 13).*

The configured Tornado™ gas cell is factory aligned before despatch for a throughput performance, but for optimum performance it will require fine alignment tuning in the particular spectrometer into which it is to be installed and used. Alignment is achieved by adjusting the mirrors (**3**) in the optical unit (**1**). To gain access to the mirrors remove the optical units cover plate (**4**) by unscrewing the two cover plate thumbscrews (**5**). (See Fig 5.)

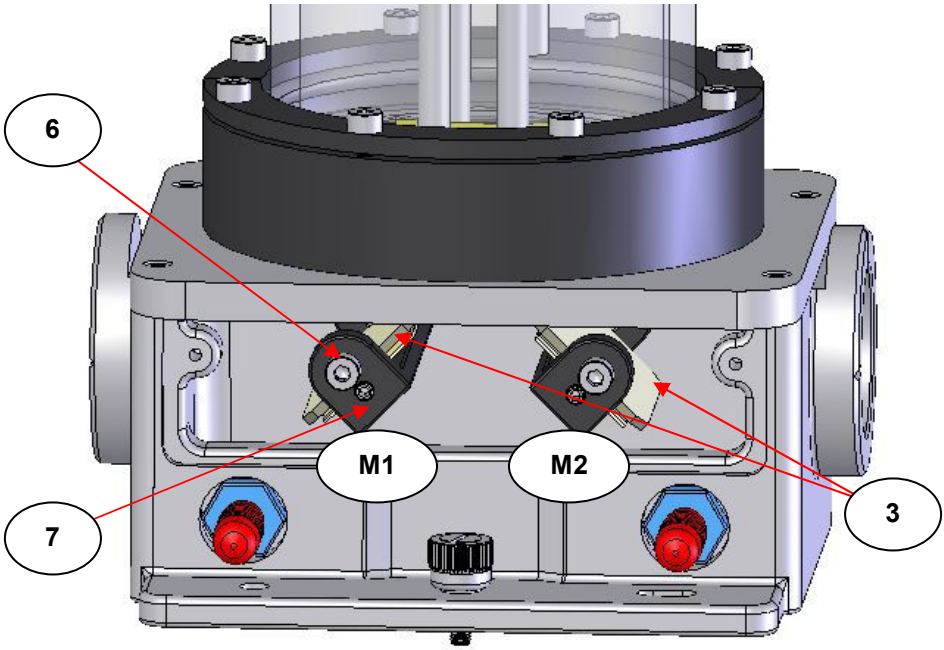

Fig 6. Tornado™ Gas Cell Optical Unit with Cover Plate Removed

The transfer optical unit (**1**) is a simple system of two mirrors to deflect the source beam into and collect from the gas cell, and then to deflect it to the detector. Fig 6. shows the optical unit (**1**) with cover plate (**4**) removed and the internal mirrors (**3**) on their adjustable mirror carriage assemblies (**M1** and **M2**). The mirror carriage assemblies have two screw fixings. The M4 x 5mm cap head screw (**6**) is used to rotate the mirror (**3**) surface. The M4 x 12mm grubscrew with cone point (**7**) is used to tilt the mirror (**3**) surface.

For an alignment procedure the actual configuration of the build of Tornado™ gas cell for the infrared beam direction through the sample compartment determines which mirror carriage assembly (**M1** or **M2**) becomes the output mirror (**3**). Looking from the front of the spectrometer the source of light to detector can pass from a left to right (**LR**) or right to left (**RL**) direction. From Fig 6. for use in a spectrometer with **LR** beam direction, **M2** becomes the output mirror (**3**). For a **RL** beam direction **M1** becomes the output mirror (**3**).

Note: *For the Tornado™ gas cell build itself, for **LR** and **RL** (source to detector) optical systems the field mirror (**FM**) in the gas cell will be oriented such that it appears as an inverted 'T' when the gas cell has been installed in the spectrometer and viewed from the front or above.*

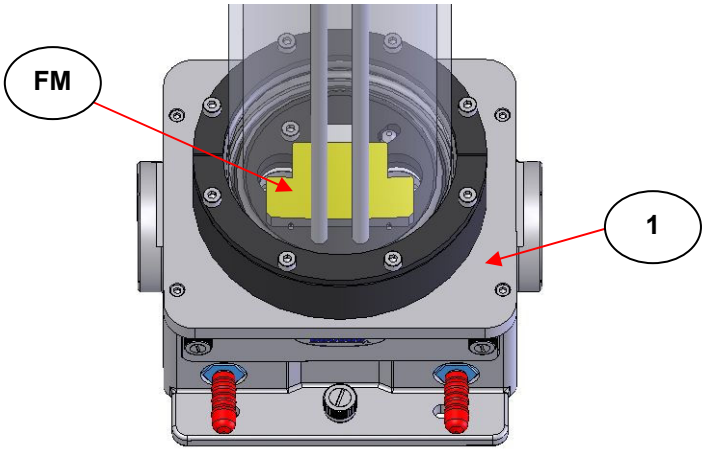

Fig 7. Orientation of FM for (LR) or (RL) Beam Direction

When installing a pre-aligned fixed (**F**) pathlength Tornado™ gas cell into the spectrometer for the first time some signal throughput should be registered at the detector.

Note: *For a typical alignment procedure, as follows, we have used the **RL** beam orientation as an example with **M1** becoming the output mirror.*

Using any appropriate beam energy monitoring signal from the FTIR spectrometer itself adjust the **M1** output mirror (**3**) initially, **only,** for rotation turning screw (**6**) clockwise or anticlockwise. You may see an improvement in the overall signal at the detector from rotation of the mirror in either direction. If you move away from a peak maximum throughput reading by clockwise rotation, stop and slowly rotate the screw (**6**) in the opposite direction. When a peak maximum throughput reading has been reached, leave the mirror (**3**) at the rotated setting.

Now, adjust the **M1** output mirror (**3**) for its angle of tilt by turning the grubscrew (**7**) clockwise or anticlockwise and observe the throughput signal reading. Similarly, if by clockwise rotation the peak maximum reduces, then rotate the screw (**7**) in the opposite direction.

When you have an optimum peak reading for the pathlength setting of your Tornado™ gas cell in your spectrometer system, from adjustment of the **output mirror M1 alone**, the gas cell can be considered correctly aligned. However, you may be able to slightly improve the overall throughput by slight adjustment of the **input mirror M2** now, by similar rotation and tilt adjustments of this mirror (**3**) by the screws (**6**) and (**7**) respectively.

Important: *When making any adjustment to either the **M1** (output) or **M2** (input) mirror (**3**) complete the action by bringing back to an optimum peak signal reading before moving to the **other** mirror (**3**) for further adjustment.*

If you do alter the setting of the input mirror **M2** slightly from an alignment procedure, it may then be necessary to readjust the output mirror **M1** again for rotation and tilt to get a fine “balance” for the mirror (**3**) settings in the optical unit (**1**) alone.

Specac would recommend use of the laser alignment accessory P/N GS24500 when carrying out any alignment or adjustments to the transfer optical unit mirrors (**3**), so that the pattern of light spots on the internal **FM** of the gas cell can be seen.

For an **RL** beam orientation alignment, if the **input** transfer optical unit mirror (**3**) is adjusted to try and improve the overall signal throughput, it is important to maintain the correct position of the light spot pattern on the **FM**. A slight beam positioning error from the input objective mirror (for an **RL** beam it will be **OM2**), will mean that the light spot pattern of this fixed (**F**) pathlength cell will be lost. Establishment of the light spot pattern, for the particular pathlength that has been fixed by the **OM1** and **OM2** mirrors being glued permanently into position on the mirror carriage frame, ensures the final beam pass through the gas cell will be towards the **output** transfer optical unit mirror (**3**) and hence can be deflected to the detector.

Features on the Optical Unit

There are features on the optical unit (**1**) of the Tornado™ gas cell that allow it to be operated in a purged environment (i.e. filling the optical unit with N_2 (Nitrogen) gas), if using a spectrometer with sealed optics.

At the front of the optical unit (**1**), there are two purge port fittings (**8**). For non-purged operation, the protective rubber sealing covers are kept in position to cap off these flow ports, but to purge, the rubber seal covers are removed by pulling them off of the barbed ended purge port fittings. With their removal flexible purge tubing (silicone rubber) can be connected in place to the barbed tubing connections. One of the ports (**8**) acts as an inlet and the other as an outlet for gas flow. (See Fig 8.). The cover plate (**4**) is not removed to purge the optical unit.

When appropriate tubing is connected, establish a flow of N_2 gas to purge the optical unit (**1**) free of any residual atmospheric conditions (air, water vapour, excess CO_2 etc). Purging the optical unit (**1**) with N_2 gas can help in low level measurements of CO_2 vapour within a gaseous species inside the gas cell itself.

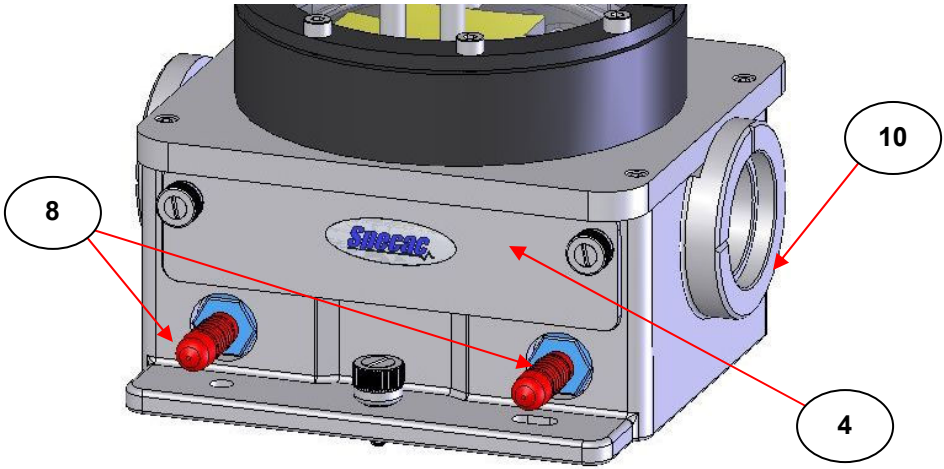

Fig 8. Purge Ports on Optical Unit of Cyclone Gas Cells

To allow the optical unit (**1**) to be purged efficiently when the Tornado™ gas cell is installed into the sample compartment of a spectrometer, it is necessary to fit the flexible purge bellows (**9**) that are supplied as Specac P/N GS10707 to the optical unit (**1**).

Note: *It is recommended that purge bellows (**9**) are fitted during use to help stabilize the instrument background, even if the accessory is not being purged.*

Fitting Purge Bellows (P/N GS10707) to the Optical Unit

The purge bellows (**9**) push fit over the circular aperture ports (**10**) at each end of the optical unit (**1**). (See Fig 8.) The purge bellows (**9**) may need to be cut to a shorter length for a better fit within the sample compartment when fitted to the optical unit (**1**). With the Benchmark™ base plate secured, and Tornado™ gas cell installed correctly into position on the Benchmark™ baseplate, measure the approximate distance between the spectrometer side walls from the source and detector ports and the flat end surface of the optical unit (**1**) (Dimension 'X' – see Fig 9).

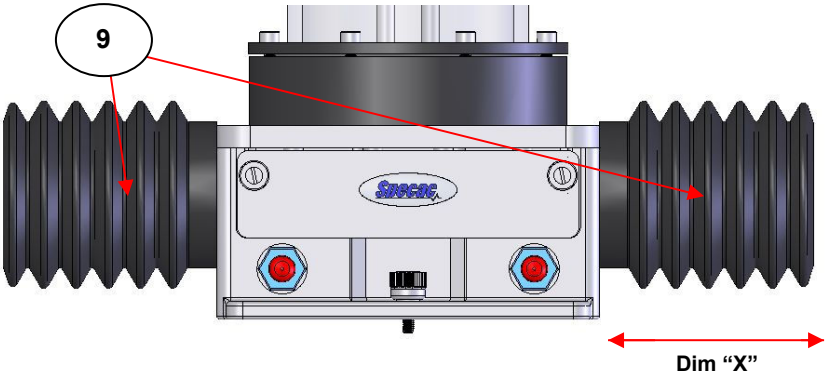

Fig 9. Purge Bellows (9) Fitted to Cyclone™ Optical Unit (1)

With the Benchmark™ base plate secured, and Tornado™ gas cell installed correctly into position on the Benchmark™ baseplate, measure the approximate distance between the spectrometer side walls from the source and detector ports and the flat end surface of the optical unit (**1**) (Dimension 'X' – see Fig 9).

Using a sharp razor blade, take care to cut lengths of the flexible purge bellows (**9**) which are equivalent to the measured length (**X**) plus an additional 10 mm for each purge bellow.

Tip: *It is easier to cut the purge bellow (**9**) between the hard ridges.*

Unscrew the fixing thumb screw (**2**) and remove the Tornado™ gas cell away from the Benchmark™ baseplate and from the sample compartment.

Fit the flexible purge bellows (**9**) over both circular aperture ports (**10**) (as seen at Fig 9.) and compress sufficiently to enable the gas cell and purge bellow assembly to fit back into the spectrometer on the Benchmark™ baseplate.

Ensure the purge bellows (**9**) are not obstructing the beam and then tighten the fixing thumb screw (**2**) to secure the Tornado™ gas cell optical unit (**1**) back onto the Benchmark™ base plate.

Desiccator Storage Caps

For storage of a Tornado™ gas cell a set of desiccator storage caps (P/N GS24150) can be fitted over the circular aperture ports (**10**) to keep the internal conditions of the optical unit (**1**) dry and moisture free. The purge ports fittings (**8**) must be sealed with their rubber covers and the front cover plate (**4**) must also not be removed.

One of the desiccator caps (**11**) is simply a cover. The other cap (**12**) contains a desiccant material which will maintain a dry atmosphere within the optical unit (**1**). This in turn will preserve the life, especially of KBr windows, if fitted in a cell. When still active as a desiccant, the cap (**12**) face will be blue in colour. When pink in colour, the desiccant has been exhausted. The desiccant can be reactivated by placing the cap (**12**) in an oven at 120°C for four hours.

Fig 10. Desiccator Storage Caps P/N GS24150

8. Tornado™ Gas Cell Bodies

The Tornado™ gas cell bodies are supplied in borosilicate glass (**G**) or nickel coated aluminum (**M**).

The borosilicate glass (**G**) bodied cell should show much less absorption of acidic vapors than a metal (**M**) bodied cell to minimise any potential future contamination (memory effects) of such residual vapours in the gas cell. However, choice of the Tornado™ gas cell body may depend upon the pressure of the gas to be analysed.

The pressure rating of a (**G**) cell is lower than that for an (**M**) cell.
(**G**) Tornado™ gas cells are rated to 14.7 psi.
(**M**) Tornado™ gas cells are rated to 125 psi.

Safety Note:

*KBr (**K**) windows **should not** be used in (**M**) gas cells as they will break at the elevated pressures obtainable with these types of cells. For safety reasons (**M**) gas cells are supplied with CaF2 (**C**) or ZnSe (**Z**) windows only.*

Inlet and Outlet Gas Flow Tubes

Common to all of the Tornado™ gas cells for either a (**G**) or (**M**) bodied gas cell are inlet (**13**) and outlet (**14**) gas flow tubes in stainless steel material. These gas flow tubes are finished at the top of the gas cell with their own red rubber caps as supplied. (See Fig 11.) The gas flow tubes are open ended 1/4" O.D. tubes for connection to suitable gas flow piping by compression fitting unions etc, connections for plumbing to an (inlet) gas supply and (outlet) gas flow or vacuum pump facility. The tops of the inlet (**13**) and outlet (**14**) gas flow tubes can also be adapted by connection to the Tornado™ vacuum gas cell inlet (**15**) and outlet (**16**) tap valves, Specac P/N GS24161 – (See Fig 12.)

The inlet tube (**13**) is distinguished from the outlet tube (**14**) for gas flow, such that the inlet tube (**13**) passes all of the way down the inside the gas cell body to exit at the base of the gas cell. (See Fig 11). The

outlet tube (**14**) is shorter in length and gases flow in from the gas cell at the top. In this way a gas cell is filled from the bottom to the top to enable complete filling of the gas cell for either static or flow measurement purposes.

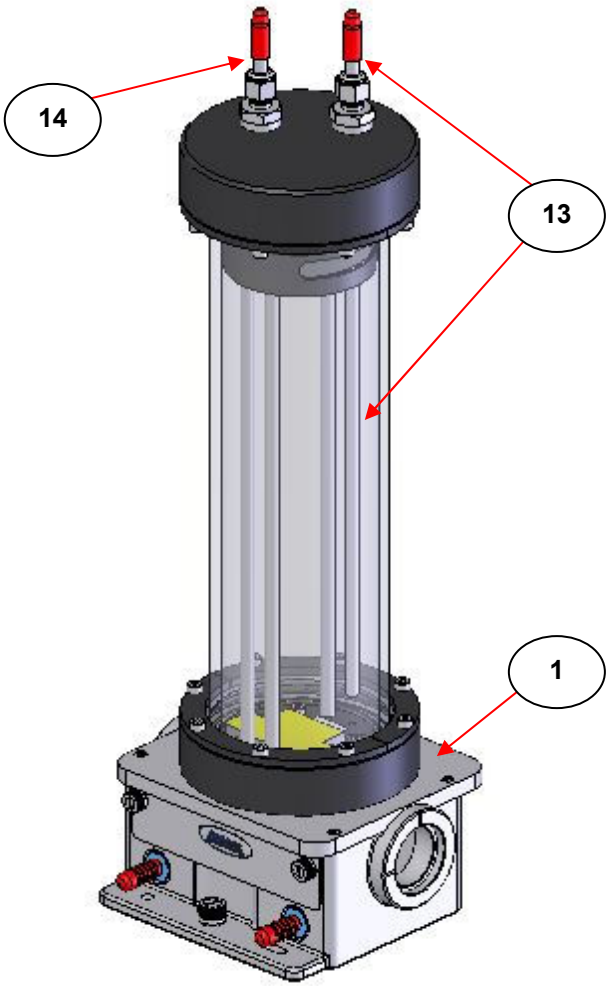

Fig 11. Tornado™ T5 Gas Cell to Show Inlet and Outlet Gas Tubes

Vacuum Gas Cell Inlet and Outlet Tap Valves (P/N GS24160)

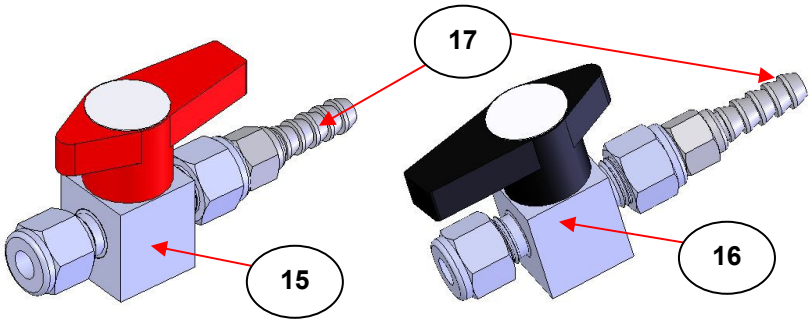

Fig 12. Tornado™ Vacuum Gas Cell Inlet (Red Tap) and Outlet (Black Tap) Valves - Specac P/N GS24161

Fig 12. shows the Tornado™ vacuum gas cell inlet (**15**) and outlet (**16**) tap valves. The colour of the taps and their arrow direction when the taps are open indicates the direction of gas flow. If these taps are fitted to the inlet (**13**) and outlet (**14**) gas flow tubes, the Tornado™ gas cell can be operated in a **flow through mode** for vapour measurement with both valves (**15)** and (**16**) open.

To operate the Tornado™ gas cell in a **static mode** for vapour measurement, allow the gas to fill the cell via the inlet tube (**13**) with both valves (**15**) and (**16**) open. To seal the gas in the gas cell, cease the flow of the gas by closing the outlet valve (**16**) and then the inlet valve (**15**) as soon as possible after.

The inlet (**15**) and outlet (**16**) tap valves have “barbed” hose type connections (**17**) for fitting of 1/4" O.D. (or 6mm O.D.) flexible gas tubing. However, the barbed hose type connections (**17**) can be removed by undoing their fixing nut (**18**) and replacing with 1/4” stainless steel tubing with olive/ferrule and nut connections for alternative plumbing to an (inlet) gas supply and (outlet) gas flow or vacuum pump facility.

Pressure Gauge Kits (P/N GS24160)

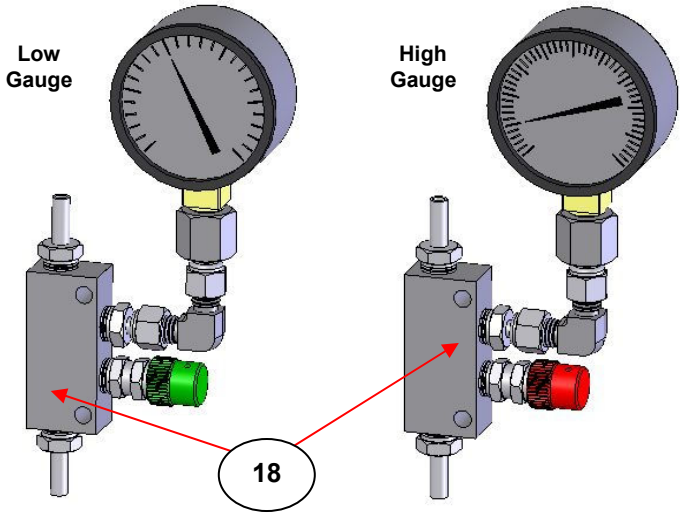

Fig 13. Low and High Pressure Gauge Kits P/N GS24160

For all of the Tornado™ gas cell variants a low (**L**) or high (**H**) pressure gauge kit P/N GS24160 can be fitted for measurement of the gas pressure within the gas cell environment. The pressure gauge kit of parts (**18**) can be purchased separately for fitting to a Tornado™ gas cell, or these parts may have already been configured and fitted to the gas cell that has been ordered and supplied. (An (**L**) or an (**H**) letter is included in the part number of the Tornado™ gas cell ordered.) Either the (**L**) or (**H**) pressure gauge kit of parts (**18**) is fitted between the top of the outlet gas flow tube (**14**) and the outlet on/off valve tap (**16**), if this part has been obtained via P/N GS24161 (See Fig 12.) .

The (**L**) pressure gauge is rated up to a maximum operating pressure of 14.7psi, whereas the (**H**) pressure gauge is rated up to 125psi. (**G**) bodied gas cells can only have (**L**) pressure gauge kits (**18**) fitted, but (**M**) bodied cells rated to a higher pressure capability can be fitted with either (**L**) or (**H**) pressure gauge kits.

Gas Line Connections to the Tornado™ Gas Cell for Safe Operation Using Pressurised Gases

Although the Tornado™ gas cells are designed to be used at ambient temperature conditions only and there is minimal risk for potential over-pressurisation of a gas environment being created from static (non-flow) containment of a gas within a fixed volume with no increase in the temperature, nevertheless Specac would highly recommend to have **a pressure safety device** plumbed into a gas line connection that is made to the **outlet** gas tube (**14**).

The low (**L**) or high (**H**) pressure gauge kit of parts (P/N GS24160) ideally should be fitted to the Tornado™ gas cell to facilitate the inclusion of a pressure gauge indicator along with an over-pressure event safety line that can be vented to a safe place of containment (e.g. a fume hood).

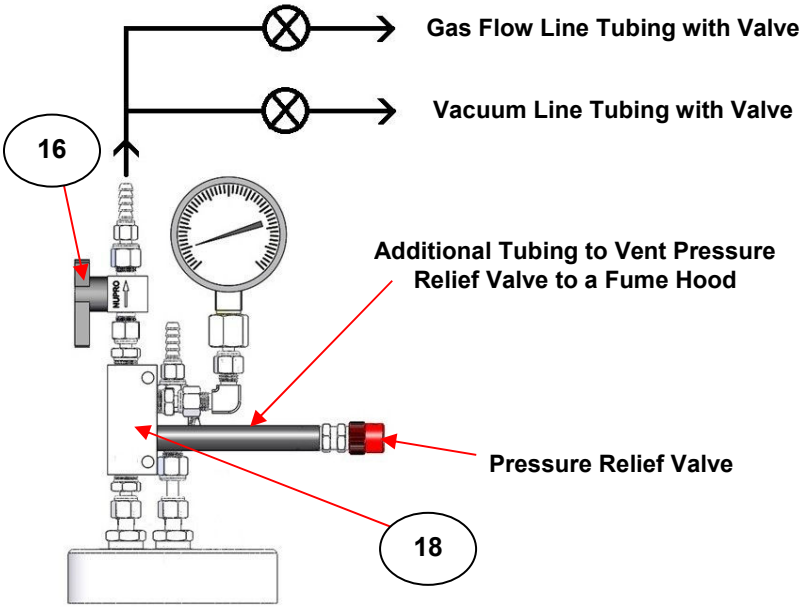

Fig 14. Schematic for Suggested Safety, Vacuum and Flow Gas Line Connectivity for Safe Operation of Tornado™ Gas Cells

On the body of the pressure gauge (**18**) there is a corresponding set pressure relief valve assembly fitting beneath the low (**L**) or (**H**) pressure gauge as fitted. Specac suggest and advise that this set pressure relief valve is re-sited to a safe containment area such as a fume hood by fitting an additional and appropriate length of stainless steel tubing between the pressure gauge body and the pressure relief valve. (See schematic Fig 14.)

Inclusion of such a pressure safety device with associated gas line connectivity is needed to vent away safely any potential excess build-up of the pressure in the gas cell chamber itself to prevent any accidental damage to the windows that have been fitted and/or compromising of the seals as fitted. Failure of the seals and window components under excess pressure risks a release of any gas conditions into the sample compartment of the spectrometer being used and increases the risk to any operator.

As shown in the schematic at Fig 14**,** along with the consideration for safety in operation for any potential over-pressure events, suggested gas line connections have been made from the outlet tube (**14**) fitted with an outlet valve tap (**16**) (from the kit of parts as P/N GS24160) to separate vacuum and flow lines with their own on/off valve taps. Both the safety over pressure line and additional flow line are routed to terminate in a safe containment area such as a fume hood. Any exhaust port(s) from a vacuum pumping system for the vacuum line should also ideally be routed to vent off the gas to a safe area too, such as a fume hood environment.

From connection in this way of these gas lines to a Tornado™ gas cell, the safety over pressure line at the pressure gauge kit of parts (**18**) as fitted is “open” all the time (no on/off tap/valve is incorporated in the safety line), if the gas cell is to be used in a static or flow mode of operation for gas conditions or if there is a need to evacuate the gas cell using a vacuum pump line.

Depending upon the circumstances of operation needed for the Tornado™ gas cell at ambient temperature conditions, the valve taps on the outlet valve (**16**), vacuum line and flow line can be opened or closed accordingly to control the pressure and allow for safe operation

of the equipment. The setting of the valve taps as open or shut can be tabulated as follows for particular experimental conditions with regards as to which line is operable.

Gas Cell Operating Condition	Outlet Valve Assembly (16)	Valve on Flow Line	Valve on Vacuum Line
Over Pressure Monitoring	Open or Shut	Open or Shut	Open or Shut
Gas Flow	Open	Open	Shut
Vacuum	Open	Shut	Open

9. Tornado™ Gas Cell Windows

KBr (**K**), CaF2 (**C**) or ZnSe (**Z**) windows are used as standard in the Tornado™ gas cells. (Other window materials may be supplied if specially requested by contacting Specac.)

For the T5, T10 and T20 size cells there are **two** windows used at the base of the gas cell. One window allows for an input beam of light from the optical units **input** mirror (**3**) to reach the **OM1** and the other window allows for an output beam of light from the **OM2** to pass through to the optical units **output** mirror (**3**).

The "nominal" window dimensions for each gas cell are shown in the following table.

Gas Cell	KBr Window P/N GS24153	CaF2 Window P/N GS24155	ZnSe Window P/N GS24154
Tornado™ T5 P/N GS24205	29.0mm dia x 6.0mm thick (2)	29.0mm dia x 4.0mm thick (2)	29.0mm dia x 4.0mm thick (2)
Tornado™ T10 P/N GS24210	29.0mm dia x 6.0mm thick (2)	29.0mm dia x 4.0mm thick (2)	29.0mm dia x 4.0mm thick (2)
Tornado™ T20 P/N GS24220	29.0mm dia x 6.0mm thick (2)	29.0mm dia x 4.0mm thick (2)	29.0mm dia x 4.0mm thick (2)

The windows are sealed into position by use of an O-ring, PTFE gasket and clamp ring assembly. It may be necessary to gain access to the windows to:

1) Change them in the gas cell for a different window material.
2) Replace the windows because they have become damaged.
3) Clean the windows because they have become contaminated.

Window Access for Tornado™ T5, T10 and T20 Cells

The procedure to gain access to the windows is followed for both (**G**) and (**M**) version body T5, T10 and T20 gas cells. There are slight differences in construction of the T5 gas cell to the T10 and T20 versions, but in essence the procedure for window access is the same

for all three sizes of gas cells. Specac recommend the wearing of gloves to prevent touching the window material and causing contamination when handling.

Separating the T5 Gas Cell from its Optical Unit

The T5 gas cell is secured to the transfer optical unit (**1**) by four M4 x 8mm screws (**19**) located on the underside of the optical unit top plate. (See Figs 15 and 16.) Two of the four screws (**19**) at the rear of the optical unit (**1**) are readily accessible, but the other two screws (**19**) at the front of the optical unit (**1**) require removal of the optical units front cover plate (**4**) to gain access.

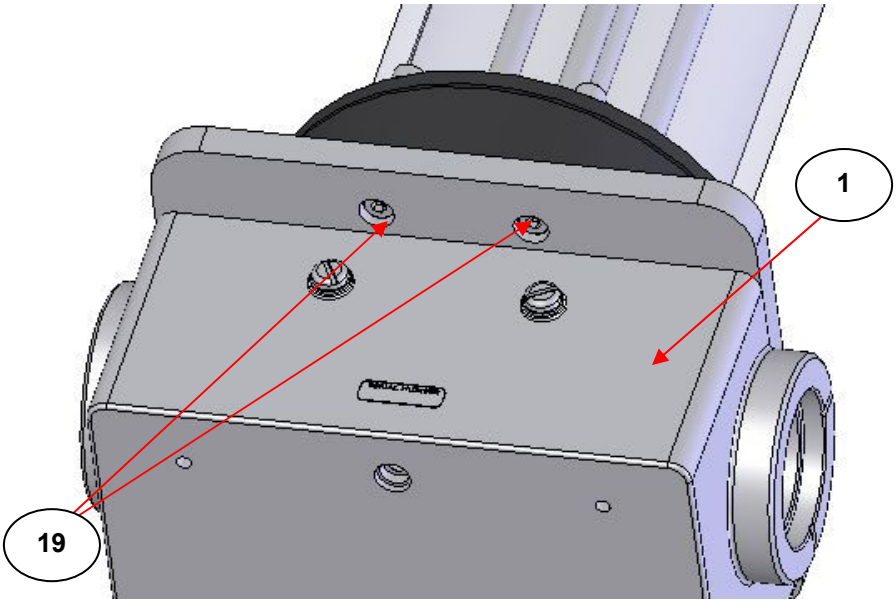

Fig 15. Rear View of Tornado™ T5 Gas Cell Showing Fixing Screws (19) for Gas Cell to the Optical Unit (1)

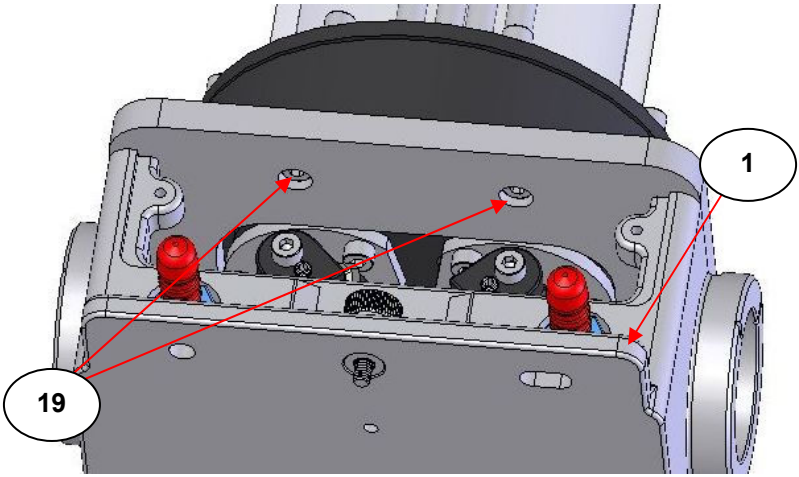

Fig 16. Front View of Tornado™ T5 Gas Cell Showing Fixing Screws (19) to the Optical Unit (1) - Front Cover Plate (4) Removed

To carry out the procedure for unscrewing of the four screws (**19**) it is recommended to have the gas cell lying on its front, on a secure level workbench surface, to undo the rear screws and then turned over to lay on its back to undo the front screws. When the four screws (**19**) have been removed the gas cell can be separated from the optical unit. (See Fig 17 for resulting gas cell assembly).

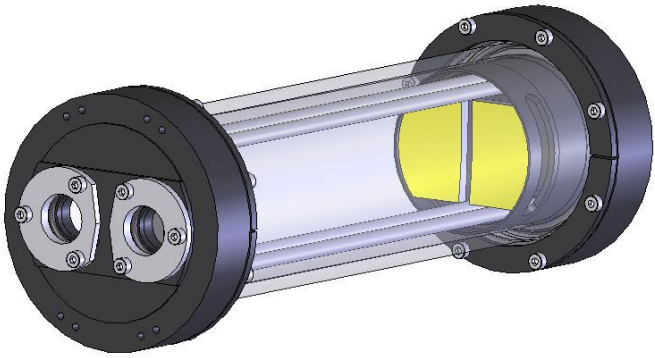

Fig 17. Bottom View of T5 Gas Cell Separated from Optical Unit Separating the T10 and T20 Gas Cell from their Optical Units

The procedure to separate the T10 and T20 gas cells from their optical units is exactly the same as for the T5 size gas cell, except that the two front fixing screws (**19**) of the four are accessible **without** the need to remove the front cover plate (**4**). (See Fig 18.)

Note: *Fixing screws (**19**) are M4 x 12mm size for T10 and T20 cells.*

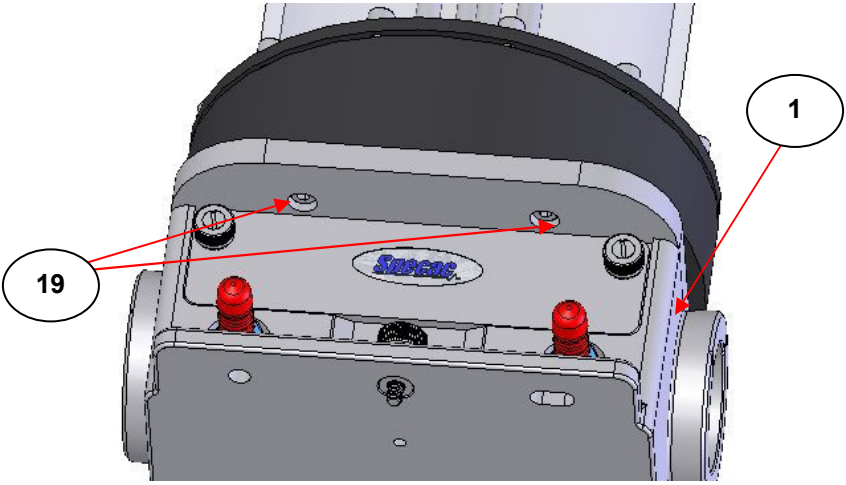

Fig 18. Front View of Tornado™ T10 and T20 Gas Cells Showing Fixing Screws (19) to the Optical Unit (1)

For separation of a T10 or T20 gas cell from the optical unit (**1**) please follow the instructions for the T5 cell on pages 28 and 29.

Window Removal from T5, T10 and T20 Gas Cells

When the optical unit (**1**) has been separated from the Tornado™ gas cell cylinder body access can be gained to the windows of at the base of the cell. Tornado™ T5, T10 and T20 gas cells have two window assemblies of parts that contain nominal 29mm diameter windows at a thickness pertaining to the specific window material (see table page 27).

Note: *For the purposes of explanation, Figs 19 and 20 show the T5 cell parts which are the same for T10 and T20 cells too.*

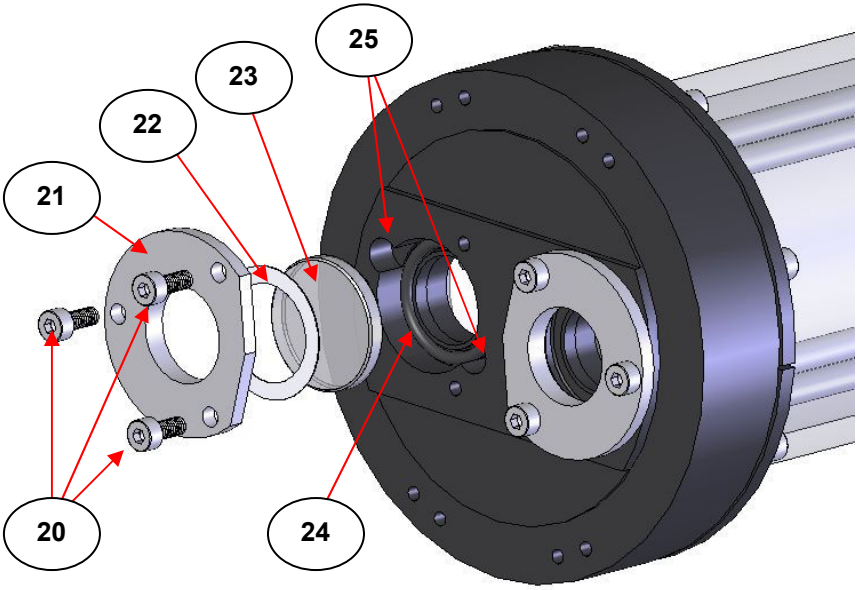

Fig 19. Window Assembly of Parts Separated at the Base of the Tornado™ T5 Gas Cell

Lay the Tornado™ gas cell body onto a smooth level work surface. At the base of the Tornado™ gas cell proceed to unscrew anticlockwise the three M4 x 10mm cap head screws (**20**) that hold the window flange clamp plate (**21**) in position. Remove the clamp plate (**21**) to reveal the protective PTFE washer (**22**) held between the clamp plate and the window (**23**). Set the three cap head screws (**20**), clamp plate (**21**) and PTFE washer (**22**) parts carefully to one side.

Beneath the window (**23**) is a sealing O-ring (**24**). The window (**23**) may be quite securely fixed to the O-ring (**24**) and so to assist in the window removal, there are a couple of access grooves (**25**) whereby a small screwdriver or suitable tool can be inserted. The tool used can

then be **very carefully** pressed against the side edge of the window, to apply a force to help in the windows release from the O-ring (**24**).

When the window (**23**) is removed, the O-ring (**24**) may be stuck to the window and so will be removed too, or it may still be retained in its recess and has to be prised carefully out of the gas cell. Check the condition of both the window (**23**) and the sealing O-ring (**24**) and replace with new components if necessary when reassembling.

Fitting of a new window material, or the same window after it has been cleaned, is the reverse procedure to dismantling of the parts. Having placed the O-ring (**24**) back into its recess, holding the gas cell vertically, carefully fit the window (**23**) into place. Now carefully position the PTFE washer (**22**) and then the clamp plate (**21**) centrally (and the correct way up – see detail below) over the PTFE washer (**22**), making sure the screw holes of the clamp plate (**21**) are aligned with their location holes in the base of the gas cell. Fit and tighten the three M4 screws (**20**) into position by turning them in sequence as follows.

Screw (20) Tightness for Window (23) Fitting and Sealing

For specific refitting of the window (**23**) into position, tighten all three screws (**20**) initially to finger tightness, ensuring that the clamp plate (**21**) is level and that there is a uniform gap all the way around the circumference between the clamp plate (**21**) and base of the gas cell. Proceed to tighten each screw (**20**) for a quarter clockwise turn (one at a time in rotation configuration – screw 1, screw 2, screw 3, etc) to ensure evenness of fit of the window assembly components for sufficient sealing.

Increasingly, with each quarter turn, the screws (**20**) will become more difficult to tighten.

Warning: *Be careful not to overtighten the screws (**20**) to avoid damage to the window (**23**).*

Window Flange Clamp Plate (21) Detail

For **all** Tornado™ gas cells (T5, T10 and T20), KBr (**K**) windows are thicker than their CaF2 (**C**) or ZnSe (**Z**) window material equivalents.

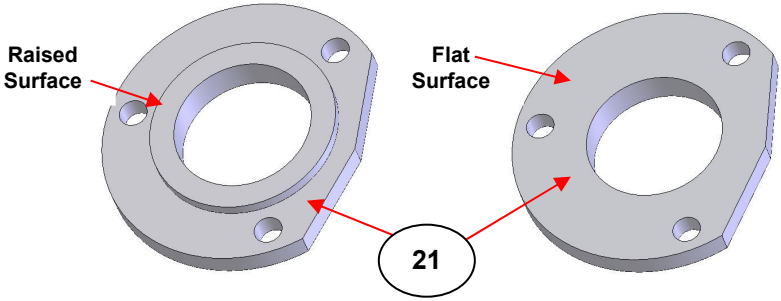

Fig 20. Tornado™ C5 Window Flange Clamp Plate

The window clamp plate (**21**) for the T5, T10 and T20 size gas cells has two different surfaces. (See Fig 20.) One side has a raised surface and the other side is flat. In the construction of the window assembly of parts seen at Fig 19, the flat surface for the clamp plate (**21**) is seen to be on the outermost side. This means that for this shown sequence of assembly of parts, the **raised** surface of the clamp plate (**21**) is in contact with the PTFE washer (**22**) for clamping and sealing a thinner CaF2 (**C**) or ZnSe (**Z**) window (**23**) into position. If a thicker KBr (**K**) window (**23**) is being clamped into position, then the **flat** surface of the clamp plate (**21**) must be in contact with the PTFE gasket (**22**).

Note: ***Raised*** *surface in contact with* ***thinner (Z)*** *and* ***(C)*** *windows.*
Flat *surface in contact with* ***thicker (K)*** *windows.*

Therefore, when refitting a window into position, ensure that the clamp plate (**21**) is located the right way up for the specific window thickness.

Warning: *The clamp plate (**21**) could crush a thicker KBr window when tightening, if replaced the wrong way up.*

10. Mirrors and Mirror Carriage Frames

All Tornado™ gas cells are provided with gold coated mirror surfaces on quartz glass supports for the **OM1**, **OM2** and **FM** mirrors. (Page 9)

The mirrors themselves are glue adhesive fitted to the mirror carriage frame. Specifically, the **OM1** and **OM2** mirrors are glue set at an angle corresponding to a specific fixed pathlength option for the Tornado™ gas cell type. (e.g. a 5m pathlength for the T5 mirror carriage frame).

The gold mirror surfaces also have an antireflection protective coating and offer typically 98% reflectance performance (at 2000cm^{-1}).

Mirror Cleaning and Mirror Frame Replacement

To clean the mirrors or replace the mirror carriage frame assembly, the following procedure should be adopted for all versions of Tornado™ T5, T10 and T20 gas cells.

T5, T10 and T20 Gas Cell Outer Cylinder (G) or (M) Body Removal

For removal of the outer cylinder (**G**) or (**M**) body of T5, T10 and T20 gas cells, figures for the T5 gas cell have been used as an example.

To gain access to the mirror frame assembly inside the gas cell, the outer surrounding gas cylinder (**26**) of a (**G**) or (**M**) body cell is removed from the optical unit (**1**).

For the T5 size cell this is achieved by unscrewing and removing the **eight** lower M4 x 16mm screws (**27**) to the lower flange clamp ring plate (**28**) that holds the gas cylinder in position. (See Fig 21.)

For the T10 and T20 size cells there are **twelve** lower M4 x 16mm screws (**27**) to unscrew and remove from the lower flange ring clamp plate (**28**).

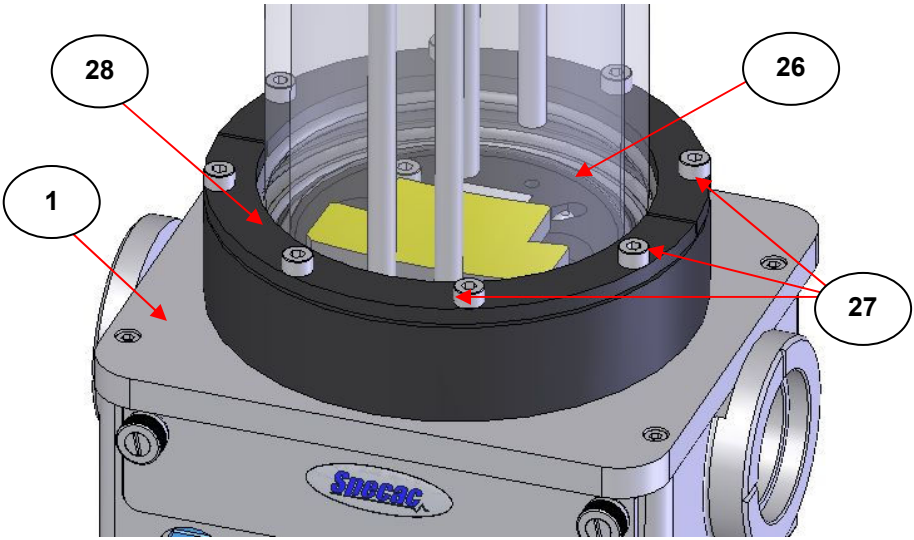

Fig 21. T5 Gas Cell Outer Cylinder (G) or (M) Assembly Removal

When the screws (**27**) have been removed from the lower flange clamp ring, lift off vertically the T5 gas cell outer cylinder assembly (**26**) away from the optical unit (**1**) and mirror carriage frame (**29**). It is possible the cylinder assembly (**26**) may be stuck to the lower sealing O-ring (**30**) within the gas cell chamber, but by careful manipulation of the cylinder assembly (slight rocking and twisting of this assembly against the lower sealing O-ring), it can be lifted up and away. You will be left with two separate assemblies of parts as seen at Fig 22.

When the outer cylinder assembly (**26**) has been removed from the optical unit assembly of parts (**1** and **29**) access can be gained to remove the mirror carriage frame assembly (**29**). The mirror carriage frame assembly is held in place by a single M4 x 12mm screw (**31**). Remove the screw (**31**) by unscrewing anticlockwise and carefully pull the mirror carriage frame assembly (**29**) up and away from the base of the cell and the location stud (**32**). (See Fig 23.) The lower sealing O-ring (**30**) for the T5 cell can also be seen in position from Fig 22.

Fig 24. shows the removed mirror carriage frame assembly (**29**).

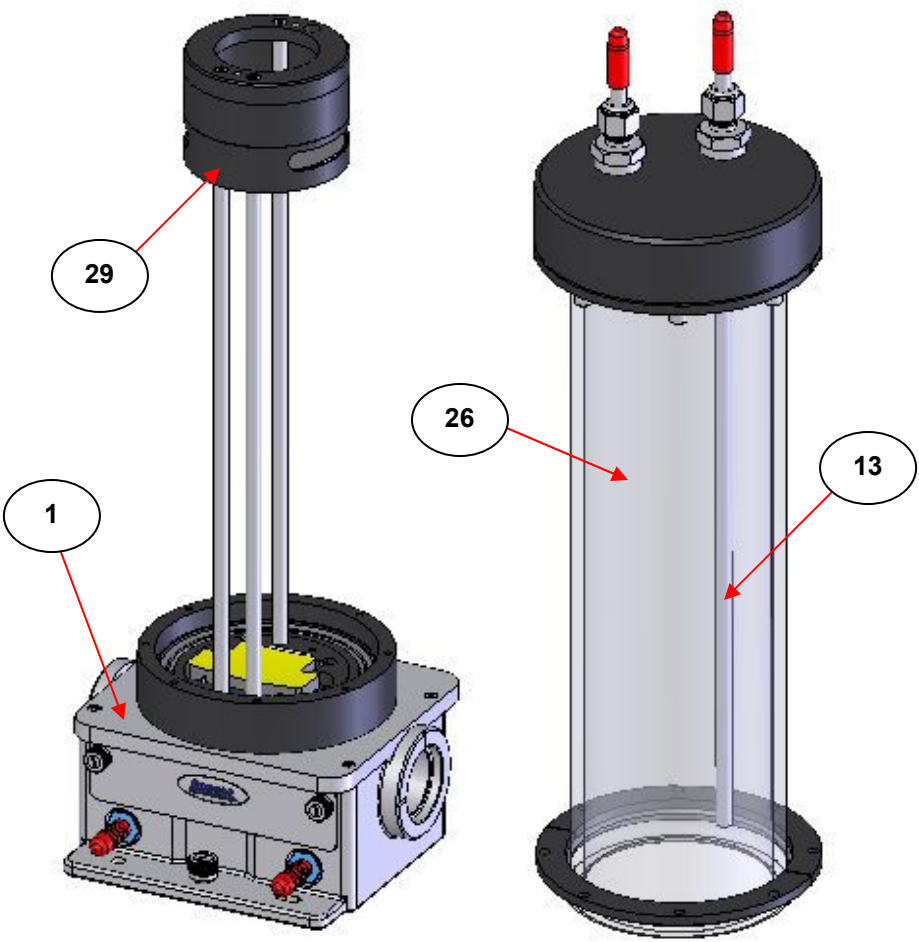

Fig 22. Tornado™ T5 Outer Cylinder Assembly Removed From Optical Unit and Mirror Carriage Assembly

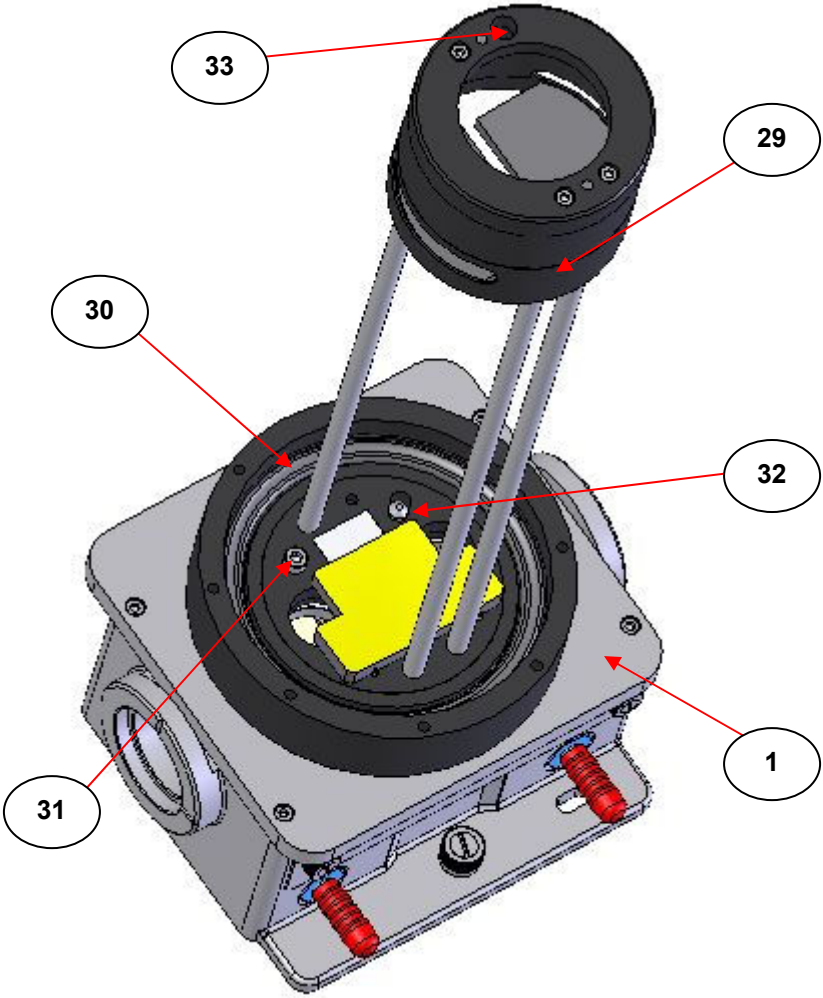

Fig 23. Tornado™ T5 Gas Cell Mirror Carriage Frame Assembly Showing Detail at Base of Gas Cell

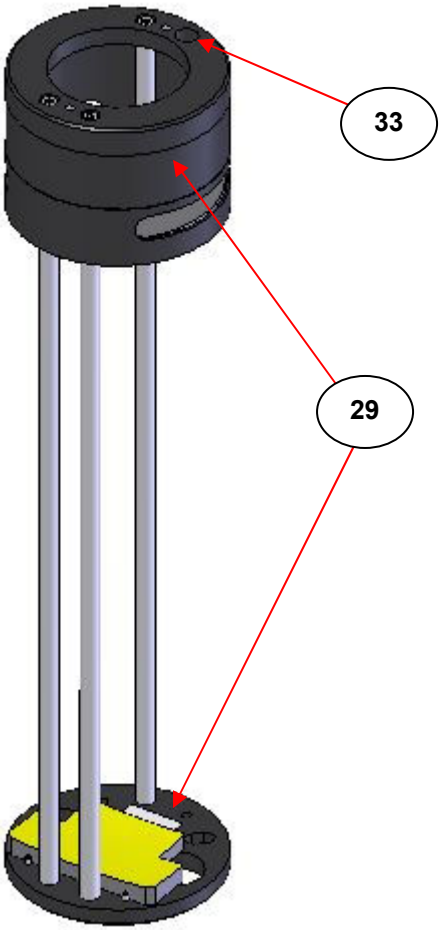

Fig 24. Tornado™ T5 Mirror Carriage Frame Assembly

With removal of the mirror carriage frame assembly (**29**) for easier access, the frame and mirrors can be cleaned using suitable solvents and cleaning materials. Care must be taken when cleaning the gold mirrored surfaces. Only **very fine lens tissue** should be used to avoid abrasion and consequent possible loss of signal throughput.

Reassembly of Mirror Carriage Frame and Outer Cylinder Assembly – T5, T10 and T20 Cells

Refit the mirror carriage frame assembly (**29**) back into its correct position to the base of the cell over the location stud (**32**) and securing with the M4 x 12mm screw (**31**). (See Fig 23.)

Before refitting of the outer cylinder assembly (**26**) check that the lower sealing O-ring (**30**) is in a good and suitable condition. Take the outer cylinder assembly (**26**) and place over the mirror carriage frame (**29**) now secured to the optical unit (**1**) in the same orientation as it was removed. It is essential that the long gas inlet tube (**13**) inside the outer cylinder assembly locates correctly and passes through the circular hole (**33**) at the top of the mirror carriage frame assembly (**29**). (See details on Figs 23 and 24.)

Note: *For the T20 gas cell there is a specific location guide pillar at the base where the gas inlet tube (**13**) is positioned. Ensure for any T20 cell that the gas inlet tube (**13**) passes into this guide.*

Lower the outer cylinder assembly (**26**) into position ensuring it sits correctly over the lower O-ring seal (**30**). Slide the lower flange ring clamp plate (**28**) down to the base of the cylinder assembly and align the M4 screw holes with the holes at the base of the cell.

Note: *For (**G**) body gas cells the flange ring clamp plate (**28**) covers a **second** sealing O-ring (**30**) which actually creates the gas tight seal when compressed against the (**G**) body. For (**M**) body gas cells there is **no** second O-ring (**30**) used to create the seal, as the (**M**) body seals against the O-ring (**30**) retained in the base of the gas cell.*

Proceed to retighten the eight or twelve M4 x 16mm screws (**27**) into position to pull the flange ring clamp plate (**28**) tight to seal the O-ring(s) (**30**) against the (**G**) or (**M**) cylinder body. Ensure when tightening the M4 screws (**27**) that there is an even and level gap all the way around the circumference of the ring clamp plate (**28**) and between the base fitting of the cell, such the cylinder assembly (**26**) is tightened correctly back in position.

11. Cleaning/Care of Tornado™ Gas Cells

After use of the Tornado™ gas cell it is recommended that the following procedures are adopted to properly care for the accessory.

1. Flush the cell with dry N_2 (Nitrogen) gas to remove any residual contaminants. If gases for analyses have been introduced at higher than room temperature conditions, this will help to remove any condensed vapor on the components of the cell.

2. If any parts such as the gas cell body or mirrors require cleaning then suitable solvents may be water, methanol, ethanol and acetone. Avoid chlorinated (or halogenated) solvents for cleaning as these will attack the epoxide glue used for fixing the **OM1**, **OM2** and **FM** into position. When cleaning any of the mirrors (in the gas cell and in the optical unit) **always** use a very gentle soft lens tissue moistened with a suitable solvent and dab at the surfaces rather than wiping to minimize the risk of scratching and abrasion to the mirror surfaces.

3. If they are available, fit the desiccator storage caps P/N GS24150 to the transfer optical unit (**1**). (See page 19). These prevent moisture and dust from contaminating the windows on the gas cell and mirrors in the optical unit (**1**) whilst being stored.

4. Place the Tornado™ gas cell back into its protective carry case or into a dry storage cabinet such as the Specacabinet P/N GS19100.

Notes On Cleaning

When cleaning any removed **window material** being used in the Tornado™ gas cell, it is **very important to take care** to avoid damage to the window materials**.** As also mentioned in the Safety Considerations (Section 2, page 5), of the three standard window materials supplied that can be fitted in the gas cell, ZnSe is potentially

the most hazardous in terms of risk of toxicity if it comes into contact with the skin.

Note: ***Always wear gloves to protect yourself and the window material.***

Solvents such as water, methanol, acetone, hexane, chloroform etc are suitable to use for cleaning purposes, but avoid use of any solvents that are “wet” or contain trace amounts of water, as KBr window materials will be damaged. CaF_2 and ZnSe window materials are generally chemically tolerant of a wide range of aqueous based solvents or solutions for cleaning purposes, but only sample solutions that fall within the pH range of pH4 to pH11 are tolerated by the ZnSe window material. Stronger acidic or basic solutions if introduced will irreparably damage any ZnSe windows that are fitted.

Caution! *If in doubt that your solvent for cleaning may be damaging to the window material being used with the Tornado™ gas cell, always try to test a fragment of the window material type, if possible, with the chemical first.*

When wiping away any solid (condensed) residues (if present) on the window surfaces, use a very soft lens tissue moistened with the appropriate solvent to avoid scratches being caused on the surface of the window material. Scratches and blemishes to the window surface will result in poor light throughput for the transmission technique (more risk of light scatter) and an overall degradation in the Tornado™ gas cell performance.

Datasheet for Potassium Bromide (KBr) Material

General

Medium for making Potassium Bromide pellets for IR spectroscopy.
When fused together as a solid can be polished and used as a transmission window material. Hygroscopic material similar to Sodium Chloride (NaCl).
Soluble in water, glycerine and alcohols. Slightly soluble in ether.
Fairly good resistance to mechanical and thermal shock.
Molecular formula: KBr.
Chemical Abstracts Service (CAS) No: 7758-02-3.

Physical Data

Appearance: Odourless, white or colourless crystalline solid.
Melting point: 730°C.
Boiling point: 1380°C.
Vapour pressure: 1mm Hg at 795°C.
Specific gravity: 2.75 g cm^{-3}.
Solubility in water: 53.48g/100g at 0°C.
Hardness: 6 Kg/mm^2.
Refractive Index: 1.54 (at 2000cm-1 - wavenumbers).
Spectroscopic transmission range: 43,500 to 400 cm-1 (wavenumbers).

Stability

Stable. Incompatible with strong oxidising agents, strong acids, bromine trifluoride and bromine trichloride.

Toxicology

Harmful if ingested in large amounts, if inhaled, or if in repeated contact with the skin.

Personal Protection

Always wear safety spectacles and gloves when handling the powder or window material.
Allow for adequate ventilation.

Storage

Keep powder or windows stored in a cool, dry container.

Datasheet for Calcium Fluoride (CaF_2) Material

General

Known as Calcium Fluoride, Calcium Difluoride, Fluorspar or Irtran 3.
When powder is fused together, is used as a transmission window material.
Insoluble in water, resists most acids and alkalis. Is soluble in ammonium salts.
Its high mechanical strength makes it particularly useful for high pressure work.
Brittle material sensitive to mechanical and thermal shock. Does not fog.
Molecular formula: CaF_2.
Chemical Abstracts Service (CAS) No: 7789-75-5.

Physical Data

Appearance: Odourless, white or colourless crystalline solid.
Melting point: 1360°C.
Boiling point: 2500°C.
Solubility in water: 0.0017g/100g at 0°C.
Hardness: 158 Kg/mm^2.
Refractive Index: 1.40 (at 2000cm-1 - wavenumbers).
Spectroscopic transmission range: 77,000 * to 900 cm-1 (wavenumbers).

Stability

Stable.Incompatible with acids.

Toxicology

Harmful if ingested in large amounts, if inhaled, or if in repeated contact with the skin.

Personal Protection

Always wear safety spectacles and gloves when handling the powder or window material.
Allow for adequate ventilation.

Storage

Keep powder or windows stored in a cool, dry container.
(* UV Grade material required for this range limit.)

Datasheet for Zinc Selenide (ZnSe) Material

General

Toxic and hard yellow coloured crystalline powder when fused together as a solid can be used as a transmission window material or as a crystal material for attenuated total reflectance (ATR) FTIR spectroscopy.
Insoluble in water, but attacked by strong acids and bases. (pH range 4 to 11 tolerant).
Organic solvents have no effect.
Fairly brittle as a window material and sensitive to thermal and mechanical shock.
Molecular formula: ZnSe
Chemical Abstracts Service (CAS) No: 1315-09-9.

Physical Data

Appearance: Yellow crystals, granular powder or amber coloured window material
Melting point: 1515°C at 1.8 atmospheres. (26.5psi)
Solubility in water: 0g/100g at 0°C.
Hardness: 120 Kg/mm^2.
Refractive Index: 2.43 (at 2000cm-1 - wavenumbers).
Spectroscopic transmission range: 20,000 to 500 cm-1 (wavenumbers).

Stability

Stable. Reacts with acids to give highly toxic hydrogen selenide. May be air and moisture sensitive. Incompatible with strong acids, strong bases and strong oxidising agents.

Toxicology

Toxic if small amounts are inhaled or swallowed. In stomach toxic hydrogen selenide (H2Se) is liberated. Skin and eye irritant. Danger of cumulative effects from frequent handling without protection.

Personal Protection

Always wear safety spectacles and gloves when handling the powder or window material. Allow for good ventilation.

Storage

Keep powder or windows stored in a cool, dry container, with appropriate safety labelling.

12. Spares for Tornado™ Gas Cells

GS24150 Pair of Desiccator Storage Caps for transfer optic ports of all Tornado™ Cells.

GS24153 KBr (**K**) Windows for Tornado™ Gas Cells. (Specify T5, T10 or T20 gas cell.)

GS24154 ZnSe (**Z**) Windows for Tornado™ Gas Cells. (Specify T5, T10 or T20 gas cell.)

GS24155 CaF2 (**C**) Windows for Tornado™ Gas Cells. (Specify T5, T10 or T20 gas cell.)

GS24160 Cyclone™ and Tornado™ Long Pathlength gas cell pressure gauge kit. (Specify either low or high pressure gauge.)

GS24161 Tornado™ Long Pathlength gas cell vacuum/gas inlet and outlet taps with push on hose connectors kit.

GS24206 Essential Spares Kit for Tornado™ T5 Gas Cell.

GS24207 Essential Spares Kit for Tornado™ T10 and T20 Gas Cells.

GS24252 Series Gold mirrors on frame for Tornado™ Gas Cells. (Specify T5, T10 or T20 gas cell and pathlength.)

GS24500 Laser Alignment Accessory (for use with all Benchmark™ mounted accessories).

13. Compatibility Guide

This guide shows which Tornado™ gas cell type can be used within a range of spectrometer sample compartments.
Key: F - Fits. DNF – Does Not Fit.

FTIR Instrument	T5 Cell P/N GS24205	T10 Cell P/N GS24210	T20 Cell P/N GS24220
Bomem M100	F	F	F
Bomem MB100	F	F	F
Bruker IFS66	F	F	F
Bruker Tensor, Vertex, Vector Instruments	F	F	F
Agilent Instruments	F	F	F
Mattson Genesis	F	F	F
Mattson Galaxy	F	F	F
Midac	F	F	F
Nicolet 500, Avatar, Nexus, iS10, iS50 Instruments	F	F	F
Nicolet iS5	F	F	F
Perkin Elmer 2000 (GX)	F	F	F
Perkin Elmer Spectrum One, 100, 400, Frontier Instruments	F	F	F
Perkin Elmer Spectrum Two	F	DNF	DNF
Jasco 400/600V, 5000/7000 Intruments	F	F	F
Shimadzu 8400, Prestige 21, IRAffinity, Tracer Instruments	F	F	F

Part Description for "Bubble" Numbered Items

(**1**) Optical unit for Tornado™ gas cell.
(**2**) Fixing thumbscrew of optical unit.
(**3**) Mirrors in optical unit.
(**4**) Optical unit cover plate.
(**5**) Fixing screw for cover plate.
(**6**) M4 x 5mm cap head screw to rotate mirror surface.
(**7**) M4 X 12mm grub screw to tilt mirror surface.
(**8**) Optical unit purge port fitting.
(**9**) Purge bellows.
(**10**) Circular aperture port on optical unit.
(**11**) Desiccator storage cap.
(**12**) Desiccator storage cap with desiccant.
(**13**) Inlet gas flow tube.
(**14**) Outlet gas flow tube.
(**15**) Inlet tube on/off valve fitting.
(**16**) Outlet tube on/off valve fitting.
(**17**) On/off valve "barbed" hose connection fitting.
(**18**) Pressure gauge kit of parts.
(**19**) Fixing screws of Tornado™ gas cell to optical unit (Cap head M4 x 8mm for T5, M4 x 12mm for T10 and T20).
(**20**) Window clamp plate fixing screw (Cap head M4 x 10mm).
(**21**) Window clamp plate.
(**22**) Window clamp plate PTFE washer.
(**23**) Window for Tornado™ gas cell.
(**24**) Sealing O-ring for Tornado™ gas cell window.
(**25**) Window access grooves.
(**26**) (**G**) or (**M**) Tornado™ gas cell cylinder body.
(**27**) Cylinder body lower flange clamp plate fixing screw (Cap head M4 x 16mm).
(**28**) Cylinder body lower flange clamp plate.
(**29**) Tornado™ mirror carriage assembly.
(**30**) Lower sealing O-ring for (G) or (M) Tornado™ gas cell body.
(**31**) Mirror carriage frame fixing screw (Cap head M4 x 12mm).
(**32**) Location stud for mirror carriage frame assembly.
(**33**) Circular hole for gas inlet tube location.

Notes for Tornado™ Gas Cell Use

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